The EUMETSAT Network of Satellite Application Facilities

NWC SAF

Support to Nowcasting and Very Short Range Forecasting

# Scientific and Validation Report for the Automatic Satellite Image Interpretation Processors of the NWC/GEO


NWC/CDOP2/GEO/ZAMG/SCI/VR/ASII-NG, Issue 1.0

*15 October 2016*


*Applicable to*

*GEO-ASII-NG-v1.0 (NWC-047)*


**Prepared by ZAMG**

**REPORT SIGNATURE TABLE**

| Function | Name | Signature | Date |
|---|---|---|---|
| Prepared by | A. Jann (ZAMG) | | *15 October 2016* |
| Reviewed by | R. Goler, I. Meirold-Mautner (ZAMG) | | *15 October 2016* |
| Authorised by | Pilar Rípodas, AEMET *SAFNWC Project Manager* | | *15 October 2016* |

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# 1. INTRODUCTION

The EUMETSAT's "Satellite Application Facilities" (SAFs) 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 NWC SAF webpage, http://www.nwcsaf.org.

## 1.1 SCOPE AND PURPOSE OF THE DOCUMENT

This document is the first Validation Report for the MSG Automatic Satellite Interpretation – Next Generation Product (PGE17).

This document contains a description of the validation method and the corresponding results for the above-mentioned product.

Concerning the second product of the Met.Systems suite, ASII/PGE10, it is scientifically frozen and hence not subject to any further validation during the current project phase. Please consult [RD.4] for the latest validation report.

## 1.2 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| **ASII-NG** | Automatic Satellite Image Interpretation – Next Generation |
| **EUMETSAT** | European Organisation for the Exploitation of Meteorological Satellites |
| **IR** | Infrared |
| **MSG** | Meteosat Second Generation |
| **NWCSAF** | SAF to support NoWCasting and Very-Short-Range Forecasting |
| **NWP** | Numerical Weather Prediction |
| **PGE** | Product Generation Element |
| **SAF** | Satellite Application Facility |
| **SEVIRI** | Spinning Enhanced Visible and Infrared Imager |
| **SW** | Software |
| **WV** | Water Vapour |

## 1.3 REFERENCES

### 1.3.1 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://www.nwcsaf.org.

| Ref | Title | Code | Vers | Date |
|---|---|---|---|---|
| [AD.1] | Proposal for the Second Continuous Development and Operations Phase (CDOP) March 2012 – February 2017 | NWC/CDOP2/MGT/AEMET/PRO | 1.0d | 15/03/11 |
| [AD.2] | NWCSAF Project Plan | NWC/CDOP2/SAF/AEMET/MGT/PP | 1.9 | 15/10/16 |
| [AD.3] | System and Components Requirements Document for the SAFNWC/GEO | NWC/CDOP2/GEO/AEMET/SW/SCRD | 1.2 | 15/10/16 |
| [AD.4] | Interface Control Document for Internal and External Interfaces of the NWC/GEO | NWC/CDOP2/GEO/AEMET/SW/ICD/1 | 1.2 | |
| [AD.5] | Interface Control Document for the NWCLIB of the SAFNWC/GEO | NWC/CDOP2/GEO/AEMET/SW/ICD/2 | 1.2 | 30/10/15 |
| [AD.6] | Data Output Format for the NWC/GEO | NWC/CDOP2/GEO/AEMET/SW/DOF | 1.2 | |
| [AD.7] | Architectural Design Document for the NWC/GEO | NWC/CDOP2/GEO/AEMET/SW/ACDD | 1.2 | |
| [AD.8] | NWC SAF Product Requirements Document | NWC/CDOP2/SAF/AEMET/MGT/PRD | 1.9 | 15/10/16 |

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

### 1.3.2 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://www.nwcsaf.org

| Ref | Title | Code | Vers | Date |
|---|---|---|---|---|
| [RD.1] | The Nowcasting SAF Glossary | NWC/CDOP2/SAF/AEMET/MGT/GLO | | |
| [RD.2] | User Manual for the Automatic Satellite Image Interpretation Processors of the NWC/GEO: Science Part | NWC/CDOP2/GEO/ZAMG/SCI/UM/ASII | 1.0 | 15/10/16 |
| [RD.3] | Algorithm Theoretical Baseline Document for the Automatic Satellite Image Interpretation Processors of the NWC/GEO | NWC/CDOP2/GEO/ZAMG/SCI/ATBD/ASII | 1.1 | 15/10/16 |
| [RD.4] | Validation Report for "Automatic Satellite Image Interpretation" (ASII-PGE10, v2010) | SAF/NWC/CDOP/ZAMG/SCI/VR/4 | 1.0 | 20 April 2010 |

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

# 2. GENERAL ASPECTS OF THE VALIDATION APPROACH

## 2.1 BACKGROUND AND SCOPE

The ASII-NG module became ready-for-release rather late (and in a rudimentary version compared to what was originally intended), which prohibited a thorough evaluation of its meteorological value. We constrain ourselves here to a few rather technical aspects, in order to illustrate certain types of validation methods to be done in greater detail in the future, and to give first conclusions on how development shall continue in the immediate future. Also, we solely cover the parameter “probability of occurrence of tropopause folding”, which is the only one included in NWC/GEO release 2016. As the complementing components are currently only in a prototype-SW stage, the consideration of other parameters is deferred to later investigations.

