The EUMETSAT Network of Satellite Application Facilities

NWC SAF

Support to Nowcasting and Very Short Range Forecasting

User Manual for the “Automatic Satellite Image Interpretation – Next Generation” Processors of the NWC/GEO: Science Part

NWC/CDOP3/GEO/ZAMG/SCI/UM/ASII-NG, Issue 1.0.1

1 October 2019

Applicable to

GEO-ASII-NG-v2.0 (NWC-048)

which is comprised of

GEO-ASII-TF-v2.0

GEO-ASII-GW-v1.0

Prepared by ZAMG

REPORT SIGNATURE TABLE

Function	Name	Signature	Date
Prepared by	A. Jann (ZAMG)		*1 October 2019*
Reviewed by	A.Wirth (ZAMG)		*1 October 2019*
Authorised by	Pilar Rípodas SAFNWC Project Manager		*1 October 2019*

DOCUMENT CHANGE RECORD

Version	Date	Pages	CHANGE(S)
1.0	*1 October 2019*	18	Initial version (derived from NWC/CDOP2/GEO/ZAMG/SCI/UM/ASII, v1.0 by removing the ASII parts (without change bars)). Change bars indicate changes in the ASII-NG sections w.r.t. the quoted starting point. Gravity wave detection as a new sub-product.
1.0.1	*1 October 2019*	18	Version for SAFNWC/GEO v2018.1 (GOES-R patch).

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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 User Manual for the "Automatic Satellite Image Interpretation – Next Generation" Product (PGE17 of the NWC/GEO software).

This document contains practical information for the daily use of the products. 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 [AD.11].

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 – Next Generation Products (PGE17) are detailed in the NWC/GEO Software User Manual.

The latest validation of the algorithms used to extract the MSG Automatic Satellite Image Interpretation – Next Generation (PGE17) is reported in a validation report [RD.2].

1.3 SOFTWARE VERSION IDENTIFICATION

This document is compliant with the ASII-NG/PGE17 version of the 2018 NWC/GEO software package delivery. It was decided that the individual products assembled under the ASII-NG label should be as separated as possible in order to facilitate version control and other programme-managerial tasks. In version 2018, there are two sub-modules which could indeed be totally separated, as there are only negligible synergies between them:

- the ASII-GW (gravity wave detection) module, v1.0, and
- the ASII-TF (tropopause folding detection) module, v2.0.

1.4 IMPROVEMENTS FROM PREVIOUS VERSION

Technical adaptation to GOES-R input accomplished for the gravity wave product.

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
ASII	Automatic Satellite Image Interpretation
ASII-GW	Gravity wave detection sub-product of ASII-NG
ASII-NG	ASII next generation
ASII-TF	Tropopause folding detection sub-product of ASII-NG
ECMWF	European Centre for Medium-range Weather Forecast
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
IR	Infrared
MSG	Meteosat Second Generation
NWP	Numerical Weather Prediction
PGE	Product Generation Element
SAF	Satellite Application Facility
SEVIRI	Spinning Enhanced Visible and Infrared Imager
UTC	Universal Time Coordinated
WV	Water Vapour
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (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	1.3	12/07/19
[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	2.2	01/04/19
[AD.5]	Interface Control Document for Internal and External Interfaces of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/ICD/1	1.1	01/10/19
[AD.6]	Interface Control Document for the NWCLIB of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/ICD/2	1.1	01/10/19
[AD.7]	Data Output Format for the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/DOF	1.1	01/10/19
[AD.8]	Component Design Document for the NWCLIB of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/ACDD/NWCLIB	2.0.1	31/07/18
[AD.9]	NWC SAF Product Requirements Document	NWC/CDOP3/GEO/AEMET/MGT/PRD	1.1	21/12/18
[AD.10]	User Manual for the Tools of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SCI/UM/Tools	1.0	21/01/19
[AD.11]	Algorithm Theoretical Basis Document for the "Automatic Satellite Image Interpretation – Next Generation" Processor of the NWC/GEO	NWC/CDOP2/GEO/ZAMG/SCI/ATBD/ASII-NG	2.1.1	01/10/19

