# ASII – Automatic Satellite Image Interpretation

*NWCSAF Event Week (18th – 22nd Nov. 2013)*

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# ASII – Automatic Satellite Image Interpretation



## Outline

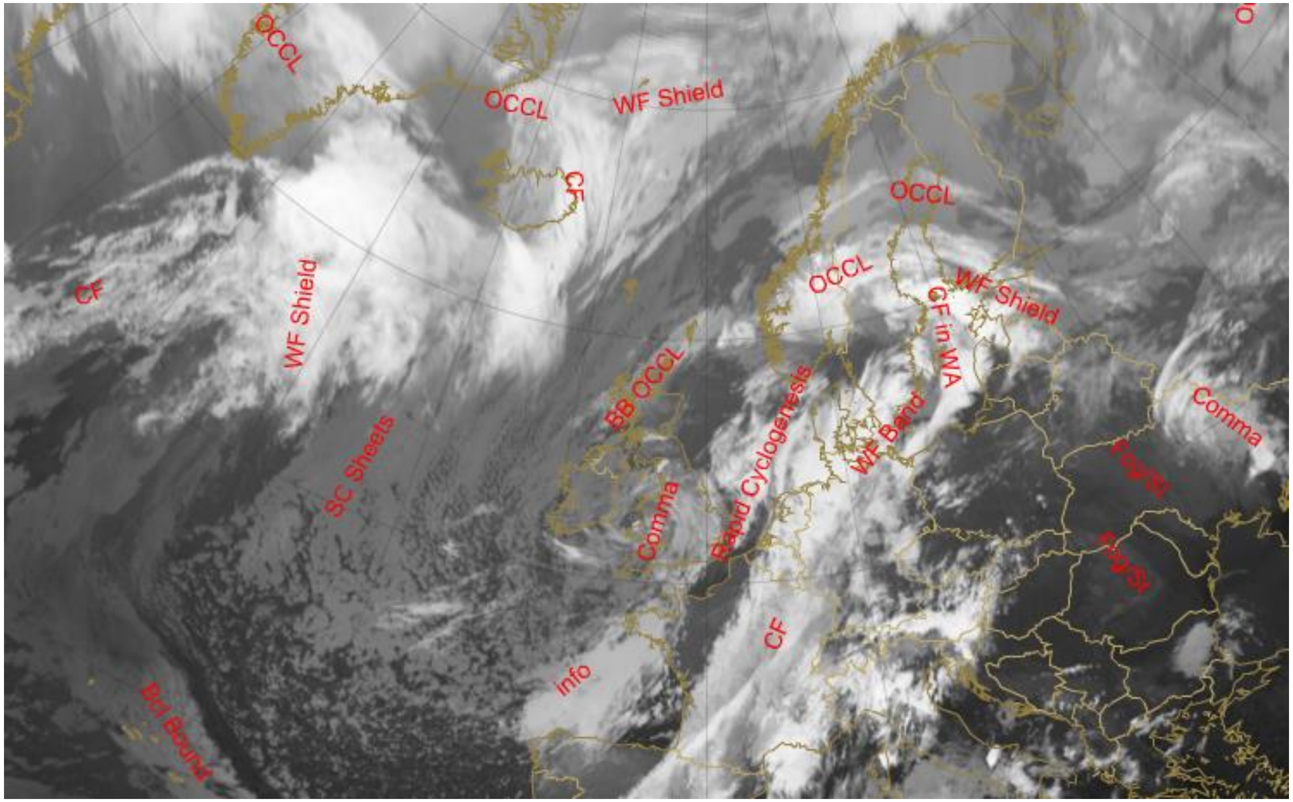
- Conceptual models
- Basic principles of image analysis
- Frontal areas
- Frontal sub-structures
- Meso-scale conceptual models
- Validation and concluding remarks

# ASII – Automatic Satellite Image Interpretation

## Conceptual models



ASII analyses cloud features of the satellite image in terms of Conceptual Models.

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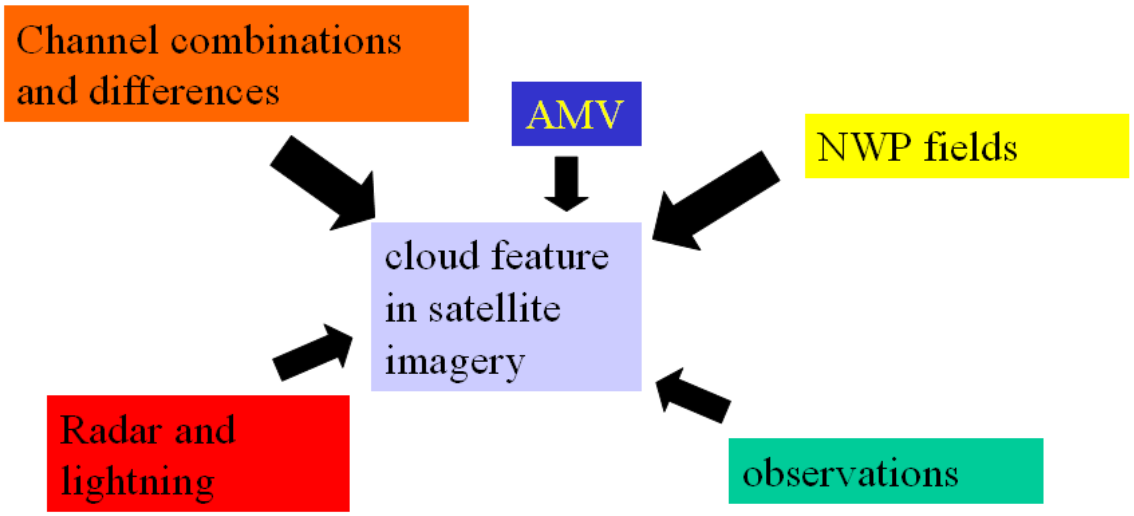
## Conceptual models



**A conceptual model is a mental picture of an idealized atmospheric process.**



# ASII – Automatic Satellite Image Interpretation

## Conceptual models



ASII analyses 12 different conceptual models
ASIINWP analyses 15 different conceptual models

| | |
|---|---|
| Cold Front<br>c | Jet Fibres<br>F |
| Warm Front<br>w | Upper Level Low<br>ul |
| Occlusion<br>o | Comma Cloud<br>co |
| Frontal Wave<br>~ | Lee Cloud<br>L |
| Jet Wave<br>~ | Cellular Cold Air Cloudiness z |
| Front Intensification by Jet<br>ji | Enhanced Cumuli<br>ec |

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# ASII – Automatic Satellite Image Interpretation



## Basic image processing tools:

- Image segmentation and classification
- Image filtering
- Locating maxima/minima (from image or NWP data)
- Neighbourhood related functions

## Advanced image processing tools:

- Detection of frontal rear sides
- Identification of S-shaped pattern
- Fibre detection
- Hough knots

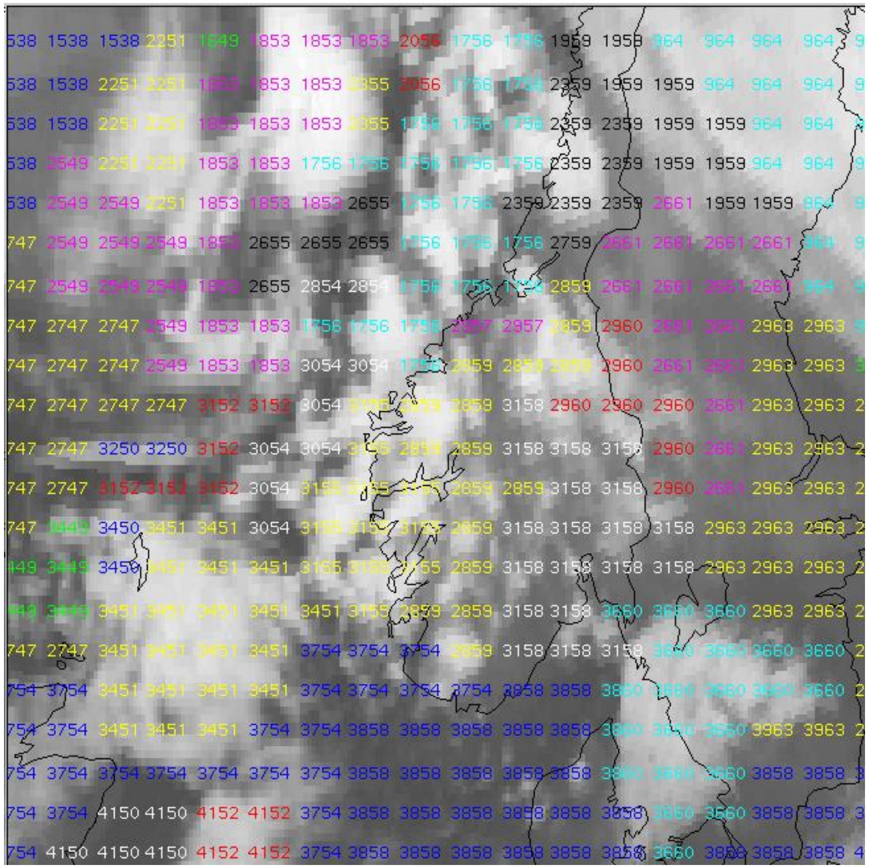
# Basic image processing tools

## Image segmentation



During the process of image segmentation, areas of similar brightness and texture are identified as coherent areas.

This process divides the satellite image into regions of same optical appearance for the human observer.

