
 NWC SAF	 ZAMG	User Manual for the Automatic Satellite Image Interpretation Processor of the NWC/GEO: Science Part	<b>Code:</b> NWC/CDOP3/GEO/ZAMG/SCI/UM/ASII <b>Issue:</b> 2.0.1 <b>Date:</b> 28 February 2022 <b>File:</b> NWC-CDOP3-GEO-ZAMG-SCI-UM-ASII_v2.0.1.docx <b>Page:</b> 1/86
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# User Manual for the Automatic Satellite Image Interpretation Processor of the NWC/GEO: Science Part



NWC/CDOP3/GEO/ZAMG/SCI/UM/ASII, Issue 2.0.1

28 February 2022

*Applicable to*



*GEO-ASII-v2.4.3 (NWC-046c)*

**Prepared by ZAMG**

 	<p>User Manual for the Automatic Satellite Image Interpretation Processor of the NWC/GEO: Science Part</p>	<p><b>Code:</b>NWC/CDOP3/GEO/ZAMG/SCI/UM/ASII <b>Issue:</b> 2.0.1 <b>Date:</b> 28 February 2022 <b>File:</b>NWC-CDOP3-GEO-ZAMG-SCI-UM-ASII_v2.0.1.docx <b>Page:</b> 2/86</p>
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### DOCUMENT CHANGE RECORD

Version	Date	Pages	CHANGE(S)
1.0	21 January 2019	84	Release 2018; ASII-NG parts removed.
2.0.1	28 February 2022	86	Release 2021; Code refurbishment; updates in references; no scientific changes. Concerning the document as such, minor changes in the “References” and transfer of information on output files and error codes from SUM/2 to this document.

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## 1. INTRODUCTION

The EUMETSAT “Satellite Application Facilities” (SAF) are dedicated centres of excellence for processing satellite data, and form an integral part of the distributed EUMETSAT Application Ground Segment (<http://www.eumetsat.int>). This documentation is provided by the SAF on Support to Nowcasting and Very Short Range Forecasting, NWCSAF. The main objective of NWCSAF is to provide, further develop and maintain software packages to be used for Nowcasting applications of operational meteorological satellite data by National Meteorological Services. More information can be found at the NWCSAF webpage, <http://nwc-saf.eumetsat.int>. This document is applicable to the NWCSAF processing package for Meteosat Second Generation satellites, NWC/GEO.

### 1.1 SCOPE OF THE DOCUMENT

This document is the Product User Manual for the MSG Automatic Satellite Image Interpretation Product (PGE10 of the NWC/GEO software).

This document contains practical information for the daily use of the product. This document is intended for the meteorologist giving some principal information on the abilities and limitation of the product output.

### 1.2 SCOPE OF OTHER DOCUMENTS

The algorithms used in this software are described in the Algorithm Theoretical Basis Document [RD.4].

Details of input and output data format of the products are also described in the Interface Control Documents [AD.5] for the External and Internal Interfaces of the NWC/GEO and in the MSG Output Product Format Definition [AD.7].

The general architecture of the software (interface with the NWCSAF software, architecture of the PGE) is described in the Architectural Design Document [AD.8].

The product generator elements are described in the corresponding Software Component and Version Description.

Instructions how to install, configure and execute the NWC/GEO software in order to extract the MSG Automatic Satellite Image Interpretation Product (PGE10) are detailed in the NWC/GEO Software User Manual.

The latest validation of the algorithms used to extract the MSG Automatic Satellite Image Interpretation (PGE10) is reported in a validation report [RD.3].

### 1.3 SOFTWARE VERSION IDENTIFICATION

This document is compliant with the ASII/PGE10 version of the 2021 NWC/GEO software package delivery.

### 1.4 IMPROVEMENT FROM PREVIOUS VERSION



Code refurbishment with the focus on improved handling of virtual memory; no scientific changes.



## 1.5 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

See [RD.1] for a complete list of standard acronyms for the SAF project. Some specific abbreviations used herein include:

AD	Applicable Document
AMV	Atmospheric Motion Vectors
ASII	Automatic Satellite Image Interpretation
ASIINWP	Automatic Satellite Image Interpretation including NWP fields
BUFR	Binary Universal Form from the Representation of meteorological data
CA	Cold air Advection
CAC	Cold Air Cloudiness
Cb	Cumulonimbus
CC	Convective Cells
CEOF	Complex Empirical Orthogonal Function
CF	Cold Front
CM	Conceptual Model
COST	European Cooperation on Scientific and Technical Research
DI	Dry Intrusion
EC	Enhanced Cumulus
ECMWF	European Centre for Medium-range Weather Forecast
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
IR	Infrared
JI	Front Intensification by Jet Streak
MSG	Meteosat Second Generation
NWP	Numerical Weather Prediction
OCCL	Occlusion
PGE	Product Generation Element
PV	Potential Vorticity
PVA	Positive Vorticity Advection
PVU	Potential Vorticity Unit
RC	Rapid Cyclogenesis
RSV	Relative Shear Vorticity
RV	Relative Vorticity
SAF	Satellite Application Facility
SAFNWC	SAF to support NoWCasting and Very-Short-Range Forecasting
SEVIRI	Spinning Enhanced Visible and Infrared Imager

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SH	Showalter Index
SUM	Software User Manual
TA	Temperature Advection
TFP	Thermal Front Parameter
ULL	Upper Level Low
UTC	Universal Time Coordinated
WA	Warm air Advection
WF	Warm Front
WV	Water Vapour
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (= Central Institute for Meteorology and Geodynamics, Vienna)

## 1.6 REFERENCES

### 1.6.1 Applicable documents



The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X].

For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the current edition of the document referred applies.

Current documentation can be found at the NWC SAF Helpdesk web: <http://nwc-saf.eumetsat.int>.

Ref	Title	Code	Vers	Date
[AD.1]	Project Plan for the NWCSAF CDOP3 phase	NWC/CDOP3/SAF/AEMET/MGT/PP	1.0	06/03/18
[AD.2]	NWCSAF CDOP3 Project Plan Master Schedule	NWC/CDOP3/SAF/AEMET/MGT/PP/MasterSchedule	1.1	28/02/18
[AD.3]	Configuration Management Plan for the NWC SAF	NWC/CDOP3/SAF/AEMET/MGT/CMP	1.0	21/02/18
[AD.4]	System and Components Requirements Document for the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/SCRD	2.1	21/01/19
[AD.5]	Interface Control Document for Internal and External Interfaces of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/ICD/1	1.0	21/01/19
[AD.6]	Interface Control Document for the NWCLIB of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/ICD/2	1.0	21/01/19
[AD.7]	Data Output Format	NWC/CDOP3/GEO/AEMET/SW/DOF	1.0	21/01/19
[AD.8]	Component Design Document for the NWCLIB of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/ACDD/NWCLIB	2.0	27/02/17
[AD.9]	NWC SAF Product Requirements Document	NWC/CDOP3/GEO/AEMET/MGT/PRD	1.0	01/18
[AD.10]	User Manual for the Tools of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SCI/UM/Tools	1.0	21/01/19

*Table 1: List of Applicable Documents*

 	User Manual for the Automatic Satellite Image Interpretation Processor of the NWC/GEO: Science Part	<b>Code:</b> NWC/CDOP3/GEO/ZAMG/SCI/UM/ASII <b>Issue:</b> 2.0.1 <b>Date:</b> 28 February 2022 <b>File:</b> NWC-CDOP3-GEO-ZAMG-SCI-UM-ASII_v2.0.1.docx <b>Page:</b> 11/86
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### 1.6.2 Reference documents



The reference documents contain useful information related to the subject of the project. These reference documents complement the applicable ones, and can be looked up to enhance the information included in this document if it is desired. They are referenced in this document in the form [RD.X].

For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the current edition of the document referred applies.

Current documentation can be found at the NWC SAF Helpdesk web: <http://nwc-saf.eumetsat.int>

Ref	Title	Code	Vers	Date
[RD.1]	The Nowcasting SAF Glossary	NWC/CDOP2/SAF/AEMET/MGT/GLO		
[RD.2]	Wirth, A., Jann, A. and Zeiner, B. (2008): On the use of complex empirical orthogonal functions for the temporal interpolation of NWP, radar and satellite data. Proceedings, 2008 EUMETSAT Meteorological Satellite Conference, Darmstadt, 8 - 12 September 2008, EUMETSAT P. 52, ISBN 978-92-9110-082-8, ISSN 1011-3932, 8pp.			
[RD.3]	Validation Report for “Automatic Satellite Image Interpretation” (ASII-PGE10, v2010)	SAF/NWC/CDOP/ZAMG/SCI/VR/4	1.0	20 April 2010
[RD.4]	Algorithm Theoretical Basis Document for the Automatic Satellite Image Interpretation Processor of the NWC/GEO	NWC/CDOP2/GEO/ZAMG/SCI/ATBD/A SII	2.0	21/01/19

**Table 2: List of Referenced Documents**

 	<p>User Manual for the Automatic Satellite Image Interpretation Processor of the NWC/GEO: Science Part</p>	<p><b>Code:</b>NWC/CDOP3/GEO/ZAMG/SCI/UM/ASII  <b>Issue:</b> 2.0.1 <b>Date:</b> 28 February 2022  <b>File:</b>NWC-CDOP3-GEO-ZAMG-SCI-UM-ASII_v2.0.1.docx  <b>Page:</b> 12/86</p>
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## 2. DESCRIPTION OF THE NWC/GEO-ASII PRODUCTS

### 2.1 GOAL OF THE ASII PRODUCT

ASII/PGE10 of the NWC/GEO provides an automatic satellite image interpretation in terms of conceptual models (CMs). CMs are important tools for forecasters in diagnosis, nowcasting and very short range forecasting. They describe typical features in satellite images as well as in other data sources like numerical model output parameters and the physical processes causing them. A CM diagnosis can be used for detection of an ongoing process and also its development stage.

An inventory of CMs used in weather services was produced within the COST78 project, providing a collection of more than 80 CMs used in European weather services as well as a collection of the existing experiences with them (COST78, 1996). More information on CMs and their usage can be found in Bader et al. (1995) and EumeTrain (2018, 2021).

Typical features/configurations in satellite images are fundamental input to the application of conceptual models and often show the very first stages of a new development. The only way to process the huge amount of observational data (satellite and NWP data) at a temporal resolution which is useful for nowcasting is the automated detection of CMs.

PGE10 carries out the recognition of CMs along two lines:

- ASII: Automatic Satellite Image Interpretation based only on MSG SEVIRI satellite data
- ASIINWP: Automatic Satellite Image Interpretation based on MSG SEVIRI satellite data supplemented by selected key parameters from the numerical model output (Numerical model used at ZAMG: ECMWF; however, the NWCSAF application allows to use another model)

### 2.2 OUTLINE OF AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) ALGORITHMS<sup>1</sup>

#### 2.2.1 Satellite data pre-processing

Satellite images from MSG are pre-processed before they are further analysed within the ASII software. This pre-processing consists of the conversion of radiation values to temperature values, reprojection and image filtering methods to increase the performance of the search methods. Image information is transferred to a lower resolution grid to reduce computation time.

Atmospheric motion vectors (AMV) are calculated from temporally consecutive pairs of WV and IR images. While in IR images AMVs cannot be calculated in cloud free regions, they show a smooth flow pattern all over the image in WV imagery. AMVs are used to detect the evolution of convective cells and the large-scale displacement of frontal systems. They also serve for the computation of flow parameters like the vorticity and neighbourhood-related functions (e.g. lee near the mountain crest).

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<sup>1</sup> Several of the algorithms described in the manual have been developed in the framework of scientific projects supported by the Austrian Ministry for Education, Science and Culture (BM:BWK) in cooperation with the company GEPARD (J. Scheiber).

### 2.2.2 Development images

Development images are calculated from two temporally consecutive satellite images. The previous image is temporally extrapolated towards the subsequent image with help of the AMVs. The development image is calculated as difference between the extrapolated and the subsequent image. The content of the development image can therefore be interpreted as the non-advective change in the cloud field.

The development images are used for CMs which show a significant development in particular stages of their life cycle. Based on the values of the development image at a grid point, the conceptual model analysed is flagged as developing or decaying at that point.

### 2.2.3 NWP data input

At the forecast times 00, 06, 12, and 18 UTC (and - if available - 03, 09, 15 and 21 UTC), derived quantities are computed from the NWP data and interpolated to the analysis grid. The basic input data for the PGE10 software package are forecast fields on a regular longitude-latitude grid. It is required that the provided NWP data cover the entire area chosen by the user, otherwise the NWP branch of PGE10 cannot be carried out.

For time steps without corresponding NWP forecast, the NWP data are either extrapolated by means of the AMV field calculated from the WV channel or interpolated in time using a Complex Empirical Orthogonal Functions analysis approach (Wirth et al., 2008).

### 2.2.4 Ingestion of analysis information from the preceding slot ("memory")

To achieve a more continuous analysis of the satellite images, the algorithm takes into account the results from previous analyses. The software always dumps the CM analysis for one time step, which is then read and used for the analysis of the following image. The position of the memorized conceptual model is extrapolated with help of the AMVs to the following image.

### 2.2.5 Detection of contiguous areas with similar cloud structure

Using statistical methods, the IR image is segmented into coherent areas of similar cloud structures. The image segments are assigned to predefined classes with associated internal numbers (see Table 3). The classification is based on image brightness and texture. The idea behind the identification of regions of similar cloud structure is to find the outline and extent of cloud patterns which can then be assigned to conceptual models.

Class	Number
Cloudless area;	1
Bright (cold) smooth cloudiness, as characteristic for warm fronts;	11
Dark grey to grey cloudiness with smooth to medium rough texture, as it is typically observed in low cold fronts;	21
Bright to medium bright cloudiness with rough texture ; as it is typical for multi-layered frontal systems	32
Bright (cold) and small cellular cloudiness as it is typical for enhanced Cumuli;	61
Very bright (cold) and bigger cloud cells as they are typical for Cumulonimbus cloudiness;	80
Low-level cellular cloudiness as it is typical for the cold-air cellular cloudiness.	91

**Table 3:** Description of classes. The column "number" gives code numbers which are occasionally referred to in later sections.

A separate method is employed to extract the additional information "frontal" and "non-frontal" from the satellite images. While the classification analyses substructures in cloud features, this process analyses the cloud system as a whole and plots the so called "contour line" which is further analysed with pattern recognition methods e.g. detection of S-shaped lines (cf. next chapter).

## 2.2.6 Pattern recognition methods and topographic functions

Topographic functions are numerical methods that describe the position of an attribute field (e.g. maximum, minimum, ridge lines ...) either in satellite images or in NWP fields in respect to the position of other attribute fields. Such a topographic function is used for the detection of left exit regions of jet streaks (applied to numerical model fields) or for the detection of lee cloudiness (applied to the IR imagery).

Pattern recognition methods are widely used to detect characteristic structures in the IR or WV image. As an example, the S-shaped rear side of a frontal wave can be seen as a characteristic feature for this conceptual model. This pattern is automatically detected within the PGE10 software and used for the automatic detection of wave features embedded in cold fronts. As another example, the automatic detection of small convective cells (EC and Cb) is performed by a module which recognises bright, circular shaped cloud features.

Pattern recognition methods are widely used for the detection of cloud fibres, spiral structures, curved frontal cloud bands or black stripes in the WV-imagery. These methods are implemented in the detection algorithm of several conceptual models like occlusions, comma clouds, cloud fibres and many other more.

## 2.3 DESCRIPTION OF THE ASII OUTPUT

The following two tables give an overview of the symbols used for the different conceptual models in the figures below.

<b>SAT:</b>		
<b>Symbol</b>	<b>Colour</b>	<b>Conceptual Model</b>
w	red	warm front
c	blue	cold front
~	magenta	frontal wave
~	red	developing frontal wave
O	green	Occlusion
DI	cyan	dry intrusion
ec	cyan	enhanced cumulus
cb	blue	Cumulonimbus (decaying stage)
cb	yellow	Cumulonimbus (mature stage)
cb	magenta	Cumulonimbus (developing stage)
M	yellow	Meso scale Convective System
•	yellow	embedded convective cell
F	yellow	jet cloud fibres
z	yellow	cold air cloudiness
co	yellow	Comma
L	yellow	lee cloud

**Table 4:** Symbols used for the different conceptual models in the ASII (SAT) output

<b>NWP+SAT:</b>		
<b>Symbol</b>	<b>Colour</b>	<b>Conceptual Model</b>
w	red	warm front
c	blue	cold front
c	red	cold front in warm air advection
~	magenta	frontal wave
~	red	developing frontal wave
~	green	upper wave
O	green	Occlusion
DI	cyan	dry intrusion
ec	cyan	enhanced cumulus
cb	blue	Cumulonimbus (decaying stage)
cb	yellow	Cumulonimbus (mature stage)
cb	magenta	Cumulonimbus (developing stage)
M	yellow	Meso scale Convective System
•	yellow	embedded convective cell
F	yellow	jet cloud fibres
z	yellow	cold air cloudiness
co	yellow	Comma
L	yellow	lee cloud
ji	yellow	front intensification in left exit region of a jet streak
ul	yellow	upper level low

**Table 5:** Symbols used for the different conceptual models in the ASIINWP (SAT+NWP) output

## **2.3.1 Detailed description of conceptual models**



### **2.3.1.1 Cold Front (CF)**

The main physical process for the development of cold fronts is the movement of cold and dry against warm and moist air. As a consequence of this movement and relative to it, the warm air tends to glide up along this air mass boundary while the cold air tends to sink below it. This upward motion of warm and moist air often leads to condensation and subsequently to the development of clouds and precipitation.

For a detailed description see EumeTrain (2021).

#### **2.3.1.1.1 Key parameters used in the ASII product**

**Frontal area:**

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The frontal area marks extended cloud fields with a high probability of being a frontal system. CF tags are analysed within such a frontal area.

This is the only criterion which is checked in ASII for CF. Since a CF is overwritten by each of the other frontal CMs if their criteria are fulfilled as well, a CF tag only remains if NOTHING else is analysed at this place. Therefore CF tags are necessarily connected to a frontal rear side and are limited to a width less than 12 grid points (cf. warm front (WF), section 2.4.1.2).

### 2.3.1.1.2 Key parameters used in the ASIINWP product

Three types of CFs are diagnosed by the ASIINWP product by different procedures and key parameters:

- The classical CF: The detection mechanism is the same as in ASII. Remark on the “Frontal area”: No NWP fields are used actively for classical CFs although TA is used indirectly. The CF tags assigned to a classical front are thought to be under CA and are tested only later in connection with the CF in WA (see below). The CF analysis is replaced in the further analysis by other conceptual models if they are superimposed on the frontal cloud band. For instance: Cbs, MCSs, front intensification by jet streak, fibres.
- CF in WA: The CF in WA is analysed only in the ASIINWP product since TA is necessary for its analysis. But it is not the complete CM “CF in WA”: only the existence of WA within the cloud band is judged but not the existence of WA in the cold air behind the CF cloud band (which would be a necessary condition for the CM “CF in WA”). Input from ASII: “Frontal area”, “Frontal rear side” (for a CF in WA a frontal rear side must be detected; this is the main difference to a WF where no frontal rear side exists).

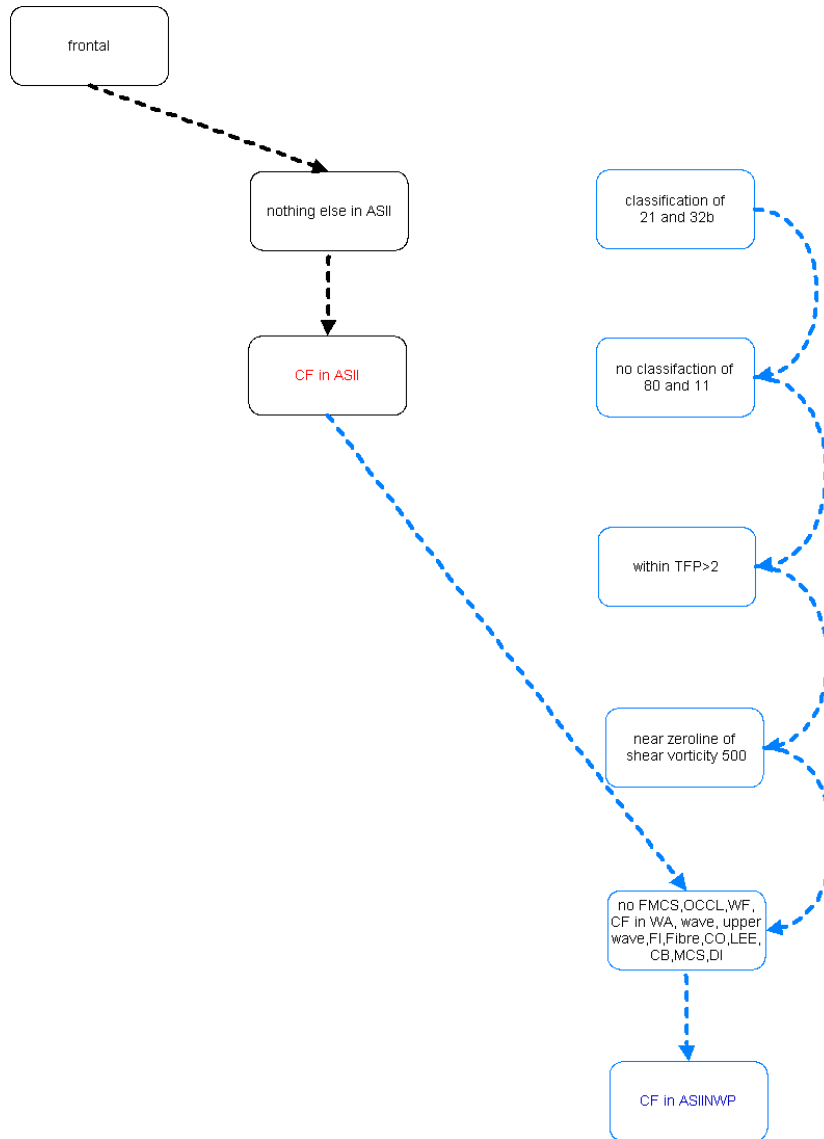
Additional parameter from NWP:

Temperature advection at 700 hPa (TA): The CF in WA has to be located in  $TA > 0$  K/12 hours.

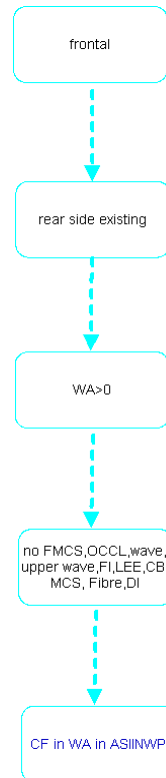
- Low CF bands: This conceptual model has been introduced for those cases where clouds do not exceed the temperature threshold necessary for the detection of a frontal area (approximately  $-15^{\circ}$  C cloud top temperature). With the thermal front parameter and a selection of typical low cloud classifications this module analyses low CF cloud bands in addition to the CFs defined by a frontal area. Key parameter “Classification”: All classifications correspond to low brightness in the IR satellite image. Key parameter “Thermal front parameter (TFP)”: Positive values of the TFP are required. Key parameter “Relative vorticity at 500 hPa (RV500)”: A probability region of 8 grid-meshes width (4 grid meshes on each side of the zero line) along the zero line of the RV500 field is applied.



