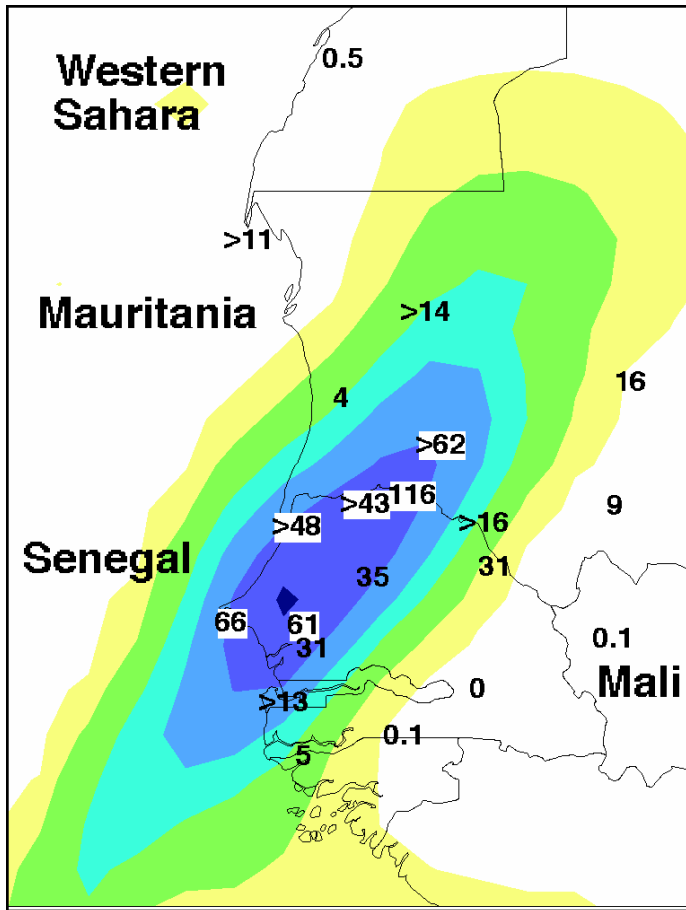


Sensitivity experiments with the
COSMO-Model -
the influence of upstream latent heating
and wave amplification on a heavy
precipitation event over West Africa

Florian Meier, Peter Knippertz
Johannes Gutenberg-University Mainz





mm

100

75

50

30

10

1

accumulated
precipitation from

06 UTC 9 to 06 UTC
11 January 2002:

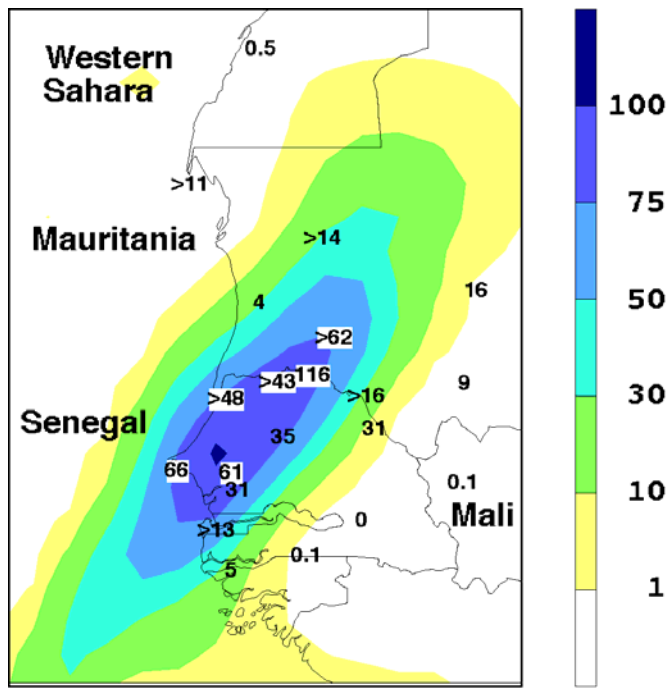
observations and
results of a

UW-NMS model
simulation

climatologic January mean: ≈ 1 mm

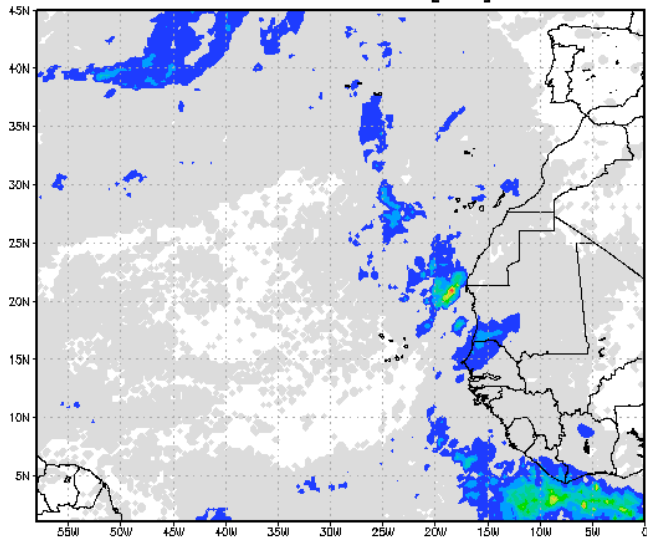
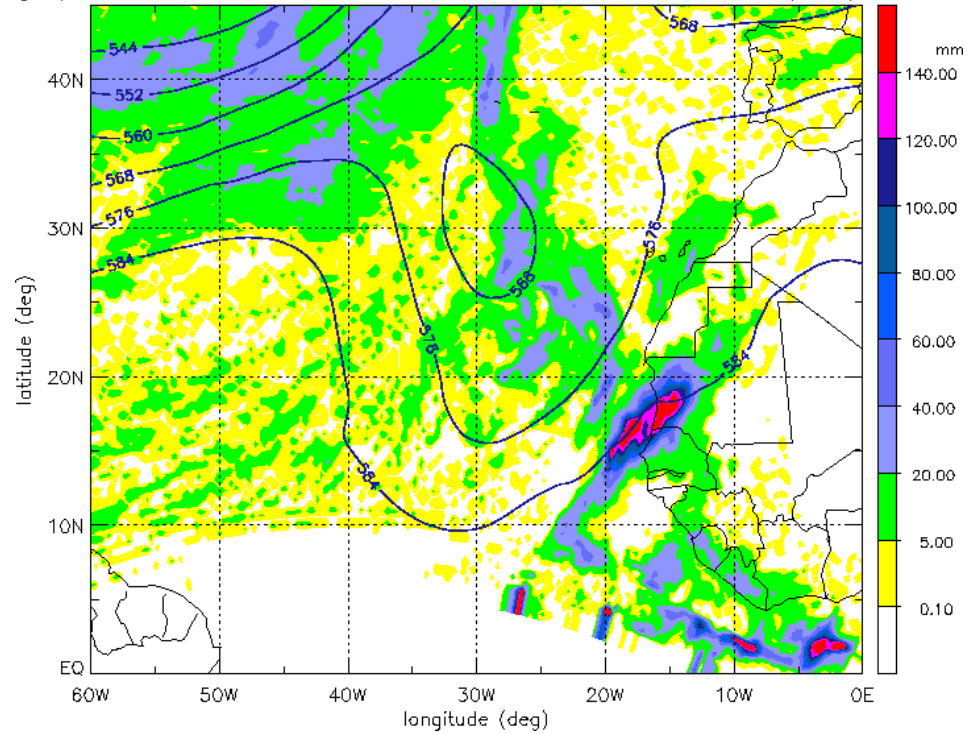
116 mm in 48h in Podor

