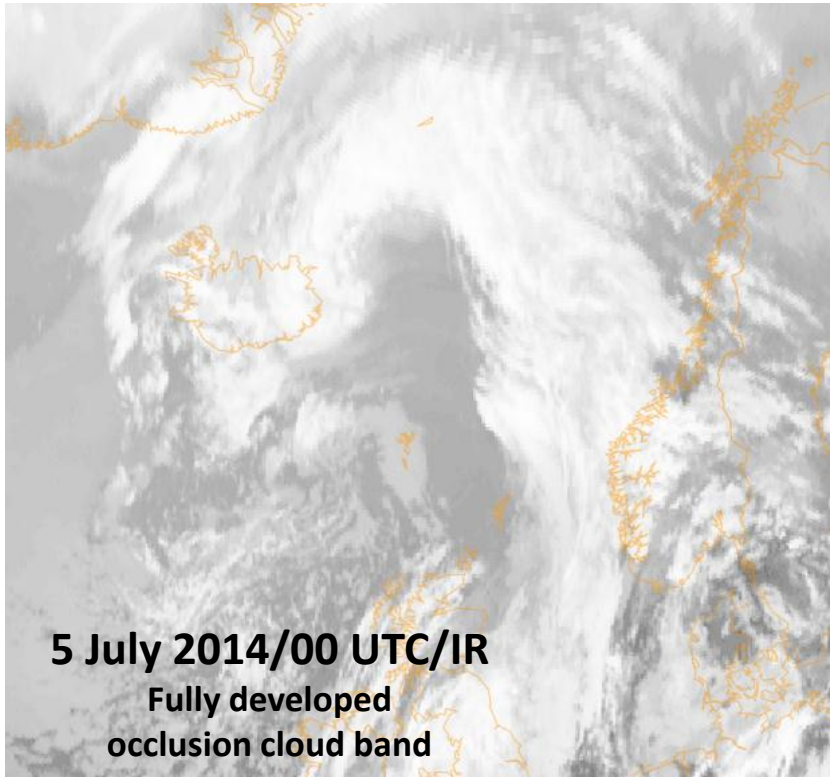
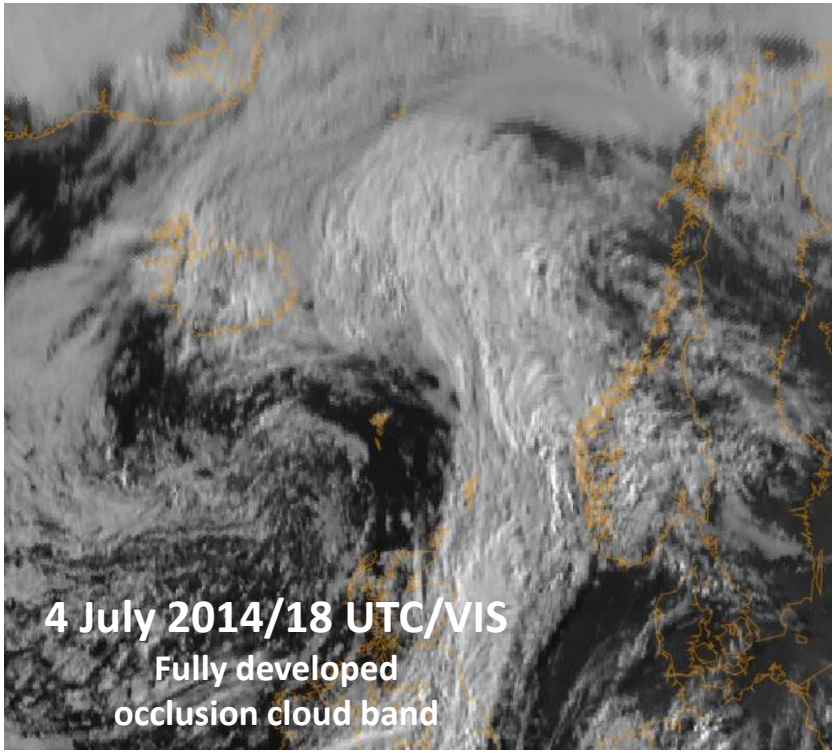
Occlusion – Cyclogenesis

Part I:

Occlusion cloud bands in comparison to CF and WFs
Concepts for cyclogenesis
Different types of cyclogenesis and examples
Numerical parameters on isobaric and isentropic surfaces

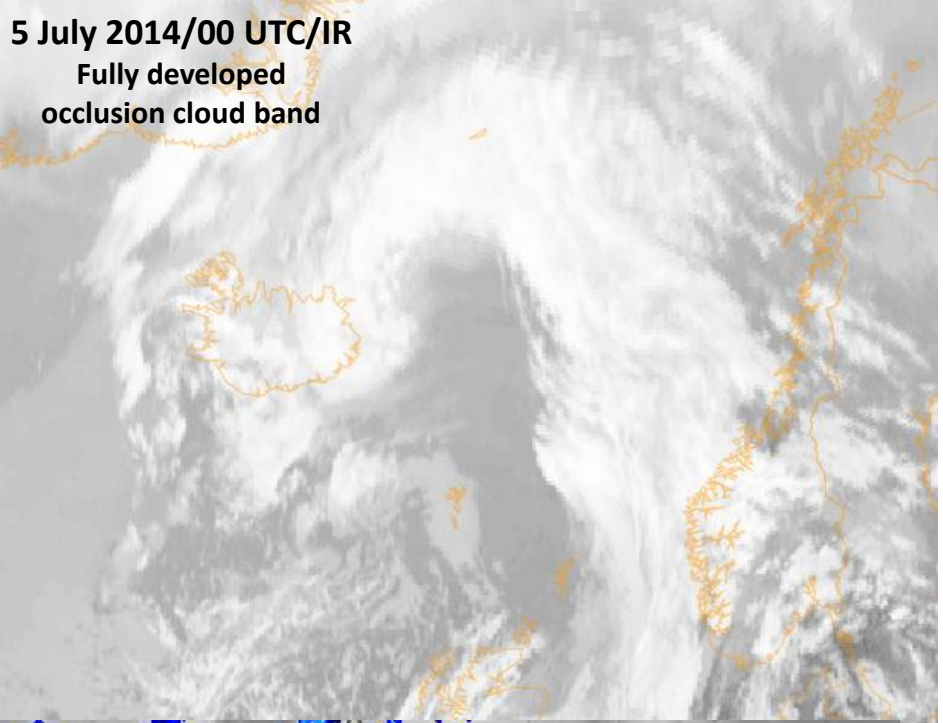


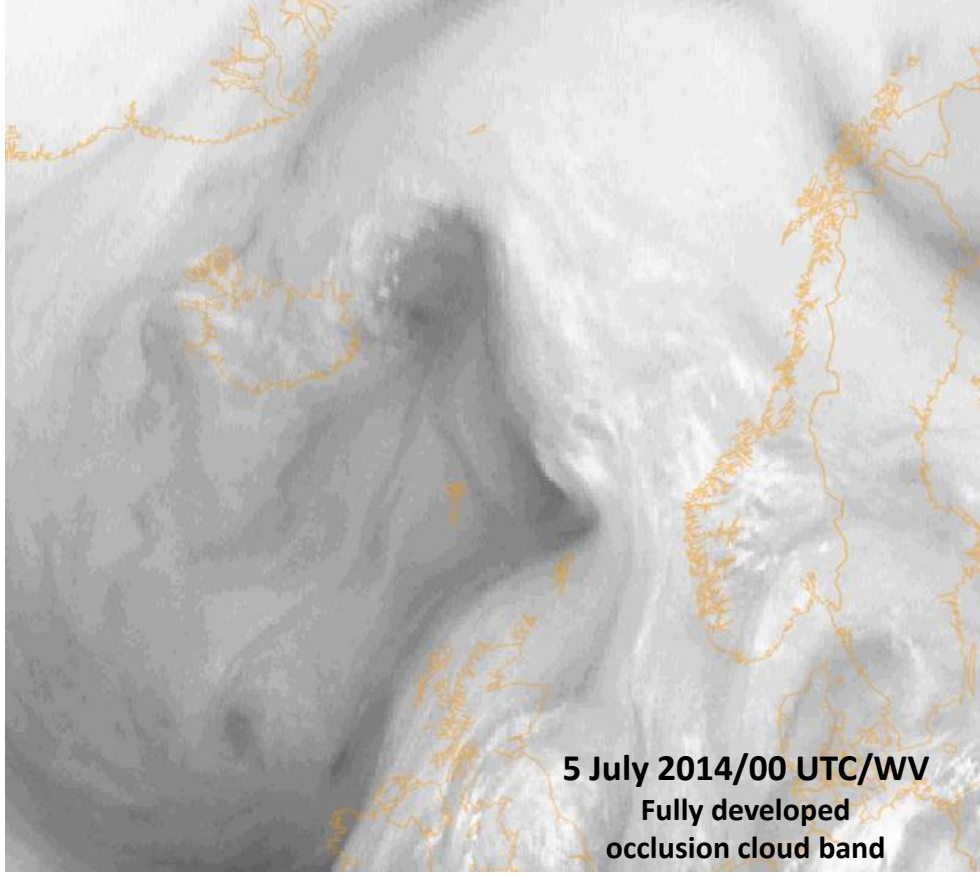


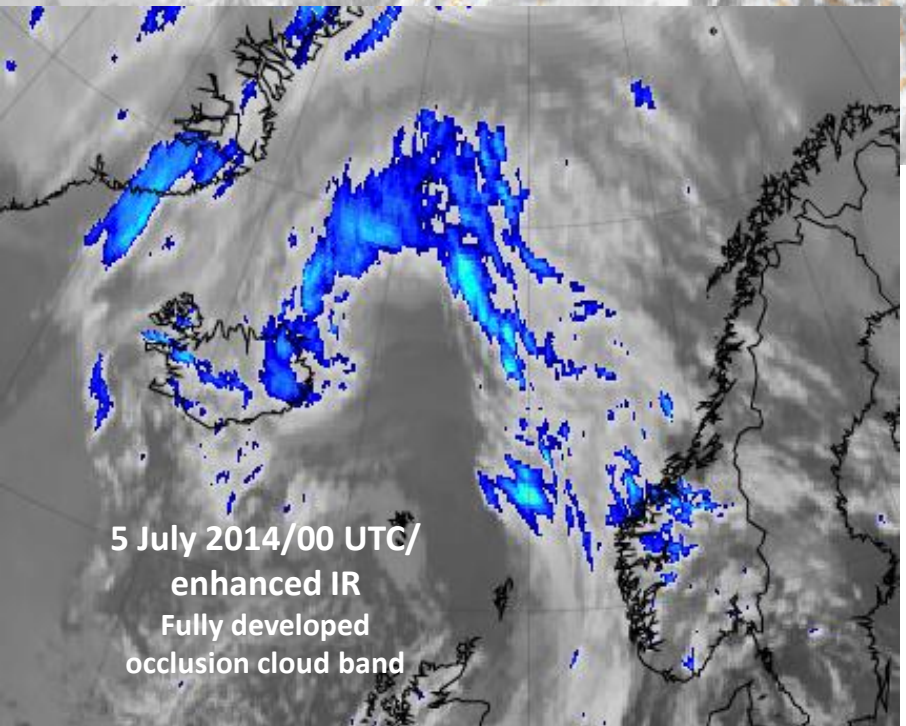
Occlusion fronts – cloud bands

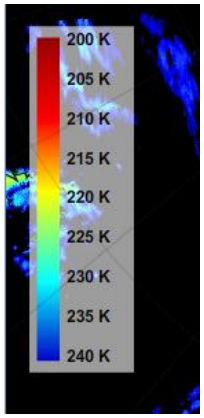
Some well-known qualities:

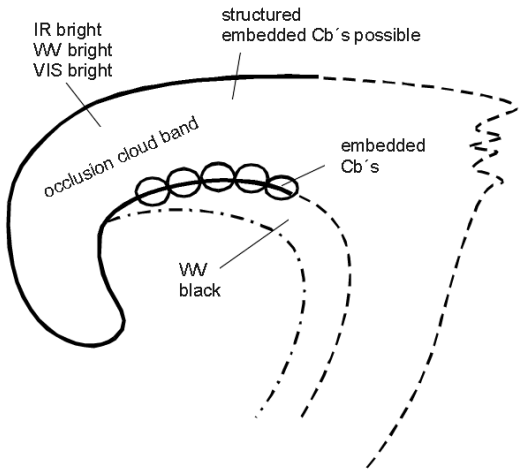
- Cloud bands that have spiral form
- They are closest to the low centres in the troposphere
- They are connected to cold front and warm front bands

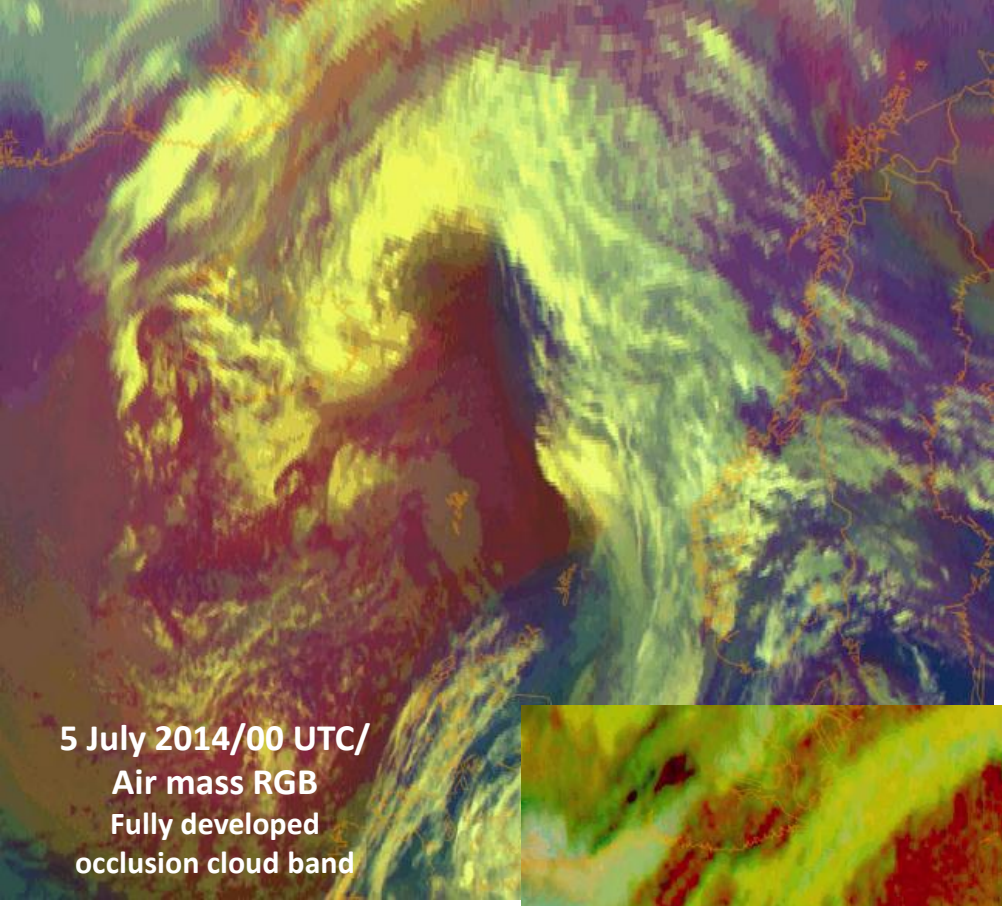

5 July 2014/00 UTC/IR
Fully developed
occlusion cloud band


5 July 2014/00 UTC/WV
Fully developed
occlusion cloud band

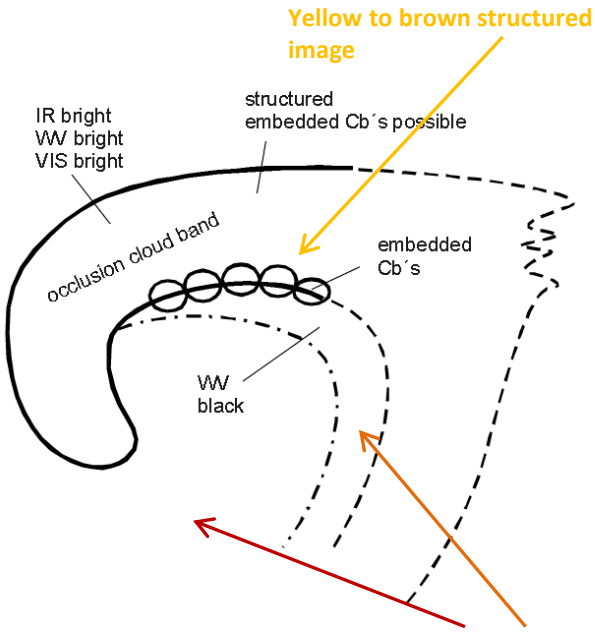

5 July 2014/00 UTC/
enhanced IR
Fully developed
occlusion cloud band


200 K
205 K
210 K
215 K
220 K
225 K
230 K
235 K
240 K


IR bright
WV bright
VIS bright
structured
embedded Cb´s possible
occlusion cloud band
embedded
Cb´s
WV
black

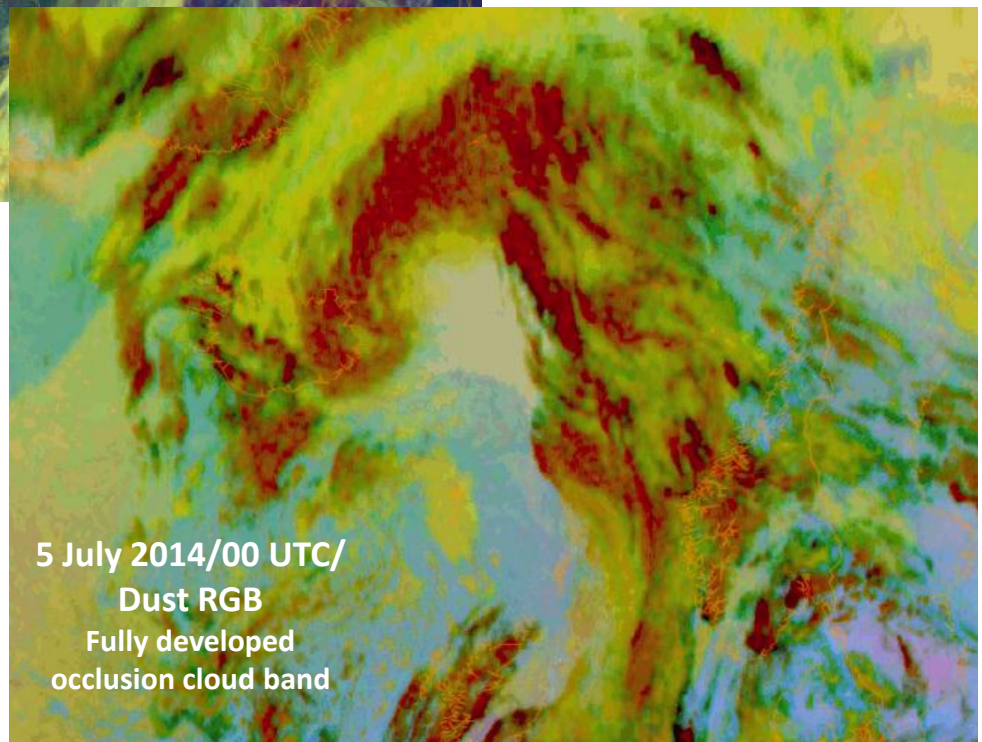


5 July 2014/00 UTC/
Air mass RGB
Fully developed
occlusion cloud band



Dark brown in air mass Image

Partly overrunning the innermost part of the occlusion cloud spiral



5 July 2014/00 UTC/
Dust RGB
Fully developed
occlusion cloud band

Occlusion front - Occlusion cloud band

- Some well-known qualities:
  - Cloud bands that have spiral form
  - They are closest to the low centres in the troposphere
  - They are connected to cold front and warm front bands

  - They develop from cold and warm front bands during the process of a cyclogenesis
  - Occlusion cloud bands are the result of a cyclogenesis process

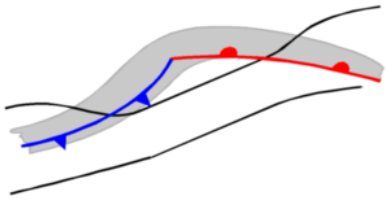
- Processes and types of cyclogenesis

Meteorological theories about cyclogenesis

- What theories about cyclogenesis are well know?
  - Classical Polar Front theory
  - Conveyor Belt Models
    - Warm conveyor Belt
    - Cold conveyor Belt
    - Upper relative stream
    - Dry intrusion
  - Importance of Upper Level Phenomena →
  - The Hoskins theory

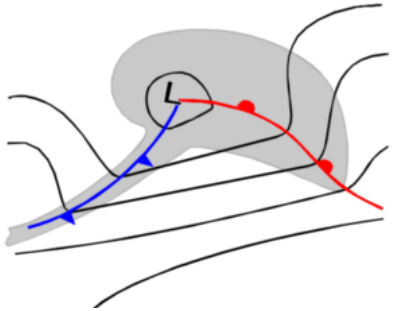
The classical Polar Front Theory (Bergeron)

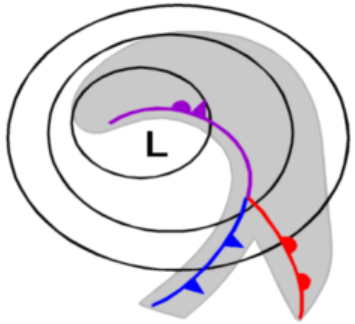
- A disturbance initiates the process
- Low centre at the surface appears
- Cold air moves fast against warm air; fronts with cloudiness develop at the baroclinic boundaries between the air masses
- Cold front moves faster than warm front – warm sector in between becomes smaller
- In the area of the low centre cold air lifts warm air, the occlusion cloud spiral develops
- **View is mainly from parameters in the lower troposphere**