## 2.2 VALIDATION DATASET

The logistic regression equation lying at the heart of the computations was derived from a training sample comprising 30 cases of manually analysed tropopause foldings. The ASII-NG module was applied to two additional/independent cases (28 August 2014, 1200 UTC, and 13 February 2015, 1200 UTC), and the results are presented and discussed in this validation report. **Figure 1** presents IR images of these two cases, together with those areas where a human analyst suspected tropopause foldings based on the standard meteorological fields available to perform such kind of analysis (SEVIRI WV6.2, NWP isentropic potential vorticity fields).

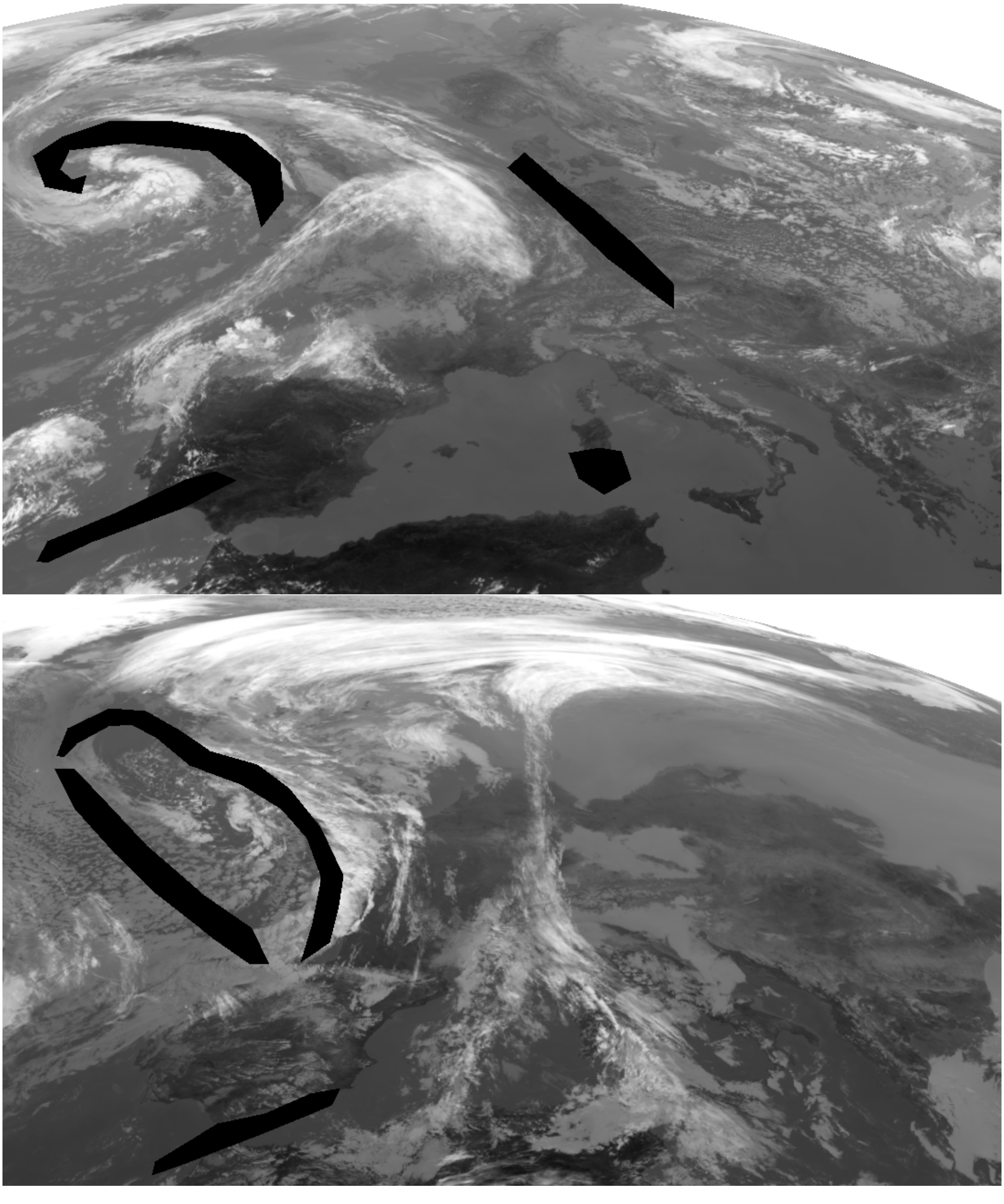


***Figure 1:*** *SEVIRI IR images of the two cases used for validation here, blackened areas are those with subjectively analysed tropopause foldings. Upper panel: 28 August 2014, 1200 UTC; lower panel: 13 February 2015, 1200 UTC.*