from Knippertz and Martin 2005



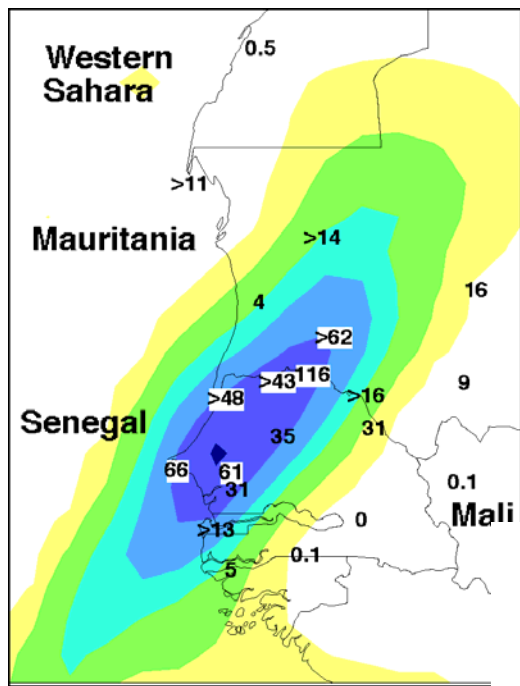
Daily TRMM 3B42(v6) 09Jan2002-11Jan2002
Accumulated Rainfall [mm]

geopotential 500 hPa 2002-01-08 00z and 48h accumulated precipitation

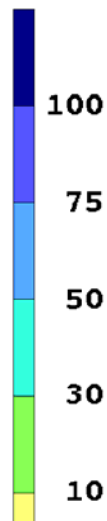


↑
COSMO-MODEL
simulation

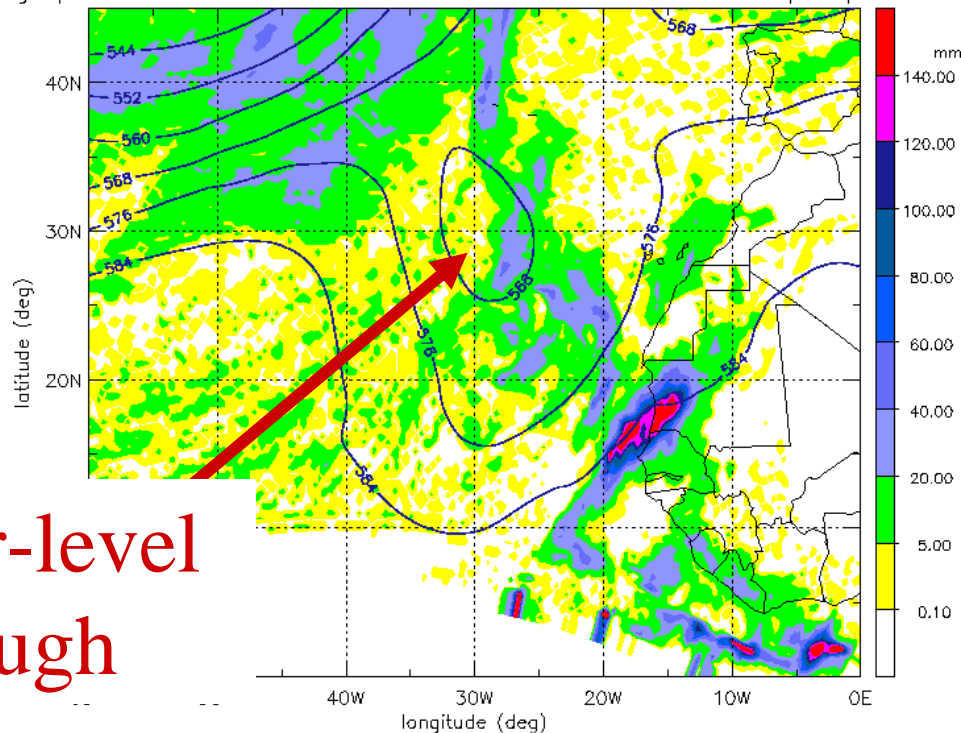
←
TRMM-satellite
observation



Daily TRMM 3B42(V6) 09Jan2002-11Ja
Accumulated Rainfall [mm]



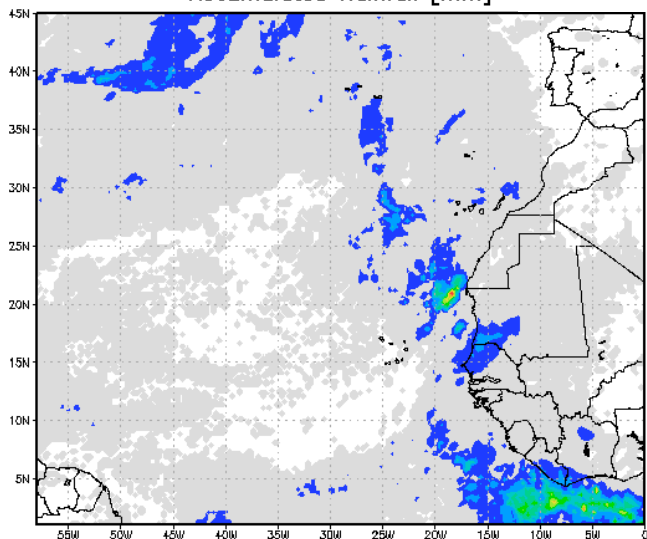
geopotential 500 hPa 2002-01-08 00z and 48h accumulated precipitation



