Zentralanstalt für Meteorologie und Geodynamik

Frontal Substructures

Synoptic and Mesoscale Analysis
Satellite Meteorology

9. October 2014

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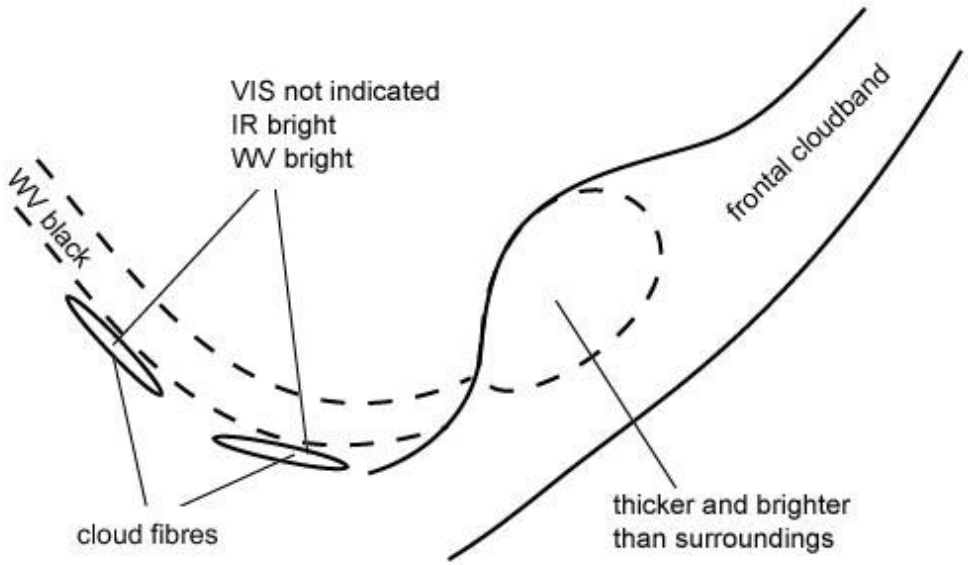
Front Intensification by crossing Jet Streak (a.k.a. FI by Jet)

- What are we looking for in satellite imagery?
- Impact on weather events
- Meteorological Physical Background

Key Parameters

Appearance in IR imagery



FI by Jet - Appearance in IR imagery

Front Intensifications can be found:

at the rear side of a cold front

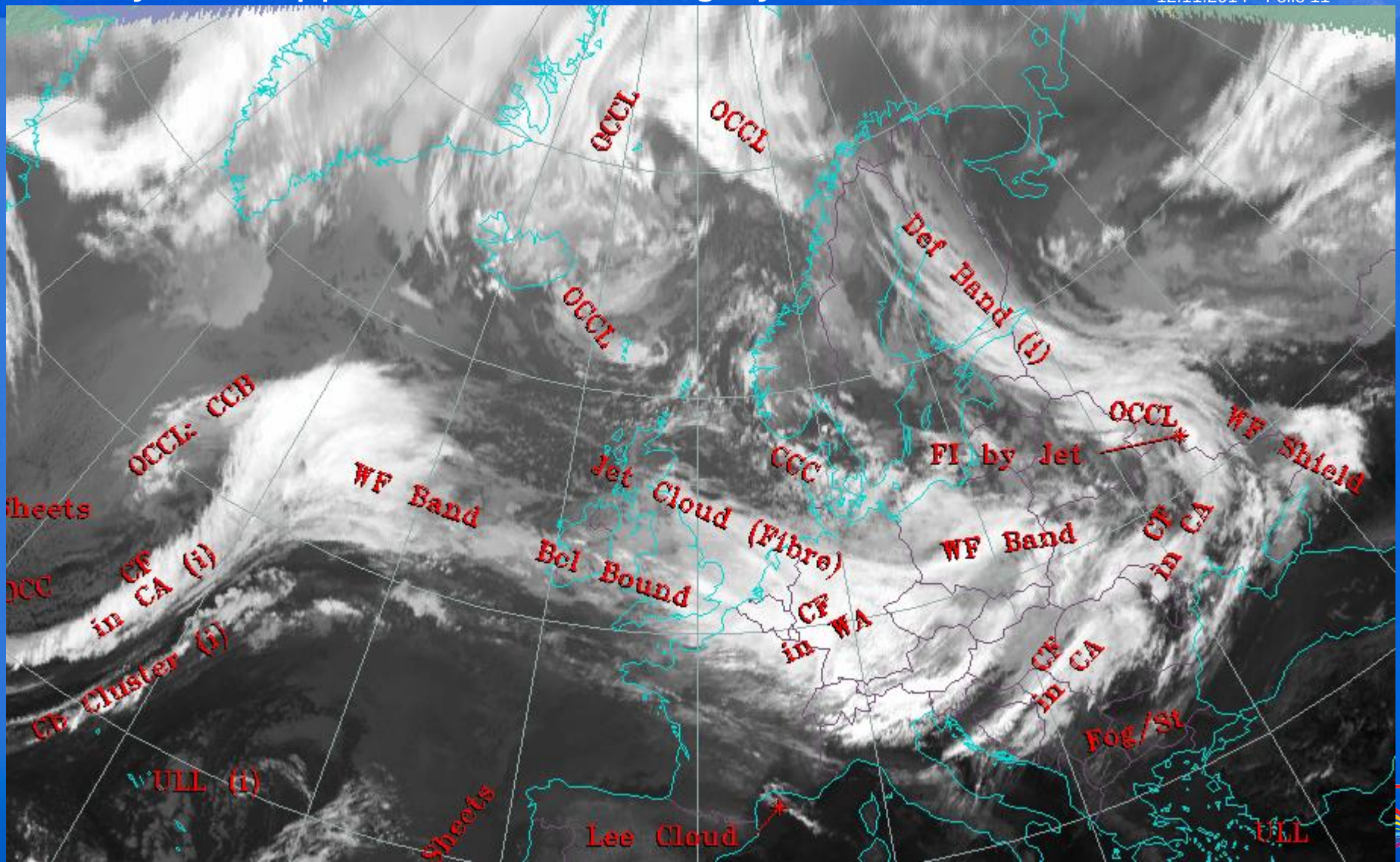
near the occlusion point (most common place)

Often left exit regions lead to cloud formation in trough regions.

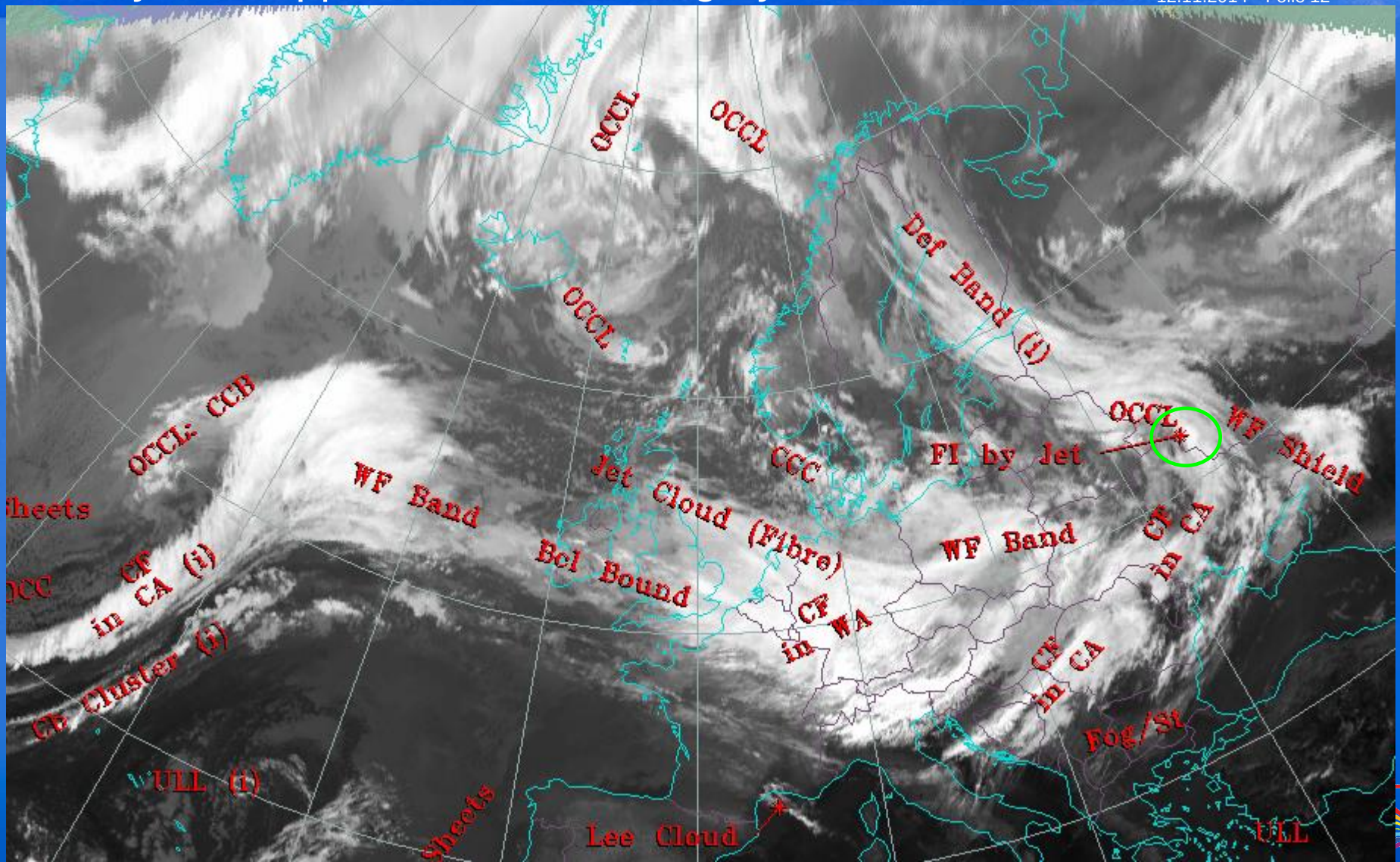
- Comma cloud formation
- Enhanced cumuli

The conceptual model FI by Jet is always linked to interaction of jets with fronts.

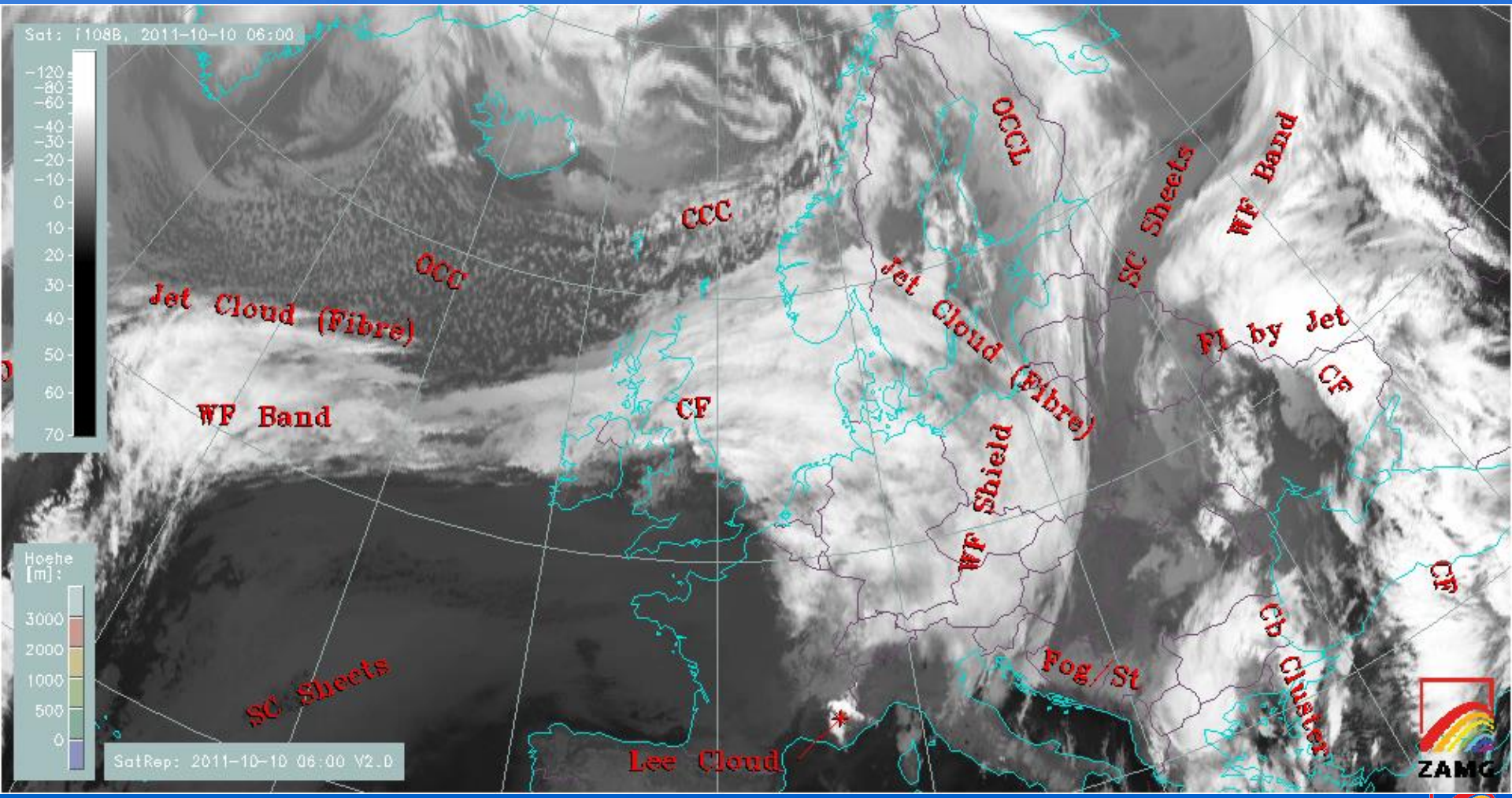
FI by Jet - Appearance in IR imagery



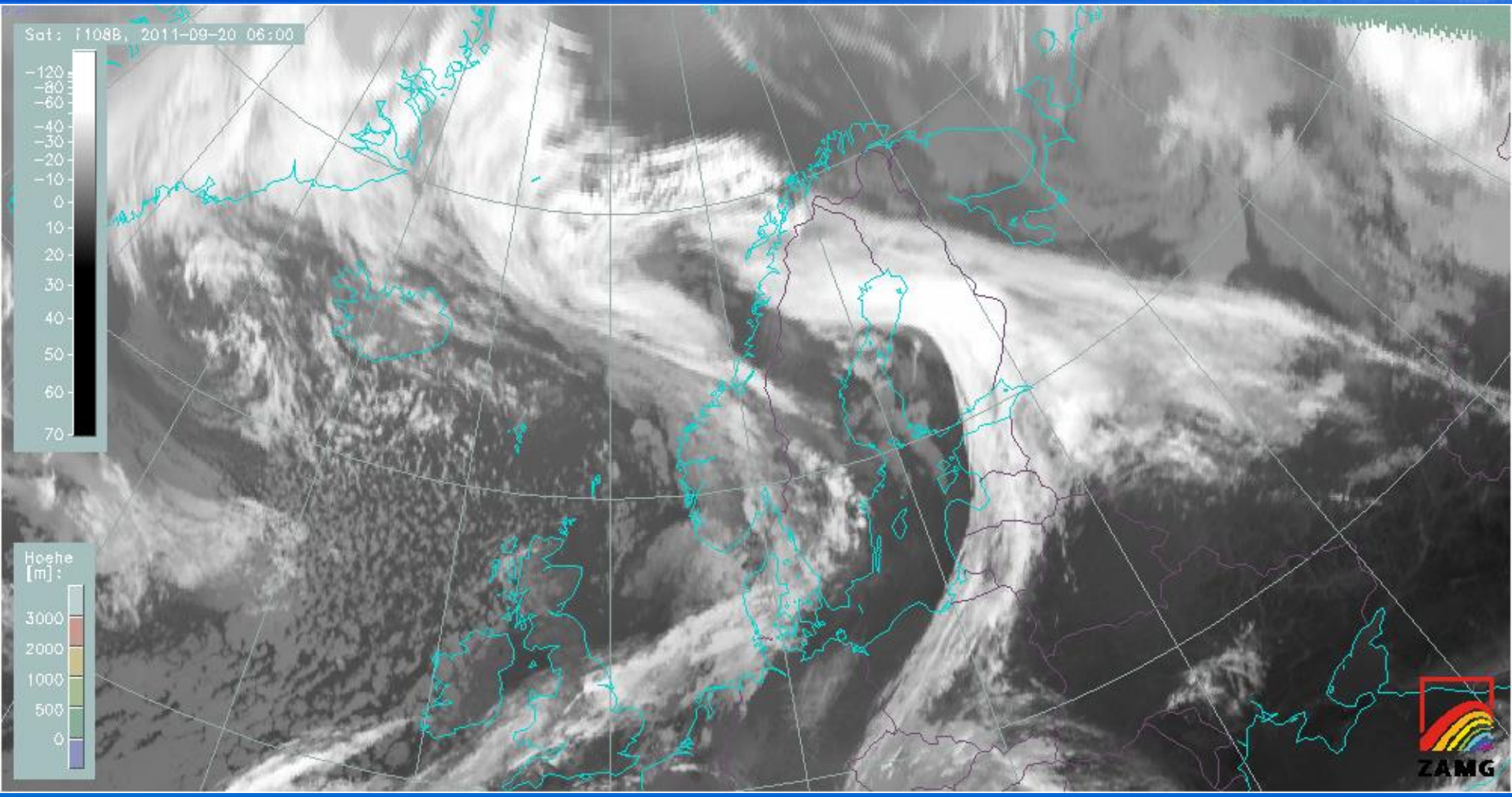
FI by Jet - Appearance in IR imagery



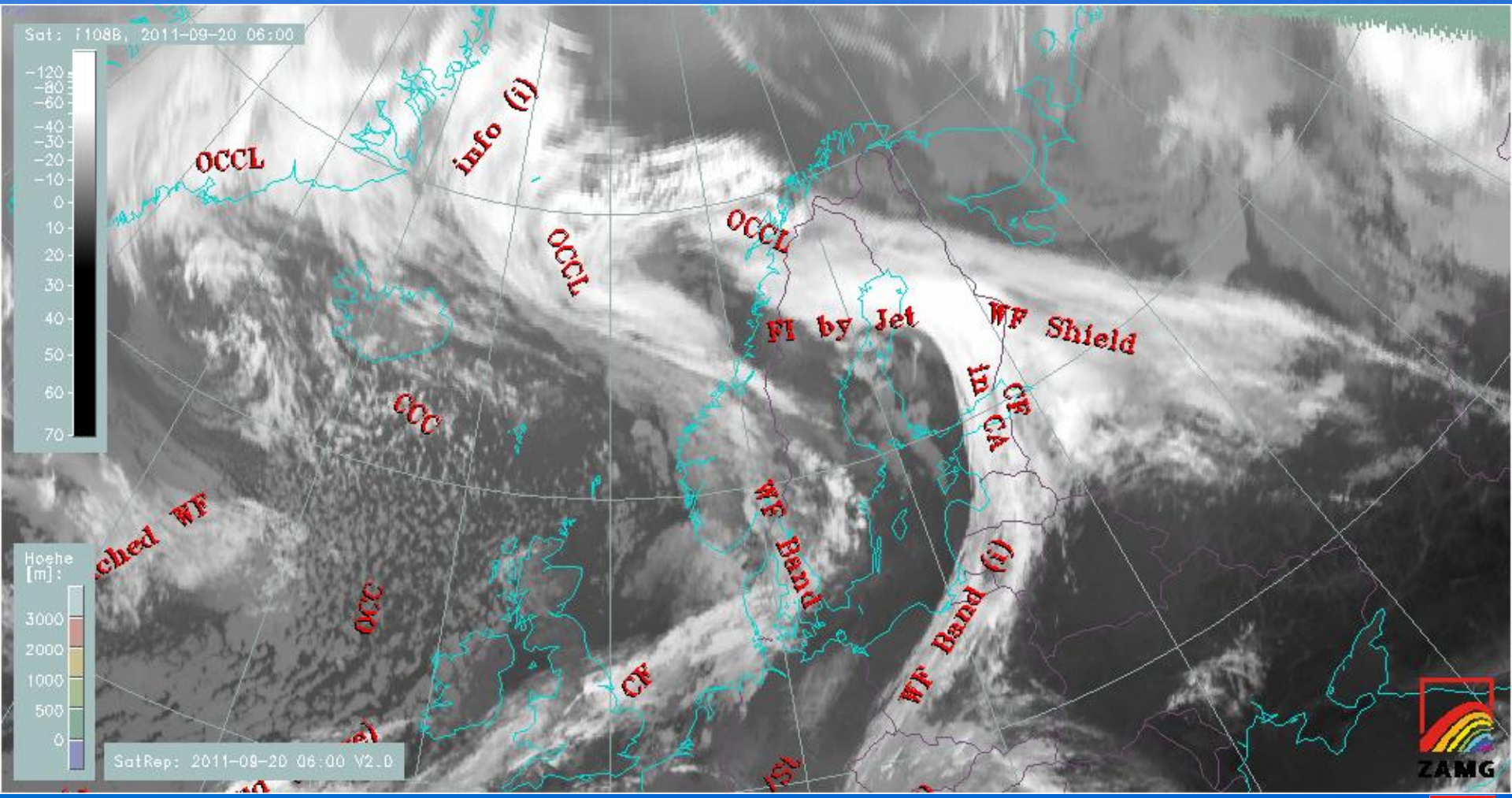
FI by Jet - Appearance in IR imagery



FI by Jet - Appearance in IR imagery



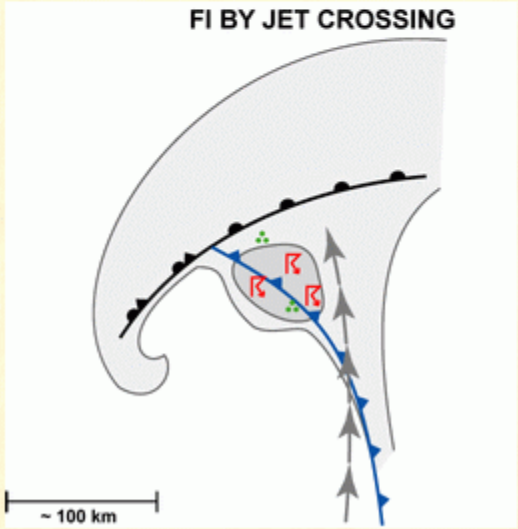
FI by Jet - Appearance in IR imagery



FI by Jet - Impact on weather events

Where there is no orography, cloudiness in middle and high levels dominates with slight to moderate rain or drizzle.

