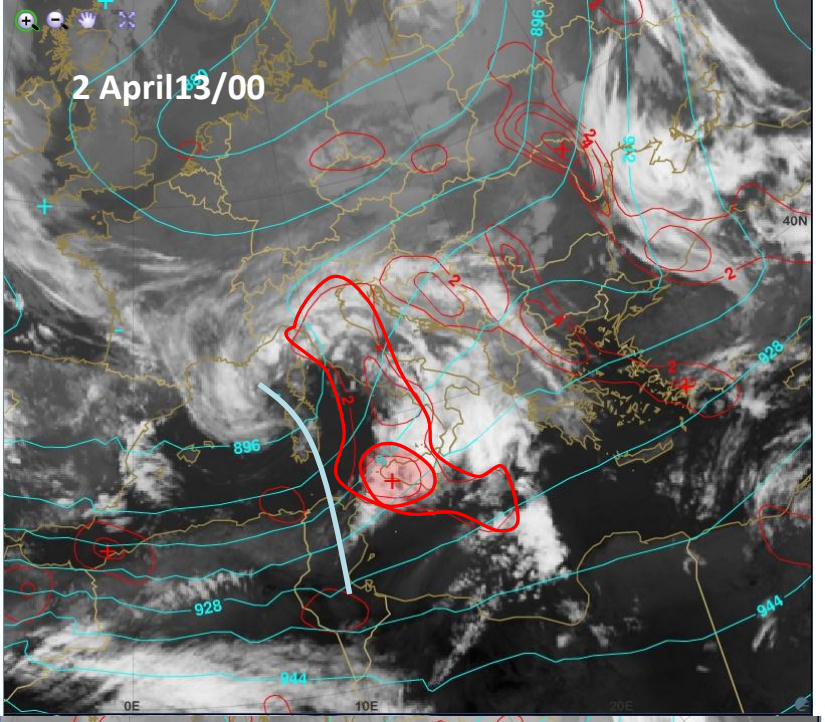
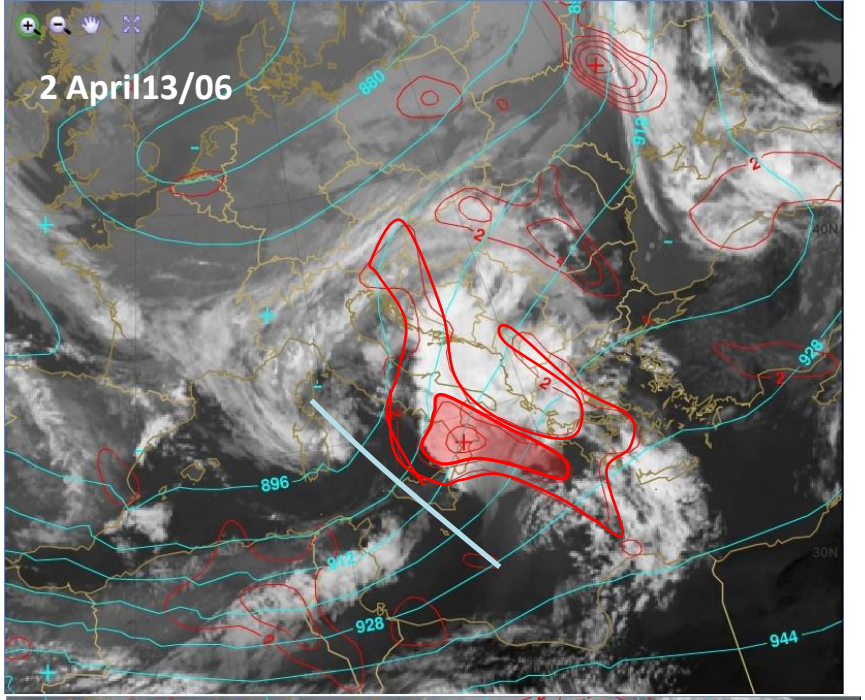
Occlusion – cyclogenesis II

Upper level influences – Hoskins theory
Rapid cyclogenesis
Other types of cyclogenesis:
Instant occlusion
Cold air Development



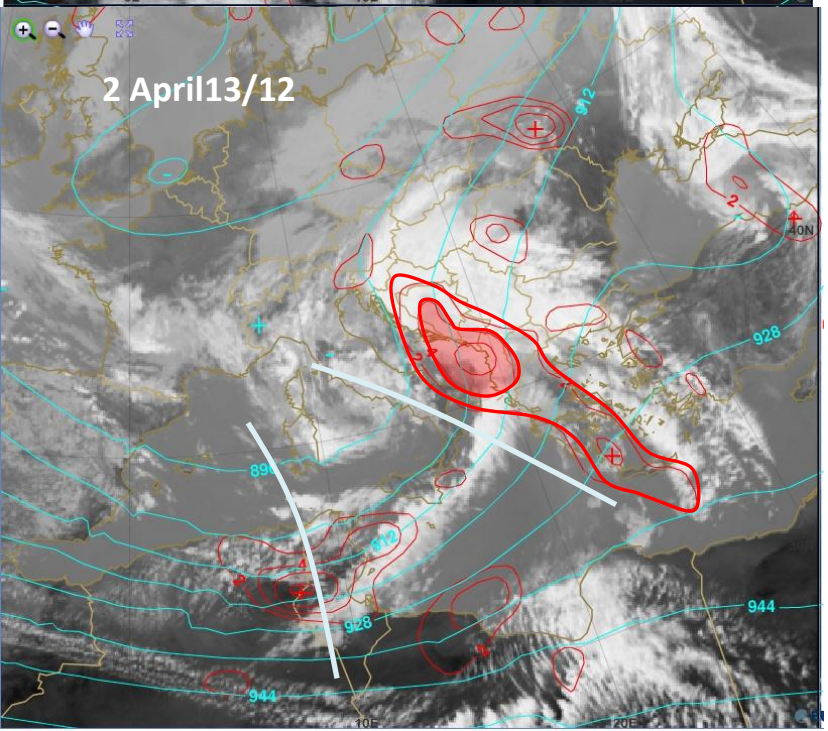


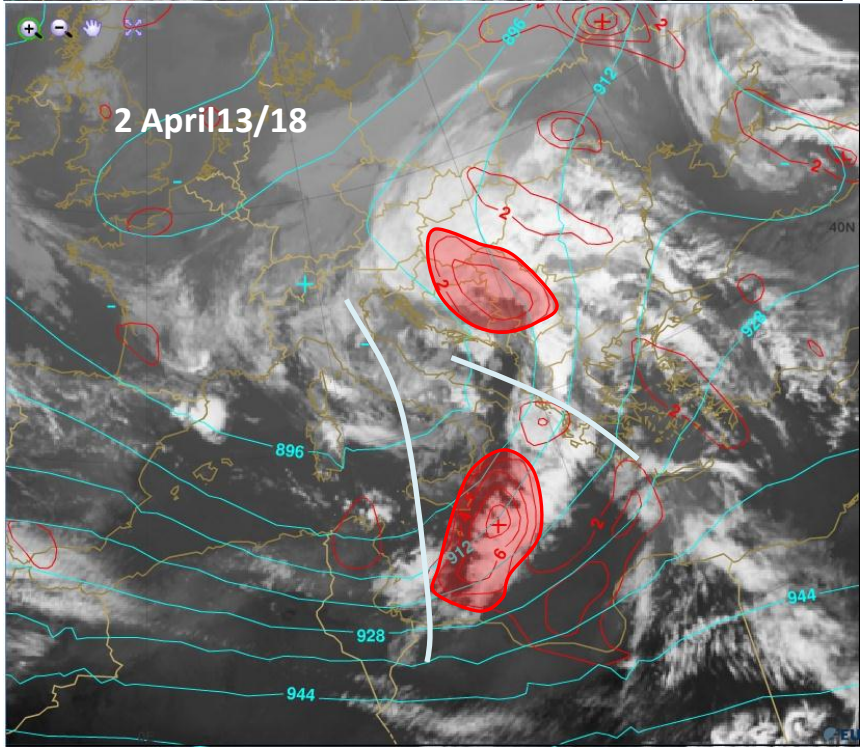
WCB type:

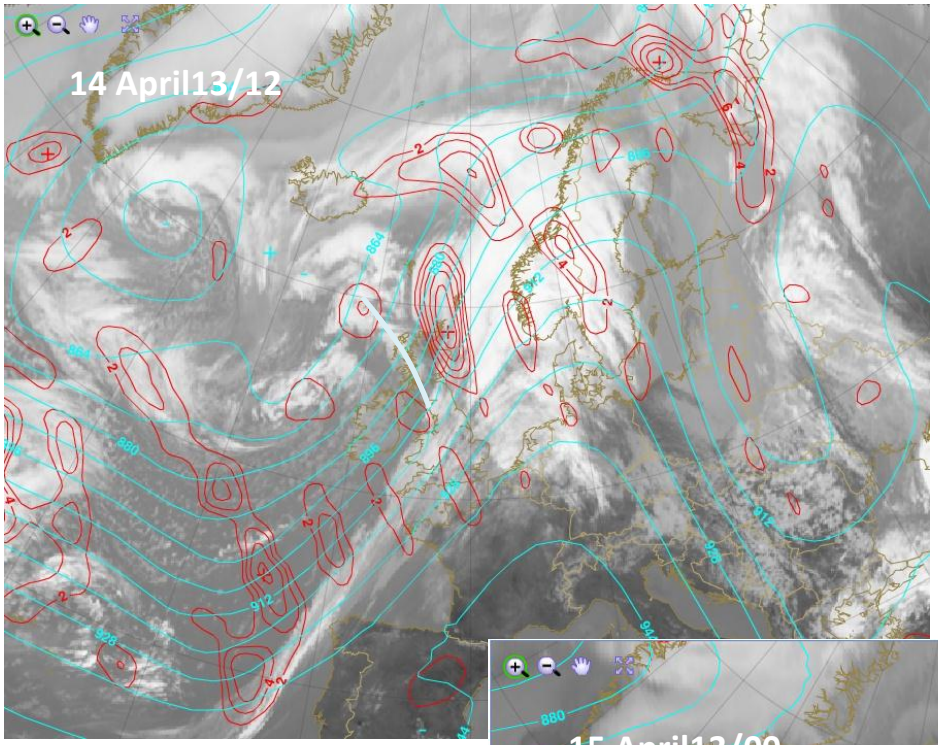
Upper level Trough 300 hPa + PVA 300hPa

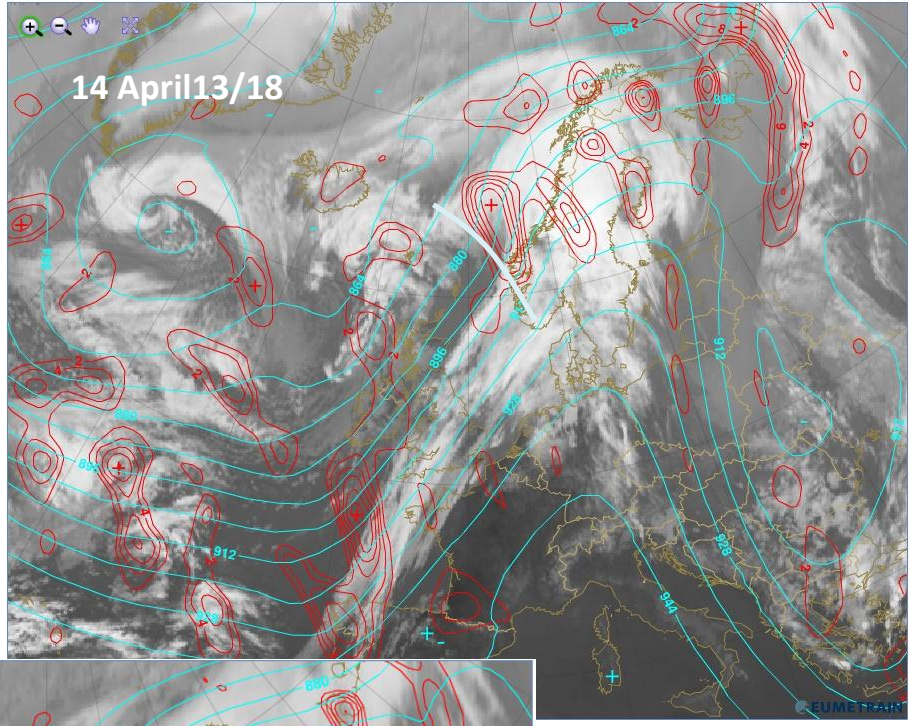
Distinct PVA maxima:

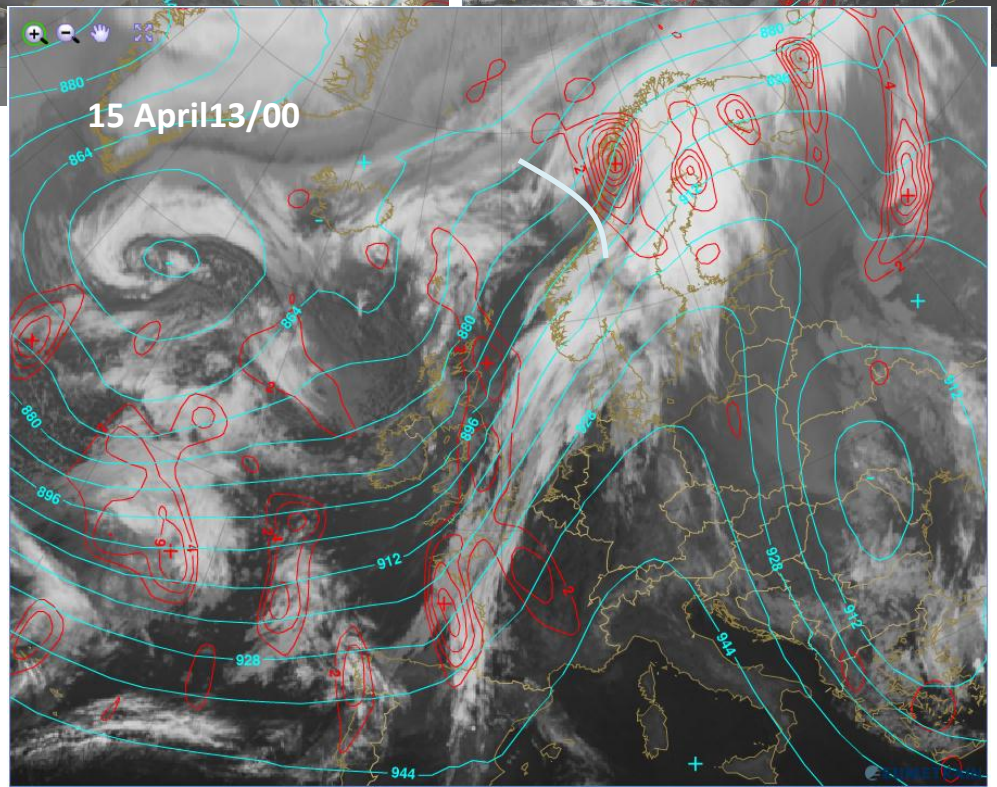
Why at this Position?











CCB type:

Upper level
Trough 300 hPa
+
PVA 300 hPa

Distinct PVA max: why so intensive

Reflectance of occlusion process / cyclogenesis in derived upper level parameters

- For Fronts Temperature Advection is a dominating parameters
- For cyclogenesis also Vorticity and Vorticity Advection are dominating parameter

Vorticity

- $\zeta = \mathrm{rot}_z \mathbf{v}_2 = \partial v/\partial x - \partial u/\partial y$
- $\eta = \zeta + f$ $\qquad f = 2\,\Omega \sin\varphi$

- cyclonic: $\zeta > 0$ (NH) $\quad \zeta < 0$ (SH)
  anticyclonic: $\zeta < 0$ (NH), $\zeta > 0$ (SH)

- Vorticity is a quality of the stream field
- Vorticity describes rotation movements

- **Vorticity is one of the parameters which are responsible for the formation of cloudiness**

Vorticity Advection

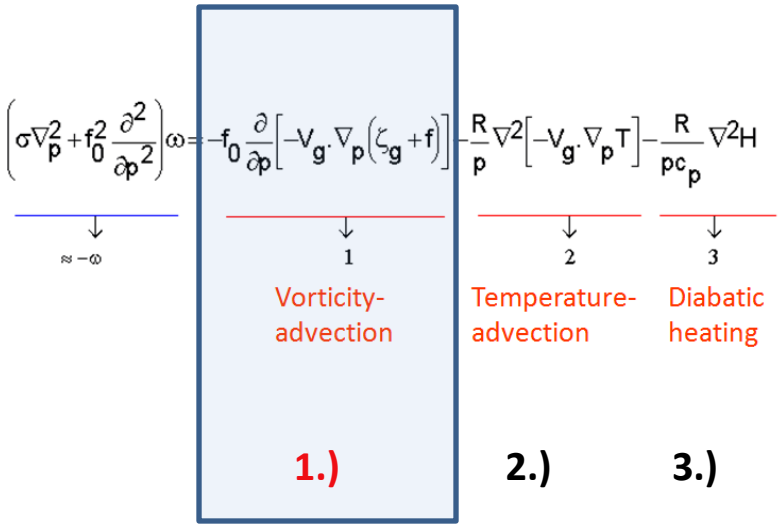
- VA = - $\mathbf{v} \cdot \nabla\zeta$ Advection of rel. vorticity
- VA = - $\mathbf{v} \cdot \nabla\eta$ Advection of abs. vorticity

- VA > 0 positive Vorticity advection: PVA
- VA < 0 negative Vorticity advection: NVA

- PVA: it becomes more cyclonic (NH) or more anticyclonic (SH)
- NVA: it becomes more antiyclonic (NH) or more cyclonic (SH)

- **The Advection of Vorticity is one of the parameters which is responsible for the development of cloudiness**

Omega equation
in a quasi geostrophic system



c_p	specific heat at constant pressure
f	Coriolis parameter
p	pressure
H	diabatic heat transfer
R	universal gas constant
T	temperature
V_g	geostrophic wind vector
ζ_g	relative geostrophic vorticity
σ	static stability
ω	vertical motion

- **Assumptions for a Quasi-geostrophic Systems:**
  - 1.) there is hydrostatic equilibrium in the vertical
  - 2.) Pressure- and vorticity fields are in a geostrophic equilibrium

- The right side in this representation of the **omega equation** consists of three terms:

- **1.)** the vertical change of the vorticity advection
- **2.)** the Laplacian of the temperature advection(the change of the horizontal gradient of the temperature advection)
- **3.)** the Laplacian of diabatic heat transfer (the change of the gradient of diabatic heat transfer)

Some basic considerations for vorticity and vorticity advection

- the vertical change of the vorticity advection
  $\partial/\partial p \,.\, (- \mathbf{v_p} \,.\, \nabla\eta)$

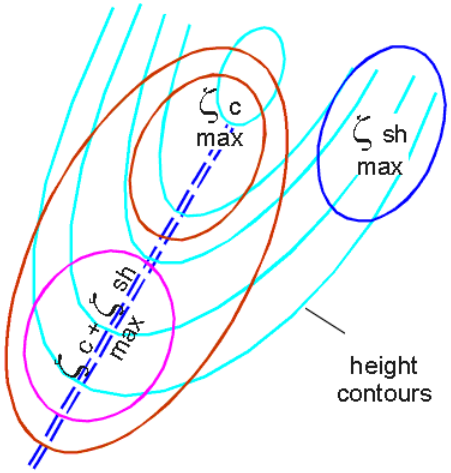
- Upward motion is connected with
  - The increase of PVA (CVA) with height
  - The decrease of NVA (AVA) with height

- In the method of analysing satellite images together with numerical model a simplification is applied:
- Instead of the vertical change of Vorticity advection only the pronounced maxima of Vorticity advection in upper levels (500, 300 hPa) are taken into account
- This needs the assumption of:
  - Increase of wind speed with height
  - This is reasonable but every time fulfilled

The significance of processes in the upper troposphere for cyclogenesis

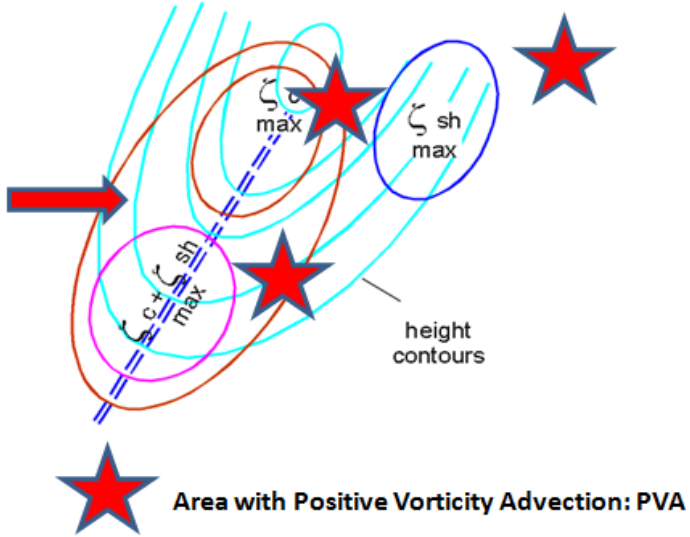
Vorticity (rotation)

- Vorticity consists of two contributions: curvature and shear vorticity
- Typical areas for Positive (Cyclonic) Vorticity values are (on the NH):
  - lows, troughs and jet streaks



Vorticity Advection

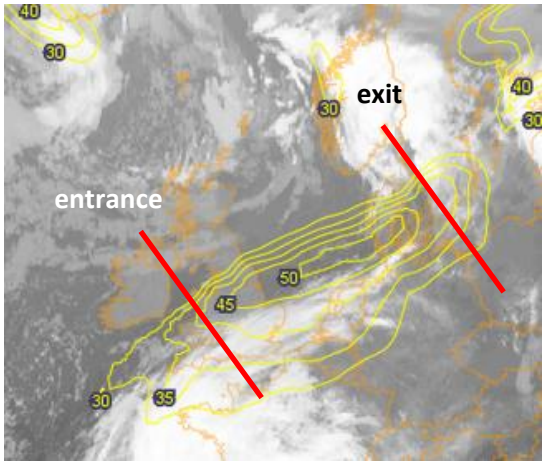
- If a weather system with high cyclonic values of vorticity is moving:
  - Downstream from Vorticity maxima becomes the troposphere more cyclonic→
  - Areas of Positive Vorticity Advection (PVA)

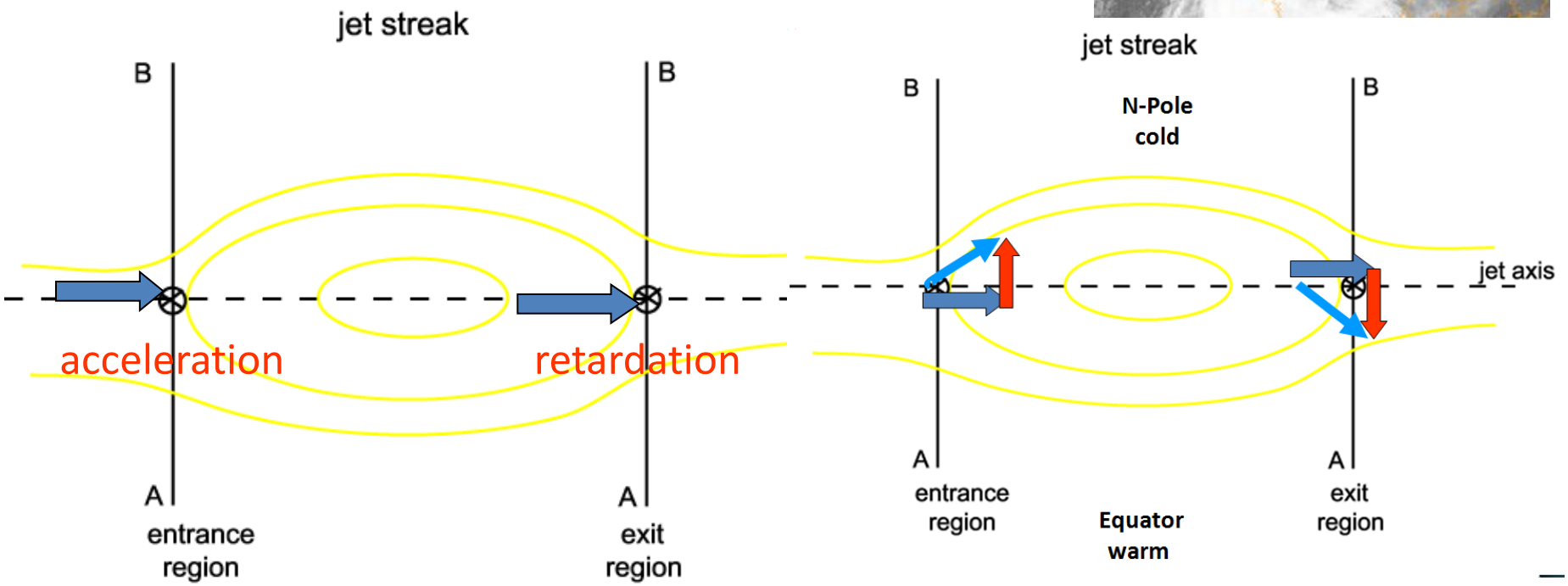


Jet streaks – 4-quadrant Model (Uccellini)

Consideration 1:

Jet streaks: Stream components in jet level





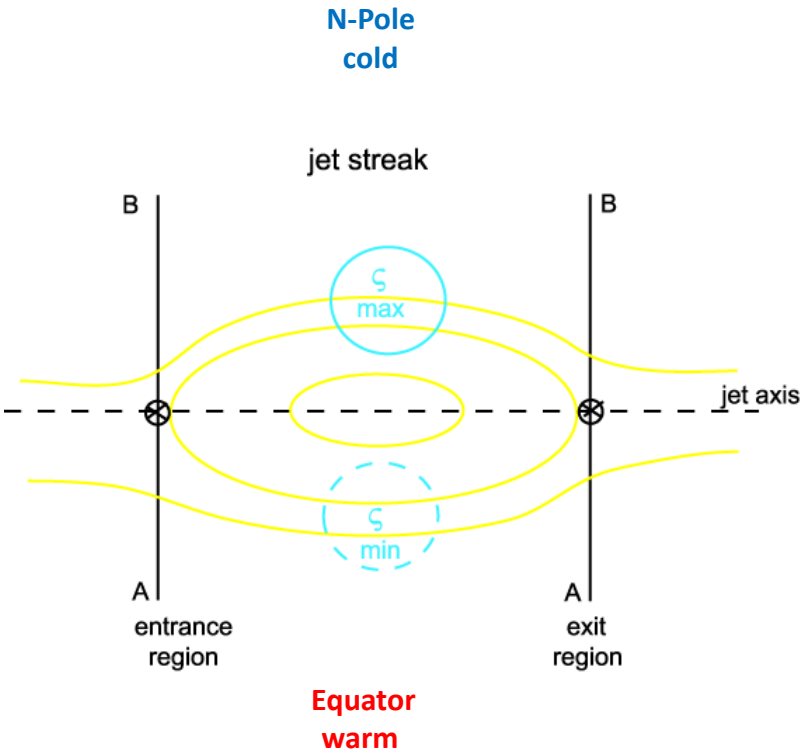
Acceleration vector

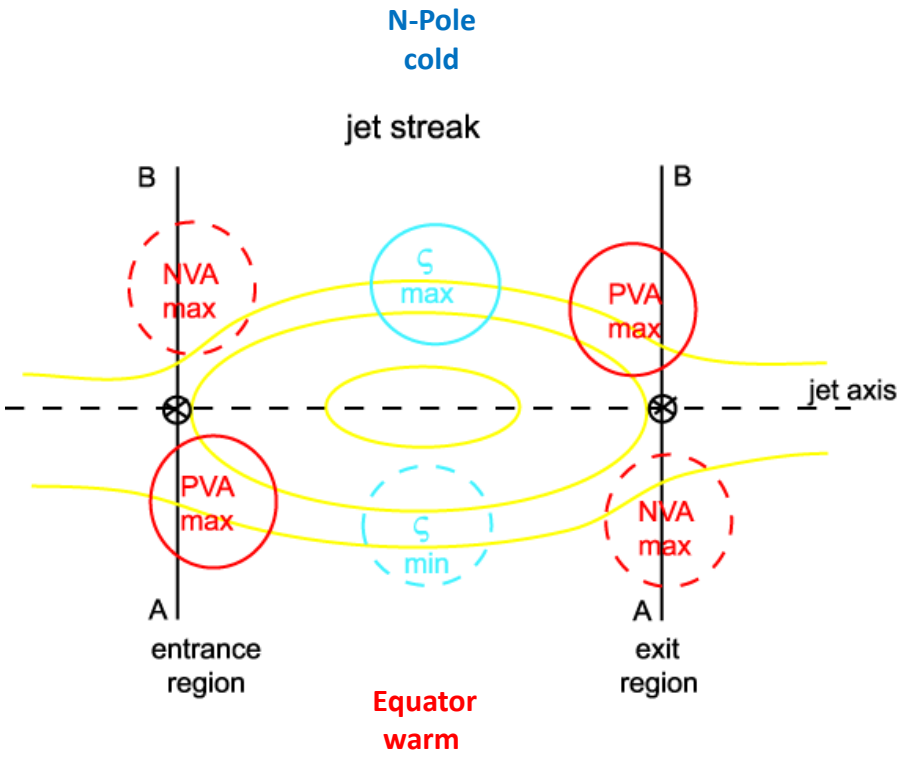
Ageostrophic Wind vector

Resulting vector

Jet streaks – 4-quadrant Model (Uccellini)