### 2.3.1.1.3 Schematics of the diagnostic procedure



**Figure 1:** Processing chain for the detection of a CF in ASII (black) and ASINWP (blue); in ASINWP the two branches are symbolising the classical CF and the low CF



*Figure 2: Processing chain for the detection of a CF in WA in ASIINWP*

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

#### 2.3.1.1.4 Practical application rules and inherent problems



##### General application rules:

- If a CF is analysed by ASII, forecasters can be sure that there is a frontal area with a frontal rear side (in terms of ASII/ASIINWP as described);
- If a classical CF is analysed in ASIINWP, forecasters can be sure that there is CA at 700 hPa within the frontal cloud band;
- If a CF in WA is analysed in ASIINWP, forecasters can be sure that there is a frontal area with a frontal rear side and  $WA > 0 \text{ K/12 h}$

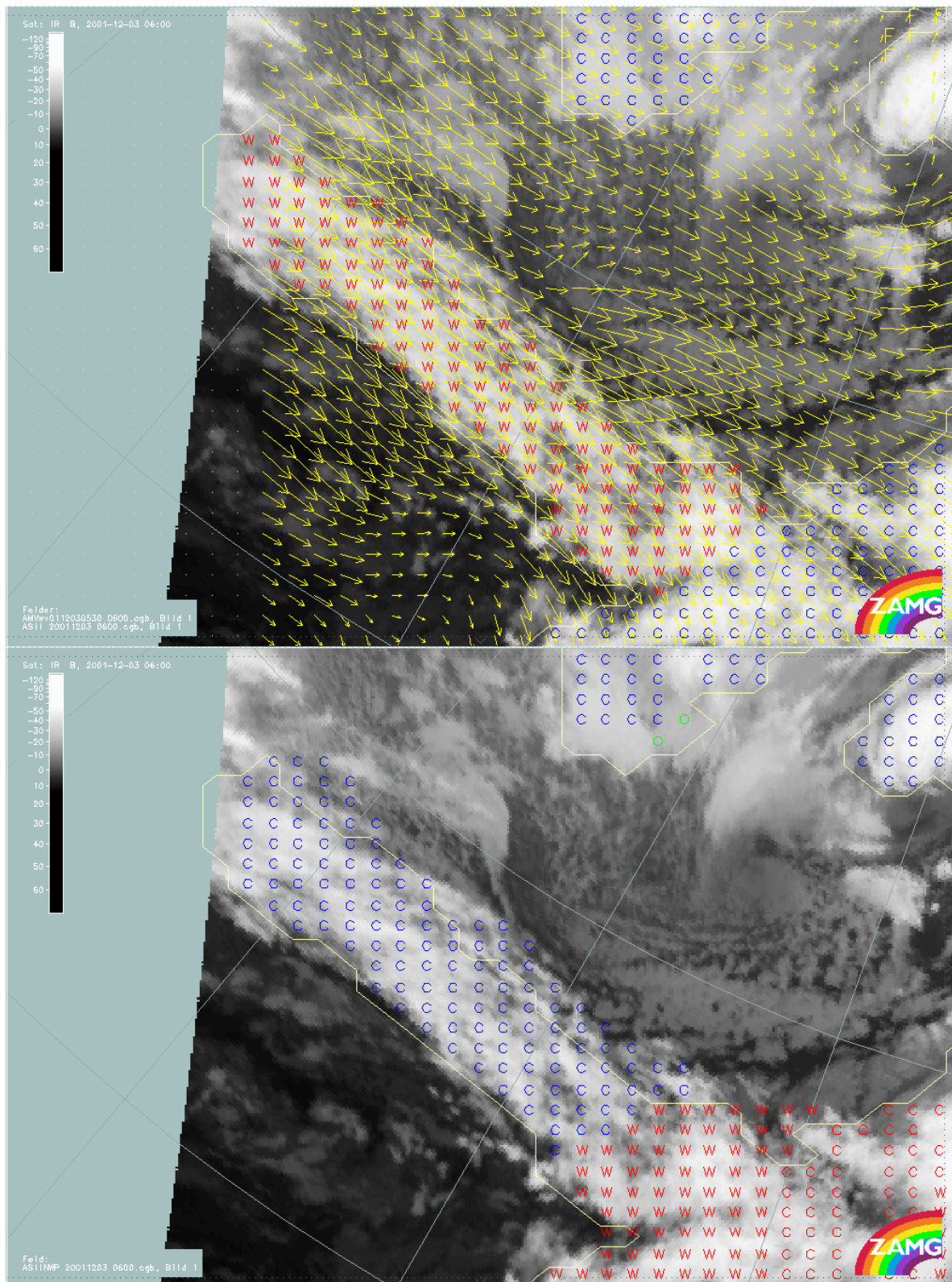
##### Comparison ASII vs. ASIINWP:

- Differences in ASII and ASIINWP CM analyses can be used to reveal details of the CF. The following examples are frequently observed:
  - ASII: CF + ASIINWP: CF in WA: this means the typical movement of a CF but the existence of WA in the area of the cloudiness; this needs not be a model error as for instance in case of Katafronts the zero line of TA is close to the frontal rear side;
  - ASII: no CF diagnosis (but e.g. comma) + ASIINWP: CF: this means that no frontal area is diagnosed either because the threshold of extension is not reached or (mostly) because the temperature threshold is not reached; this happens in case of a low CF cloud band which has some additional characteristics of a comma (see 2.3.1.9).



##### Inherent problems:

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- There are CFs which are stationary as a whole and therefore accompanied by WV AMVs which are parallel to the cloud band. Consequently these cloud bands, which are apparently CFs, are analysed as WFs in ASII. Those cases are diagnosed as CF in ASIINWP if CA is prevailing. See Figure 3.



**Figure 3:** Upper panel: 3<sup>rd</sup> December 2001, 06 UTC; ASII; WV AMVs superimposed which suggest WF conditions, hence the labelling by red 'w'. Lower panel: 3<sup>rd</sup> December 2001, 06 UTC; ASIINWP; CA changes the ASII analysis of WF into a CF

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### **2.3.1.2 Warm front (WF)**

In the case of a warm front, warm and moist air moves against cold and dry air. At the boundary of the two air masses the warmer air tends to glide over the wedge of the colder air. This process causes the development of a frontal cloud band, and therewith the precipitation which in most cases is preceding the surface front (or a front parameter like the Thermal Front Parameter TFP). For more details see EumeTrain (2021).

#### **2.3.1.2.1 Key parameters used in the ASII product**

##### **Frontal area:**

The parameter “frontal area“ (see chapter 3.1.8 in [RD.4]) is used to separate frontal systems from other systems using the horizontal extension and pixel brightness (temperature) of the comprised cloud area as main criteria. Warm fronts must be located within such a “frontal area”.

##### **Frontal rear side:**

The algorithm used for the detection of “frontal rear sides” is described in chapter 3.1.8 in [RD.4]. For WFs, they are tightly connected to the “rear side detection” of CFs. Warm front tags are analysed in a frontal area if no frontal rear side is detected.

Another possibility for a warm front analysis is the diagnosis in case of an extended shield-like cloud field. Such cloud shields are detected if the distance between frontal rear side and the corresponding leading edge of the cloud shield exceeds an empirically gained threshold of 12 grid points.

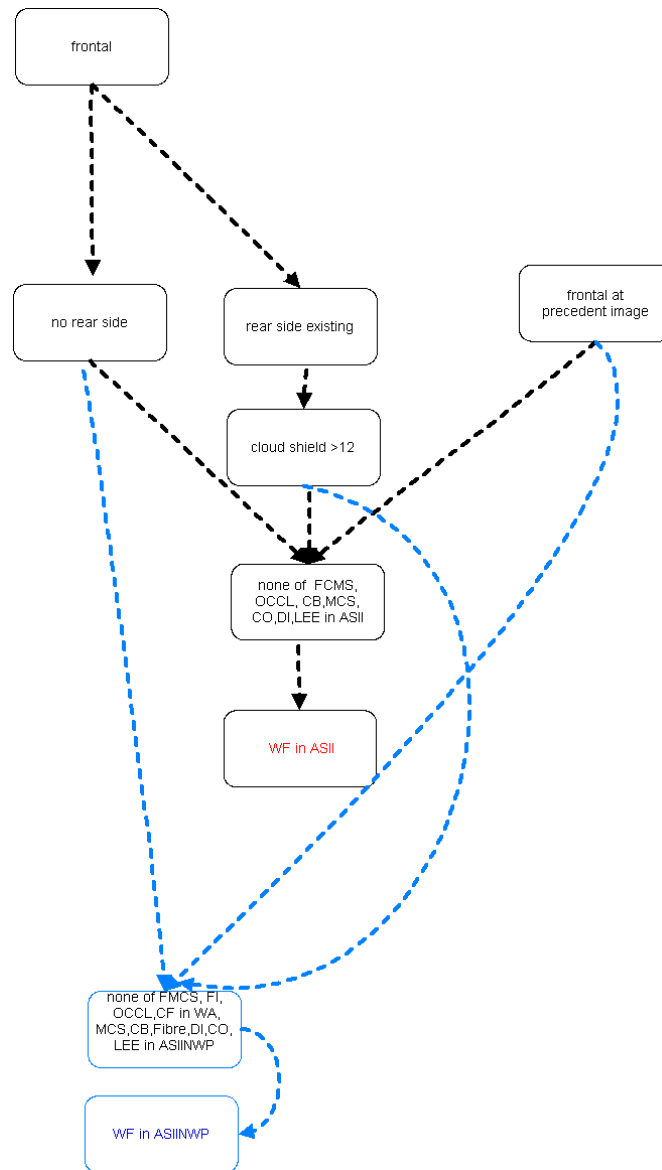
##### **Memory:**

As experience has shown, warm fronts undergo rather frequent fluctuations on a small scale. To overcome this problem, the warm front analysis from the preceding satellite image is extrapolated to the next time step with help of the AMVs and included in the present analysis.

#### **2.3.1.2.2 Key parameters used in the ASIINWP product**

The ASIINWP product uses the following criteria in the same way as ASII: “Frontal area”, “Rear side detection”, “Memory”. There are no NWP fields used for the detection of warm fronts in ASIINWP. Although synoptic experiences often show warm advection within the warm front shield, the use of TA 700 hPa has led to a significantly lower rate of detection than in ASII. Therefore the former NWP part was dropped.

### 2.3.1.2.3 Schematics of the diagnostic procedure



**Figure 4:** Processing chain for the detection of a WF in ASII (black) and ASIINWP (both black and blue arrows)



For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

### 2.3.1.2.4 Practical application rules and inherent problems

#### General application rules:

- If in ASII a WF is diagnosed forecasters can be sure:
  - either: that there is a frontal area without any frontal rear side;
  - or: that the frontal area has the form of a broad cloud shield.



#### Comparison ASII vs. ASIINWP:

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- The analyses in ASII and ASIINWP are based on the same criteria, therefore all WF in ASII are also analysed as WF in ASIINWP. There might be slight differences in cases where other conceptual models overwrite the warm front tags like the front intensification, which is only defined in ASIINWP. The differences are concerning only small (embedded) parts of the cloud shield and not the whole system.

**Inherent problems:**

- For ASIINWP no numerical fields could be found to improve the discrimination between CFs and warm fronts. A meteorologist can easily see the difference by using vertical cross sections, but a single level (or layer) was not found to be representative.
- There are CFs which are stationary as a whole and therefore accompanied by cloud-band parallel WV AMVs; consequently these cloud bands which are apparently CFs are analysed as WFs in ASII.

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### 2.3.1.3 Occlusion

The cloud band of an occlusion is the result of a classical development process starting from a wave stage represented by a cloud bulge at the rear side of a CF cloud band growing to a multi-layered, cyclonically curved synoptic-scale cloud spiral. For more details see EumeTrain (2021).

#### 2.3.1.3.1 Key parameters used in the ASII product

##### Frontal area:

An occlusion cloud band must be located within a frontal area, since it is always part of a larger frontal system. Concerning the detailed algorithm for detection of frontal areas see [RD.4].

##### WV-AMV-Vorticity:

Vorticity is calculated from the WV-AMV field. After the detection of the maximum of relative vorticity from a smoothed vorticity field, a probability region, whose extension depends upon the strength of the detected vorticity maximum, is calculated. For weaker vorticity maxima (6 – 10 units), a probability region with a radius of 9 grid meshes is assigned, for stronger vorticity maxima (> 10 units), a probability region with a radius of 12 grid meshes is assigned to take into account that occlusion cloud spirals within deeper low pressure systems can be more extended.

##### Hough knot:

This method recognises curved cloud bands by analysing the orientation of small frontal segments (for a detailed description of the algorithm see chapter 3.1.15 in [RD.4]). Around a detected Hough knot a probability region with a radius of 11 grid meshes is applied. Such a Hough knot must be situated outside the frontal area. If the criterion of the Hough knot is fulfilled, the WV AMV vorticity is not checked any more. This enables ASII to find more occlusions.

##### IR-AMV direction:

Atmospheric motion vectors, computed from the IR images, are supposed to have at least a small easterly component (i.e.  $U < 0$ ). Also, they should have either

- a northward direction or
- if southward, only a weak meridional component not exceeding 10 m/s (i.e.  $V > -10$ ).

If a combination of a

- northerly wind component exceeding 15 m/s ( $V > 15$  m/s) and
- a weak easterly wind component not exceeding 5 m/s ( $U > -5$  m/s)

is found, an occlusion analysis is excluded.



The reason for the restriction in IR-AMV wind direction is to cover the typical conditions for occlusion cloud bands and therefore exclude other CM like CF and WF.

These conditions take into account the typical streaming situation in connection with occlusion cloud bands.

##### “Frontal rear side”:

Occlusion cloud bands are at least in some parts of the cloud band subject to the criterion of the frontal rear side. Although this key parameter is not strictly necessary to identify occlusion cloud bands, it has shown useful in eliminating wrong analyses of that conceptual model.



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**Memory:**

As experience has shown, occlusions undergo rather frequent fluctuations in a small scale. To overcome this problem, the occlusion analysis from the preceding satellite image is displaced with help of the AMVs and included in the present analysis.

**Additional:**

In the detection mechanism two probability areas are involved. Occlusion tags are diagnosed across the union of the probability areas. A mechanism has been included to extend the occlusion tags (once analysed) to the limits of the cloud band. In the same way, occlusion tags are extended over a small area filled with CF tags if they are located next to or within the occlusion.

**2.3.1.3.2 Key parameters used in the ASIINWP product**

The occlusion analysis in ASIINWP adopts the ASII analysis, i.e. the occlusion analysis from the satellite image cannot be overruled by the ASIINWP analysis. Instead, ASIINWP searches for occlusions which could not be detected from the imagery alone. Additionally to the ASII criteria, the following NWP criterion is used:

**Relative vorticity at 500 and at 850 hPa:**

Occlusion cloud bands are connected to the big low pressure centres which extend throughout the whole troposphere. The field of the relative vorticity reflects the pressure field at a certain level. Therefore, thresholds have been assigned to the different levels:  $4 \cdot 10^{-6} \text{ s}^{-1}$  for the vorticity at 850 hPa and  $6 \cdot 10^{-6} \text{ s}^{-1}$  for the vorticity at 500 hPa. Both thresholds have been chosen empirically. The radius of the probability fields is 10 grid meshes for both.

**Additional:**

Occlusion tags are not allowed in a probability region along the zero line of the relative vorticity at 500 hPa. This criterion is necessary to avoid that occlusion tags are embedded in CFs.

### 2.3.1.3.3 Schematics of the diagnostic procedure

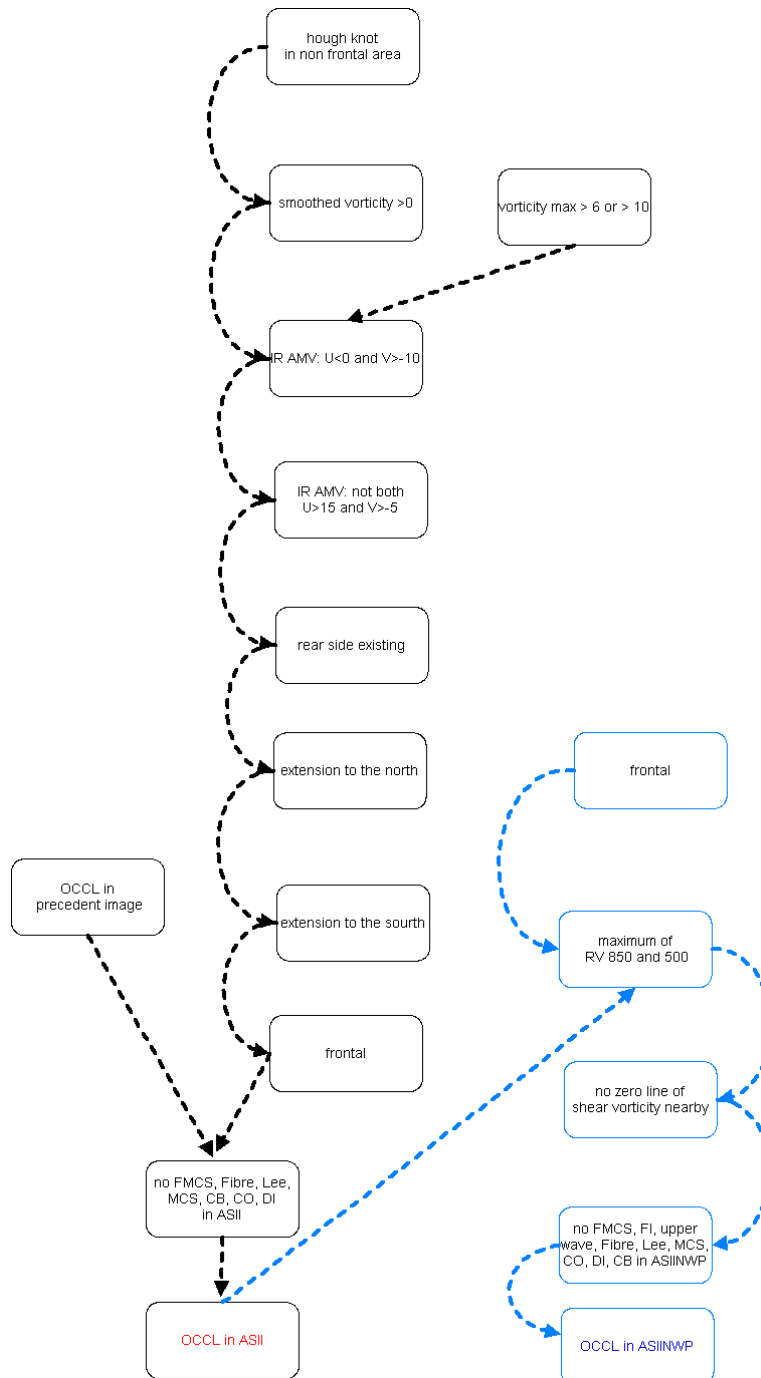


Figure 5: Processing chain for the detection of an occlusion in ASII (black) and ASIINWP (both black and blue parts)

### 2.3.1.3.4 Practical application rules and inherent problems

#### General application rules:

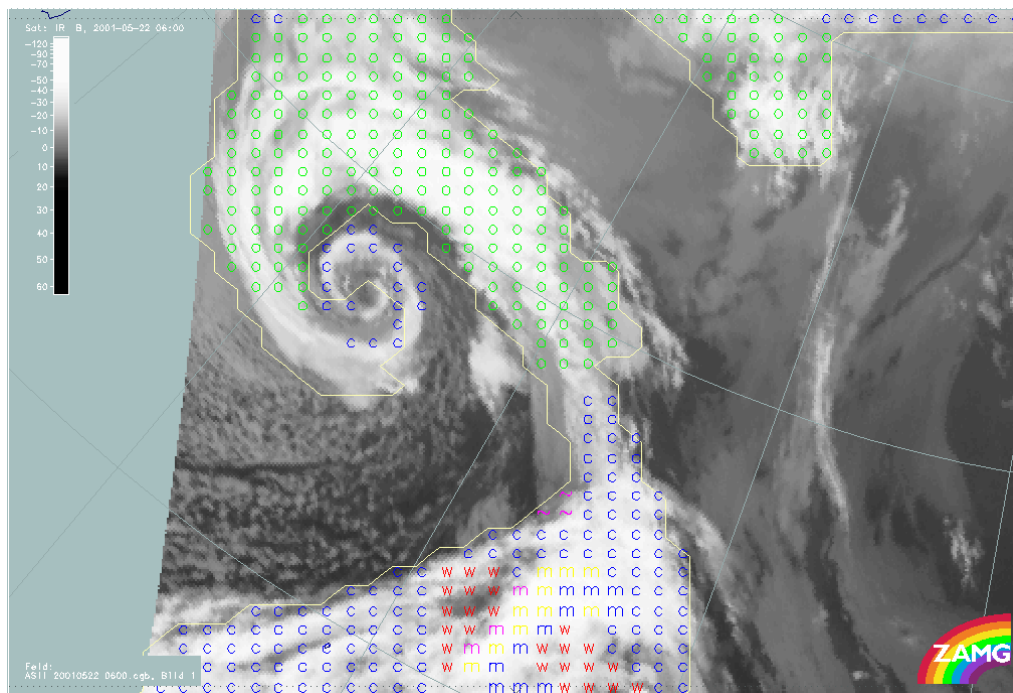
- If an occlusion is analysed in ASII, forecasters can be sure that there is an eastward component in the IR AMVs within a cloud spiral;
- If an occlusion is analysed in ASIINWP, forecasters can be sure about the spiral character as well as about an existing low pressure centre throughout the whole troposphere.

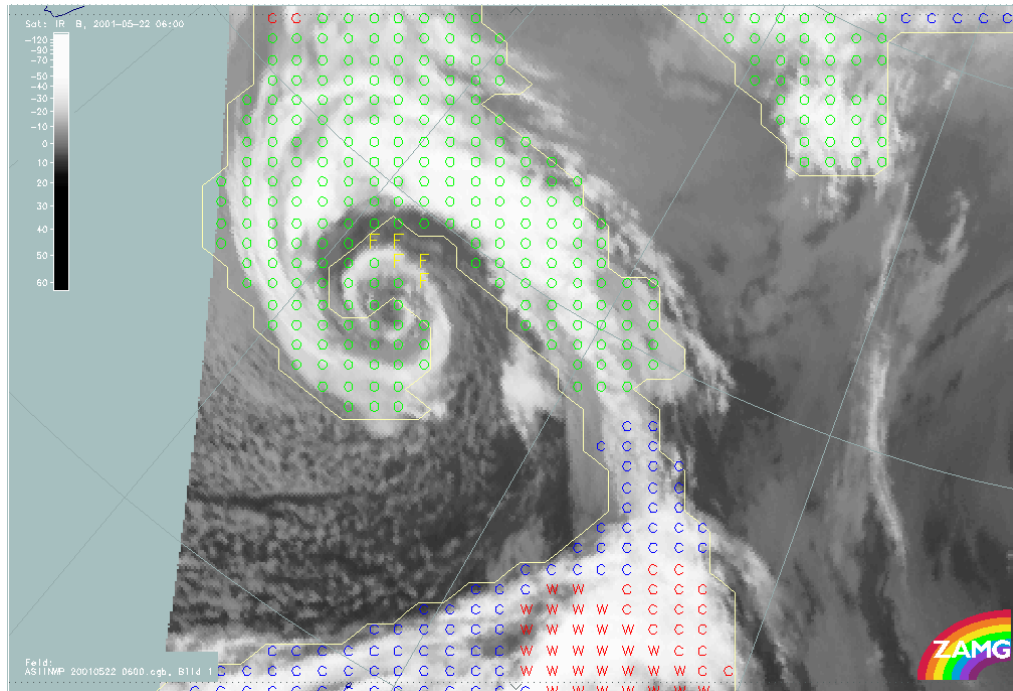
#### Comparison ASII vs. ASIINWP:

- The innermost parts of occlusions often are diagnosed as CF in ASII due to the fact that the IR AMVs are western again (see inherent problems below).
- Those areas are correctly diagnosed as occlusion with help of the criteria used in ASIINWP.
- Consequently a comparison of ASII and ASIINWP helps to correct the apparently wrong ASII diagnosis.
- Sometimes old occlusion cloud bands in dissolution are diagnosed as comma in ASII and in ASIINWP; this is an indication that the cloud area is discontinuous.



