

The Extrapolated Imagery (EXIM) product

Alexander Jann
ZAMG, Vienna, Austria

With contributions by: J. García-Pereda (AeMet Madrid) & the Nowcasting-SAF team at Météo-France Toulouse

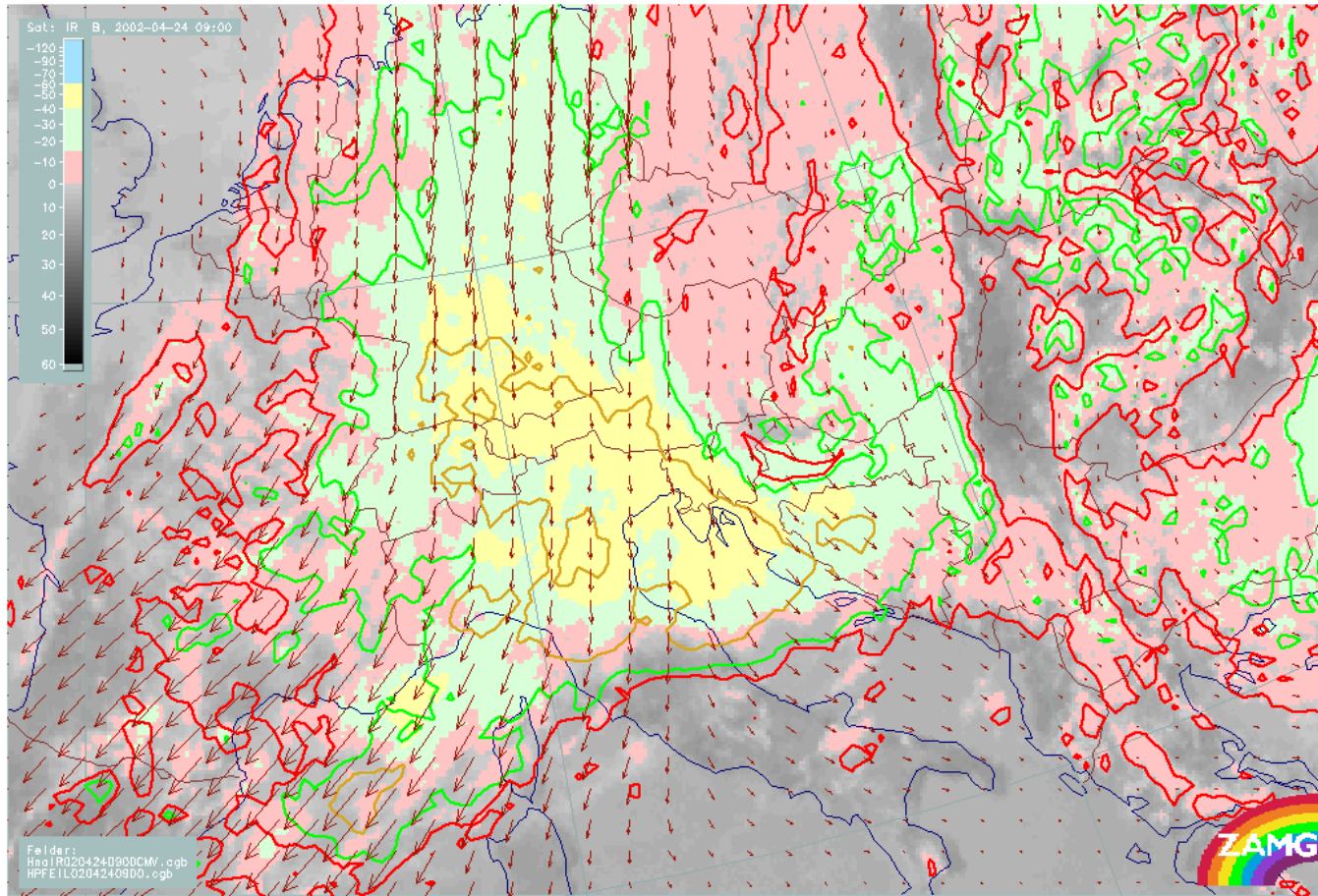
Nowcasting-SAF User Workshop, 10-12 March 2020, Madrid

Goal of EXIM

Provide

- forecast satellite images
- forecast Nowcasting-SAF products
- through kinematic extrapolation
- for lead times ≤ 1 hour

Heritage (MFG IR, +2h)

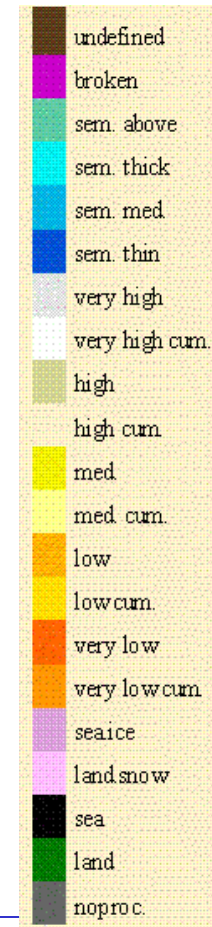
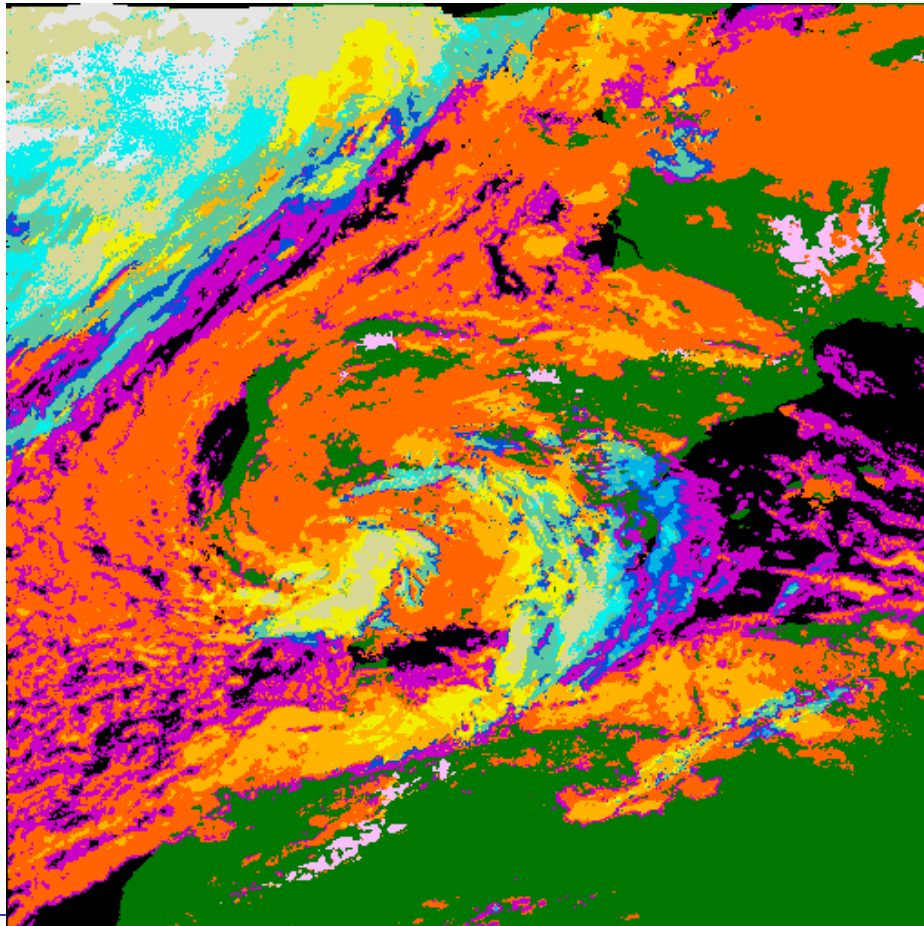


Isolines show how far the cloud field advances in the next two hours

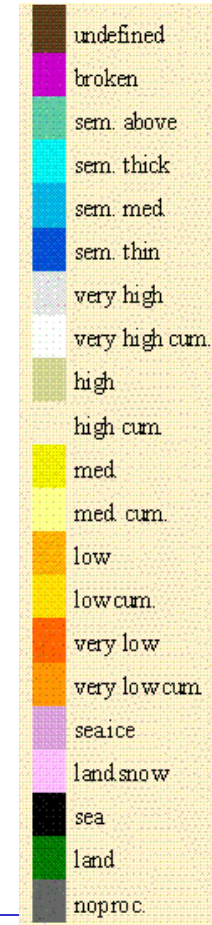
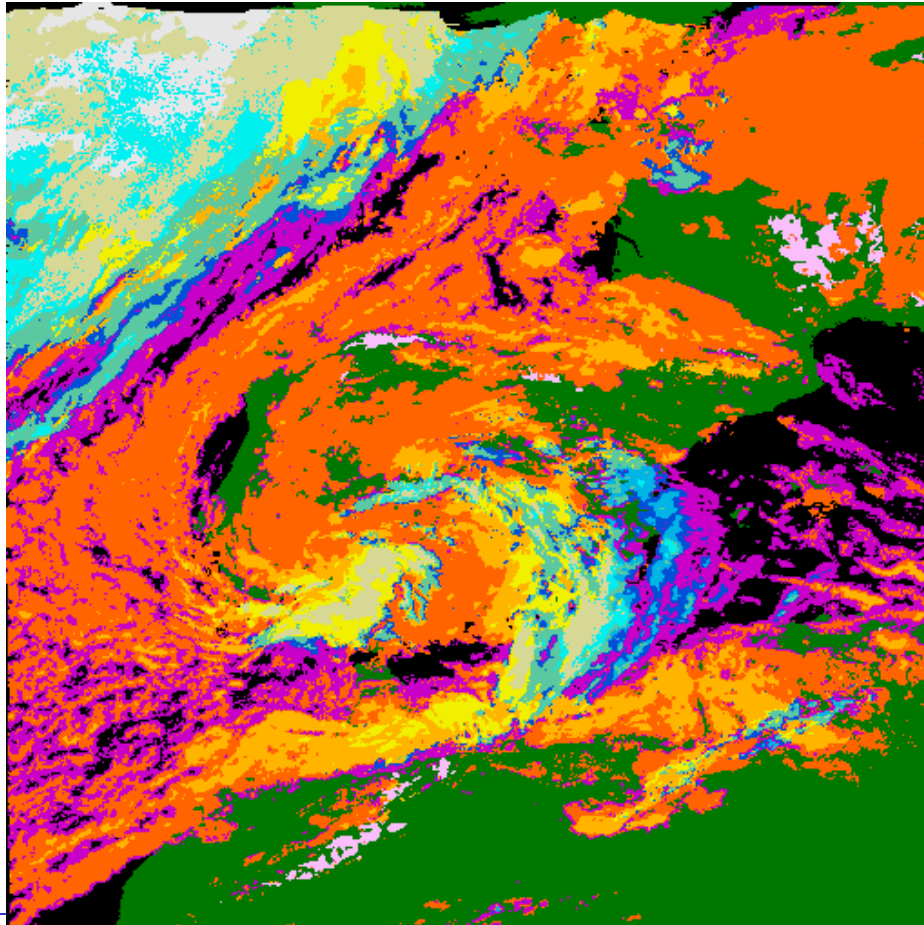
Outline of the EXIM algorithm

- Interpolate (irregularly distributed) HrW product down to pixel level
- Apply the vector field on every pixel n times (i.e. a trajectory for every pixel in nominal resolution)
- Construct the predicted image / NWCSAF product by putting pixels at their predicted positions
- (Optionally) fill gaps through nearest-neighbour or average interpolation
- Other post-processing, e.g. applying land-sea mask or writing an outage code at the edge of the image