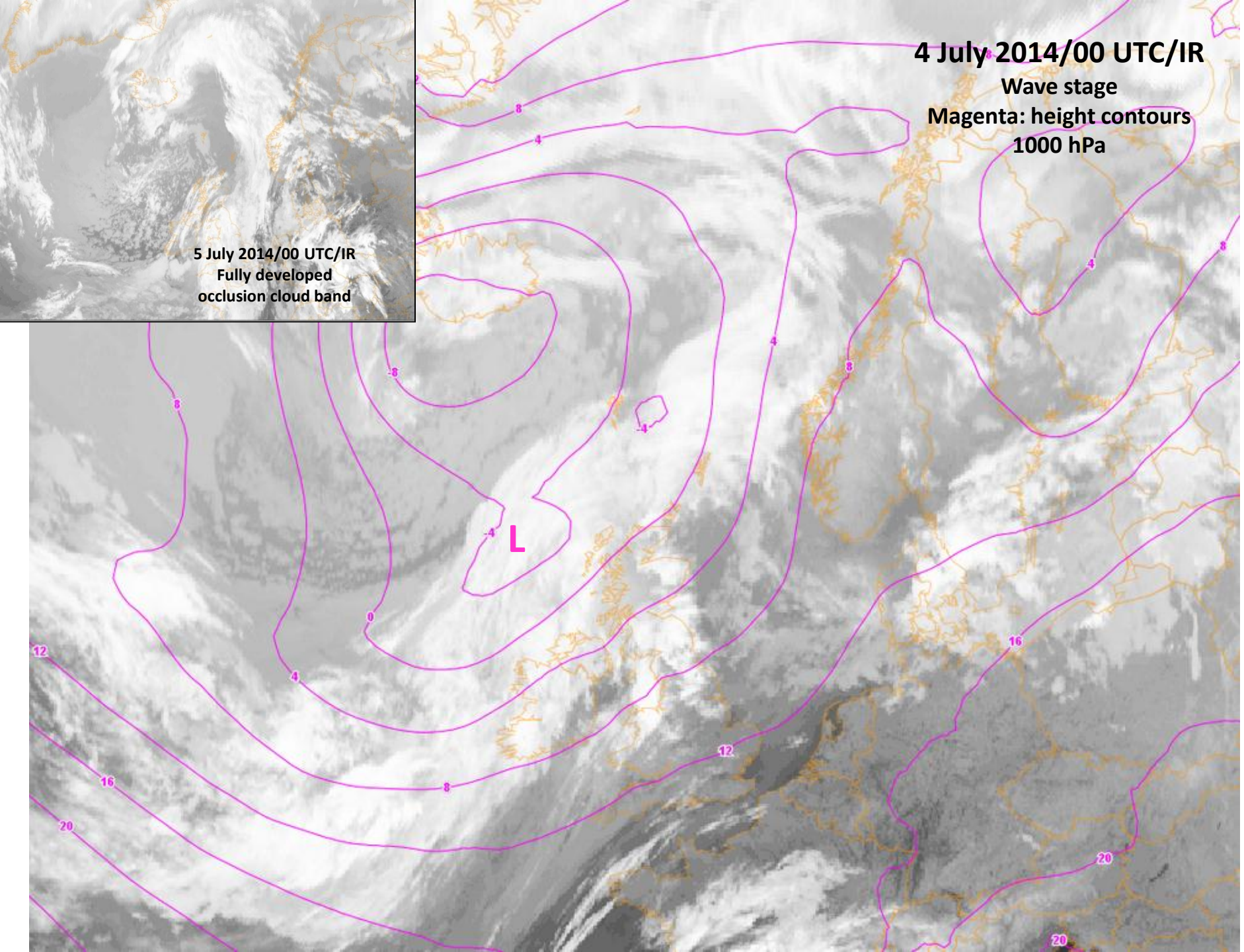
Wave stage

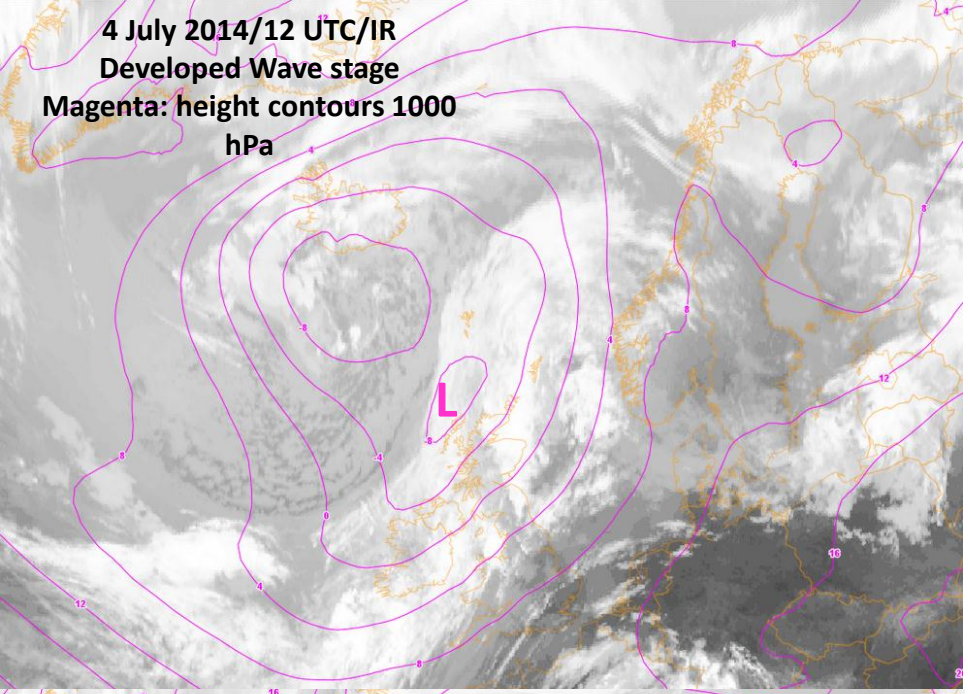
Developed wave stage

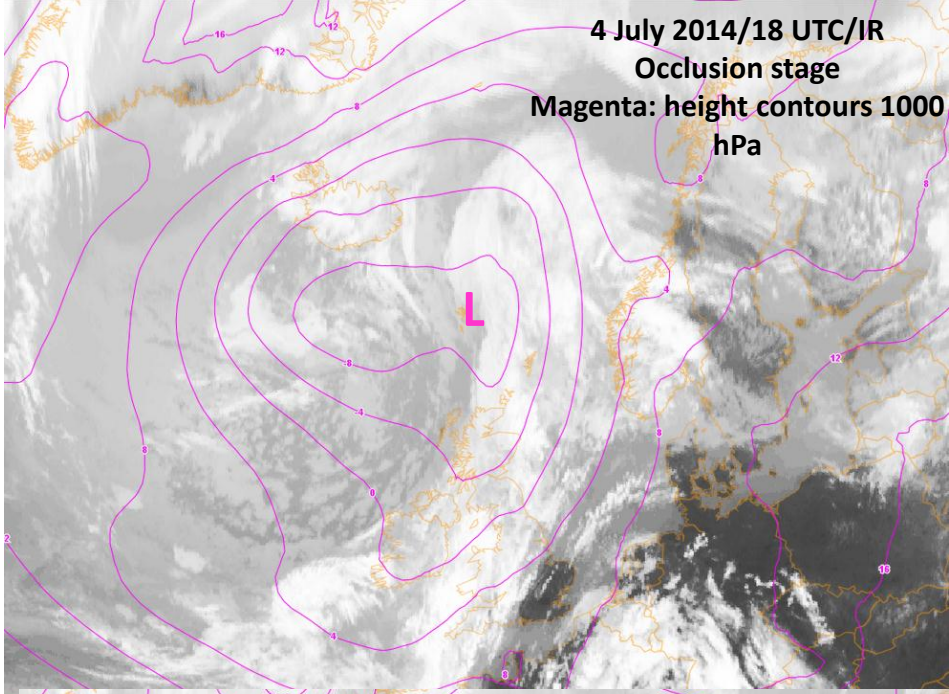


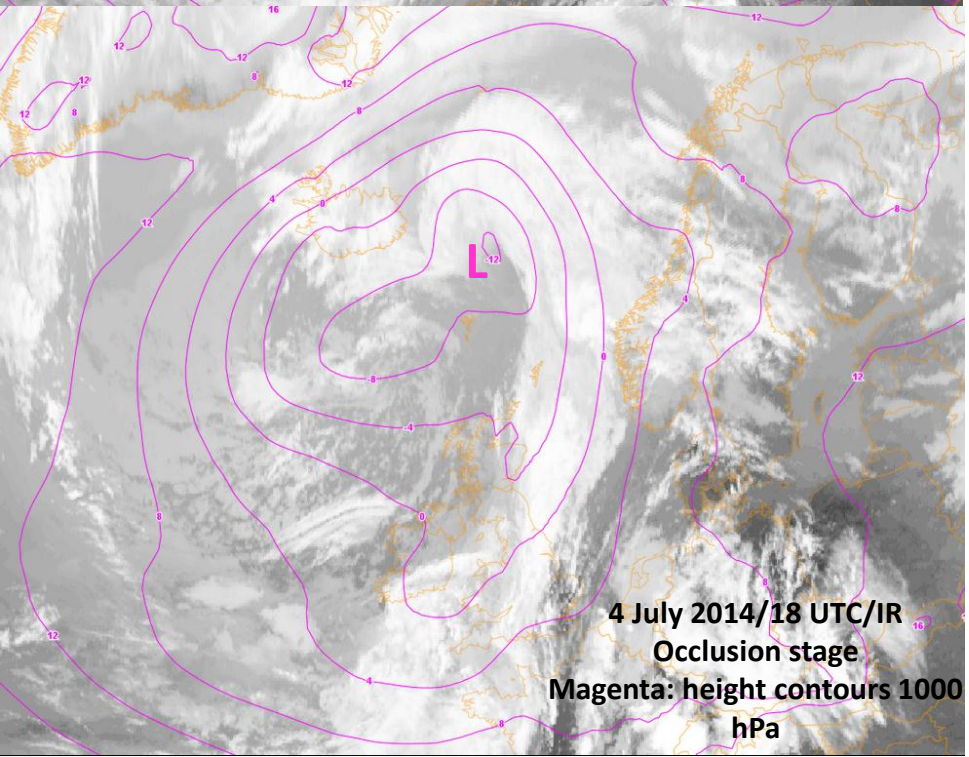


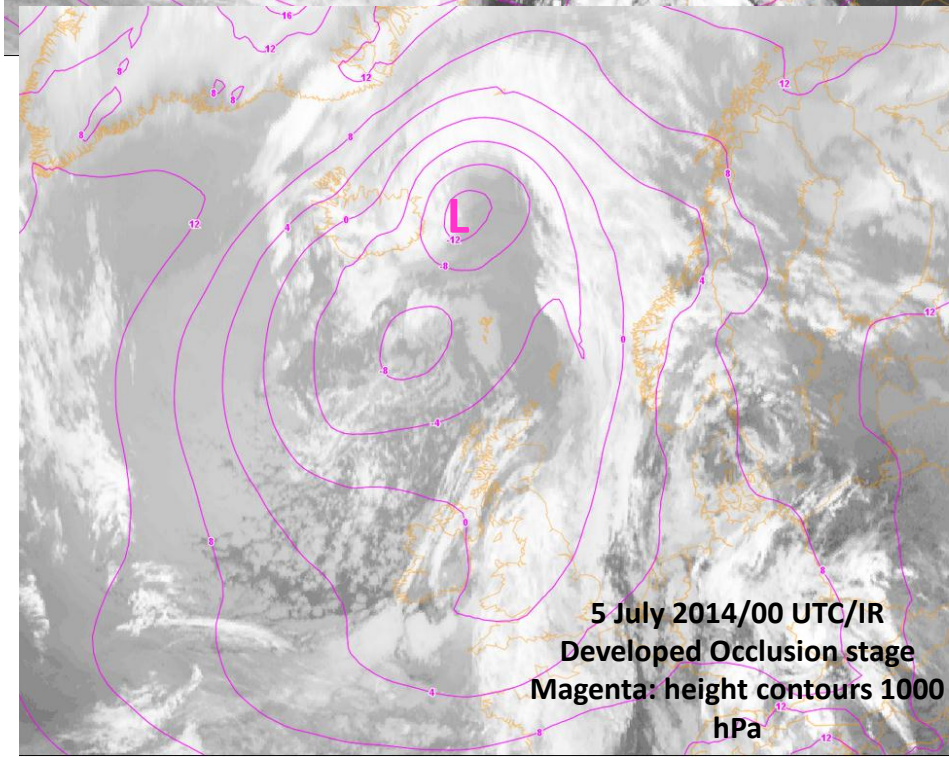
Occlusion stage

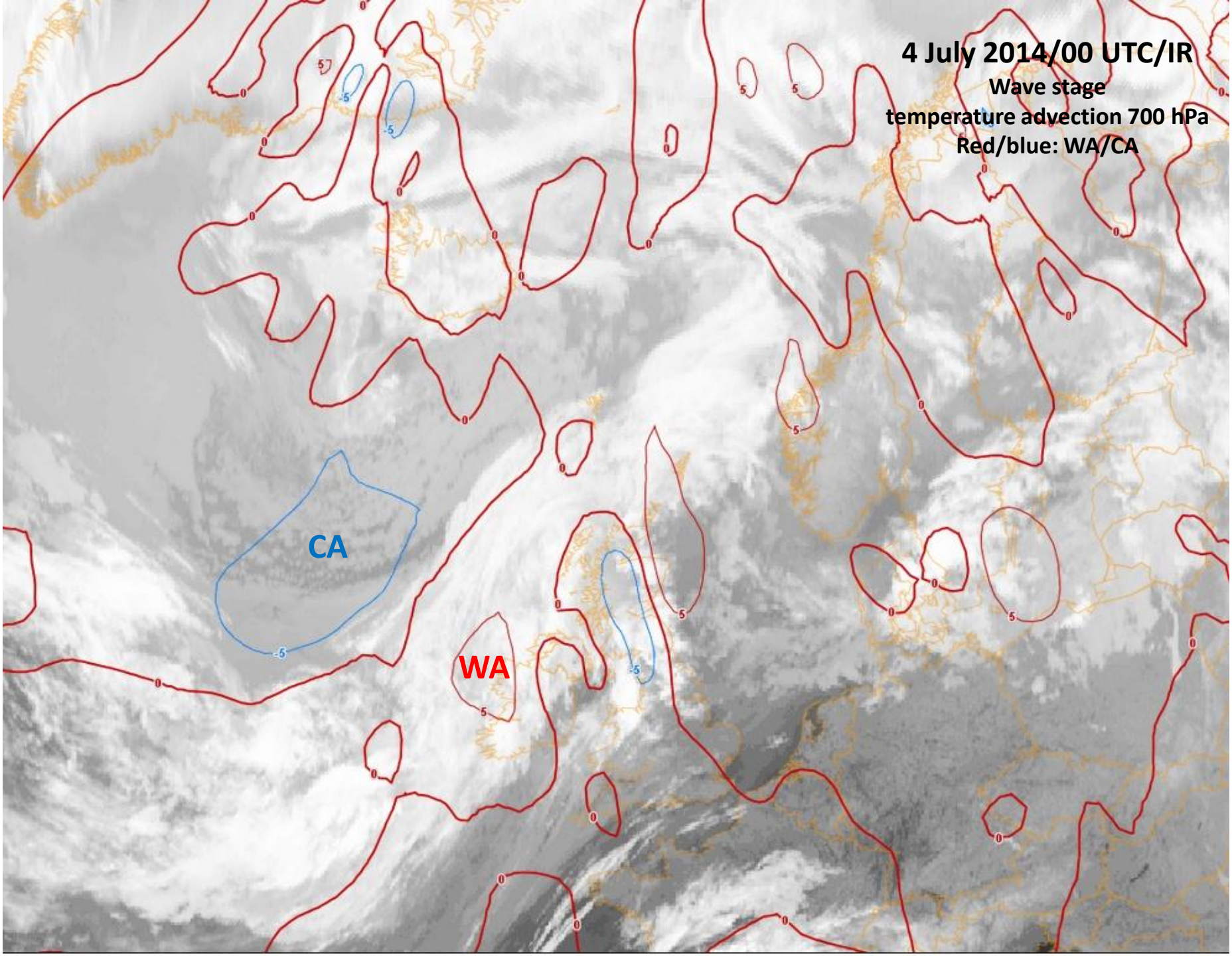

4 July 2014/00 UTC/IR
Wave stage
Magenta: height contours
1000 hPa
5 July 2014/00 UTC/IR
Fully developed
occlusion cloud band
L
-8
-4
0
4
8
12
16
20

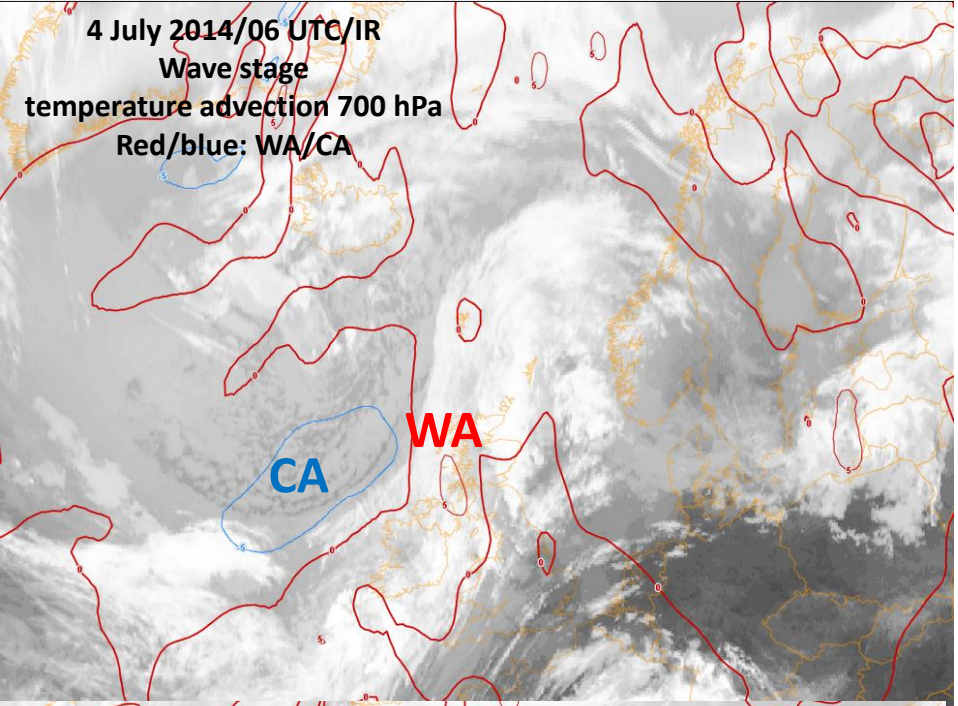

4 July 2014/12 UTC/IR
Developed Wave stage
Magenta: height contours 1000 hPa
L

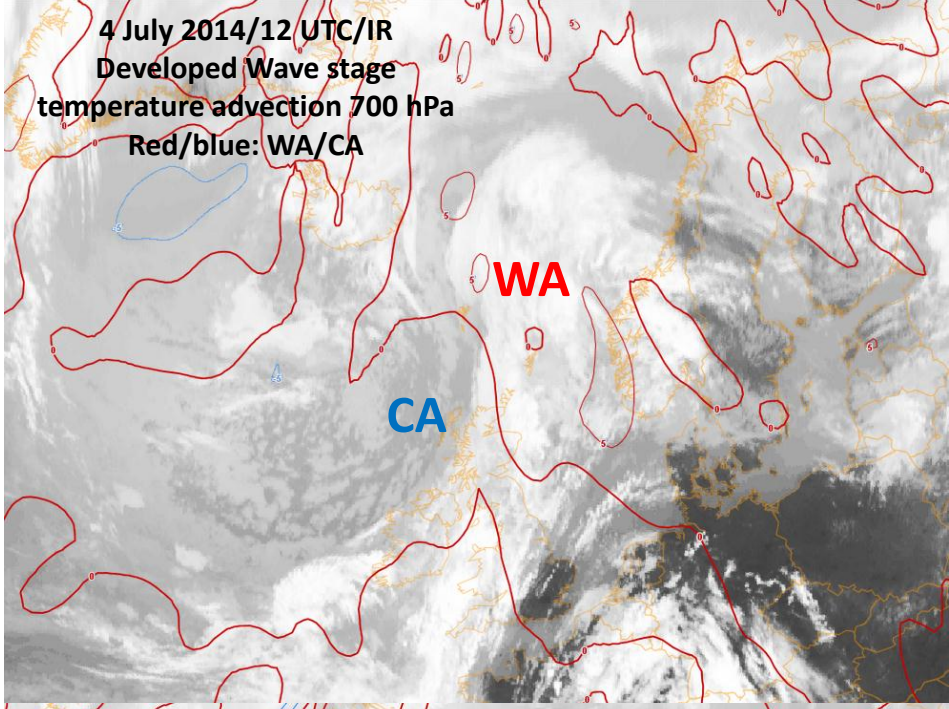

4 July 2014/18 UTC/IR
Occlusion stage
Magenta: height contours 1000 hPa
L

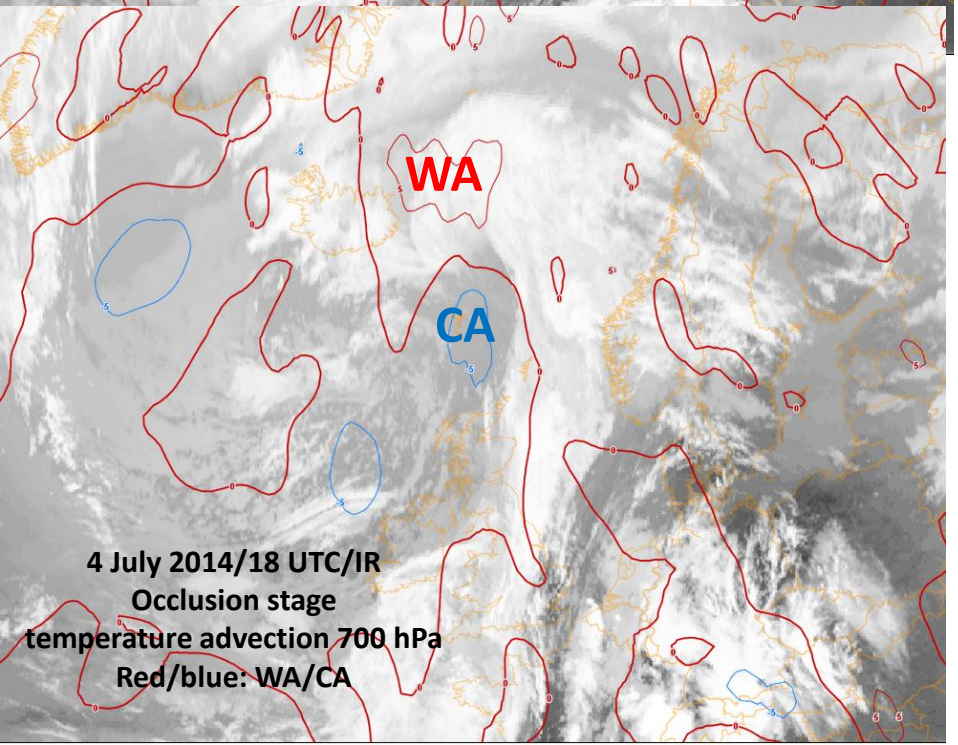

L
4 July 2014/18 UTC/IR
Occlusion stage
Magenta: height contours 1000 hPa

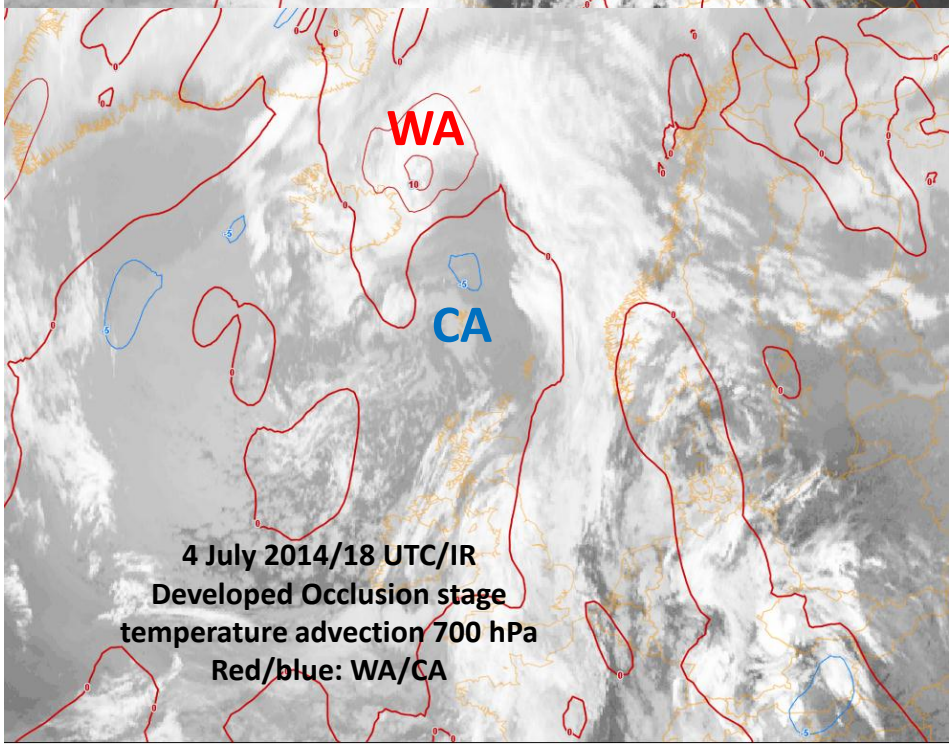

L
5 July 2014/00 UTC/IR
Developed Occlusion stage
Magenta: height contours 1000 hPa


4 July 2014/00 UTC/IR
Wave stage
temperature advection 700 hPa
Red/blue: WA/CA
CA
WA


4 July 2014/06 UTC/IR
Wave stage
temperature advection 700 hPa
Red/blue: WA/CA
WA
CA


4 July 2014/12 UTC/IR
Developed Wave stage
temperature advection 700 hPa
Red/blue: WA/CA
WA
CA


WA
CA
4 July 2014/18 UTC/IR
Occlusion stage
temperature advection 700 hPa
Red/blue: WA/CA

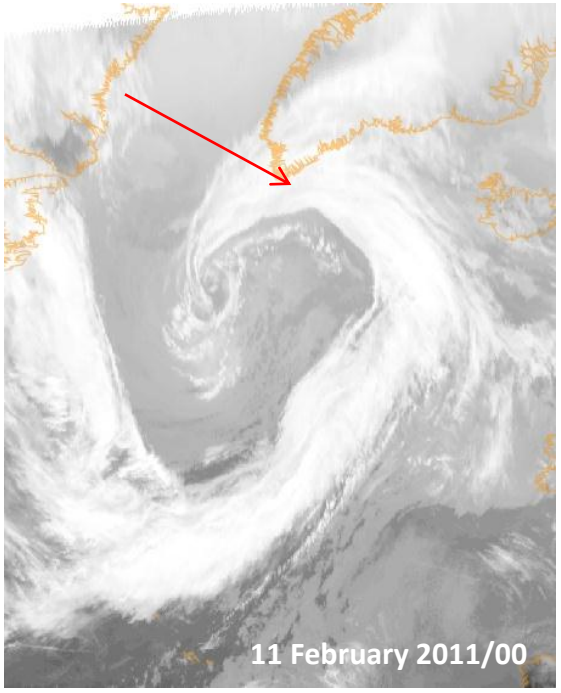

WA
CA
4 July 2014/18 UTC/IR
Developed Occlusion stage
temperature advection 700 hPa
Red/blue: WA/CA

Role of satellite images/data within these concepts

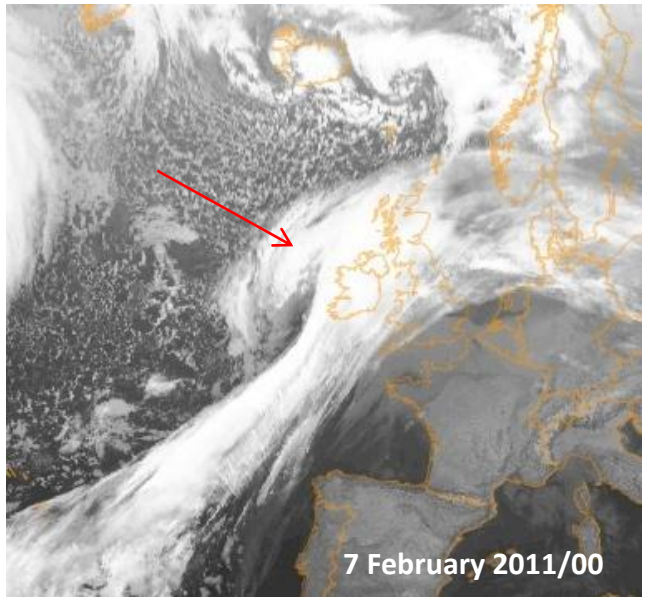
- Which of these concept ideas can be enhanced through satellite images?
- Which new facts can be seen in satellite images and added to the concepts?
  - Two different types of occlusion cloud spirals

Appearances of Occlusion cloud bands during the cyclogenesis process

- Occlusion cloud bands are spiral bands which develop from a cloud bulge (a wave area) at the rear side of a cold front band

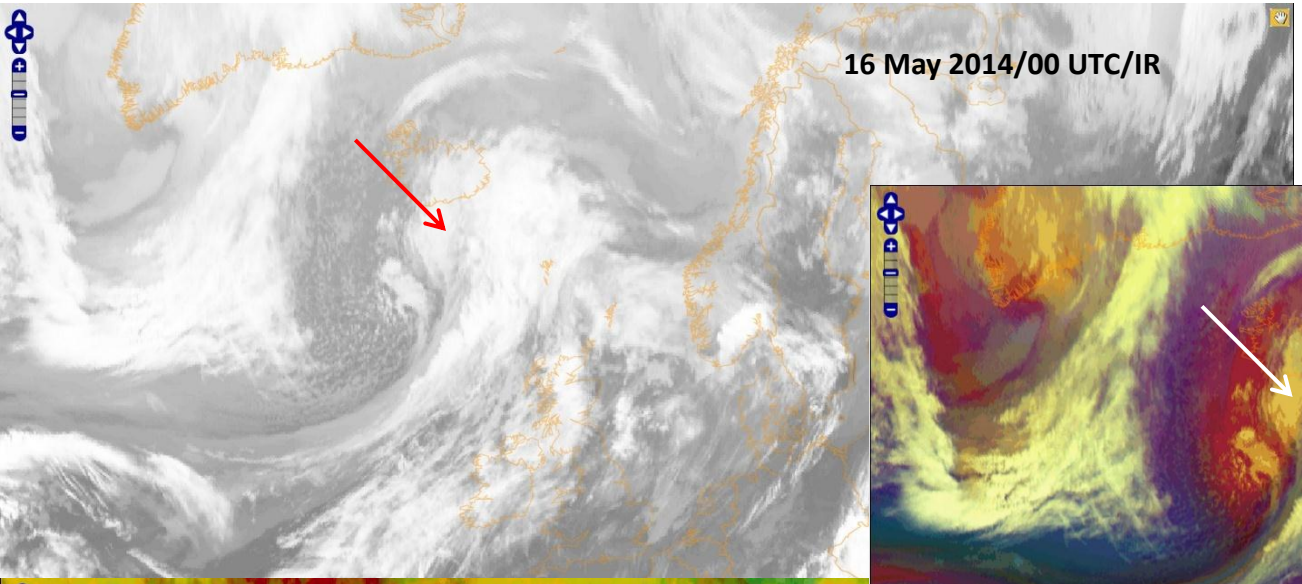


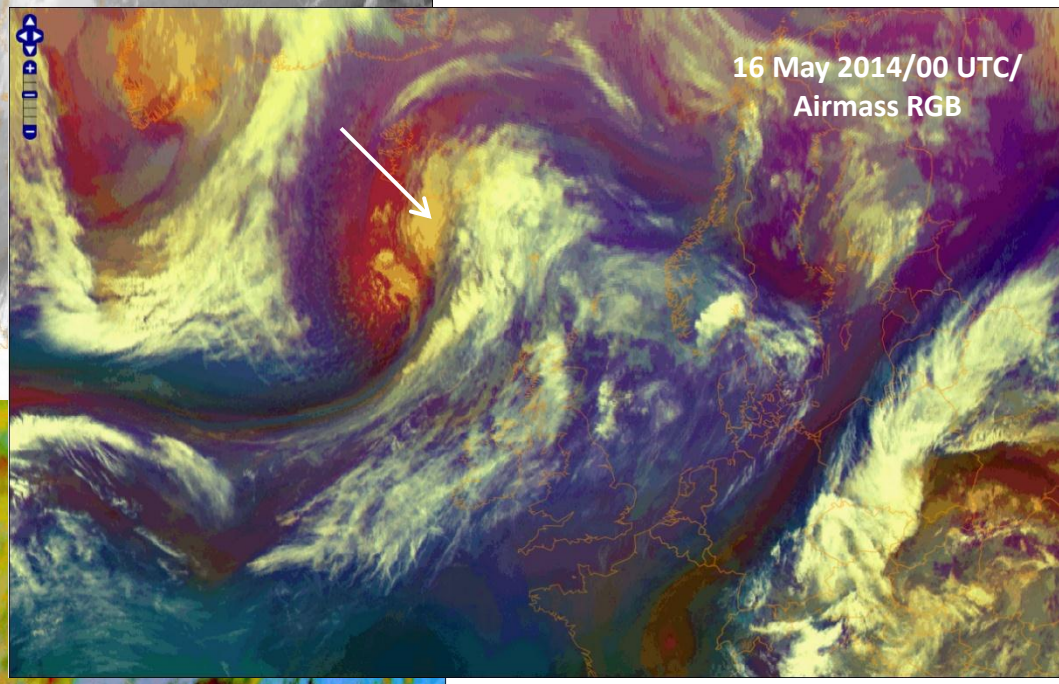
- Often occlusion cloud bands are much lower on cloud top heights than the related CF- WF bands
- It seems to grow from below the CF band from E to W and so spiraling around the low center

