The Sting Jet Hypothesis: A Case Study with the Cosmo-Model

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JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Objectives

- **Introduction to the Sting Jet Hypothesis**

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Observational investigation of the Great Storm from October 1987 from K. A. Browning

(Browning K.A., 2004, *Q.J.R.Meteorol. Soc*.)

Investigation of the 3-D Structure of the Sting Jet with a high-resolution NWP-Model

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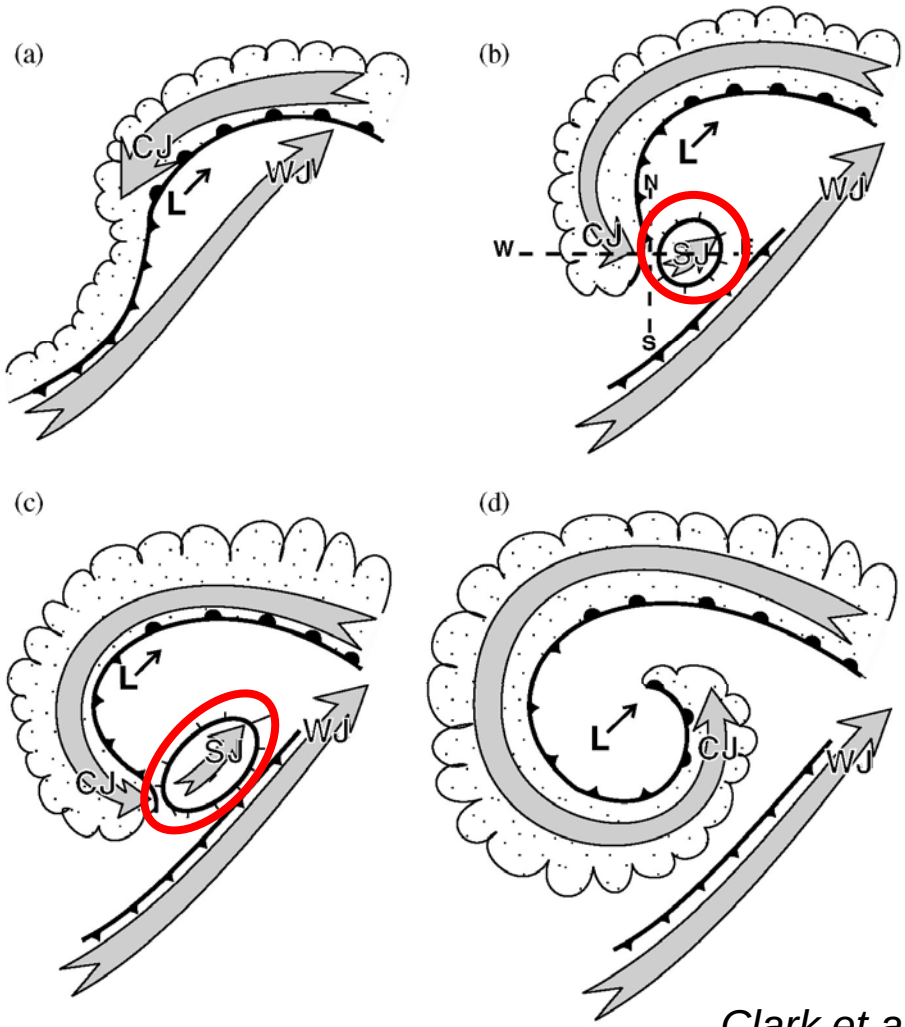
  Does the Cosmo-Model produce a SJ – structure?

  If so, investigation the origin of the Sting Jet

The Sting Jet Hypothesis

Detailed analysis of observations and high resolution model simulations lead to the concept of the sting phenomenon.



SJ appears while the cold front fractures from the warm front.

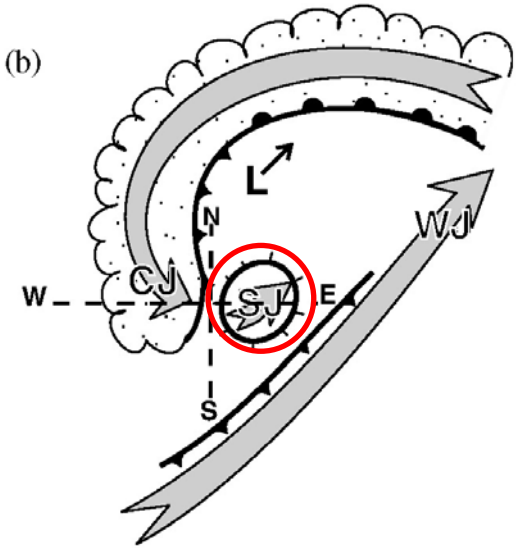
Pocket of SJ air is located within the dry slot near the tip of the cloud head.

The SJ is the region with the most damaging surface gusts.

The sting at the end of the tail!

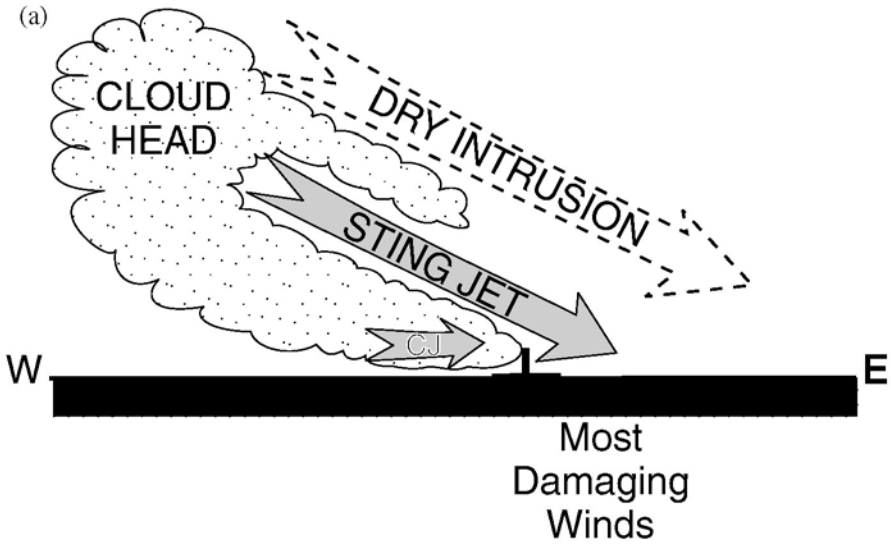
Clark et al., 2005

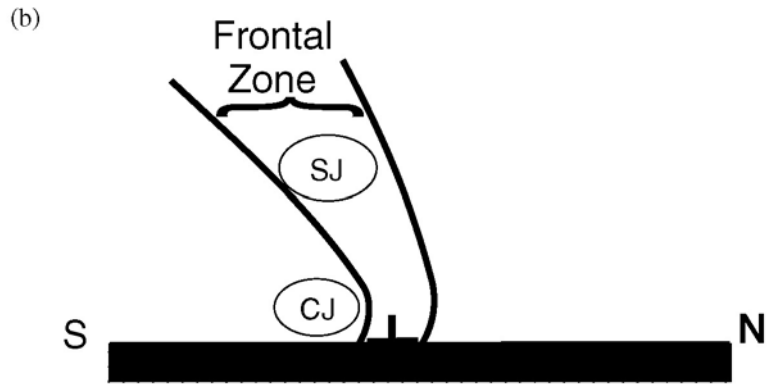
The Sting Jet Hypothesis



SJ originates within the cloud head where slantwise circulation exists.

The descent branch of this slantwise circulation may be enhanced by evaporative cooling and lead to the damaging strong surface winds.





Clark et al., 2005

Open Questions

Is the conceptual model representative for intense cyclones?

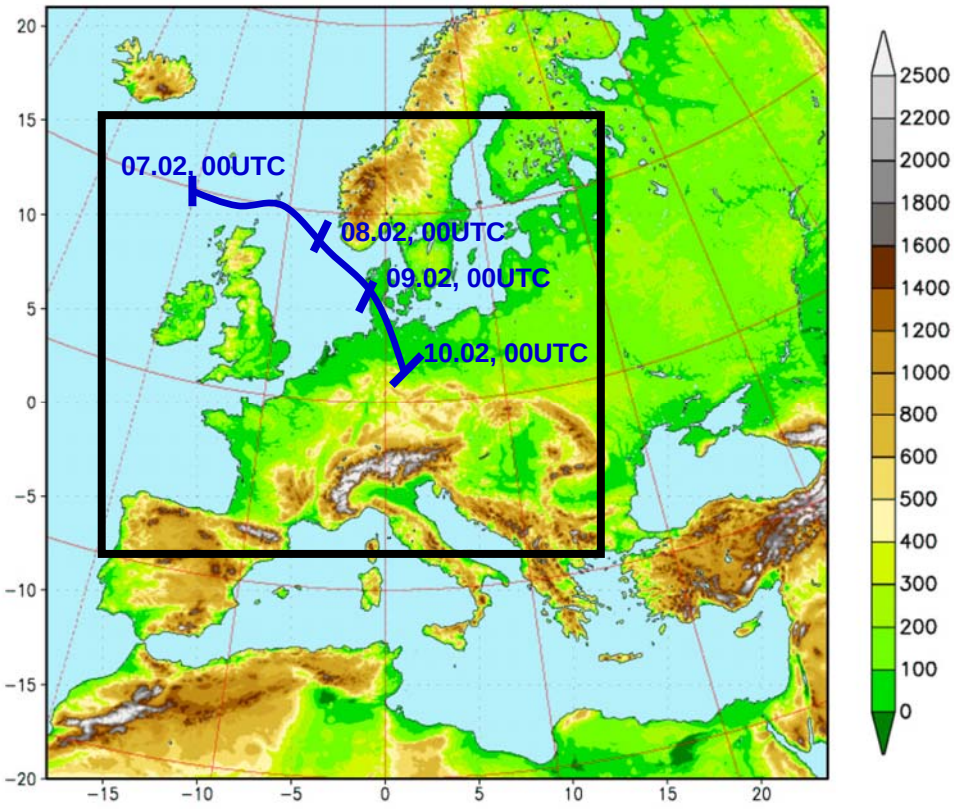
How important are sublimation/evaporation processes for the structure and the strength of the SJ?

-> Case study of the cyclone `Oili´ with the Cosmo-Model

Facts about `Oili´:

- Exists from 07 – 11 February 2006
- Origin north of Scotland, moves over North Sea and Germany
- Pressure decrease 25 hPa within 24 hours (fulfilles the `bomb criterion´ of Sanders & Gyakum)
- Strong snowfall over Central Europe
- Heavy surface wind gusts (>30 m/s)

Orography of the Cosmo-Model Domain

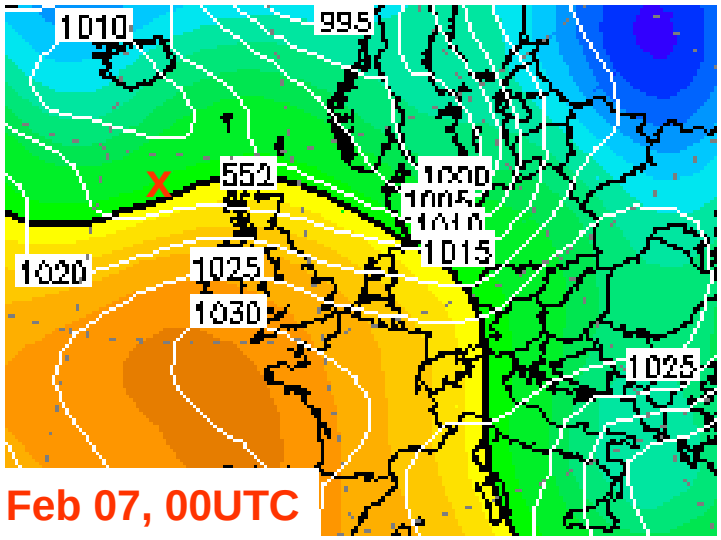


- Version 3.21
- 7km horizontal resolution
- 40 vertical layers
- Time step: 40s
- Cloud ice scheme
- Domain shifted NW to Cosmo-Domain 2

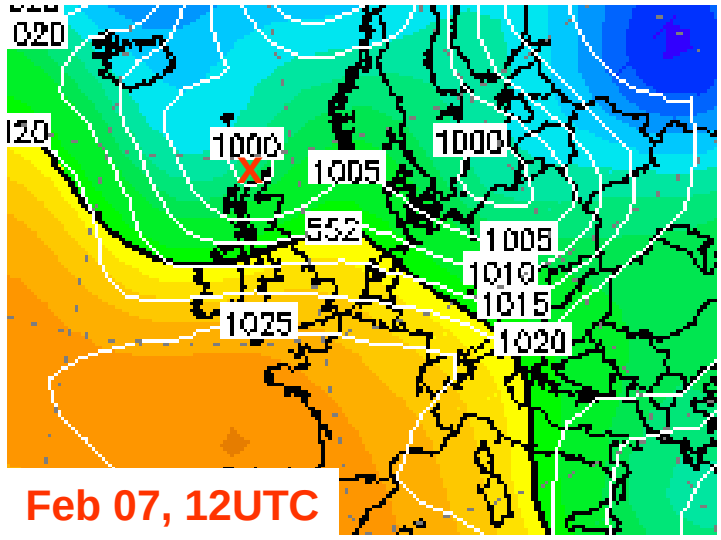
Simulations are started at 07 February 2006 at 00UTC, boundary and initial conditions from ECMWF analysis fields

The Cyclone Oili – Synoptic situation

500 hPa Geopotential (gpdm) and SLP (hPa), NCEP Reanalysis data



Feb 07, 00UTC



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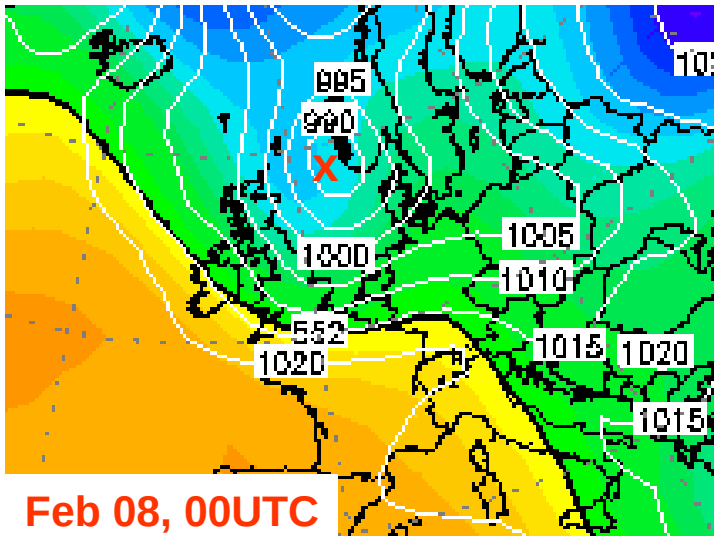

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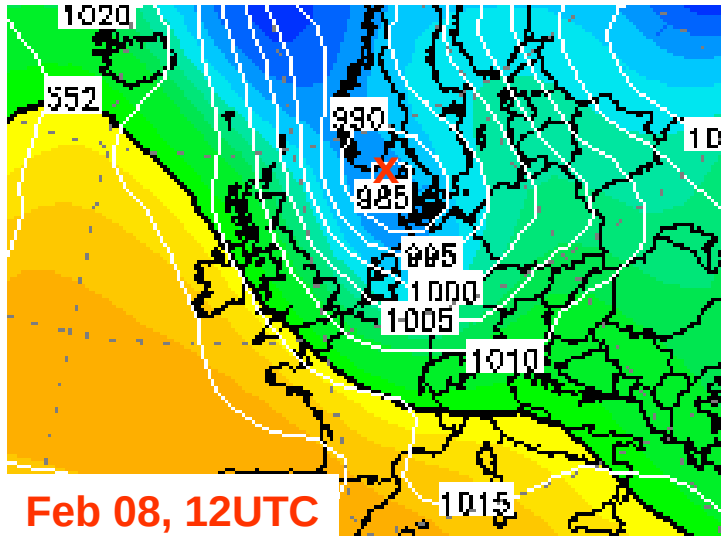

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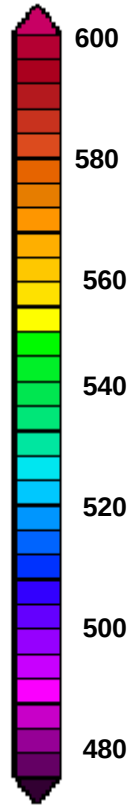
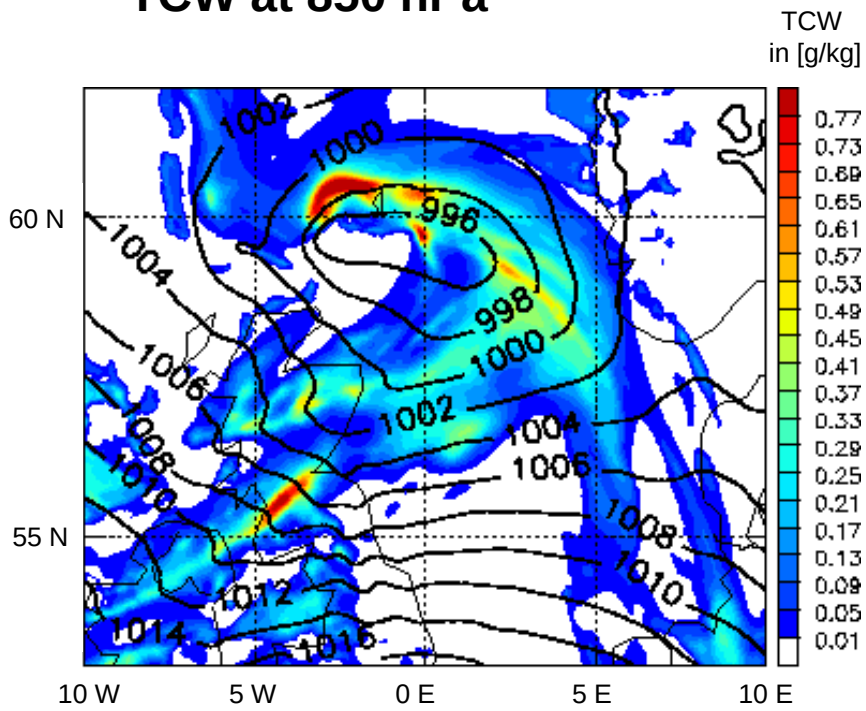


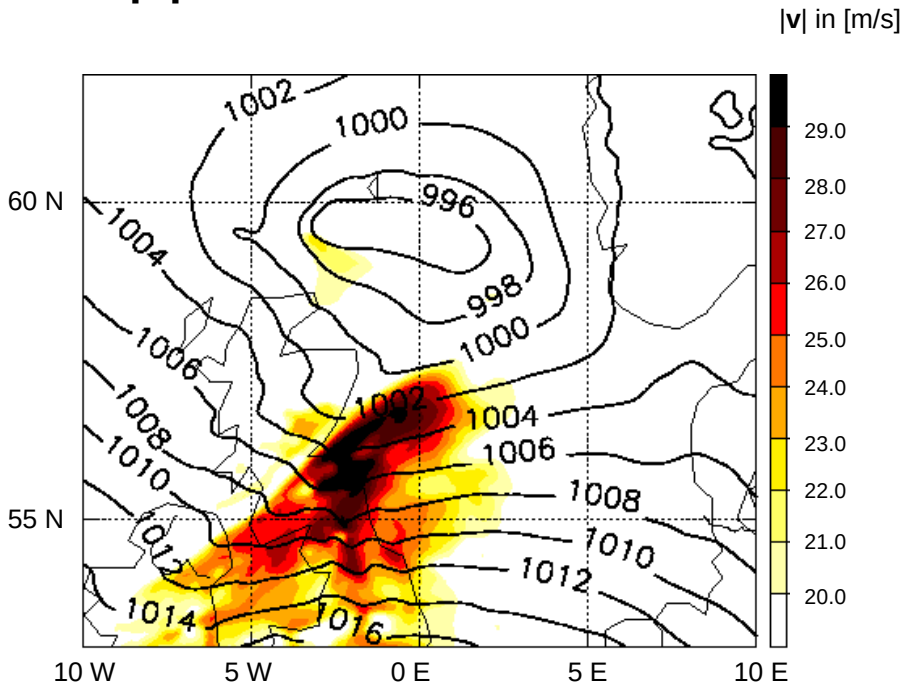
Model simulation of `Oili´

07 February 2006: 16 UTC

TCW at 850 hPa



|v| at 900 hPa



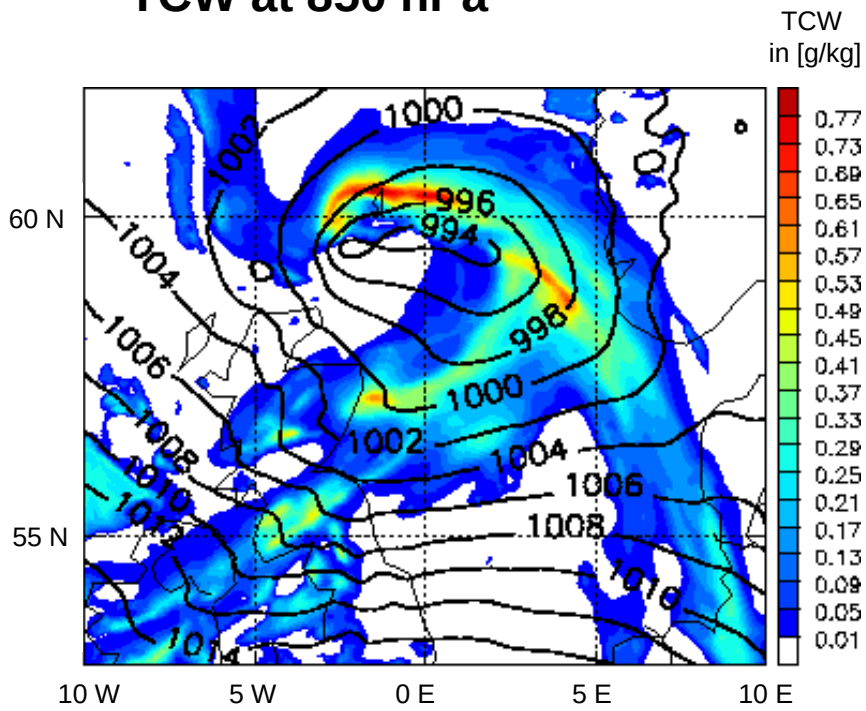
Total Condensed Water (TCW):
Sum of 4 hydrometeor mixing ratios for cloud water, cloud ice, rain and snow