Consideration 2:
Jet streaks: Distribution of vorticity and vorticity advection in jet level



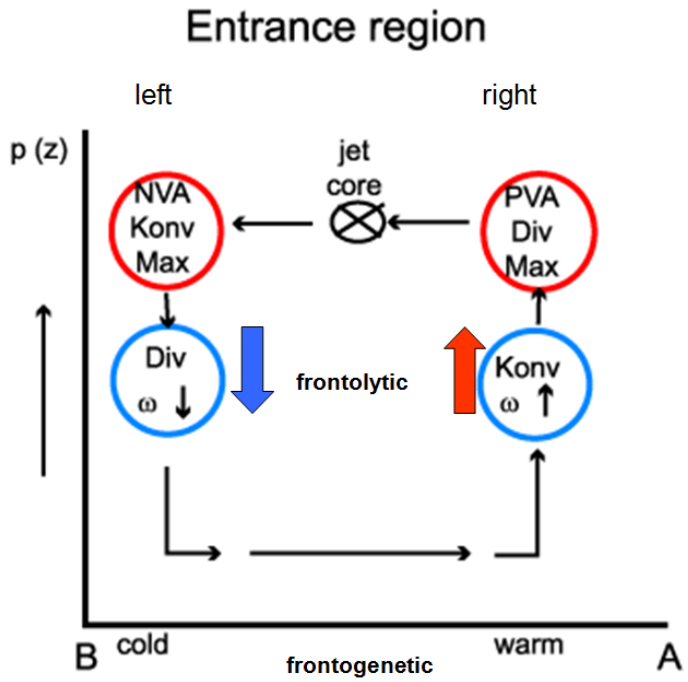


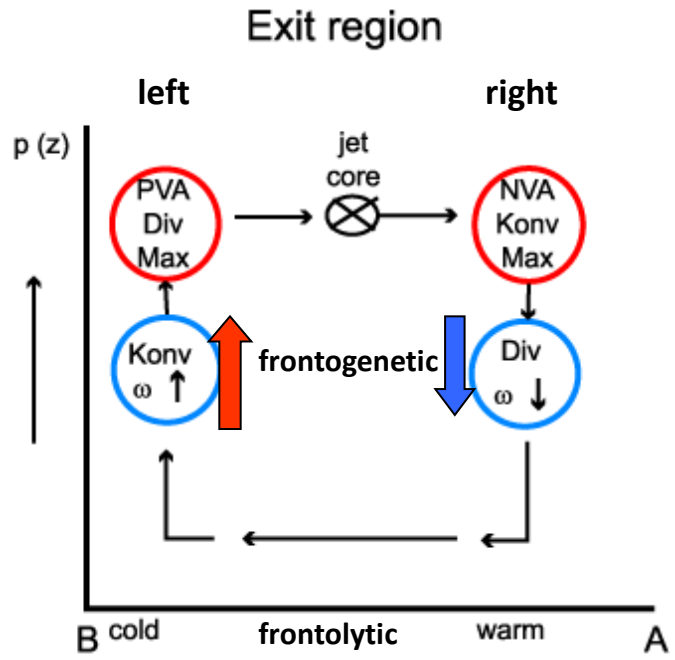
- Vorticitymaximum on the cyclonic side of a jet streak maximum (increased shear)
- Vorticityminimum on the anticyclonic side

Jet streaks – 4-quadrant Model (Uccellini)

Consideration 3: Jet streaks:

Vertical cross section in entrance ad exit region





Entrance Region:

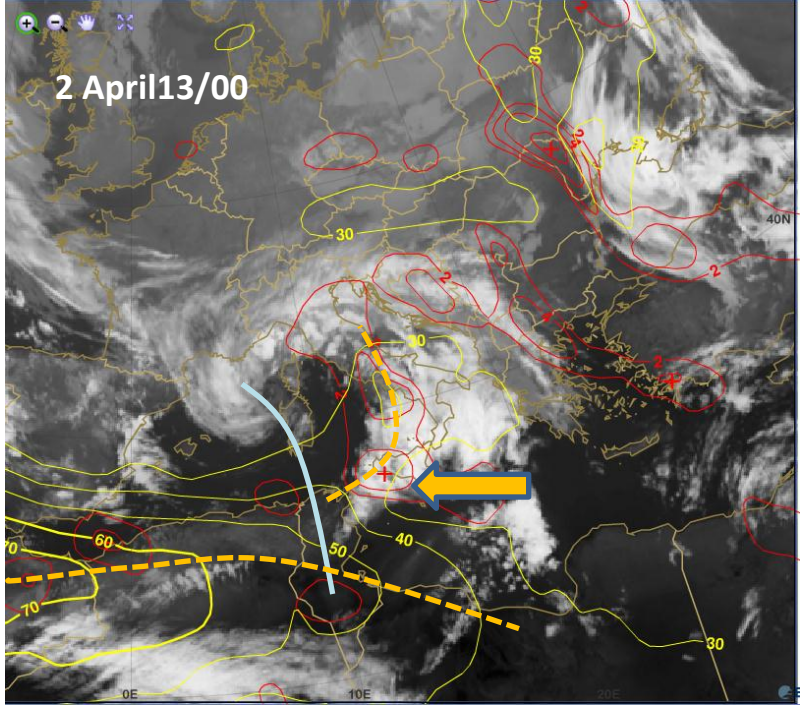
1. **Frontogenetic in low levels**
2. **Frontolytic in middle levels**
3. **Upward motion in right entrance region**

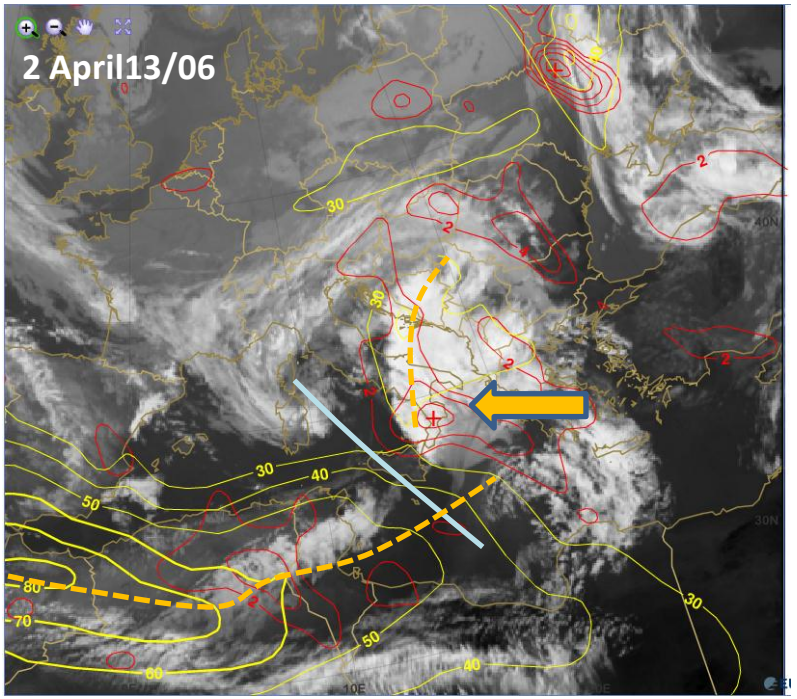
4. **Preferred area for wave developments**

Exit Region:

1. **Frontolytic in low levels**
2. **Frontogenetic in middle levels**
3. **Upward motion in left exit region**

4. **Preferred area for rapid developments**

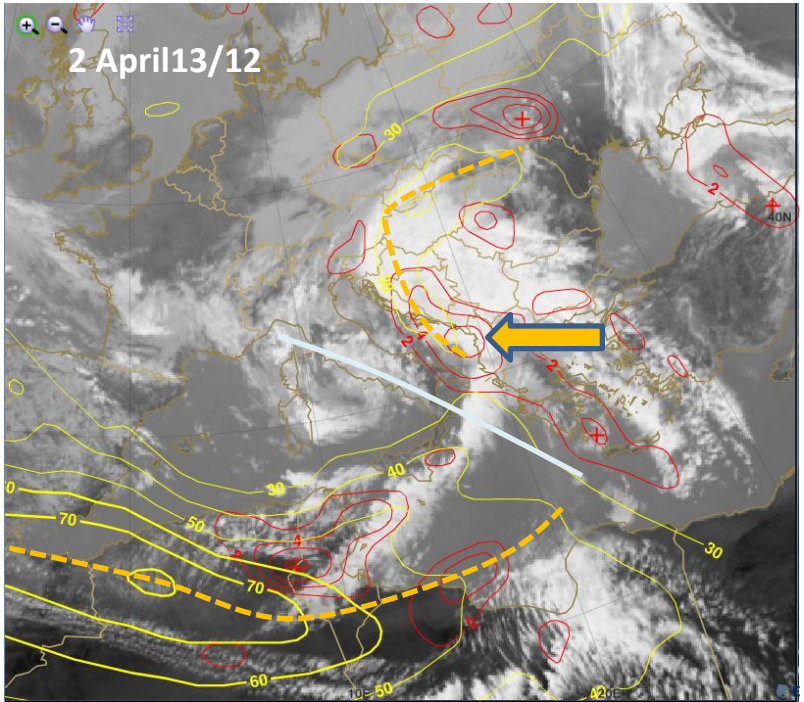


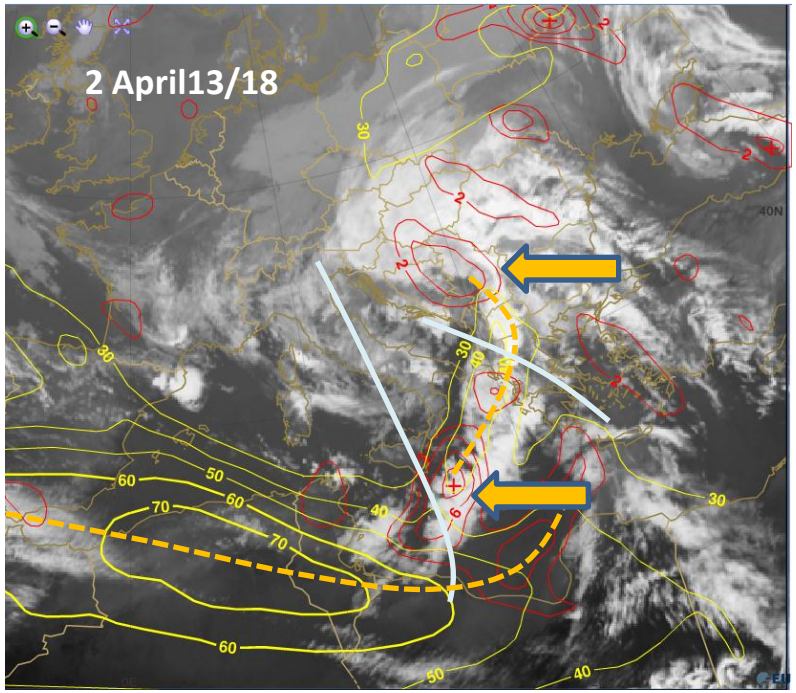


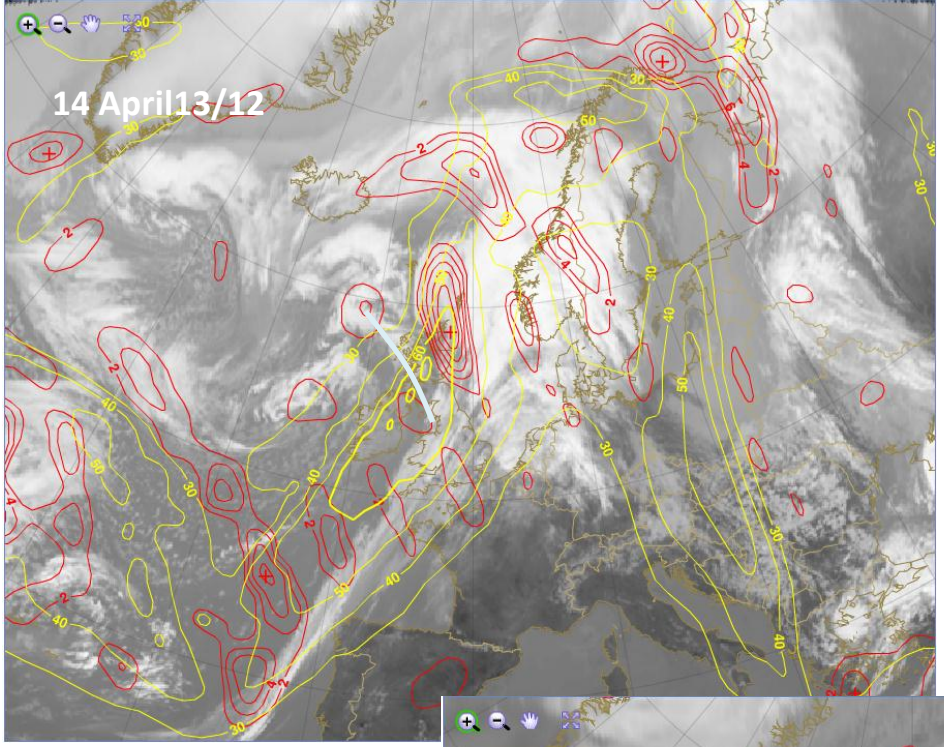
Wcb type:

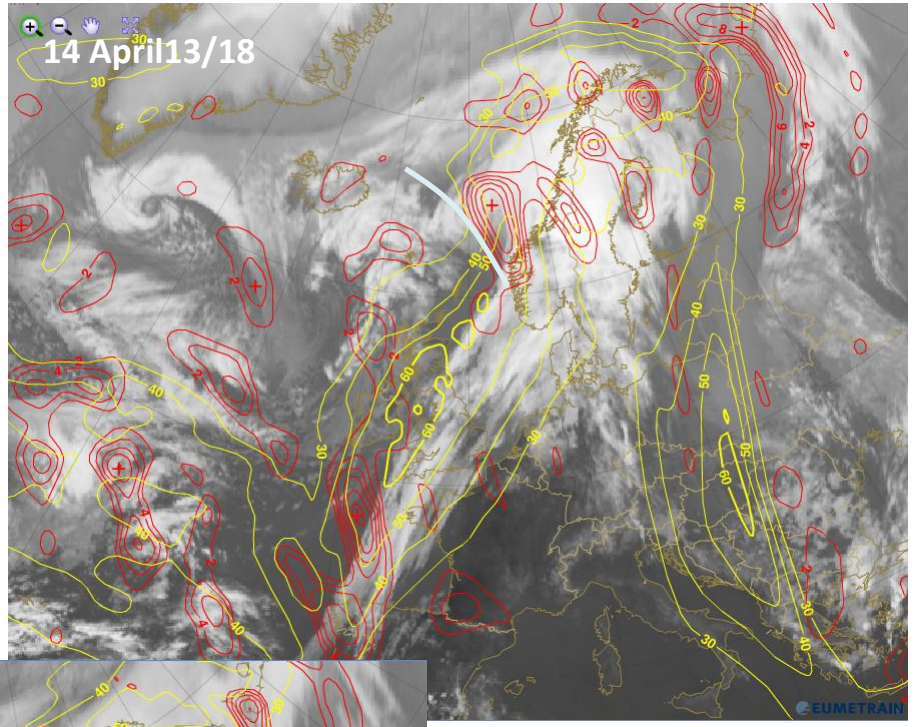
Jet streak
+
PVA

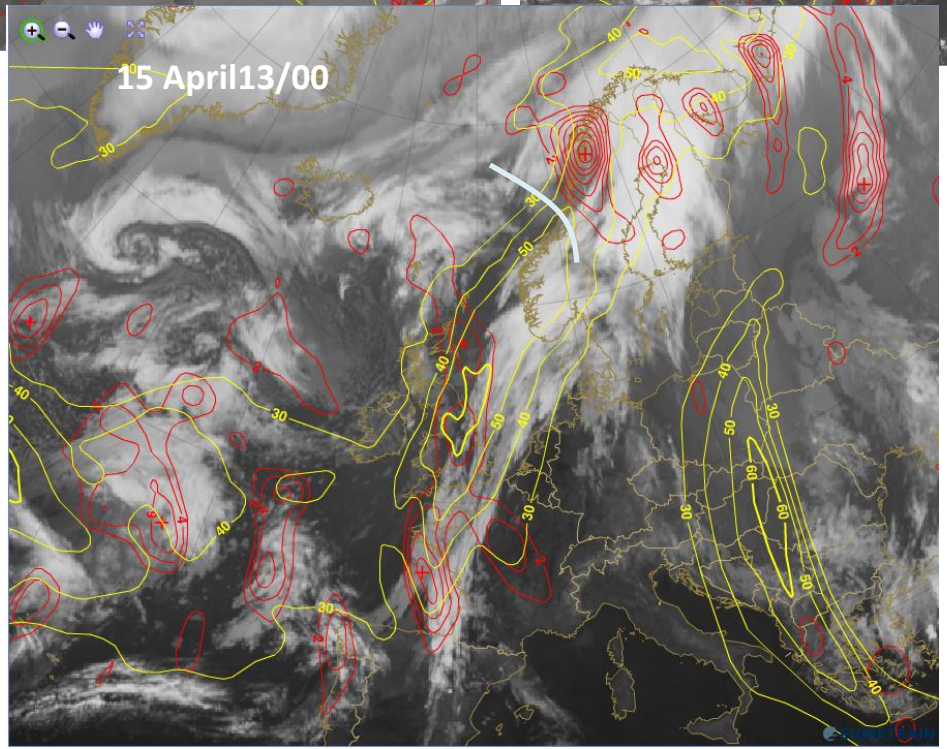
Distinct PVA maxima: in REN + LEX of two involved jets









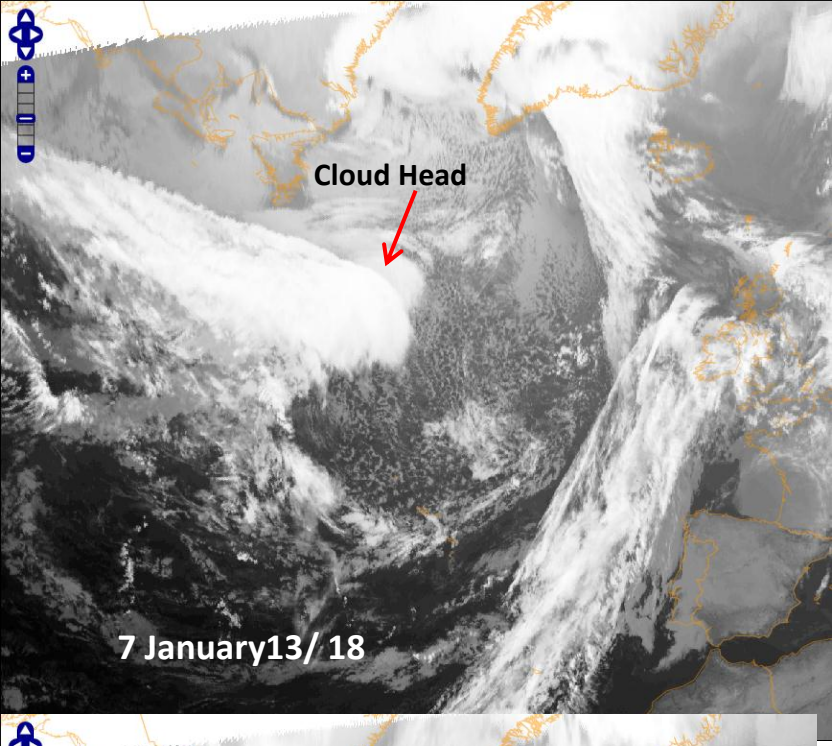


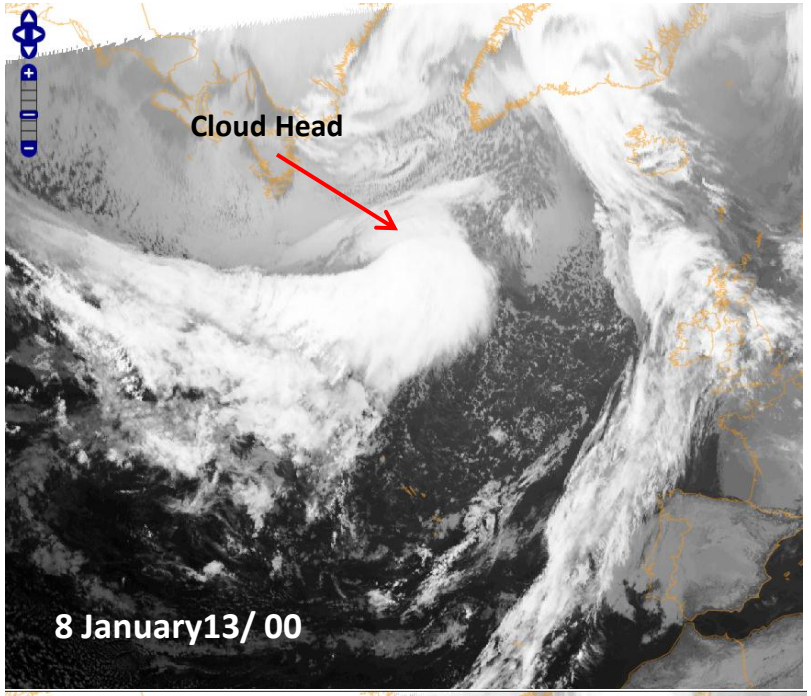
ccb type:

Upper level Trough + PVA in LEX of a jet streak

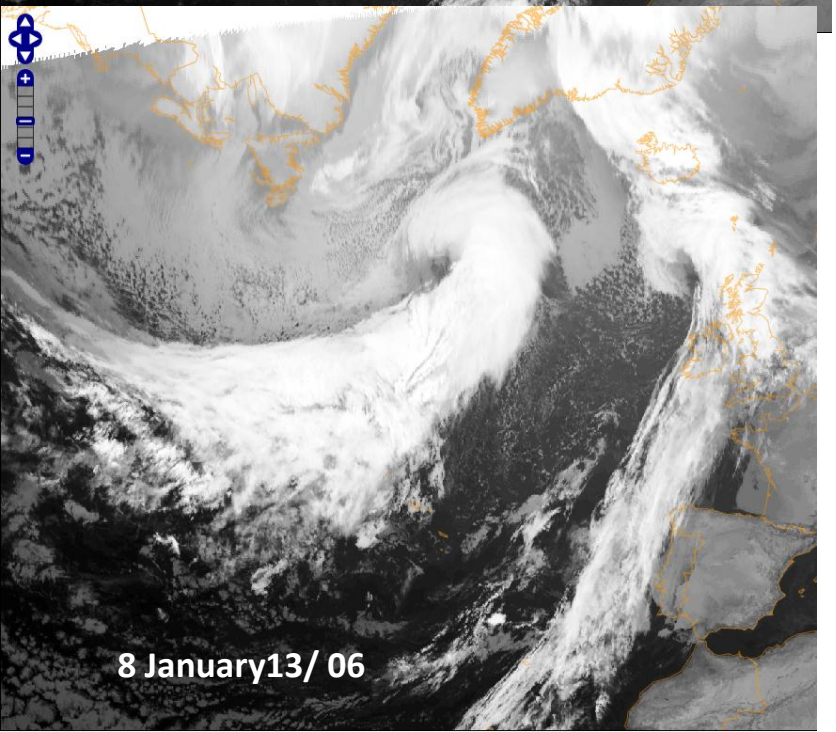
Rapid Cyclogenesis

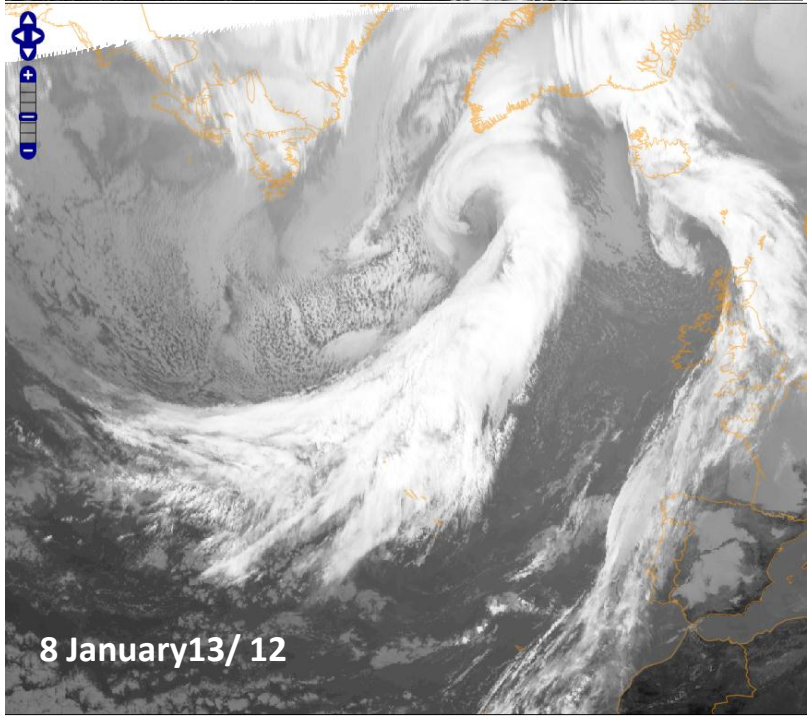
- Intensive deepening of surface low within 12 hours
- Very typical structure in satellite images which show involvement of processes in upper levels