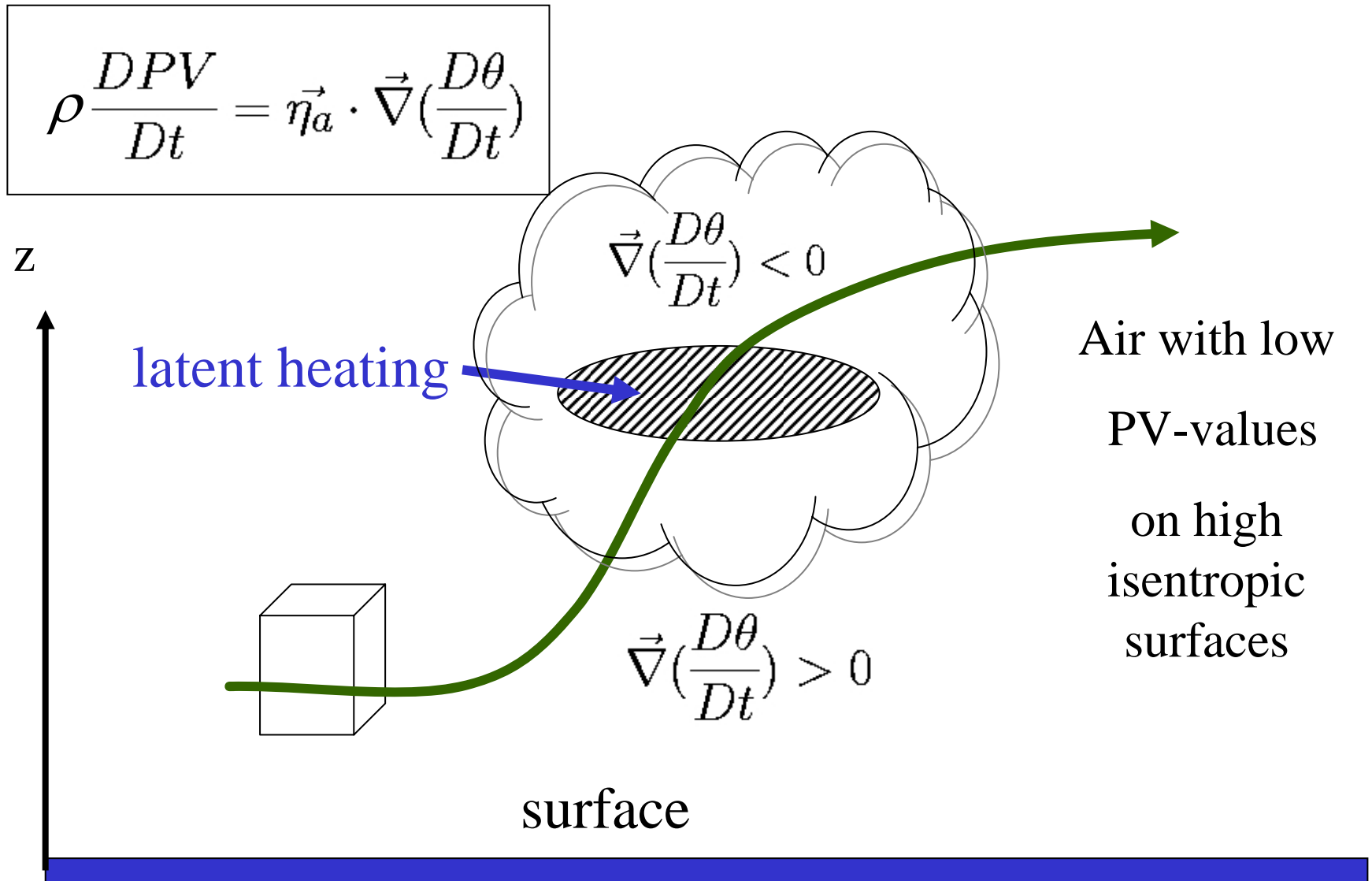
upper-level
trough

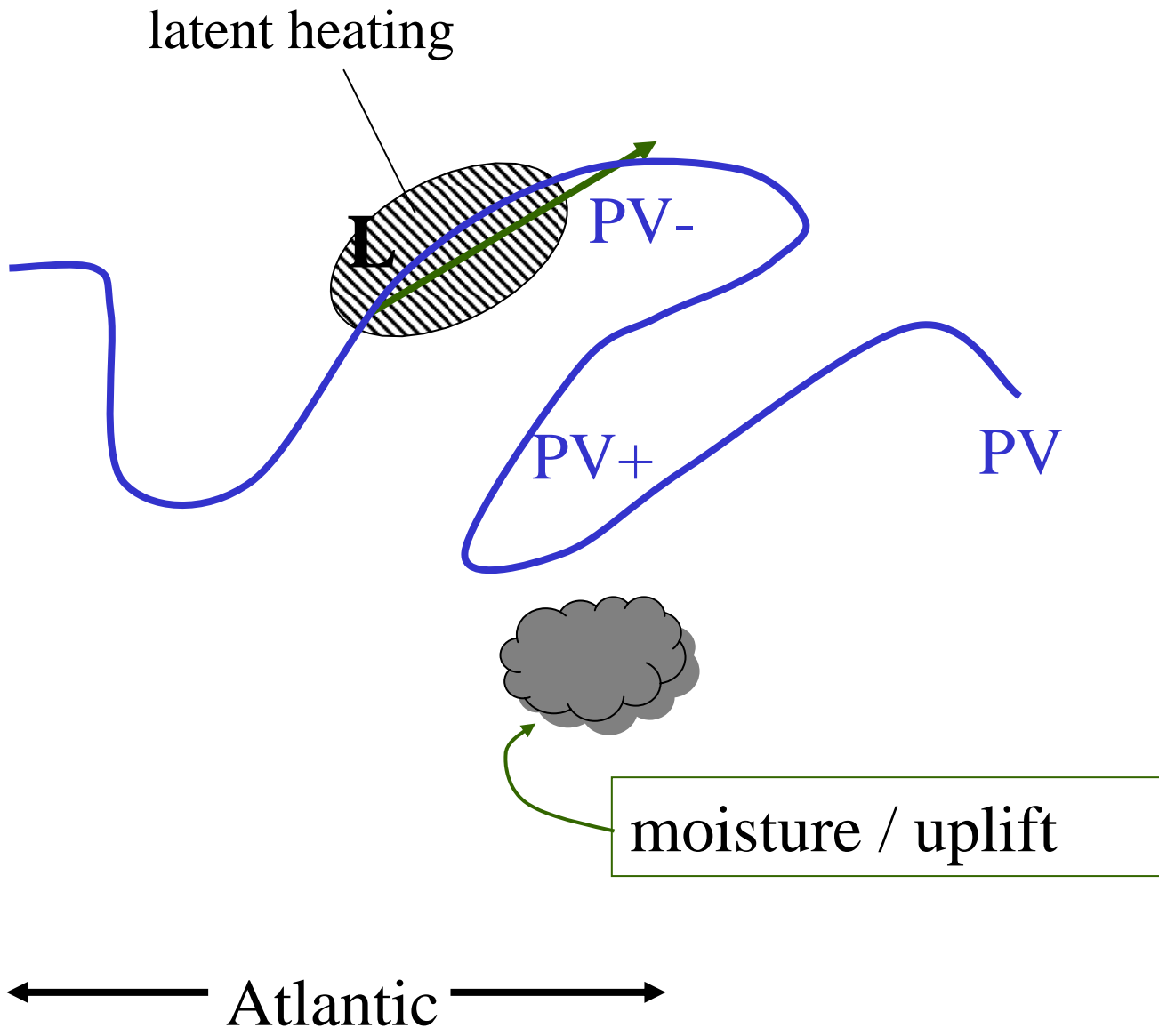
COSMO-MODEL
simulation

TRMM-satellite
observation