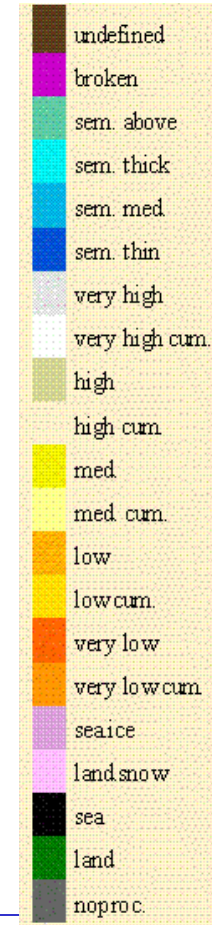
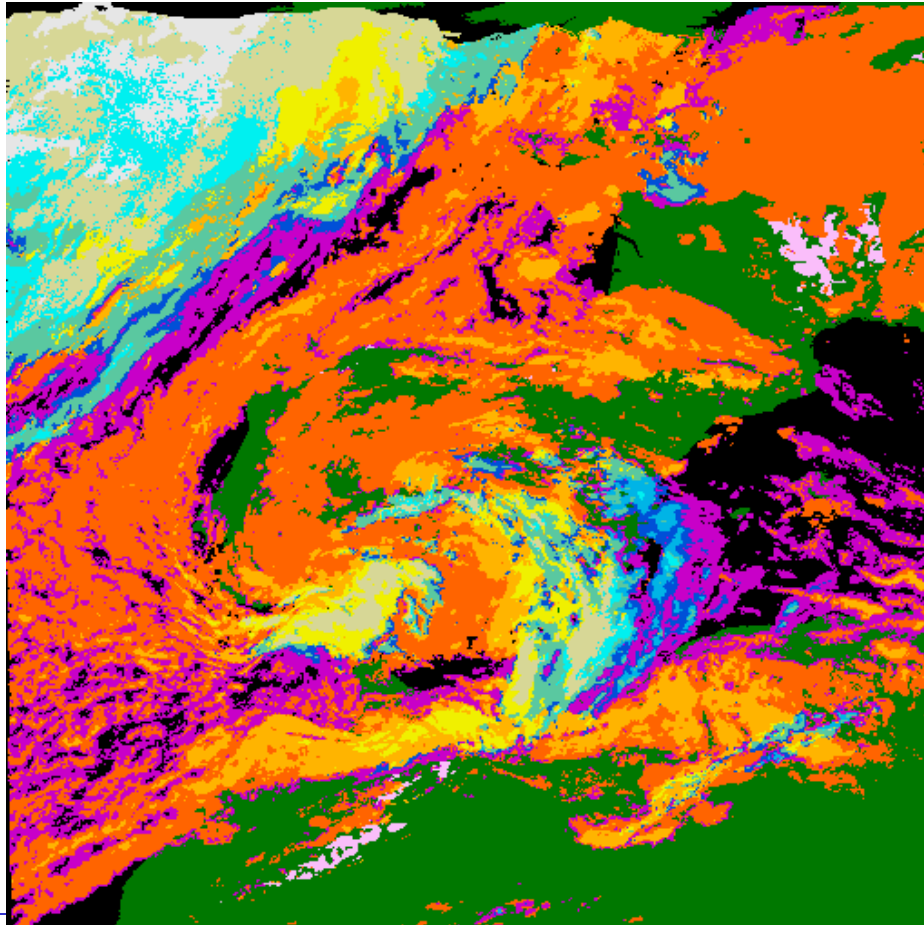
Forecast Cloud Type 12/12/2008, 11.00 + 15min



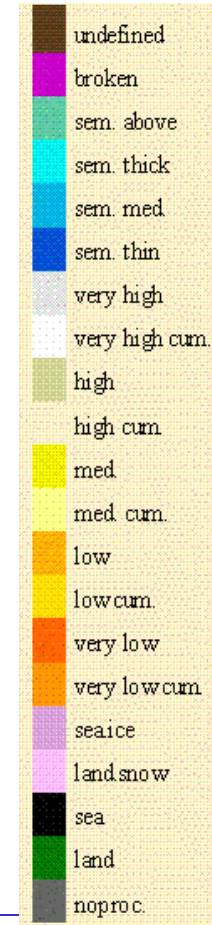
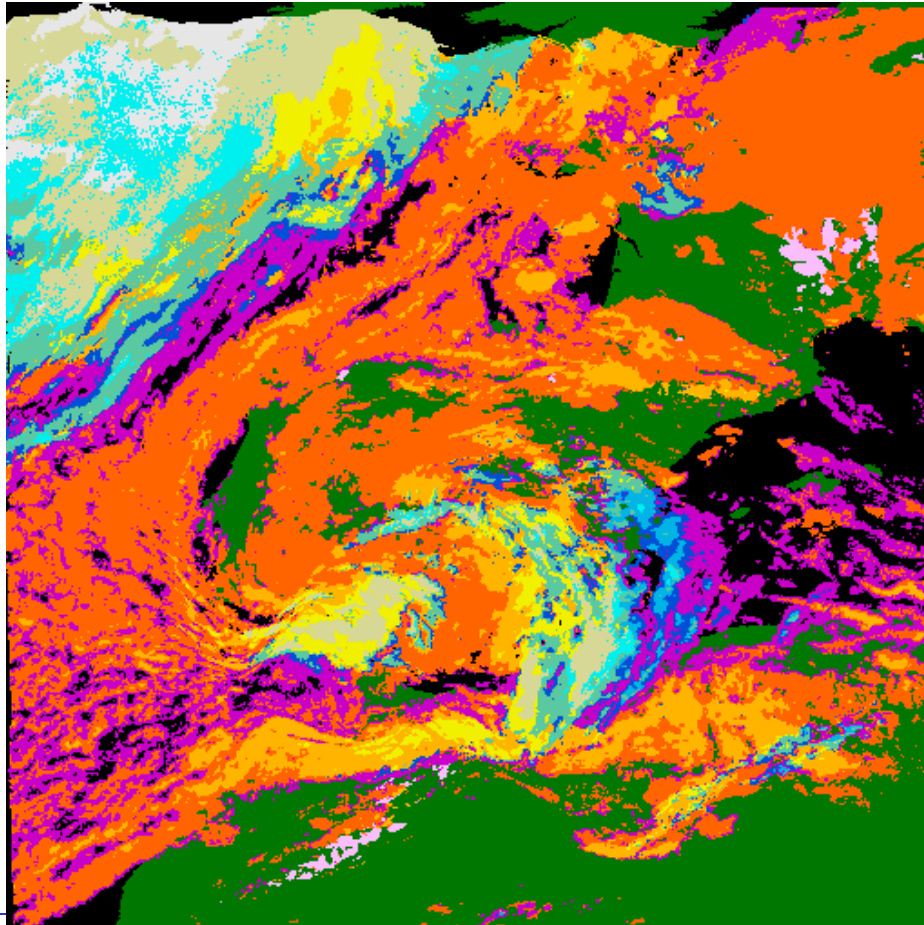
Forecast Cloud Type 12/12/2008, 11.00 + 30min



Forecast Cloud Type 12/12/2008, 11.00 + 45min



Forecast Cloud Type 12/12/2008, 11.00 + 60min



Addressing product specificities makes a difference

From the „Abstract Brochure of the 3rd European Nowcasting Conference“, Madrid, April 2019:

P15. Assessment of satellite rainfall nowcasting based on extrapolation technique

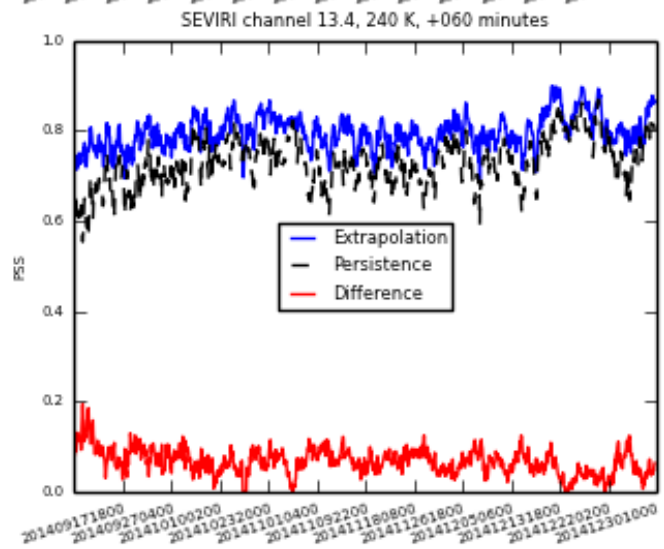
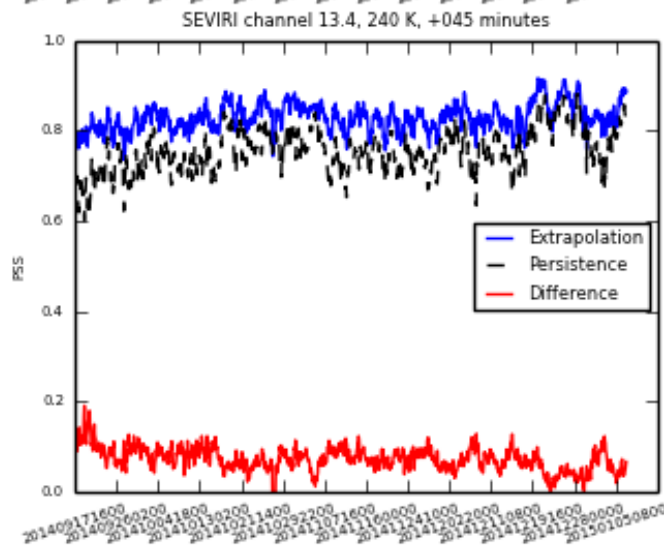
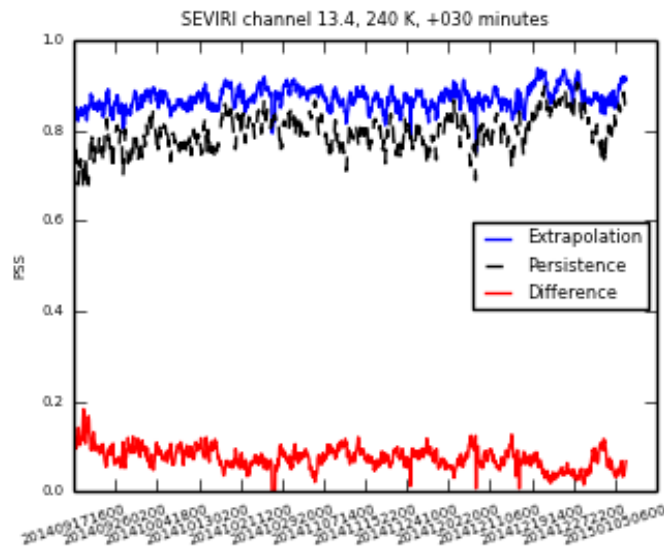
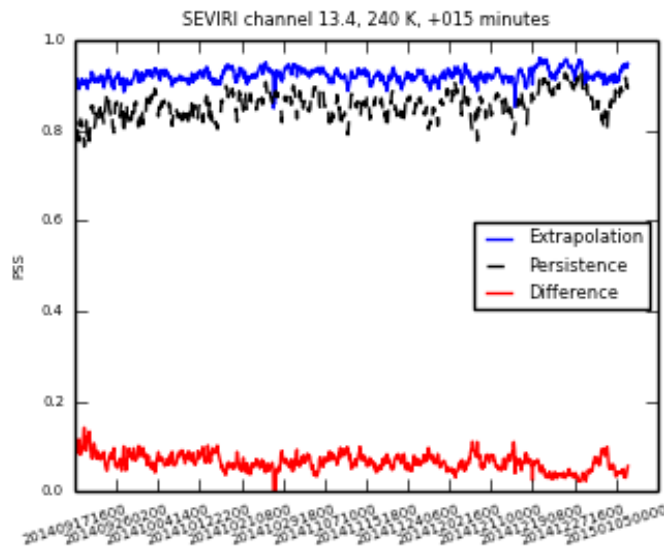
Seon-Young Jeong; Ki-Hong Park; Geun-Hyeok Ryu; Jae-Dong Jang
KMA – Korea Meteorological Agency, Republic of Korea

The National Meteorological Satellite Center (NMSC)/Korea Meteorological Agency (KMA) produce extrapolated images based on satellite data for nowcasting. THE MAPLE (McGill Algorithm for Precipitation Nowcasting and Lagrangian Extrapolation) algorithm is a technique to predict echo after several hours by Lagrangian extrapolation using motion vectors generated by VET. It is used for radar - based precipitation prediction, but it is also applied to satellite images. However, the VET technique used in MAPLE has the problem of moving the coastline or the land because it generates vectors in the clear regions and predicts them based on images. To solve these problems, the NMSC uses the EXIM (Extrapolated Imagery) algorithm to produce a prediction image. The EXIM algorithm is an algorithm developed by NWCSAF, which uses an atmospheric motion vector containing altitude information. The EXIM technique solves the previously mentioned problem by applying cloud detection and land / sea mask.

Validation

Skill - the relative accuracy of the forecast over some reference forecast. The reference forecast is generally an unskilled forecast such as random chance, persistence (defined as the most recent set of observations, "persistence" implies no change in condition), or climatology (from: <http://www.cawcr.gov.au/projects/verification/>).