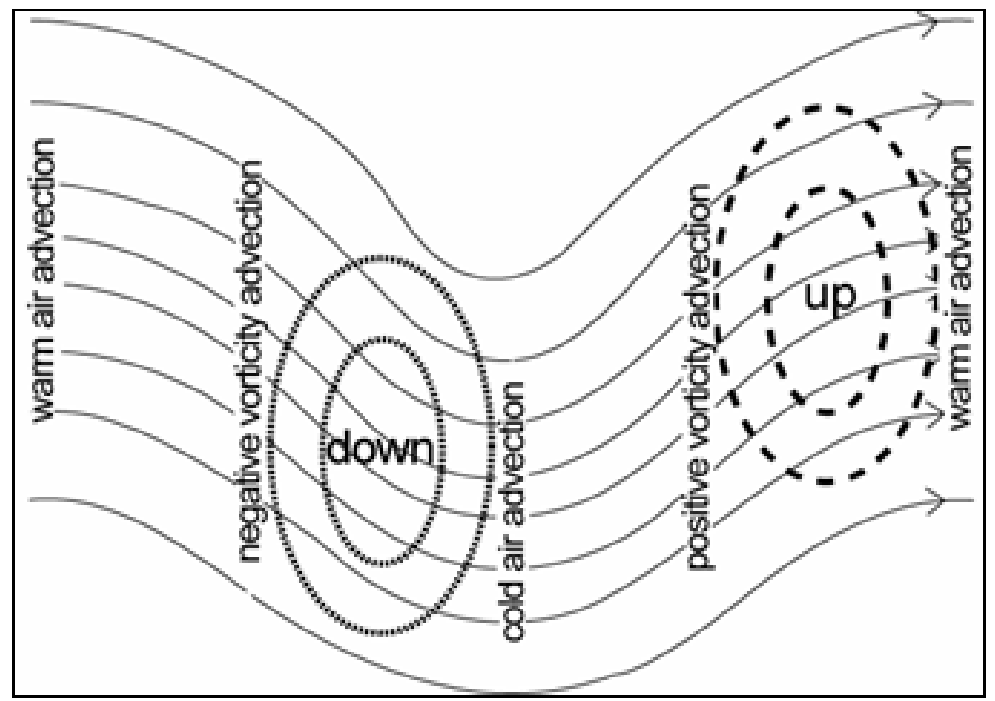
Parameter	Description
Precipitation	• Intensifying precipitation, embedded Cbs and thunderstorms. • May prolong the rainy period after the passage of the actual frontal precipitation area.
Temperature	• No significant change.
Wind (incl. gusts)	• No significant change.
Other relevant information	



Meteorological Physical Background

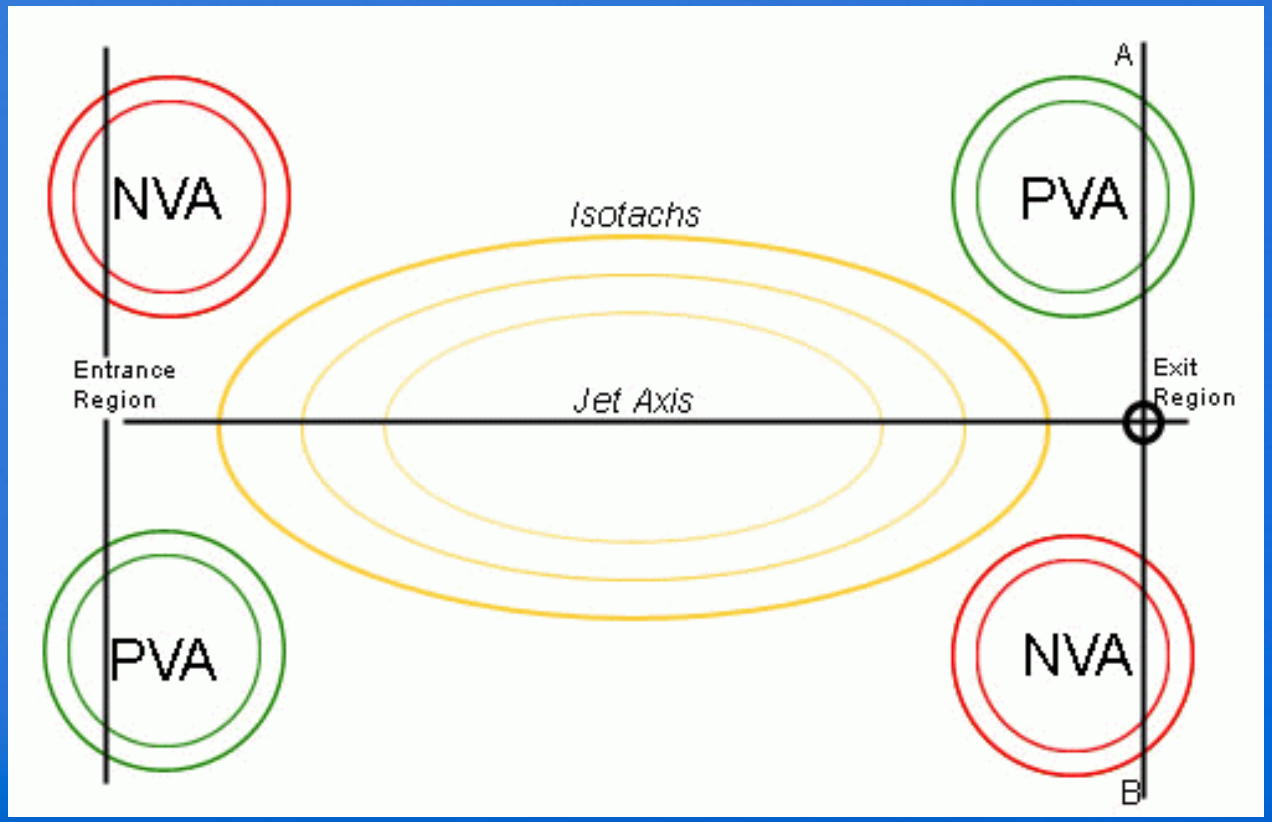
Quasi-geostrophic theory (-Omega = DVA+TA) states that vertical motion is primarily forced by:

- an increase of vorticity advection with height, and
- warm air advection.



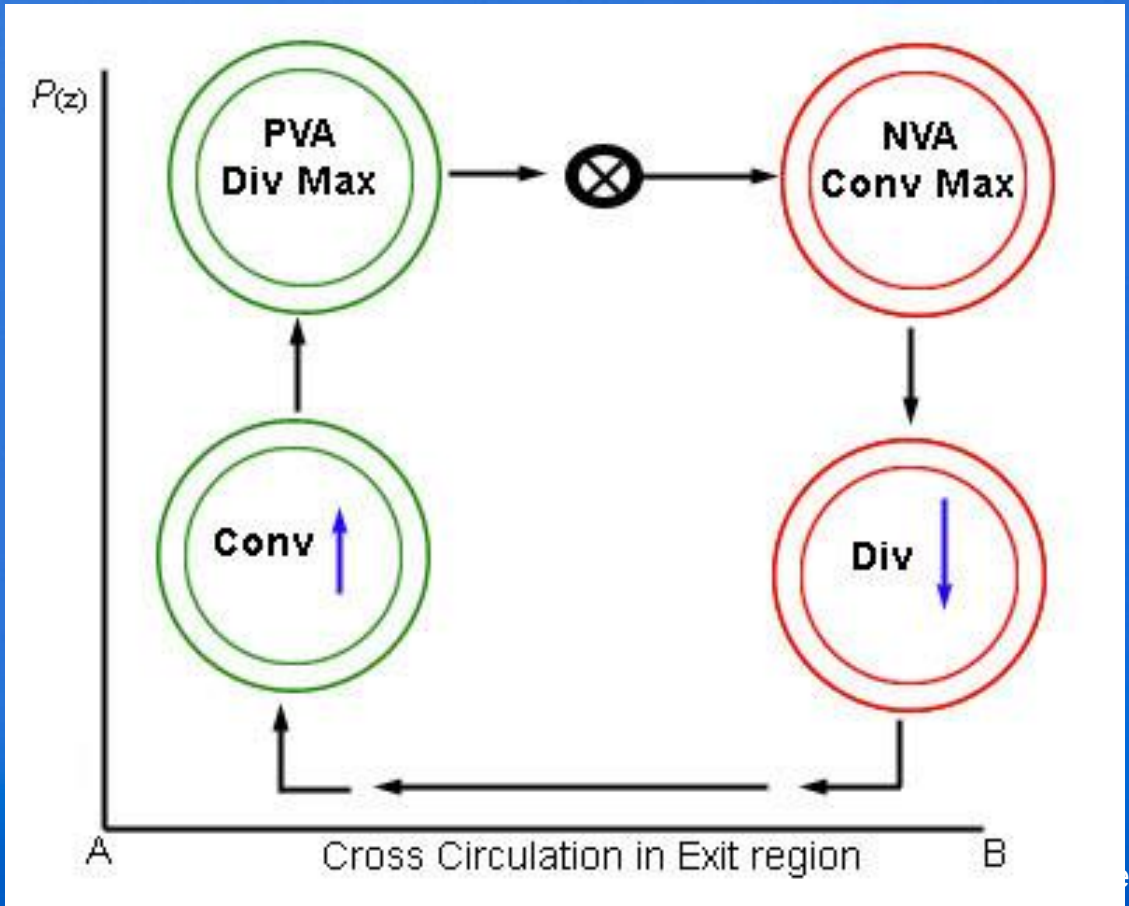
Meteorological Physical Background

The displacement of the jet streak from west to east leads to the formation of PVA/NVA fields at 300 hPa.



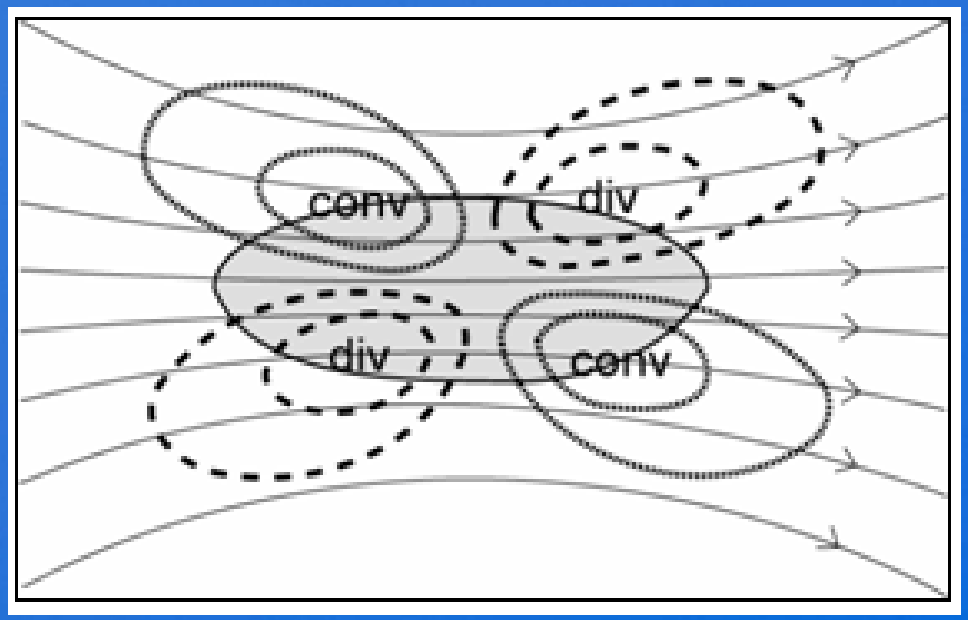
Meteorological Physical Background

The upper level dynamics induce **divergence** and **convergence** in lower levels.



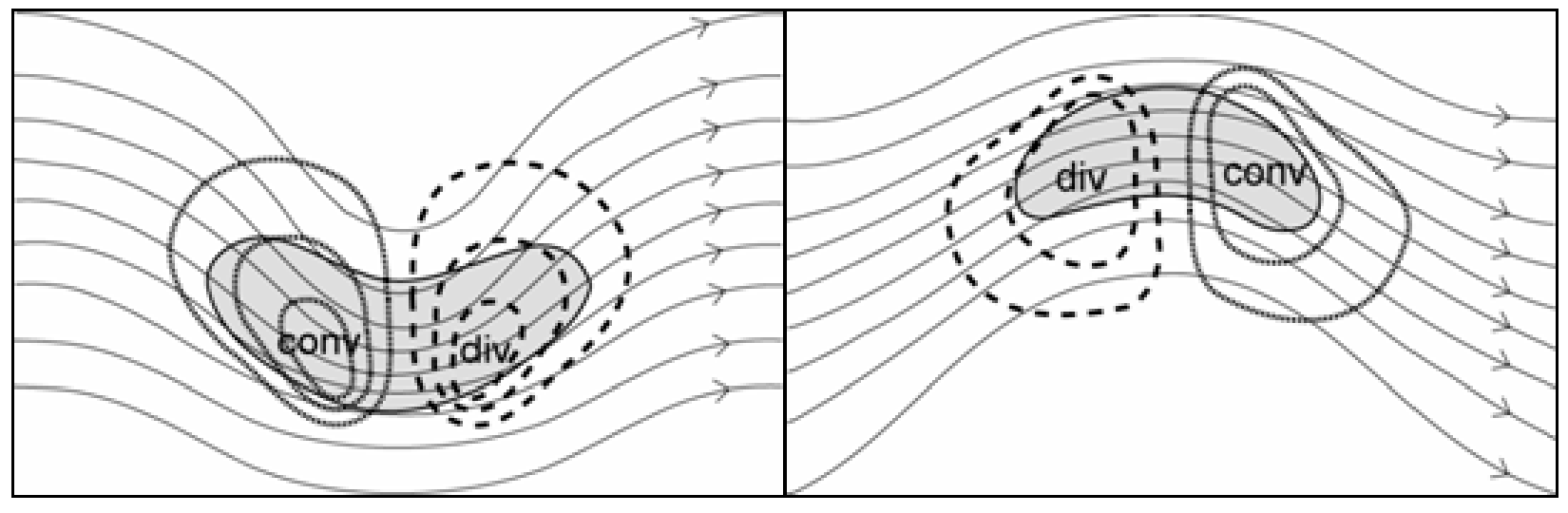
Meteorological Physical Background

According to the omega equation which states that cyclonic vorticity advection combined with warm air advection fosters the rising of an air mass, we get:



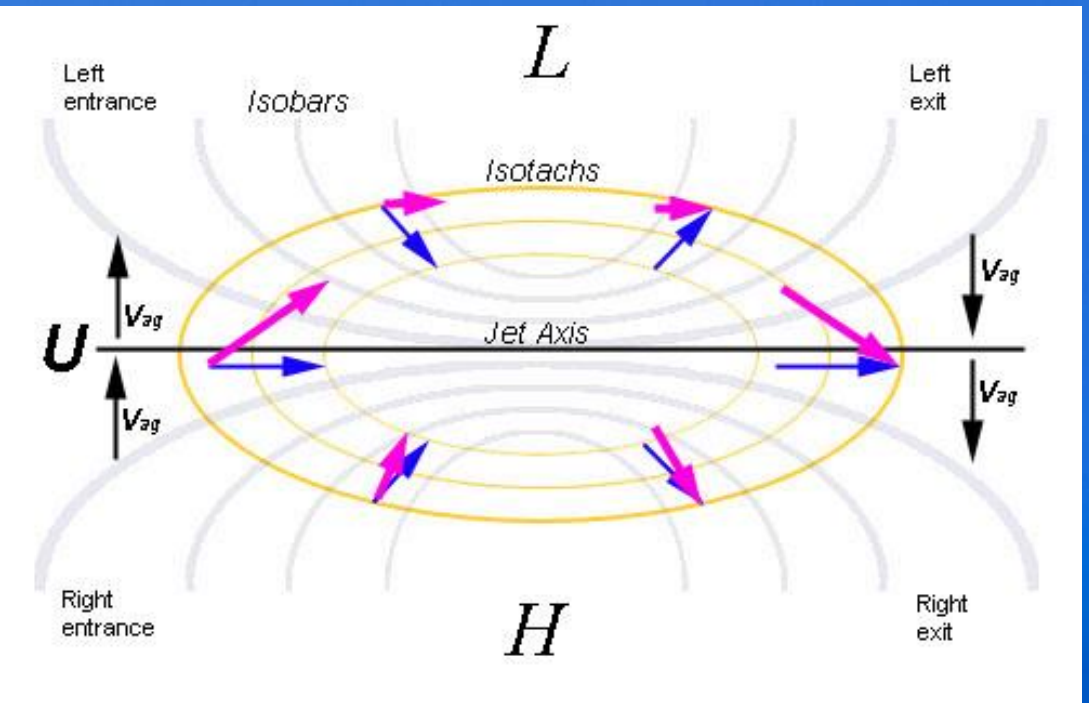
Meteorological Physical Background

In reality jet streaks are often not straight but may be cyclonically or anticyclonically curved. In the case of a cyclonically-curved jet, divergence tends to be very strong across its entire exit region, while an anticyclonic jet is associated with divergence across its entrance region.



Meteorological Physical Background

Air accelerates within the entrance region as it approaches the core of the jet streak and air decelerates within the exit region as it leaves the core of the jet streak. According to the momentum equations, the ageostrophic wind is perpendicular and to the left of the parcel acceleration vector (in the Northern Hemisphere):

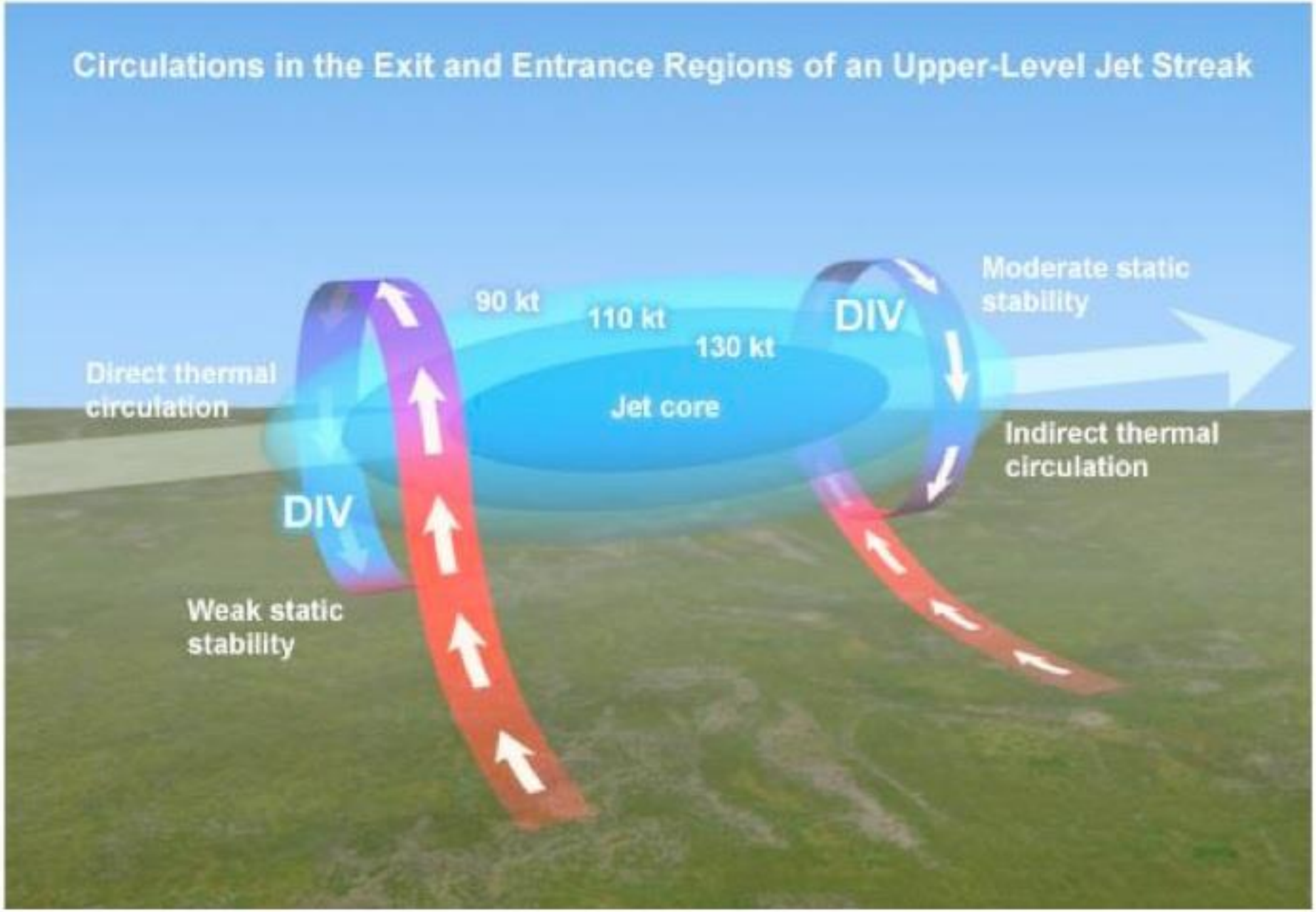


$$\mathbf{V}_{ag} = \frac{1}{f_0}\mathbf{k} \times \frac{d\mathbf{V}}{dt}$$

or in component form:

$$\frac{du}{dt} = f v_{ag}$$

$$\frac{dv}{dt} = -f u_{ag}$$

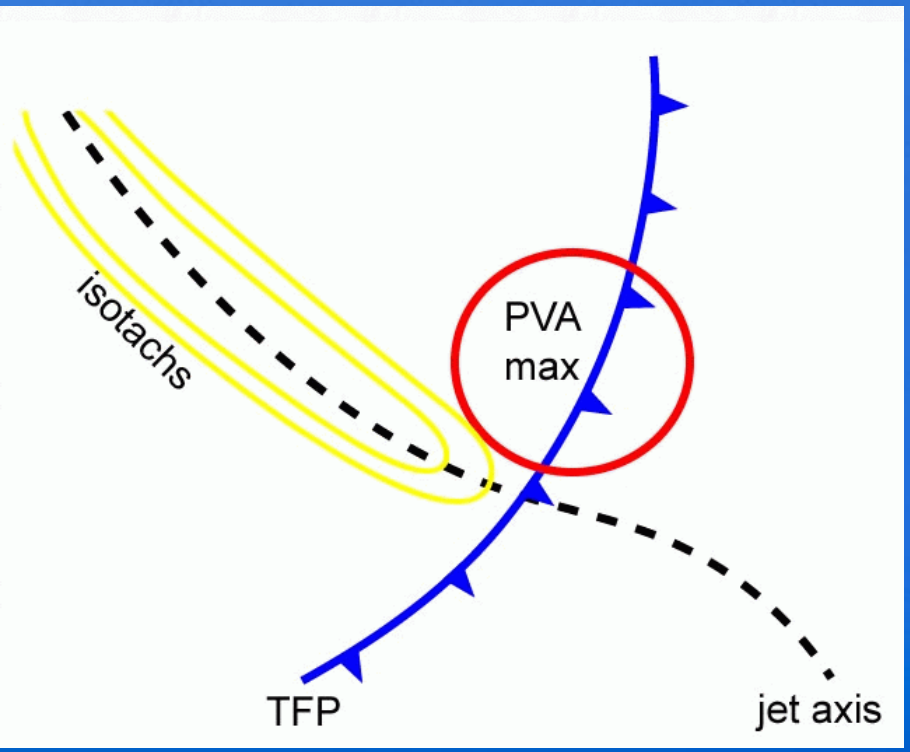

Circulations in the Exit and Entrance Regions of an Upper-Level Jet Streak
90 kt
110 kt
130 kt
Jet core
Direct thermal circulation
DIV
Weak static stability
DIV
Moderate static stability
Indirect thermal circulation