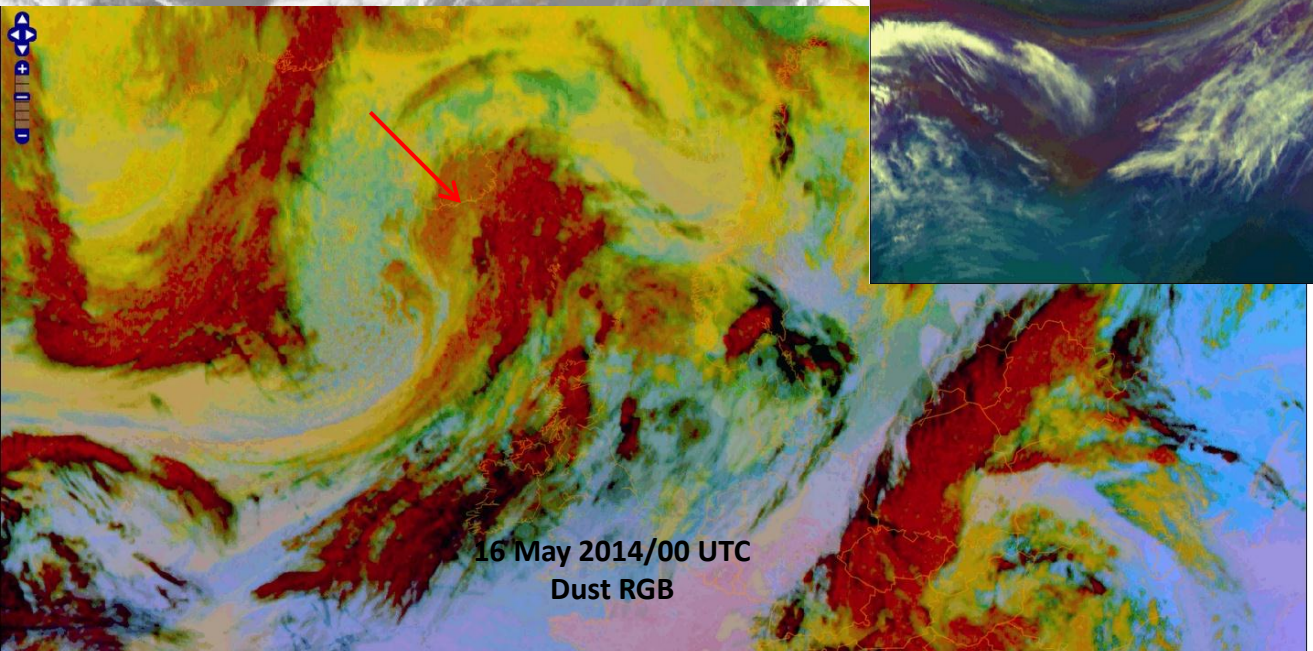


Polar front theory – CCB type best developed stage

1. Cloud spiral lower cloud tops than CF-WF bands
2. Protrudes from below WF-CF bands
3. Dry air in superimposed on cloud spiral in upper levels
4. Mainly thick cloud (brownish in Dust RGB) but lower as CF-WF bands



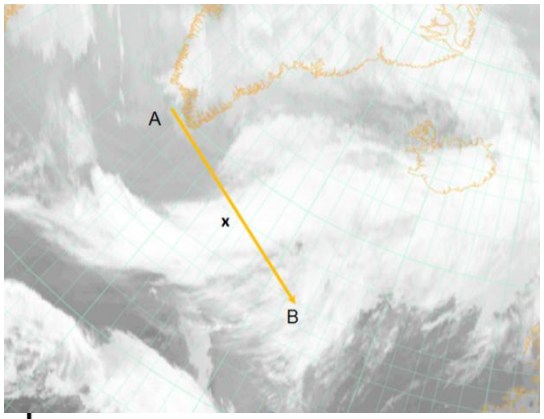


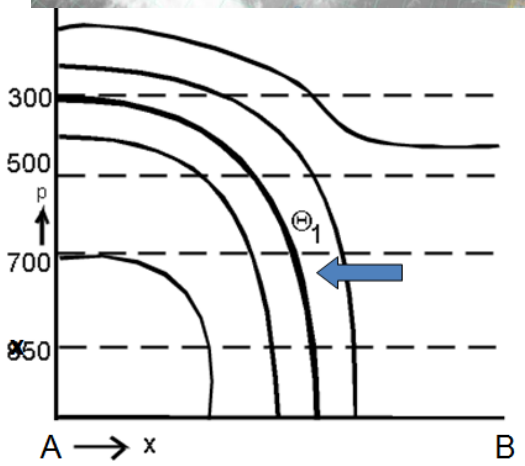


Conveyor Belt Theory

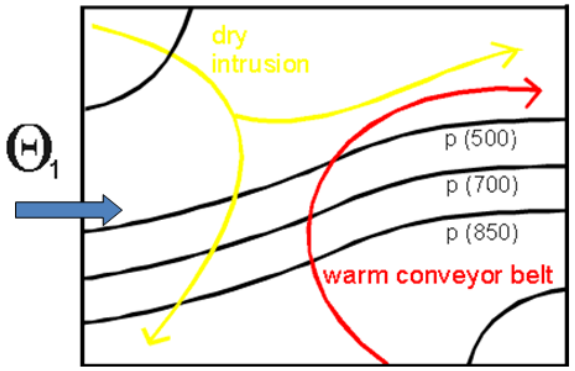
- Conveyor Belts are:

  „Air mass bodies“ transported on an isentropic surface like on a Conveyor Belt
- This transport on isentropic surfaces is by relative streams
  - Relative to system velocity; observer moves with the occlusion spiral
- Meteorology has recognised only few typical conveyor belts associated to and typical for the different fronts
- Conveyor Belt theory is not a separate view but a different, complementary view into the processes taking place in the atmosphere



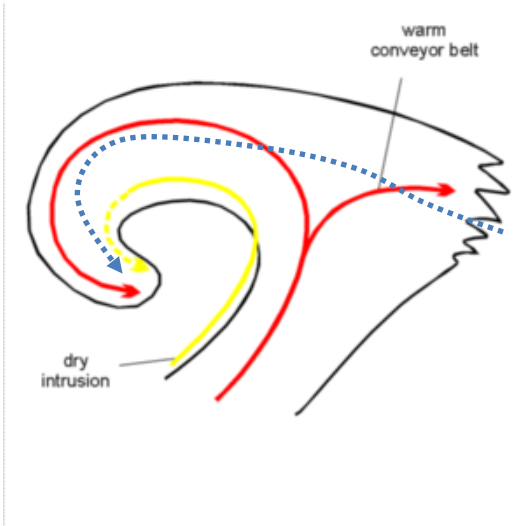


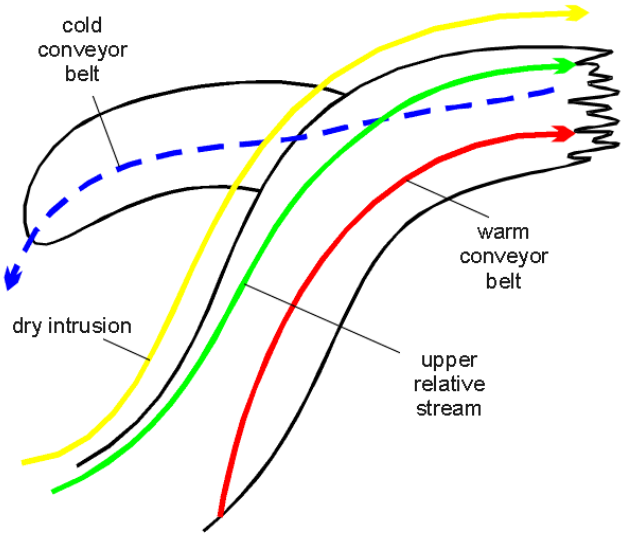
Isentrops in a vertical cross section



Isobars on an Isentropic surface

Cyclogenesis from the view of conveyor belt theory





1. **For Cold Fronts two relative streams:**
   - the warm conveyor belt
   - the dry intrusion.
2. **For Warm Front two relative streams:**
   - the warm conveyor belt and
   - The cold conveyor belt.
3. **For the Occlusion process (cyclogenesis) three/four conveyor belts:**
   - The *warm conveyor belt* is (WCB):
     - a rising relative stream
     - from south, south-eastern directions turning to north, north-eastern directions;
     - transports warm and moist air.
   - The *dry intrusion* is (DI):
     - a sinking relative stream from north-west to south-east,
     - splitting into two branches: a further sinking one to the south-west and a rising one to the north-east.

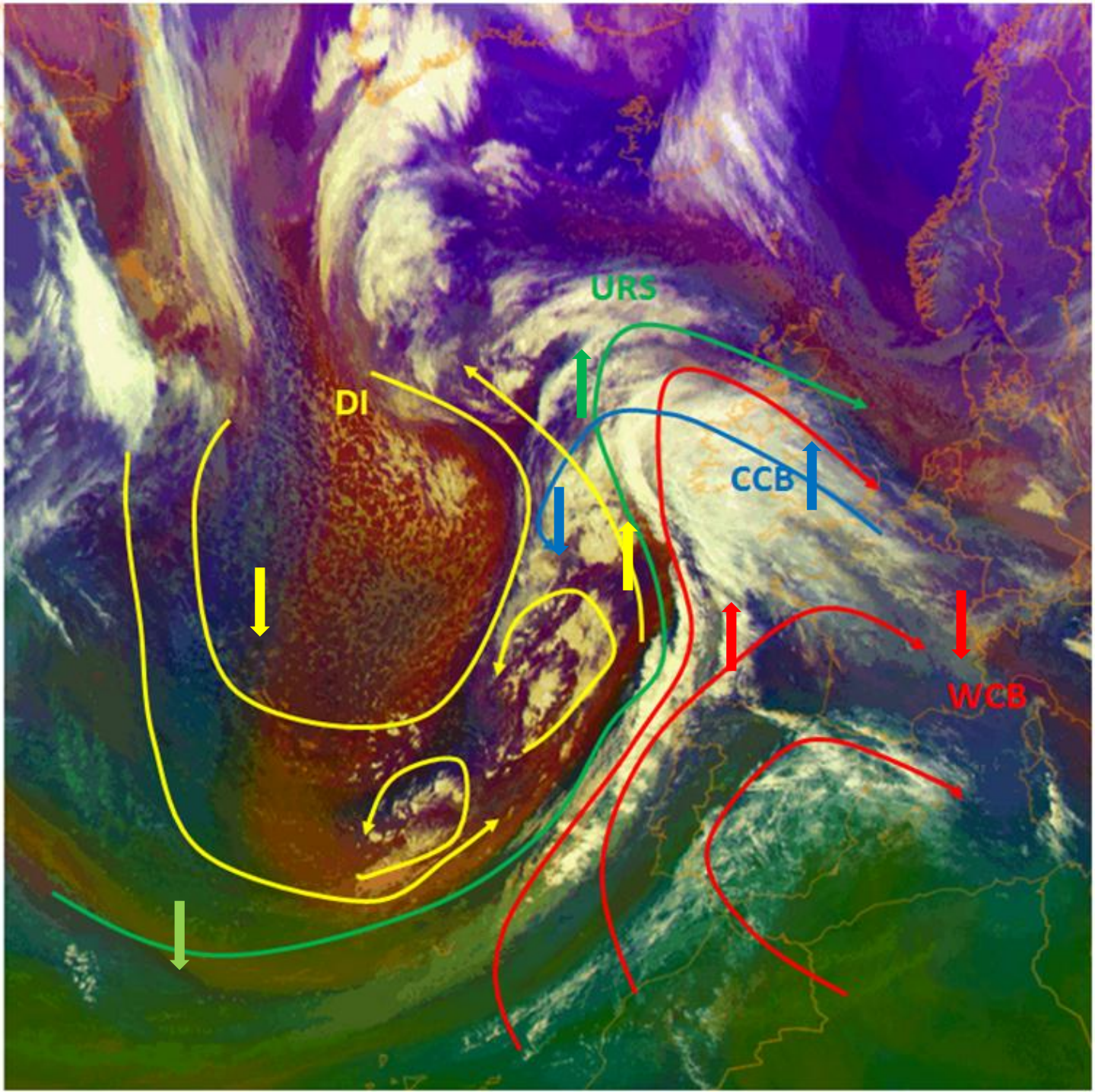
     The upper rel. stream (URS):
     - From W, NW sinmking and then parallel to the cloud band reising to E,SE
     - Less cold and dry as the DI
   - The *cold conveyor belt* is (CCB):
     - a rising relative stream from east, south-east
     - initially below the warm conveyor belt, but then
     - emerging from below
     - Splitting in two branches

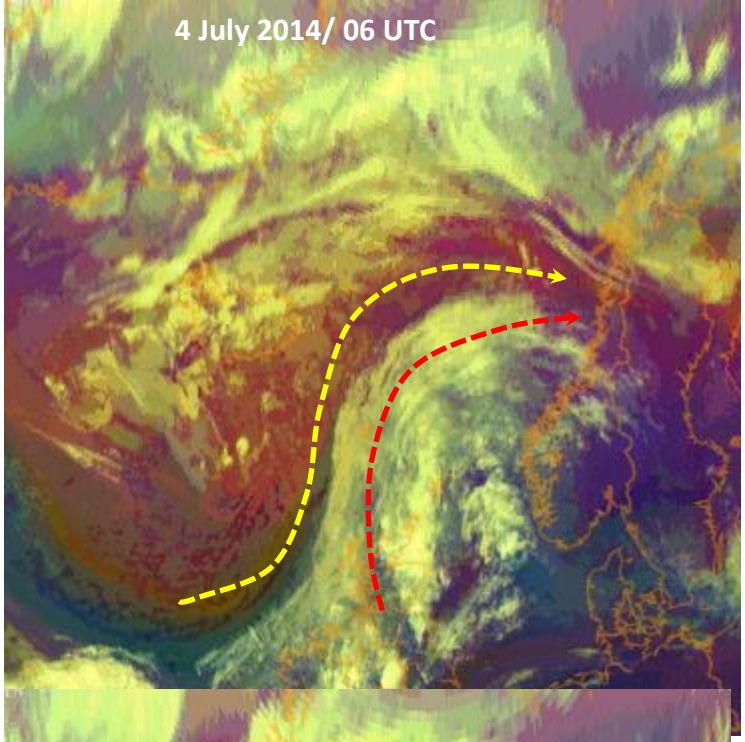
WCB: warm conveyor belt:
S,SE → N,NE
Transports warm, moist air
Air mass RGB: Green, yellowish

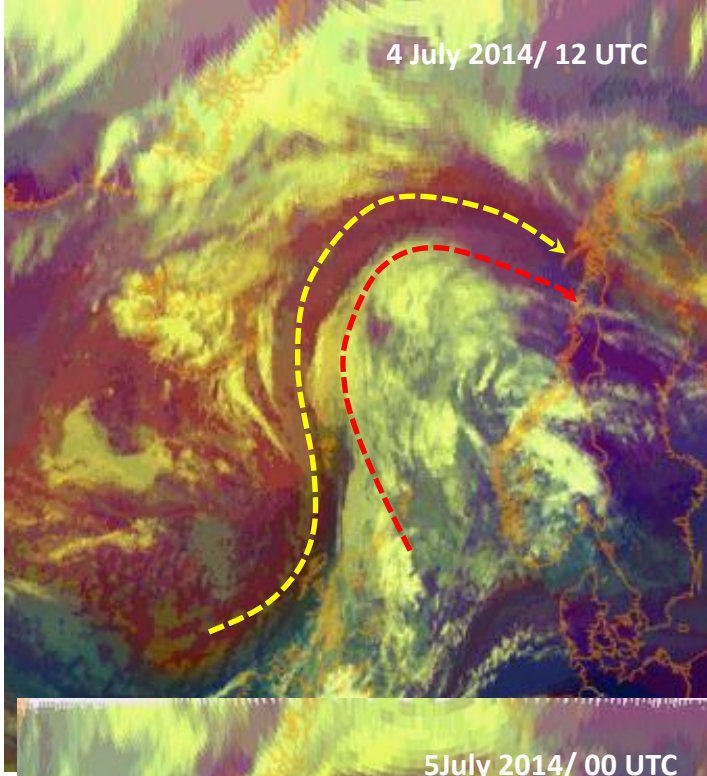
DI: Dry intrusion:
NW → SE
Splitting: NE → N
Transports: very cold dry air
Air mass RGB: brown to dark brown

URS: Upper Relative Stream
In biggest part parallel to DI but comes from more W, NW
Transports dry but less cold air
Air mass RGB: Blue to brownish

CCB: Cold Conveyor Belt
E,SE → NW →S,SE
Emerging from below the WCB
Transports moist air but less warm than in the WCB
Air mass RGB: blue

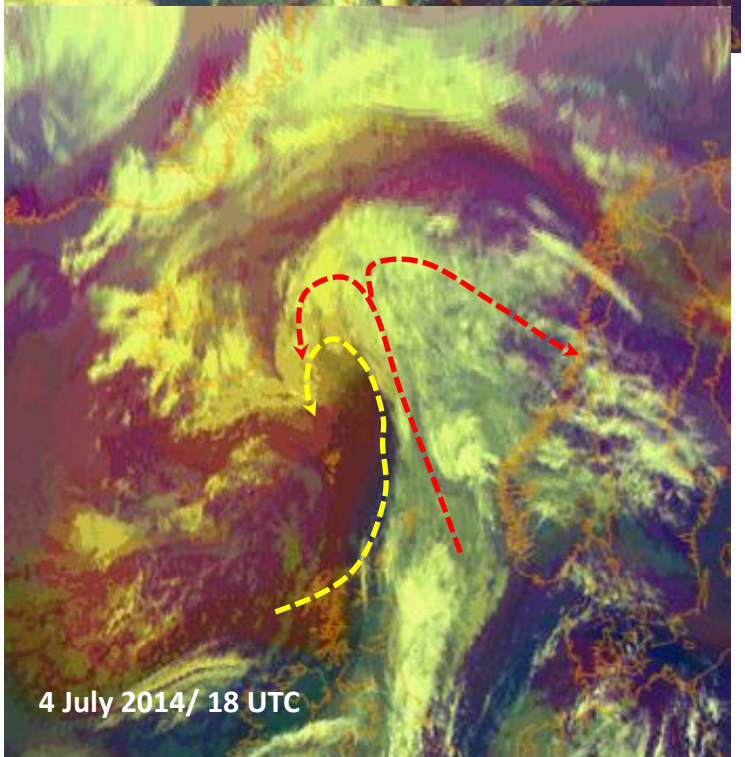


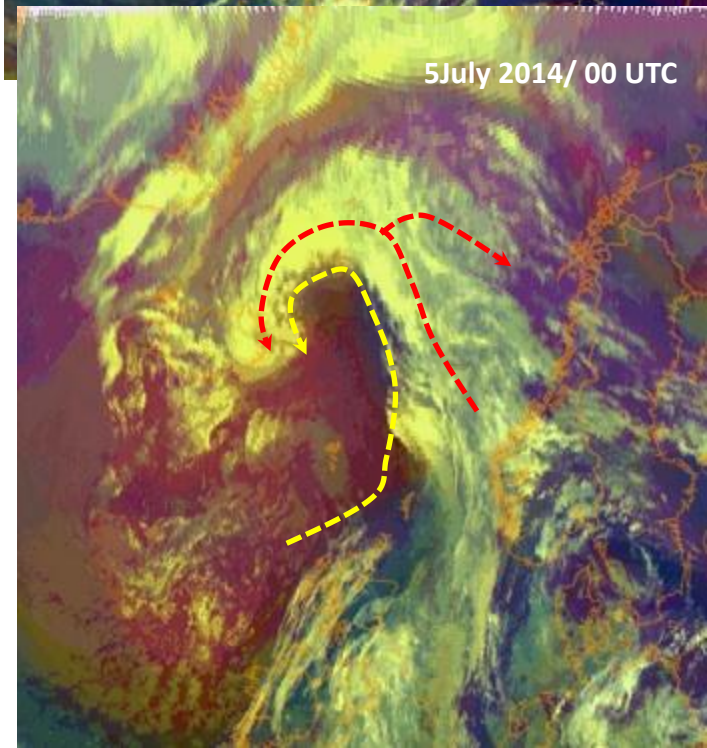


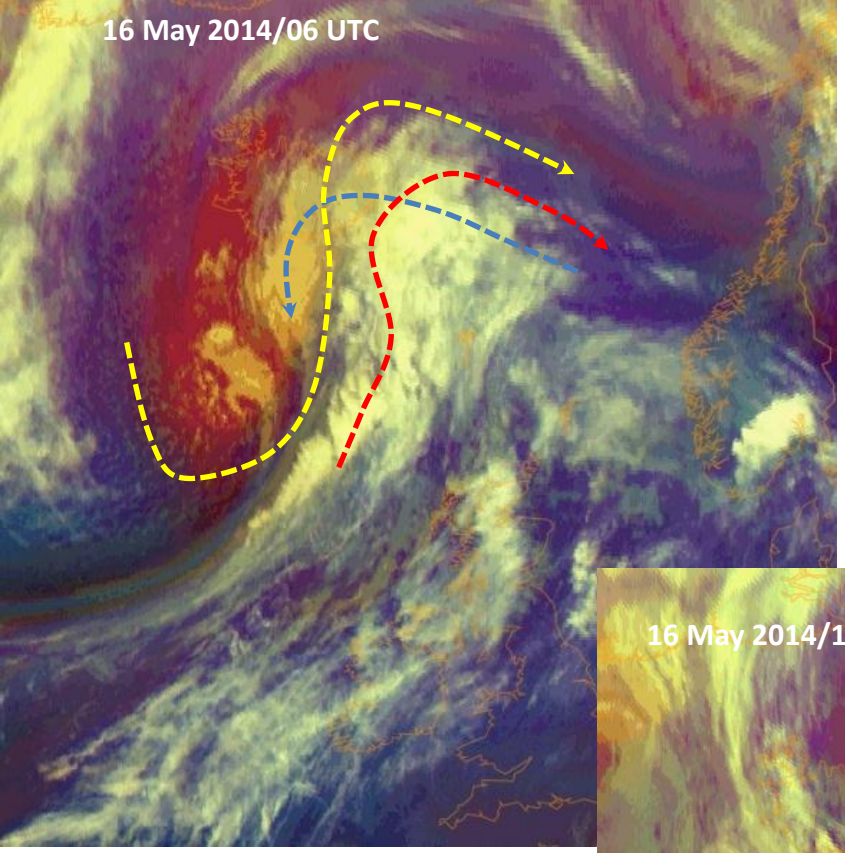


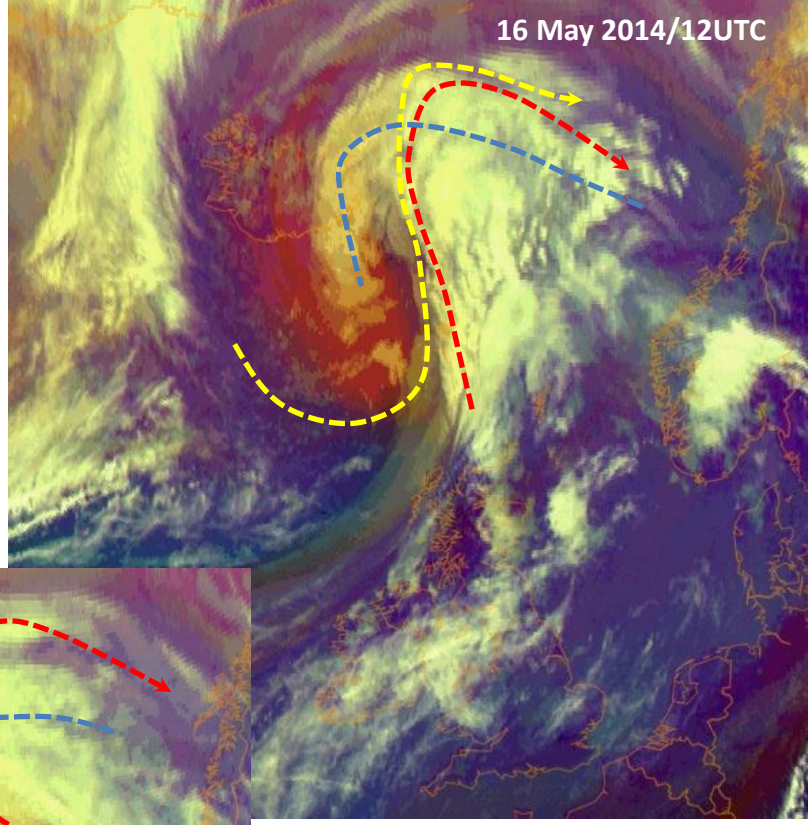
Polar front theory – WCB type sequence of development