Hence: Compare the EXIM forecast with what was actually observed 15, 30,... minutes later and verify that the displacement actually did anything positive on the (Peirce) skill score (compared to persistence)



The portfolio of EXIM products

(driven by validation results)

MSG, Himawari, GOES images

MSG:

VIS0.6

VIS0.8

IR3.9

WV6.2

WV7.3

IR8.7

IR9.7

IR10.8

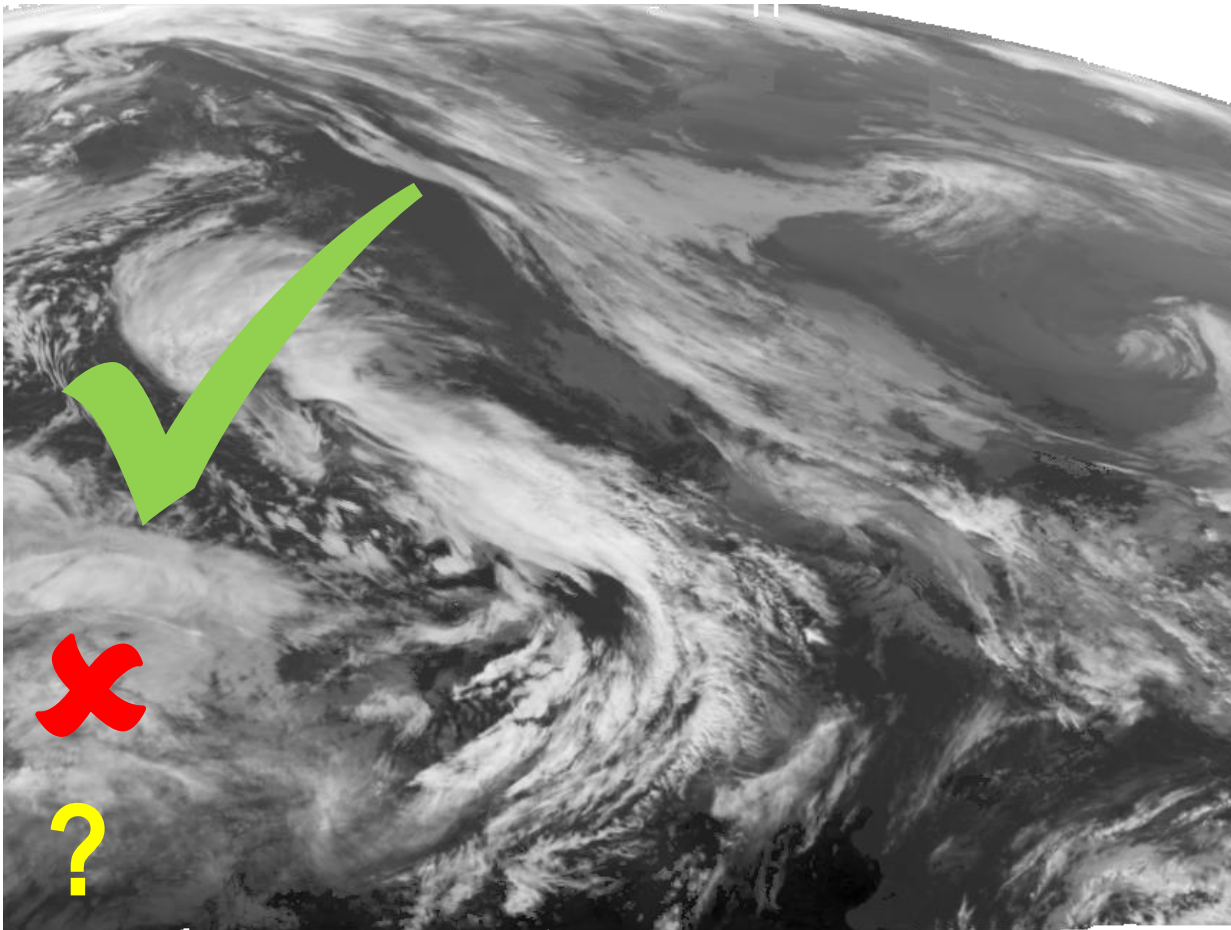
IR12.0

IR13.4

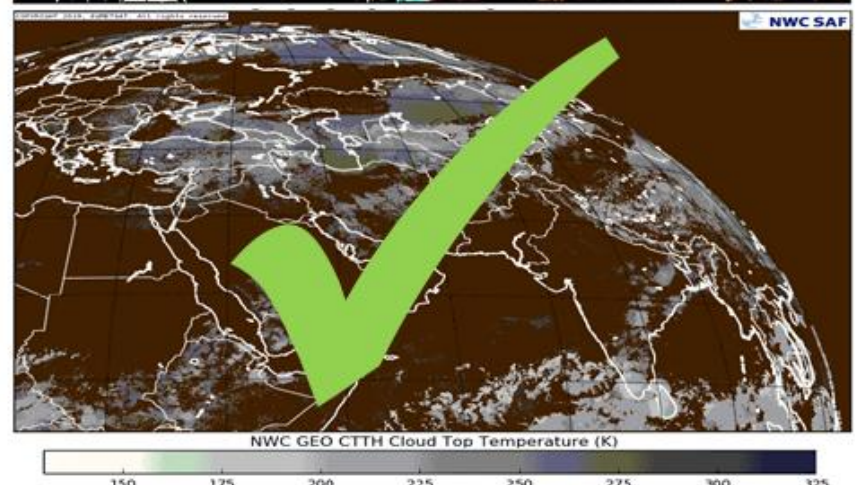
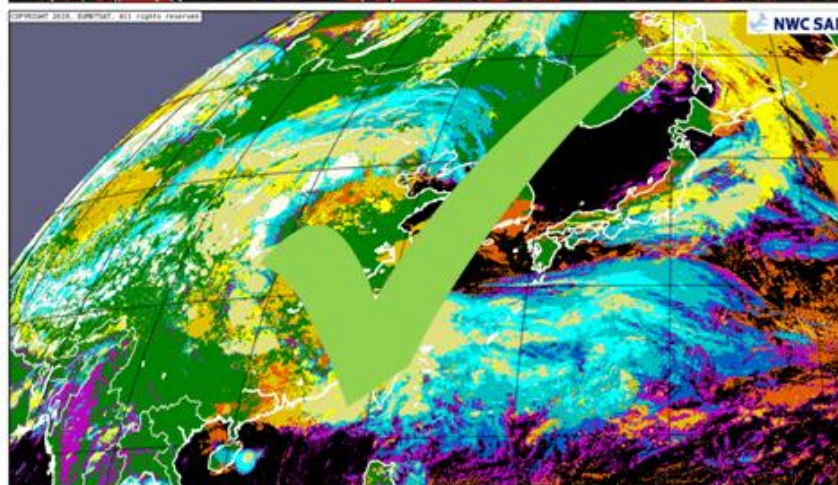
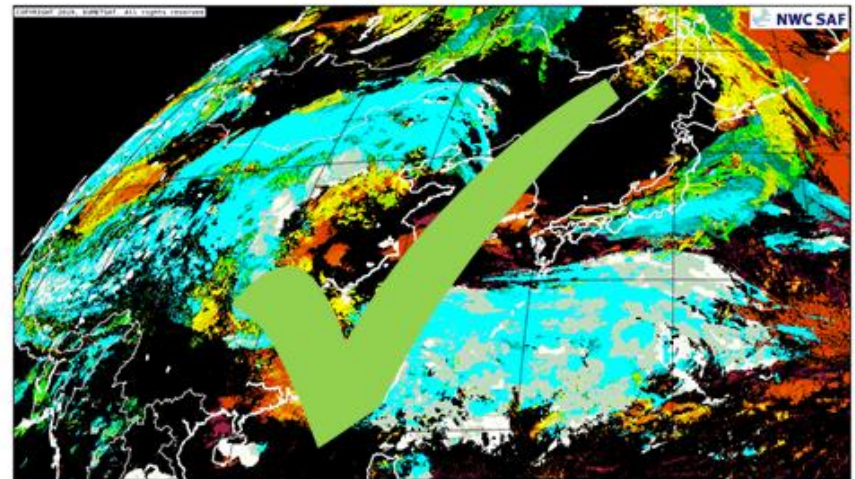
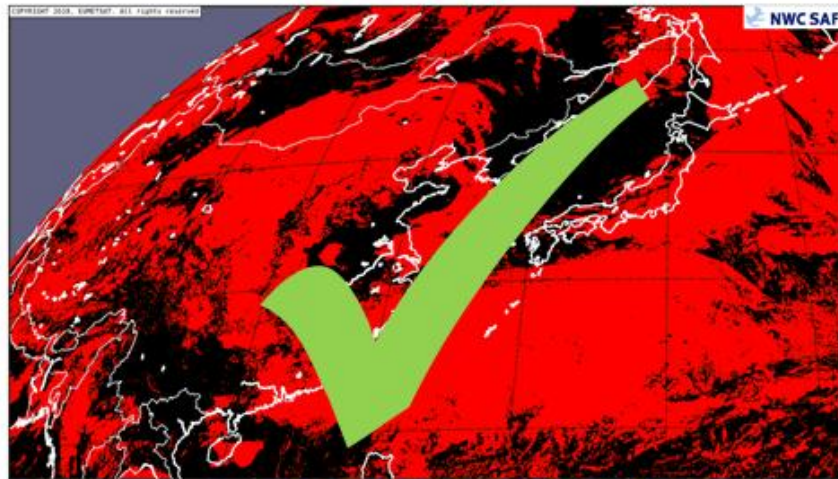
NIR1.6

HRVIS

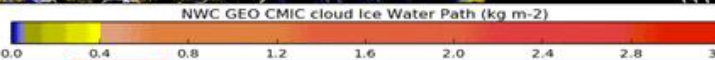
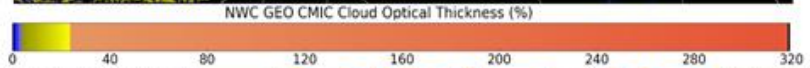
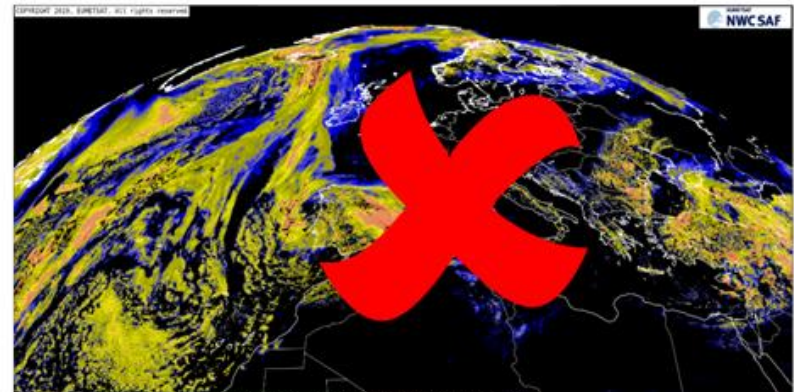
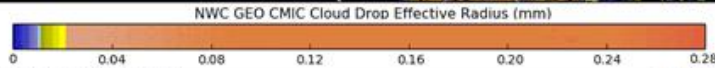
HIMAWARI, GOES:
corresponding
channels, where
available



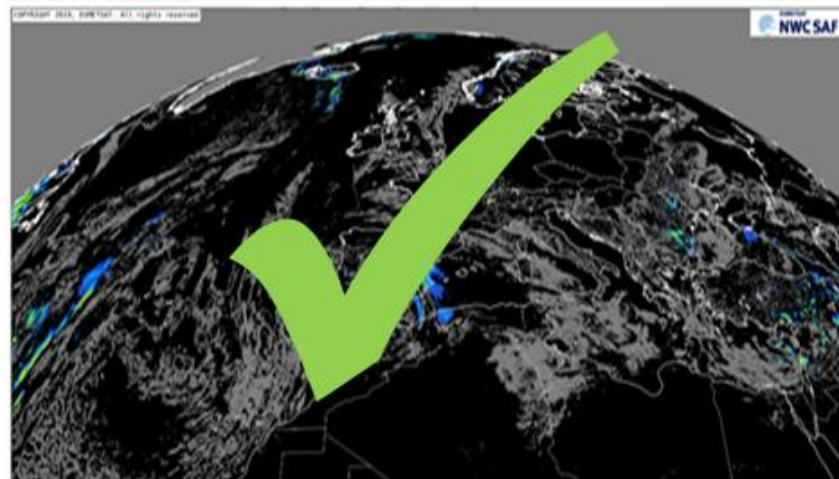
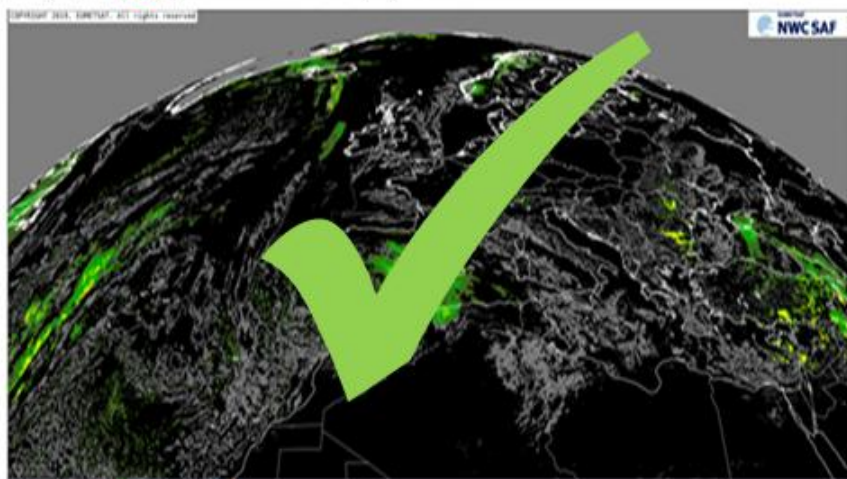
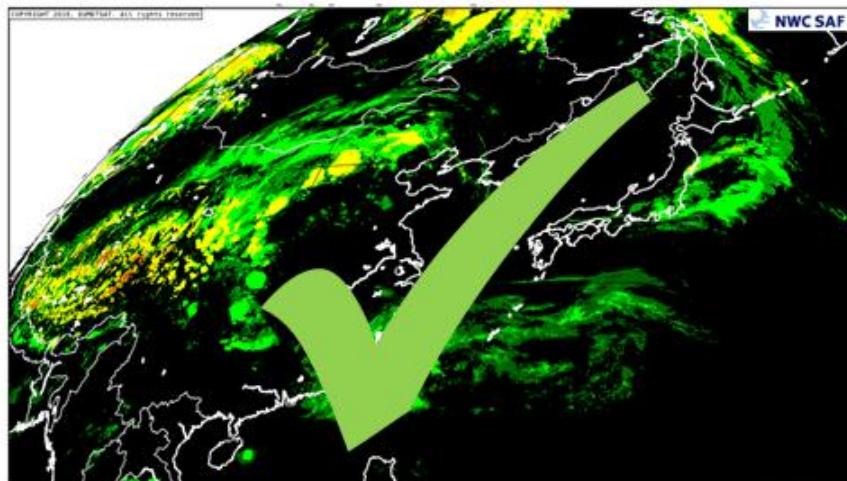
Cloud mask, cloud type, cloud top temperature & pressure & height