# 3. RESULTS

## 3.1 THE ASII-NG PRODUCT OF NWC/GEO RELEASE 2016

**Figure 2** presents "probability of occurrence of tropopause folding" for the two validation cases, using the full set of predictors. This figure (and the successors) depict the field with a blue-to-red colour table, with probabilities ~100% shown in red. The "full set of predictors" specifically comprises (cf. the ATBD [RD.3]):

1) gradient in IR9.7 brightness temperatures
2) gradient in WV6.2 brightness temperatures
3) gradient of the difference image IR9.7-IR10.8 (brightness temperatures)
4) IR9.7 brightness temperatures
5) IR10.8 brightness temperatures
6) Absolute value of the shear vorticity in 300 hPa (NWP parameter)
7) wind speed in 300 hPa (NWP parameter)
8) gradient in tropopause height from specific humidity (NWP parameter)
9) gradient in tropopause height from isentropic potential vorticity (NWP parameter)

The predictand in the regression derivation process is the subjectively analysed, binary, yes/no-information on the presence of a tropopause folding.

Eye-catching features in the obtained output fields are:

- In the summer case, clear signals from the land-sea contrast (Mediterranean region), interestingly towards particularly low probabilities;
- some "worm-shaped" artefacts spread all over the images, e.g. in the 2014 case over Sardinia or near the red zone on the left side of the 2015 case. These features are displayed more clearly in **Figure 3.**

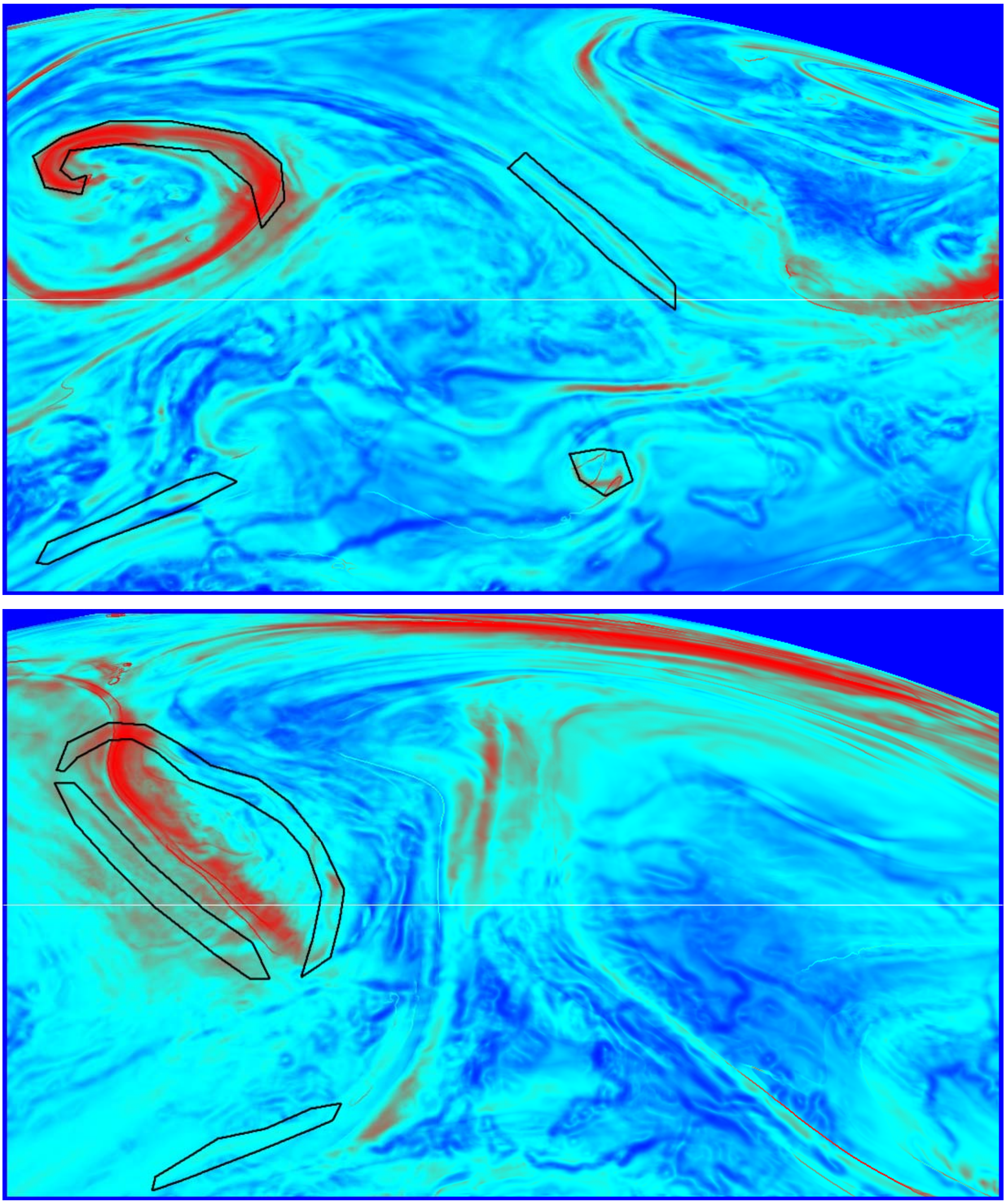
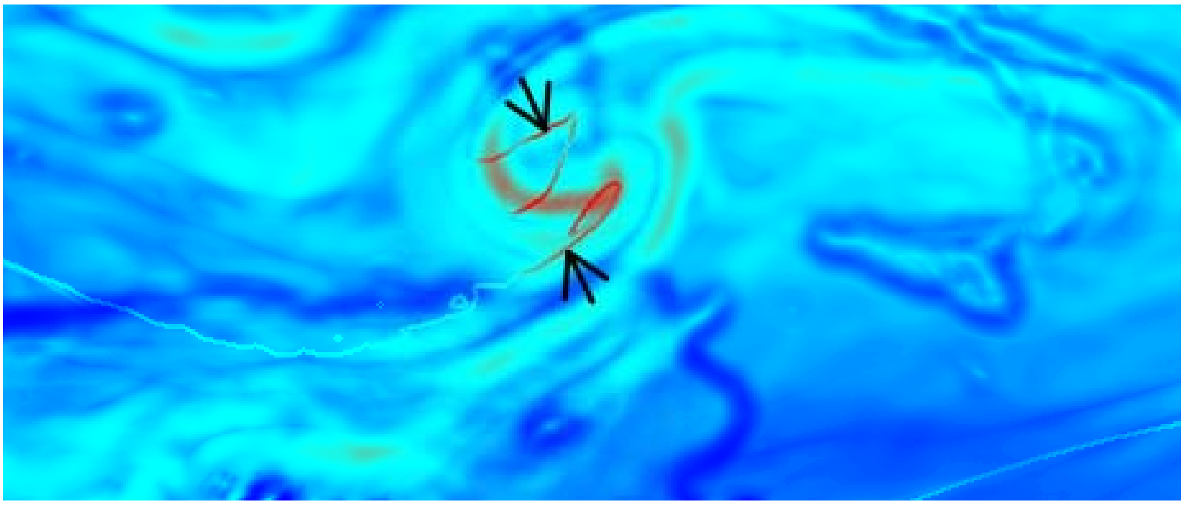