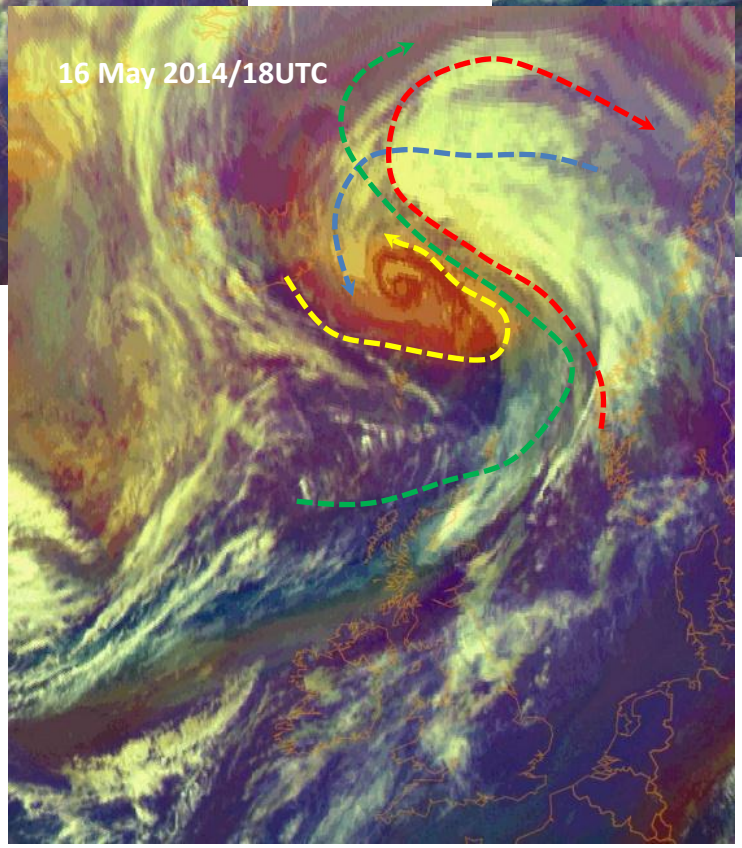
Schematics of involved Conveyor Belts









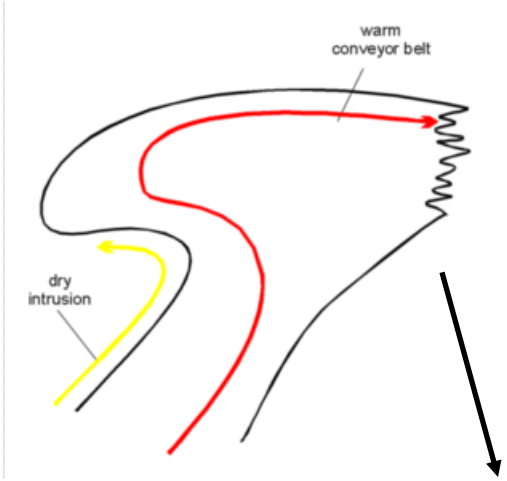


Polar front theory - CCB type: sequence of development

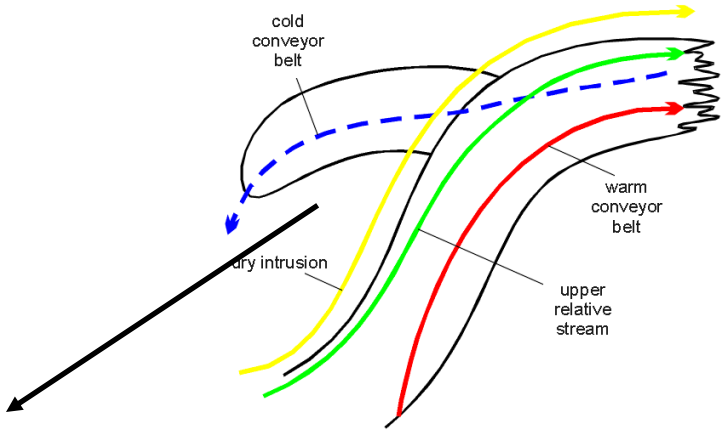
Schematics of involved Conveyor Belts

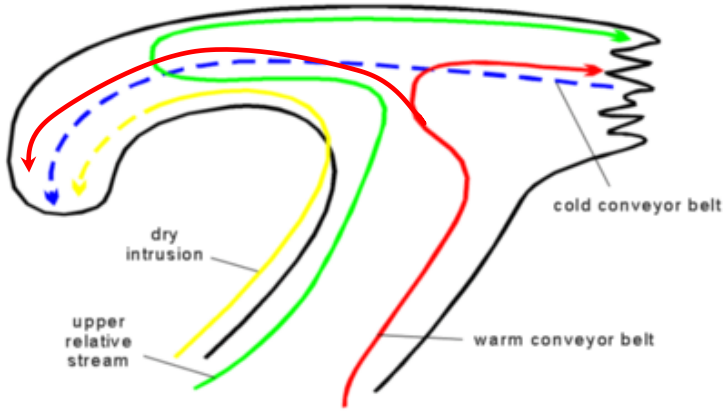
CCB to WCB transition from the view of conveyor belt theory

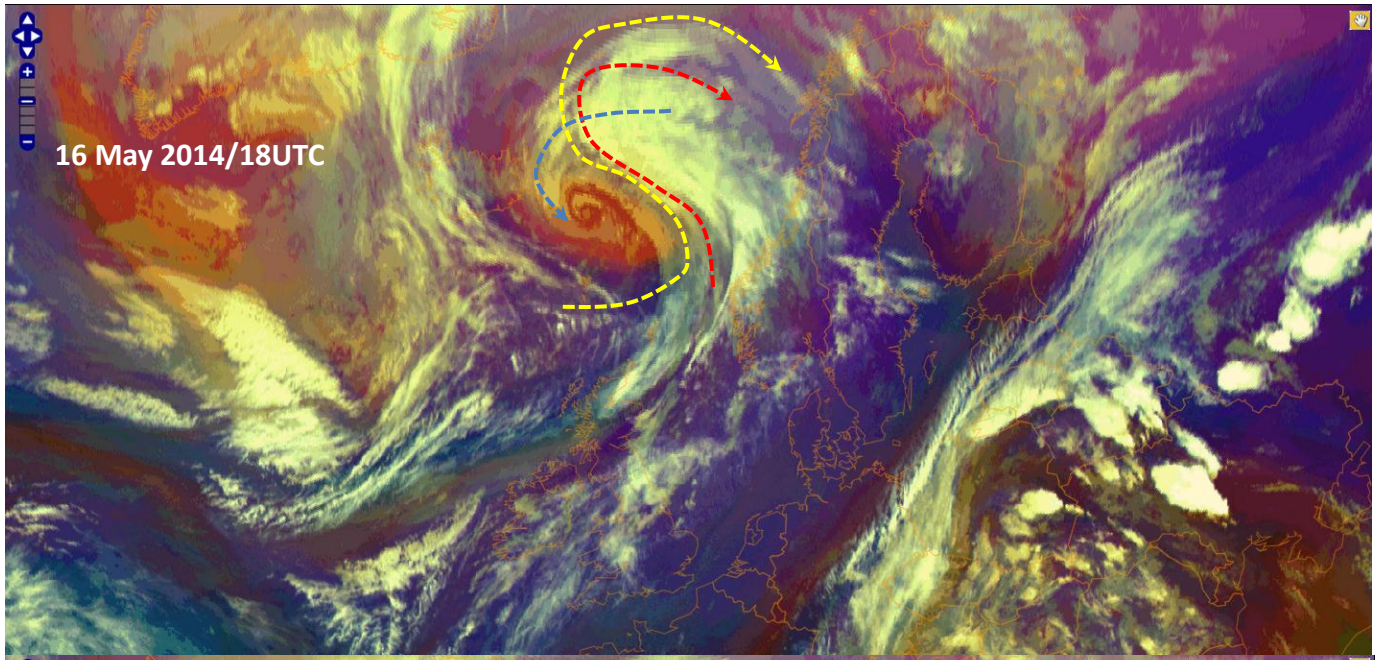
The classical Polar Front theory :
Main conveyor belt:
Warm conveyor

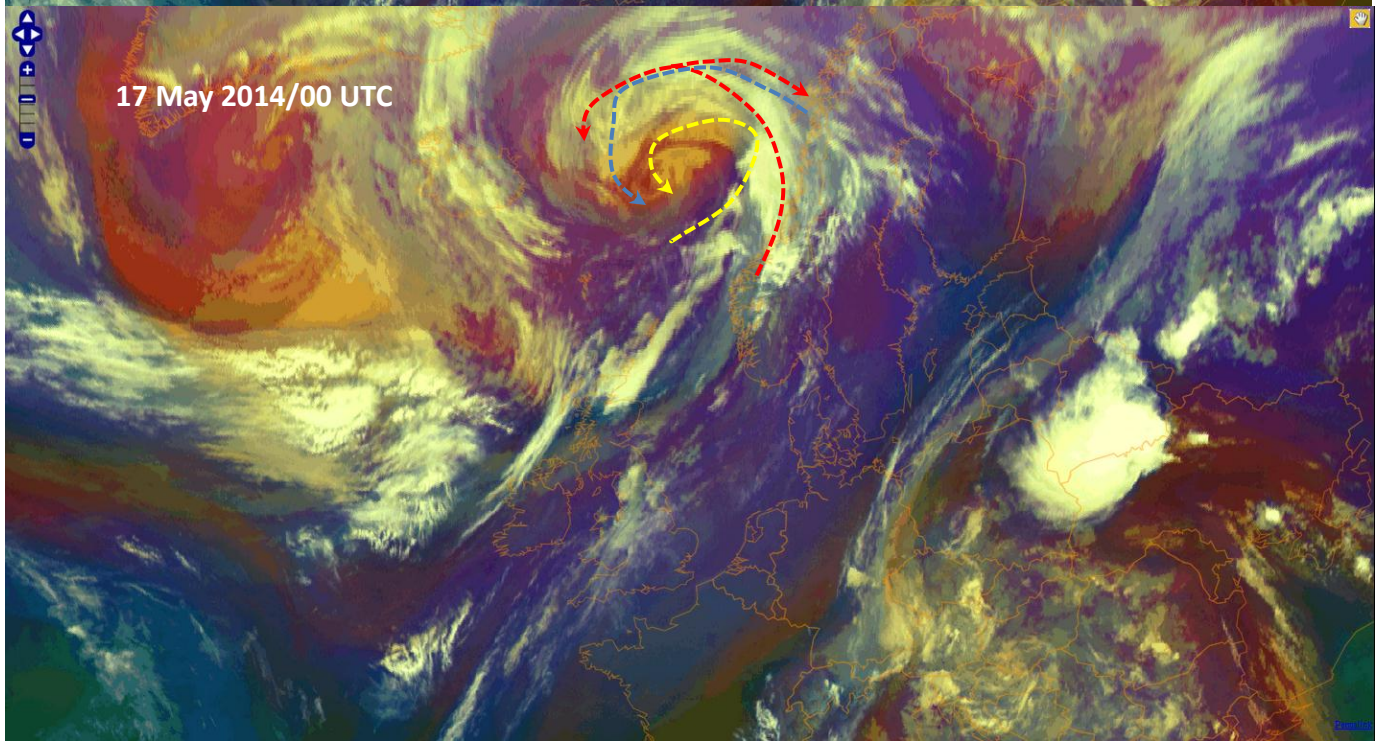


Subtype
of the classical Polar Front theory:
The Cold conveyor Belt model









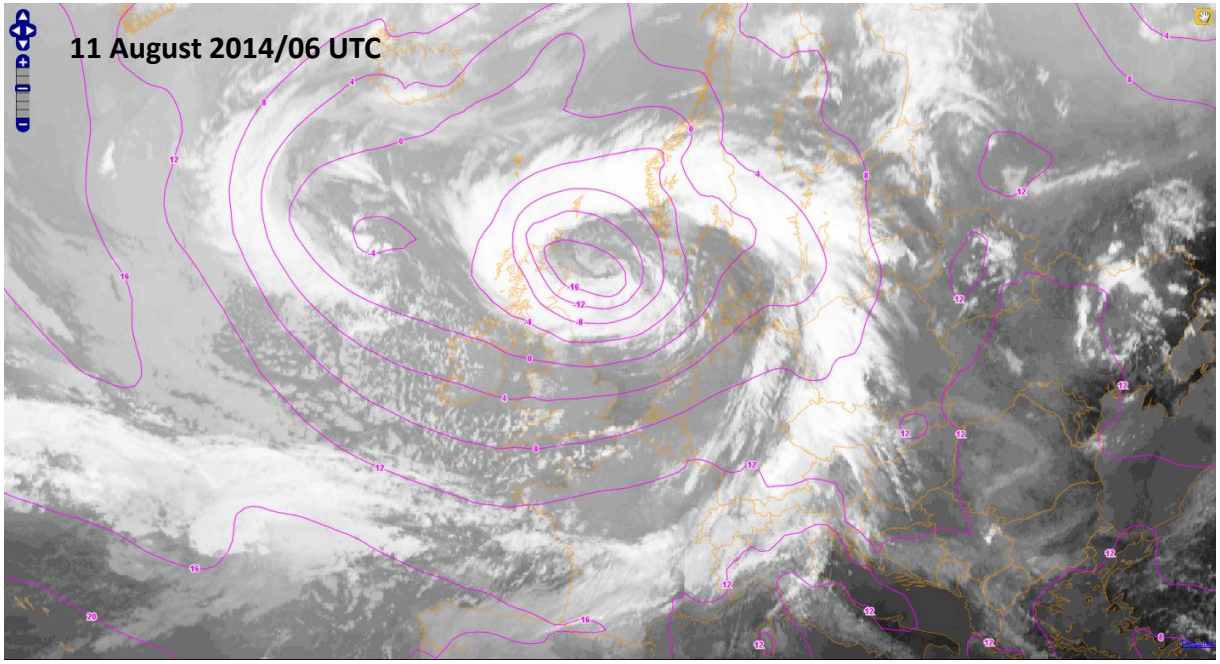
Schematics of involved Conveyor Belts

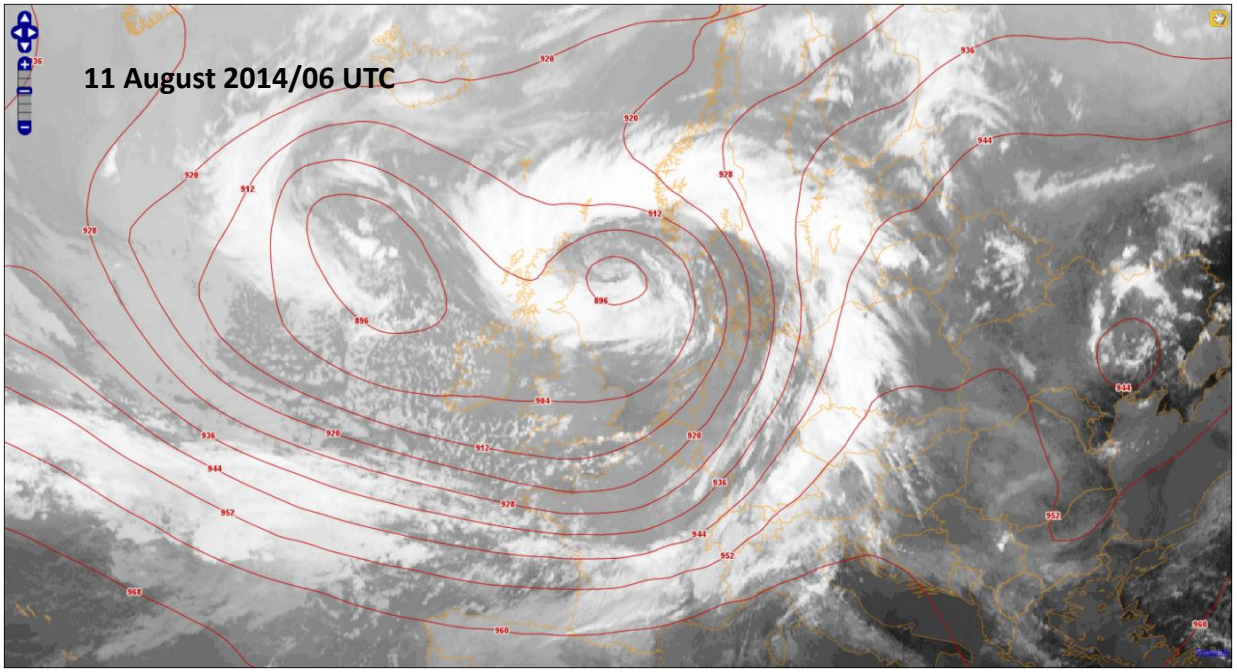
Transition Phase from CCB to WCB Occlusion/ Cyclogenesis Type

Airmass RGB images

Reflectance of occlusion process in numerical parameters

- Based on the classical Polar Front theory the following typical numerical parameters offer themselves as key parameters
  - Height Contours:
    - close to the surface (1000 hPa or surface pressure)
    - In upper levels (500 or 300 hPa)
  - Frontal parameters:
    - TFP
    - Equivalent thickness
    - Temperature advection
  - Equivalent potential temperature at 850 hPa
  - Upper level parameters:
    - Jet axis + jet streak
    - PVA
    - PV



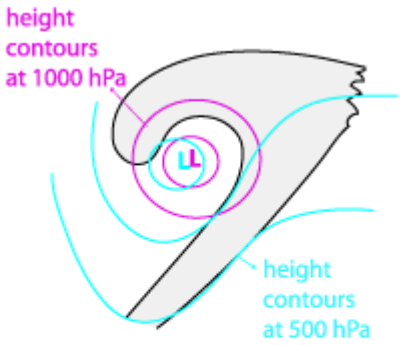


11 August 2014/ 06 UTC
Developed WCB occlusion

Magenta:
height contours 1000 hPa

Red:
Height contours 300 hPa

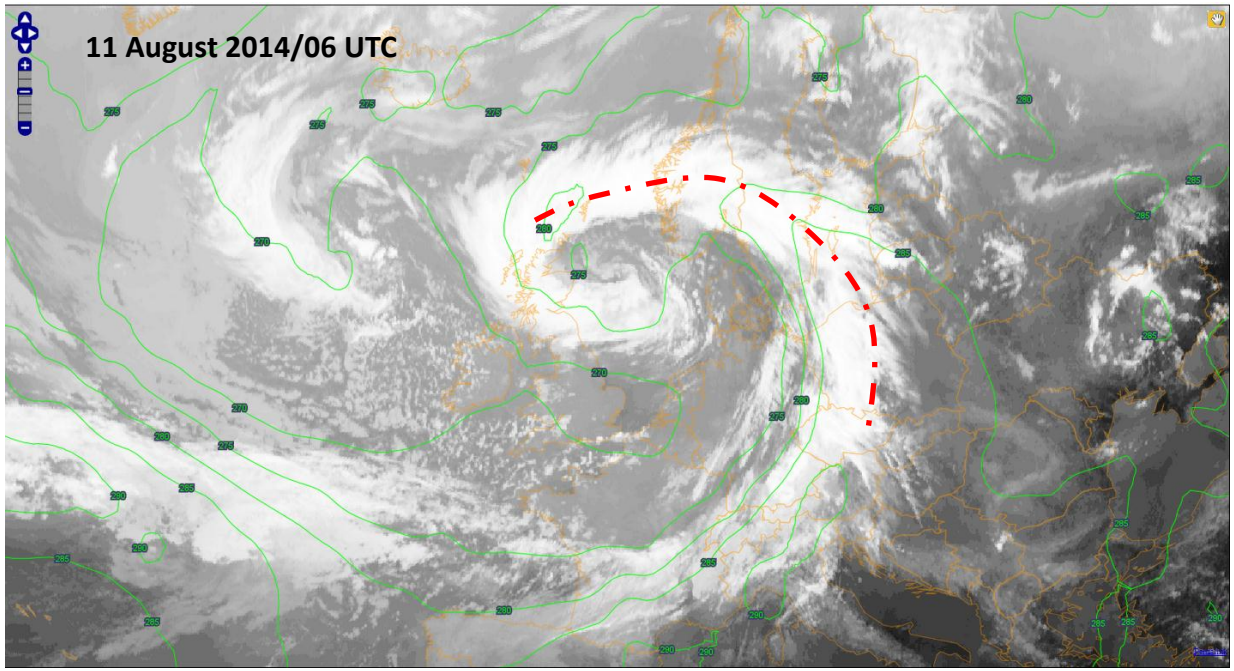
Fully developed low centre from surface to upper levels

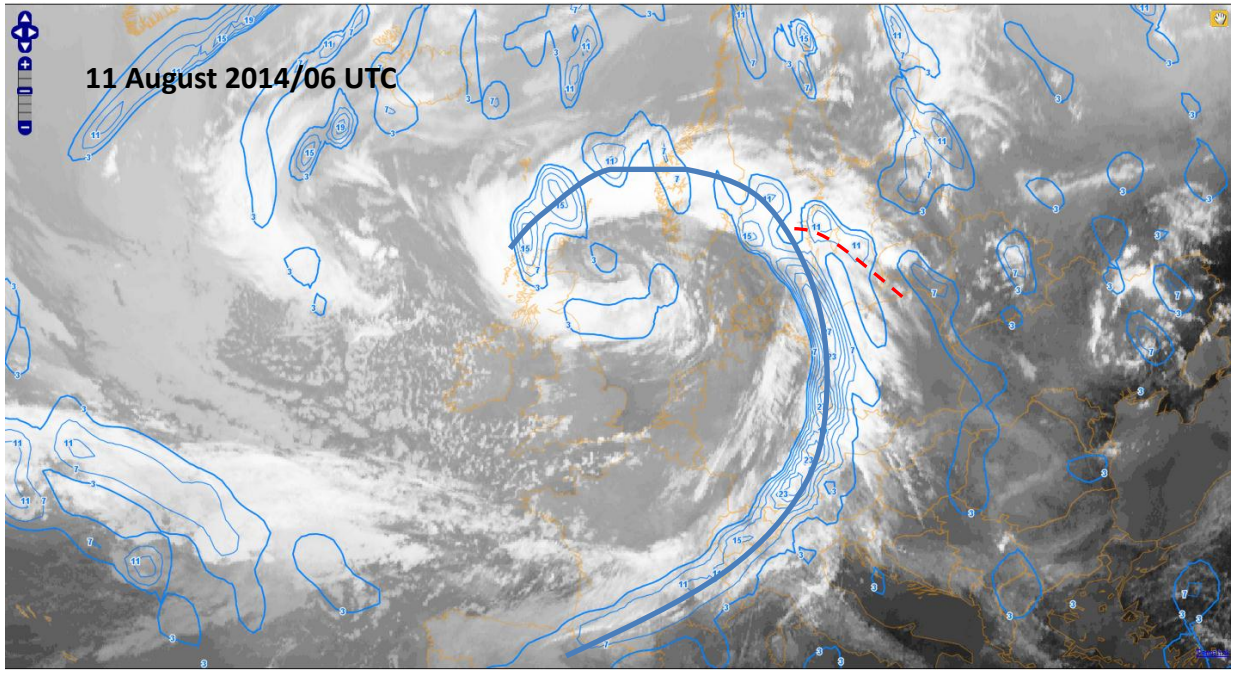


closed isolines indicate low pressure area close to the surface

distinct trough at upper level heights; far developed, closed low center probable

cloud spiral extends around low center



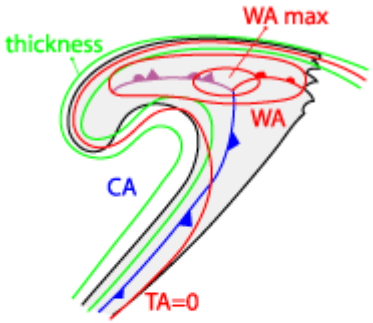


11 August 2014/ 06 UTC
Developed WCB occlusion

Green:
Equivalent thickness 500/1000

Blue:
TFP (Thermal Front Parameter)

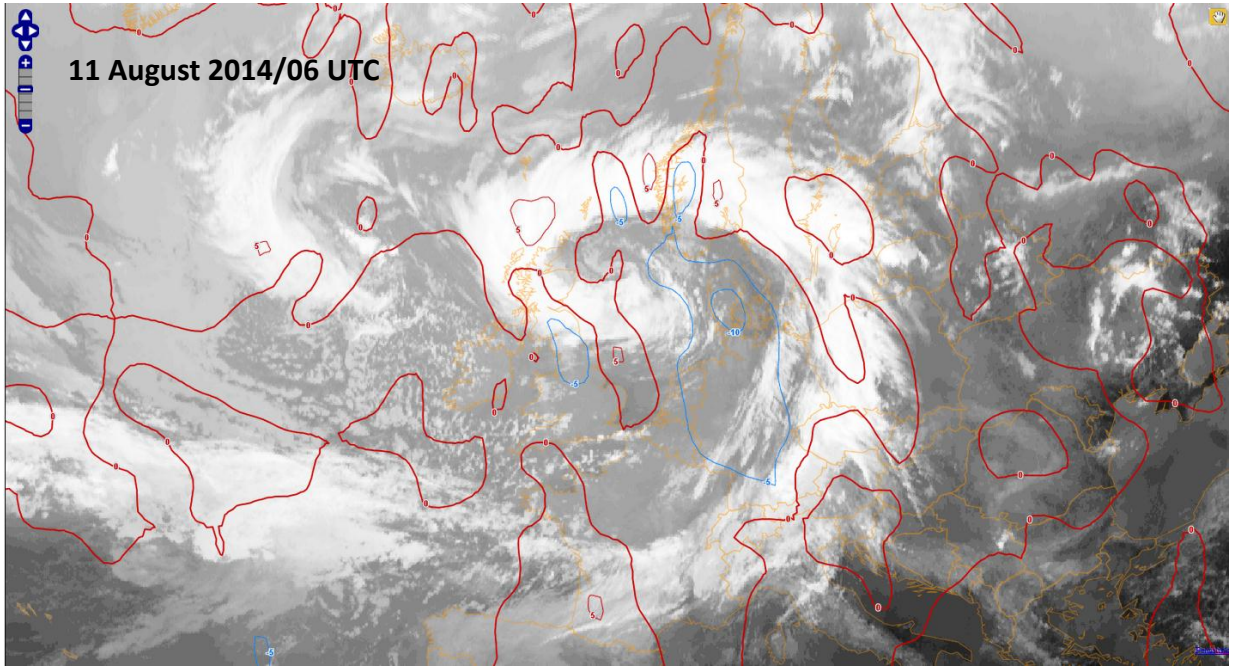
Well developed thickness ridge;
TFP moves from rear side at the CF to the centre of the occlusion cloud band

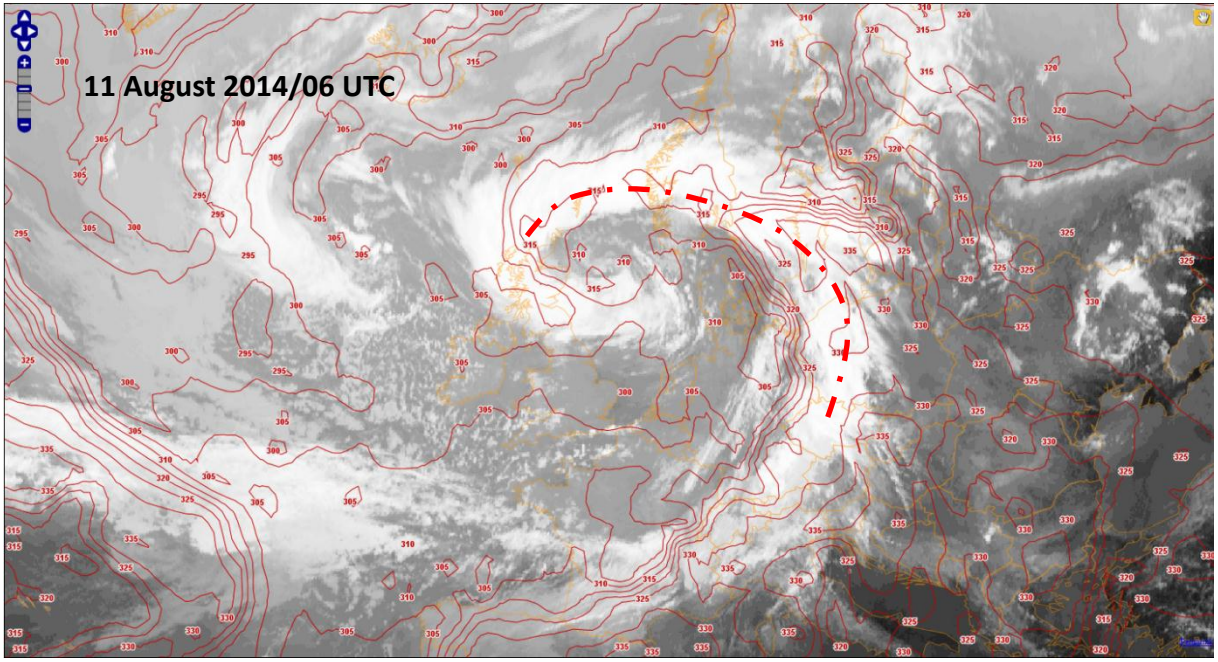


thickness ridge accompanies occl cloud spiral

TFP in center of occl cloud spiral

WA max within occl cloud spiral, max values close to point of occl





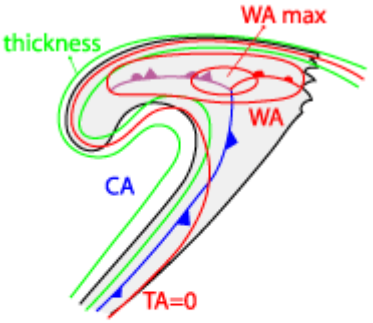
11 August 2014/ 06 UTC
Developed WCB occlusion

