METEOSAT SECOND GENERATION (MSG)

WV Channels

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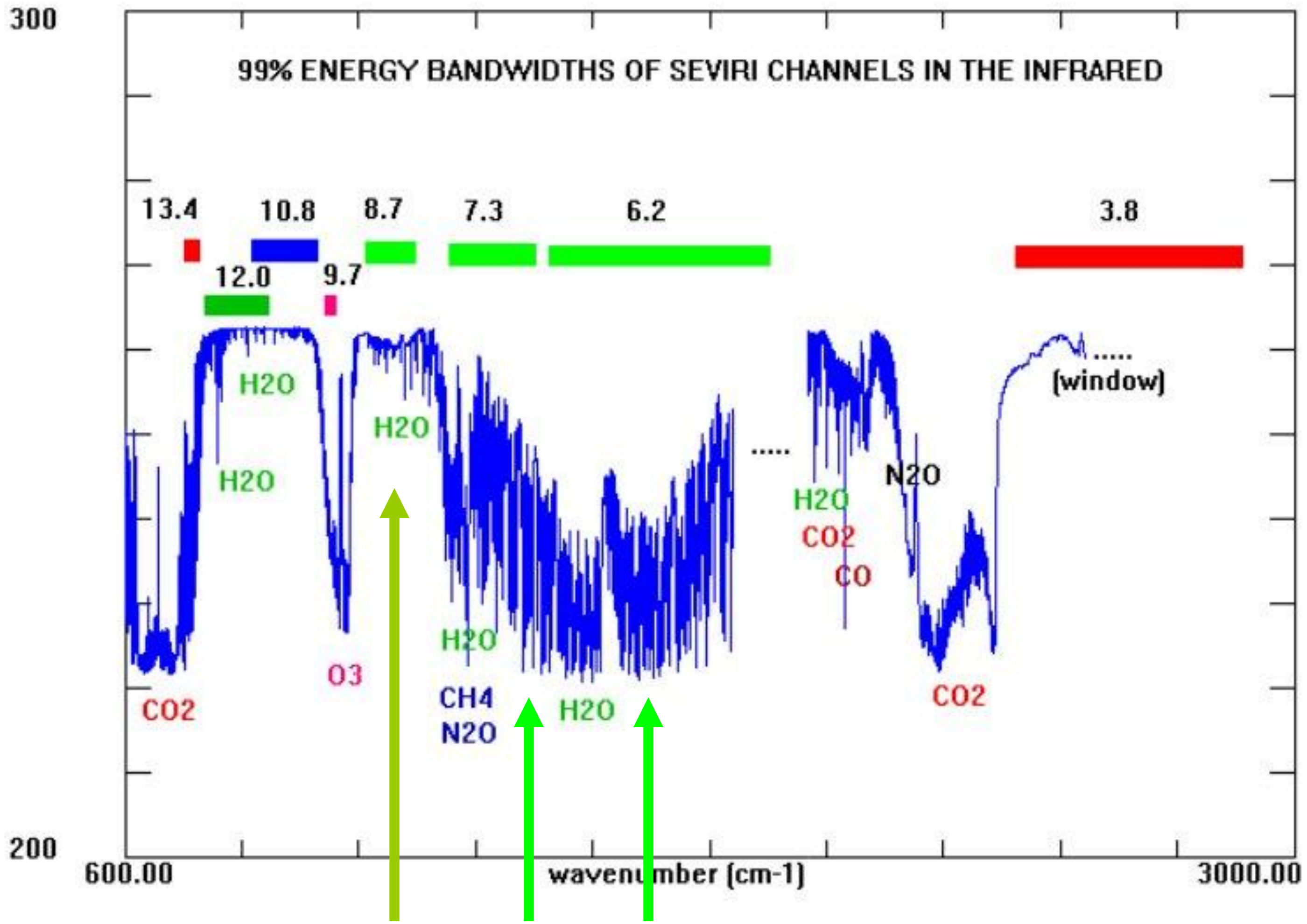
Part 1: Radiation effects from different moisture profiles

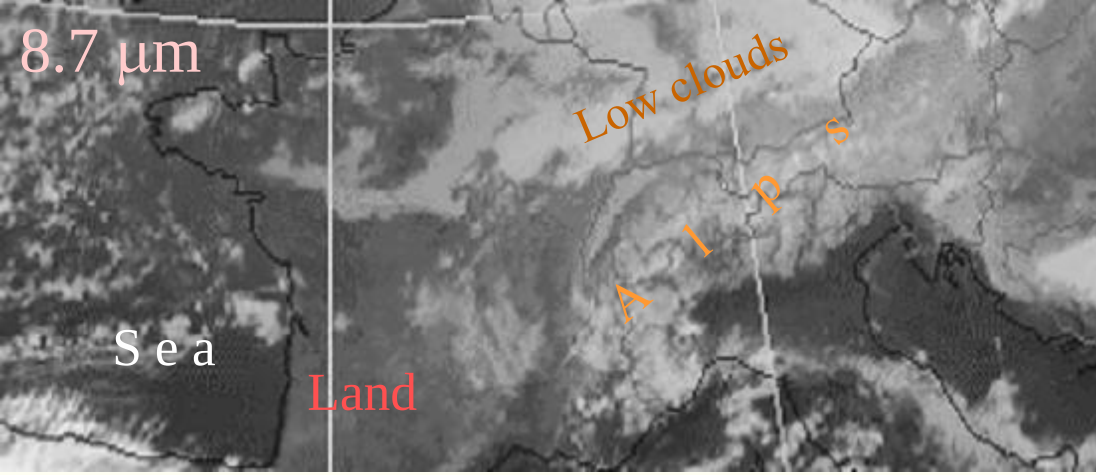
(single pixel interpretation)

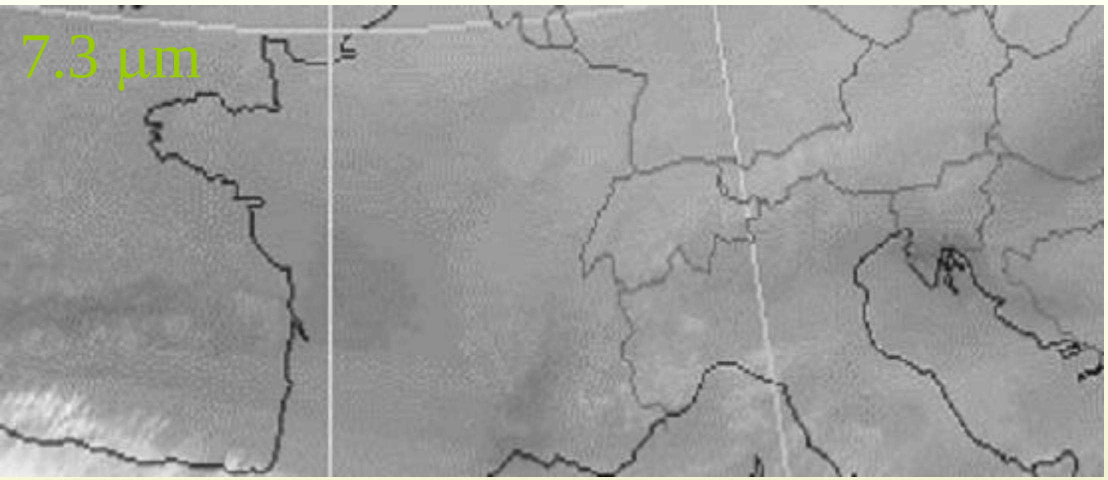


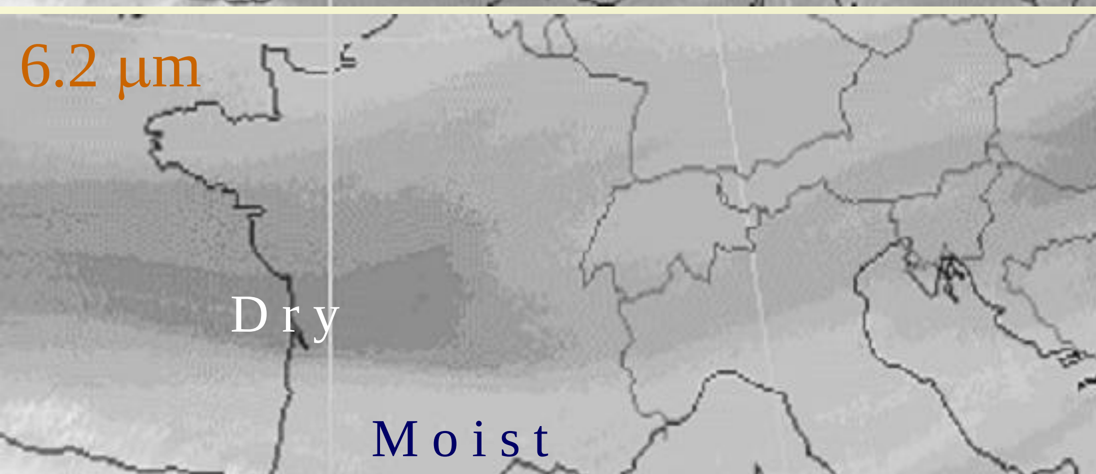
WV
6.2 µm
7.3 µm

IR / WV
8.7 µm

- Two of the 12 channels of SEVIRI radiometer of MSG are water vapour channels, centred at 6.2 and 7.3 µm in WV absorption band.
- The 8.7 µm exhibits properties of a WV and a window channel and may be considered as an IR channel in the WV absorption band.







10.8 µm channel:

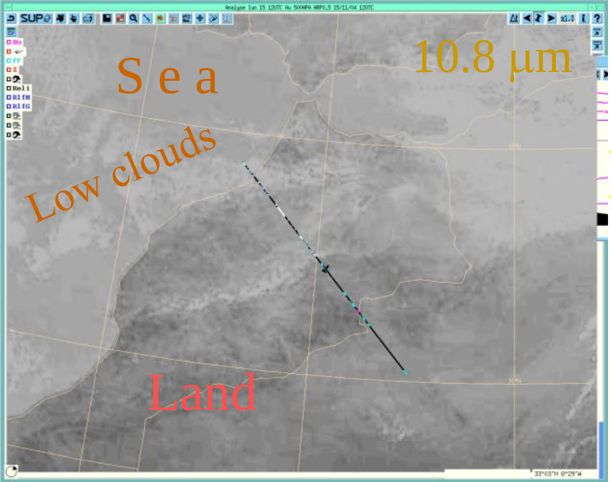
- slight absorption
- warmer sea – darker than the colder land
- low clouds, snow over Alps – white

7.3 µm channel:

- moderate absorption
- warmer sea – not visible
- low clouds, snow over Alps – lighter
- high land – visible

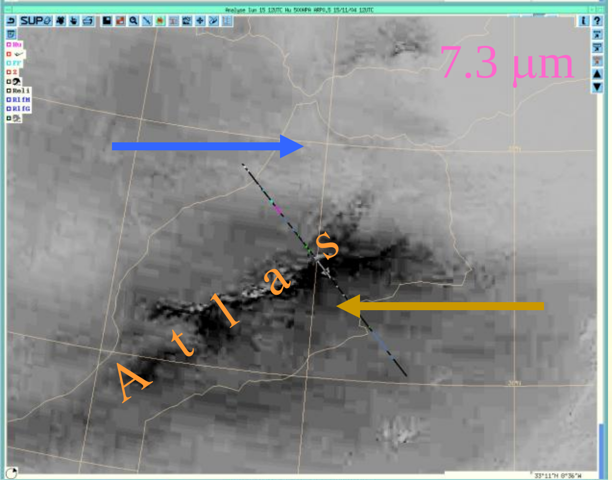
6.2 µm channel:

- strong absorption
- dry troposphere – dark
- moist troposphere – light
- low clouds, high land – not visible



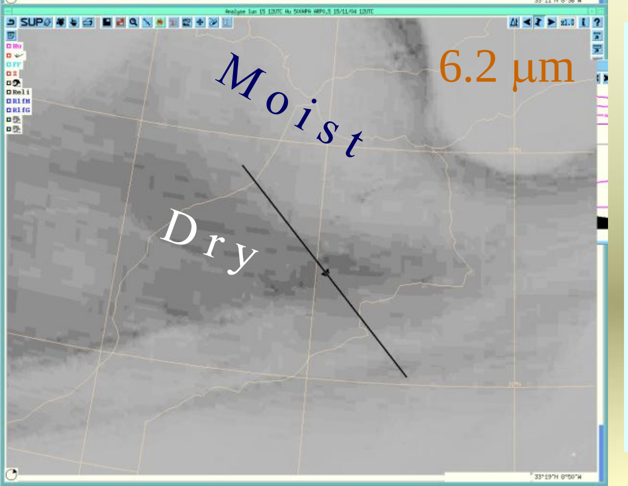
10.8 µm window channel:

- Radiation reaching the satellite is not absorbed by any atmospheric substances.
- Various objects of the earth surface and cloudiness may be distinguished due to differences in their temperature.



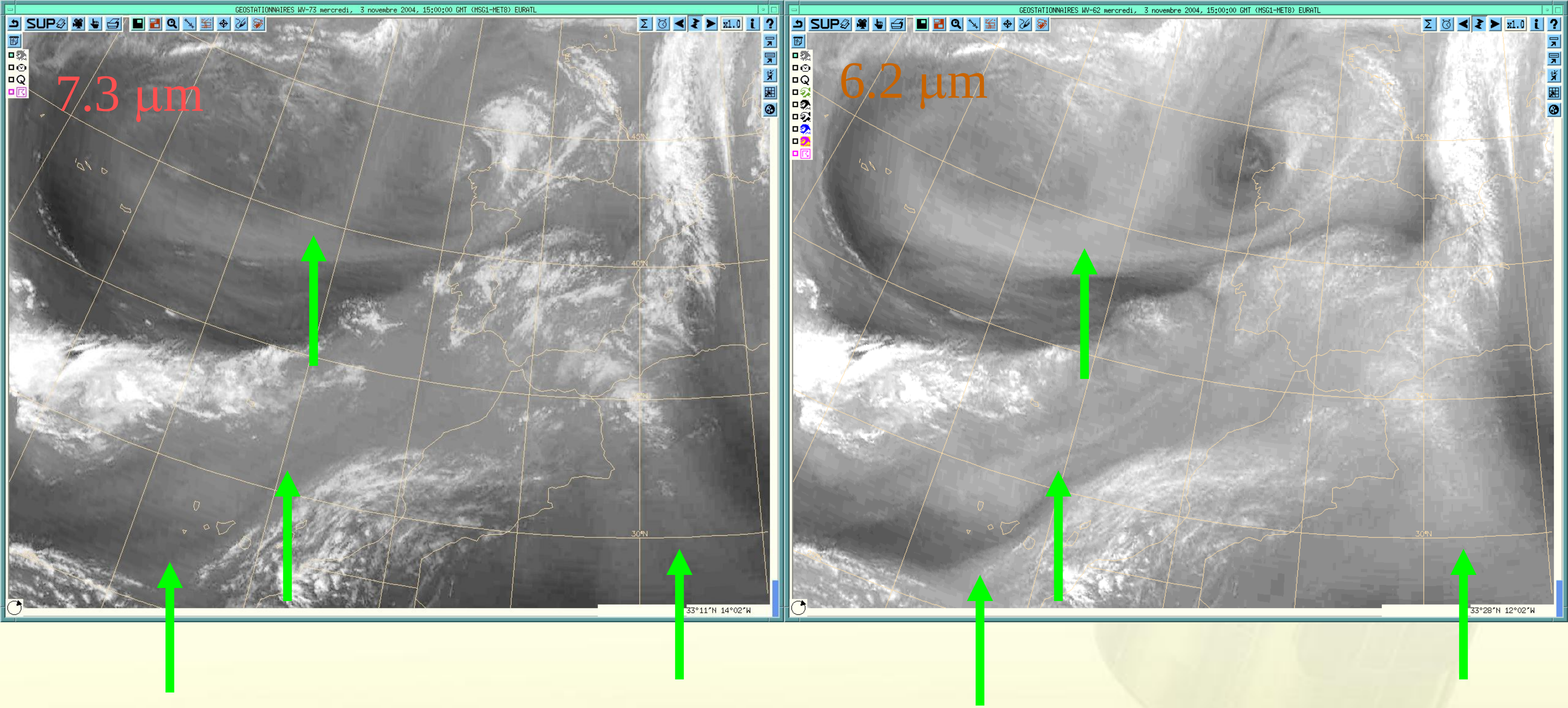
7.3 µm WV channel:

- Radiation is absorbed by mid- to low-level atmospheric moisture, higher humidity being displayed in lighter grey shades.
- High mountain surface may be seen as a dark feature if little moisture is present above.



6.2 µm WV channel:

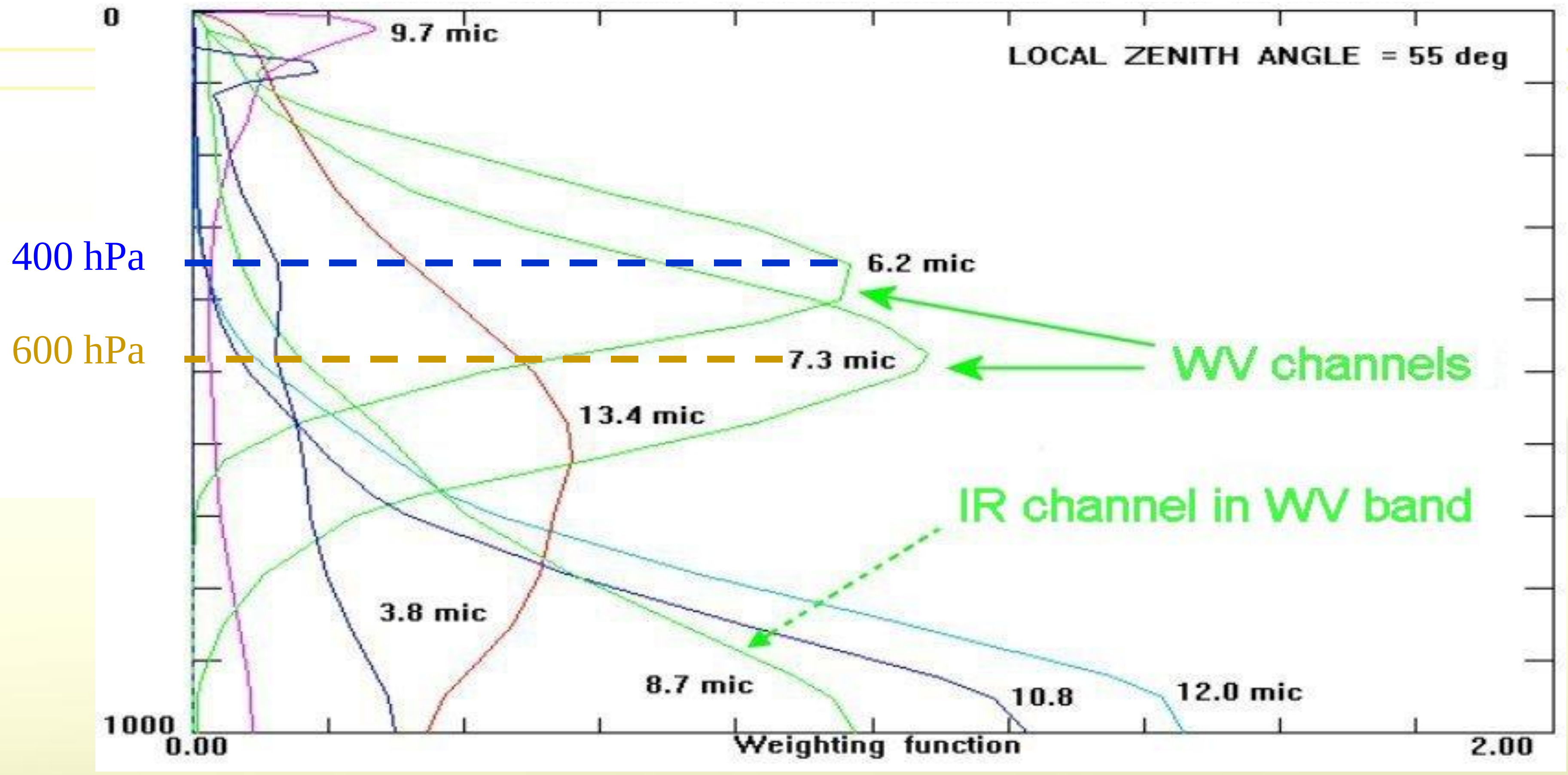
- Radiation is absorbed by upper- to mid-level atmospheric moisture, lower humidity being displayed in darker grey shades.
- Due to strong absorption, low-level features (earth surface, clouds) are not visible.



Absorption

Since the 6.2 µm radiation exhibits a larger absorption, the 6.2 µm radiation in image format better represents moisture distribution in mid- to upper troposphere over the cloud free areas.

MEAN WEIGHTING FUNCTIONS OF SEVIRI CHANNELS AT MIDDLE LATITUDES



• The WV channel weighting functions are peaking at different altitudes and the levels of maximum contribution to the total radiation emitted by moisture are different for the two channels.

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BRIGHTNESS TEMPERATURE FROM RADIATION MEASUREMENTS

- The Brightness temperature is a measure of the intensity of radiation thermally emitted by an object, given in units of temperature since the intensity of this radiation correlates with the physical temperature of the radiating body that is given by the Stefan-Boltzmann equation.
- Because of the absorption the brightness temperature derived in WV channels may be totally different from the physical temperature of the object depending on the vertical distribution of humidity.

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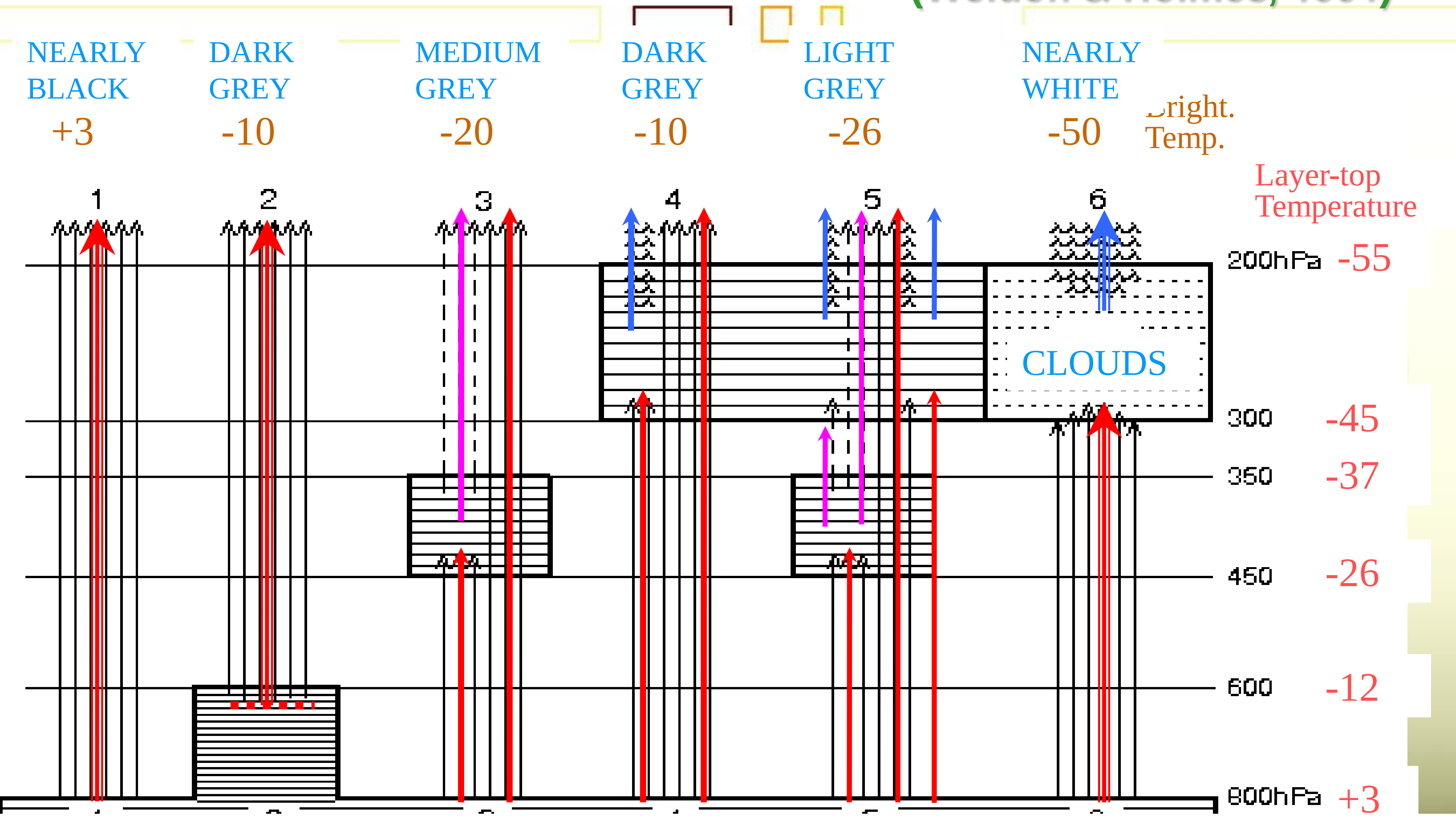
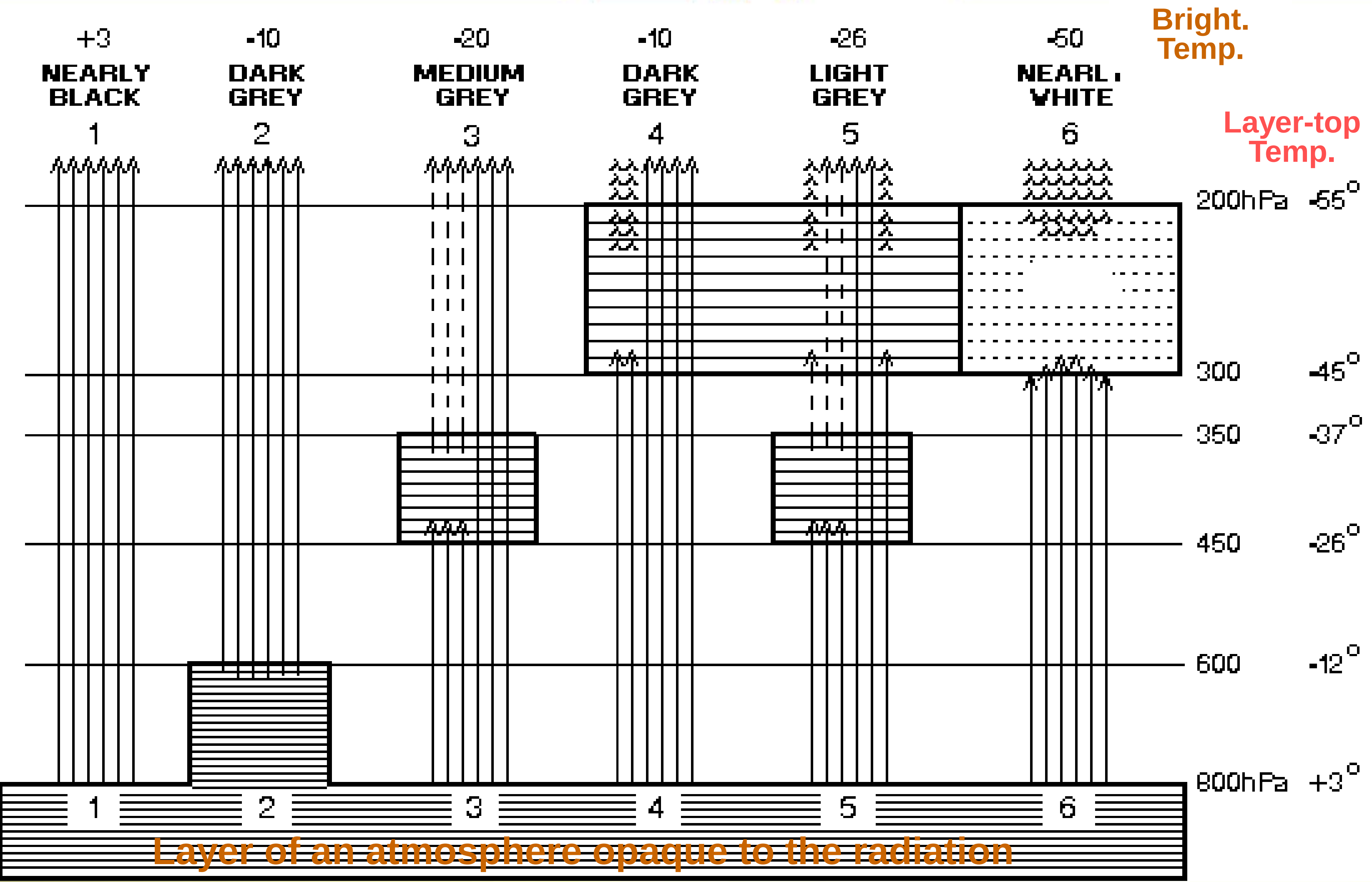
6.7 µm radiance from moisture at specific altitudes
(Weldon & Holmes, 1991)



Case (6) illustrates the response of the high-level clouds, which do not allow the radiation from below to pass through. Most of the radiation reaching the satellite originates within the cloud layer, and nearly white shades are observed on the imagery. The brightness temperature would be representative for the air temperature near the top of the high-level clouds.

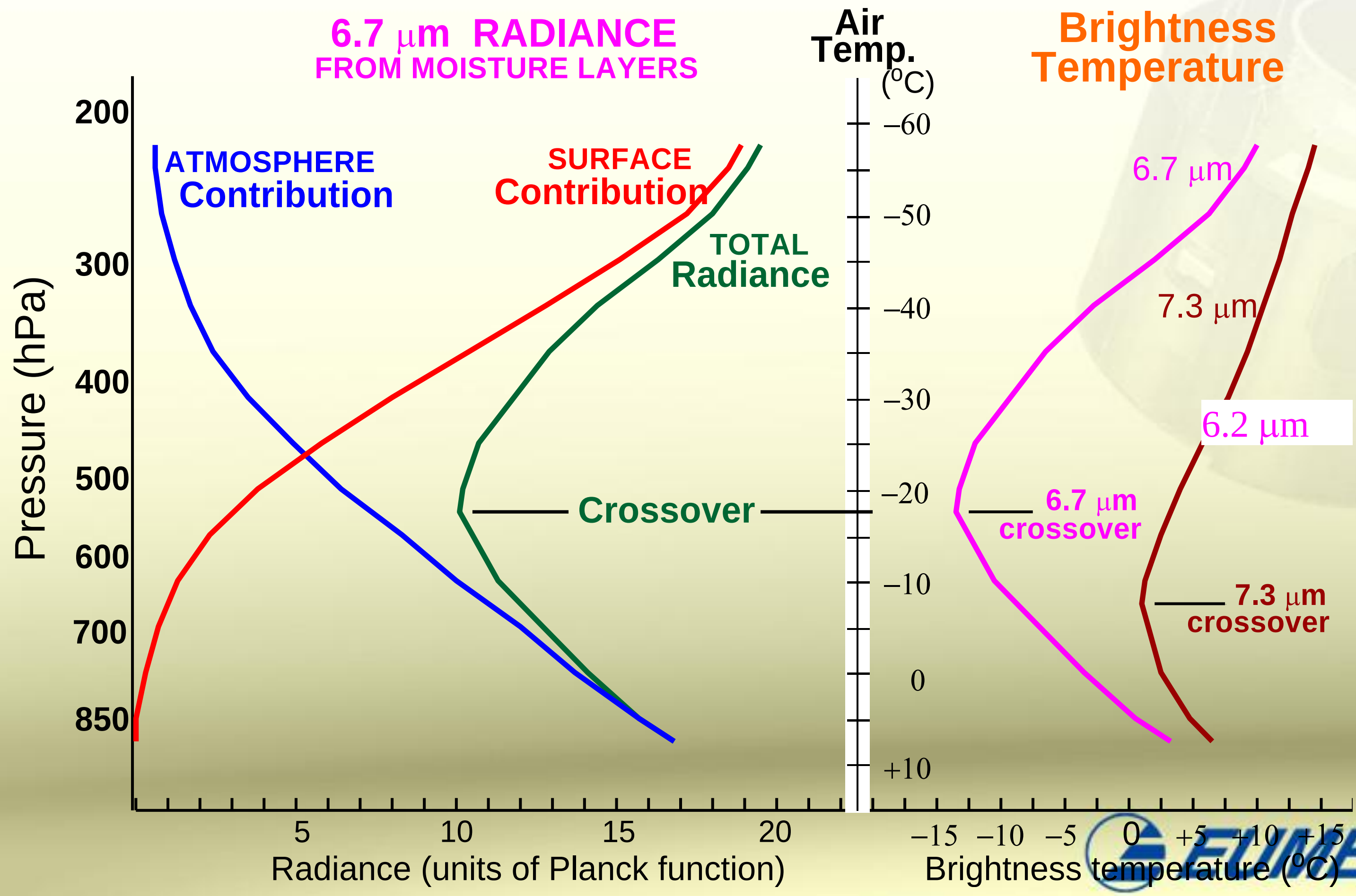
6.7 μm radiance from moisture at specific altitudes

(Weldon & Holmes, 1991)



Crossover effect (Weldon & Holmes, 1991)

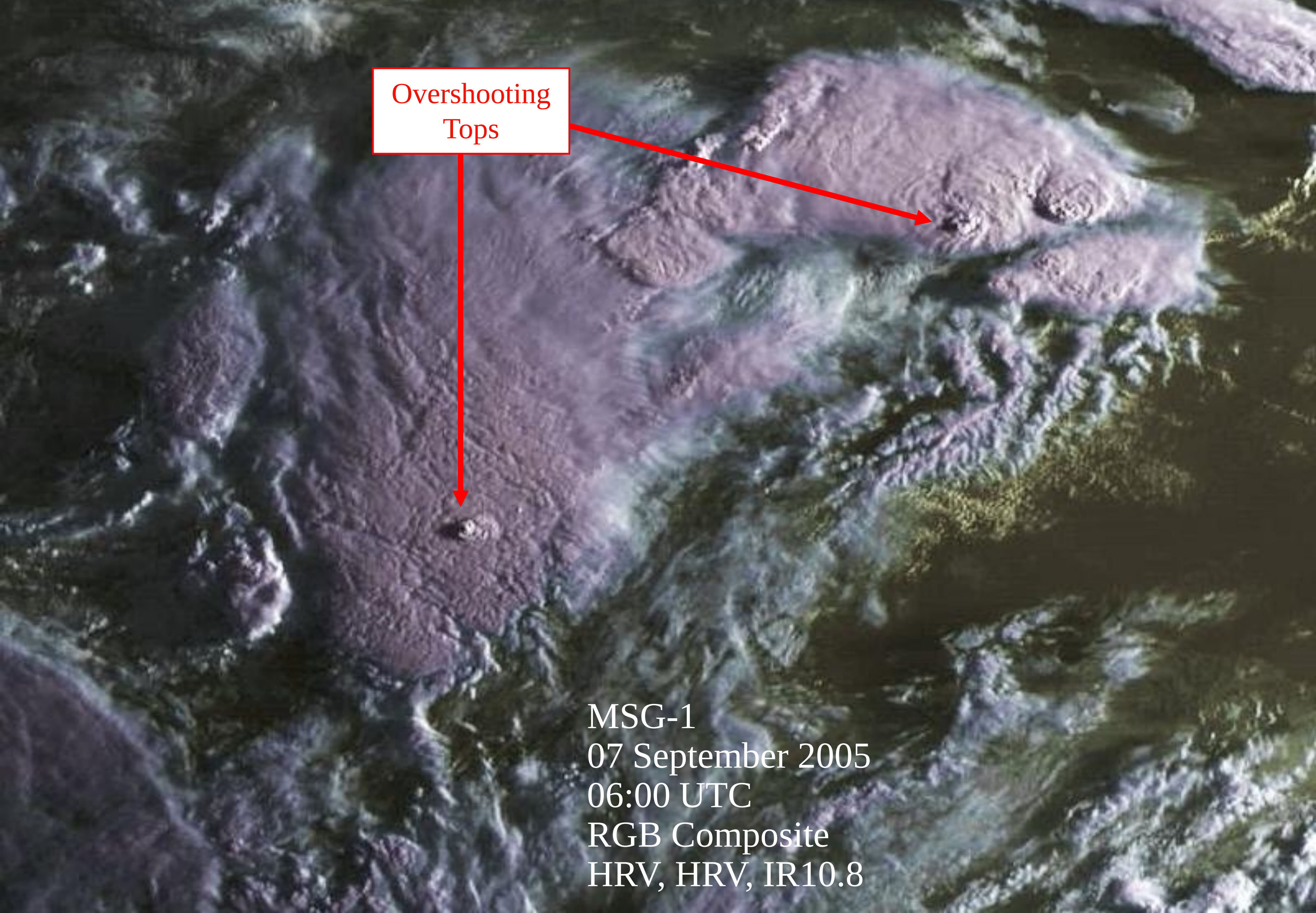
The concept is illustrated by moisture profile, divided in 14 individual moist layers, which are defined by temperature at five-degree increments from +10 ^{O}C to –60 ^{O}C.

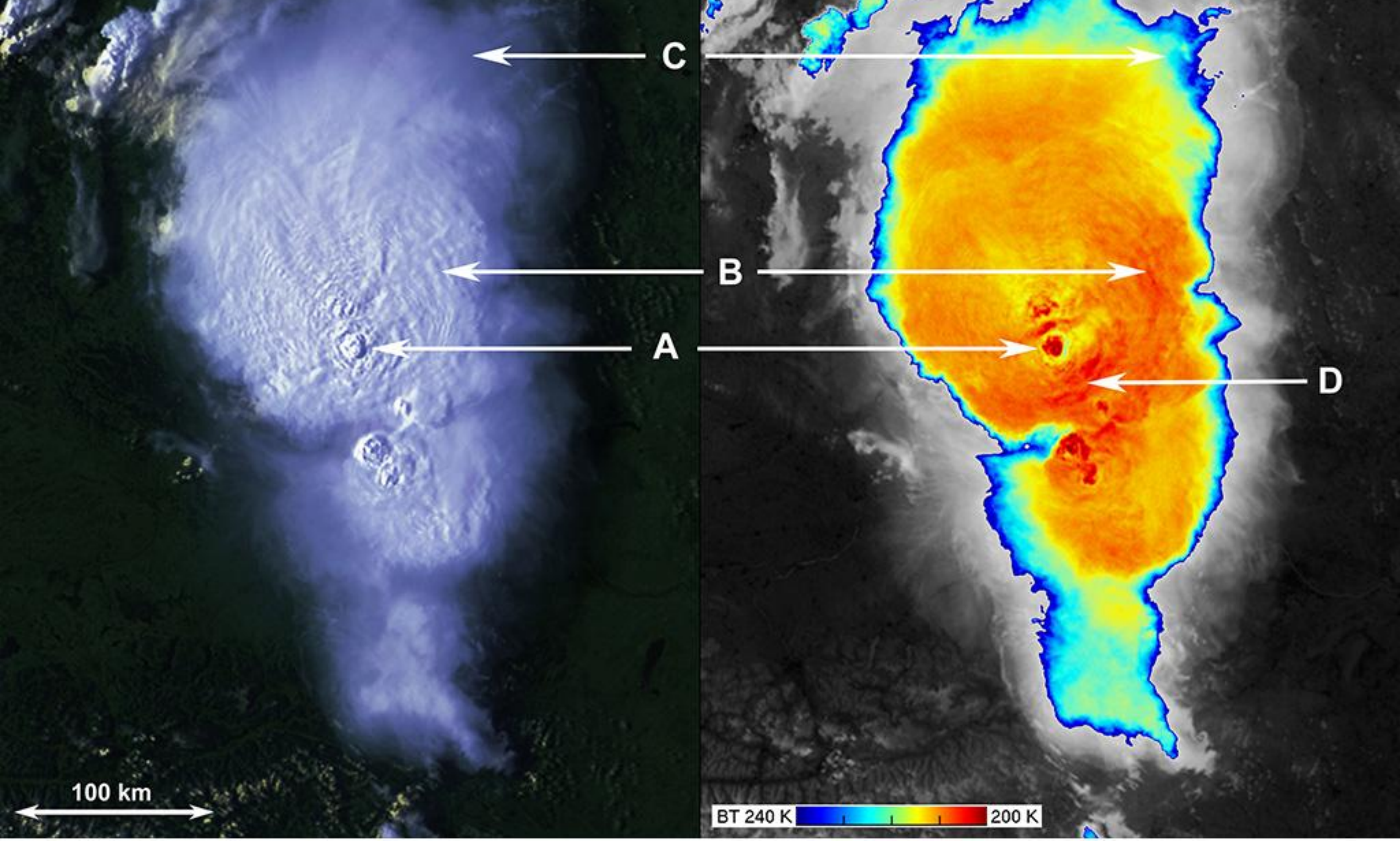


Overshooting
(very low cloud top temperatures)

Aerial Picture of Supercell with Overshooting Top
one Hour prior to Munich Hailstorm on 12 July 1984

Overshooting Tops in VIS Channels (morning)





A - overshooting top

B - gravity waves on the anvil top

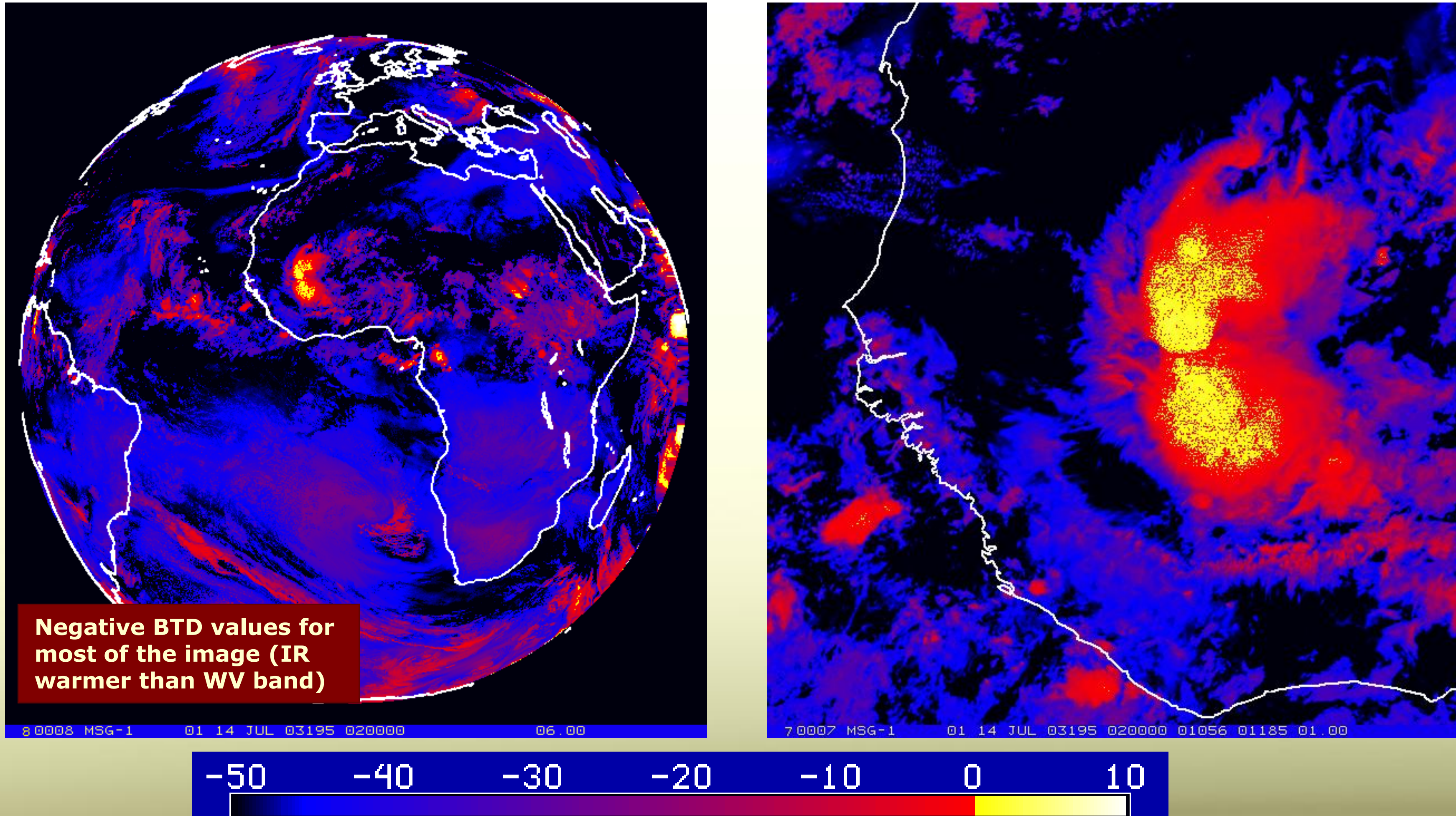
C - semitransparent part of the anvil

D - cold-U shape

NOAA-15 2006-06-25 16:08 UTC

RGB composite of AVHRR bands 1,2 and 4 (left)
and color-enhanced AVHRR band 4 (right)

Overshooting Tops in Difference WV6.2 - IR10.8



MSG-1, 14 July 2003, 02:00 UTC

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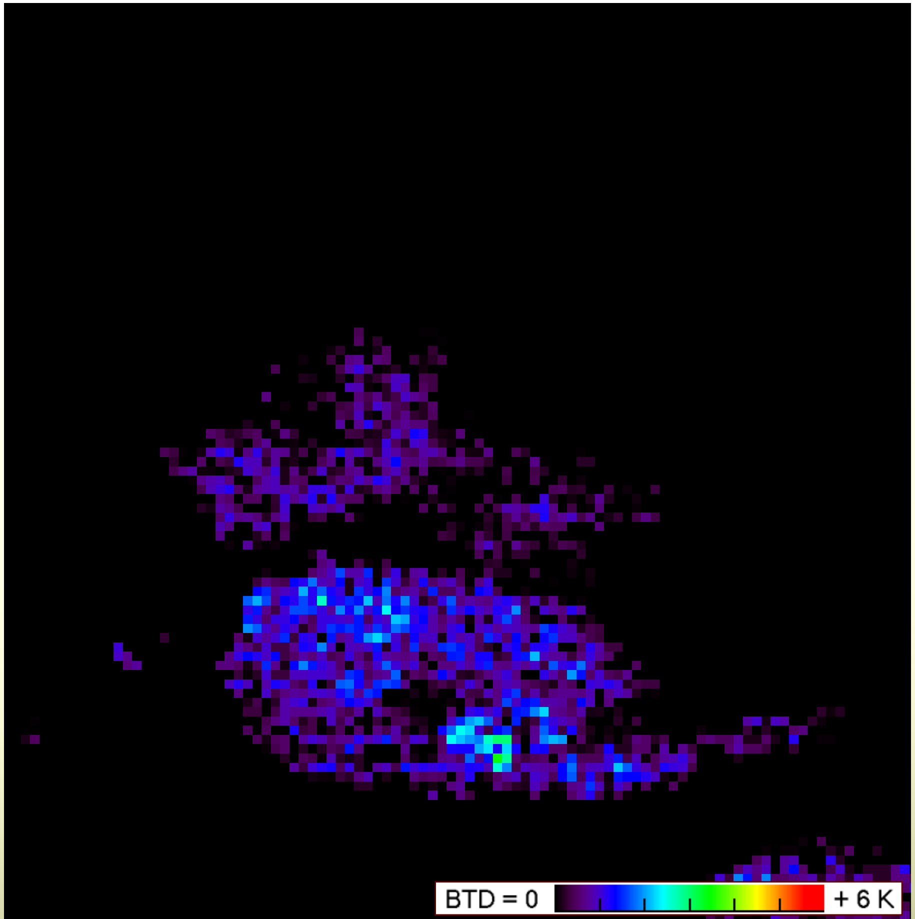
Possible Explanations for Positive BTD

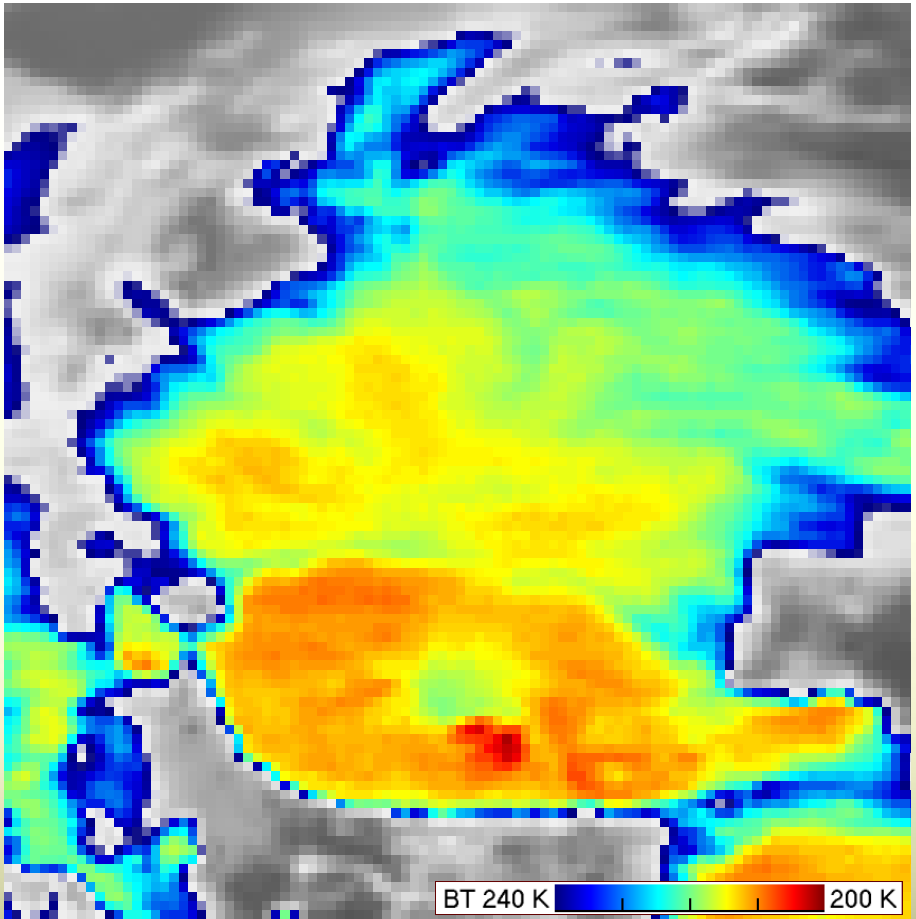
- presence of warmer moisture layer in the lower stratosphere, detectable by this method only above cold storm tops (Schmetz et al., 1997);

- emissivity/transparency differences of frozen cloud tops in WV6.2 and IR 10.8 bands (cloud top microphysics).