|v| : absolute value of horizontal wind velocity

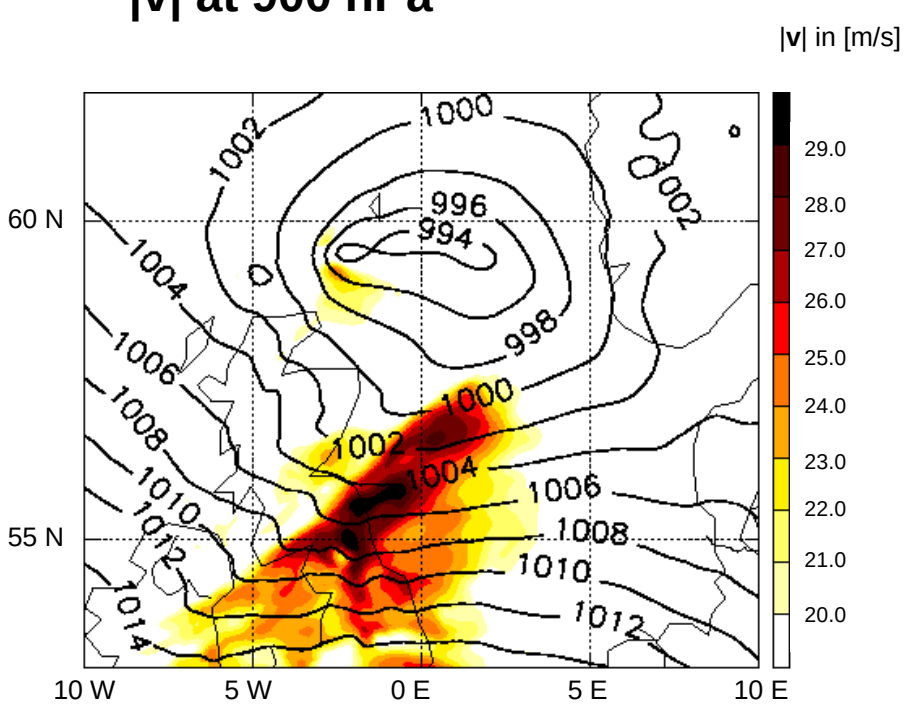
Model simulation of `Oili´

07 February 2006: 17 UTC

TCW at 850 hPa



|v| at 900 hPa



Total Condensed Water (TCW):
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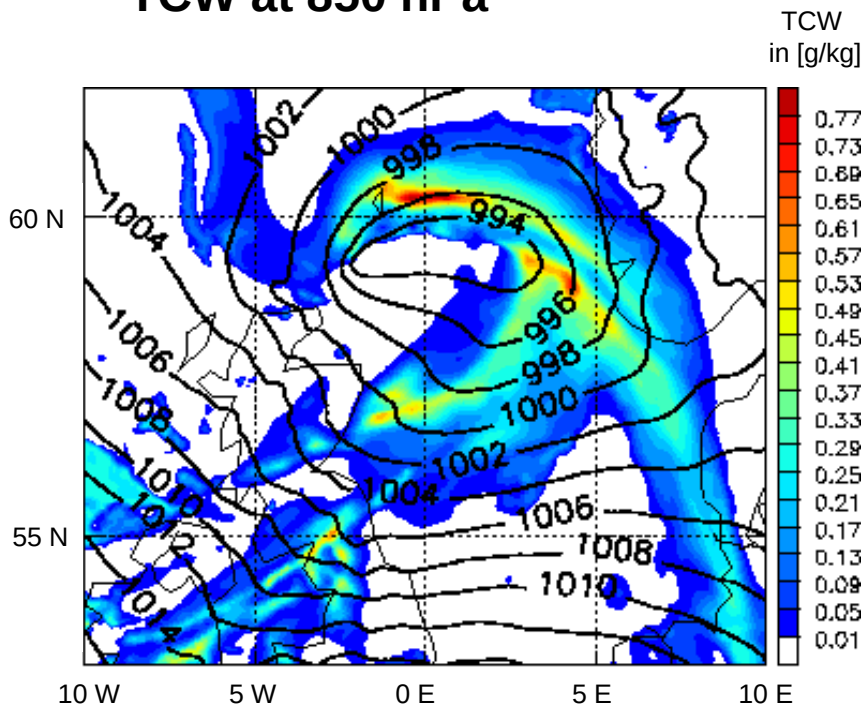
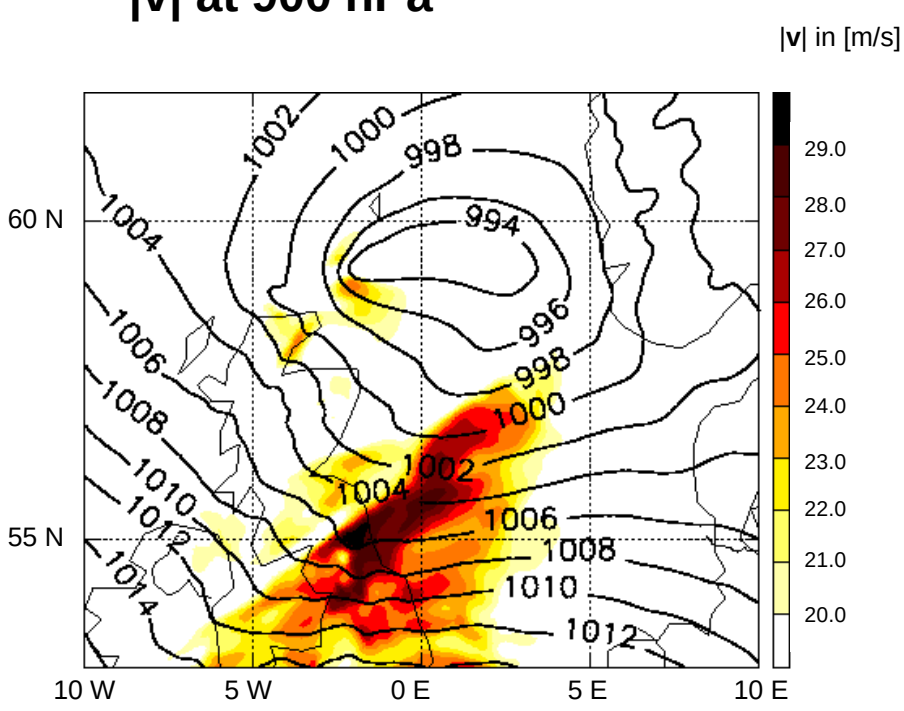
Model simulation of `Oili´

07 February 2006: 18 UTC

TCW at 850 hPa



|v| at 900 hPa



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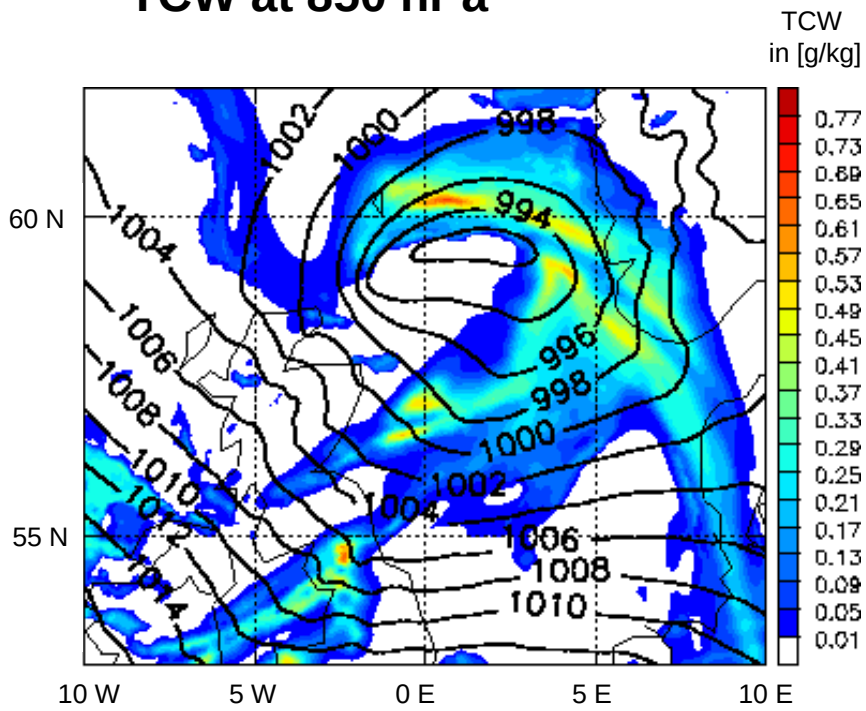
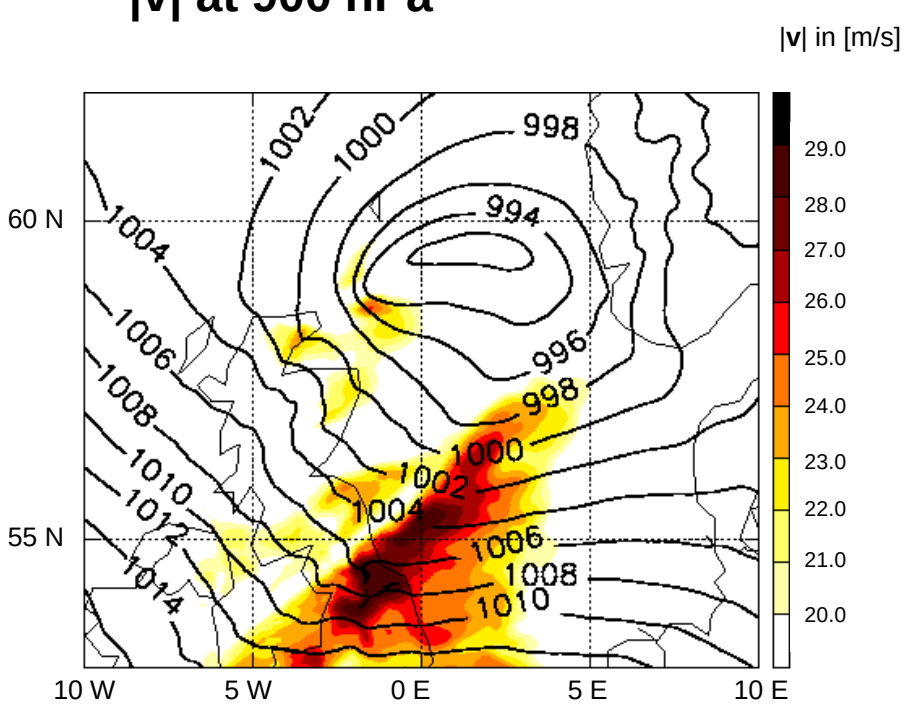
Model simulation of `Oili´

07 February 2006: 19 UTC

TCW at 850 hPa



|v| at 900 hPa



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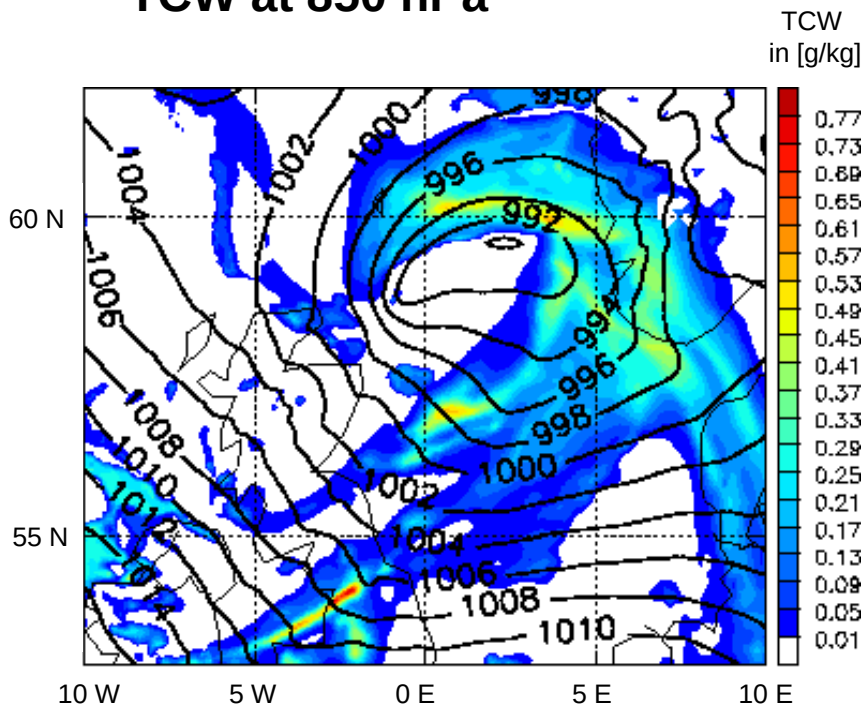
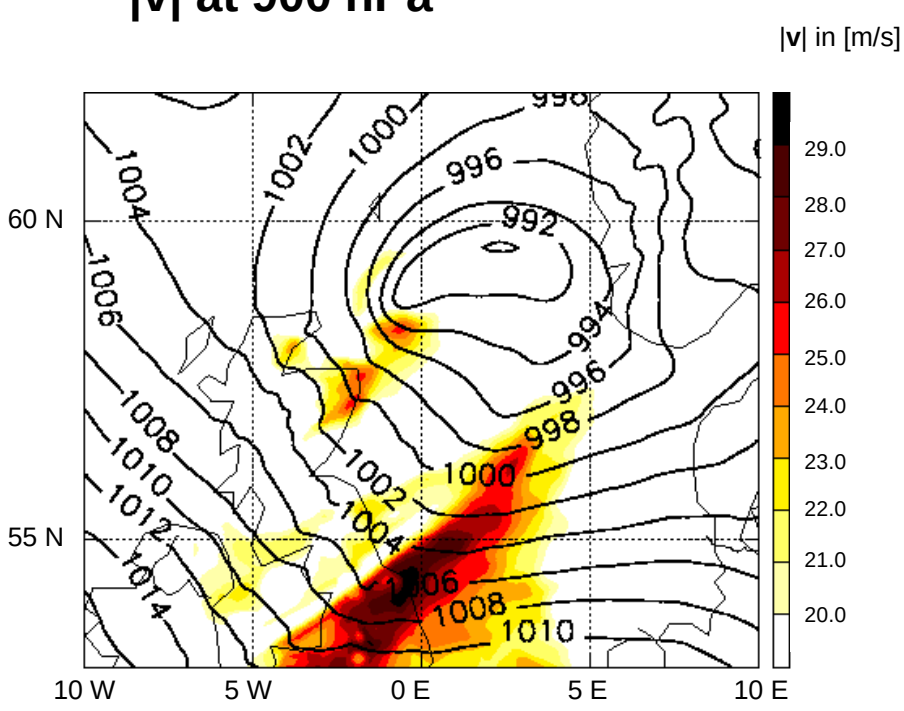
Model simulation of `Oili´

07 February 2006: 20 UTC

TCW at 850 hPa



|v| at 900 hPa



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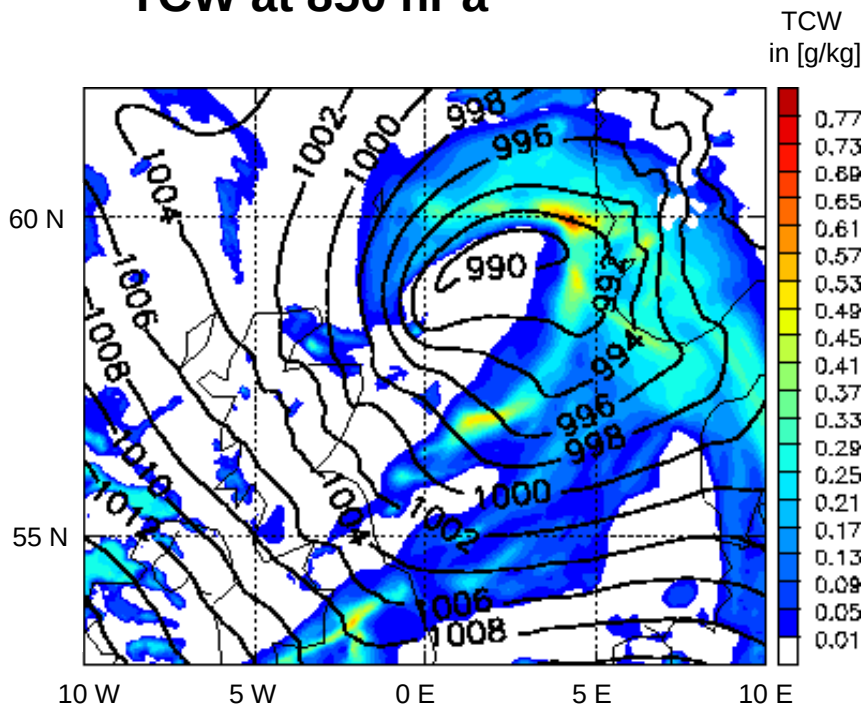
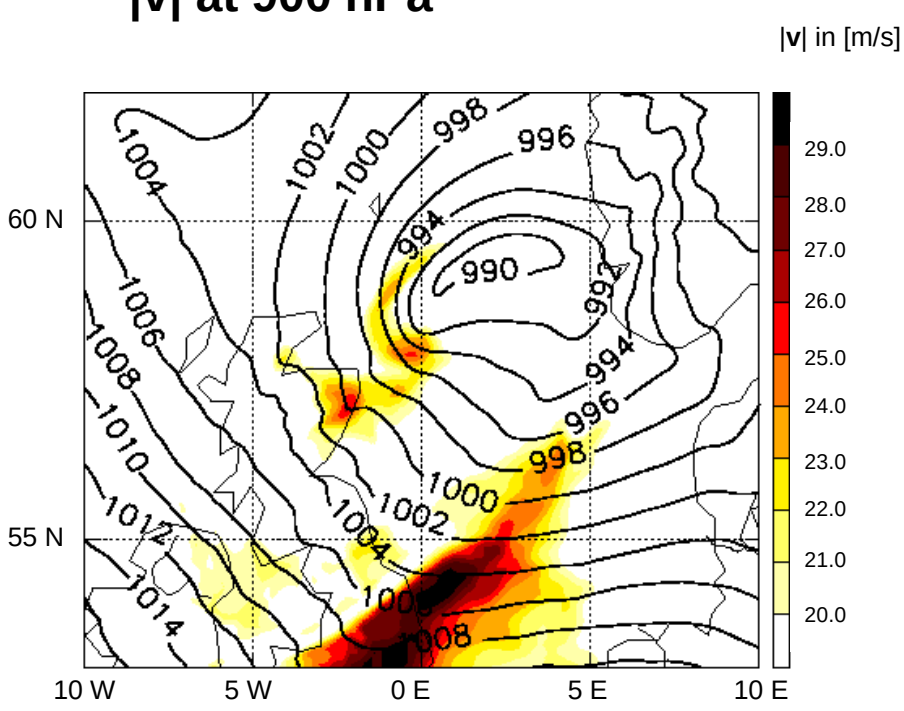
Model simulation of `Oili´

07 February 2006: 21 UTC

TCW at 850 hPa



|v| at 900 hPa



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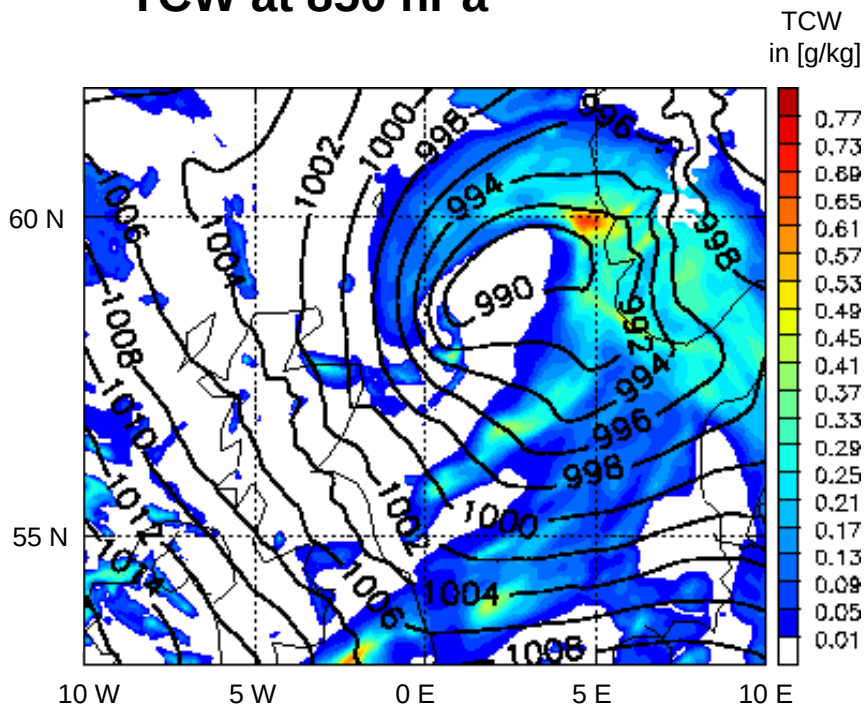
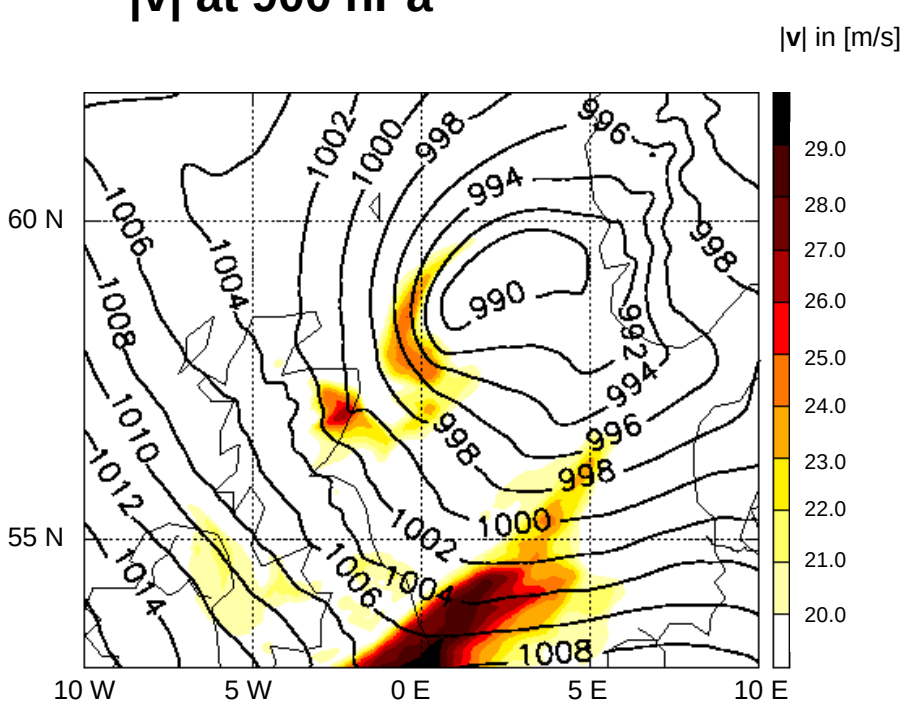
Model simulation of `Oili´

07 February 2006: 22 UTC

TCW at 850 hPa



|v| at 900 hPa



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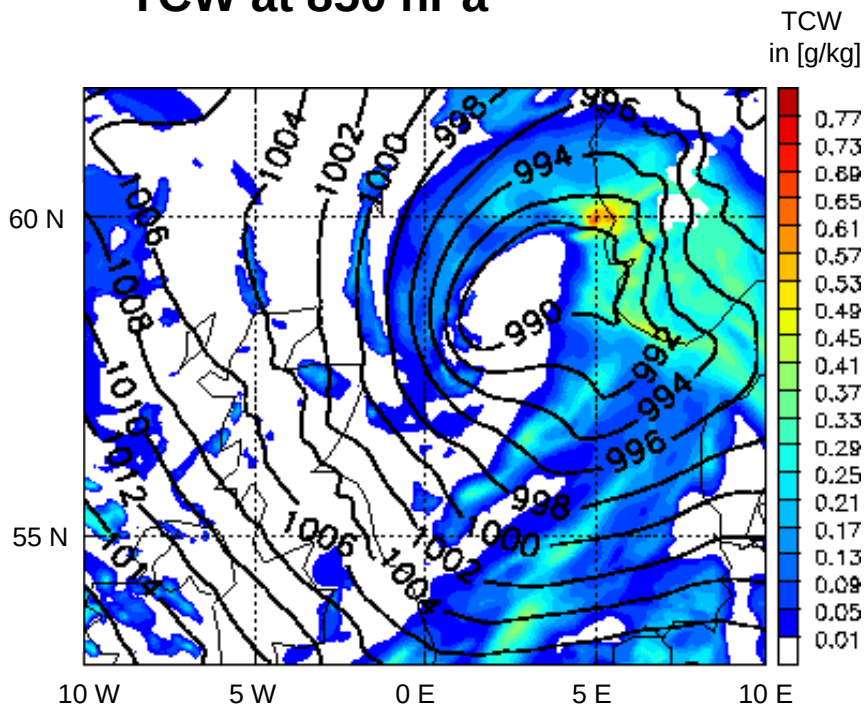
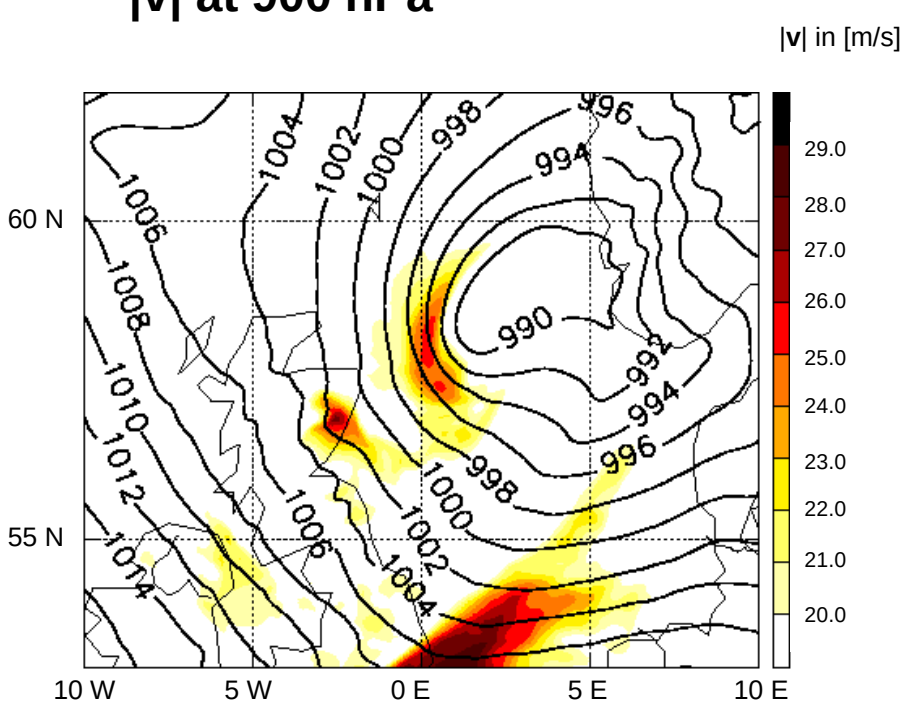
Model simulation of `Oili´