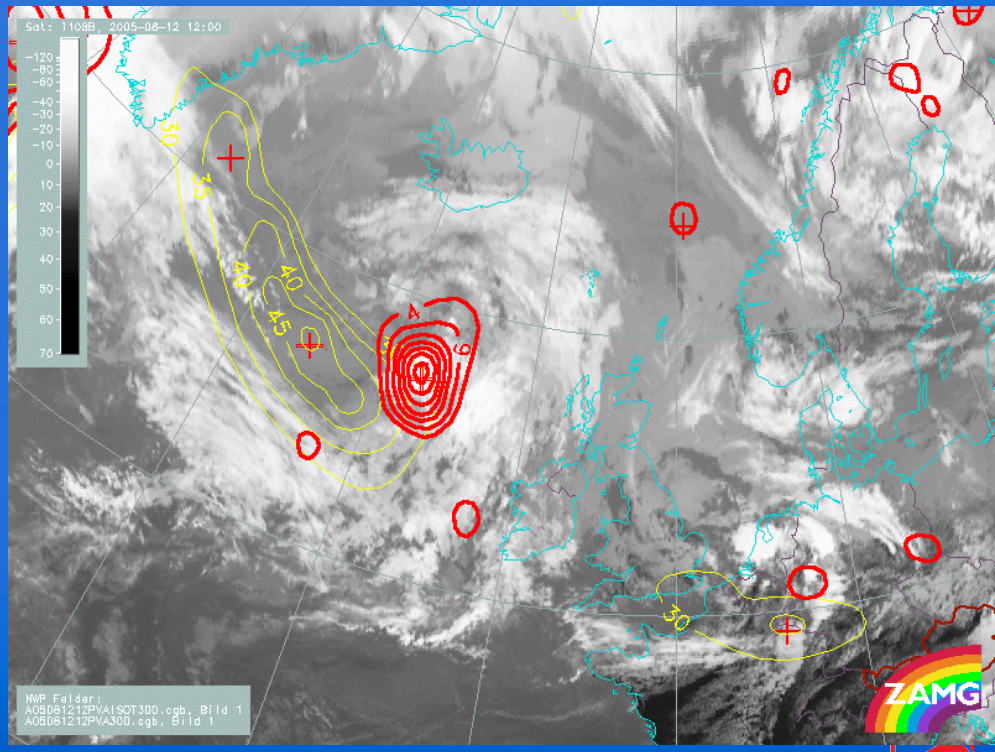
FI by Jet - Key Parameters

Isotachs (for the location of the jet streak)

PVA maximum at jet level (left exit region)

Shear vorticity

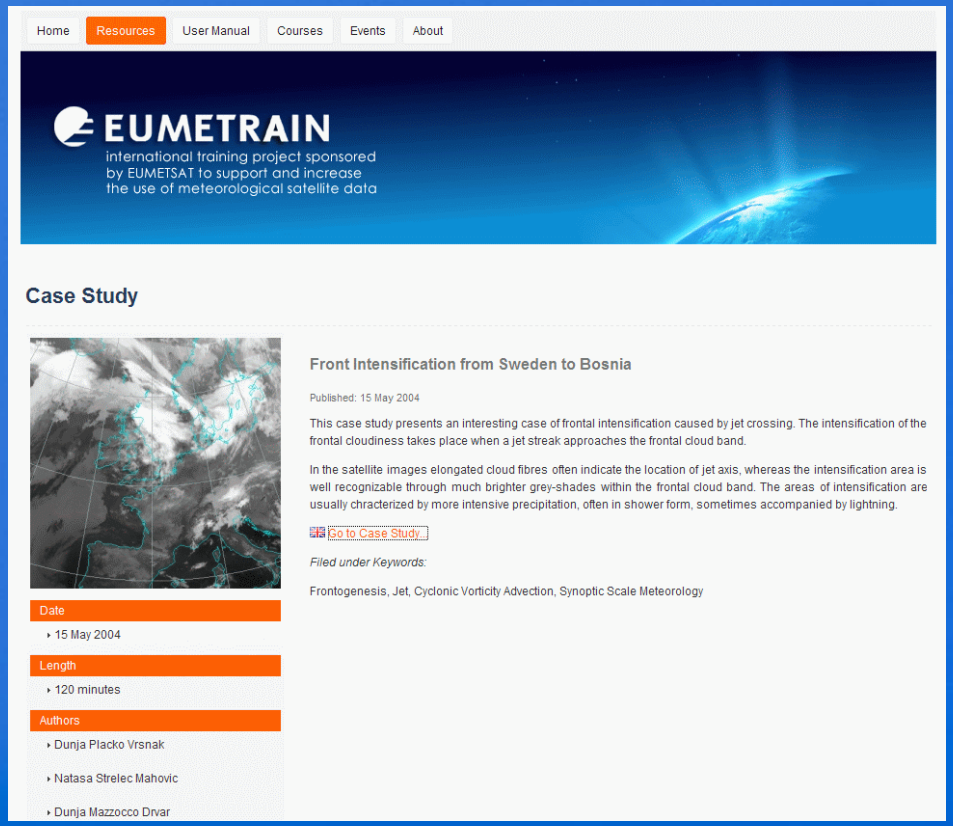




FI by Jet

For further study:

http://www.eumetrain.org/resources/front_intensification.html

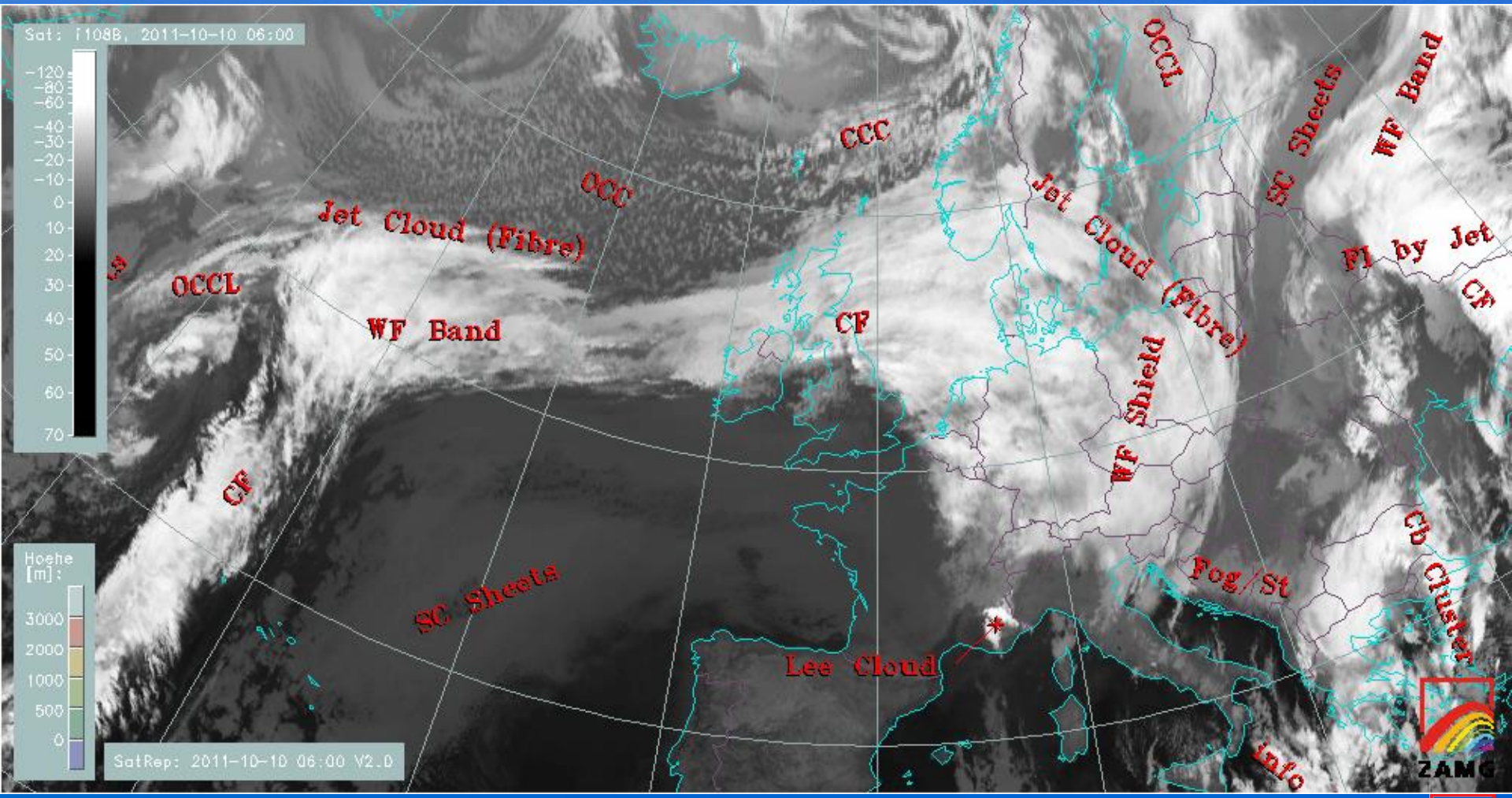


Front Decay

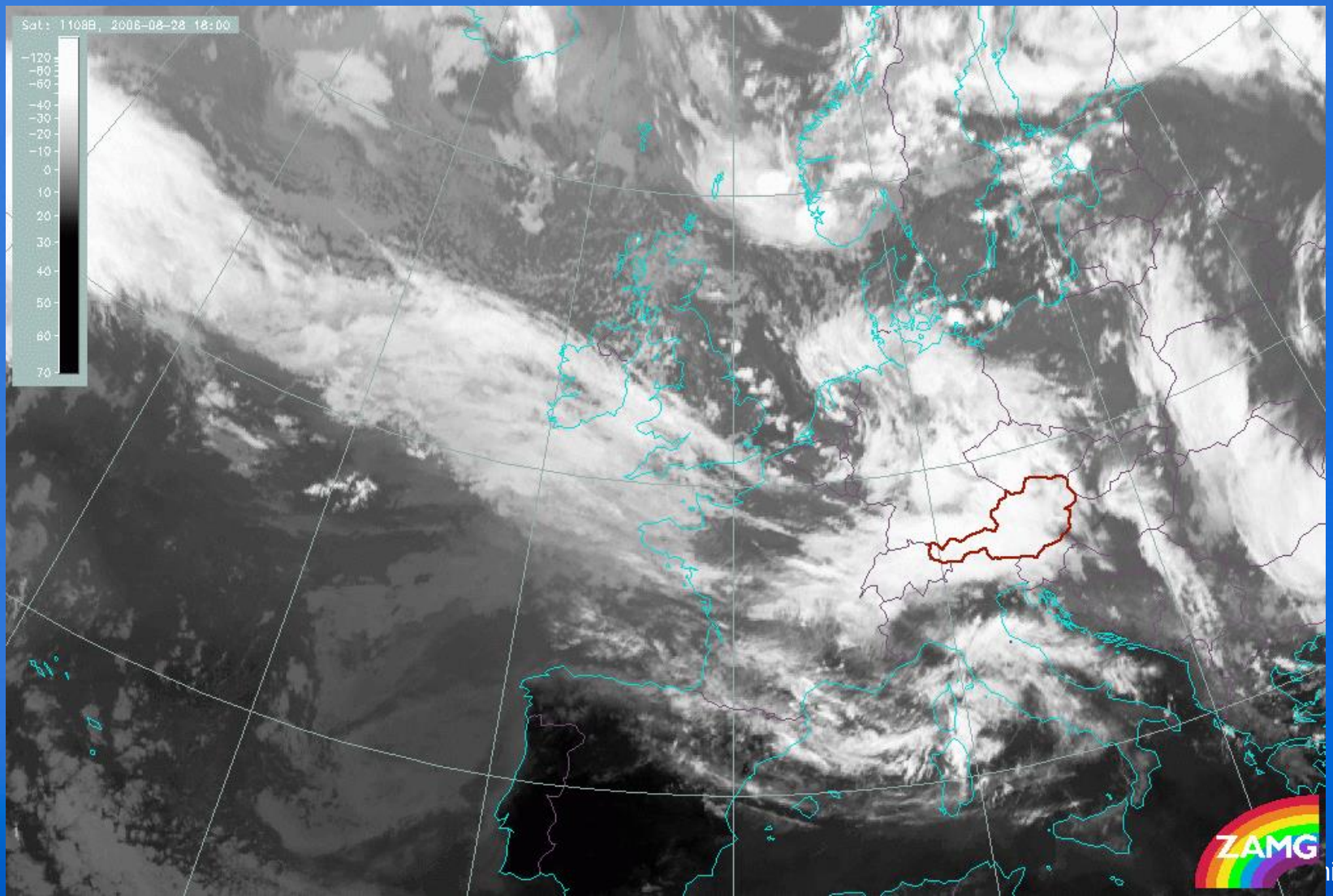
- Appearance in satellite imagery
- Weather events
- Meteorological physical background

Key Parameters

Front Decay - Appearance in satellite imagery



Front Decay - Appearance in satellite imagery



Front Decay - Weather Events

Parameter	Description

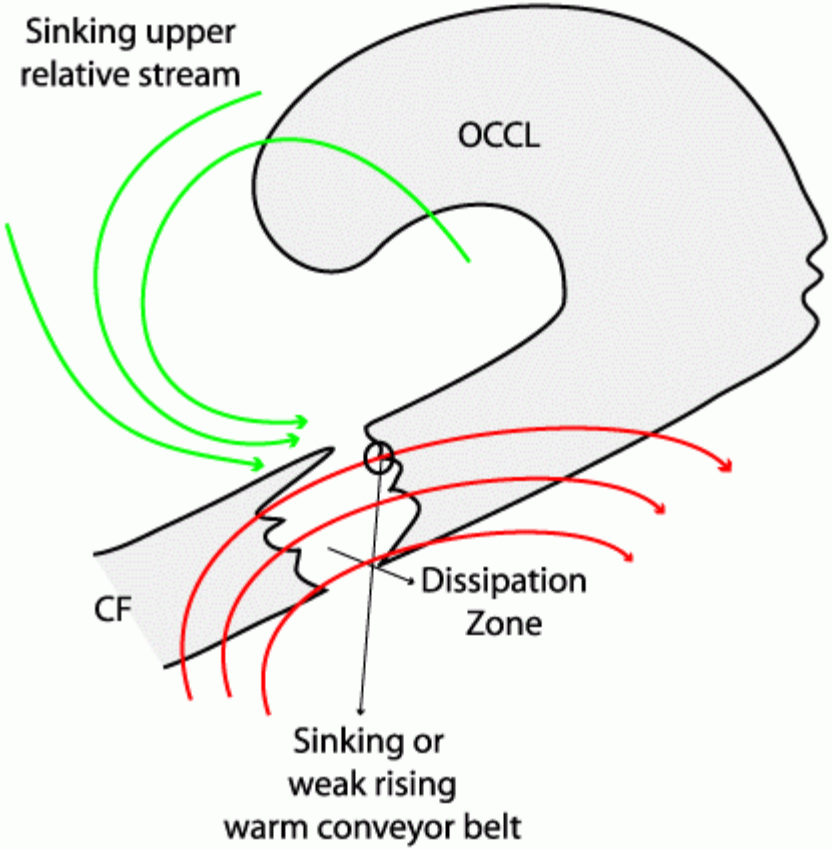
Precipitation	• The initial frontal system: precipitation in surface reports.
	• Front decay:
	  ◦ Precipitation stops over the zone of cloud dissipation in connection with growth of cloud gap
	  ◦ development of dry area
	• Upstream or downstream of the dissipation zone the front is still very active (possible areas of front intensification)

Temperature	No connection to Front Decay
Wind	No connection to Front Decay

Cloud	• The initial frontal system: multi layered cloudiness
	  ◦ Front decay: dissipation of high and middle cloudiness;
	  ◦ Dissipation of low cloudiness only at mature stage
	  ◦ When cloud gap closes up again, no significant weather events can be seen

Other relevant information	

Front Decay – Meteorological Physical Background



Front Decay is best explained relative streams:

Frontal cloud band dissolution from above by the dry intrusion.

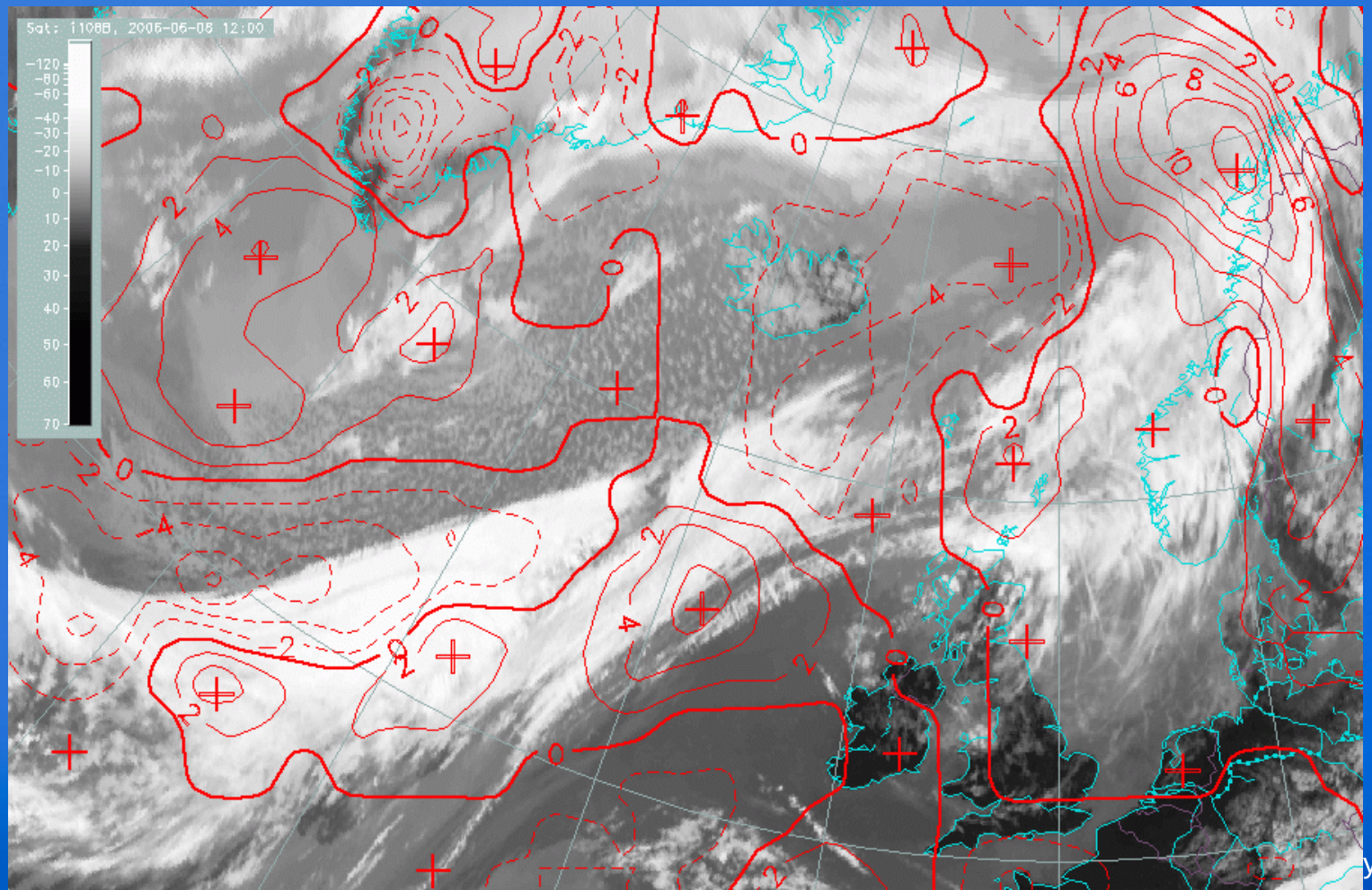
Weak or even sinking warm conveyor belt.