Red/blue
Temperature advection 700 hPa

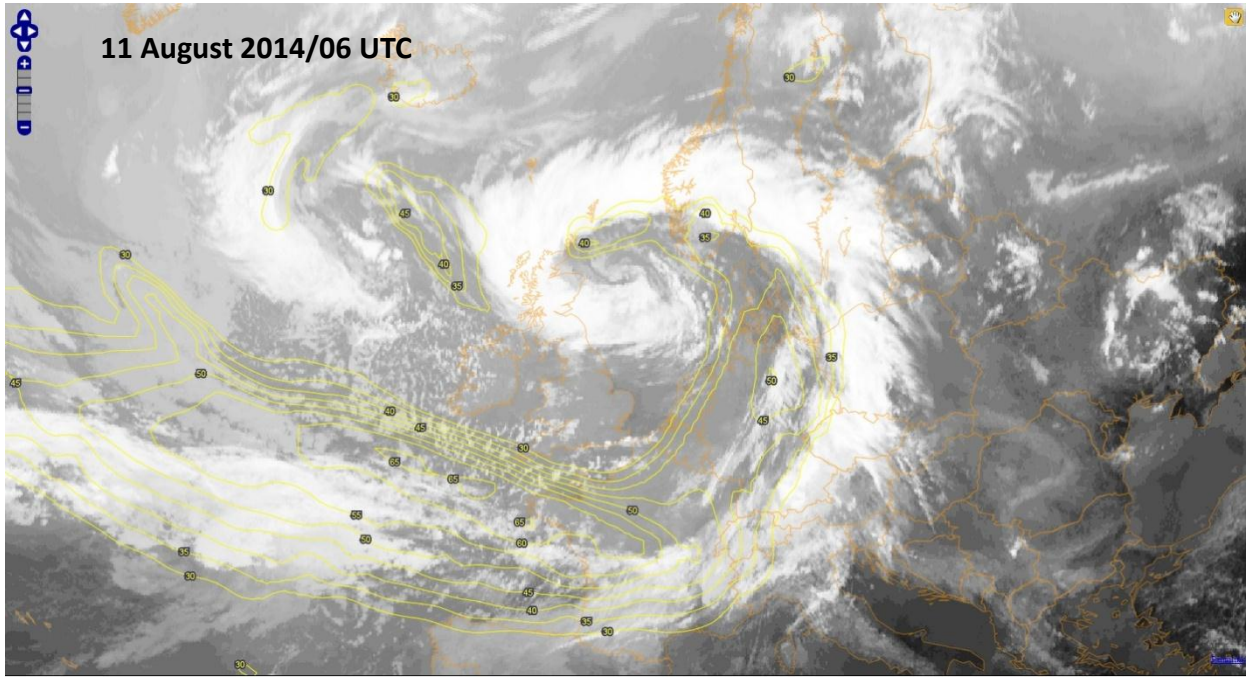
Red (below)
Equivalent potential
Temperature 850 hPa

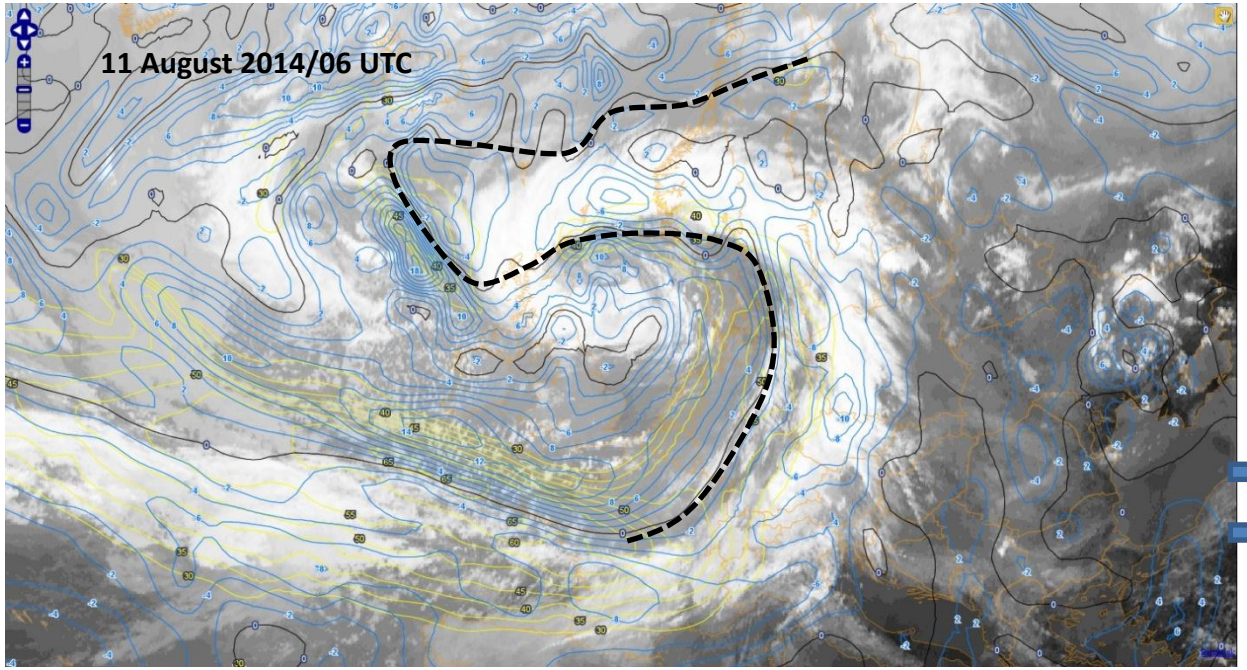
Although there is some meandering of the zero line of temperature advection 700 hPa CA (blue) is behind the cloud bands WA maxima (red) over the occlusion cloud band

Warmest air in 850 hPa over the occlusion cloud band. Same is true for 500 hPa



thickness ridge accompanies occl cloud spiral
TFP in center of occl cloud spiral
WA max within occl cloud spiral, max values close to point of occl



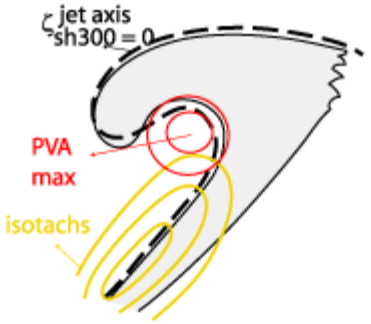


11 August 2014/ 06 UTC
Developed WCB occlusion

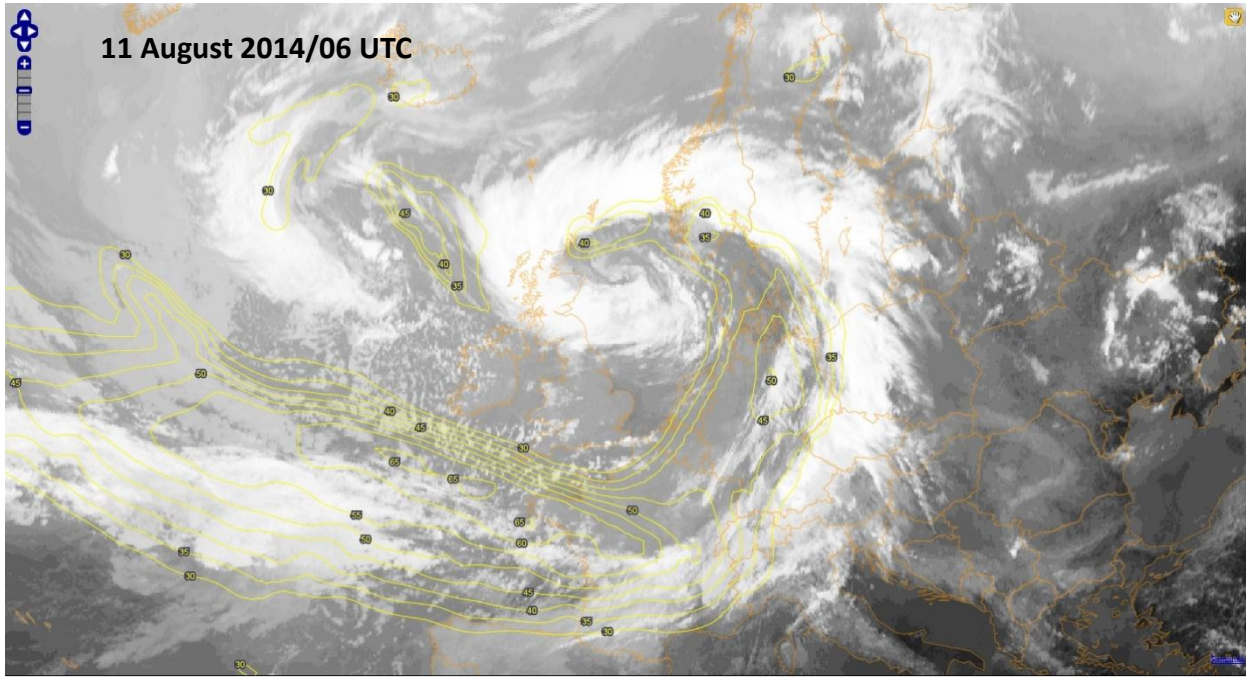
yellow
Isotachs 300 hPa; jet streak

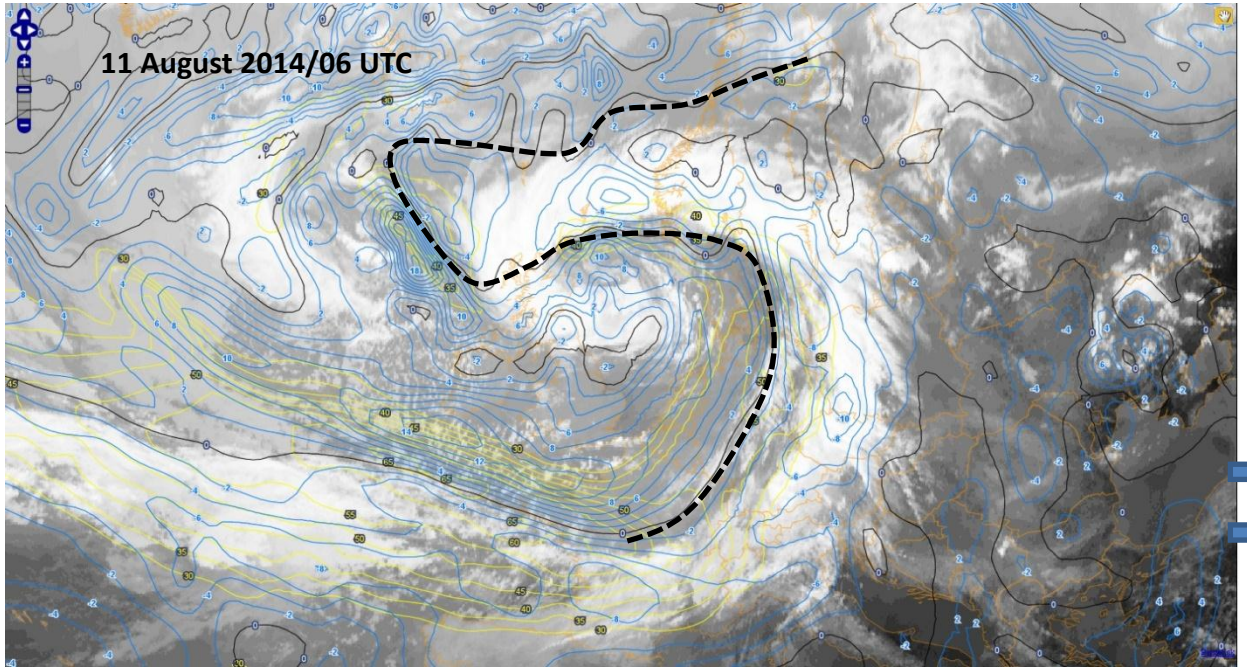
Black/blue
Shear vorticity 300 hPa; black: zero line – jet axis at 300 hPa

Jet streaks are along the rear edge of the CF and the occlusion cloud band ; jet axis moves from the inner cloud edge of the occlusion to the outer one.



jet axis (zeroline of shear vort) along inner boundary of occl cloud spiral
jet streak along CF cloud band with left exit region in the center of occl cloud spiral
PVA max at 300 hPa in the center of the occl cloud spiral and partly above occl cloud



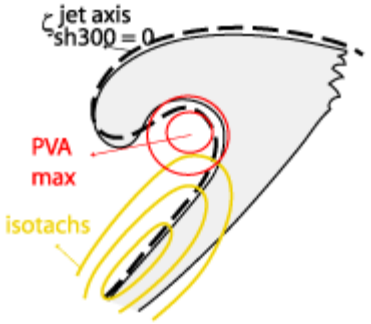


11 August 2014/ 06 UTC
Developed WCB occlusion

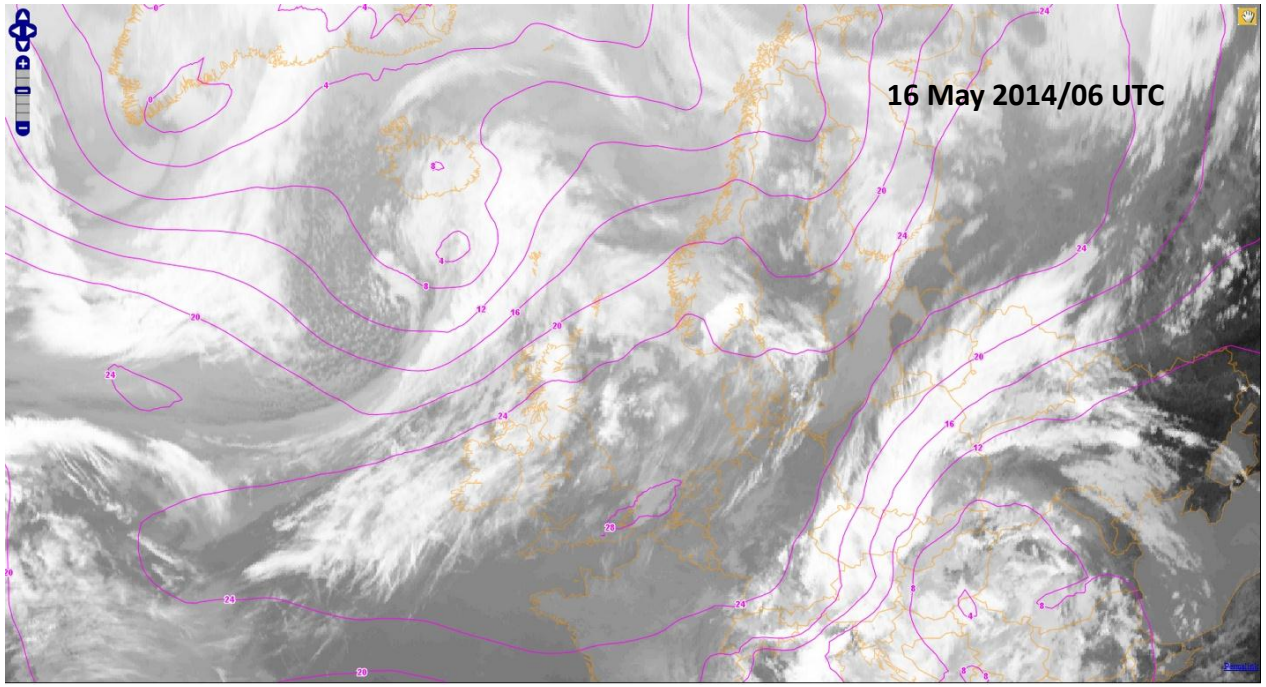
yellow
Isotachs 300 hPa; jet streak

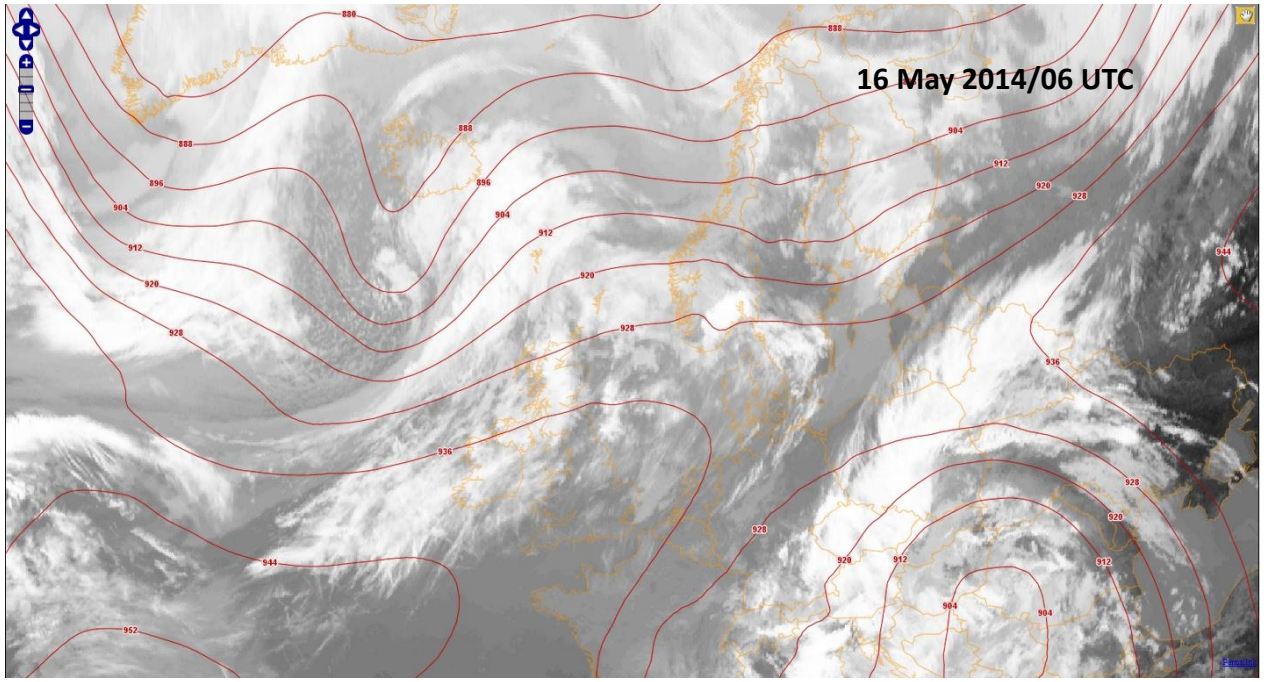
Black/blue
Shear vorticity 300 hPa; black: zero line – jet axis at 300 hPa

Jet streaks are along the rear edge of the CF and the occlusion cloud band ; jet axis moves from the inner cloud edge of the occlusion to the outer one.



jet axis (zeroline of shear vort) along inner boundary of occl cloud spiral
jet streak along CF cloud band with left exit region in the center of occl cloud spiral
PVA max at 300 hPa in the center of the occl cloud spiral and partly above occl cloud



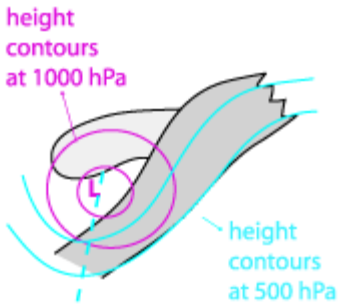


16 May 2014/ 06 UTC
Phase of CCB occlusion

Magenta:
height contours 1000 hPa

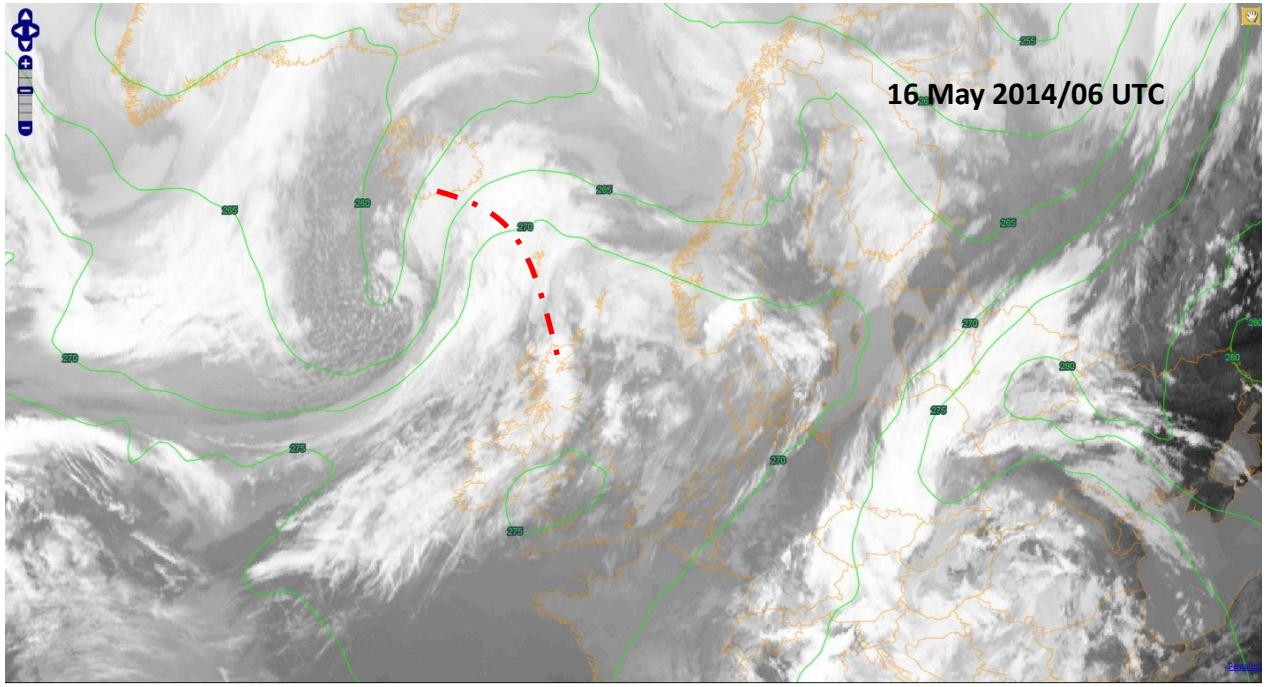
Red:
Height contours 300 hPa

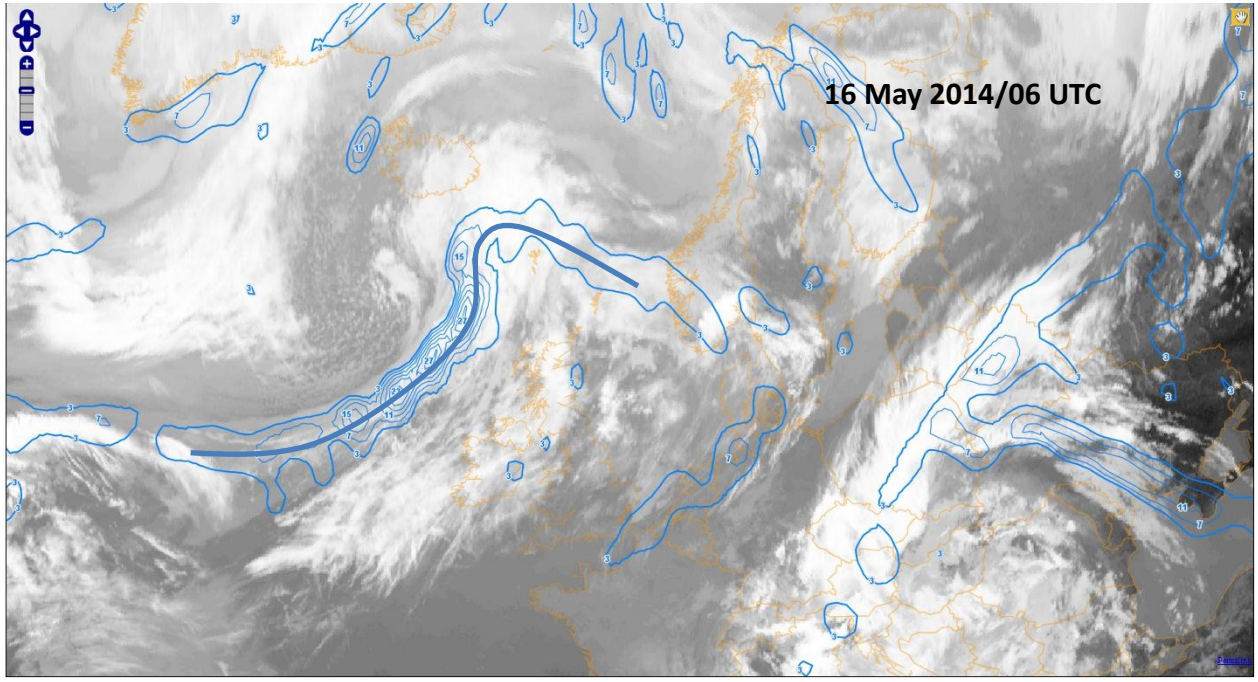
Low centre in lower layers, trough in upper levels



closed isolines indicate low pressure area close to the surface

distinct trough at upper level heights; usually less developed as for w.c.b occl; cloud spiral extends around low center and upper trough