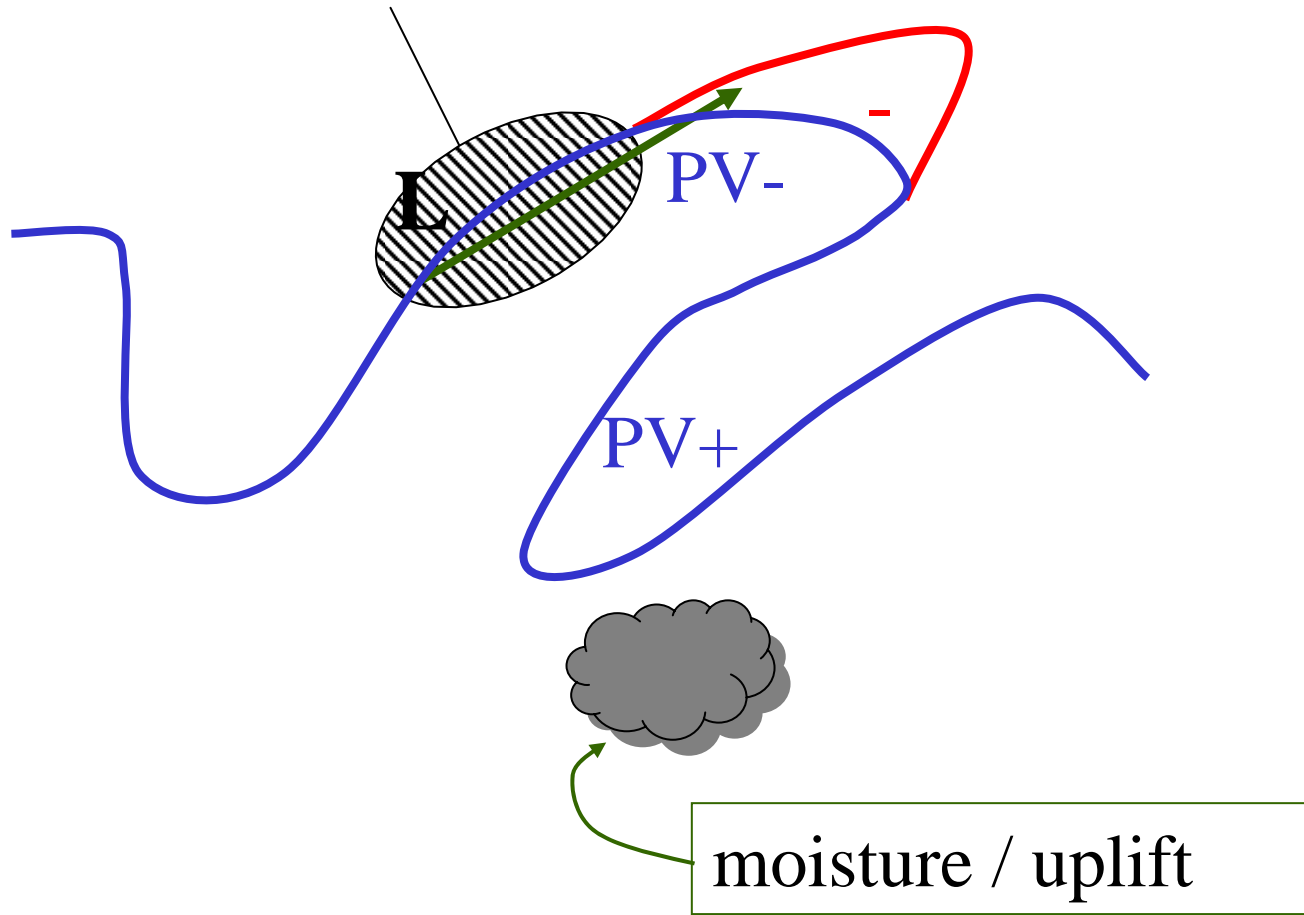


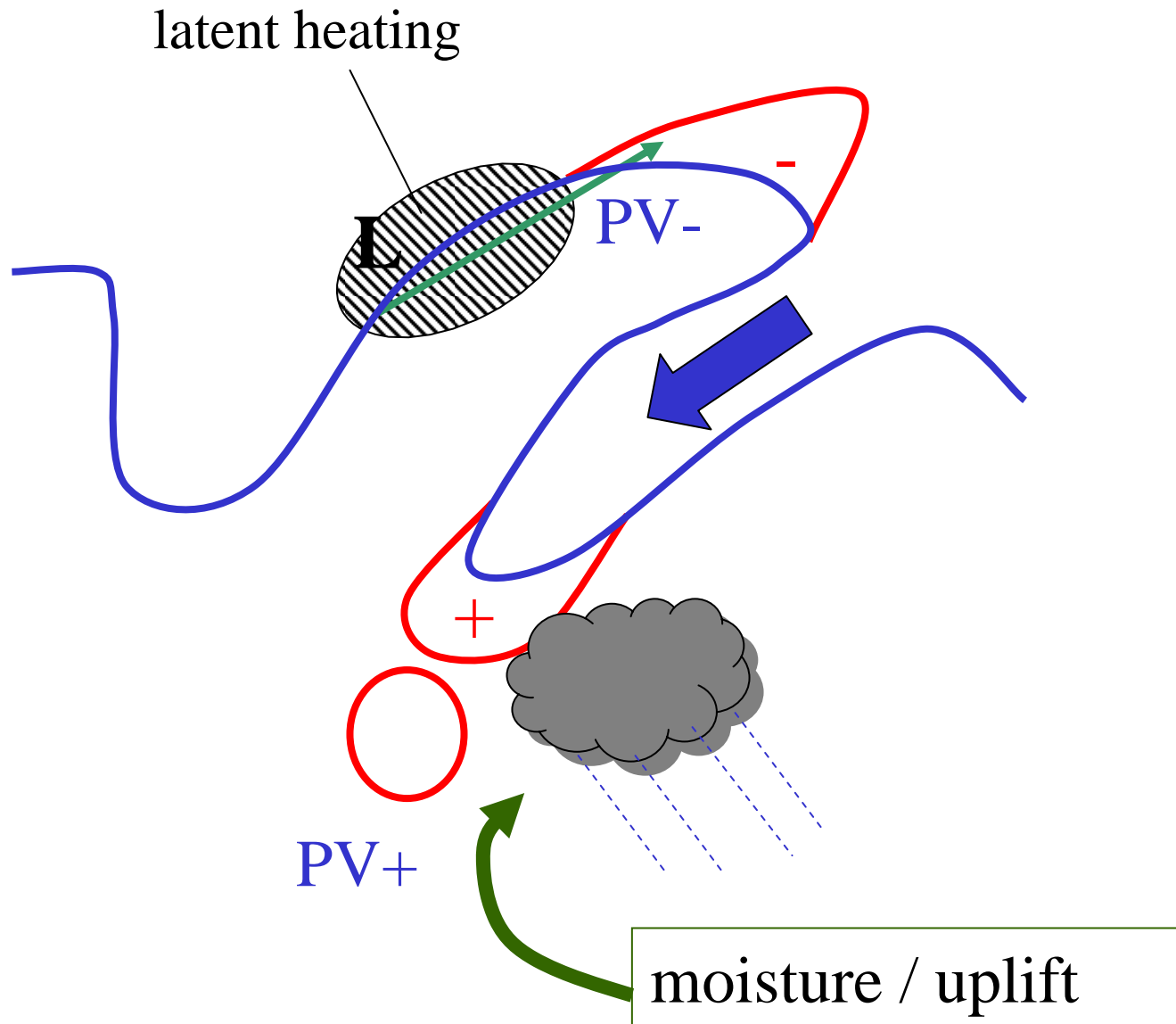
Potential vorticity (PV) modification due to latent heating