### Inherent problems

- As in ASII, an eastward component of the IR AMVs is a necessary condition, the innermost parts of the occlusion spirals very often are analysed as CFs; this wrong diagnosis cannot be avoided at the time being but should easily be handled by forecasters for instance by comparison with ASIINWP (see comparison ASII vs. ASIINWP in **Figure 6**).
- Small areas within CFs which are analysed as “occlusion” in ASII are areas within the probability regions of the WV AMV vorticity and the Hough knot and do have an eastward component in the IR AMVs; although those analyses seem to be wrong from a general synoptic view, the conditions just mentioned are fulfilled; sometimes it might indicate an early stage of a wave.





**Figure 6:** Upper panel: ASII analysis of the 06 UTC IR satellite image from 22<sup>nd</sup> May 2001. The spiralled cloud band has been analysed as occlusion (green "o" tags), however with some undesired inclusions of CF (blue \*c\*). Lower panel: ASINWP analysis of the same satellite image.

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### 2.3.1.4 **Wave**

Waves are areas within CF cloud bands where secondary cyclogenesis takes place. Such a process is indicated by a convex bulge of enhanced cloudiness at the rear side of the frontal cloud band; in case of a further development a more and more intensive spiral structure forms, leading to an occlusion cloud spiral. For more details see EumeTrain (2021).

#### 2.3.1.4.1 **Key parameters used in the ASII product**

##### **Frontal rear side:**

Waves can only appear at the rear side of CF cloud bands. For the detailed algorithm of the rear side detection see chapter 3.1.9 in [RD.4].

##### **WV-AMV curvature vorticity:**

The WV AMV curvature vorticity is calculated from the water vapour (WV)-AMV field. Vorticity maxima ( $> 4$  units) near the frontal rear side are selected and a probability region with a radius of 4 grid meshes size is chosen around the relative maximum. The relative vorticity maximum must be in the cold air behind the frontal area and consequently the probability region around the maximum overlaps the frontal cloud band.

##### **S-line detection:**

The frontal rear side at the place where a frontal wave emerges usually exhibits an S-shaped pattern. This pattern is automatically recognised. Three types of S-lines are distinguished:

- Two kinds of short S-lines: they are based on contour lines with two different enhancements.
- A type of large S-line: The same algorithm is used with some modifications in order to analyse large-scale wave structures which are accompanied by rather weak S-lines.

##### **Convex frontal rear sides:**

For a detailed description of the algorithm see [RD.4]. This algorithm is used in addition to the S-line because a large number of frontal waves do not show a complete S-structure; either CFs do not show a clear cyclonic curvature or the CF part of the wave is dissolving and hence not correctly analysed by the contour line. For a positive diagnosis of frontal waves, only one of the two algorithms needs to give a positive result. For the localisation of the wave tags see “inherent problems”.



##### **Memory:**

Waves detected with help of the S-line detection in the preceding satellite image are displaced with help of the AMVs. If they fail to fulfil the above mentioned key parameter criteria, they are once again examined with a lower curvature vorticity threshold (3 instead of 4 units).

##### **Additional:**

Once the above-mentioned criteria are fulfilled for an s-line segment (or a convex area), the wave tags are finally extended over the whole wave pattern. This facilitates the visual assignment to the affected wave pattern.

A motion-corrected image field, also called development image (see chapter 2.2.2) is used to give some hints about the development of cloudiness. A developing wave is characterised by increasing cloudiness which is reflected in positive values of deviation computed from the motion-corrected difference image. In the time period of half an hour, the pixel values in the wave region must have increased by at least 5 units. For large S-lines, no representative development value can be found for the whole wave area due to a high small-scale fluctuation of the development field; hence, no information about the stage of development can be given.

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To avoid that MCS embedded at the rear of frontal cloud bands are analysed as large waves, wave tags are suppressed in the neighbourhood of MCSs.

Occlusion cloud bands often exhibit structures which are interpreted by the S-line detection module as well as by high curvature vorticity as frontal waves, although from a synoptic point of view, they have nothing in common with the latter. To avoid this kind of wave analysis, occlusion diagnosis is dominant over waves.

#### **2.3.1.4.2 Key parameters used in the ASIINWP product**

The wave detection from ASII is also used for ASIINWP. Additionally the following NWP input data are required:

##### **PVA at 500 hPa (PVA500):**

The PVA at 500 hPa is very indicative for a wave representing its deepening. The maximum of positive vorticity advection at 500 hPa must exceed  $4 \cdot 10^{-9} \text{ s}^{-2}$  (an empirically determined threshold). The radius of the probability field is 3 grid meshes.

##### **Relative vorticity at 850 hPa (RV850):**

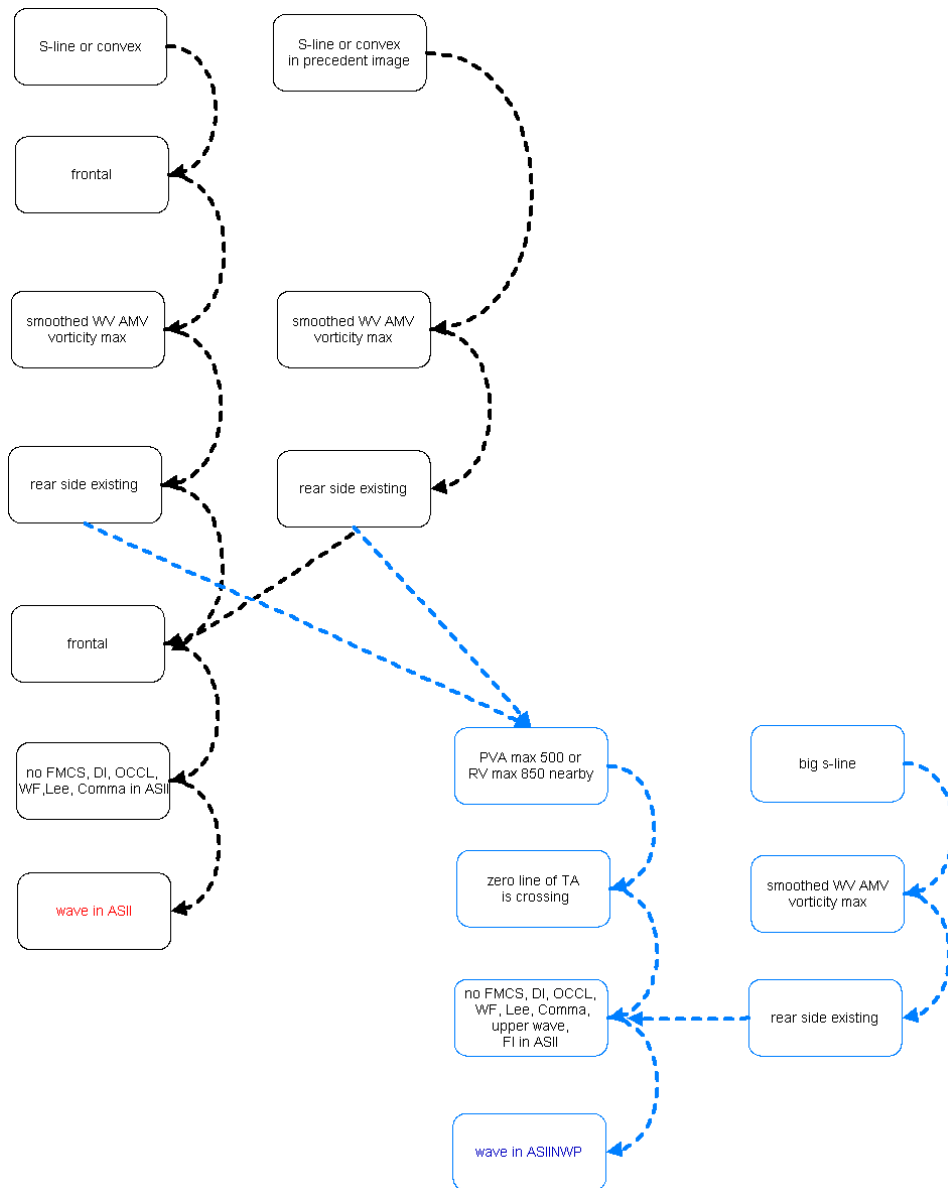
The development of frontal waves goes hand in hand with the deepening of the surface trough and the formation of a surface pressure minimum. Hence, the maximum of the relative vorticity at 850 hPa must exceed  $6 \cdot 10^{-6} \text{ s}^{-1}$ , a threshold which has been chosen empirically. The radius of the probability field is the same as for PVA500.

For the wave detection, only one of those two criteria (either PVA500 or RV850) needs to be fulfilled.

##### **Temperature advection at 700 hPa (TA700):**

The zero line of the temperature advection crosses the centre of the wave region. This criterion indicates a change of the temperature advection from CA to WA. A probability region extending 4 grid meshes to each side of the zeroline is chosen.

### 2.3.1.4.3 Schematics of the diagnostic procedure





**Figure 7:** Processing chain for the detection of a wave in ASII (black) and ASIINWP (both black and blue parts)

### 2.3.1.4.4 Practical application rules and inherent problems

#### General application rules:

- If in ASII a wave is analysed forecasters can be sure that there is a convex cloud bulge at the rear side of a frontal cloud band exceeding the implicit thresholds;
- If in ASIINWP a wave is analysed, forecasters can be sure that additionally to the existence of the cloud bulge in the cloud satellite image all other physical-meteorological conditions like WA-CA maximum, a surface pressure minimum and/or a PVA maximum at high levels are fulfilled.

#### Comparison ASII vs. ASIINWP:

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- If a wave is analysed in ASII, but not in ASIINWP, this means that at least one of the necessary NWP parameters is not fulfilled. There are some possible interpretations:
  - the wave bulge does not represent a classical front at the time of the imaging;
  - the NWP model does not yet recognise the wave and therefore the ASII diagnosis has to be observed carefully for possible further development;
  - there might be an NWP error.

### **Inherent problems:**

- The localisation of the wave tags is done according to fixed rules and does not always correspond to the physically related wave centre. The following rules are applied:
  - For a wave detection based on the S-line algorithm that part of the S is diagnosed as wave that corresponds to a frontal rear side;
  - For a wave detection based on the “convex” algorithm, that part of the convex line that corresponds to a rear side is diagnosed as wave which should be rather downstream of the physical-meteorological wave position;
  - If both detection criteria are fulfilled, the wave assignment according to the S-line is used.
- In the wave detection algorithm, rather sensitive thresholds are involved; consequently if parameters are close to these thresholds an unstable wave diagnosis might result: the wave diagnosis is interrupted for small time intervals within a longer time period where wave tag are analysed.
- Such a situation can be taken as a sign for a rather stationary wave bulge.
- Large S-lines do not contain a development value.
- The assignment of wave tags is driven by optical criteria (S-line, convex cloud bulge) and might therefore be in a wider area compared to the small scale of the position of the corresponding surface low.

### **2.3.1.5 Upper Wave**



An upper wave is accompanied in the initial stages by a convex bulge of enhanced cloudiness on the rearward side of frontal cloud bands (mainly CF), very similar to a classical wave. A detailed inspection of the images shows hardly any differences to classical wave developments. There might be a tendency that cloud edges of jet waves are sharper with very bright grey shades. The differentiation can be accomplished with help of relevant numerical parameters which show the connection to the right entrance region of a jet streak; as upper waves appear in the area of CA usually there is not much potential for a development. For more details see EumeTrain (2021).

#### **2.3.1.5.1 Key parameters used in the ASII product**

An upper wave cannot be analysed as such from the satellite imagery alone since there is no remarkable difference to the appearance of classical frontal waves. Consequently in ASII a wave will be detected in the area of an upper wave if the criteria for waves are fulfilled, i.e. if the cloud bulge is distinct enough.

The following satellite criteria are used and shortly summarised (for more details see chapter "wave", 2.4.1.4): “Frontal area”, “Frontal rear side”, “S-line detection”, “Convex frontal rear sides”.



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### 2.3.1.5.2 Key parameters used in the ASIINWP product

Whether a wave, which is detected in ASII, is a classical wave or an upper wave feature can be detected primarily with the help of the NWP fields since the satellite image gives neither reliable information about the location of a jet streak nor about the reached wind speeds. Consequently the detection of a wave bulge from ASII is used by ASIINWP, but in addition the following parameters from NWP are inspected:

#### **Wind speed at 300 hPa (V300):**

By definition, the wind speed within a jet streak has to exceed 30 m/s. The threshold chosen here is fixed at 20 m/s so that model errors like underestimation of the real wind speed or displacement of the jet axis or simply the fact that the jet level is not at 300 hPa, are taken into consideration.

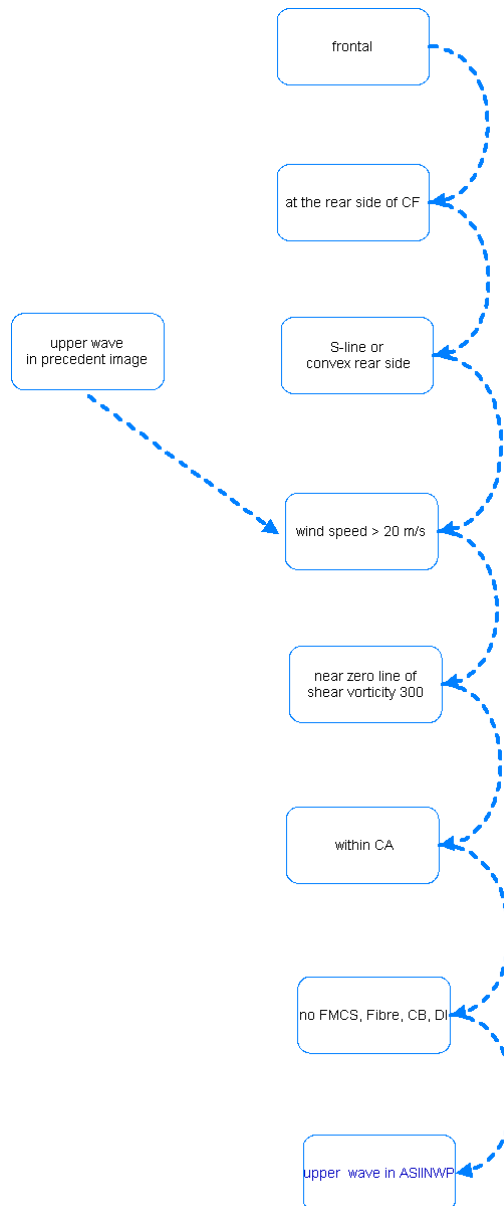
#### **Temperature advection at 700 hPa (TA700):**

As mentioned above an upper wave is located in CA. Therefore a large part of the corresponding cloud band has to be under the influence of CA.

#### **Zero line of the shear vorticity at 300 hPa (RSV300):**

As the zero line of shear vorticity indicates the jet axis a region is defined along the zero line of the shear vorticity at 300 hPa indicating the area where an upper wave is expected. The upper wave should be located within such a region.

### 2.3.1.5.3 Schematics of the diagnostic procedure



**Figure 8:** Processing chain for the detection of an upper wave in ASII (black) and ASIINWP (both black and blue parts)

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.



### 2.3.1.5.4 Practical application rules and inherent problems

#### General application rules:

- If in ASII a wave and in NWP an “upper wave” is analysed a forecaster can be sure that the wave bulge is under the influence of CA and within a jet maximum.

#### Inherent problems:

- Problems concerning the stability of the wave detection are the same as for waves (see above).

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- Upper waves appear at the rear side of CFs which are widely under CA (for instance at Anafronts) in heights around 300 hPa (jet level). Nevertheless the 700 hPa level is used for the evaluation of the temperature advection. Some misclassifications may arise from this level inconsistency.

### **2.3.1.6 Front Intensification (FI) by Jet**

If a jet streak approaches and crosses a frontal zone at a large acute angle, horizontal and vertical increase of frontal cloudiness in the left exit region of this crossing jet streak can be observed. These cloud phenomena are produced by the interaction between the circulation within the front and within the exit region of the jet streak. For more details see EumeTrain (2021).

#### **2.3.1.6.1 Key parameters used in the ASII product**

The CM “Front Intensification by jet streak crossing” cannot be found automatically from satellite information alone. The main reason is that intensification within a frontal cloud band is very similar to other CMs like for instance waves, embedded MCSs and Cbs. Nevertheless some basic frontal satellite information is necessary also for the NWP data. This is described in the chapter below.

#### **2.3.1.6.2 Key parameters used in the ASIINWP product**

##### **Frontal areas:**

The CM “FI by Jet Crossing” is a substructure of a CF. It must therefore be located within the Frontal Area.

##### **Classification:**

Frontal regions within the left exit region of a jet streak show enhanced cloudiness, sometimes with pronounced convection. Therefore the classification is characterised by categories with high pixel values and a smooth texture showing high pixel gradients at the margin of the enhanced area. The resulting classifications are indicative for bright (cold) cloudiness.

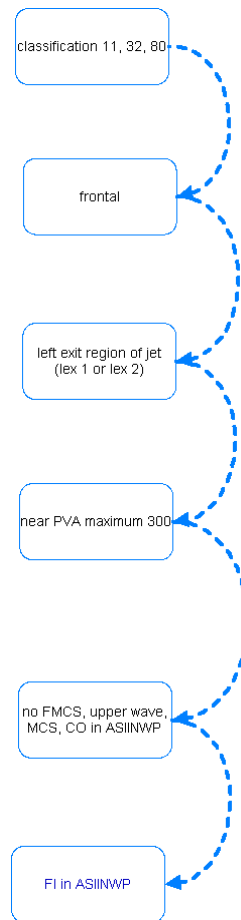
##### **Determination of the left exit region of a jet streak**

This function locates a left exit region with help of the location of the jet axis and the wind speeds. The function determines those points where the zero line of the relative shear vorticity at 300 hPa leaves the area determined by a given wind threshold. The function is applied twice, first with a wind speed threshold of 40 m/s and then with a threshold of 50 m/s. The determination of the left/cyclonic part of the exit region is given by the wind direction at the exit point and is located to the left of the jet axis.

##### **Positive vorticity advection at 300 hPa (PVA300):**

A positive vorticity maximum is required in the left exit region of the jet streak. Every PVA maximum at 300 hPa exceeding  $3 \cdot 10^{-9} \text{ s}^{-2}$  is considered. The region with possible cloud enhancement has to be located within the  $\text{PVA300} = 3 \cdot 10^{-9} \text{ s}^{-2}$  isoline.

### 2.3.1.6.3 Schematics of the diagnostic procedure



*Figure 9: Processing chain for the detection of a front intensification in ASIINWP (both black and blue parts)*

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.



### 2.3.1.6.4 Practical application rules and inherent problems

#### General application rules:

If the CM “JI” (“Front Intensification by Jet crossing”) is analysed in ASIINWP, a forecaster can be sure that a PVA maximum in connection with the left exit region of a jet streak (on its cyclonic side) is superimposed on a frontal cloud band.

#### Inherent problems:

As there is no algorithm to distinguish between a PVA maximum caused predominantly by shear (as it is the case in the left exit region of a straight jet streak) and one caused predominantly by curvature (as is the case at the rear side of a frontal cloud band) a mixing of these two situations sometimes might happen.

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### **2.3.1.7 Dry Intrusion (DI)**

A dry intrusion (DI) is characterised by a black stripe in the WV imagery, located at the rear side of a CF (indication for a Split Front), or more frequent, near the occlusion point of a well-developed frontal system. In some cases, DI-tags are located in the vicinity of the cloud head of a developing Rapid Cyclogenesis. If the latter is the case, the drying air from above indicates the progression of the cyclogenetic process. For more details see EumeTrain (2021).

#### **2.3.1.7.1 Key parameters used in the ASII product**

##### **Areas in the vicinity of fronts:**

A dry intrusion can be analysed outside the frontal area. But because of its strong connection to CF it has to be situated very near to a frontal area.

##### **Frontal rear side:**

A dry intrusion can only develop near a frontal rear side.

##### **Detection of black stripes in the WV image:**

With the pattern recognition method for the automatic detection of black stripes in WV images, elongated areas of low WV content (so-called "black stripes") are sought.

##### **Intersection of WV black stripes with the frontal rear side:**

A main characteristic of the dry intrusion is the sinking dry air at the rear side of a CF accompanied with a cloud dissolution process. The intersection of the black WV stripe with the frontal cloud band is determined automatically. In this special case the determination of the frontal cloud band is done with the algorithm to identify contiguous areas (cf 2.2.5) alone, whereas in all other cases, the frontal area is reduced by the intersection area with a black stripe.

##### **AMV vorticity:**

The CF and the drying region typically lie in areas with cyclonic vorticity. Therefore a key parameter for the location of a dry intrusion is the positive (large-scale) AMV vorticity.

##### **Memory:**

The outcome of the DI analysis from the preceding satellite image is displaced with help of the AMVs and implemented in the present analysis.

##### **Additional:**

The area where the DI tags are assigned to is dependent on the length of the intersection area with the black stripe and does not reflect the intensity of the process.

#### **2.3.1.7.2 Key parameters from the ASIINWP product**

The satellite part of ASIINWP is identical with the one from ASII. The following NWP fields are required in addition:

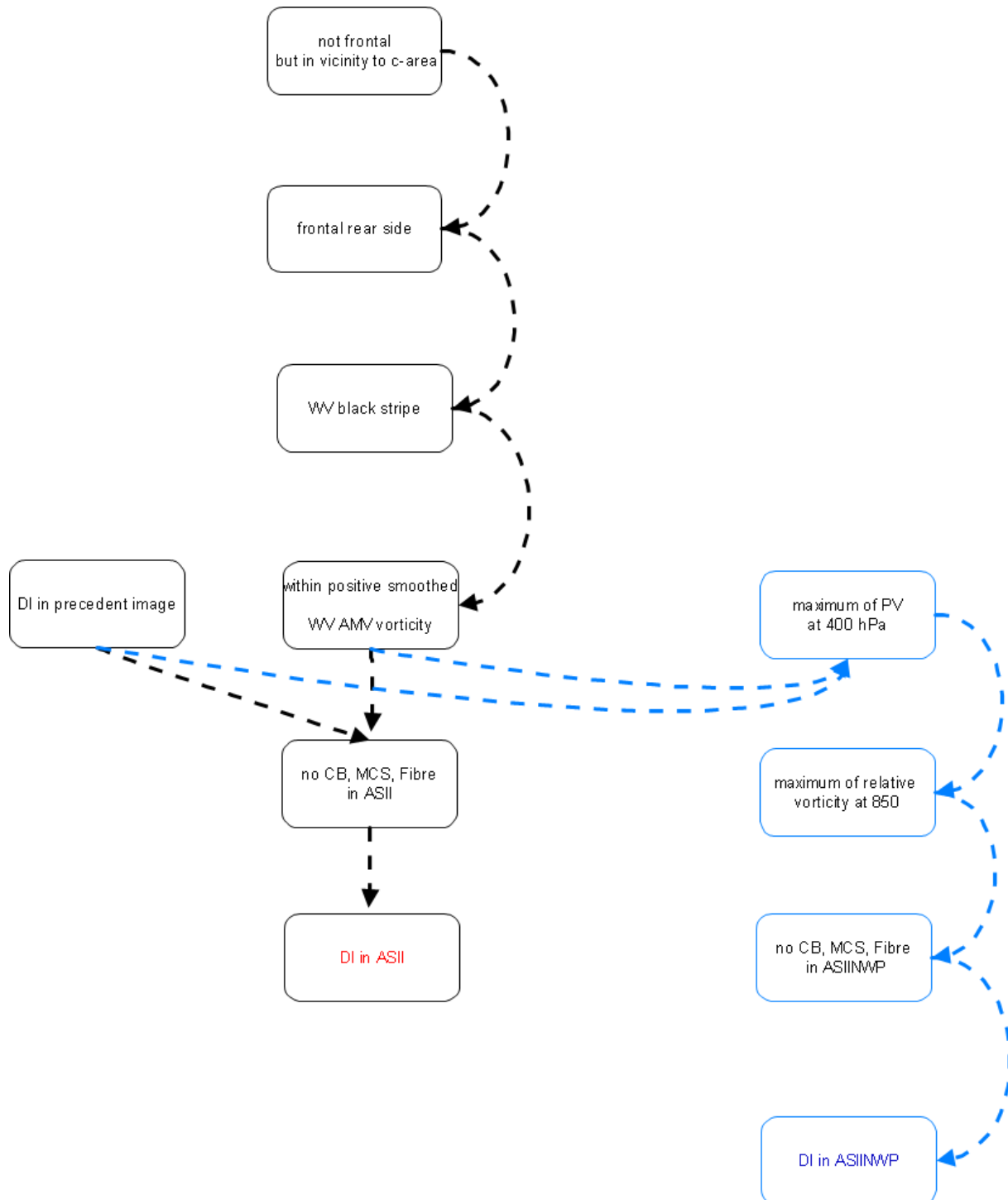
##### **Potential vorticity (PV):**

A main feature from the numerical fields is the presence of a PV maximum in the troposphere. Relative maxima on the 400 hPa level with a value  $>1.25$  PVU are sought. A probability region with a radius of 5 grid meshes around the maximum has been chosen empirically.