***Figure 2:*** *Results of applying the ASII-NG logistic regression equation to obtain "probability of occurrence of tropopause folding". Blue colour depicts probabilities near 0% (and non-analysed pixels including space); cyan around 50%; red close to 100%. Subjectively analysed tropopause foldings superimposed via black contours. Upper panel: 28 August 2014, 1200 UTC; lower panel: 13 February 2015, 1200 UTC.*



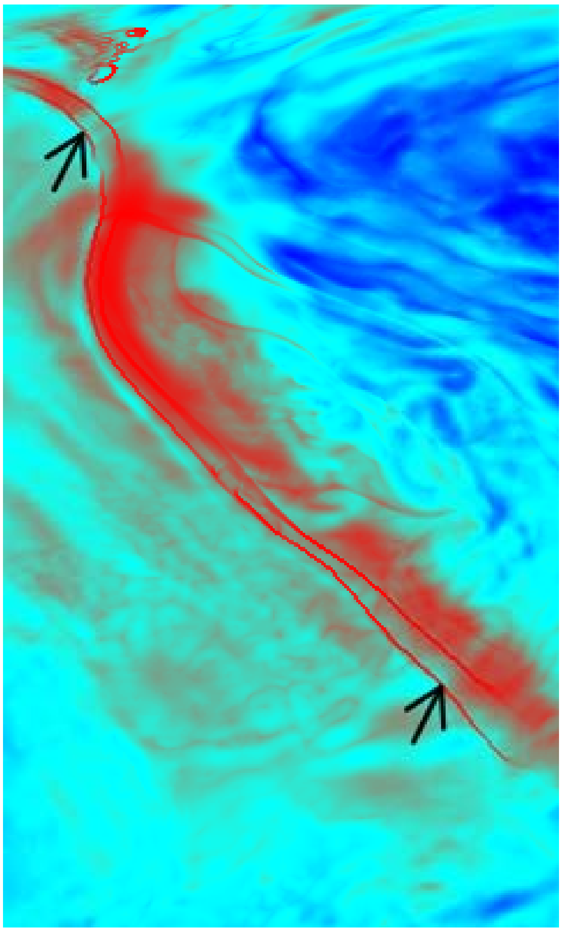


***Figure 3:*** *Close-up of regions in* ***Figure 2*** *where spurious artefacts of purely mathematical origin are found (pointed to by the arrows). Above: 28 August 2014, 1200 UTC, Sardinia, Tunisia, Sicily; left: 13 February 2015, 1200 UTC, northwestern portion of the original image.*

## 3.2 EXPERIMENTS WITH PREDICTOR SUBSETS

It is vital for a SAF product to demonstrate that the satellite input has a clear positive impact. In ASII-NG, two different tropopause height fields from NWP are input in the product derivation (which one might suspect to suffice for tropopause folding detection). Therefore, the question as to how big a role the NWP data plays in the product is particularly relevant here. Consequently, two experiments were performed where a logistic regression was derived between:

A) the yes/no-information on the presence of a tropopause folding and only the satellite input:

1) gradient in IR9.7 brightness temperatures
2) gradient in WV6.2 brightness temperatures
3) gradient of the difference image IR9.7-IR10.8 (brightness temperatures)
4) IR9.7 brightness temperatures
5) IR10.8 brightness temperatures

B) the yes/no-information on the presence of a tropopause folding and only the NWP parameters as predictors:

6) absolute value of the shear vorticity in 300 hPa
7) wind speed in 300 hPa
8) gradient in tropopause height from specific humidity
9) gradient in tropopause height from isentropic potential vorticity.