latent heating





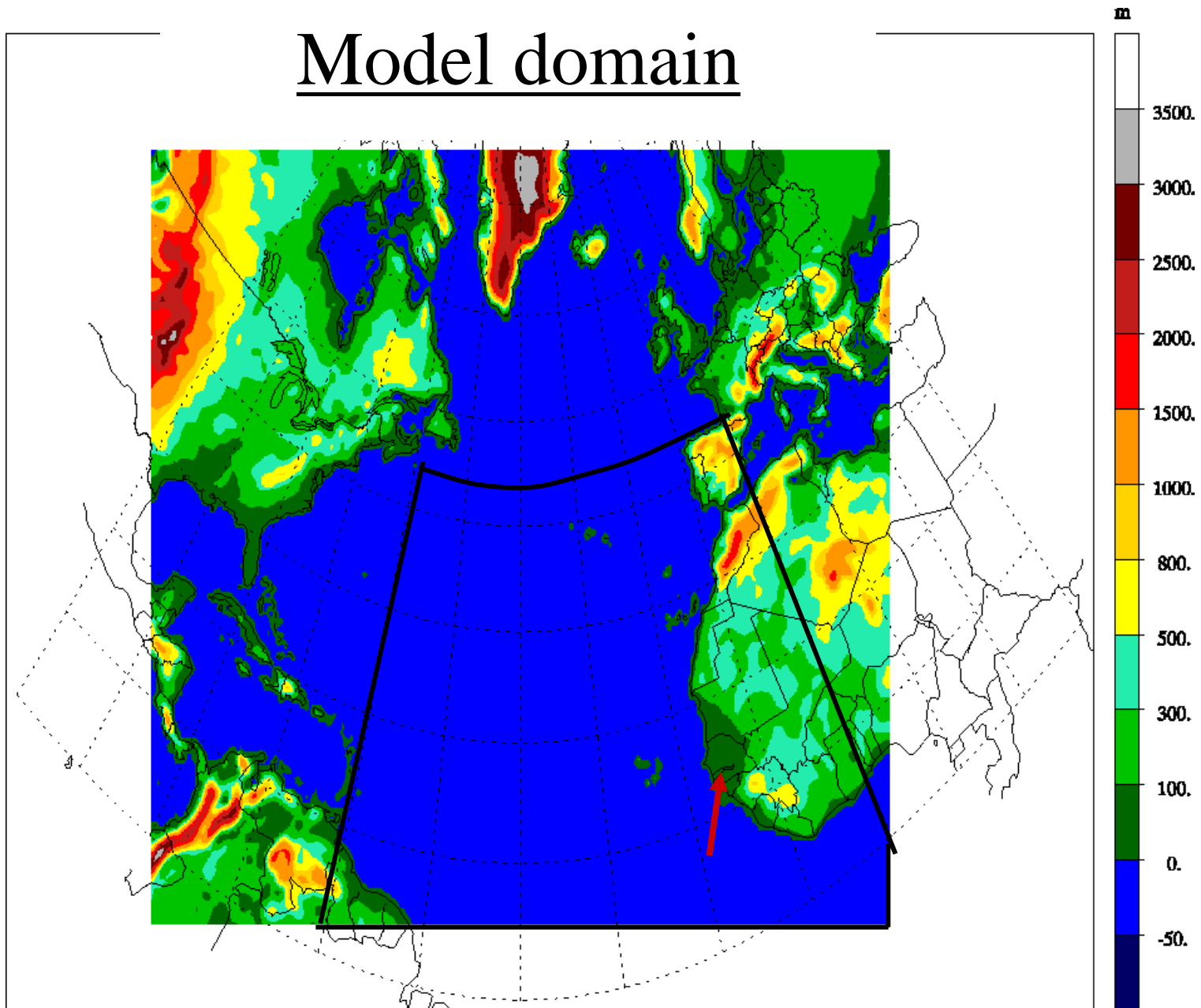
Hypothesis:

- latent heating during upstream cyclogenesis over the extratropical Atlantic
- amplification of the PV wave and enforcing of the positive PV-anomaly in front of the west African coast
- more moisture transport and forcing over West Africa
- strengthening of the precipitation event

COSMO-Model configuration

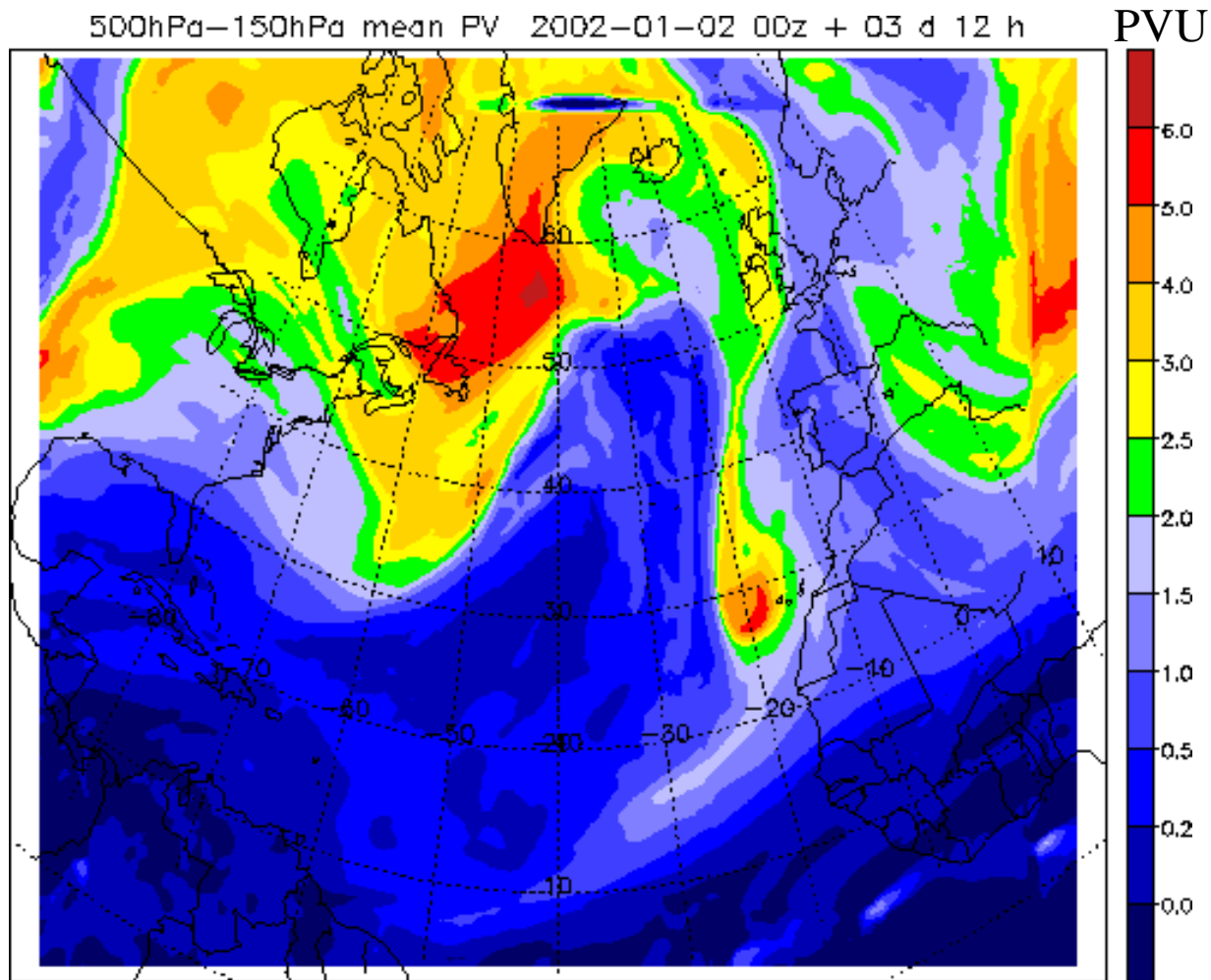
- COSMO-Model version 3.21
- resolution: $0.4^\circ \times 0.4^\circ$; 40 layers; 250x175 gp
- IFS-analyses as initial and boundary data
- cloud ice microphysics; Kain-Fritsch convection scheme
- timestep 60s; runge-kutta dynamics
- runs started on 2nd January 2002 00 UTC