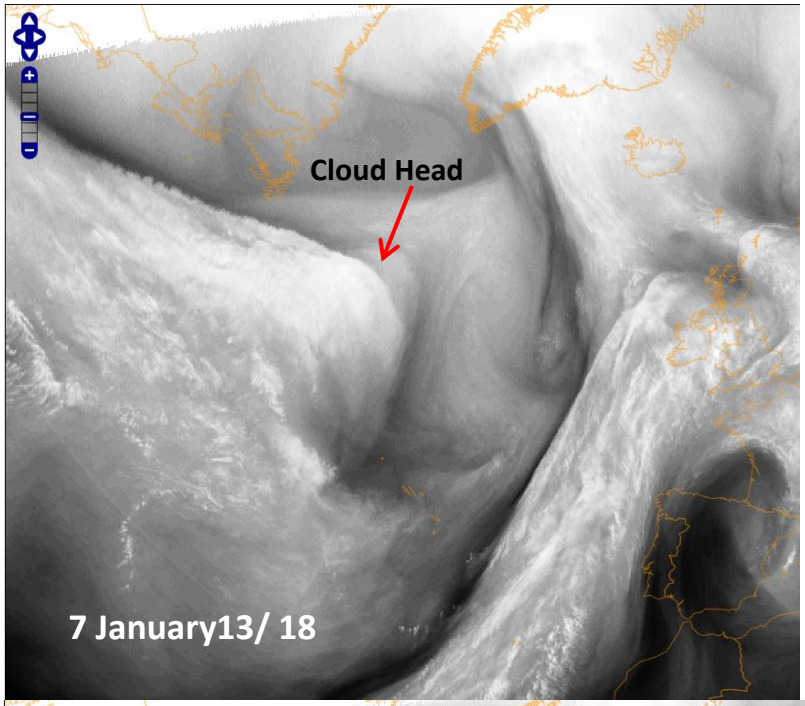




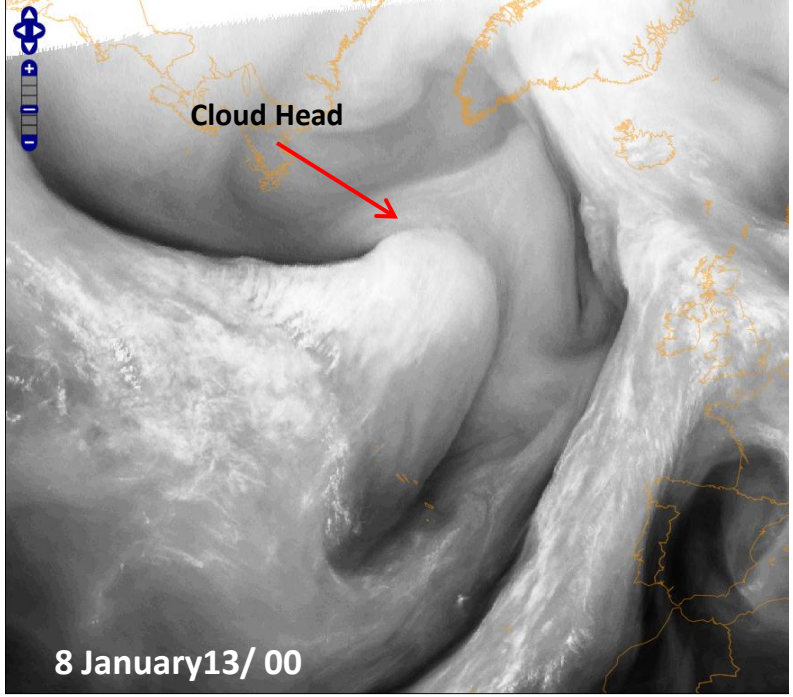
7 -8 January 2013 Rapid Cyclogenesis IR

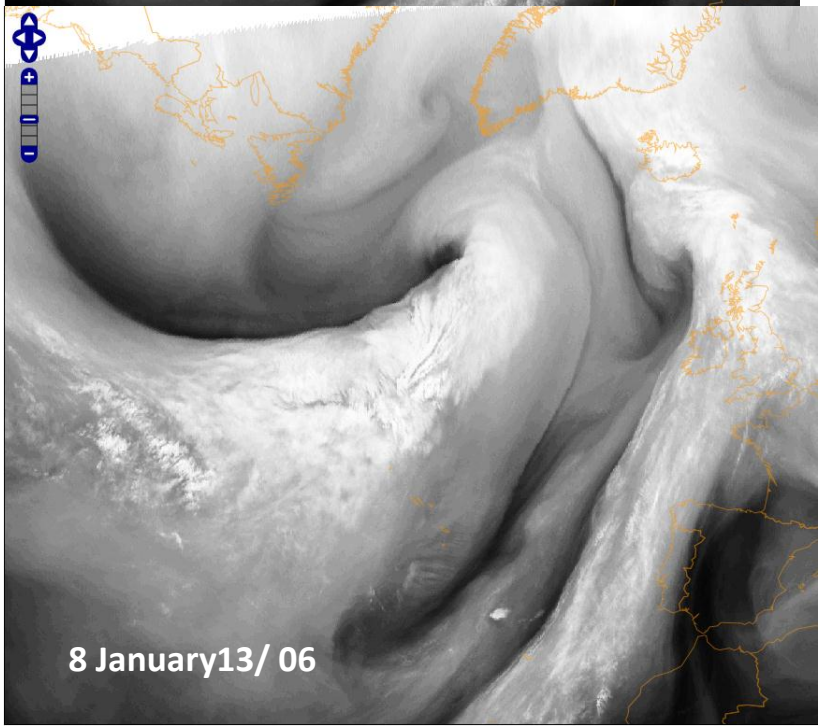


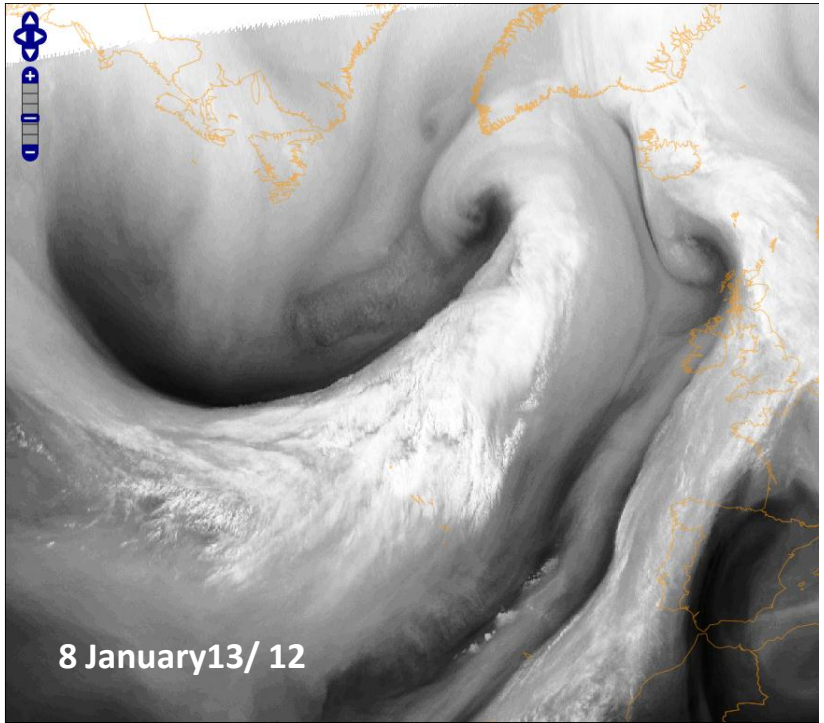


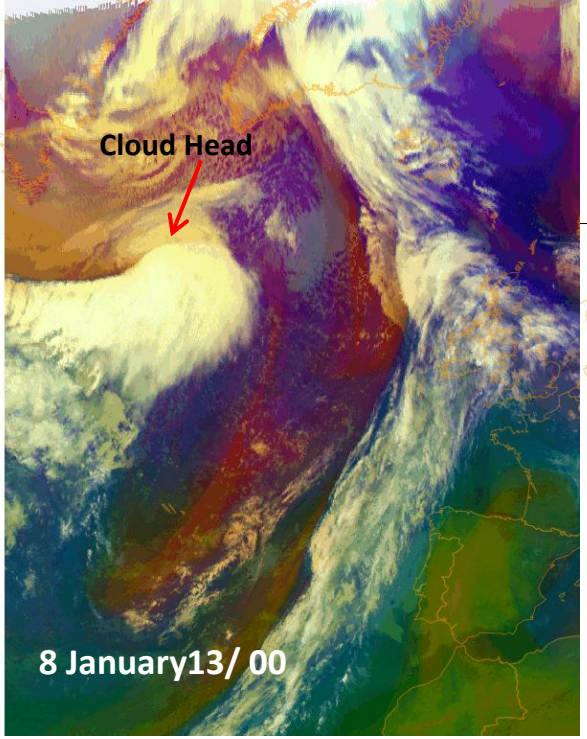


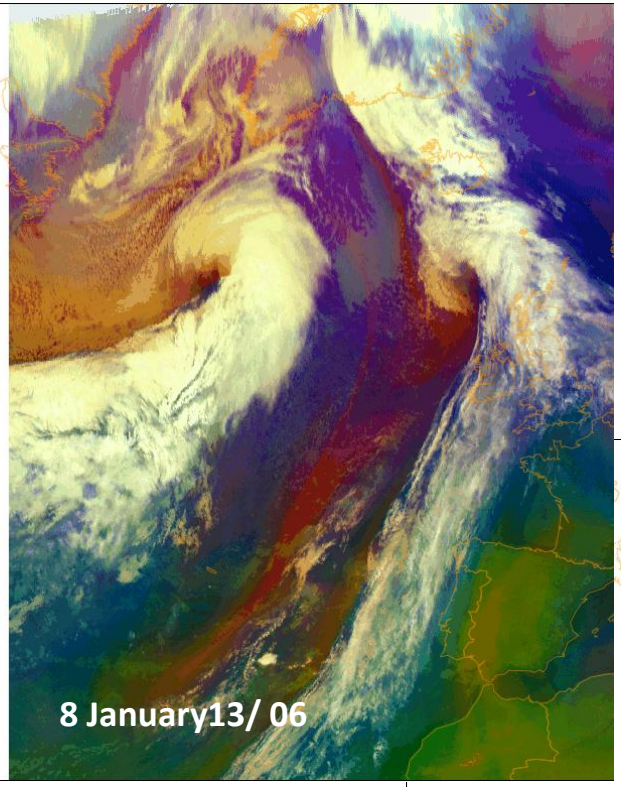
7 -8 January 2013 Rapid Cyclogenesis WV

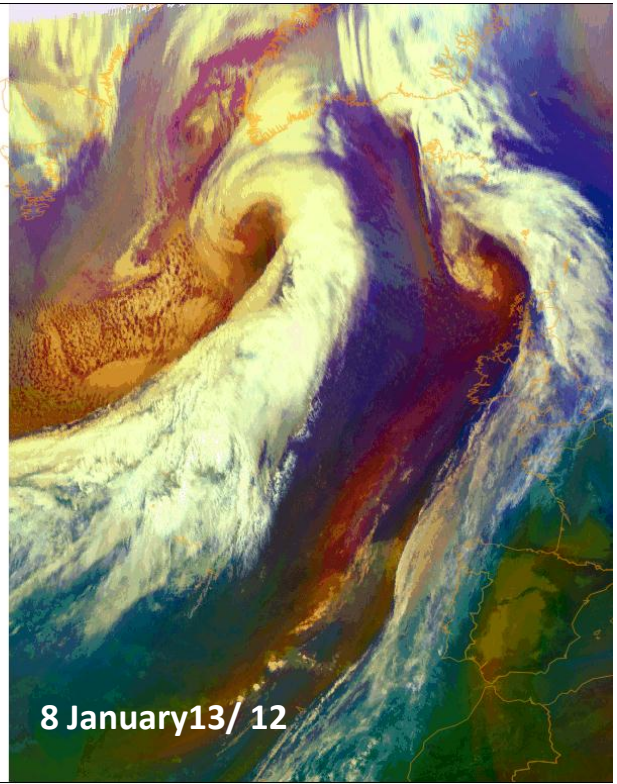




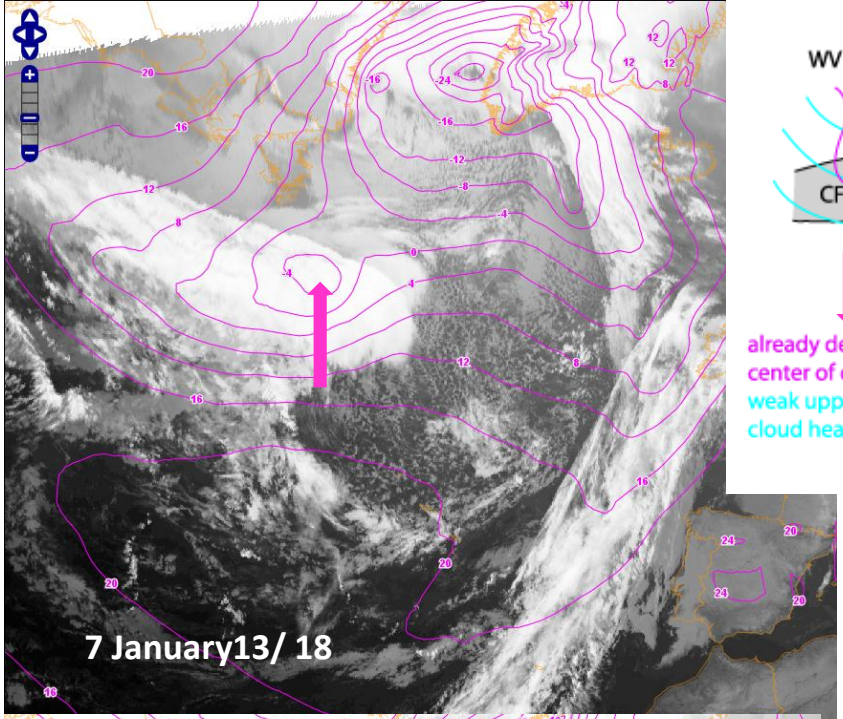


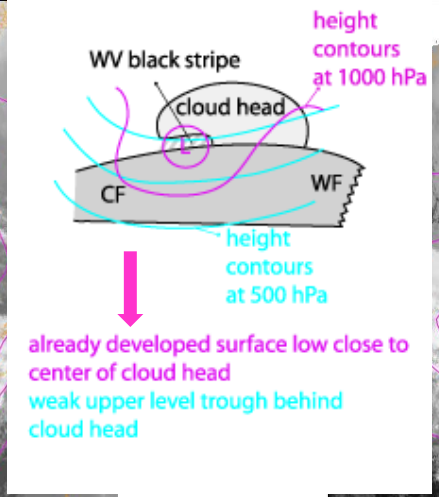




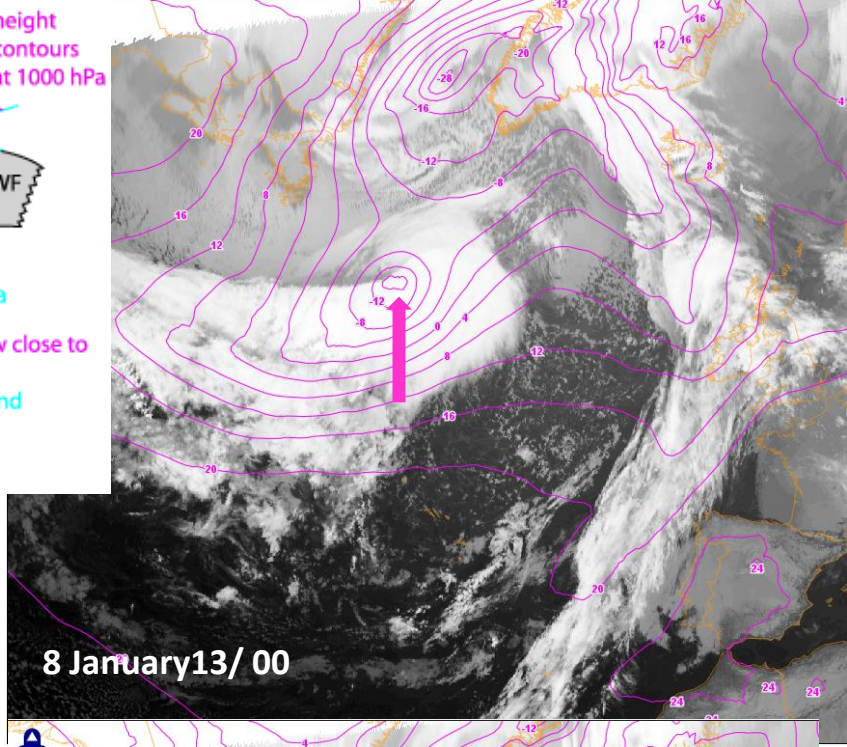


7 -8 January 2013 Rapid Cyclogenesis Air Mass RGB

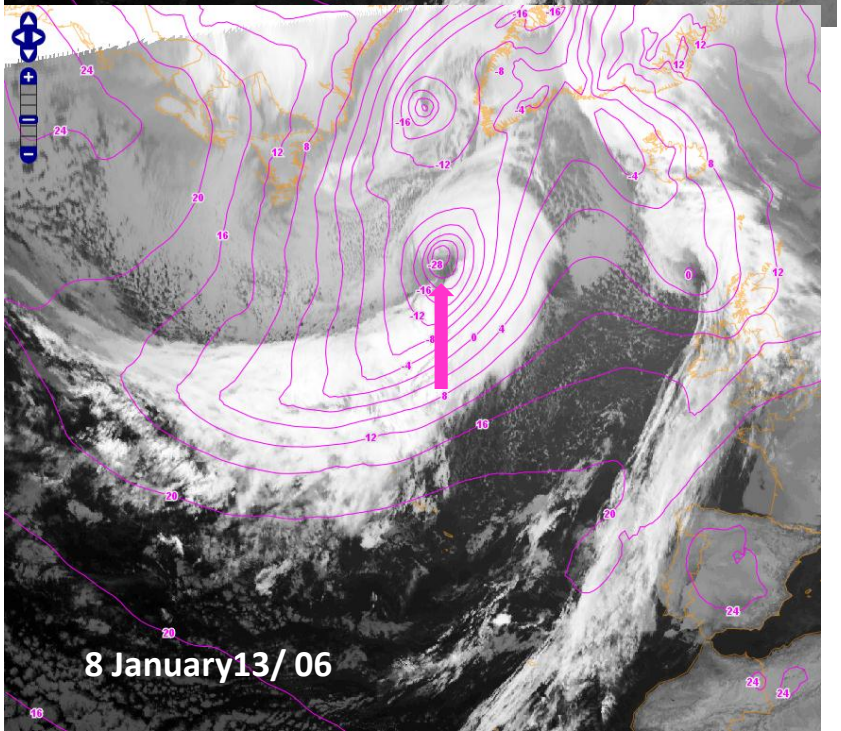


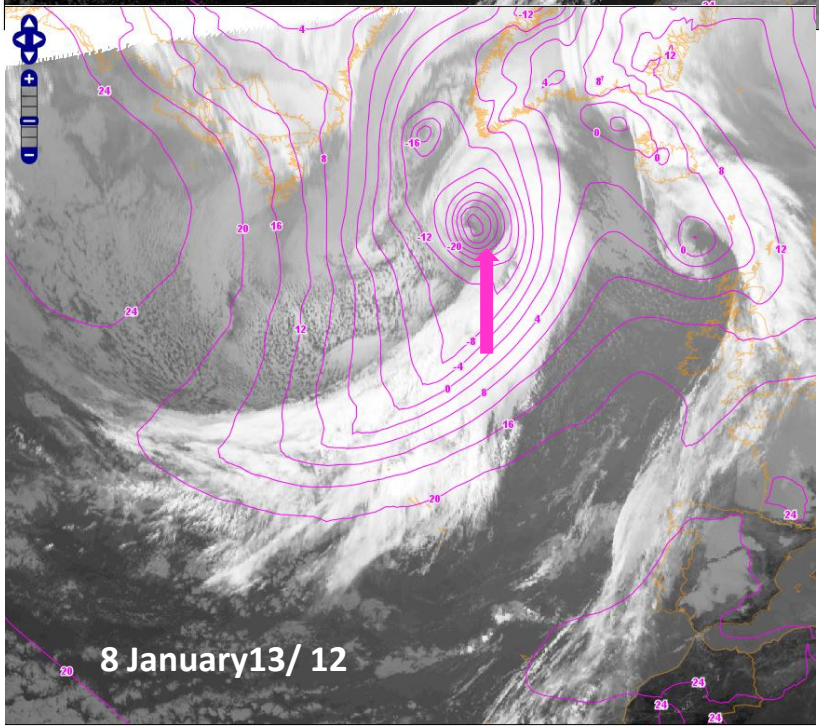


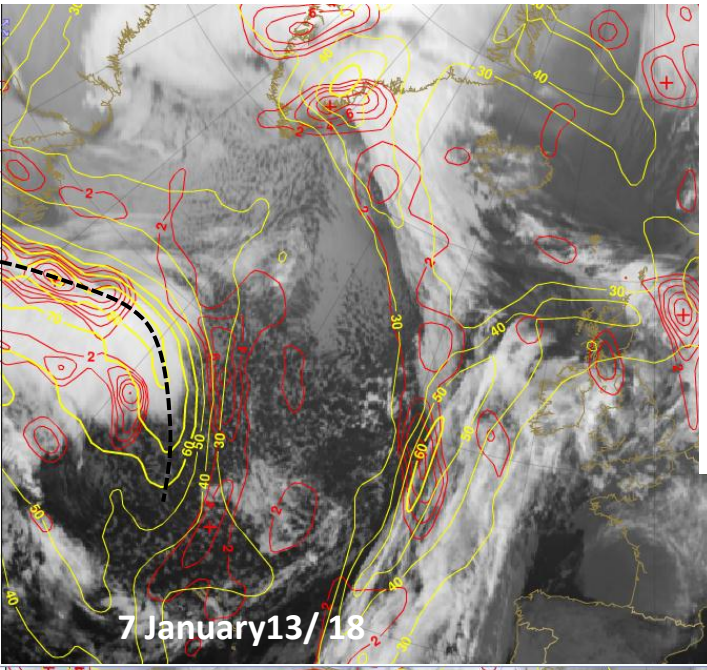
already developed surface low close to center of cloud head
weak upper level trough behind cloud head

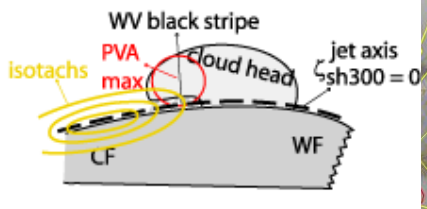


Deepening of height at 1000 hPa (close surface Low) from -4 gpm to -36 gpm within 24 hours

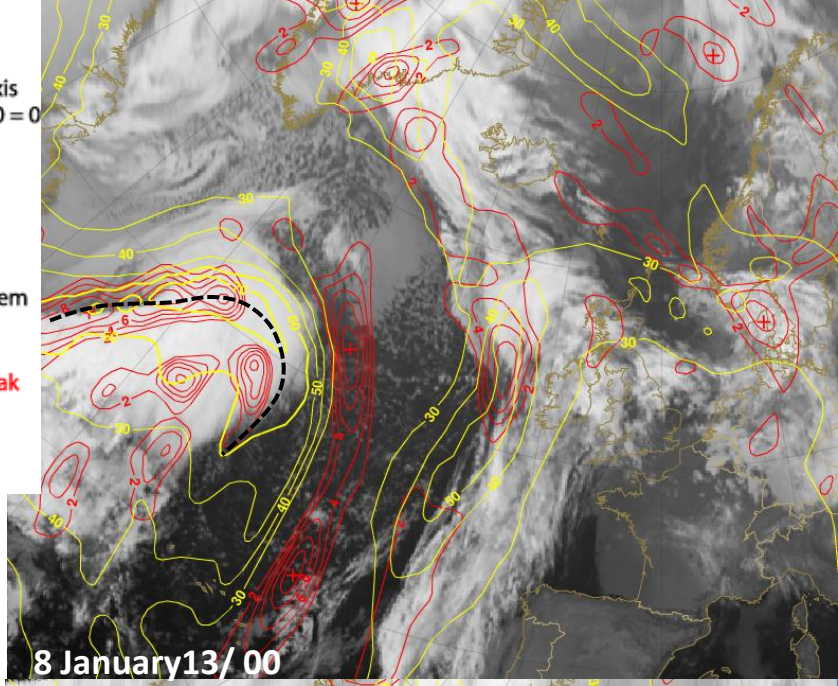








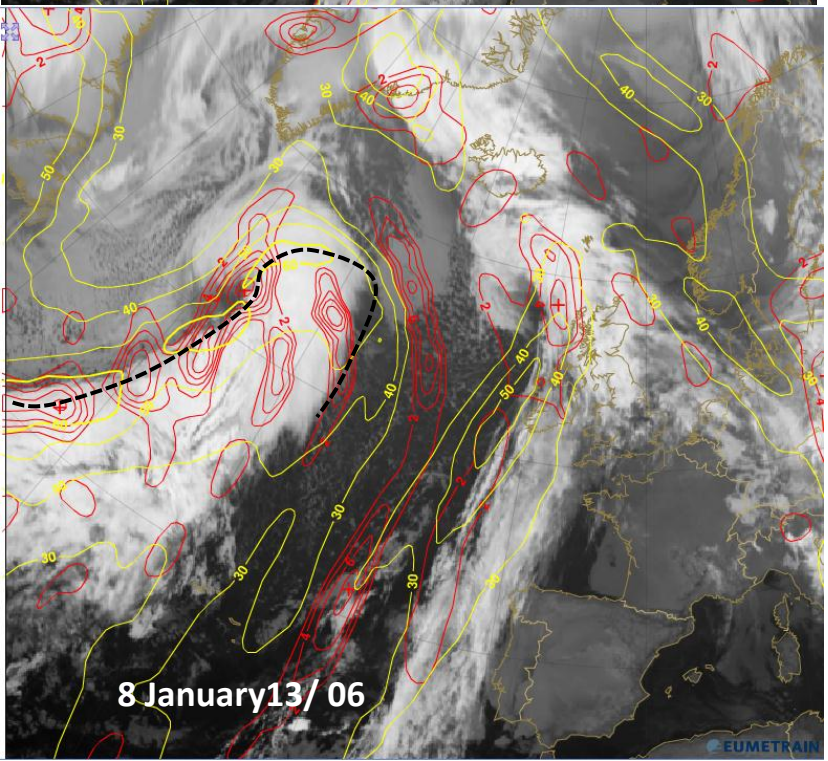
jet axis along rear side of CF-WF system
jet streak with left exit region at cloud head
PVA max in left exit region of jet streak over cloud head

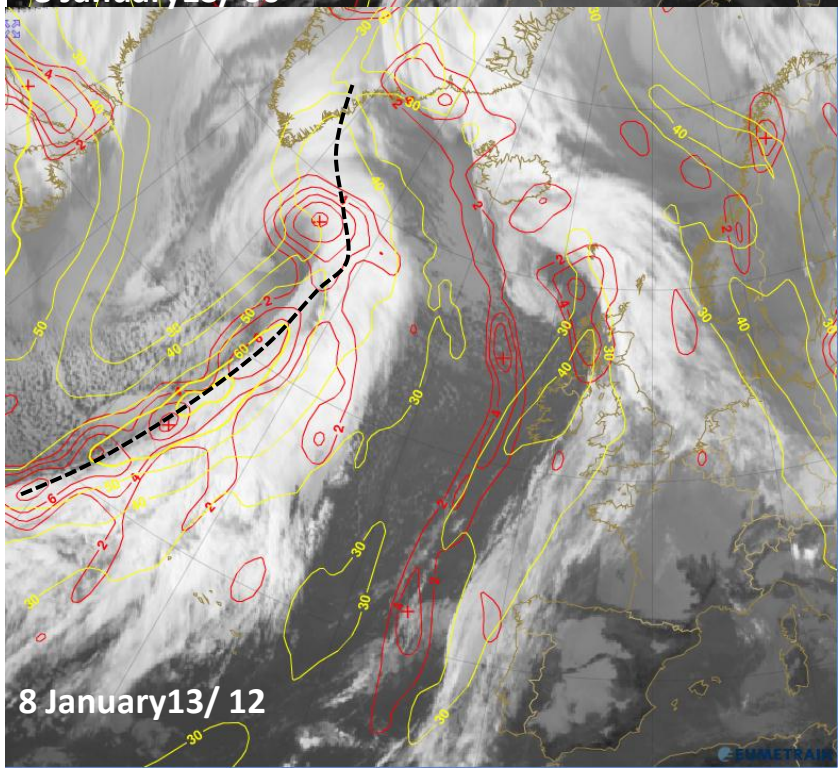


Rapid Cyclogenesis

PVA max In LEX Of intensive jet streak

Why such A rapid cyclogenesis!?