For both explanations, the BTD strongly depends on actual temperature profile near and above the tropopause !

Overshooting Tops, France

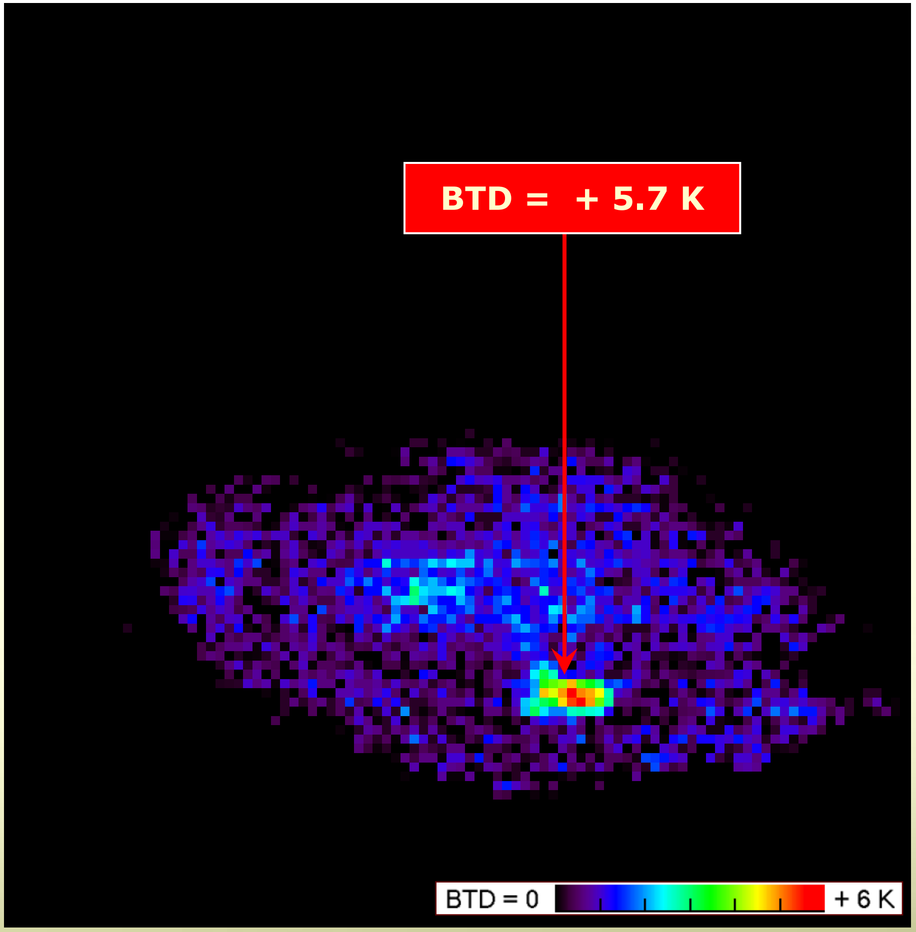


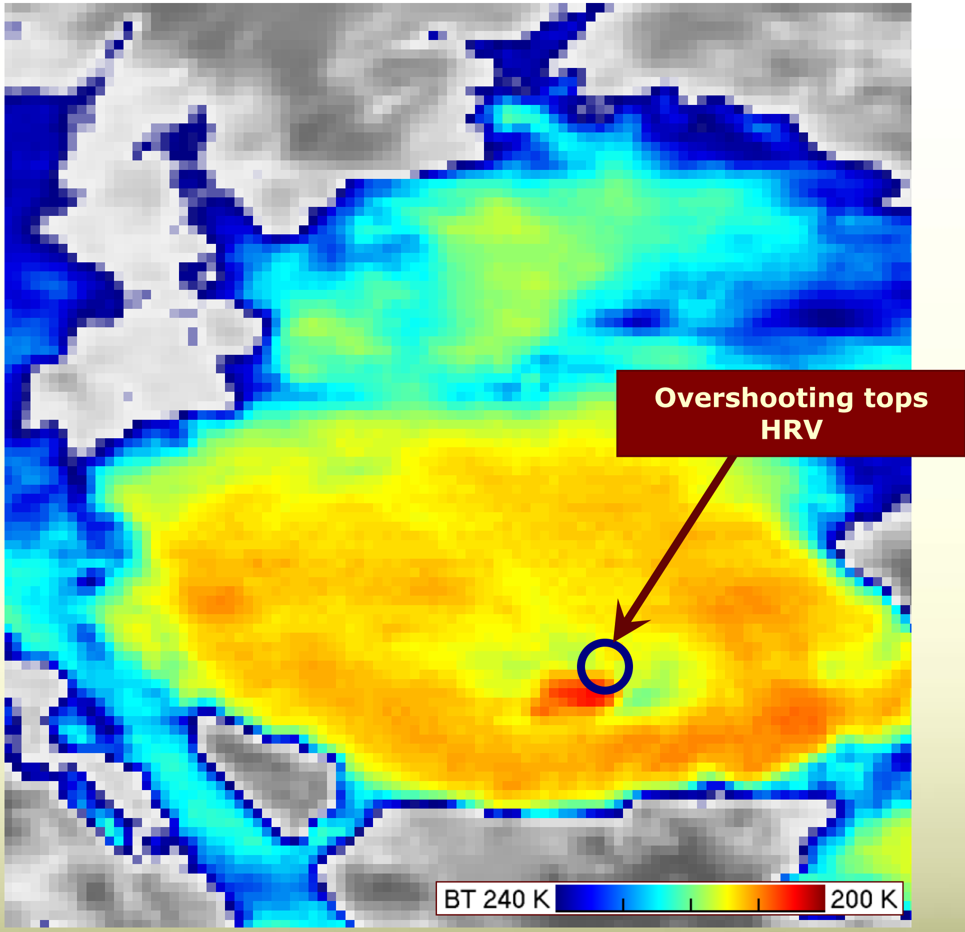


BTD WV6.2-IR10.8 IR10.8 channel

28 June 2005, 17:45 UTC, France

Overshooting Tops, France



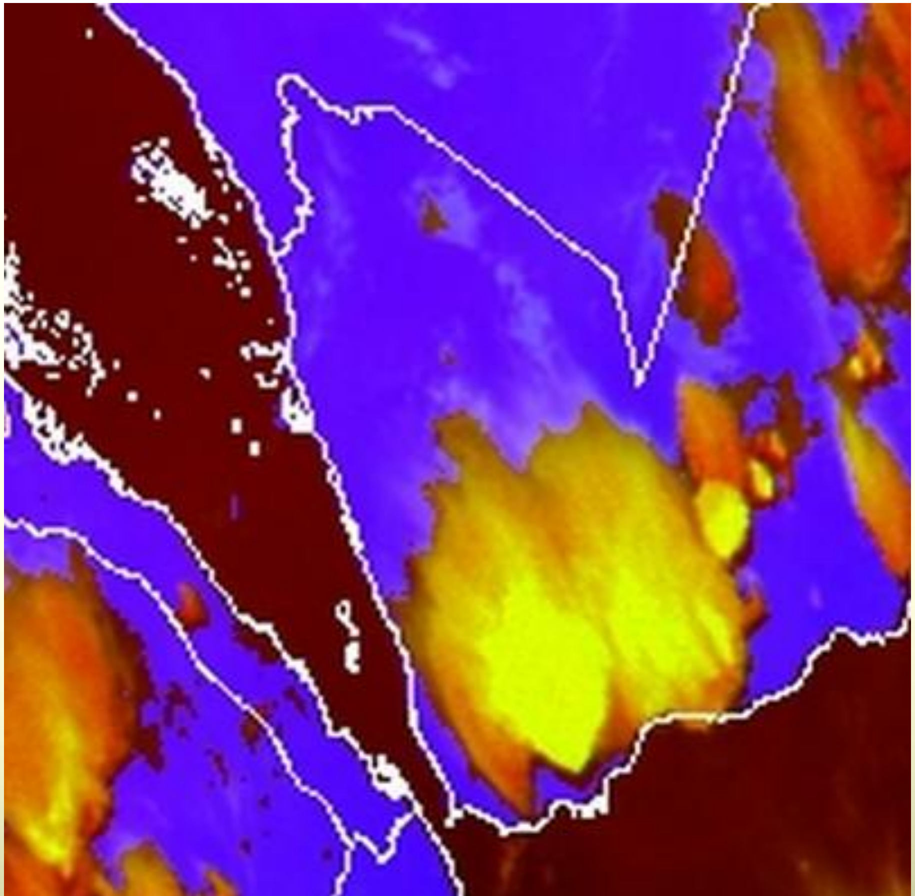


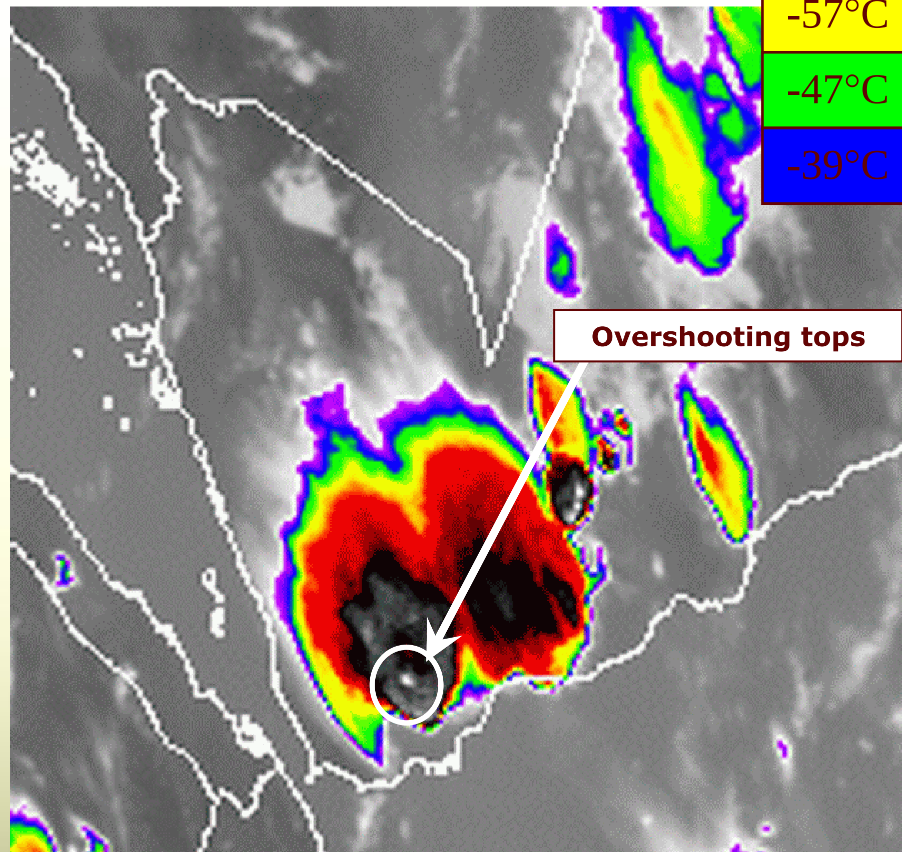
BTD WV6.2-IR10.8

IR10.8 channel

28 June 2005, 18:45 UTC, France

Overshooting Tops, Yemen





Convection RGB

IR10.8 channel

5 May 2005, 13:00 UTC

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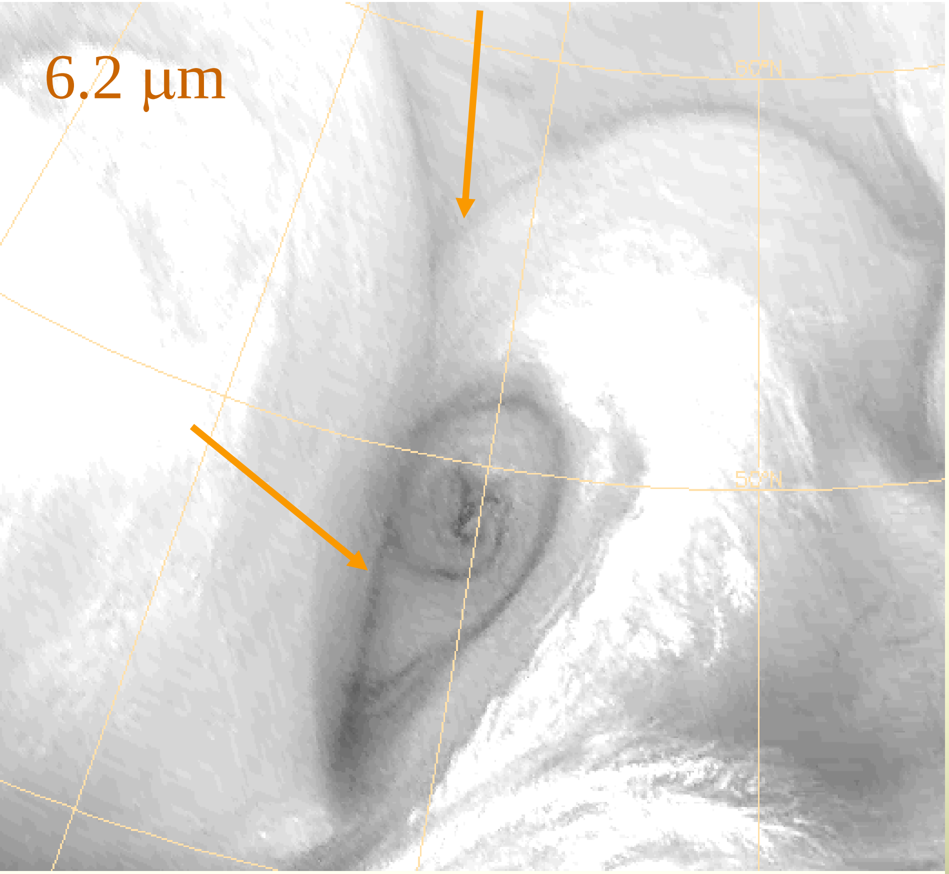
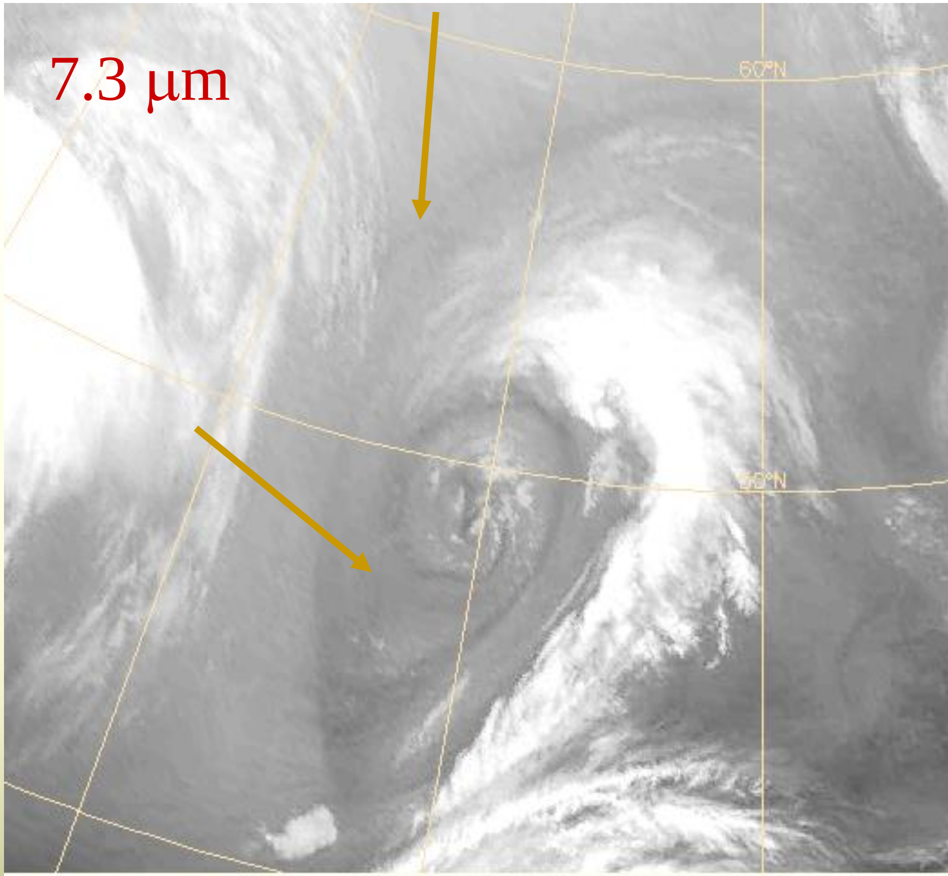
Part 2: Upper-level dynamical features seen in WV images

(pattern recognition of many pixels together)

Moisture regime at upper levels seen by MSG WV channels





The moisture regime produced by upper-level dynamics is usually much more distinctly seen by 6.2 μm radiation measurements.

Key WV Imagery Features

a) Jet-stream features (shear zones)

b) Tropopause dynamic anomalies (PV anomalies)

c) Large-scale moisture movements and surges

d) Vorticity minima / maxima

e) Deformation zones

f) Mountain Waves / Gravity Waves

Jet Streams

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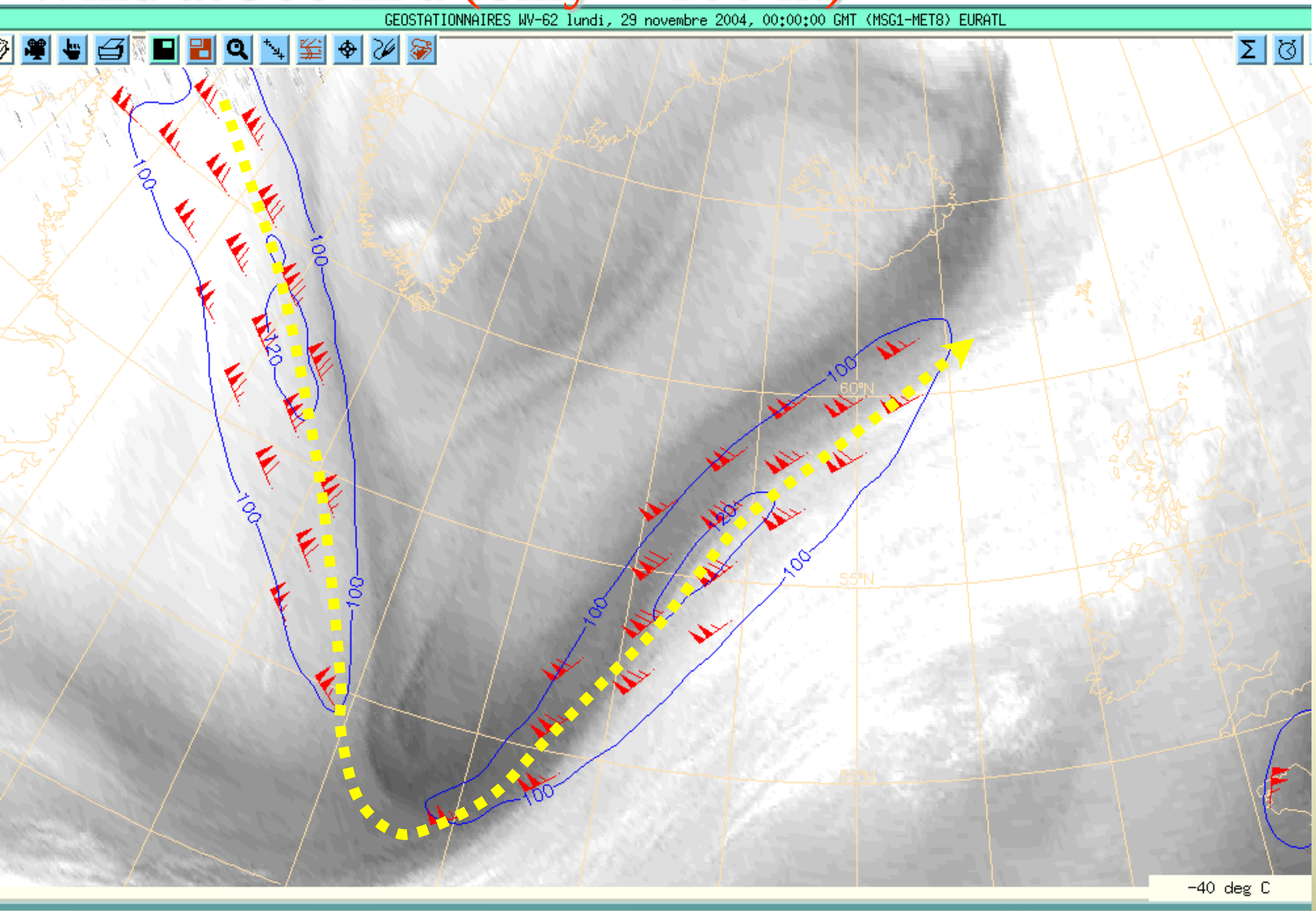
Jet-stream related patterns

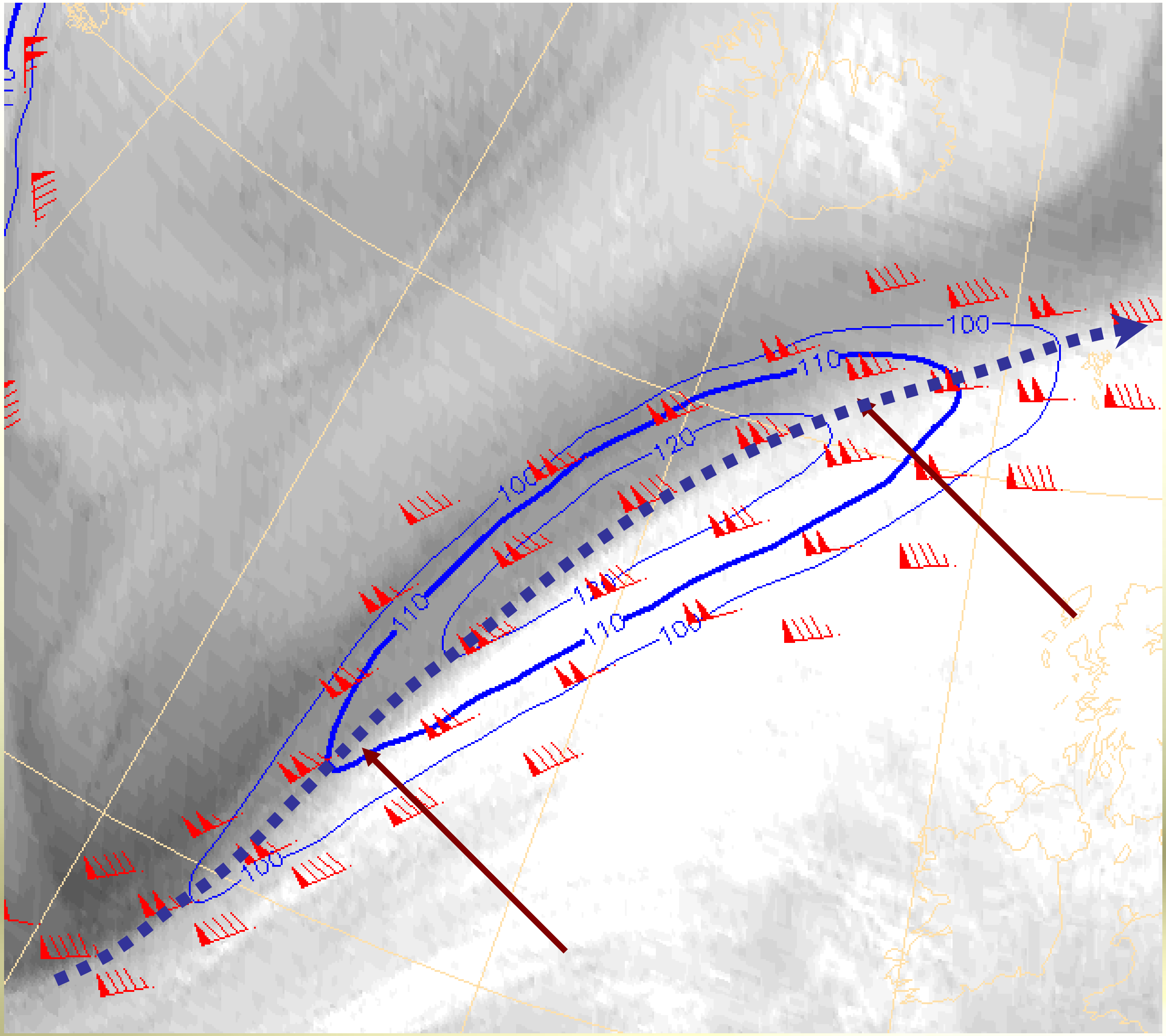
Wind at 300 hPa (only > 100 kt)



Typically, on a WV image, there are many well defined boundary features, and only some of them are associated with jet stream axes.

Jet-stream related patterns

Contours of wind speed > 100 kt / wind > 80 kt at 300 hPa



The jet axis of the maximum wind speed is likely along the most contrast part of moisture boundary in the WV image.

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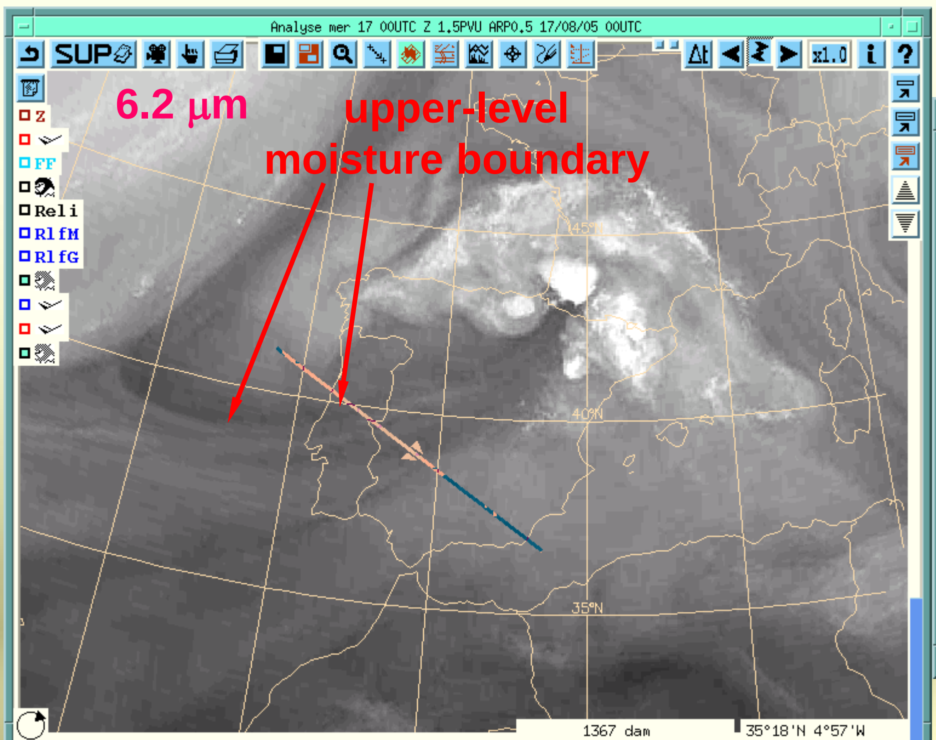
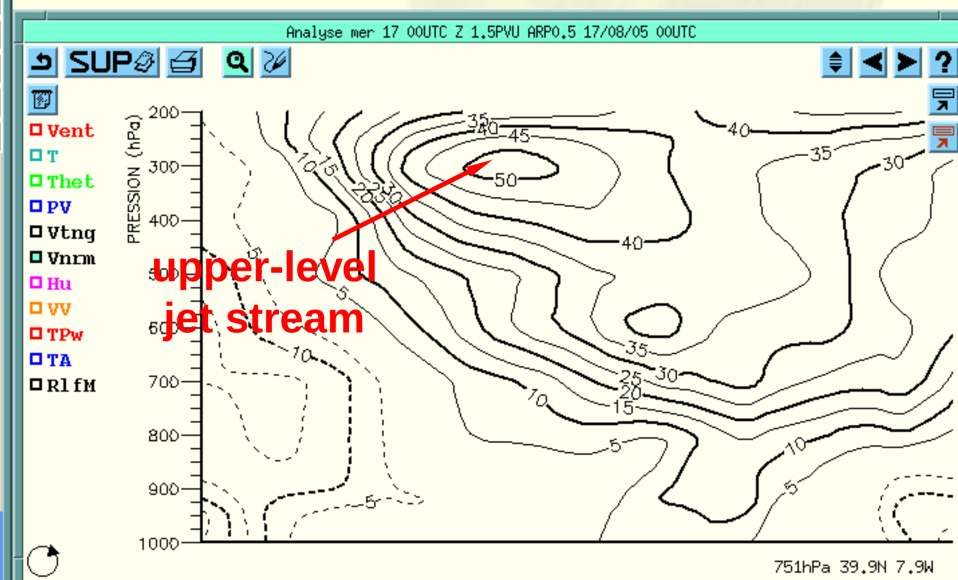
Upper-level Jet Stream Features

Upper level jet streams are visible as specific boundaries between features of quite grey shades in the 6.2 µm WV image.

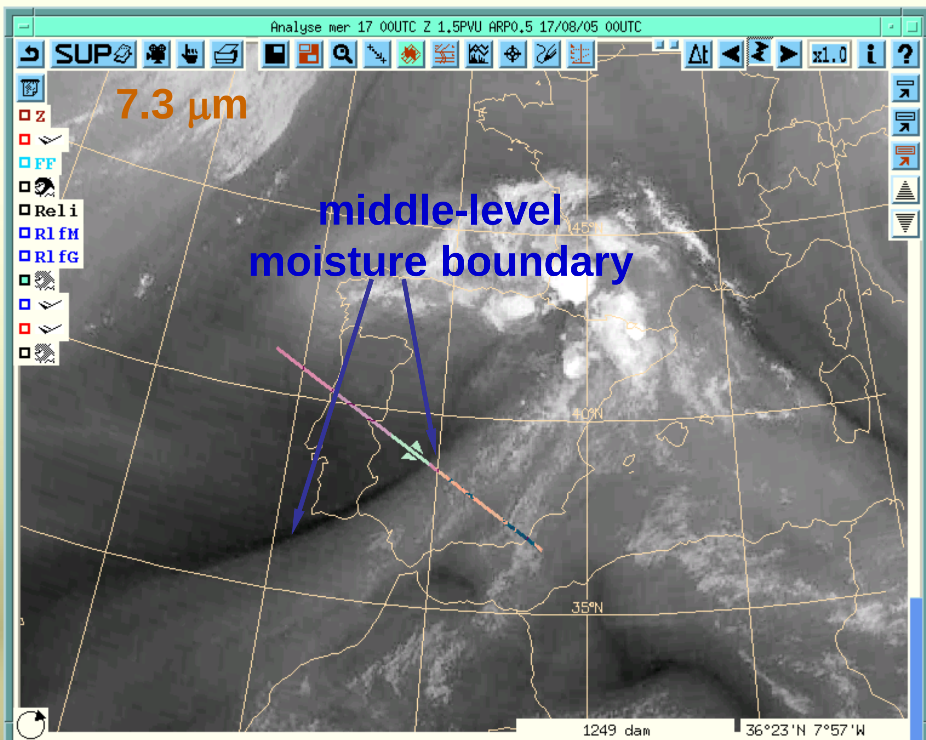


Cross-section of wind

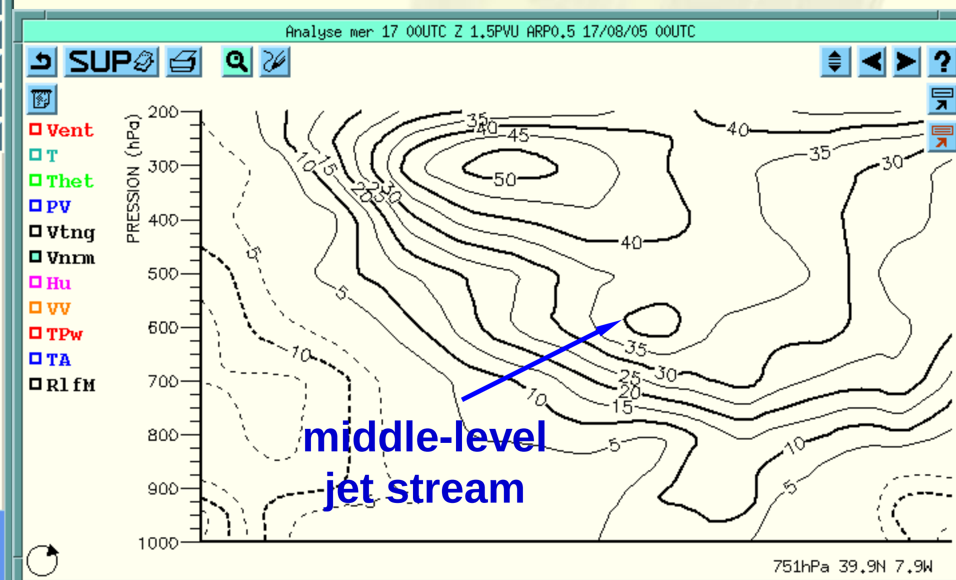


Mid-level Jet Stream Features

Middle level jet streams are visible as specific moisture boundaries in the 7.3 µm WV channel image.



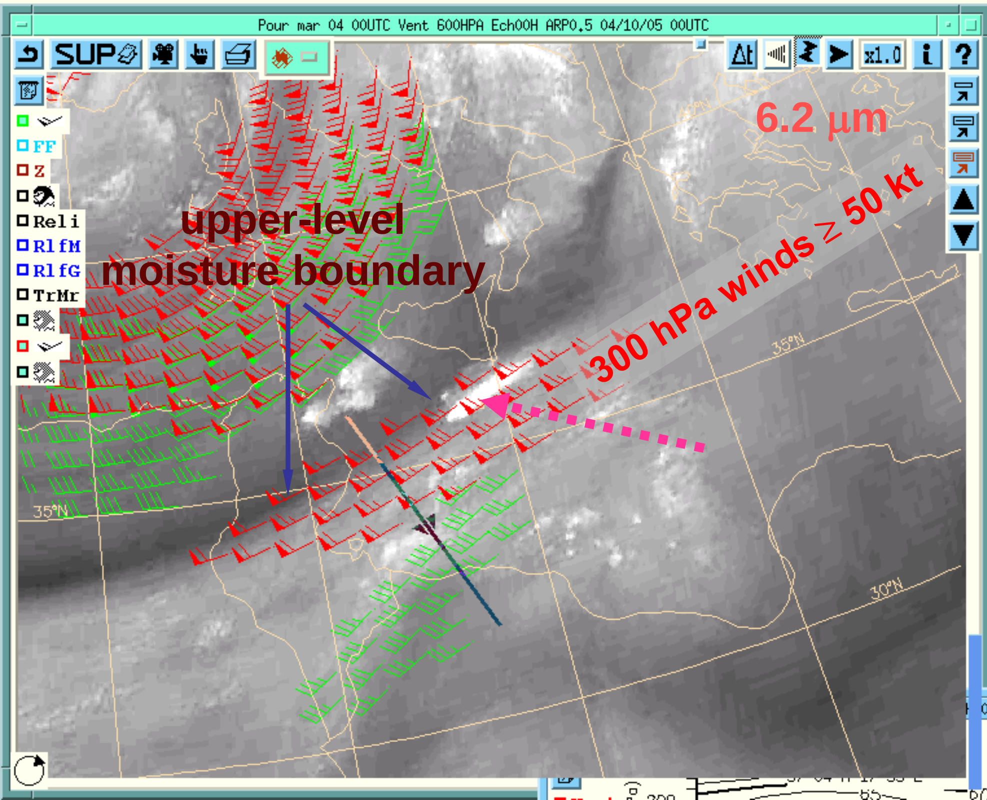
Cross-section of wind



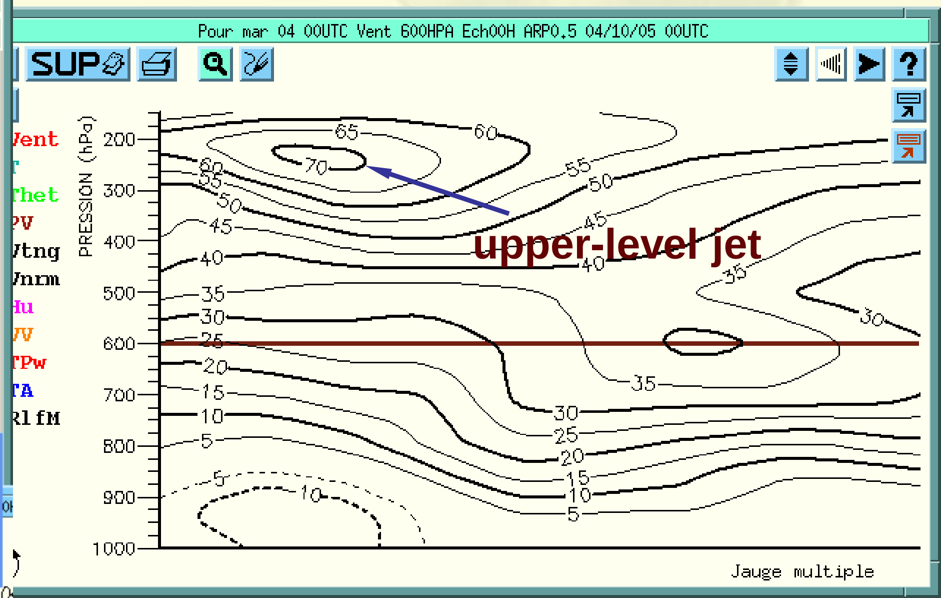
Jet Stream Features & Convection

Convection often develops along the specific moisture boundaries in the 6.2 µm WV image associated with upper-level jet streams.

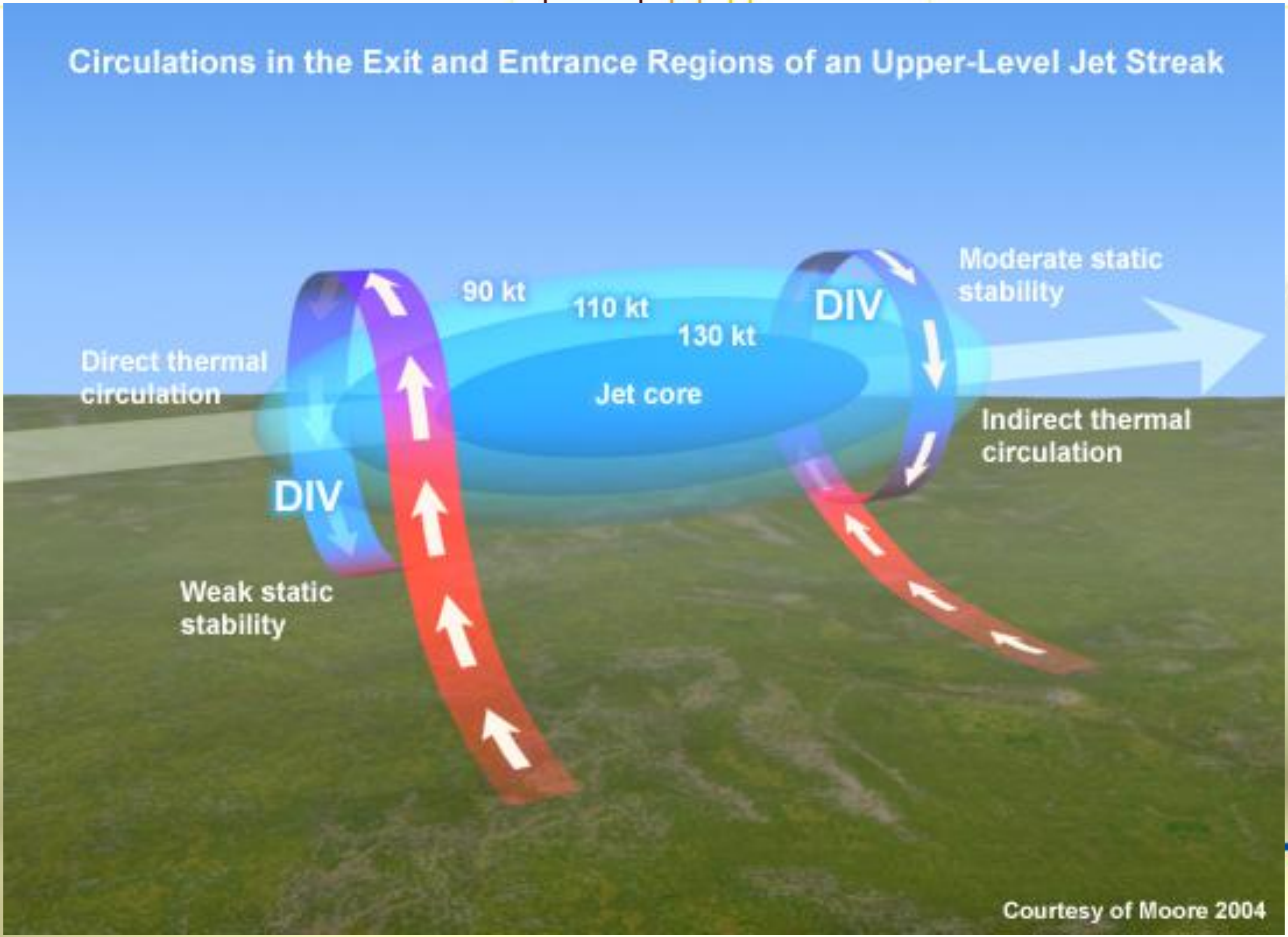
The left exit region of a jet, where upper-level divergence is present, is a region favourable for convection.