##### **The relative vorticity at 850 hPa:**



The relative vorticity maximum at 850 hPa ( $> 6 \cdot 10^{-6} \text{ s}^{-1}$ ) gives an indication for the deepening of the surface trough or the formation of a surface low. The threshold has been chosen empirically. A probability region with a radius of 5 grid meshes around the relative maximum is investigated.

### 2.3.1.7.3 Schematics of the diagnostic procedure



**Figure 10:** Processing chain for the detection of a dry intrusion in ASII (black) and in ASIINWP (both black and blue parts)

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

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#### 2.3.1.7.4 Practical application rules and inherent problems

##### General application rules:

- If a dry intrusion is analysed by ASII, forecasters can be sure that a black stripe in the WV image intersects the frontal cloud band at its rear side;
- These areas can be regarded either as a split front region (when located at the rear side of a CF) or as ongoing cyclogenetic process. In some cases (presence of a cloud head), the DI-tags are a good indicator for a developing Rapid Cyclogenesis.

##### Inherent problems:

The dry intrusion, i.e. the intersection of the frontal area with the black stripe, is a powerful tool but it is not only the sign for a rapid cyclogenesis; it can also represent a developing Kata- or Split front mostly in the area of the occlusion point; in any case the process indicates that drying from above is going on in this area but this does not necessarily mean that an RC will develop.

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### 2.3.1.8 Upper Level Low

Upper Level Lows are the result of a cut-off process at high levels (e.g. 500 hPa) without any correspondence in low levels (1000 – 850 hPa) . An upper level trough (“Trough stage”) becomes deeper and sharper and starts to be torn off from the main westerly flow (“Tear-off stage”). In the end phase the trough is cut off from the main flow to the north (“Cut-off stage”). Cloudiness connected to this process consists of remnants of a frontal cloud band at the leading side as well as convective cloud types in the centre of the trough/low. For more details see EumeTrain (2021).

#### 2.3.1.8.1 Key parameter used in the ASII product

There is no special module to analyse upper level lows in the ASII product since there is no cloudiness which typically appears only with ULLs. But cloud configurations like frontal cloud bands can be observed at the leading edge, convective cold air features in the centre and sometimes fibrous cloud elements at the rear side. Those cloud systems are diagnosed separately (for instance as comma, Cb, CF, occlusion, etc.) but their co-existence and relation to the ULL cannot be diagnosed from satellite features alone.

#### 2.3.1.8.2 Key parameters used in the ASIINWP product

The CM upper level low (ULL) is analysed only with help of NWP data. The absolute topography at 500 hPa is investigated for a local minimum and then compared with the vorticity field at 850 hPa.

##### **Absolute topography at 500 hPa:**

The upper level low is characterised by a local minimum in the absolute topography at 500 hPa. A probability region is calculated around every local minimum of the geopotential height field.

##### **Relative vorticity at 850 hPa:**

Surface lows are reflected by a maximum of the relative vorticity in lower levels of the atmosphere (e.g. 850 hPa). In case of ULLs there is no or only a very weak corresponding low in lower levels. ASIINWP uses the vorticity at 850hPa instead of the surface field because the latter is too much influenced by planetary boundary layer effects; for a positive ULL diagnosis, the vorticity field has to remain below an empirically chosen threshold of  $6 \cdot 10^{-6} \text{ s}^{-1}$ . The area where no local minimum of the relative vorticity at 850 hPa should be present has a radius of 8 grid meshes (around the prospective ULL centre).

##### **Potential vorticity:**

ULLs are areas where high values of PV have protruded far down into the troposphere. Relative maxima on the 400 hPa level with a value  $>1.25 \text{ PVU}$  are sought.

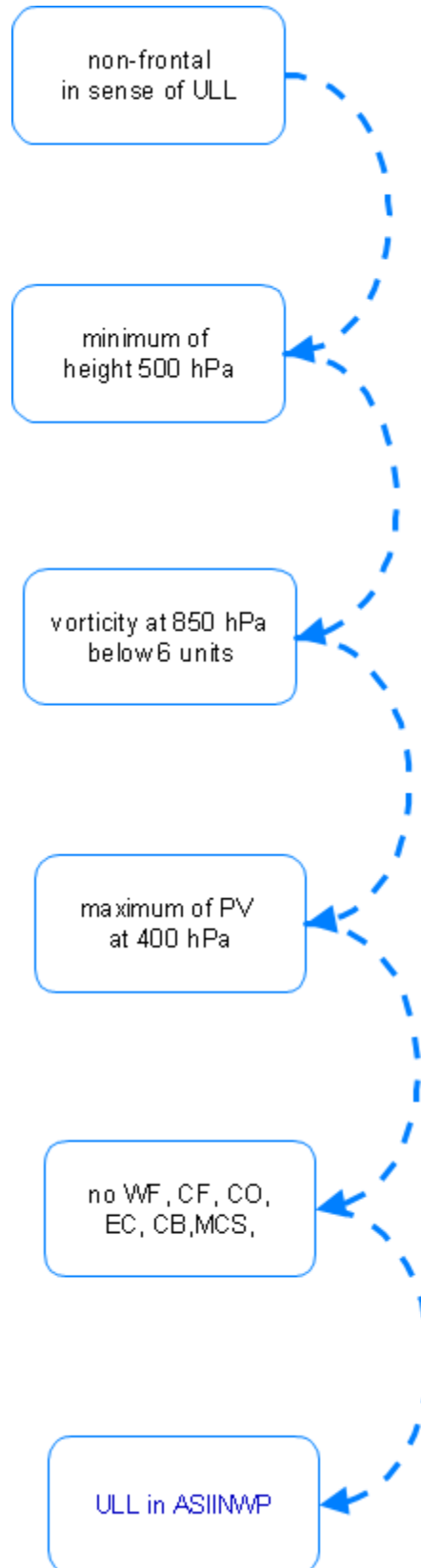
##### **Additional:**

The upper level low tags are placed in the centre of the low pressure area at 500 hPa. If frontal systems are located at the same place as the ULL, the latter are suppressed.



For similar reasons ULLs are rejected in regions where the satellite data indicate a high probability for occlusions.



### 2.3.1.8.3 Schematics of the diagnostic procedure





**Figure 11:** Processing chain for the detection of an upper level low in ASIINWP.

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For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

#### **2.3.1.8.4 Practical application rule**

If an ULL is analysed in ASIINWP, forecasters can be sure that there is a depression at 500 hPa without a corresponding depression at 850 hPa; this upper level depression might also be connected to a small scale trough.

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### **2.3.1.9 Comma Cloudiness**

A comma is a very prominent feature developing and existing in cold air. The comma cloudiness consists of a small cloud spiral consisting of white (i.e. cold) cloud cells partly overlaid by cirrus shields. Sometimes a comma head, which is the enhanced part, and a comma tail, which consists of much smoother and warmer cloud tops, can be discriminated. The scale is between 200 and 1000 km which is much smaller than for a frontal cloud spiral. For more details see EumeTrain (2021).

#### **2.3.1.9.1 Key parameters used in the ASII product**

##### **Sub-frontal area:**

The algorithm for determining frontal areas has been adapted to identify cloud structures of comma size, using the size of the comprised cloud area as main criterion.

##### **WV-AMV vorticity:**

Since comma clouds usually form in the trough region behind a frontal system, the comma detection module searches for an area of the (smoothed) WV AMV vorticity field which exceeds 2 units.

##### **Cloud curvature:**

Starting from the analysis of the cloud texture which represents the main direction of the cloud elements, the curvature radius of the detected comma cloud features is computed. The curvature has to exceed a prescribed threshold in order to fulfil the comma criterion.

##### **Memory:**

Comma clouds from the preceding image are displaced with help of the WV-AMVs to the relevant position in the present analysis.

##### **Additional:**

If the probability regions (WV-AMV vorticity and radius of cloud curvature) cover only parts of the comma, the diagnosis is extended to the whole sub-frontal area.

#### **2.3.1.9.2 Key parameters used in the ASIINWP product**

The NWP branch of the comma detection module uses the same information from the satellite images as ASII. The following NWP criteria are added to the analysis, of which at least one must be fulfilled:

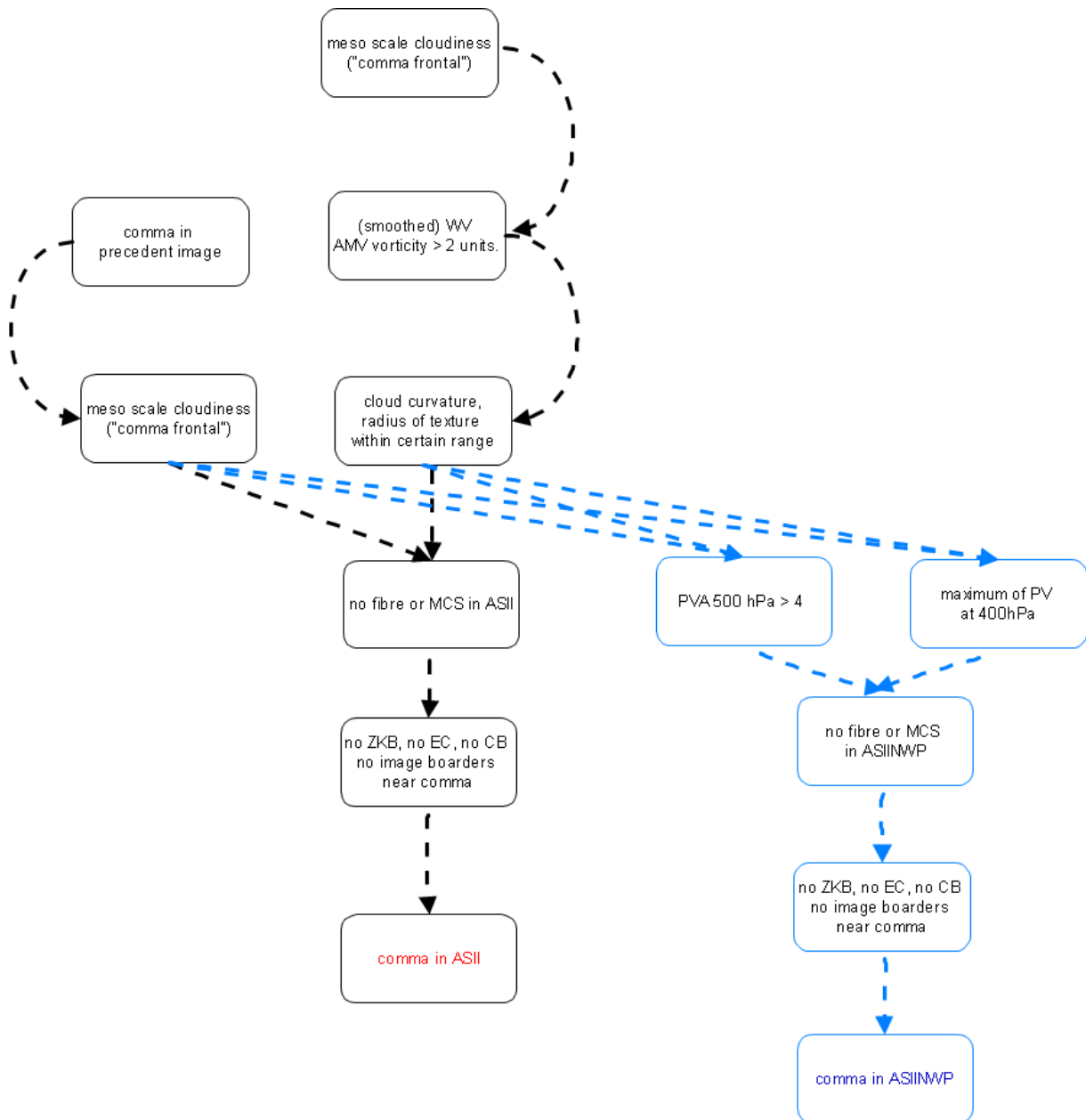
##### **Positive vorticity advection at 500 hPa (PVA500):**

A maximum of the PVA500 field is required for the comma analysis. The threshold for the PVA maximum at 500 hPa is  $4 \cdot 10^{-9} \text{ s}^{-2}$  which is an empirically chosen value. A probability area with a radius of 2 grid meshes around the relative maximum is evaluated.

##### **Potential vorticity (PV):**

A main feature from the numerical fields is the presence of a PV maximum in upper layers of the troposphere. Relative maxima on the 400 hPa level with a value  $>1.25 \text{ PVU}$  are sought.

#### **2.3.1.9.3 Schematics of the diagnostic procedure**





**Figure 12:** Processing chain for the detection of a comma in ASII (black) and in ASIINWP (both black and blue branches)

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

#### 2.3.1.9.4 Practical application rules and inherent problems

##### General application rules:

- If a comma is analysed in ASII, forecasters can be sure that there exists a meso-scale/sub-frontal cloud spiral embedded in a cyclonic wind field;
- If a comma is analysed in ASIINWP, forecasters can be sure that there exists a meso-scale/sub-frontal cloud spiral which is influenced by an upper level vorticity feature.
- Commas might have Cbs and MCSs embedded.

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### Comparison ASII vs. ASIINWP:

If a comma is diagnosed in ASII but not in ASIINWP, the model fields do not confirm the satellite analysis (e.g. the upper level triggering is not existing or too weak)

### Inherent problems:

- The most important problem arises when the comma cloud is close to a CF or occlusion cloud band. The contour line merges in this case the frontal system with the comma cloud and flags both as "frontal". This is caused by the fact that the contour line is derived from a smoothed image. The advantage of this method to determine continuous frontal cloud bands turns into a disadvantage when different cloud systems are close together.

### 2.3.1.10 Enhanced Cumulus (EC)

Enhanced Cumulus cloudiness is an area with cloud cells of increased convective activity, embedded within the cold air cloudiness at the rear of CFs. It is active in respect to shower and thunderstorm activity. For more details see EumeTrain (2021).

#### 2.3.1.10.1 Key parameters used in the ASII product

The EC detection module uses a convective cell detection module (cf. 2.2.6) based on IR satellite pattern. The same detection algorithms are used for the detection of CBs. The output is refined by a difference image (MSG channel 5 – 9) to sort out inactive, convective cell like cloud pattern from active ECs.

#### Frontal area:

This is an indirect usage: Small scale cloud systems (like ECs) are not allowed within a frontal area.

#### WV-AMV vorticity:

ECs usually develop in the upper level trough area behind CFs, in a region characterised by cyclonic vorticity. Therefore the vorticity computed from WV AMVs must be  $> 2$ .

#### CC-Algorithm (Convective Cell detection – Algorithm):

The convective cell detection algorithm has been adapted to the typical EC pattern. Two kinds of ECs are analysed to take seasonal variations into account (for details see chapter 3.1.12 in [RD.4]). For the summer season, ECs show a lower mean brightness and a smaller extension while in the winter season also more extended ECs with a higher mean brightness do exist. This algorithm has been extended by the pattern matching algorithm for CBs.

#### Memory:

The outcome of the CC-Algorithm from the preceding satellite image is displaced with help of the AMVs and assigned to the present analysis if the other two criteria (WV AMV-vorticity and frontal area) are fulfilled.

#### Additional:

CB and EC are very similar phenomena seen from the involved physical processes. Nevertheless we differentiate these two conceptual models. A main criterion for separation is their respective location to frontal systems. EC can be found at the rear side of CFs, i.e. in an upper level trough. CBs are located in the unstable air of a thickness ridge, e.g. in front of a frontal system or in areas with weak pressure gradients.

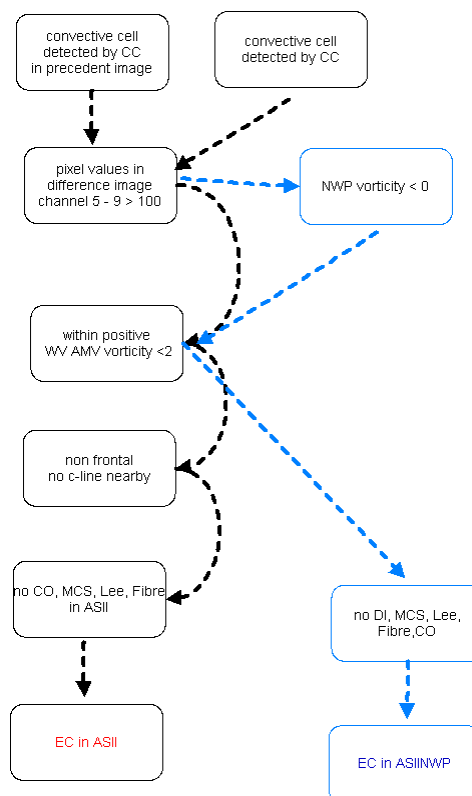
### 2.3.1.10.2 Key parameters used in the ASIINWP product

All satellite input parameters from ASII are used in the ASIINWP product. The following NWP input is required:

#### Vorticity at 500 hPa:

EC must be situated in an area with vorticity at 500 hPa above  $2 \times 10^{-6} \text{ s}^{-1}$ .

### 2.3.1.10.3 Schematics of the diagnostic procedure



**Figure 13:** Processing chain for the detection of EC in ASII (black) and in ASIINWP (both black and blue branches)



For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

### 2.3.1.10.4 Practical application rules and inherent problems



#### General application rules:

- If “EC” is diagnosed in ASII or ASIINWP forecasters can be sure that there is a cluster of bright (cold) small convective cells in a large scale area with cyclonically curved WV AMV streamlines.
- There are five different CMs in ASII/ASIINWP dealing with convective cloud features: Cbs and Cb cluster, MCS (Mesoscale Convective Systems), EC (Enhanced Cumuli), commas and cold air cloudiness.
- If “EC” are diagnosed, forecasters can be sure that:
  - smaller convective cells than those diagnosed for MCS are forming a cluster;
  - it does not form a mesoscale curved cloud feature (as a comma).

#### Comparison ASII vs. ASIINWP:

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If “EC” is only diagnosed in ASII but not in ASIINWP, the PVA condition used in ASIINWP is not fulfilled.

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### **2.3.1.11 Cumulonimbus Cluster (Cb)**

Cumulonimbus clusters are aggregations of single Cbs. While the latter are small scale phenomena, the Cb clusters are mesoscale cloud phenomena with an average diameter of approximately 200 km. Cumulonimbus clusters (Cbs) are not restricted to frontal zones, but can develop in the unstable air of the warm sector or in the cold air behind a CF. Cb clusters in warm air do not develop at the boundary of two air masses like cold or warm fronts, but ahead of the CF in the area of a thermal ridge. Cb clusters often are also embedded in cellular cold air cloudiness with tops reaching only to the lower levels of the troposphere. For more details see EumeTrain (2021).

#### **2.3.1.11.1 Key parameters used in ASII**

##### **CC-Algorithm (Convective Cell detection – Algorithm):**

As for the detection of enhanced cumuli, the results from the automatic detection of convective cells (4 cell types) are used for the recognition of CBs.

##### **Motion corrected difference image (see chapter 2.2.2):**

Three stages of the life cycle of convective cells are classified with help of the motion-corrected difference image: developing, mature and decaying:

- Developing Cb: the mean value of all pixels within the grid mesh has increased by more than 10 units in the last half an hour.
- Mature Cb: the mean value of all pixels within the grid mesh has increased by 0 to 10 units in the last half an hour.
- Decaying Cb: the mean value of all pixels within the grid mesh has decreased in the last half an hour.

The detection of Cbs is excluded in trough regions (e.g. behind CFs). There, convective cells are analysed as ECs.

Fibre-like cloud bands are often analysed as a chain of small Cbs. To reduce this kind of false detection, the fibre detection module is used.

Cb cluster located within a frontal system are flagged as embedded convective systems (cf. Table 4 and Table 5).

#### **2.3.1.11.2 Key parameters used in ASIINWP**

The NWP branch of the Cb detection module is based on the same satellite criteria as the ASII branch. The Showalter index is taken as further information from NWP data:

##### **Showalter index:**

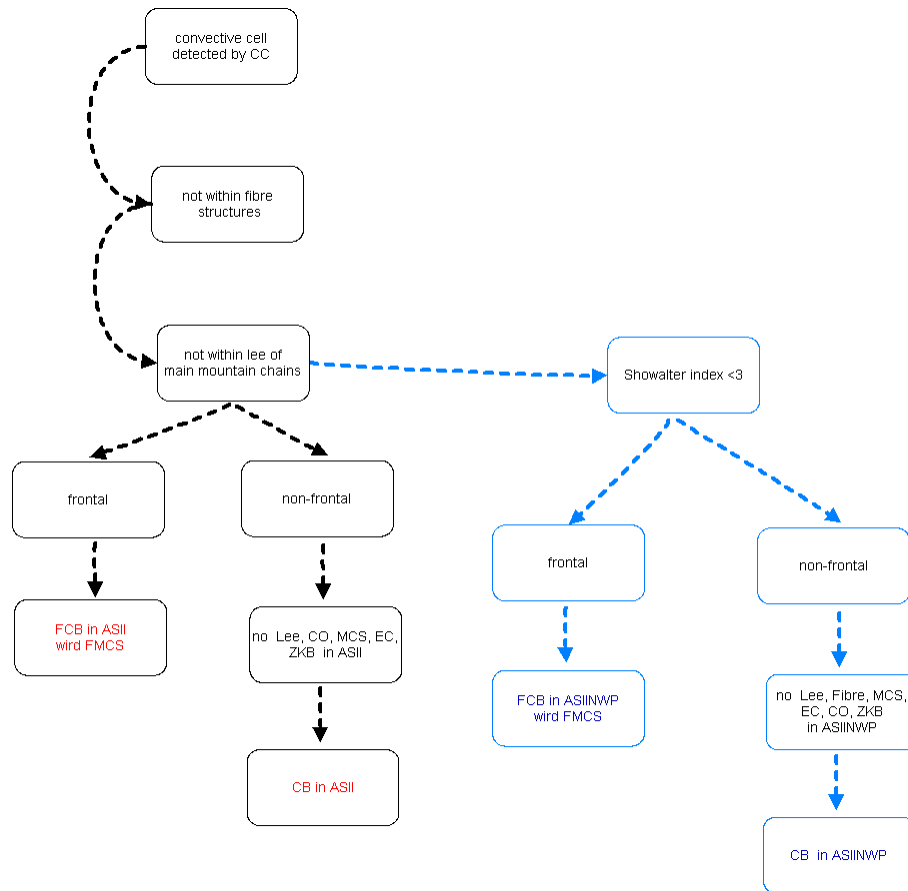
The threshold of the Showalter index is chosen with +3 K. Above that value, air masses are considered as stable and Cb development should not take place, below 3 K the stratification is considered as unstable. Therefore areas with Cbs which are detected in ASII and not in ASIINWP give hints for a stable stratification of the troposphere.