**Figure 4** contrasts the pure-satellite and pure-NWP outcomes for the 2014 case, while **Figure 5** shows the analogous display for the 2015 case. The pure-NWP figures show greater contrasts and stronger signals (and also the “worm-shaped” artefacts are clear to see, giving an indication of where to search for their cause[1]. Conversely, the land-sea patterns in the product clearly originate from the satellite branch, as expected since the NWP fields concern higher levels of the troposphere.).

In the 2014 case, three of the four subjectively selected zones of tropopause folds (in the lower left corner, over Sardinia and Central Europe) appear more prominently[2] in the pure-satellite panel than in the pure-NWP panel.

For the 2015 case, the “satellite” branch looks quite inferior (though also in this case, there is a unique signal over Central Europe/Italy; the same is true in the image centre of the NWP panel, however; it would be an interesting task for a thorough meteorological validation to find out if any of these signals points to a relevant zone not easily spotted and overlooked by the analyst[3]).

In another experiment to isolate the possible influence the NWP tropopause height may have on the results, only the first 7 parameters of those listed above were used. The results of both cases using this modified set of predictors are shown in **Figure 6**. The main patterns shown earlier do not change significantly when the two tropopause height fields are omitted. Furthermore, these pictures are free from the worm-shaped artefacts, suggesting that one of the tropopause height parameters caused them. A visualization of both fields in question (not shown here) showed that the gradient in tropopause height from isentropic potential vorticity was the cause of the undesired features.

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[1] Note added in June 2016: As the delay of some reviews opened a window of opportunity, a smoothing of the tropopause height fields was incorporated into v2016 in a last-minute effort in order to mitigate the spurious signals.

[2] Although the signal is admittedly less distinct than one may wish.

[3] Such a detailed investigation why the strong signals do not all correspond to the diagnosed tropopause folds was not attempted due to a lack of available time and resources. Ideally one would involve more human analysts in such an exercise; with just one person performing an analysis of tropopause foldings, this cannot be actually considered a sort of ground truth. In fact, an independent reviewer remarked that - *in his view* - the high-probability zone at the Western edge of the ASII-NG analysis for the 2015 case (**Figure 2**), west of the UK, better reflects the actual position of the tropopause fold than the two “subjective” zones delineated in that area.

One final point that needs to be addressed here concerns an example received during the SW integration process for release 2016 (**Figure 7**). Apart from the already mentioned "worms", a regular square pattern can be spotted, with occasional strong signals at the edge of such squares. These patterns surely originate from the bilinear interpolation of coarse-resolution NWP data down to pixel resolution (+subsequent ASII-NG-specific gradient operations exercised upon the fields). It is not yet fully understood what aspect of the NWP input used in **Figure 7** causes the pattern to be so prominent (while it was not spotted in **Figure 2-Figure 6**), however from theoretical reasoning this consequence of the used numerical procedures is not unexpected. The ASII-NG developers hence should investigate ways to mitigate the issue through improved NWP data processing (different interpolation or gradient computation schemes, subsequent filtering, etc). A similar comment should be raised with respect to the noisy patterns at the edge of the domain of **Figure 7**; either the mathematical operations at the edge can be successfully adapted[4] or alternatively, the product should be masked out there (which was the proceeding in **Figure 2-Figure 6** which is why we have not seen these patterns earlier in this report).

[4] Note added in June 2016: As the delay of some reviews opened a window of opportunity, this adaptation was incorporated into v2016 in a last-minute effort.