Cloud microphysics (only cloud phase amenable to the EXIM approach)

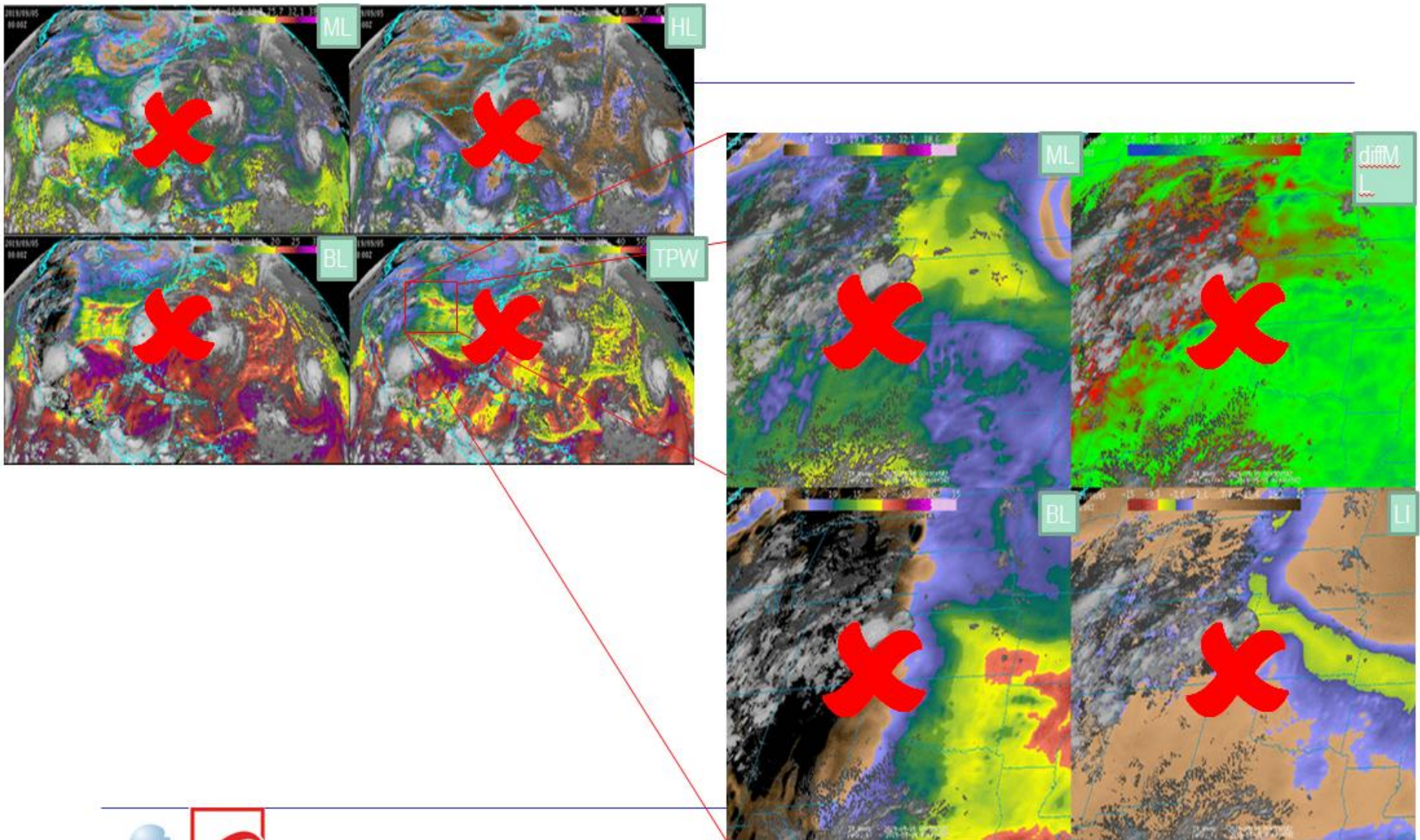


Precipitation products

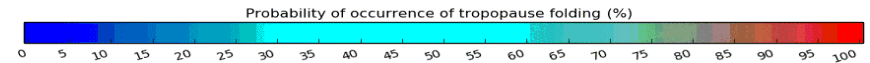
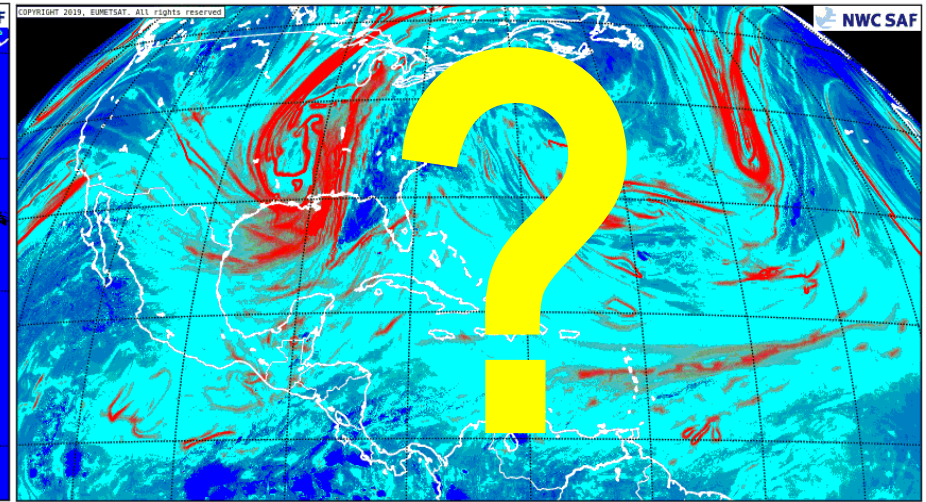
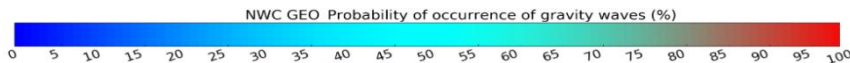
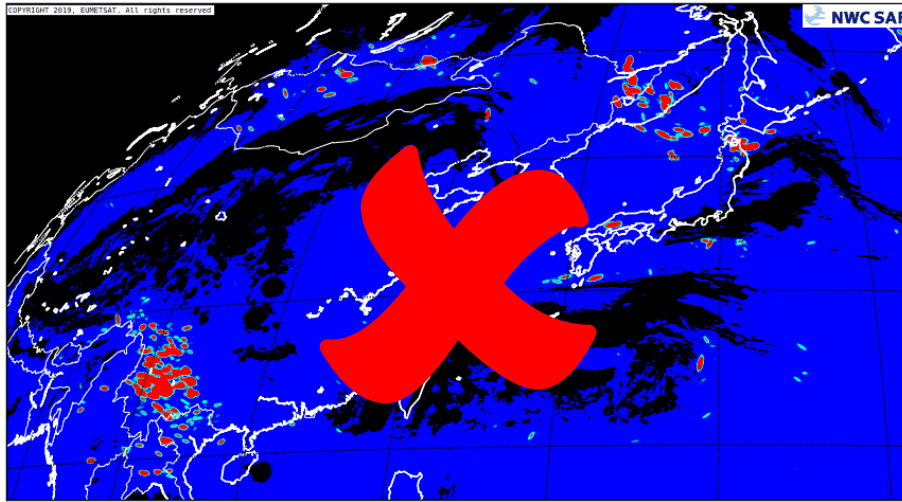


iSHAI – imaging Satellite Humidity and Instability

Parameters considering the entire tropospheric column →



Automatic Satellite Image Interpretation: Gravity wave & tropopause folding probabilities



**Gravity waves not expected
to move with the
Atmospheric Motion Vector**

Convection products

- **“CI – Convection Initiation”**: not considered a candidate for EXIM: **“Probability of a cloudy pixel to become a thunderstorm in 15-60 minutes”** does not move with the **Atmospheric Motion Vector!**
- **“RDT – Rapidly Developing Thunderstorms”** likewise not considered a candidate because the cells follow their own rules concerning movement
!! Actually not needed since RDT offers its own object-oriented forecast of the convective cell position!!

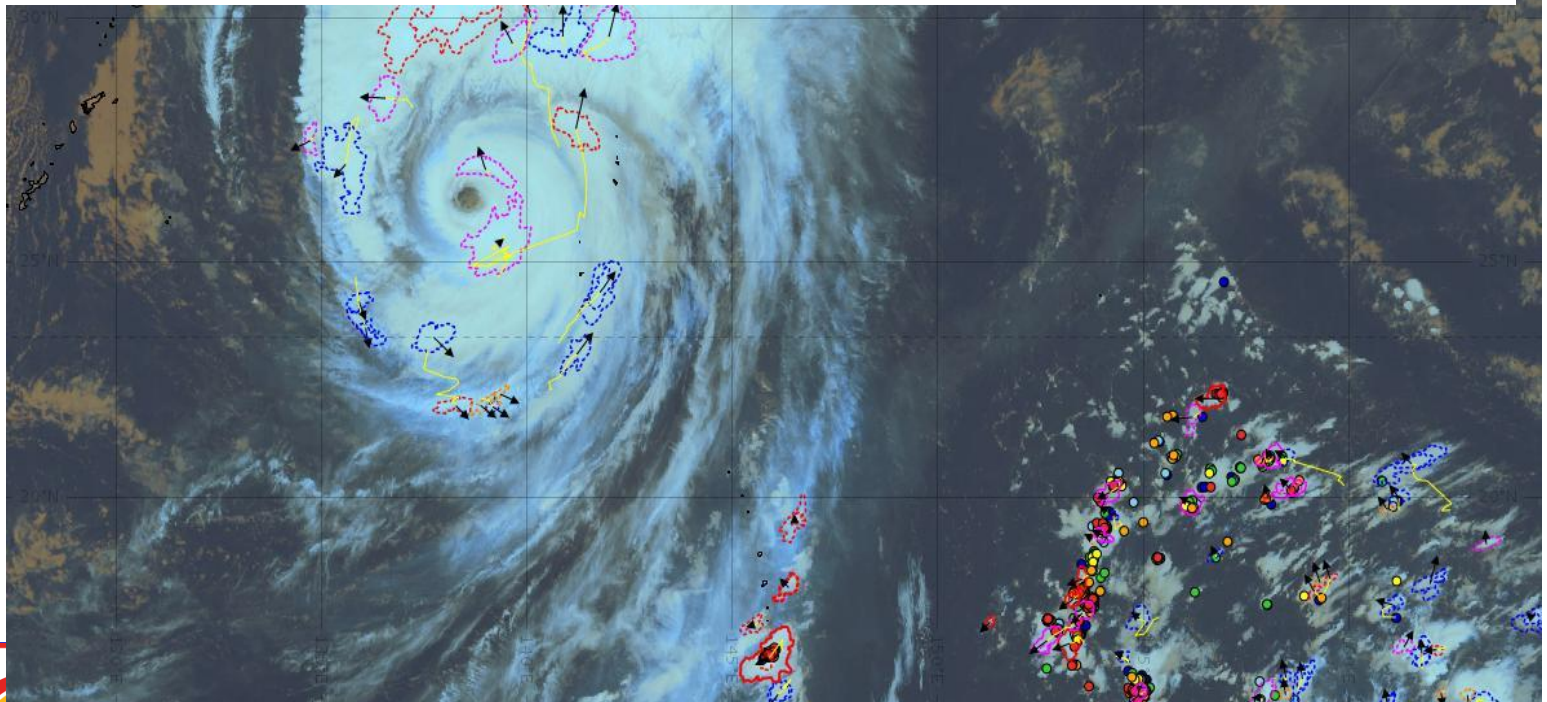
RDT-CW with a +1h forecast of convective cells