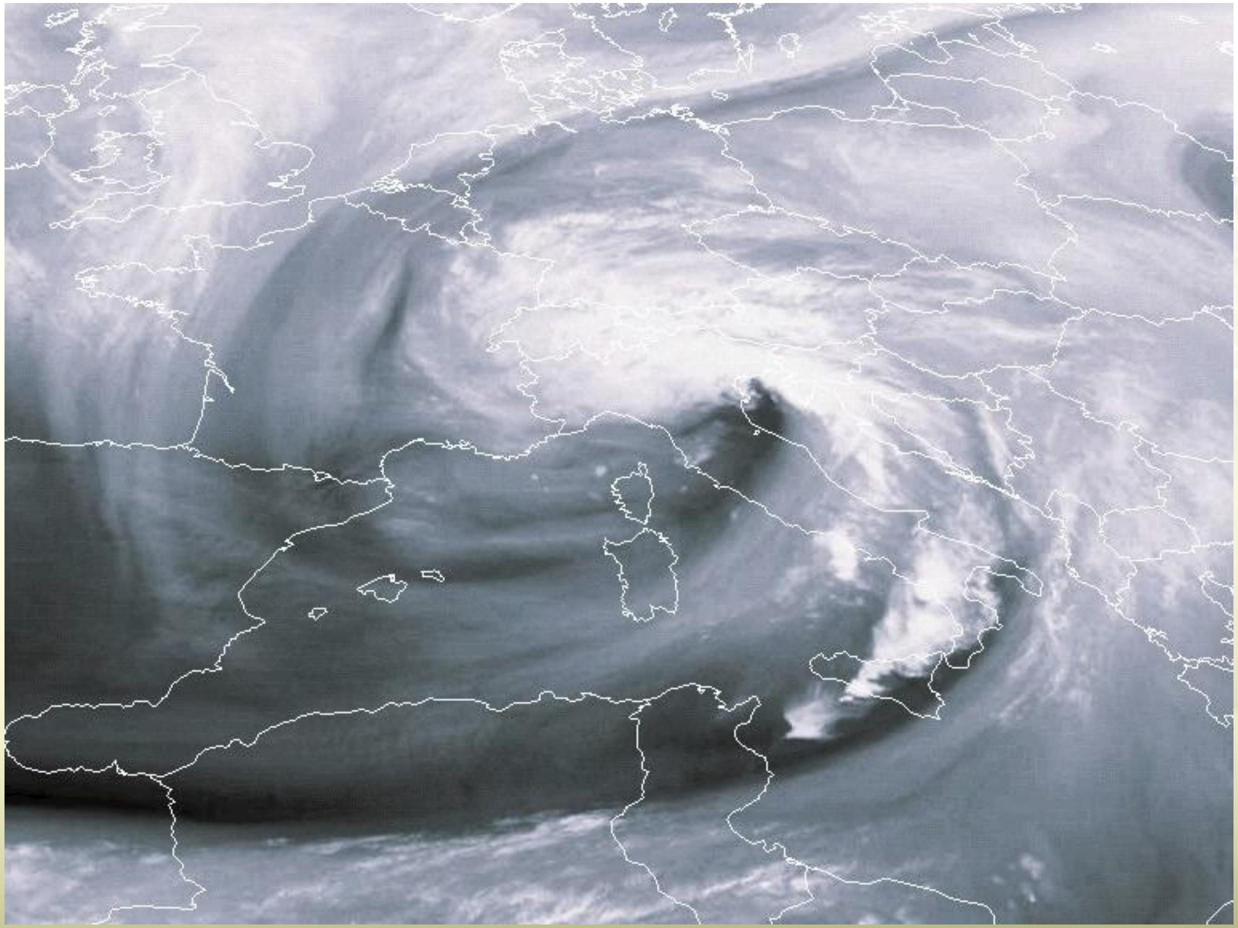
Cross-section of wind



Jet Streak


Circulations in the Exit and Entrance Regions of an Upper-Level Jet Streak
90 kt
110 kt
130 kt
DIV
Moderate static stability
Direct thermal circulation
Jet core
Indirect thermal circulation
DIV
Weak static stability
Courtesy of Moore 2004

Severe Convection, Mediterranean Sea



Met-8, 3-4 October 2005, WV6.2 channel

Severe Convection: Example

Met-6, 23-24 June 2002, WV channel (rapid scans)

CLICK HERE

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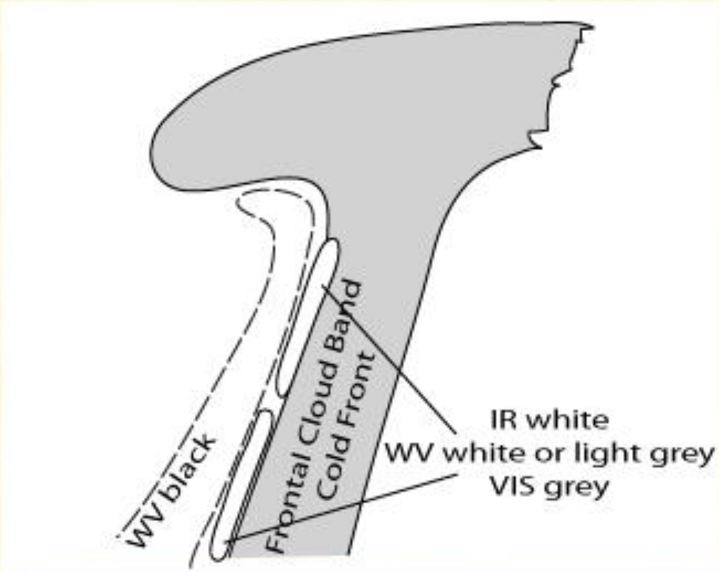
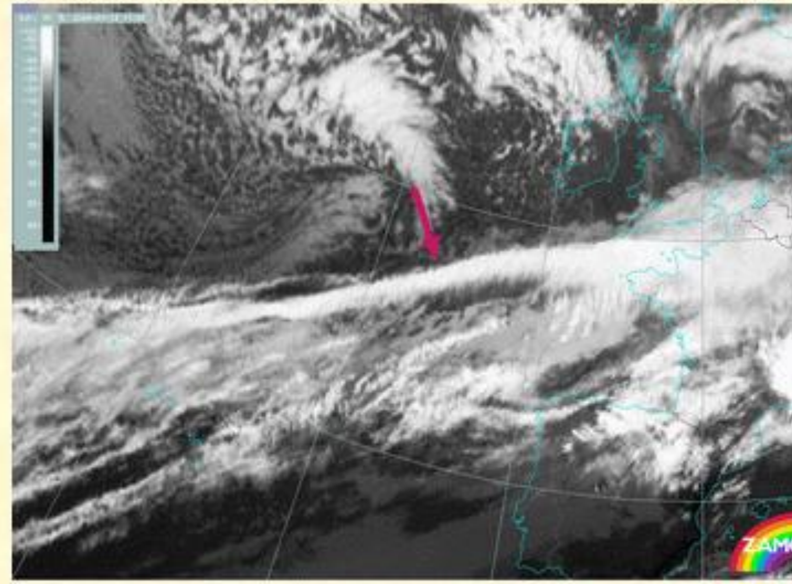
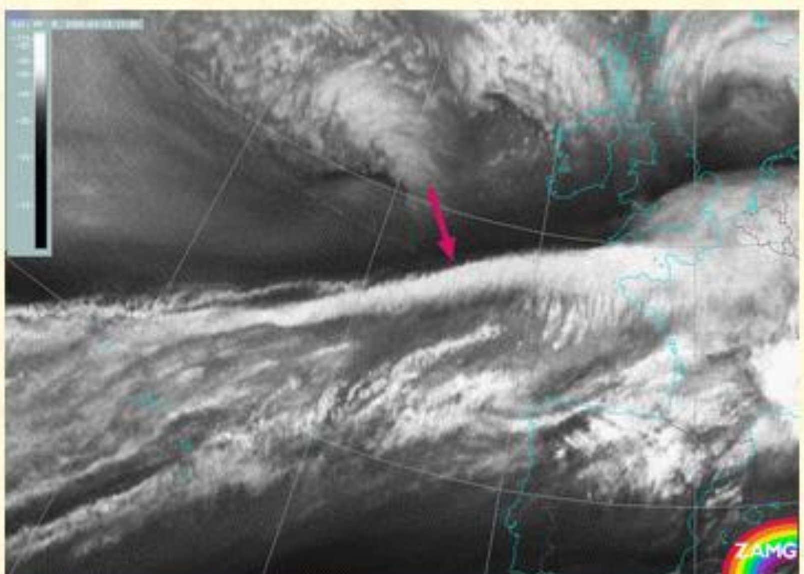
Jet Fibres - Cloud Structure In Satellite Images

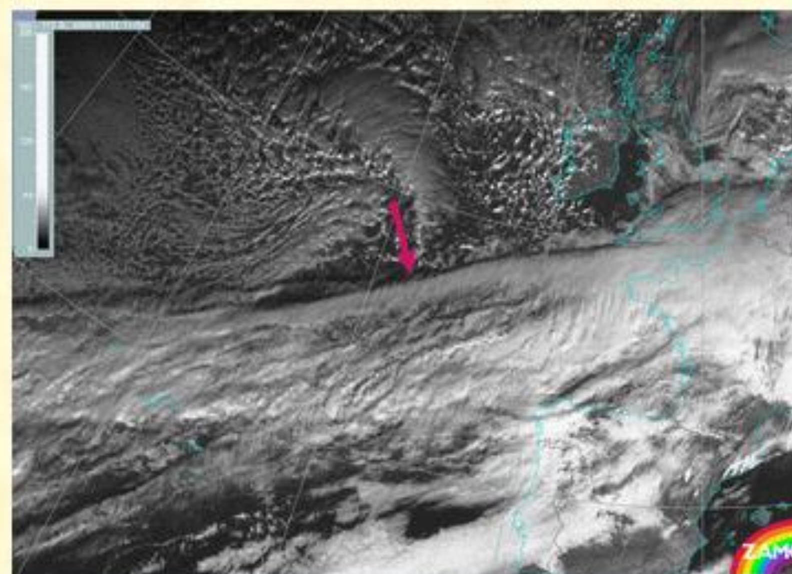


13 January 2004/11.00 UTC - Meteosat IR image



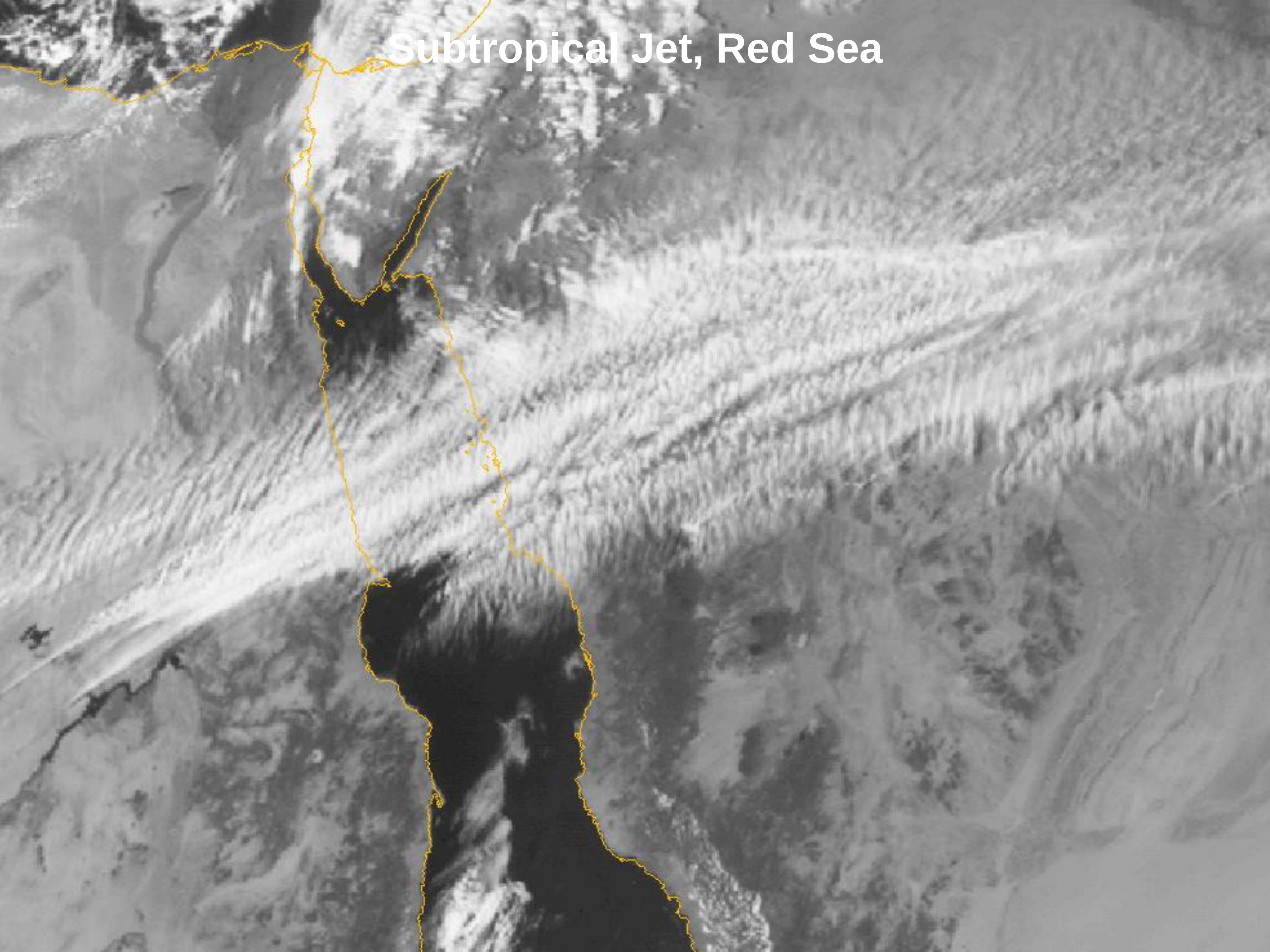


13 January 2004/11.00 UTC - Meteosat WV image

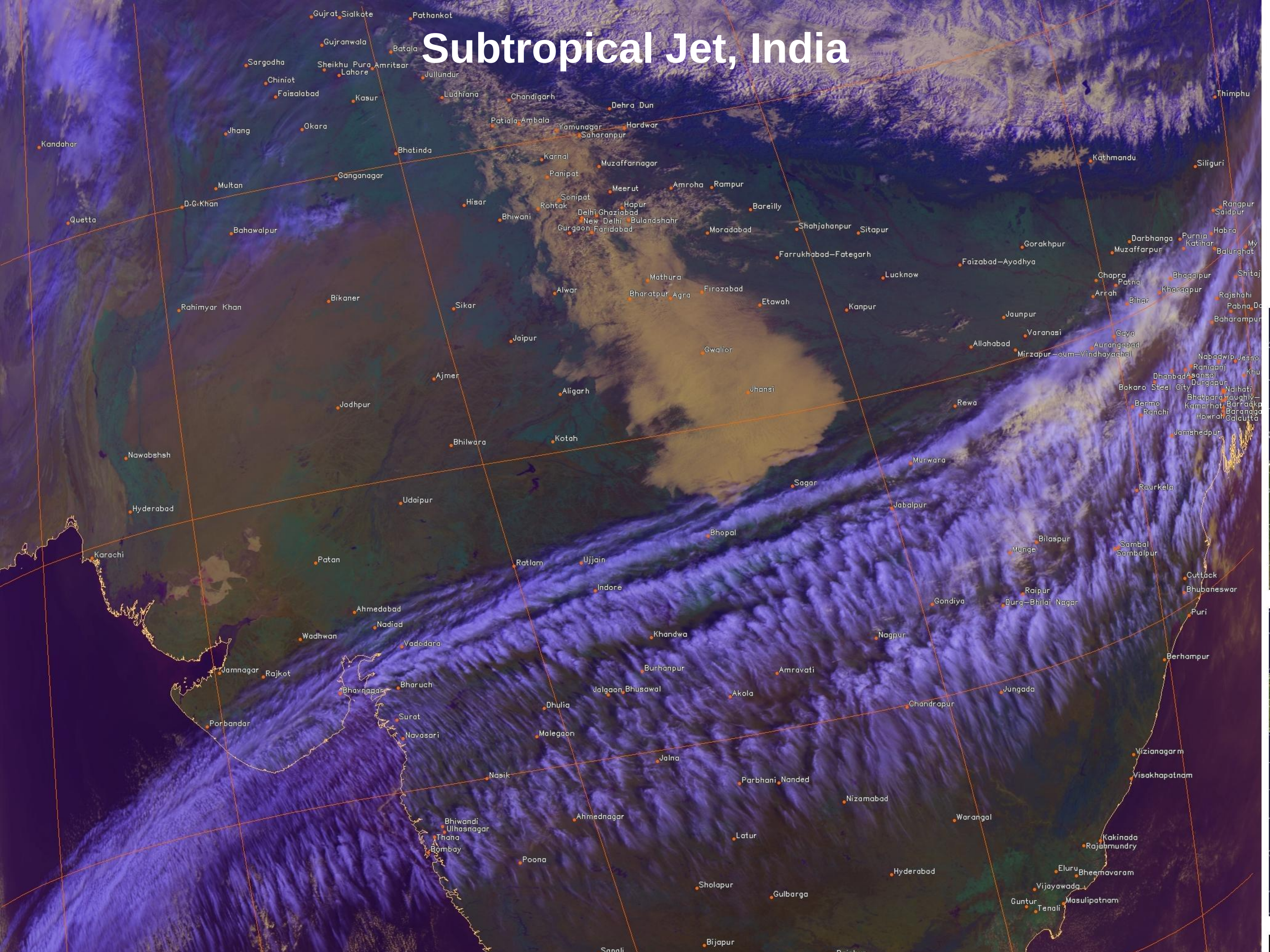


13 January 2004/11.00 UTC - Meteosat VIS image

Subtropical Jet, Red Sea

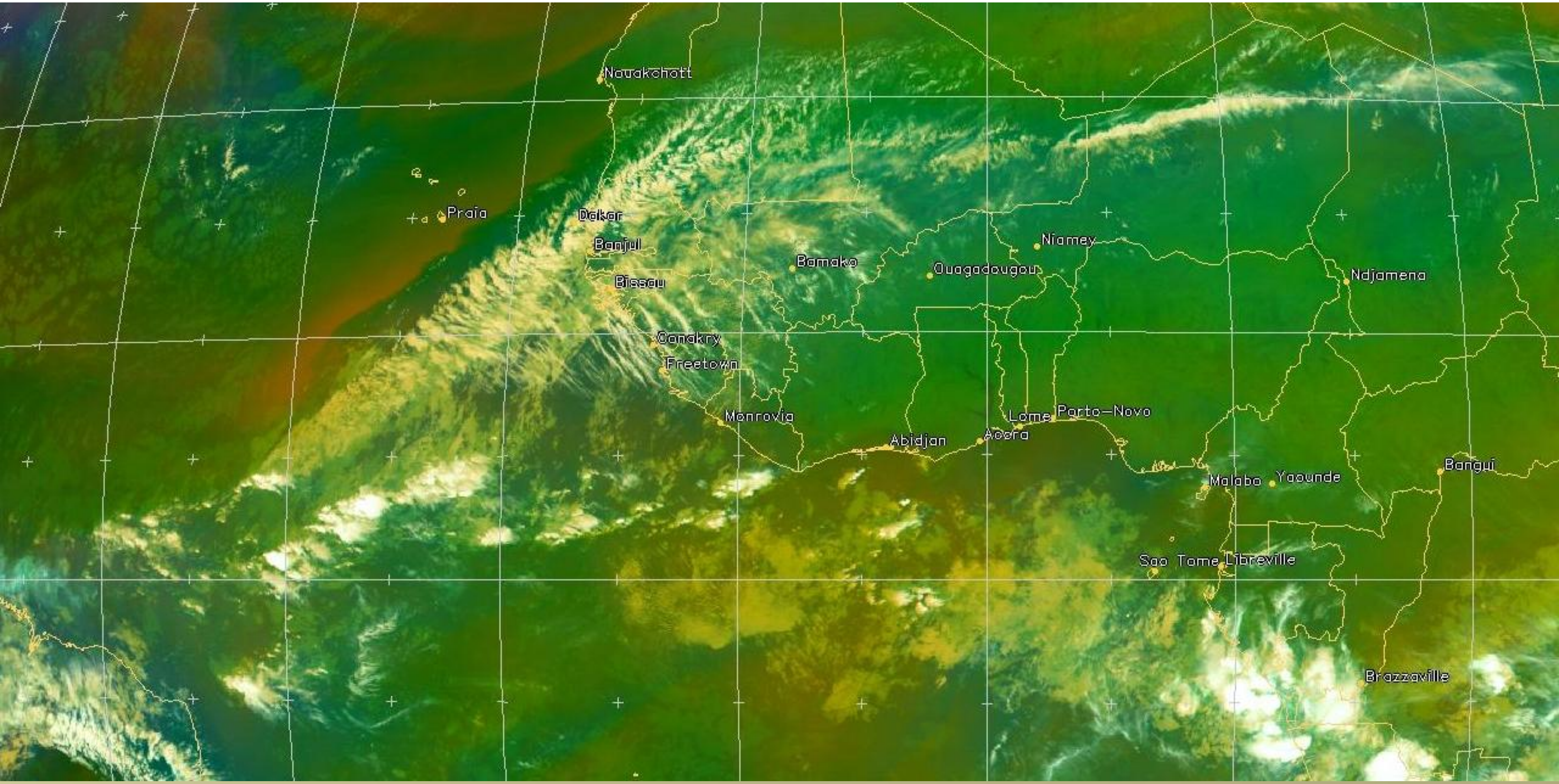


Subtropical Jet, India

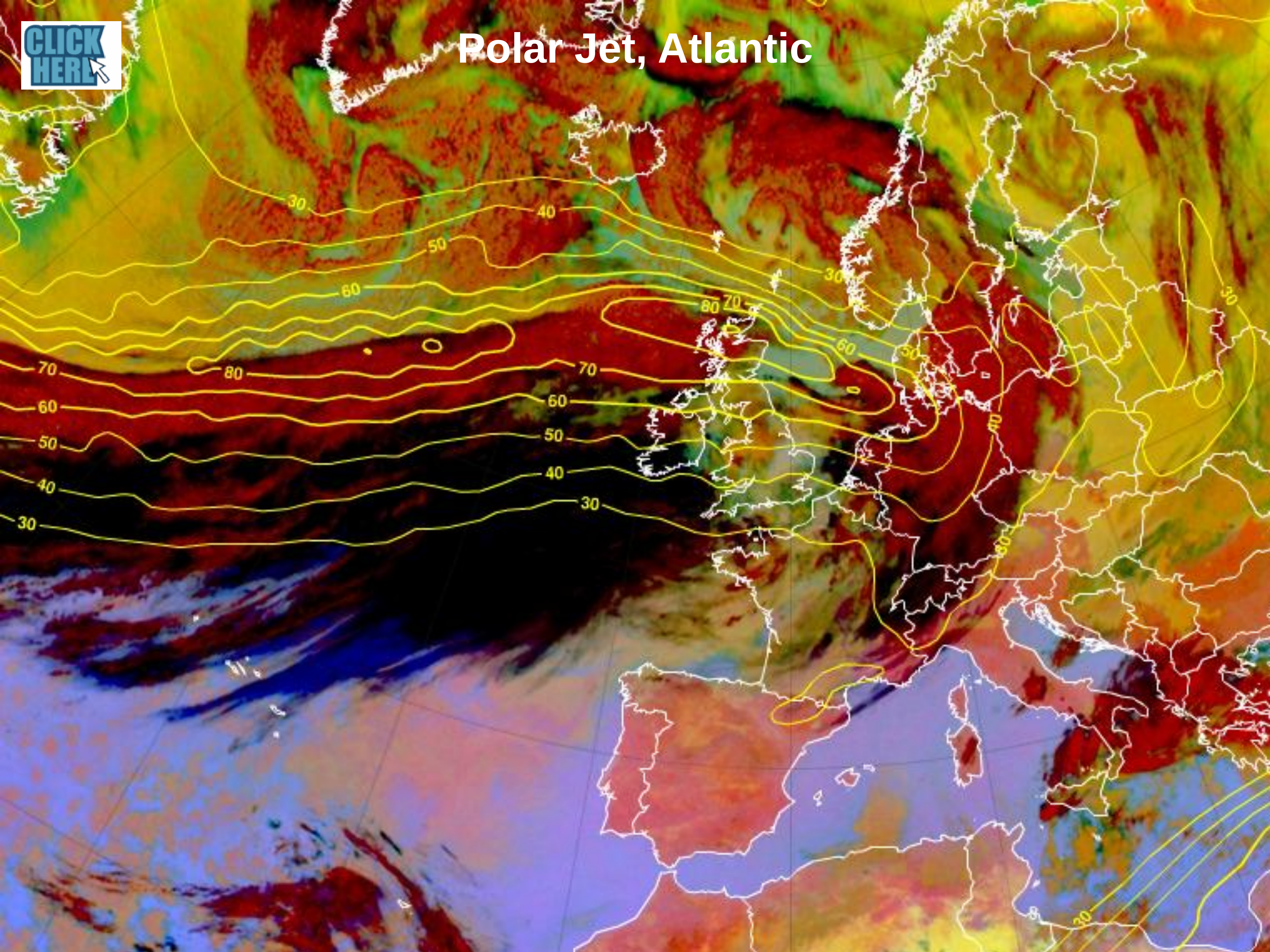


Subtropical Jet, Sahara

Subtropical Jet, West Africa

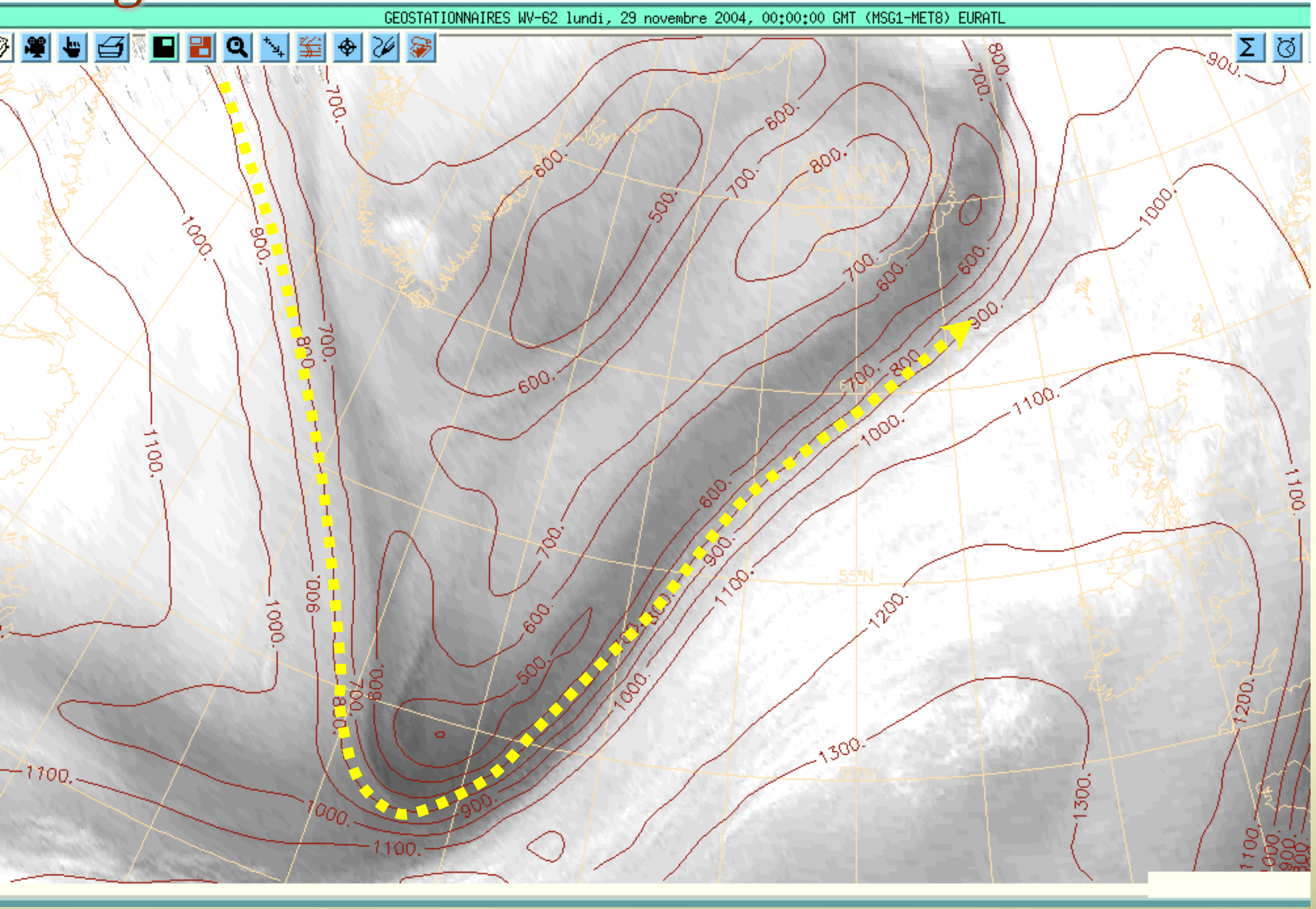


Polar Jet, Atlantic



Potential Vorticity

Heights of the constant surface of PV = 1.5 PVU



The jet stream axes are present along the boundaries of different moisture regimes produced by significant tropopause foldings, indicated by strong gradient in geopotential of the 1.5 PVU surface.

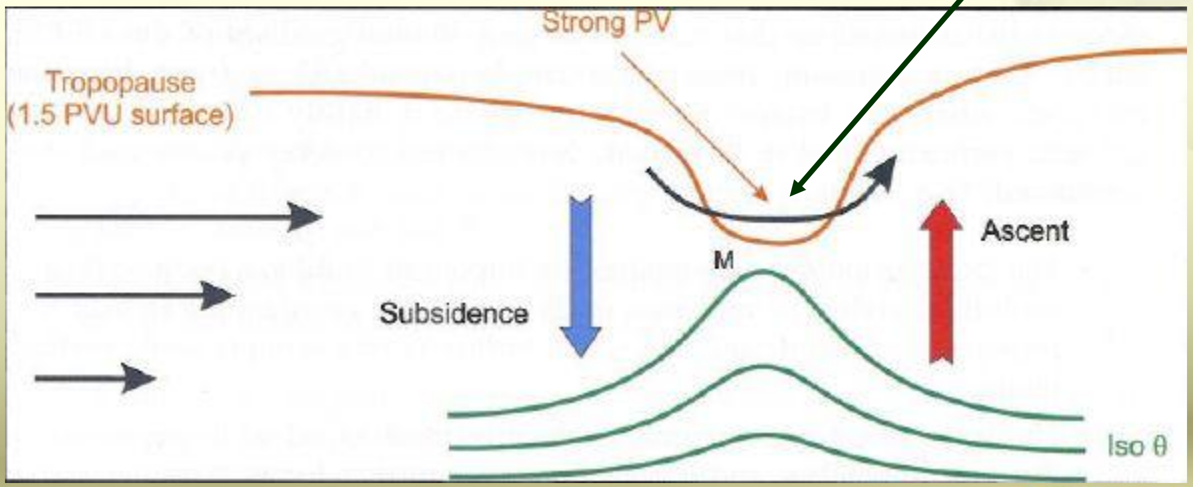
PV Anomalies
Tropopause Dynamic Anomalies

Potential Vorticity (PV)

= Stability * Absolute vorticity

- **Growing from ground to stratosphere**
- **Conserved along the flow (except for turbulence or heating)**
- **Positive PV anomalies induce ascents ahead**

Dry stratospheric air



(Isentropic) Potential Vorticity (PV)

$$IPV = -g\,(\zeta_{\Theta} + f)\frac{\partial \Theta}{\partial p}$$

f	Coriolis parameter
g	gravitational acceleration
p	pressure
IPV	potential vorticity
Θ	potential temperature
ζ_{Θ}	relative isentropic vorticity

(Isentropic) Potential Vorticity (PV)

- The isentropic potential vorticity (IPV) is the potential vorticity calculated on an isentropic surface (constant θ).
- The two main advantages of the potential vorticity (with certain assumptions) are: conservation and invertibility

(Isentropic) Potential Vorticity (PV)

- Under the assumption that the relative vorticity is zero, the potential vorticity increases rapidly from the troposphere to the stratosphere due to the significant change of the static stability
- Typical changes of the potential vorticity within the area of the tropopause are from 1 (tropospheric air) to 4 (stratospheric air) IPV units (*10-6 m-2 s-1 K kg-1)
- Today in most of the literature the so-called IPV anomaly, which separates the tropospheric from the stratosperic air is defined by 2 IPV (or 1.5 IPV) units
- This surface is also referred to as the height of the dynamical tropopause

(Isentropic) Potential Vorticity (PV)

- Air masses with IPV values exceeding 2 (1.5) units indicate therefore by definition stratospheric air working its way down at the rear end of (cold) fronts

- Usually this dry intrusion extends down to 300 hPa, sometimes to 400 hPa

- In cases of rapid cyclogenesis the dry intrusion can extend down to a level of 500 hPa

(Isentropic) Potential Vorticity (PV)

- Many isolines close to the IPV = 2 unit line indicate a steep tropopause orography
- This steepness can be more easily visualized if the height of the IPV = 2 unit surface is drawn, instead of IPV values at a certain isentropic surface
- In general, a steep isentropic potential vorticity gradient is associated with strong dynamic development in the tmosphere

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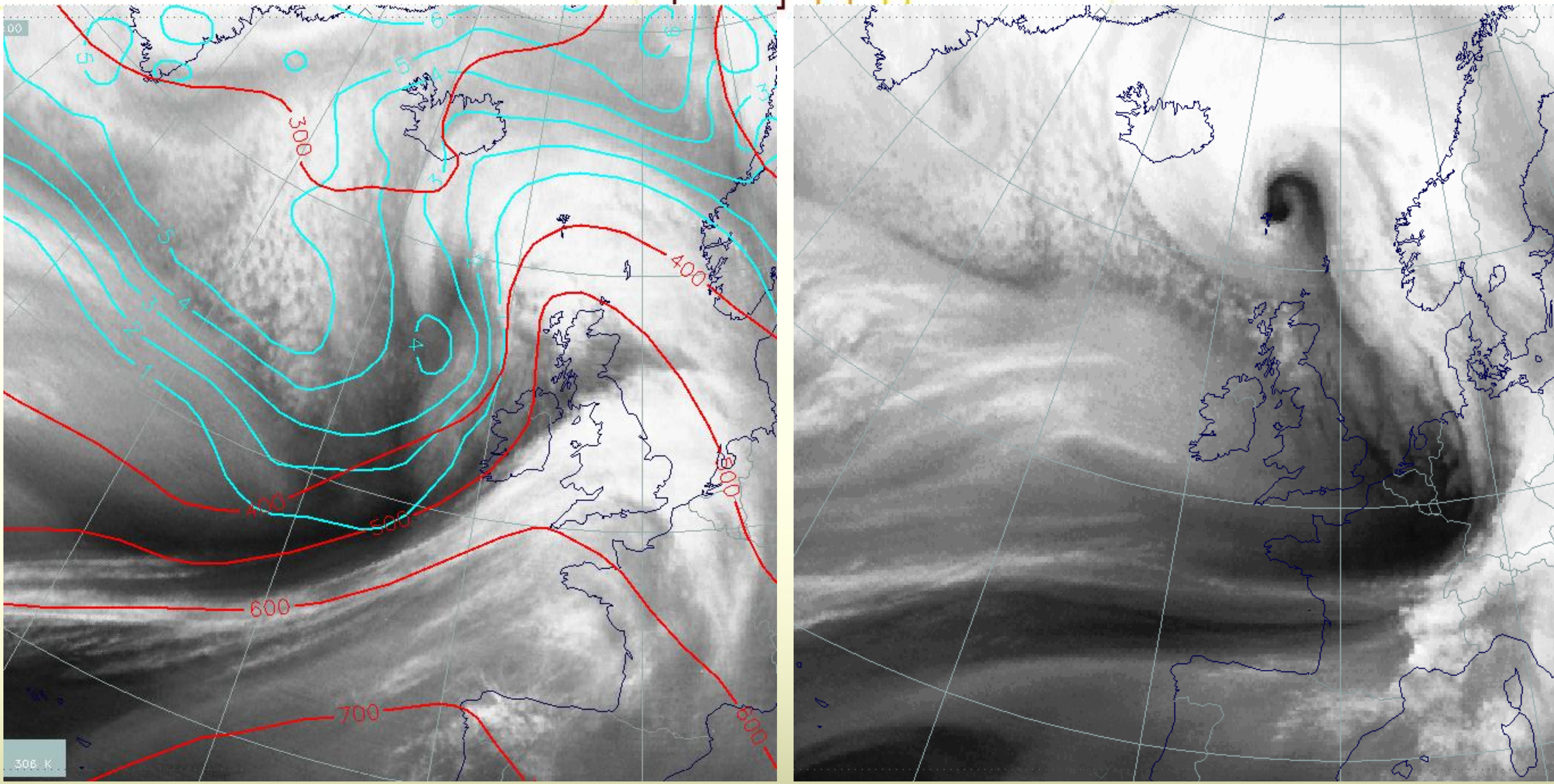
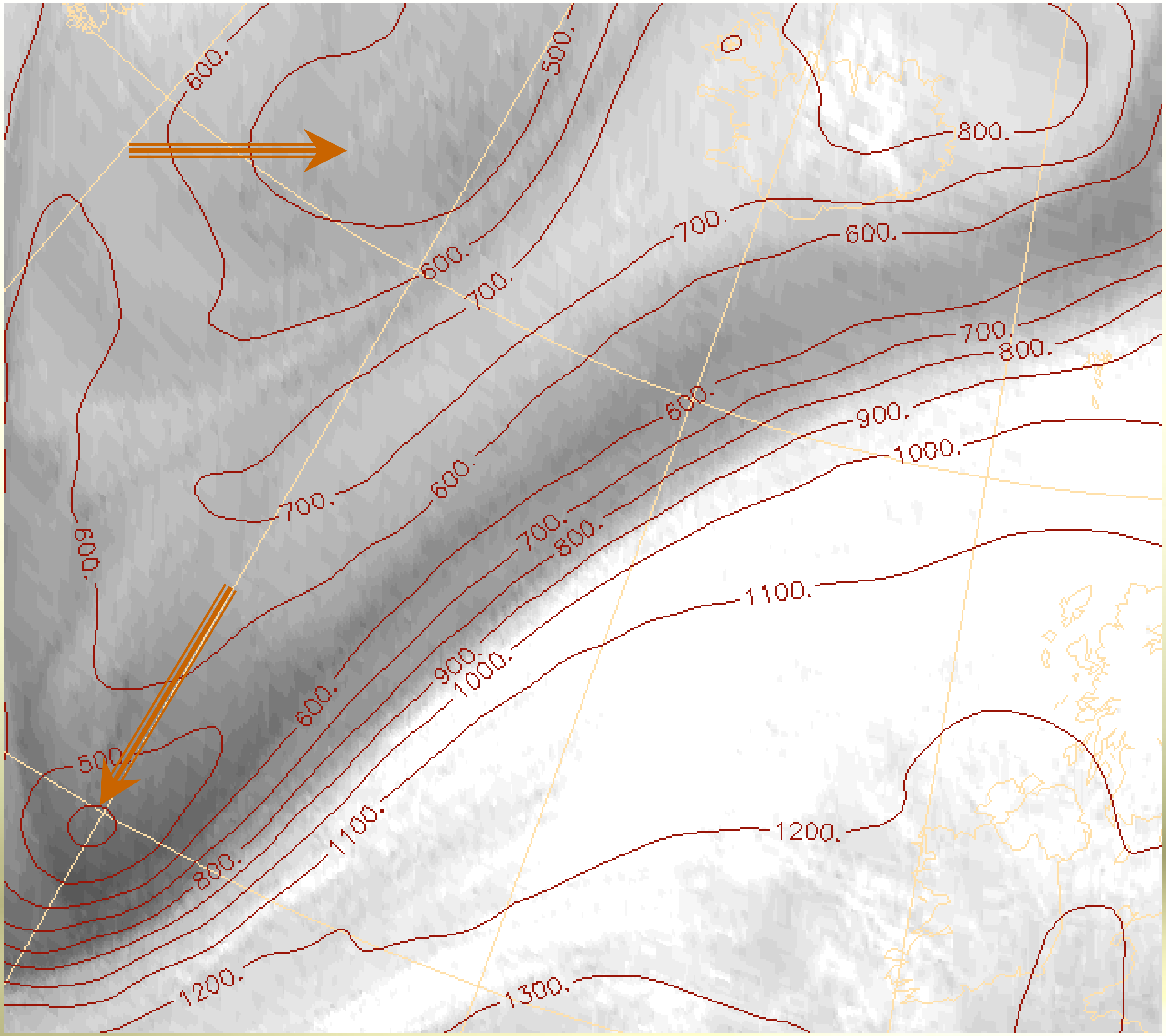
(Isentropic) Potential Vorticity (PV)



Left: 19 February 1997/12 UTC - WV; isentropic potential vorticity on the isentropic surface of THETA=306 K; lines: red: isobars, cyan: isentropic potential vorticity Right: 20 February 1997/00 UTC - WV

WV imagery and mid/upper level dynamical fields

6.2 µm image & 1.5 PVU surface heights



Low tropopause heights are correlated with the dark zones in the imagery.