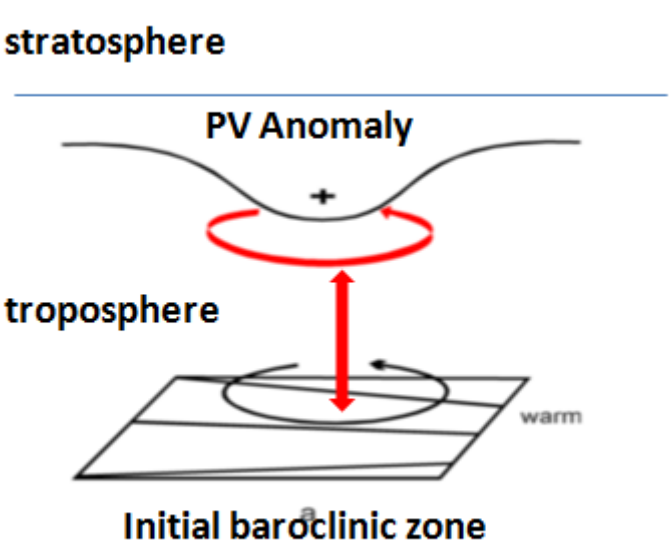
The significance of processes in the upper troposphere for cyclogenesis: Potential Vorticity (PV)

- PV = - g (f + ζ_θ) $\partial\theta$ / ∂p = const

- PV (IPV) is constant for adiabatic processes; that means constant on isentropic surfaces
- Product of vorticity and stability is constant on isentropic surfaces $\Rightarrow$

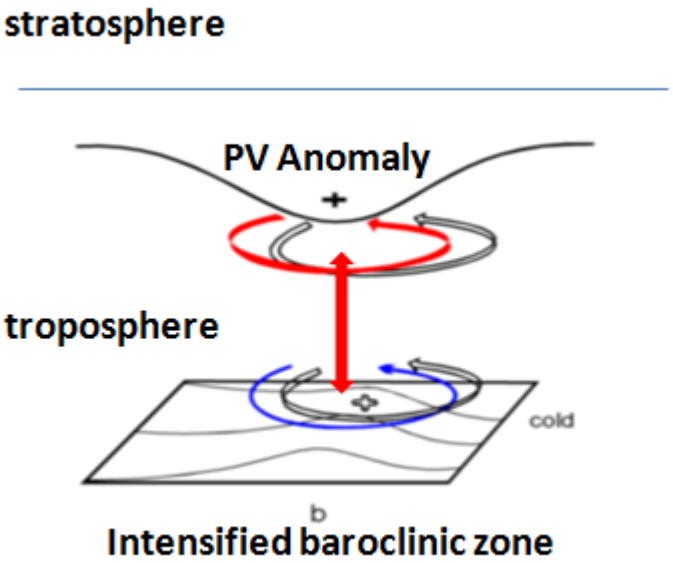
- PV has very high values in stratosphere >= 2 units (NH); <= -2 units (SH)
- If stratospheric air with the inherent PV protrudes downward from stratosphere into troposphere - static stability decreases and (because of conservation) cyclonic vorticity has to increase there
- This is a motor for enhancing cyclogenesis

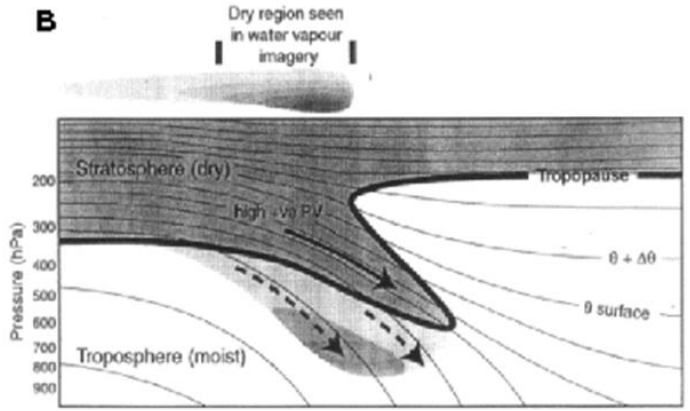
The significance of processes in the upper troposphere for cyclogenesis: Potential Vorticity (PV) PV Anomalies - Hoskins theory

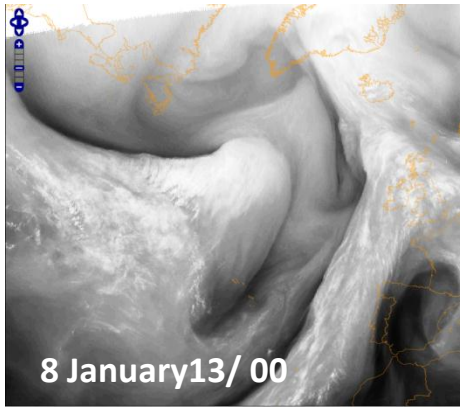


Interaction and mutual intensification of cyclonic circulation:

Rapid cyclogenesis







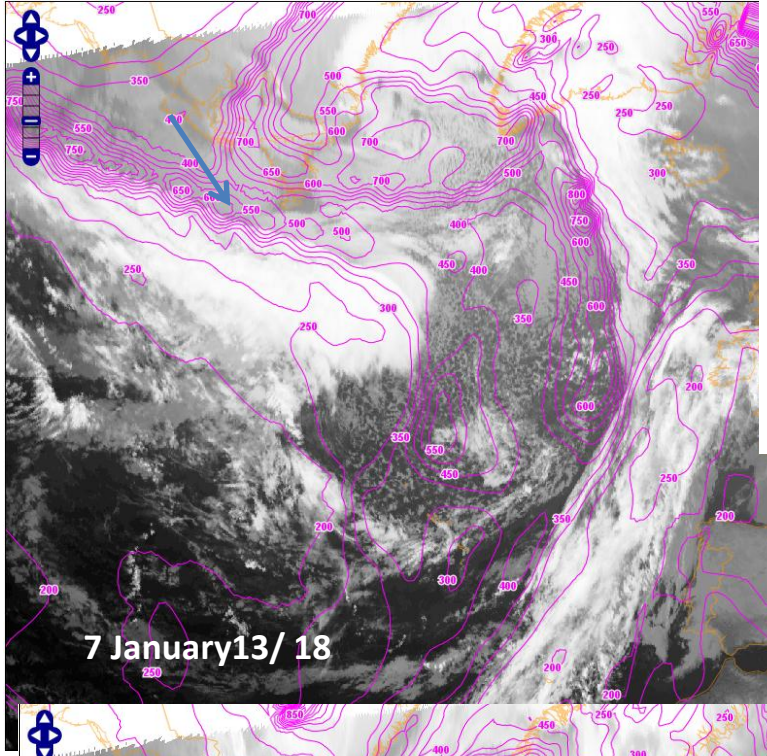
Importance of PV and PV anomaly

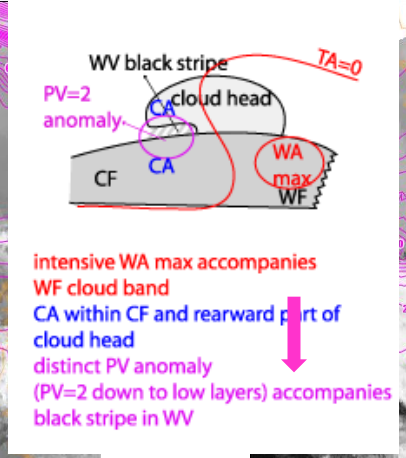
- The height of PV >= 2 units (-2 on SH) shows how far the air from stratosphere has protruded downward

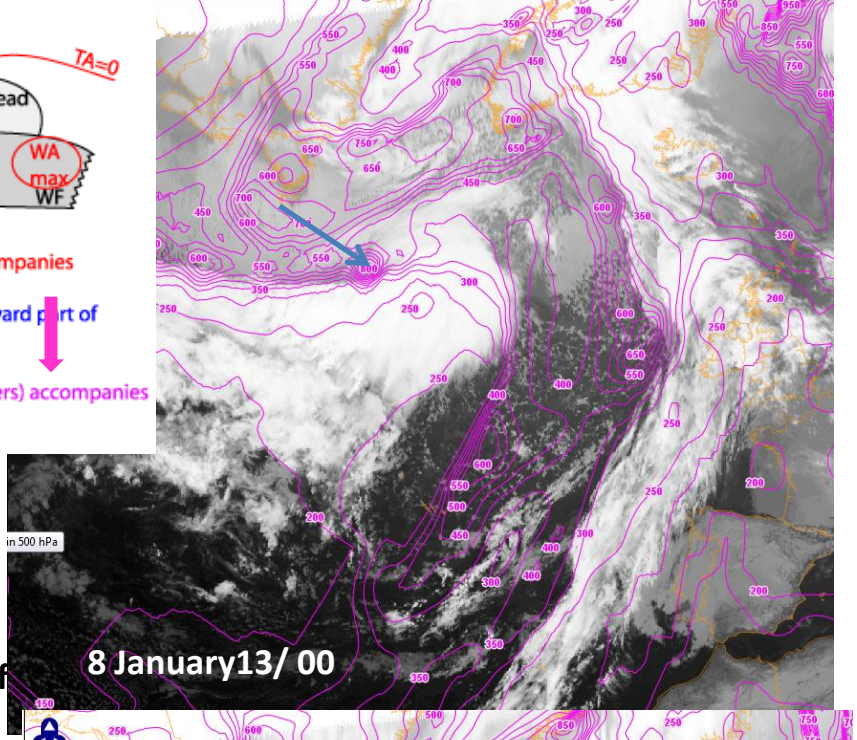
- In case of classical cyclogenesis the typical height is 400 – 500 hPa
- In case of a rapid cyclogenesis it is down to 600 – 700 hPa and at same time the intensification of the lower tropospheric PV values takes place

- Consequently rapidly a “tunnel” of high PV values from tropopause down to surface develops

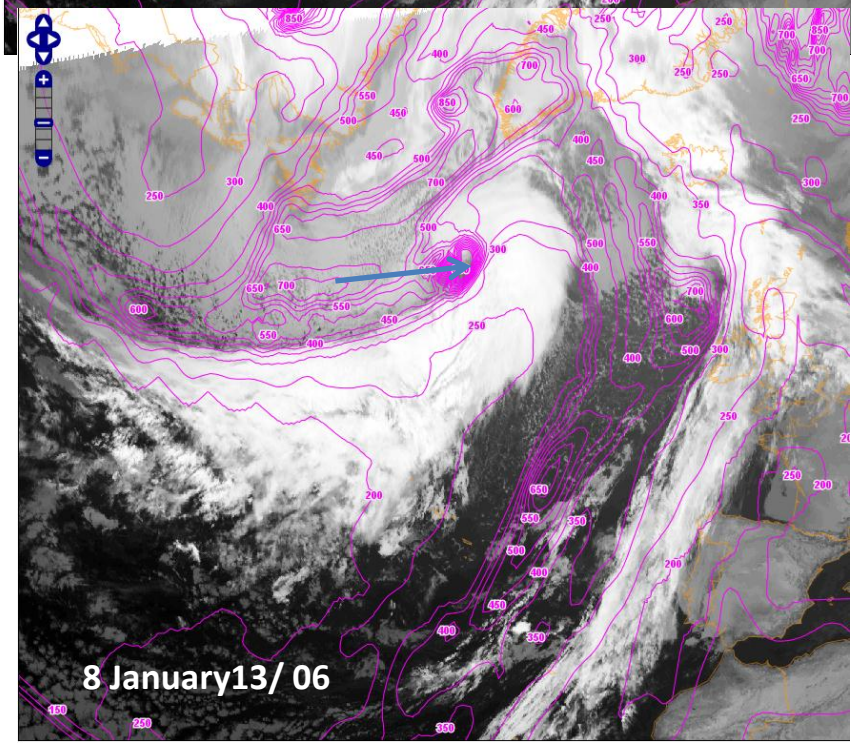
- Vertical cross sections can show the downward protrusion below the frontal surface

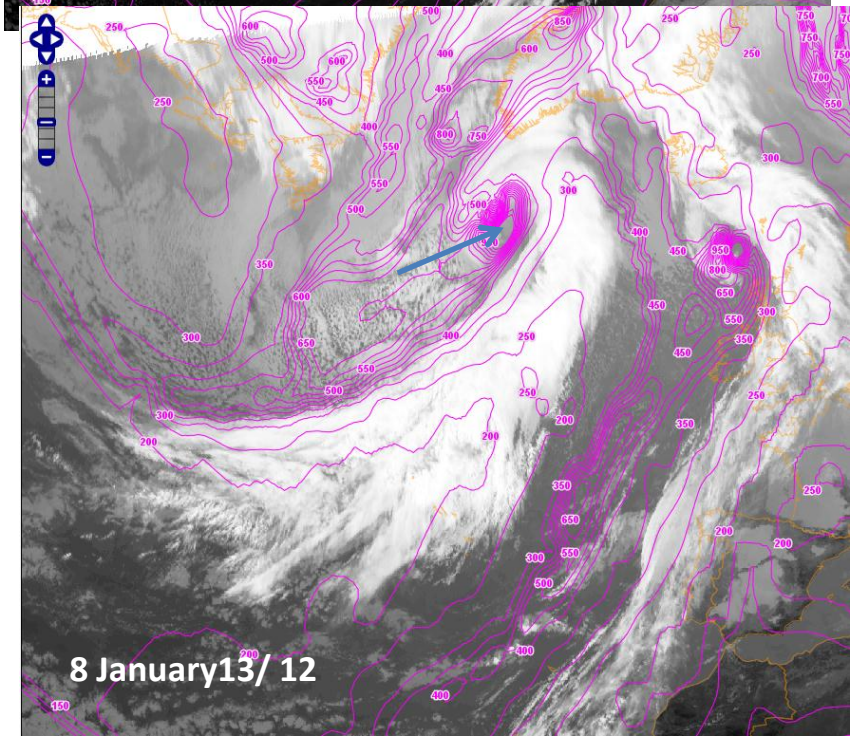


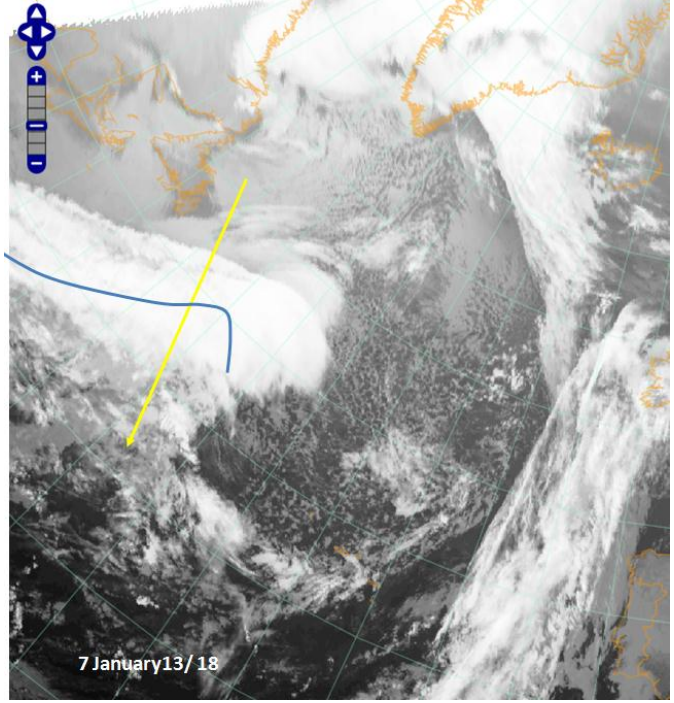




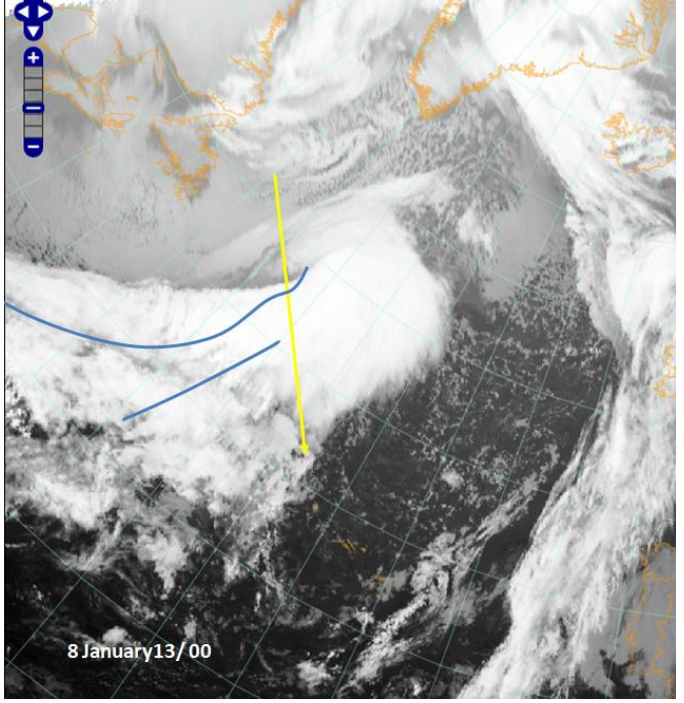
Height of PV (magenta)

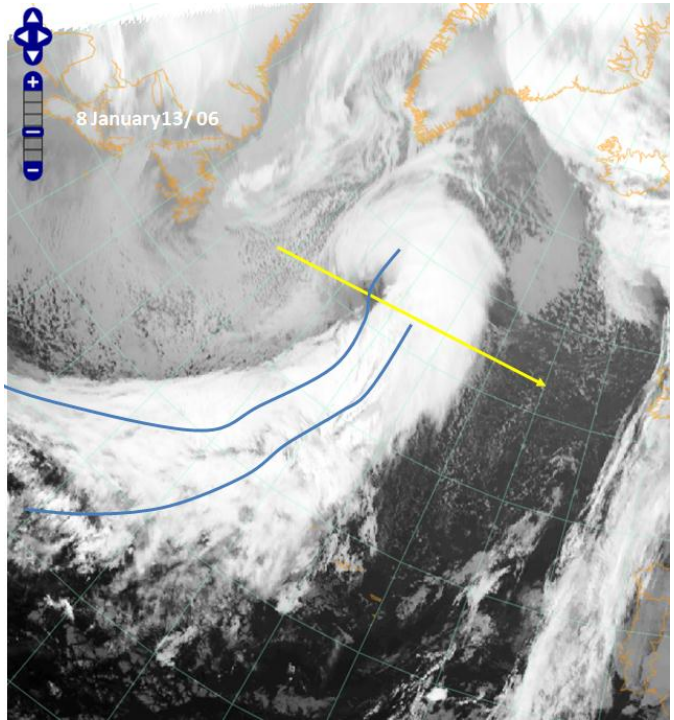


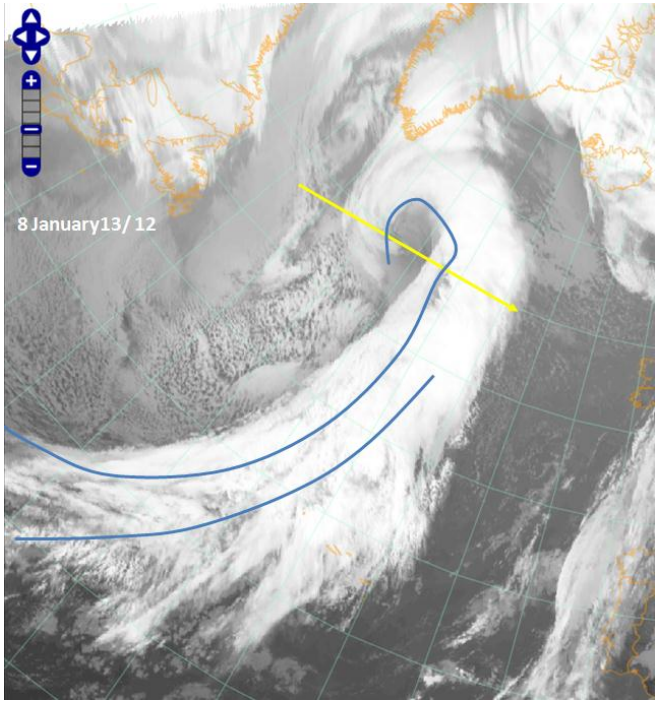


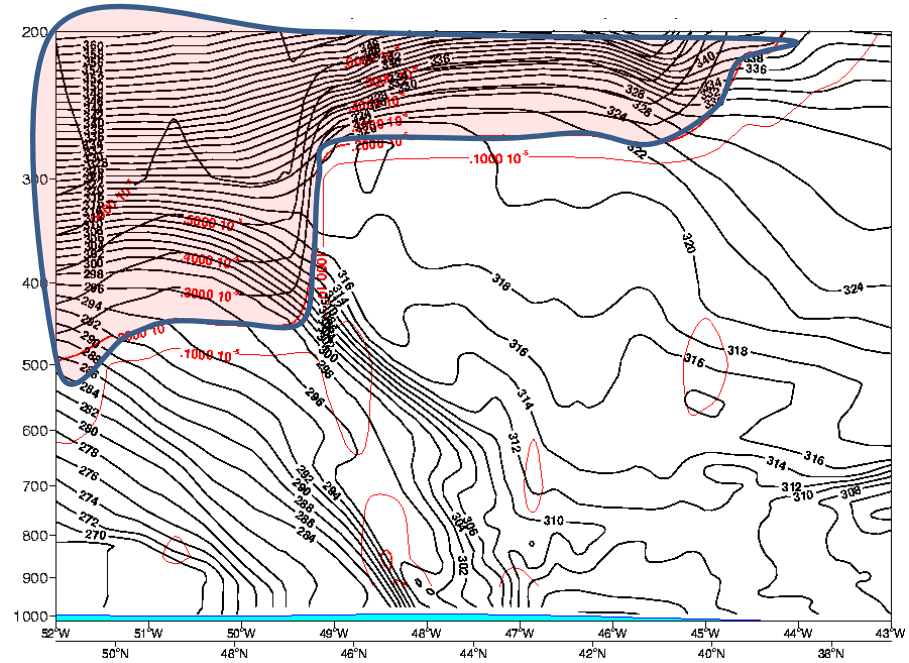


Vertical cross section lines through the centre of the Rapid cyclogenesis

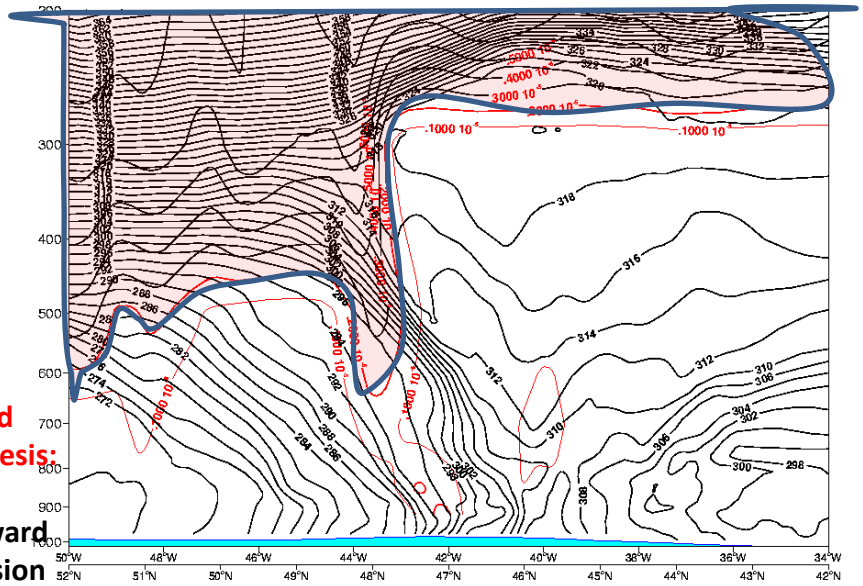








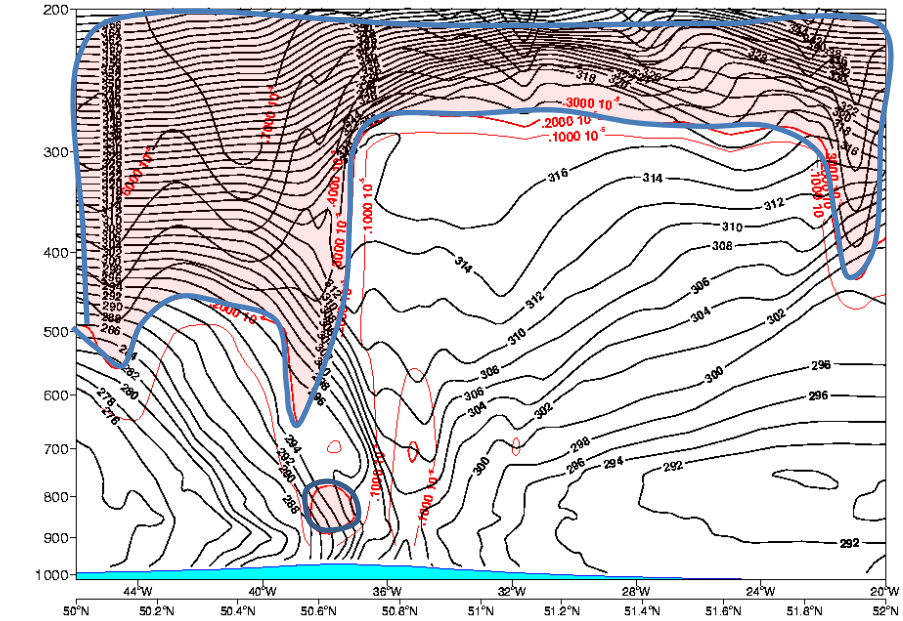
7 January13/ 18



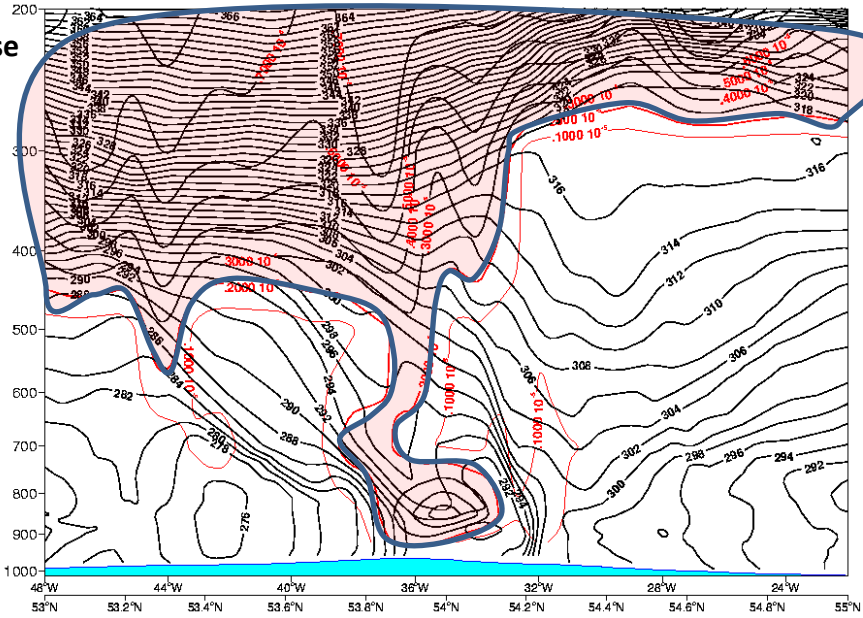
8 January13/ 00

Rapid Cylogenesis:

Downward Protrusion of stratospheric Air "tropopause folding"