07 February 2006: 23 UTC

TCW at 850 hPa



|v| at 900 hPa



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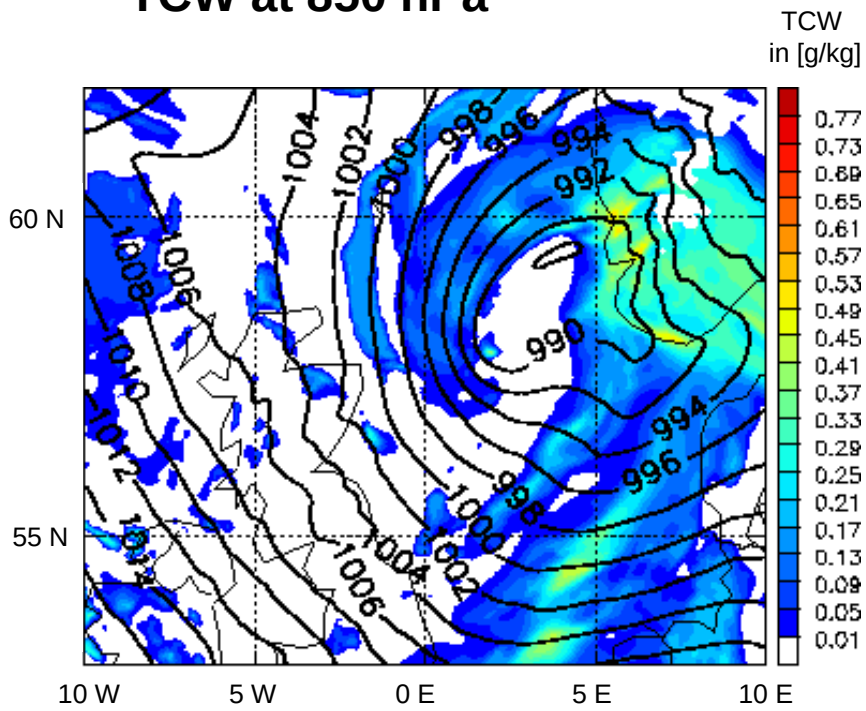
Model simulation of `Oili´

08 February 2006: 00 UTC

TCW at 850 hPa



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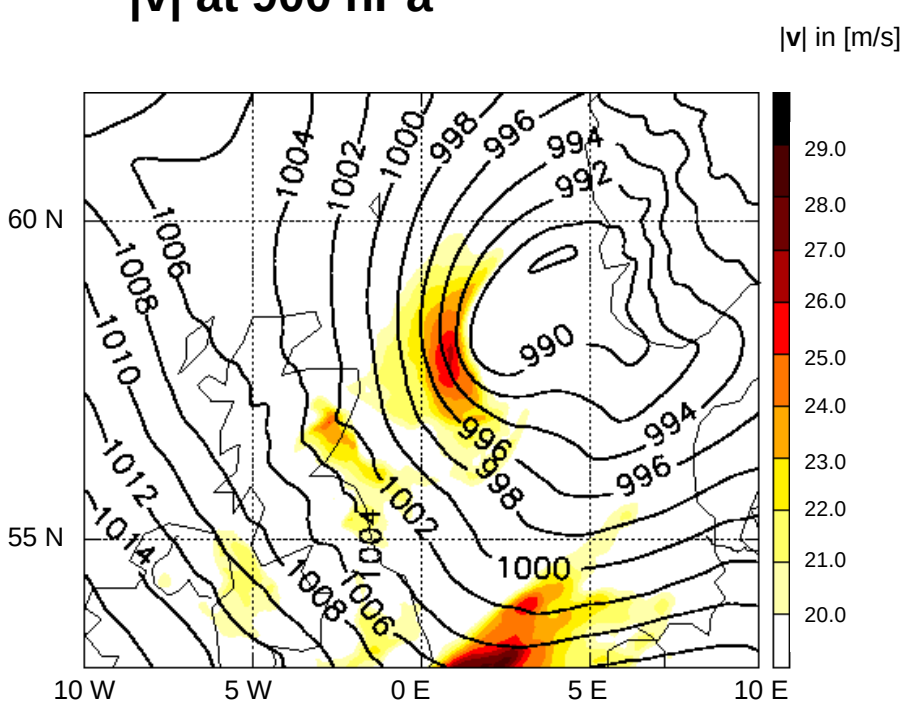

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08 February 2006: 01 UTC

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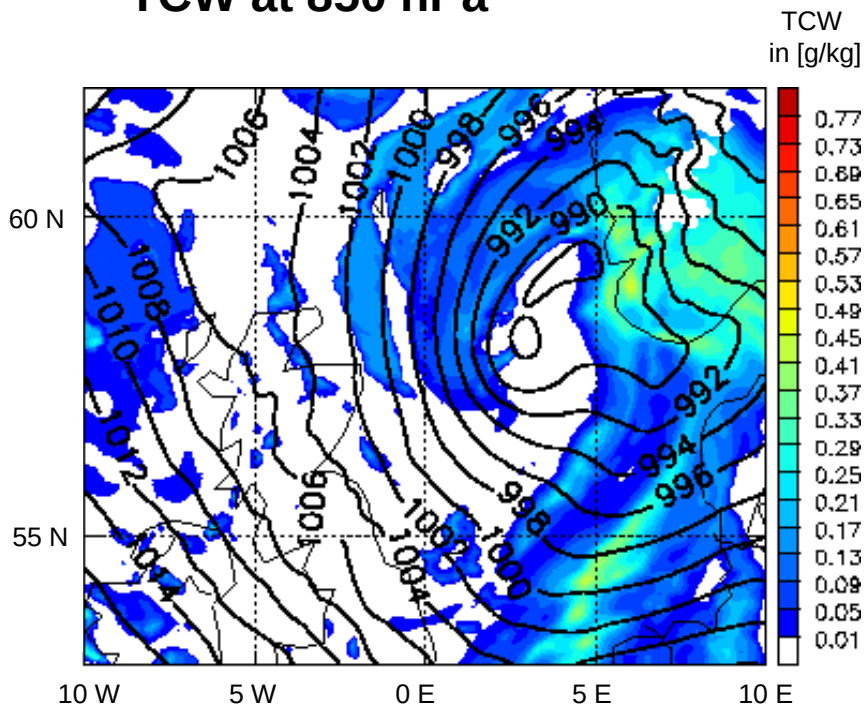

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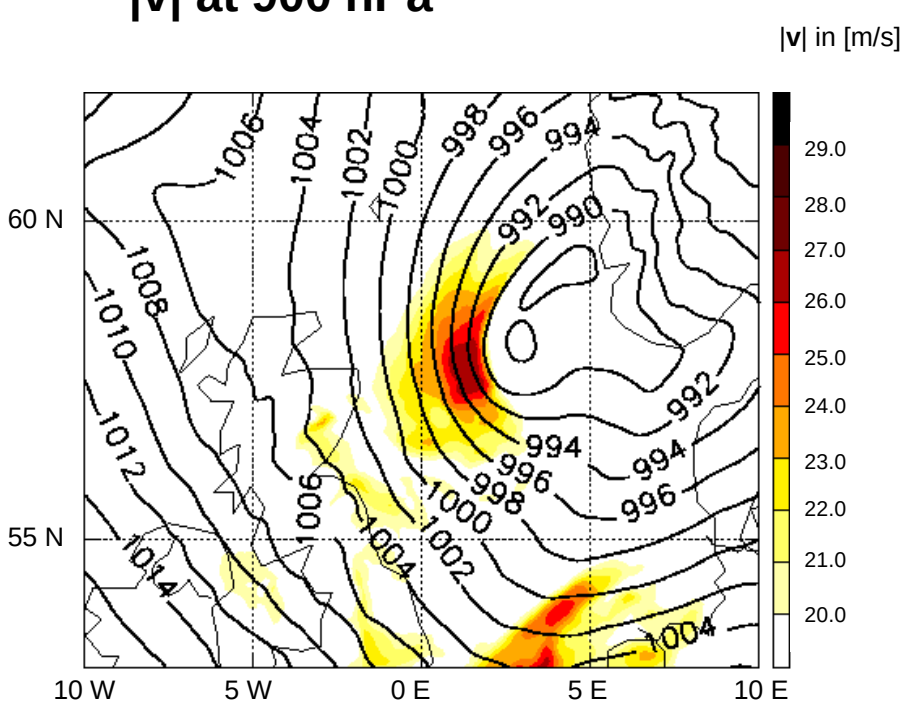

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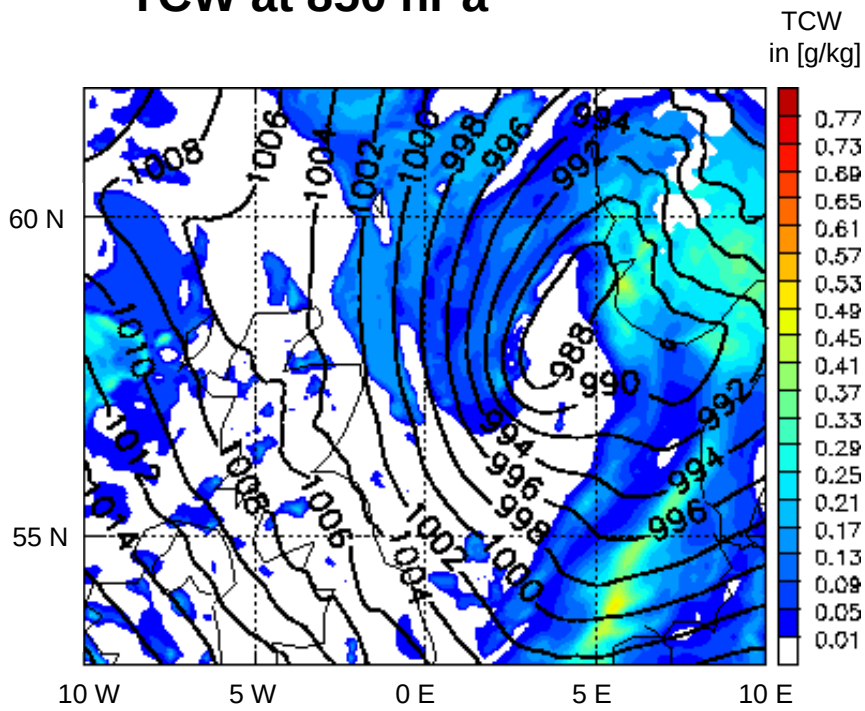
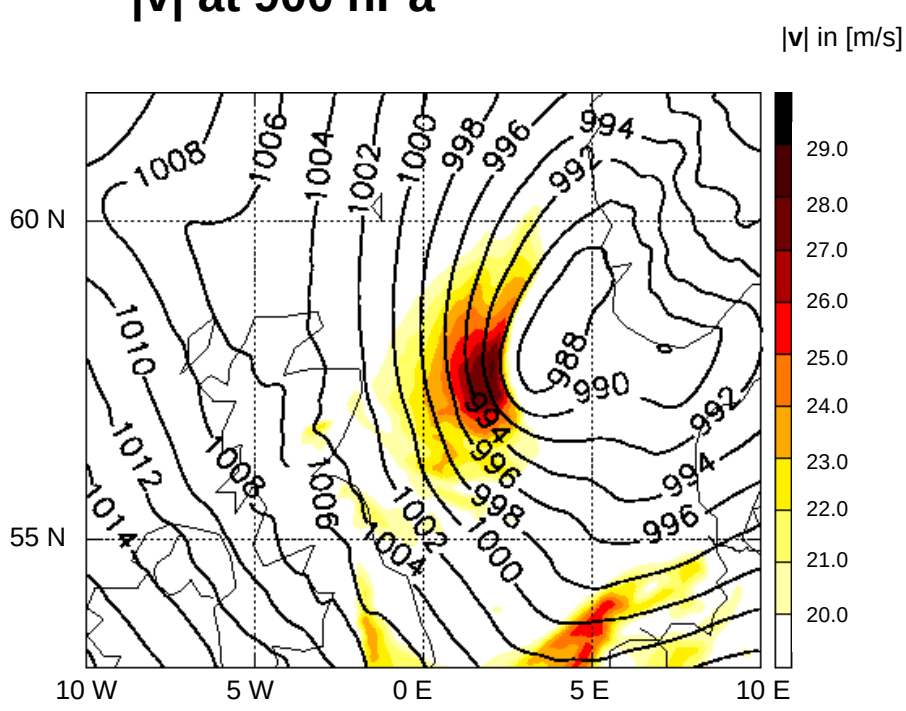
Model simulation of `Oili´

08 February 2006: 02 UTC

TCW at 850 hPa



|v| at 900 hPa



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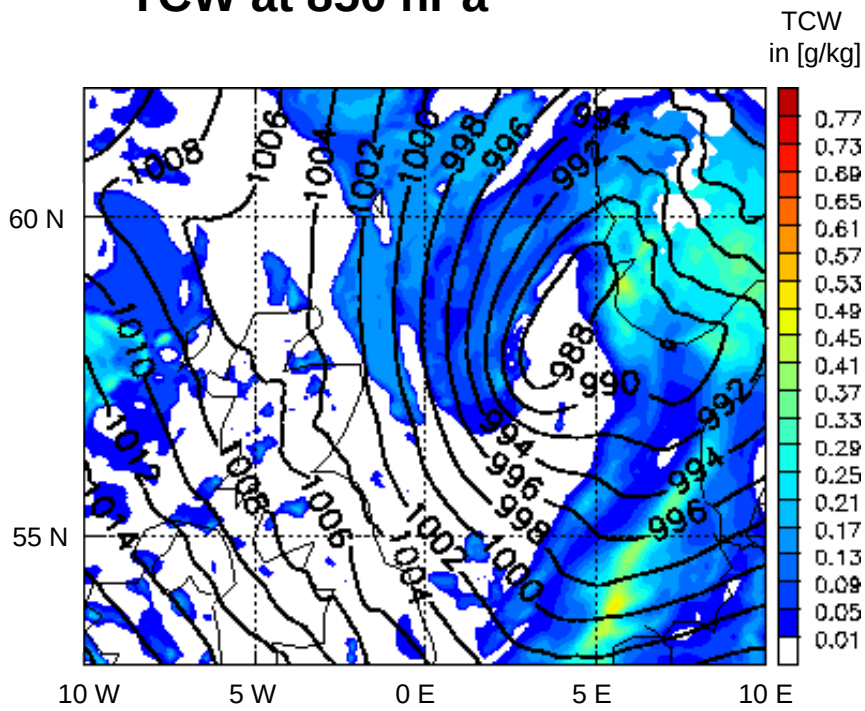

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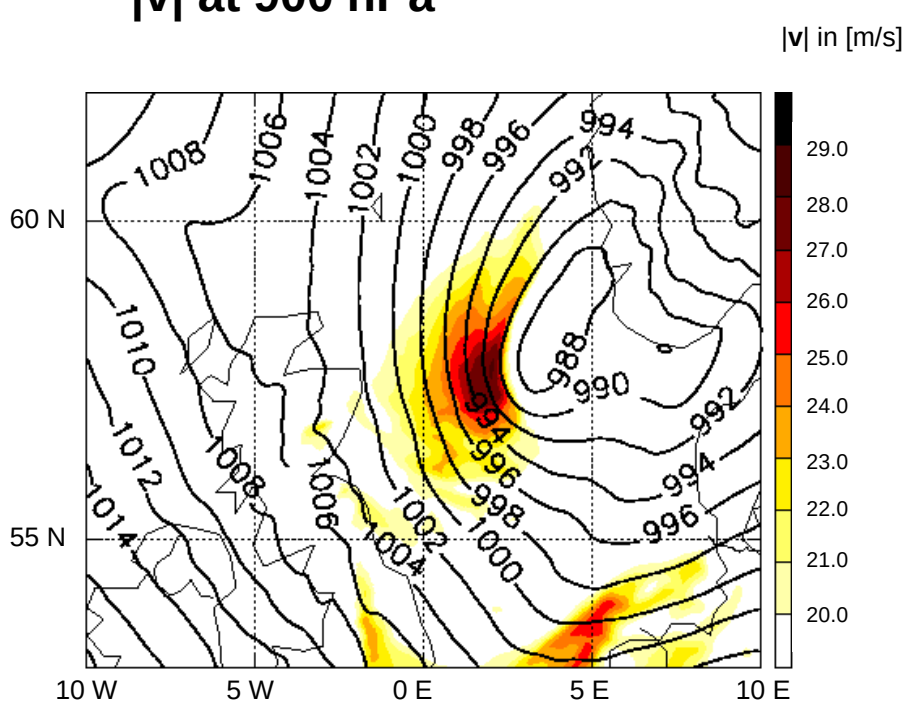

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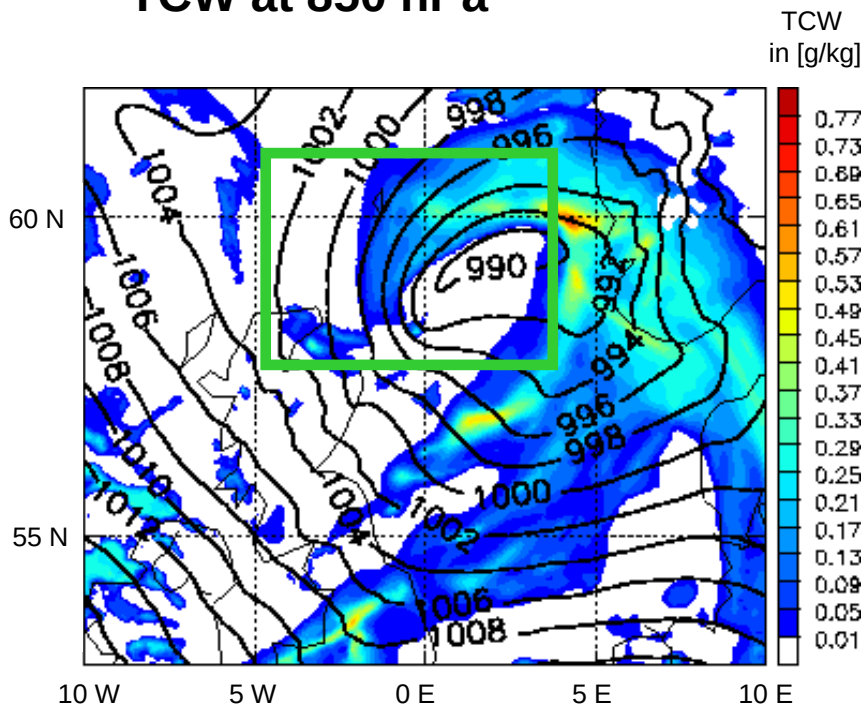

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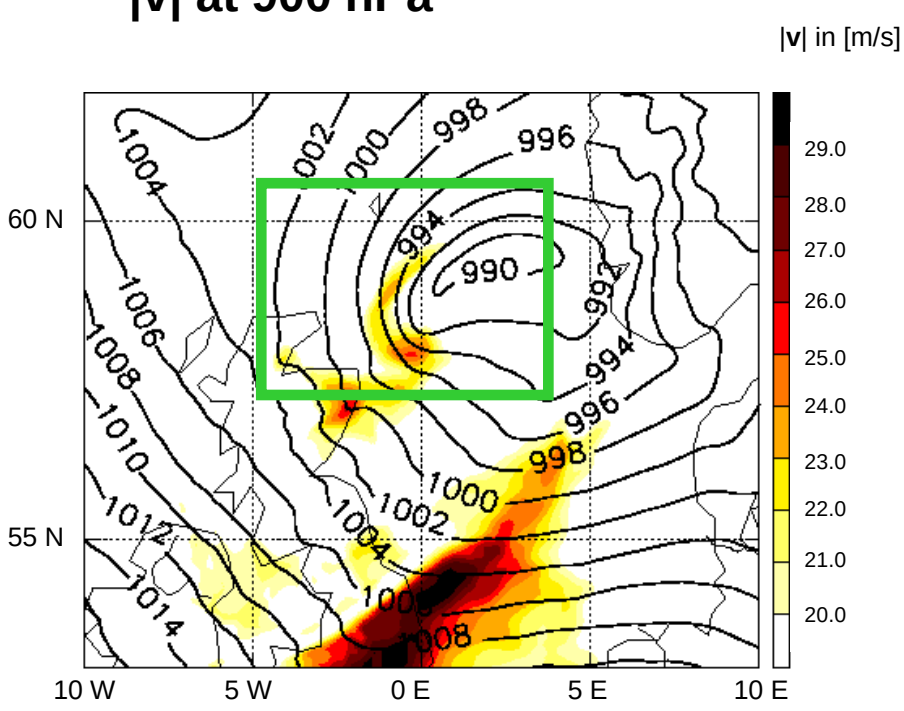