Model domain



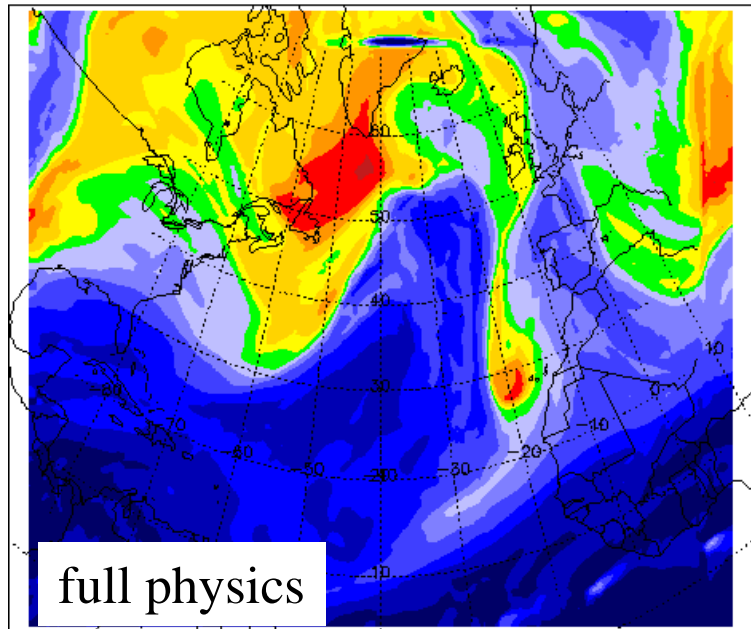
Sensitivity experiments:

- control run with “full physics”
- *completely dry run*
- latent heat constants ≈ 0
- temperature tendencies concerning $lh = 0$
 - in the whole domain
 - in parts of the domain
 - until day five of simulation



500-150 hPa mean PV control run
2002-01-05 12UTC

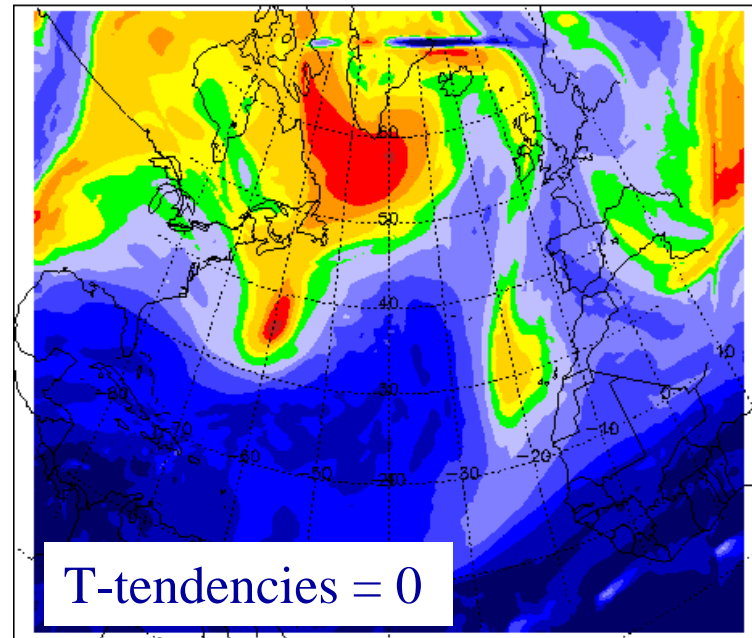
500hPa-150hPa mean PV 2002-01-02 00z + 03 d 12 h



PVU

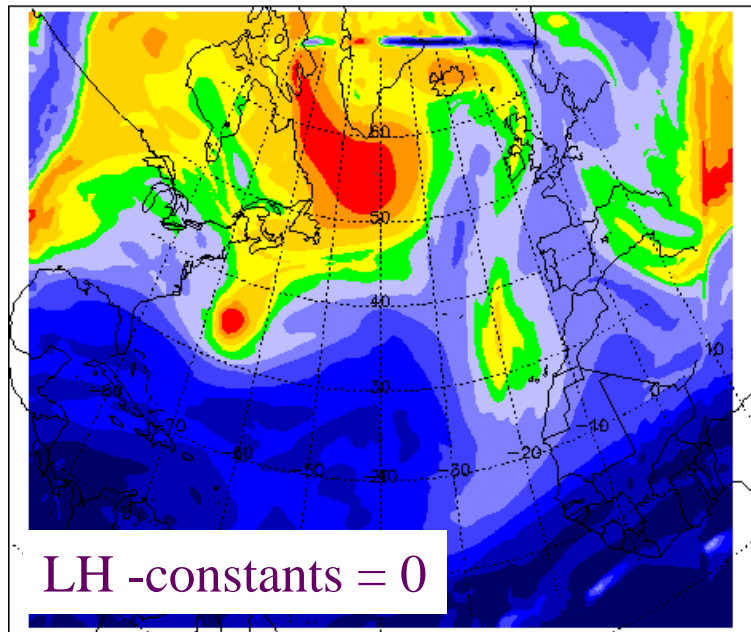
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.5
0.2
0.0

500hPa-150hPa mean PV 2002-01-02 00z + 03 d 12 h



PVU
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.5
0.2
0.0

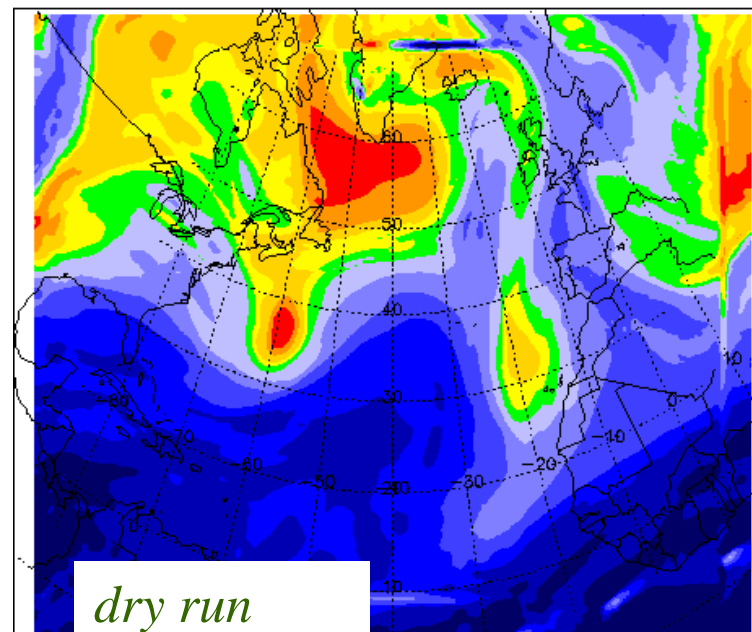
500hPa-150hPa mean PV 2002-01-02 00z + 03 d 12 h