Example of **RDT** produced with Himawari-8 10th October 2019 - 18:00Z

18h00Z RGB image and WWLLN flashes superimposed with 18h00Z **analysed RDT**

Outlines depend on RDT's characteristics

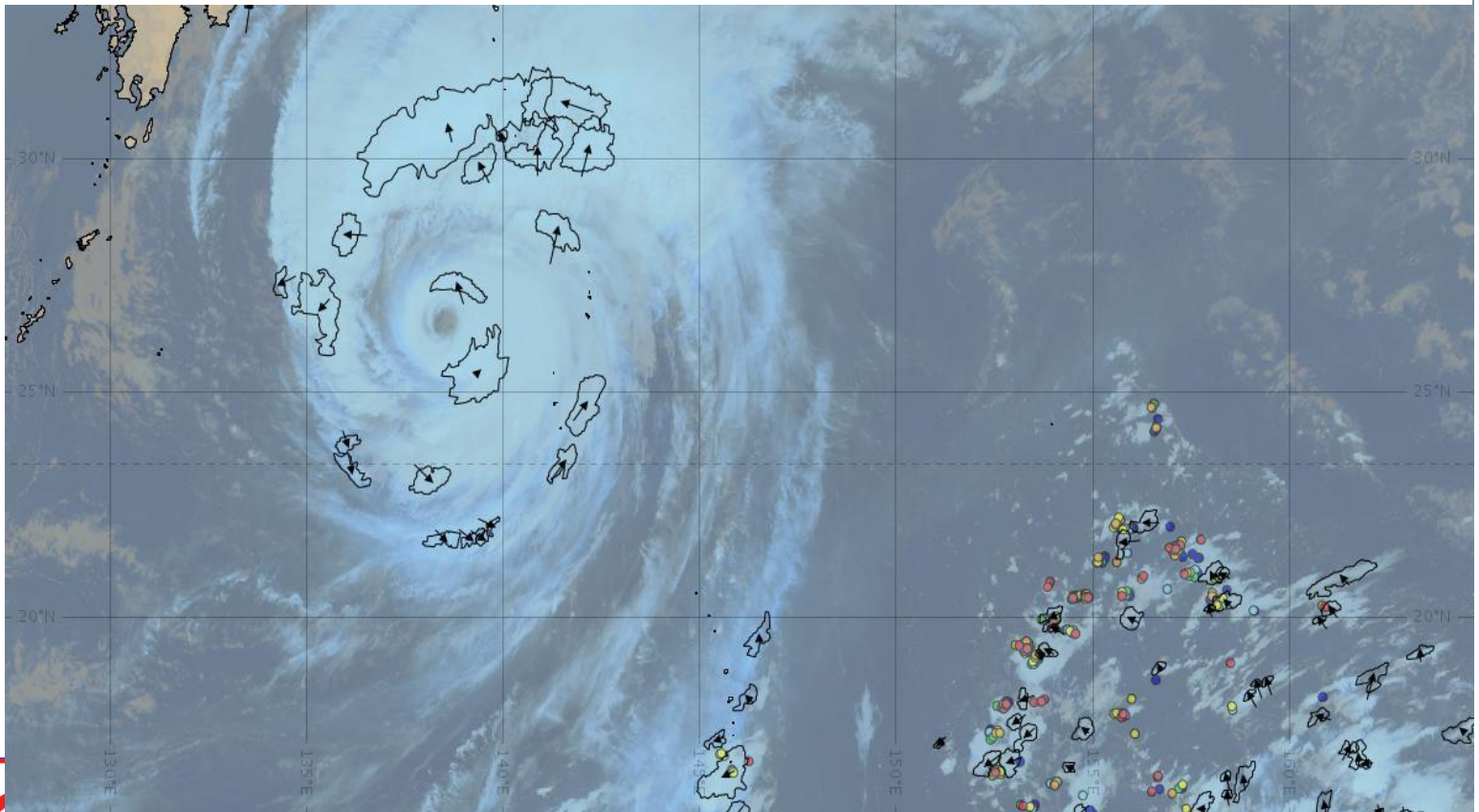
Motion vector estimate will be used to **estimate future displacement**



RDT-CW, validating the +1h forecast

Example of **RDT** produced with Himawari-8 10th October 2019 - 19:00Z

19h00Z RGB image and WWLLN flashes superimposed with **1h-forecast RDT-CW cells**



Some subjects of debate

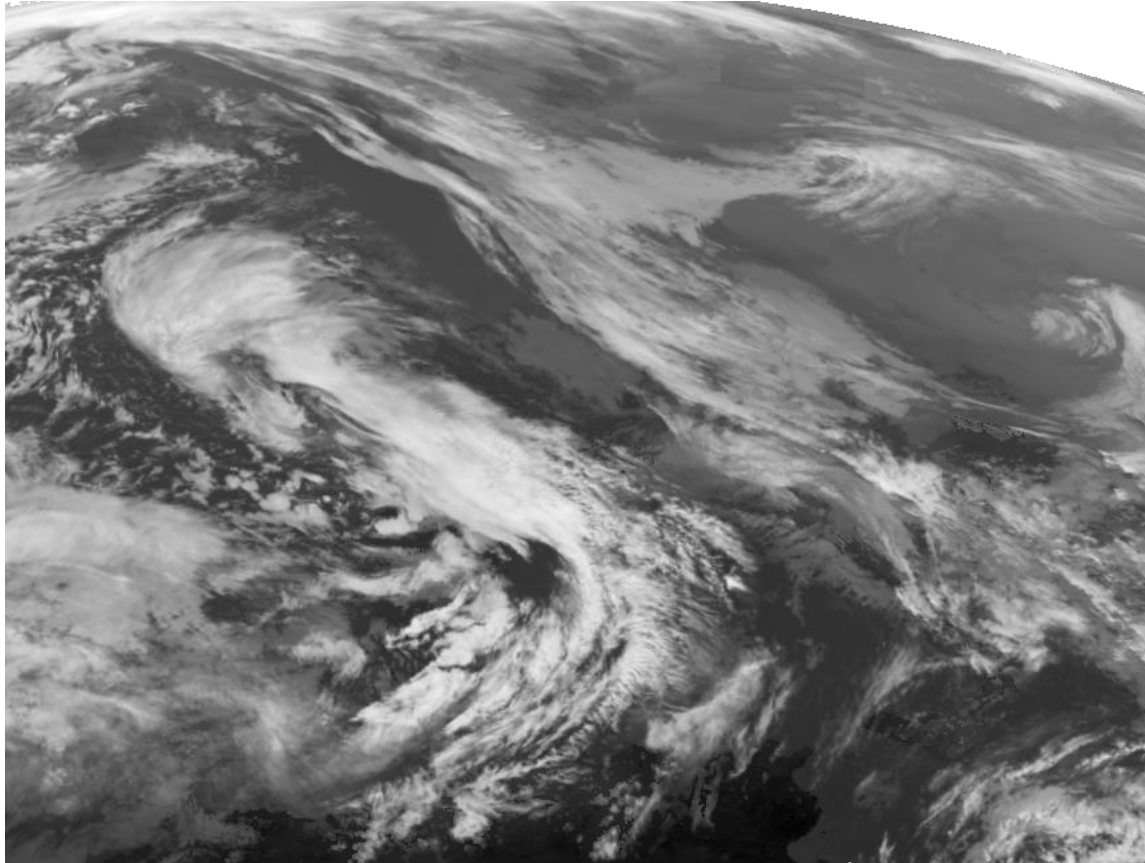
(→ options in the EXIM software)

#1: Handling of cloudfree areas – revisited (for forecast satellite images)

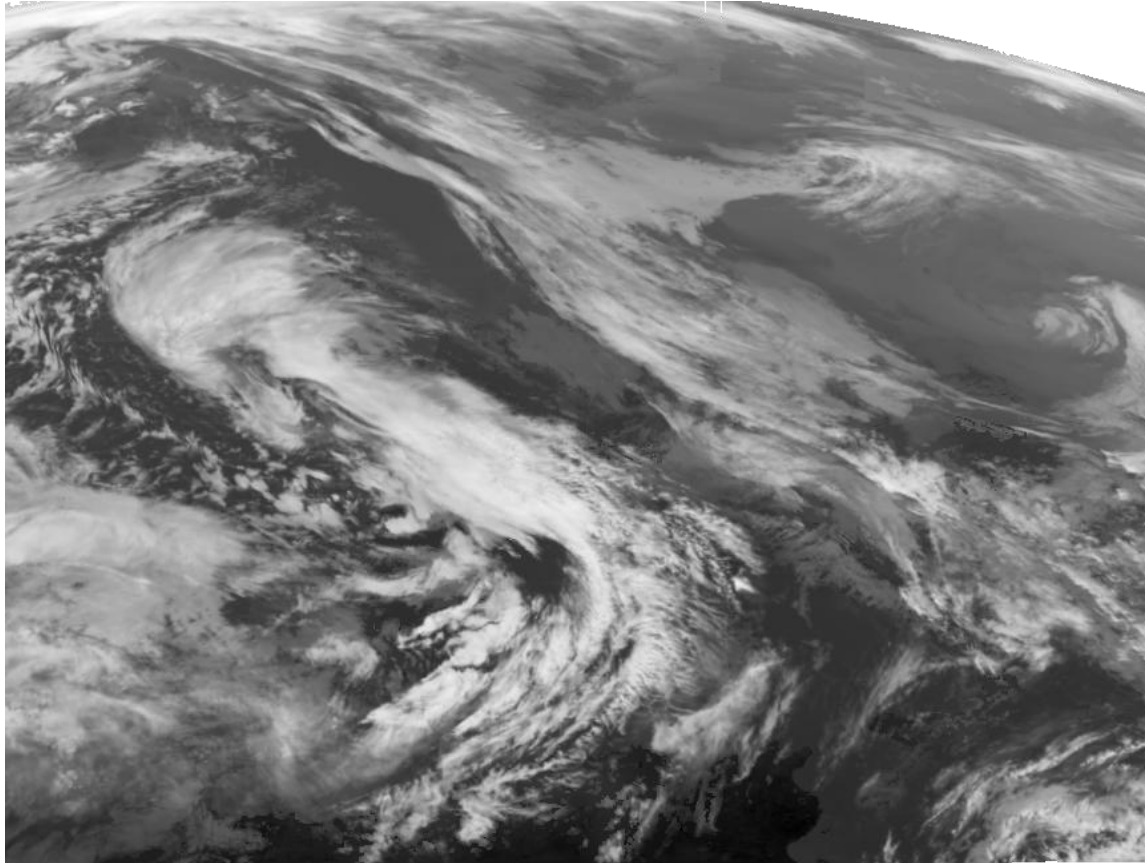
Which temperature value to write at a pixel predicted to be cloudfree? Pursued approach:

- if it was cloudfree in the observation, copy the value
- if it was cloudy in the beginning, seek nearby cloudfree land (sea) pixels, if the pixel is a land (sea) pixel and average temperatures found there
- Any attempt to take the diurnal cycle or orography into account is considered overambitious

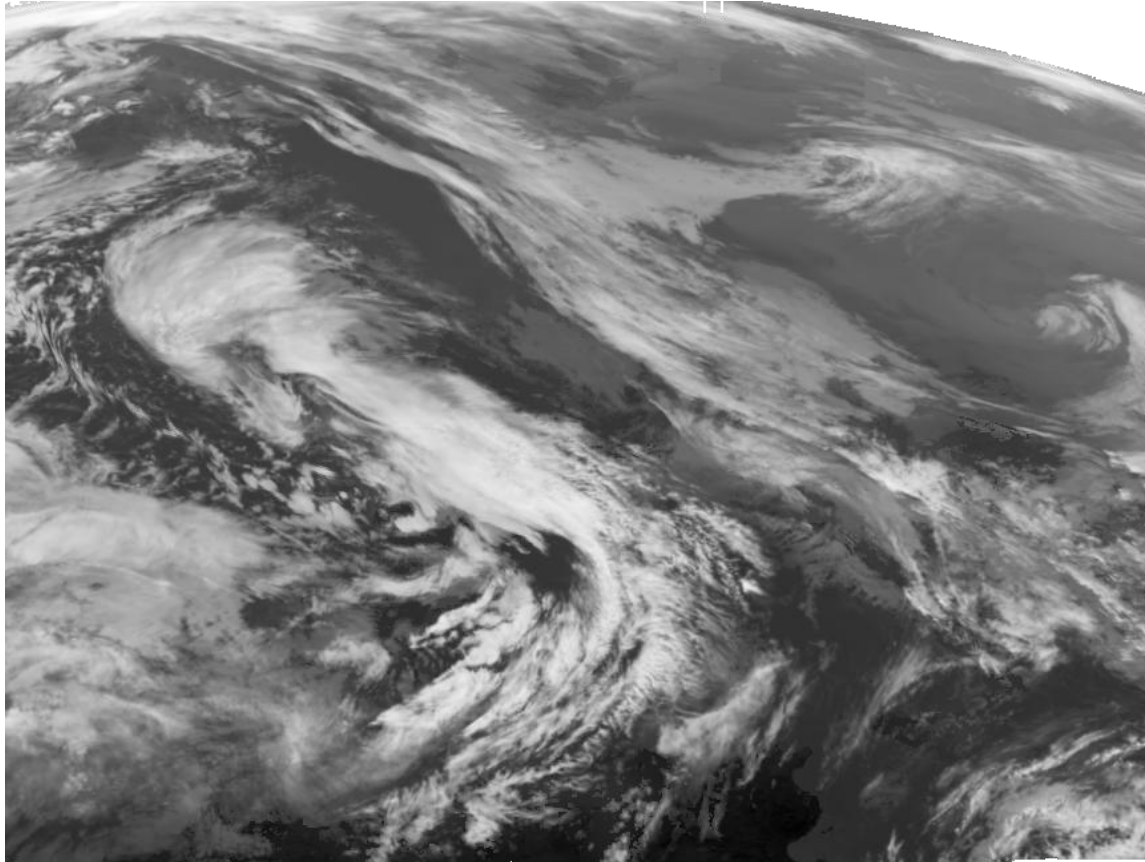
Forecast IR 10.8 image, 3 February 2017, 10.00 UTC + 15 min