##### **Additional:**

Cb cluster located within a frontal system are flagged as embedded convective cells (cf. Table 4 and Table 5).



### 2.3.1.11.3 Schematics of the diagnostic procedure



**Figure 14:** Processing chain for the detection of a Cb in ASII (black) and in ASIINWP (both black and blue branches)



For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

### 2.3.1.11.4 Practical application rules and inherent problems



#### General application rules:

- If Cbs are diagnosed in ASII forecasters can be sure that there are bright convective cells with some stages of development assigned.
- If Cbs are diagnosed in ASIINWP forecasters can be sure that there are bright convective cells in an unstable environment with some stages of development assigned.
- There are five different CMs in ASII/ASIINWP dealing with convective cloud features: Cbs and Cb cluster, MCSs (Mesoscale Convective Systems), ec (Enhanced Cumuli), commas and cold air cloudiness.
- If Cbs are diagnosed forecasters can be sure that:
  - the size is smaller than it is necessary for an MCS
  - it does not form a mesoscale curved cloud feature (as a comma)

#### Inherent problems:

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- The deviation value is computed as mean value for a whole grid mesh. Consequently the deviation value for individual cells within one grid mesh is falsified.
- A major problem arises when Cbs develop in mountainous regions. The ASII Cb detection module cannot differentiate between lee cloudiness and large Cbs from classification alone. One possibility for discrimination is the usage of a stability parameter in ASIINWP. In a stable atmosphere, Cb classifications are eliminated and replaced by lee cloudiness classification.

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### **2.3.1.12 Mesoscale Convective Systems (MCS)**

Thunderstorms appear on different scales:

- Single-cell storms (which mostly are too small to be detected in Meteosat images)
- Multi-cell storms (which consist of several single cells in different stages of development)
- Super-cell storms (which are huge single-cell storms)

Another term commonly used in satellite meteorology is the Mesoscale Convective System (MCS) which forms on a bigger scale. MCSs usually describe multi cell storms, but sometimes also are formed by super cell storms.

There exist many definitions for MCS in literature. One frequently used is: Deep convective system which is considerably larger than an individual thunderstorm; it is often marked by an extensive middle-to-upper tropospheric stratiform anvil cloud of several hundred kilometres in breadth. For more details see EumeTrain (2021).

#### **2.3.1.12.1 Key parameters used in the ASII product**

The MCS module is based on two different methods to extract MCSs from the satellite image: The first method uses the image classification output, which is based on the analysis of image texture, while the second method uses the Convective Cell-algorithm (CC-algorithm) which is an extraction method on pixel basis.

##### **A) Classification method**

With this method only extended MCSs are diagnosed. In the ideal case an MCS consists of classification 11 (smooth and bright pixels, cf. Table 3) in the centre and is encircled by classification 80 (high brightness gradient between pixels). A neighbourhood function is used to detect this juxtaposition

##### **B) CC-algorithm**

The following criteria are used:

- Temperature threshold
- Relative temperature minimum
- Temperature difference between centre and surroundings.



Both extraction methods have to be fulfilled and the motion corrected difference image is applied for the analysis of the life cycle (see chapter 2.2.2).

##### **Difference image (MSG channel 5 – 9)**

The difference image (channel 5-9) is used to detect high reaching MCS. The temperature difference is useful for determining the cloud top height relative to the tropopause. Positive values of the temperature difference correspond with convective cloud tops that are at or above the tropopause.

##### **Difference image (MSG channel 10 – 9)**

The difference image (channel 10 – 9) is used to detect cirrus clouds. From the satellite viewing angle, the active part of MCS cloud often cannot be determined. This IR temperature difference recognises shallow cirrus clouds (anvil cloud) and helps restricting the MCS analysis to the active part of the system.

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**AMV vorticity:**

The vorticity derived from AMV has to be smaller than 2 units.

**Memory:**

The outcome of the CC-Algorithm from the preceding satellite image is displaced with help of the AMVs and assigned to the present analysis.

**Additional:**

If the analysed cloud feature with classification 11 and 80 nearby is too large (> 60 grid meshes), which sometimes happens in warm front shields, then it is not analysed as MCS anymore.

MCS located within a frontal system are flagged as embedded convective system (cf. Table 4 and Table 5).

**2.3.1.12.2 Key parameters used in the ASIINWP product**

All detection methods from ASII except the AMV vorticity are used for ASIINWP. In addition to this, a stability index and vorticity is used from the NWP data.

**Stability index:**

The MCSs analysed from the satellite data are considered reliable when they are located within unstable air masses (i.e. Showalter index below 3 K). The MCS analysis is rejected, if the Showalter index is above 3 K. Therefore differences in ASII and ASIINWP can be explained by a stability parameter revealing an unstable or stable troposphere.

**Vorticity:**

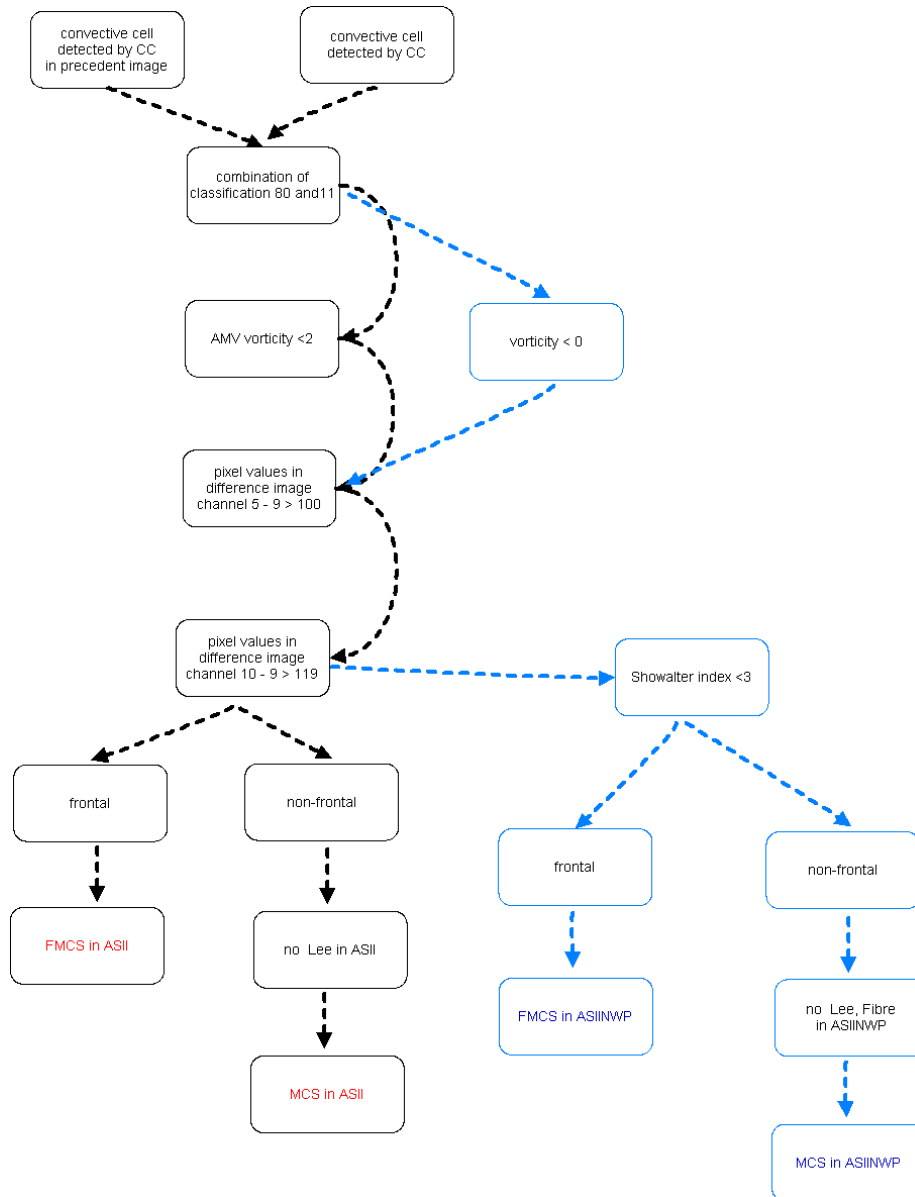
The MCSs must be situated within negative vorticity.

**Additional:**

An MCS is also considered to lie in unstable air if only a small part of the cloud cell lies in a region with a Showalter index < 3 K. The idea behind is to correct for possible uncertainties in the numerical model fields.

MCS located within a frontal system are flagged as embedded convective system (cf. Table 4 and Table 5).

### 2.3.1.12.3 Schematics of the diagnostic procedure





**Figure 15:** Processing chain for the detection of an MCS in ASII (black) and in ASIINWP (both black and blue branches)

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

### 2.3.1.12.4 Practical application rules and inherent problems

#### General application rules:

- If MCSs are diagnosed in ASII forecasters can be sure that there are extended bright convective cells with some stages of development assigned.
- If MCSs are diagnosed in ASIINWP forecasters can be sure that there are extended bright (cold) convective cells in an unstable environment with some stages of development assigned.

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- There are five different CMs in ASII/ASIINWP dealing with convective cloud features: Cbs and Cb cluster, MCSs (Mesoscale Convective Systems), ec (Enhanced Cumuli), comma clouds and cold air cloudiness.
- If MCSs are diagnosed forecasters can be sure that:
  - the size is bigger than it is necessary for a Cb;
  - the brightness is higher than for the single cells forming an “ec”;
  - it does not form a mesoscale curved cloud feature (as a comma);

#### **Comparison ASII vs. ASIINWP:**

- If MCSs are diagnosed in ASII but not in ASIINWP this means that the configuration of an extended convective cell is fulfilled but it appears in a stable area and consequently the MCS diagnosis is cancelled.
- Differences can also occur due to different vorticity fields: AMV vorticity used in ASII can be different from NWP vorticity used in ASIINWP.

#### **Inherent problems:**

- A major problem arises when MCSs develop in mountainous regions. The ASII MCS detection module cannot differentiate between lee cloudiness and MCSs from classification alone. One possibility for discrimination is the usage of a stability parameter.
- When MCSs are analysed from image features alone (ASII branch), they are quite often analysed as embedded MCSs in frontal cloud bands (even within warm fronts). In this case a comparison between ASII and ASIINWP gives hints about stability.

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### **2.3.1.13 Cold air cloudiness**

Cold air cloudiness (open cell convection) develops at the rear side of CFs, during a cold air outbreak at locations where air-sea temperature difference is greatest. The convection is often only 2-3 km deep, the deepest convection occurs ahead of upper troughs. The diameter of the open cells usually increases downstream with a typical aspect ratio of up to 30:1 (diameter:height).

#### **2.3.1.13.1 Key parameters used in the ASII product**

##### **Classification:**

The detection of cold air cloudiness (open cells) is primarily based on the cloud classification. The cellular cloud pattern is represented in classifications with high pixel brightness variations.

##### **WV-AMV vorticity:**

For the identification of the location of the open cloud cells at the position of an upper level trough, the same criterion as for the location of ECs is used, i.e. the vorticity computed from WV AMVs must be positive ( $> 2$ ).

##### **Memory:**

The position of the previously detected cold air cloudiness is memorised and tracked with help of the AMV.

##### **Additional:**

Cold air cloudiness is never embedded in frontal areas (“frontal” as defined in ASII).

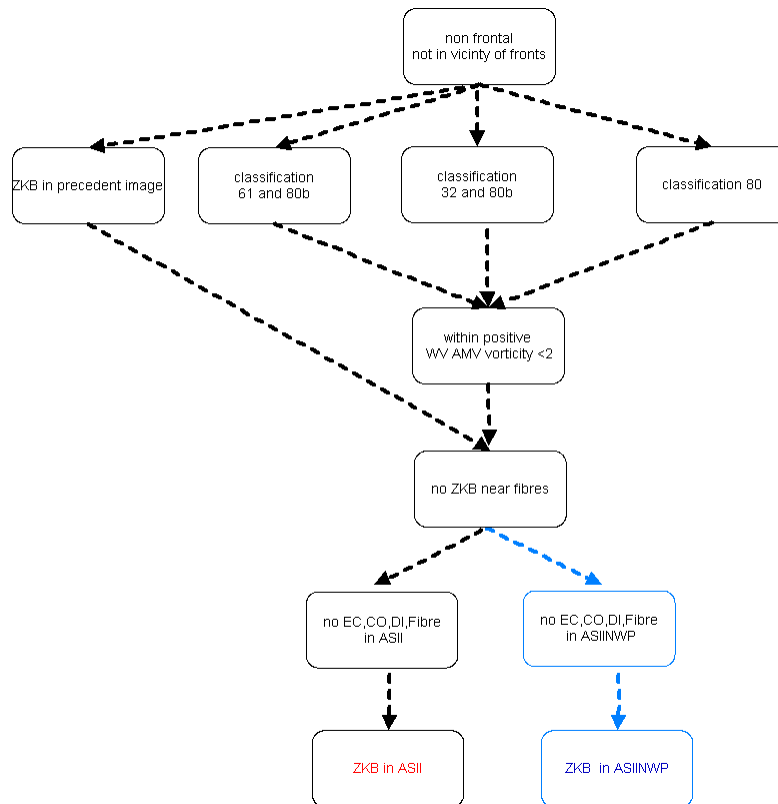
The cold air cloudiness analysis is suppressed at grid-meshes located directly in the vicinity of frontal areas.

The cold air cloudiness analysis is also suppressed if it is situated near fibres.

#### **2.3.1.13.2 Key parameters used in the ASIINWP product**

At the time being, no input parameters are required from the model fields. The open convective cells detection is purely based on parameters derived from the IR and WV satellite images.

### 2.3.1.13.3 Schematics of the diagnostic procedure



**Figure 16:** Processing chain for the detection of a cellular cold air cloudiness in ASII (black) and in ASIINWP (both black and blue branches)

For ranking rules used to decide between two conceptual models appearing feasible at the same location consult Appendix 1.

### 2.3.1.13.4 Practical application rules and inherent problems

#### General application rules:

When “Cold Air Cloudiness” is analysed in ASII or ASIINWP, the forecaster can be sure that the system detects cloud cells located in a trough region.

#### Inherent problems:

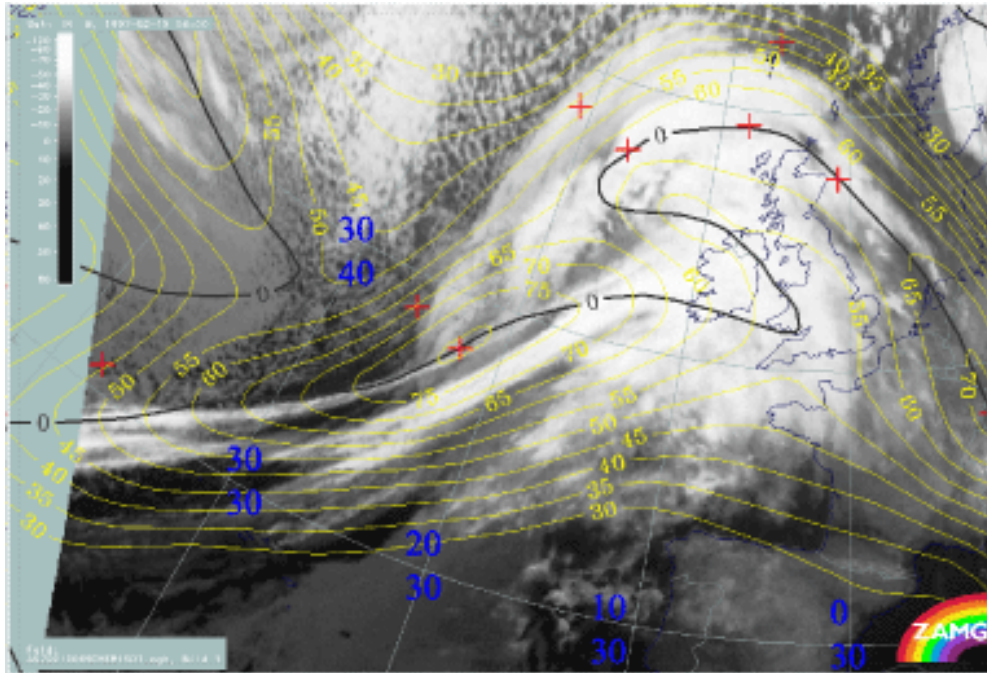
- Since the open convective cells are detected with help of the image classification, it may happen that fewer regions with cold air cloudiness are analysed than the human observer can detect. To avoid an over-analysis of open cells, only those image classifications are used which show in any case widespread convective cells.
- In winter time, open convective cells are often extended over wide areas and exhibiting a very compact structure. These areas are often misinterpreted as frontal areas.

### 2.3.1.14 Fibres

Cloud fibres are narrow cloud lines with a width in the order of magnitude of several tens of kilometres which can extend in length to several thousands of kilometres. They are very bright (cold) in the IR and WV image but only grey, translucent in the VIS image. This is because they develop and exist in high levels close to or directly at the jet axis but on the anticyclonic side.



Their synoptic importance is not only the indication of a jet axis but also the indication for an interaction of fronts with the jet streak. For more details see EumeTrain (2021).



**Figure 17:** IR-satellite image from 19 February 1997, 06 UTC; the fibre extends from about 40N/35W across the Atlantic to about 50N/20W; it accompanies the jet axis (black line is zero line of shear vorticity at 300 hPa)

#### 2.3.1.14.1 Key parameters used in the ASII product

With the automatic fibre detection algorithm all fibre-like cloud structures are detected independent from their physical environment. In ASII the aim is to identify only those cloud fibres which give a hint for the presence of a jet streak at higher levels. Therefore, the WV imagery is also used, especially the automatic recognition of black stripes, to find out the possible location of the jet axis. The following criteria are used:

##### **Automatic fibre detection:**

ASII uses a pattern recognition method to detect fibre-like cloud structures.

Four types of fibres are detected. Two of them are short fibres, one is a medium fibre and the last one is a long fibre. Fibres are arranged according to length and thickness:

- short and thick
- short and thin
- medium and thin
- long and thin

##### **Detection of black stripes in the WV image:**

For details of the WV stripe algorithms see chapter 3.1.13 in [RD.4]. As mentioned above, only the combination of fibre structures and black stripes is diagnosed.

##### **Memory:**

The outcome of the automatic fibre detection from the preceding satellite image is displaced with help of the AMVs and assigned to the present analysis.

**Additional:**

Due to a high similarity of the typical fibre classification to the Cbs the latter are eliminated when they are located within the grid mesh or within one grid mesh distance to the fibre.

**2.3.1.14.2 Key parameters used in the ASIINWP product**

The satellite part is identical with the ASII analysis. In addition the following NWP criteria have been implemented:

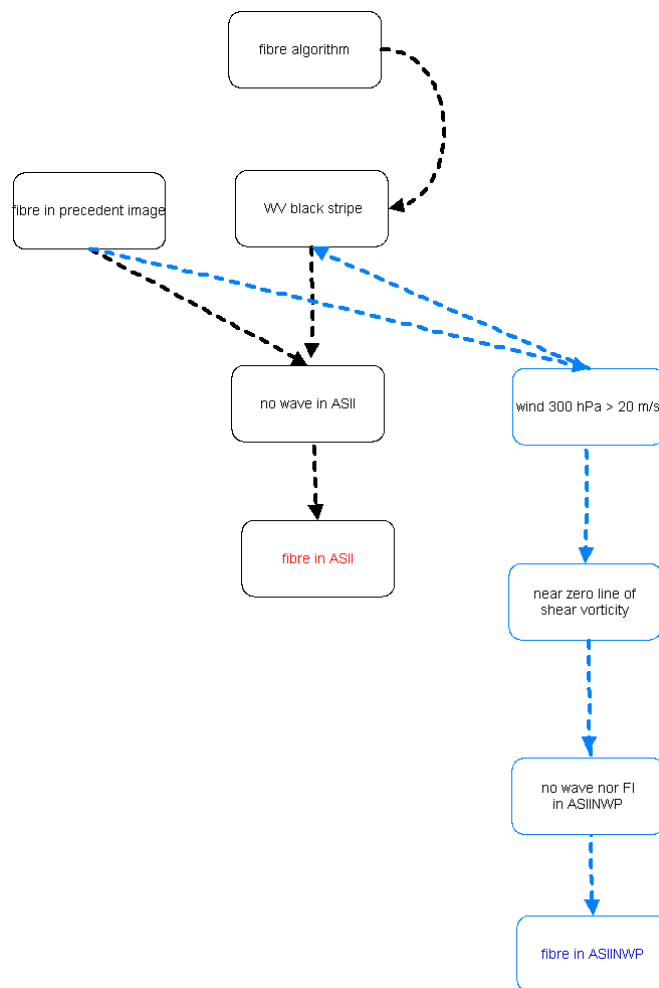
**Wind speed at 300 hPa (FF300):**

The cloud fibre has to be located within the 20 m/s isoline of the 300 hPa wind field.



**Zero line of the shear vorticity at 300 hPa (RSV300):**

The detected cloud fibre also has to be located in a probability region along the zero line of the shear vorticity at 300 hPa which marks the axis of a jet streak. The probability region extends 4 grid meshes in each direction of the zeroline.

**2.3.1.14.3 Schematics of the diagnostic procedure**



**Figure 18:** Processing chain for the detection of a fibre in ASII (black) and in ASIINWP (both black and blue parts)

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For ranking rules used to decide between two conceptual models appearing feasible at the same location consult Appendix 1.

#### **2.3.1.14.4 Practical application rules and inherent problems**

##### **General application rules:**



- If a fibre is detected in ASII forecasters can be sure that a fibre feature is next to a black stripe in the WV image; a situation which is very indicative for a jet axis.
- If a fibre is detected in ASIINWP forecasters can be sure that a fibre feature is next to a black stripe in the WV image and accompanied by a jet streak (wind speed and jet axis) at 300 hPa.

##### **Comparison ASII vs. ASIINWP:**

If a fibre is detected in ASII but not in ASIINWP, the model fields do not confirm the satellite analysis (e.g. no jet streak is superimposed).

##### **Inherent problems:**

- There are rather sensitive thresholds, for instance concerning width in the automatic fibre detection algorithm. Consequently, some typical fibre configurations have to be fixed. This can lead to the fact that some fibres which fail the threshold even only marginally are not detected.
- If smaller Cbs are configured in form of lines with small distances between the single cells they might be wrongly diagnosed as fibre.

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### 2.3.1.15 Lee cloudiness

Lee cloudiness is the result of an orographically influenced air flow on the lee side of the mountain crest. Depending on the atmospheric conditions two kinds of cloudiness can be observed:

- Lee waves, which are characterised by narrow cloud bands quite perpendicular to the wind direction. The wave length can range from few kilometres to some tens of kilometres. They can be observed most easily in high resolution images (like from polar-orbiting satellites). Their crests are always white in the visible picture but in the IR image they can vary from white to dark grey.
- High lee cloudiness which consists of Cirrus cloudiness reaching from the mountain chain into the leeward side, in some cases up to the extent of 1000 kilometres and more. They are lee waves with a much longer wave length. They are very bright (cold) in the IR images. Sometimes they can be detached from the mountain by strong winds and then seem to start far away from the obstacle.