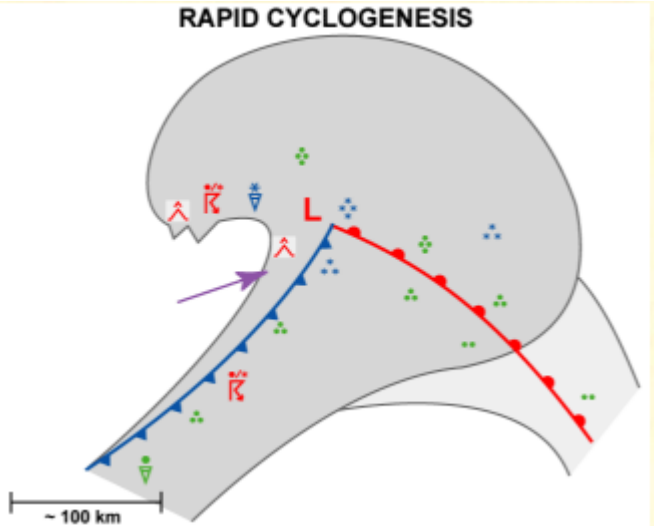


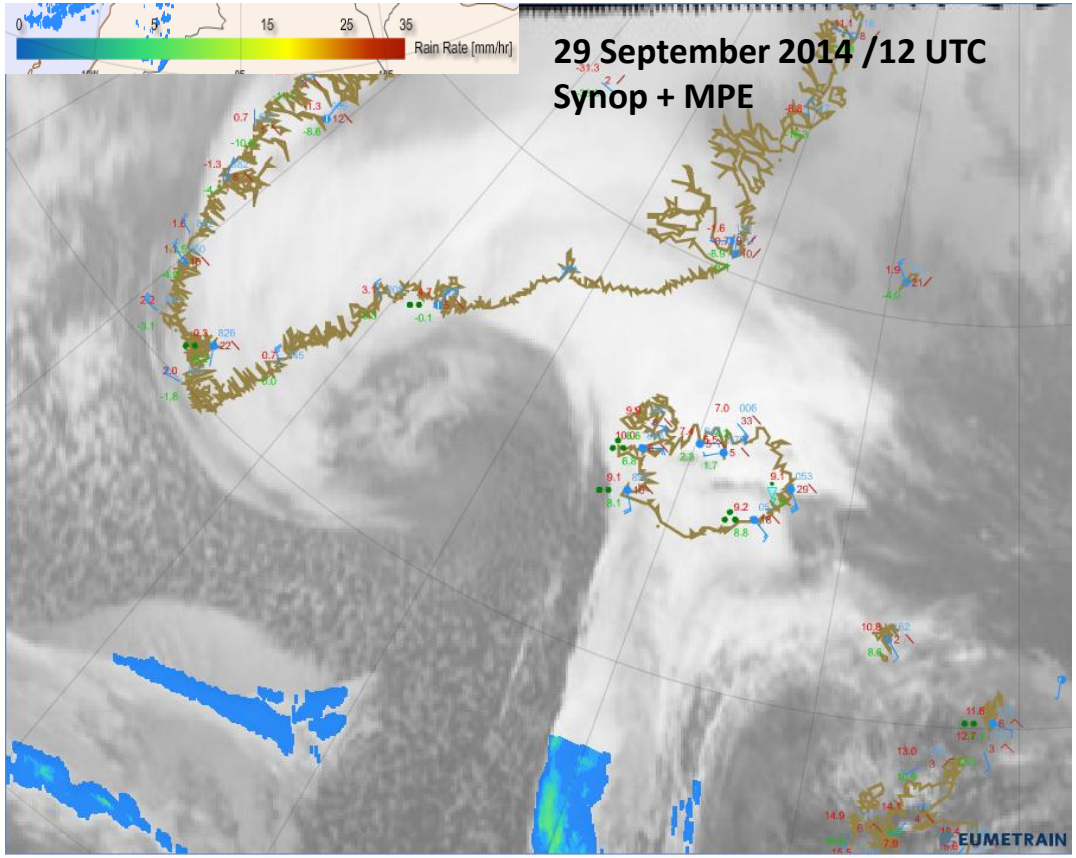
8 January13/ 06

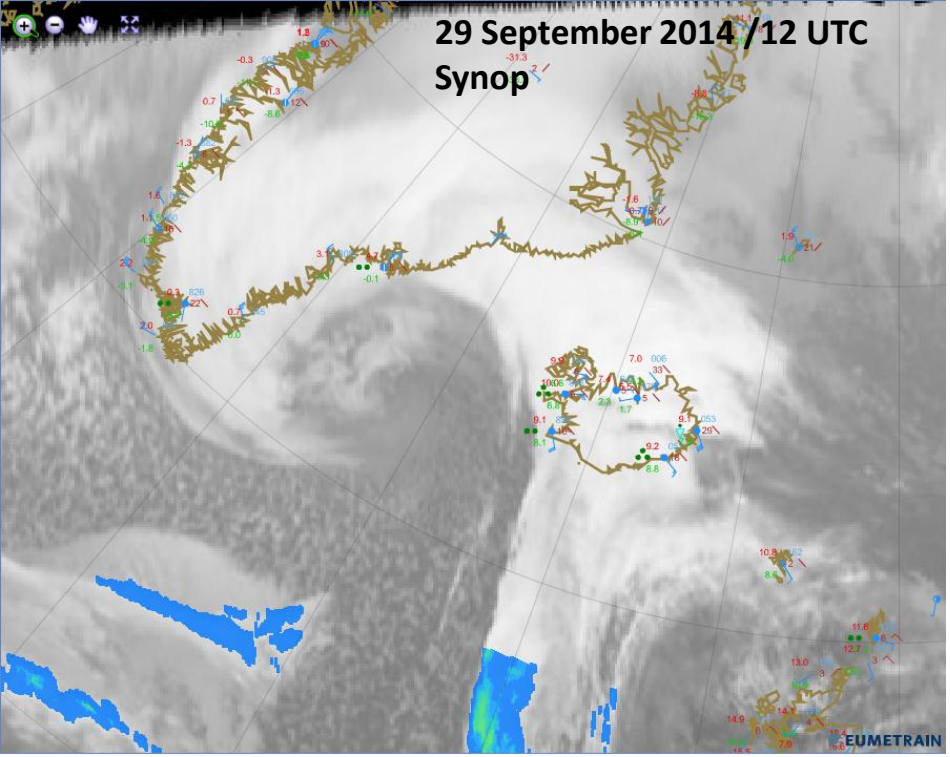


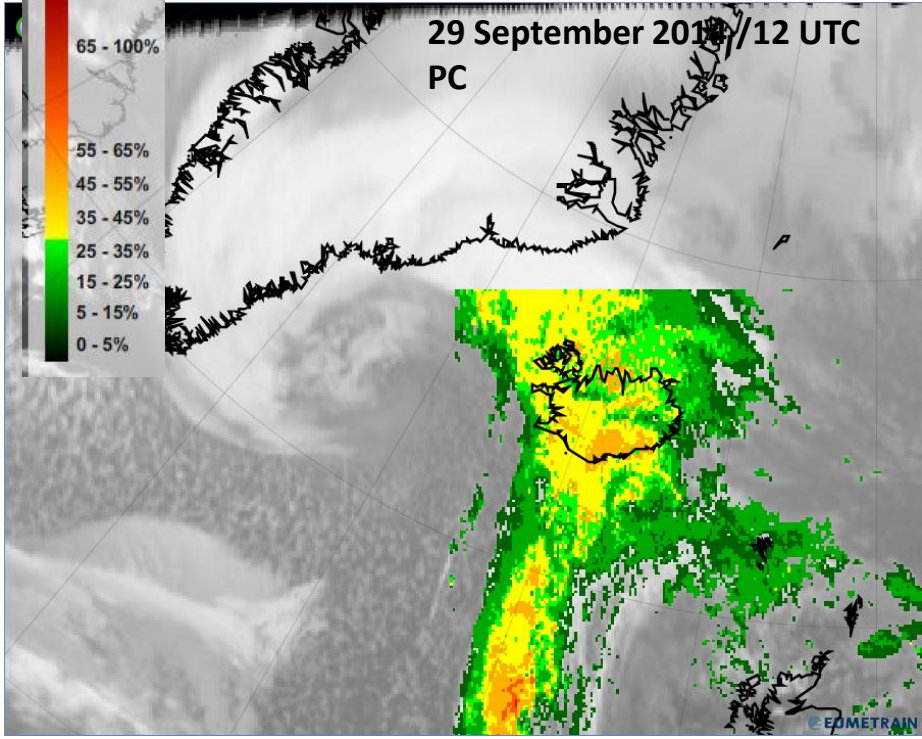
8 January13/ 12

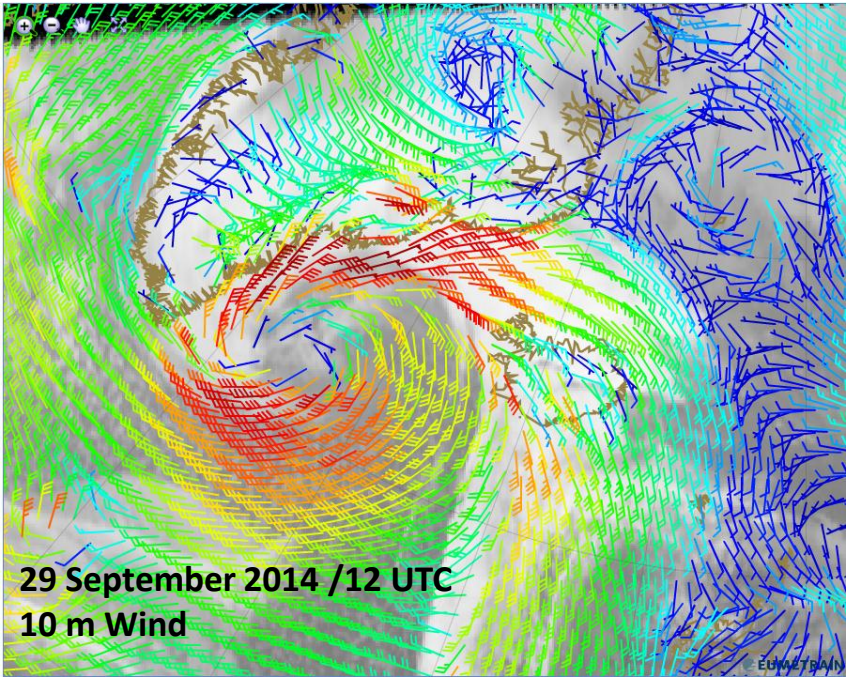
Parameter	Description
Precipitation	• Intense precipitation associated with the Warm Conveyor Belt. • Thunderstorms within the inner edge of the cloud head at the western side of the surface low.
Temperature	• Strong rise in surface temperature within the area of Warm Conveyor Belt.
Wind (incl. gusts)	• Strong winds within the area of the cloud head. In extreme cases winds reaching hurricane force. • Very strong gusts in the transition zone between dark and white in the WV channels near the cold front and the cloud head
Other relevant information	• Very strong pressure falls and rises. In the initial stage, falls ahead exceed the rises behind.

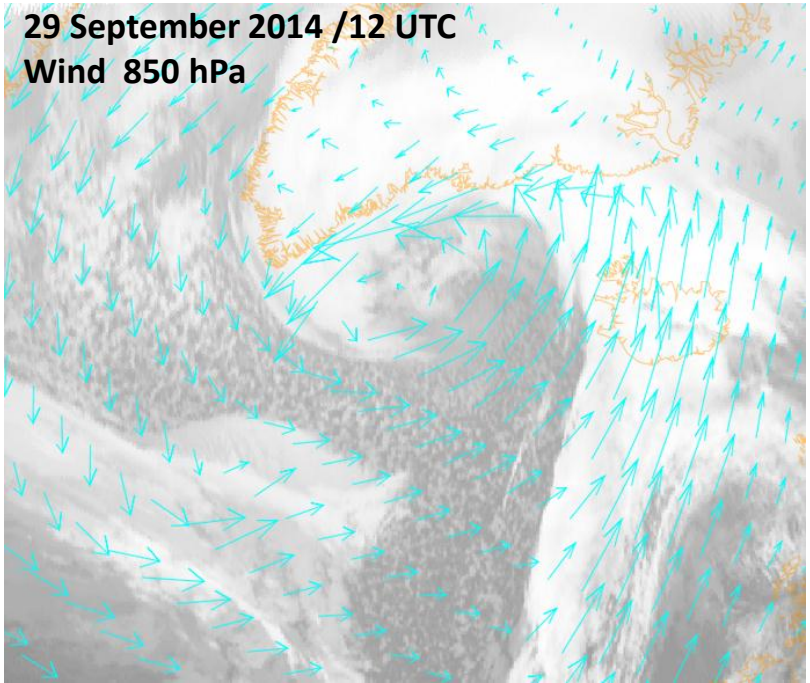


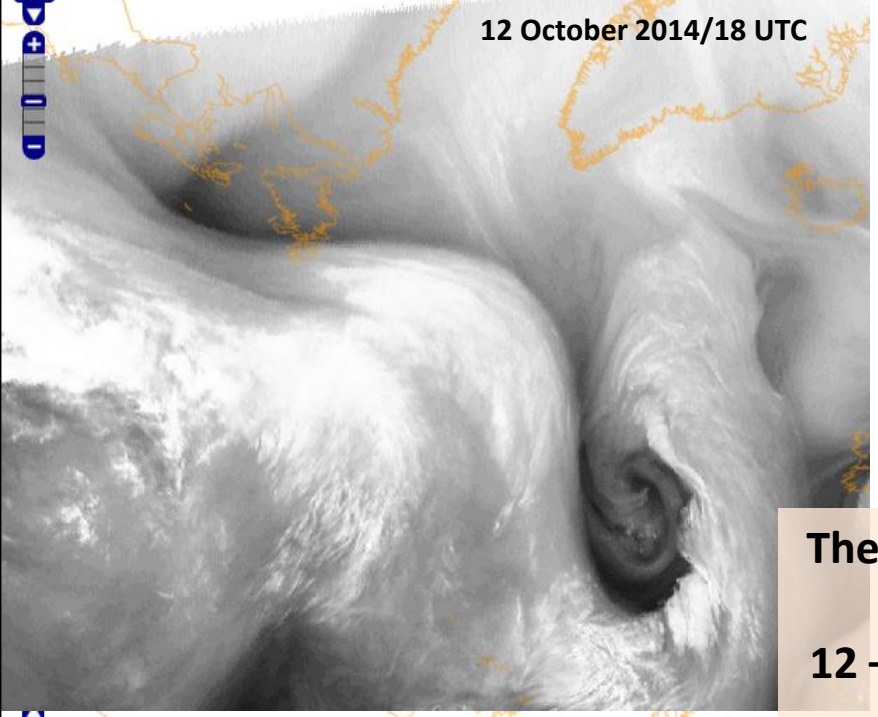


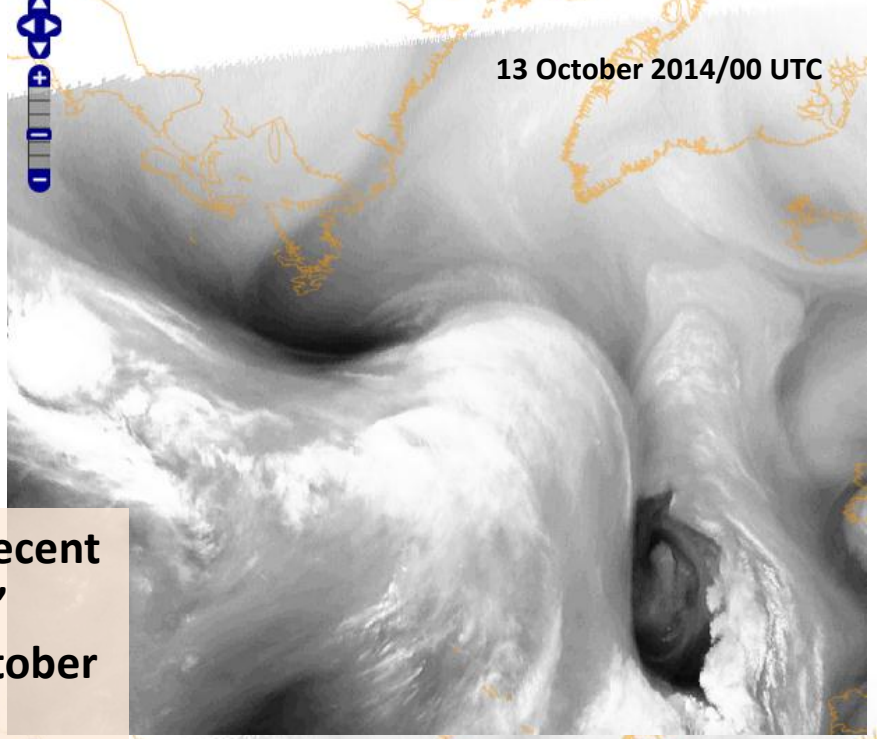

29 September 2014 /12 UTC
Synop
EUMETRAIN


65 - 100%
55 - 65%
45 - 55%
35 - 45%
25 - 35%
15 - 25%
5 - 15%
0 - 5%
29 September 2014 /12 UTC
PC
EUMETRAIN

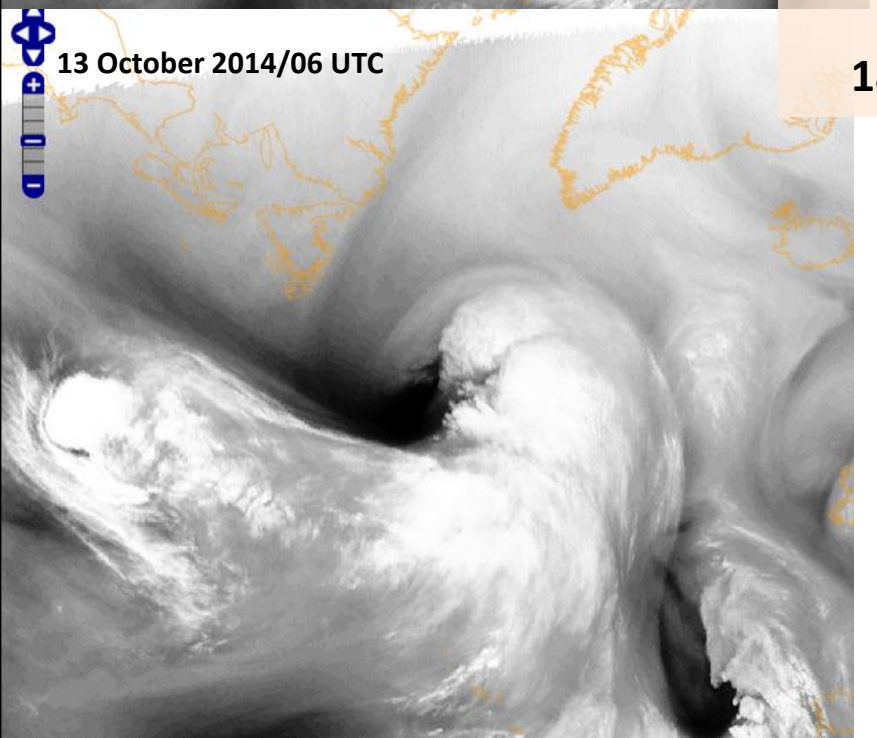

29 September 2014 /12 UTC
10 m Wind

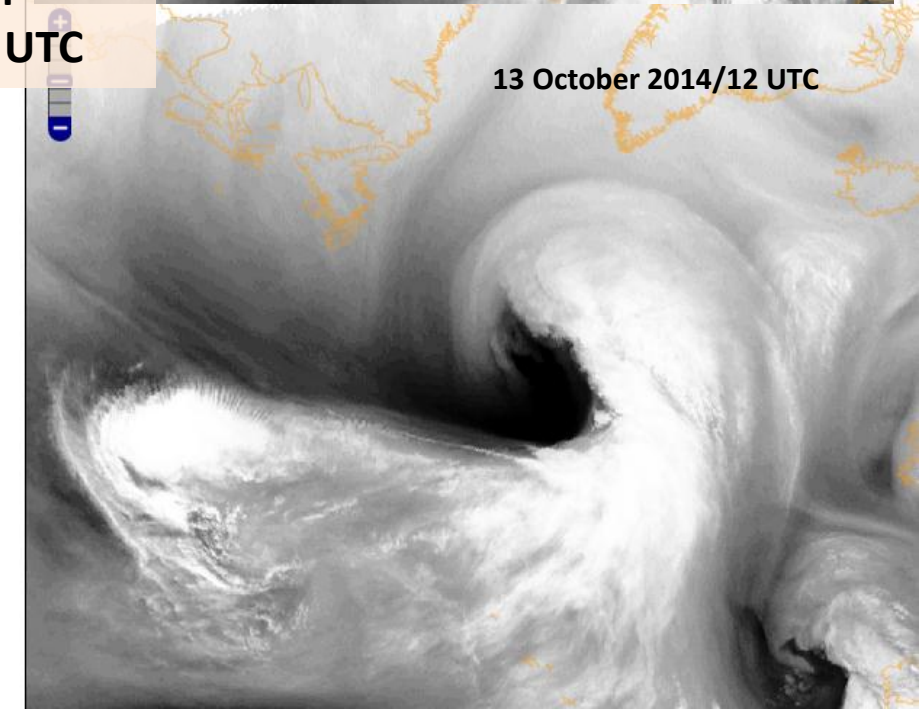

29 September 2014 /12 UTC
Wind 850 hPa





The most recent "Racy"
12 – 13 October 2014
18 – 12 UTC





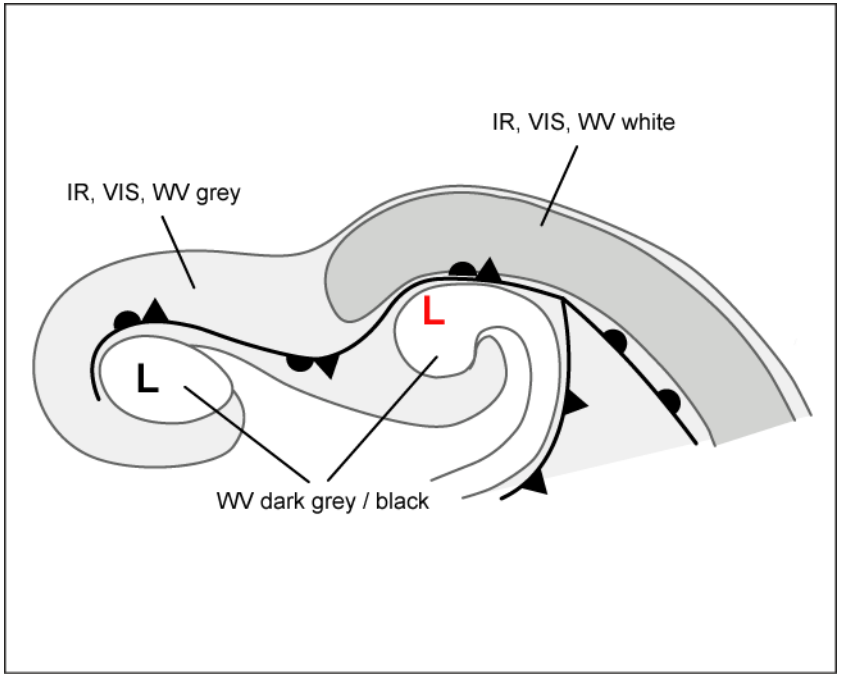
Special Developments at and with occlusion cloud bands

- Substructures developing at occlusion cloud band after some time
  - Development of secondary low centers at occlusion cloud band

- Development of occlusion cloud bands deviating from the classical theories:
  - Back bent occlusion
  - Cold Air Development
  - Instant occlusion

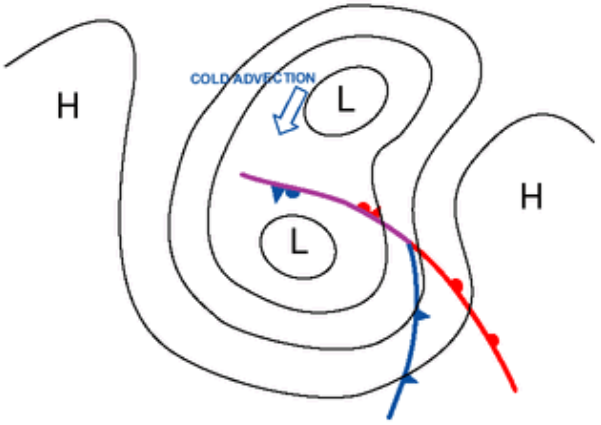
Secondary Low Centers at Occlusion Cloud bands

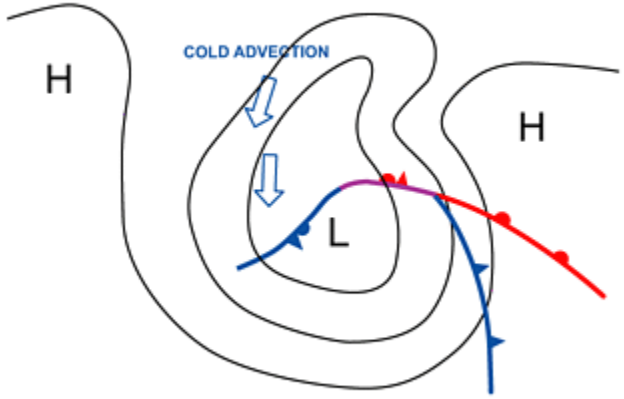
- A secondary Low develops at an occlusion cloud band if there is :
  - a distinct maximum of vorticity both shear and curvature components
  - a jet streak on the cyclonic side of the occluded front and parallel to it
  - Wind velocity in the jet streak are at least 50 m/s



Backbent Occlusion

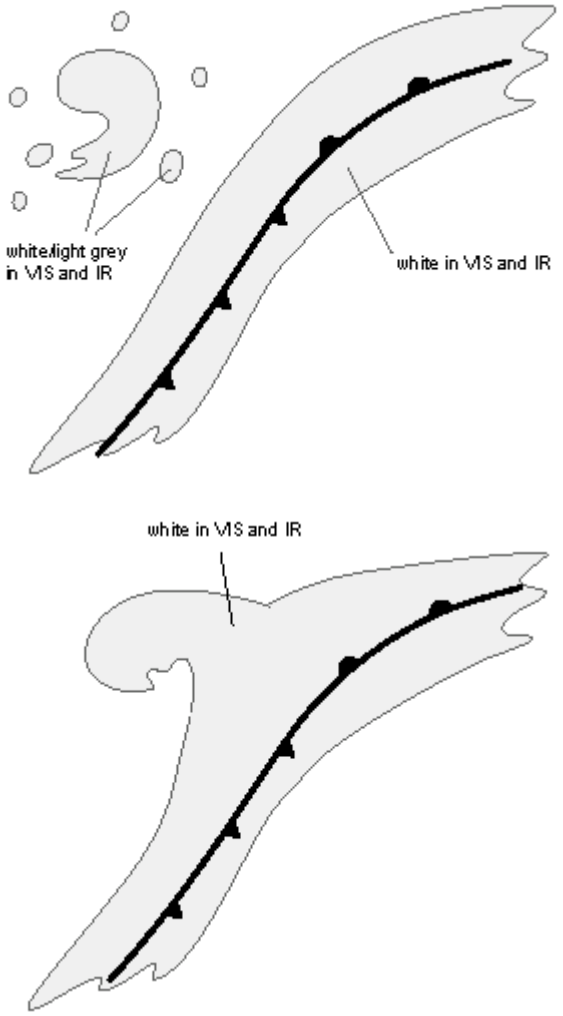
- Describes a development where the curved occlusion spiral changes to a cyclonic curvature
- This part takes the qualities of a Cold front
- Therefore the former occlusion propagates eastward as a cold front
- The main reason for this is a protruding cold air mass at the rear of the former occlusion band
- Consequently upper level height fields and temperature advection are the main key parameters