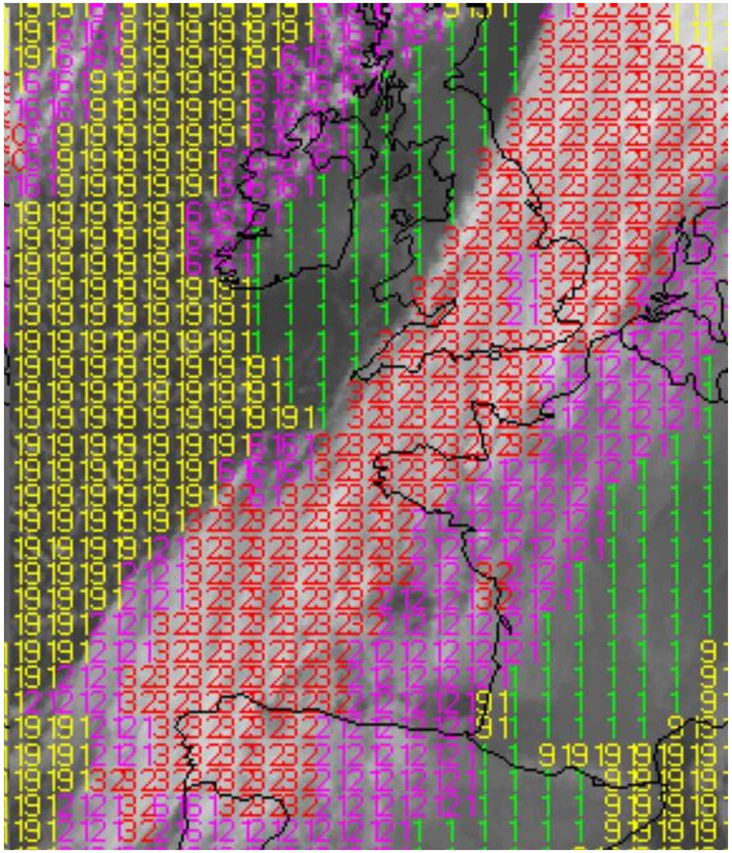


# Basic image processing tools

## Image classification



| **Class** | **Number** |
|---|---|
| Cloudless area; | 1 |
| Bright 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 and small cellular cloudiness as it is typical for enhanced Cumuli; | 61 |
| Very bright and bigger cloud cells as they are typical for Cumulonimbus cloudiness; | 80 |
| Low cellular cloudiness as it is typical for the cold-air cellular cloudiness. | 91 |



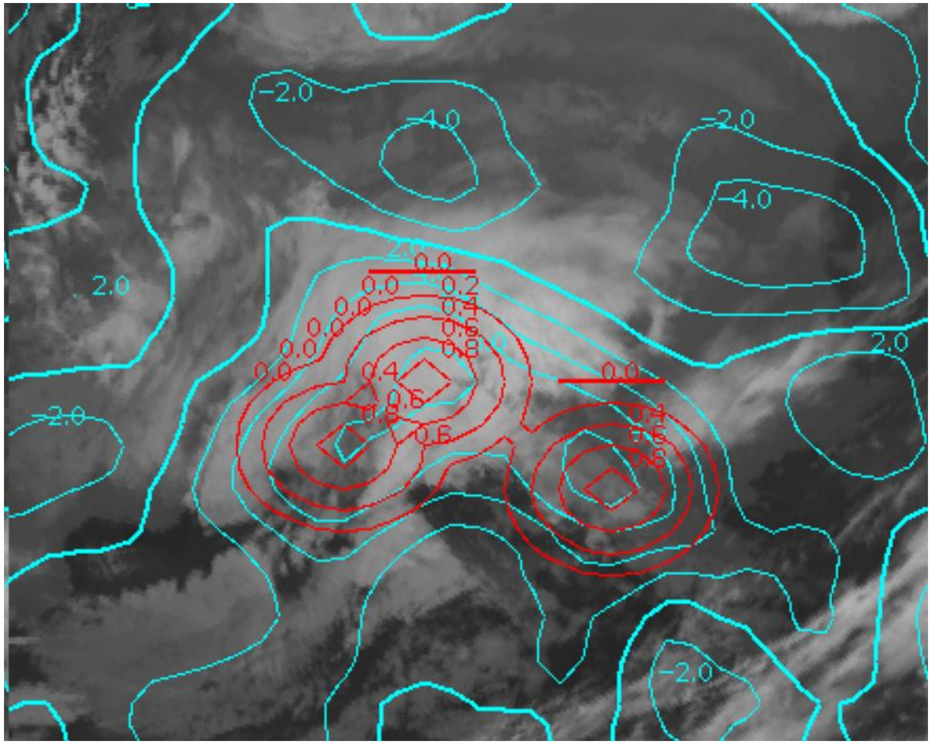
# Basic image processing tools

## Locating maxima/minima from image and NWP data



Local extremes from brightness temperature fields or from NWP fields are converted into a probability field (0-100%).

The probability of being near such a local extreme is assigned to each grid mesh of the processing area.



# Classification of frontal areas

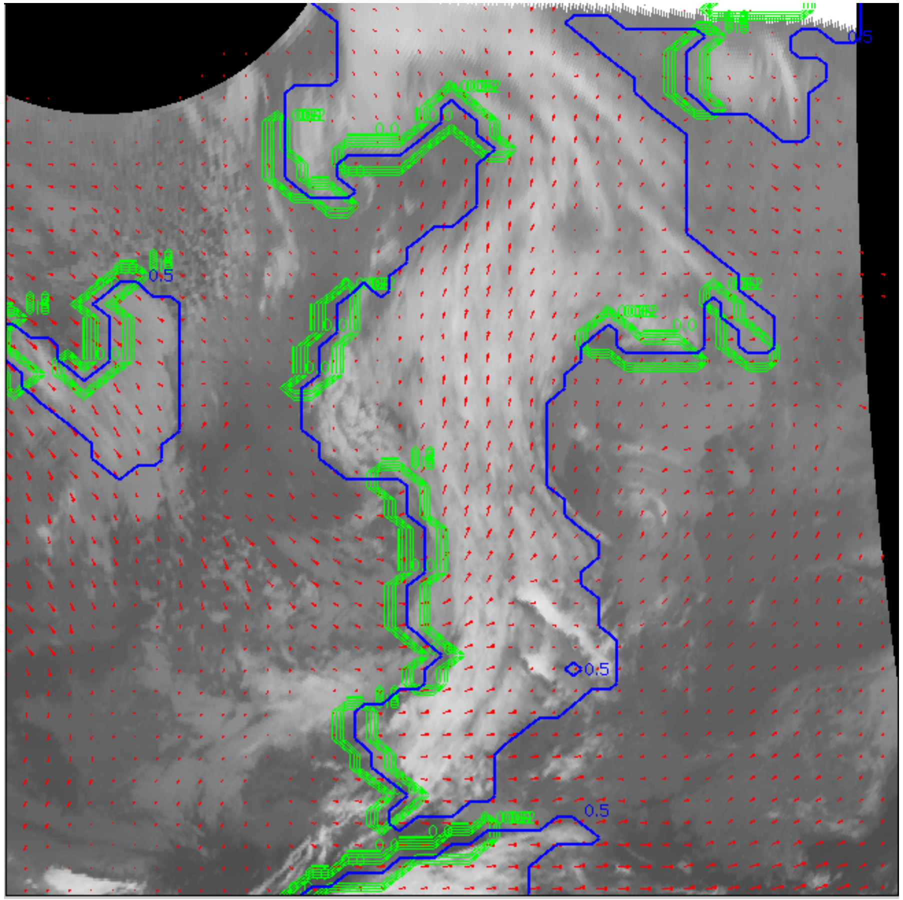
## Cold and warm fronts



Cold and warm fronts have a similar (coupled) detection algorithm.

• In a first step, large coherent cloud features are detected from the IR image.

• With help from the „Atmospheric Motion Vectors“ (AMV), frontal rear sides are identified.



# Classification of frontal areas

<u>Cold and warm fronts</u> *(example from 12 Nov. 2013; 06:00 UTC)*



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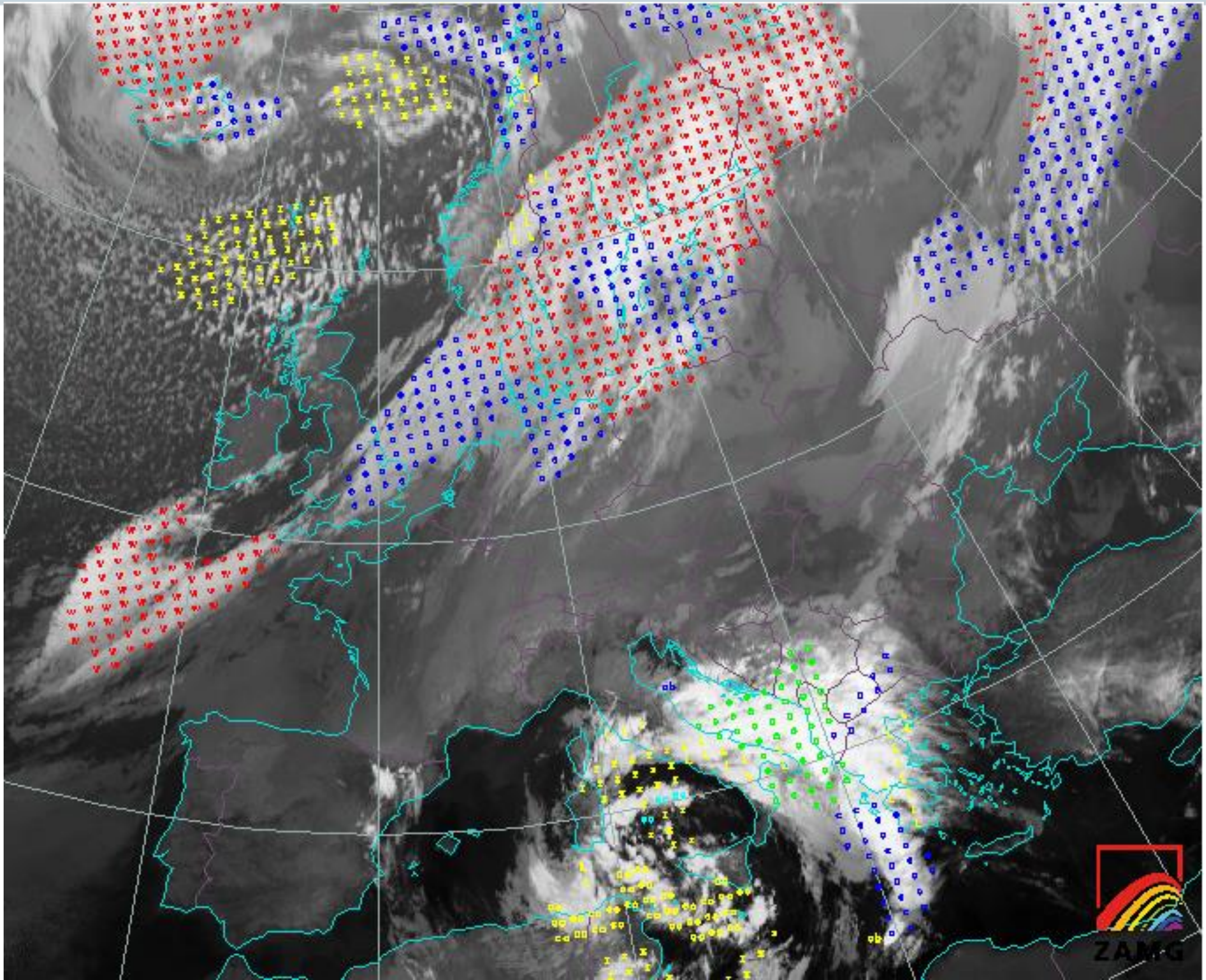


# Classification of frontal areas

## Cold and warm fronts



The ASIINWP analysis for the differentiation between CF and WF is based on the ASII (satellite data only) module.