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Potential Vorticity (PV) in Weather Forecasting

Bjoern Roesting
Met.no

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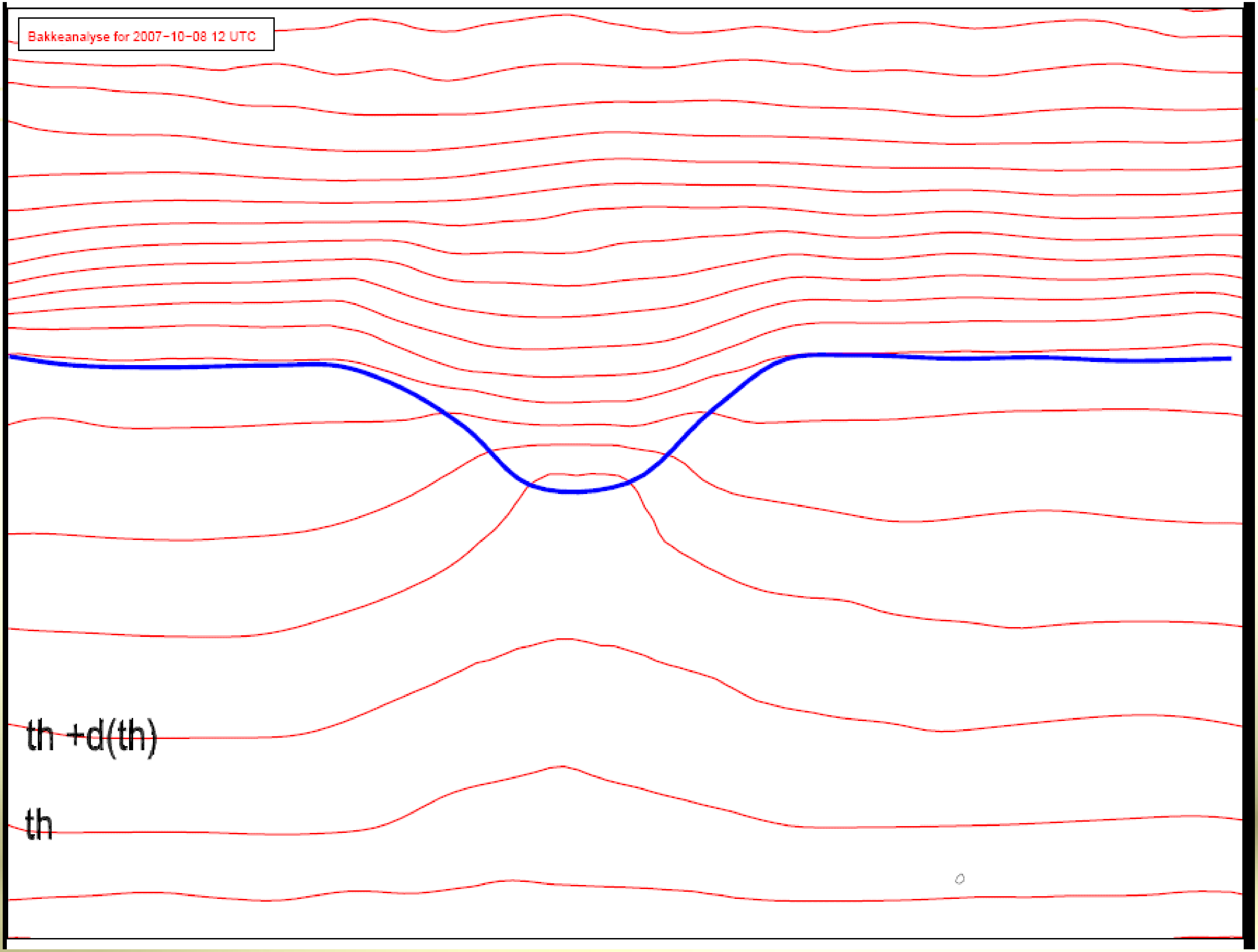
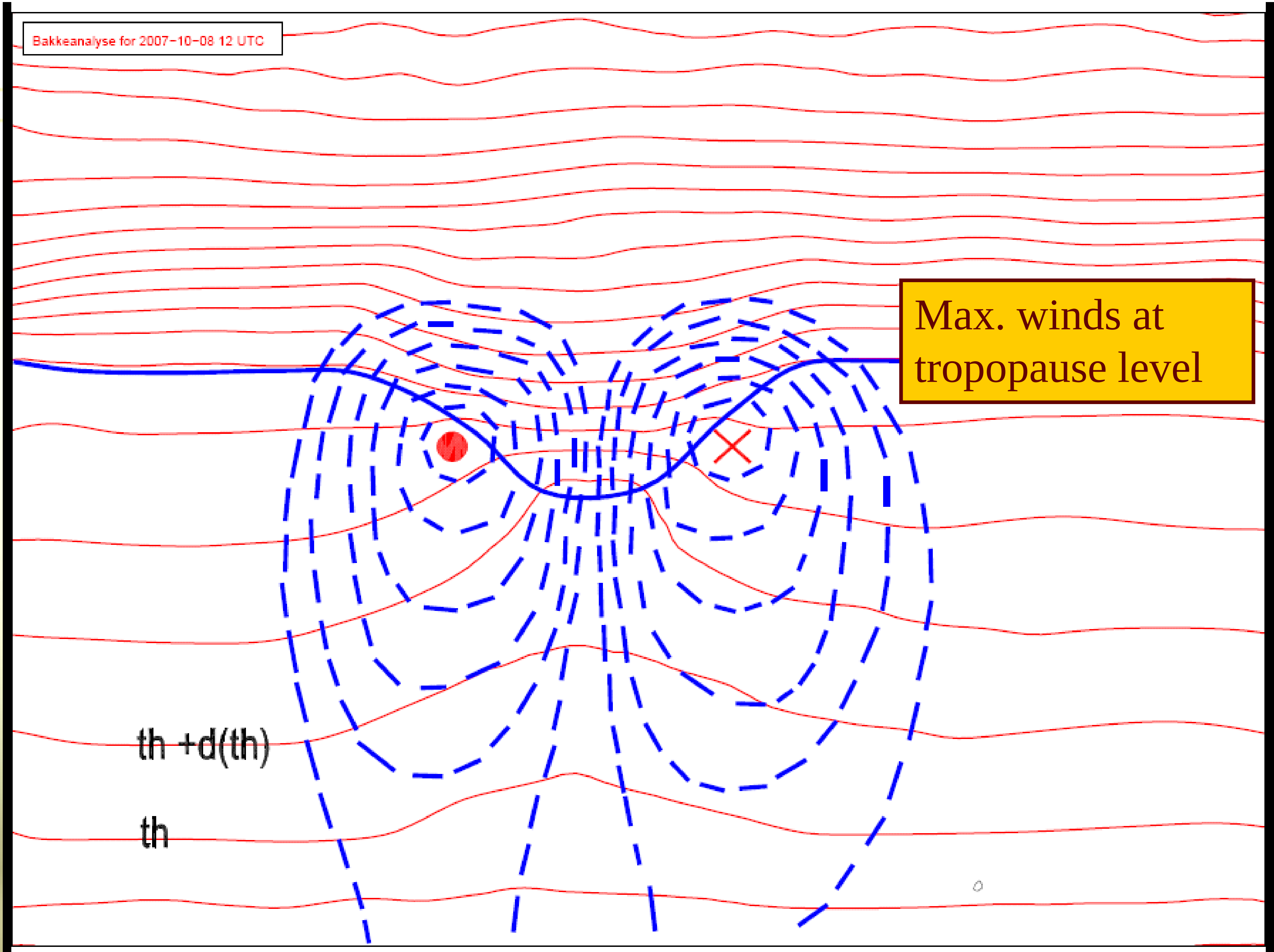
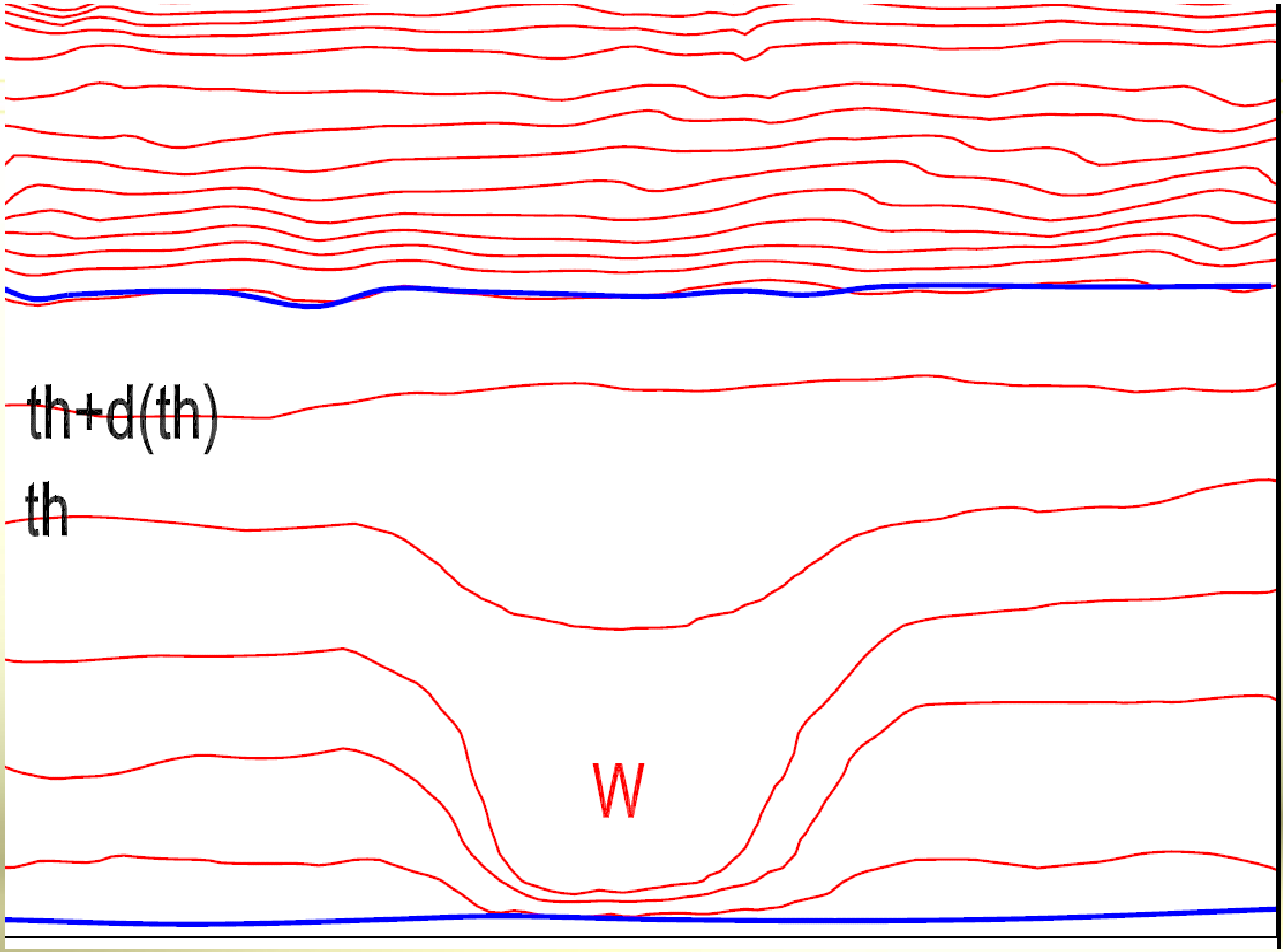
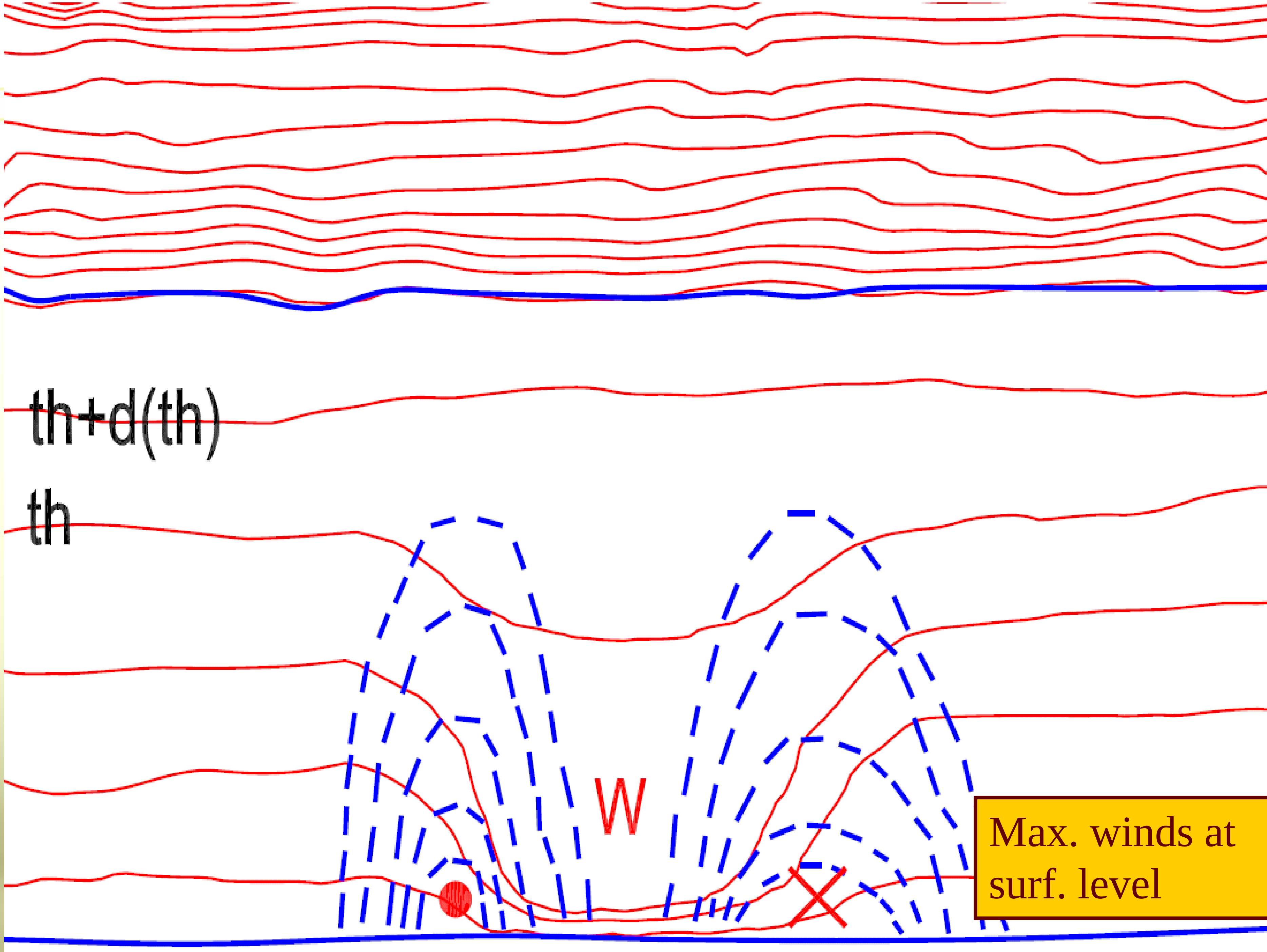
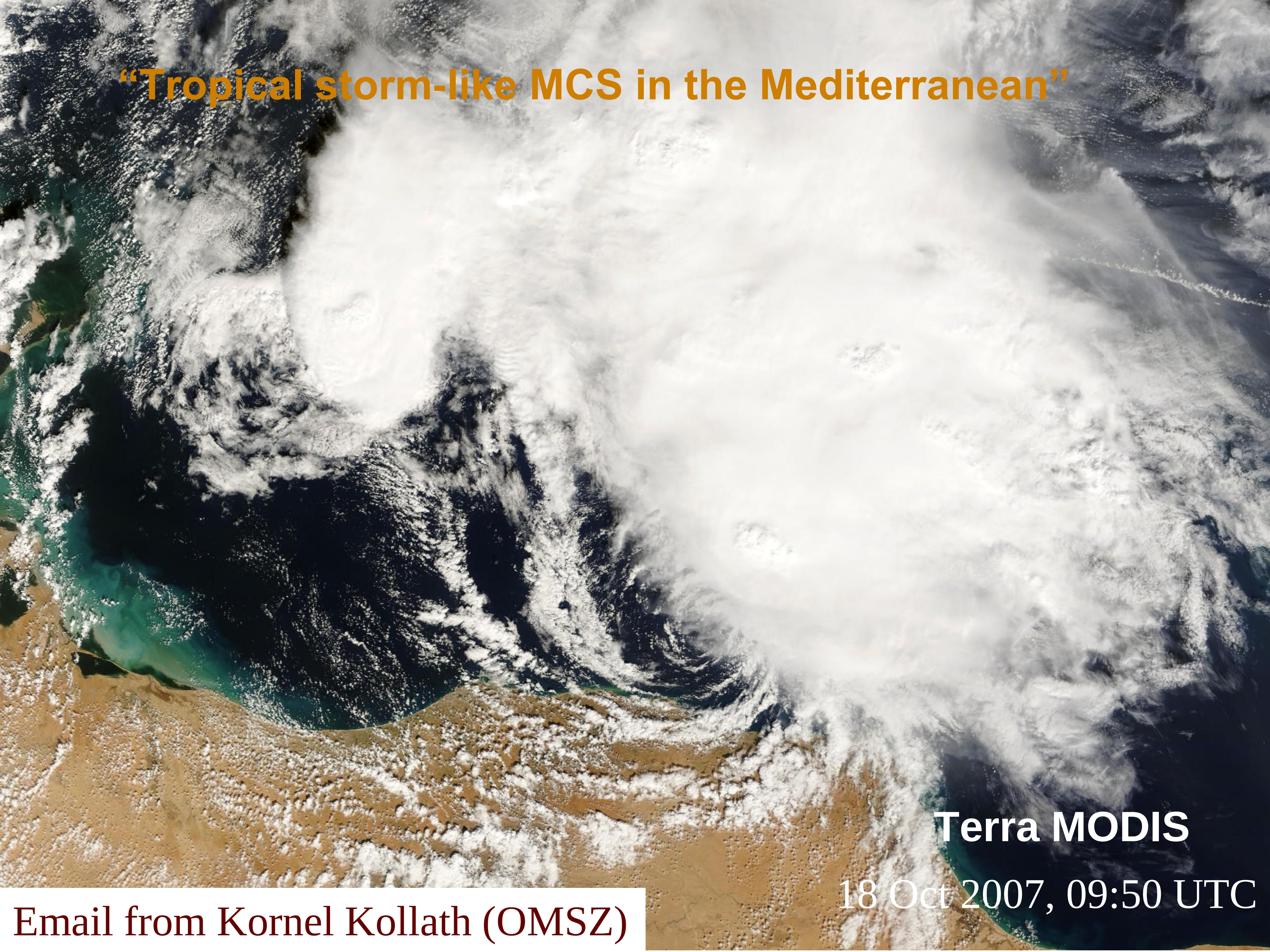

Bakkeanalyse for 2007-10-08 12 UTC
th +d(th)
th


Bakkeanalyse for 2007-10-08 12 UTC
Max. winds at tropopause level
th +d(th)
th


th+d(th)
th
W

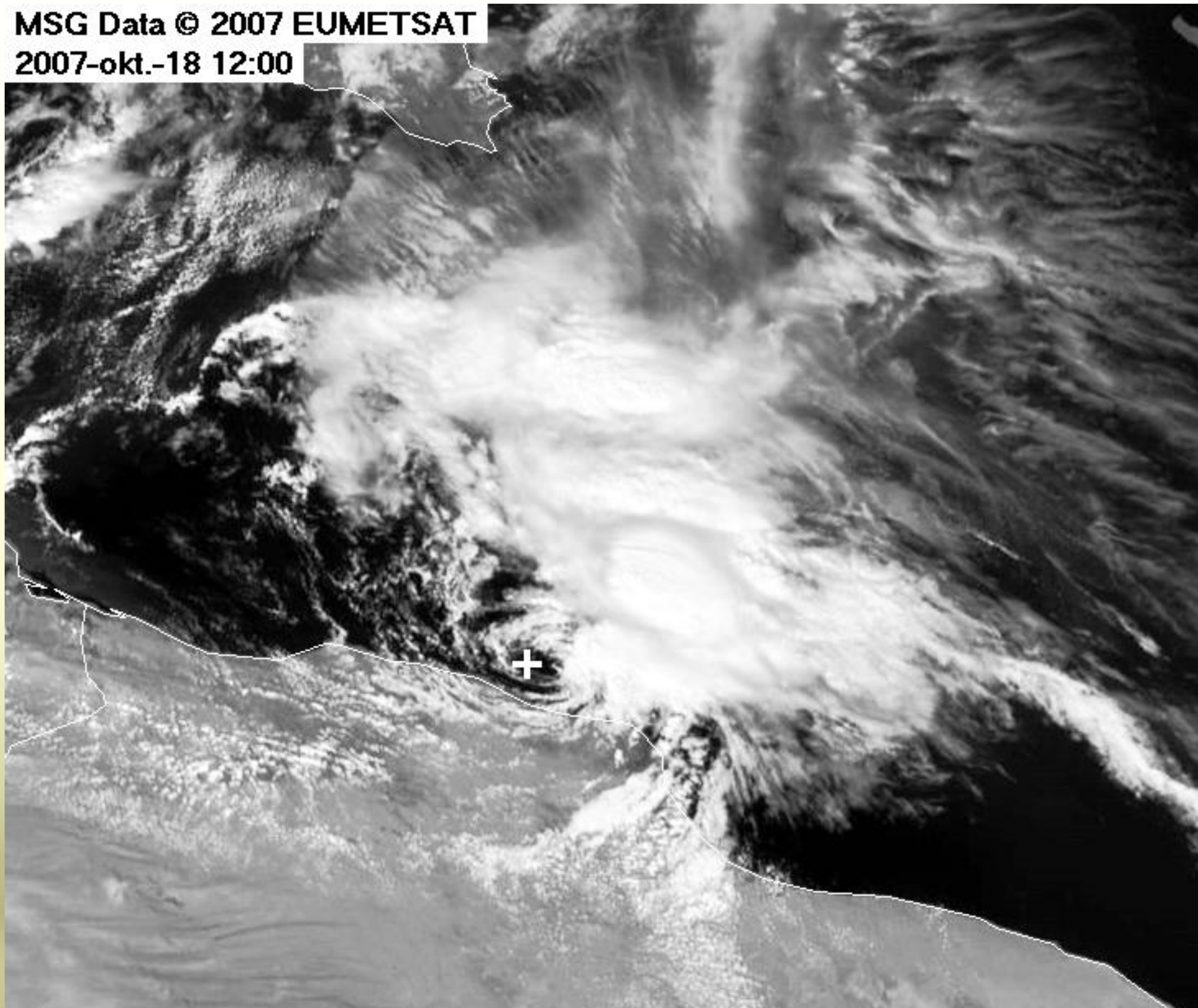

th+d(th)
th
W
Max. winds at surf. level

"Tropical storm-like MCS in the Mediterranean"

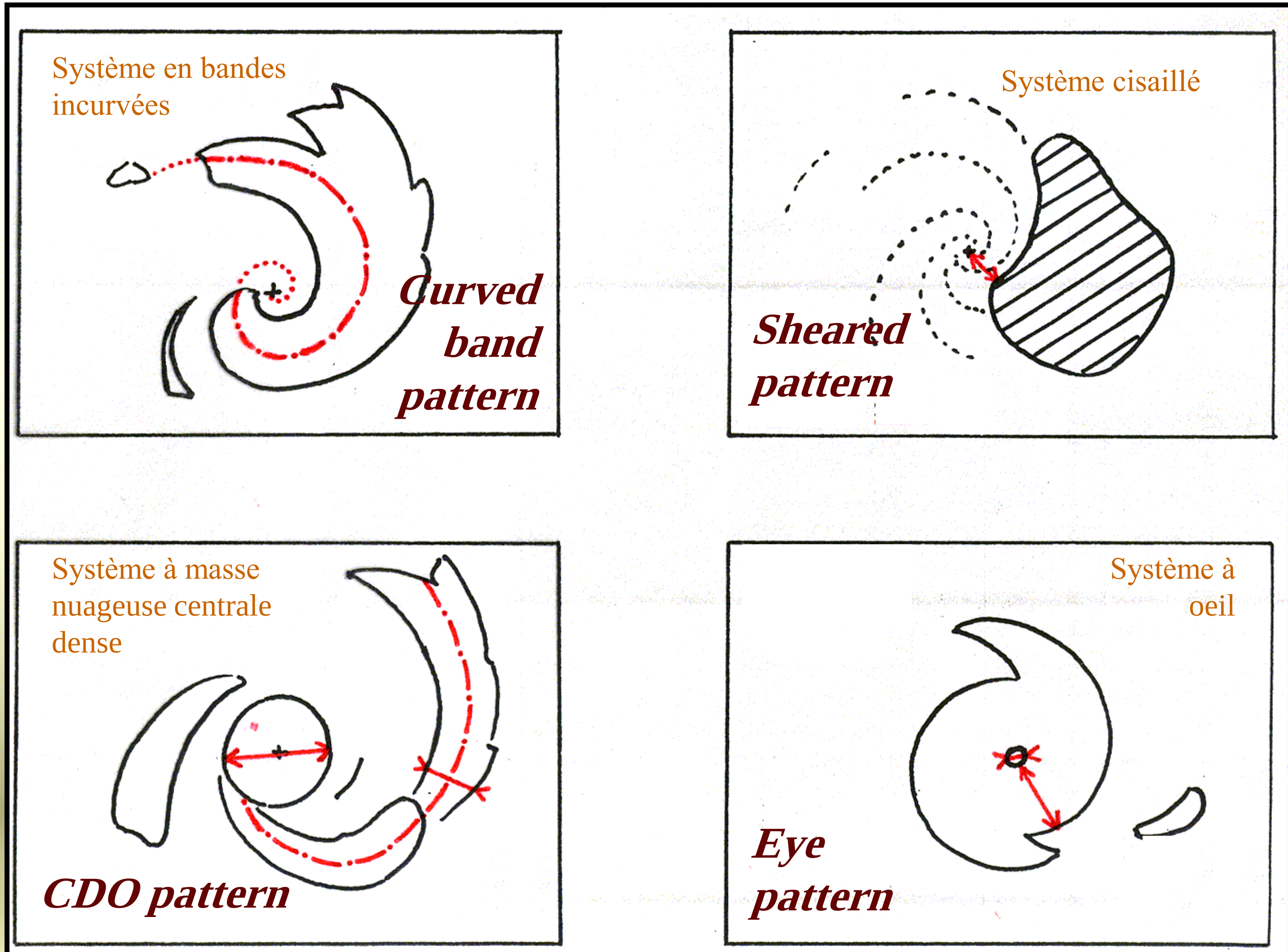


Email from Kornel Kollath (OMSZ)

Loop 07:30 – 15:45 UTC

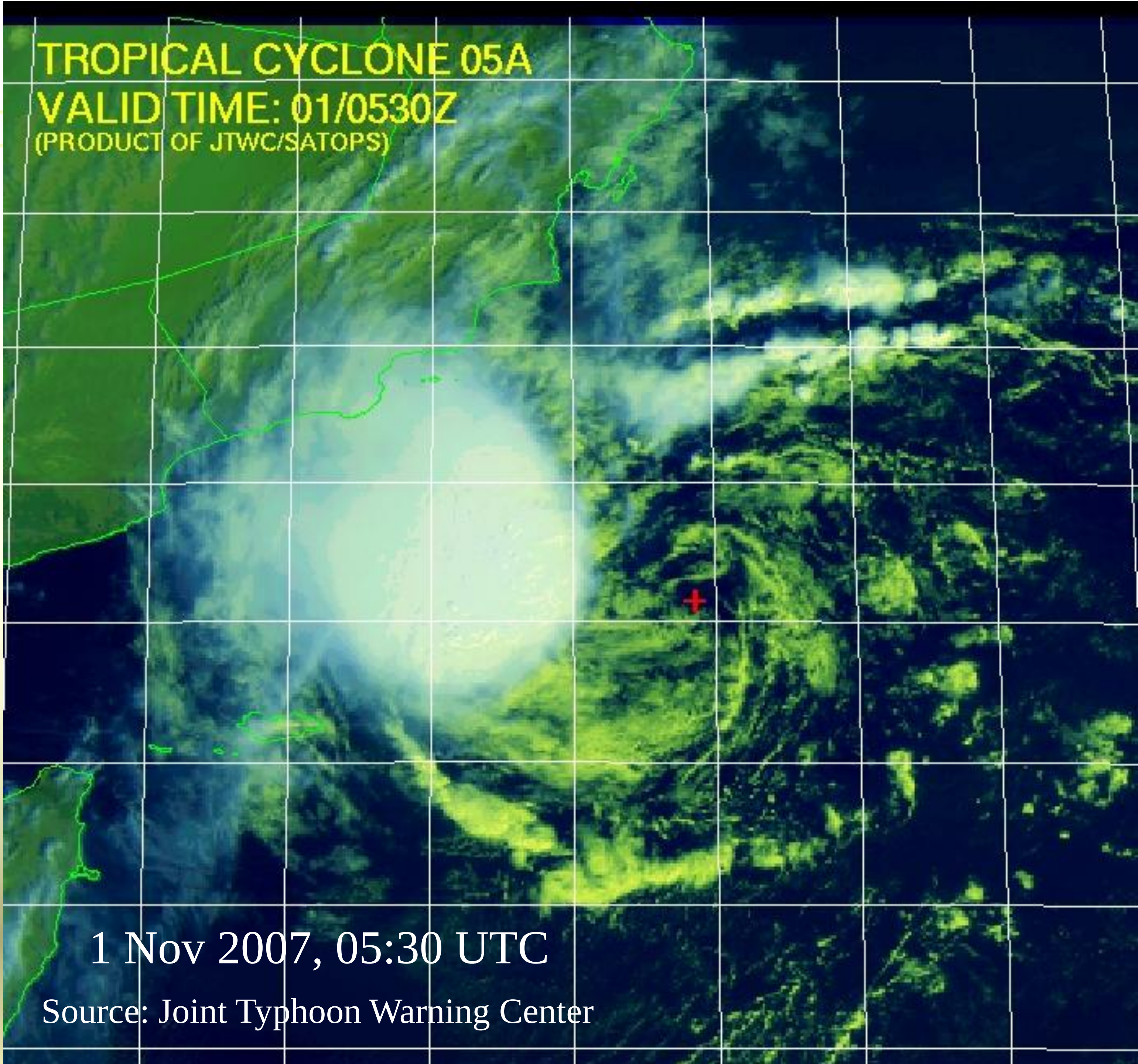


Tropical Cyclones: the four major cloud patterns



From: Philippe Caroff (Meteo France)

Which Pattern is this?



1 Nov 2007, 05:30 UTC

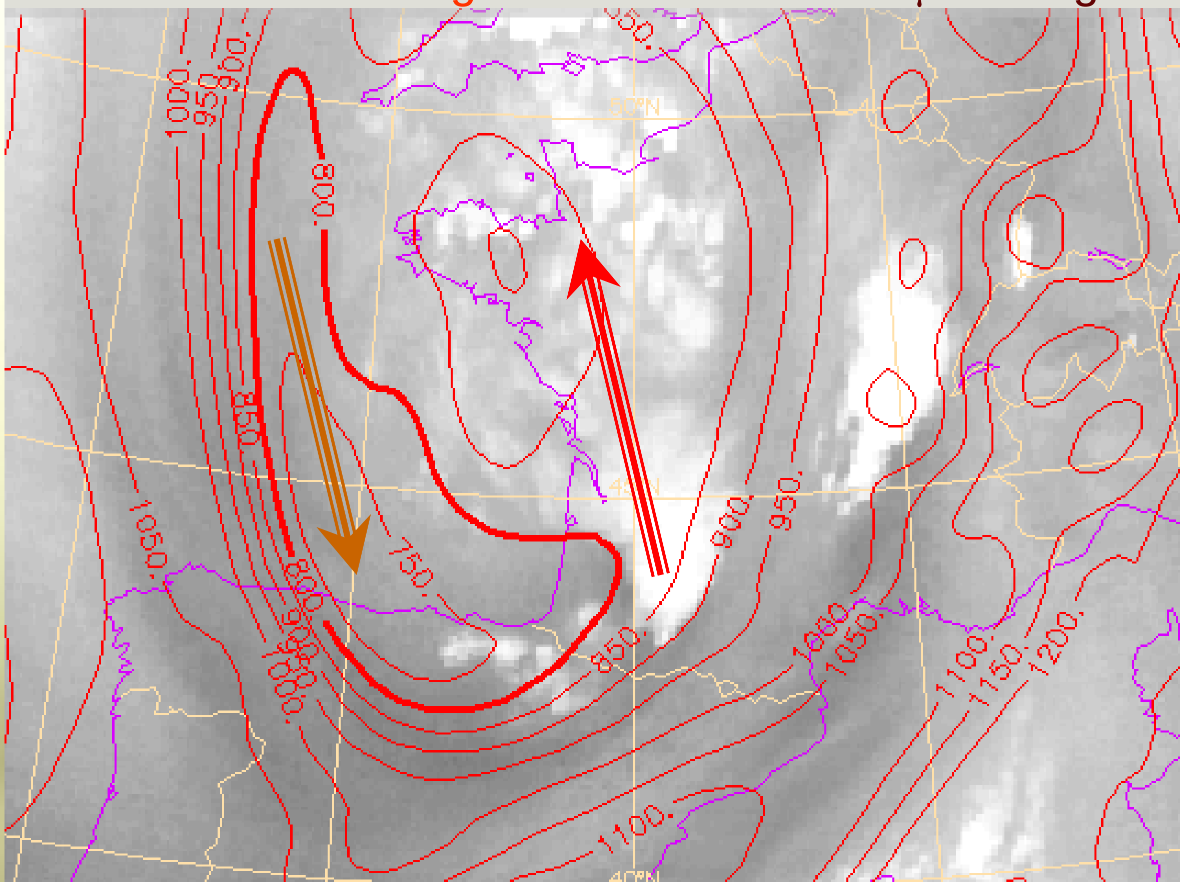
Source: Joint Typhoon Warning Center

Tropopause Dynamic Anomalies

At the low heights of the 1.5 PVU surface:

- **Descending motions in upper-mid troposphere**
- **Dark WV image grey shades**

1.5 PVU surface height contours over 6.2 µm image



At an area of a higher 1.5 PVU surface:

- **Ascending motion in upper-mid troposphere**
- **Light WV image grey shades**

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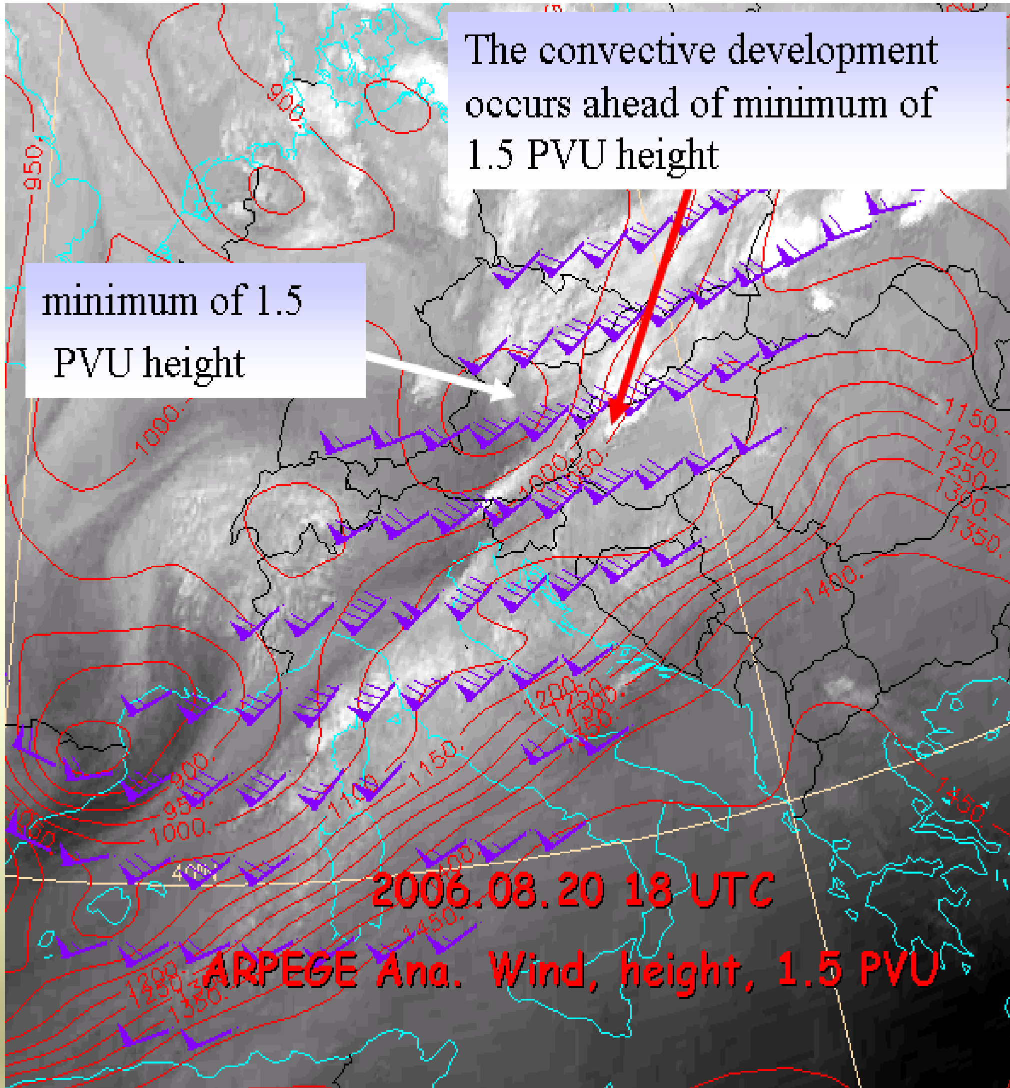
Budapest storm, 20 August 2006



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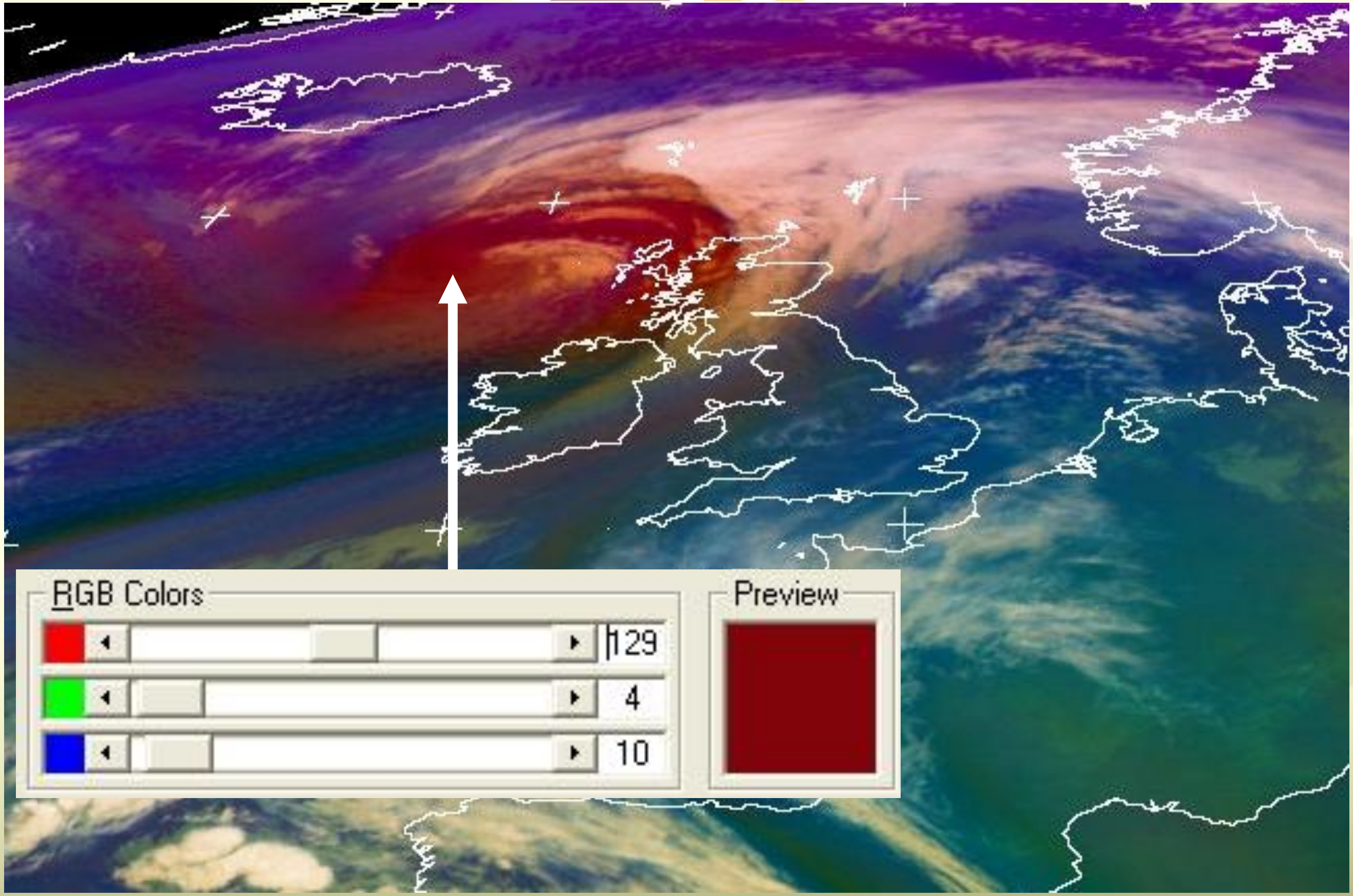
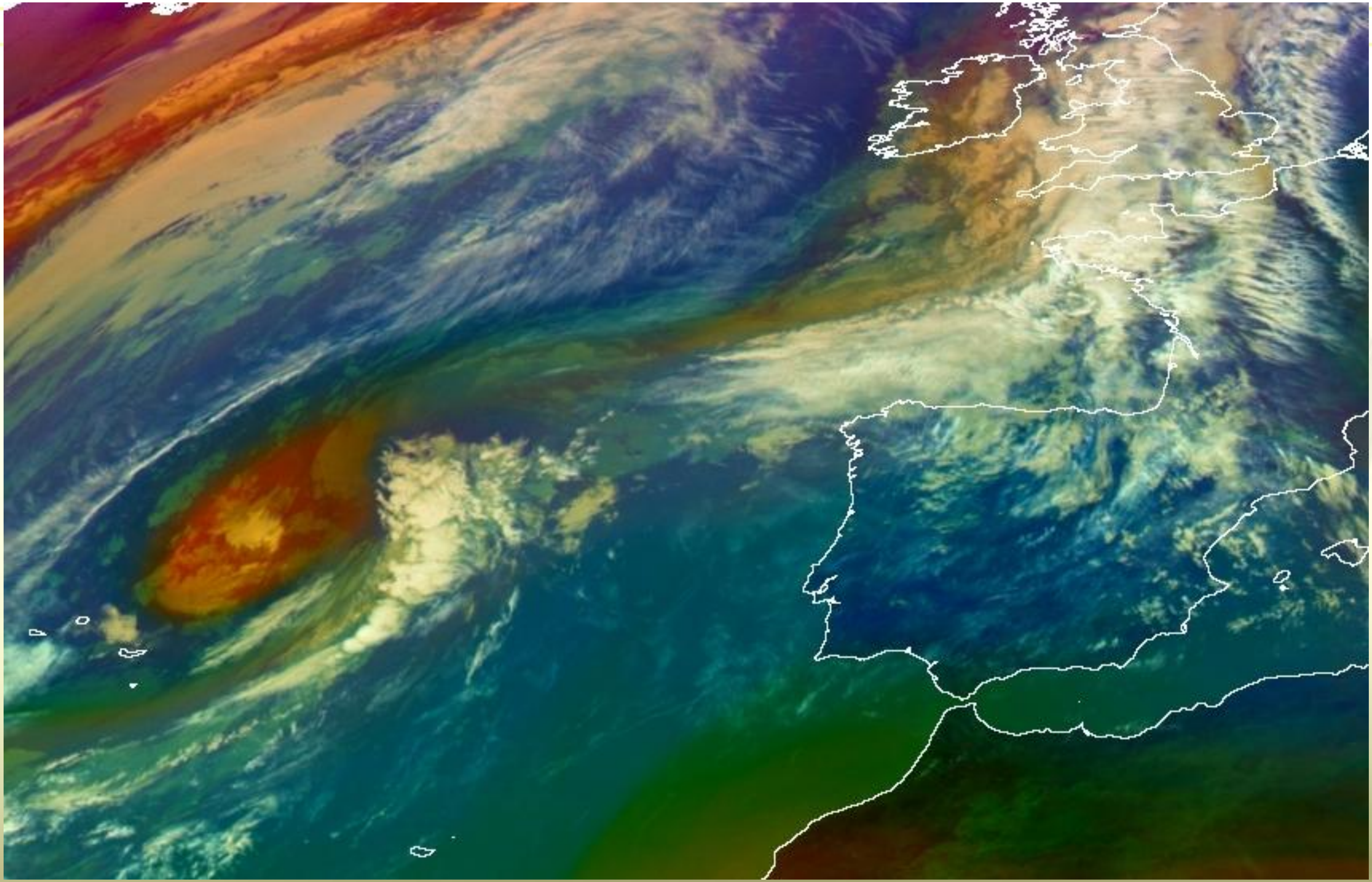
Tropopause Dynamic Anomalies seen in Airmass RGB