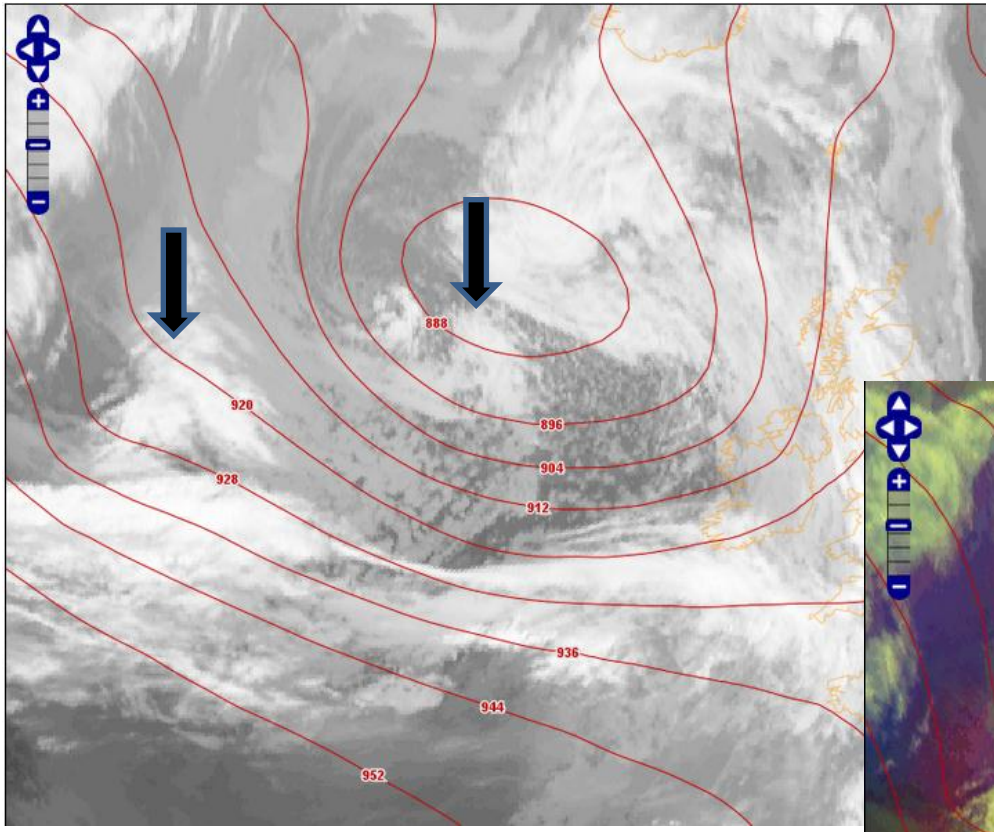




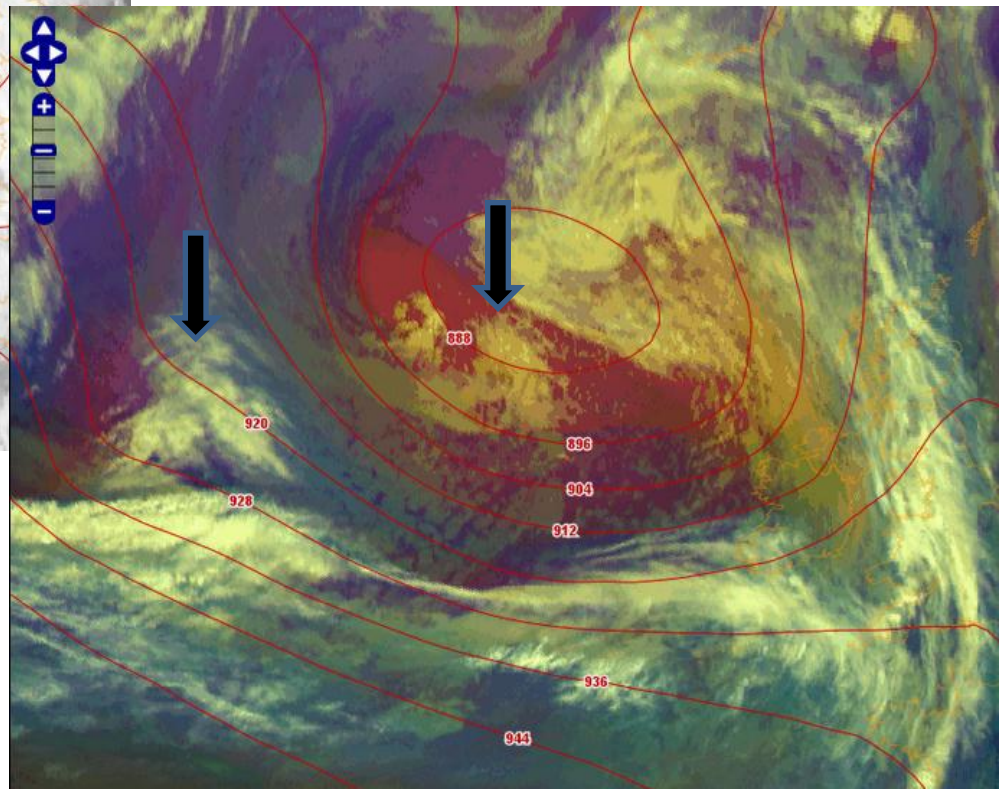
Instant Occlusion

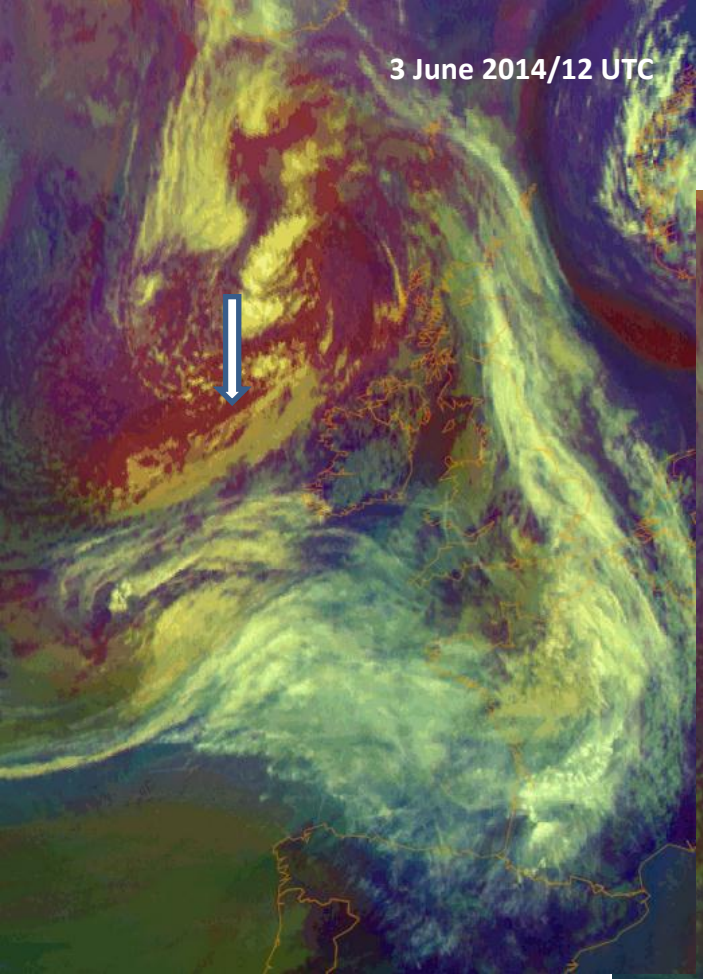
- Describes a development where a comma features in the cold air behind a frontal cloud band approaches the cloud band and finally merges with the cloud band
- Consequently the appearance of an occlusion spiral happens suddenly – “Instant occlusion”
- Different displacement velocities are the pre-condition for such a process

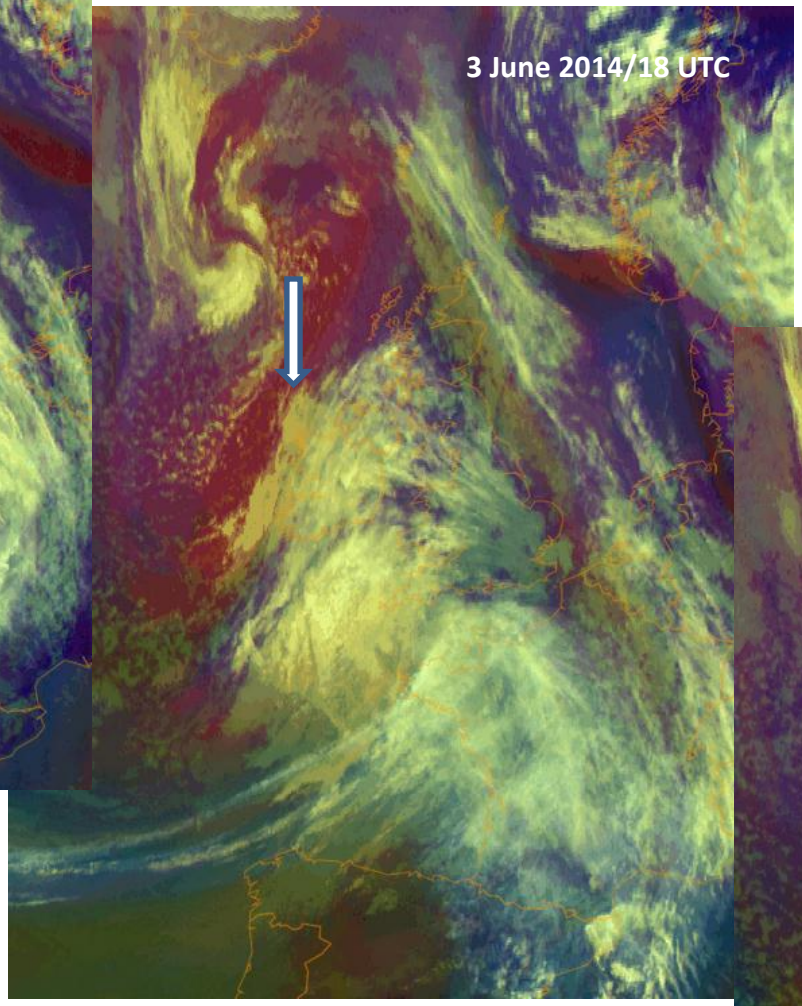


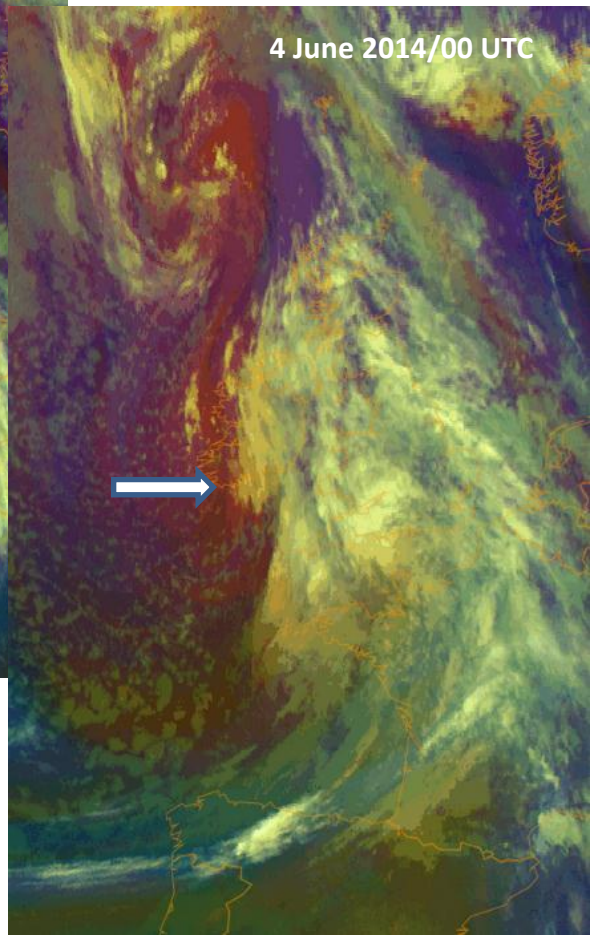


Initial stage
3 June 2014/00 UTC

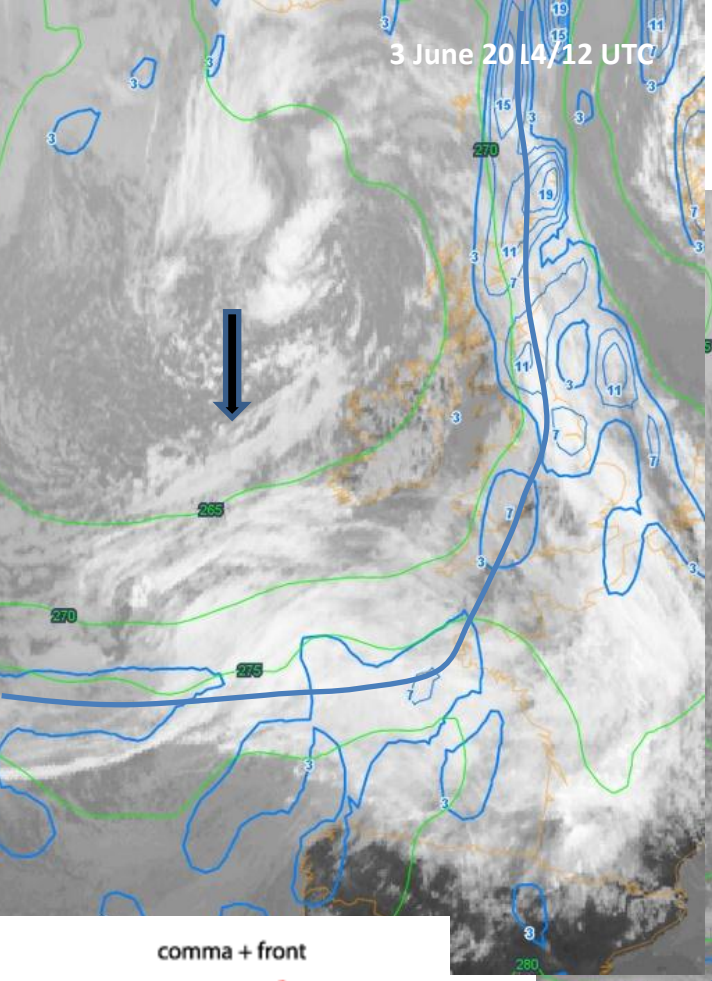


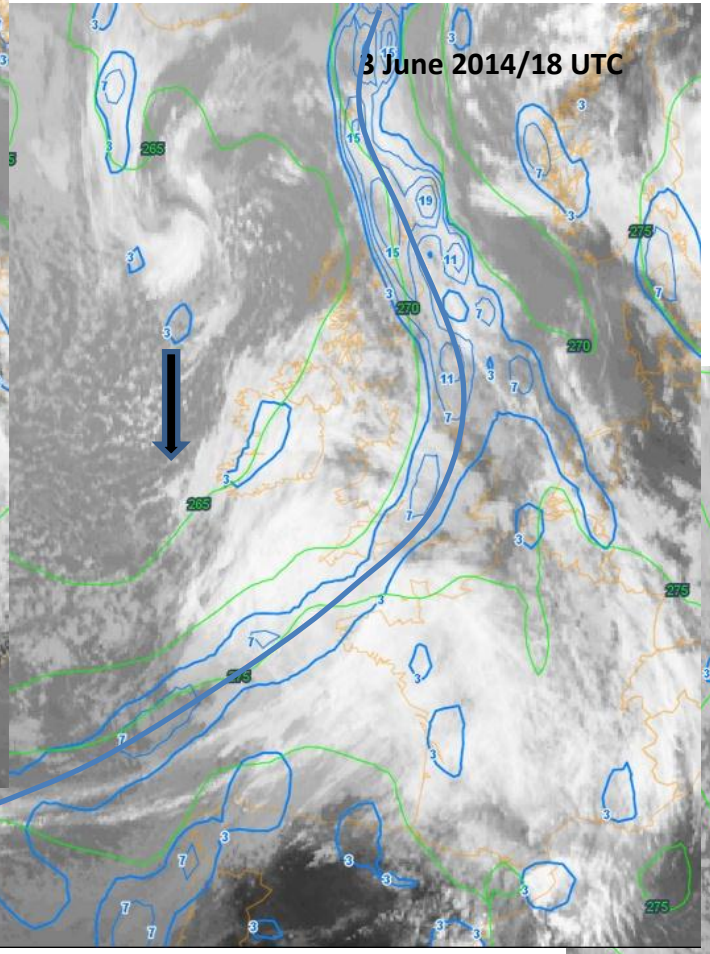


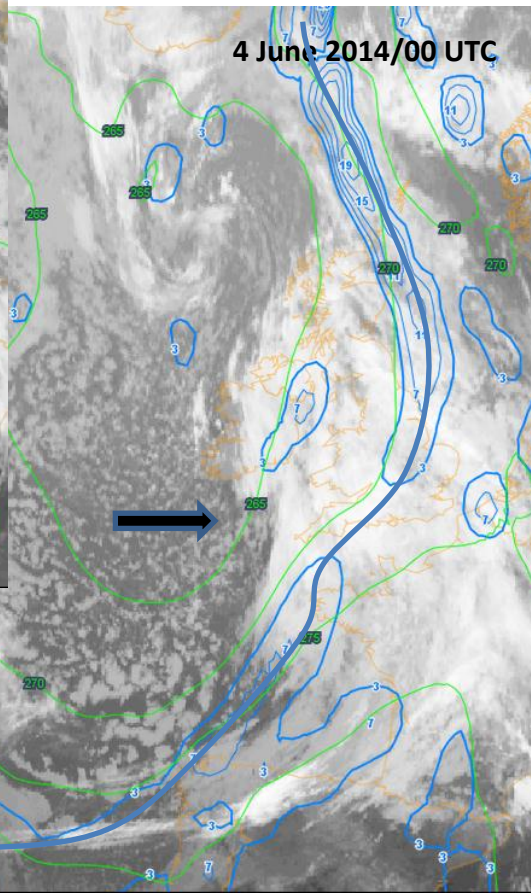


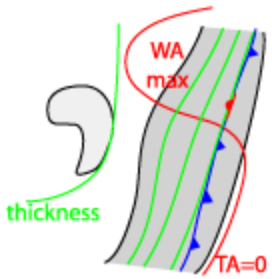


3 – 4 June 2014
Instant Occlusion
Airmass RGB
images





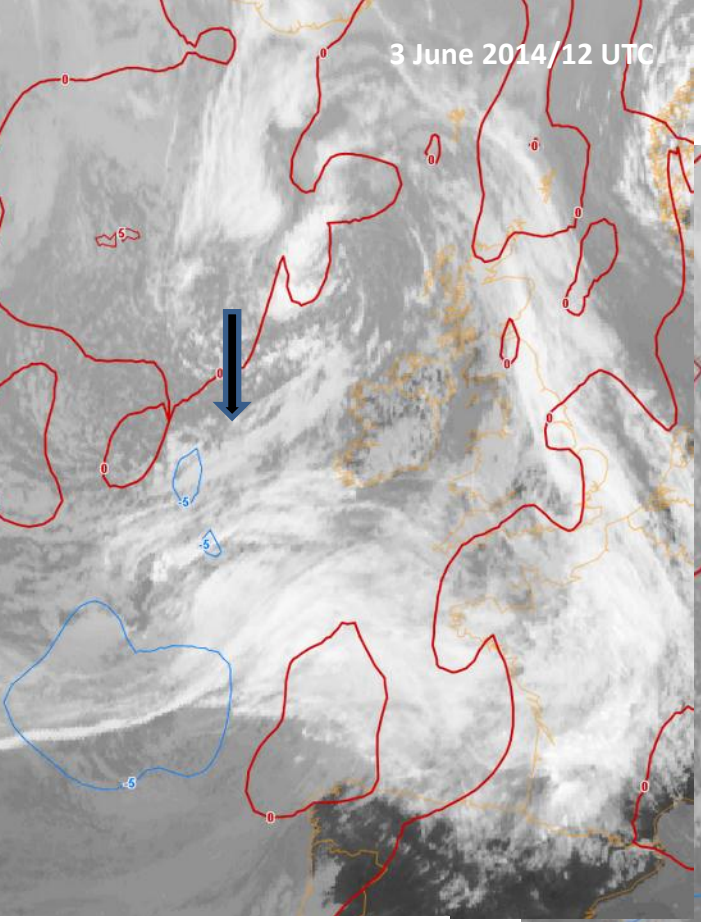


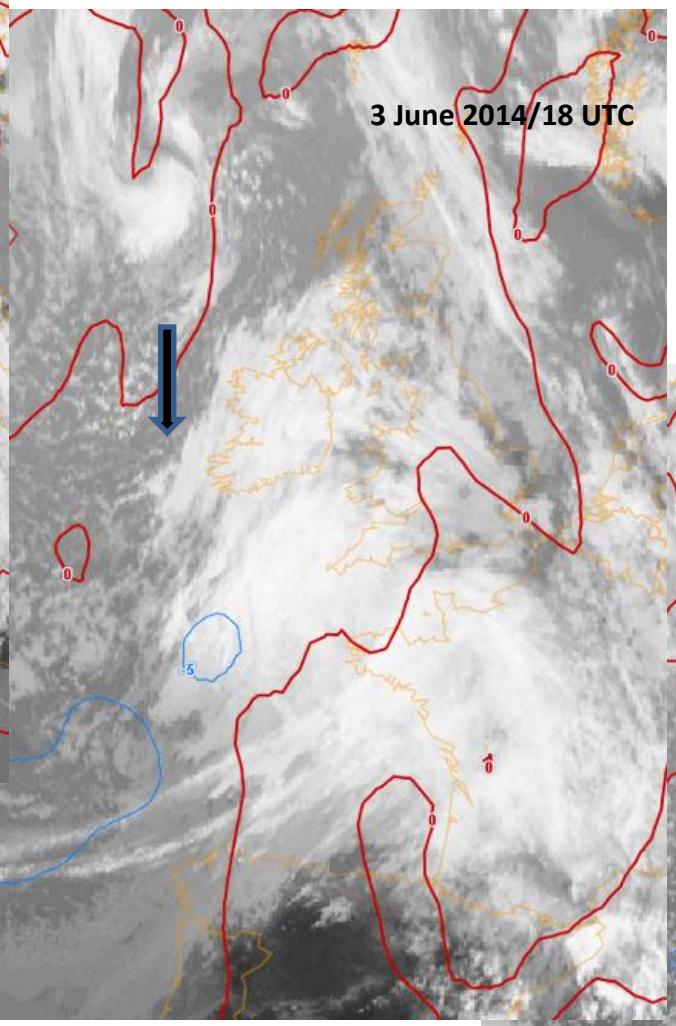


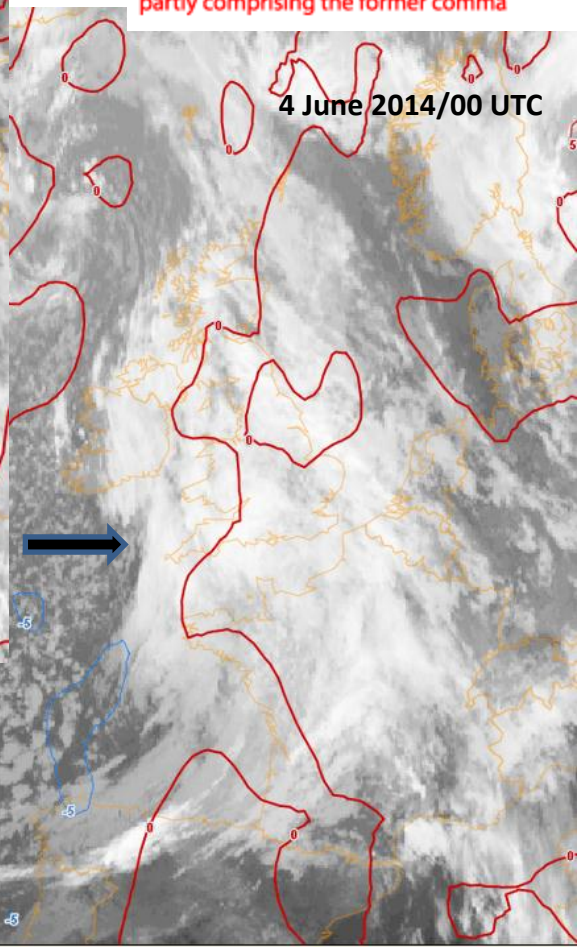
high gradient of thickness within frontal cloud band;
comma within thickness trough
slight WA max within cloud bulge

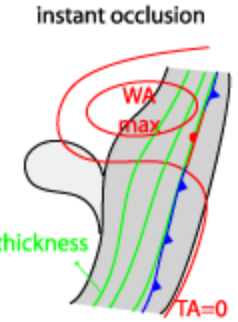
main zone of thickness gradient still within frontal cloud band;
intensified WA max within cloud bulge partly comprising the former comma

3 – 4 June 2014
Instant Occlusion
Green: equiv. Thickness
Blue: TFP

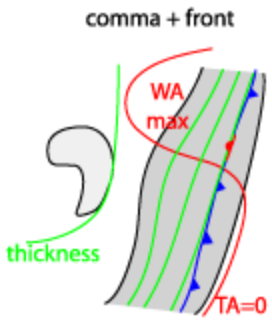






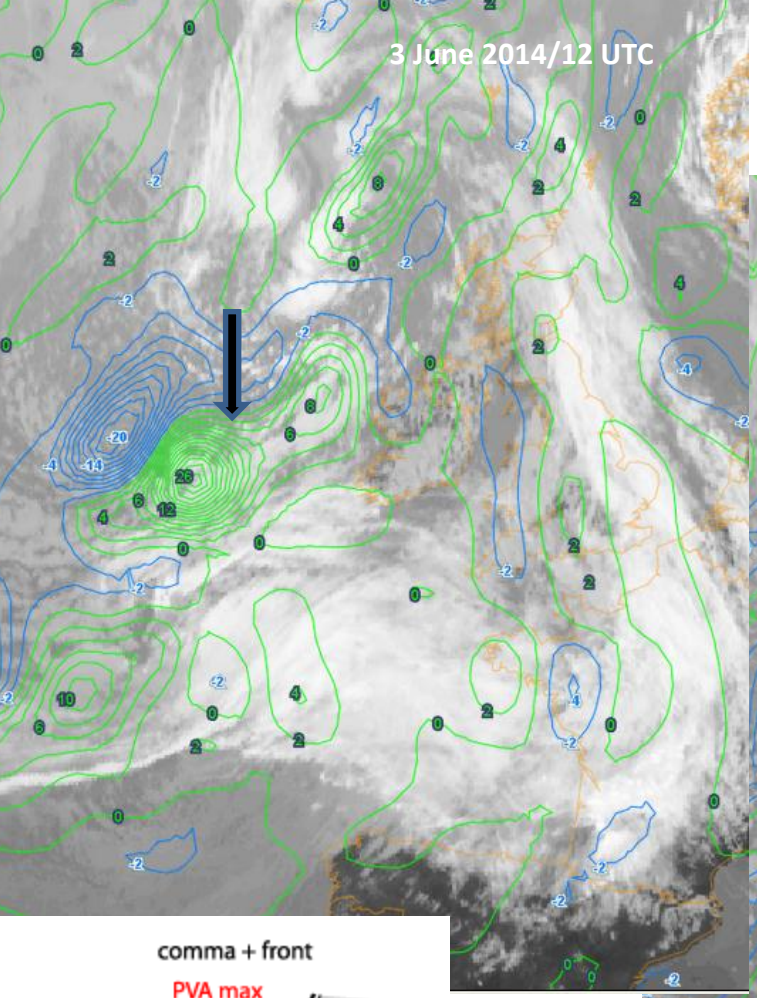


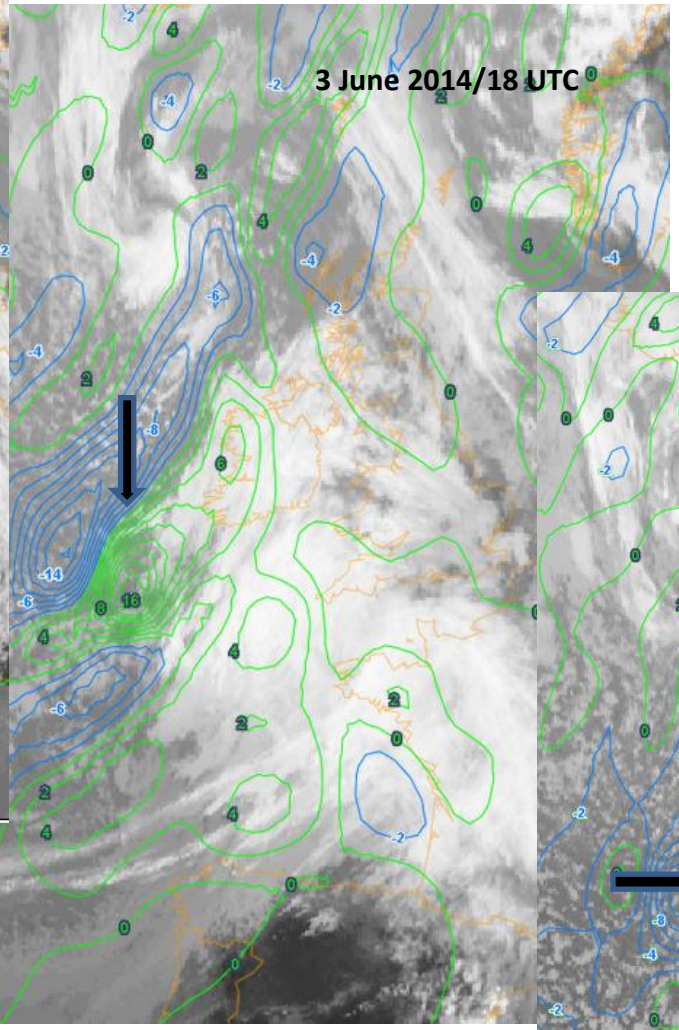
main zone of thickness gradient still within frontal cloud band;
intensified WA max within cloud bulge partly comprising the former comma