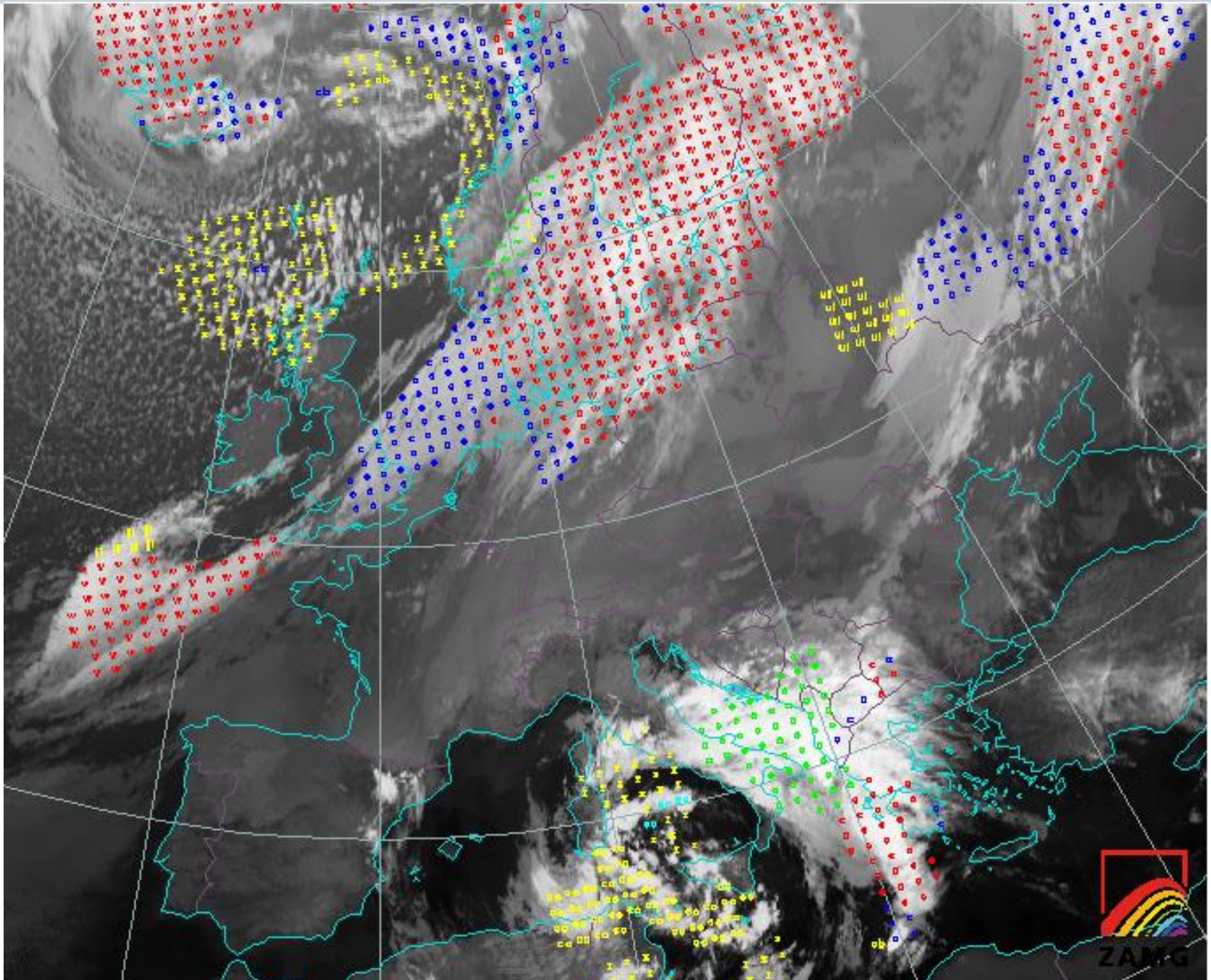
ASIINWP makes use of the TA field at 700 hPa.

- ASII WF + warm air advection → ASIINWP warm front
- ASII WF + cold air advection → ASIINWP cold front
- ASII CF + warm air advection → ASIINWP CF under WA
- ASII CF + cold air advection → ASIINWP CF

# Classification of frontal areas



## <u>Cold and warm fronts in ASIINWP</u> *(12 Nov. 2013; 06:00 UTC)*



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# Classification of frontal areas

## Occlusions

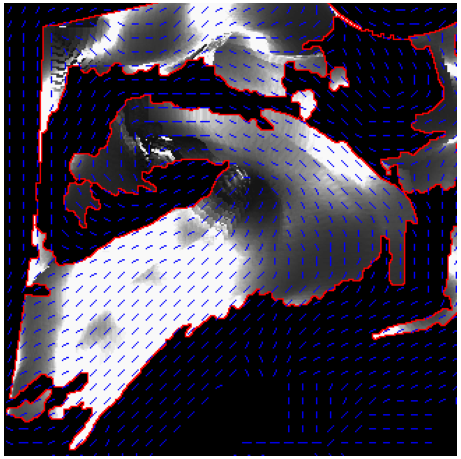


The analysis of occluded frontal systems from satellite images is primarily based on their characteristic shape – the curved cloud band.

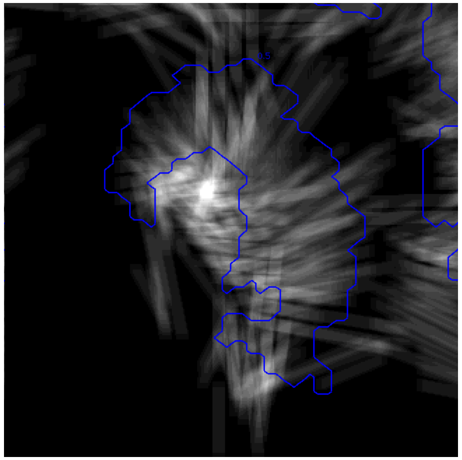
The objective analysis of cloud band curvature is done in 2 steps:

1. Analysis of the orientation of the cloud band
2. Drawing of Hough knots

1



2



# Classification of frontal areas

Occlusions *(example from 1. November 2013; 00:00 UTC)*



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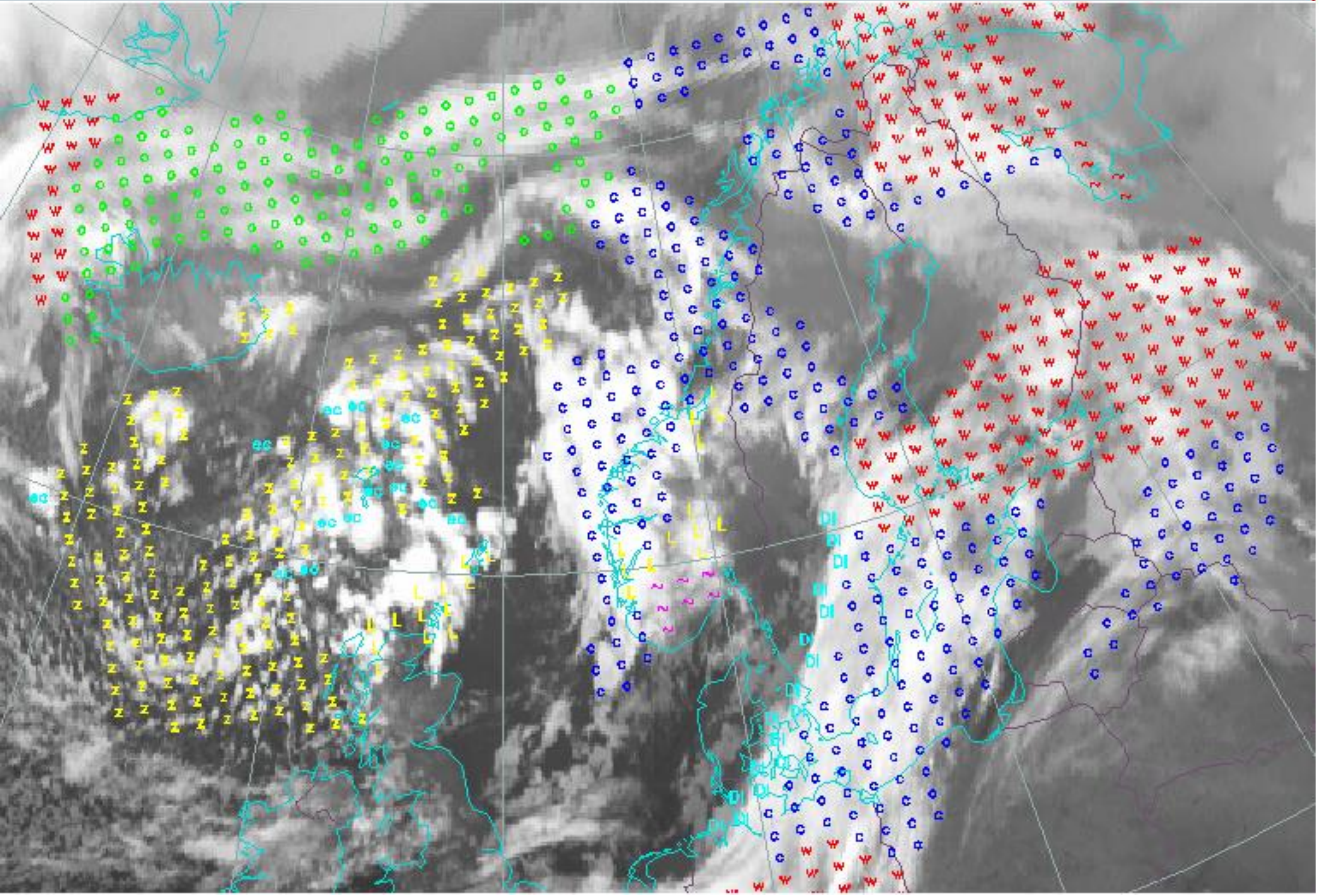


# Classification of frontal areas

## Occlusions



ASIINWP makes use of the satellite pattern recognition method to detect occlusions with additional NWP fields:

- Relative vorticity at 850 and 500 hPa

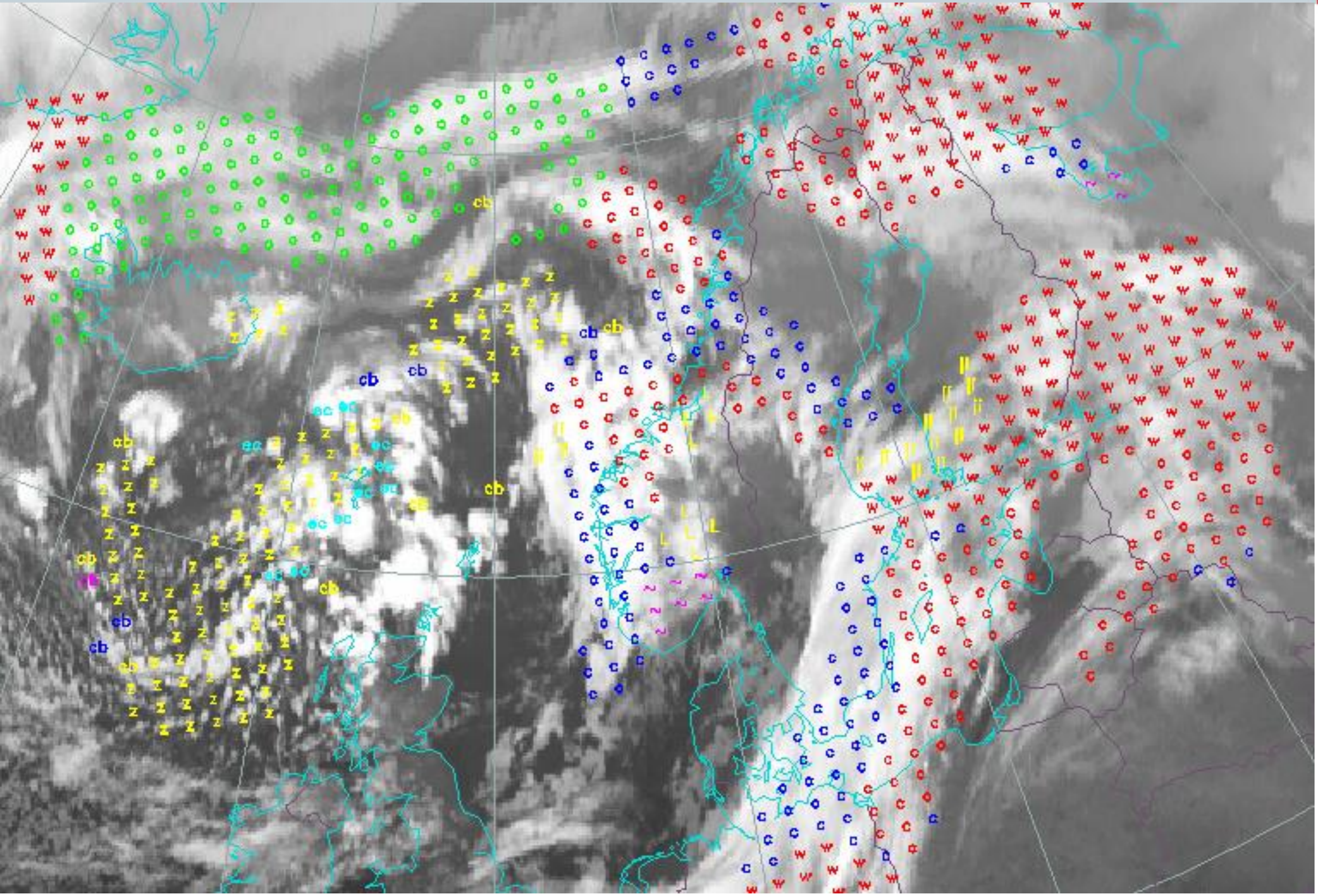
↓

The ASIINPW analysis either confirms, extends or dismisses the ASII analysis.

# Classification of frontal areas

<u>Occlusions</u> *(example from 1 November 2013; 00:00 UTC)*



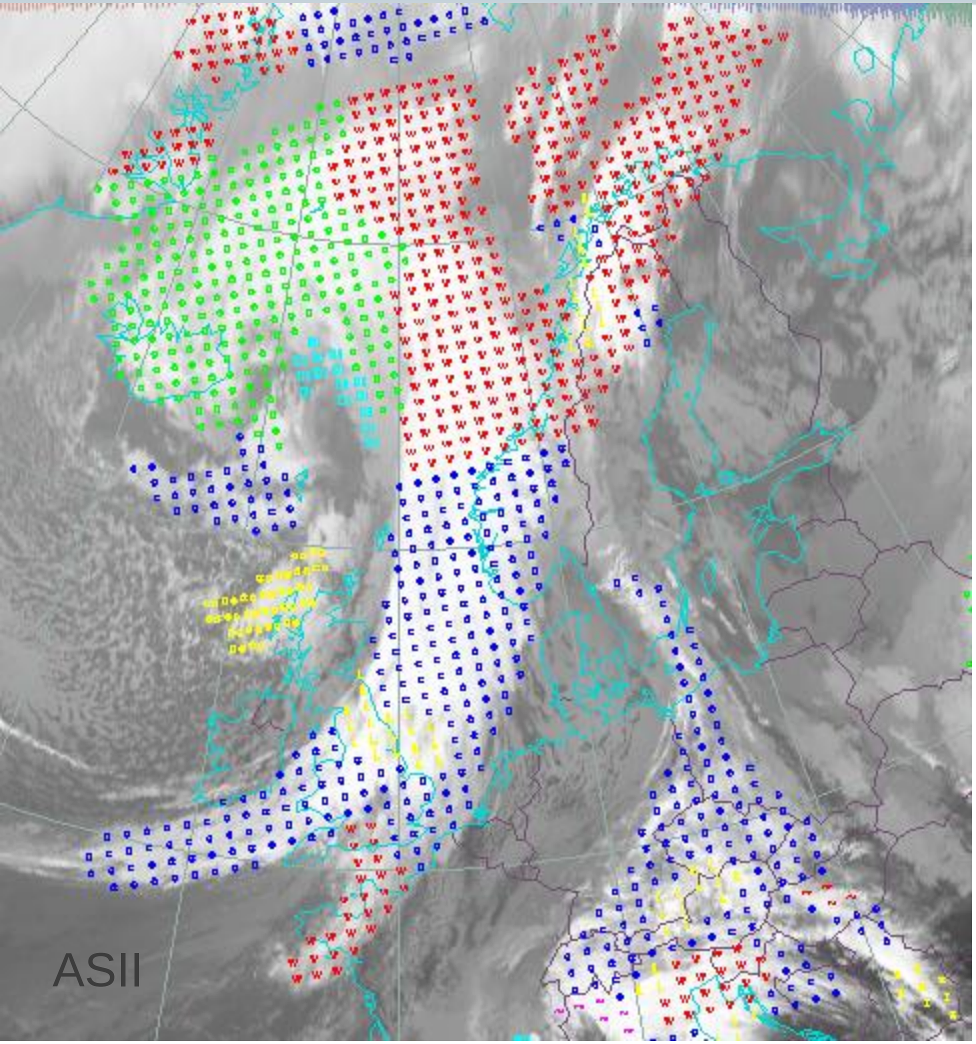


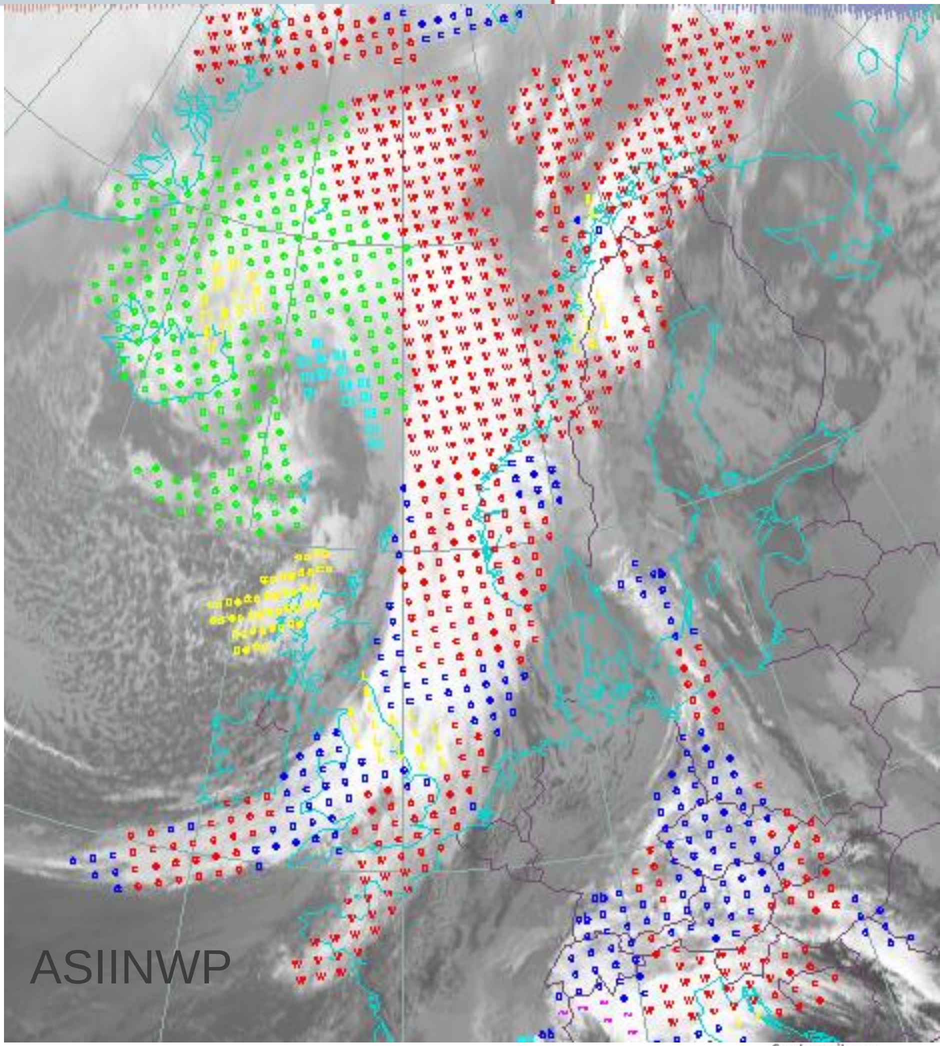
ASIINWP

# Classification of frontal areas



## <u>Occlusion</u> *(15. September 2013; 12:00 UTC)*



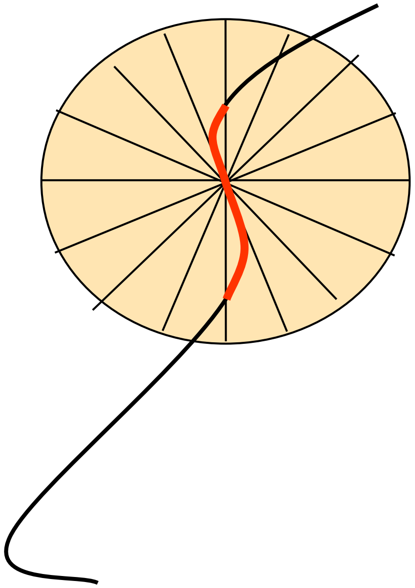

Geodynamik

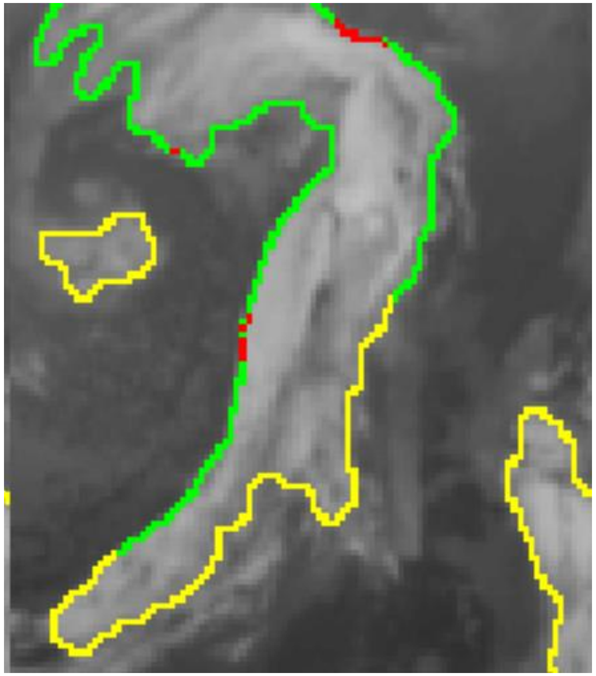
# Frontal sub-structures

## Frontal waves and jet waves



The detection of wave pattern in a frontal cloud band is performed by a pattern recognition module.