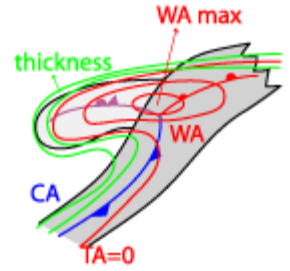


16 May 2014/ 06 UTC
Phase of CCB occlusion

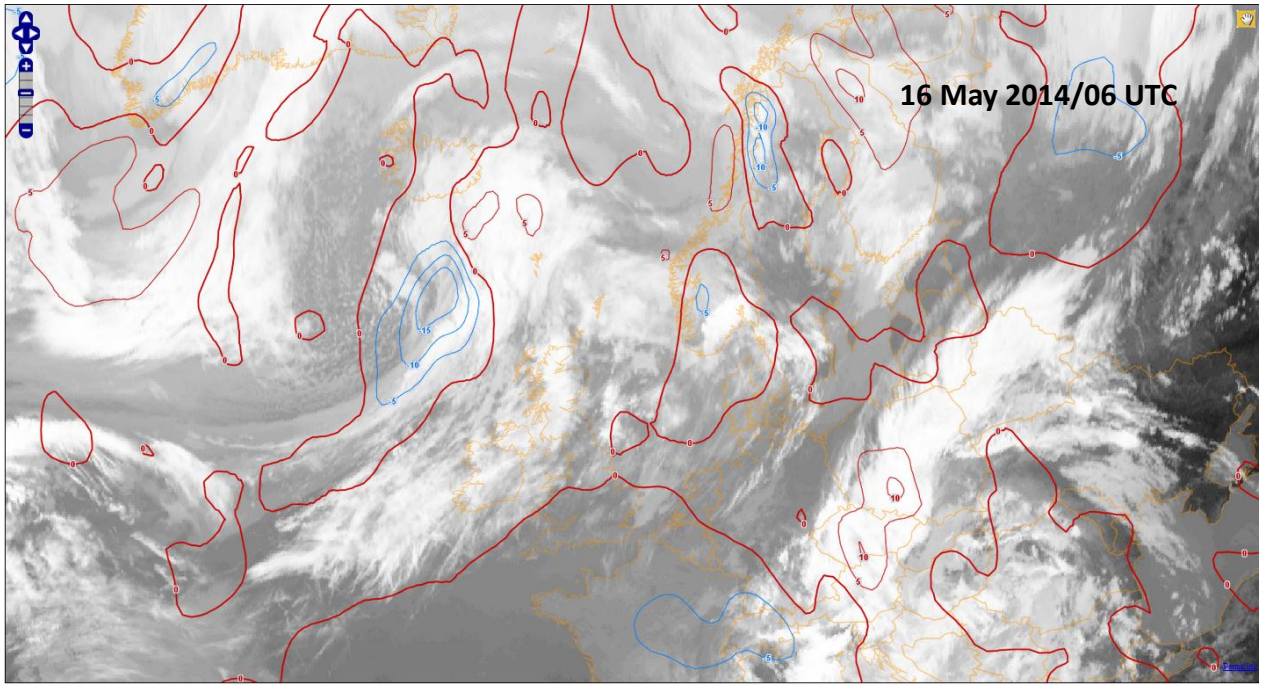
Green:
Equivalent thickness 500/1000

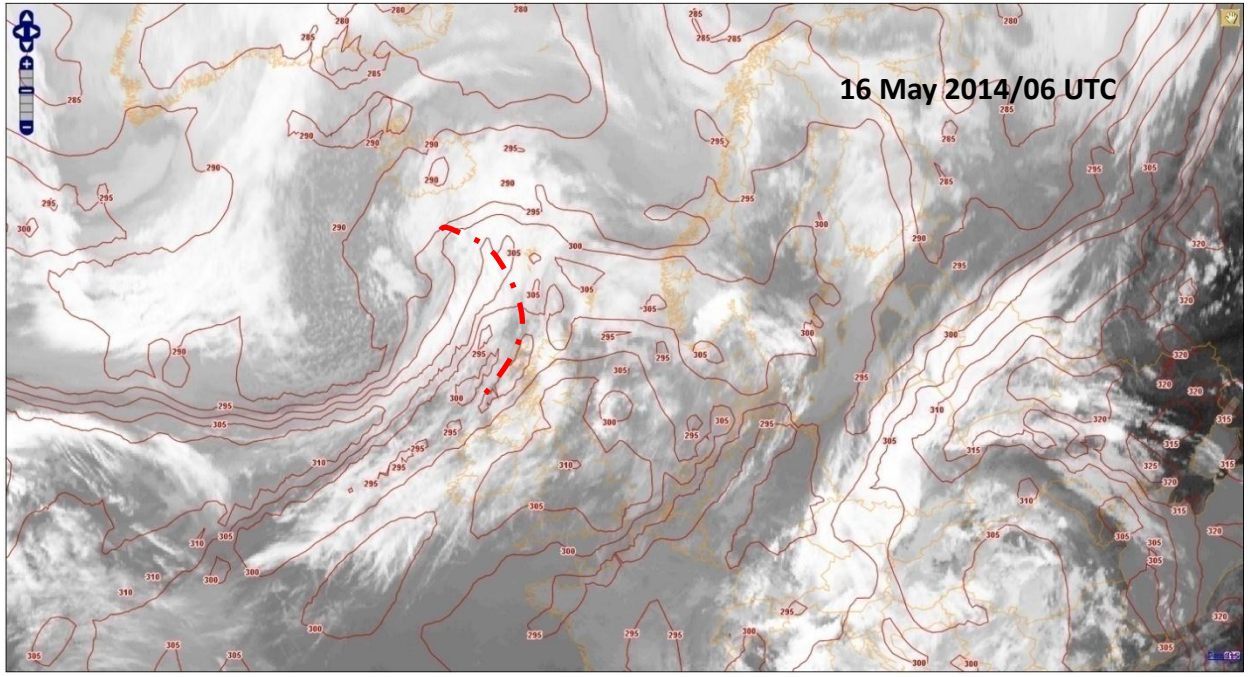
Blue:
TFP (Thermal Front Parameter)

thickness ridge, but much smoother than for wcb occlusion;
TFP accompanies CF and WF;
not yet the ccb occlusion band t



thickness ridge accompanies occl cloud spiral
TFP in center of occl cloud spiral
WA max within occl cloud spiral, max values close to point of occl





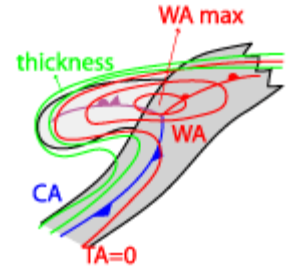
16 May 2014/ 06 UTC
Phase of CCB occlusion

Red/blue
Temperature advection 700 hPa

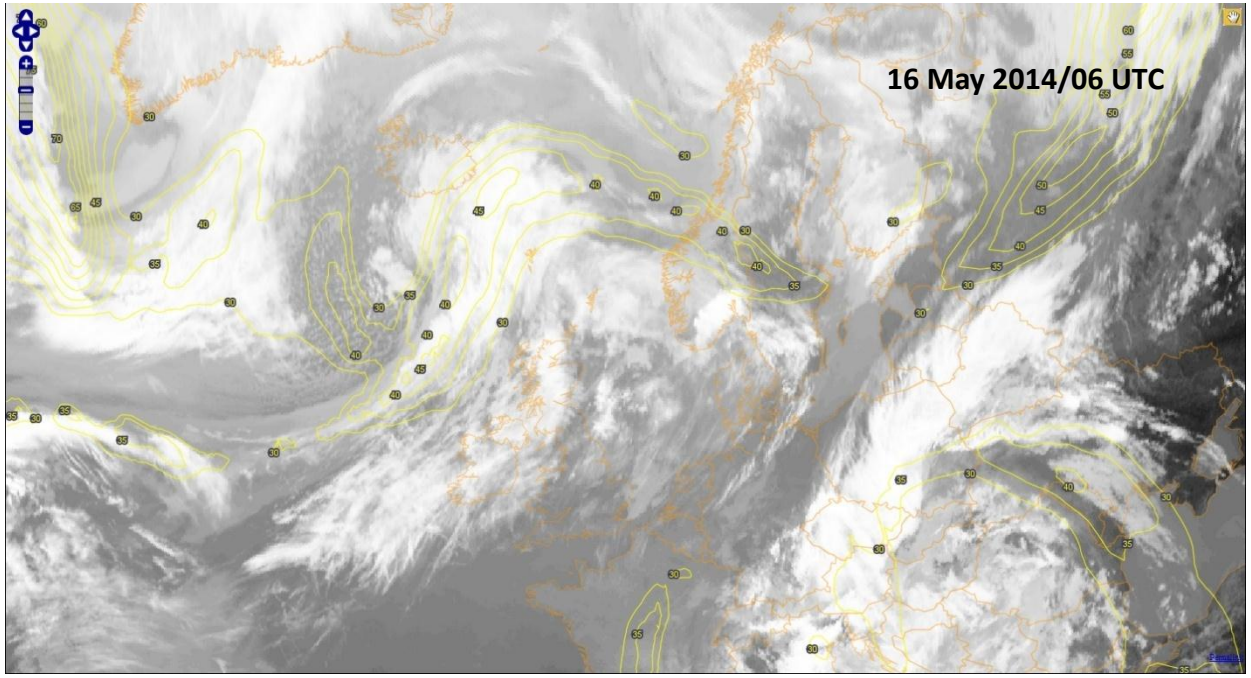
Red (below)
Equivalent potential
Temperature 850 hPa

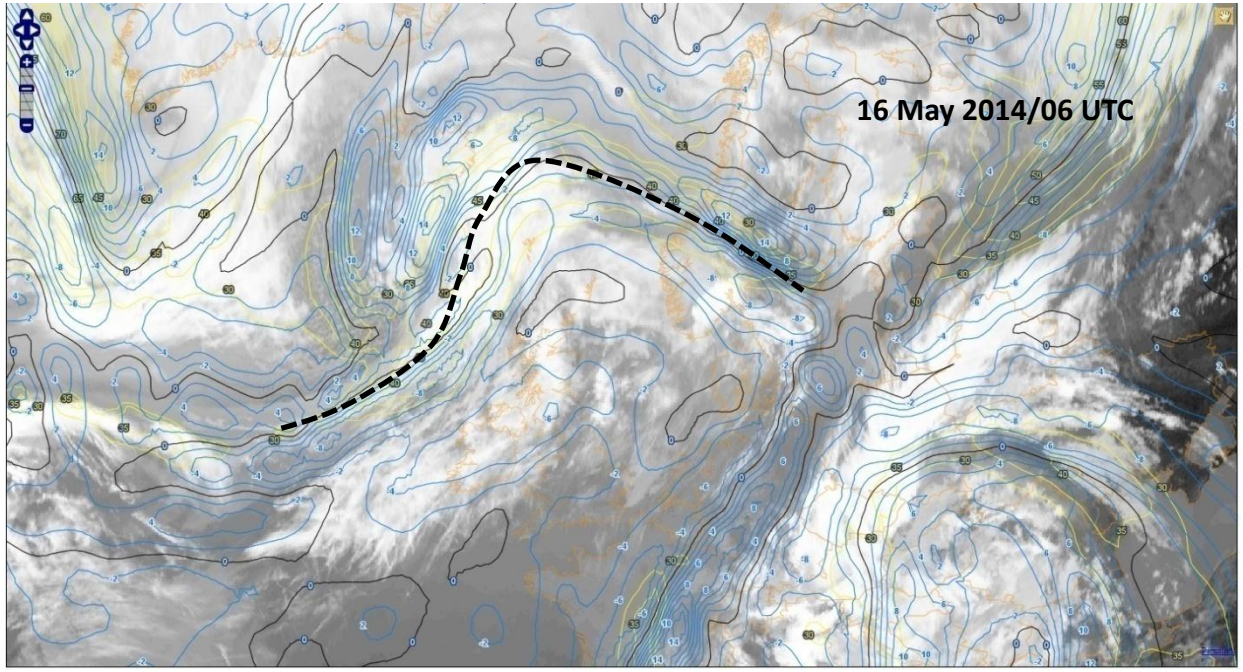
Ccb occlusion cloud band partly still under CA; WA max develops

Warmest air in 850 hPa moves in direction of ccb occlusion cloud band; at 500 hPa still colder air over the ccb occlusion band



thickness ridge accompanies occl cloud spiral
TFP in center of occl cloud spiral
WA max within occl cloud spiral, max values close to point of occl



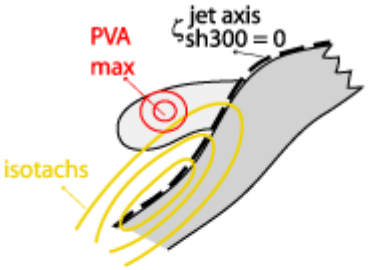


16 May 2014/ 06 UTC
Phase of CCB occlusion

yellow
Isotachs 300 hPa; jet streak

Black/blue
Shear vorticity 300 hPa; black: zero line – jet axis at 300 hPa

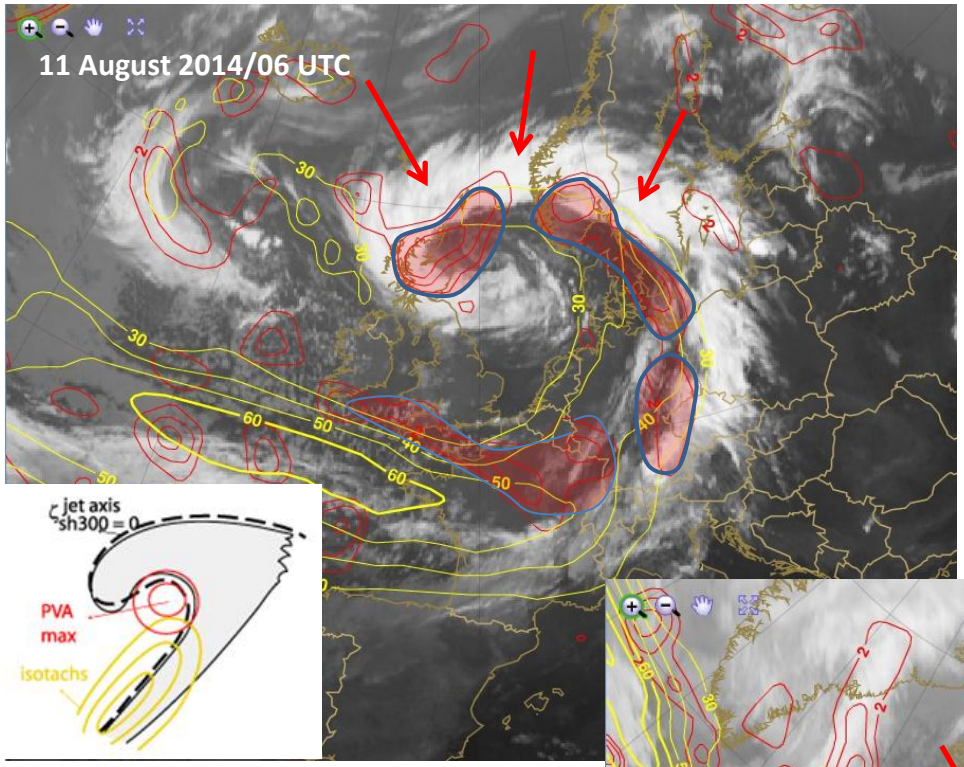
Jet streaks are along the rear edge of the CF and WF band occlusion cloud band on the cyclonic side of the jet axis



jet axis (zeroline of shear vort) along rear side of CF and leading side of WF; crosses ccb occl cloud band

jet streak along CF - WF cloud boundary with left exit region over ccb occl cloud band

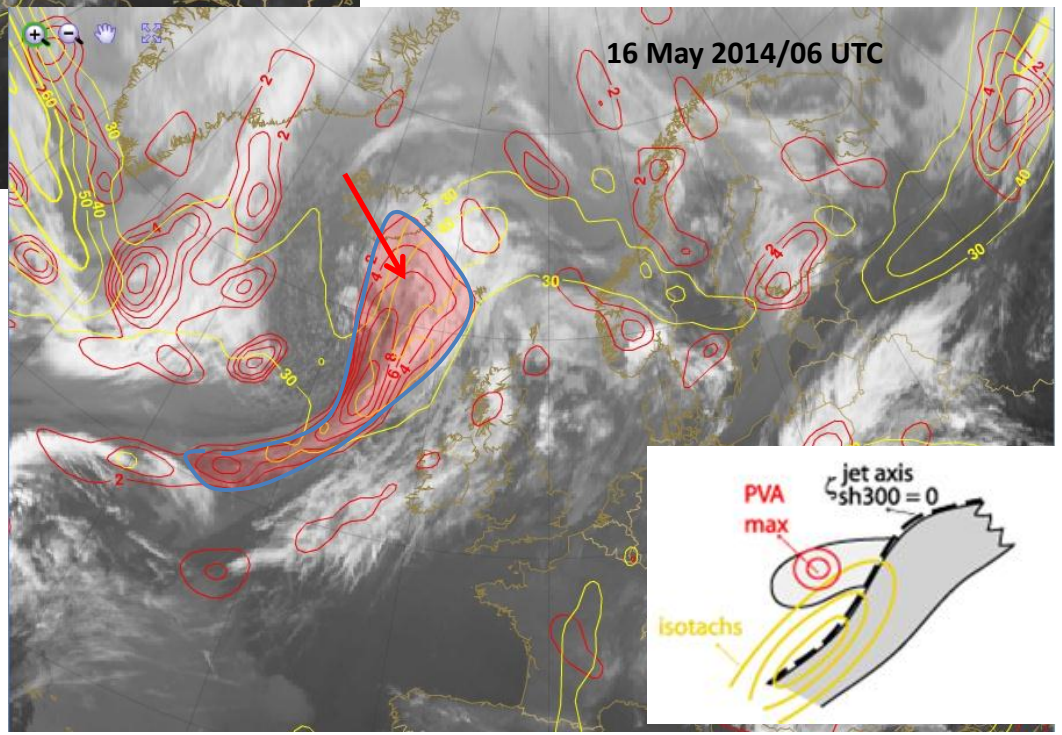
PVA max at 300 hPa over ccb occl cloud displaced in direction to the spiral center



14 August 2014/06 UTC
WCB occlusion
PVA maxima at 300 hPa mostly behind the wcb occlusion cloud band

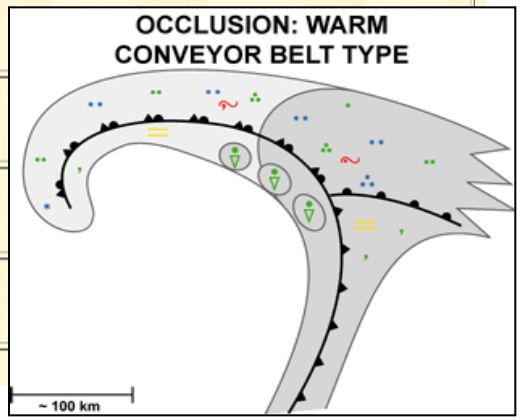
WCB - CCB

Differences in the relation between cloud configurations and jet streak and PVA maxima



16 May 2014/06 UTC
CCB occlusion
PVA maxima at 300 hPa over the ccb occlusion cloud band

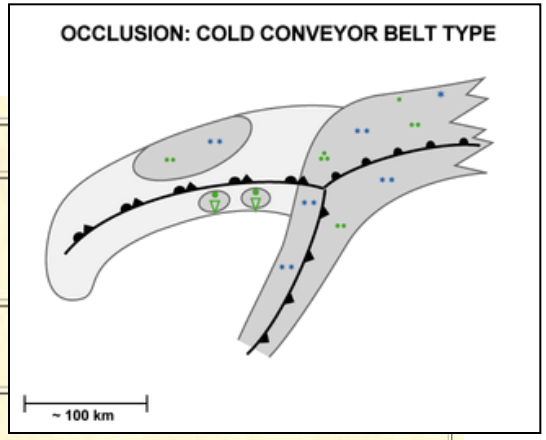
Parameter	Description
Precipitation	• Broad precipitation bands (5-50 km wide) are found within and ahead of the surface front. Maximum precipitation close to the Occlusion point (in contrast to Occlusion: Cold Conveyor Belt Type). • At the rear part of the cloud spiral showers and thunder, even hail.
Temperature	• Seasonal dependence: rising temperatures in wintertime, cool conditions in the summer.
Wind (incl. gusts)	• Moderate to strong winds. The most intense wind on the outer edge of the cloud spiral.
Other relevant information	• Generally, Occlusions are connected with multi-level cloudiness. Therefore the weather activities are highly variable.



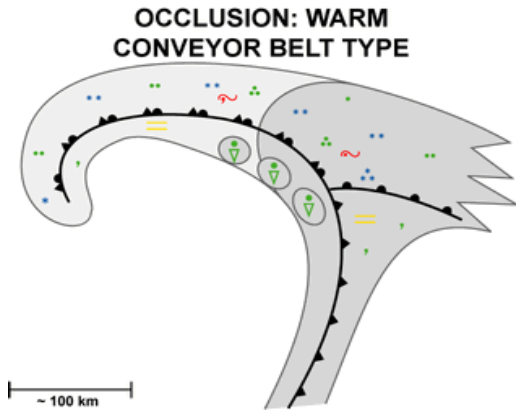
WCB

Weather

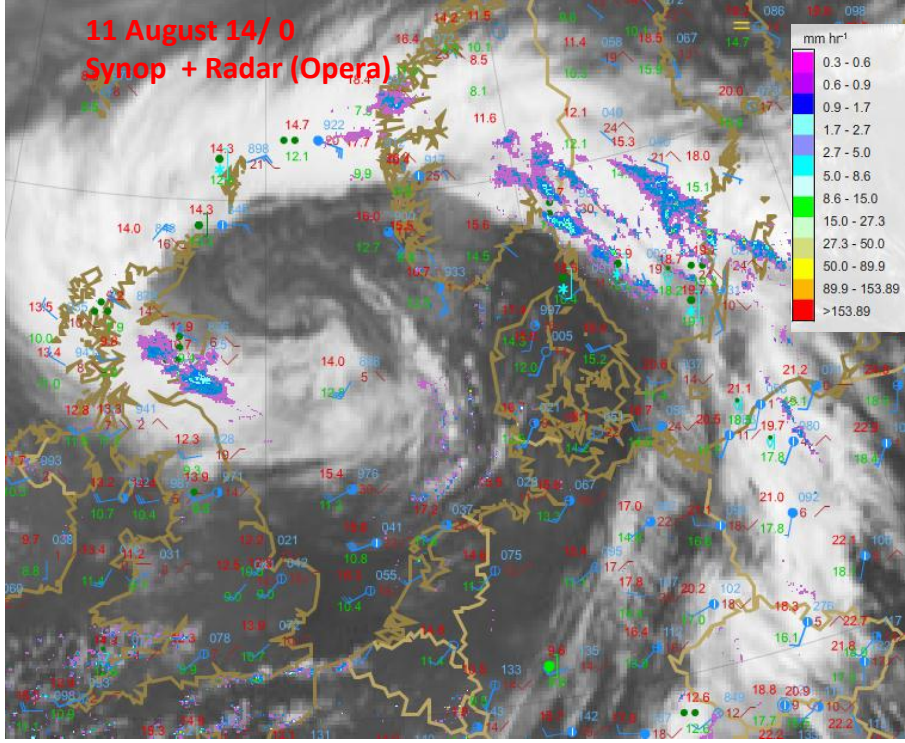
CCB

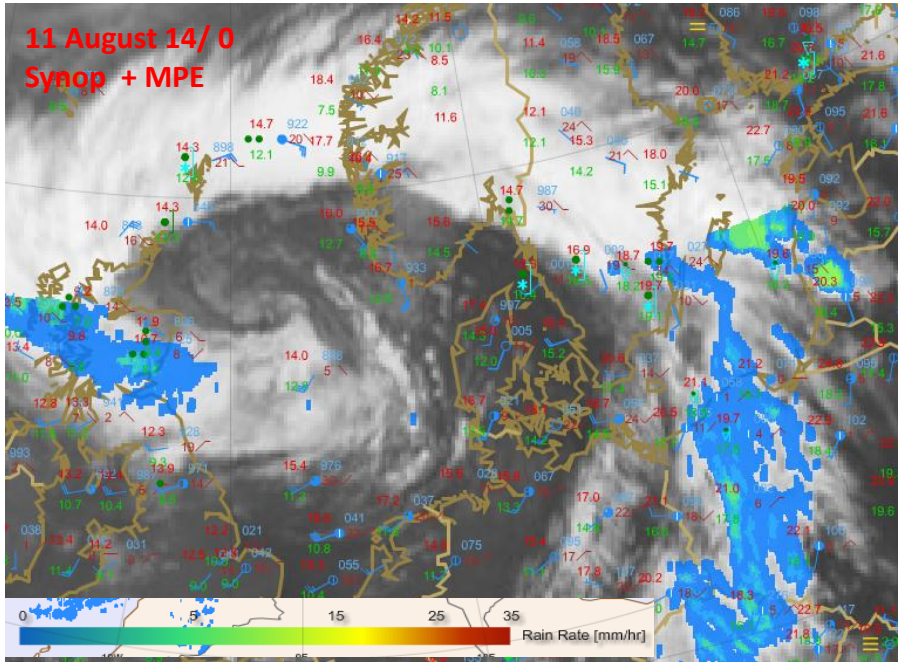


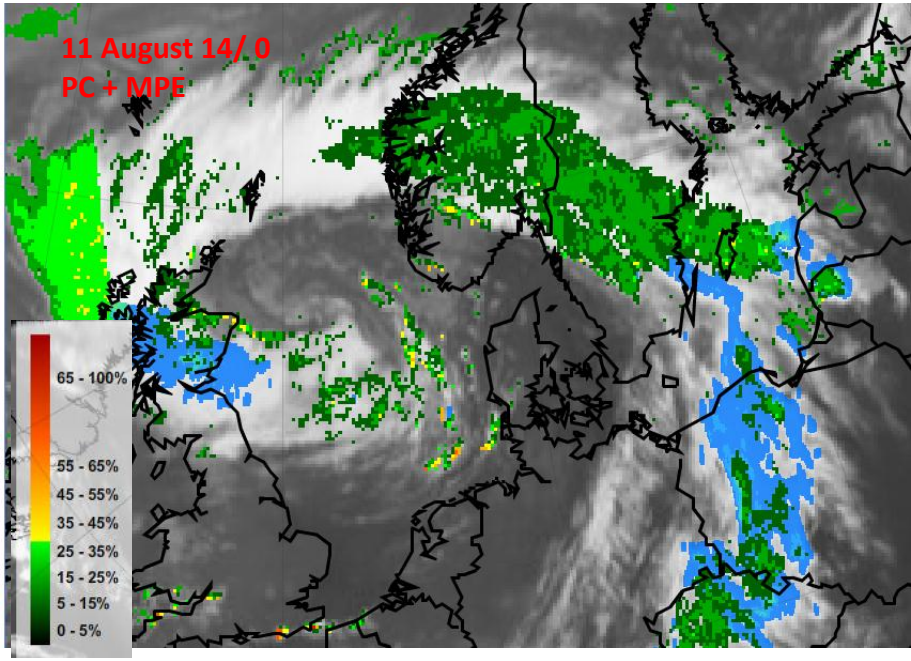
Parameter	Description
Precipitation	• Intensive precipitation within and especially ahead of the Occlusion point. • Rainbands typically oriented parallel to the occluded front (5-10 km wide).
Temperature	• Rising temperature associated with the passage of the secondary Occlusion.
Wind (incl. gusts)	• Strong winds circulating around secondary vortex, veering of the wind associated with the passage of the secondary Occlusion.
Other relevant information	• rear part of cloud spiral close to Occlusion point, possibly situated to the left exit region of a jet streak, is predestined for convective development due to potentially unstable troposphere.