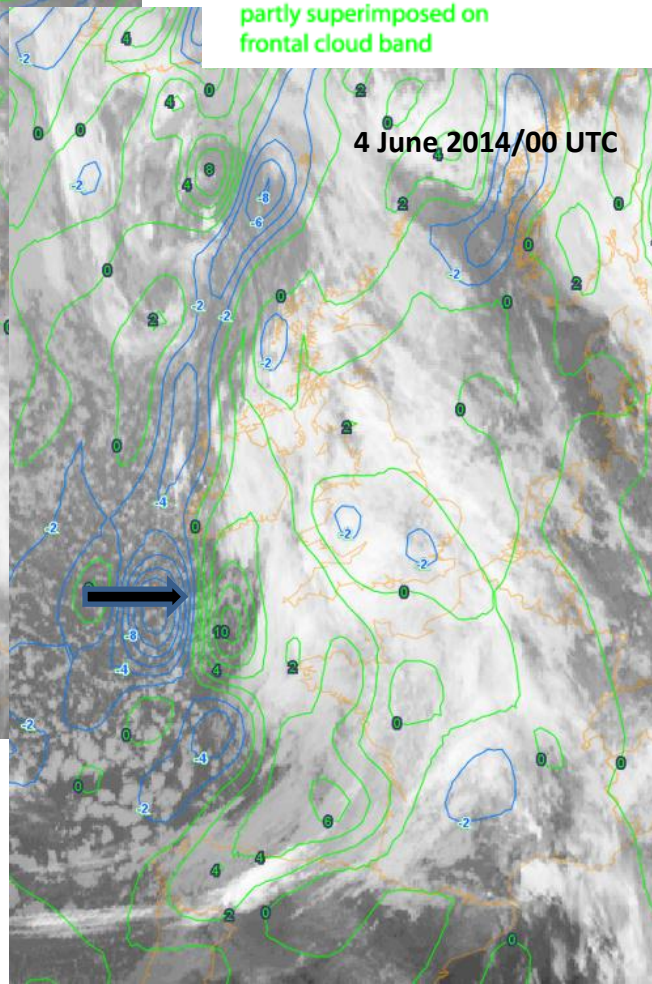


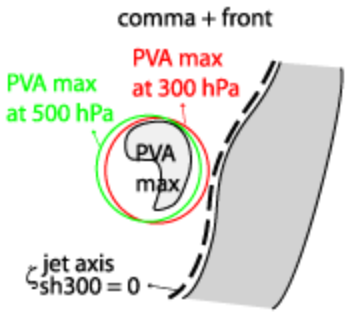
high gradient of thickness within frontal cloud band;
comma within thickness trough
slight WA max within cloud bulge

3 – 4 June 2014
Instant Occlusion
Red/blue: temperature advection 700 hPa
Red: WA, blue: CA

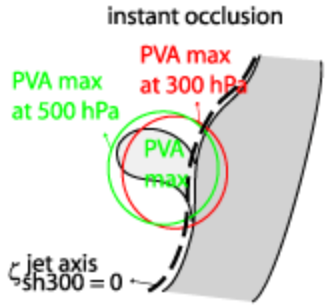








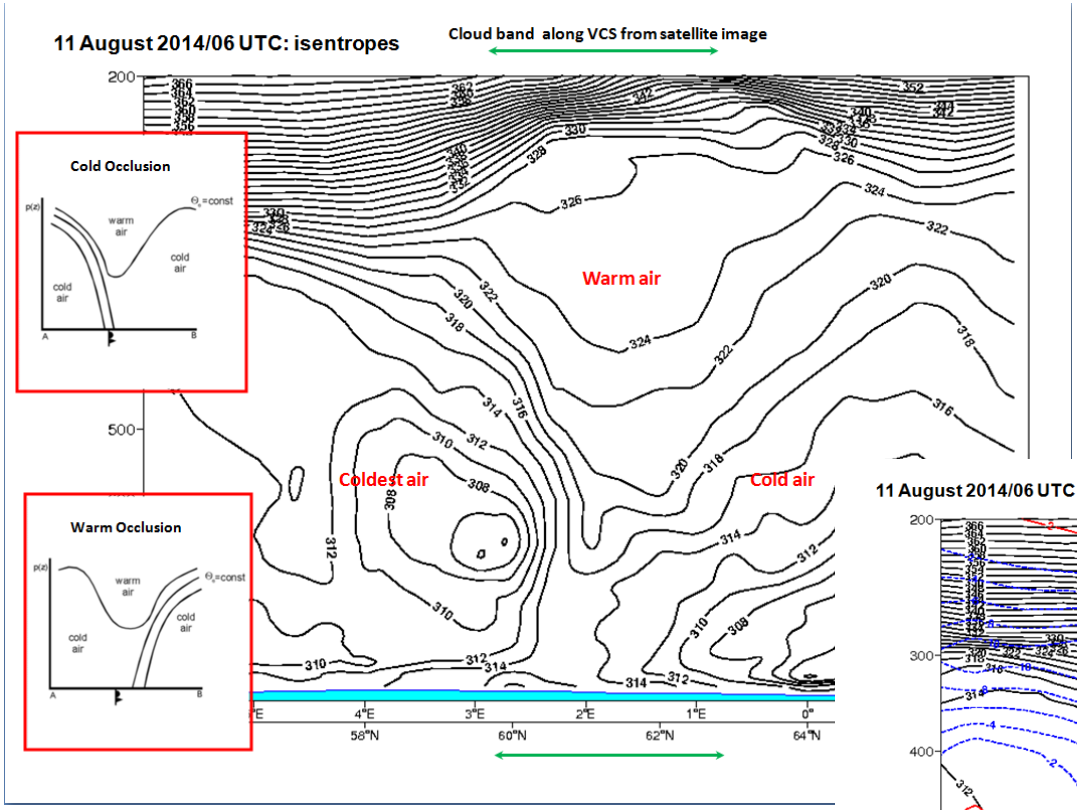
jet axis along rear side of frontal cloud band
PVA max at 500 hPa and 300 hPa above comma

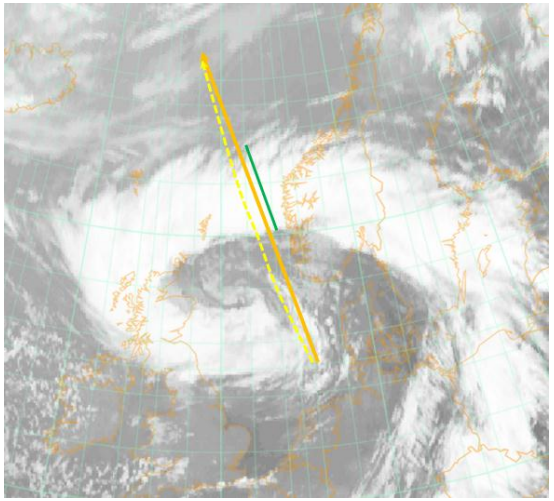


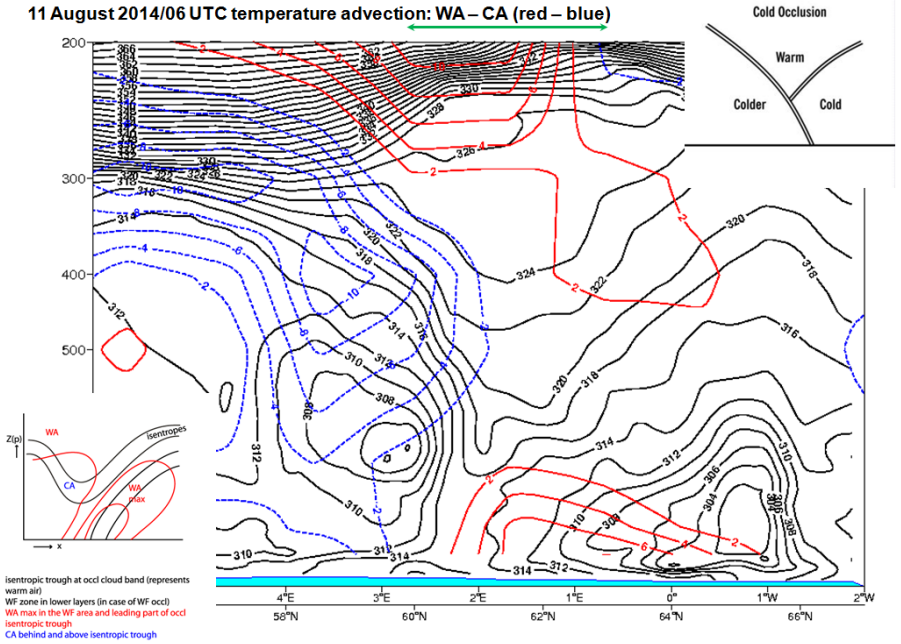
jet axis along rear side of frontal cloud band
PVA max accompanies comma and is partly superimposed on frontal cloud band

3 – 4 June 2014
Instant Occlusion
Green/blue: Vorticity advection 700 hPa
Green: PVA, blue: NVA

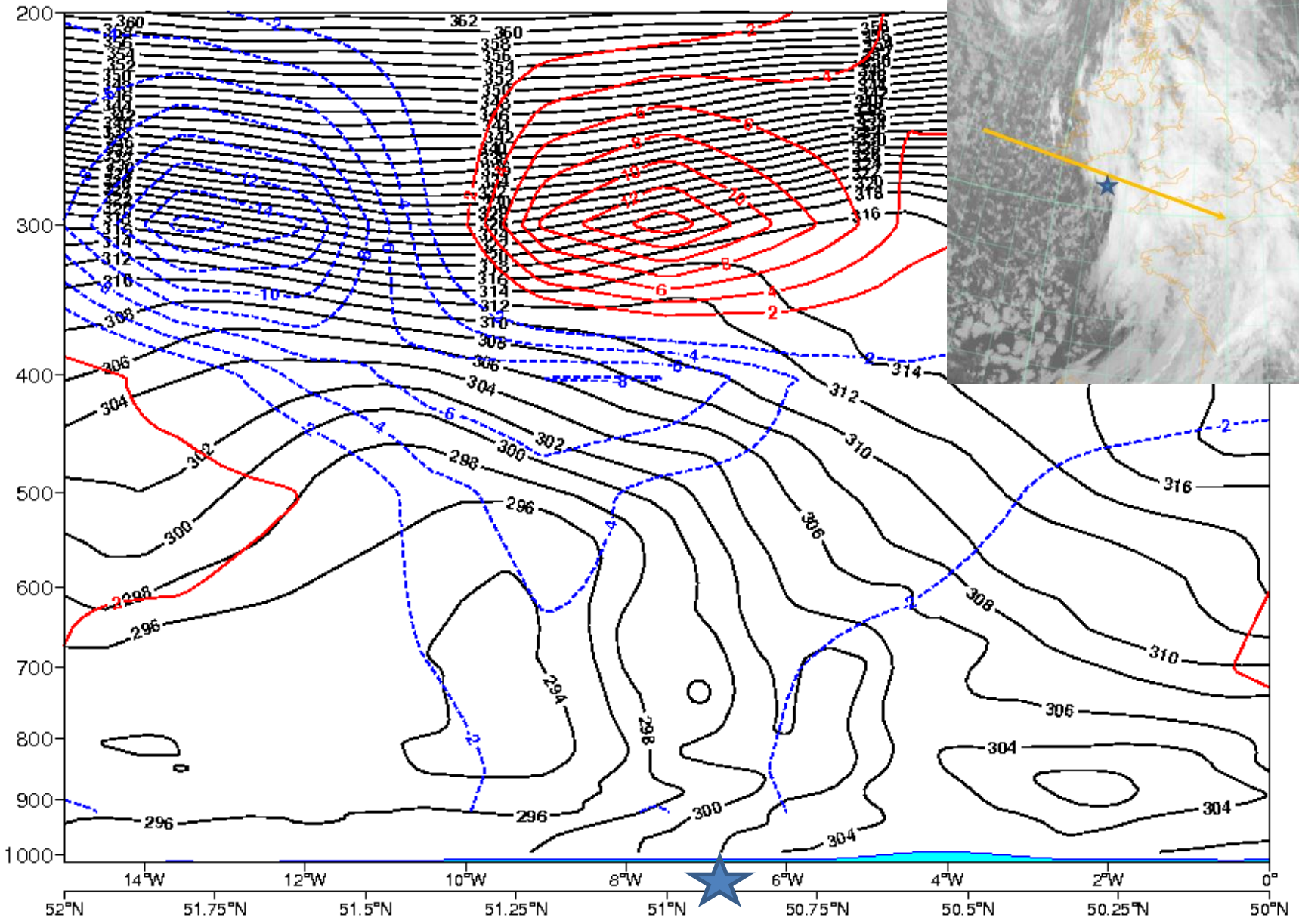
What typical features do we expect for a classical occlusion process ?



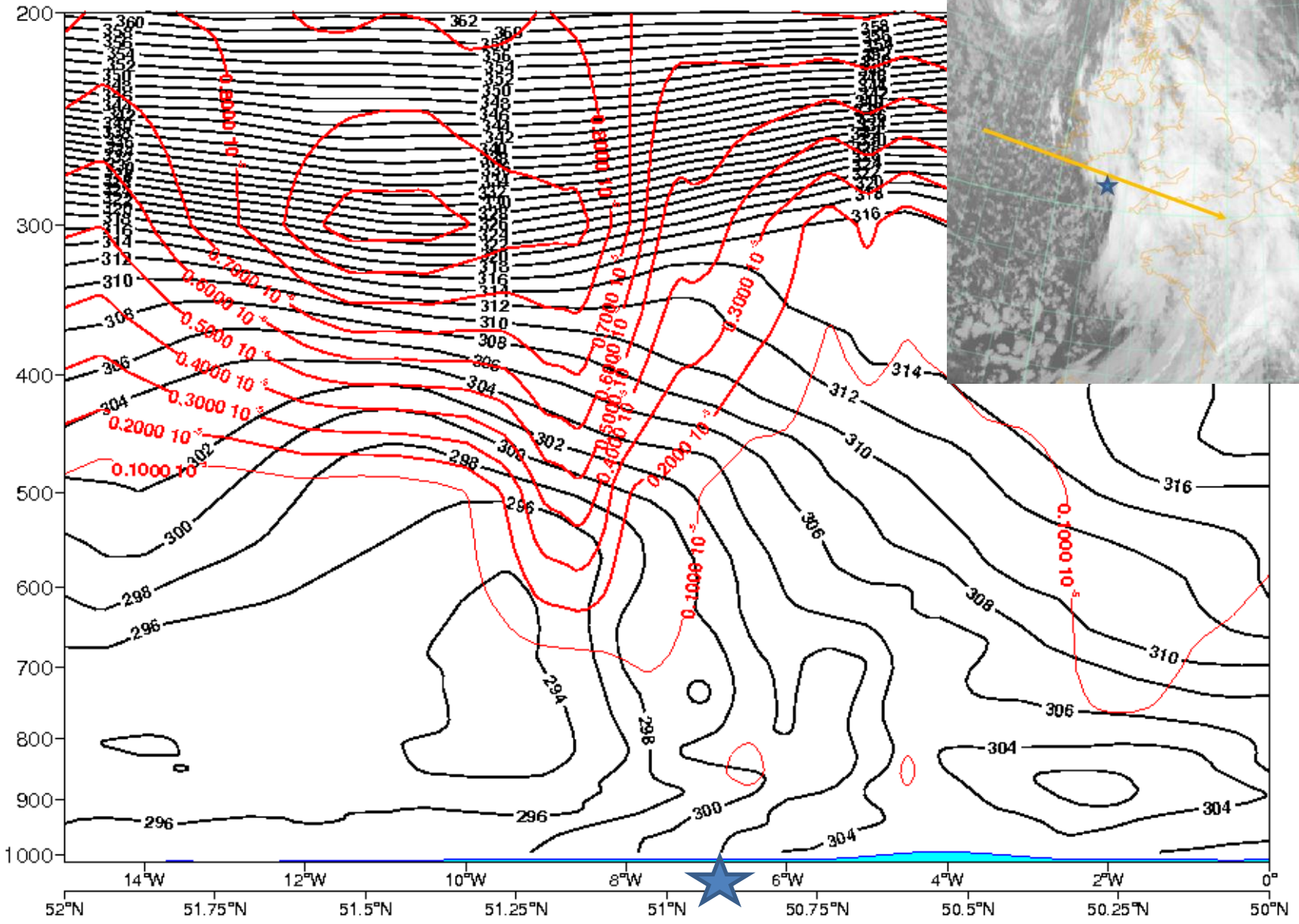




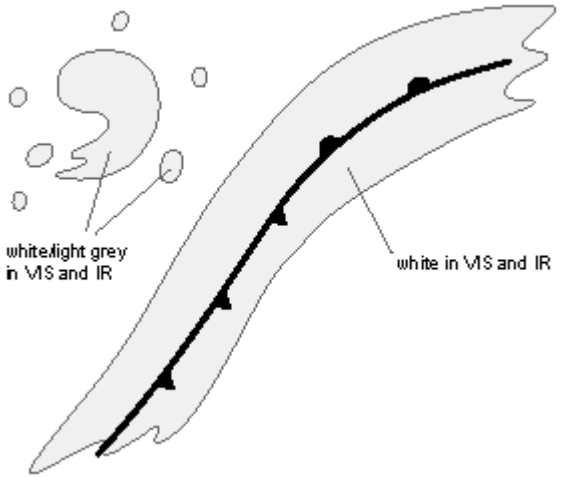
4June14/00

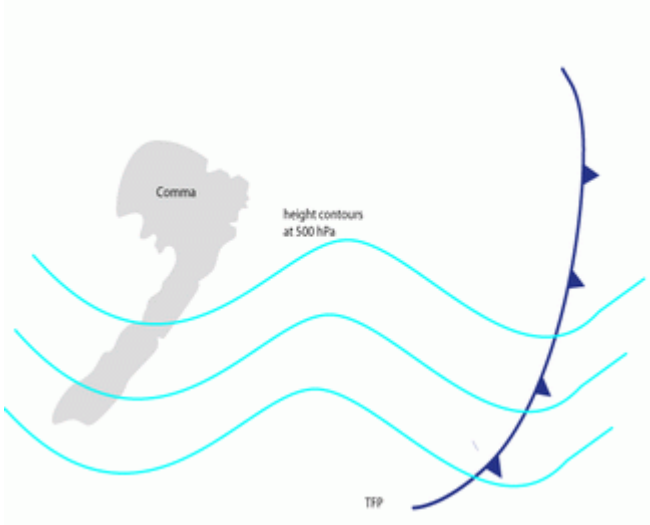

200
300
400
500
600
700
800
900
1000
14°W
12°W
10°W
8°W
6°W
4°W
2°W
0°
52°N
51.75°N
51.5°N
51.25°N
51°N
50.75°N
50.5°N
50.25°N
50°N

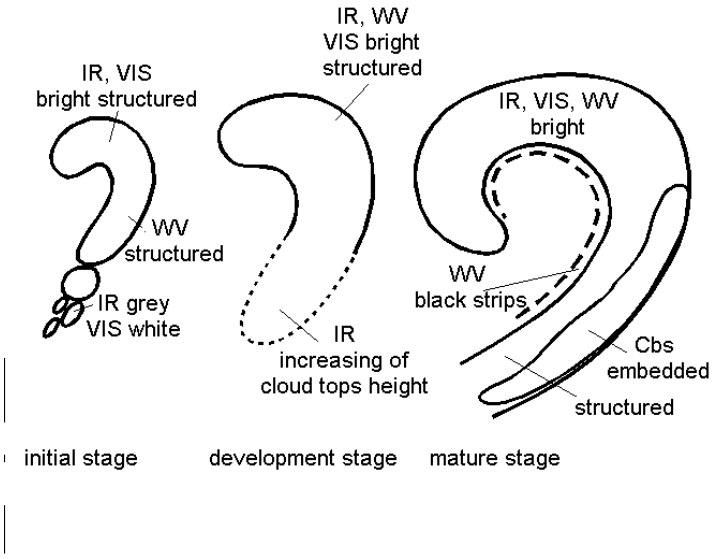
4June14/00

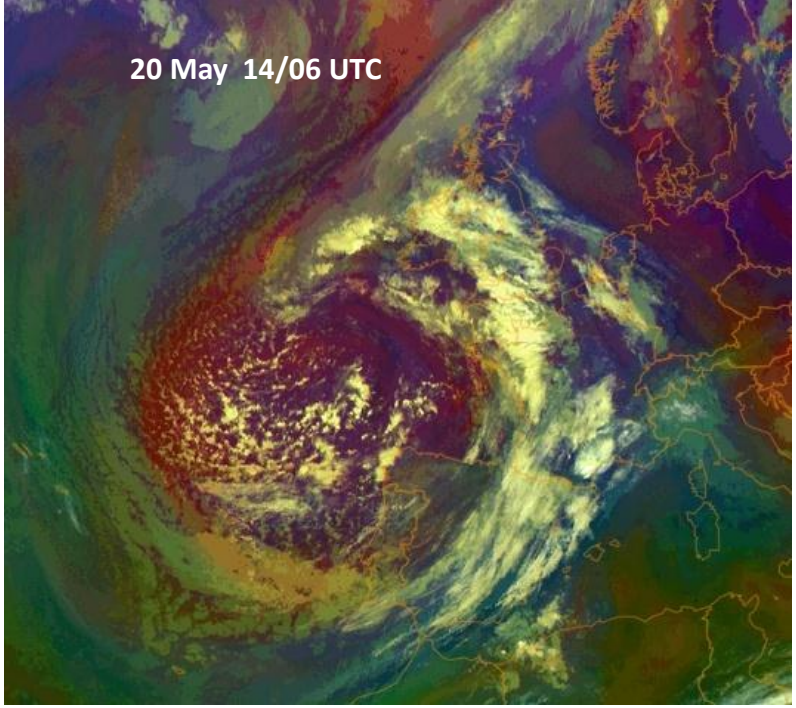

200
300
400
500
600
700
800
900
1000
14°W
12°W
10°W
8°W
6°W
4°W
2°W
0°
52°N
51.75°N
51.5°N
51.25°N
51°N
50.75°N
50.5°N
50.25°N
50°N

Cold Air Development (CAD)