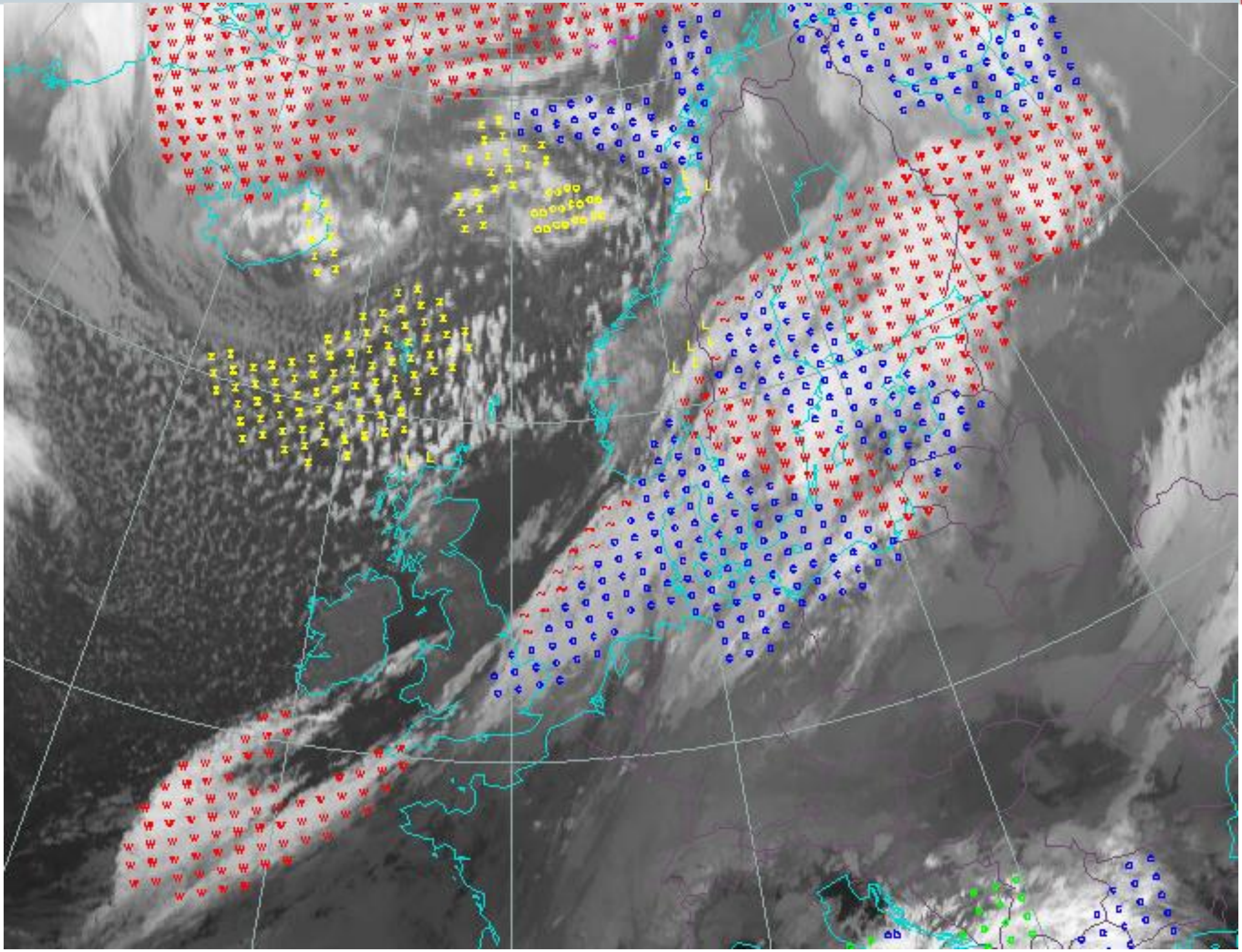




# Frontal sub-structures

## <u>Frontal waves and jet waves</u> *(12. November 2013; 06:45 UTC)*





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# Frontal sub-structures

## Frontal waves and jet waves



ASIINWP makes use of the satellite pattern recognition method to detect frontal waves with additional NWP fields:

- PVA maximum at 500 hPa
- Relative vorticity at 850 hPa
- Temperature advection at 700 hPa

↓

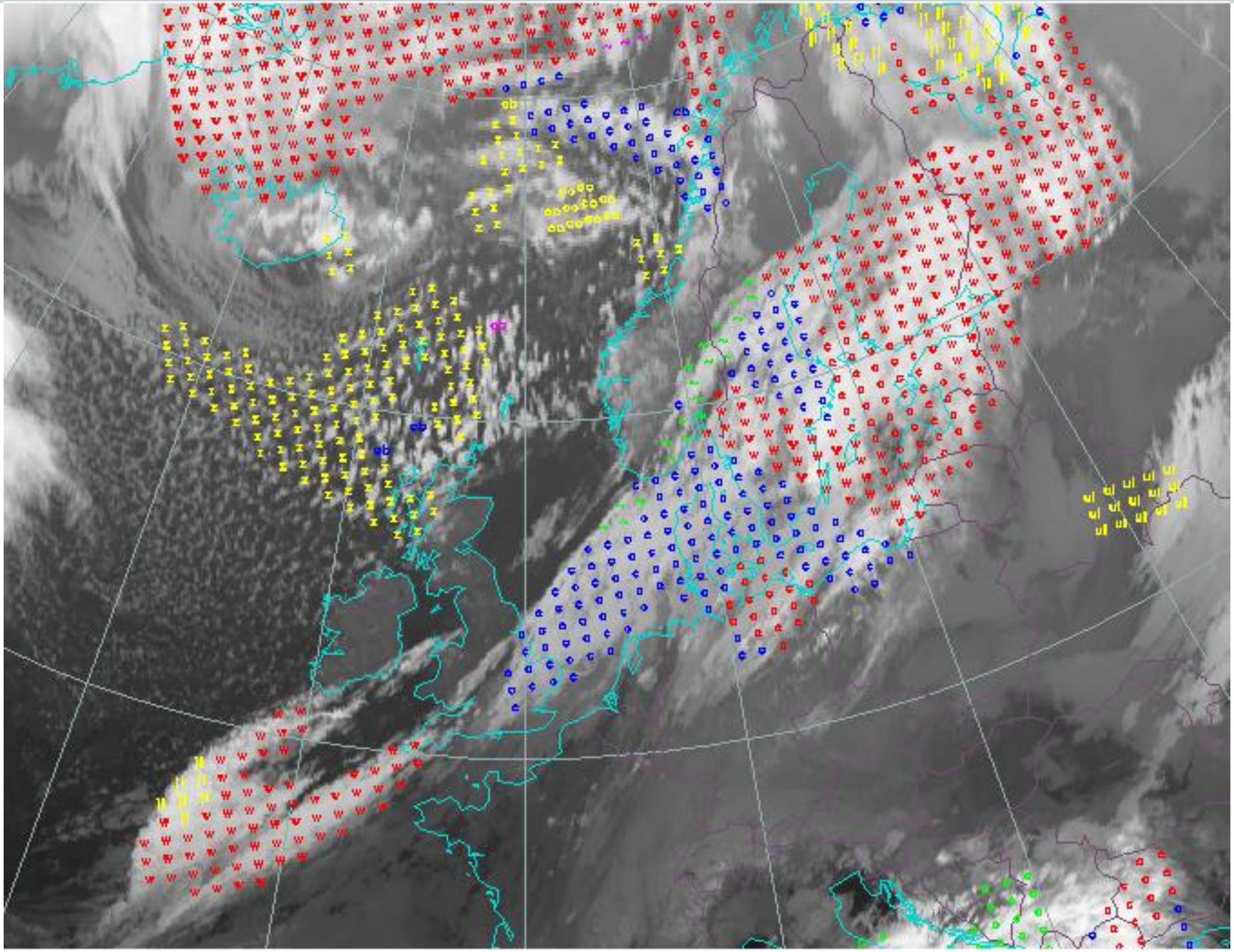
The ASIINPW analysis either confirms or dismisses the ASII analysis.

# Frontal sub-structures

<u>Frontal waves and jet waves</u> *(12. November 2013; 06:45 UTC)*



ASIINWP



# Frontal sub-structures

## Frontal waves and jet waves



Once a wave structure is detected in the satellite image, ASIINWP checks for „upper wave“ using the following model data:

- Wind speed at 300 hPa
- Shear vorticity at 300 hPa
- Temperature advection at 700 hPa

↓

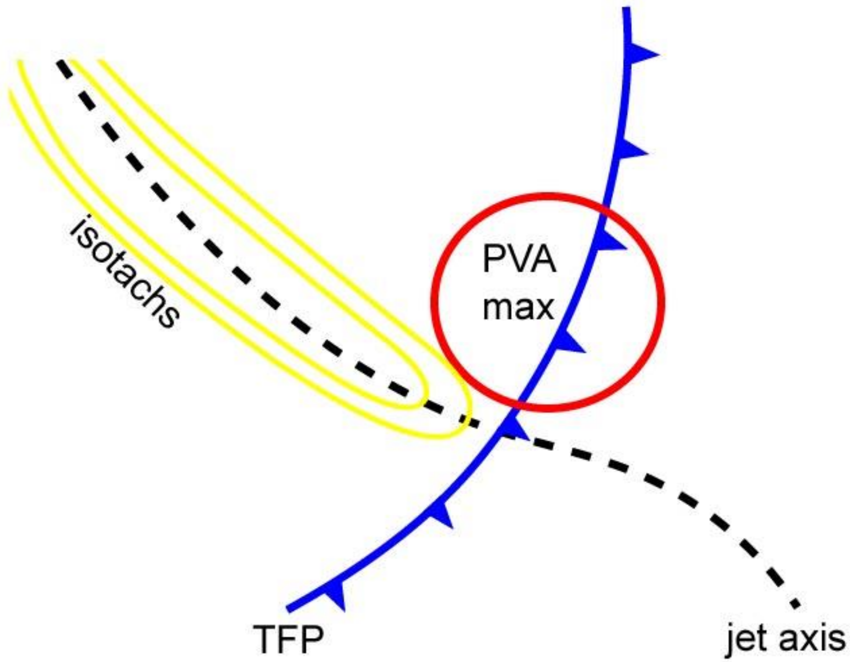
ASIINWP changes the frontal wave to upper wave if the NWP fields confirm the latter.