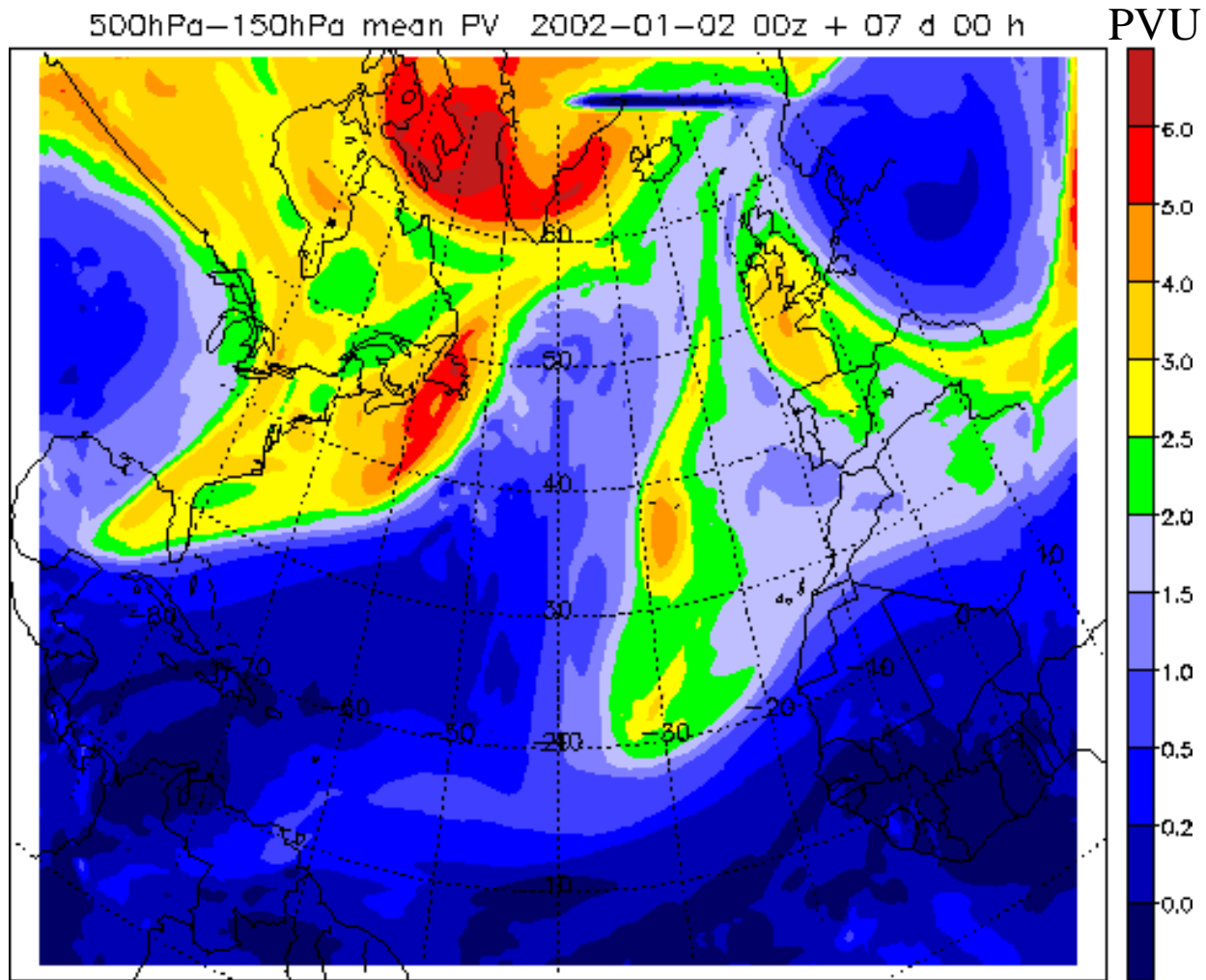
PVU
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.5
0.2
0.0

PVU

500hPa-150hPa mean PV 2002-01-02 00z + 03 d 12 h

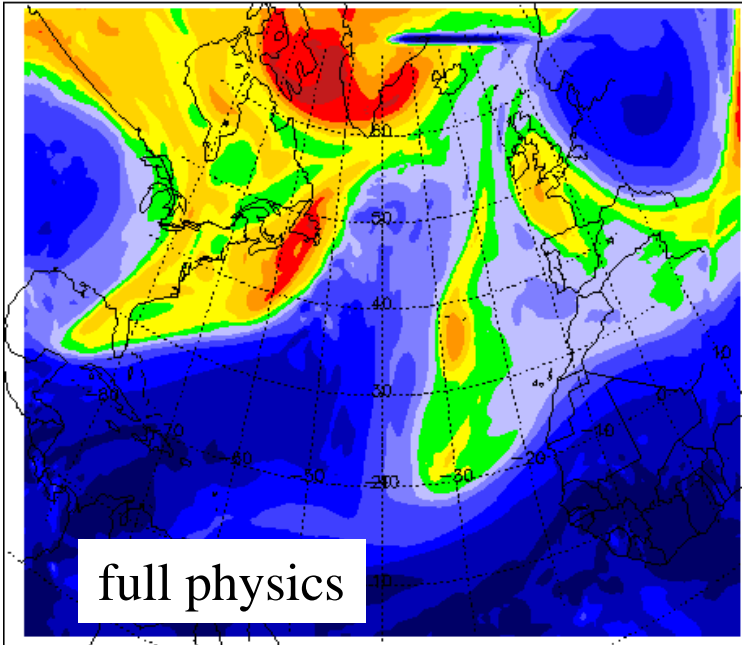


PVU
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.5
0.2
0.0

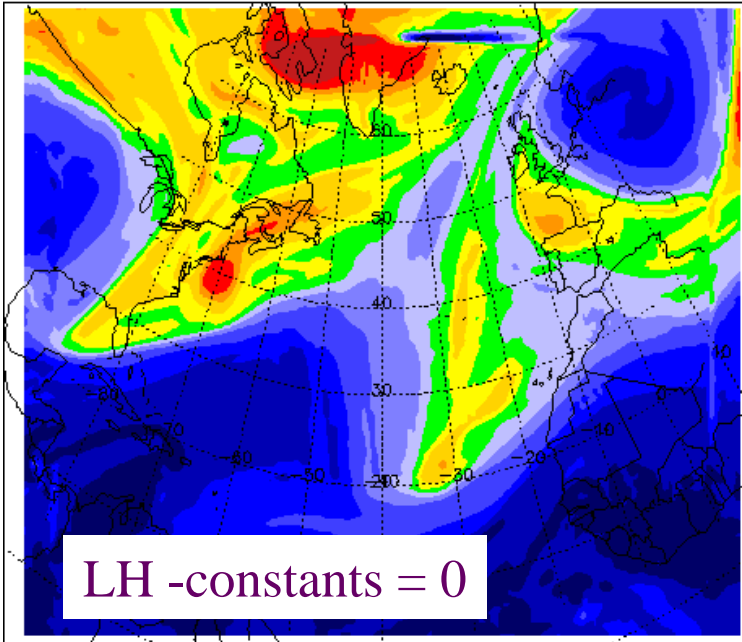


500-150 hPa mean PV control run
2002-01-09 00UTC

500hPa-150hPa mean PV 2002-01-02 00z + 07 d 00 h



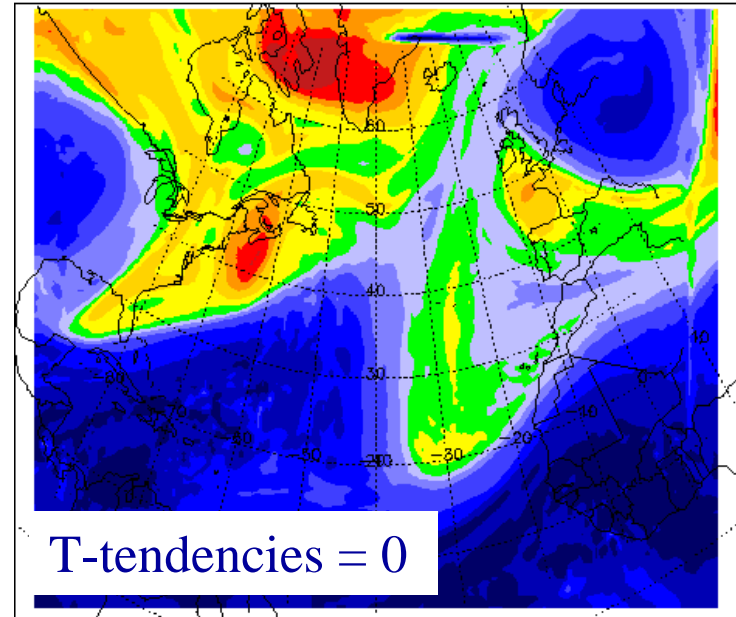
500hPa-150hPa mean PV 2002-01-02 00z + 07 d 00 h