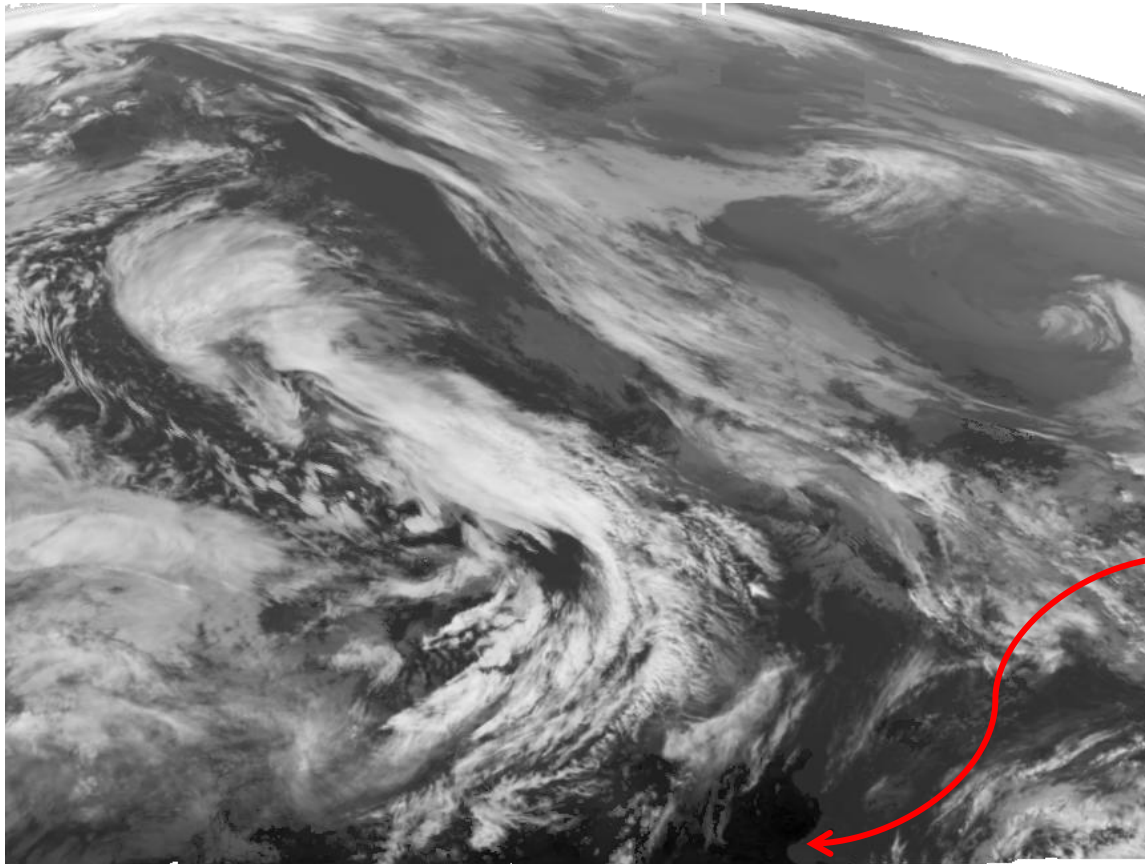
Forecast IR 10.8 image, 3 February 2017, 10.00 UTC + 30 min



Forecast IR 10.8 image, 3 February 2017, 10.00 UTC + 45 min

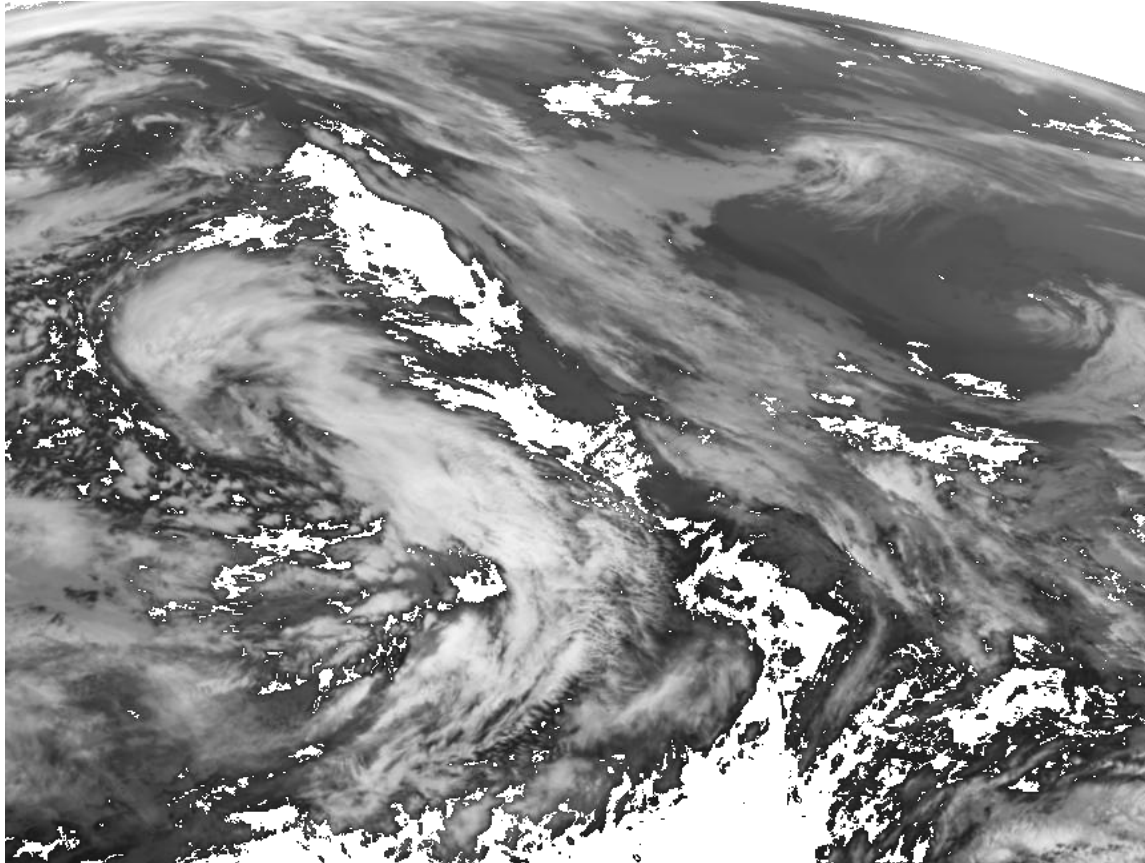


Forecast IR 10.8 image, 3 February 2017, 10.00 UTC + 60 min

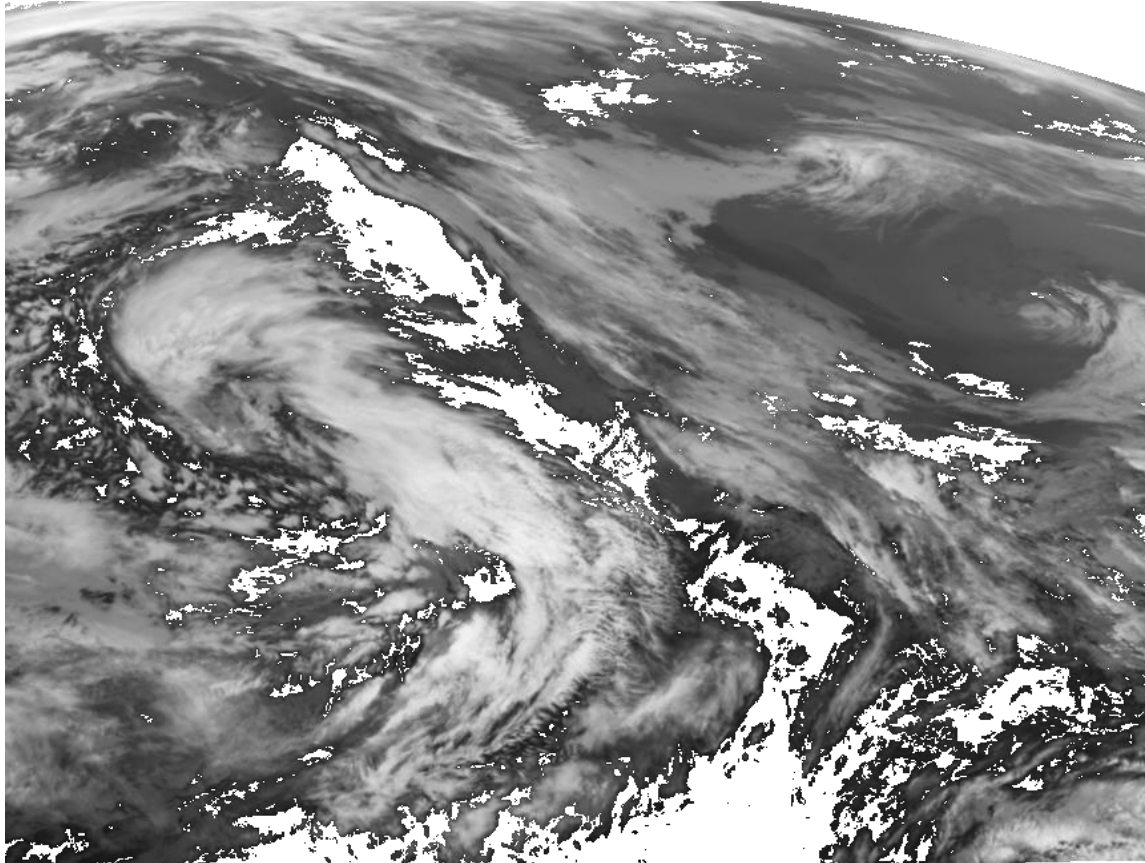


Tunisian coastline
preserved

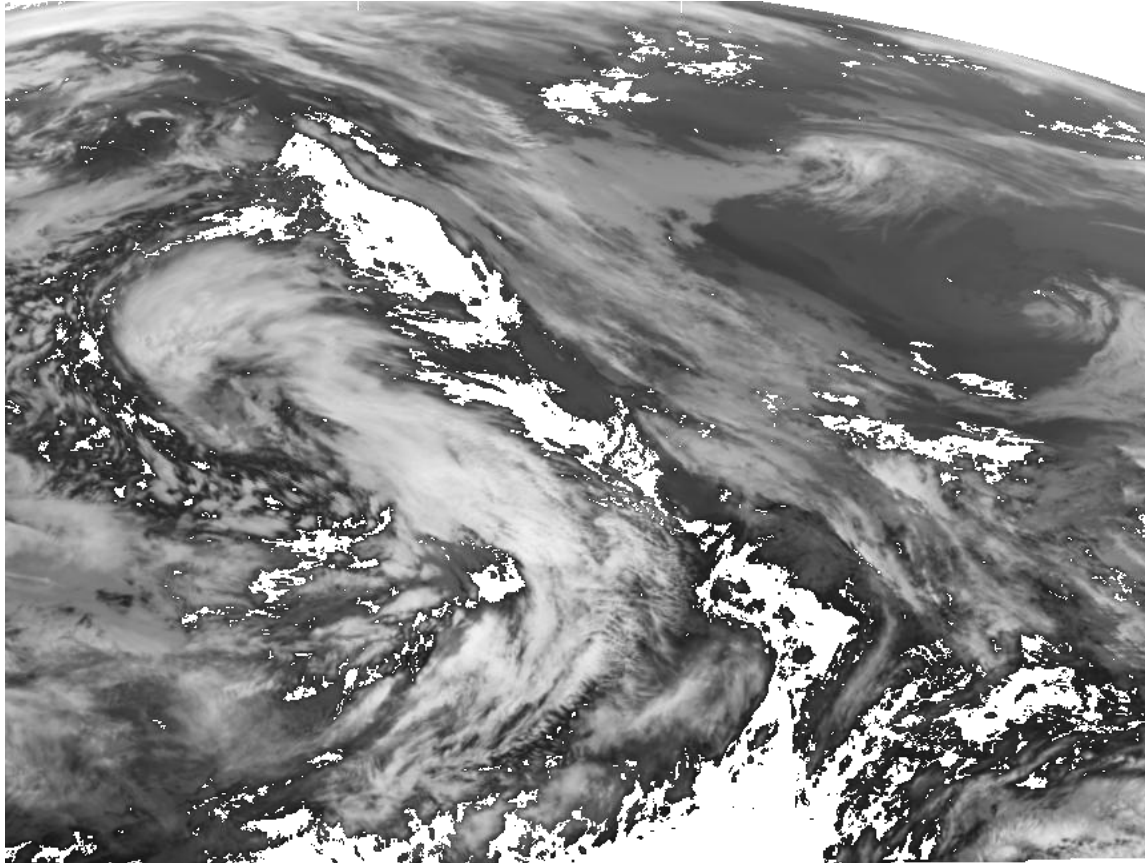
If one doesn't trust the filling...