# Frontal sub-structures

## Front intensification by jet



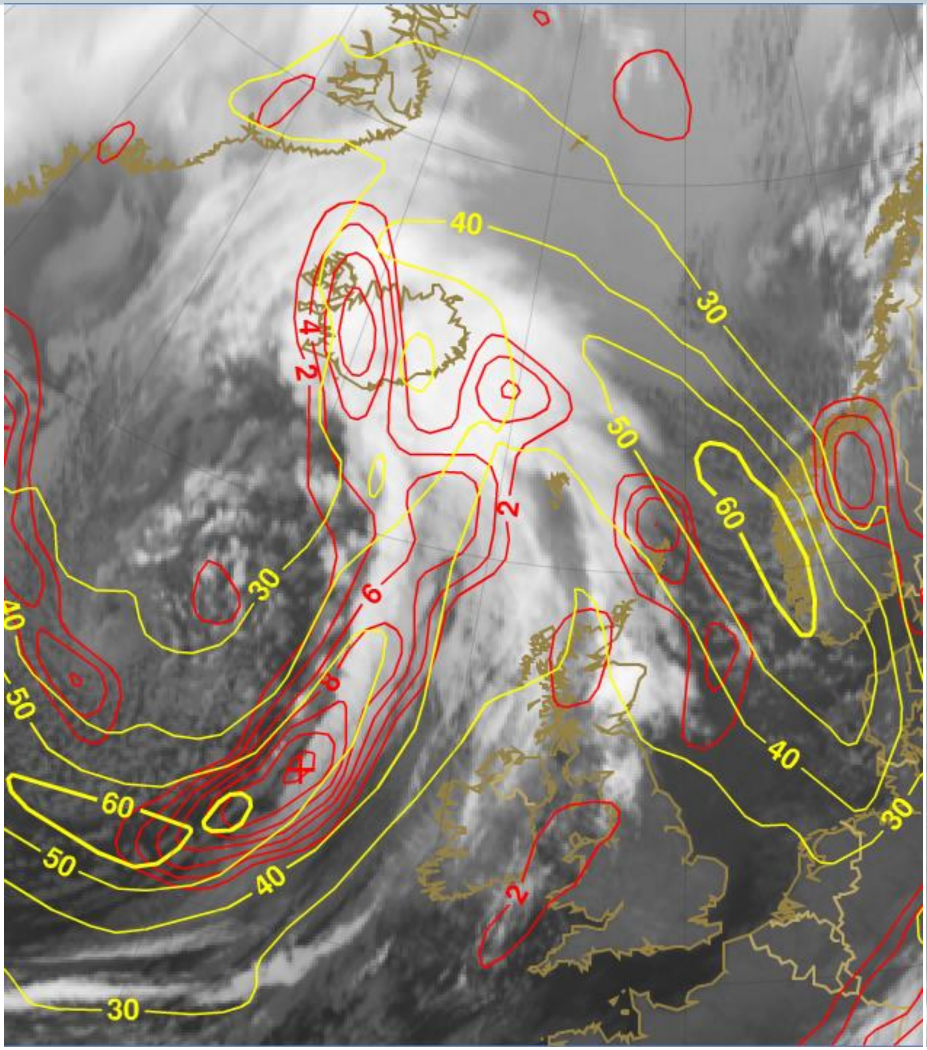
Some conceptual models cannot be analysed from the satellite image alone.

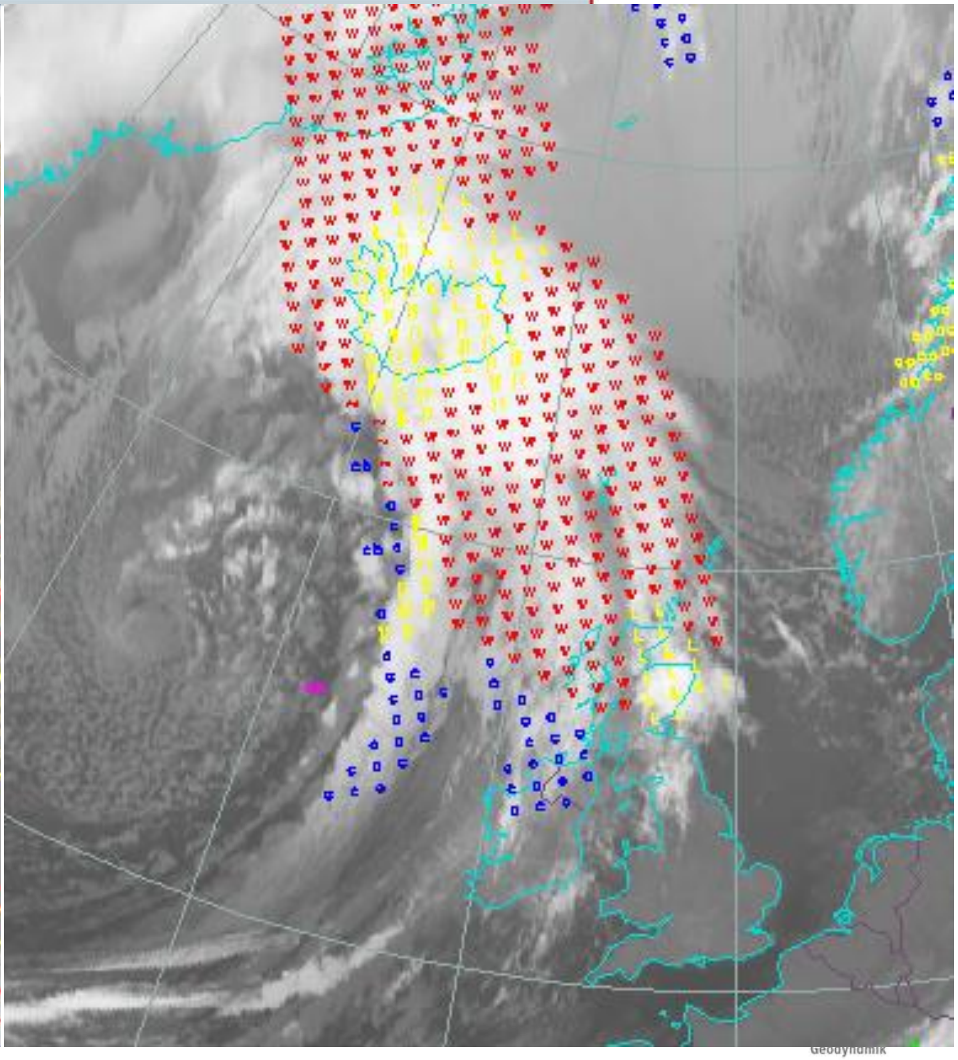


# Frontal sub-structures

## Front intensification by jet



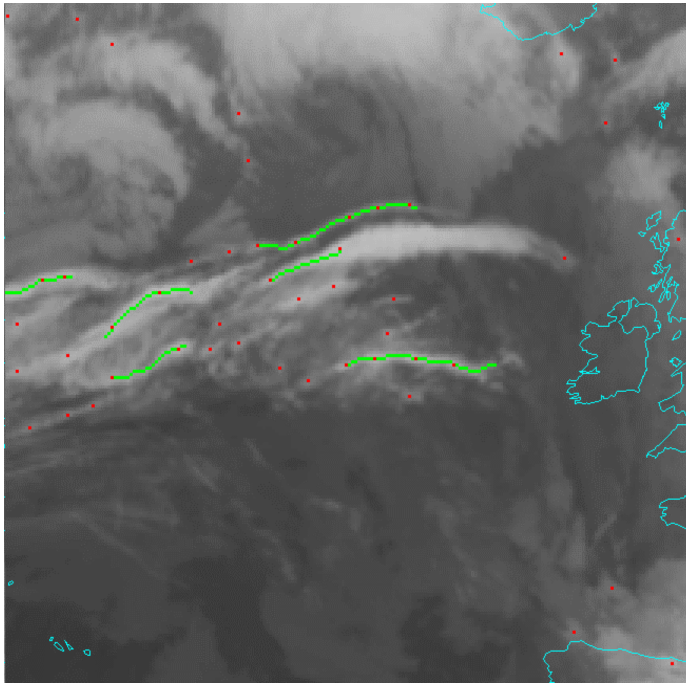


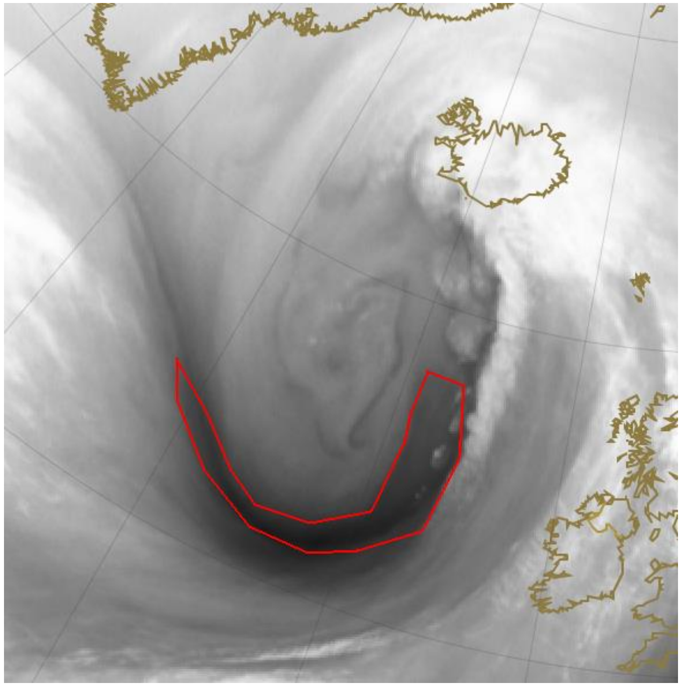



## Jet cloud fibres



The detection of jet cloud fibres is based on a pattern recognition module.
As the position of jet axes is unknown without NWP fields, the position of a black WV stripe is taken as indicator for a jet.