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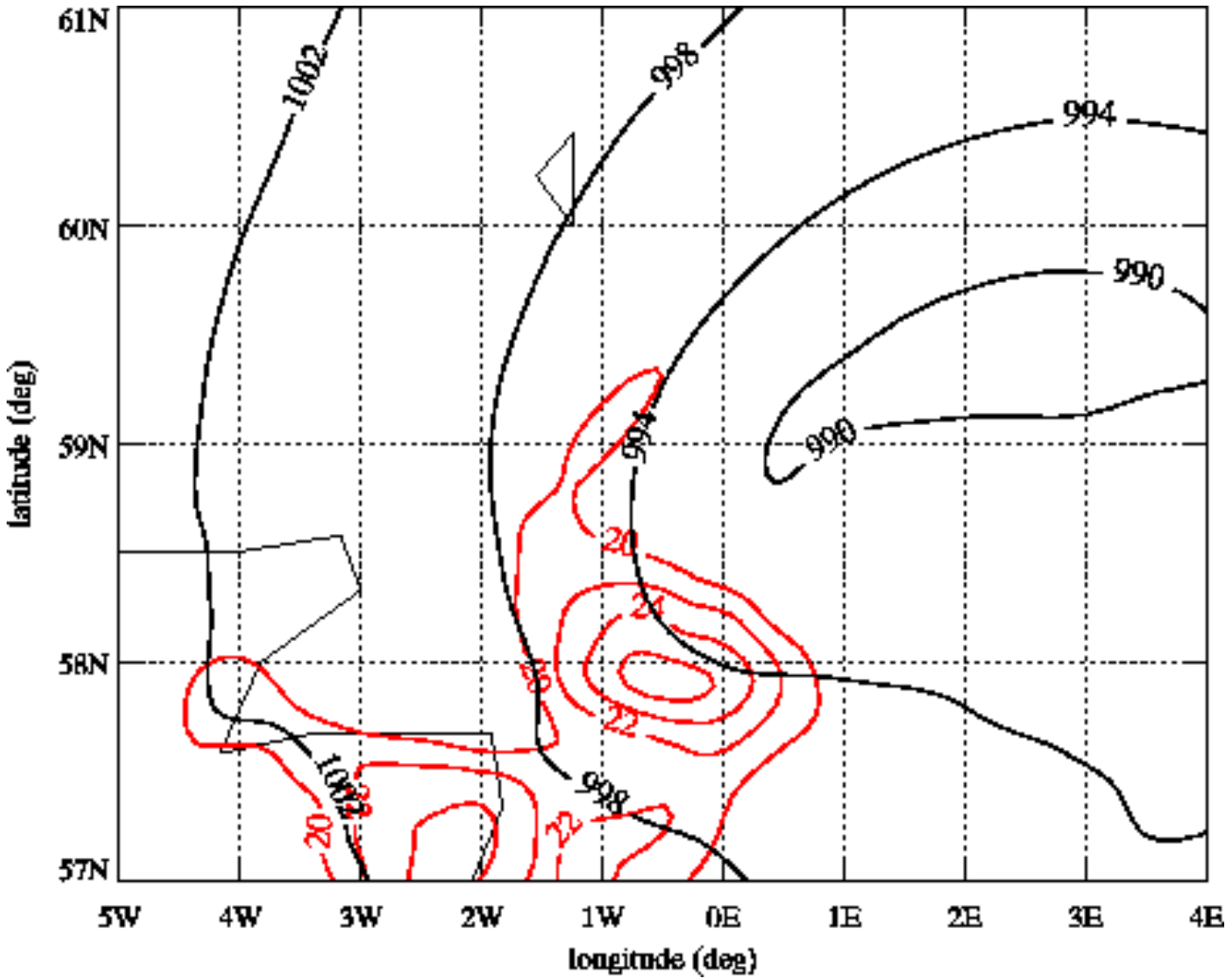
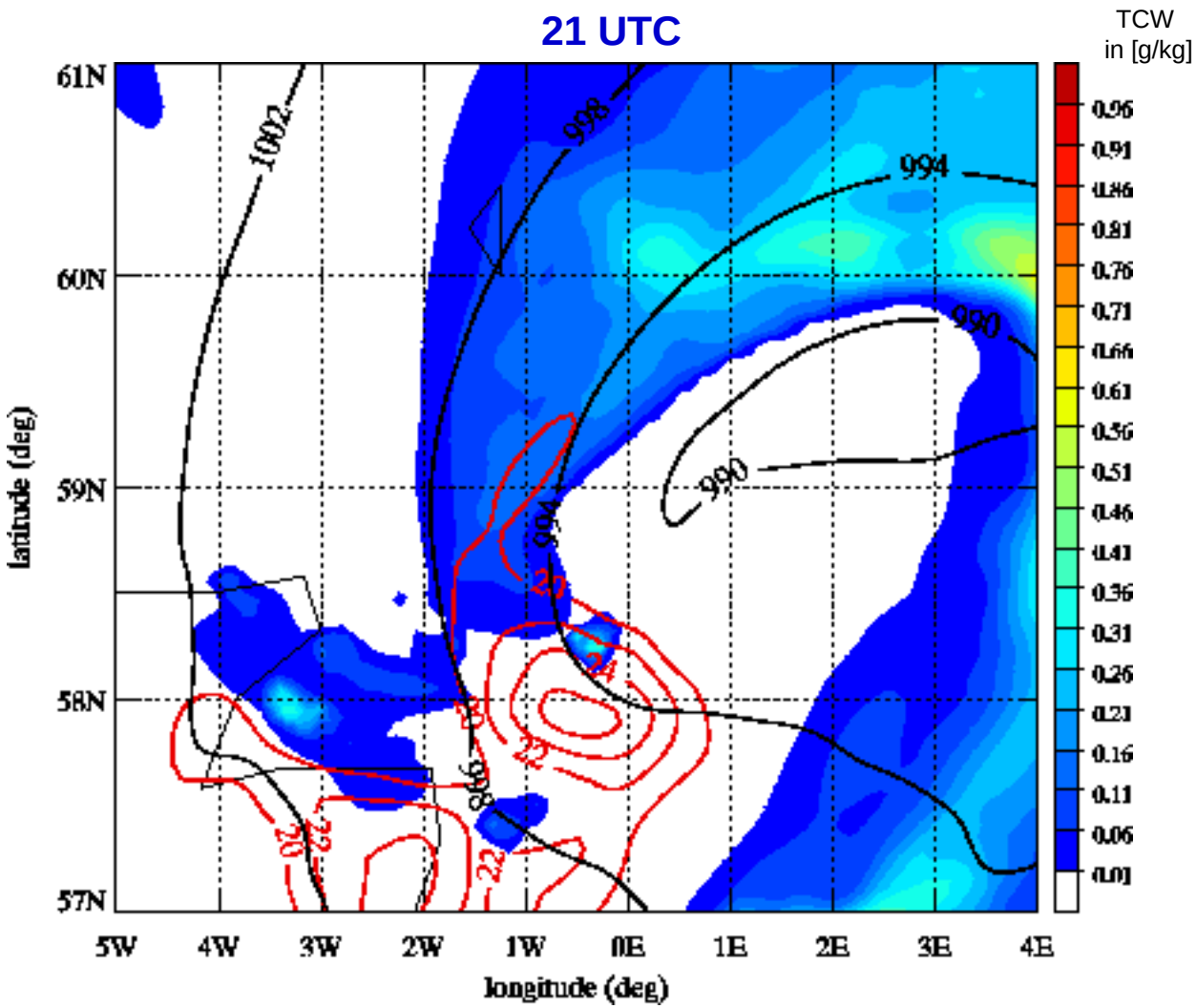
Model simulation of `Oili´

21 UTC



SLP (black contours), |**v**| at 900 hPa (red contours)

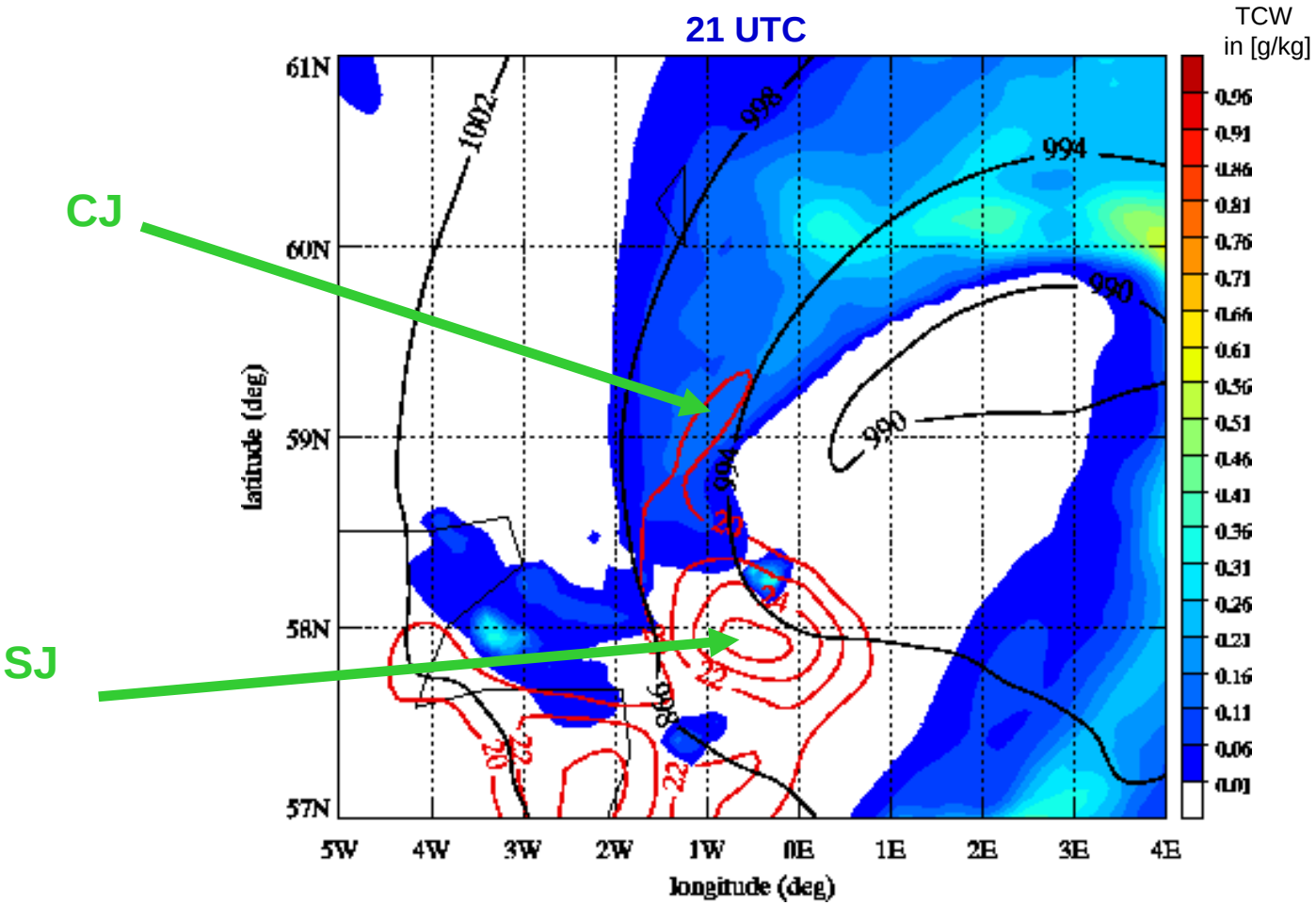
Model simulation of `Oili´



850hPa TCW (colors), SLP (black contours), |**v**| at 900 hPa (red contours)

Model simulation of `Oili´

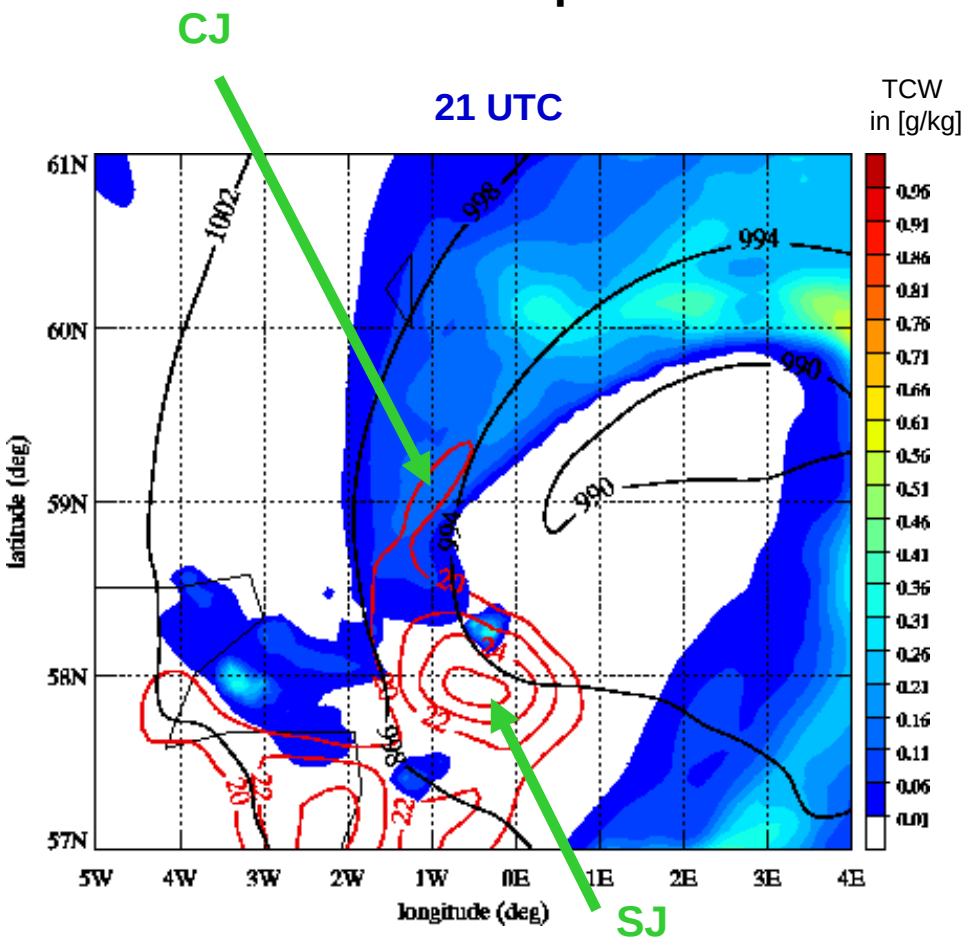
Sting Jet and Cold Jet can be identified in 900 hPa horizontal wind velocity field

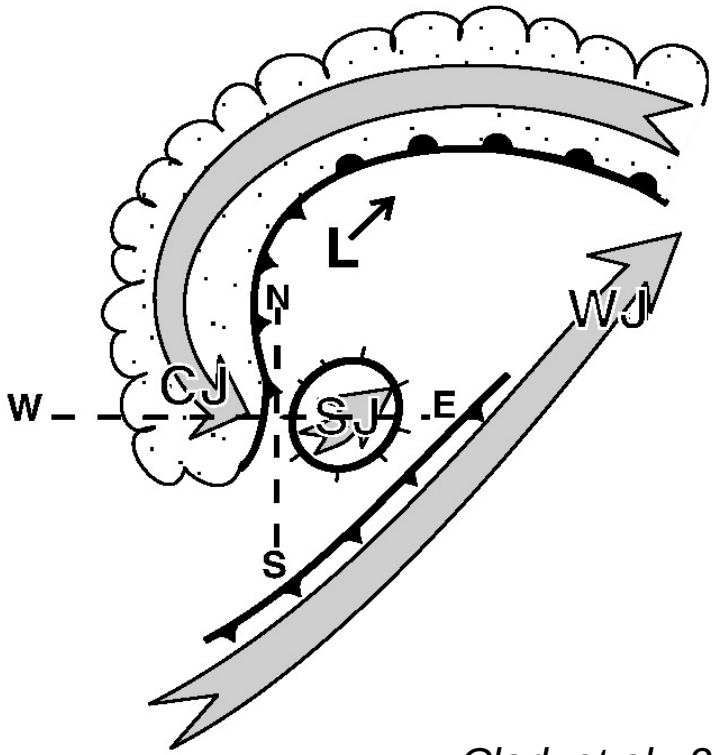


850hPa TCW (colors), SLP (black contours), |**v**| at 900 hPa (red contours)

Model simulation of `Oili´

Comparison of `Oili´ with conceptual model





Clark et al., 2005

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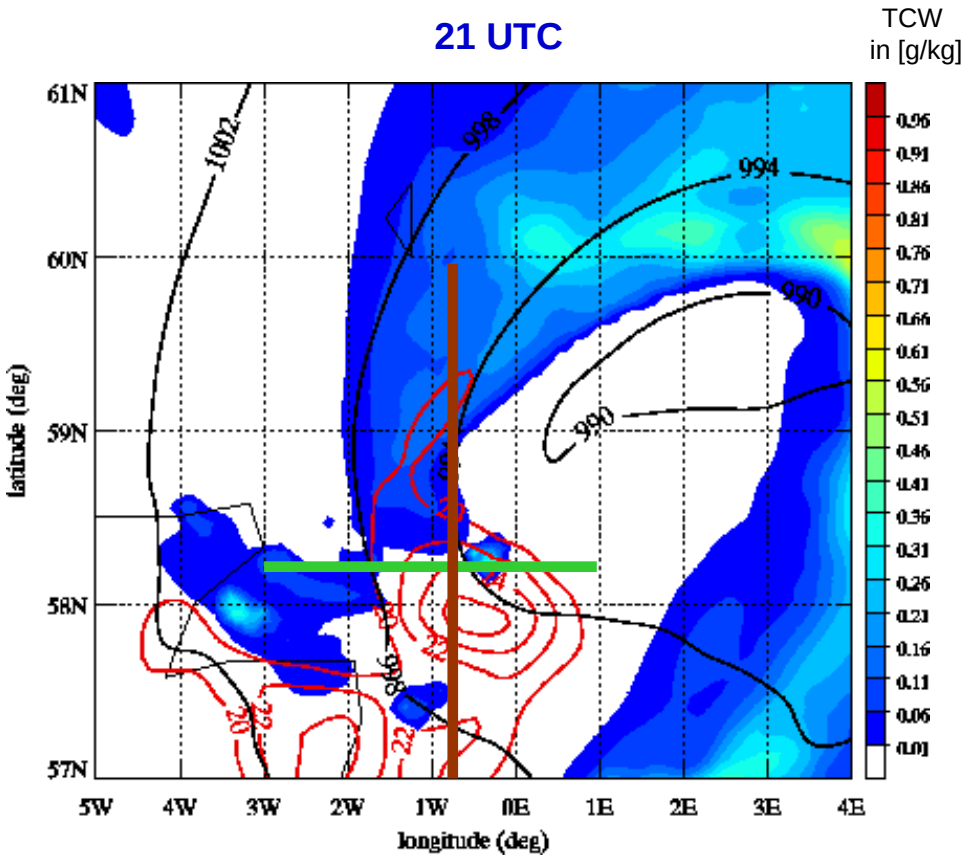
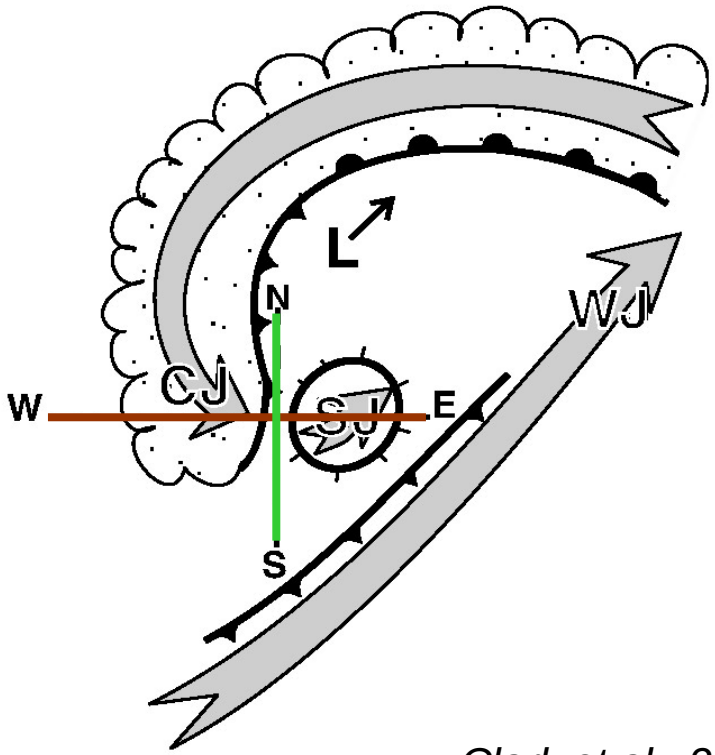
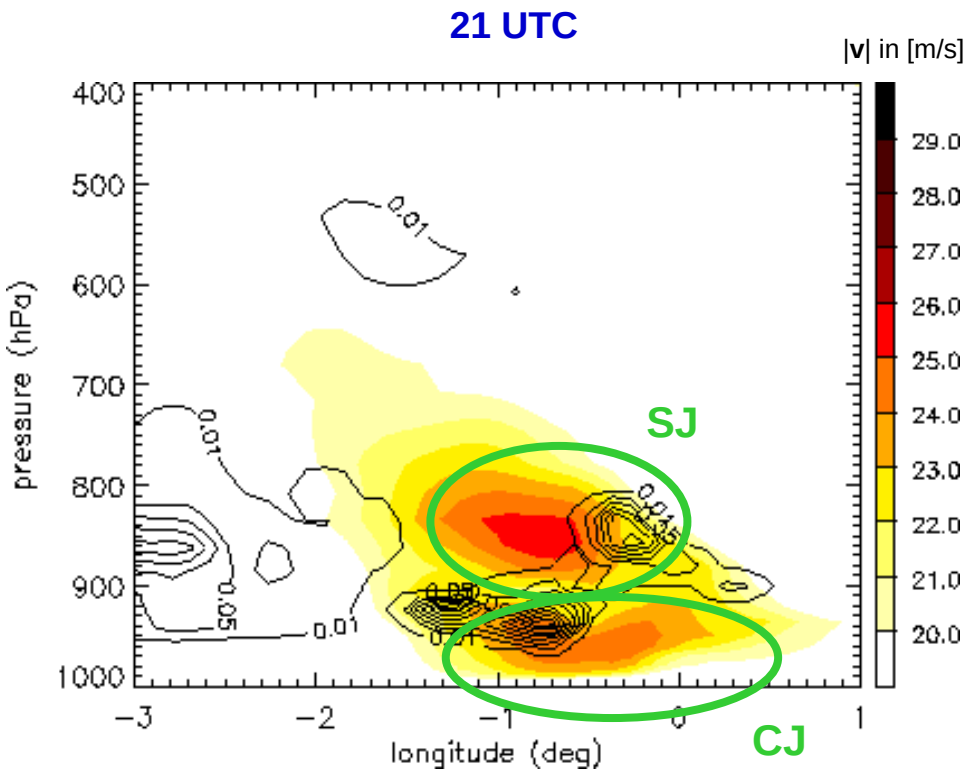




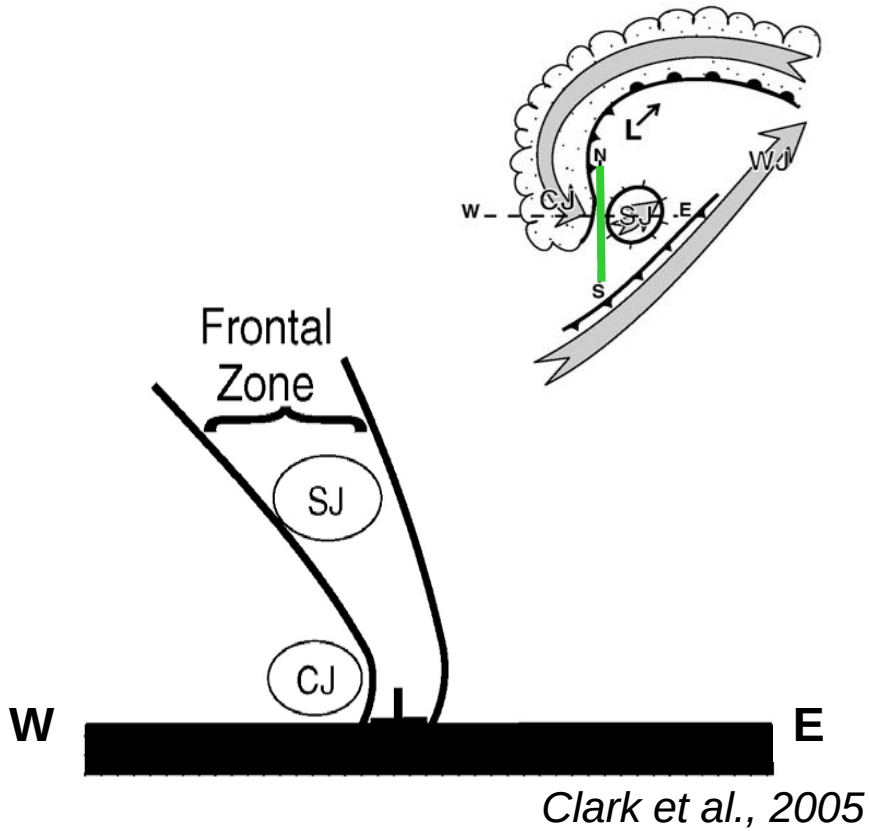
Clark et al., 2005

850hPa TCW (colors), SLP (black contours), |**v**| at 900 hPa (red contours)