MSG-1, 30 October 2006, 20:00 UTC

EUMETSAT

Tropopause Dynamic Anomalies seen in Airmass RGB



MSG-1, 22 October 2007, 12:00 UTC

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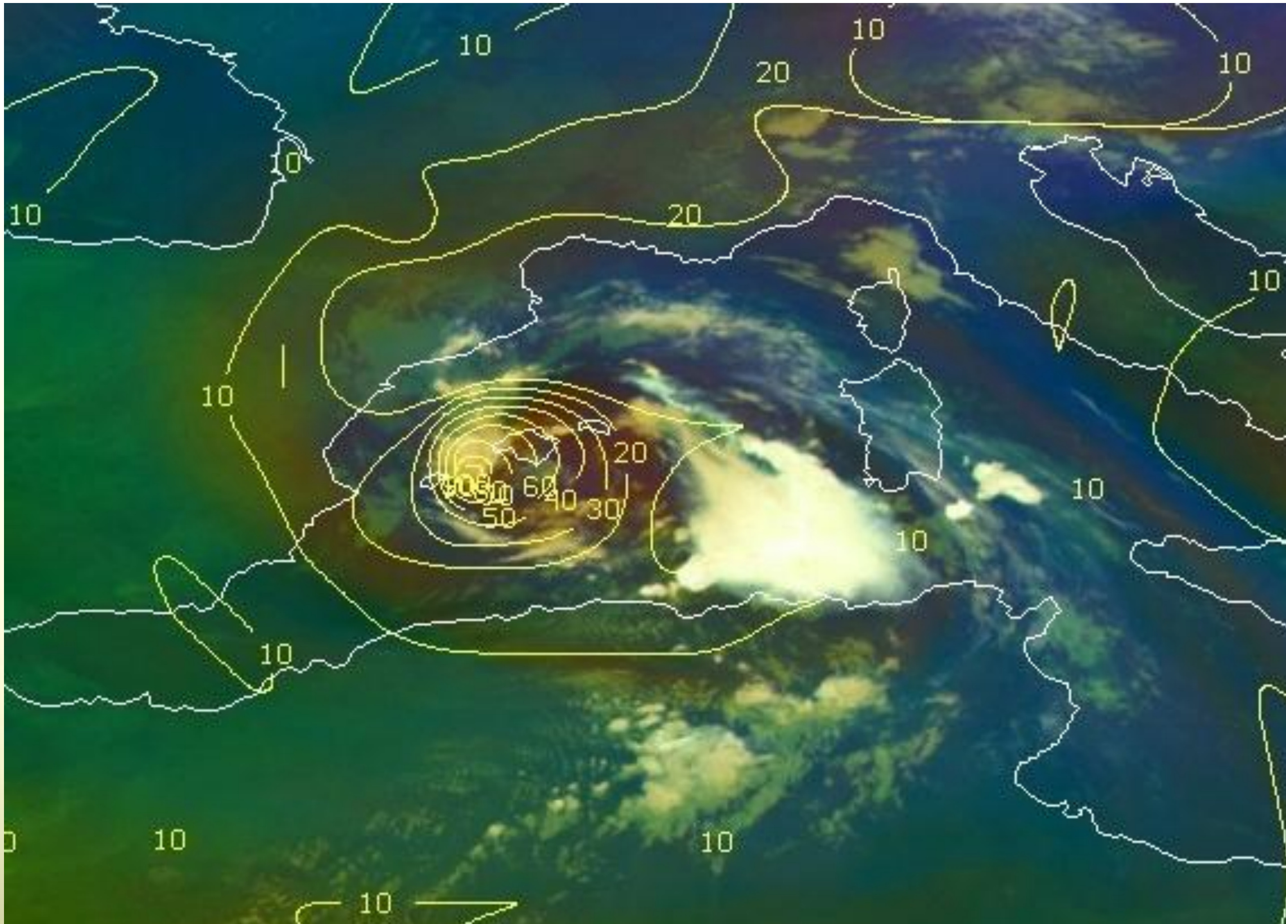
PV Anomaly (Cut-off Low) Mediterranean



MSG-1, 13 October 2006, 06:45 UTC
ECMWF PV Analysis 300 hPa

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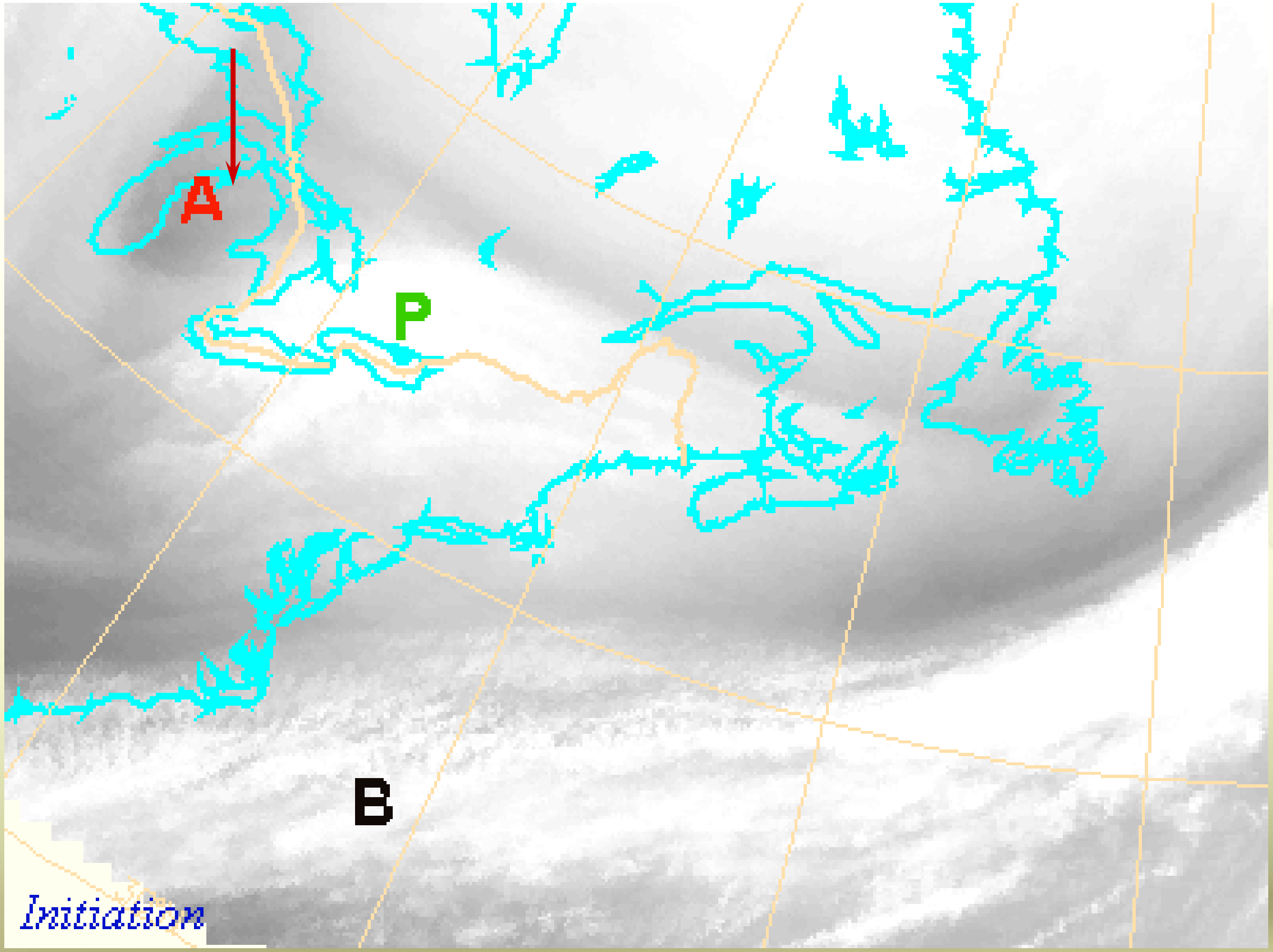
WV imagery patterns of cyclone dynamics



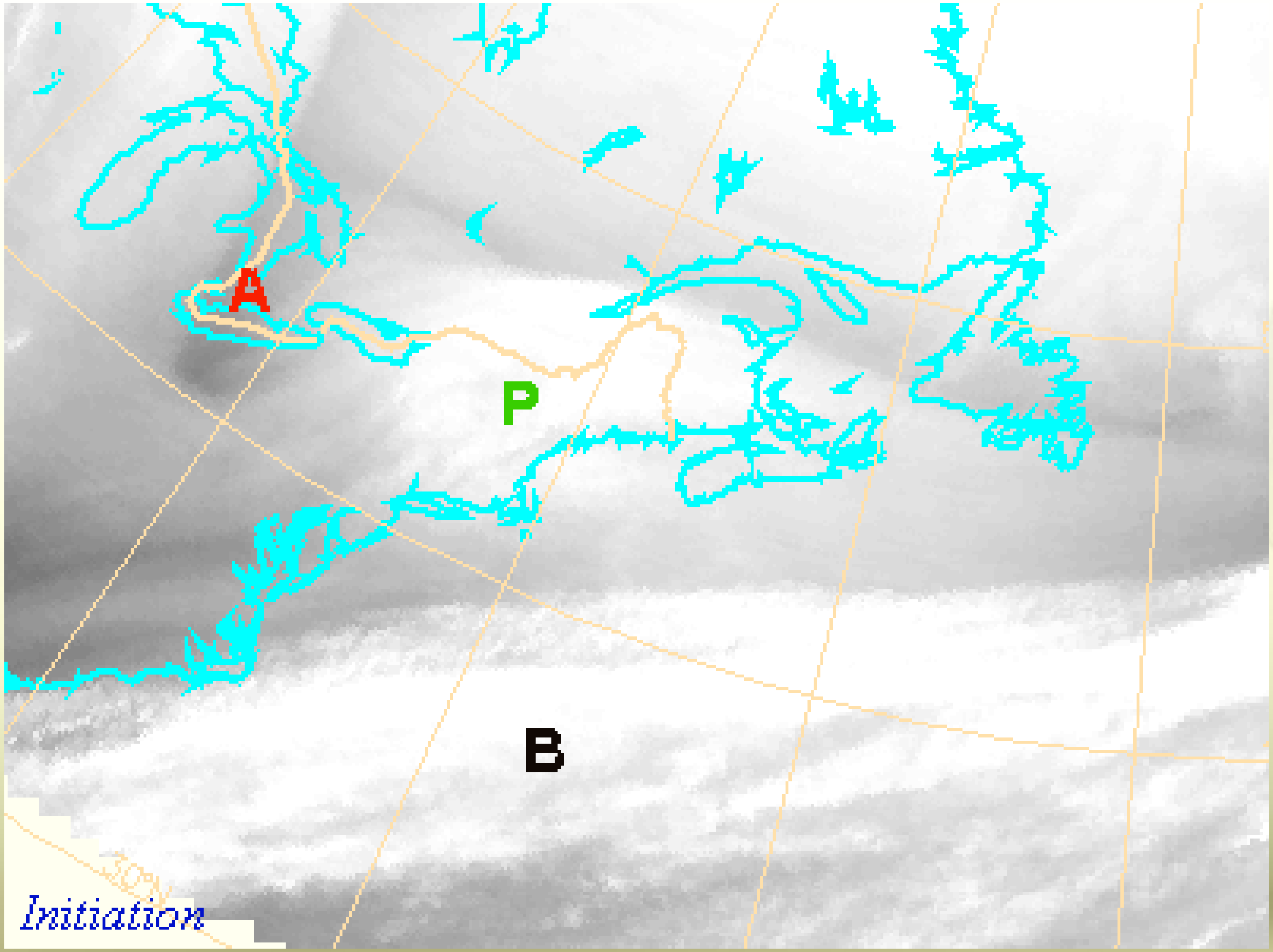
A : tropopause anomaly as a precursor of cyclogenesis

B : baroclinic zone as seen in moist ascent

P : cloud head

I : dry intrusion

WV imagery patterns of cyclone dynamics



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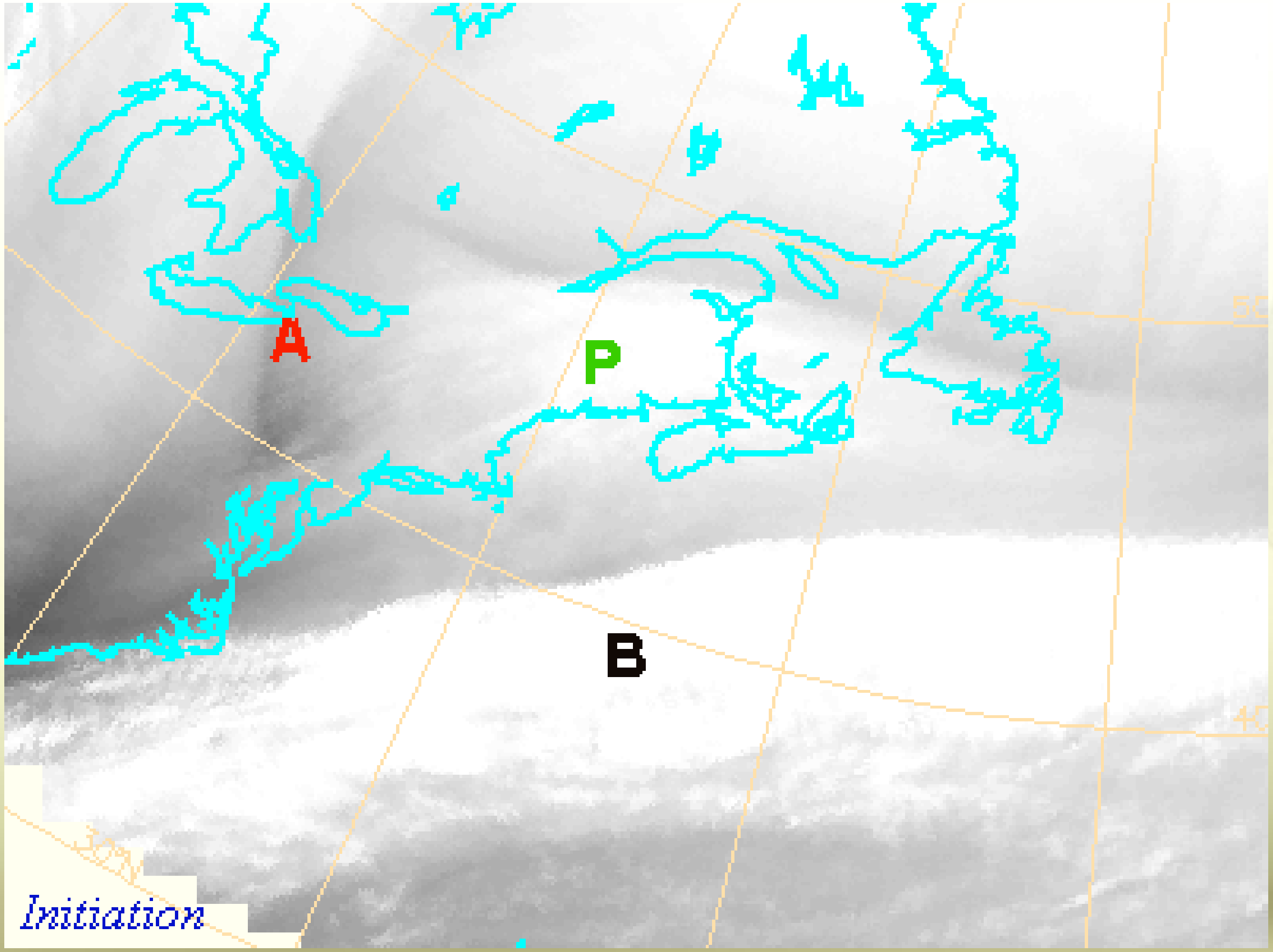

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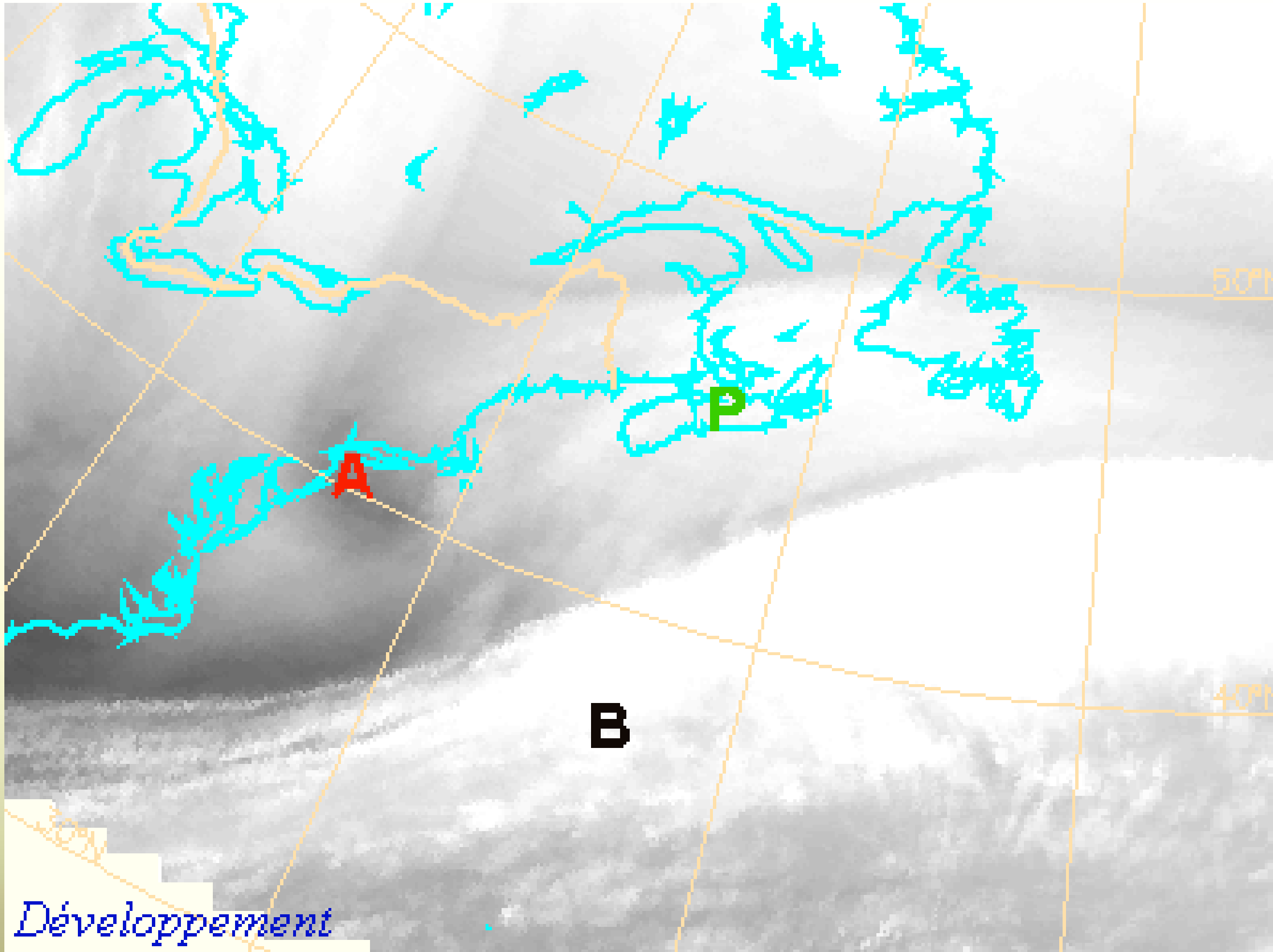
WV imagery patterns of cyclone dynamics



A : tropopause anomaly as a precursor of cyclogenesis

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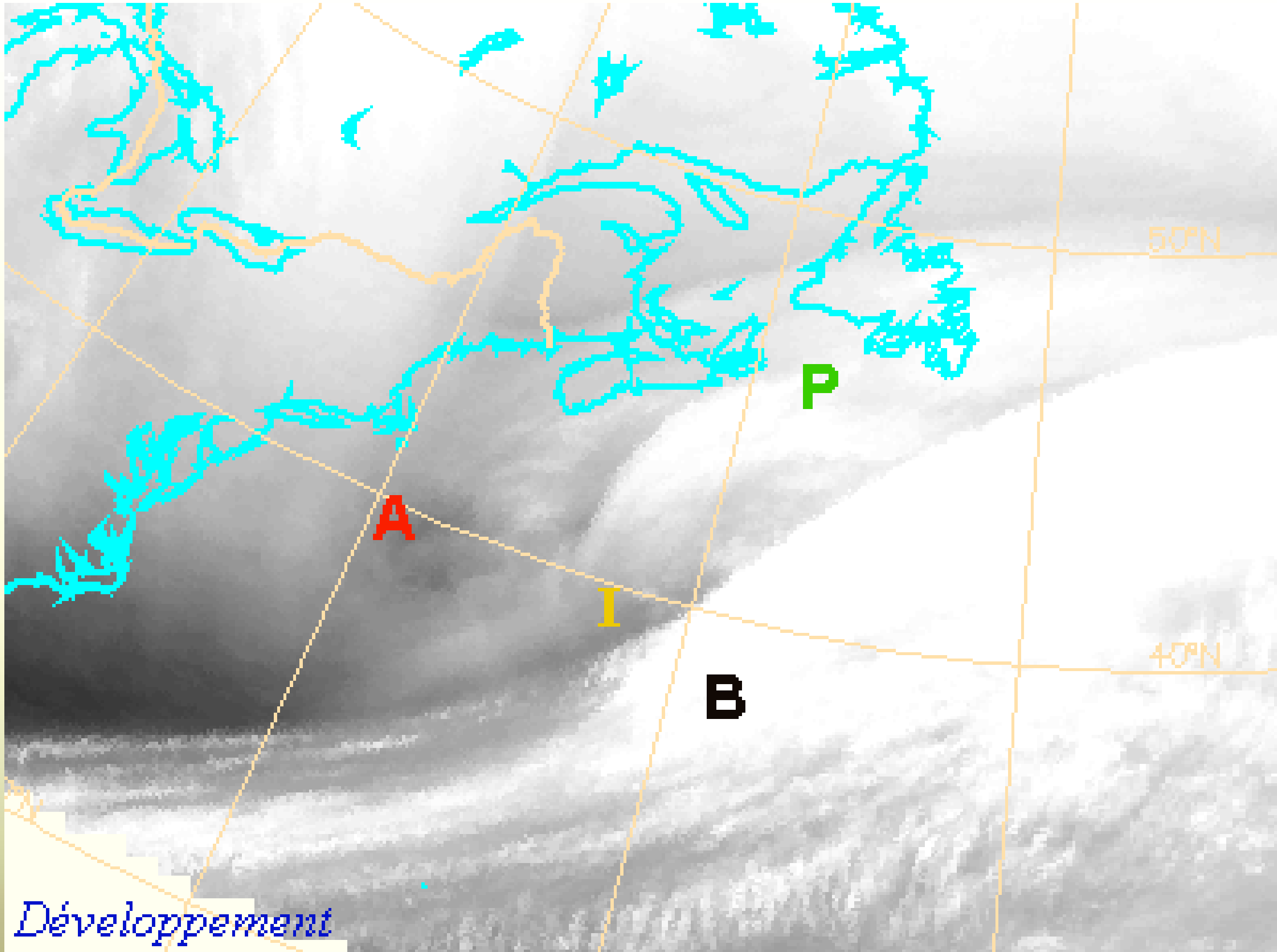
EUMETSAT

WV imagery patterns of cyclone dynamics



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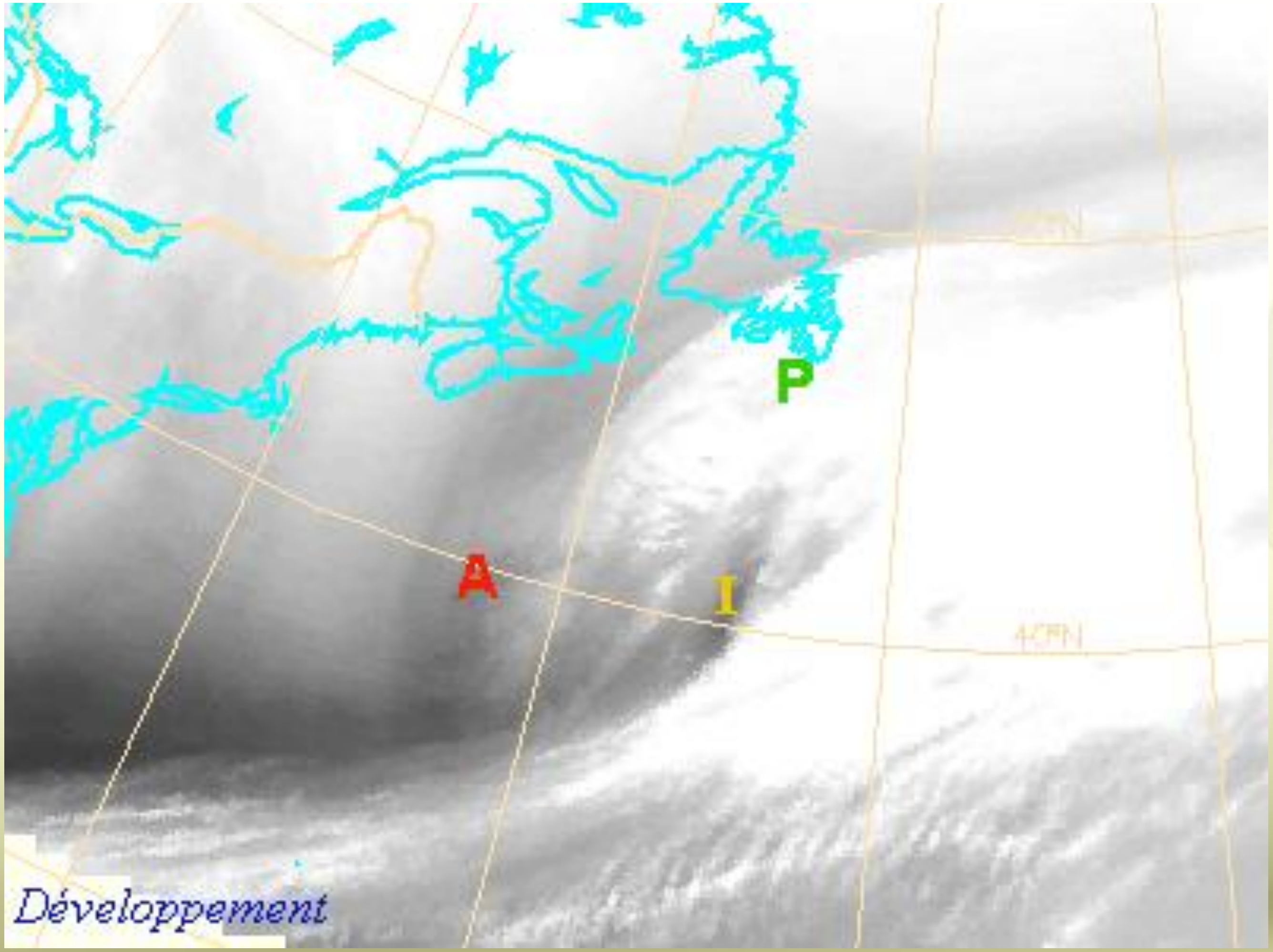
WV imagery patterns of cyclone dynamics



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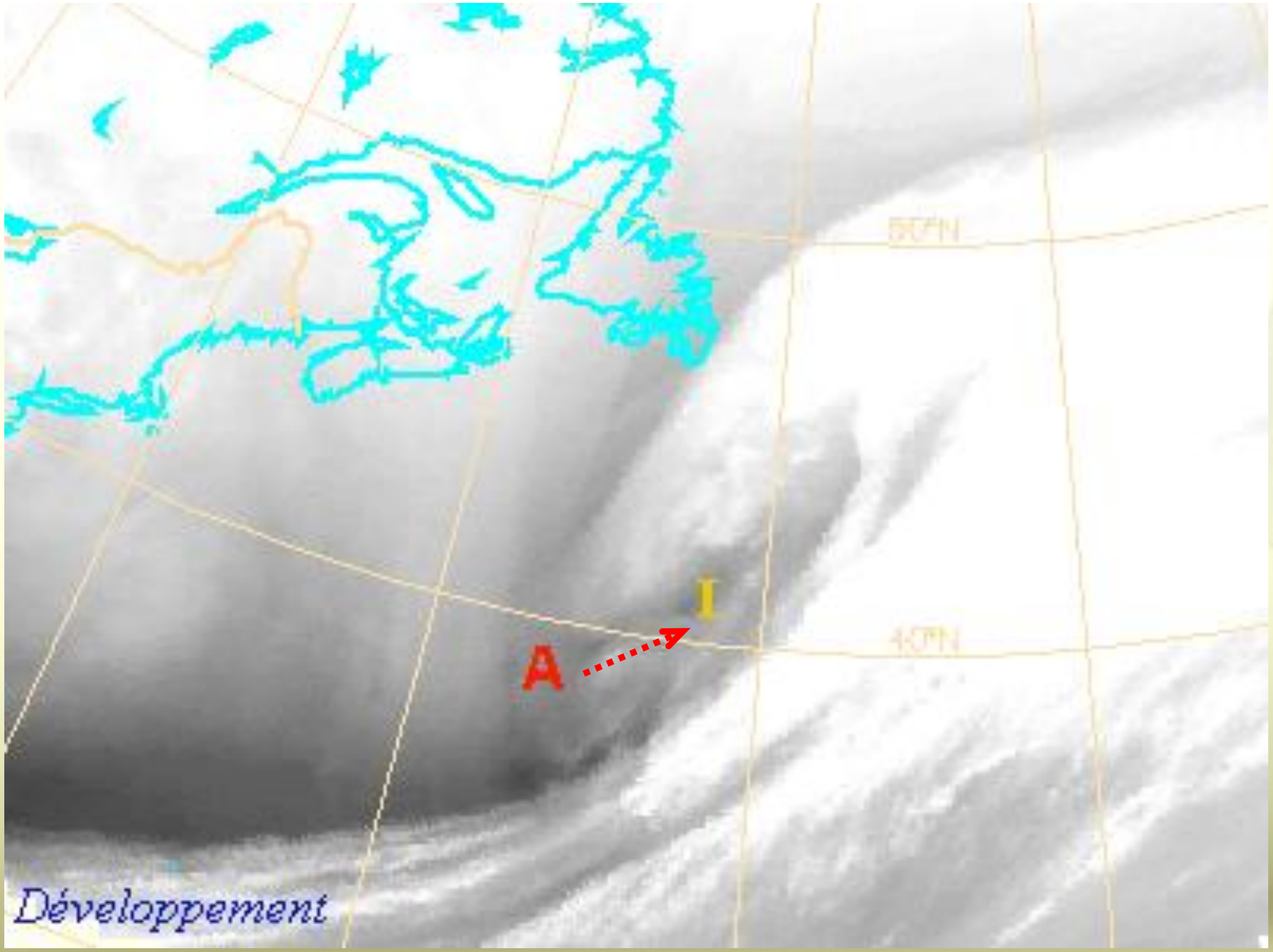
WV imagery patterns of cyclone dynamics



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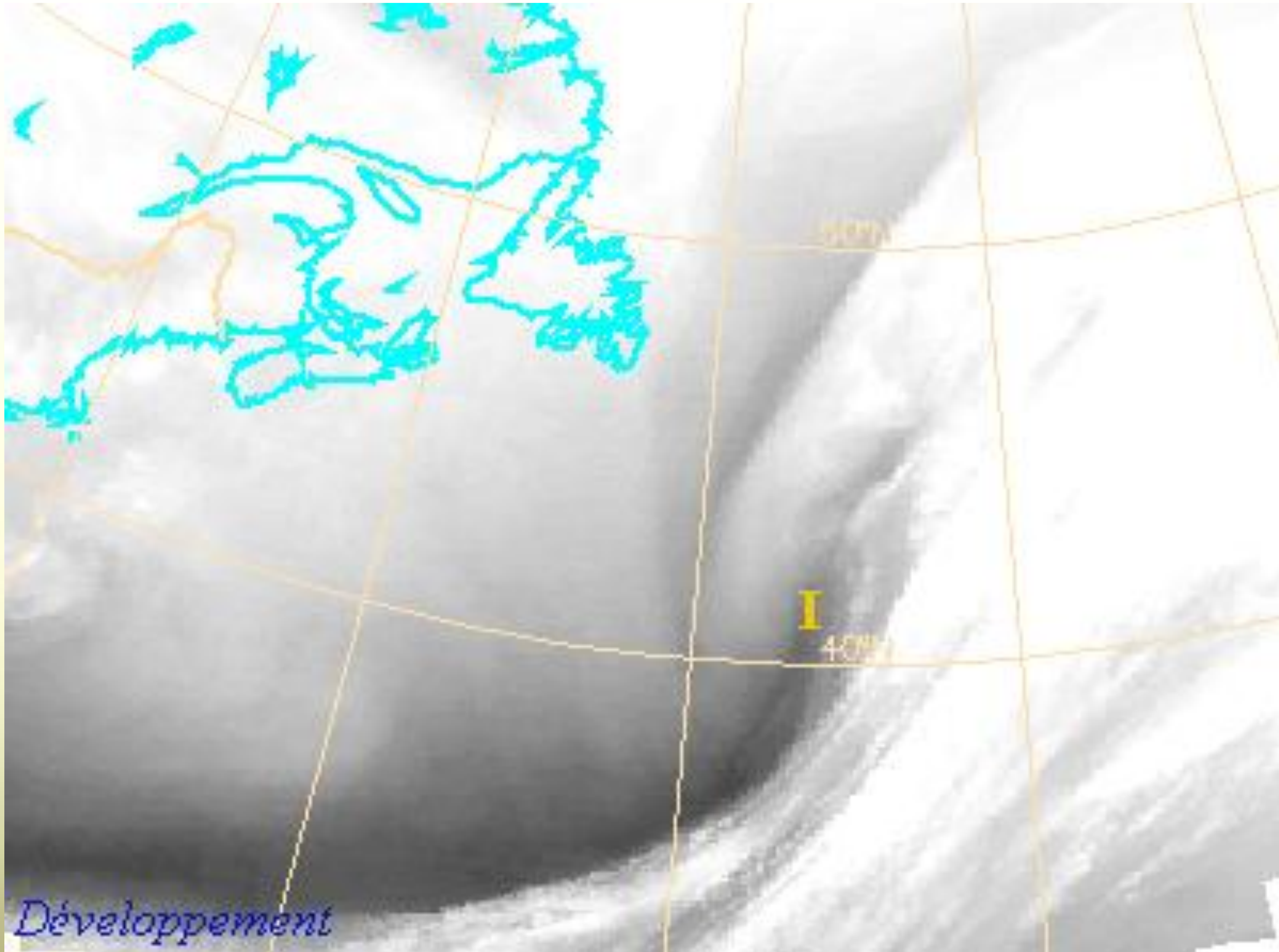
EUMETSAT

WV imagery patterns of cyclone dynamics



A : tropopause anomaly as a precursor of cyclogenesis

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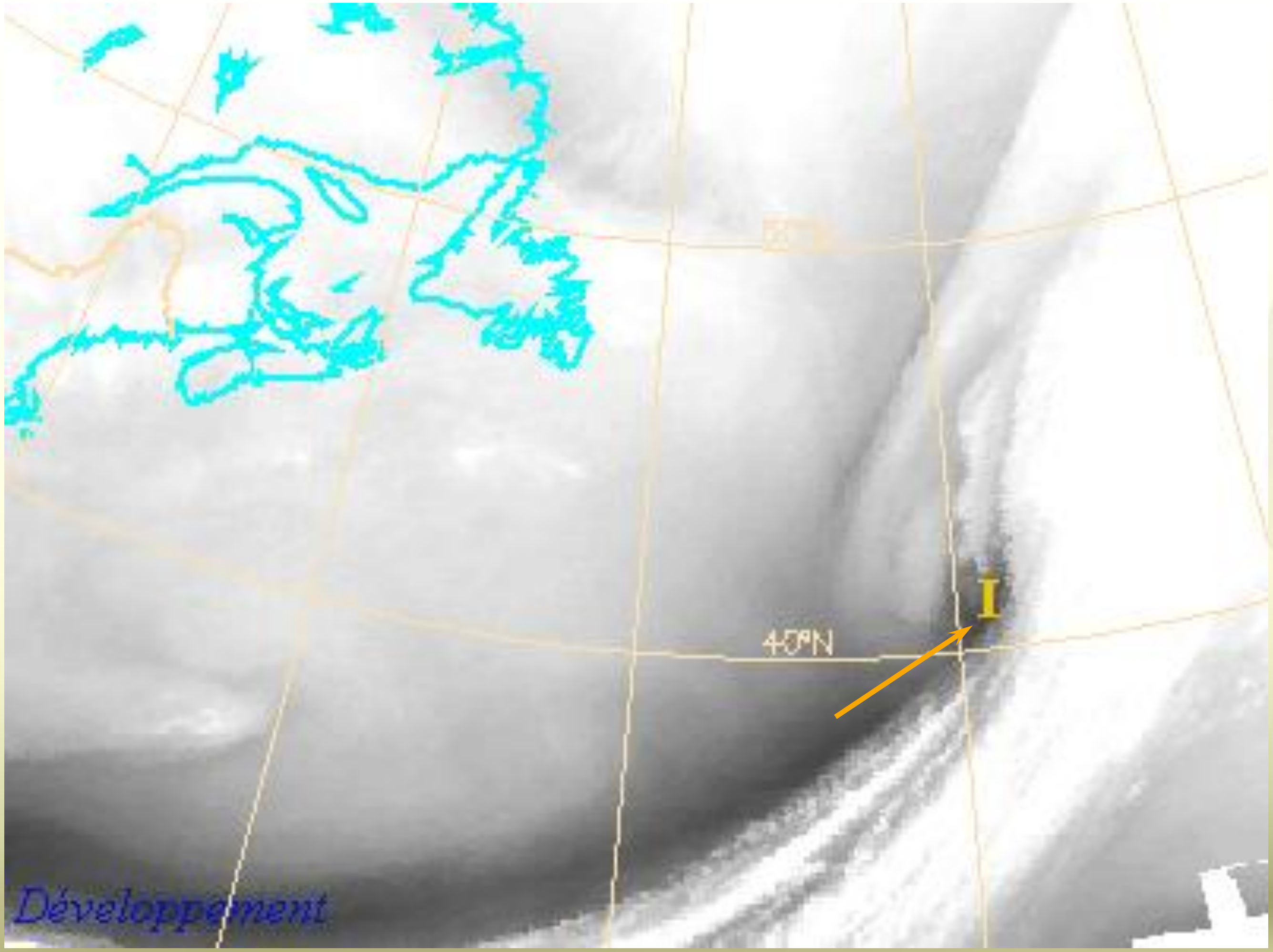
EUMETSAT

WV imagery patterns of cyclone dynamics



A : tropopause anomaly as a precursor of cyclogenesis

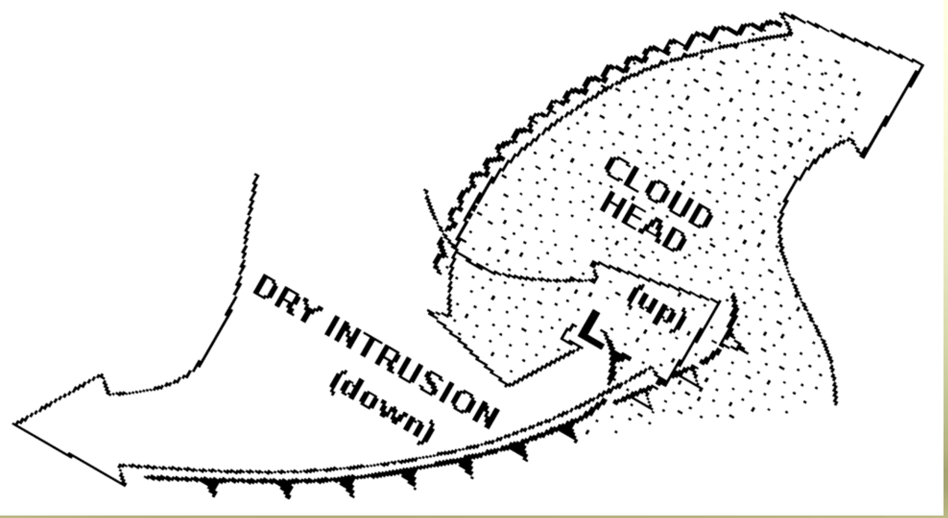
B : baroclinic zone as seen in moist ascent

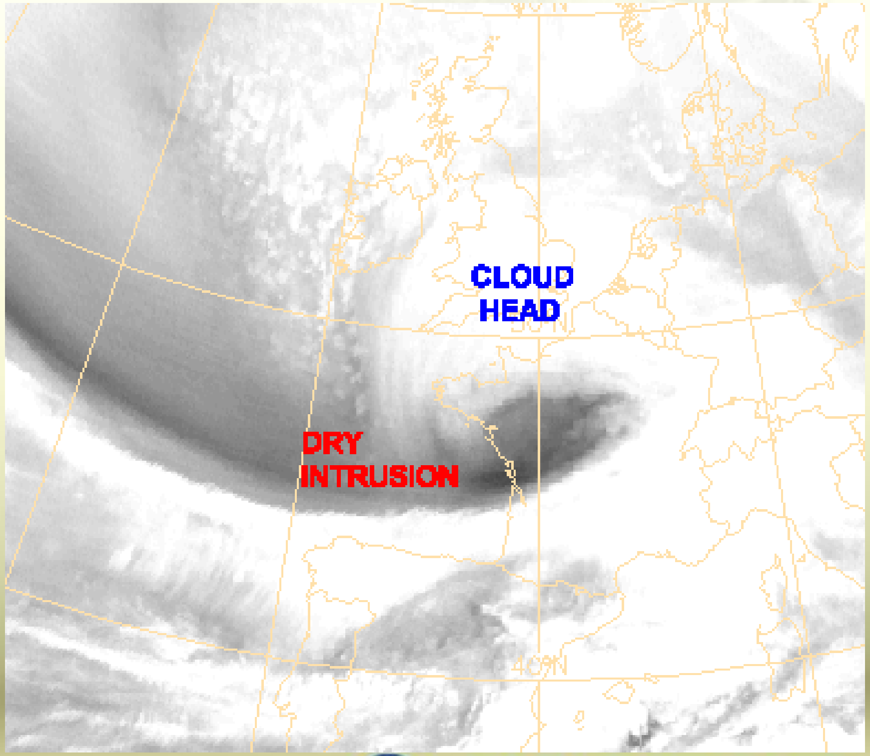
P : cloud head

I : dry intrusion

Dry intrusion: Very dry air, which comes down to low levels near cyclones and forms a coherent region of dry air.