No embedded convective cells, stable stratification or only weak instability.

Cold air advection within the frontal cloud band is often observed.

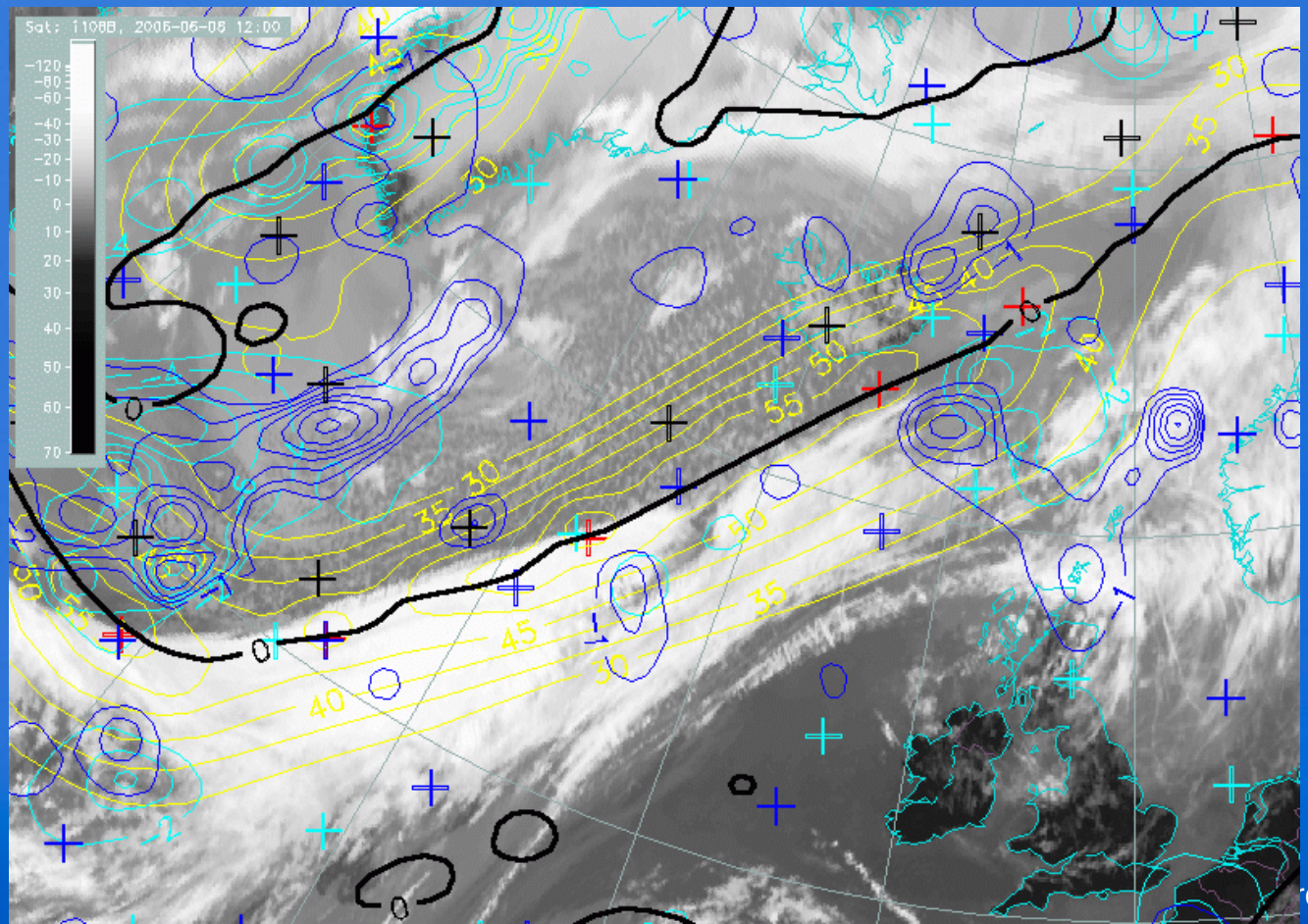
Front Decay – Key Parameters

Cold air advection mainly in higher levels, often down to 700 hPa.



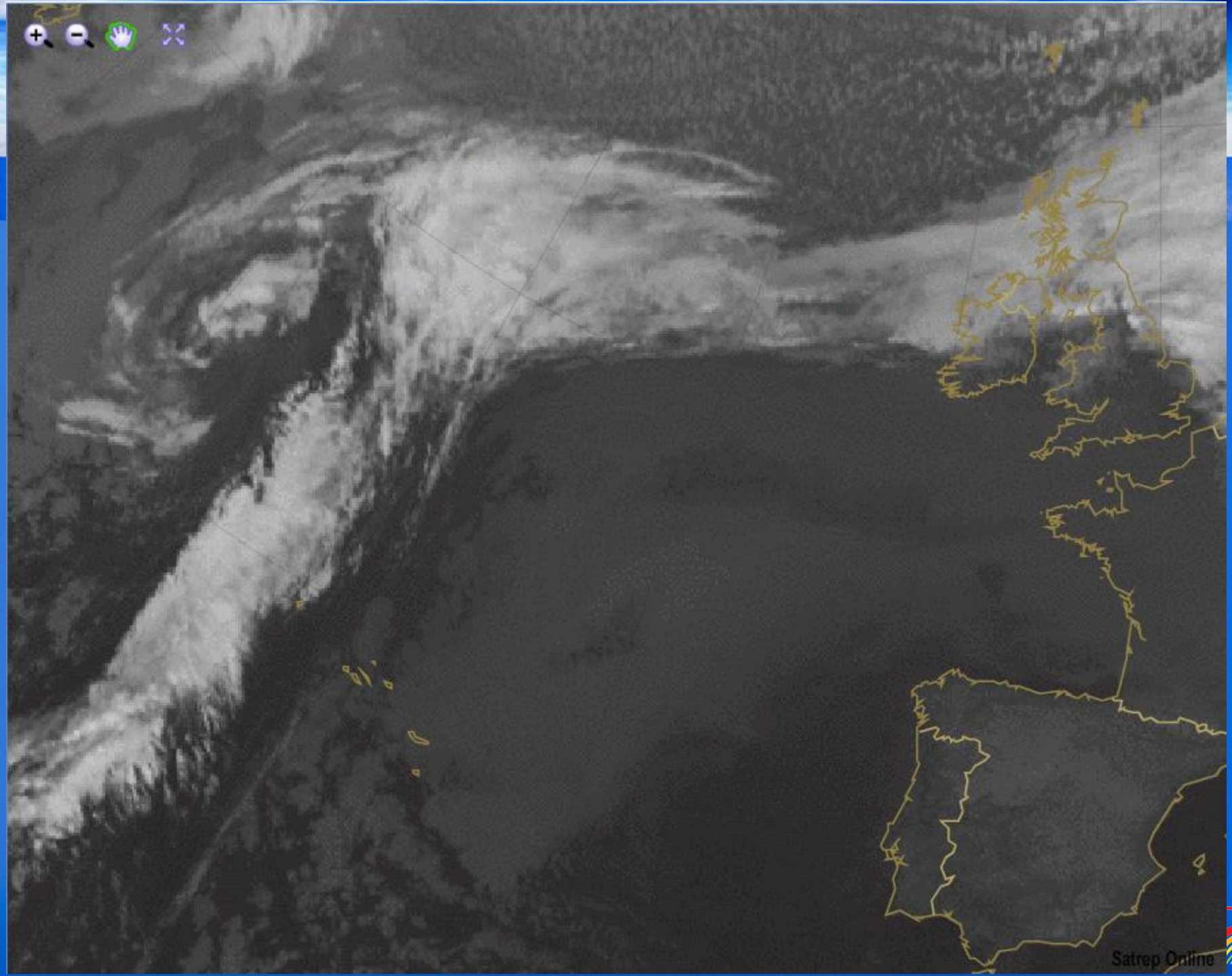
Front Decay – Key Parameters

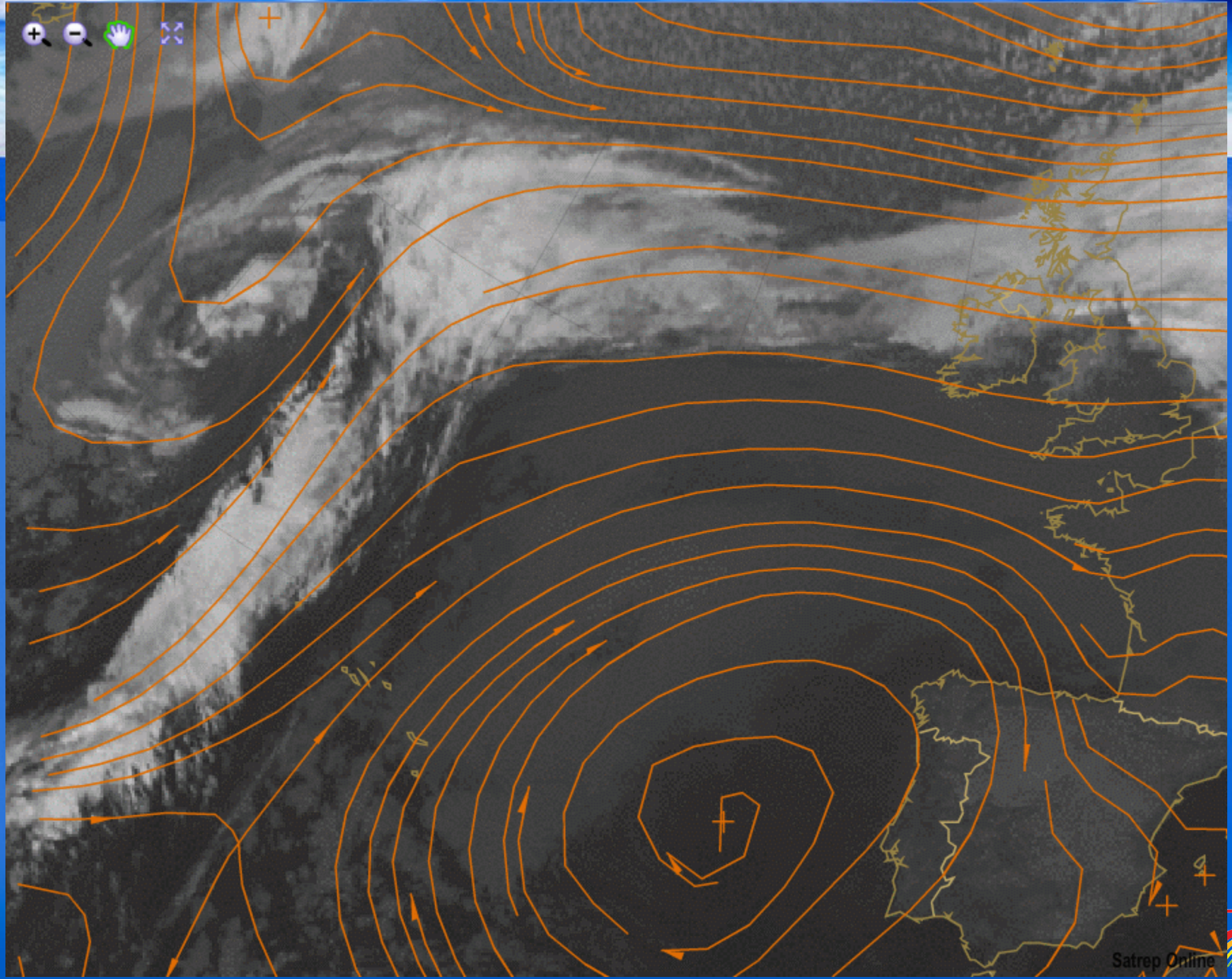
Negative vorticity advection may play a role, but is seldom observed in the model fields (right exit region).

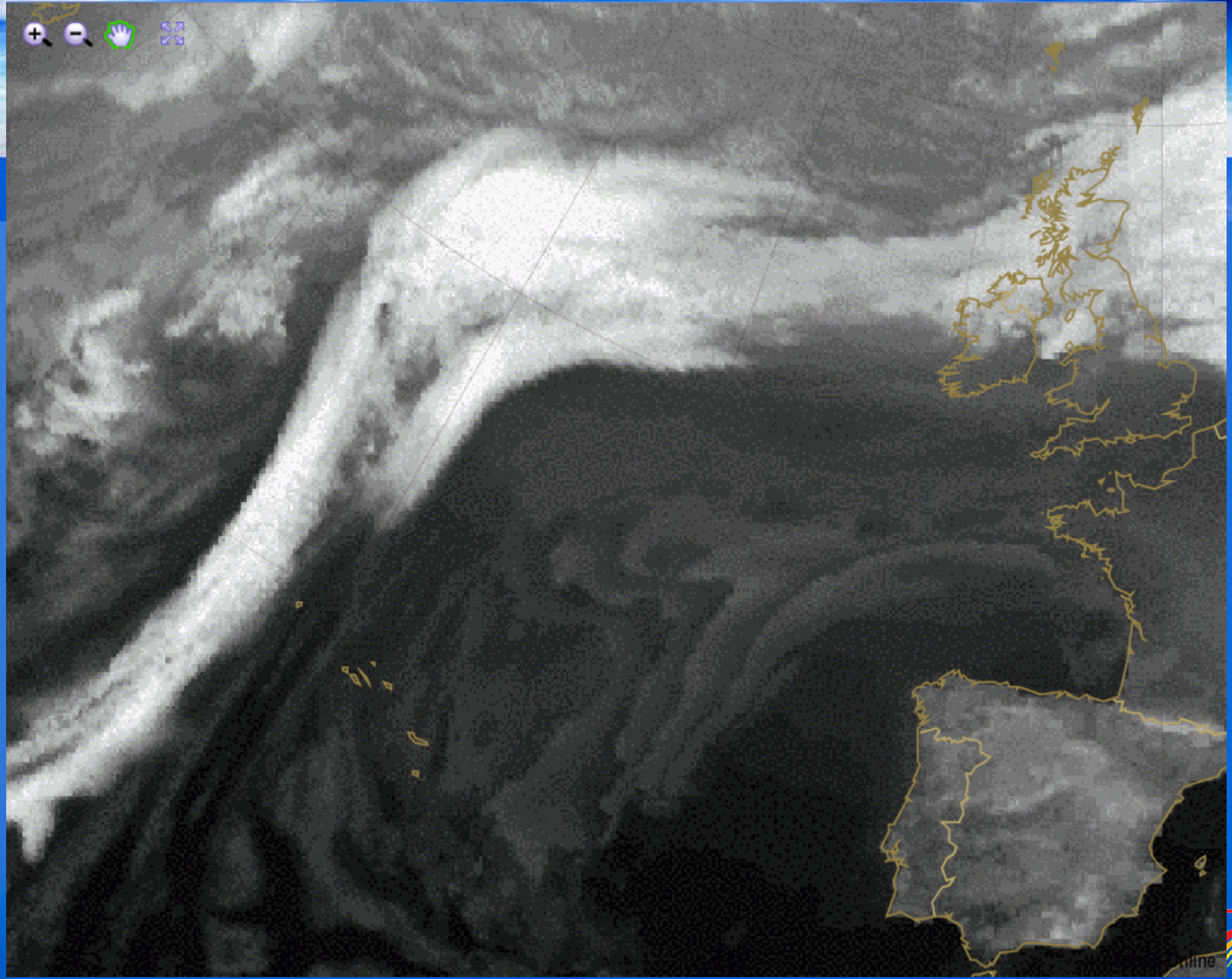


Front Decay - Summary

- Front Decay is often located in the CF shortly upstream of the occlusion point.
- Easy to detect in the IR image.
- Upper level phenomenon, low level frontal characteristics remain unaffected, unless the dry intrusion is very strong and protruding into low levels (rare).
- Front Decay must not be mistaken for a low cold front, especially in frontal zones where warm and cold front are alternating.


Satrep Online

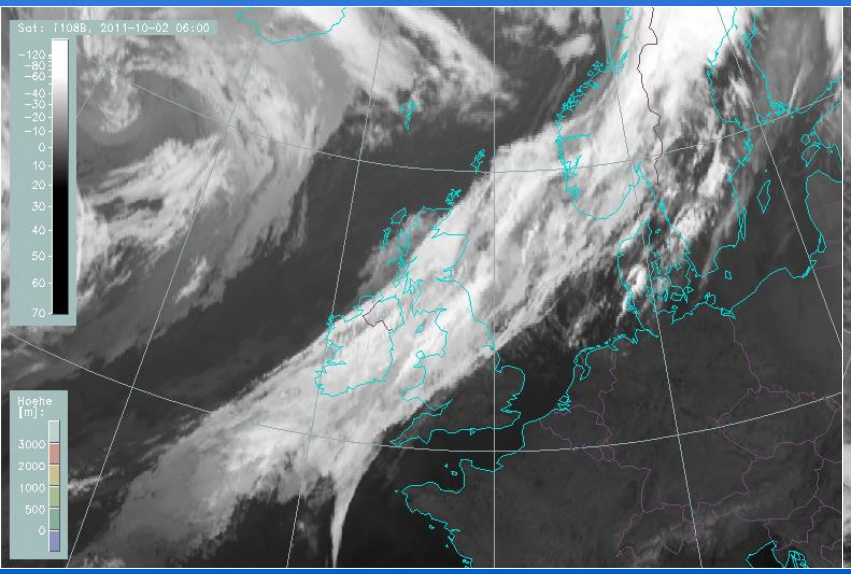

Satrep Online

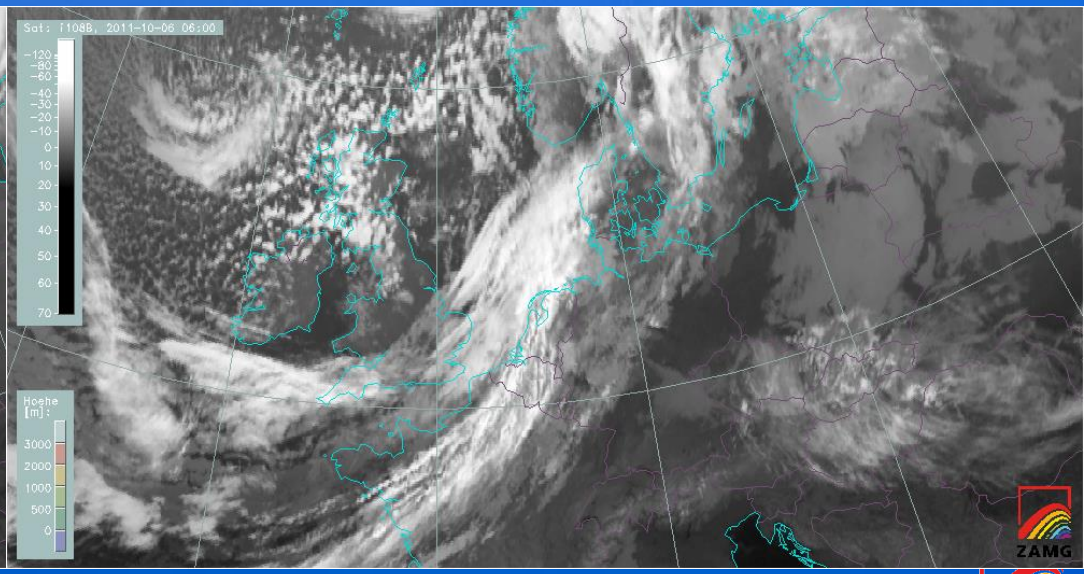


Frontal Waves and Upper Waves

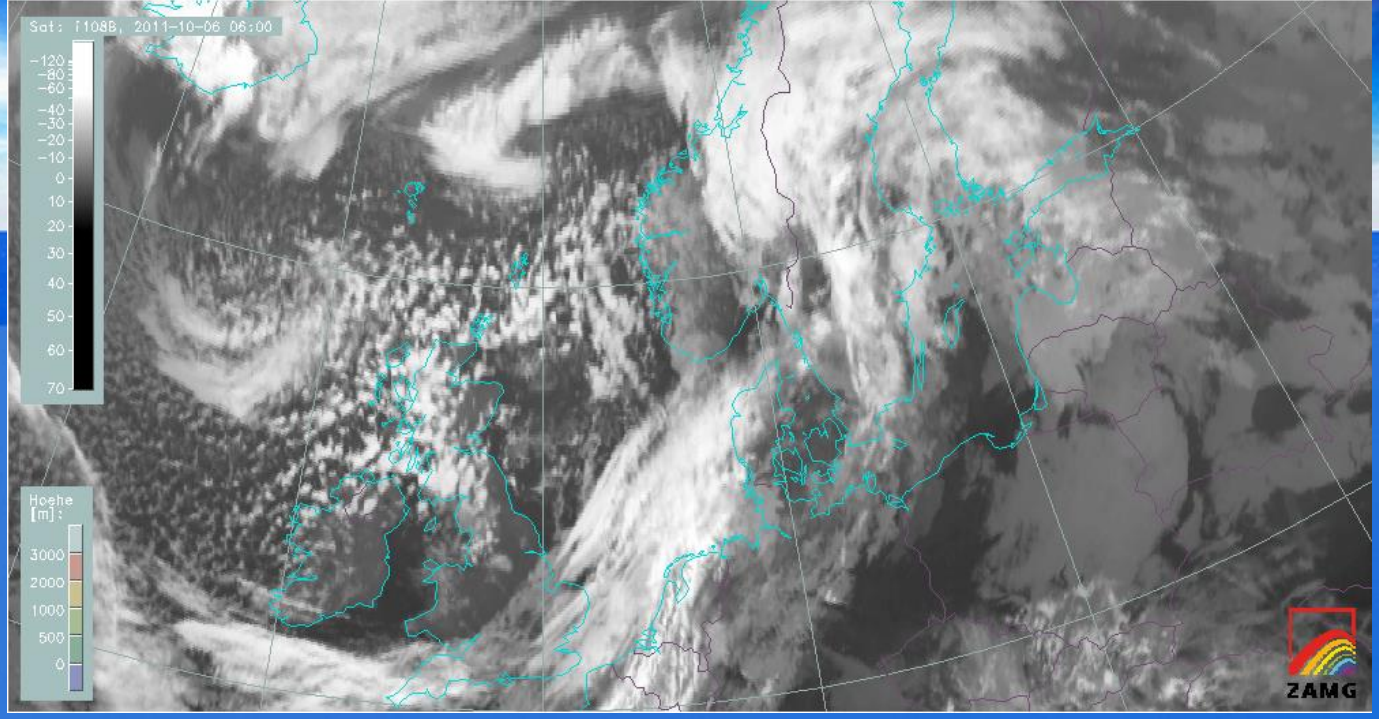
Upper waves and **frontal waves** in their early stage are very similar from the satellite point of view. Nevertheless there are some fundamental differences concerning their life cycle and their key parameters from the model fields.