For more details see EumeTrain (2021). Note: The lee cloudiness detection in ASII and ASIINWP deals only with the type of high lee cloudiness.

#### 2.3.1.15.1 Key parameters used in the ASII product

##### **Mountain mask:**



At present the following mountain ranges are taken into account:

- Alps
- Apennine
- Carpathian mountains
- Central and South Italy
- Corsica
- England
- Greenland
- Iceland
- Pyrenees
- Peloponnes
- Sardinia
- Scotland

The mentioned mountain ranges are introduced into the algorithm as one straight barrier; they are not differentiated into sub-parts with different orientation or valleys.

##### **Wind field (WV-AMVs):**

Lee cloudiness is a phenomenon which can best be seen in the IR image loop. Cloudiness remains stationary for many hours at the upwind edge close to the mountain chain. The strong winds, necessary for the development of lee waves, are reflected in the WV motion vectors. An empirical

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threshold of 10m/s is chosen, to differentiate lee cloudiness from orographically induced convection.

**Pixel brightness difference:**

Typical lee cloudiness forms at the lee side of an orographic barrier, consequently high pixel values are located at one side of the mountain range and lower pixel values (land surface or lower cloud) on the other side. It has shown useful to set a minimum threshold for the brightness (temperature) of the lee cloudiness at -44°C. If this condition is fulfilled, the detection module checks the other side of the mountain range (windward side). There, cloudiness should have pixel values below -44°C. The rather cold threshold of -44°C is motivated by barrage cloudiness which often appears in combination with Lee cloudiness.

**Memory:**

The lee cloud analysis from the preceding satellite image is displaced with help of the AMVs and assigned to the present analysis.

**Additional:**

If MCSs with a classification 11 and 80 (cf. Table 3) are detected, lee cloudiness tags (if analysed) are suppressed. Classification 11 and 80 represents an extended area of very bright mean pixel values and are therefore very close to the pixel threshold of 175 chosen for the lee cloudiness.

**2.3.1.15.2 Key parameters used in the ASIINWP product**

The satellite part of the lee cloud detection module in the NWP branch is the same as in ASII. Additionally the following NWP parameter is used:

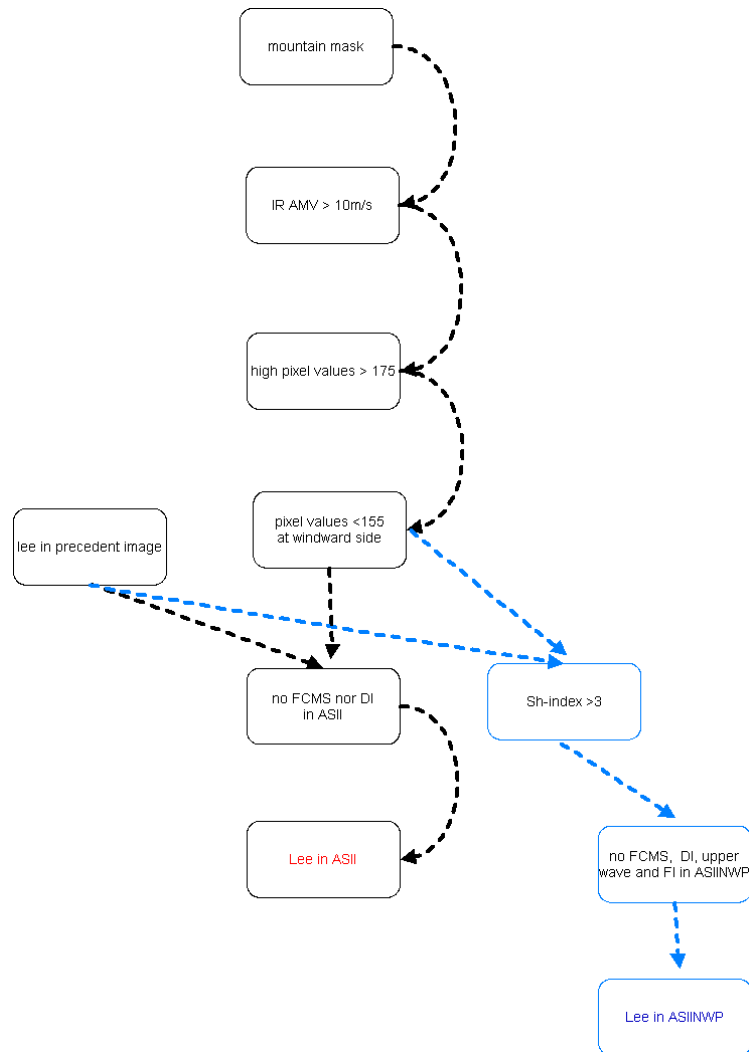
**Stability:**

As discussed below, lee cloudiness is often confused with MCS or Cbs in the mere satellite analysis. One attempt to eliminate MCS or Cb analysis in favour of lee cloudiness is to introduce a stability index. Stable stratification with a Showalter index above 3 K is required for lee cloudiness.

**Additional:**

If MCSs (combination of classification 11 and 80) are detected, lee cloudiness tags (if analysed) are suppressed. A subsequent check according to instability is discussed above.

### 2.3.1.15.3 Schematics of the diagnostic procedure



**Figure 19:** Processing chain for the detection of lee clouds in ASII (black) and in ASIINWP (both black and blue branches)

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

### 2.3.1.15.4 Practical application rules and inherent problems



#### General application rules:

- If lee cloud is diagnosed in ASII forecasters can be sure that there is some orographically induced cloudiness at the mountain range, showing higher and colder tops at the lee side of the mountains with WV motion vectors  $> 10\text{m/s}$ .
- If lee cloudiness is confirmed by ASIINWP, forecasters can also be sure that the model fields exhibit a stable stratification.

#### Comparison ASII vs. ASIINWP:

If there is lee cloud analysed in ASII but not in ASIINWP this means that there is an unstable troposphere and the existing cloud might be Cbs or MCSs.

#### Inherent problems:

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- Cbs, MCSs and lee cloudiness are three types of cloudiness which often show similar patterns in the IR image. Especially convective cells formed in mountainous areas are hard to discern from lee cloudiness. More often, lee cloudiness is analysed as MCS or Cb cluster due to its classification (80 or/and 11) and the high contrast between overcast and cloud free areas.
- Detached lee cloudiness which is already far from its originating mountain (and hence the mountain mask) cannot be detected.
- Problems also arise when lee cloudiness is embedded in a frontal cloud band, because the pixel difference between windward and lee side often is not fulfilled.

### 2.3.2 Summary of rules for identification of conceptual models

CM	meteorological content	
	ASII	ASIINWP
<b>WF</b>	frontal area without frontal rear side frontal area in broad shield form	frontal area without frontal rear side frontal area in broad shield form
<b>CF (classical)</b>	frontal area	frontal area frontal area under CA (or WA < 0 K/12h))
<b>CF in WA</b>	-----	frontal area with frontal rear side frontal area under WA > 0
<b>low CF</b>	-----	low cloud system (classification) thermal front parameter zeroline of vorticity at 500 hPa
<b>occlusion</b>	frontal area with spiral form IR-AMVs have E-component	frontal area with spiral form low in deep layer of troposphere
<b>wave</b>	s-line OR convex bulge at rear side of frontal area	s-line OR convex bulge at rear side of frontal area WA-CA, PVA max at 500 OR low-level low
<b>upper wave</b>	convex bulge at rear side of frontal area	convex bulge at rear side of frontal area CA and within jet streak
<b>FI by Jet</b>	-----	convective/multilevel part of frontal area PVA max in left exit region of a jet streak
<b>Dry intrusion</b>	frontal area black stripe in WV intersects frontal area	frontal area black stripe in WV intersects frontal area  PV low down in troposphere depression at low levels (850 hPa)
<b>ULL</b>	-----	Upper level depression no depression at low levels
<b>comma</b>	sub-frontal cloud spiral WV-AMV vorticity > 2 units	sub-frontal cloud spiral upper level triggering (PV OR PVA at 500 hPa) WV-AMV vorticity > 2 units
<b>EC</b>	cluster of bright small cells cyclonic area (WV AMVs)	cluster of bright small cells cyclonic area (WV AMVs)  relative vorticity in 500 hPa $\geq 2 \cdot 10^{-6} \text{ s}^{-1}$
<b>Cb</b>	bright convective cells three stages of development	bright convective cells three stages of development unstable troposphere
<b>MCS</b>	extended bright convective cells  WV-AMV vorticity < 2 units	extended bright convective cells  unstable troposphere relative vorticity in 500 hPa $< 2 \cdot 10^{-6} \text{ s}^{-1}$
<b>fibre</b>	fibre feature next to a black stripe in WV	fibre feature next to a black stripe in WV jet streak: (wind speed + zeroline of shear vorticity at 300 hPa)
<b>Lee cloudiness</b>	bright cloud in the lee of mountains IR AMVs stationary at mountain ridge	bright cloud in the lee of mountains IR AMVs stationary at mountain ridge stable troposphere
<b>Cold air cloudiness</b>	Cellular cloudiness located in a trough region	Cellular cloudiness located in a trough region

*Table 6: "Meteorological content" for each conceptual model, depending on the processing branch (ASII or ASIINWP). In some cases it is sufficient that at least one criterion is fulfilled. Then, 'OR' indicates the possible choice.*





### 2.3.3 Synoptic explanations for corresponding and controversial classifications of conceptual models in Automatic satellite image interpretation with NWP (ASIINWP) and without NWP inclusion (ASII)

ASII	ASIINWP	EXPLANATION
(nothing)	CF (classical)	Only low CF cloud band
CF (classical)	CF (classical)	Classical CF cloud band or CF cloud band in CA
CF (classical)	CF in WA	CF cloud band under WA
CF (classical)	Occlusion	Some occlusion parameters for satellite features not fulfilled but model parameters indicate occl. Often observed at innermost part of cloud spiral where AMVs have western component
CF (classical)	FI by Jet	CF with cloud intensification by a crossing jet streak (FI by Jet)
WF	WF	Classical WF band or WF shield
WF	CF (classical)	Stationary CF WF in ASII indicates cloud parallel AMVs
WF	CF in WA	Occurs very seldom: in case of small areas (sometimes only small stripes) within a WF shield where a rear side is detected; usually the WF diagnosis is the correct one
WF	upper wave	Occurs very seldom and only in cases of WF shields: CA in model fields supports a CF instead of the WF and consequently allows a upper wave to be detected;
WF	Occlusion	Some satellite features for an occlusion are not fulfilled but model parameters support an occlusion
WF	Lee cloudiness (within WF)	Occurs very seldom: One parameter (information on cloud development) for Lee detection in ASII not fulfilled
WF	FI by Jet (within WF)	Occurs very seldom: Model fields indicated left exit region and PVA max. in the WF area
occlusion	Occlusion	Classical occlusion cloud band
occlusion	Lee cloudiness (within occlusion)	Occurs very seldom: One parameter (information on cloud development) for Lee detection in ASII not fulfilled
occlusion	FI by Jet	Occlusion cloud band with an area of cloud intensification by jet crossing (FibyJet) superimposed
wave	CF (classical)	NWP fields do not support the wave analysis from satellite imagery
wave	Occlusion	Only in cases where CF in ASII and O in ASIINWP: cloud bulges at the rear side of occlusion bands are not allowed to be identified as waves

wave	Wave	Classical wave with potential for further development
wave	upper wave	Cloud bulge in satellite images exists but model fields diagnose only Upper wave; no potential for further development
wave	Cb, MCS (embedded)	Cloud bulge detected in the satellite image is not diagnosed by model data as wave but is the result of Cbs and MCSs
wave	Fibre	Cloud bulge detected in the satellite image is not diagnosed by model data as wave but as fibre which indicates a distinct jet axis in this area
wave	FI by Jet	Cloud bulge at the rear side of a frontal cloud band is the result of an intensification by a crossing jet (FibyJet)
Dry intrusion	CF (classical), CF in WA, occlusion, WF, upper wave, wave, fibre, MCS, Cb, FI by Jet, lee cloudiness	Satellite images show dry air overrunning a frontal cloud band but model parameters do not support a jet axis there
Dry intrusion	Dry intrusion	Black stripe crosses frontal cloud band at the rear side and model parameters support a jet axis there
Lee cloudiness	Lee cloudiness	Classical lee cloud
Lee cloudiness	Cb, MCS	Lee cloud analysis from the satellite imagery but unstable stratification (Showalter index)
Lee cloudiness (embedded)	CF (classical), CF in WA, occlusion, WF	Lee cloud detected in satellite images within frontal areas is not supported by model parameters
Lee cloudiness	FI by Jet	Cloud features detect Lee but model parameters support intensification by a crossing jet; lee detection might be neglected
Lee cloudiness	(nothing)	Occurs very seldom: Lee cloud detected from satellite features occur in unstable troposphere but cloud tops are too warm for convective cells
fibre	Fibre	Indication for a fibre at a jet axis
fibre	(nothing)	fibre can be seen in satellite image but model does not indicate a jet axis
Fibre	CF (classical), occlusion, WF, MCS, Cb, EC, comma, upper wave, wave, lee cloudiness	Fibre can be seen in satellite image but model does not indicate a jet axis
Fibre	FI by Jet	Occurs very seldom: Fibre indicates the jet axis which leads to an intensification within the frontal band
Cb	Cb	Typical Cb in image and model parameters
Cb	(nothing)	Cb-like feature but stable troposphere
Cb	CF (classical), CF in WA, occlusion, WF	Model parameters indicate a stable troposphere within the frontal cloud systems
Cb	FI by Jet	FI by jet area contains embedded Cbs

MCS	MCS	Typical MCS in image and model data
MCS	Lee cloudiness, (nothing), comma	MCSs detected within mesoscale features are under stable conditions;
MCS (embedded)	CF (classical), CF in WA, occlusion, WF	Cloud features for MCS do exit, but Showalter index indicates a stable troposphere
EC	EC	Typical EC cloud in images and model fields
EC	(nothing)	EC cloud detected in satellite image but no PVA max at 500 hPa
EC	Lee cloudiness	Occurs very seldom: Convective appearance of cloud but stable troposphere
comma	Comma	Typical comma cloud in satellite image and model fields
comma	Lee cloudiness	Occurs very seldom: Comma not supported model fields; lee remains if detected before
comma	Upper-level low	Comma feature appears within an ULL area
comma	(nothing)	Typical comma in satellite features but model parameters do not confirm comma (PV, PVA)
Cold air cloudiness	Cold air cloudiness	Cold air cloudiness
Cold air cloudiness	Upper-level low	Upper level low cannot be detected in ASII

**Table 7:** Explanation for controversial classifications in ASII and ASIINWP

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### 3. IMPLEMENTATION OF THE ASII PGE

#### 3.1 ASII SOFTWARE INSTALLATION

The implementation of the PGE10 software follows the general implementation procedure of components of the NWC/GEO software (see the software part of the Software Users Manual of the NWC/GEO software for more details). Basically, the following steps are needed to run the PGE10 software:

1. Create or update configuration files (system, region and run configuration files) according to their format (see the Interface Control Document ICD/1 for the External and Internal Interfaces of the NWC/GEO [AD.5]). Files are situated in \$SAFNWC/config. The region configuration file has to be present in that directory, too.
2. Algorithm configuration files are located in directory "\$SAFNWC/import/Aux\_data/ASII". These ASII/PGE10 input files are provided with the software package, installed together with it, and are not foreseen for modification by users.
3. For producing the subproduct ASIINWP including NWP data, the original NWP data has to be available in the directory \$SAFNWC/import/NWP\_data/ for runs at 00, 06, 12, and 18 UTC (and - if available - 03, 09, 15 and 21 UTC). For other slots, the NWP data are extrapolated by means of the AMV from the WV channel. This requires dumps of the processed NWP data in the DATABUF directory "\$SAFNWC/tmp". The precursor run of PGE10 automatically creates the required data.
4. Ensure that the SEVIRI image file in HRIT format (mandatory input) is available in the directory \$SAFNWC/import/Sat\_data/ (current and previous slot required).
5. Verify that the environment variable BUFR\_TABLES is set to \$SAFNWC/COTS/bufrdc\_000400/bufrtables/. The BUFR\_TABLES definition is required during all PGE10 runs and should therefore be established permanently e.g. by including it into the .cshrc/.bashrc file. Unlike other environment definitions, the final "/" was found to be necessary.
6. Make sure that the following supplementary files are available:
  - a) \$SAFNWC/COTS/bufrdc\_000400/bufrtables/B000000000098002001.TXT,
  - b) \$SAFNWC/COTS/bufrdc\_000400/bufrtables/D000000000098002001.TXT.



These files are not included in the PGE10 distribution because they are packed into other libraries also delivered with NWC/GEO. The listed files should be available after unpacking the full NWC/GEO SW package, as described in the relevant documentation.

Then, the processing of PGE10 is automatically monitored by the task manager (see the Software Users Manual for the Task Manager of the NWC/GEO software).

#### Submitting ASII/PGE10 in stand-alone mode, not using the task manager:

Ensure that all required input data are available in their respective directories, and that pre-requirements listed under items 1-6 are fulfilled. Note that the processed NWP data in "\$SAFNWC/tmp" (item 3. in above list) is only available if through runs for precursor slots, the opportunity has been given to extrapolate the NWP data in time from the model input runs at 00, 06, 12, or 18 UTC (03, 09, 15 and 21 UTC are accepted as well, if available).

ASII/PGE10 can be called as follows (from the directory where it is situated):

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./GEO-ASII-v243 yyyy-mm-ddThh:mm:ssZ <region configuration file> <model configuration file>

example:

./ GEO-ASII-v243 2015-06-26T12:00:00Z test\_asii.cfg safnwc\_ASII.cfm

### 3.2 OUTPUT FILES OBTAINED DURING GEO-ASII PRODUCT GENERATION

The following output files will be generated if the GEO-ASII runs successfully:

- The conceptual model diagnosis sub-product based on satellite data alone  
 S\_NWC\_ASII-SAT\_<MSGi>\_<region>-VISIR\_<YYYY-MM-DDThh:mm:ssZ>.buf  
 in the directory \$SAFNWC/export/ASII
- For the conceptual model diagnosis sub-product based on satellite data plus NWP data  
 S\_NWC\_ASII-SAT+NWP\_<MSGi>\_<region>-VISIR\_<YYYY-MM-DDThh:mm:ssZ>.buf  
 in the directory \$SAFNWC/export/ASII
- Temporary files which are used during the run for the subsequent slot  
 ZA\_{NWP, MEM, MEMNWP}<YYYY-MM-DDThh:mm:ssZ>  
 in the directory \$SAFNWC/tmp

Optional output: If the user sets the entries OUTPUT\_IR\_AMV and/or OUTPUT\_WV\_AMV in the model configuration file for GEO-ASII to YES, the following result file(s) shall be obtained:

- AMVs from the IR channel:  
 S\_NWC\_ASII-IRAMV\_<MSGi>\_<region>-VISIR\_<YYYY-MM-DDThh:mm:ssZ>.buf  
 in the directory \$SAFNWC/export/ASII
- AMVs from the WV channel:  
 S\_NWC\_ASII-WVAMV\_<MSGi>\_<region>-VISIR\_<YYYY-MM-DDThh:mm:ssZ>.buf  
 in the directory \$SAFNWC/export/ASII

Note: GEO-ASII will not work with corrupt images!

### 3.3 HOW TO IMPLEMENT THE TEMPORAL INTERPOLATION OF NWP VIA CEOF (FOR ASII)

For slots without corresponding NWP forecast, two alternative ways of obtaining the required NWP data exist:

- 1) The “classical” method - used in PGE10 since 1996 - works via extrapolation by means of the AMV from the WV channel.
- 2) An interpolation technique based on Complex Empirical Orthogonal Function analysis (e.g. [RD.2]) can optionally be exploited. Thereby, one can ensure a continuous analysis from the Satellite+NWP branch (the approach pursued so far led to outages until the next forecast date in case of gaps in WV image provision).

Method 2) is available for the first time in v2011 and deemed superior to the NWP handling used earlier. However, as the newly implemented algorithm makes use of third-party algebraic modules, for which (legal) reservations on the direct distribution together with the NWC/GEO package exist, the default method installed during NWC/GEO installation is still the extrapolative

one. With a few simple steps, however, users may activate the modules performing the new interpolation technique:

- 1) Download and unpack Numeric.24.2.tar.gz from <http://sourceforge.net/projects/numpy/files/Old%20Numeric/24.2/>. This package contains the necessary LAPACK and FFTPACK source code files
  - fftpack.c, in subdirectory Numeric-24.2/Packages/FFT/Src;
  - f2c\_lite.c, blas\_lite.c, dlpack\_lite.c, dlamch.c and zlapack\_lite.c, in the subfolder Numeric-24.2/Src;
  - f2c.h, in subdirectory Numeric-24.2/include/Numeric/.

The mentioned C files \*.c should be transferred to the directory \$SAFNWC/src/ASII, the include file f2c.h should be placed in the directory \$SAFNWC/include/ASII/Numeric.

- 2) Once the files are in the right place, go to \$SAFNWC/src/ASII and type



```
make -f makefile.ceof
```

As ASII/PGE10 uses common NWCSAF libraries, the prerequisite is that the NWCSAF package as a whole has been properly installed beforehand, as described in the NWCSAF top-level documentation. The last-mentioned command then simply results in an overwriting of the previously generated executable \$SAFNWC/bin/GEO-ASII-v243. One may at any time go back to the version with the extrapolative NWP handling by typing `make a11` while being in the \$SAFNWC/src/ASII directory.

### 3.4 NWC/GEO-ASII DIAGNOSTIC ERRORS



The following table shows the whole list of errors and warnings that can appear during the execution of the NWC/GEO-ASII PGE, the reasons causing these errors and warnings, and the way the NWC SAF user can try to solve them. In any case, if the errors or warnings persist, the NWC SAF Helpdesk should be contacted.