Conceptual model
(Browning, 1997)





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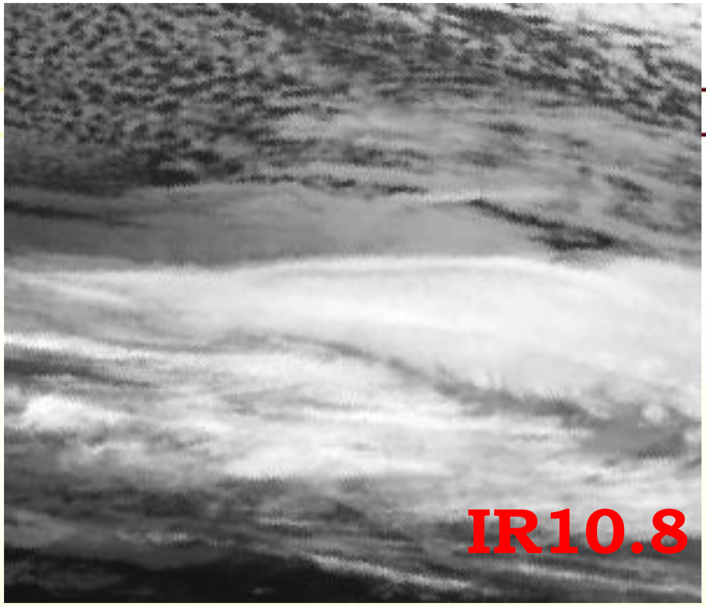
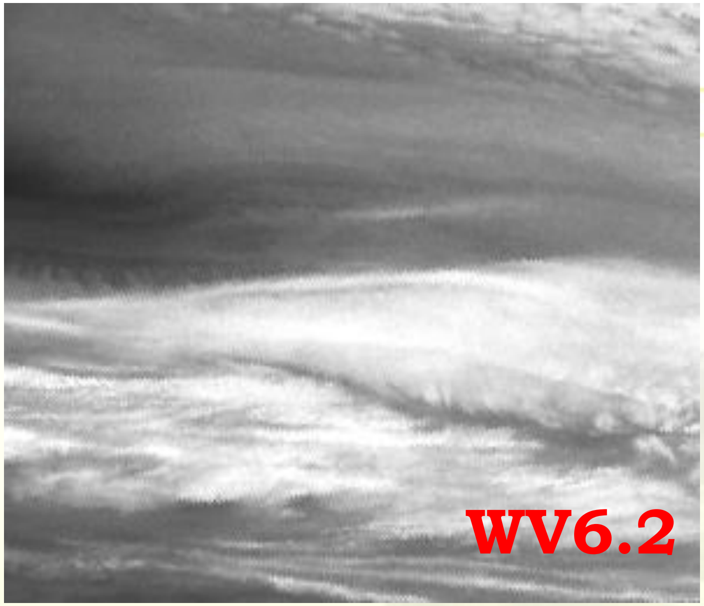
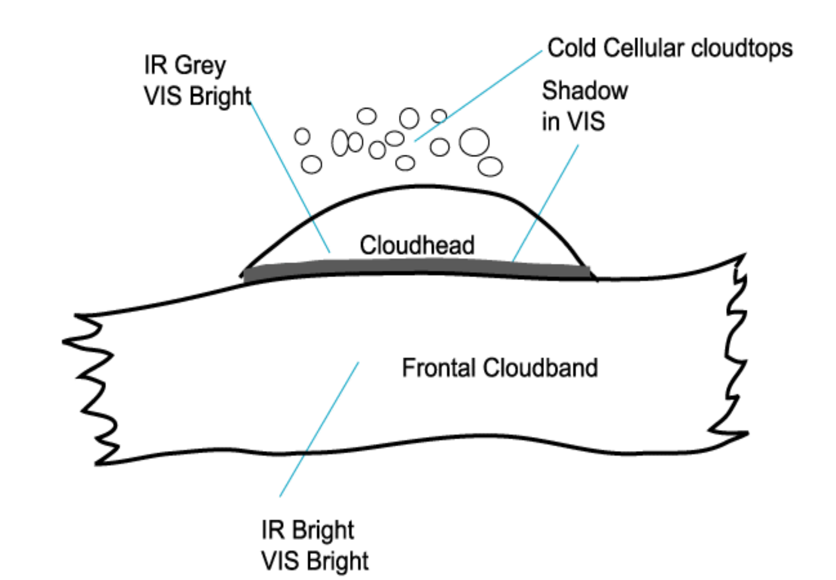
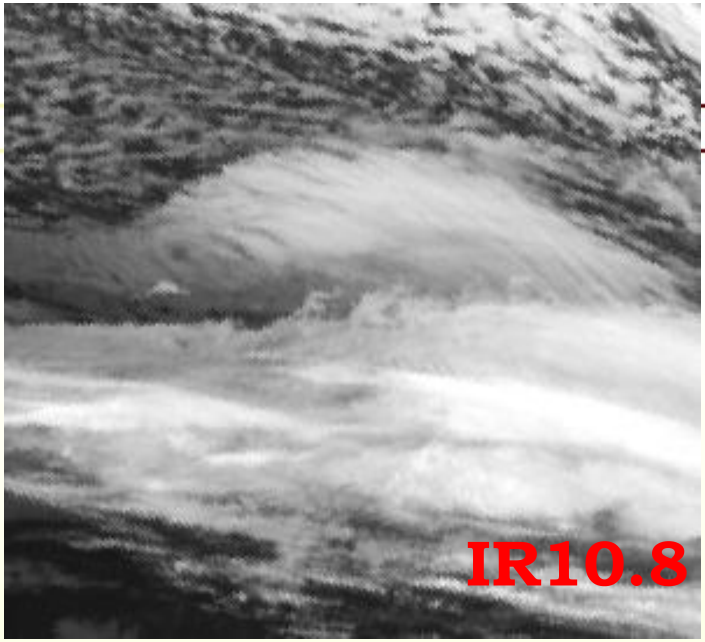


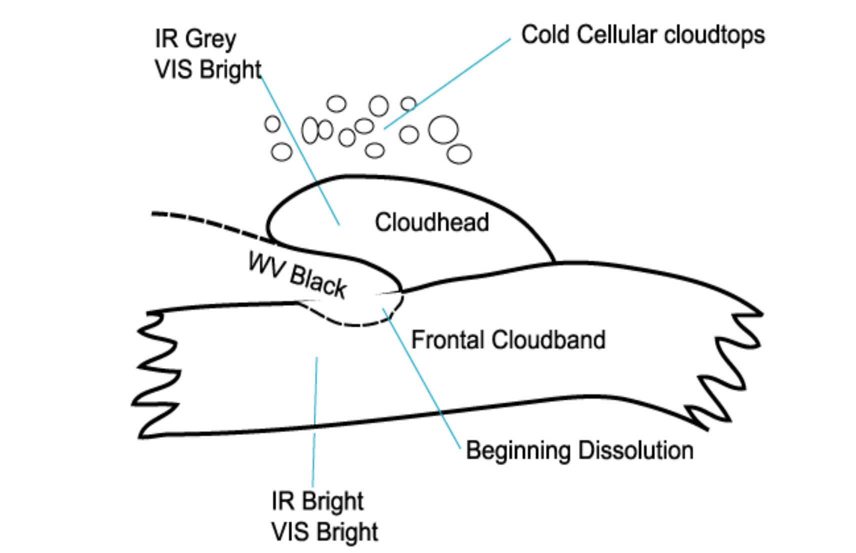


Initial Stage





Advanced Stage I



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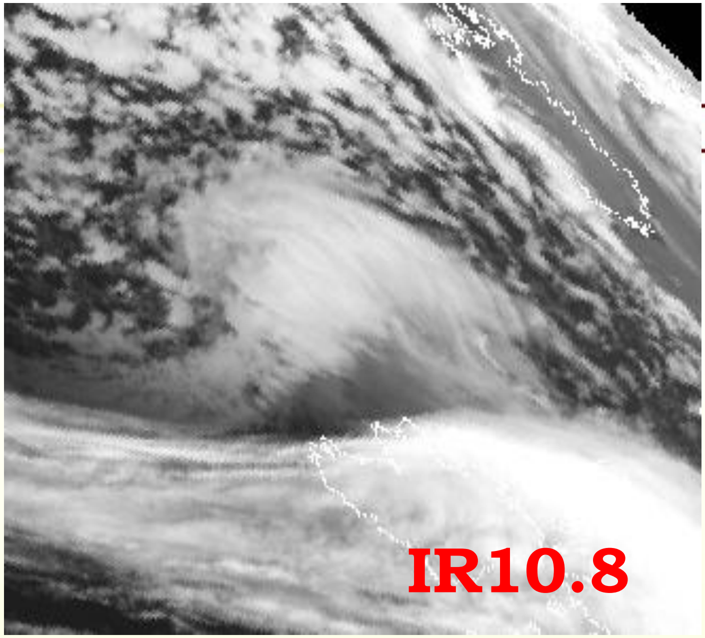
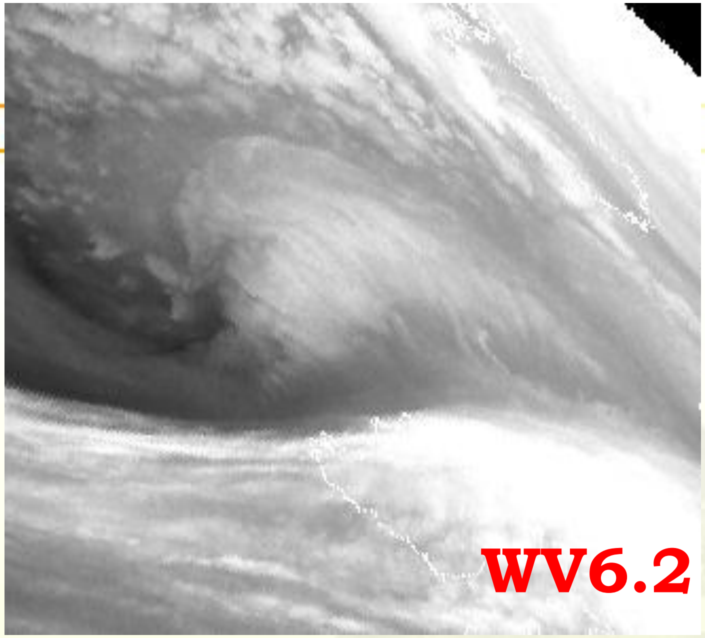
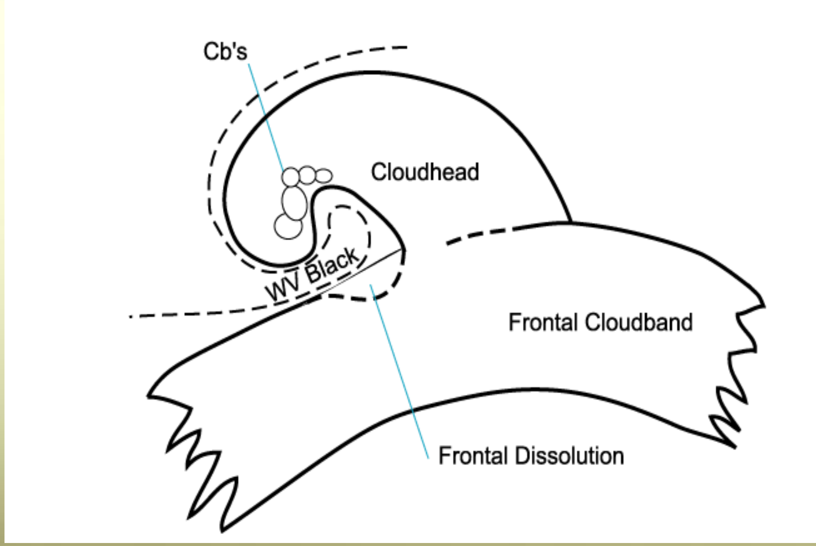
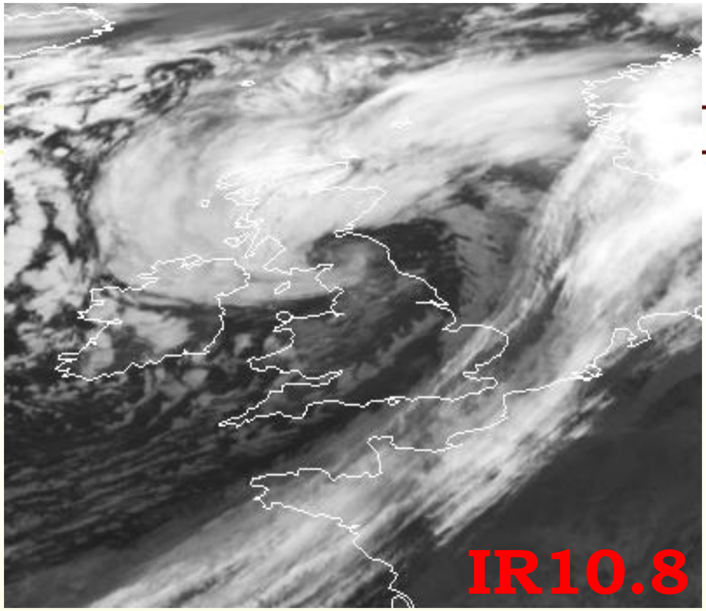
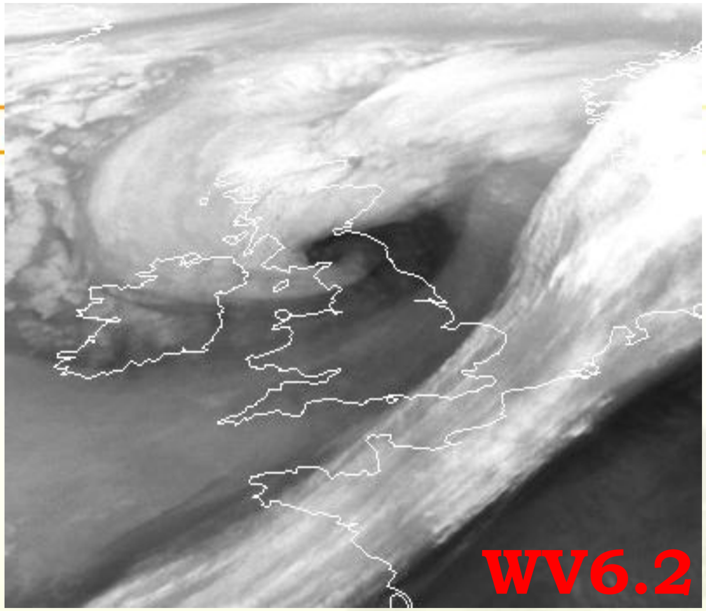


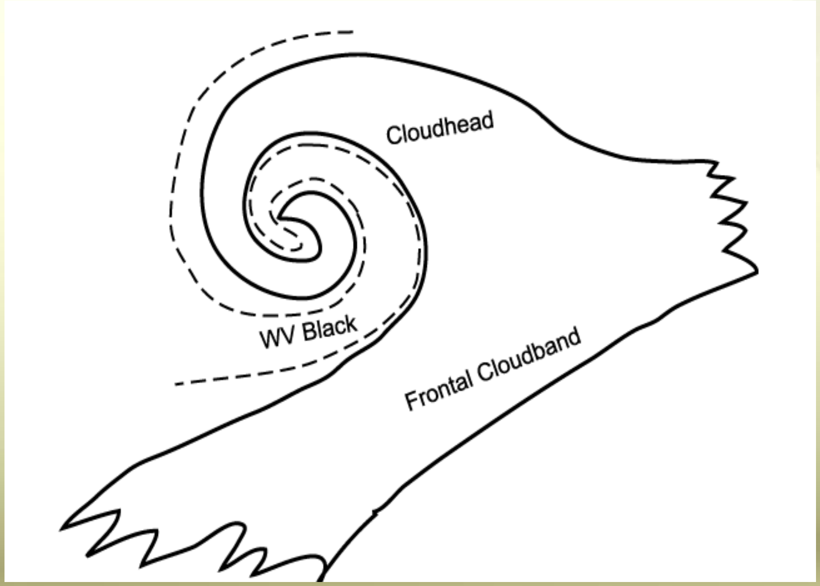


Advanced Stage II



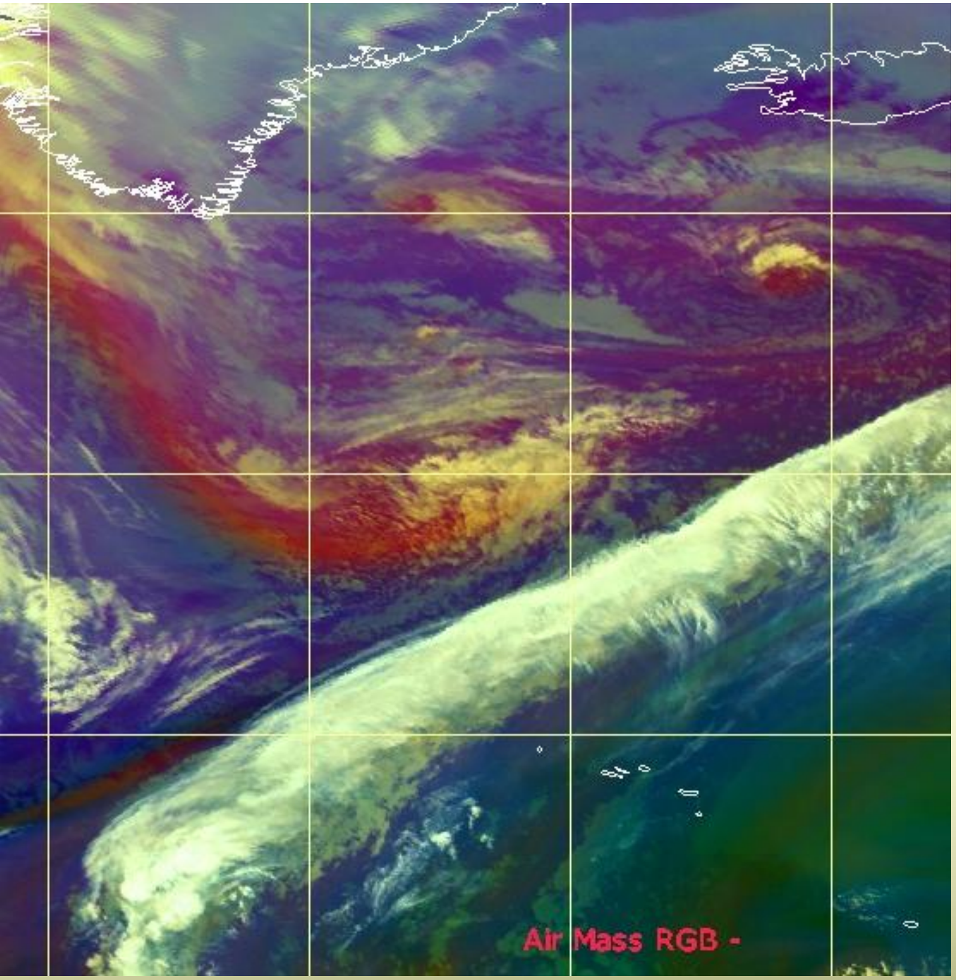


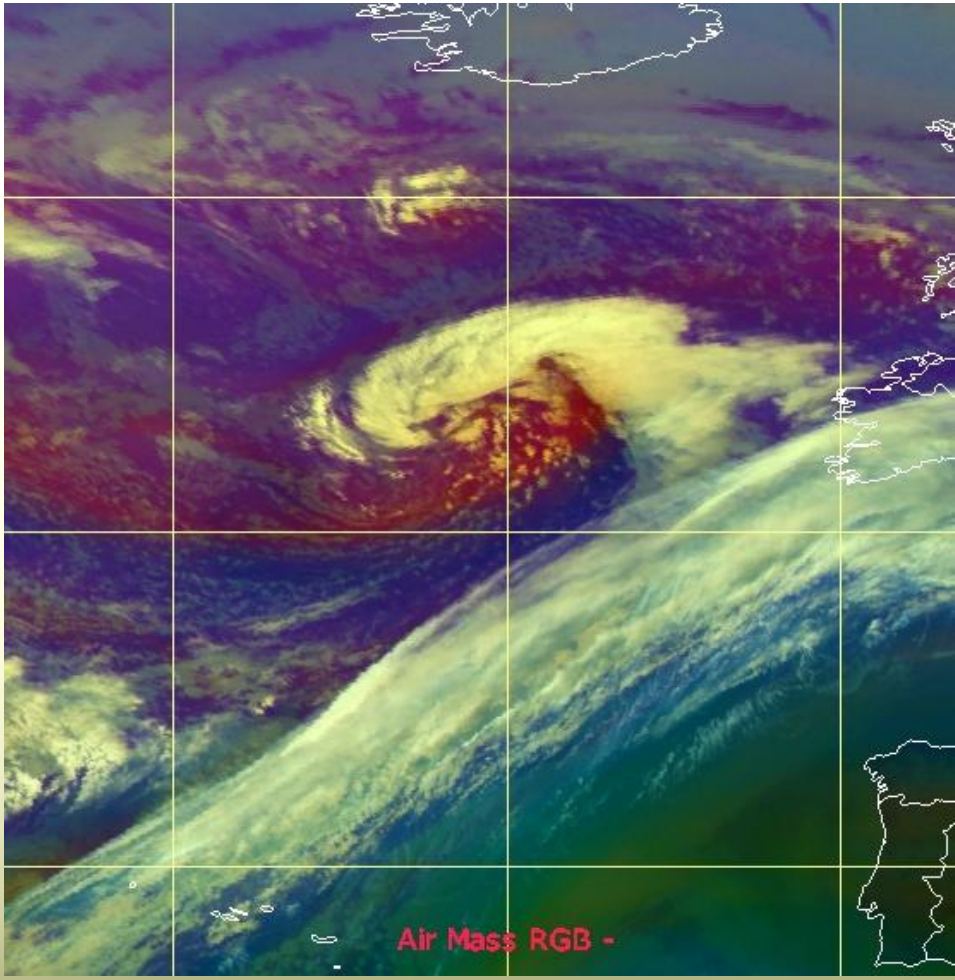




Mature Stage

Rapid Cyclogenesis seen in Airmass RGB





8 May 2007, 11:00 UTC

9 May 2007, 8:00 UTC

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Moisture Movements and Surges

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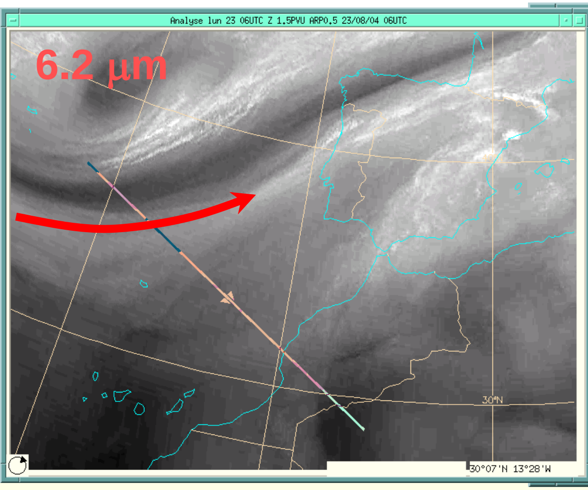
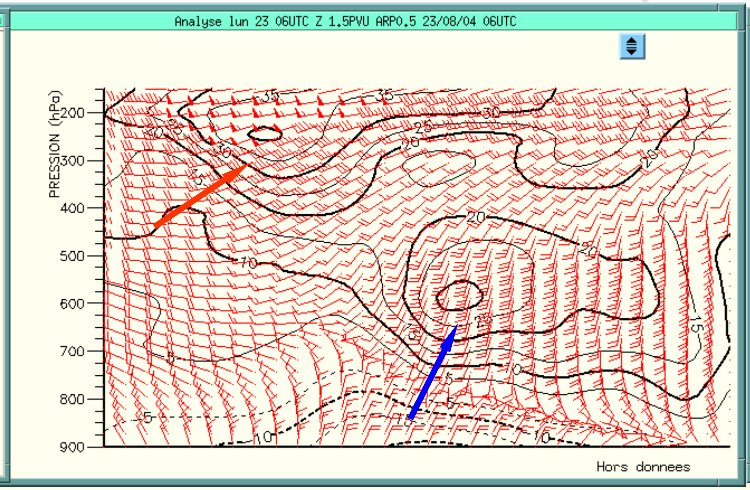
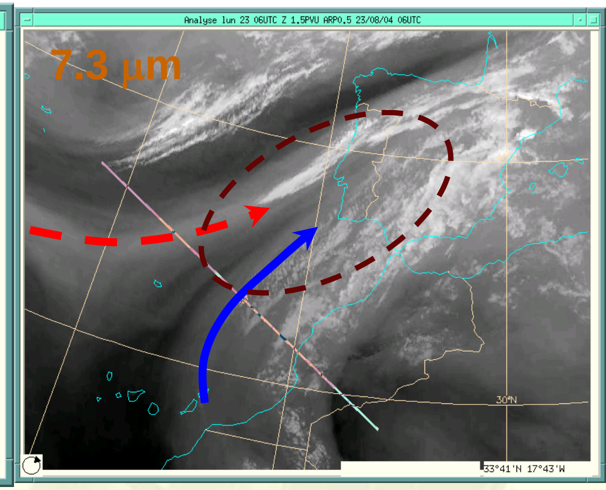
Moisture Convergence

Cross-section of wind vectors/speed







Strengthening vertical and horizontal motions associated with the two jets creates a dynamic environment of moisture convergence.

The convergent moisture movements maintain the moisture supply in a deep layer that is necessary for intense convection development.

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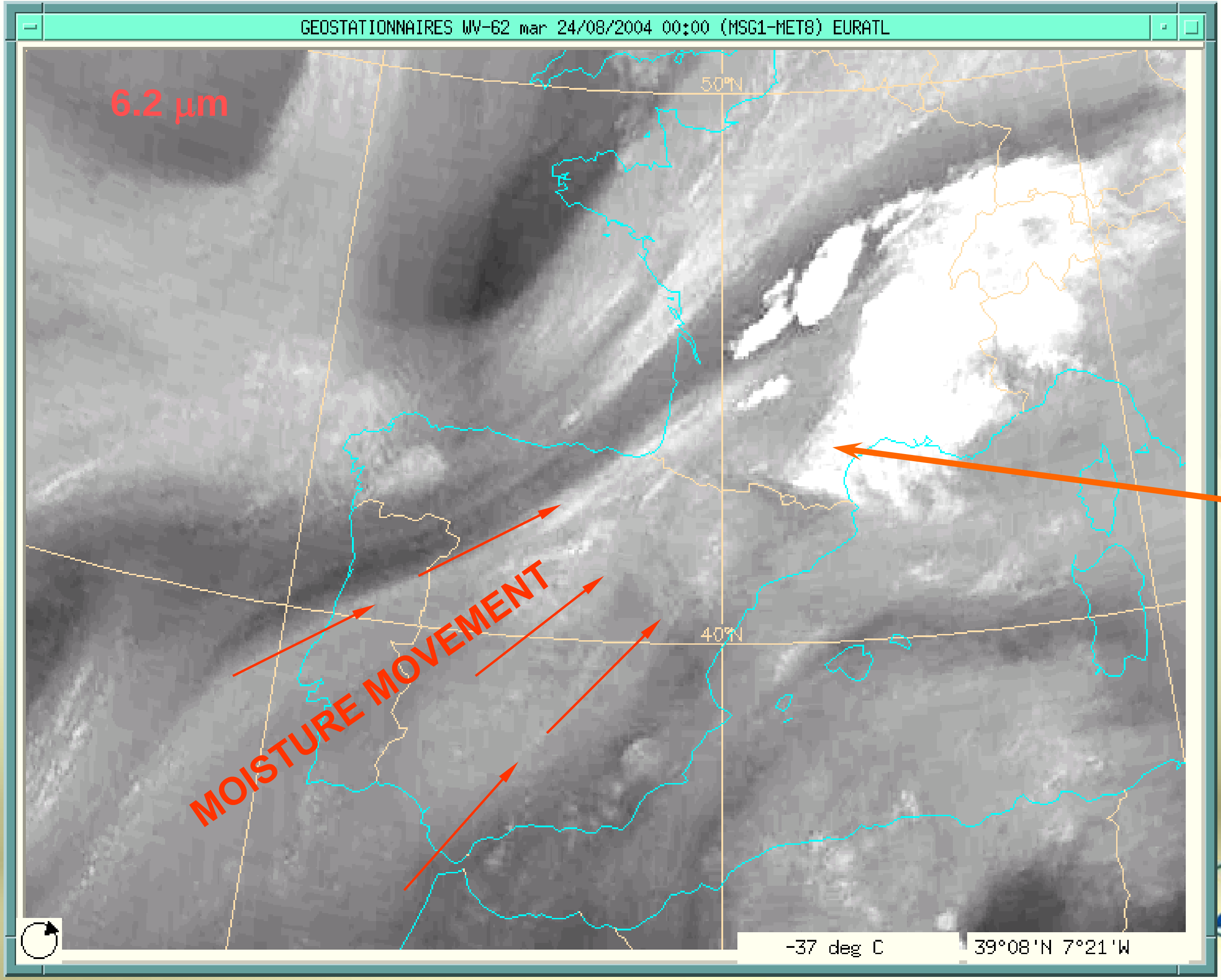
Images in the WV channels of MSG are tools for observing large scale movements associated with jet streams at two layers that maintain the moisture supply in the mid- to upper-level environment of intense convection.



area favorable for convection

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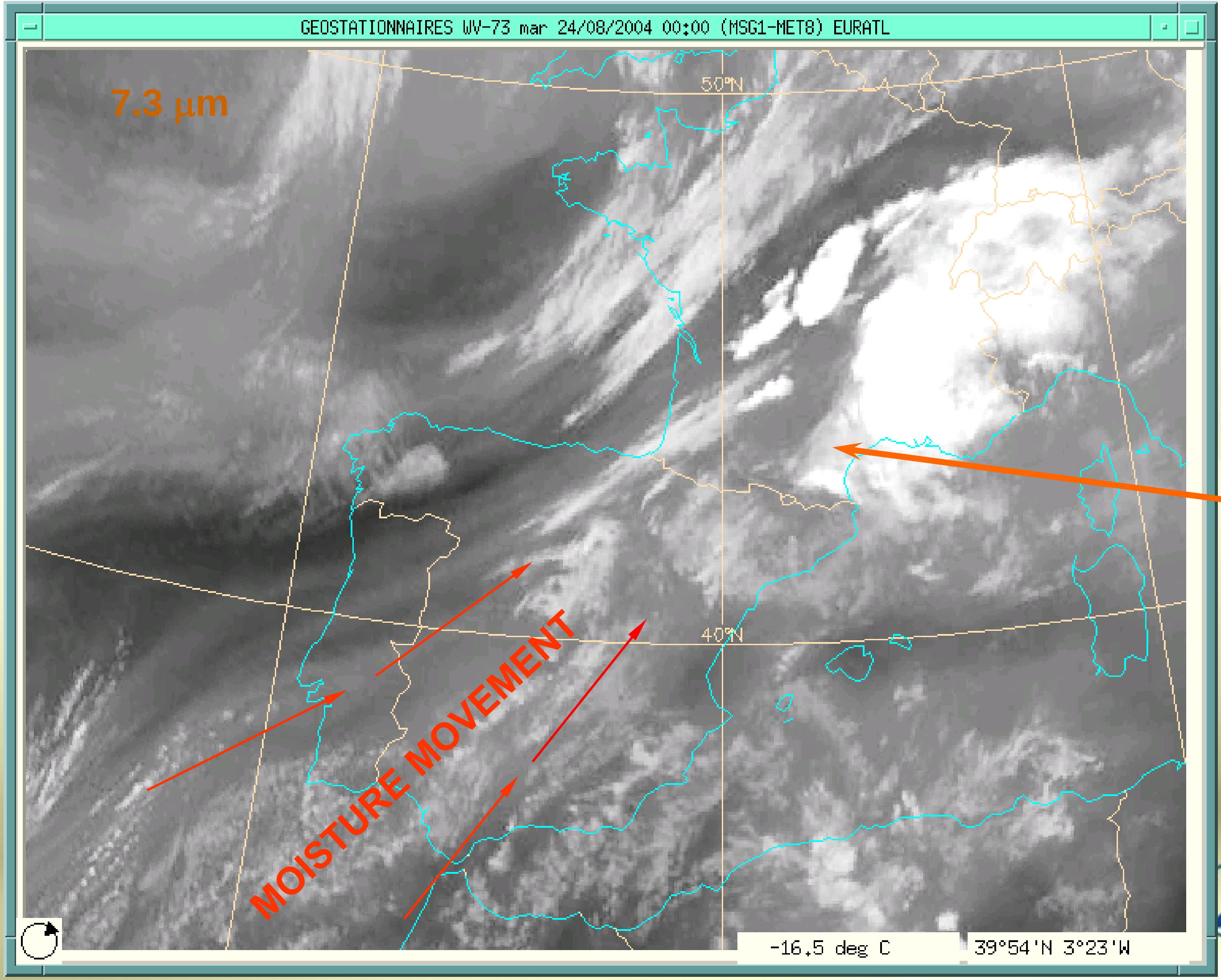
Changes in structure and behaviour of jet stream WV features at upper and middle troposphere may be extrapolated to predict time changes in the related conditions for intense convection.



area favorable for convection

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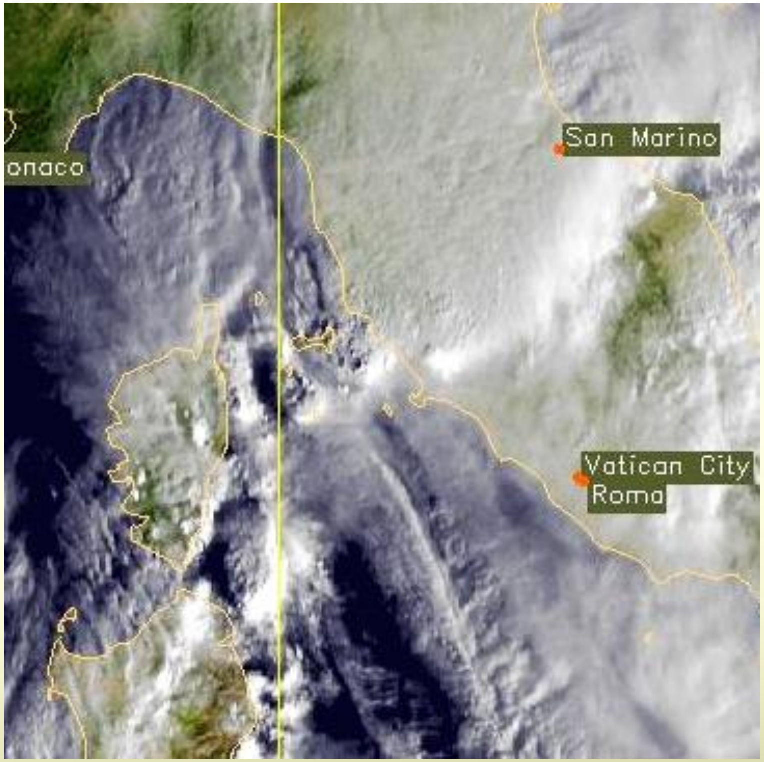
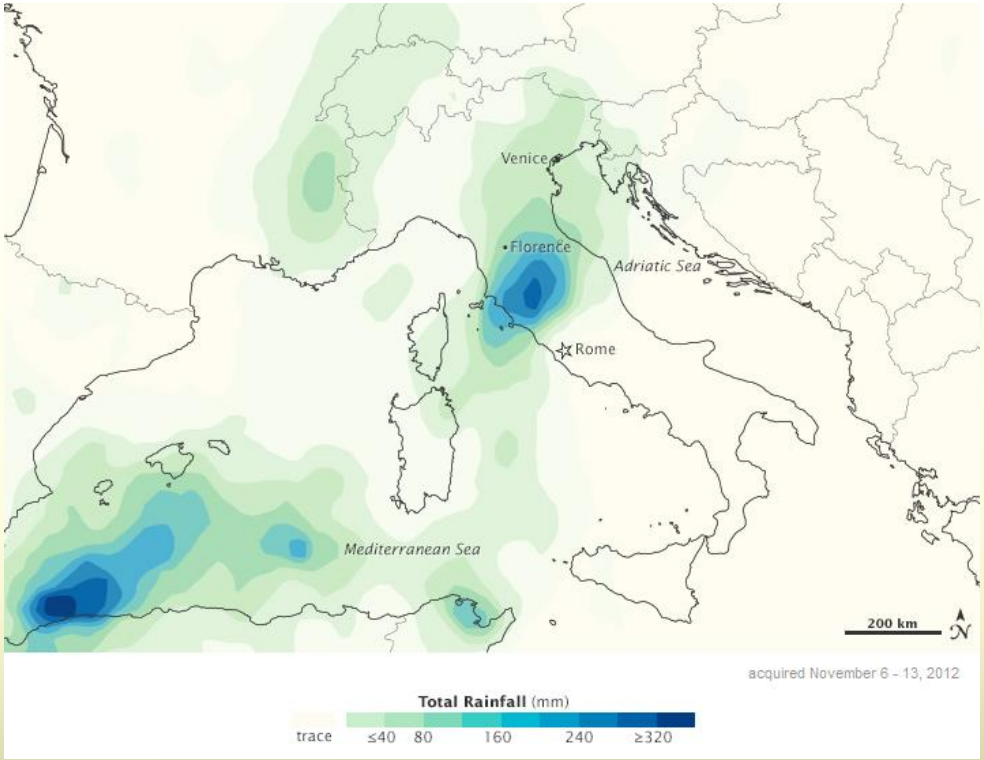
Flash Flood Tuscany (Italy), 12 November 2012



Met, HRV



Satellite-based rainfall estimate (NASA)

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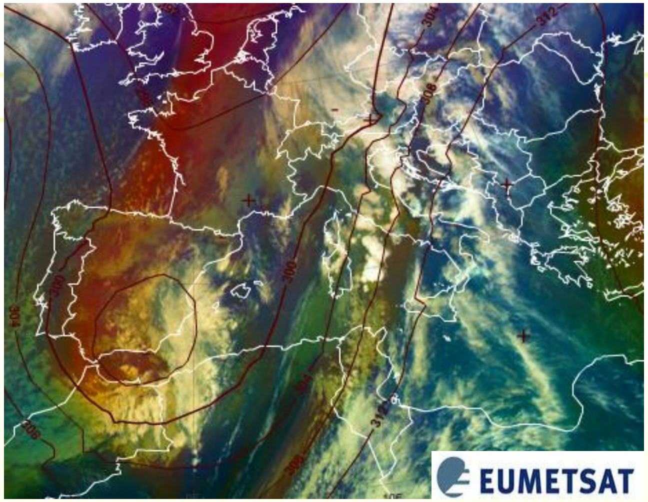
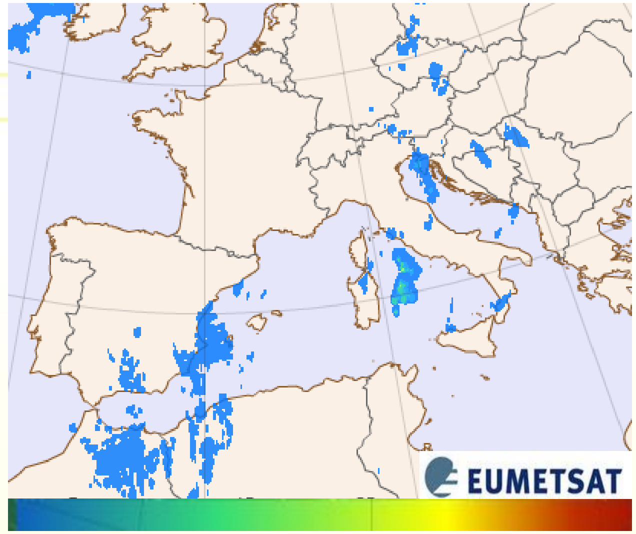
Meteosat-9 RGB Air Mass and H700
12 UTC 11 Nov 2012

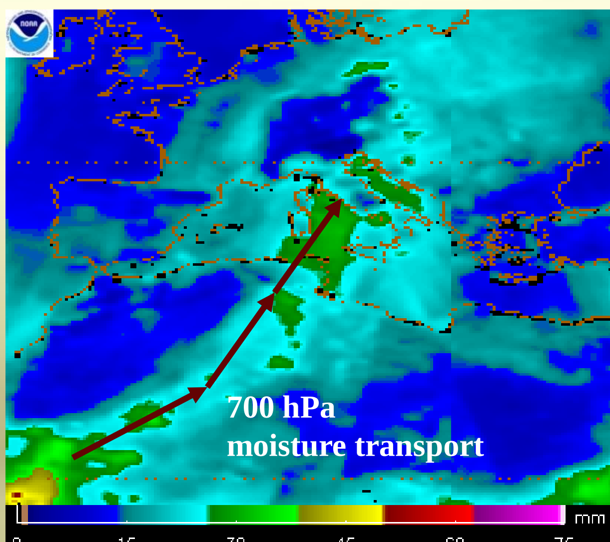


Meteosat-9 MPE
12 UTC 11 Nov 2012

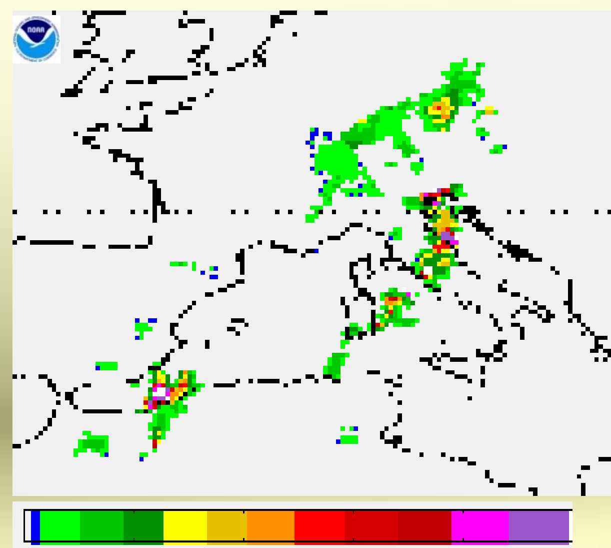


0 5 10 25 35mm/hr

Blended Total Precipitable Water (TPW) 12 UTC 11 Nov 2012



Blended LEO Instantaneous Rain Rates 12 UTC 11 Nov 2012



0 2 4 6 8 10+ mm

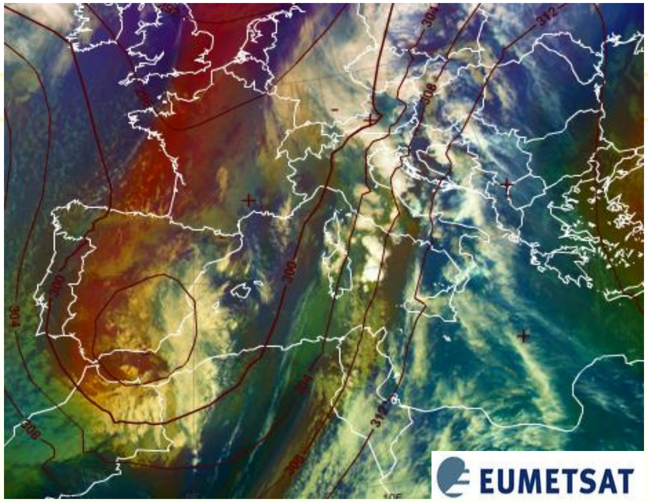
NOAA Blended TPW Products

CLICK HERE

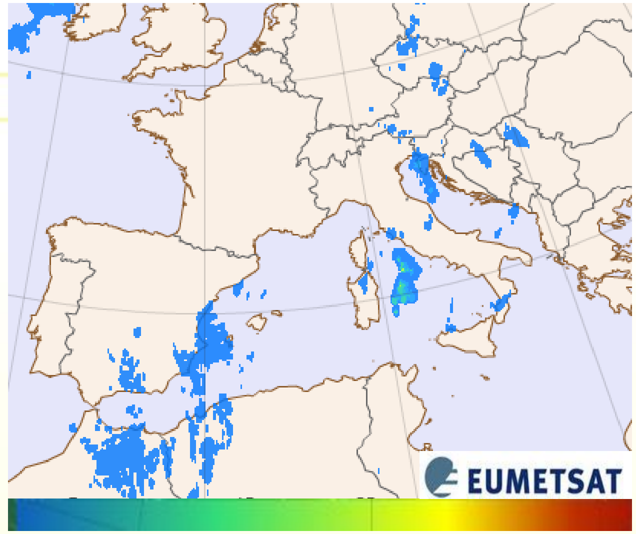
Prepared by Sheldon Kusselson

EUMETSAT

Meteosat-9 RGB Air Mass and H700
12 UTC 11 Nov 2012

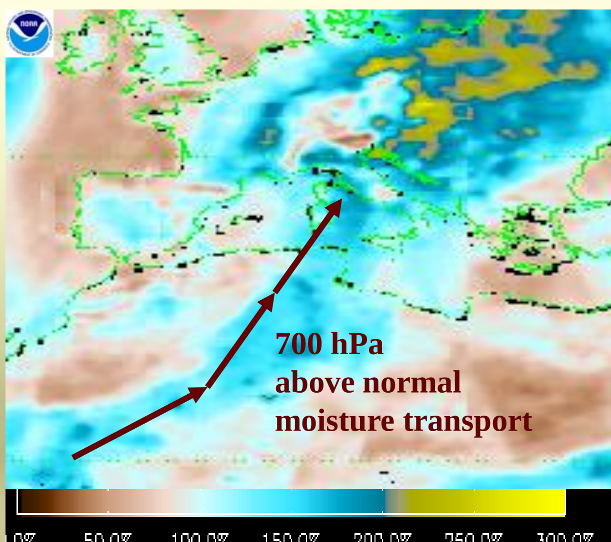


Meteosat-9 MPE
12 UTC 11 Nov 2012

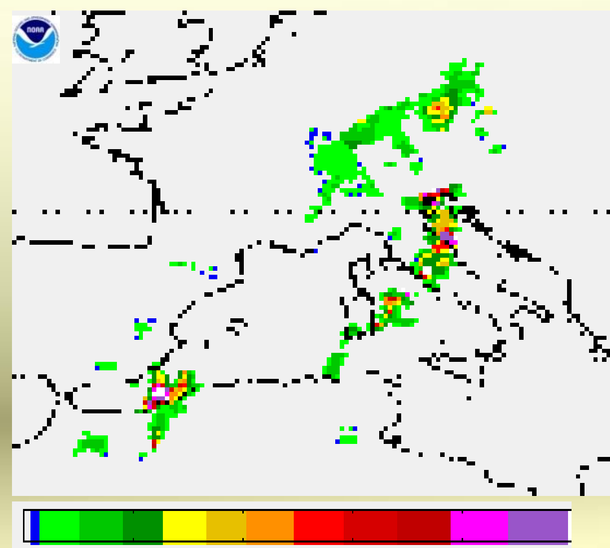


0 5 10 25
35mm/hr

Blended TPW Percent of Normal
12 UTC 11 Nov 2012



Blended LEO Instantaneous Rain Rates 12 UTC 11 Nov 2012



0 2 4 6 8 10+
mm

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Prepared by Sheldon Kusselson

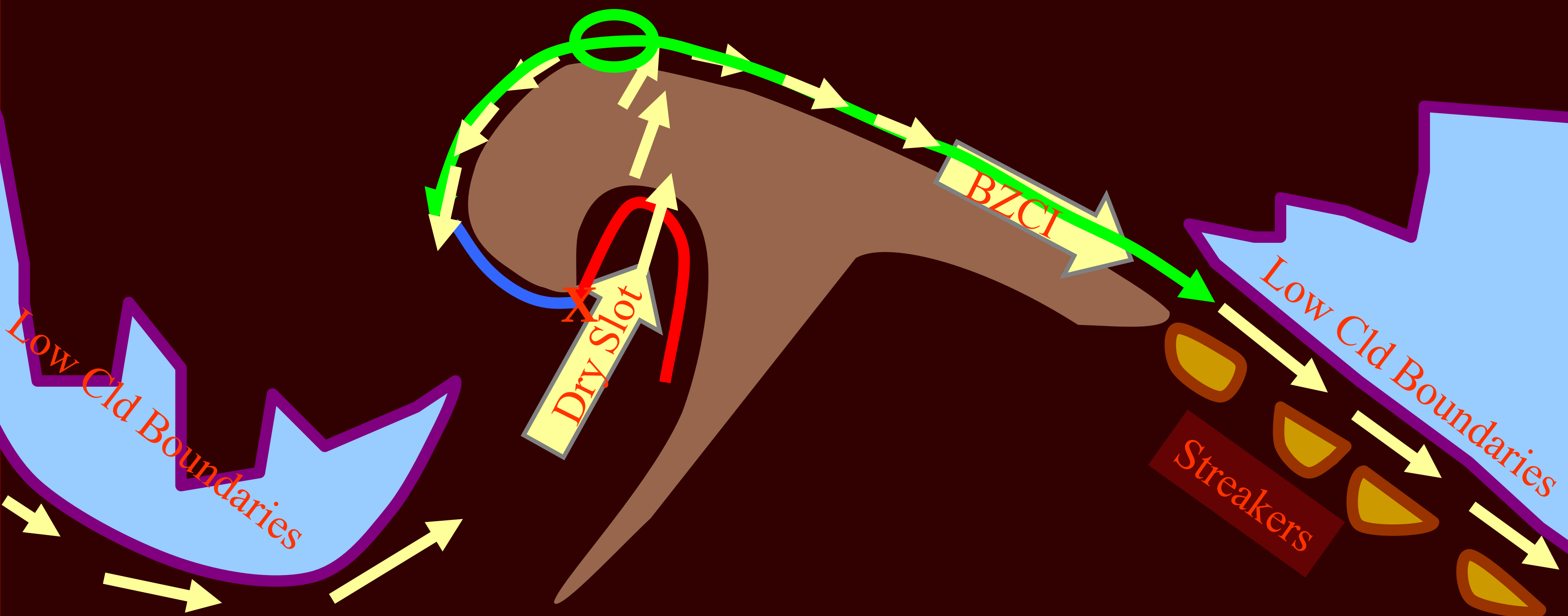
Vorticity Minima / Maxima
Deformation Zones

Satellite Meteorology
Dynamic Feature Analyisis and Diagnosis
Phil Chadwick, Canada

- Moisture Edges
- Moisture Circulations

EUMeTrain CAL: Recognition and Impact of Vorticity Maxima and Minima in Satellite Imagery

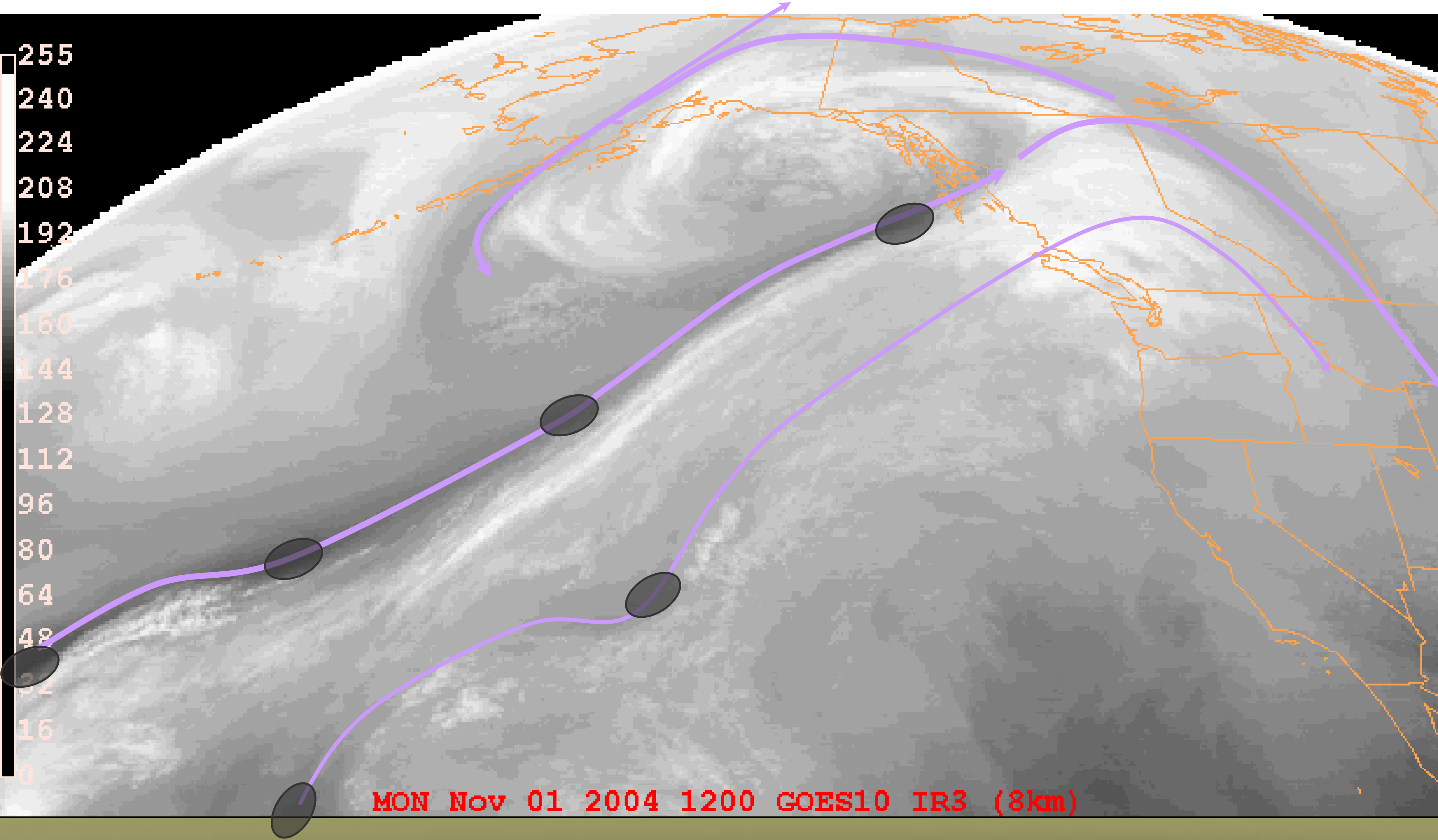
Jet Axis – Moisture Edge



Each dynamic feature creatively painted…

Is a piece of the atmospheric puzzle…

They can only go together one way…



Where are the moisture edges?