To better see these differences, they will be treated together.

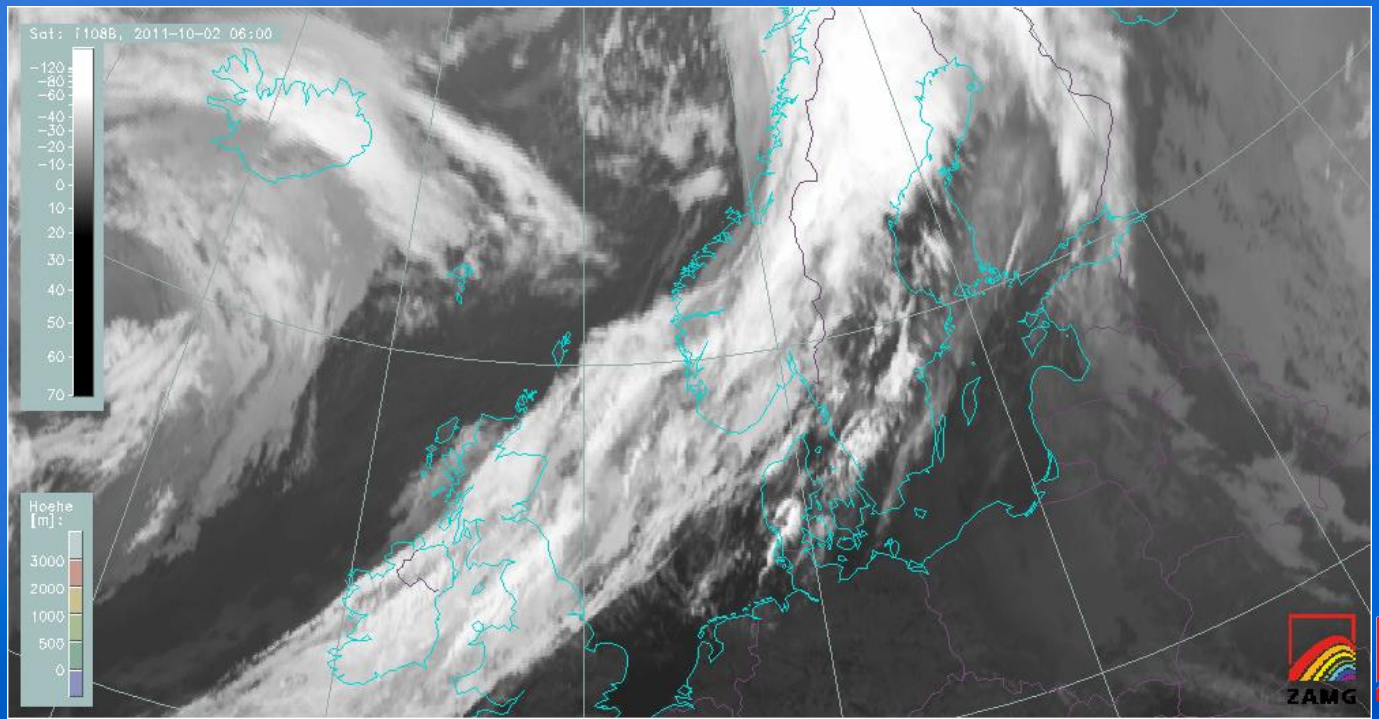




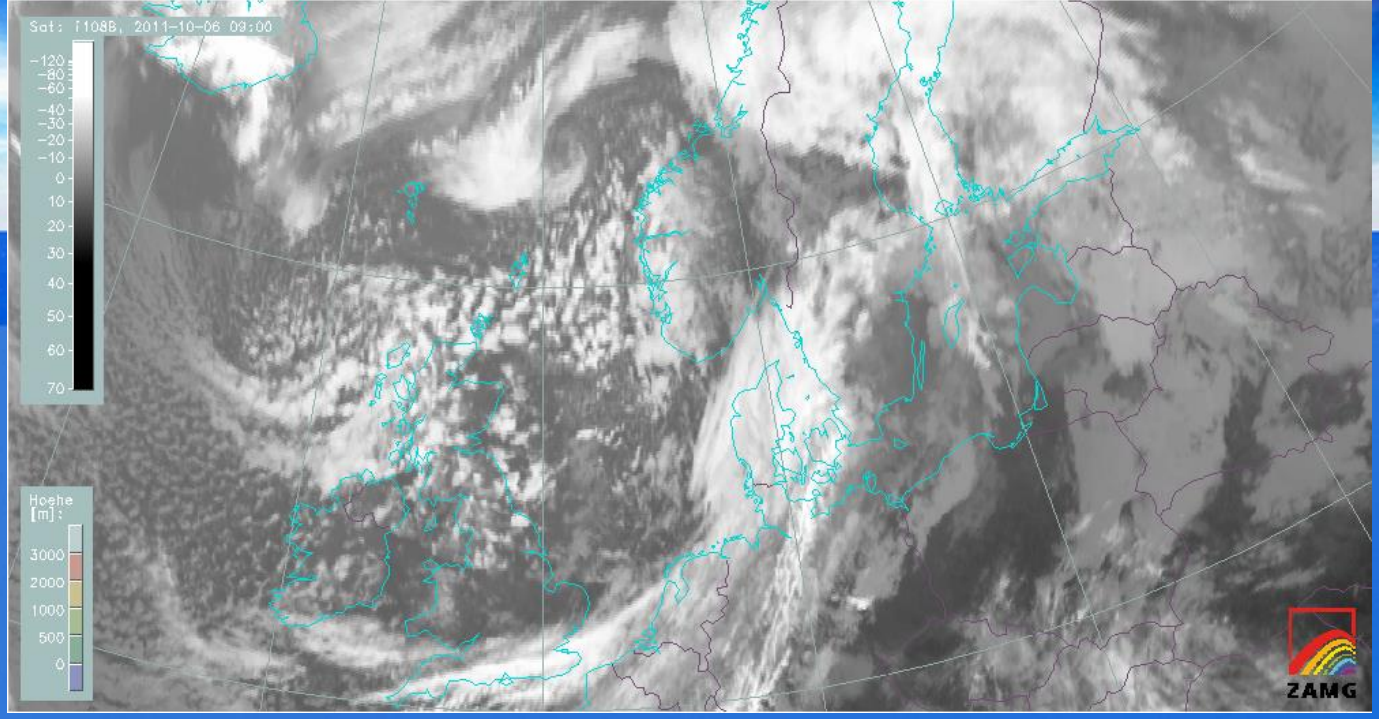
upper wave



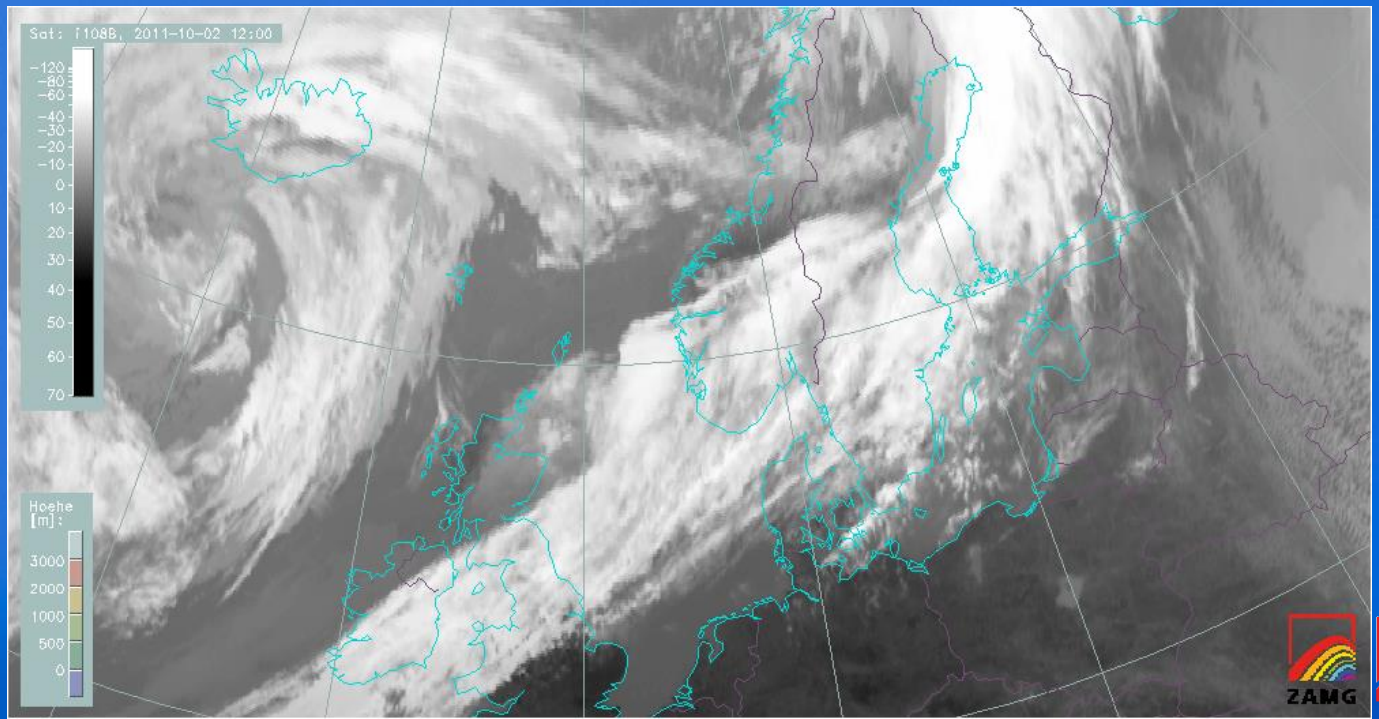
frontal wave



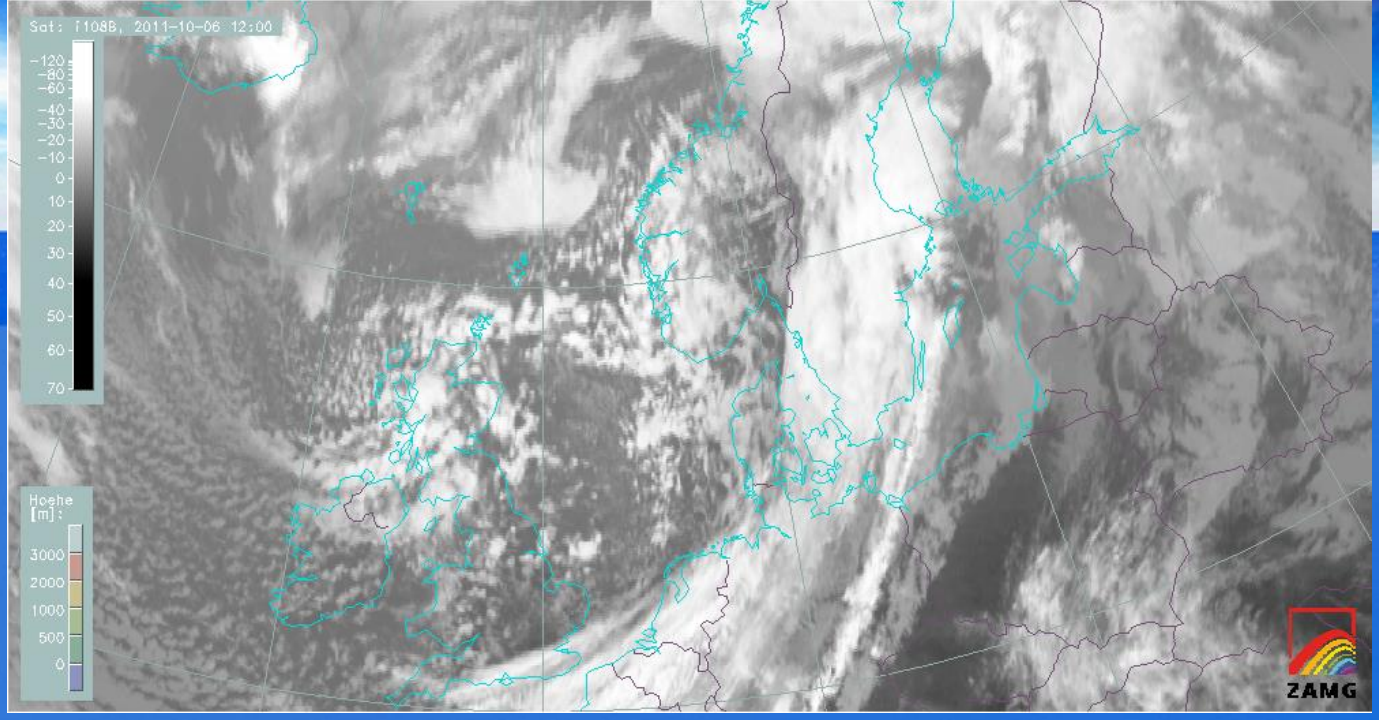
upper wave



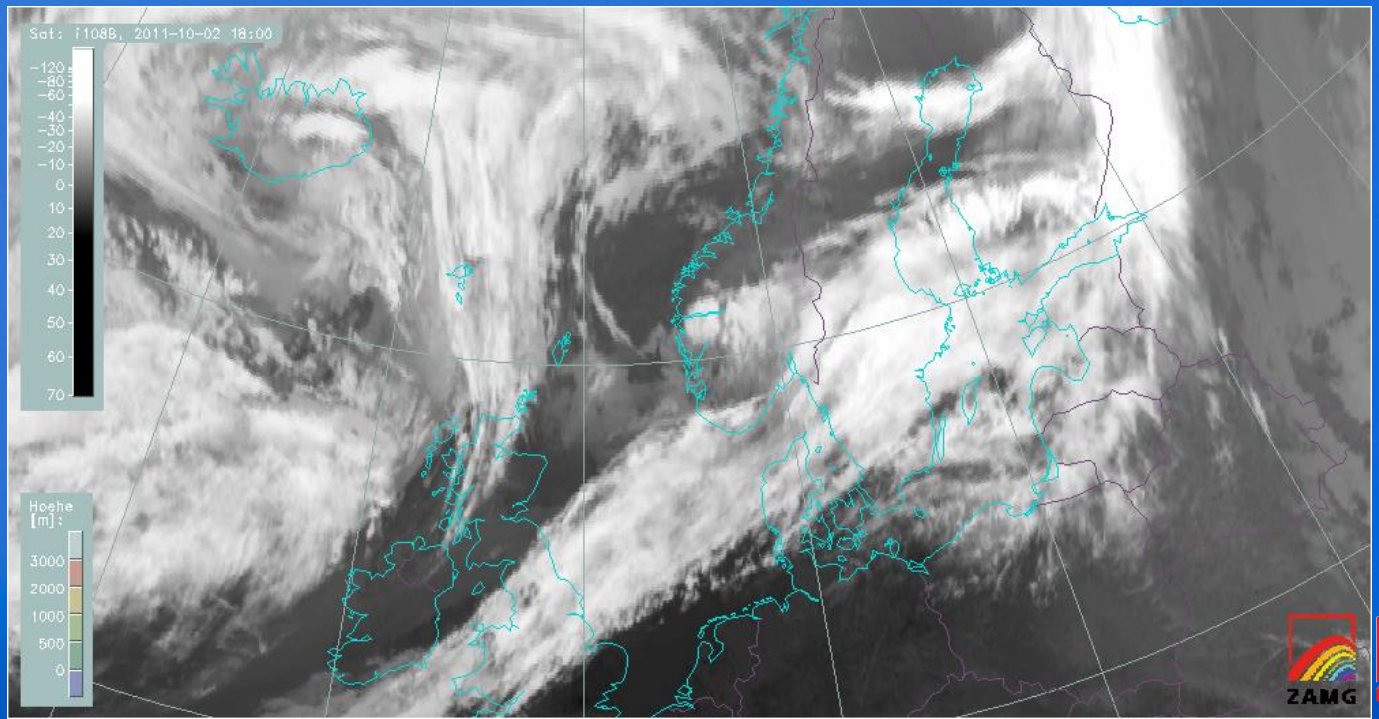
frontal wave



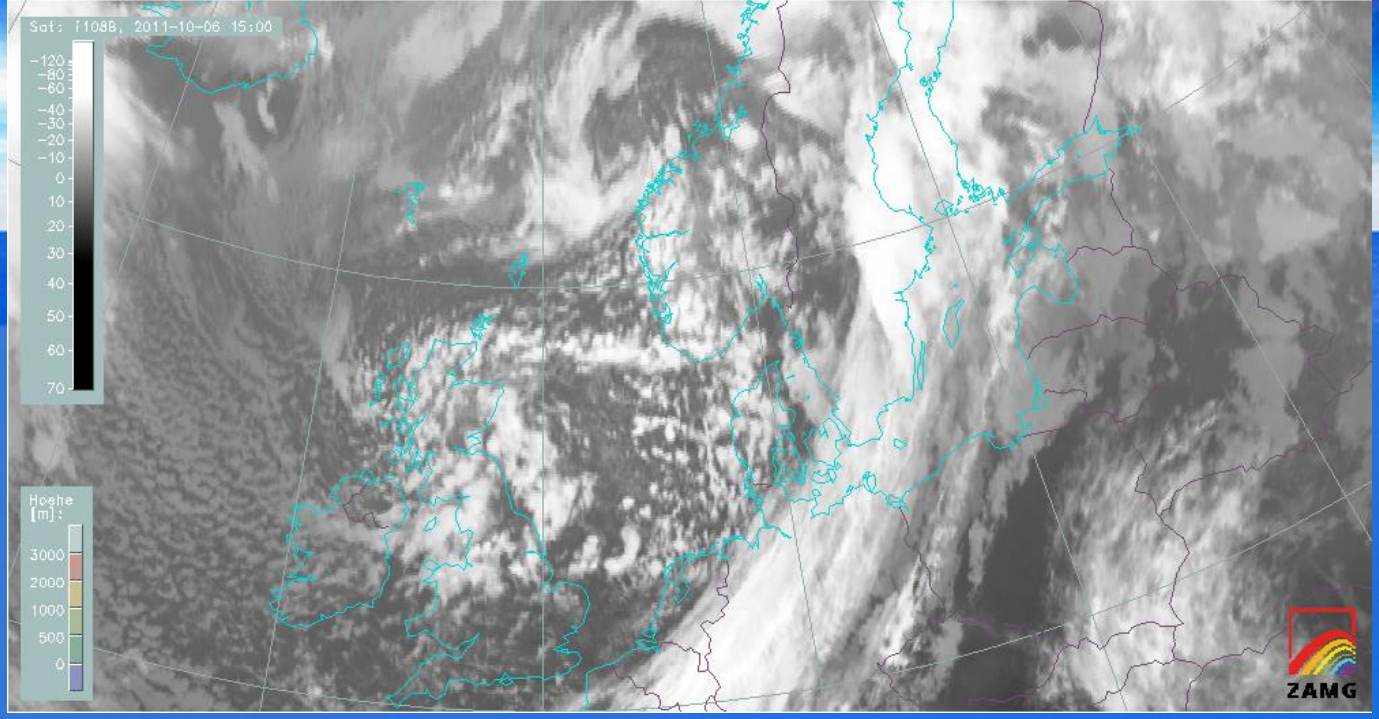
upper wave



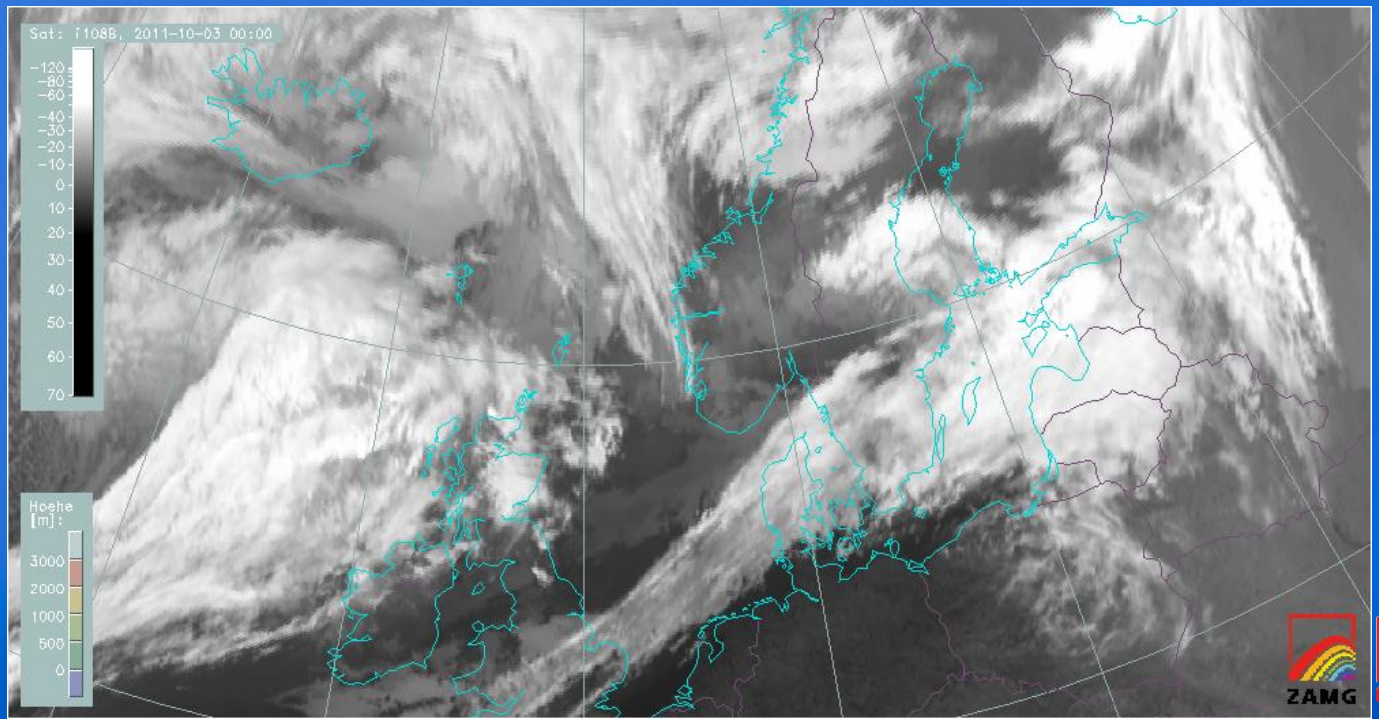
frontal wave



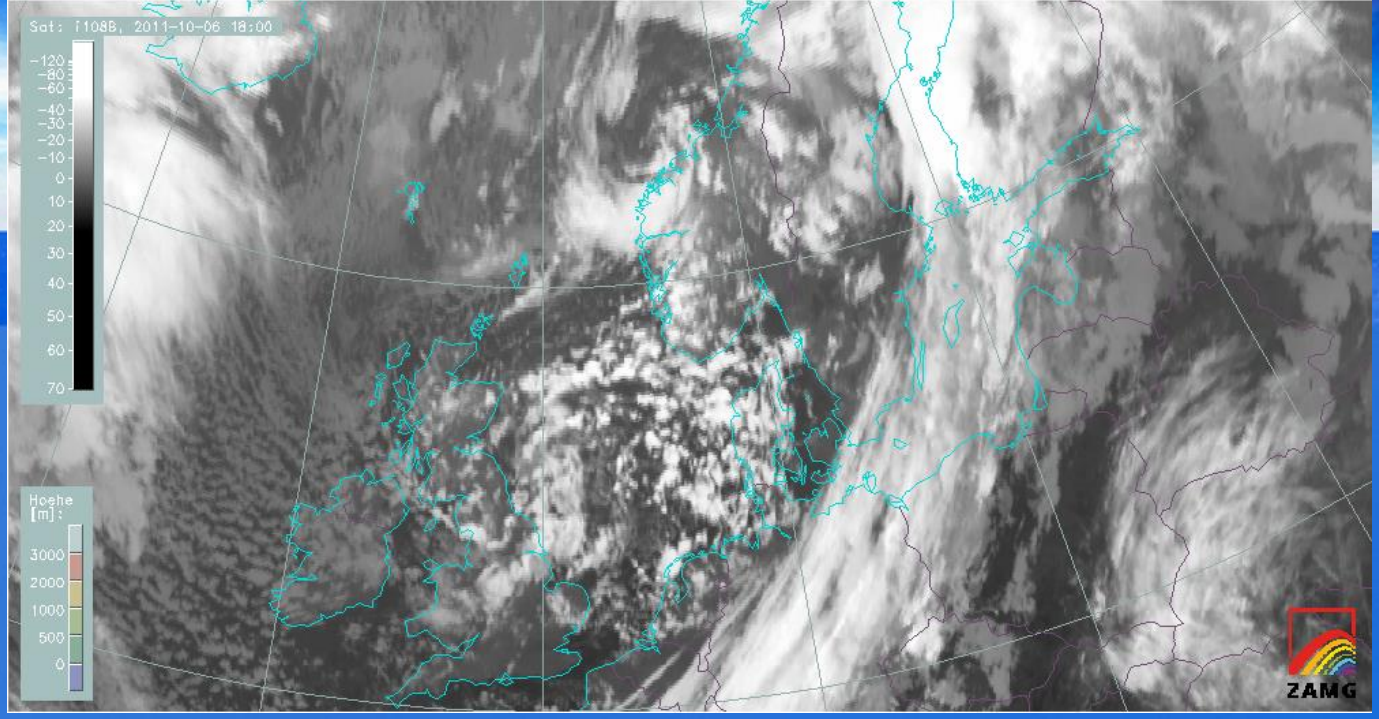
upper wave



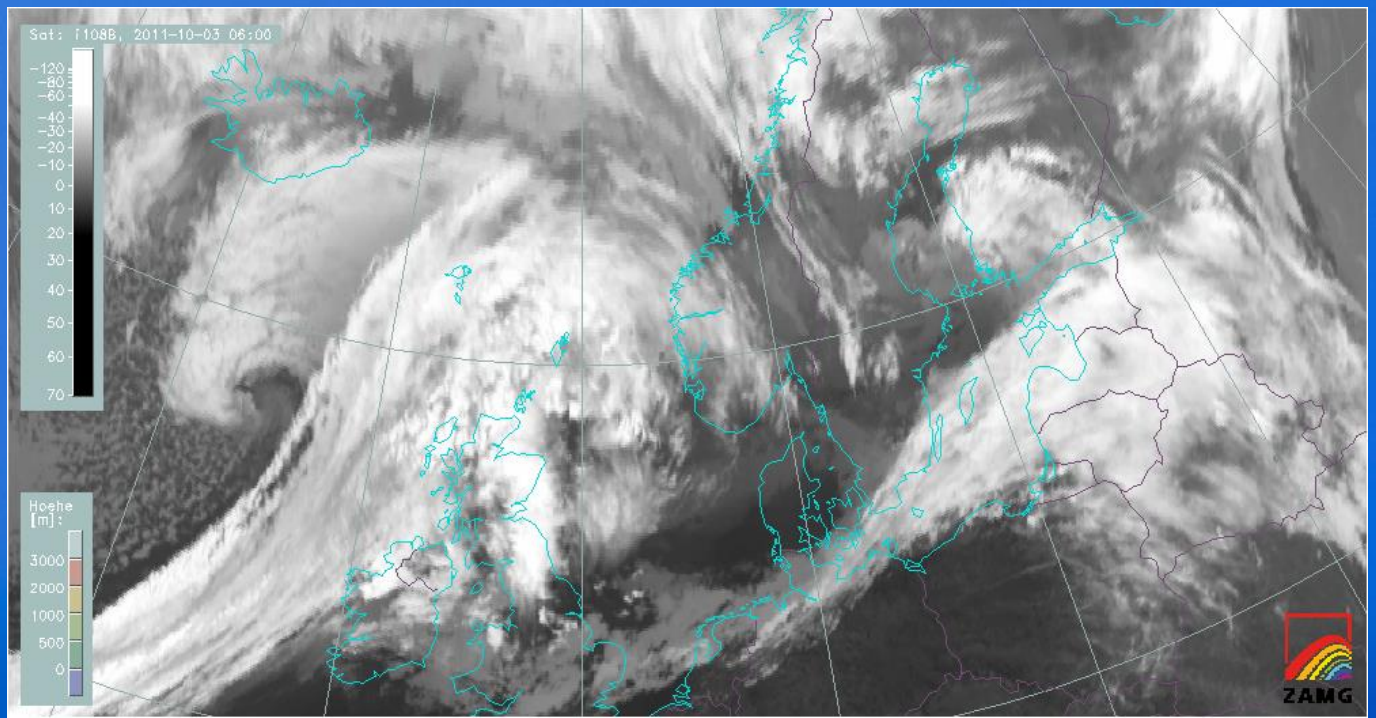
frontal wave



upper wave



frontal wave



Frontal Waves and Upper Waves: life cycle

Most fundamental differences in the **life cycle**:

- The upper wave is tightly connected to a jet streak. It shows no evolution and moves along the CF rear side towards the occlusion point.

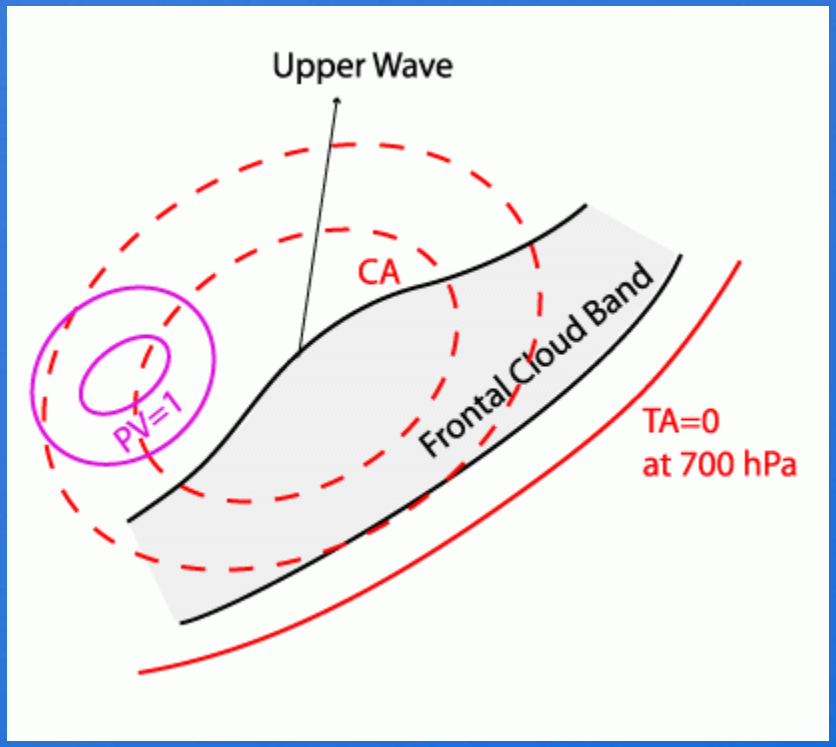