Code (E/W)	Message	Comment	Recovery action
E	“Usage: %s YYYY-MM-DDThh:mm:ssZ <region_conf_file> <model_conf_file>”	Error when launching	Check instruction for launching the ASII PGE
E	All messages related to NWCLIB time handling functions: NwcTimeSetStr, NwcTimeSetT	Time input when launching PGE may be wrong.	Check the slot time input when launching PGE.
E	All messages including the following strings: “memory allocation” “allocation error” “Unable to allocate” “Error allocating” “not allocated” “cannot be allocated”	Problem of memory allocation	Check memory

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Code (E/W)	Message	Comment	Recovery action
E	All messages containing the following string: “ERROR when opening”	Problem to open an existing file or to create a new file.	Check permission and disk space on the directory. Check presence of the requested file. The recovery actions depends on the type of file: <ul style="list-style-type: none"> <li>– for missing configuration files, copy them from delivered SW;</li> <li>– for missing file to be input by user: check why they are missing; for new file, check permission/disk space on the directory.</li> </ul>
E	All messages containing the strings: “mod(el)_conf(iguration)_file” “PRODIO_CONF_FILE” “CONF_FILE_ERROR” “couldn’t find all parameters for...”	Problem when looking for configuration file or reading a key from it.	Check corresponding configuration file for presence and content. If needed, copy them from delivered SW.
E	All messages containing the strings: “OUTPUT_PRODUCT...ERROR” “Error initiating/writing/finalizing...” “Error in module Write...” “coding failed”	Problem to send output to file.	Check permission and disk space on the output directories.
E	All messages (and knock-on messages) related to <ul style="list-style-type: none"> <li>• NWCLIB initialization functions: NwcRegionSet, NwcCFRead, NwcSatInit</li> <li>• NWCLIB Reading function NwcSatReadBand</li> <li>• NWCLIB numerical function NwcNavGetLatLon</li> </ul>		Consult NWCLIB-specific documentation
E	“Due to missing image precursor data...”	Neither the data from -15 minutes nor from -30 minutes available	Not much can be done except to ensure a stable image provision
E	Messages stating in which part / which subroutine the problem occurred	Introduced mainly to facilitate debugging activities by the developers	Such messages should have been preceded by another error message (in most cases on memory allocation) → see the recovery actions under these categories

*Table 8: List of possible errors reported by GEO-ASII, v2021.*

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## 4. INPUTS AND CONFIGURABLE PARAMETERS FOR THE ASII PRODUCT GENERATION ELEMENTS

### 4.1 LIST OF INPUTS



- SEVIRI IR imagery, channel 10.8, current and previous slot (time difference  $\leq 30$  minutes)
- SEVIRI IR imagery, channel 12.0, current time slot.
- SEVIRI WV image, channel 6.2, current and previous slot (time difference  $\leq 30$  minutes)
- NWP data
- Supplementary invariable input files:
  - BUFR templates
  - Description of centres of gravity for classification process (cf. chapter 3.1.3.2 in [RD.4])
  - Rules and empirical numerical parameters for devising conceptual model classifications from raw input quantities

### 4.2 CONFIGURABLE PARAMETERS

The configurable parameters can be found in the model configuration file for the PGE10, which is separated into two parts. The first section contains three parameters that can be set by the user (Then, starting with the entry PGE\_ID, the rest of the model configuration file is constituted by a section that should be touched only by the institute responsible for development/maintenance of PGE10, which at present is ZAMG.) The user has the options to suppress the PGE10 core product if only the computation of atmospheric motion vectors is desired. The dump of BUFR files with infrared and water vapour AMVs is handled by the other two configurable parameters. The three parameters work independently, so any combination of ASII and AMV output can be achieved:

Keyword	Description	Type	Possible Value(s)
NO_ASII__AMV_ONLY	Decide whether the ASII computations should be suppressed (choice of "YES" is appropriate if AMVs are the only desired output)	chain of characters	YES or NO
OUTPUT_IR_AMV	Decides whether there should be an explicit IR AMV output	chain of characters	YES or NO
OUTPUT_WV_AMV	Decides whether there should be an explicit WV AMV output	chain of characters	YES or NO



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## 5. SUMMARY OF AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) VALIDATION RESULTS

The automatic image analysis product has been validated against the manually generated SatRep for 06 and 12 UTC (cf. the PGE10 validation report [RD.1]). The validation period for ASII comprised 8.5 months, starting on 4<sup>th</sup> April 2006 and ending on 12<sup>th</sup> December 2006.

The SatRep was a manually generated analysis of the IR and WV image in terms of conceptual models. This analysis has been taken as a reference against which the automatic analysis of ASII has been validated. Please consult the full ASII validation report [RD.1] for details, particularly about the definitions of "right" and "wrong" ASII diagnoses.

Amongst the frontal categories in the ASII validation (without model fields), the CF category gives satisfying results with a detection rate of 60% followed by the WF category with a significantly lower detection rate of 48% and the occlusions with only 35%. In ASIINWP (including model fields), the overall CF and WF detection performs similar with a 60% detection rate for CFs, 48% for WFs. The detection of occlusions works better when model parameters are included (42%).

Non-frontal categories, lee cloudiness (26%) and jet fibres (12%) are poorly detected. Convective systems show a seasonal variation, being better detected in summer time. Cb clusters (62%) are better detected than MCS (48%), but both are less performing in ASIINWP probably because of inaccurately predicted stability parameters. Convection in cold air (EC and Comma) is less often detected with 22% and 27% respectively. The best detection rate is obtained for the Closed Convective Cells with almost 65%.

Some conceptual models are only available in ASIINWP. FI by Jet is detected in 44% of all cases, more than half of the ULL (53%) analysed in the SatRep are detected in ASIINWP. The Upper Wave is detected in almost 40% of all SatRep cases.

In summary it can be said that best performances are obtained for frontal categories and small scale convective patterns in the warm sector as well as in the cold air behind a CF. Amongst the least satisfactory conceptual models, one has to mention the frontal waves in ASIINWP (detection rate 14%), the jet cloud fibres and the Open Cell Convection (13% in both ASII and ASIINWP).

Since the validation report 2007 [RD.1] has been issued, the main changes in PGE10 were



- a) a different scheme of front detection based on temporal changes of image pixel values
- b) a new fibre detection algorithm (prompted by the poor detection found in the extensive validation campaign)

So the current PGE10 can be expected to have a better detection rate w.r.t. fibres. Item a) should have little effect on the detection rates; it tends to reduce the false alarms of frontal systems over cold cloudfree land; yet the exact numbers of false alarms were not statistically considered during the validation campaign.

PGE10 version 2010 for the first time allowed a flexible selection of the analysis grid. This opened the possibility to assess the uncertainty of the obtained classifications that are due only to algorithmic and not meteorological factors. In the most recent validation report [RD.3], two tests have been performed with this focus



- A gradual decrease in size of the considered analysis region (i.e. removing the outermost grid points without changing the coordinates of the remaining ones).
- ASII analyses on equally sized grids which are slightly shifted against each other.

20 test cases from all seasons and with various synoptic situations were used for the statistics.

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It was found that the detection of conceptual models worked satisfactorily stable when the size of the analysis area grid was reduced, in particular for conceptual models where the detection is largely based on local pixel analysis (e.g. enhanced cumuli, cumulonimbus and mesoscale convective systems). On the other hand, frontal conceptual models turned out to be more sensitive: if the reduction of the analysis area removes too much of the system, it is not accepted as a front anymore since the PGE10 decision tree explicitly checks for the areal extent as one criterion. The results suggest the user to select a region for the analysis larger than his region of interest, so that the analysis for *each* conceptual model over the central region of interest is not negatively impacted by boundary effects. For example, users on the European mainland are advised to use a region extending from Iceland to the eastern part of Europe including Turkey.

The second investigation dealt with small shifts of the analysis grid with respect to a reference grid. These shifts were about a tenth of the size of a grid mesh. For small-scale conceptual models which were the worst performers (e.g. Cumulonimbus, fibres ...), these small shifts for the grid were enough to bring the agreement between the two analyses down to 50-75%. The most likely explanation for this result is that, when these systems are close to the border of a certain grid cell, they often are assigned to the adjacent grid points if the grid changes slightly. For frontal categories of larger extent, such phenomena do not have the same effect (percentage-wise), which could have been expected since small shifts affect the position of the detected conceptual model relatively marginally. Fronts are among the best performers with correspondence rates above 80%.

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## 6. WELL-KNOWN PROBLEMS AND RECOMMENDATION FOR USE

Pattern recognition methods - as used in ASII - to analyse the structure of satellite cloud fields are time-consuming. This constrained the developers to concentrate on essential patterns, reducing the number of automatically detected conceptual models. Similar conceptual models, e.g. baroclinic boundary and CF, are not distinguished and have the same CM name.

Conceptual models are idealized descriptions. In reality, the variability in the appearance of meteorological phenomena makes it frequently difficult, even for the trained human analyst, to be certain about the right classification of a certain cloud system. It cannot be expected that the empirical spread defined for a meteorological parameter in such an automated system as ASII will catch every instance to yield the right yes/no-decisions. The human analyst in cases of doubt has some mechanisms not accessible to ASII:

- the option to give little or no weight to features not fitting to a "pre-classification";
- the option to interpret image loops over a period which is "as long as necessary". Though ASII takes into account the analyses of the preceding slot, that powerful technique of looping and viewing the genesis of systems is obviously hard to imitate fully in an automated system.

Inferior performance has to be expected at the boundaries of the covered domain (pattern recognition techniques generally benefit from a larger vicinity) and in far-northern regions where the reduced spatial resolution blurs the image features.

For ASII's practical application rules and inherent problems, please refer to the end of each conceptual model chapter.

Though no explicit validation/tests were done to evaluate the impact of NWP resolution, some experience on this subject was still gained during the ASII development over the years. The spatial resolution used for development was 1.5 degrees. Meanwhile, ZAMG runs operationally at 1 degree (and in some experiments on 0.5 degree) resolution and so far found no reason for concern. On the other hand, it is known that some derived quantities show confusing patterns in LAMs - e.g. as soon as any little trough in the wake of a mountain chain is resolved, there is an associated zone of strong positive vorticity advection with no connection to a synoptic-scale meteorological system (= misleading for the ASII algorithm). Consequently (and perhaps surprisingly at first sight), the use of LAM resolution may well be detrimental to the product.

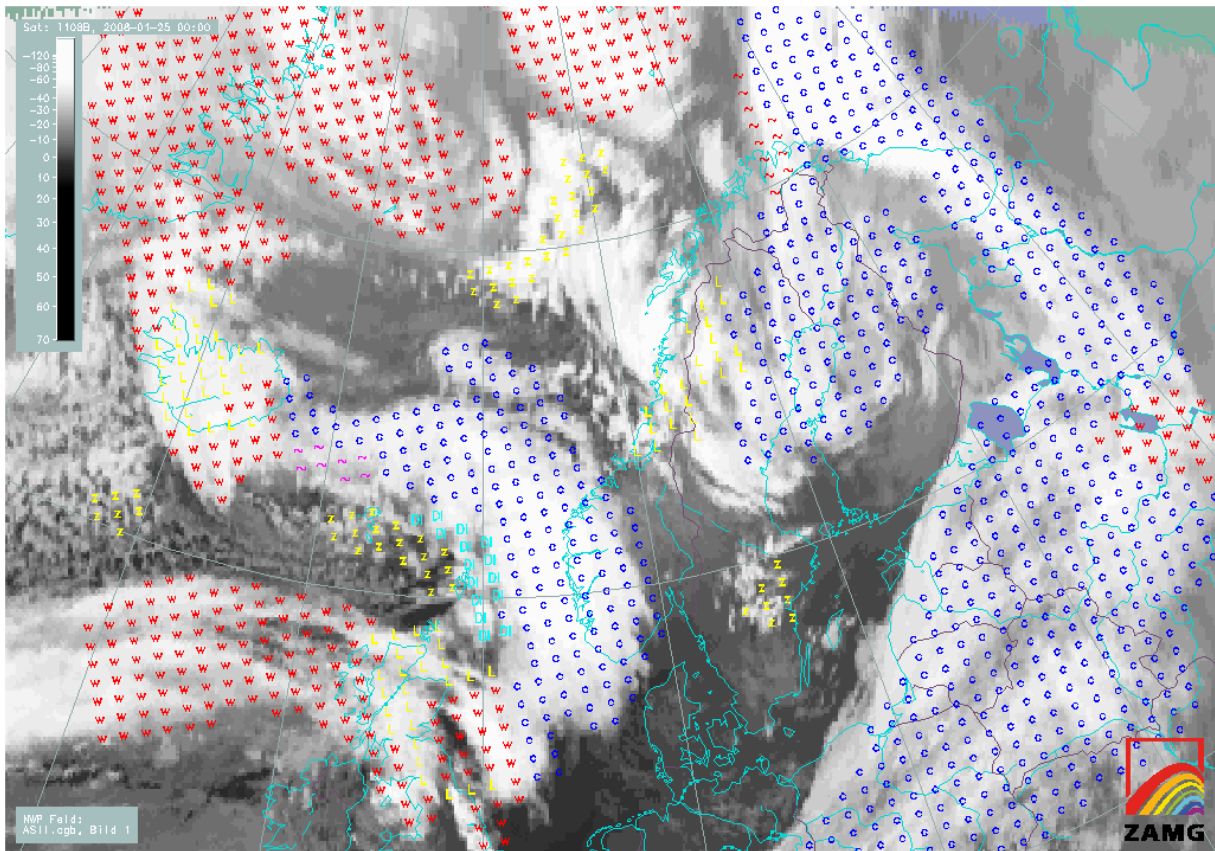
On the temporal resolution, both section 3.3 and chapter 3.1.4 in the ATBD reflect the efforts done to improve upon the linear interpolation of NWP data, which we found unsatisfactory. Yet, it's still mere interpolation and a physical model must be cleverer than that, so one is on the safe side to predict that it is worthwhile to use 1-hourly data.

If the NWP data are extrapolated with WV AMV, another – purely technical – consideration applies: If the WV channel provision has gaps, the extrapolation may not be carried out. And once it failed, subsequent extrapolations have no input to deal with, hence the ASIINWP branch is suppressed until the next GRIB input becomes available. It goes without saying that higher temporal resolution of the NWP data therefore has a beneficial effect on the duration of the outage.

## 7. EXAMPLES OF PRODUCT VISUALISATIONS

### 7.1 ASII CONCEPTUAL MODELS

**Figure 20** shows the visualisation of an ASII product within the ZAMG environment (the visualization is not part of the NWCSAF software), depicting in symbolic manner the analysed conceptual models at the analysis grid points. The meaning of the symbols used in the graphics here (and at the reference product site hosted by AEMET) follows Tables 4 and 5.



**Figure 20:** PGE10 analysis for 25 January 2008, 0000 UTC (ASII).

For convenience, the FORTRAN 77 source code of the production program is included next. Users are probably interested most in the sections on BUFR decoding, hence these parts are highlighted by boldface printing. The BUFRDC software, freely available from ECMWF, is used here (subroutines PBOPEN, PBBUFR, BUFREX, PBCLOSE); note that the BUFR decoding sections are identical for the two sub-products. The other parts of the program mainly contain commands to accomplish the graphics output by the MAGICS package.

```
#
C THIS IS A DEMO BUFR DECODING ROUTINE FOR CONCEPTUAL MODEL/LONGITUDE/
C LATITUDE INFORMATION SUBMITTED BY SAFNWC ASII ROUTINES
C AUTHOR: ALEXANDER JANN / ZAMG / VIENNA, AUSTRIA
C CREATION DATE: 02/08/2001
C THIS IS INTENDED TO REPRESENT A USEFUL SUPPORT TO USERS OF THE
C SAFNWC/MSG SOFTWARE PACKAGE, BUT COMES WITHOUT WARRANTY OF ANY KIND.
```

```
PROGRAM SAFNWC_ASII_BUF
PARAMETER (JSEC0=3, JSEC1=40, JSEC2=64, JSEC3=4, JSEC4=2)
```



PARAMETER (JELEM=20000, JSUP=9, JBYTE=80000)  
PARAMETER (KELEM=20000, KVALS=80000, KVALS1=80000)

DIMENSION KBUFF(20000), KSUP(JSUP)  
DIMENSION KSEC0(JSEC0),KSEC1(JSEC1),KSEC2(JSEC2),KSEC3(JSEC3)  
DIMENSION KSEC4(JSEC4)

#ifndef R\_4

REAL\*8 VALUES(KVALS1)

#else

REAL VALUES(KVALS1)

#endif

CHARACTER\*80 CVALS(KVALS)  
CHARACTER\*24 CUNITS(KELEM)  
CHARACTER\*64 CNAMES(KELEM)

CHARACTER\*80 EXPORT\_PATH, CGBNAMEINTRO, MM



DIMENSION CONTOURX(20000),CONTOURY(20000)  
CHARACTER\*2 MARKSYM(20000)  
CHARACTER\*80 CONCMOD(20)  
CHARACTER\*10 COLOURS(20)  
CHARACTER\*2 SYMBOLS(20)

DATA CONCMOD/'warm front', 'cold front',  
+ 'cold front under warm air advection',  
+ 'front intensification by jet streak crossing',  
+ 'enhanced cumuli','dry intrusion',  
+ 'cold air cloudiness',  
+ 'mature cumulonimbus','growing cumulonimbus',  
+ 'decaying cumulonimbus','occlusion','comma',  
+ 'non-developing wave','developing wave','upper wave',  
+ 'upper level low','mesoscale convective system',  
+ 'lee cloudiness','jet cloud (fibres)',  
+ 'embedded convective cell'/

DATA COLOURS/'RED', 'BLUE',  
+ 'RED',  
+ 'YELLOW',  
+ 'CYAN','CYAN',  
+ 'YELLOW',  
+ 'YELLOW', 'MAGENTA',  
+ 'BLUE','GREEN','YELLOW',  
+ 'MAGENTA','RED','GREEN',  
+ 'YELLOW','YELLOW',  
+ 'YELLOW', 'YELLOW',  
+ 'YELLOW'/

DATA SYMBOLS/'w','c',  
+ 'c',  
+ 'ji',  
+ 'ec','DI',  
+ 'z',  
+ 'cb','cb','cb',  
+ 'o','co','~','~','~',  
+ 'ul','m',  
+ 'L','F',  
+ '.'/

CGBNAMEINTRO='SAFNWC\_MSG2\_ASII\_200801250000\_Region\_ZAMG\_'  
N=GETENV('SAFNWC',EXPORT\_PATH)  
EXPORT\_PATH=EXPORT\_PATH(1:INDEX(EXPORT\_PATH,'-1)//)/export/PGE10/  
INDEXPO=INDEX(EXPORT\_PATH,'-1)

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C OPEN MAGICS, DEFINE GRAPHICAL DEVICE AND FIX GEOGRAPHICAL AREA

```
CALL POPEN
CALL PNEW ('SUPER_PAGE')
CALL PNEW ('PAGE')
CALL PSETI ('WORKSTATION_COUNT',1)
CALL PSETC ('WORKSTATION_1','CGM_BINARY')
CALL PSETC ('PAGE_FRAME','OFF')
MM = 'MAGICS_METAFILE='//EXPORT_PATH(1:INDEXPO)//'ASII.cgb'
JI = PUTENV(MM)
CALL PSETC ('SUPER_PAGE_FRAME','ON')
CALL PSETR ('SUPER_PAGE_X_LENGTH',29.7)
CALL PSETR ('SUPER_PAGE_Y_LENGTH',24.0)
CALL PSETR ('PAGE_X_LENGTH',29.7)
CALL PSETR ('PAGE_Y_LENGTH',24.0)
CALL PSETC ('SUBPAGE_MAP_PROJECTION','POLAR_STEREOGRAPHIC')
CALL PSETC ('SUBPAGE_MAP_AREA_DEFINITION','CORNERS')
CALL PSETR ('SUBPAGE_MAP_VERTICAL_LONGITUDE',0.0)
CALL PSETR ('SUBPAGE_LOWER_LEFT_LONGITUDE',-29.5)
CALL PSETR ('SUBPAGE_LOWER_LEFT_LATITUDE', 22.6)
CALL PSETR ('SUBPAGE_UPPER_RIGHT_LONGITUDE',73.1)
CALL PSETR ('SUBPAGE_UPPER_RIGHT_LATITUDE', 56.3)
CALL PSETR ('SUBPAGE_X_POSITION',2.23)
CALL PSETR ('SUBPAGE_Y_POSITION',1.05)
CALL PSETR ('SUBPAGE_X_LENGTH',22.41)
CALL PSETR ('SUBPAGE_Y_LENGTH',17.85)
```

```
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C DECODE BUFR FILE CONTAINING THE SAFNWC/ASII-SATonly PRODUCT
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

```
IRET=0
CALL PBOPEN (IUNIT,EXPORT_PATH(1:INDEXPO)//
+ CGBNAMEINTRO(1:INDEX(CGBNAMEINTRO,'.'))/'SATonly.buf',r',IRET)
IF (IRET .NE. 0) GOTO 13
```

```
IERR=0
IRET=0
KBUFL=0
```

11 CONTINUE

C EXTRACT COORDINATES OF ONE CONCEPTUAL MODEL (AND ITS DESIGNATION)

```
CALL PBUFFR (IUNIT,KBUFF,JBYTE,KBUFL,IRET)
IF (IRET .EQ. -1) GOTO 13
KBUFL=KBUFL/4+1
KEL=KELEM
CALL BUFREX (KBUFL,KBUFF,KSUP,KSEC0,KSEC1,KSEC2,KSEC3,KSEC4,
+ KEL,CNAMES,CUNITS,KVALS,VALUES,CVALS,KERR)
```

```
IF (VALUES(1) .EQ. 0.) GOTO 11 ! NEXT CONCEPTUAL MODEL
```

C GET INDEX OF CURRENT CONCEPTUAL MODEL

```
DO 111 K=1,20
NAMELENGTH=MIN(INDEX(CONCMOD(K),' ') -1,32)
IF (CVALS(1)(1:NAMELENGTH) .EQ.
+ CONCMOD(K)(1:NAMELENGTH)) INDEXCM=K
111 CONTINUE
```

```
DO 12 K=1,VALUES(1)
CONTOURY(K)=VALUES(2*K)
CONTOURX(K)=VALUES(2*K+1)
MARKSYM(K)=SYMBOLS(INDEXCM)
```

12 CONTINUE

C PLOT THE CONCEPTUAL MODEL WITH CORRECT COLOUR AND SYMBOL

```
CALL PSET1R('SYMBOL_INPUT_X_POSITION',CONTOURX,K-1)
CALL PSET1R('SYMBOL_INPUT_Y_POSITION',CONTOURY,K-1)
CALL PSETC('SYMBOL_TABLE_MODE','OFF')
CALL PSETC('LEGEND','OFF')
CALL PSETC('LEGEND_ENTRY','OFF')
CALL PSETC('SYMBOL_TYPE','TEXT')
CALL PSET1C('SYMBOL_INPUT_TEXT_LIST',MARKSYM,K-1)
CALL PSETC('SYMBOL_COLOUR',COLOURS(INDEXCM))
CALL PSETR('SYMBOL_HEIGHT',0.09)
CALL PSYMB
```

GOTO 11 ! NEXT CONCEPTUAL MODEL

C CLOSE BUFR FILE, CLOSE MAGICS

13 CALL PBCLOSE(IUNIT,IRET)  
CALL PCLOSE

C RE-OPEN MAGICS, DEFINE GRAPHICAL DEVICE AND FIX GEOGRAPHICAL AREA

```
CALL POPEN
CALL PSETI('WORKSTATION_COUNT',1)
CALL PSETC('WORKSTATION_1','CGM_BINARY')
CALL PSETC('PAGE_FRAME','OFF')
MM = 'MAGICS_METAFILE='//EXPORT_PATH(1:INDEXPO)//'ASIINWP.cgb'
JI = PUTENV(MM)
CALL PSETC('SUPER_PAGE_FRAME','ON')
CALL PSETR('SUPER_PAGE_X_LENGTH',29.7)
CALL PSETR('SUPER_PAGE_Y_LENGTH',24.0)
CALL PSETR('PAGE_X_LENGTH',29.7)
CALL PSETR('PAGE_Y_LENGTH',24.0)
CALL PSETC('SUBPAGE_MAP_PROJECTION','POLAR_STEREOGRAPHIC')
CALL PSETC('SUBPAGE_MAP_AREA_DEFINITION','CORNERS')
CALL PSETR('SUBPAGE_MAP_VERTICAL_LONGITUDE',0.0)
CALL PSETR('SUBPAGE_LOWER_LEFT_LONGITUDE',-29.5)
CALL PSETR('SUBPAGE_LOWER_LEFT_LATITUDE', 22.6)
CALL PSETR('SUBPAGE_UPPER_RIGHT_LONGITUDE',73.1)
CALL PSETR('SUBPAGE_UPPER_RIGHT_LATITUDE', 56.3)
CALL PSETR('SUBPAGE_X_POSITION',2.23)
CALL PSETR('SUBPAGE_Y_POSITION',1.05)
CALL PSETR('SUBPAGE_X_LENGTH',22.41)
CALL PSETR('SUBPAGE_Y_LENGTH',17.85)
```

C !!!  
C DECODE BUFR FILE CONTAINING THE SAFNWC/ASII-SAT/NWP PRODUCT  
C !!!