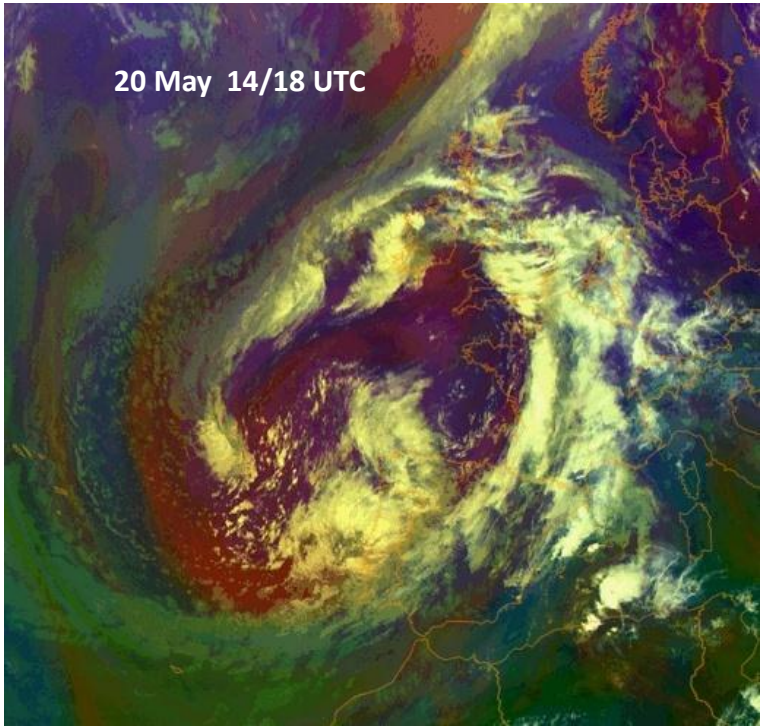


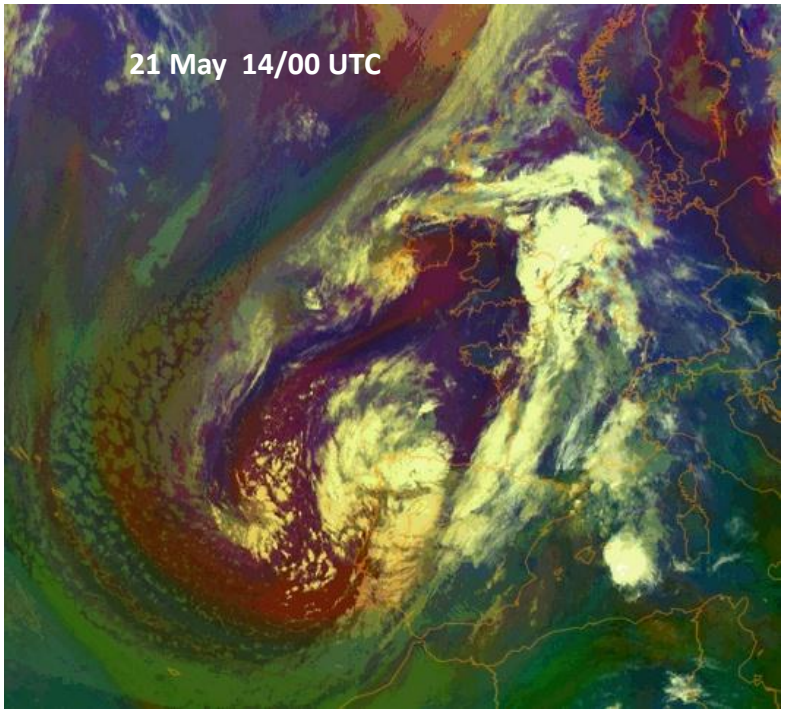


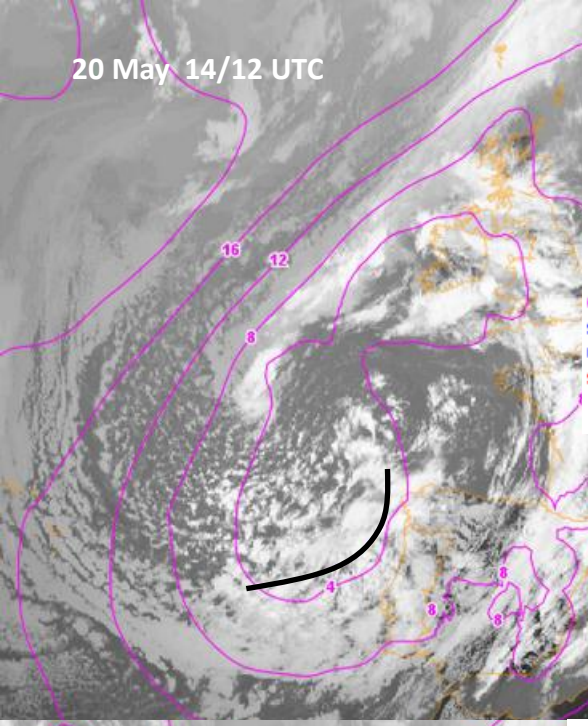
20 – 21 May 2014

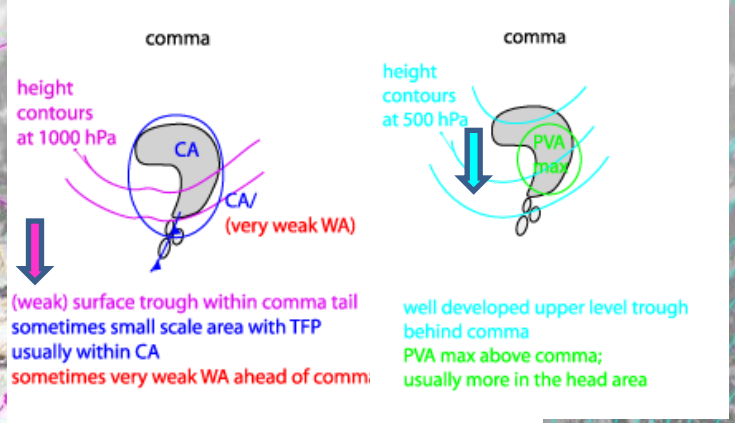
CAD Cold Air Development

Air mass RGB

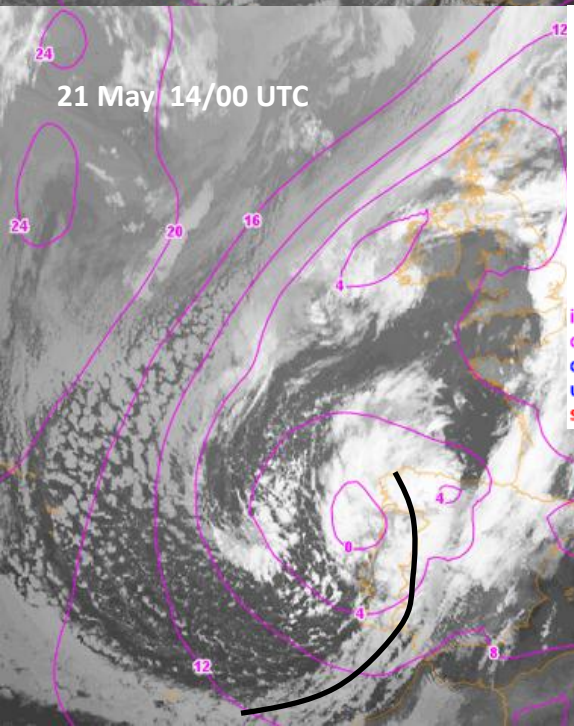


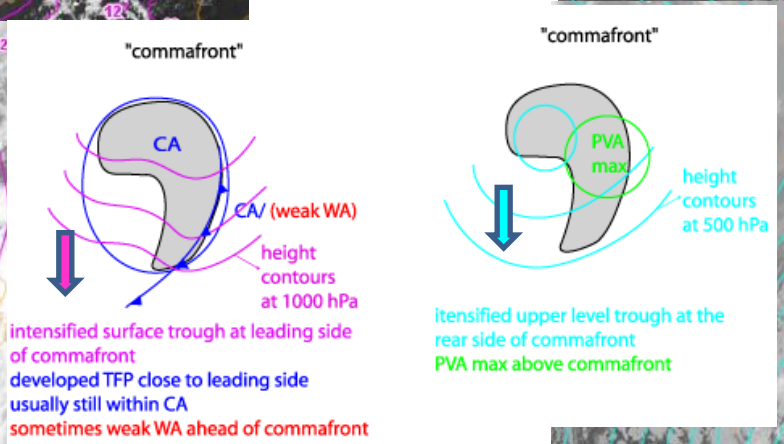




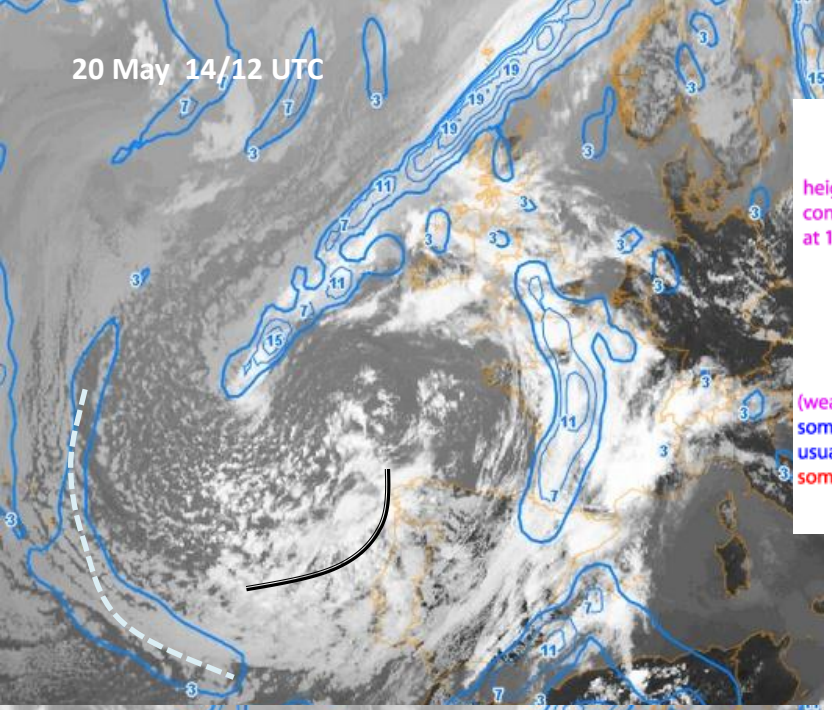


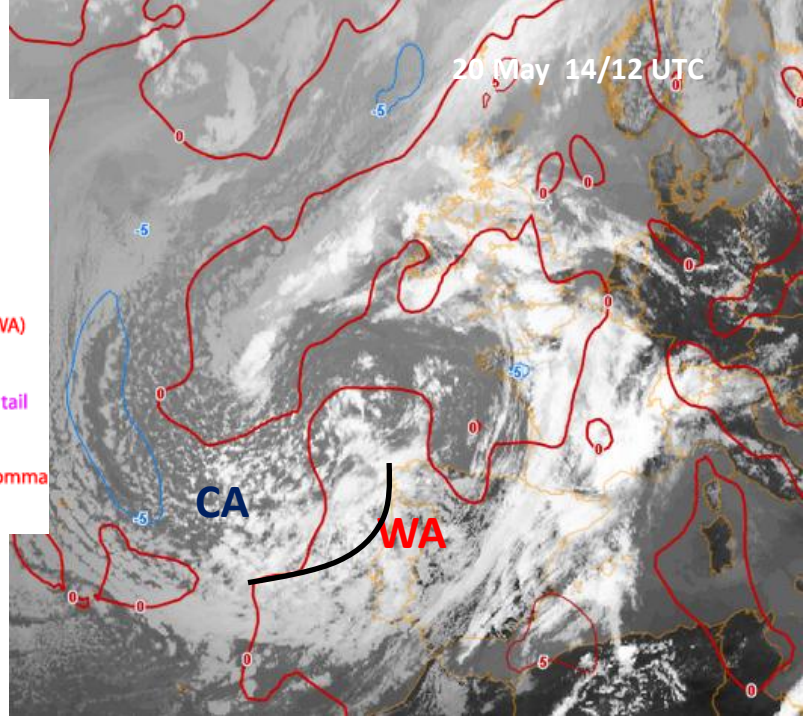
20 – 21
May 2014
CAD
Cold Air
Development



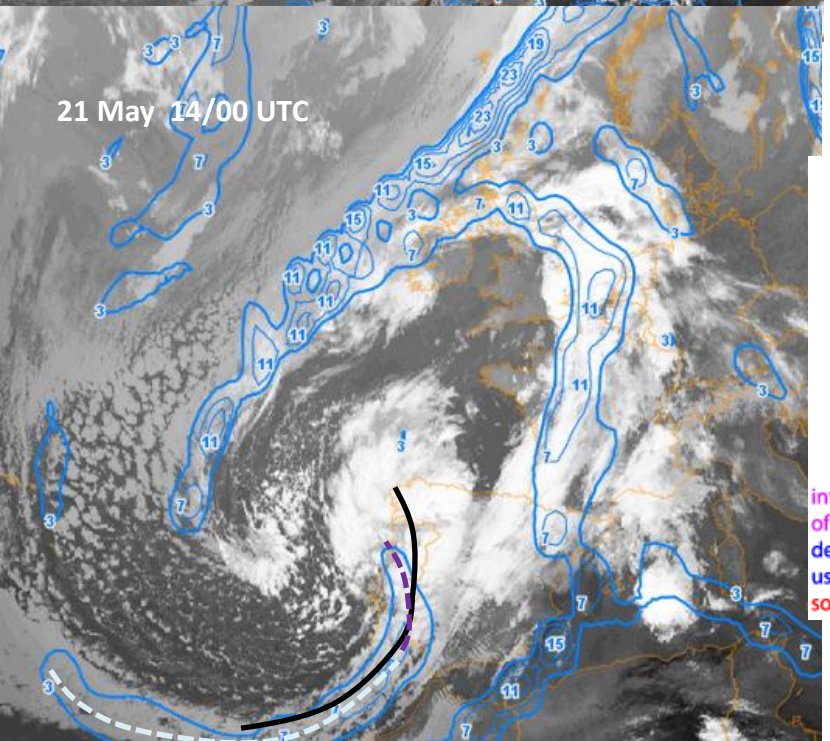


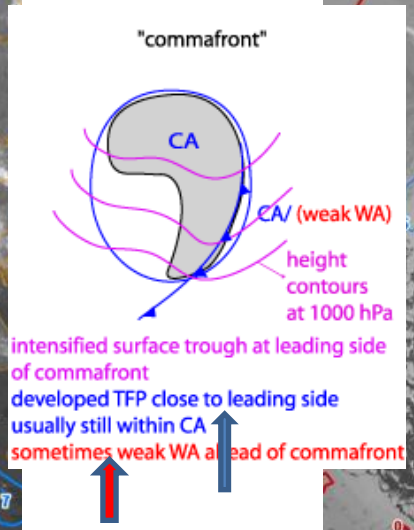
Cyan: height
500 hPa
Magenta:
height 1000 hPa

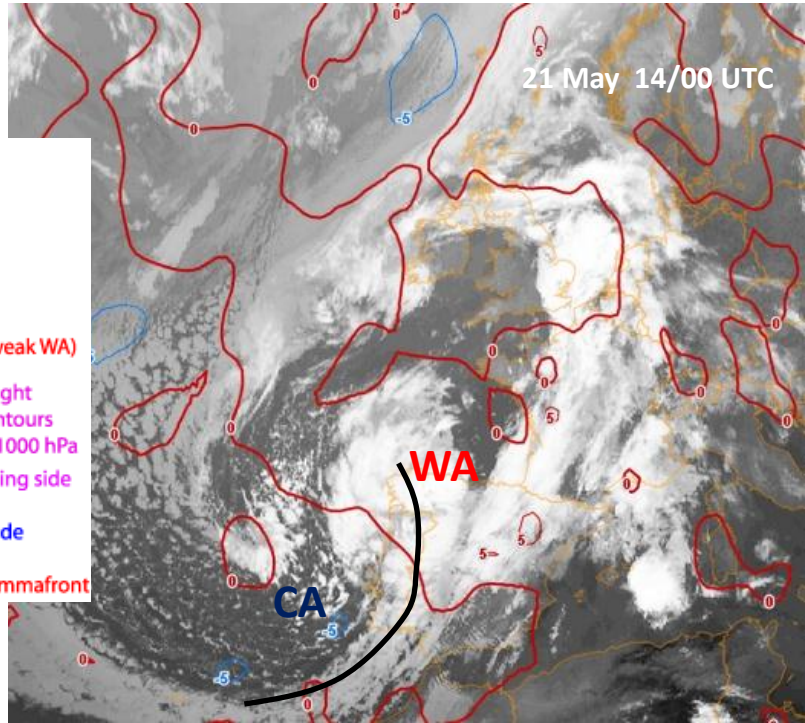


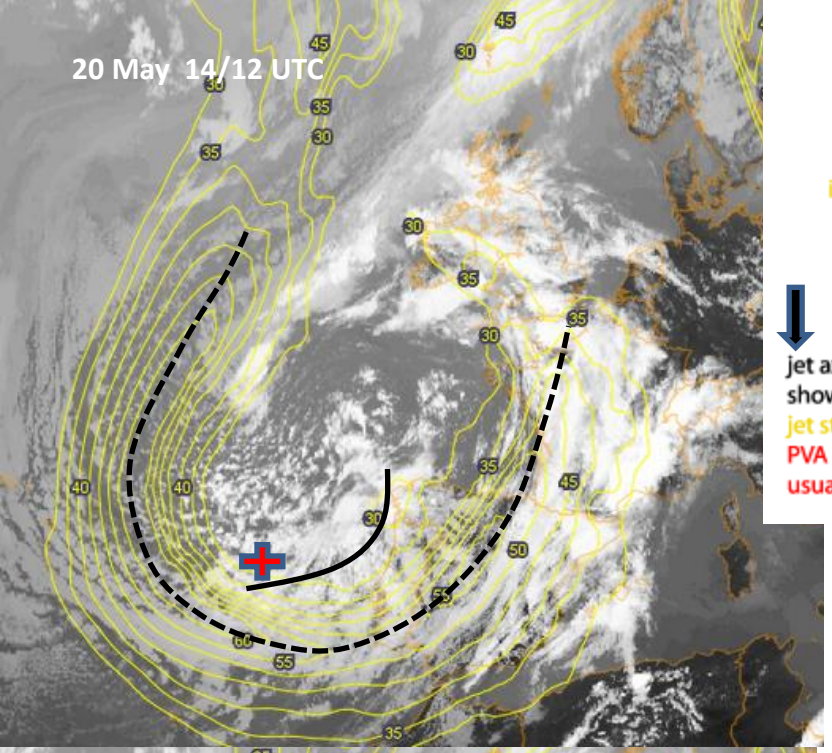


Left: TFP
Right: temperature advection

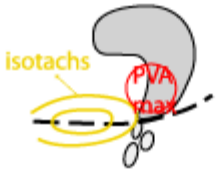




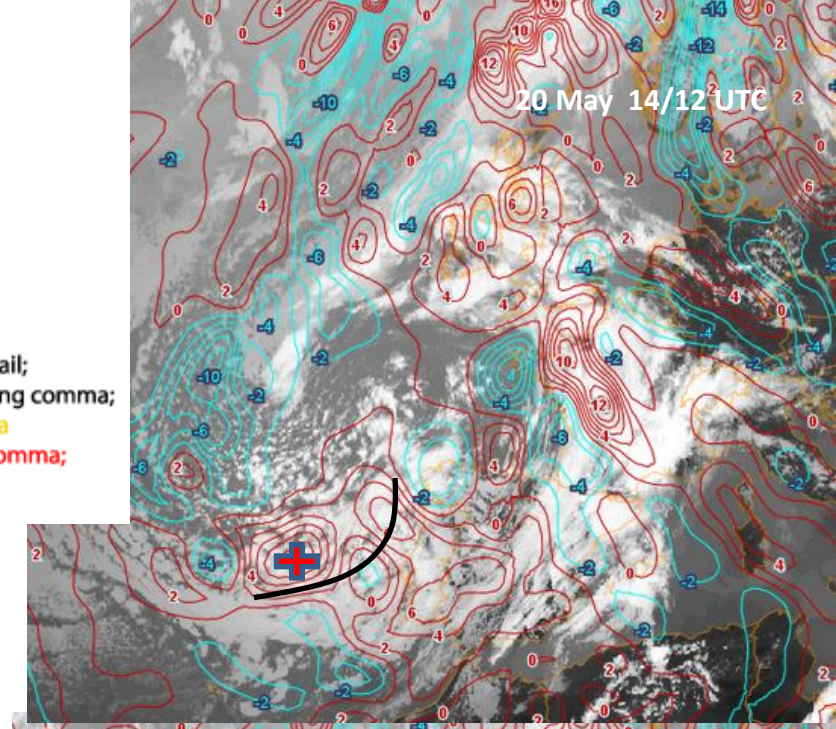




comma

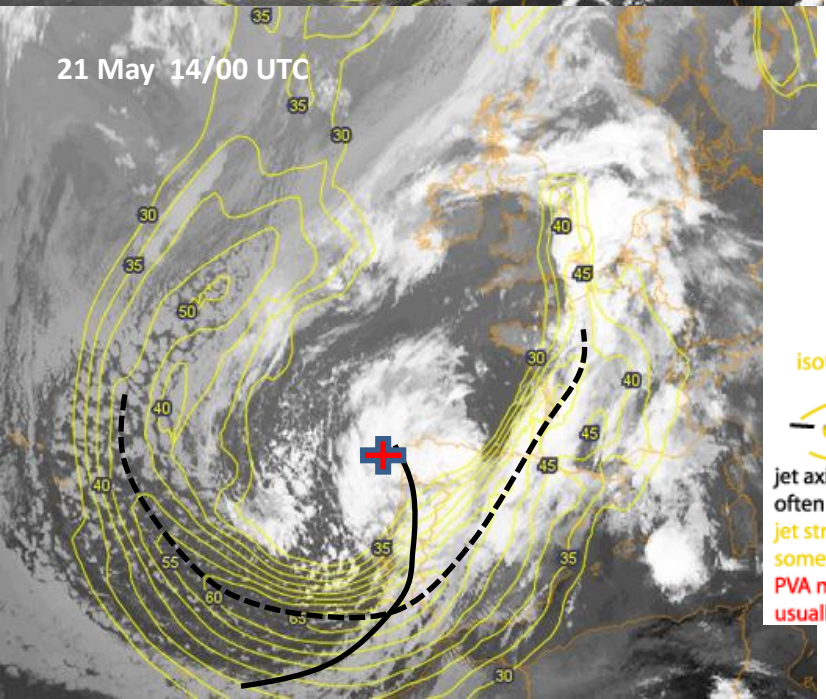


jet axis close to the comma tail;
shows tendency for overtaking comma;
jet streak approaches comma
PVA max at 300 hPa above comma;
usually more over the tail

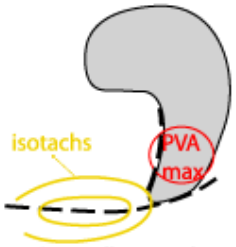


Left: isotachs 300

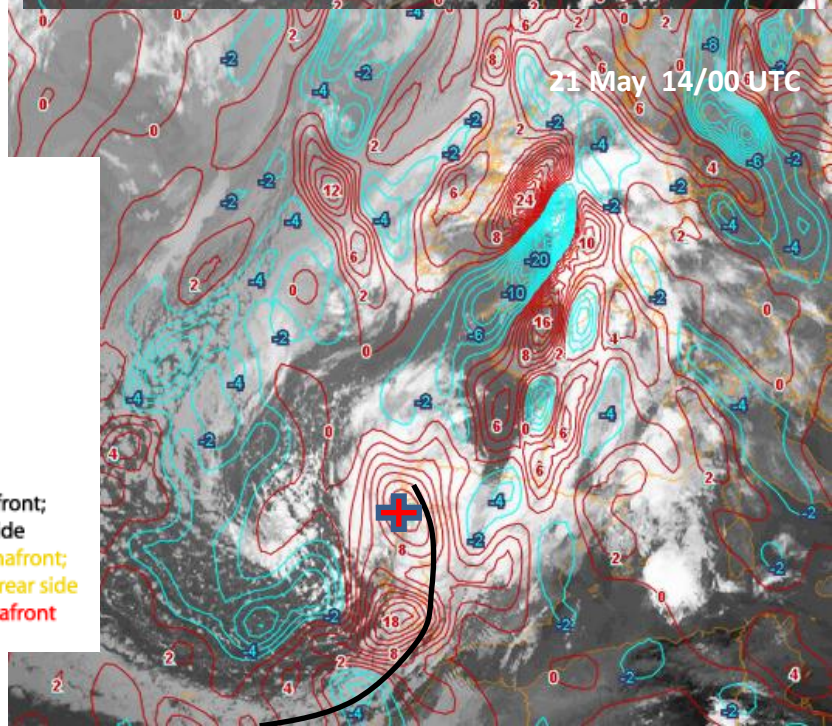
Right: vorticity advection 300



"commafront"

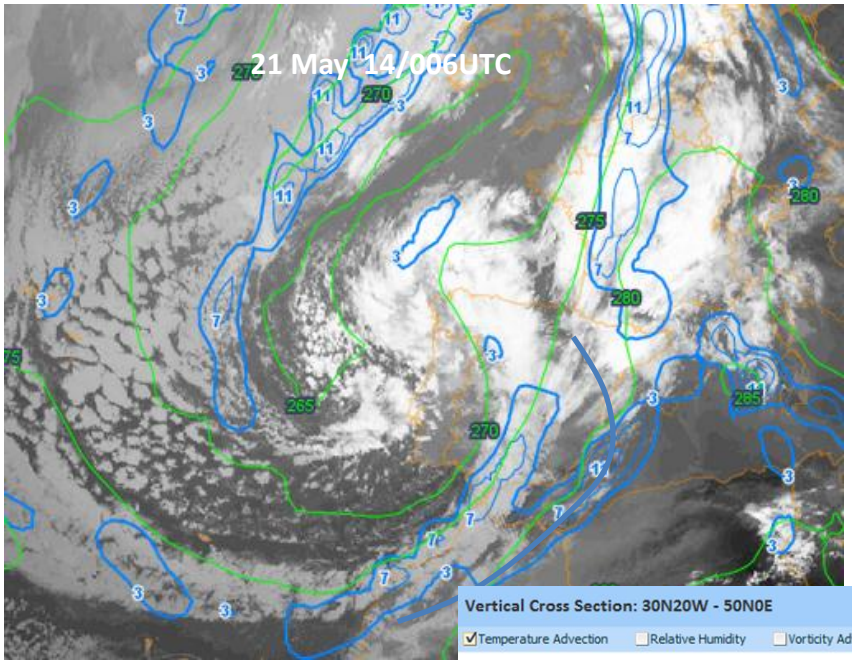


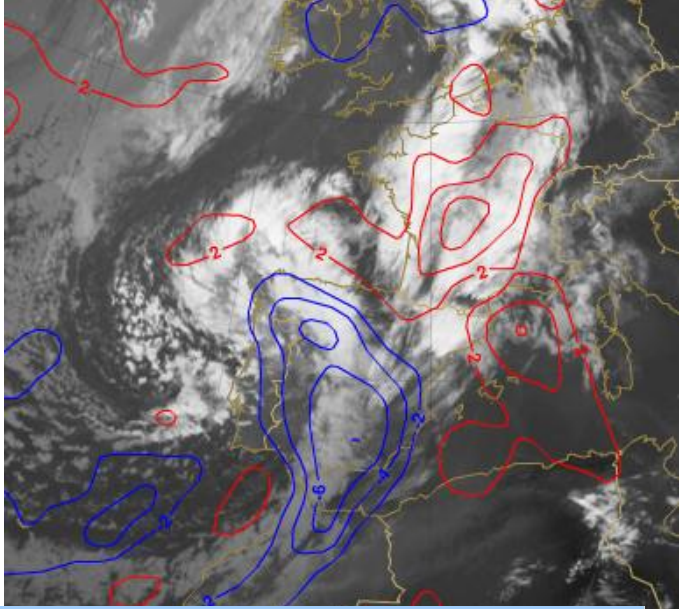
jet axis usually overtakes commafront;
often second branch along rear side
jet streak usually overtakes commafront;
sometimes second branch along rear side
PVA max at 300 hPa above commafront
usually in the southern part

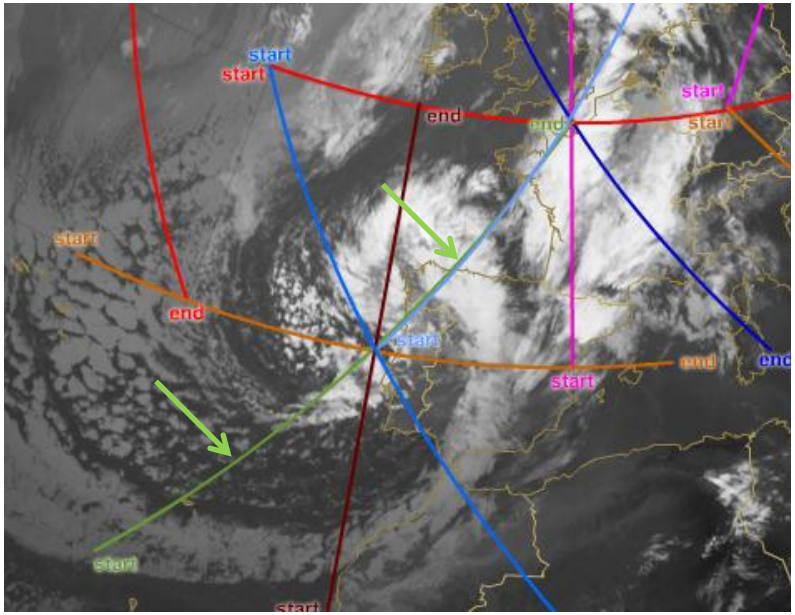


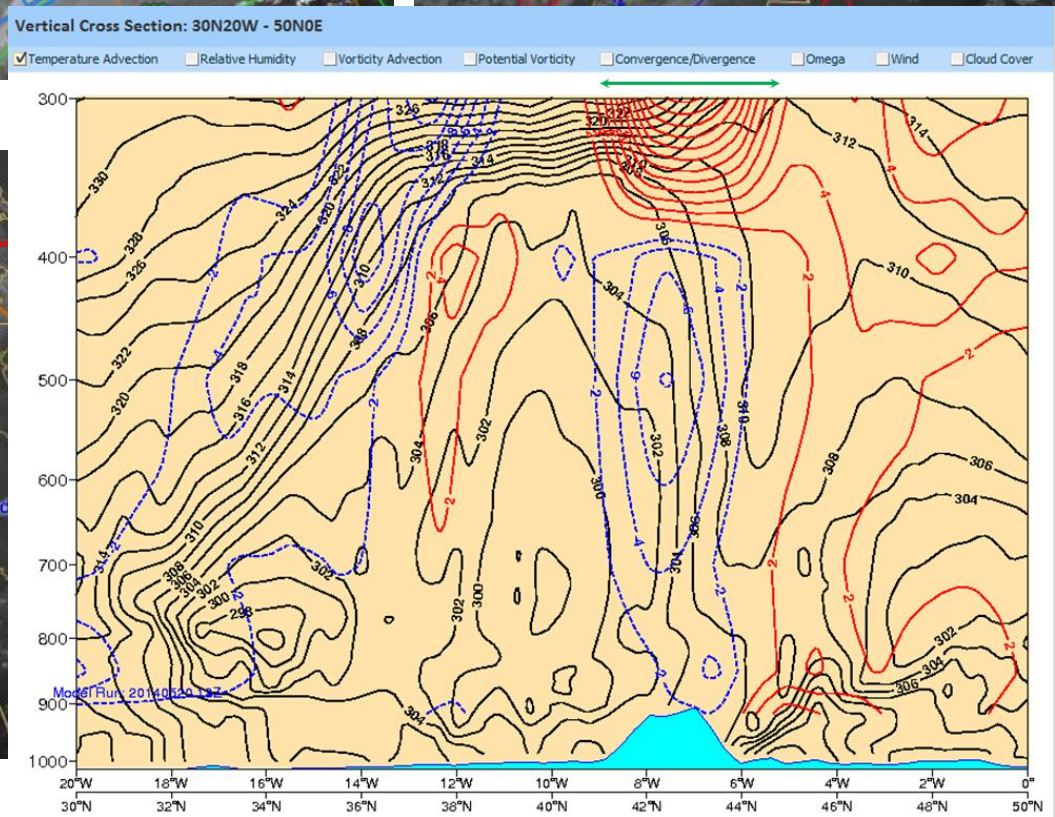
Fully developed stage of a CAD:

Lack of WF





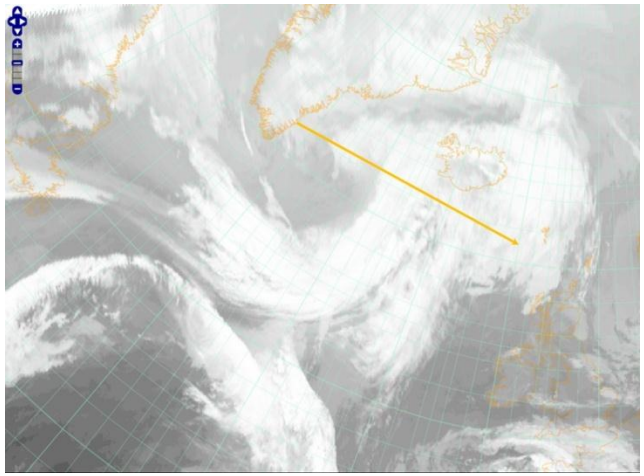




Enough for today!

Homework:

- Go to EUMeTrain e-port
- Look into the case of 1 July 2014/ 06
  - The image of 1 July 2014/06 UTC is supposed to be a development stage of a rapid cyclogenesis. Prove if this is true or not and if yes describe the material (satellite images, numerical parameters and VCS) which supports your findings.
  - You can use for this the template
- In the homework ppt in the course page you find additional VCSs and hints



- Don’t hesitate to start a discussion about new, interesting or difficult topics with me

Enough for today!

Any Questions already now?
The Students Forum is open for all questions coming up later!

Thank you for your attention!
Meet you in the Students Forum and in Langen!