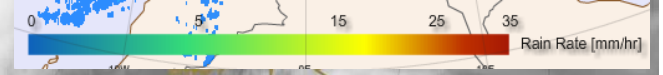
MPE: Multi-sensor Precipitation Estimate (Eumetsat)
PC: Precipitating Clouds (Nowcasting SAF)
Radar: Composite of Surface Rain Rate (Opera)



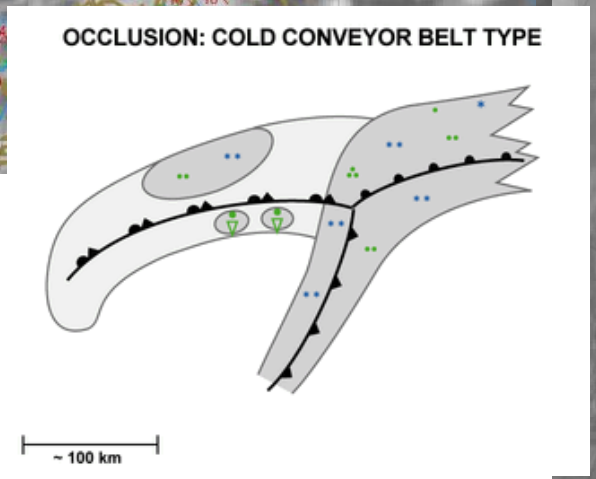




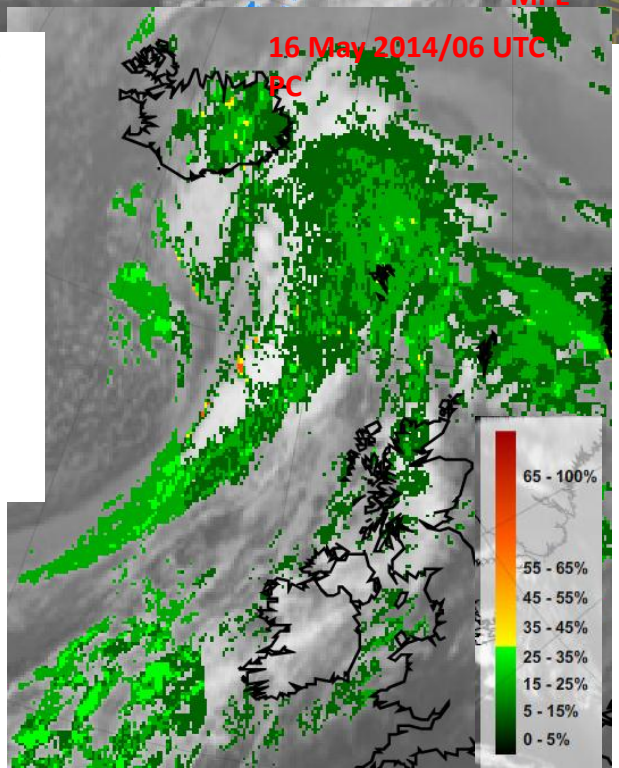
16 May 2014/06 UTC
Synop measurements



16 May 2014/06 UT
MPE



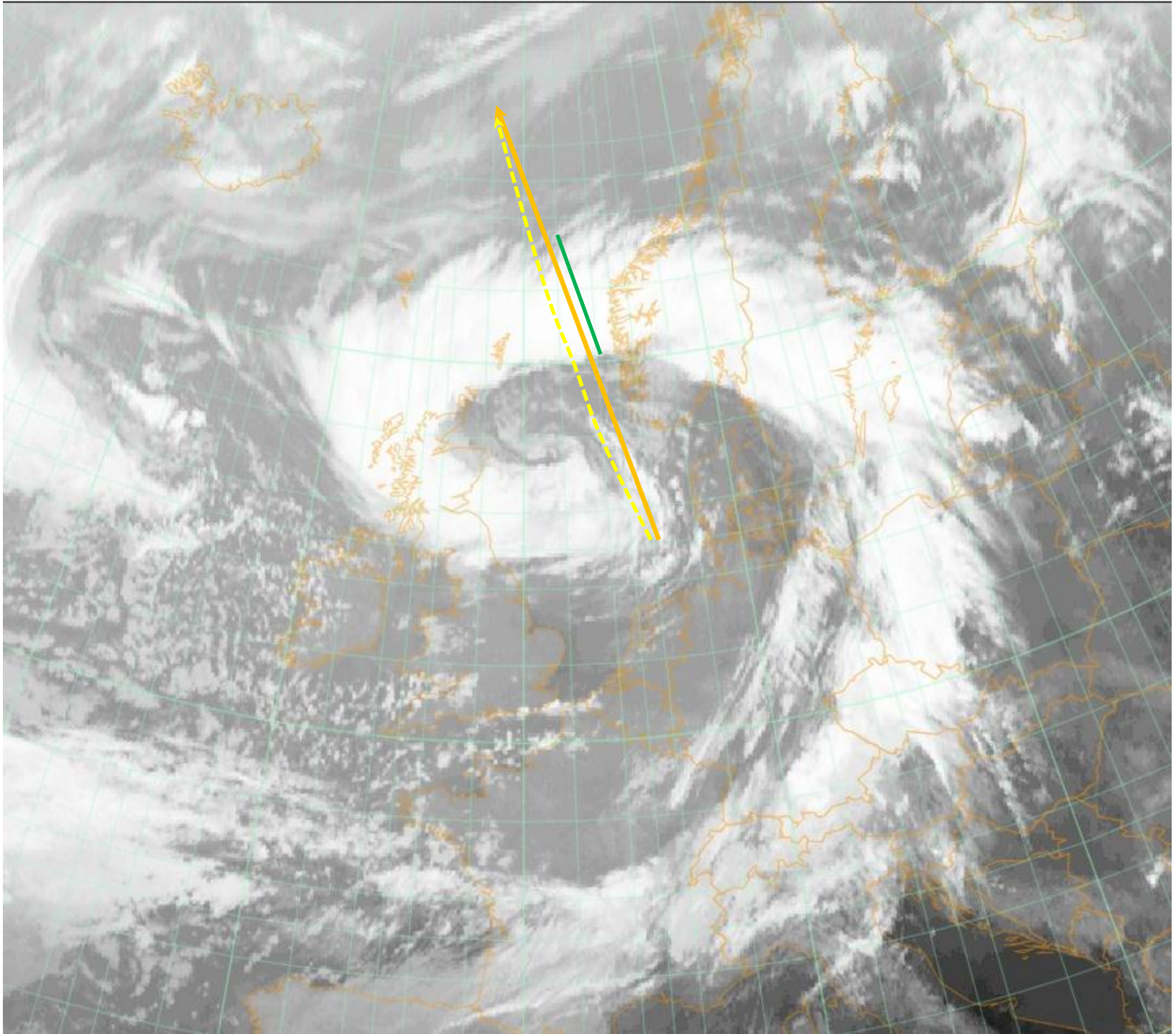
16 May 2014/06 UTC
PC



MPE: Multi-sensor Precipitation Estimate (Eumetsat)
PC: Precipitating Clouds (Nowcasting SAF)
Radar: Composite of Surface Rain Rate (Opera)

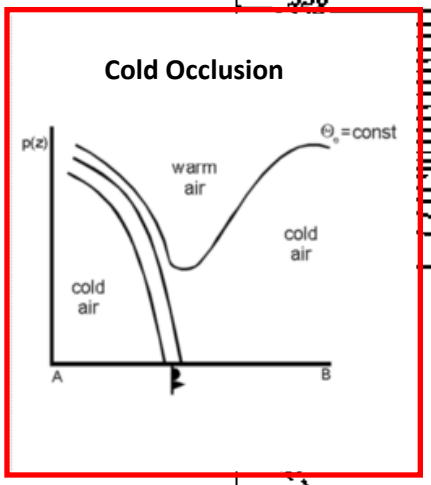
Relevant Numerical Key Parameters in Vertical Cross Sections

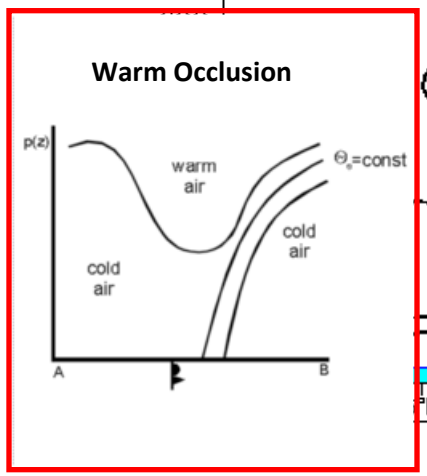
- Based on the classical Polar Front theory the following typical numerical parameters offer themselves as key parameters
  - Isentrops
  - Temperature advection
  - Rel. Humidity / cloudiness
  - Divergence + upward motion
  - Vorticity Advection
  - Potential Vorticity > 2 PV unit



11 August 2014/06 UTC: isentropes

Cloud band along VCS from satellite image





200

500

Warm air

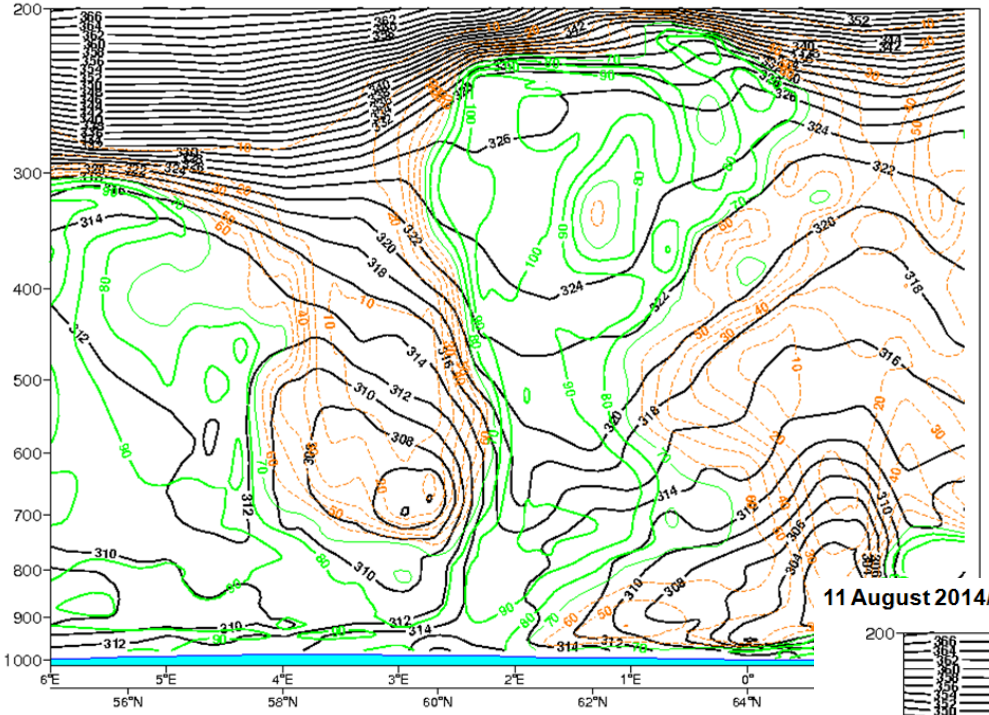
Coldest air

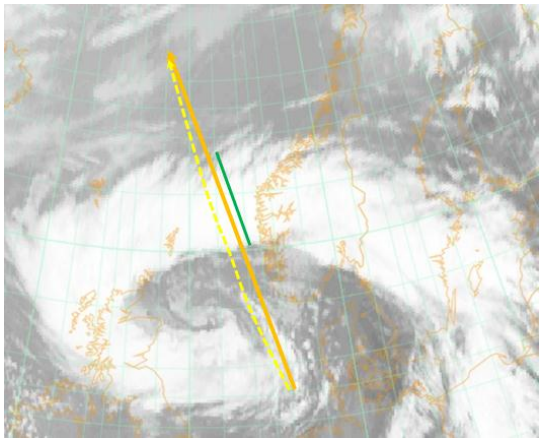
Cold air

4°E 3°E 2°E 1°E 0° 1°W 2°W

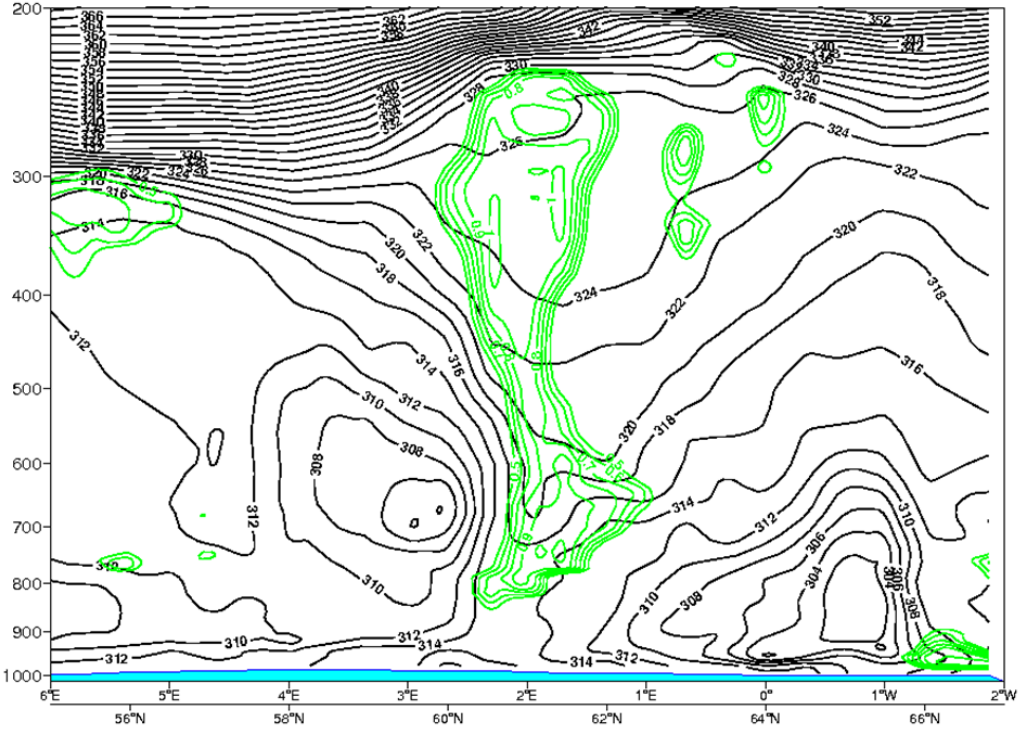
58°N 60°N 62°N 64°N 66°N

11 August 2014/06 UTC rel. humidity

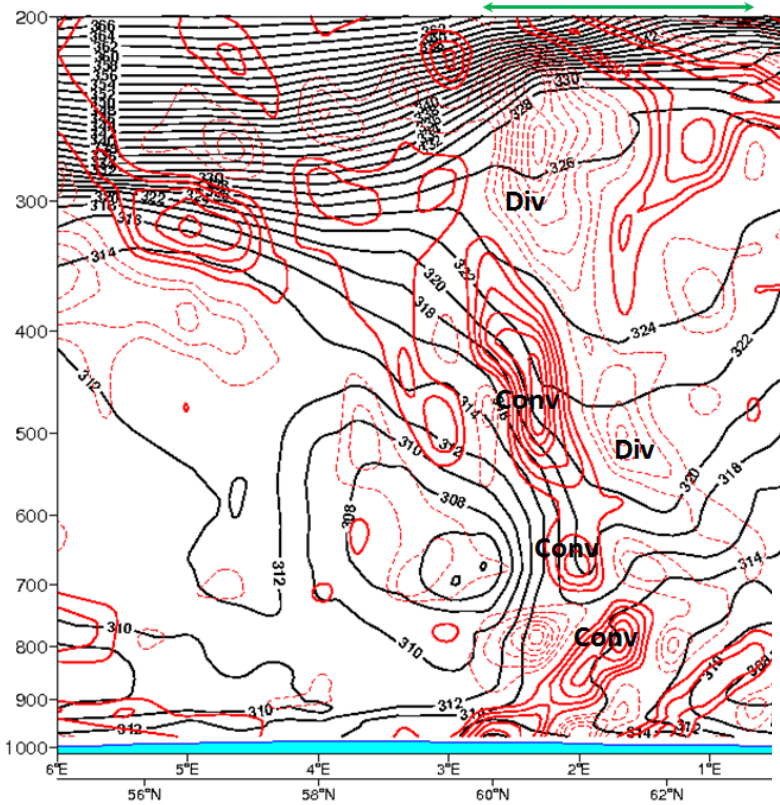


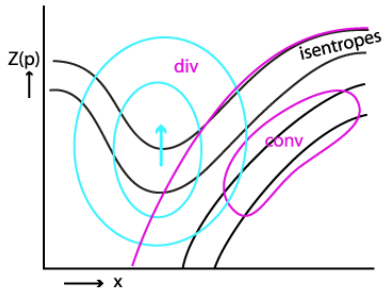


11 August 2014/06 UTC cloud cover



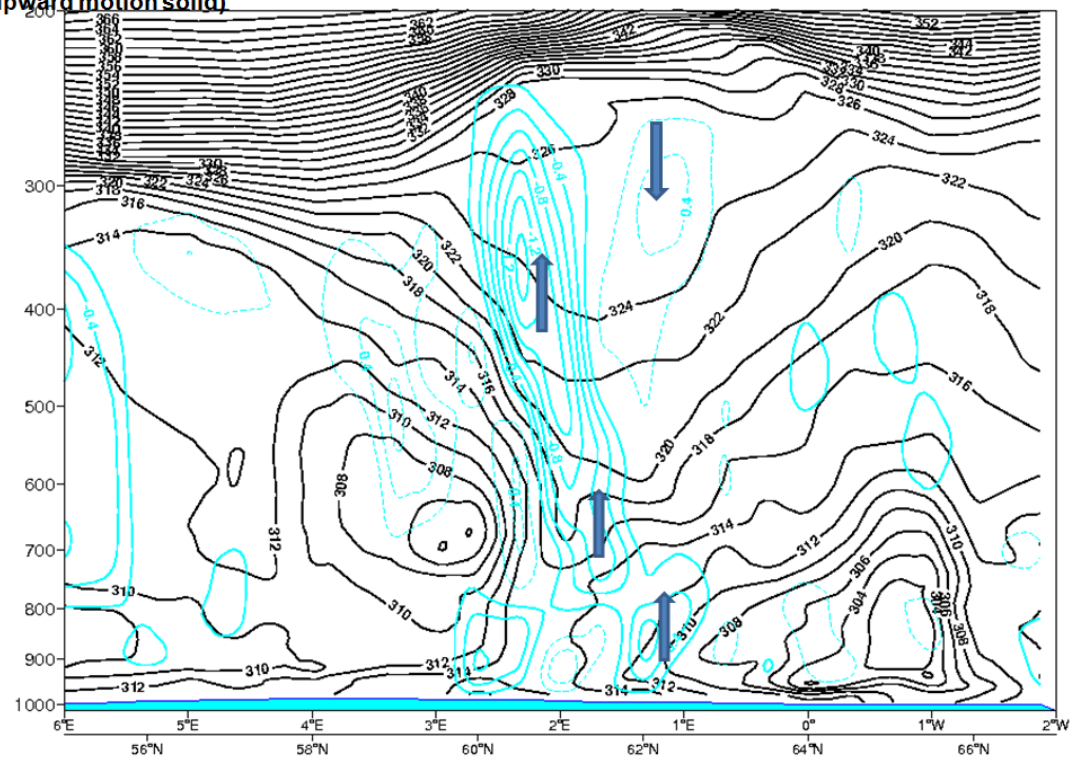
11 August 2014/06 UTC divergence – convergence (dashed, solid)

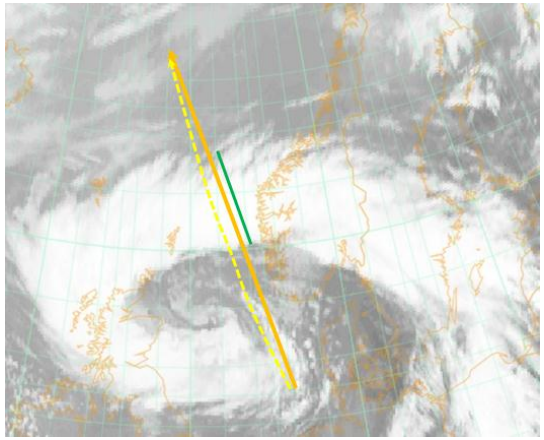




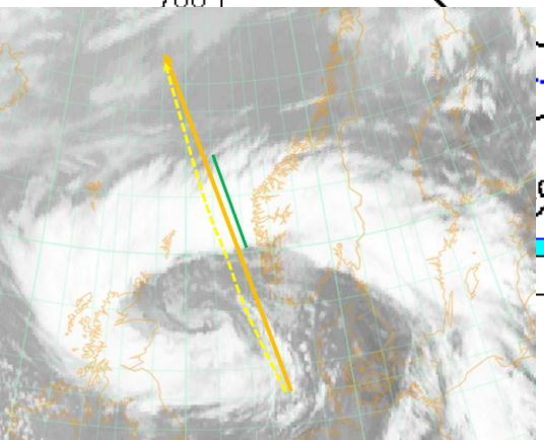
convergence zone in the WF part and lower parts of isentropic trough, divergence above
upward motion within isentropic trough

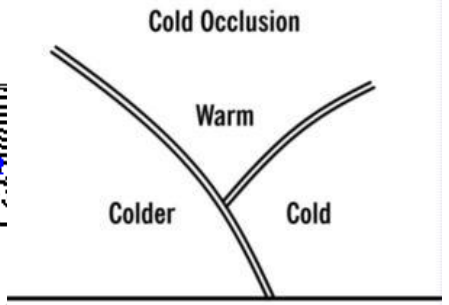
11 August 2014/06 UTC VCS Line omega (upward motion solid)

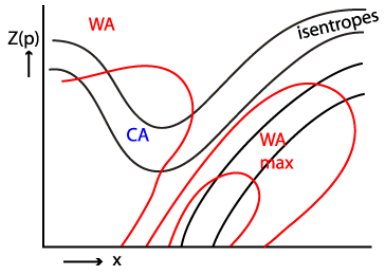




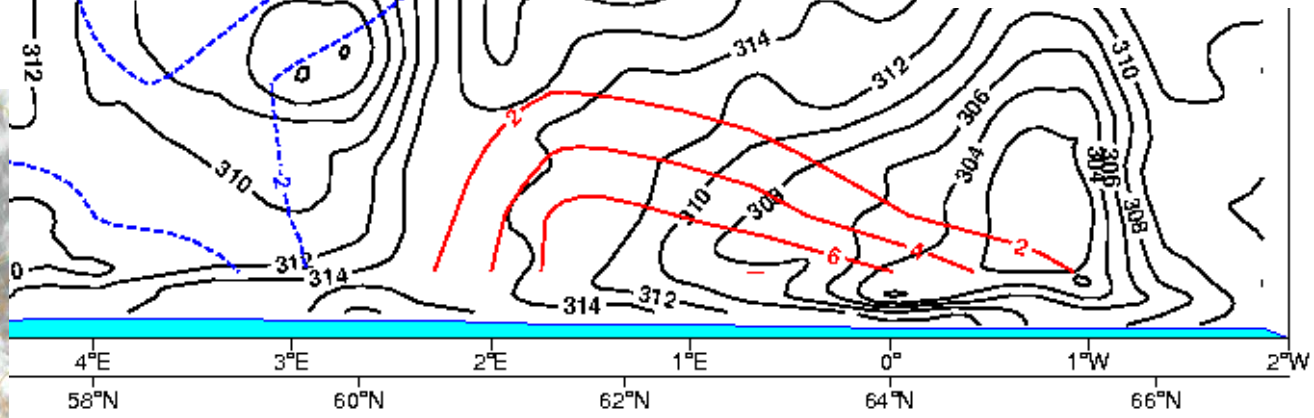
11 August 2014/06 UTC temperature advection: WA – CA (red – blue)



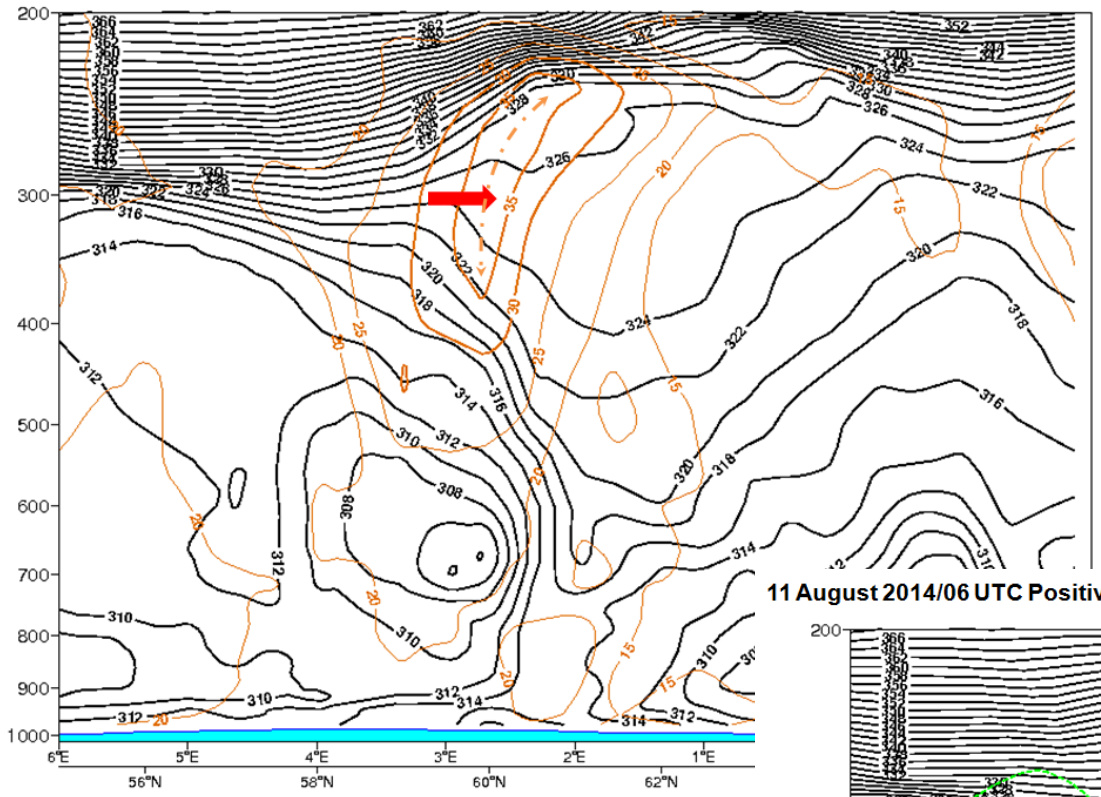


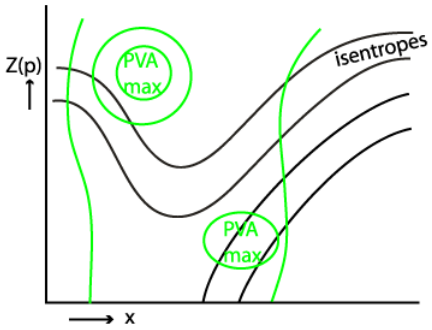


isentropic trough at occl cloud band (represents warm air)
WF zone in lower layers (in case of WF occl)
WA max in the WF area and leading part of occl isentropic trough
CA behind and above isentropic trough