***Table 1:** List of Applicable Documents*

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	2.1	03/02/17
[RD.2]	Scientific and Validation Report for the "Automatic Satellite Image Interpretation – Next Generation" Processors of the NWC/GEO	NWC/CDOP3/GEO/ZAMG/SCI/VR/ASII-NG	1.0	21/01/19

***Table 2:** List of Referenced Documents*

2. DESCRIPTION OF THE NWC/GEO-ASII-NG PRODUCTS

2.1 GOAL OF THE ASII-NG PRODUCTS

ASII-NG/PGE17 utilizes concepts established during the development of ASII in CDOP, but based on new algorithmic components developed during CDOP-2 and CDOP-3, especially the probabilistic method of logistic regression. The new product differs also in its focus on only a few selected phenomena of particularly high user interest and in its output of probability-of-occurrence on a pixel-by-pixel basis.

In its first development stage, ASII-NG focuses on the detection of turbulence from characteristic patterns (i.e. lee waves, jet-induced turbulence and tropopause folding). Algorithms based on pattern recognition methods are exploiting the image data provided by the MSG (or Himawari or GOES-R) satellite and are complemented by NWP data, where suitable, to give an objective analysis of regions with increased likelihood of turbulence.

Later, ASII-NG shall be extended by additional products, such as the detection of in-flight icing potential. Both phenomena, i.e. turbulence and icing, represent threats for civil aviation. The intention is to develop more accurate and timely diagnoses of conditions leading to ice accretion on aircraft during flight.

2.2 DESCRIPTION OF AUTOMATIC SATELLITE INTERPRETATION – NEXT GENERATION PRODUCTS

The ASII-NG products are encoded in standard NWCSAF netCDF output files. As such, they feature many standard entries/matrices common to all NWC/GEO netCDF products; such contents are described in the NWCSAF Data Output Format Document [AD.7]. There is one file per slot per sub-product, and the output files are located by default in $SAFNWC/export/ASII; the naming follows the schematic S_NWC_ASII-<*sub-product*>_MSG*i*_<*region*>-VISIR_*YYYYMMDD*T*hhmmss*Z.nc (examples: S_NWC_ASII-GW_MSG3_global-VISIR_20150626T120000Z.nc and S_NWC_ASII-TF_MSG3_global-VISIR_20150626T120000Z.nc).

Apart from the standard fields, the netCDF file holds the following ASII-NG-specific fields:

- (ASII-TF) "asii_turb_trop_prob": derived probability for occurrence of tropopause folding; for each pixel a value between 0 and 100%, with failure to derive it at a certain pixel indicated by code 255.
- (ASII-TF) "asii_turb_trop_prob_status_flag": giving more details on reasons why "asii_turb_trop_prob" could not be derived at a certain pixel. 0=everything OK, probability computed; otherwise:
    - bit 1 set: problem in "stripe in WV6.2"
    - bit 2 set: problem in "(gradient in) WV6.2"
    - bit 3 set: problem in "gradient of the difference image IR9.7-IR10.8"
    - bit 4 set: problem in "shear vorticity" (NWP parameter)
    - bit 5 set: problem in "wind speed" (NWP parameter)
    - bit 6 set: problem in "tropopause from specific humidity" (NWP parameter that may require model levels in great height)
- (ASII-GW & ASII-TF) asii_turb_prob_pal: turquoise (0)-to-red (100%) palette

- (ASII-GW) "asii_turb_wave_prob": derived probability for presence of gravity wave; for each pixel a value between 0 and 100%, with failure to derive it at a certain pixel indicated by code 255.
- (ASII-GW) "asii_turb_wave_prob_status_flag": giving more details on reasons why "asii_turb_wave_prob" could not be derived at a certain pixel. 0=everything OK, probability computed; otherwise:
    - bit 1 set: not a valid WV7.3 pixel
    - bit 2 set: pixel filtered by temperature threshold in WV7.3
- the common processing conditions and quality flags (described in [AD.7]) for these products bear the names asiigw_conditions/asiitf_conditions and asiigw_quality/ asiitf_quality.