Two distinct wind maxima according to `Sting – Jet´ theory

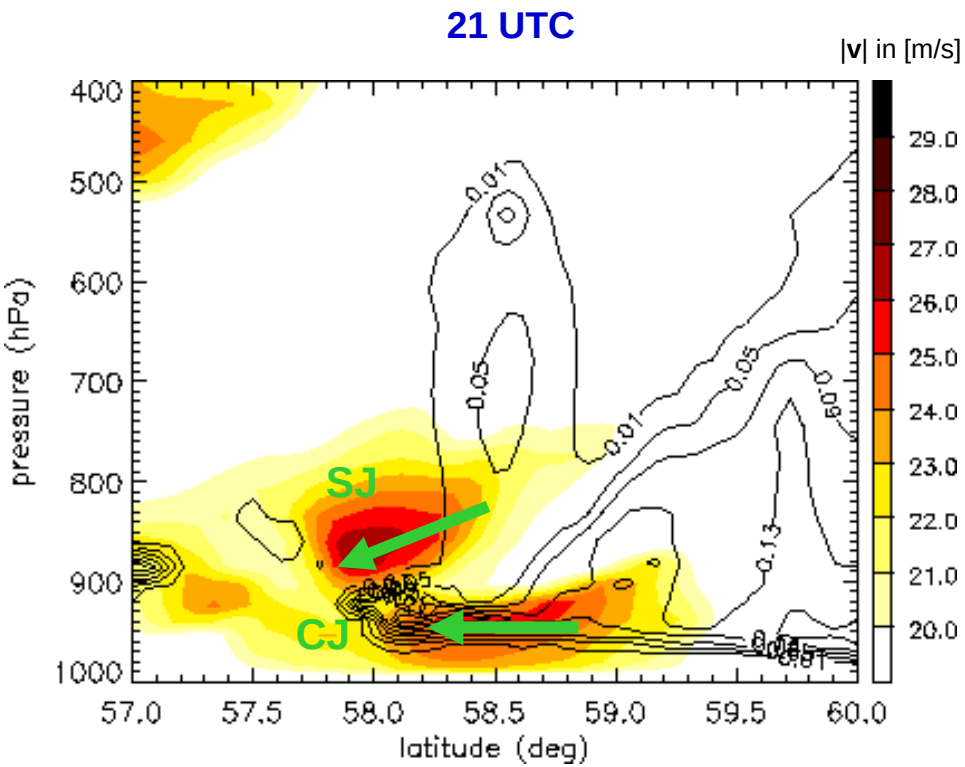


Absolut value of horizontal wind velocity, TCW in g/kg as contours

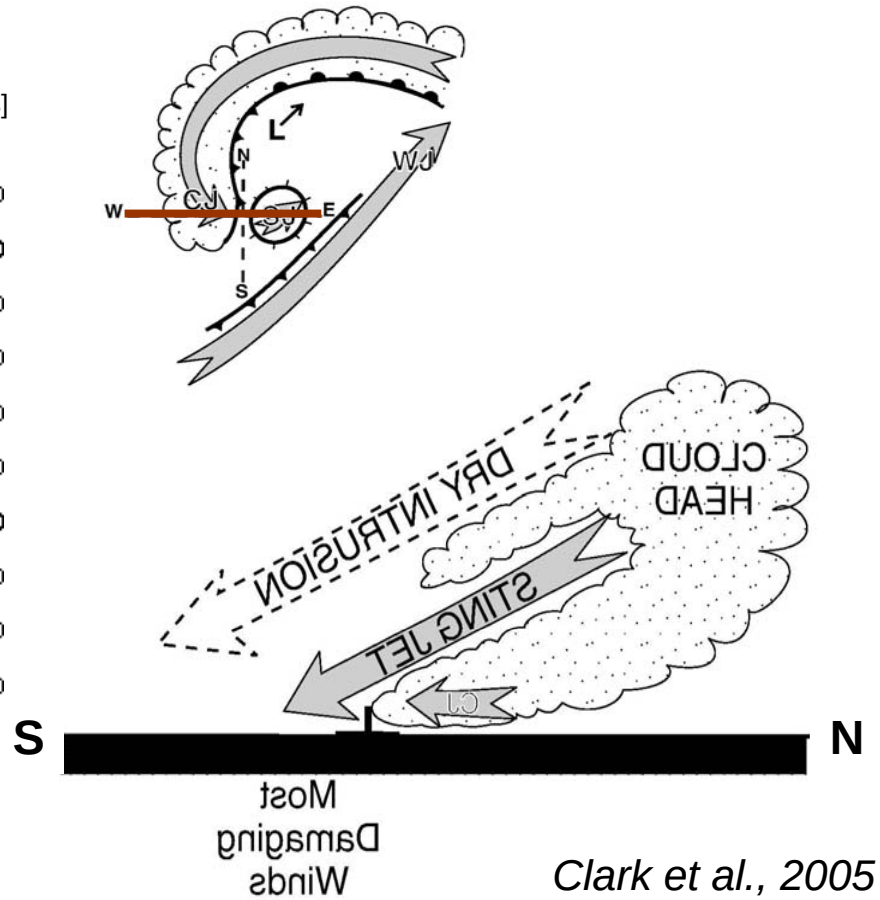


Clark et al., 2005

Two distinct wind maxima according to `Sting – Jet´ theory

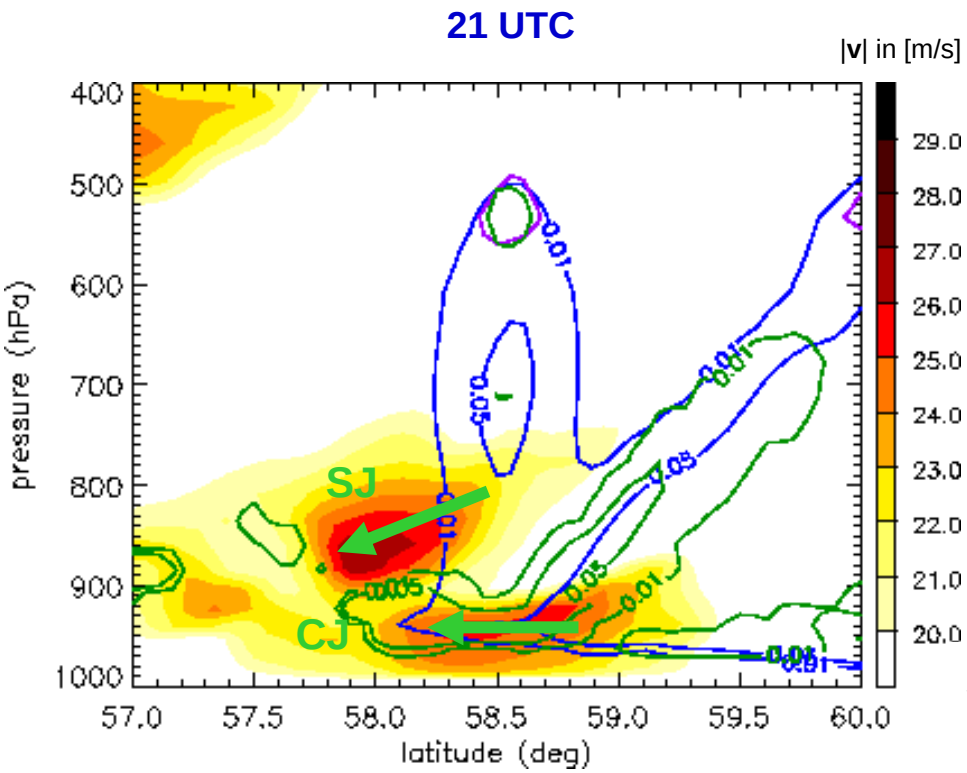


Absolut value of horizontal wind velocity, TCW in g/kg as contours

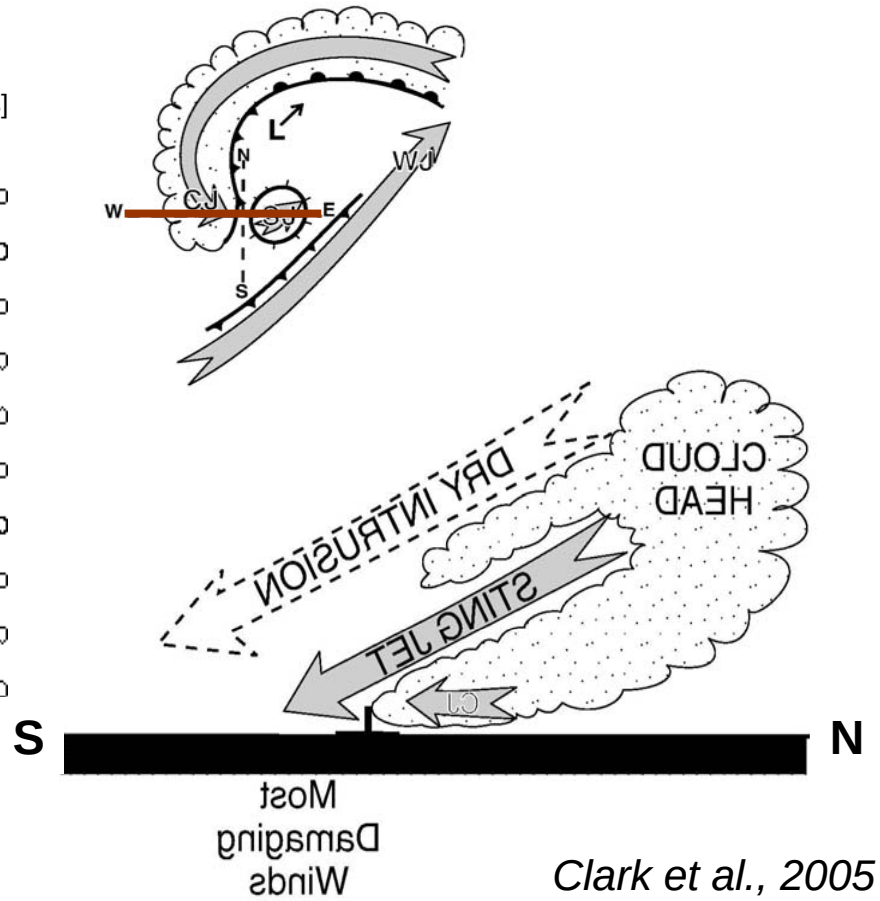


Clark et al., 2005

Two distinct wind maxima according to `Sting – Jet´ theory



Absolut value of horizontal wind velocity,
Hydrometeors in g/kg as contours
QI, QC, QS

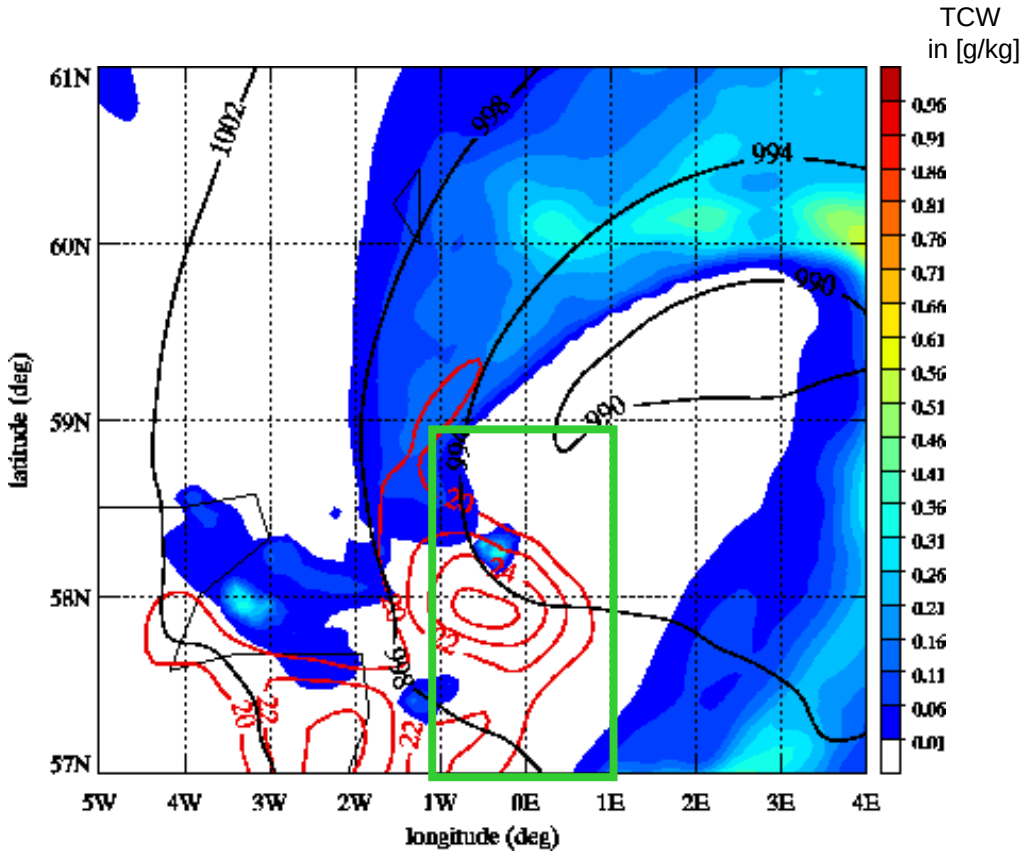


Clark et al., 2005

History of air that contributes to the SJ

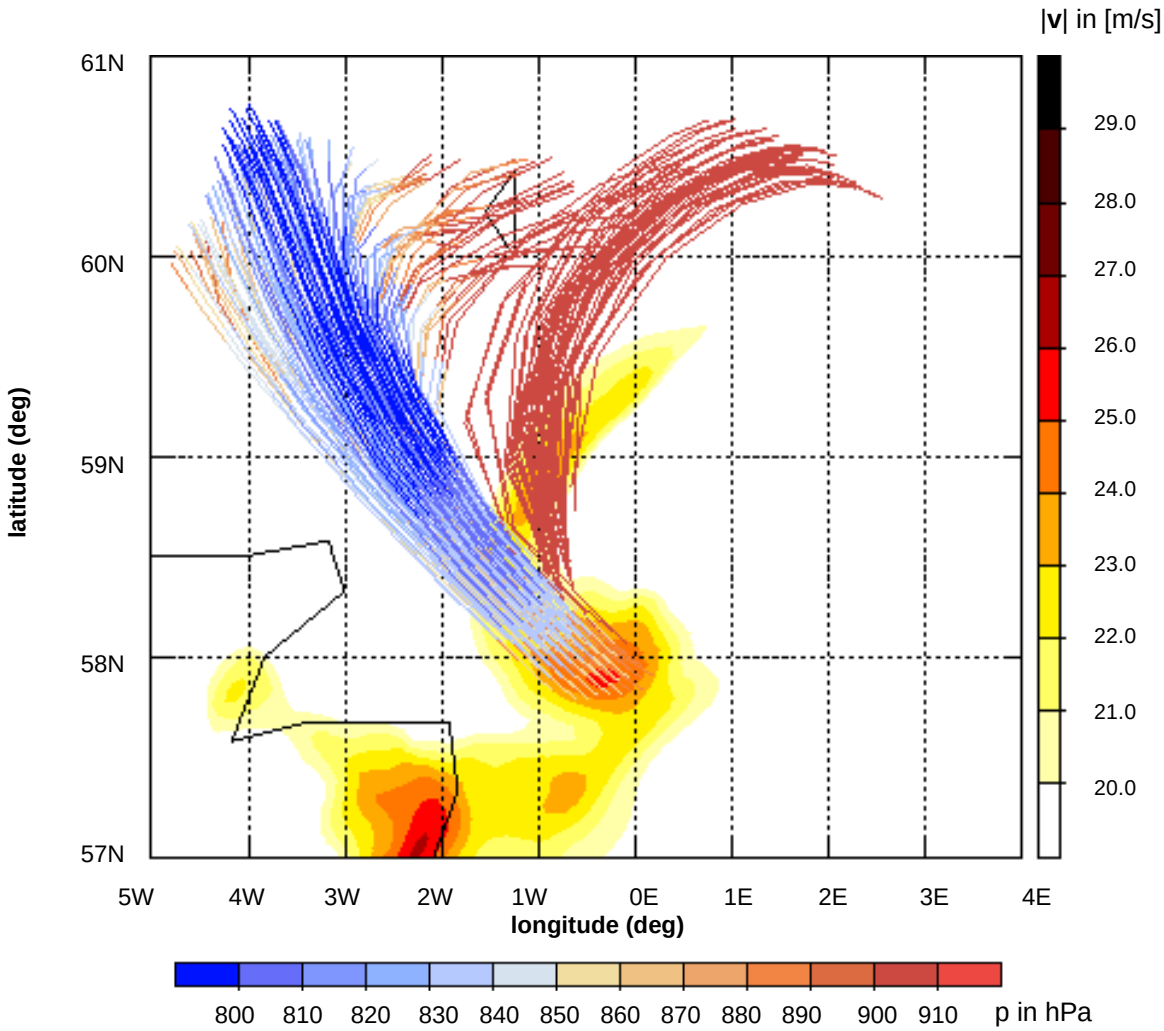
Calculation of 6 hours backward trajectories from gridpoints :

- within the green box (horizontal)
- below 3000 m above Sea Level (vertical)
- with |v| > 25 m/s



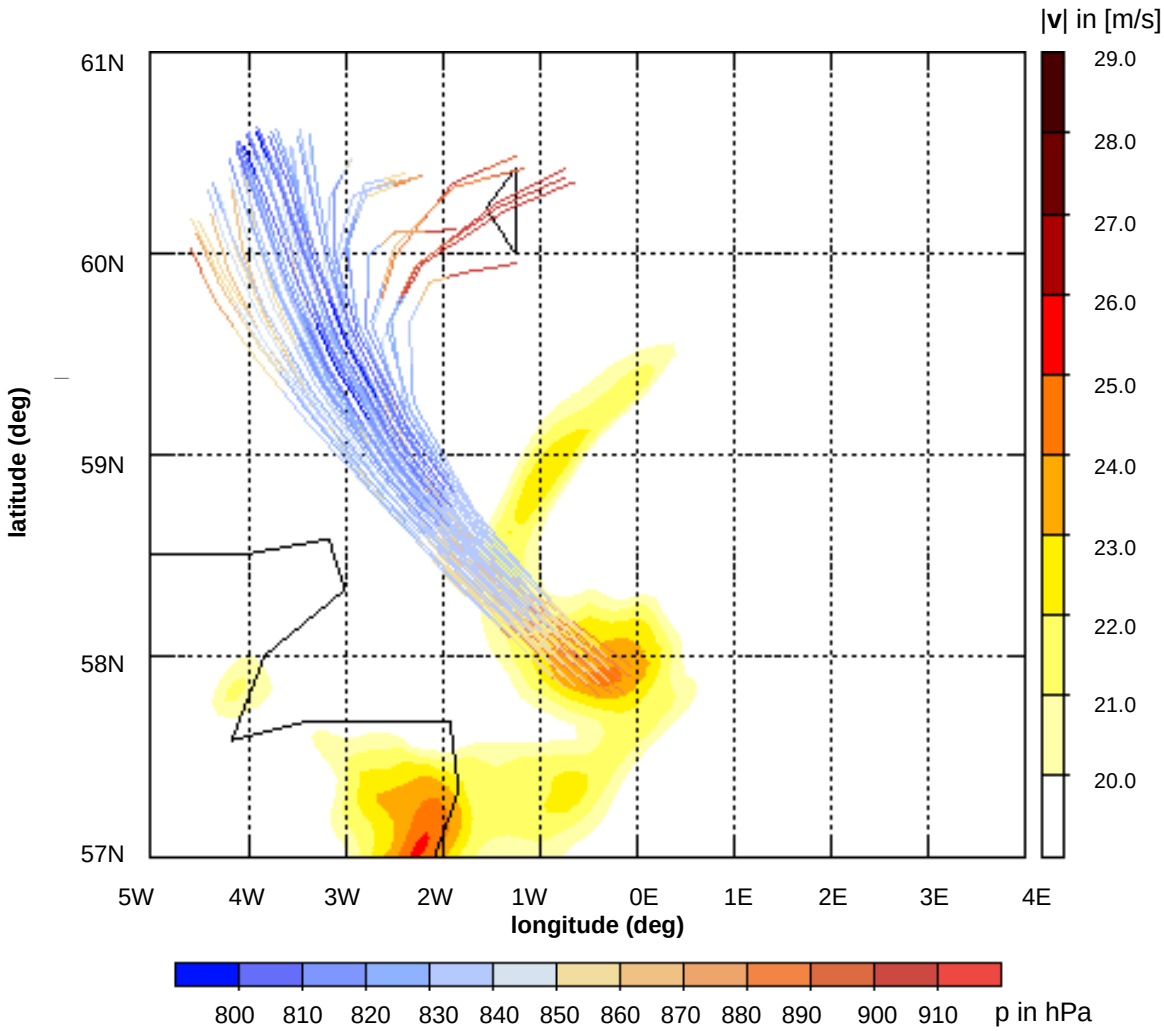
History of air that contributes to the SJ

SJ: Air coming from NW and descent in the last 2 hours
CJ: Air from N down in the boundary layer for the last 6 hours



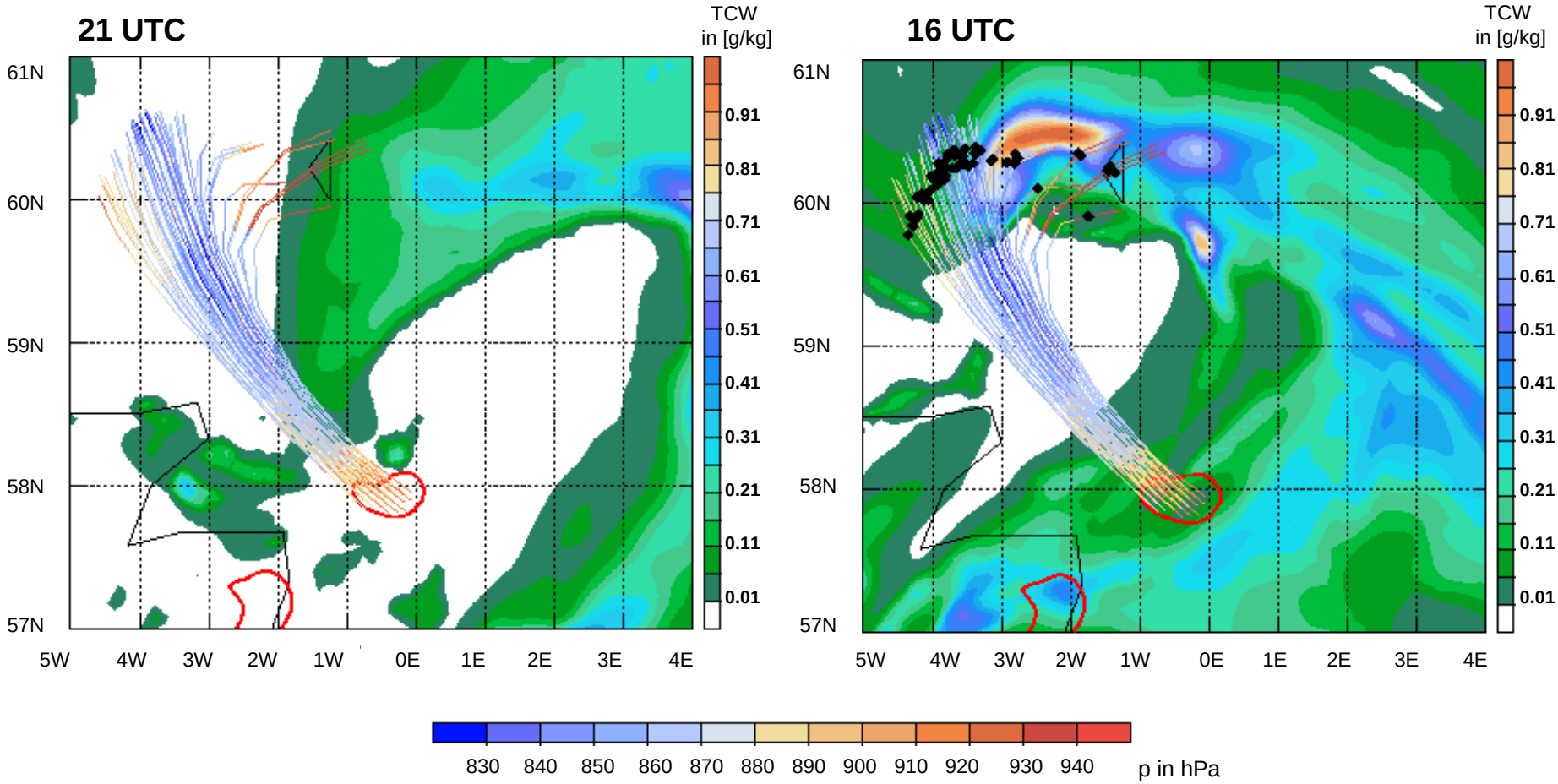
History of air that contributes to the SJ