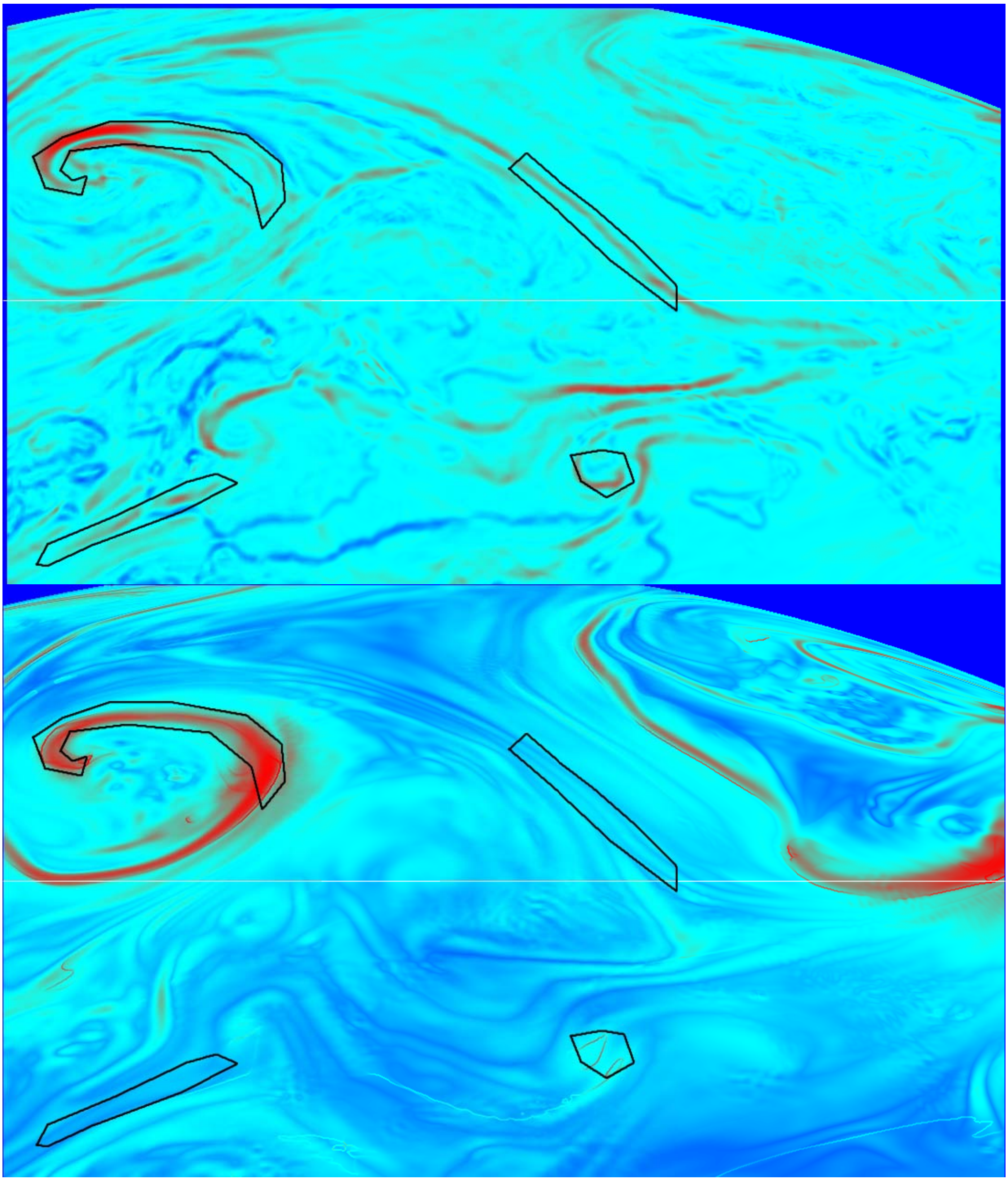

***Figure 4:*** *Results of applying logistic regression equations derived from ASII-NG satellite predictors only (upper panel) and NWP predictors only (lower panel); same colour coding as in* ***Figure 2****; validation case of 28 August 2014, 1200 UTC.*