- The frontal wave often develops into a synoptic scale system, it is the initial stage of a cyclogenesis.

Meteorological Physical Background

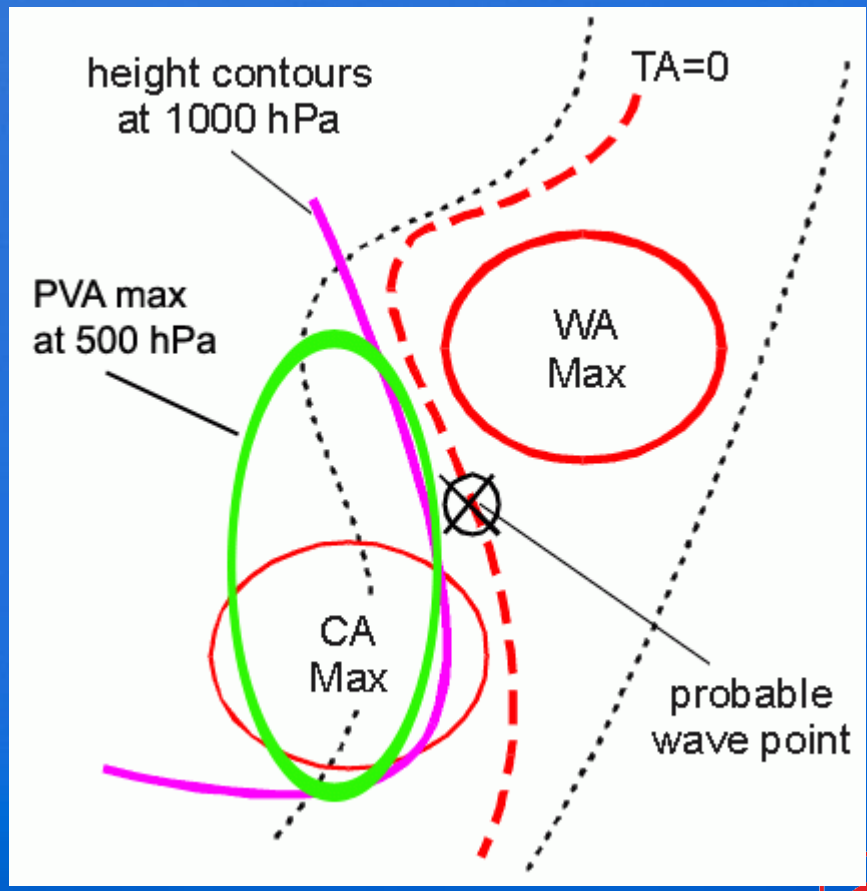
upper wave	frontal wave
Upper air feature driven by a jet streak	Mid to low level feature driven by a developing surface low
The CF is under cold air advection	A weak WA – CA dipole is developing
Shear vorticity prevails	Curvature vorticity is equally important
PVA maximum from trough along the rear side of the CF	Distinct PVA maximum from developing low

Key Parameters: Temperature Advection

upper wave

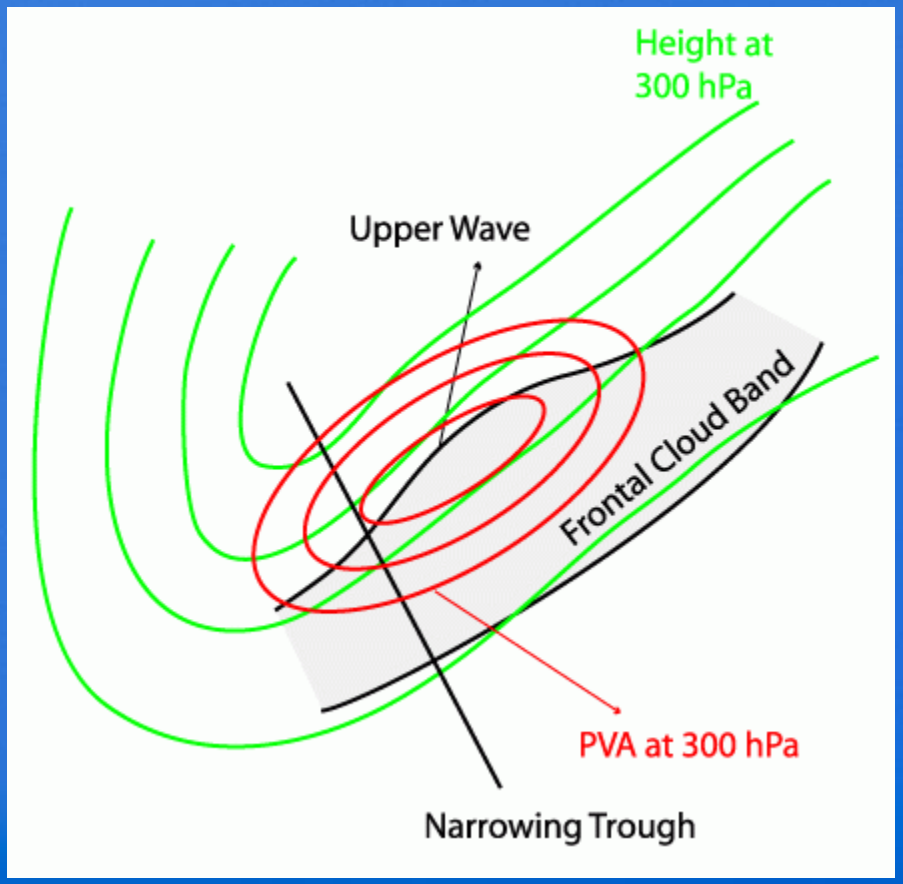


frontal wave

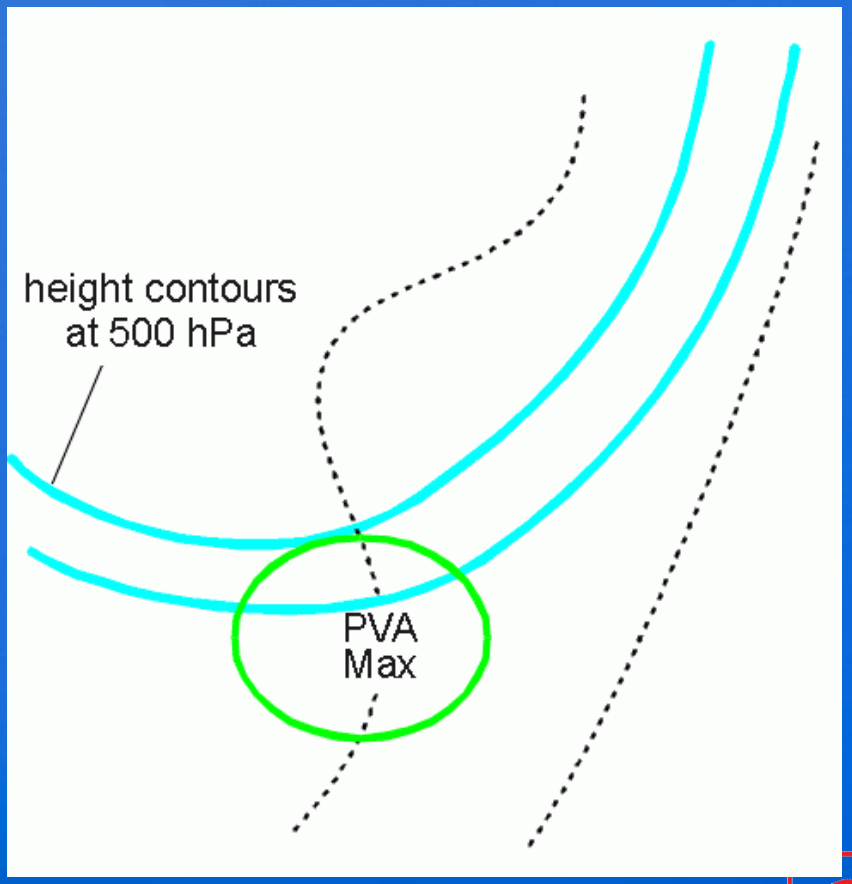


Key Parameters: Vorticity Advection

upper wave

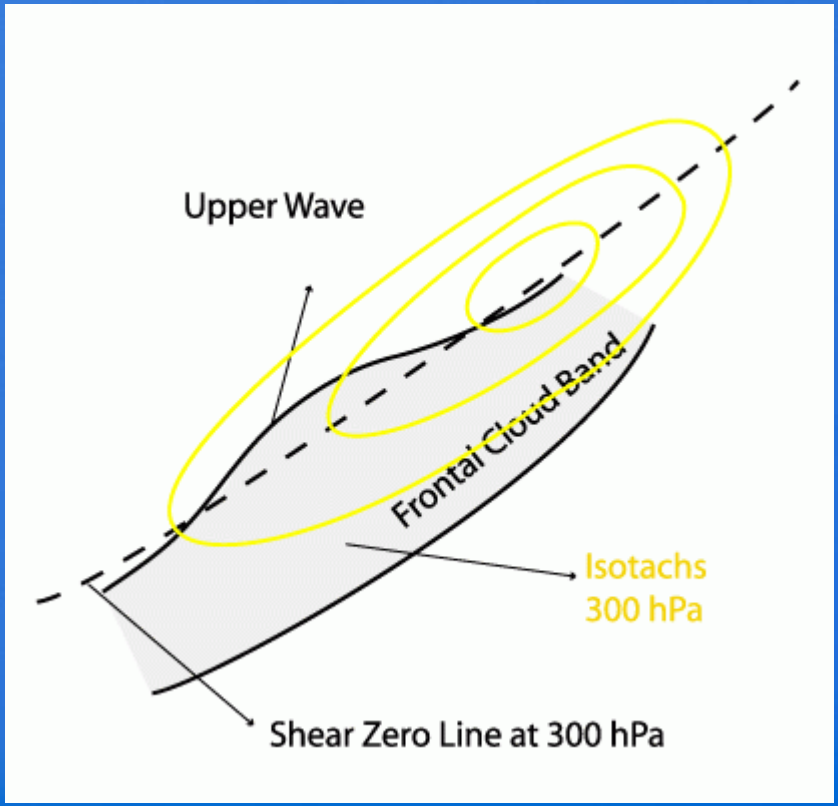


frontal wave

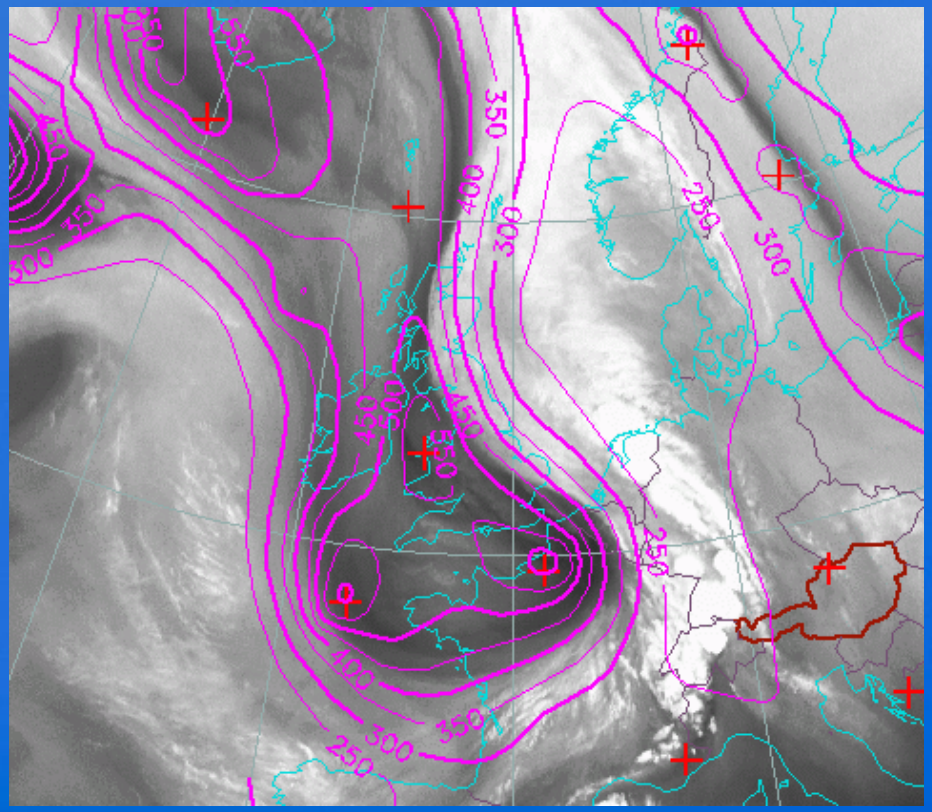


Key Parameters

upper wave

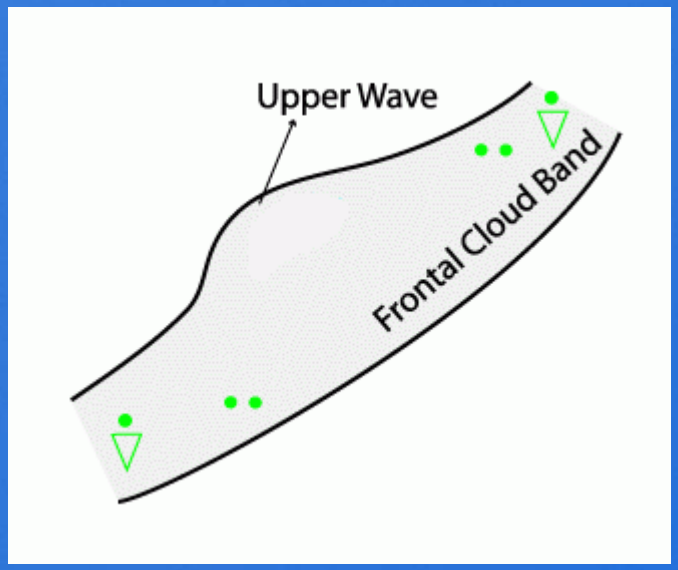


frontal wave (PV)