SJ: Air coming from NW and descent in the last 2 hours
Starting criterion: |v| > 26 m/s



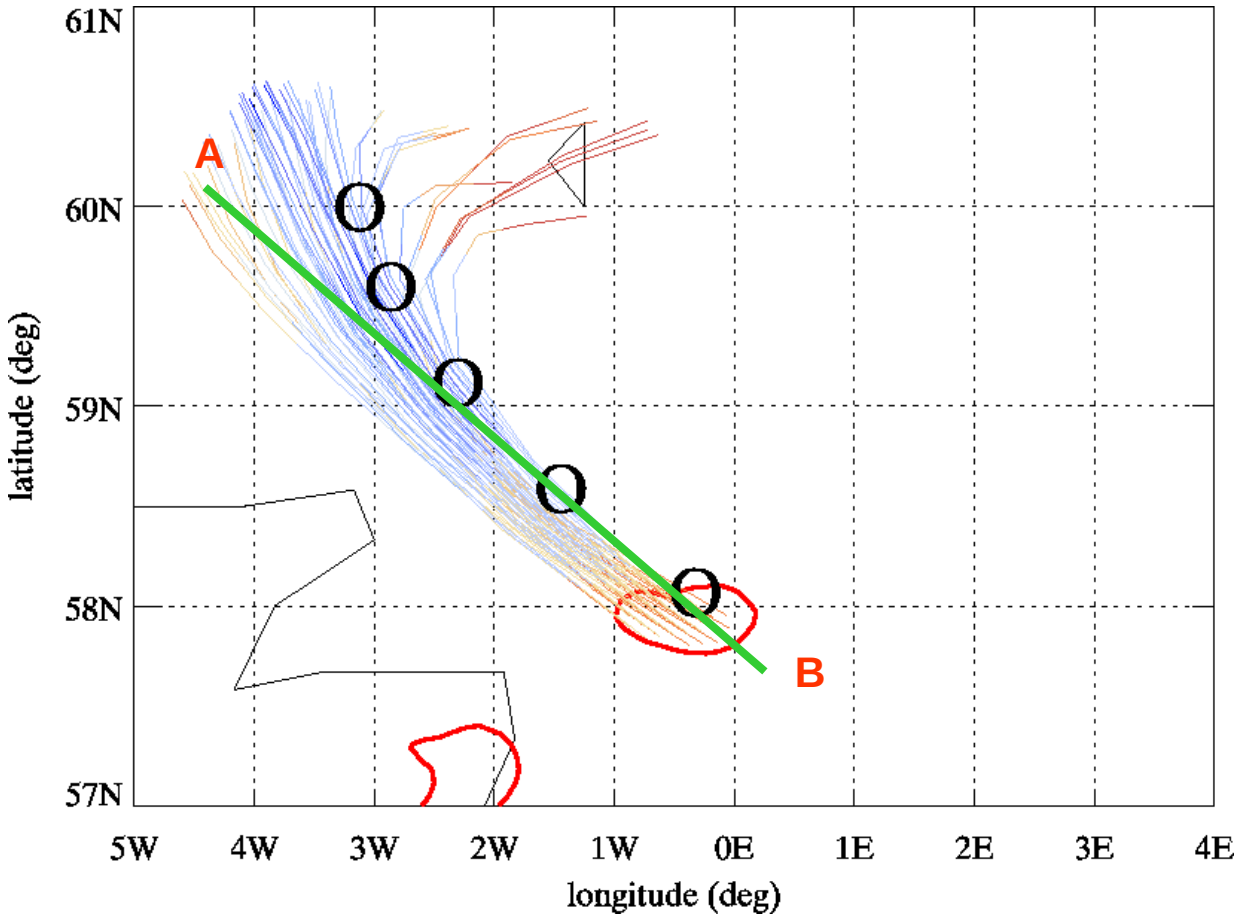
History of air that contributes to the SJ

850 hPa TCW, 900 hPa horizontal wind velocity > 24 m/s (red contour),
6 h backward trajectories



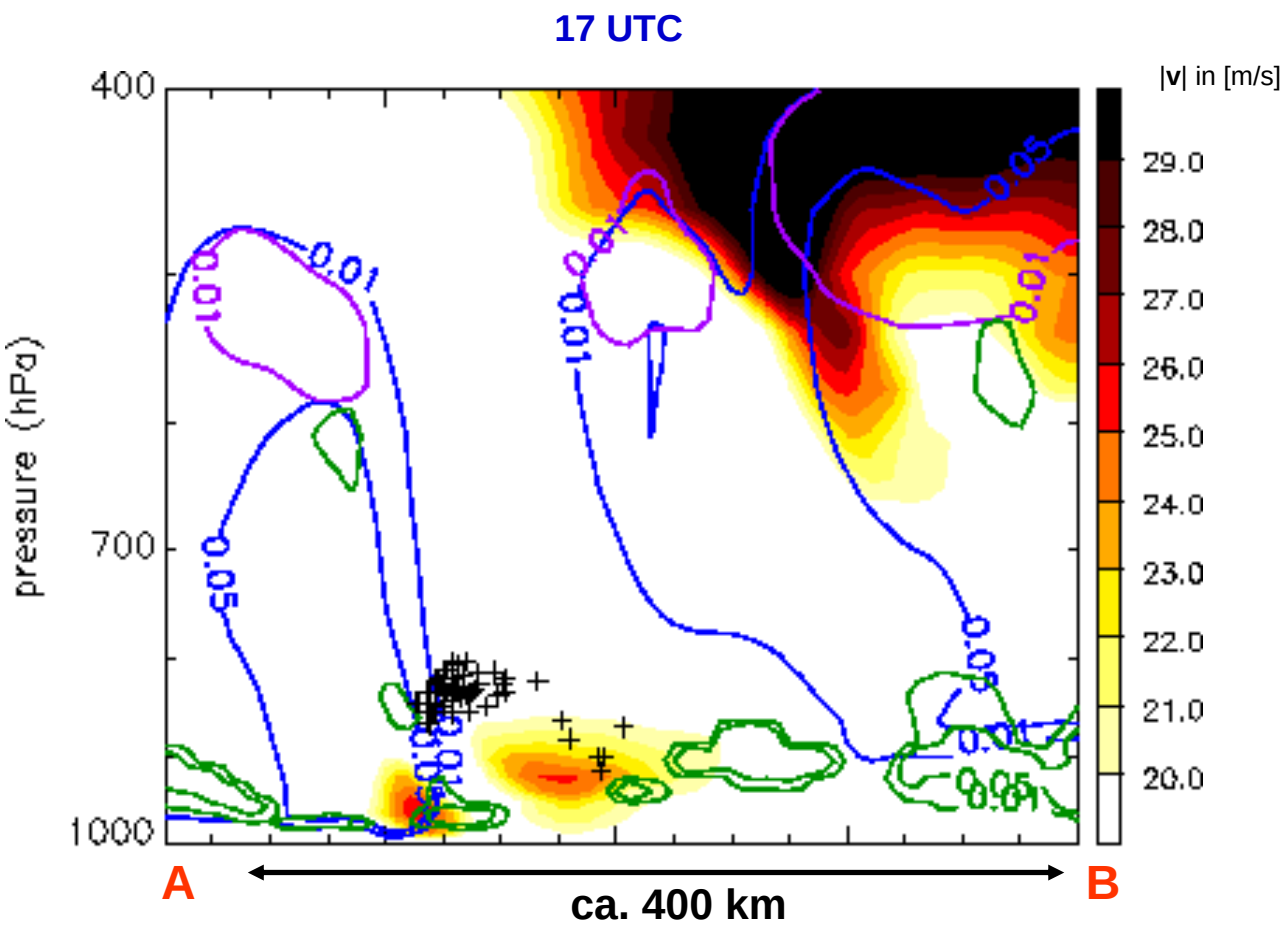
History of air that contributes to the SJ

Mean position of the trajectory ensemble marked every hour by the circles, green line marks vertical cross section.



History of air that contributes to the SJ

Vertical cross sections along mean location of the trajecories
Colors: Horizontal wind velocity |**v**|
Contours: QI,QC,QS
+ : position of every trajectory projected on cross section



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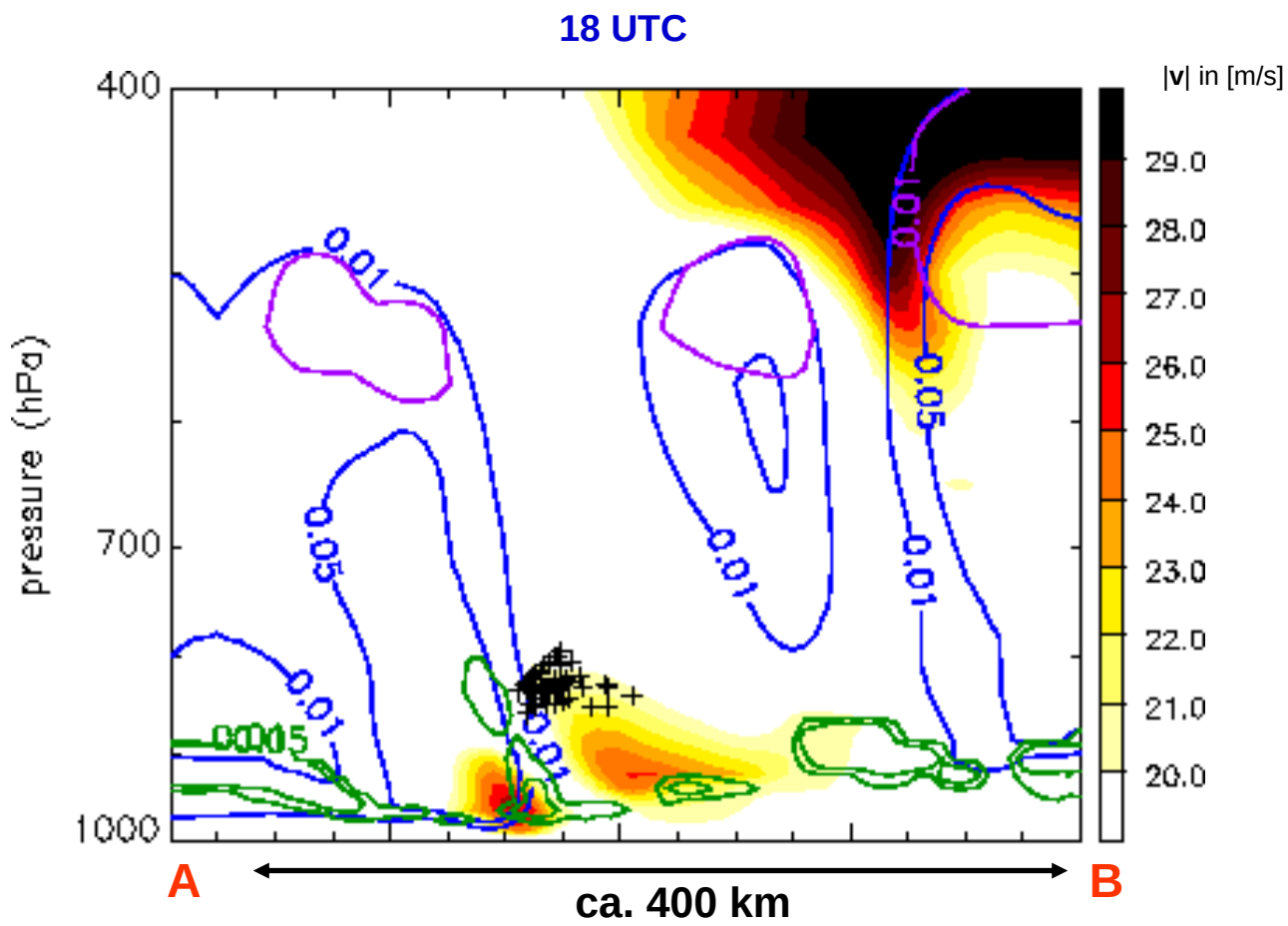

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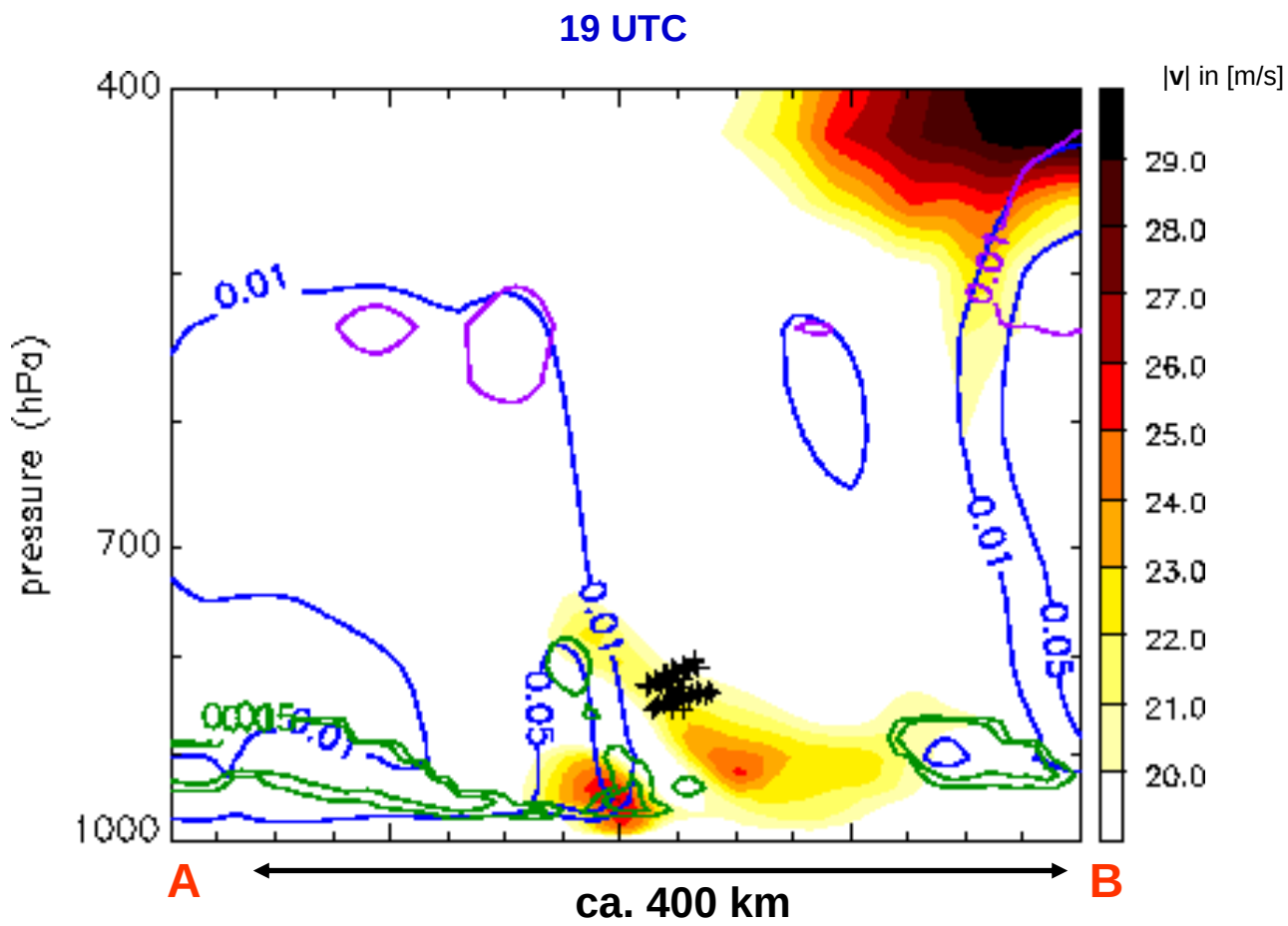

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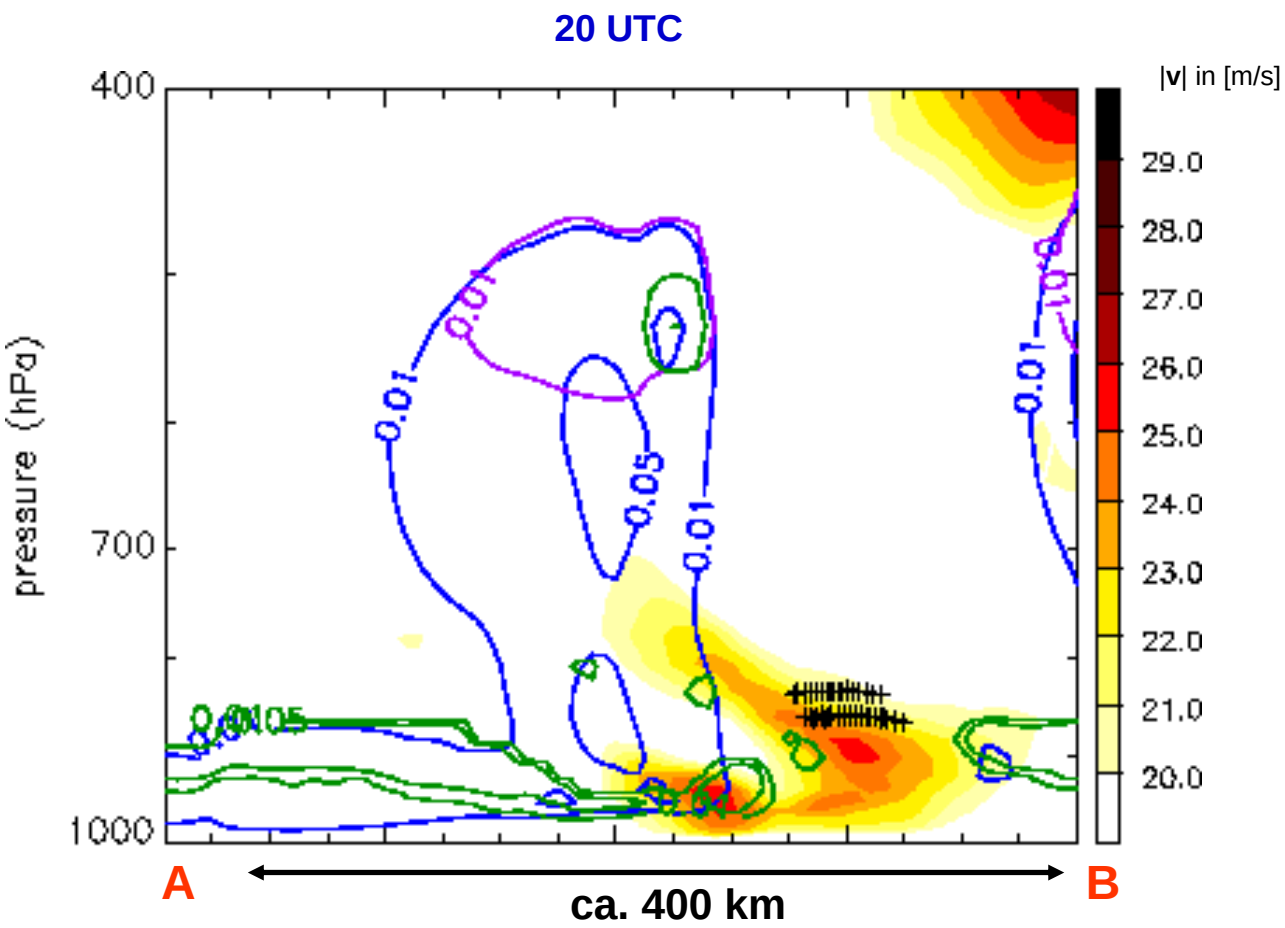