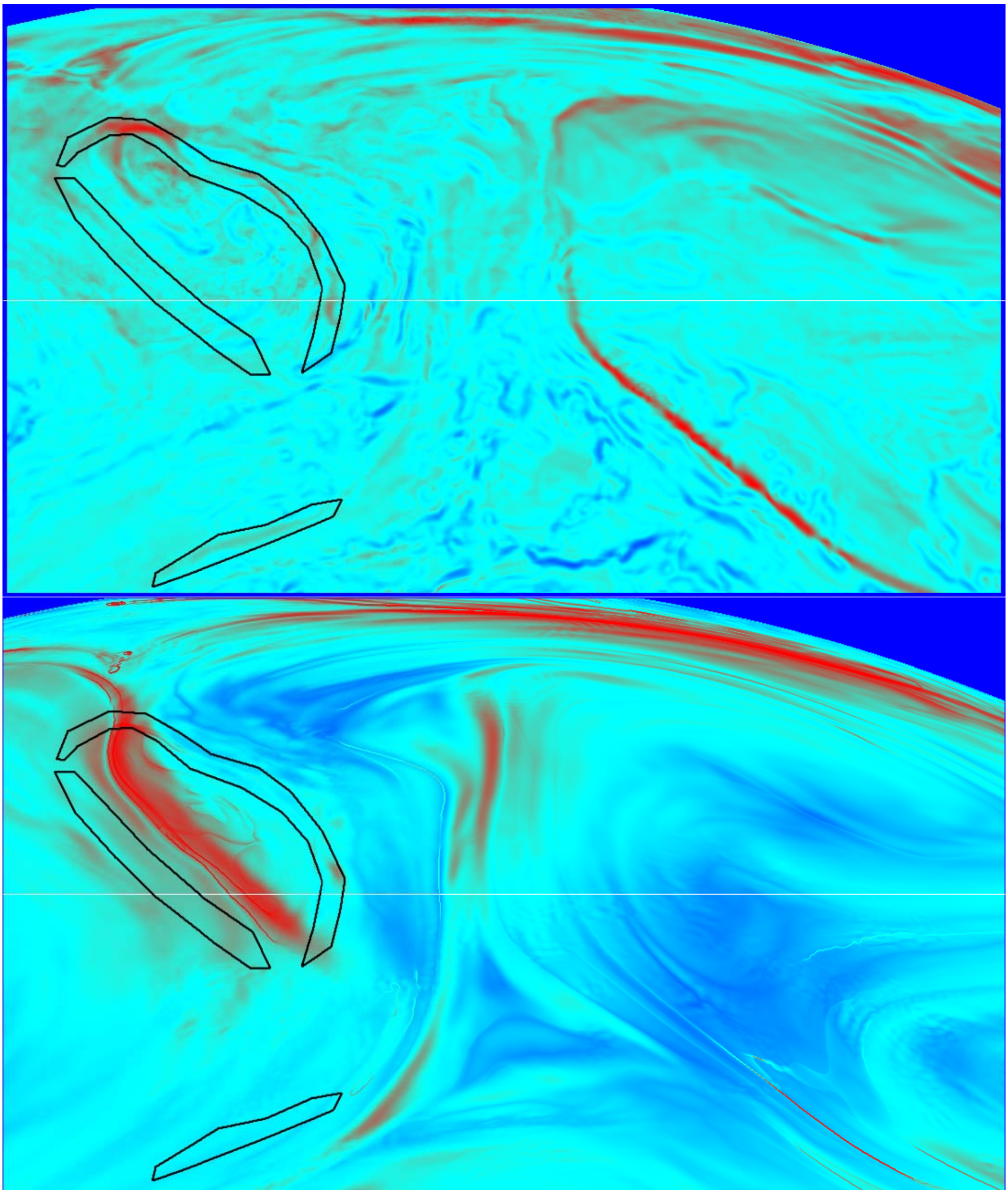

***Figure 5:*** *As in Figure 4, but for 13 February 2015, 1200 UTC.*

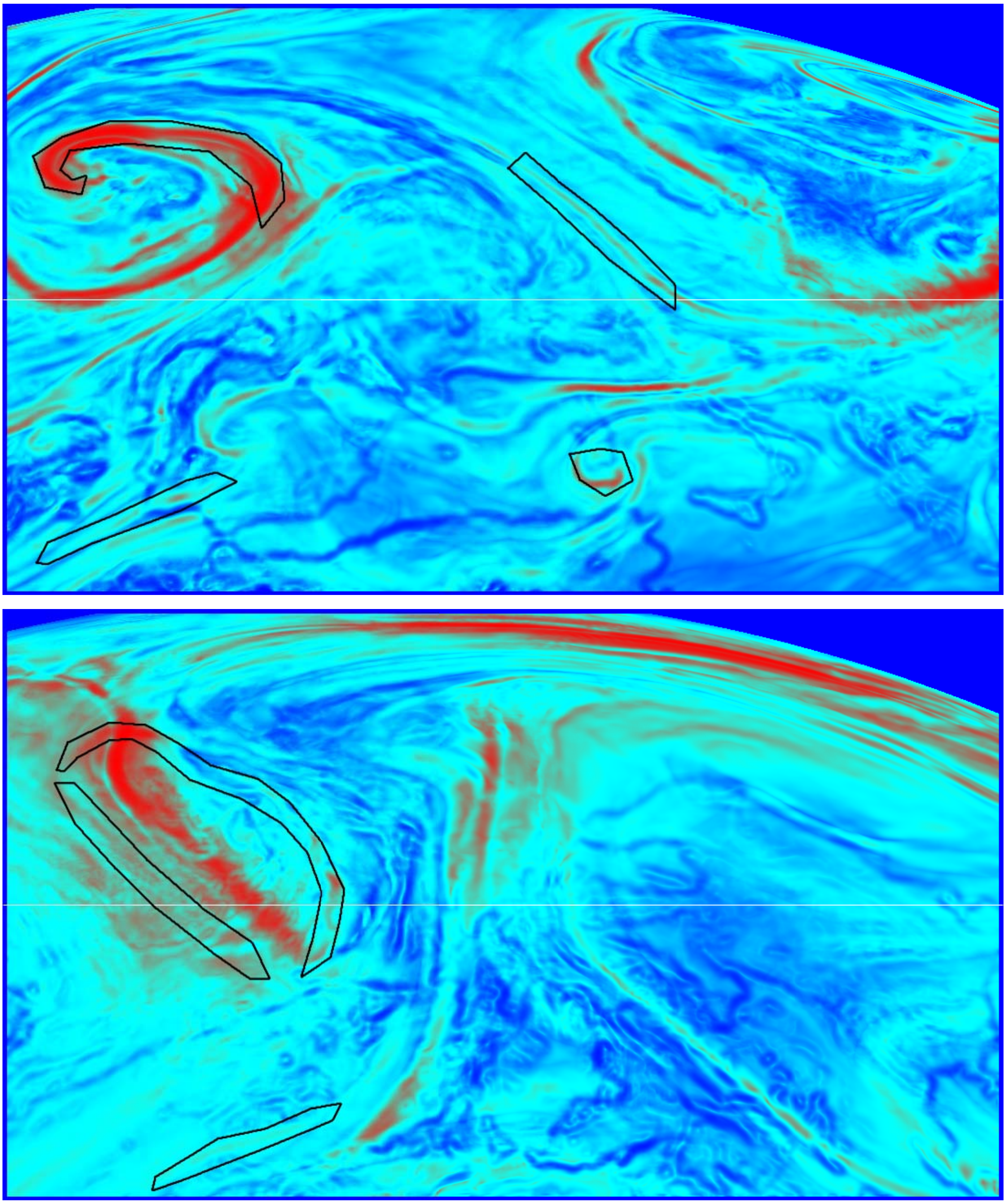

***Figure 6:*** *Results of applying the logistic regression equation derived from all ASII-NG predictors except the tropopause heights; same colour coding