The "product completeness" field in the netCDF file derives from the number of processed pixels divided by the total number of pixels (a baseline effect is to be expected if the processing region has space pixels in it). For the "product quality" of ASII-GW, a value of 1 is assigned to all pixels where all tests could be carried out. If this is not possible (typically at the edge of the domain), the quality should be lower – as the computational effort to determine the degree of incompleteness should be saved, the "average reduced quality" of 0.5 is assigned to such pixels; the netCDF variable then is computed as the average over all non-space pixels. Under normal circumstances, this is merely a function of region geometry and should therefore be a constant for a given region. For ASII-TF, no viable strategy has been devised so far to derive a global product quality figure which would provide additional value over the information contained in "asii_turb_trop_prob_status_flag" (the major conceptual difference to ASII-GW being that the product is completely suspended at any pixel where one ingredient is missing; nevertheless, as the NWCSAF netCDF model requires the figure, it is currently arbitrarily set to 100%).

3. IMPLEMENTATION OF THE ASII-NG PGES

ASII-NG is extracted by PGE17 of the NWC/GEO software package. Detailed information on how to run this software package is available in the "Software User Manual for the NWC/GEO application".

The implementation of the ASII-NG software follows the general implementation of components of the NWC/GEO software (see the software part of the Users Manual of the NWC/GEO software for more details).

Basically, the following steps are needed to run the ASII-NG software:

1. Create or update configuration files (system, region, model and run configuration files) according to their format (see the Interface Control Document ICD/1 [AD.5]). Files are situated in $SAFNWC/config.
2. Algorithm configuration files are situated in the directories $SAFNWC/import/Aux_data/ASII-GW and $SAFNWC/import/Aux_data/ASII-TF. These PGE17 input files are provided with the software package, installed together with it, and are not foreseen for modification by users.
3. Ensure that the remapped NWP data has been made available in the DATABUF directory "$SAFNWC/tmp" (only needed by ASII-TF at the time being).
4. Ensure that the SEVIRI image file in HRIT format (mandatory input) (or the Himawari input) is available in the directory $SAFNWC/import/Sat_data/.

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

<u>Submitting GEO-ASII-NG,v2018.1 in stand-alone mode, not using the task manager:</u>

Ensure that all required input data are available in their respective directories, and that pre-requirements listed under items 1-4 are fulfilled.

The ASII-GW executable GEO-ASII-GW-v10 can be called as follows (from the directory where it is situated, which normally should be $SAFNWC/bin):

GEO-ASII-GW-v10 YYYY-MM-DDThh:mm:ssZ <region_conf_file> <model_conf_file>

Example:

GEO-ASII-GW-v10 2015-06-26T12:00:00Z test_asii.cfg safnwc_ASII-GW.cfm

The ASII-TF production follows an analogous scheme:

GEO-ASII-TF-v20 YYYY-MM-DDThh:mm:ssZ <region_conf_file> <model_conf_file>

Example:

GEO-ASII-TF-v20 2015-06-26T12:00:00Z test_asii.cfg safnwc_ASII-TF.cfm

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

4.1 ASII-TF

4.1.1 List of inputs

- SEVIRI IR imagery, channel 9.7, current slot
- SEVIRI IR imagery, channel 10.8, current slot.
- SEVIRI WV image, channel 6.2, current slot
- NWP data (temperature, relative humidity, wind)

4.1.2 Configurable parameters

N/A in NWC/GEOv2018.

4.2 ASII-GW

4.2.1 List of inputs

- SEVIRI WV image, channel 7.3, current slot

4.2.2 Configurable parameters

N/A in NWC/GEOv2018.