```
IRET=0
CALL PBOPEN (IUNIT,EXPORT_PATH(1:INDEXPO)//
+ CGBNAMEINTRO(1:INDEX(CGBNAMEINTRO,'.'))//SAT+NWP.buf',r',IRET)
IF (IRET .NE. 0) GOTO 23
```

```
IERR=0
IRET=0
KBUFL=0
```

21 CONTINUE

C EXTRACT COORDINATES OF ONE CONCEPTUAL MODEL (AND ITS DESIGNATION)

```
CALL PBBUFR (IUNIT,KBUFF,JBYTE,KBUFL,IRET)
IF (IRET .EQ. -1) GOTO 23
KBUFL=KBUFL/4+1
```

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```

KEL=KELEM
CALL BUFREX (KBUFL,KBUFF,KSUP,KSEC0,KSEC1,KSEC2,KSEC3,KSEC4,
+ KEL,CNAMES,CUNITS,KVALS,VALUES,CVALS,KERR)

IF (VALUES(1) .EQ. 0.) GOTO 21 ! NEXT CONCEPTUAL MODEL

C GET INDEX OF CURRENT CONCEPTUAL MODEL

DO 211 K=1,20
NAMELENGTH=MIN(INDEX(CONCMOD(K),' ') -1,32)
IF (CVALS(1)(1:NAMELENGTH) .EQ.
+ CONCMOD(K)(1:NAMELENGTH)) INDEXCM=K
211 CONTINUE

DO 22 K=1,VALUES(1)
CONTOURY(K)=VALUES(2*K)
CONTOURX(K)=VALUES(2*K+1)
MARKSYM(K)=SYMBOLS(INDEXCM)
22 CONTINUE

C PLOT THE CONCEPTUAL MODEL WITH CORRECT COLOUR AND SYMBOL

CALL PSET1R('SYMBOL_INPUT_X_POSITION',CONTOURX,K-1)
CALL PSET1R('SYMBOL_INPUT_Y_POSITION',CONTOURY,K-1)
CALL PSETC('SYMBOL_TABLE_MODE','OFF')
CALL PSETC('LEGEND','OFF')
CALL PSETC('LEGEND_ENTRY','OFF')
CALL PSETC('SYMBOL_TYPE','TEXT')
CALL PSET1C('SYMBOL_INPUT_TEXT_LIST',MARKSYM,K-1)
CALL PSETC('SYMBOL_COLOUR',COLOURS(INDEXCM))
CALL PSETR('SYMBOL_HEIGHT',0.09)
CALL PSYMB

GOTO 21 ! NEXT CONCEPTUAL MODEL

C CLOSE BUFR FILE, CLOSE MAGICS

23 CALL PBCLOSE(IUNIT,IRET)
CALL PCLOSE

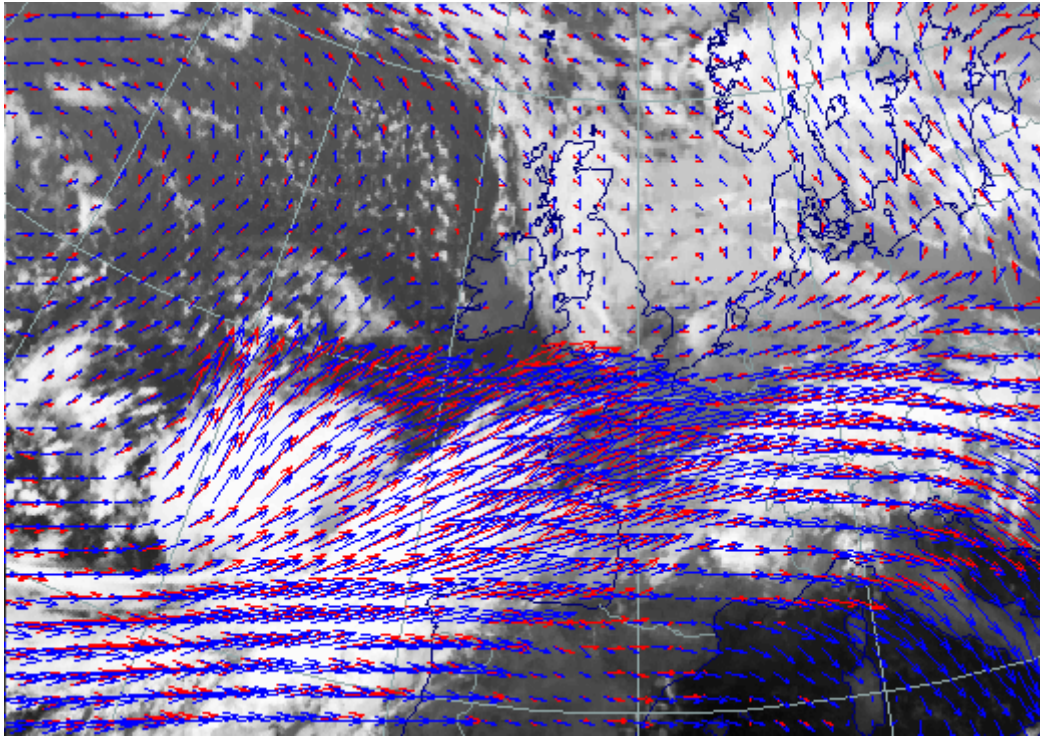
END

```

## 7.2 ATMOSPHERIC MOTION VECTORS

**Figure 21** shows the visualisation of the optional AMV products of the NWC/GEO ASII product.





*Figure 21: Infra-red (red) and water-vapour (blue) AMV fields as derived for input into the PGE10 analysis for 14 October 2002, 0600 UTC.*

For convenience, the FORTRAN 90 source code of an example plotting program is given in the following. Users are probably most interested in the sections on BUFR decoding; hence these parts are highlighted by boldface printing. The BUFRDC software, freely available from ECMWF, is used here (subroutines PBOPEN, PBBUFR, BUFREX, PBCLOSE); note that the BUFR decoding sections are identical for the two AMV fields. The other parts of the program mainly contain commands to accomplish the graphics output by the MAGICSS++ package (which in principle is able to digest BUFR input directly; this functionality is, however, not exploited here in order to also support users of other visualization software).

```



!      THIS IS A DEMO BUFR DECODING ROUTINE FOR AMV/LONGITUDE/
!      LATITUDE INFORMATION GENERATED BY SAFNWC ASII ROUTINES
!      AUTHOR:      ALEXANDER JANN / ZAMG / VIENNA, AUSTRIA
!      CREATION DATE: 13/05/2011
!      THIS IS INTENDED TO REPRESENT A USEFUL SUPPORT TO USERS OF THE
!      SAFNWC/MSG SOFTWARE PACKAGE, BUT COMES WITHOUT WARRANTY OF ANY KIND.

PROGRAM SAFNWC_ASII_BUFR
PARAMETER(  JSUP=9, JSEC0=3,  JSEC1=40,  JSEC2=4096 ,JSEC3=4, &
           JSEC4=2, JELEM=160000, JBUFL=300000, JBYTE=440000, KELEM=160000, &
           JBPW=32, KVALS=4096000)

DIMENSION KSUP(JSUP) , KSEC0(JSEC0), KSEC1(JSEC1)
DIMENSION KSEC2(JSEC2), KSEC3(JSEC3), KSEC4(JSEC4)
INTEGER, DIMENSION(JBUFL) :: KBUFF
REAL*8, DIMENSION(KVALS) :: VALUES

CHARACTER (LEN=64), DIMENSION(KELEM) :: C NAMES
CHARACTER (LEN=24), DIMENSION(KELEM) :: C UNITS
CHARACTER (LEN=80), DIMENSION(KELEM) :: C VALS

```

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```

!          !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!          DECODE BUFR FILE CONTAINING THE SAFNWC/ASII IR-AMV PRODUCT
!          !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

IRET=0
CALL PBOPEN (IUNIT,'SAFNWC_MSG2_ASII_201105130715_Region_ZAMG_.IRAMV.buf', &
'r',IRET)
IF (IRET .NE. 0) GOTO 13

!          OPEN MAGICS, DEFINE GRAPHICAL DEVICE AND FIX GEOGRAPHICAL AREA

CALL POPEN
CALL PSETC ('OUTPUT_FORMAT','PS')
CALL PSETC ('OUTPUT_NAME','PGE10c')
CALL PSETC ('PAGE_ID_LINE','OFF')
CALL PSETC ('SUBPAGE_MAP_PROJECTION','POLAR_STEREOGRAPHIC')
CALL PSETC ('SUBPAGE_MAP_AREA_DEFINITION','CORNERS')
CALL PSETR ('SUBPAGE_MAP_VERTICAL_LONGITUDE',0.0)
CALL PSETR ('SUBPAGE_LOWER_LEFT_LONGITUDE',-29.5)
CALL PSETR ('SUBPAGE_LOWER_LEFT_LATITUDE', 22.6)
CALL PSETR ('SUBPAGE_UPPER_RIGHT_LONGITUDE',73.1)
CALL PSETR ('SUBPAGE_UPPER_RIGHT_LATITUDE', 56.3)
CALL PCOAST

!          EXTRACT COORDINATES AND COMPONENTS OF ATMOSPHERIC MOTION VECTORS



CALL PBBUFR (IUNIT,KBUFF,JBYTE,KBUFL,IRET)
IF (IRET .EQ. -1) GOTO 13
KBUFL=KBUFL/4+1
KEL=KELEM
CALL BUFREX (KBUFL,KBUFF,KSUP,KSEC0,KSEC1,KSEC2,KSEC3,KSEC4, &
KEL,CNAMES,CUNITS,KVALS,VALUES,CVALS,KERR)
CALL PSETC ('INPUT_FIELD_SUBPAGE_MAPPING','LOWER_LEFT')
CALL PSETR ('INPUT_FIELD_LATITUDE_STEP',0.1075) ! DUMMY
CALL PSETR ('INPUT_FIELD_LONGITUDE_STEP',0.165) ! DUMMY
CALL PSETC('WIND_ARROW_COLOUR','RED')
CALL PSETC('WIND_LEGEND','OFF')
!          Plot the AMVs one by one (irregular field)
DO K=1,INT(VALUES(1))
    AMVLAT=VALUES(4*K-2)
    AMVLONG=VALUES(4*K-1)
    AMVUCOMP=VALUES(4*K)
    AMVVCOMP=VALUES(4*K+1)
    CALL PSETR ('INPUT_FIELD_INITIAL_LATITUDE',AMVLAT)
    CALL PSETR ('INPUT_FIELD_INITIAL_LONGITUDE',AMVLONG)
    CALL PSET2R('INPUT_WIND_U_COMPONENT',AMVUCOMP,1,1)
    CALL PSET2R('INPUT_WIND_V_COMPONENT',AMVVCOMP,1,1)
    CALL PWIND
END DO
CALL PCLOSE

13      CALL PBCLOSE(IUNIT,IRET)

!          !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!          DECODE BUFR FILE CONTAINING THE SAFNWC/ASII WV-AMV PRODUCT
!          !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

IRET=0
CALL PBOPEN (IUNIT,'SAFNWC_MSG2_ASII_201105130715_Region_ZAMG_.WVAMV.buf', &

```

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```
'r',IRET)
IF (IRET .NE. 0) GOTO 23
```

```
! RE-OPEN MAGICS, DEFINE GRAPHICAL DEVICE AND FIX GEOGRAPHICAL AREA
```

```
CALL POPEN
CALL PSETC ('OUTPUT_FORMAT','PS')
CALL PSETC ('OUTPUT_NAME','PGE10d')
CALL PSETC ('PAGE_ID_LINE','OFF')
CALL PSETC ('SUBPAGE_MAP_PROJECTION','POLAR_STEREOGRAPHIC')
CALL PSETC ('SUBPAGE_MAP_AREA_DEFINITION','CORNERS')
CALL PSETR ('SUBPAGE_MAP_VERTICAL_LONGITUDE',0.0)
CALL PSETR ('SUBPAGE_LOWER_LEFT_LONGITUDE',-29.5)
CALL PSETR ('SUBPAGE_LOWER_LEFT_LATITUDE', 22.6)
CALL PSETR ('SUBPAGE_UPPER_RIGHT_LONGITUDE',73.1)
CALL PSETR ('SUBPAGE_UPPER_RIGHT_LATITUDE', 56.3)
CALL PCOAST
```

```
! EXTRACT COORDINATES AND COMPONENTS OF ATMOSPHERIC MOTION VECTORS
```



```
CALL PBBUFR (IUNIT,KBUFF,JBYTE,KBUFL,IRET)
IF (IRET .EQ. -1) GOTO 23
KBUFL=KBUFL/4+1
KEL=KELEM
CALL BUFREX (KBUFL,KBUFF,KSUP,KSEC0,KSEC1,KSEC2,KSEC3,KSEC4, &
KEL,CNAMES,CUNITS,KVALS,VALUES,CVALS,KERR)
CALL PSETC ('INPUT_FIELD_SUBPAGE_MAPPING','LOWER_LEFT')
CALL PSETR ('INPUT_FIELD_LATITUDE_STEP',0.1075) ! DUMMY
CALL PSETR ('INPUT_FIELD_LONGITUDE_STEP',0.165) ! DUMMY
CALL PSETC('WIND_ARROW_COLOUR','BLUE')
CALL PSETC('WIND_LEGEND','OFF')
```

```
! Plot the AMVs one by one (irregular field)
```

```
DO K=1,INT(VALUES(1))
AMVLAT=VALUES(4*K-2)
AMVLONG=VALUES(4*K-1)
AMVUCOMP=VALUES(4*K)
AMVVCOMP=VALUES(4*K+1)
CALL PSETR ('INPUT_FIELD_INITIAL_LATITUDE',AMVLAT)
CALL PSETR ('INPUT_FIELD_INITIAL_LONGITUDE',AMVLONG)
CALL PSET2R('INPUT_WIND_U_COMPONENT',AMVUCOMP,1,1)
CALL PSET2R('INPUT_WIND_V_COMPONENT',AMVVCOMP,1,1)
CALL PWIND
```

```
END DO
CALL PCLOSE
```

```
23 CALL PBCLOSE(IUNIT,IRET)
END
```

 	<p>User Manual for the Automatic Satellite Image Interpretation Processor of the NWC/GEO: Science Part</p>	<p><b>Code:</b>NWC/CDOP3/GEO/ZAMG/SCI/UM/ASII <b>Issue:</b> 2.0.1 <b>Date:</b> 28 February 2022 <b>File:</b>NWC-CDOP3-GEO-ZAMG-SCL-UM-ASII_v2.0.1.docx <b>Page:</b> 84/86</p>
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## 8. REFERENCES

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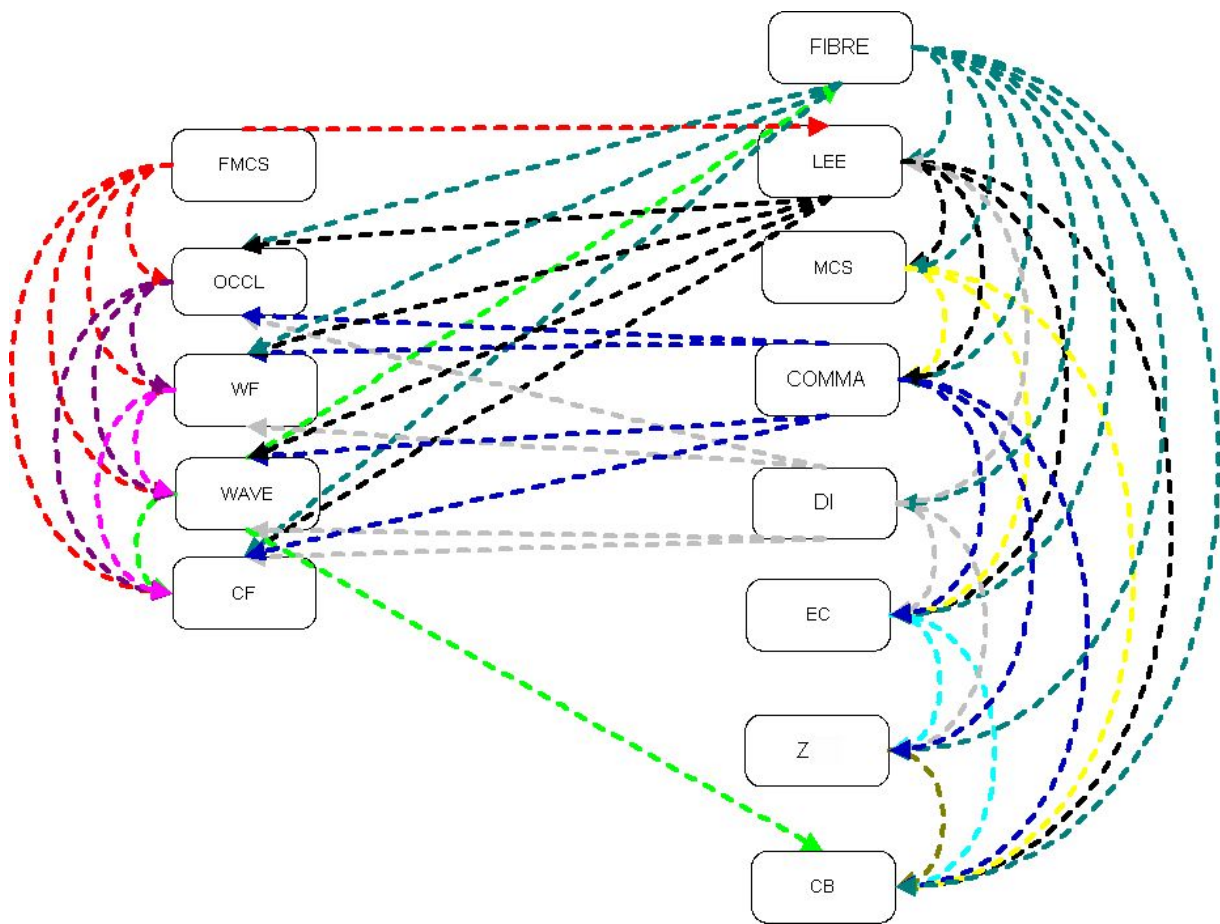
Eumetrain (2021): [SatManu - Manual of Synoptic Satellite Meteorology](http://www.eumetrain.org/satmanu/index_conc.html). Online at [http://www.eumetrain.org/satmanu/index\\_conc.html](http://www.eumetrain.org/satmanu/index_conc.html) (accessed: 19 April 2021)

Wirth, A., Jann, A. and Zeiner, B. (2008): On the use of complex empirical orthogonal functions for the temporal interpolation of NWP, radar and satellite data. Proceedings, 2008 EUMETSAT Meteorological Satellite Conference, Darmstadt, 8 - 12 September 2008, EUMETSAT P. 52, ISBN 978-92-9110-082-8, ISSN 1011-3932, 8pp.

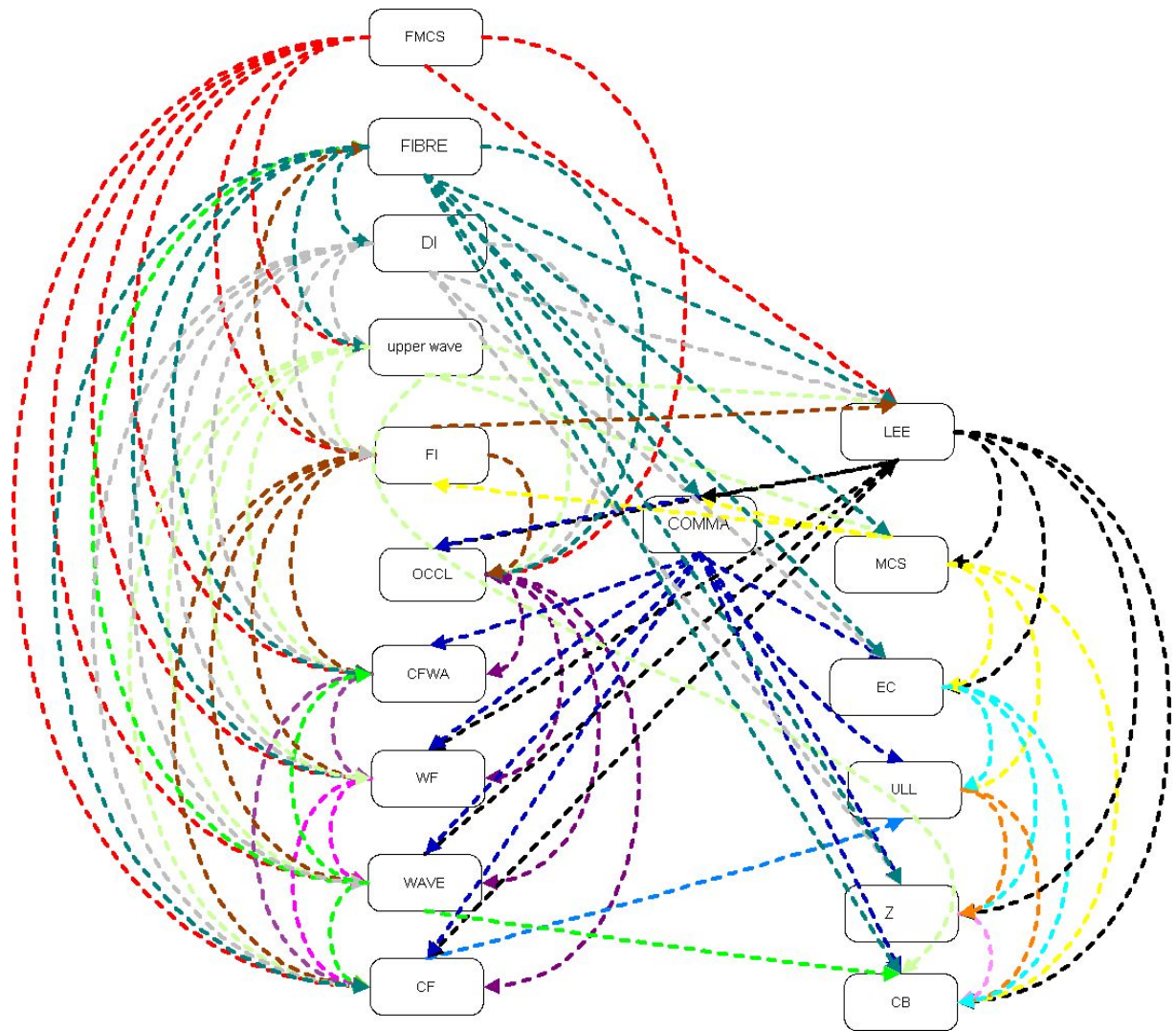
## APPENDIX 1: RANKING AMONG SIMULTANEOUSLY DIAGNOSED CONCEPTUAL MODELS

The following graphics summarise the ranking between the detected conceptual models, when two or more conceptual models are deemed acceptable for the same grid point. The following diagram table is valid for ASII, the subsequent one for ASIINWP.

Between the frontal and non-frontal conceptual models, only few ranking rules exist. This is the case as these conceptual models never happen to be on the same grid point because the necessary conditions for them are excluding one another.



**Figure 22:** Ranking diagram for ASII CM analyses: the arrows are drawn from the conceptual model which is overwriting to that one which is overwritten. The colours correspond to the CM which is overwriting. The left column comprises the frontal CMs, the right column the small and mesoscale CMs. As an example, comma is overwritten by fibre, lee and MCS. On the other hand, comma analysis overwrites occlusion, WF, wave, CF, EC, cellular clouds and CBs.



*Figure 23: Ranking diagram for ASIINWP CM analyses: the arrows are drawn from the conceptual model which is overwriting to that one which is overwritten. The colours correspond to the CM which is overwriting. The left column comprises the frontal CMs, the right column the small and mesoscale CMs.*