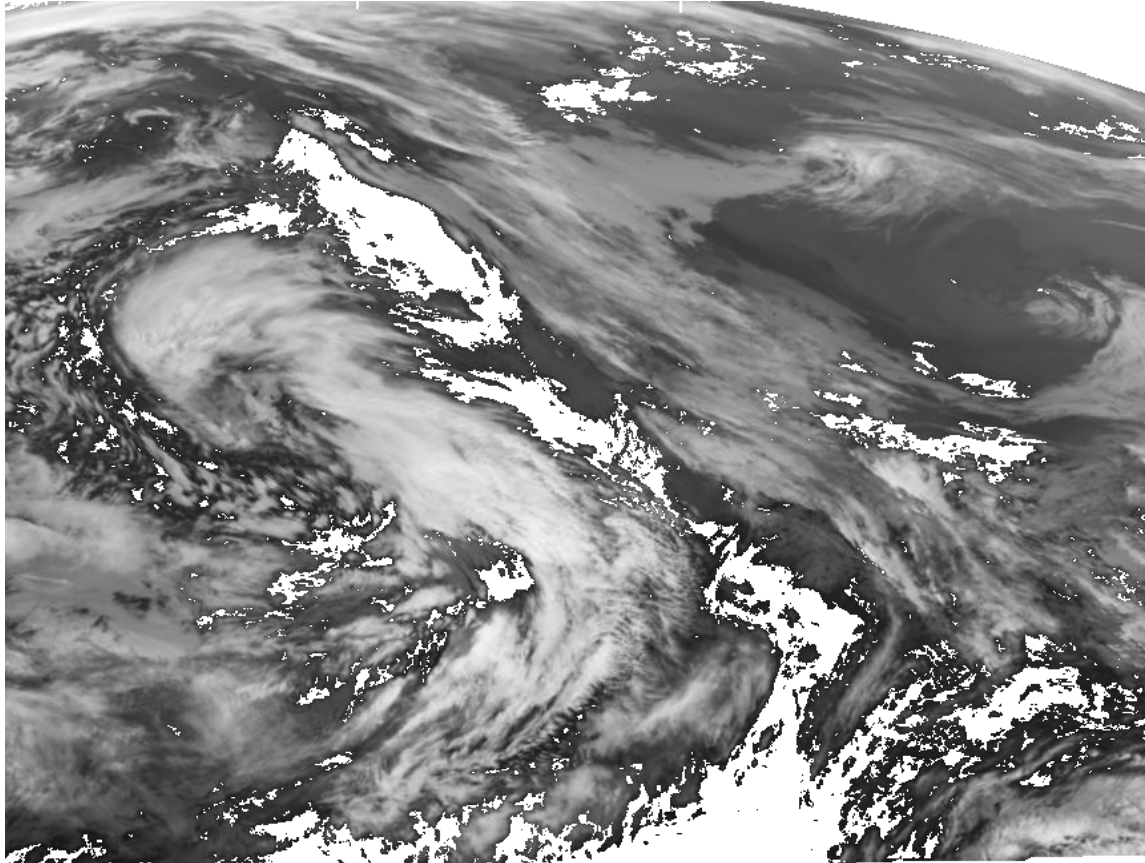
...option to mask the cloudfree areas



Forecast IR 10.8 image, 3 February 2017, 10.00 UTC + 45 min

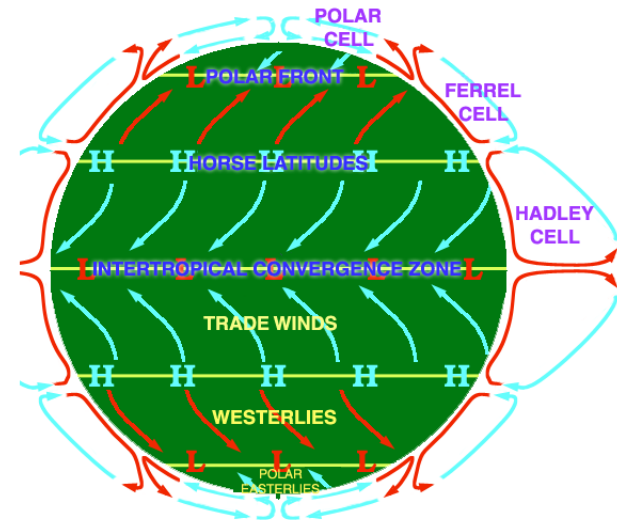


Forecast IR 10.8 image, 3 February 2017, 10.00 UTC + 60 min



#2: How to deal with vectors in different layers?

- Creating the displacement field from every available atmospheric motion vector normally yields the extrapolation with the highest skill scores
- However, the critics of this statistical view score a point when referring to atmospheric circulation:



Source: https://en.wikipedia.org/wiki/Atmospheric_circulation

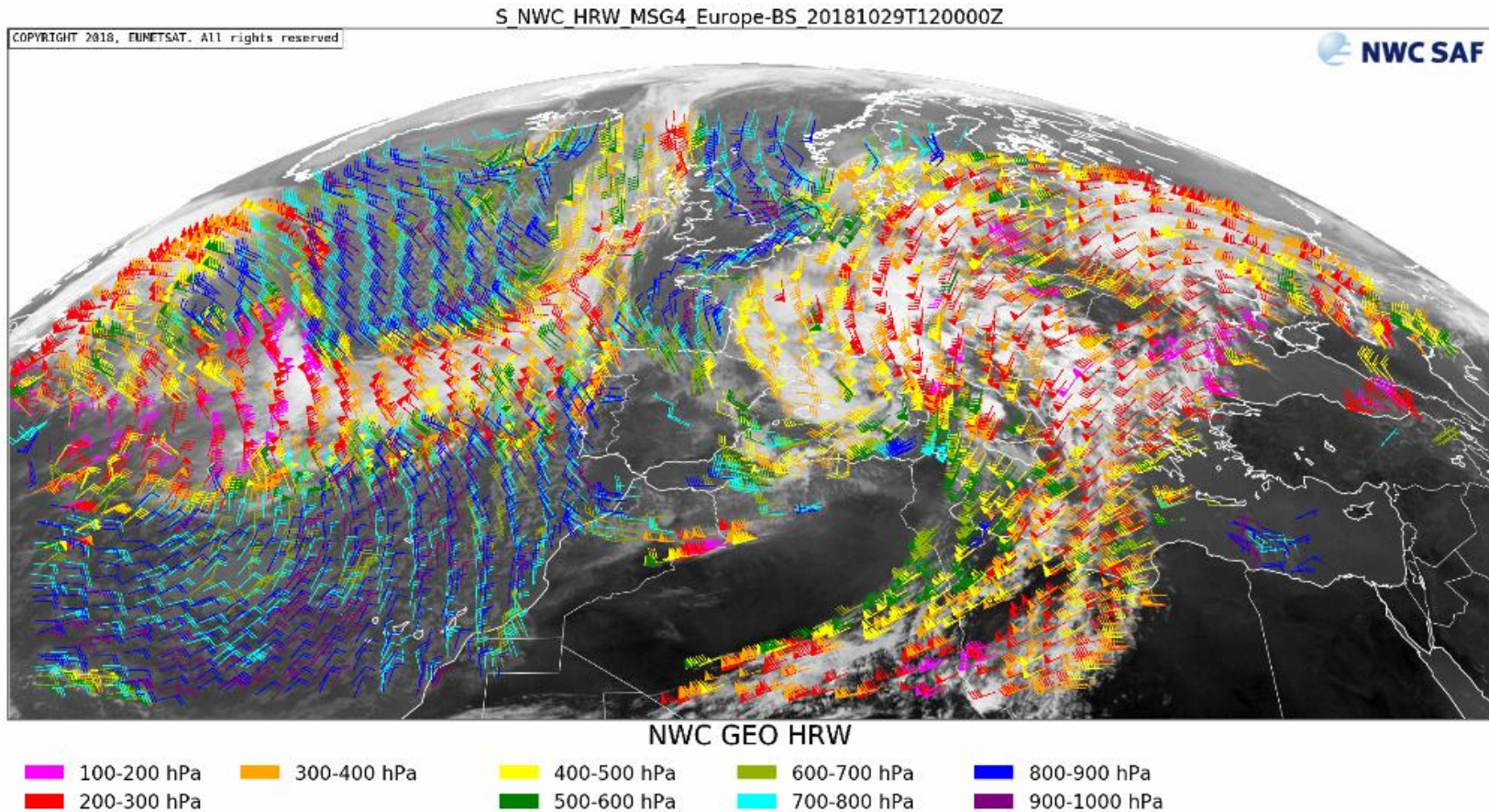
„Solution“: User-configurable handling of vectors in different layers!

- **As the perception of “how far apart is too far?” varies, the software allows individual settings of upper and lower boundaries of the layer(s) from which motion vectors are taken**
- **Two-layer approach implemented, working with two displacement fields, one in an upper layer and one below**

How to handle pixels in the “wrong layer”?

- We first employed a “better-than-nothing” approach, still displacing them along the trajectory suggested by the selected AMVs (in the two-layer approach taking the displacement fields with the nearest atmospheric motion vectors).
- When being strict on physical principles, one has to reject the displacement of high-layer pixels with low-layer winds (and vice versa)
- Inevitable drawback: many pixels for which it becomes unjustifiable to apply any displacement → gaps in the product