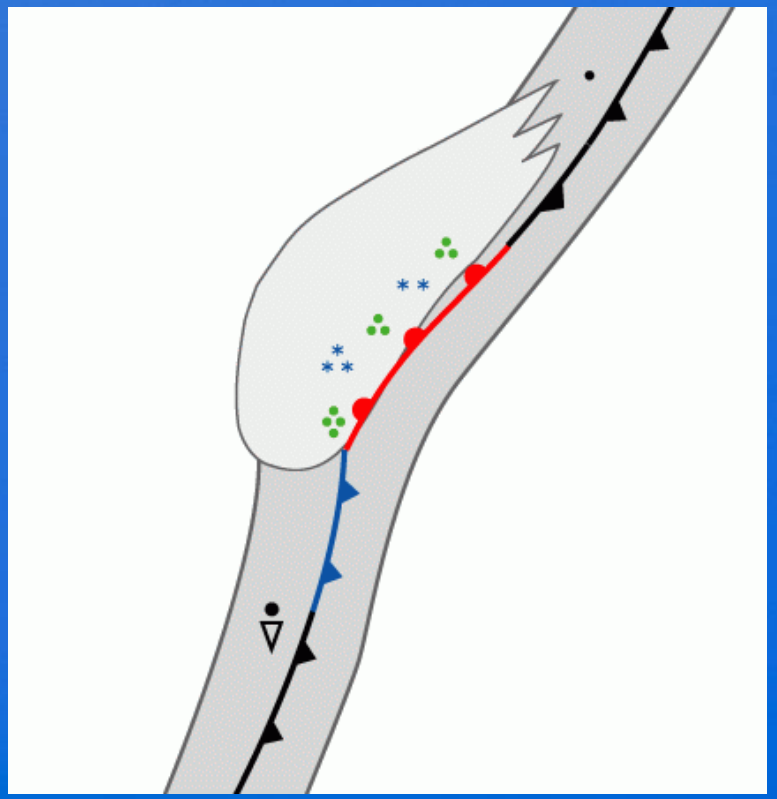
Frontal Waves and Upper Waves: Weather Events

upper wave



No precipitation under the upper wave bulge.

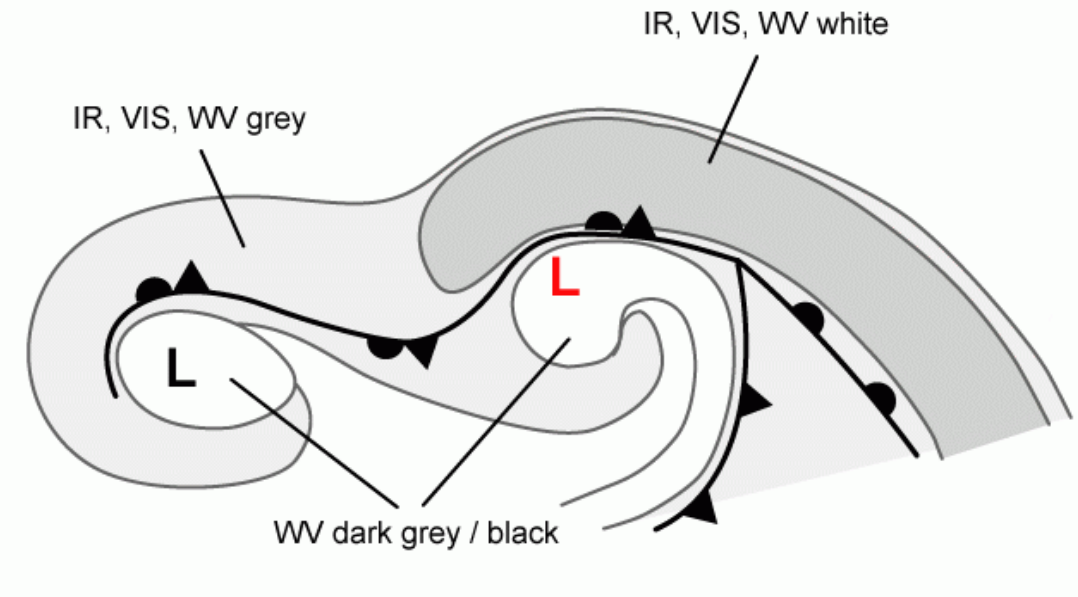
frontal wave

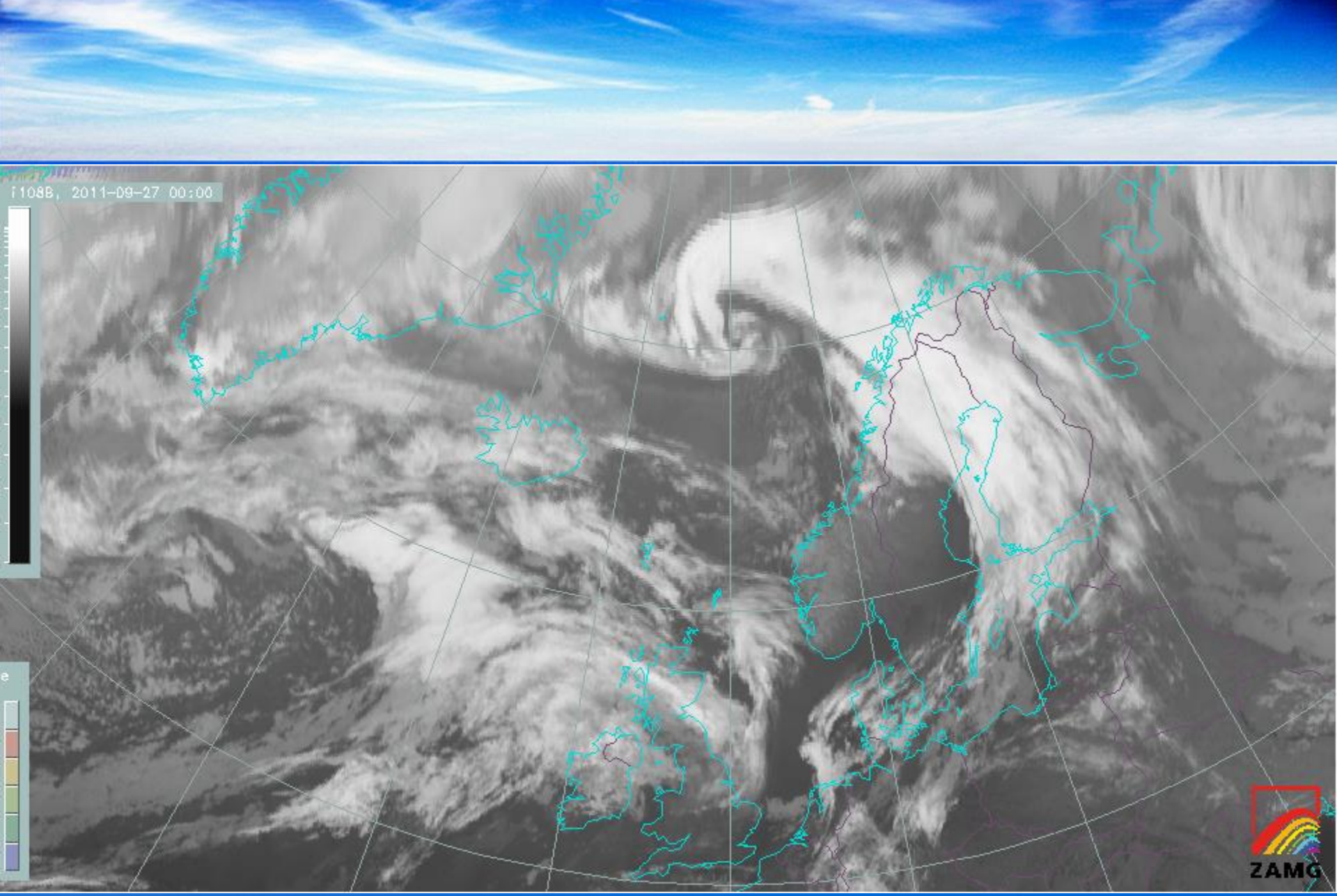


Secondary Low Centers in Occlusions (a.k.a. Occlusion 2nd Low)

Occlusions 2nd low are very often observed in satellite imagery and easy to detect.

They are formed by a developing secondary low between the main low and the occlusion point.

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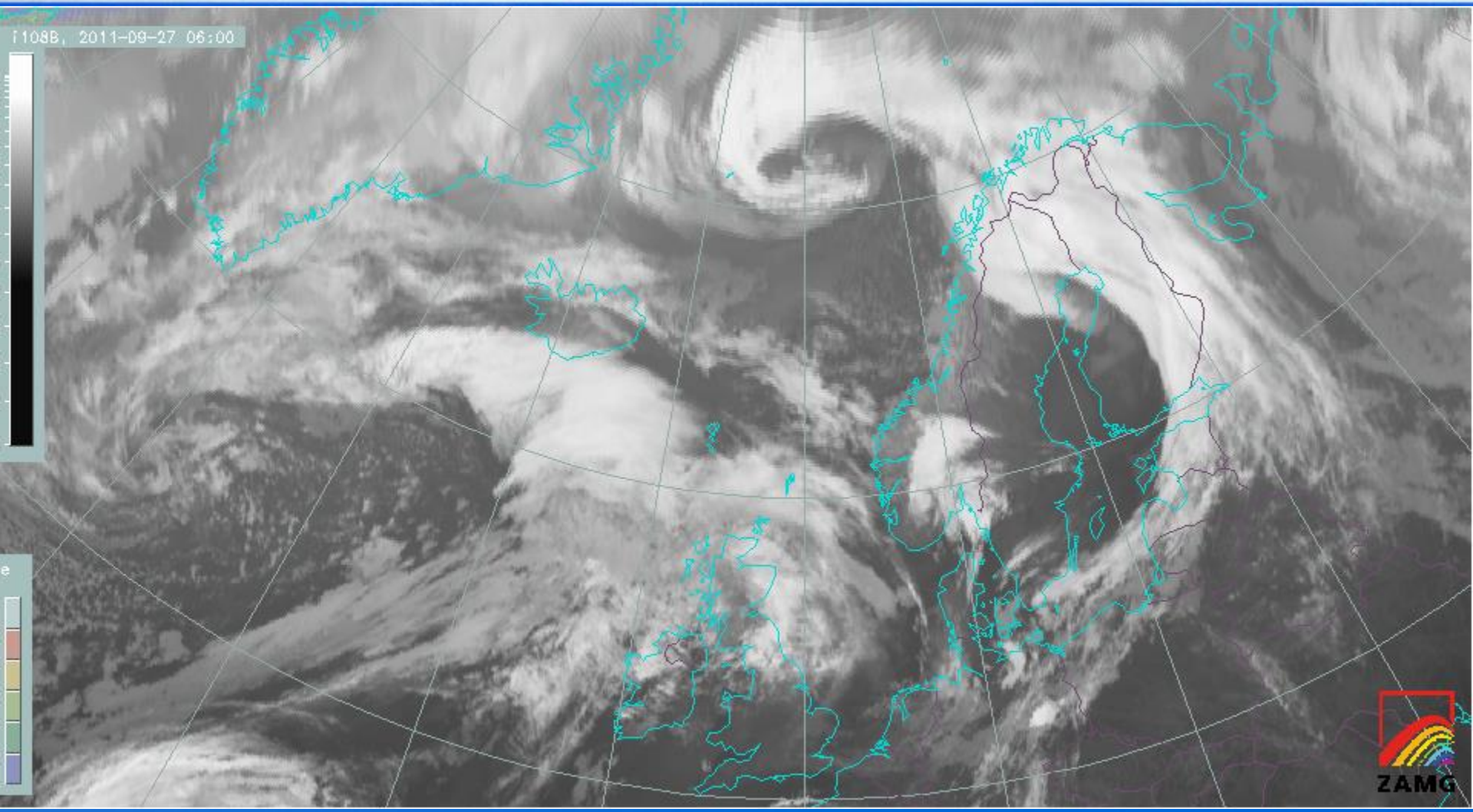
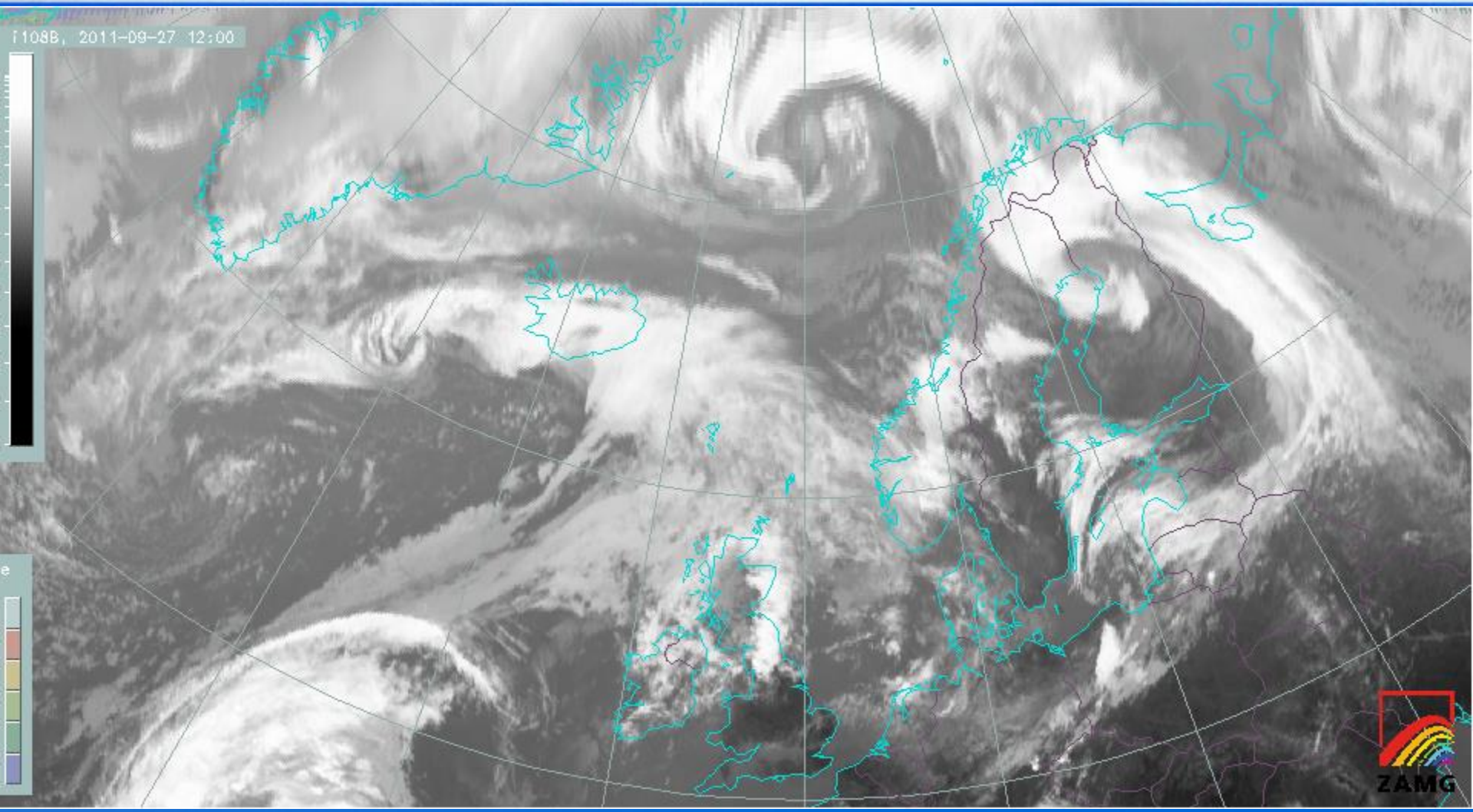
ZAMG


MSG-2, IR108B, 2011-09-27 06:00
ZAMG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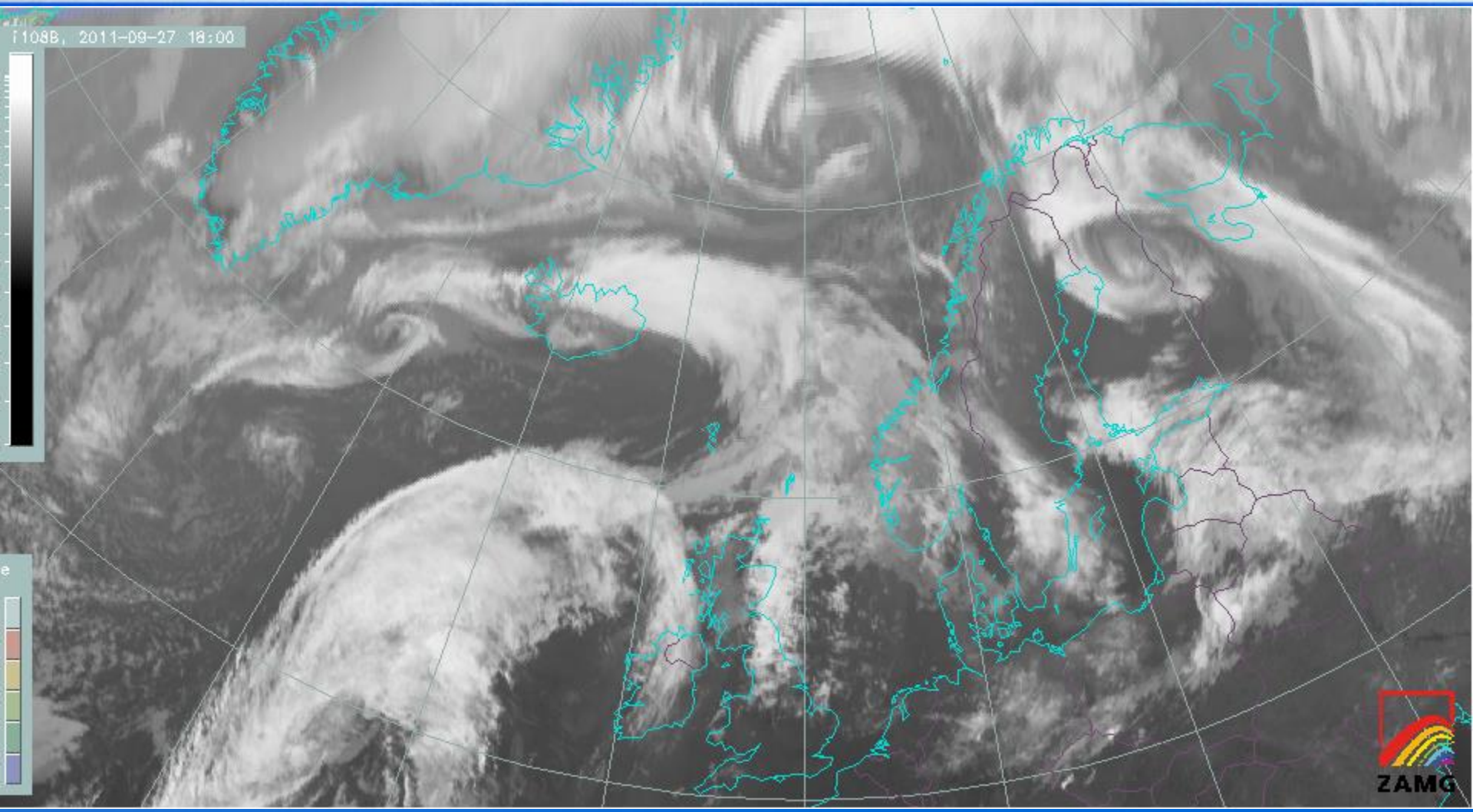
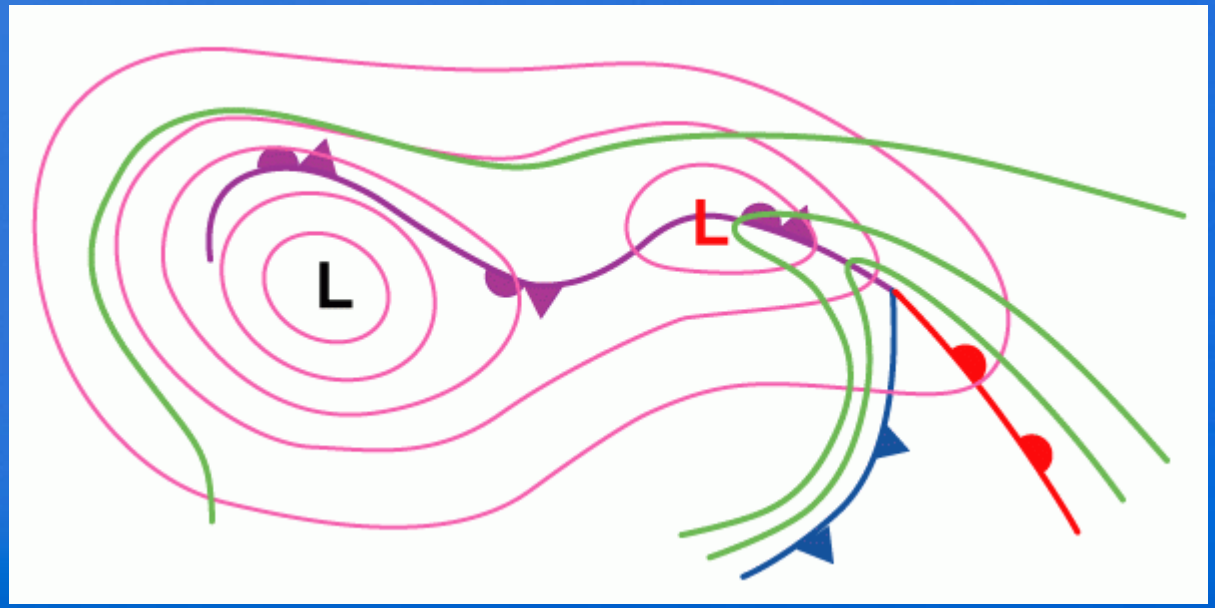
ZAMG