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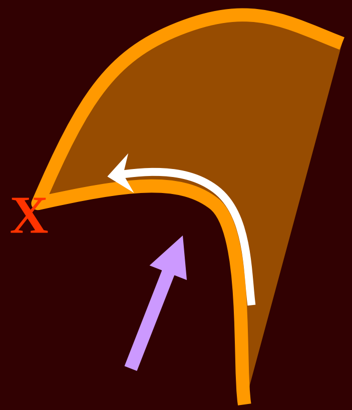
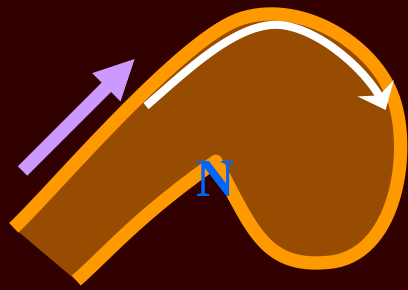
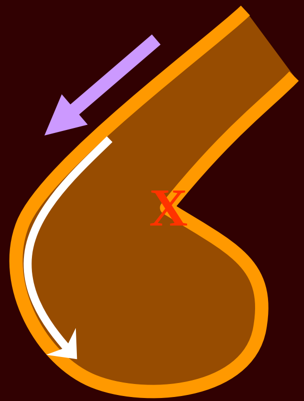
Shear Dominated Vorticity Patterns



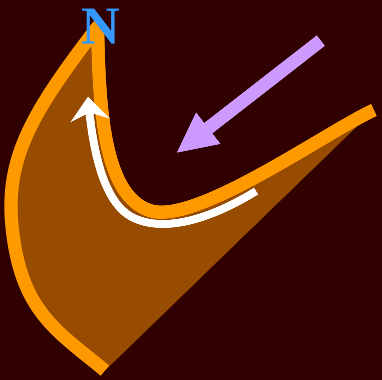
Equatorward Shear



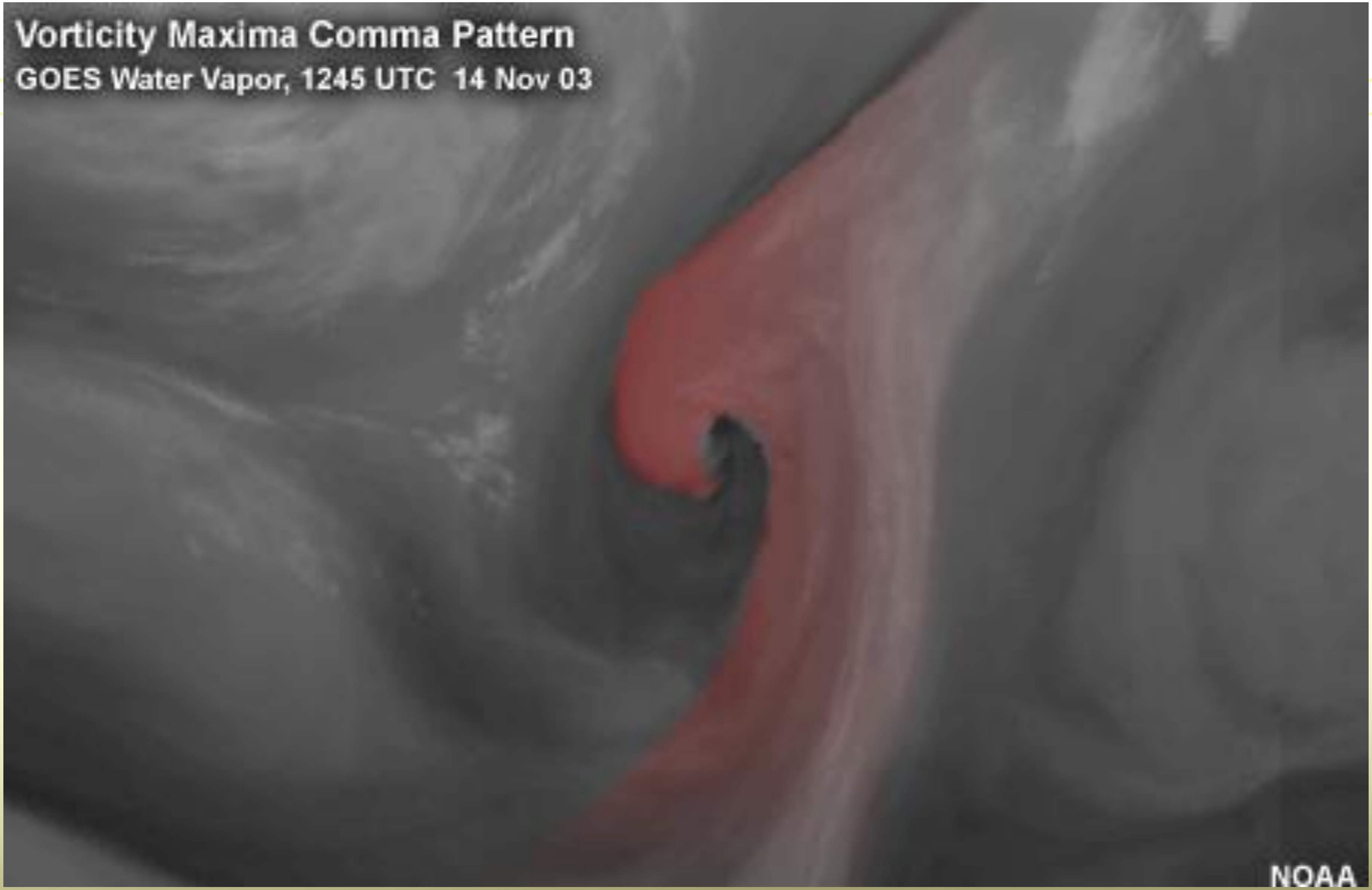
Poleward Shear



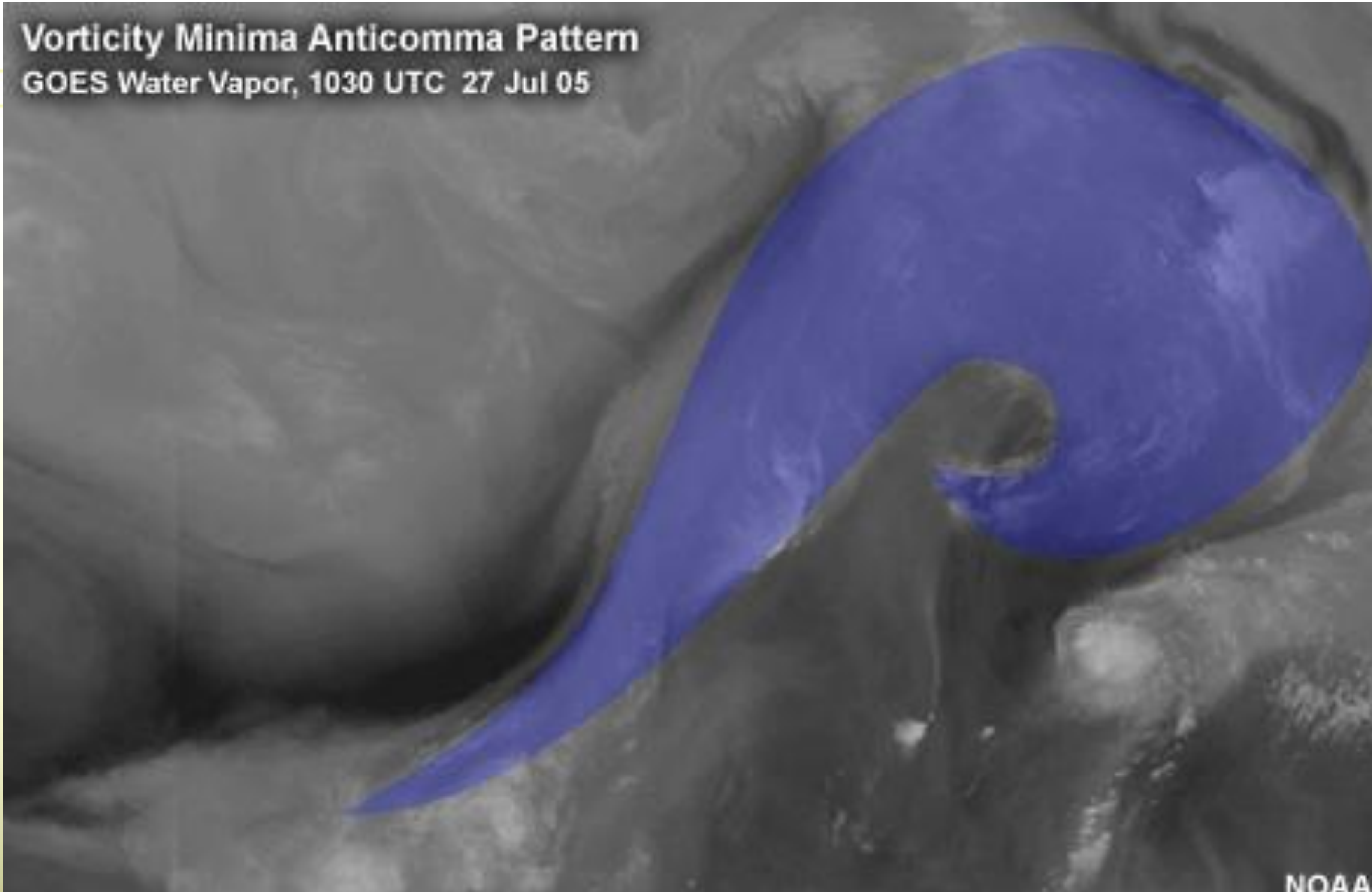
Poleward Shear



Equatorward Shear


Vorticity Maxima Comma Pattern
GOES Water Vapor, 1245 UTC 14 Nov 03
NOAA

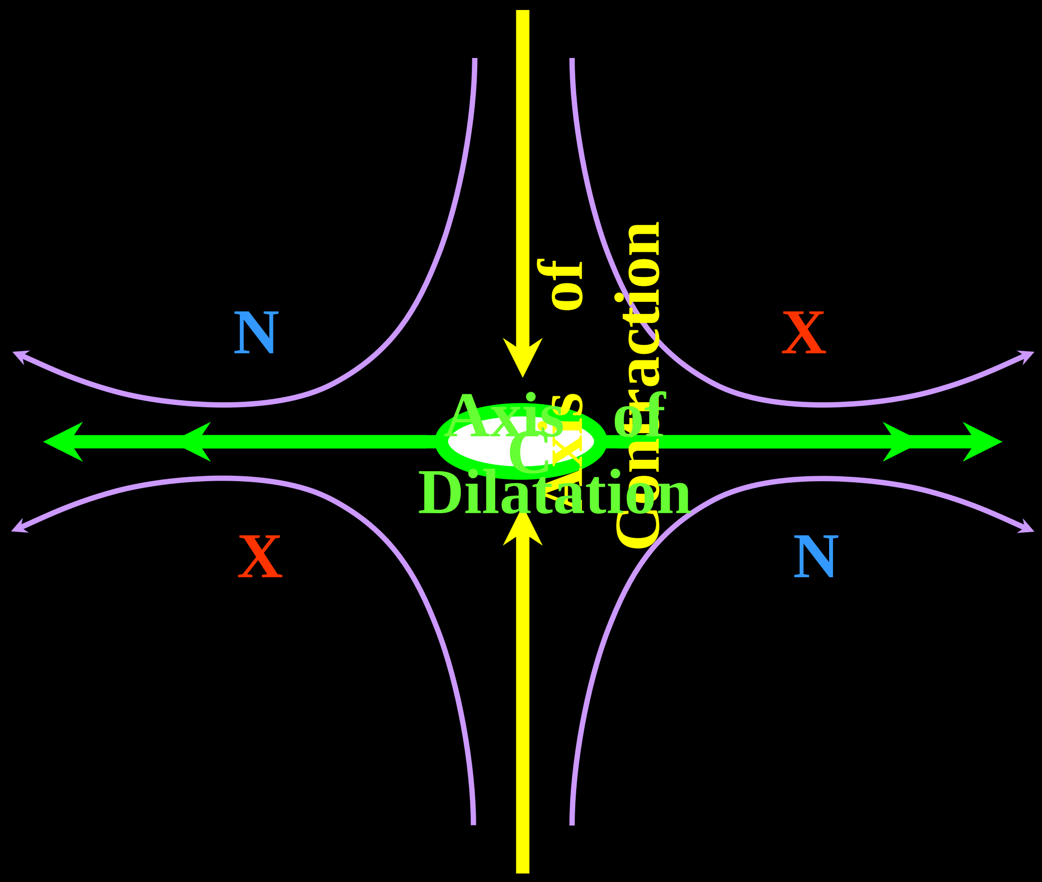
EUMETSAT


Vorticity Minima Anticomma Pattern
GOES Water Vapor, 1030 UTC 27 Jul 05
NOAA

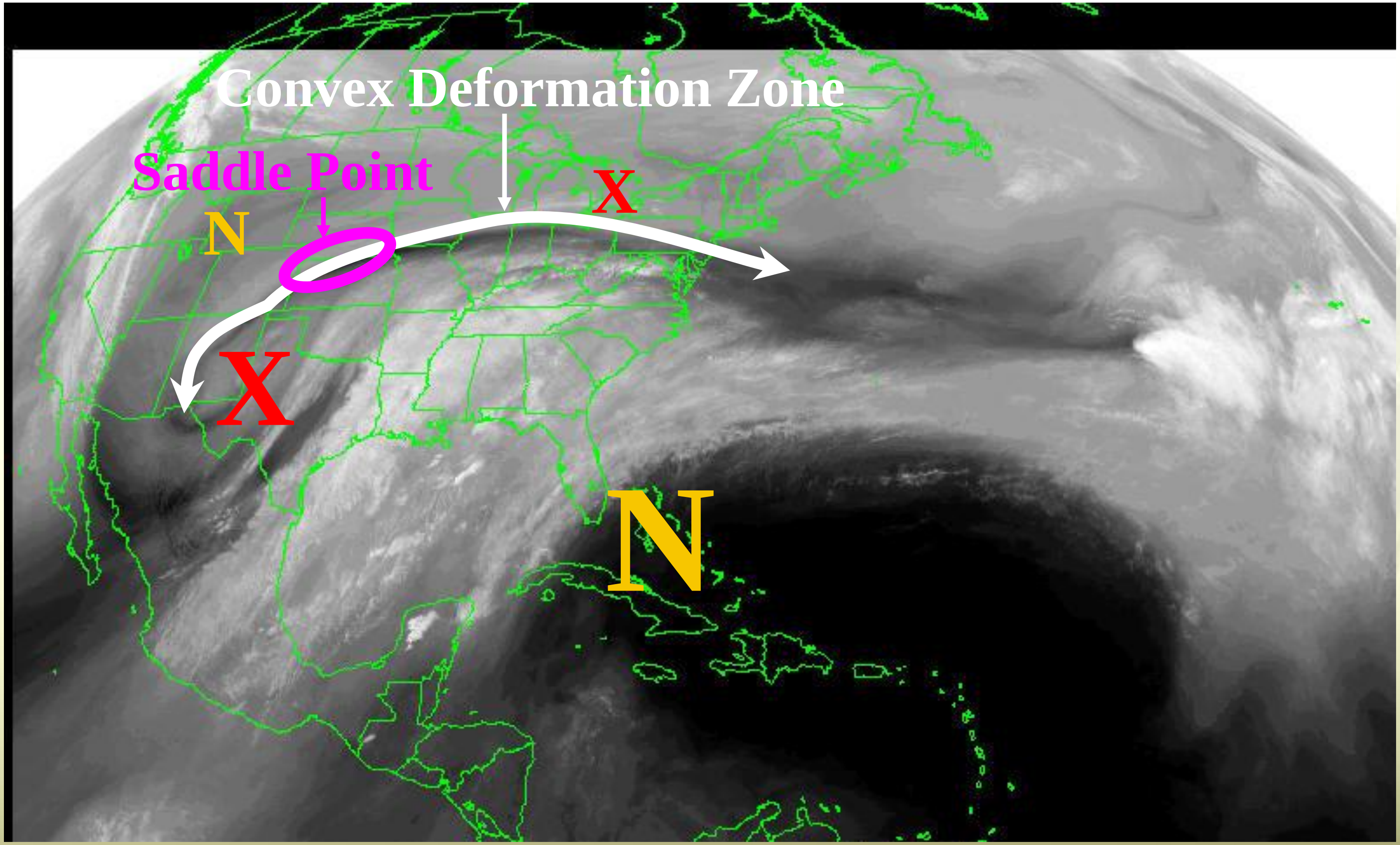
EUMETSAT

Deformation Zone Components

(from Phil Chadwick)



Features seen in WV Images



GOES-12, 14 February 2004, 00:15 UTC, WV Channel

Source: NOAA & P. Chadwick

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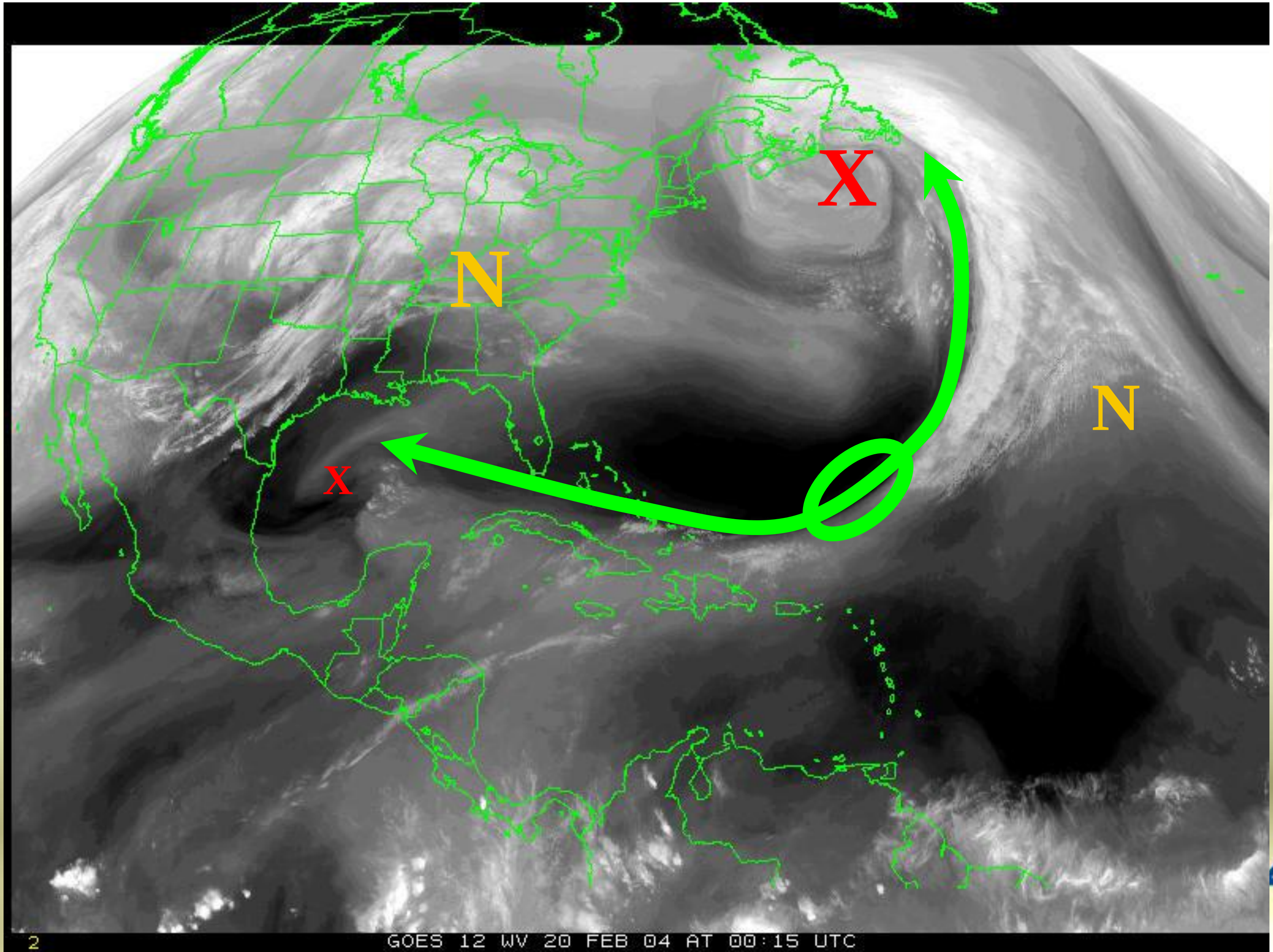
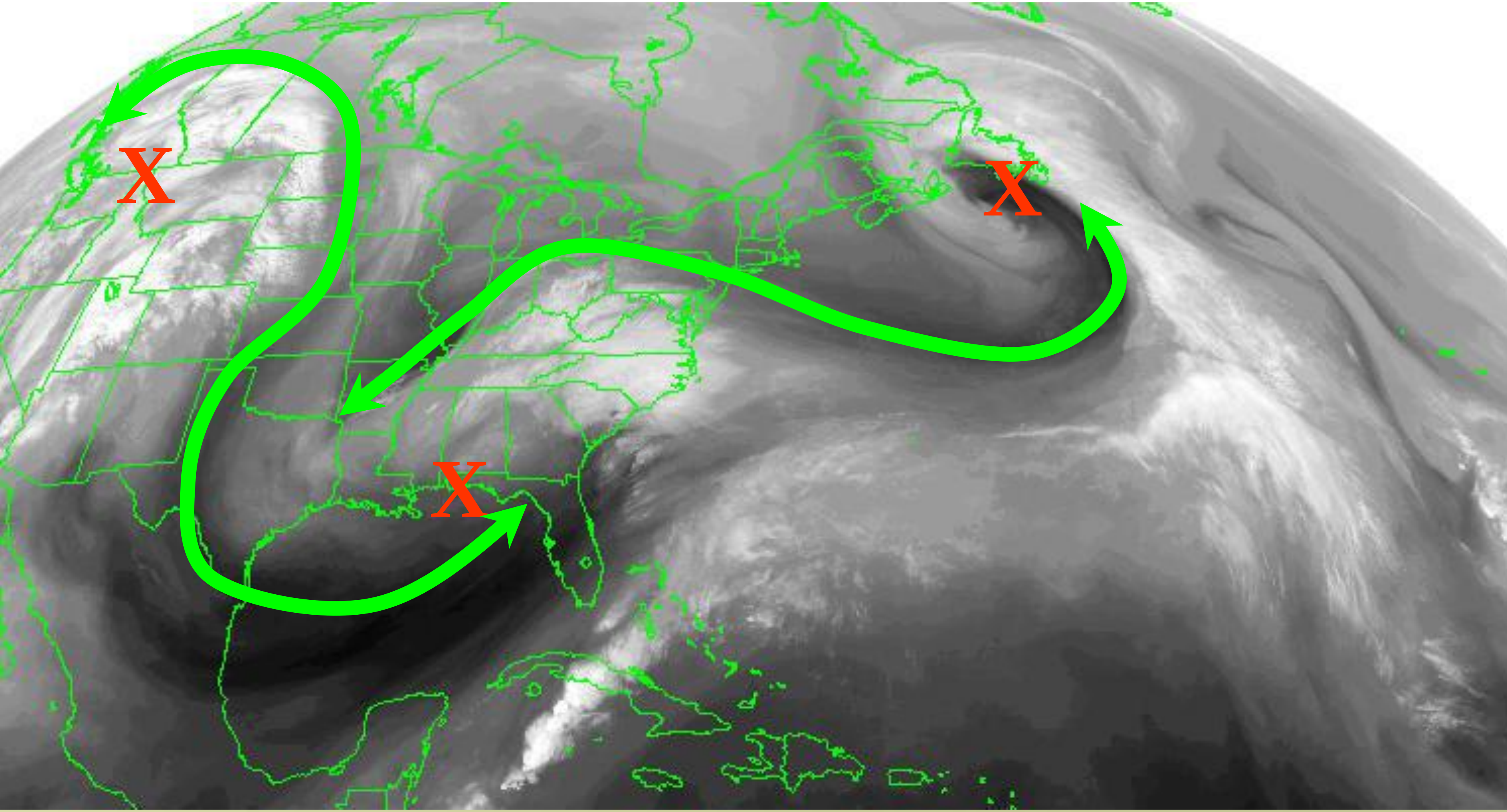
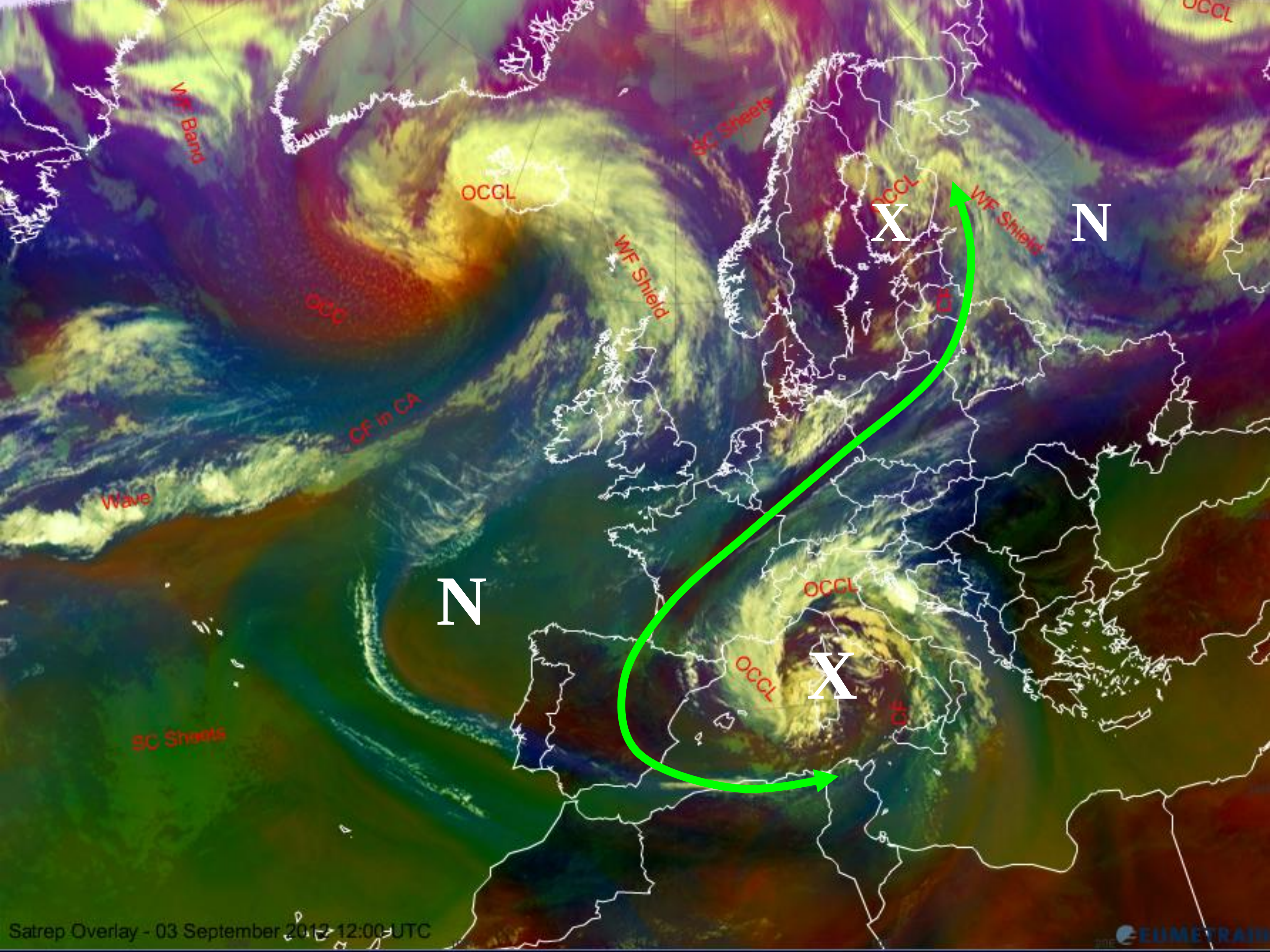
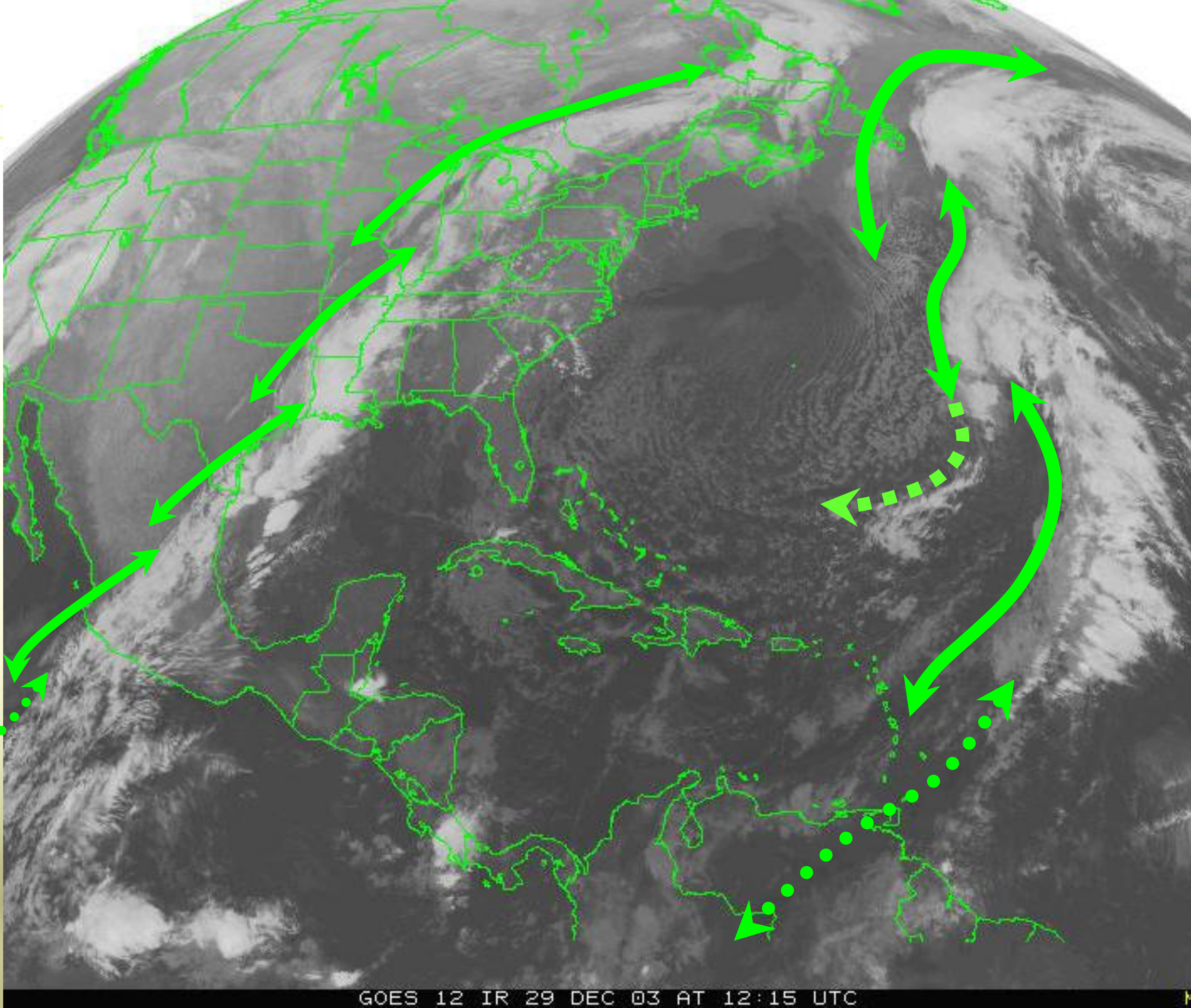
Concave Deformation Zone

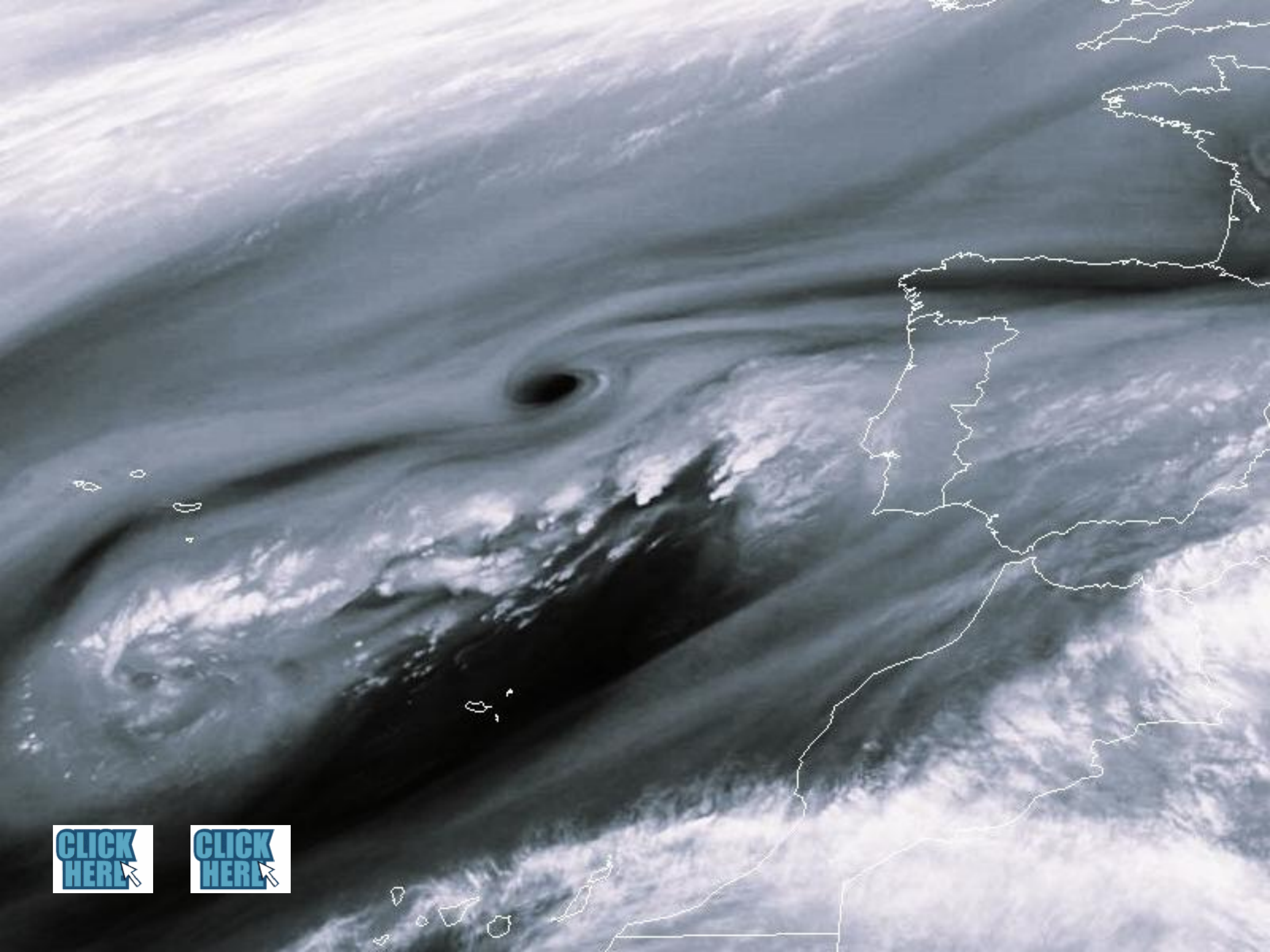



X
X
X



OCCL
WF Band
SC Sheets
OCCL
WF Shield
X
N
OCCL
WF Shield
OCC
CF
CF in CA
Wave
N
OCCL
OCCL
X
CF
SC Sheets
Satrep Overlay - 03 September 2012 12:00 UTC


GOES 12 IR 29 DEC 03 AT 12:15 UTC


CLICK HERE
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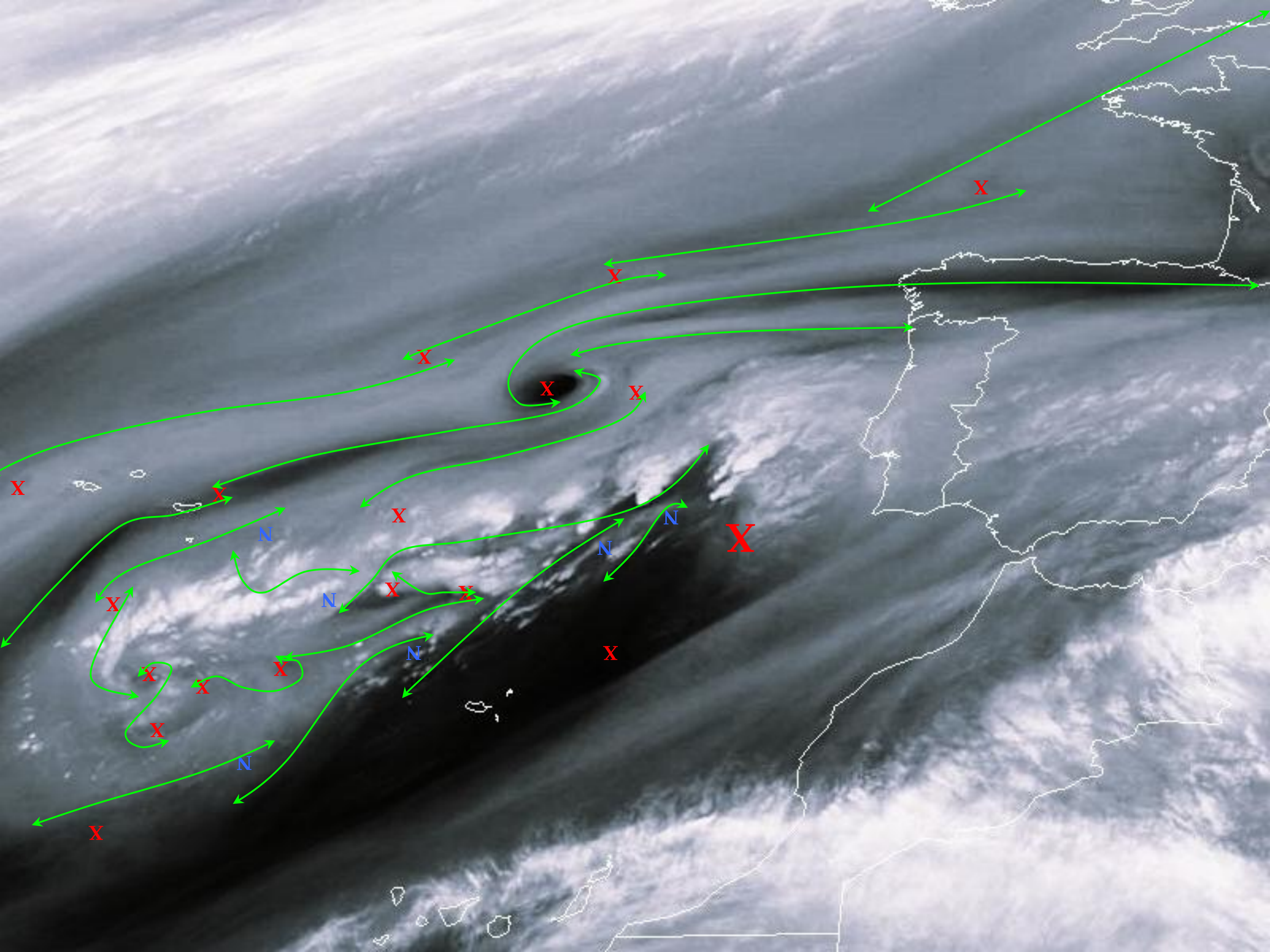
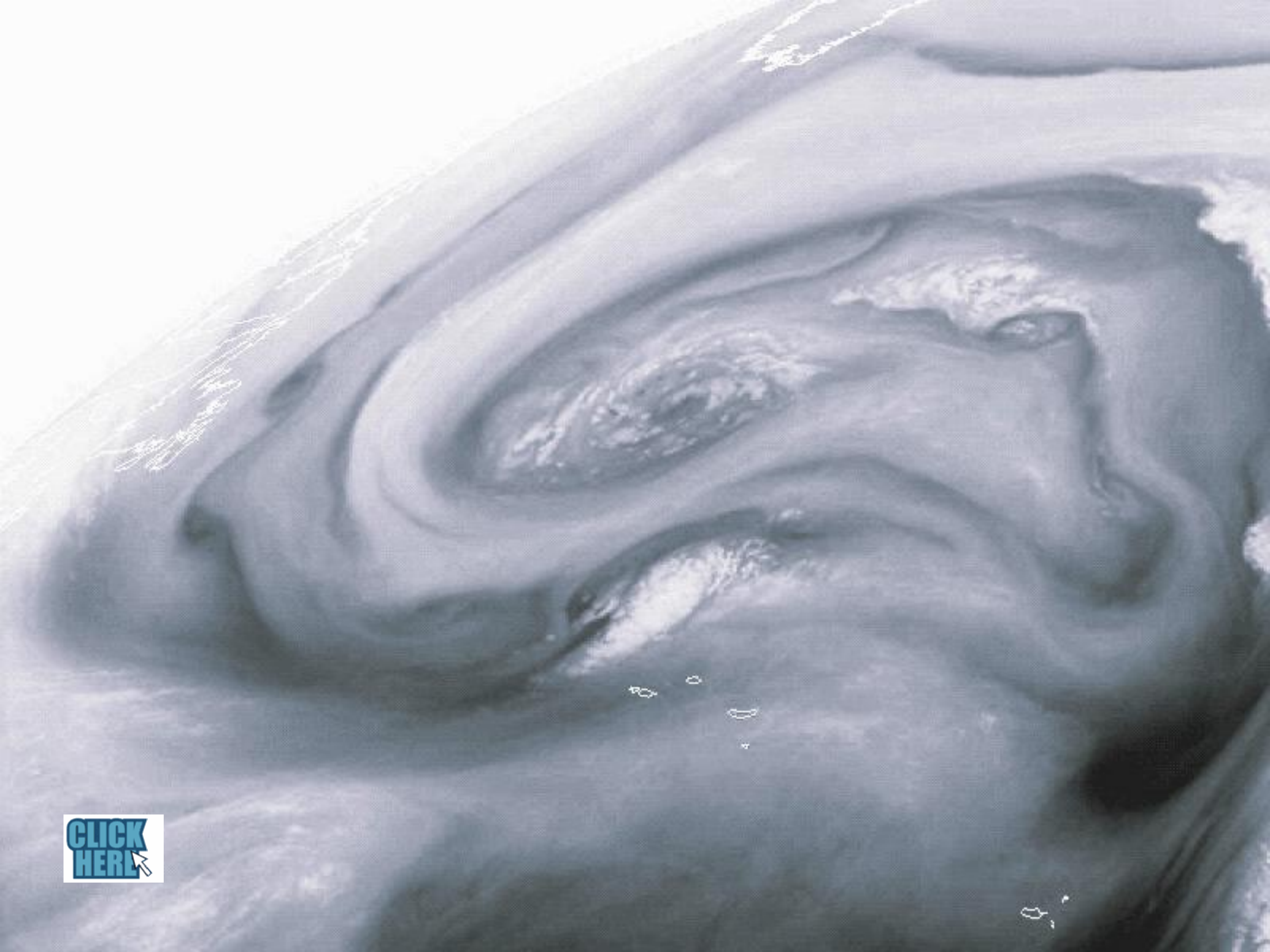

X
N

Bigger whorls have smaller whorls
That feed on their velocity
And little whorls have smaller whorls
And so on to viscosity….