An example HrW field, colours indicating assigned heights

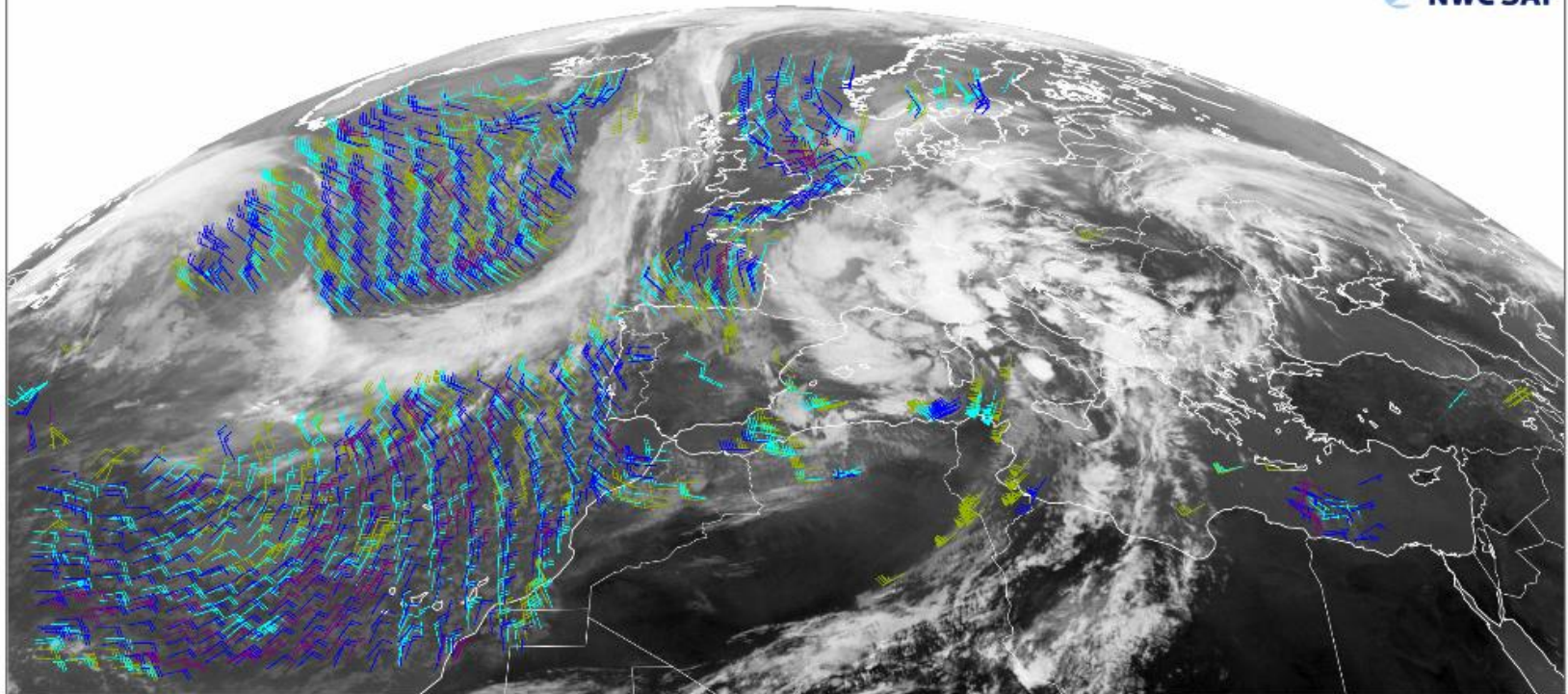


Situation at the lower level

S_NWC_HRW_MSG4_Europe-BS_20181029T120000Z

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NWC SAF



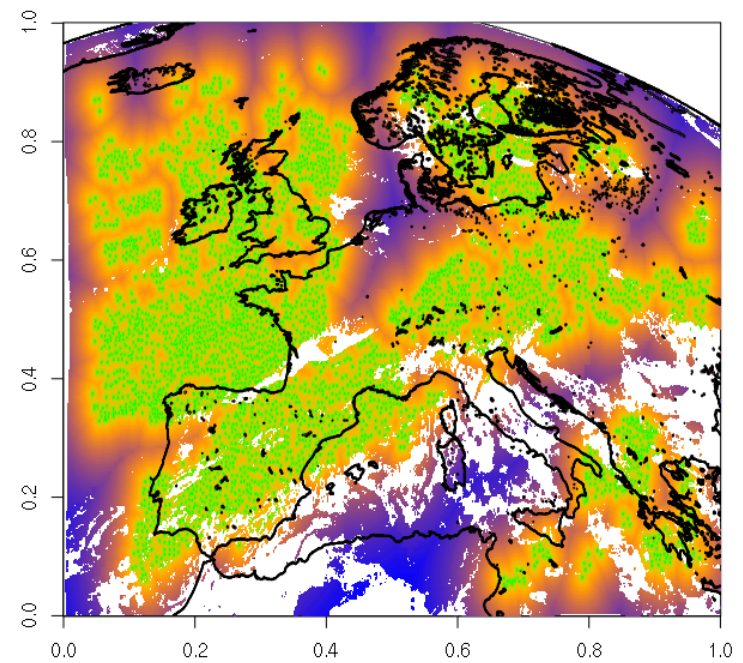
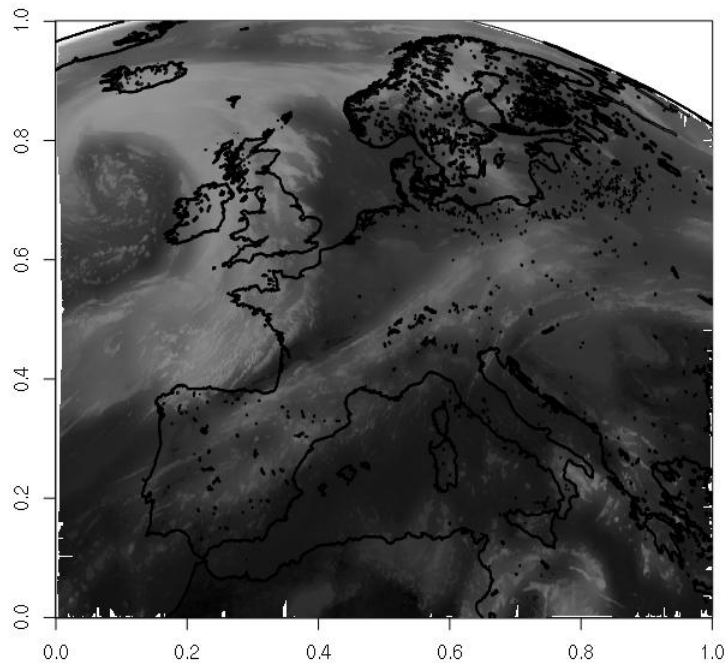
NWC GEO HRW

600-700 hPa	800-900 hPa
700-800 hPa	900-1000 hPa

Consequences for the next release

- **Option to include the cloud top height product**
 - to mask pixels from layers not covered by the wind input
 - to strictly displace high-layer (low-layer) pixels with the high-layer (low-layer) motion
- **Include in the quality flag information about the distance to the closest vector (enabling the user to mask even more pixels deemed questionable)**

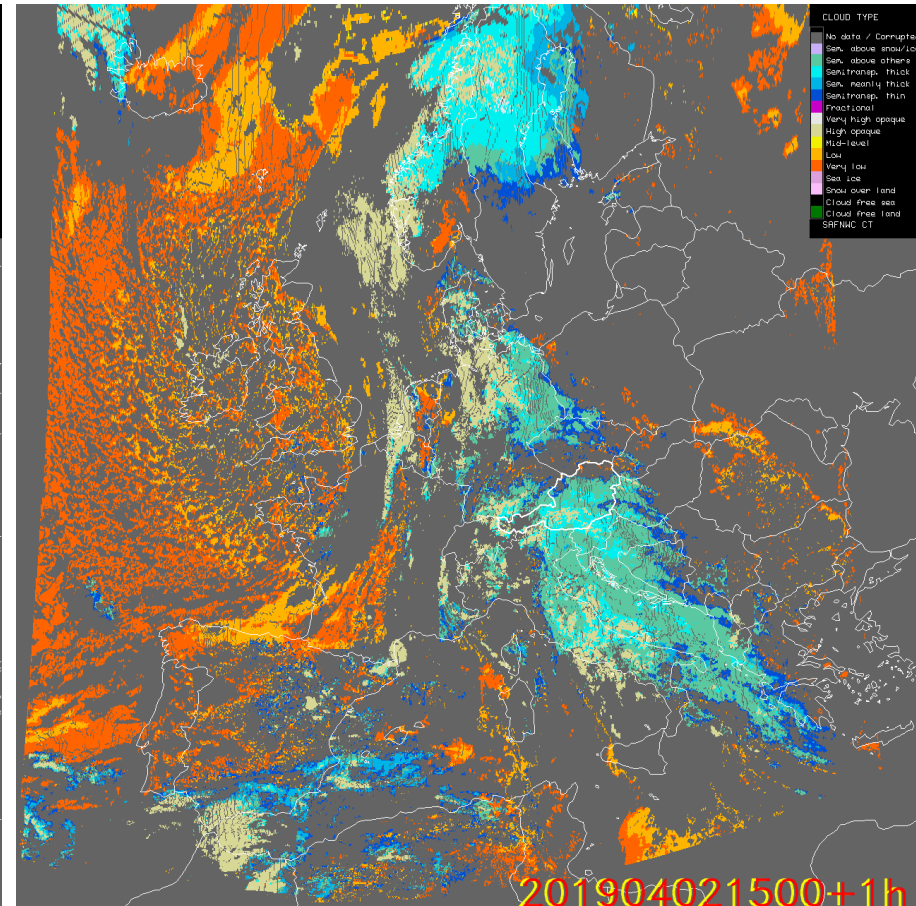
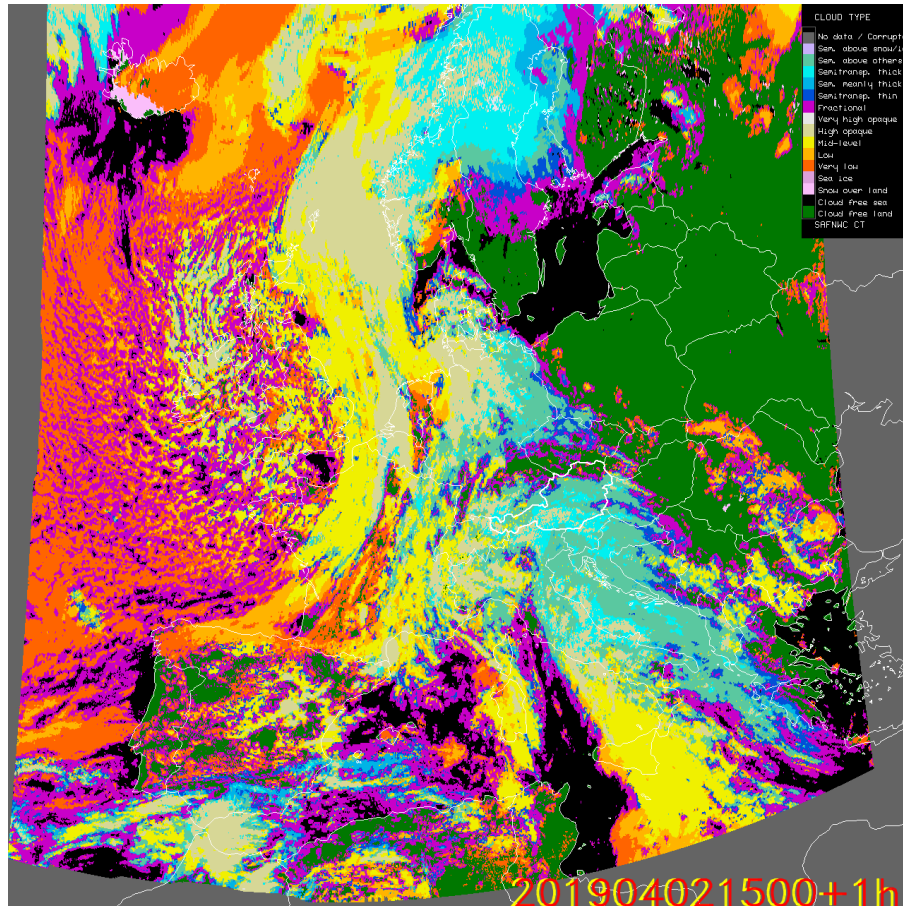
Forecast IR image + „nearest vector flag“



Example: Cloud type forecast, two-layer approach, 0-400 hPa + 700-1000 hPa

„Classical“

„Physical“



#3: How do we handle day/night differences?

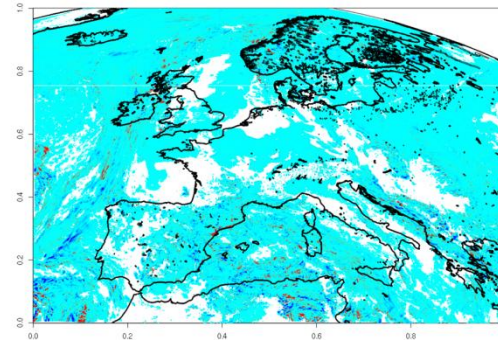
- **Intrinsic in some channels**
 - **VIS: might be „corrected“ – but: are there any users for forecast visible images? Do they need such a correction?**
 - **IR3.9: mask dusk/dawn? – but: are there any users for forecast 3.9 images?**
- **Some of the products are based on different algorithms for day and night, respectively (with different quality of the results) - do we need flagging?**

#3: How do we handle day/night differences?

- Intrinsic in some channels
 - VIS: might be „corrected“ – but: are there any users for forecast visible images? Do they need such a correction?
Solved in November: KMA indicated a need for this
 - IR3.9: mask dusk/dawn? – but: are there any users for forecast 3.9 images?
- Some of the products are based on different algorithms for day and night, respectively (with different quality of the results) - do we need flagging?

Status today

- „Extrapolated Imagery“ by default delivers forecasts of the cloud products, but users can select any arbitrary set of the indicated EXIM portfolio
- Scientifically validated for MSG, technically capable of handling Himawari and GOES-N/-R input
- Allows the setting of the preferred HrW layer
- Offers a difference image for quick visual judgement on the current extrapolation quality



Anticipated status at vMTG 2021+

- **Technically capable of handling MTG**
- **Faster code, offset by 10-minute interval and higher number of pixels**
- **Allows the CTTH-based filtering of pixels outside the selected HrW layer(s)**
- **Provides „distance of the nearest suitable vector“ as additional quality indicator (potentially exploited by users for further output filtering)**

Status in a farther future

- **Thoroughly scientifically validated for MTG**
- **Extrapolated satellite channels have their „native resolution“ (requires more trajectory computations)**
- **VIS images corrected for sun zenith angle**
- **User requirements gathered at the 2020 User WS taken on-board**

THANK YOU FOR YOUR ATTENTION!

Dr. Alexander Jann
Section Head, NWP/Remote Sensing
Division "Data, Methods, Modeling"
Zentralanstalt für Meteorologie und Geodynamik
Hohe Warte 38
A-1190 Vienna
AUSTRIA
E-Mail: Alexander.Jann@zamg.ac.at
Tel.: +43 1 / 36 0 26 / 2316