5. SUMMARY OF AUTOMATIC SATELLITE IMAGE INTERPRETATION – NEXT GENERATION (ASII-NG) VALIDATION RESULTS

5.1 ASII-GW

The ASII-NG gravity wave detection sub-product ASII-GW directs the meteorologist in a time-saving manner to those areas where gravity waves can be seen in WV7.3. False detections are kept at very low rates, and their occurrence is understandable from the construction of the algorithm and the optical appearance of the affected meteorological phenomena. It is fortunate that these phenomena can be quickly identified as "something else" through visual inspection. Nevertheless, to obtain an even cleaner product, it is desirable to find a way to eliminate cases of incorrectly flagged areas of marine stratocumulus (especially disturbing during the cold season). Any progress in this area should also bring us closer to applicability of the technique to other channels, where the false-alarm rate is currently too high, but where gravity waves are sometimes indicated that are not visible in the currently used WV7.3 channel.

5.2 ASII-TF

The ASII-NG tropopause fold detection sub-product is tuned to detect stronger variations of the tropopause height. Validation of the indicated tropopause fold positions by the ASII-TF product has been done against pilot reports (PIREP) and IASI derived tropopause heights.

Visual inspection of the ASII-TF output with IASI-derived tropopause gradients shows a fairly good consistency regarding the position of the tropopause folds; the ASII-TF product showing even more details than the sounding data, and it also seems to be more sensitive to smaller height variations.

When comparing the ASII-TF output against PIREPs, only turbulence reports from higher atmospheric levels have been considered. Here, turbulence experienced by aircrafts is mainly caused by wind shear at jet level. Strong wind bands at around 300 hPa are often found near tropopause folds. This geographical connection has been used to examine the relation between the position of the observed turbulence and the location of the tropopause fold. The obtained results show that most turbulence reports (87%) are issued within or close to tropopause folds identified by the ASII-TF product, when turbulence originates from wind shear.

Although tropopause folds are good indicators for the position of jet streaks, tropopause folds are not the root cause of turbulence. Hence, in case the ASII-TF product is intended to be used as turbulence warning tool, factors like vertical and/or horizontal wind shear should also be considered by the forecaster.

6. WELL-KNOWN PROBLEMS AND RECOMMENDATION FOR USE

These products are aimed to be part of the inputs for decision making by meteorologists, yet cannot be used as a stand-alone automatic warning tool. The products are satellite products searching for features favourable for turbulence but NOT the turbulence itself. As CAT by definition is a clear-air phenomenon there may be areas of turbulence which cannot be detected by any remote sensing tool. Therefore, the absence of signals in satellite imagery does not preclude the presence of CAT. In other words, even assuming the detection algorithms are working perfectly, the detection rate of CAT will never reach 1.

As computation of tropopause heights is one ingredient of ASII-TF, it is recommended that NWP data are provided up to the 50 hPa level to ensure that the tropopause is captured (on the other hand, it was found for the GFS model that the humidity fields in layers above 30 hPa are not dependable. Random fluctuations with often unrealistic increases at high levels accidentally satisfy the tropopause criteria. In order to avoid such erroneous signals, the ASII-TF software simply omits NWP input from layers with <30hPa pressure, as the tropopause should be located in lower layers anyway).

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.

The adaptation of ASII-NG to Himawari/GOES-R had a purely technical scope, yet there is no reason to question the functionality of the ASII-GW algorithm on the Himawari or GOES-R 7.3 µm channel. ASII-TF, however, uses SEVIRI IR 10.8 µm which is approximated by the Himawari 11.2 µm in NWC/GEO. Actually, the channel difference IR 9.7 µm – IR 10.8 µm enters ASII-TF's logistic regression relation in form of its gradient field, some uncertainty on the applicability of the used SEVIRI-derived regression relation remains at present. Though the module could be technically run for Himawari/GOES-R with little or no adaptation effort, there is the mentioned risk and Himawari/GOES-R ASII-TF hence formally is not part of release 2018.

Due to higher false alarm rates for IR/VIS input, the ASII-GW algorithm is released only in its application to the WV7.3 channel. Often enough, gravity waves are clearly seen in other channels (especially HRVIS) but hardly in the WV7.3 recorded at the same time. These situations will be mastered only after augmentation of the current algorithm, along the lines outlined in Jann (2019).