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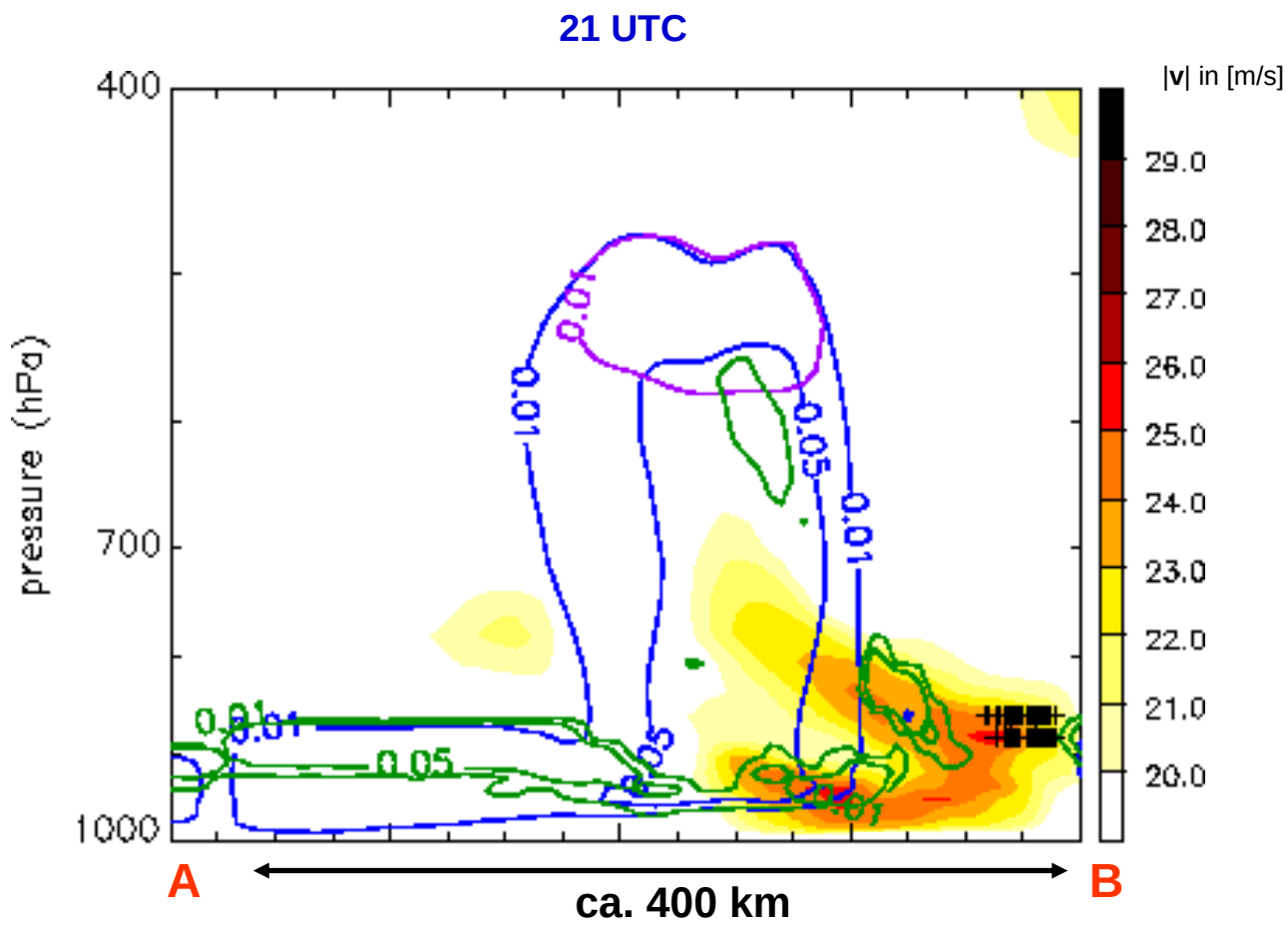
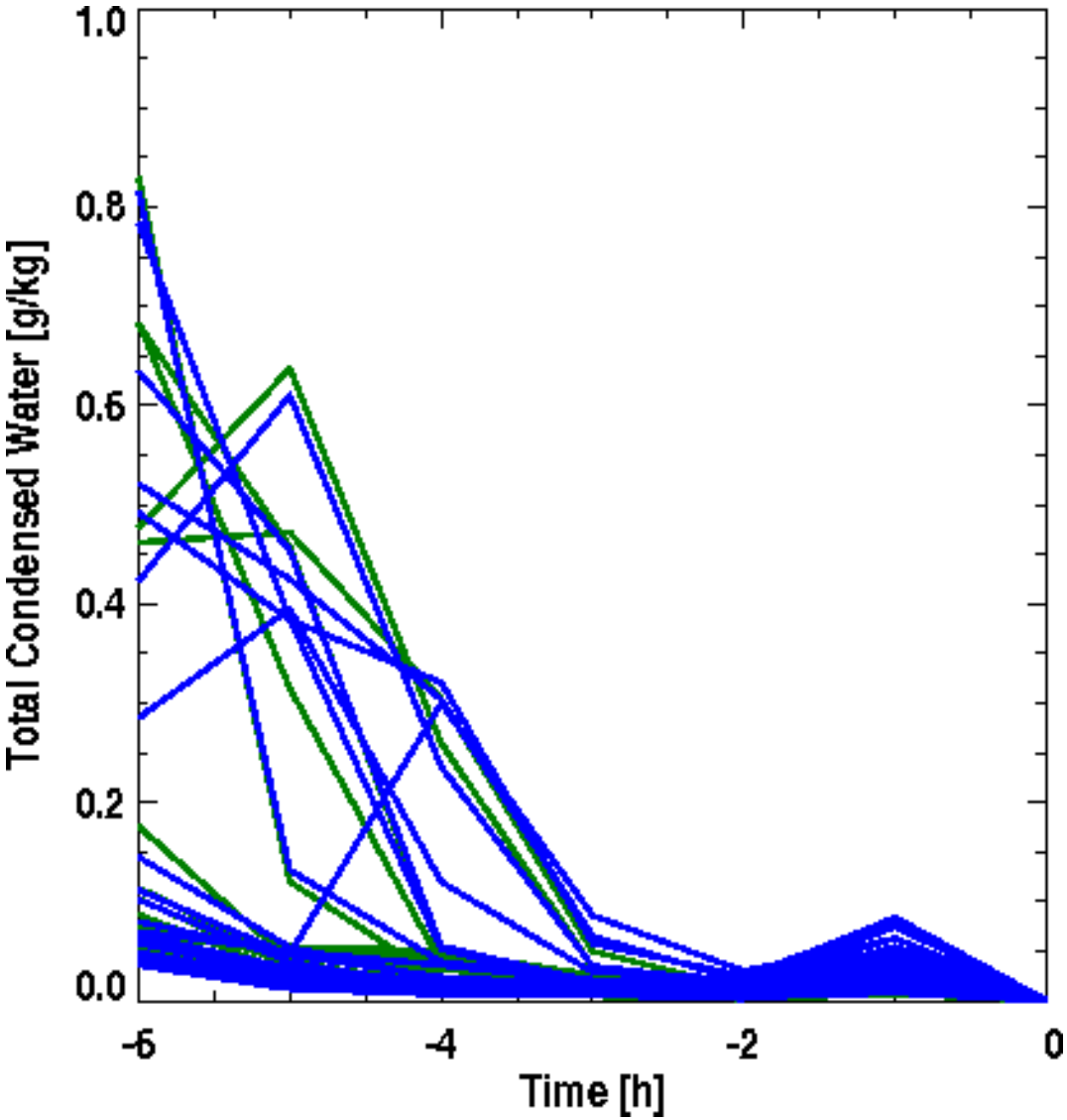


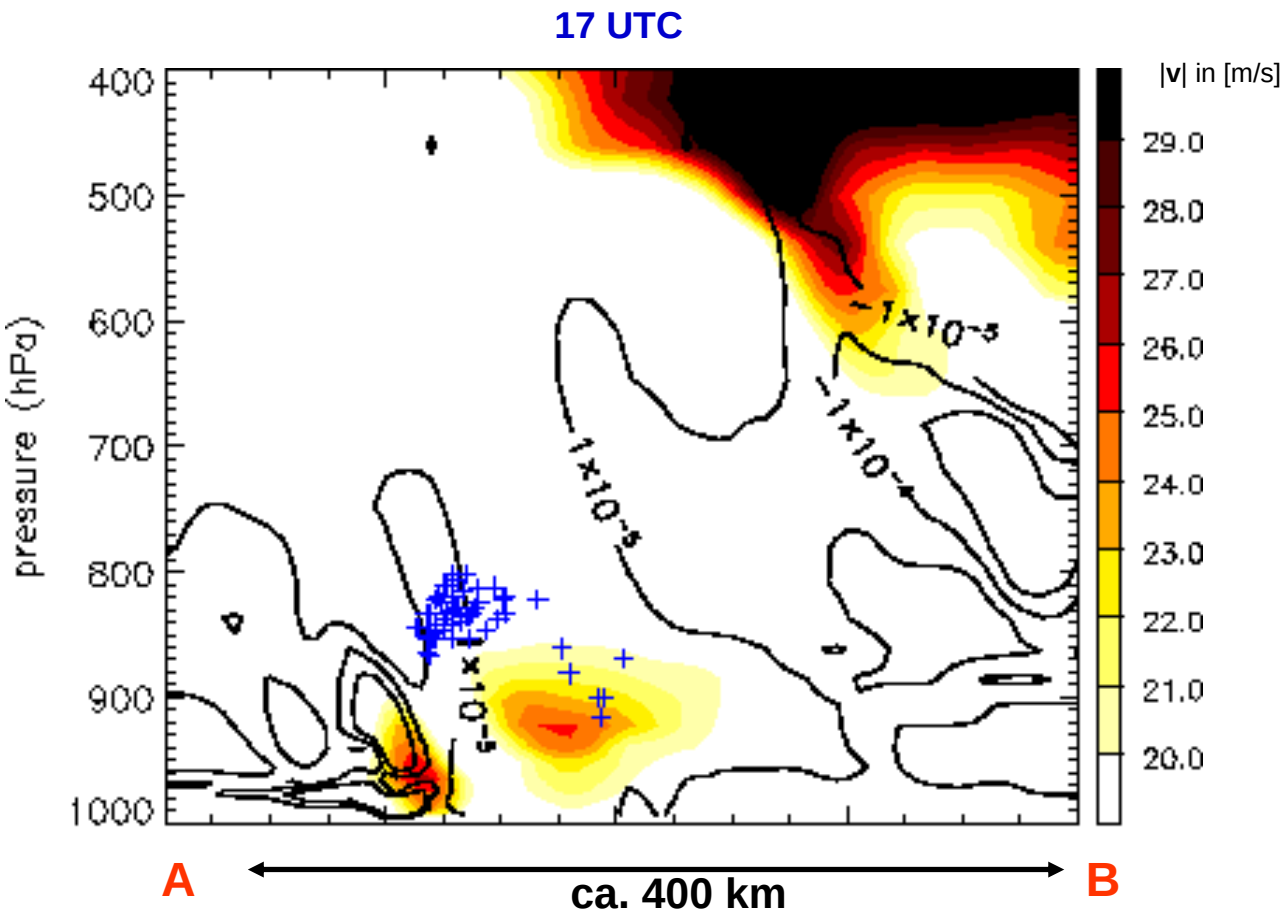
History of air that contributes to the SJ



TCW of trajectories:
Some trajectories contain hydrometeors (mostly snow) some hours before contributing the SJ

History of air that contributes to the SJ

Vertical cross sections along mean location of the trajecories
Colors: Horizontal wind velocity |**v**|
Instantaneous negative temperature tendencies due to microphysic processes
+ : position of every trajectory projected on cross section



History of air that contributes to the SJ

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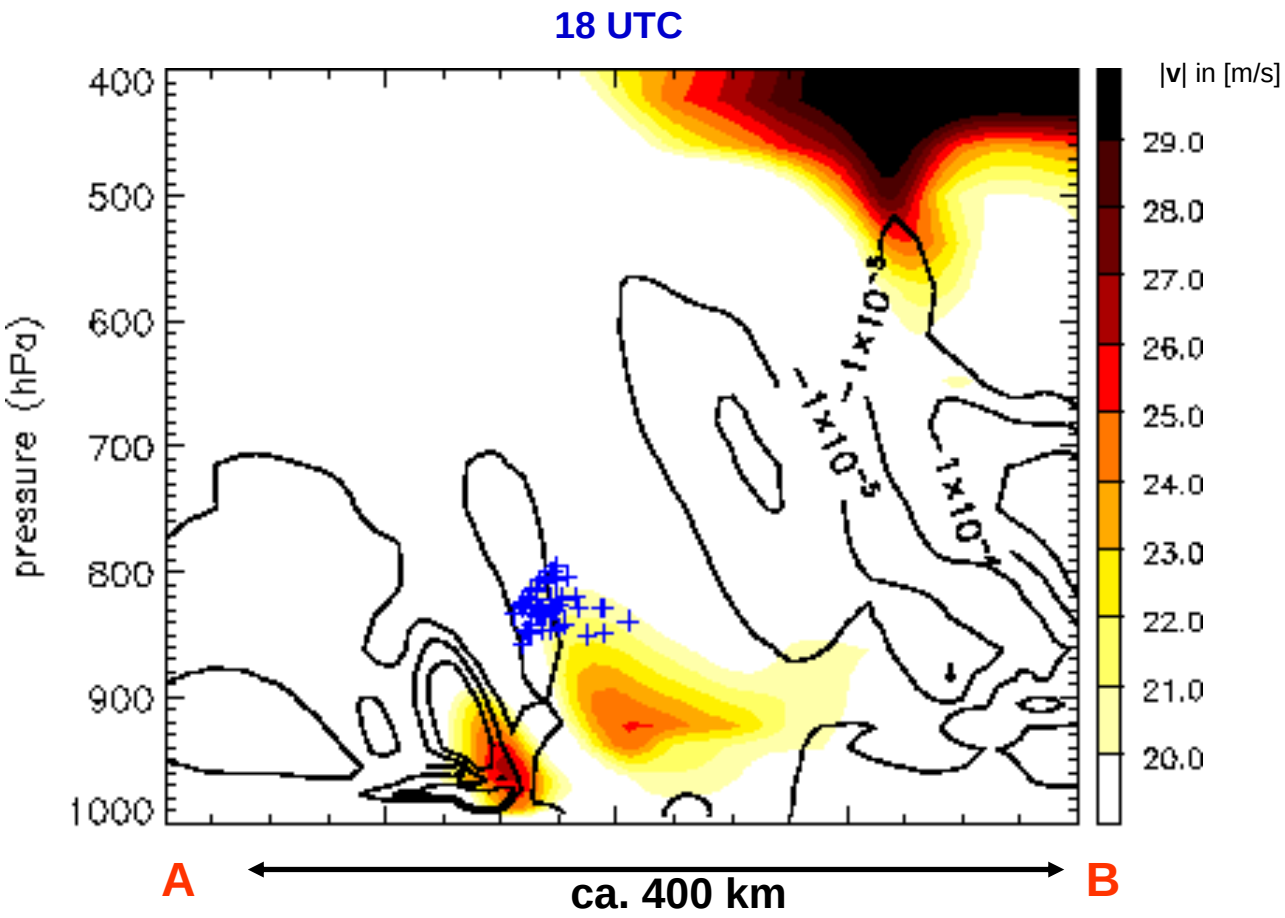

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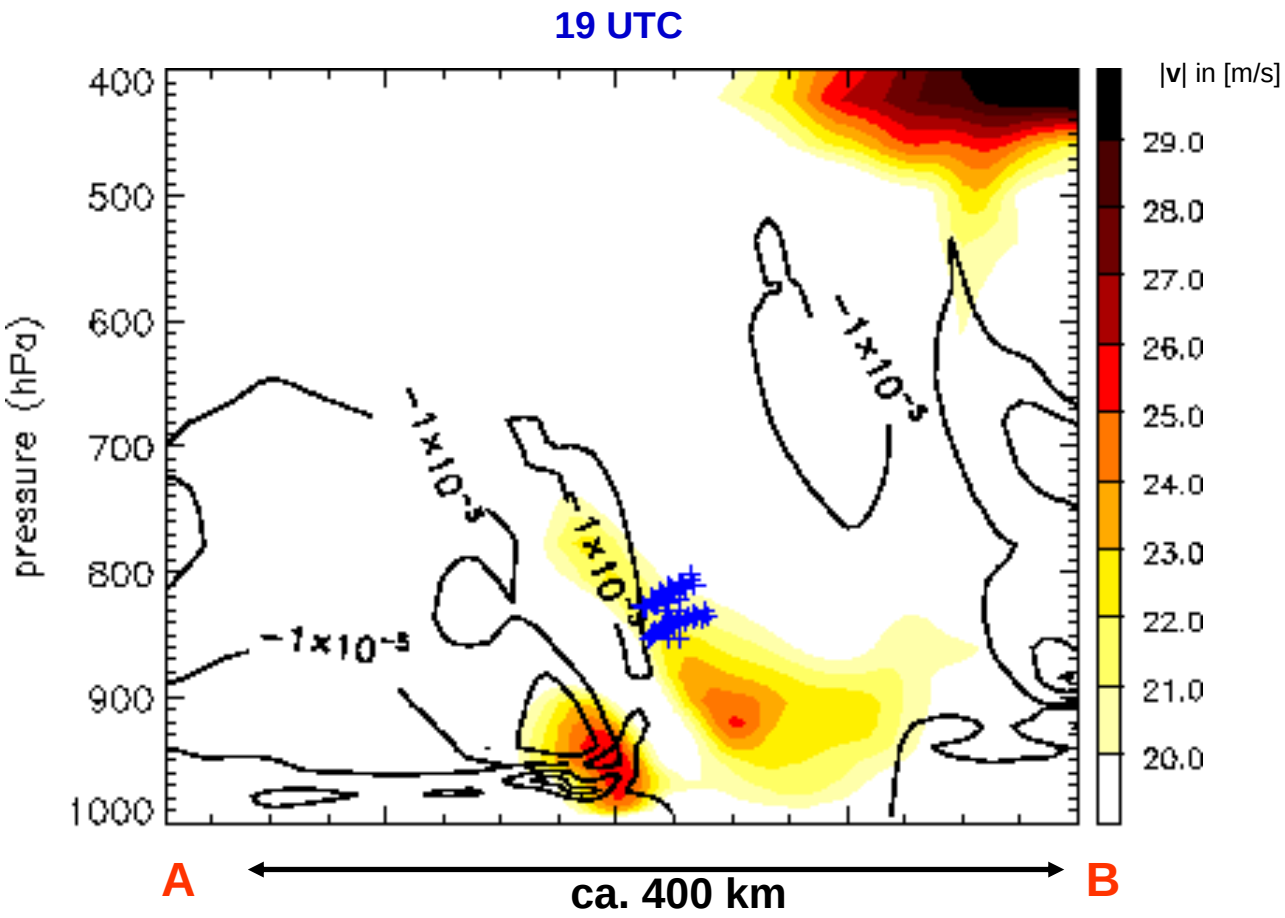

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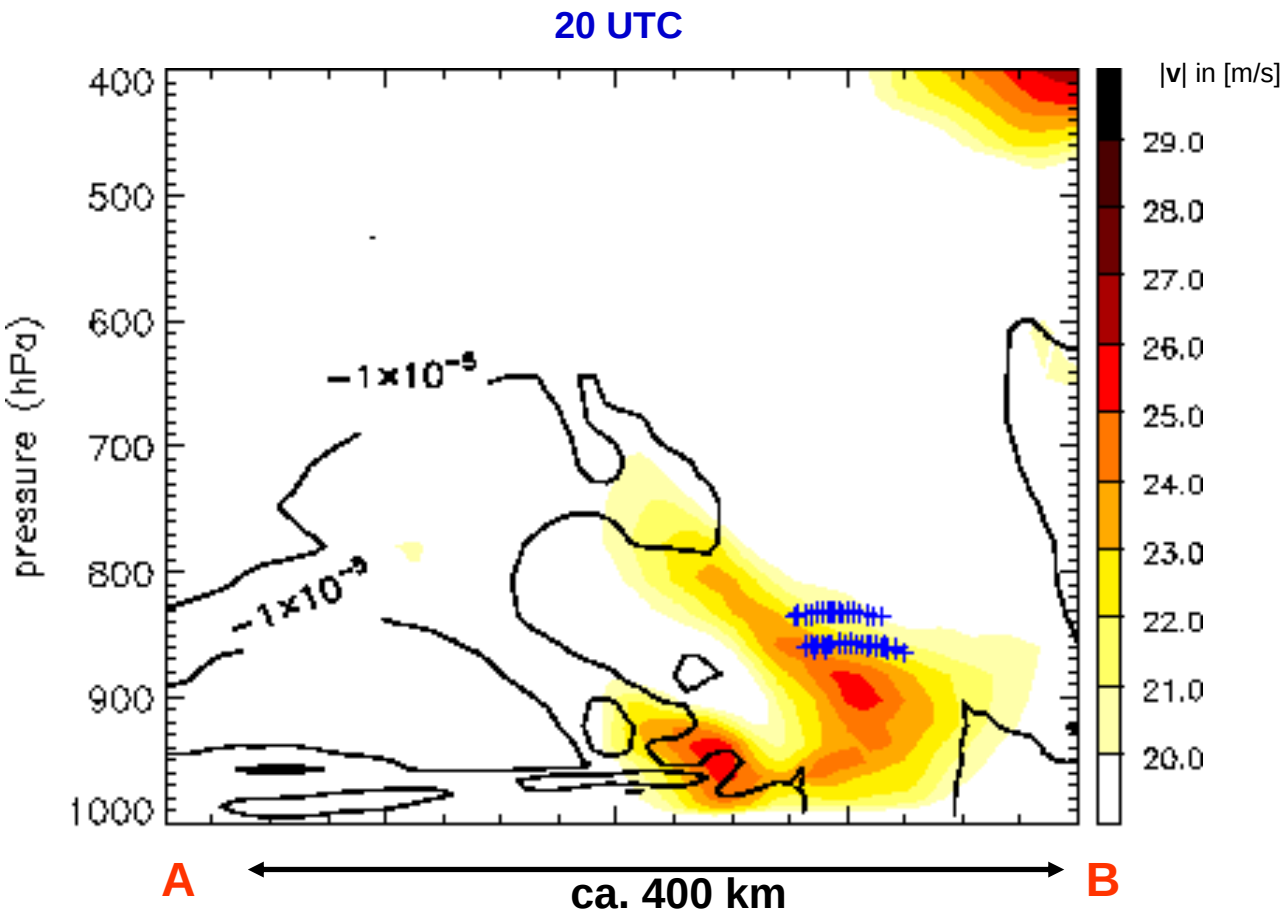

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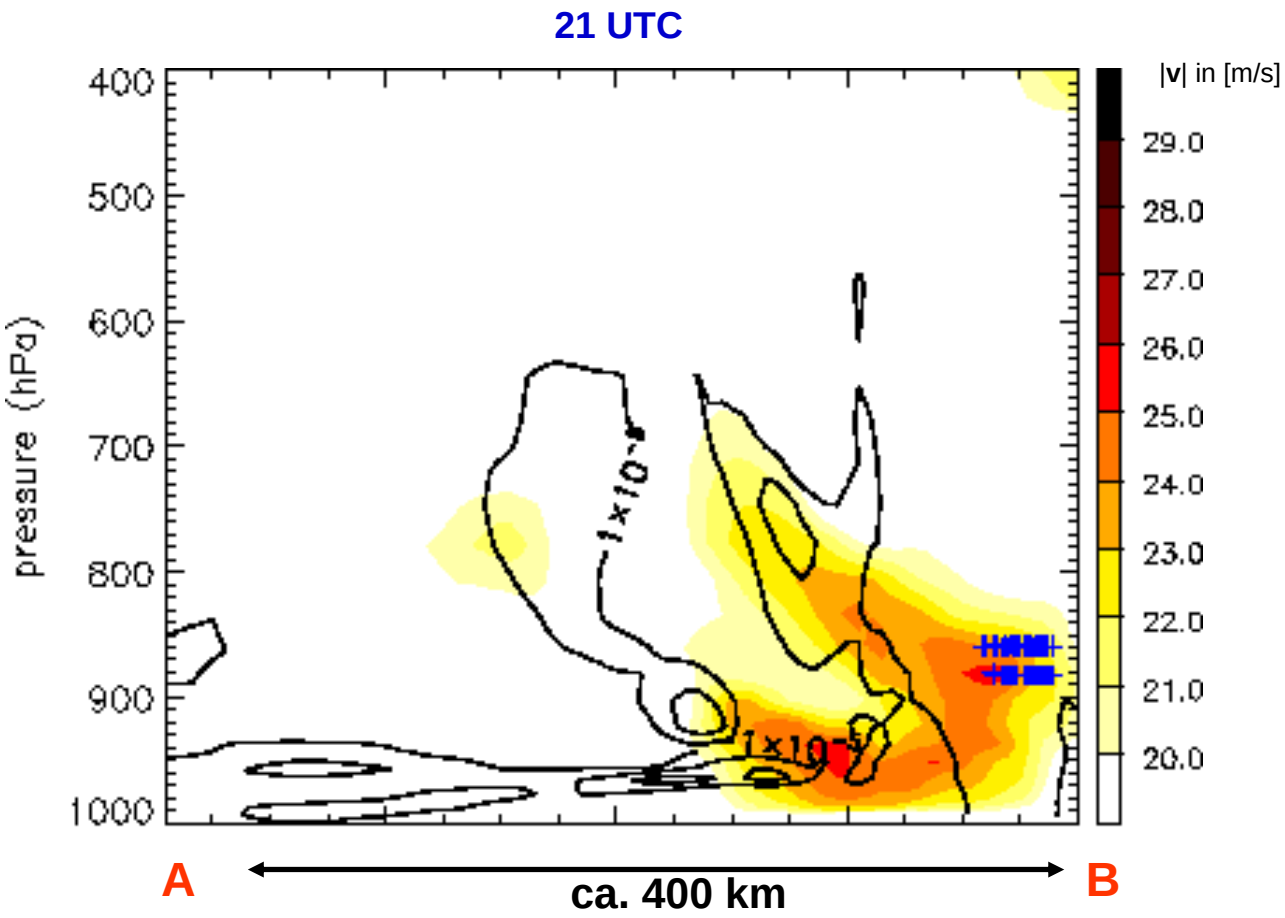
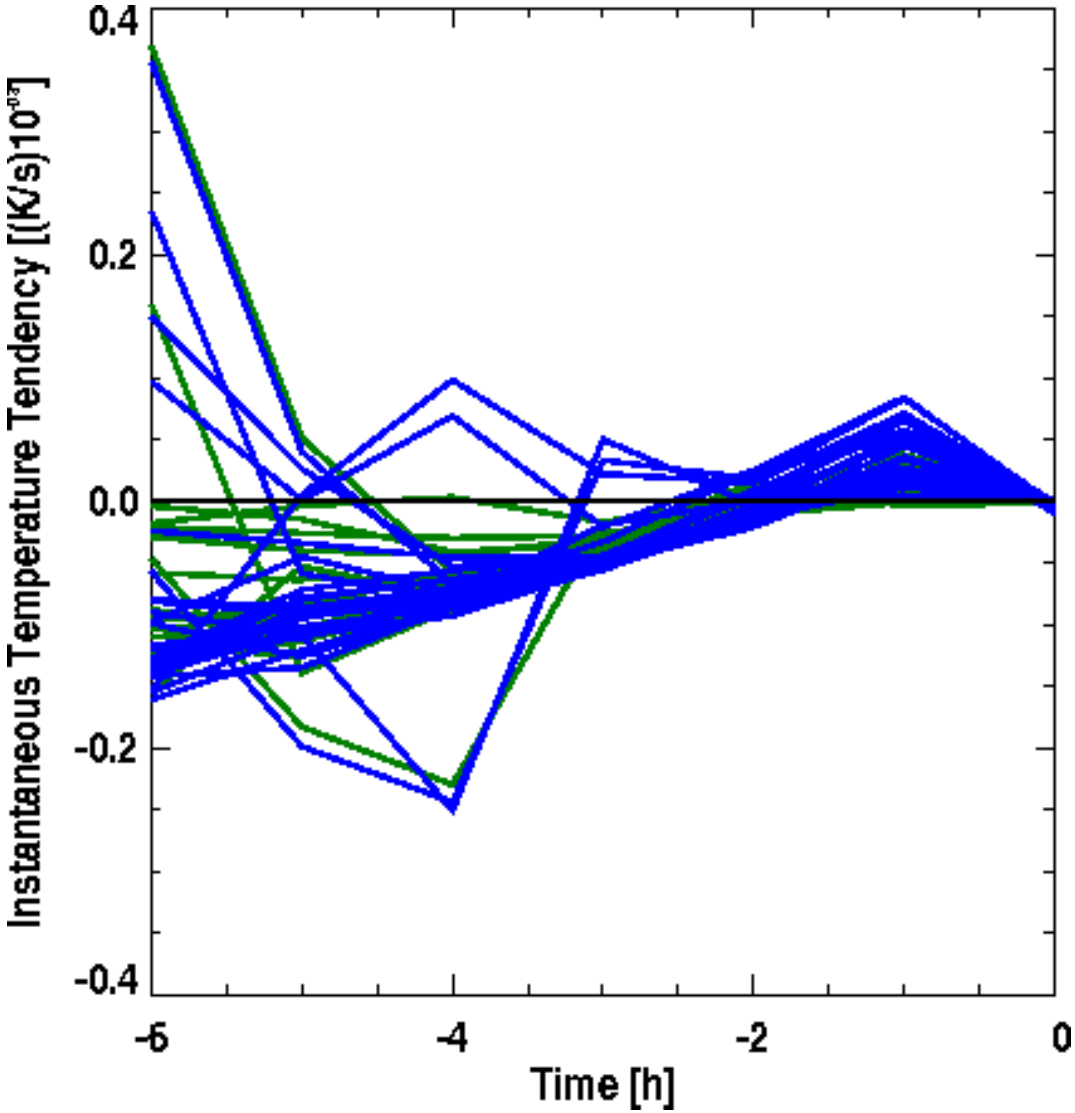


History of air that contributes to the SJ



TCW of trajectories:
Most trajectories show negative temperature tendencies due to microphysical processes.