Richardson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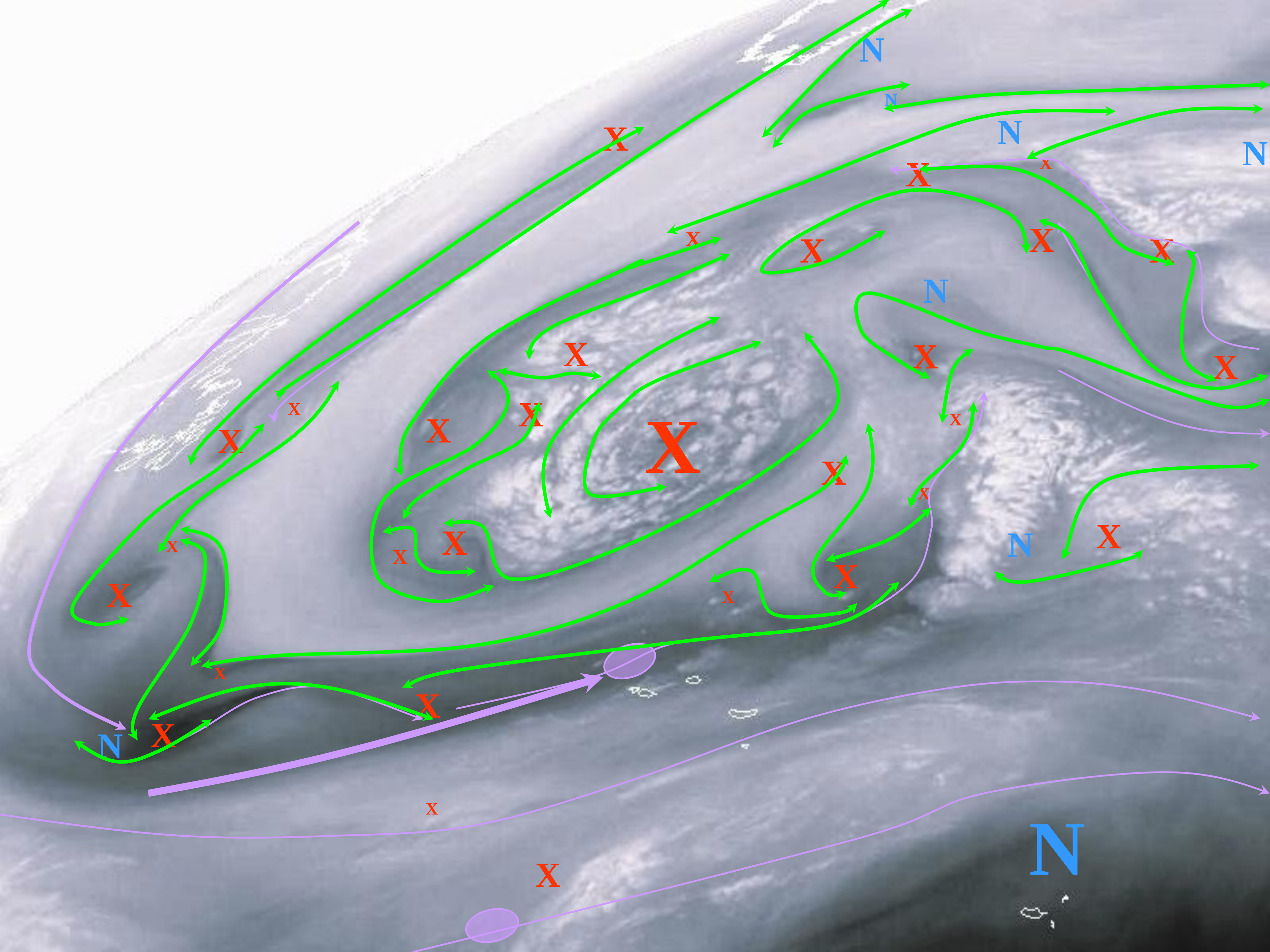
N
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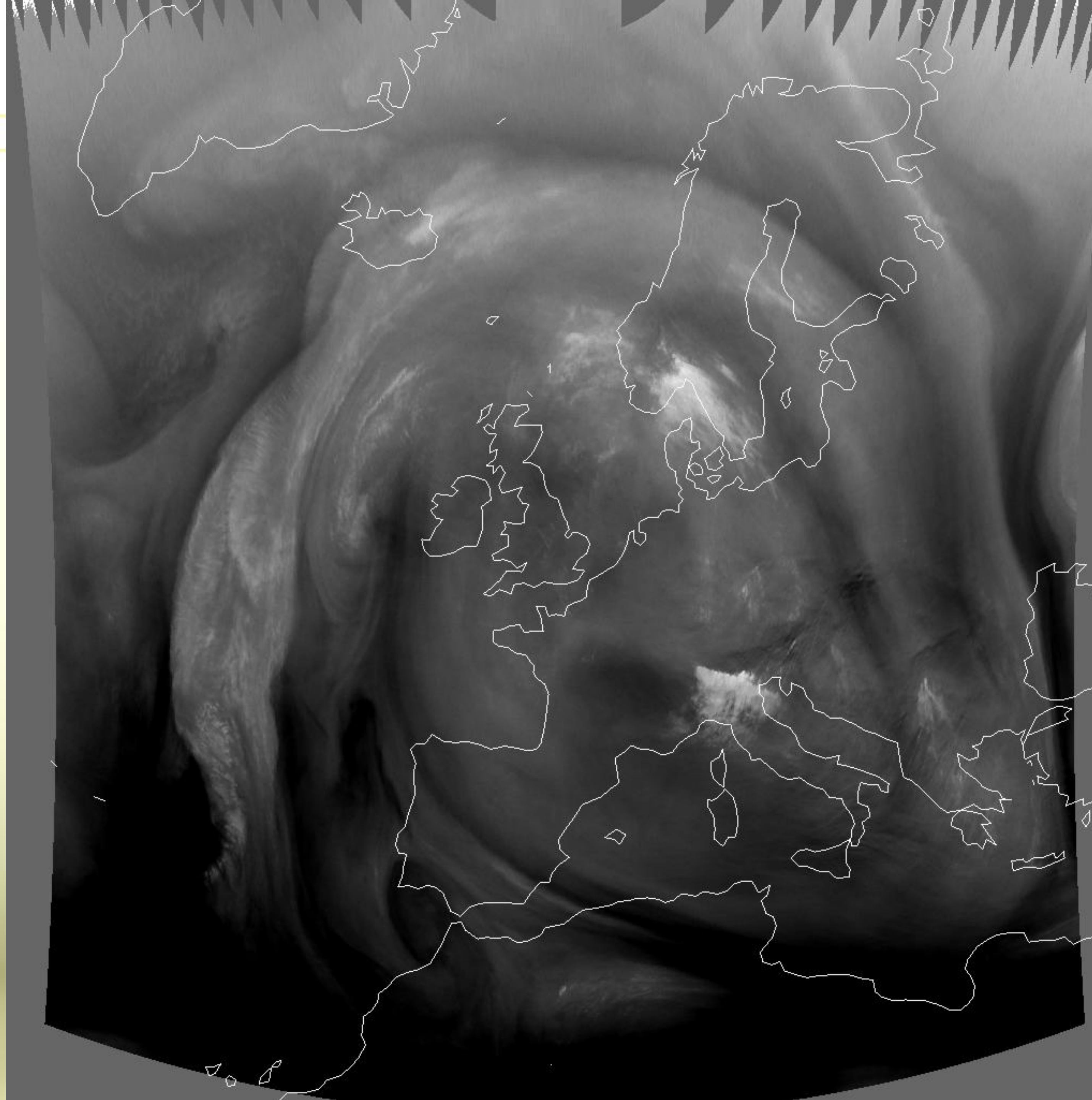
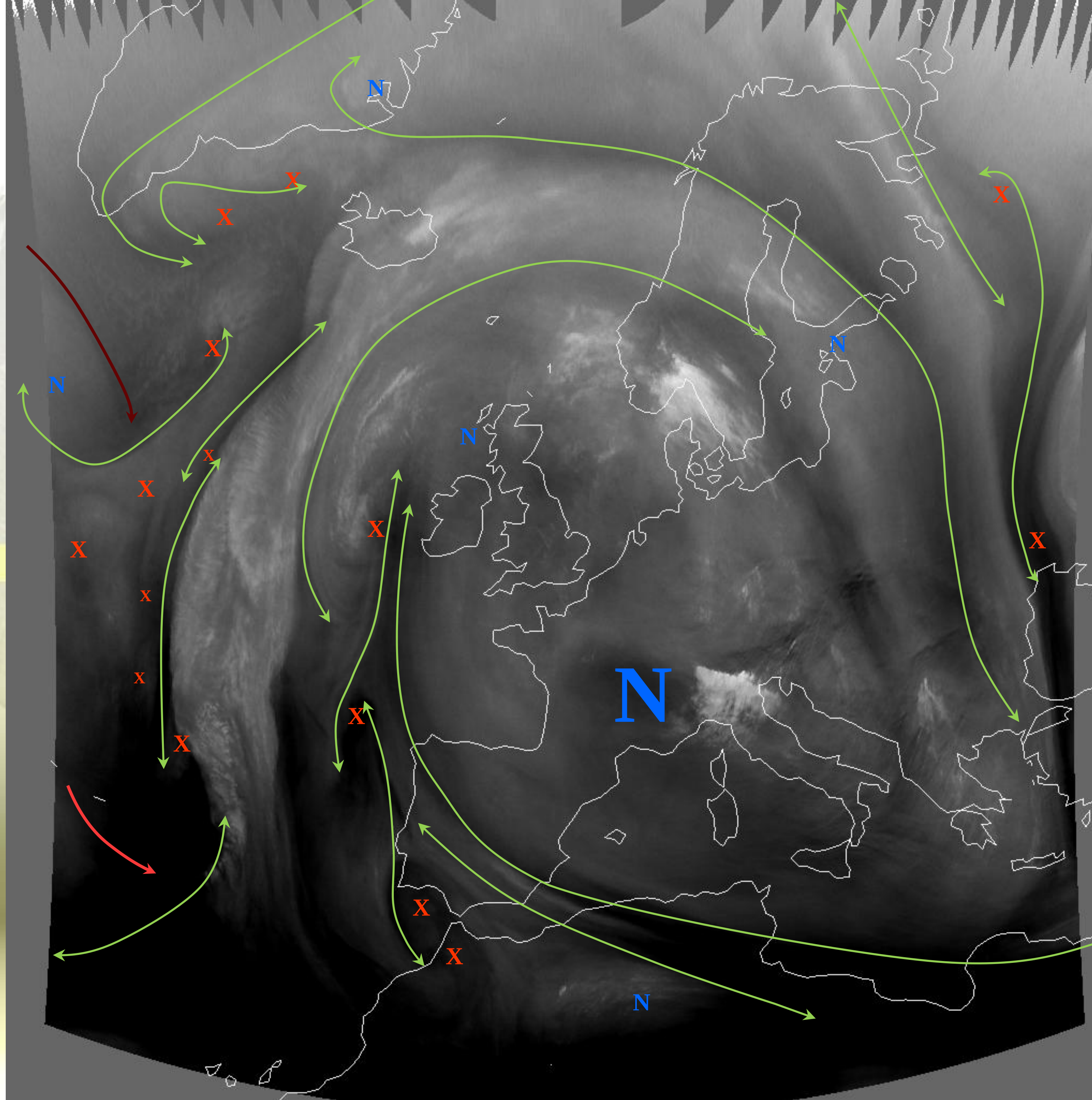
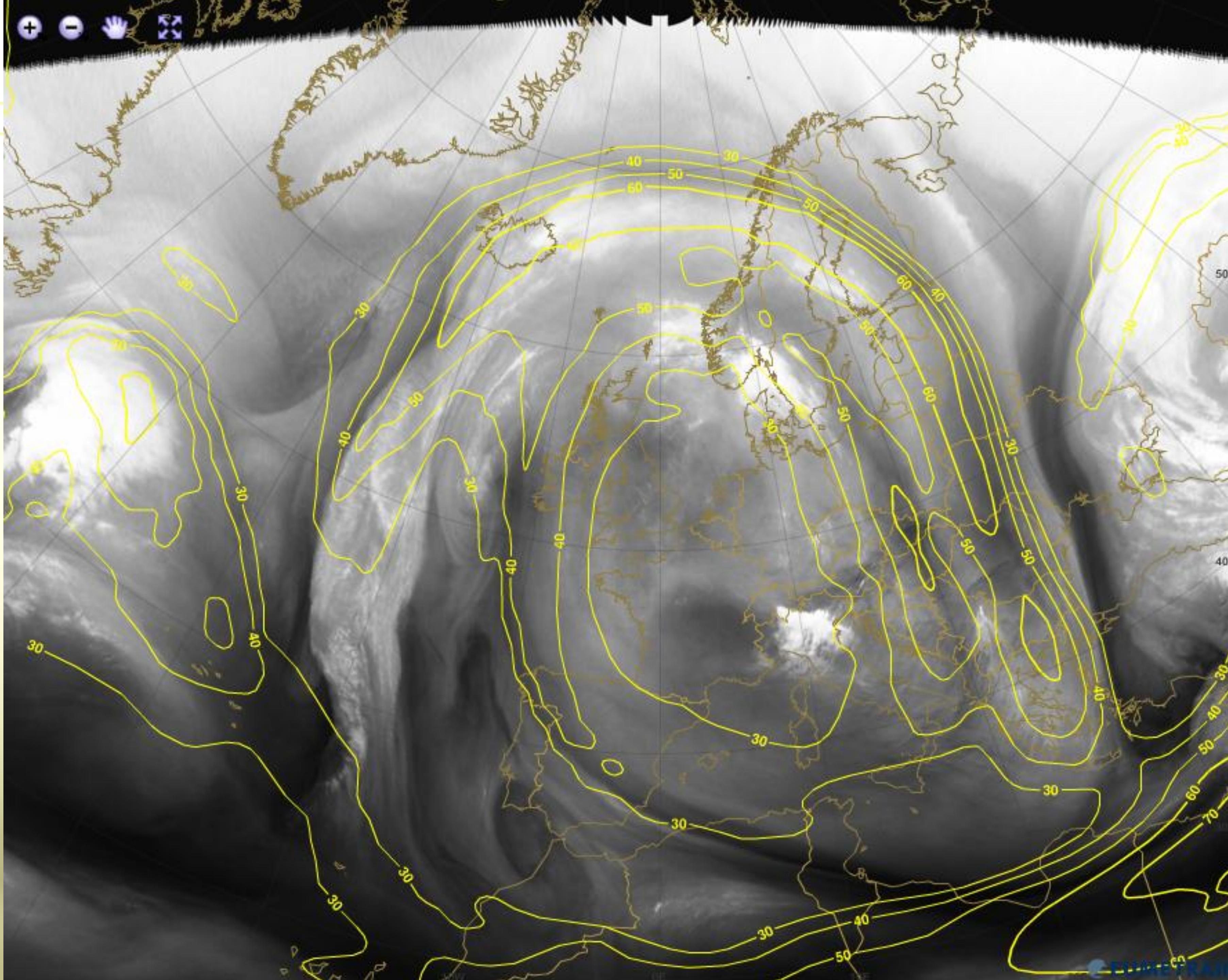


CLICK HERE

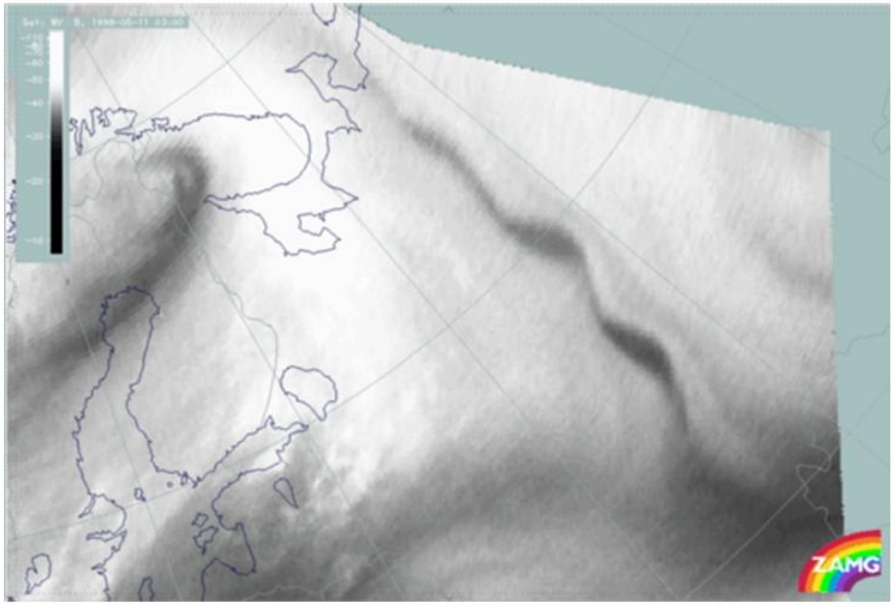
SAT

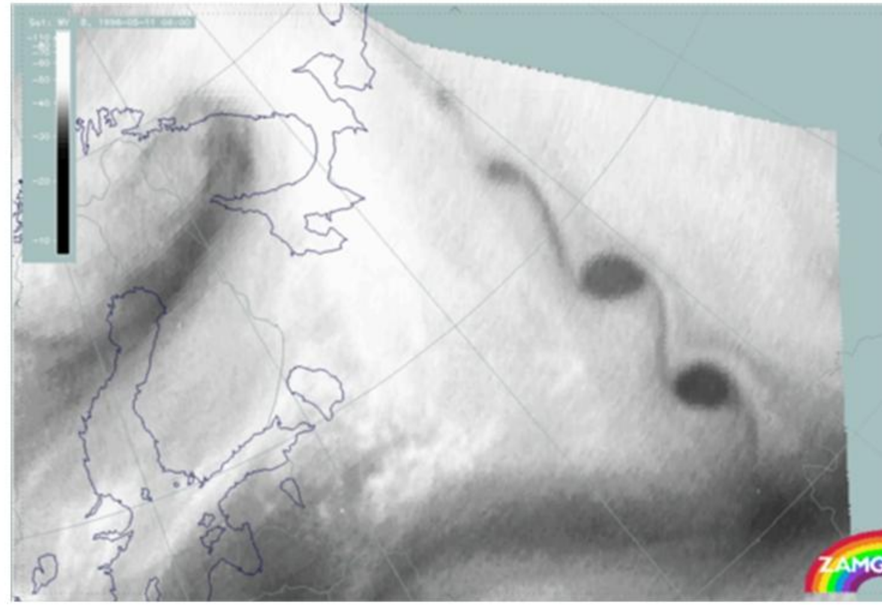
X

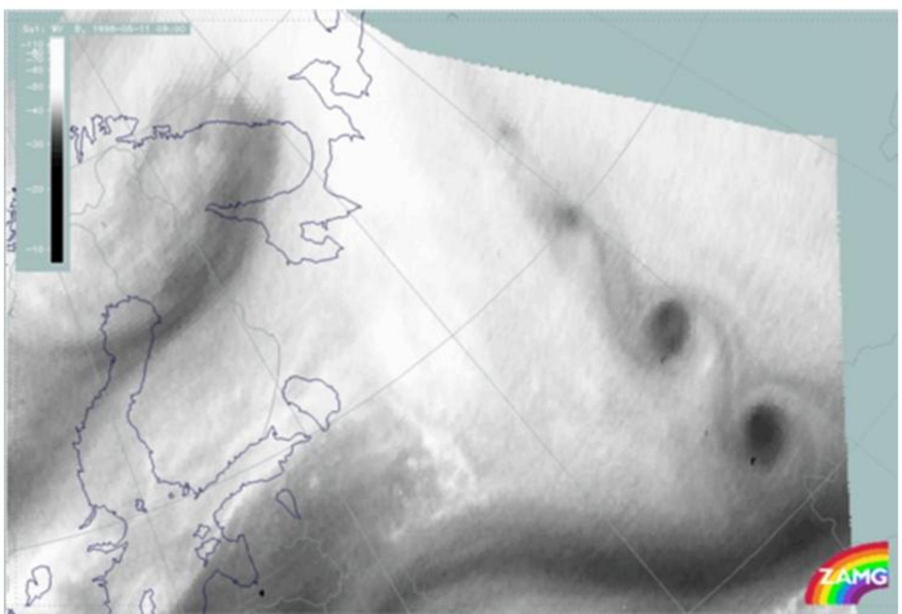



50N
40N

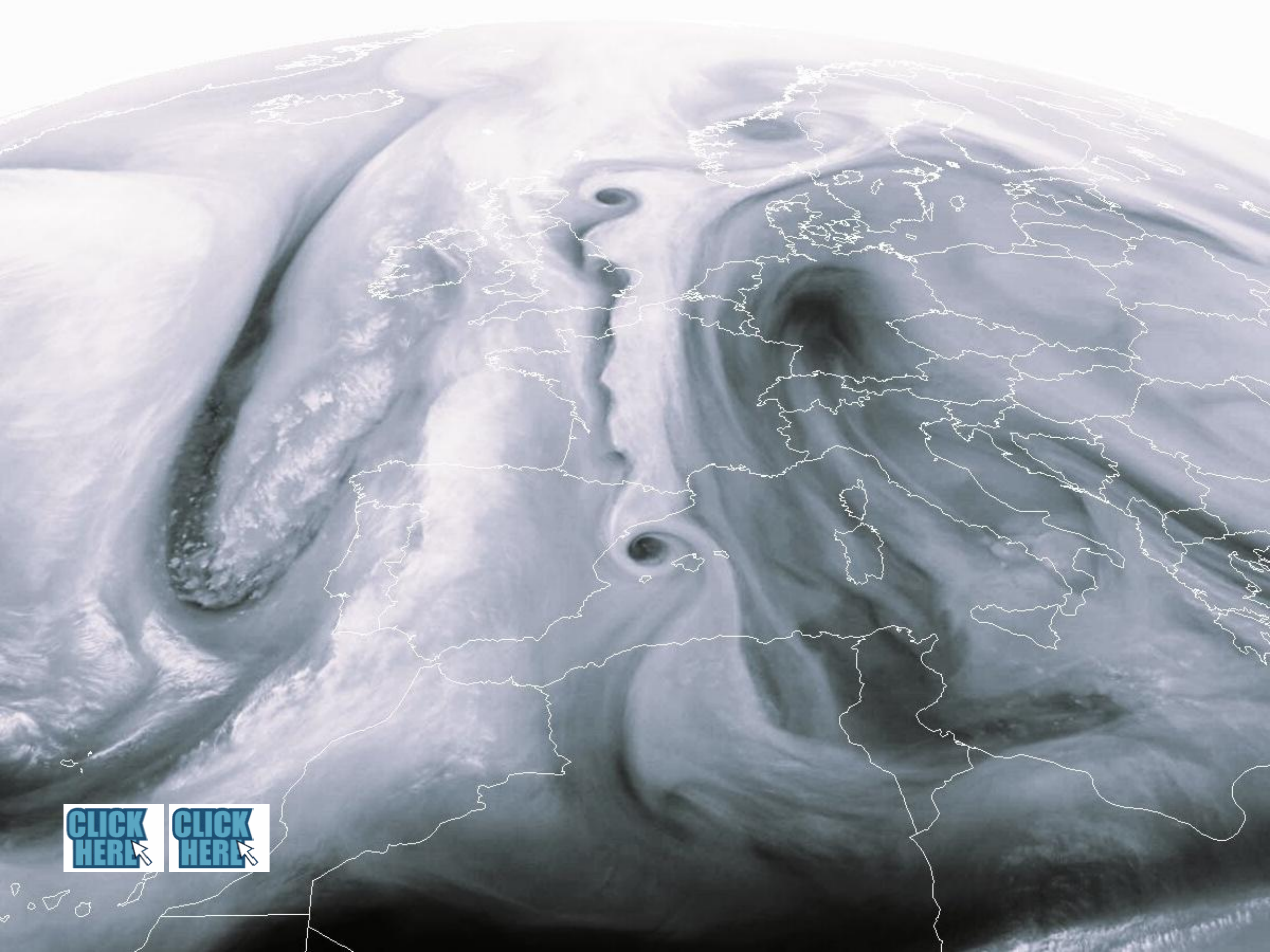
Water Vapour Eyes and Eddies







11 May 1998/03,06,09 UTC - WV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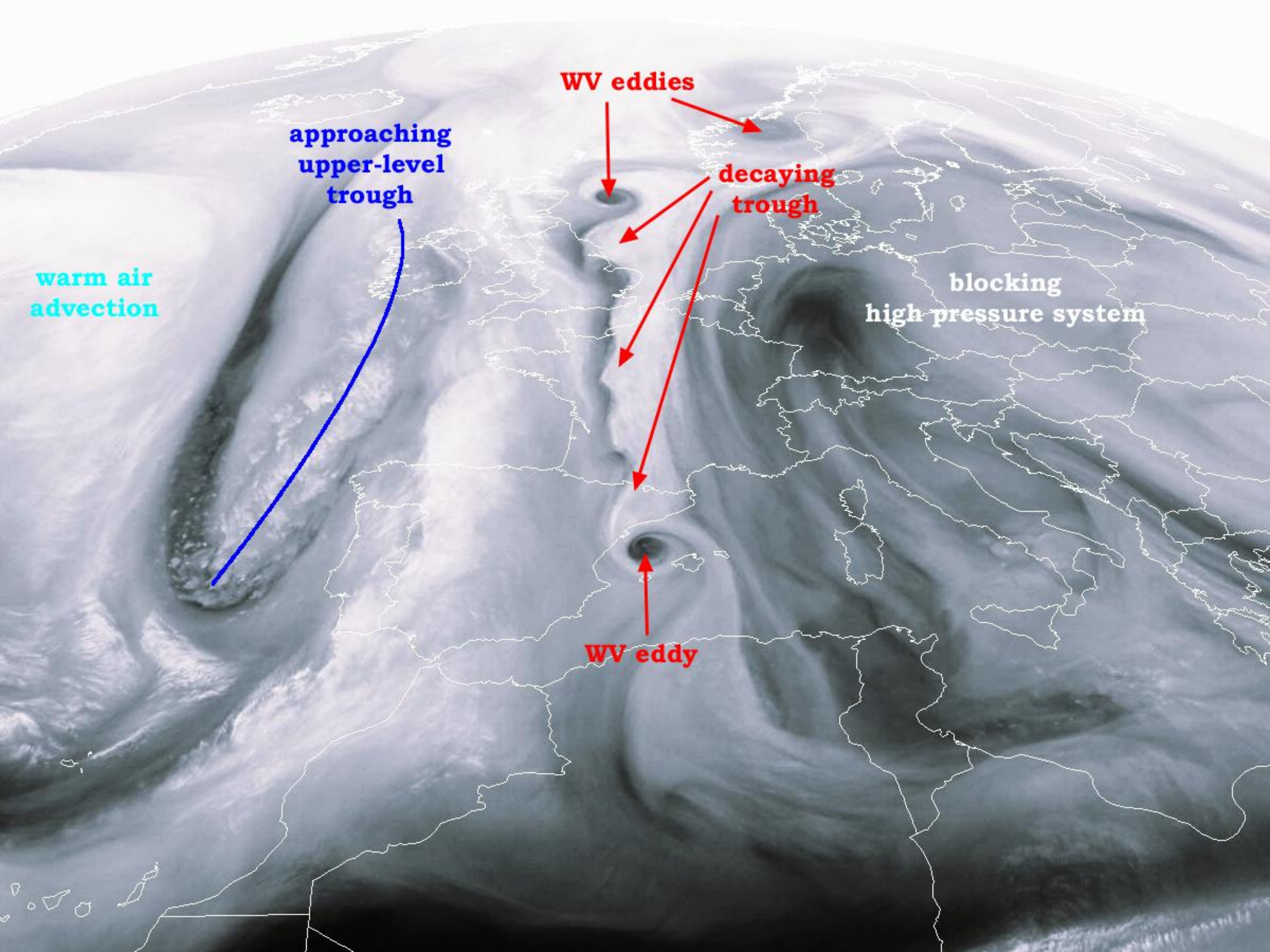
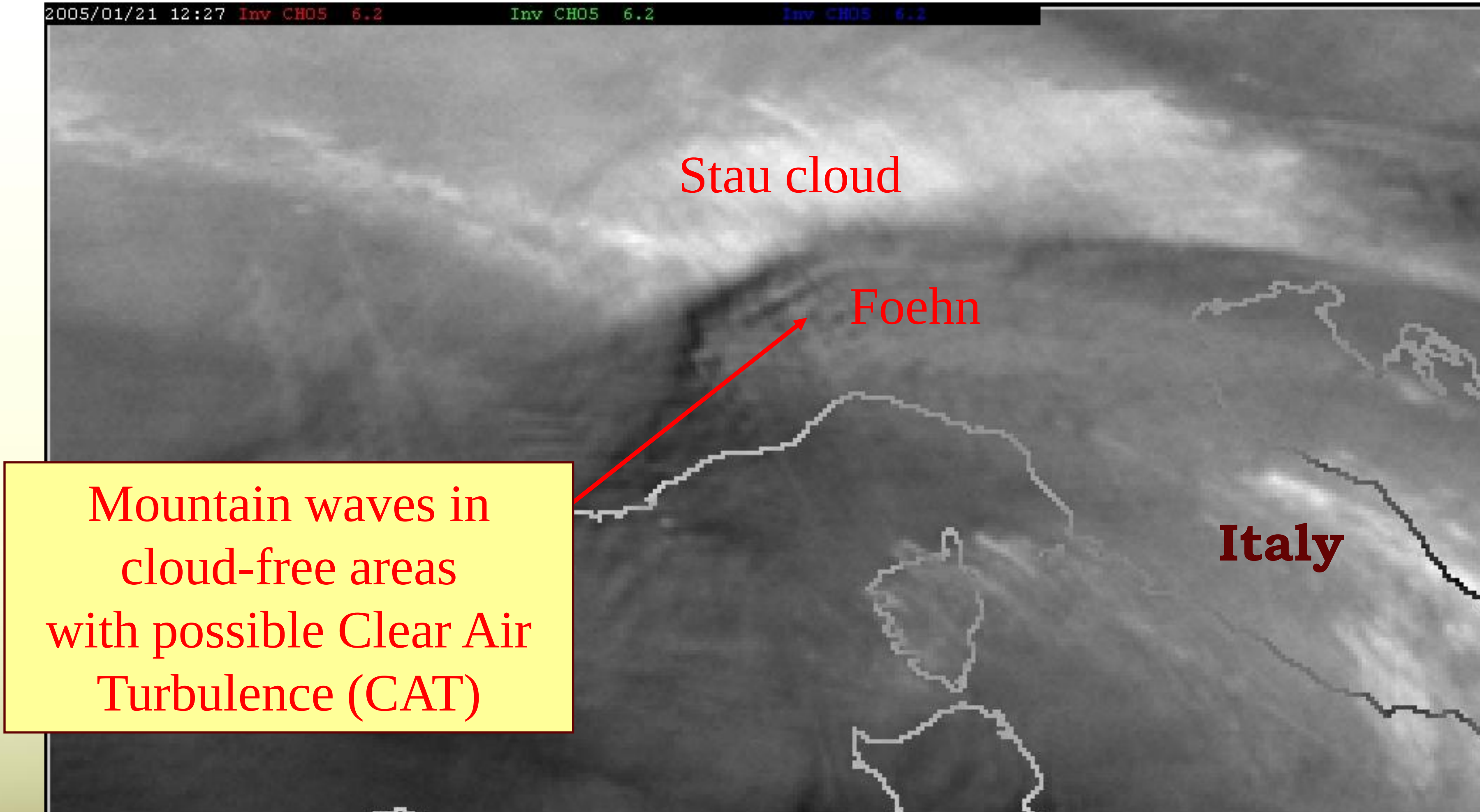

WV eddies
approaching
upper-level
trough
decaying
trough
warm air
advection
blocking
high pressure system
WV eddy

Mountain Waves / Gravity Waves

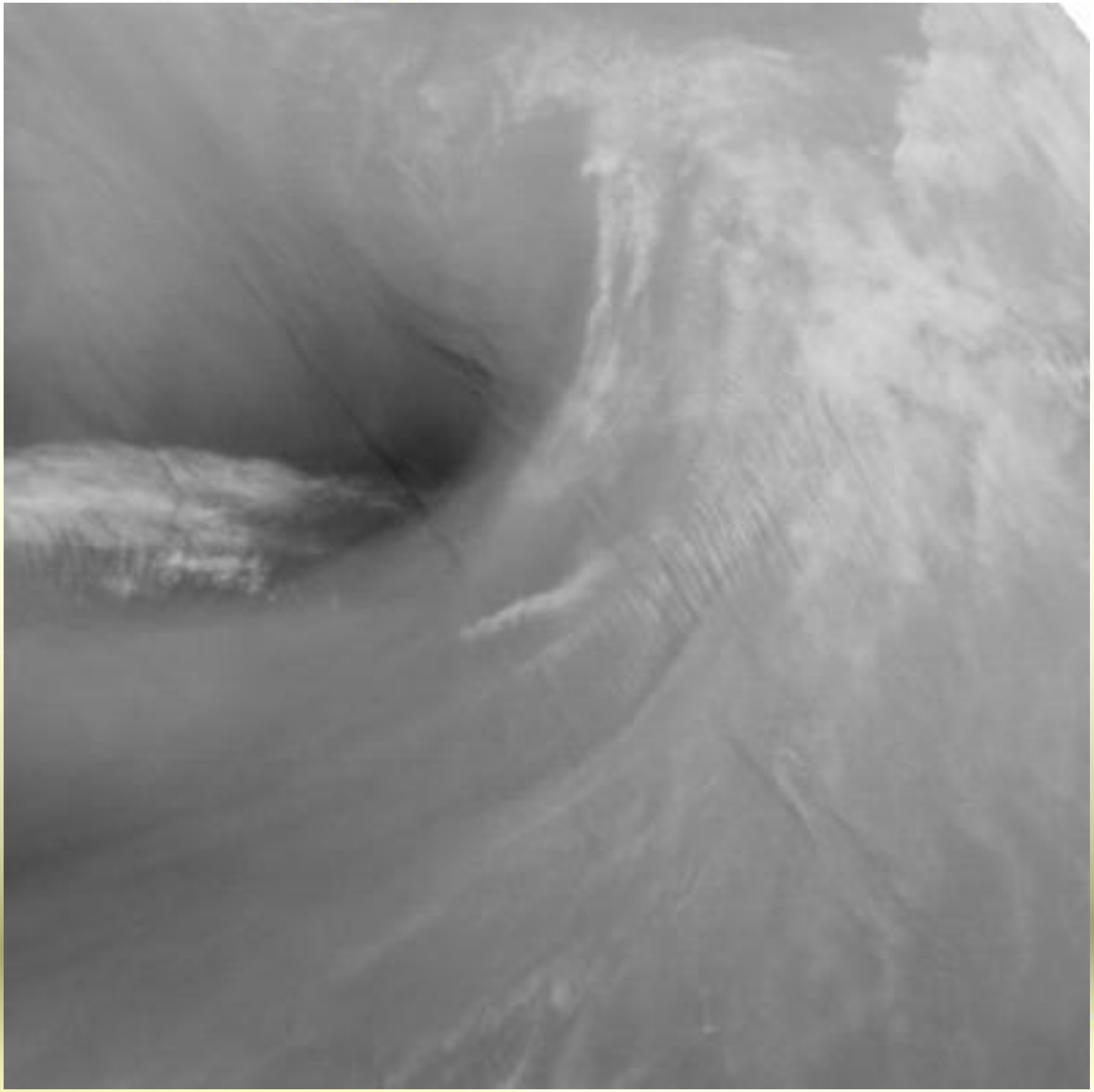
Mountain Waves seen in WV Images



MSG-1, 21 January 2005, 12:15 UTC, Channel 05 (WV6.2)

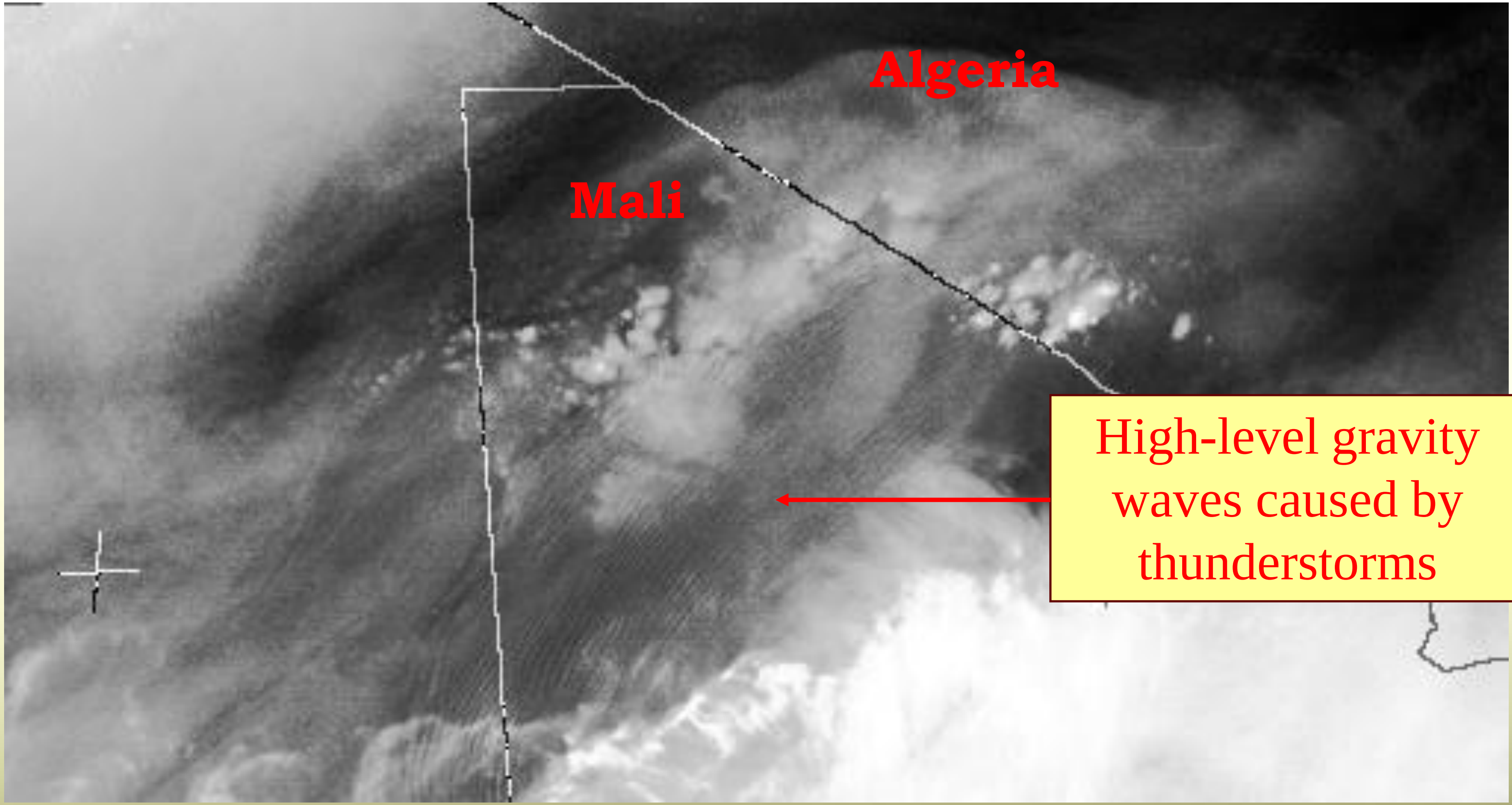
EUMETSAT

Mountain Waves over the Red Sea



Met-6, WV
26 March 1998

Features seen in WV Images



MSG-1, 25 June 2005, 14:15 UTC, Channel 05 (WV6.2)

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Operational Applications of 6.2 and 7.3 WV Images

- The radiation in **6.2 μm** band is highly absorbed by water vapour and it is more useful to be **displayed and applied in image format for operational purposes**.
- The **7.3 μm** channel is able to detect low-level moisture, thus it is sensible to the moisture content at these altitudes.
- Therefore, images in **7.3 μm** channel may be interpreted **for studying low level humidity features**.

Operational Applications of WV6.2 Images

a) Jet-stream features (shear zones, turbulence)

b) Tropopause dynamic anomalies (PV anomalies)

c) Large-scale moisture movements and surges

d) Vorticity minima / maxima

e) Deformation zones

f) Mountain Waves / Gravity Waves

References

Santurette, P., Georgiev C. G., 2005. Weather Analysis and Forecasting: Applying Satellite Water Vapor Imagery and Potential Vorticity Analysis. ISBN: 0-12-619262-6. Academic Press, Burlington, MA, San Diego, London. Copyright ©, Elsevier Inc. 179 pp.

Weldon, R. B., Holmes, S. J., 1991. Water vapor imagery: interpretation and applications to weather analysis and forecasting, *NOAA Technical. Report*. NESDIS 57, NOAA, US Department of Commerce, Washington D.C., 213 pp.

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