7. EXAMPLES OF PRODUCT VISUALISATIONS

The ASII-NG output files are in netCDF format, a widespread standard for which several handy visualization and data extraction tools exist. As an example, **Figure 1** features a tool called "HDF Explorer" (which, despite of its name, can also be used to quickly look into NWCSAF netCDF files).

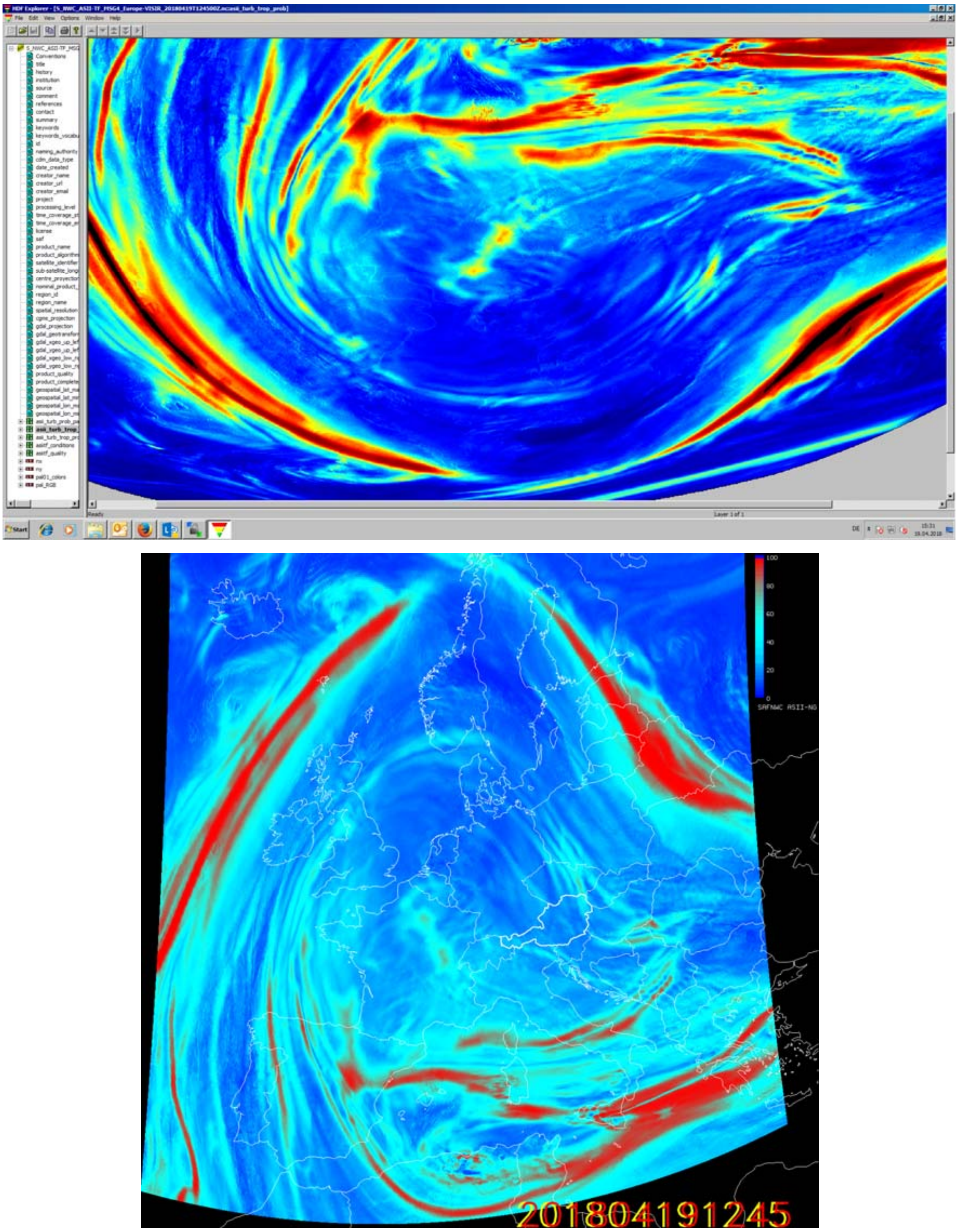
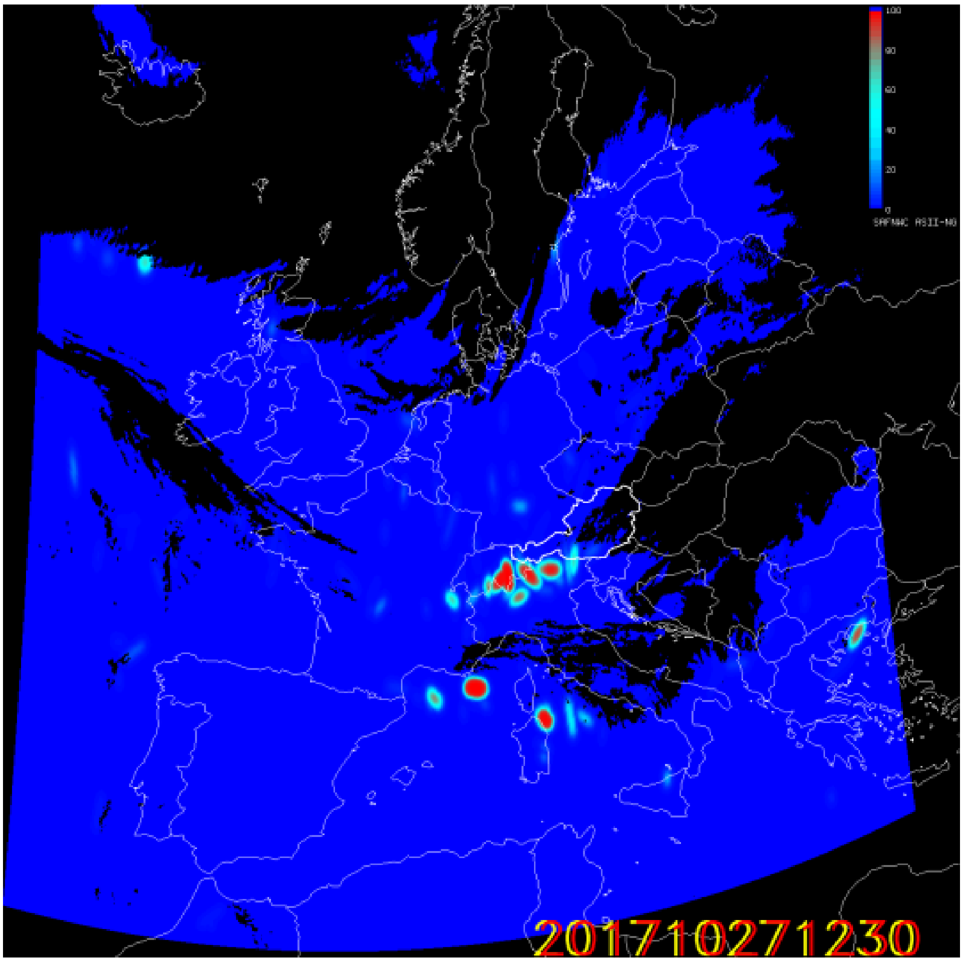