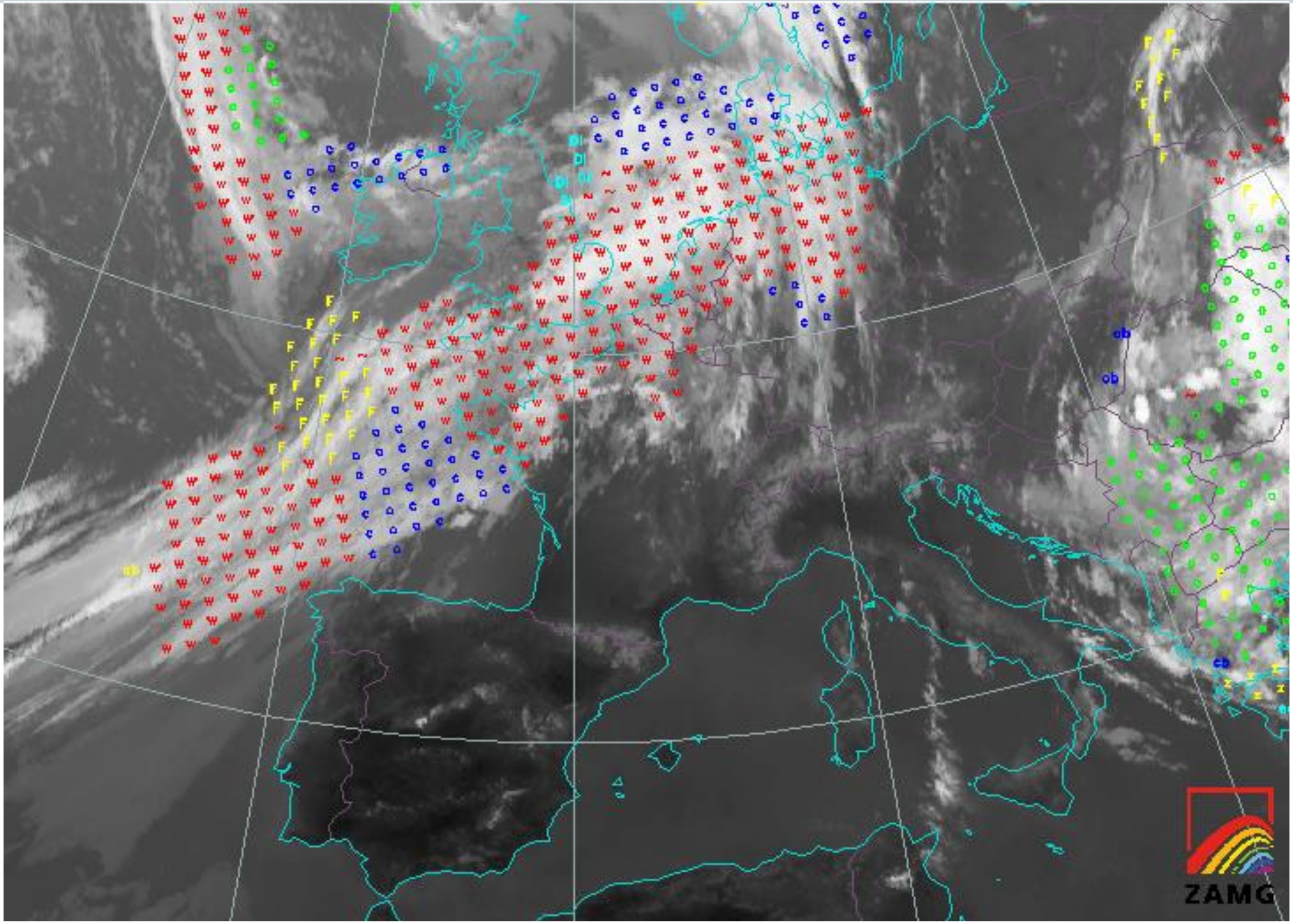




# Meso-scale conceptual models

## <u>Jet cloud fibres</u> *(12. June 2013; 18:00 UTC)*



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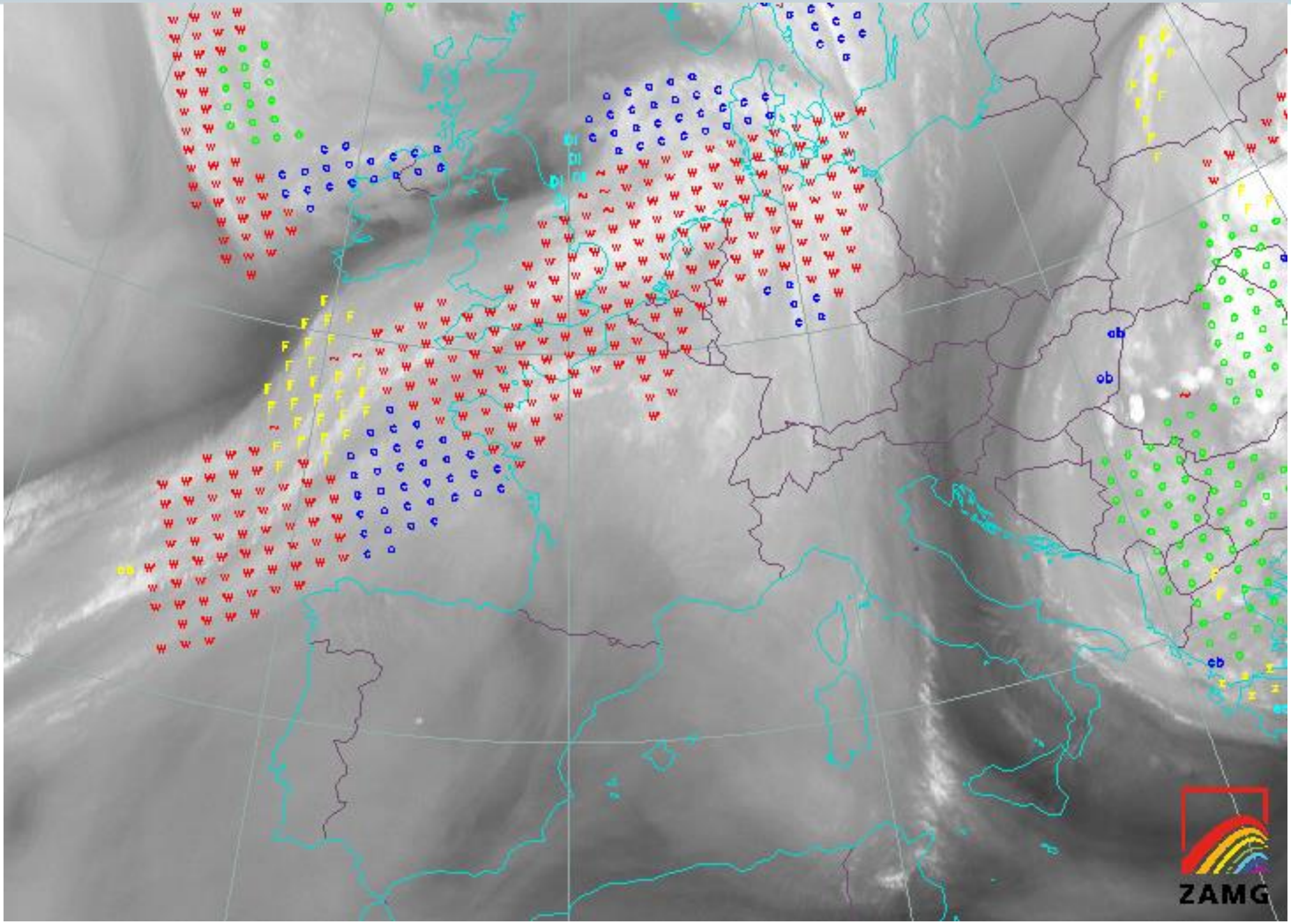
# Meso-scale conceptual models



## Jet cloud fibres *(12. June 2013; 18:00 UTC)*

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# Meso-scale conceptual models

## Jet cloud fibres



Once a fibre structure is detected in the satellite image, ASIINWP makes use of the following NWP fields:

- Wind speed at 300 hPa
- Shear vorticity at 300 hPa

↓

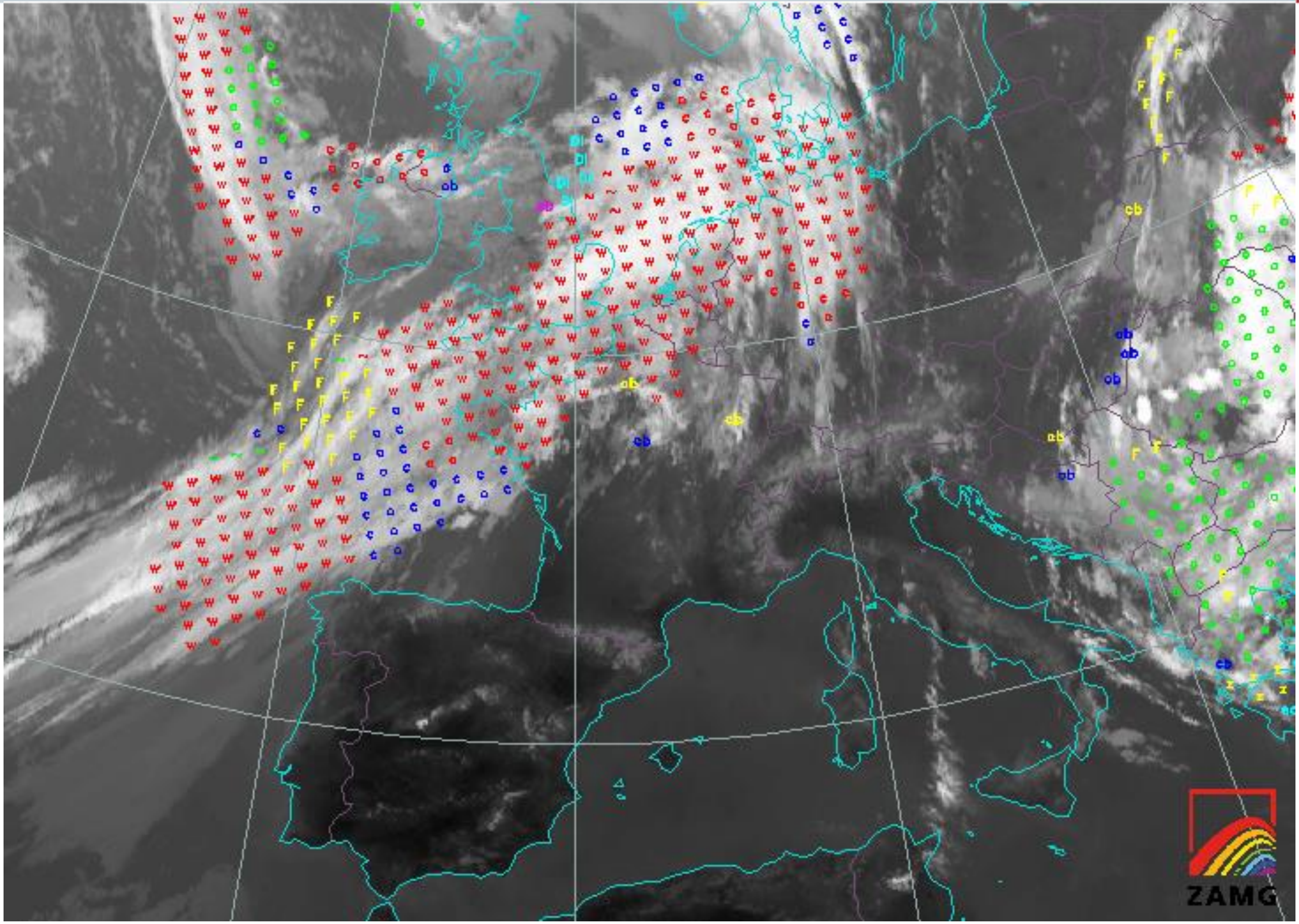
ASIINWP either confirms or dismisses the ASII analysis.