Conclusions

- **Case study from Browning and Clark of the Great Storm (October 1987) lead to the conceptual model of the Sting-Jet**

- **Results of model simulation of the intense cyclone `Oili´ provides capability of a detailed analysis of the SJ-phenomenon**

-> Main features of the conceptual model are represented by the model simulation for `Oili´.

Location and 3D – structure of the SJ corresponds well with the conceptual model.

Trajectory analysis showed that air within the SJ was in contact with with air that contains hydrometeors.

Outlook

- Quantitative verification of the simulated cyclone with observational data.

- Investigation of the SJ of `Oili´ at later times to study the evolution of the SJ in time.

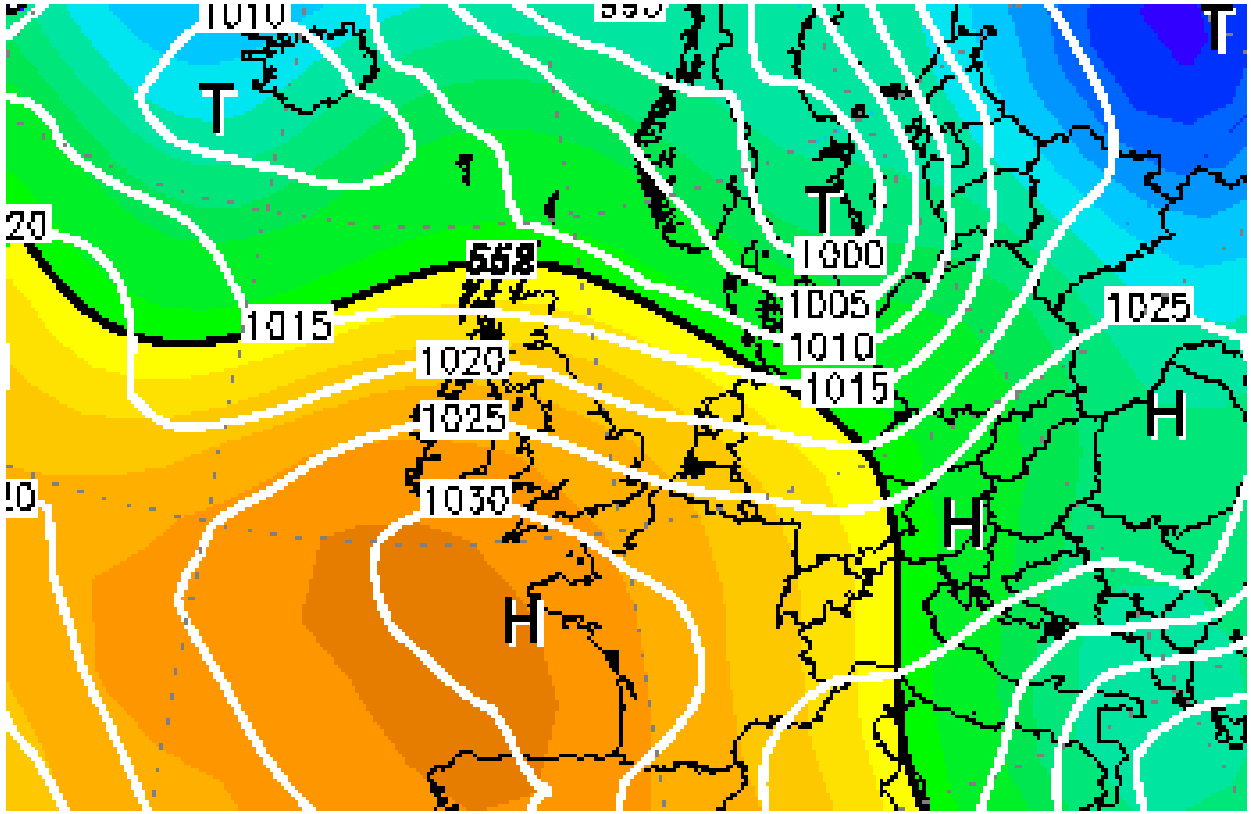
- Detailed analysis of the role of the evaporative/sublimation processes for the structure and the strenght of the SJ.

  -> Influence of different cloud microphysic parameterizations (e.g. three category ice scheme including graupel, two moment microphysic scheme) to the simulated SJ.

The Cyclone Oili – Synoptic situation

10 February 2006, 00UTC

500 hPa Geopotential (gpdm) and SLP (hPa)

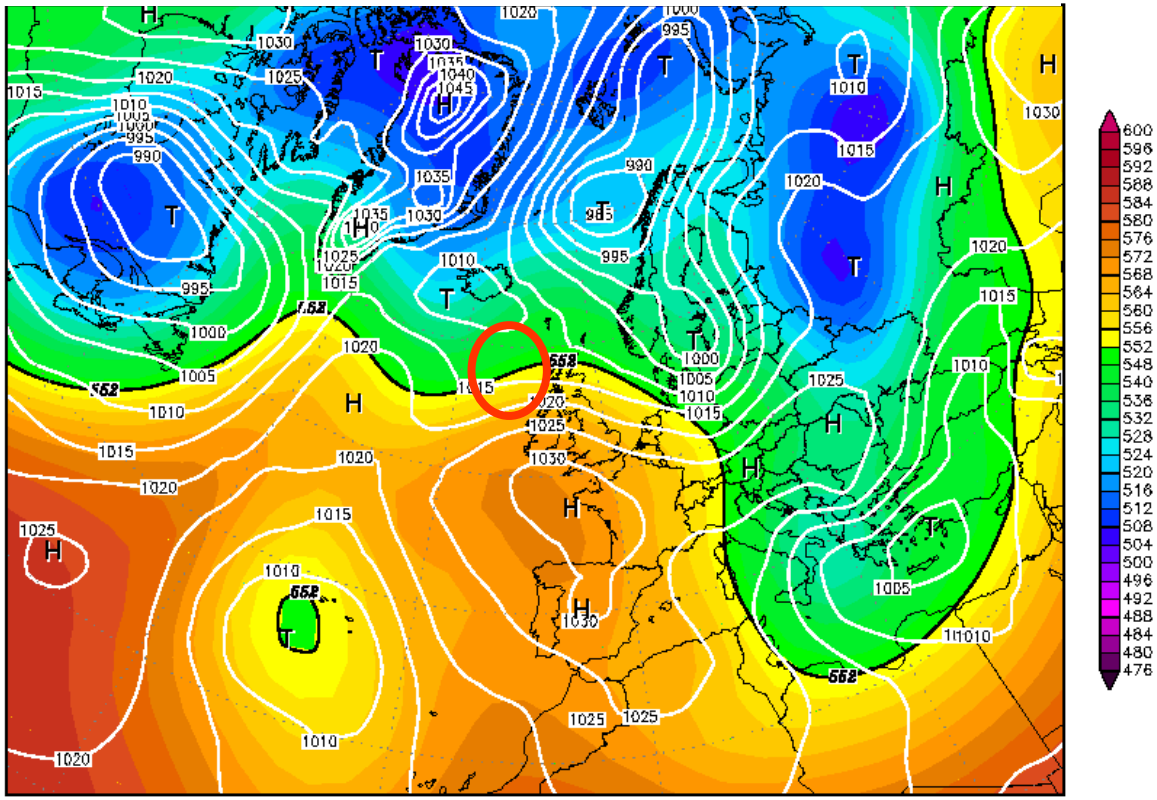


NCEP Reanalysis data

The Cyclone Oili – Synoptic situation

07 February 2006, 00UTC

500 hPa Geopotential (gpdm) and SLP (hPa)



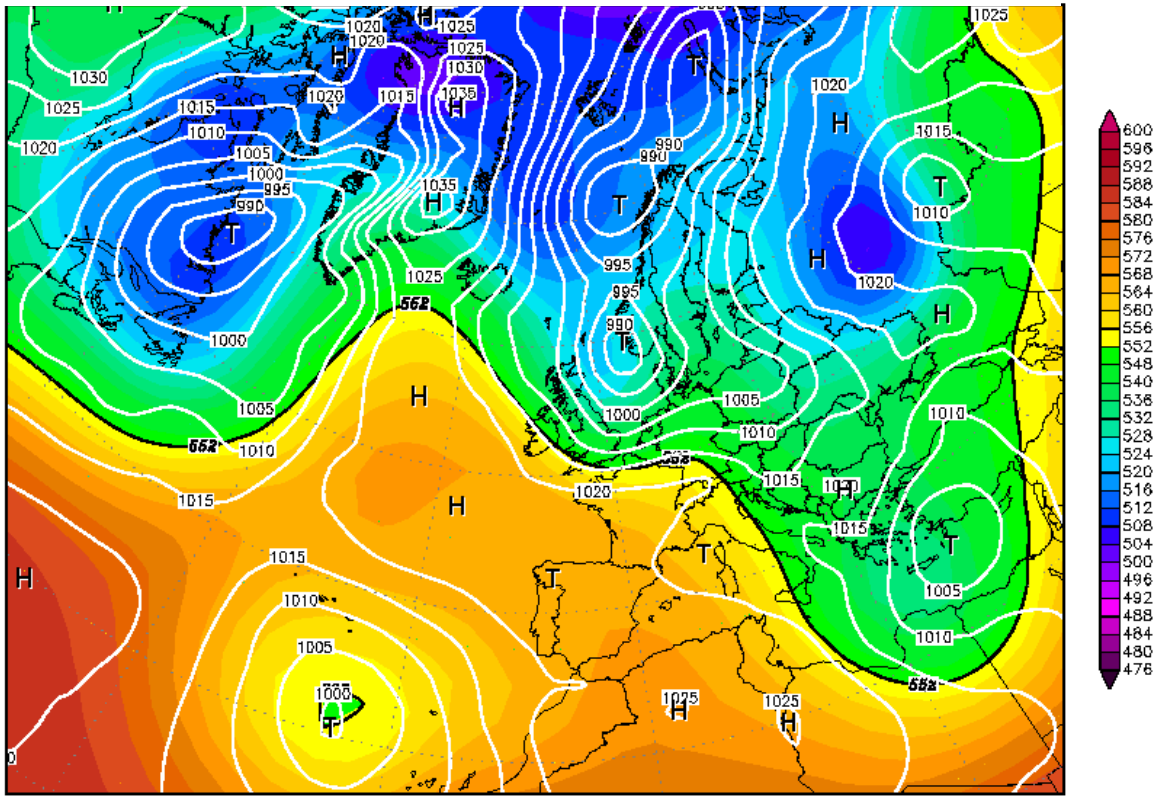
NCEP Reanalysis data

- `Oili´ originates between Iceland and Scotland
- SLP about 1010 hPa (06 UTC)
- rapid cyclogenesis
- SLP about 995 hPa (18 UTC)

The Cyclone Oili – Synoptic situation

08 February 2006, 00UTC

500 hPa Geopotential (gpdm) and SLP (hPa)



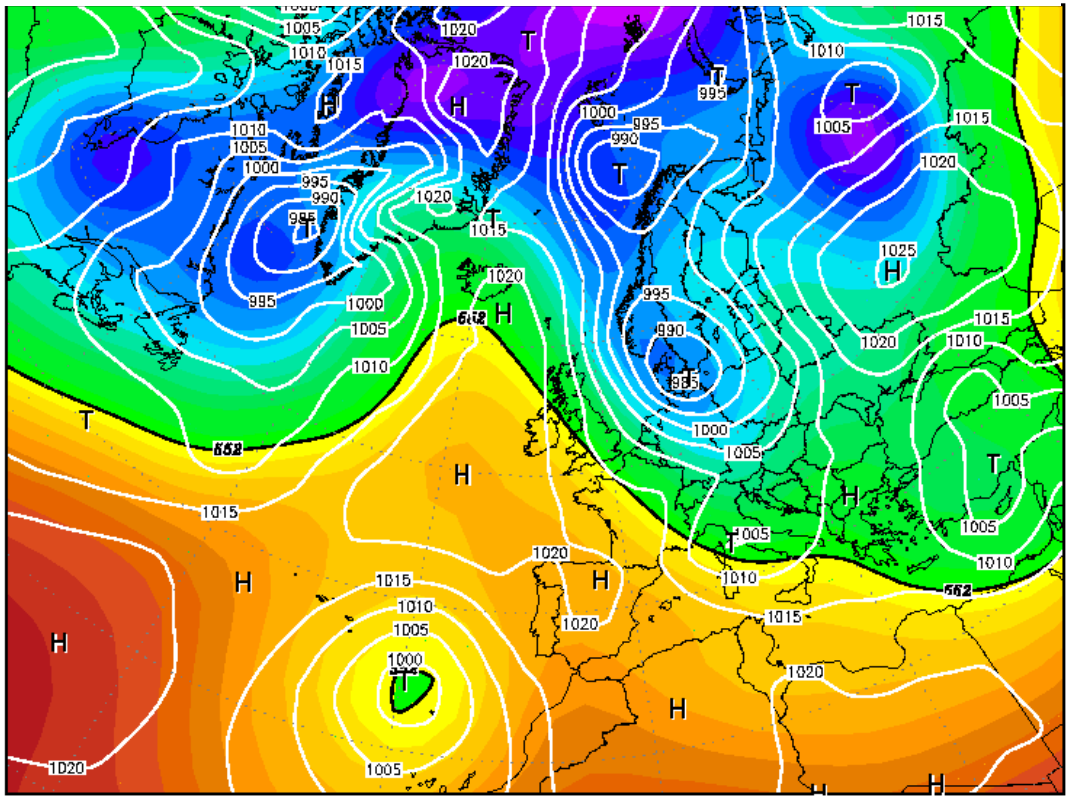
NCEP Reanalysis data

- `Oili´ located to the south of Norway
- SLP about 990 hPa
- Cyclogenesis is finished at about 06 UTC with SLP of 985 hPa
- Pressure decrease about 25 hPa within 24 hours
- 500 hPa trough overruns surface low

The Cyclone Oili – Synoptic situation

09 February 2006, 00UTC

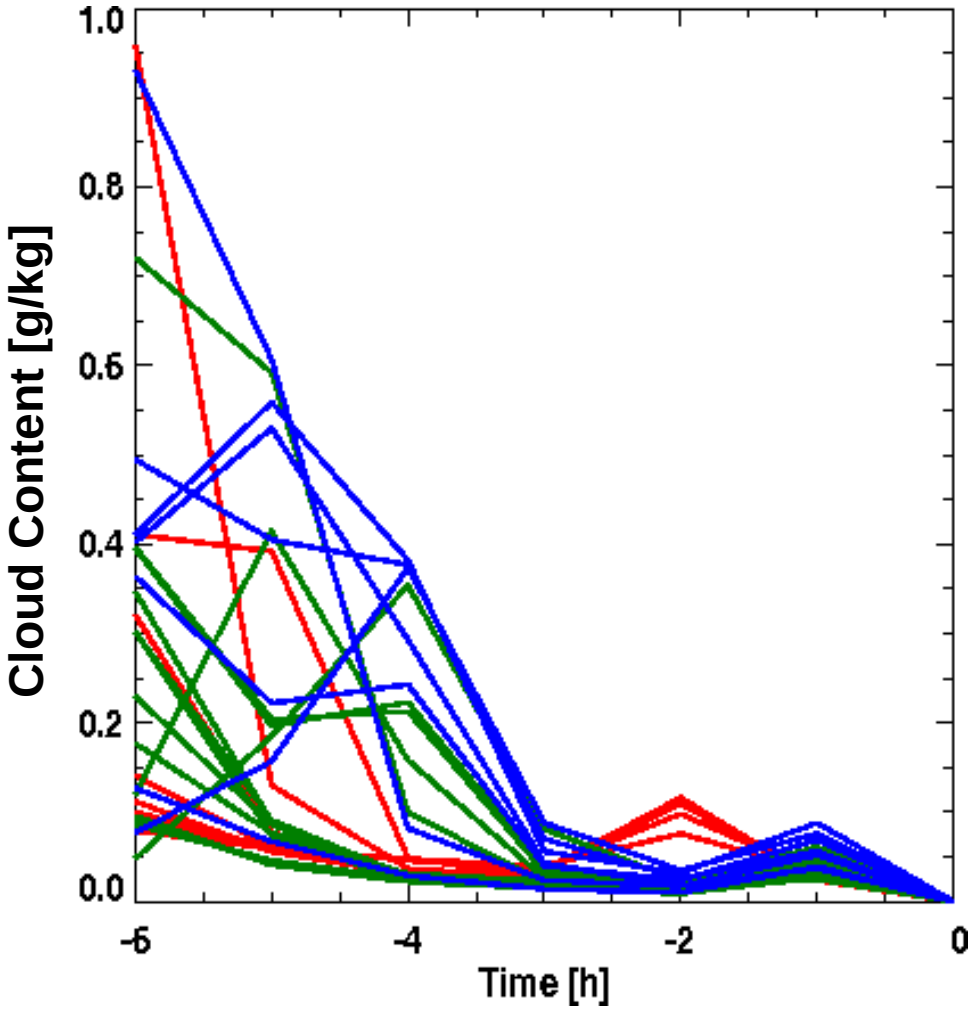
500 hPa Geopotential (gpdm) and SLP (hPa)



NCEP Reanalysis data

- `Oili´ located over Danmark
- SLP about 985 hPa
- `Oili´ lead to heavy precipitation and strong surface gusts over Europe (mountainous regions)

History of air that contributes to the SJ

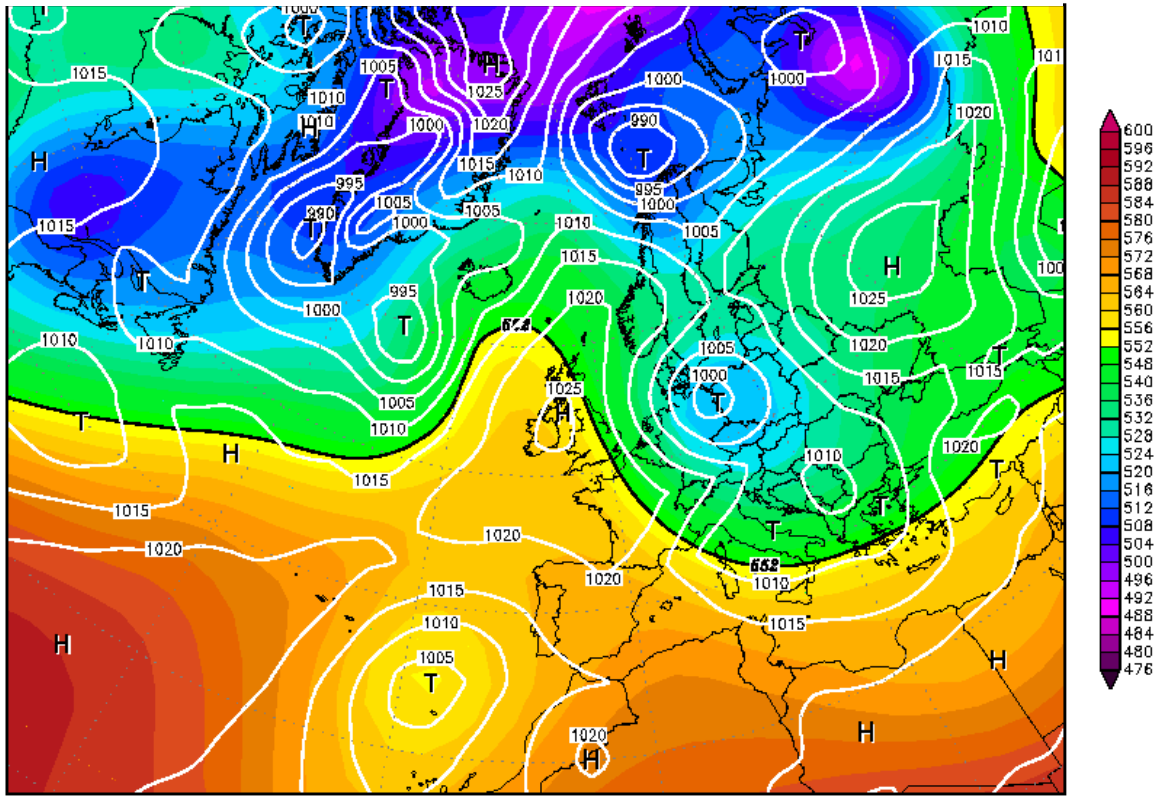


Air parcels start inside clouds and end in cloud free region

The Cyclone Oili – Synoptic situation

10 February 2006, 00UTC

500 hPa Geopotential (gpdm) and SLP (hPa)



NCEP Reanalysis data