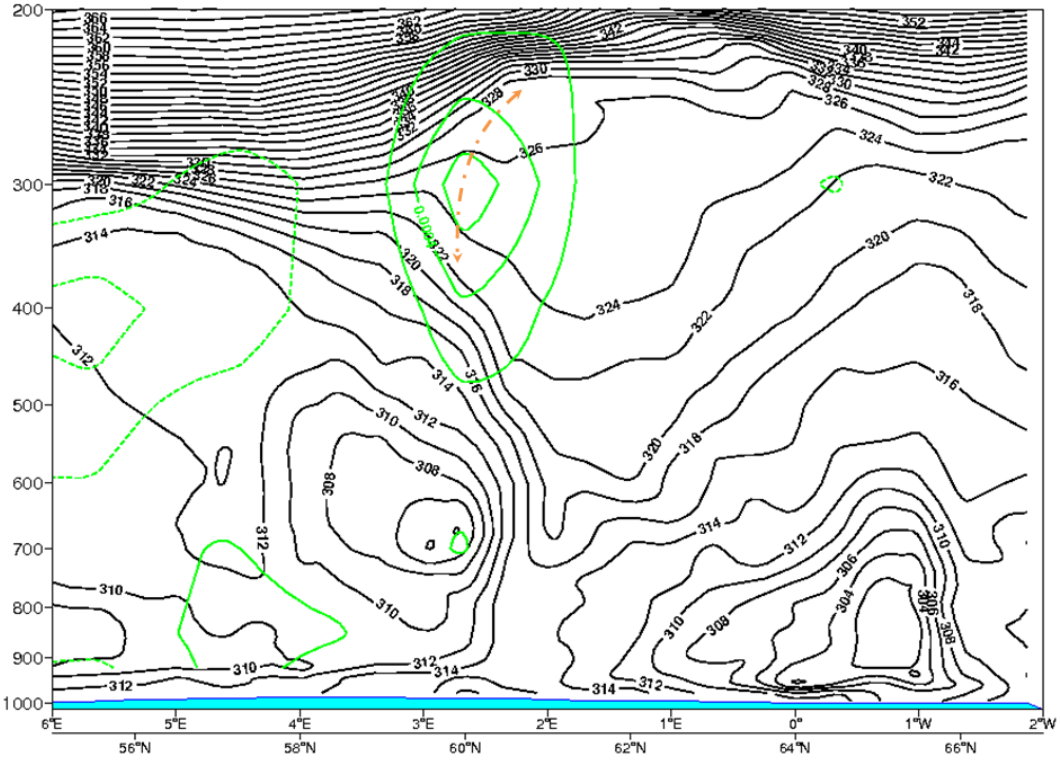
11 August 2014/06 UTC isotachs

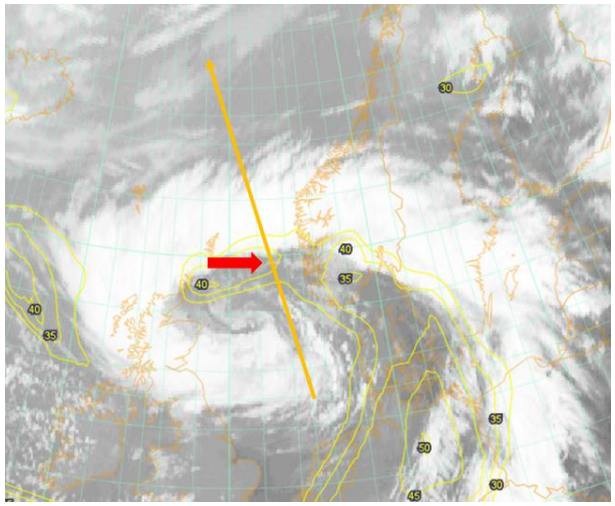




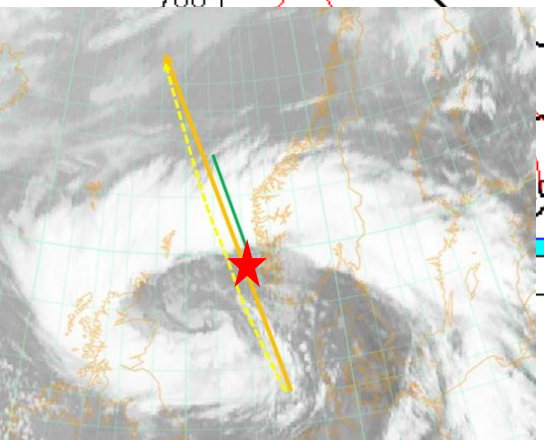
Upper level PVA max at the rear of the isentropes trough (upper air feature);
PVA max at low levels in front of the isentropic trough (movement of surface low)

11 August 2014/06 UTC Positive vorticity advection PVA (solid)





11 August 2014/06 UTC Potential Vorticity (PV) >2 PV units: stratospheric air mass (heavy solid)

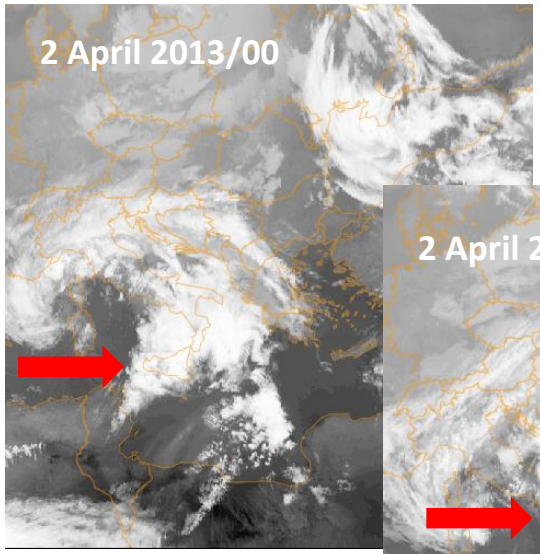


200
300
400
500
600
700

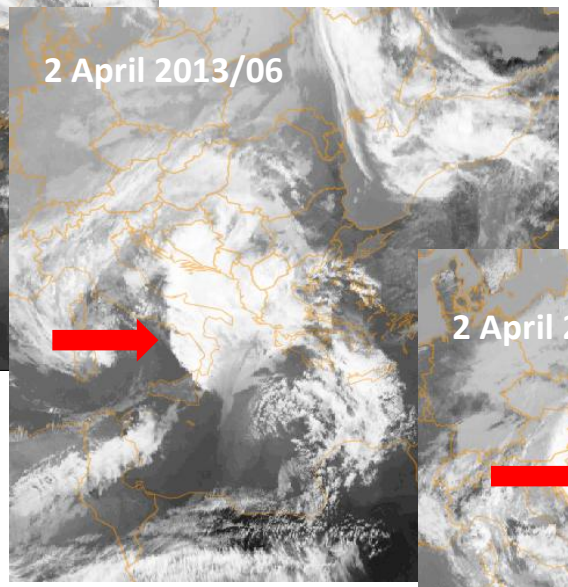
4°E 3°E 2°E 1°E 0° 1°W 2°W

58°N 60°N 62°N 64°N 66°N

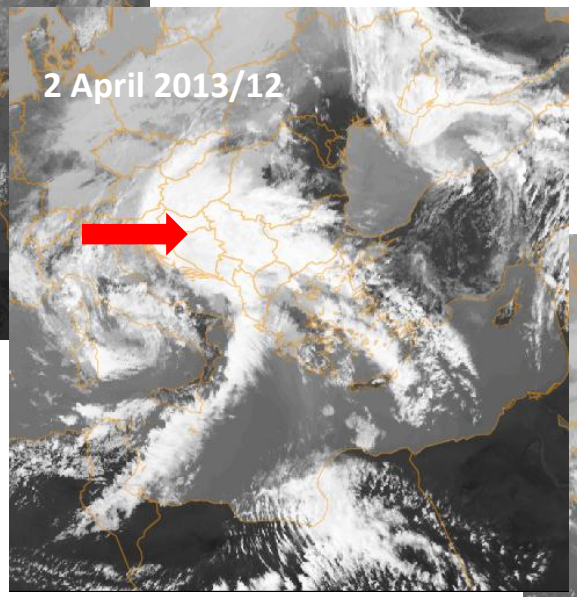
Deeper insight in upper level parameters: WCB type



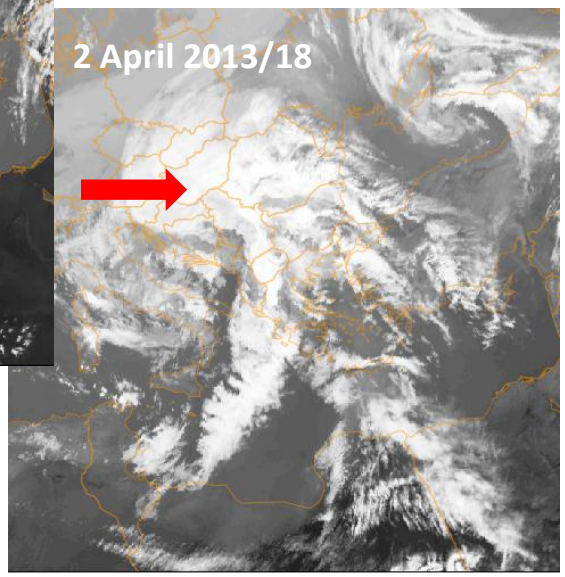
Wave



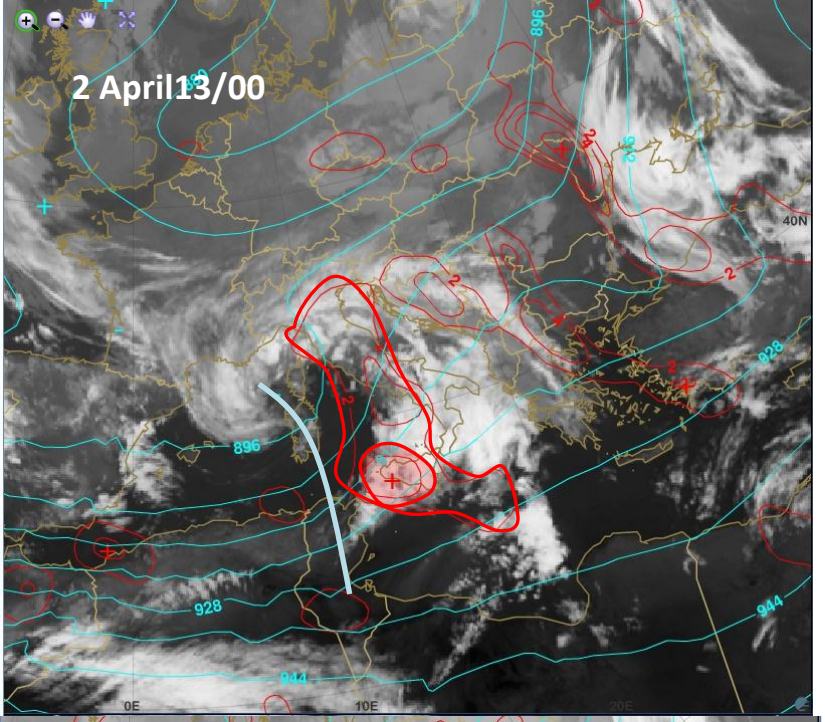
Developed Wave

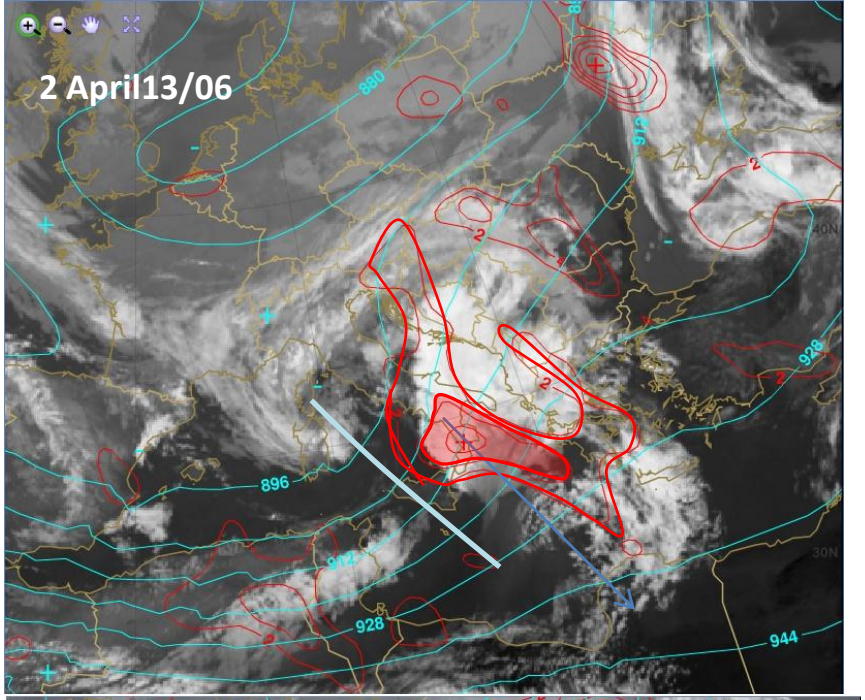


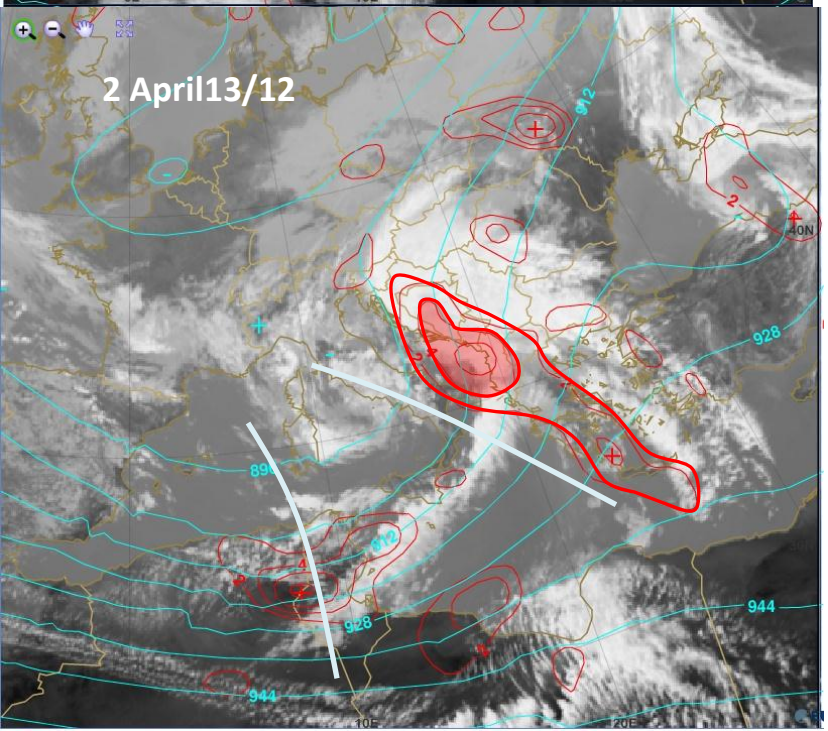
Occlusion

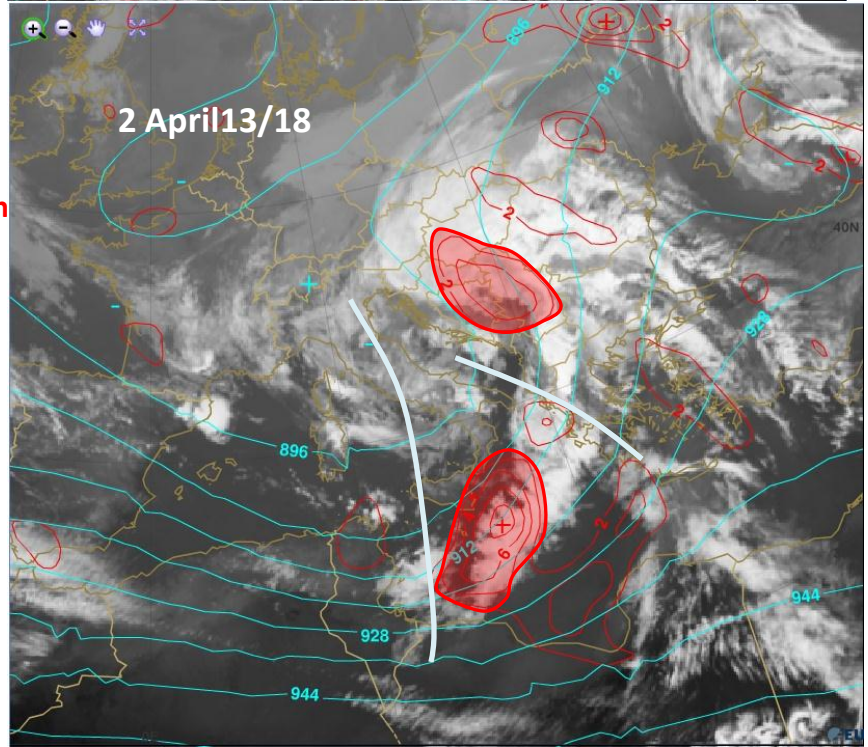


Developed Occlusion









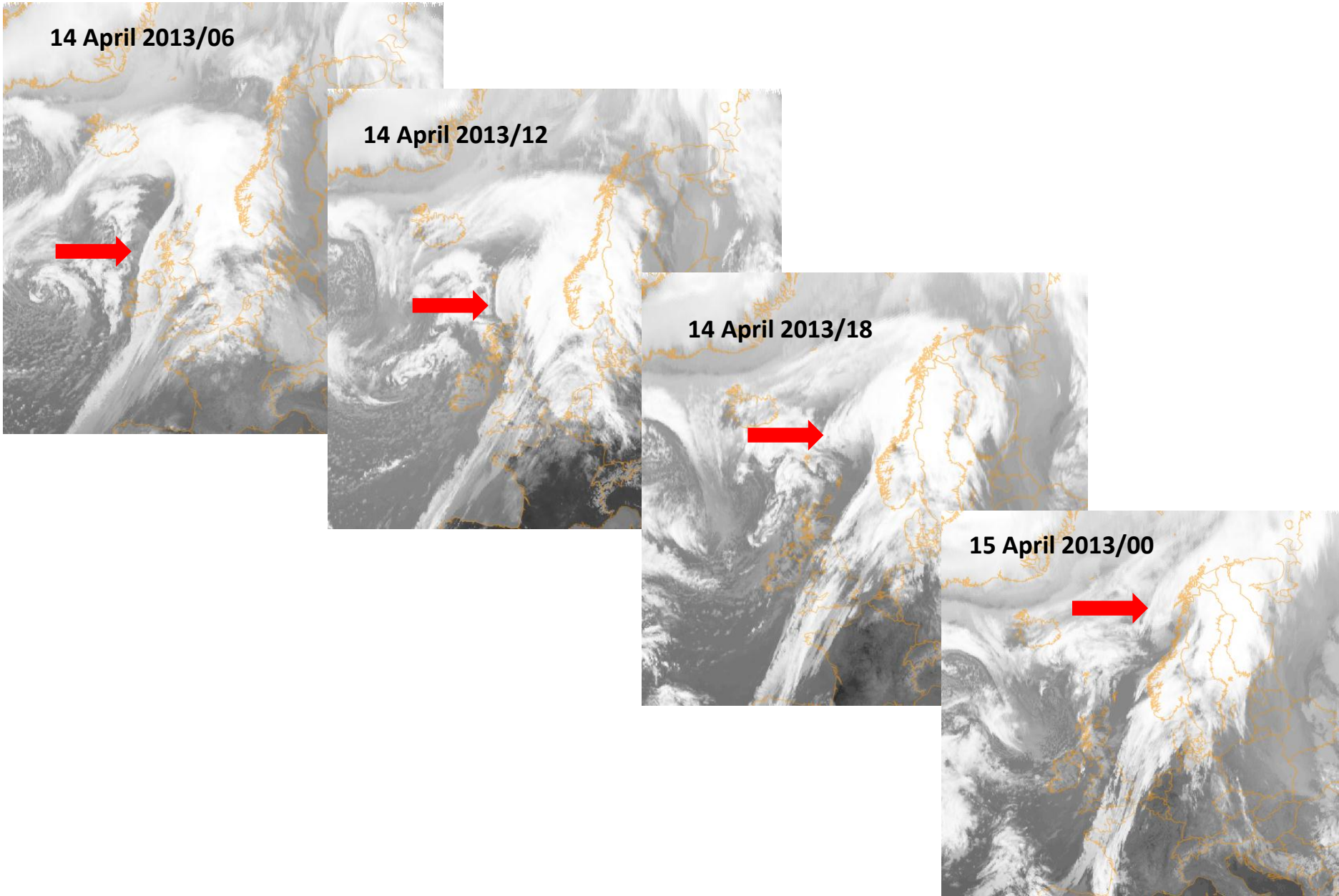
WCB type:

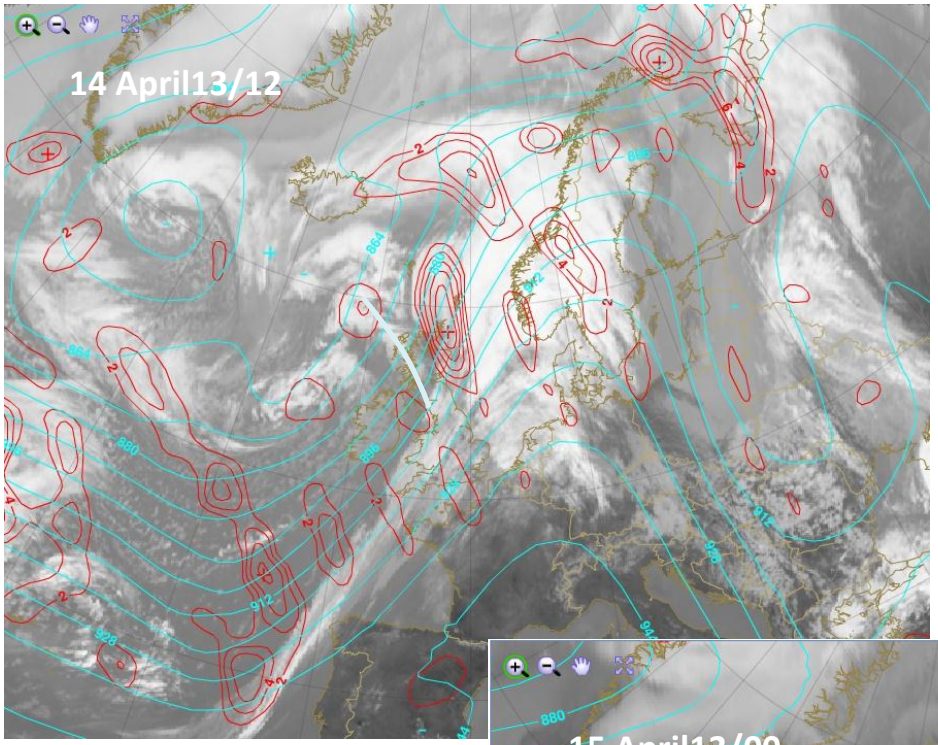
Upper level Trough 300 hPa + PVA 300hPa

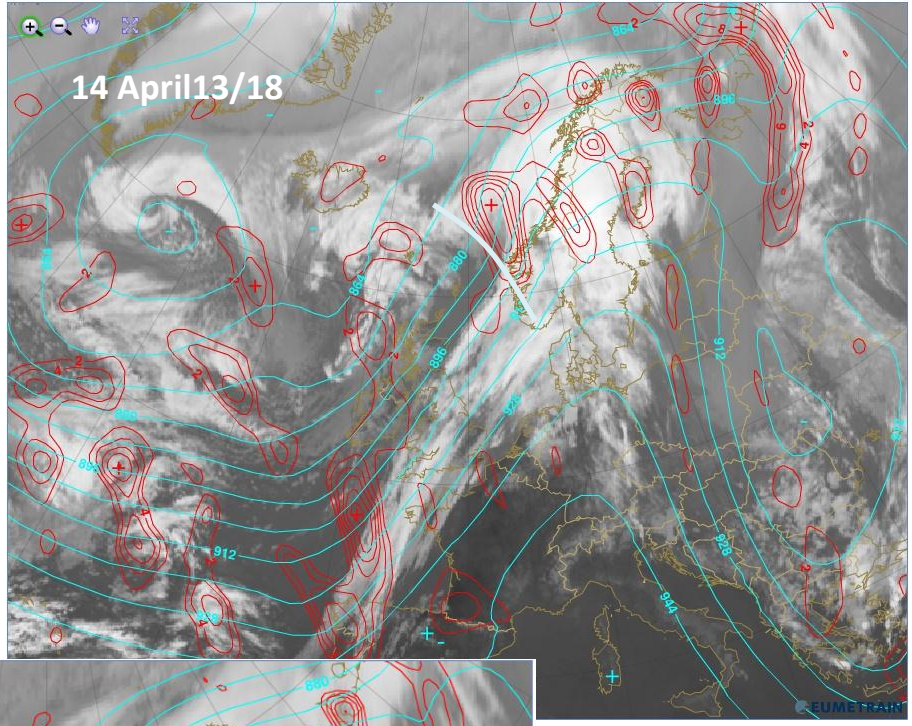
Distinct PVA maxima in area of WCB occlusion development

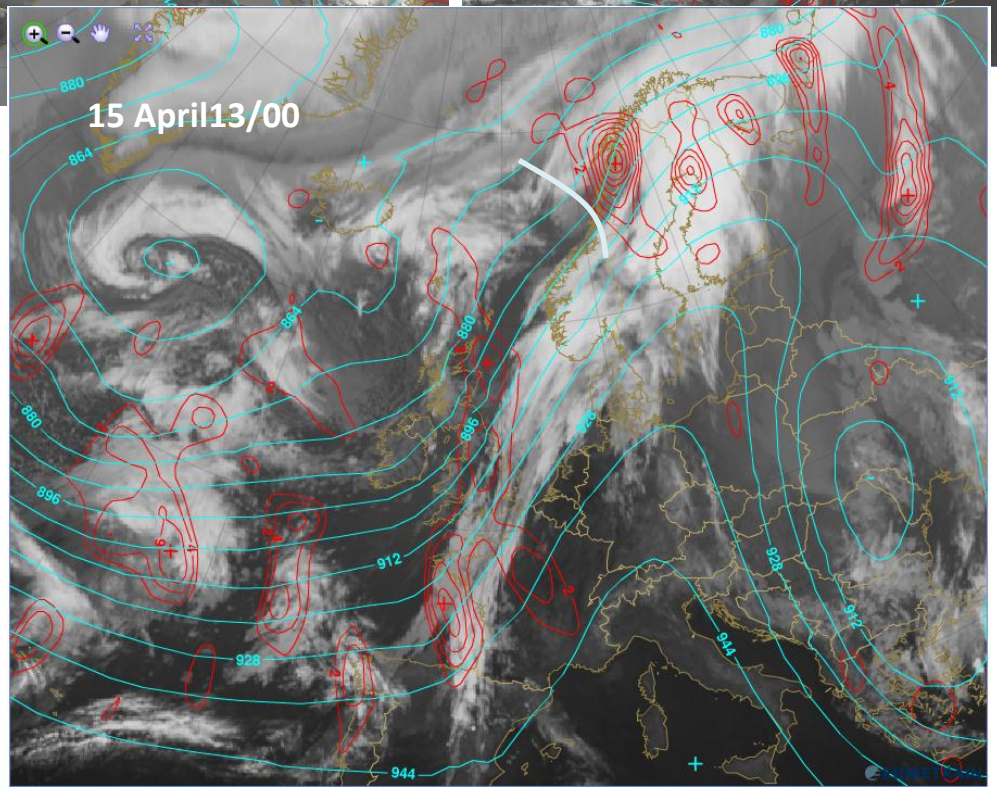
Why at this Position?

Deeper insight in upper level parameters: CCB type









CCB type:

Upper level
Trough 300 hPa
+
PVA 300 hPa

Distinct PVA max
in area of
CCB occlusion
development

Why so
Intensive ?

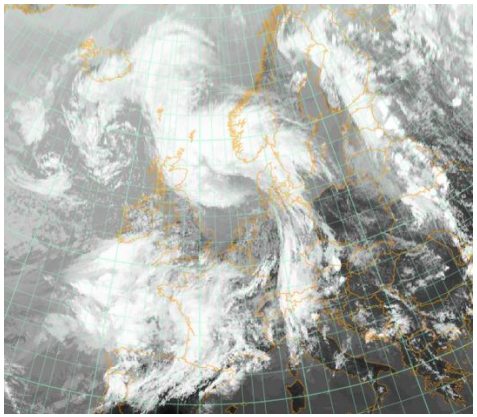
Topics to be added

- Role of upper levels
  - Role of vorticity advection (PVA, NVA)
  - Role of jet and jet streaks (Uccellini)
  - Role of Potential Vorticity (PV) (Hoskins)

Enough for today!

Homework:

- Go to EUMeTrain e-port
- Look into the case of 9 August 2014/12UTC
- Take the ppt in the course page as basis for your work



- 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!
See you on Thursday!