MSG1 IR108B, 2011-09-27 18:00
ZAMG

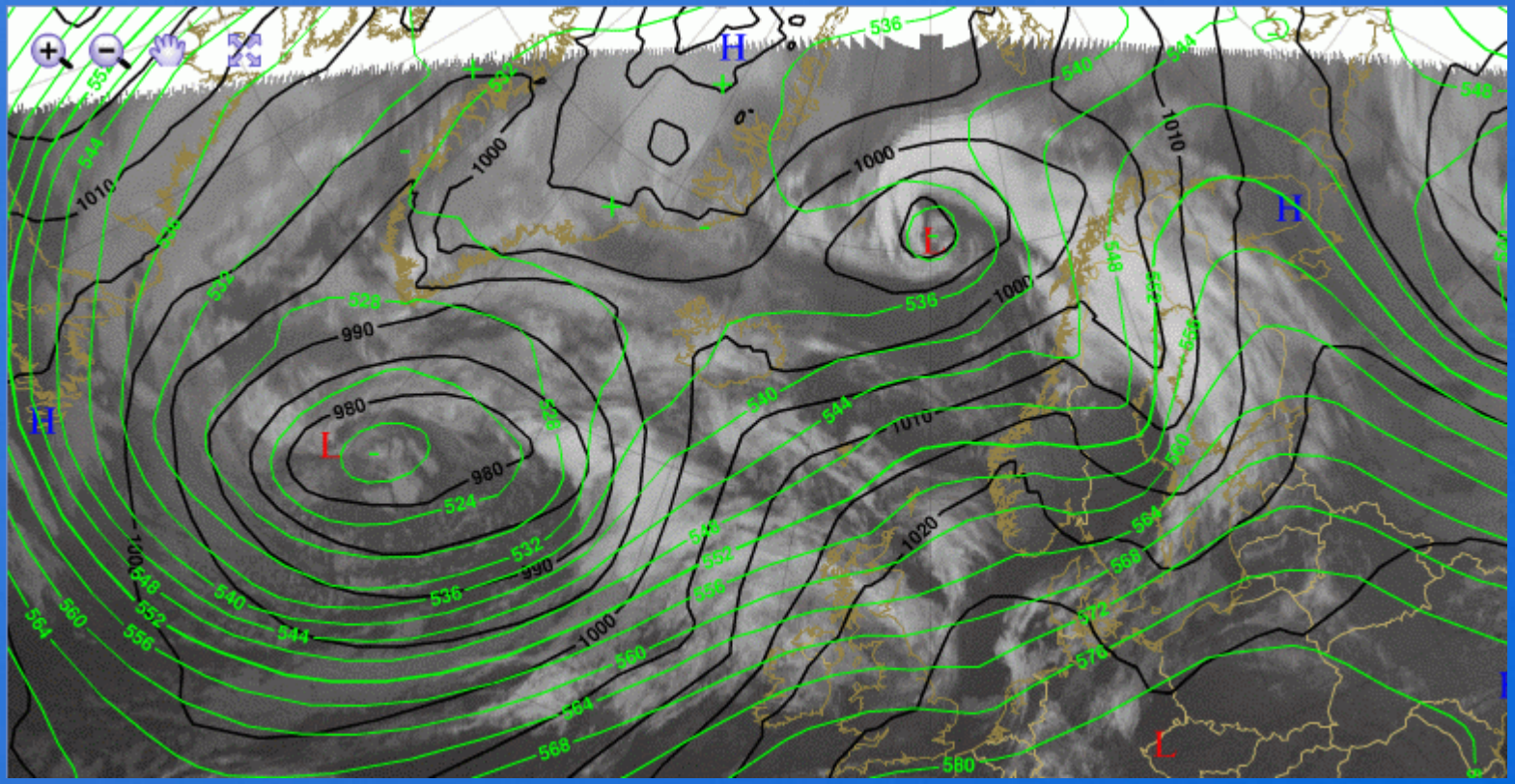
Occlusion 2nd Low: Key Parameters

The new cloud spiral within the occlusion cloud band is formed because of a newly forming low. Therefore the key parameters are closely related to this low:

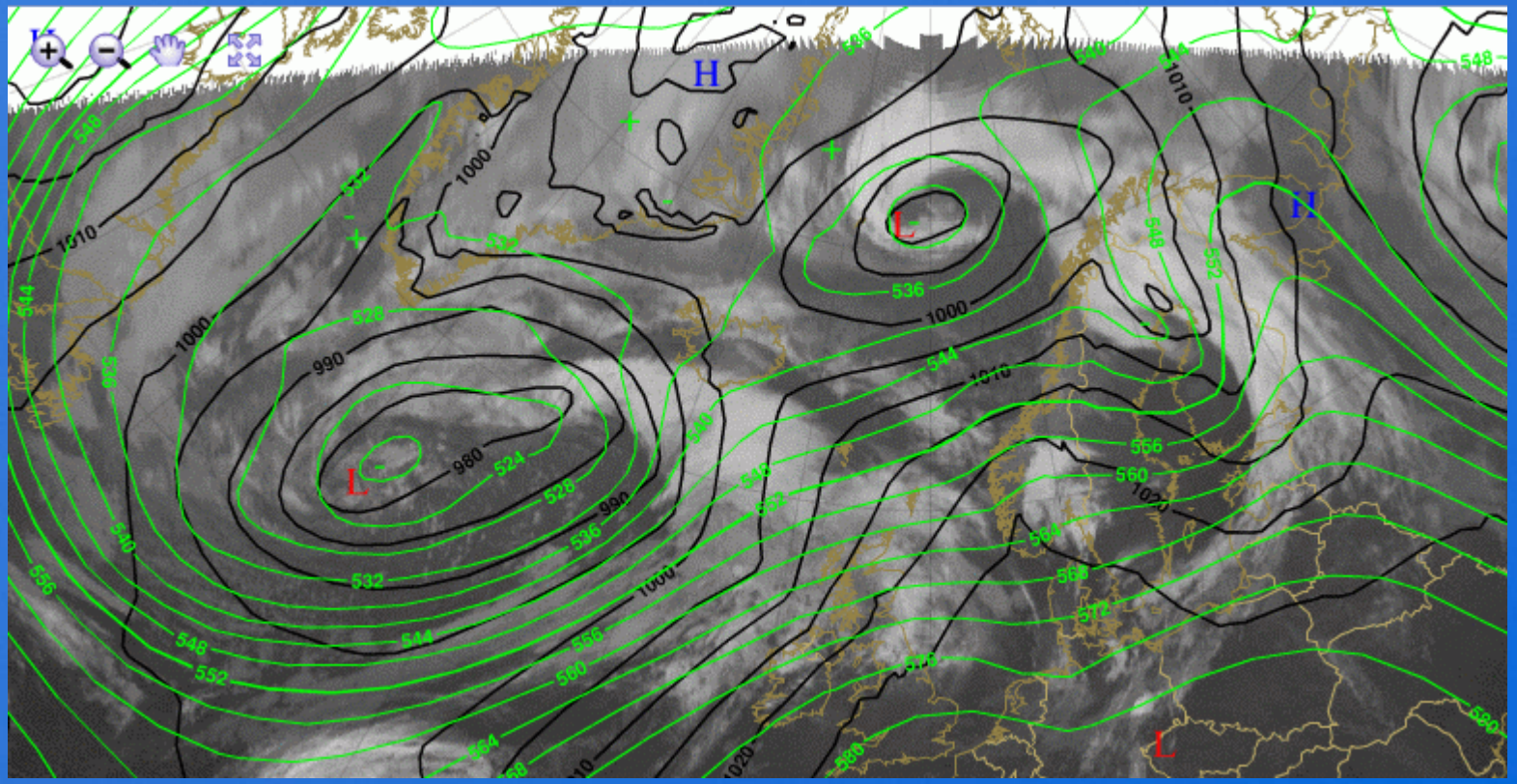
- Height contours 1000 hPa
- Relative vorticity (500 and 1000 hPa)



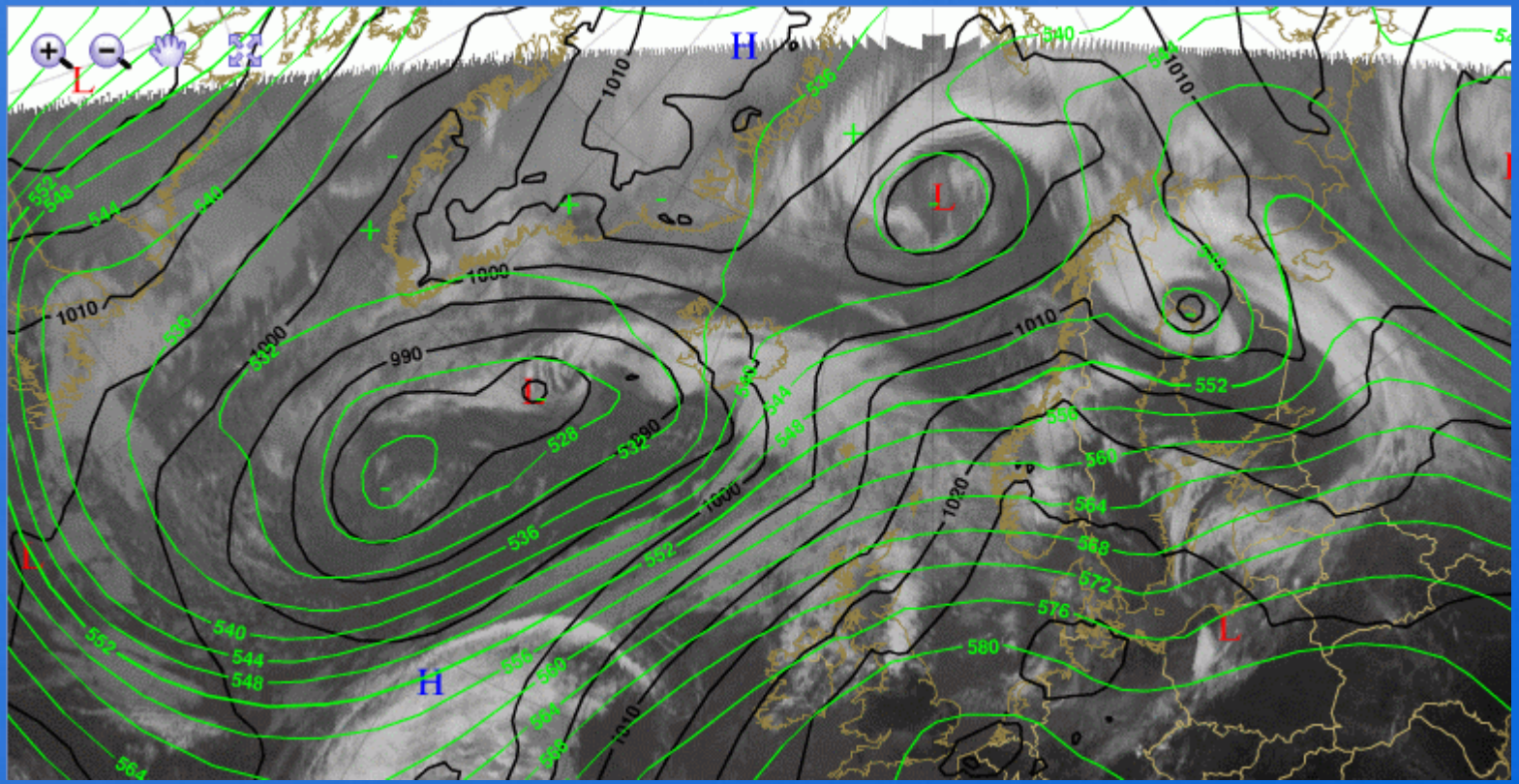
green: H500, black: MSLP



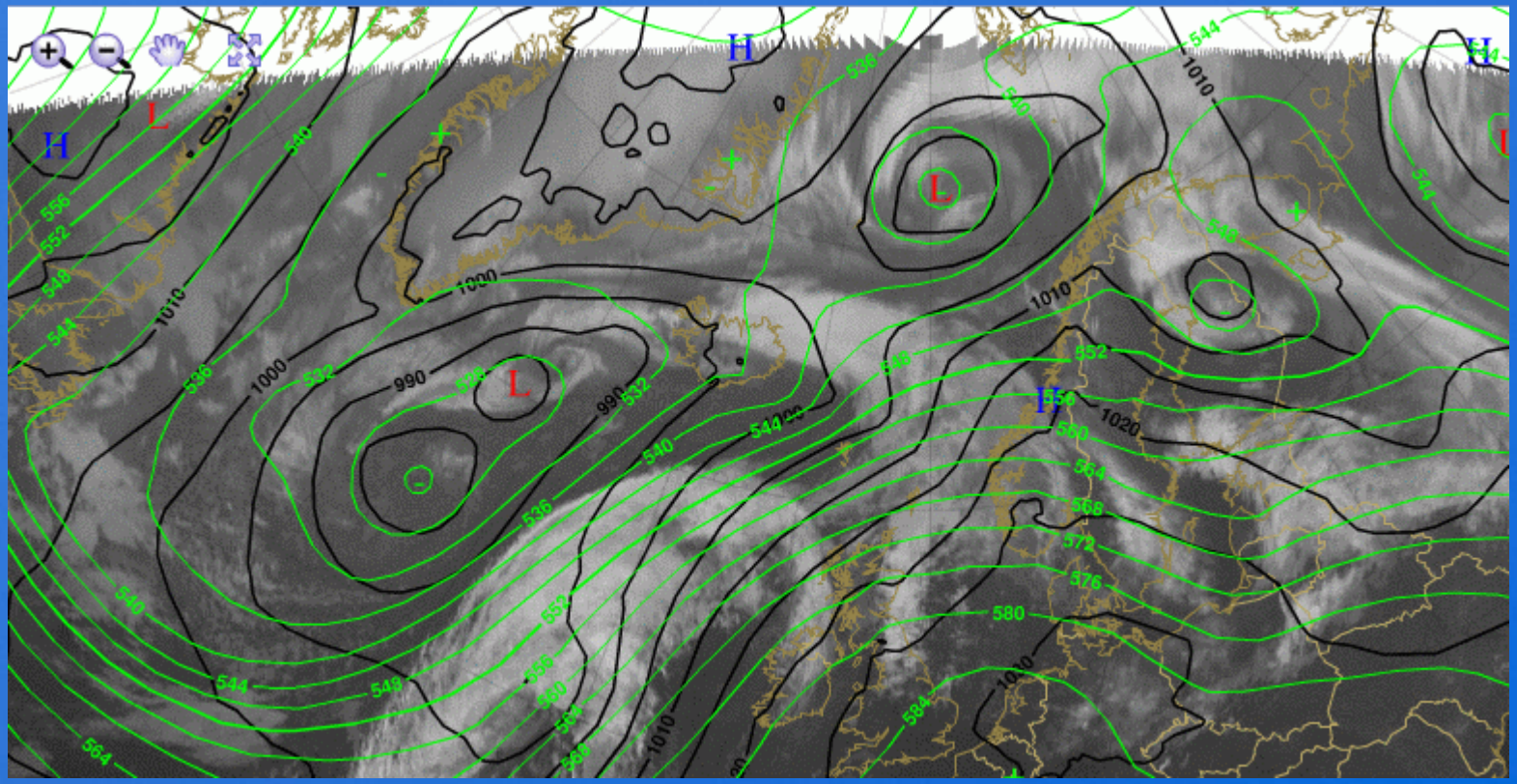
green: H500, black: MSLP



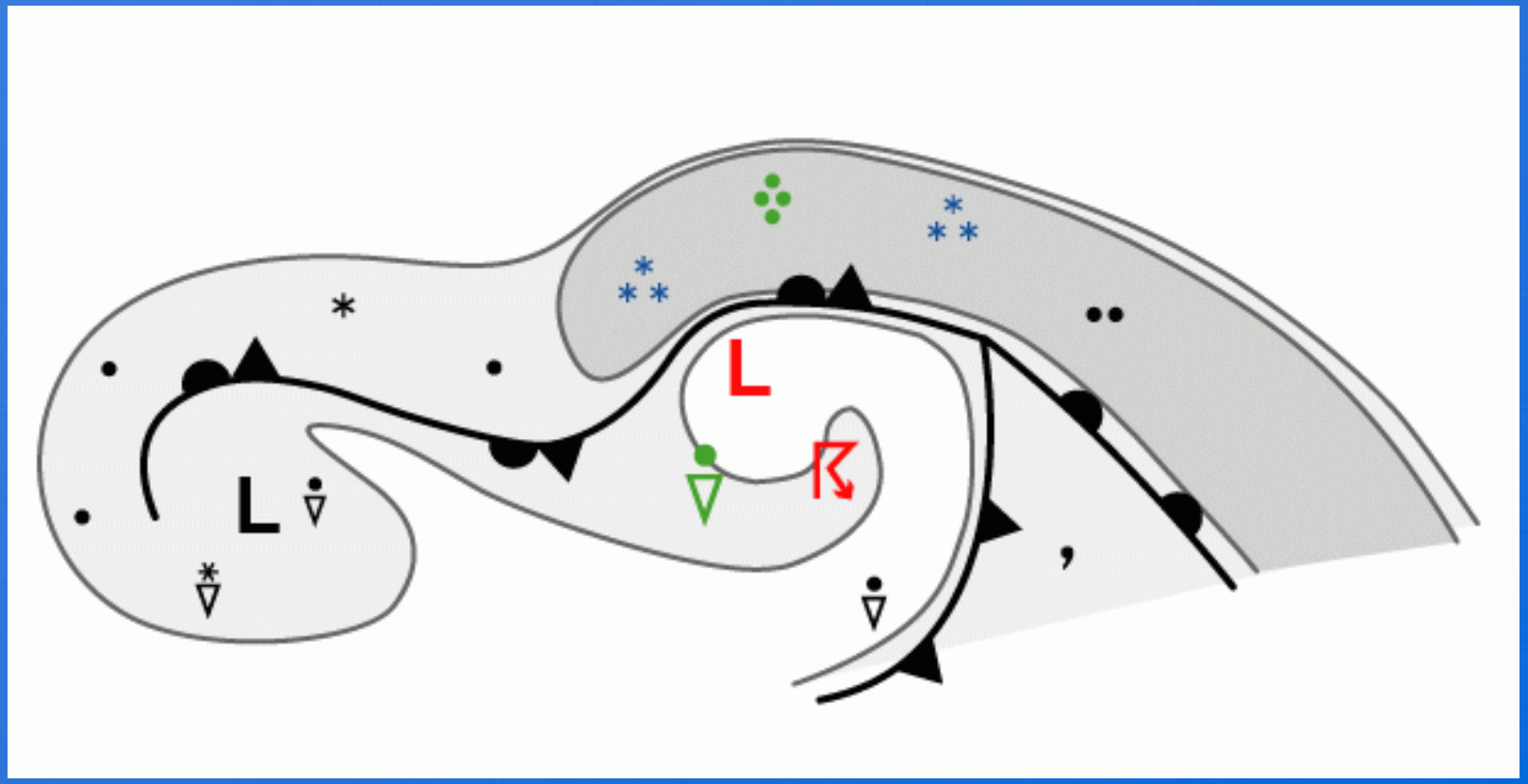
green: H500, black: MSLP



green: H500, black: MSLP



Occlusion 2nd Low: Weather Events




The End