# Meso-scale conceptual models

## Jet cloud fibres



ASIINWP



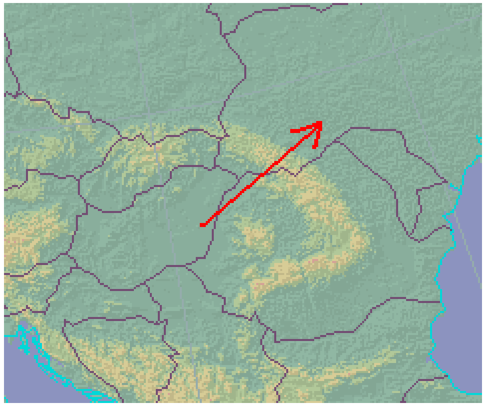
# Meso-scale conceptual models

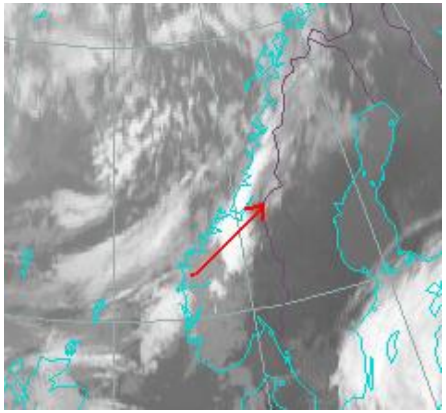
## Lee Cloud

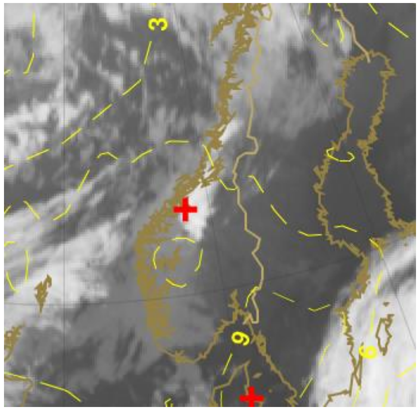


The Lee cloud detection module in ASII is mainly based on satellite information and the geographical position of the mountain range and clouds.
The algorithm comprises the following steps:

- Detection of a cross mountain wind with AMV
- Brightness difference between windward and lee side of the mountains
- Stability index for ASIINWP



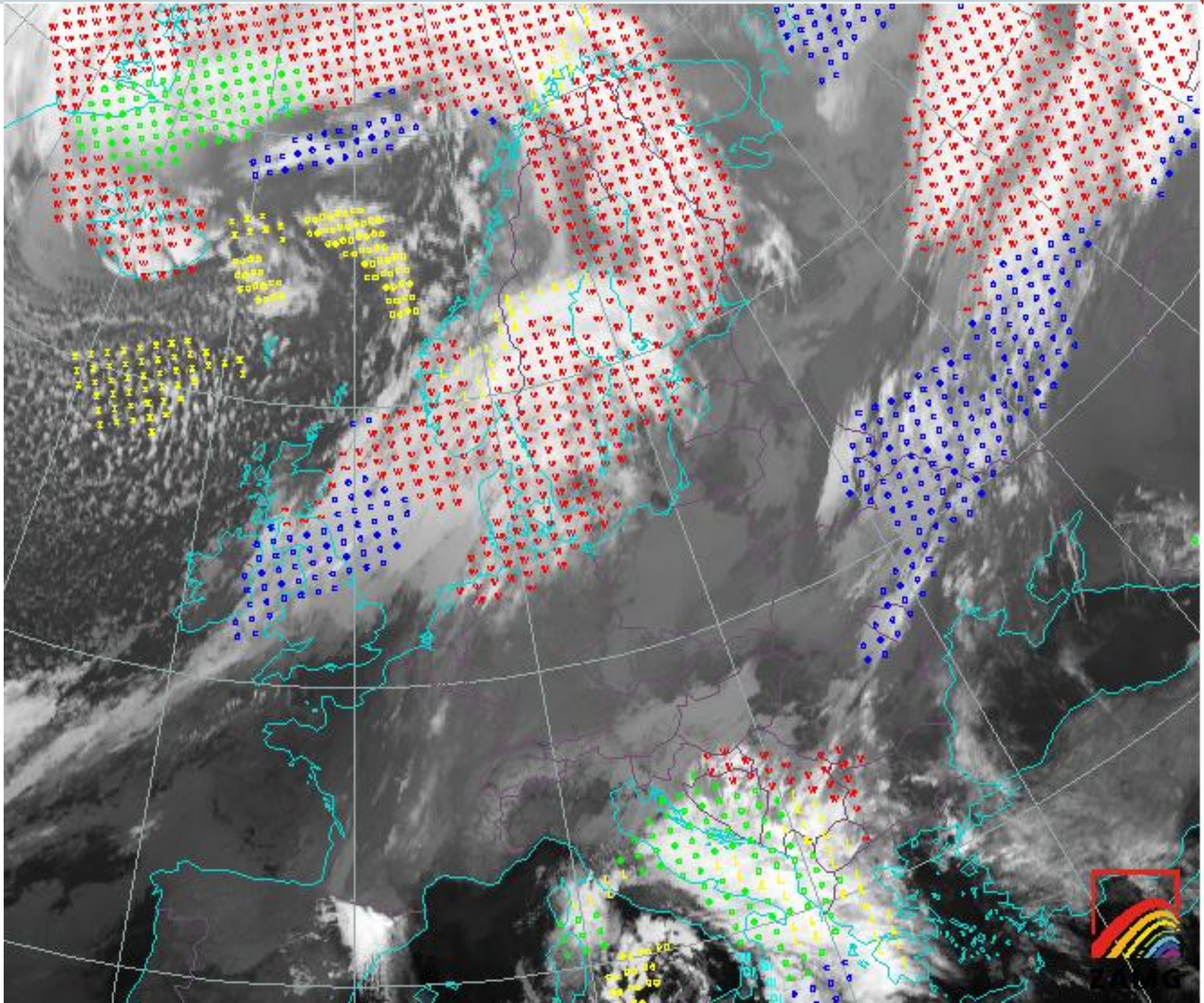




# Meso-scale conceptual models

## Lee Cloud *(12. November 2013; 00:00 UTC)*





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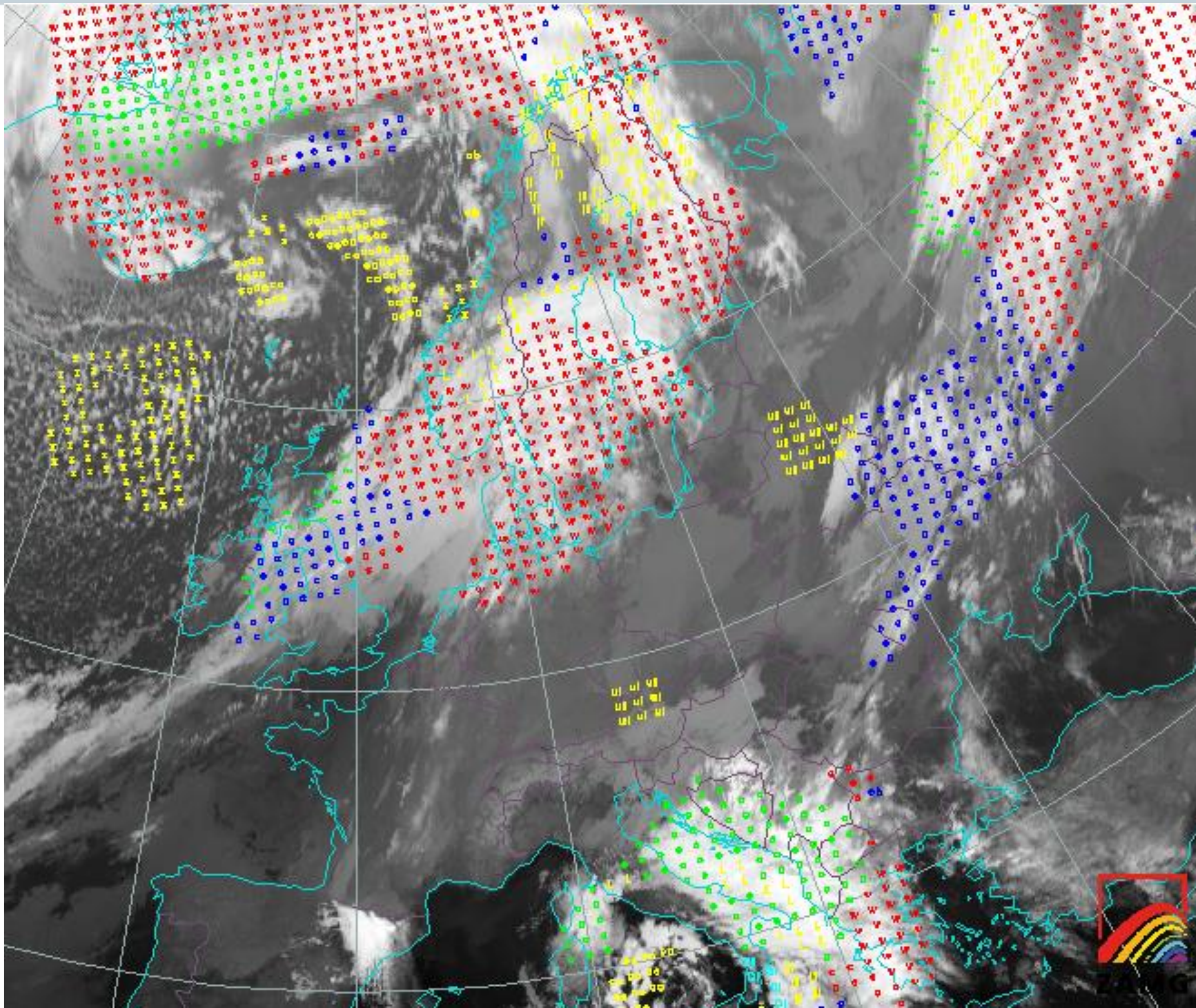
# Meso-scale conceptual models

Lee Cloud *(12. November 2013; 00:00 UTC)*





ASIINWP

# Validation and concluding remarks



• Validation of the ASII product proved very difficult because an objective reference system is missing.
• Validation was done against a manual synoptic analysis.
• ASII has a limited number of CM, compared to a much larger number of CM in the manual analysis.
• The manual analysis labels a synoptic system without defining its exact dimensions, while the ASII analysis labels an area.
• Systems at image borders are often misclassified.
• The detection rate is much lower compared to a manual analysis.
• Detection rates vary from 20% to 60%, depending on the CM.
• Detection rates for frontal systems are among the best, CM with smaller extension are among the poorest detected.
• Detection rates for WF and CF are much better then for Occlusions.
• Stability of the frontal analysis in time is not satisfying.

# Validation and concluding remarks



• ASII uses a threshold technique which proved to be a handicap when considering the wealth of pattern and sizes in nature.
• The use of NWP data not always increases the detection efficiency.
• The usage of derived model data (e.g. advection fields) revealed problematic for the combination of fixed thresholds and varying model resolution.

# Final words …



• ASII delivers a first guess of the synoptic systems of the IR image.
• It is available every 15 minutes.
• But it remains an expert system, which needs the experience of a meteorologist to be correctly interpreted.