as in* ***Figure 2****; upper panel: case of 28 August 2014, 1200 UTC; lower panel: 13 February 2015, 1200 UTC.*

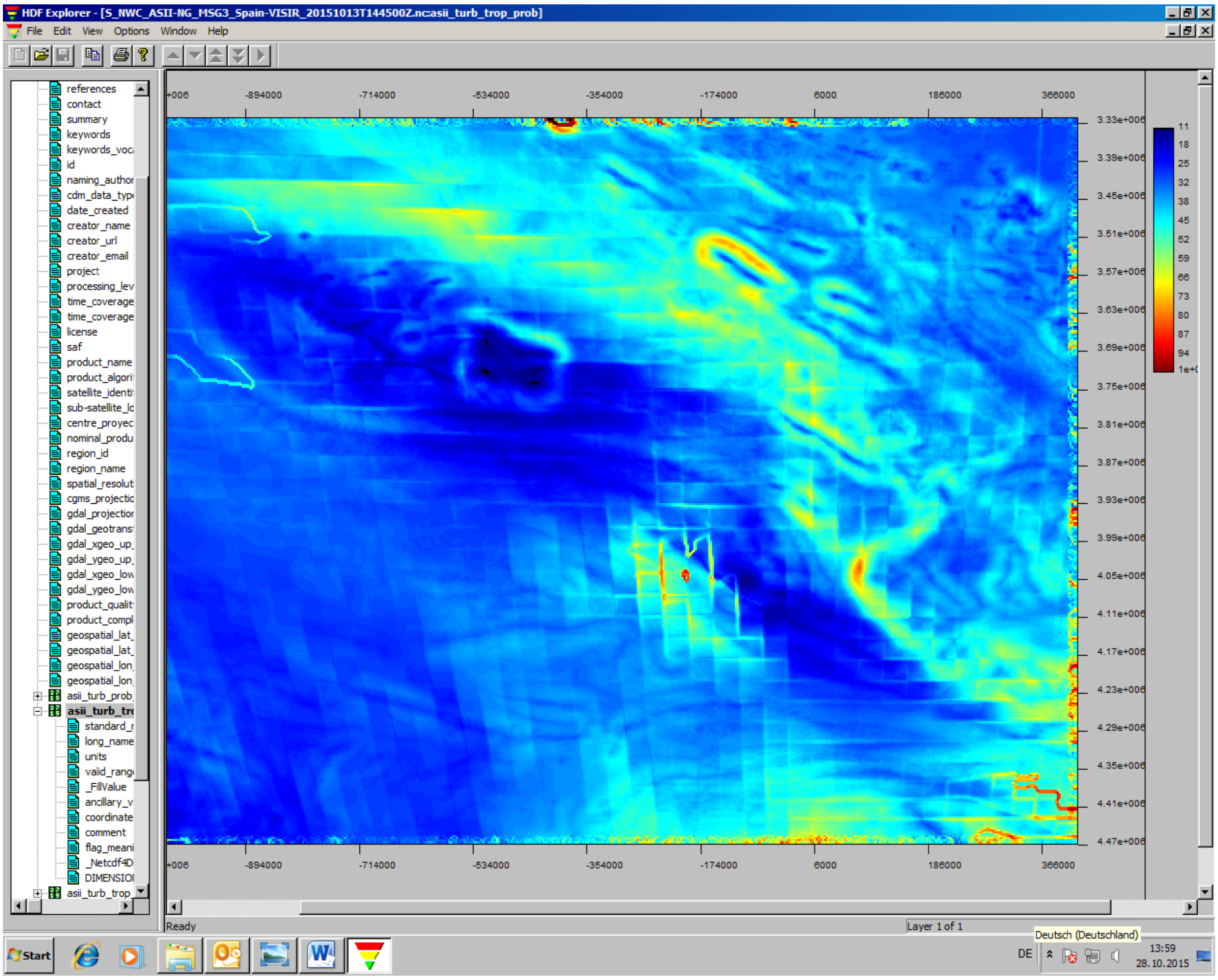

***Figure 7:*** *ASII-NG's "probability of occurrence of tropopause folding", as obtained on the NWCSAF integration platform on 13 October 2015, 1445 UTC.*