Figure 1: *Example quicklook displays of ASII-TF's "probability of occurrence of tropopause folding" for 19 April 2018, 1245 UTC. Upper panel: as shown in the "HDF Explorer" (a simple viewer that does not interpret/add geographical information); lower panel: as shown on the ZAMG monitoring website using the colour palette included in the output file.*



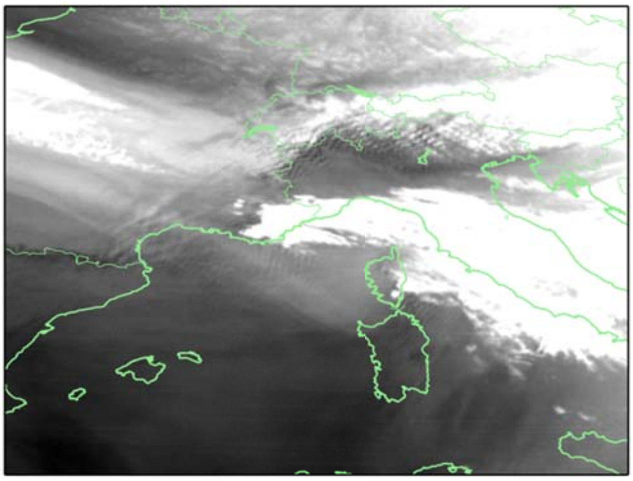


Figure 2: *Case of 27 October 2017, 1230 UTC. Uppermost panel: The probability-of-occurrence of gravity waves, as analysed by the ASII-GW module on the basis of the WV7.3 image (the colour table runs from dark blue = 0% to red=100%; the black areas are those masked by a temperature threshold used to avoid random signals in thick clouds; this is the colour palette included in the output file) Lower panel: Excerpt of the used WV7.3 image.*

Both ASII-NG products contain a turquoise (0)-to-red (100%) palette in the field asii_turb_prob_pal of their respective netCDF output files. **Figure 1** shows the selected case also in this colouring scheme, **Figure 2** features an example ASII-GW display produced with this suggested colour table. In this figure, the WV7.3 image is added on a separate display so the product can be verified against the patterns subjectively detected in the image. As the ASII-GW product is very amenable to isoline representation, such a verification can be conveniently accomplished also within a single image, as in **Figure 3**.

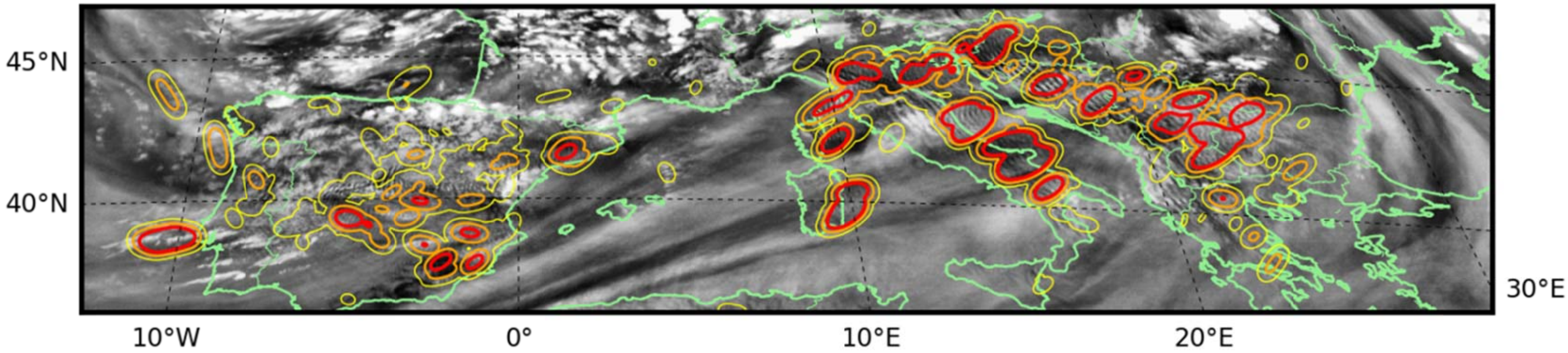


Figure 3: *The WV7.3 image of 29 June 2017, 1400 UTC, over Mediterranean Europe, superimposed by the 1, 50 and 99% isolines of probability of gravity-wave occurrence, as indicated by the ASII-GW product, v2018.*

8. REFERENCES

Jann, A. (2019): Objective detection of stripe patterns in satellite imagery caused by gravity waves: Lessons learnt from the southern hemisphere. *Trans. R. Soc. S. Afr.*, **74,** 163-172, https://doi.org/10.1080/0035919X.2019.1596176.