PVU

6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.5
0.2
0.0

500hPa-150hPa mean PV 2002-01-02 00z + 07 d 00 h

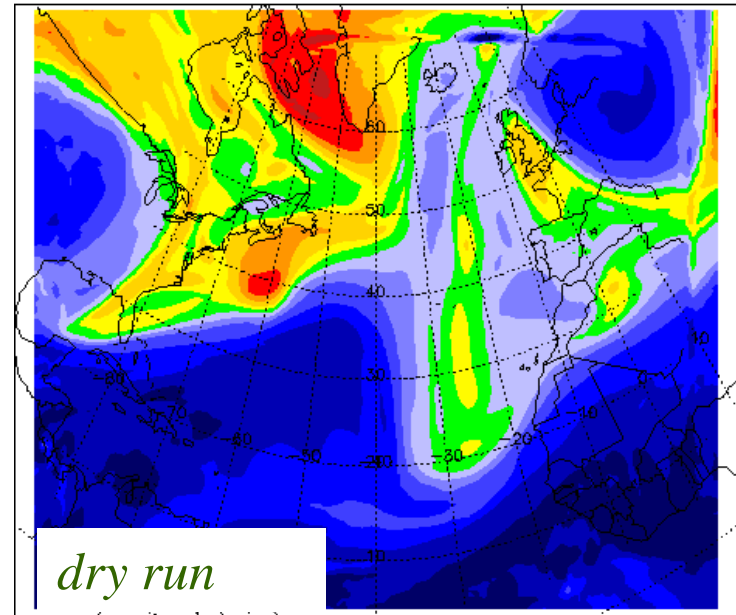


PVU
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.5
0.2
0.0

PVU

6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.5
0.2
0.0

500hPa-150hPa mean PV 2002-01-02 00z + 07 d 00 h



PVU
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.5
0.2
0.0

< 970hPa

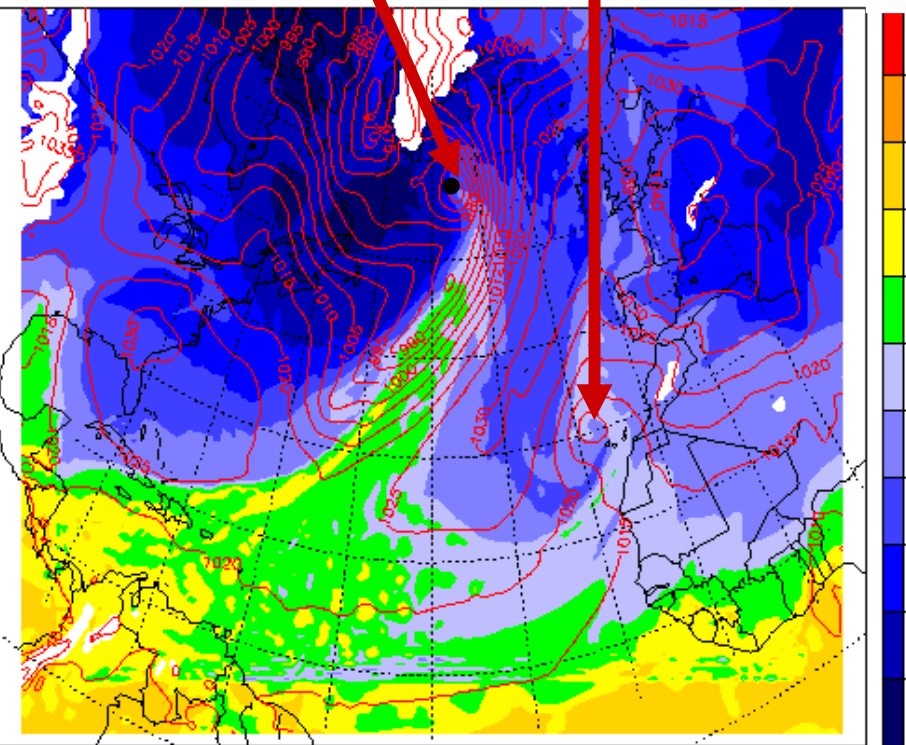
< 1010hPa

< 990hPa

< 1020hPa

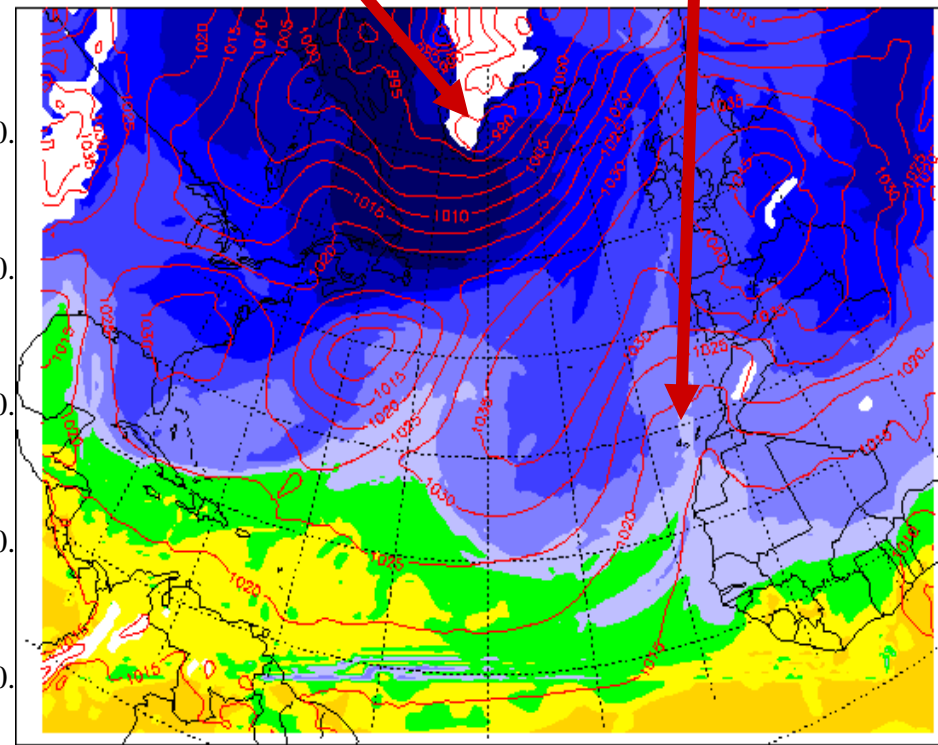
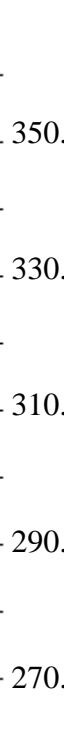
ThetaE on 850 hPa and SLP 2002-01-02 00z + 03 d 12 h

K



full physics

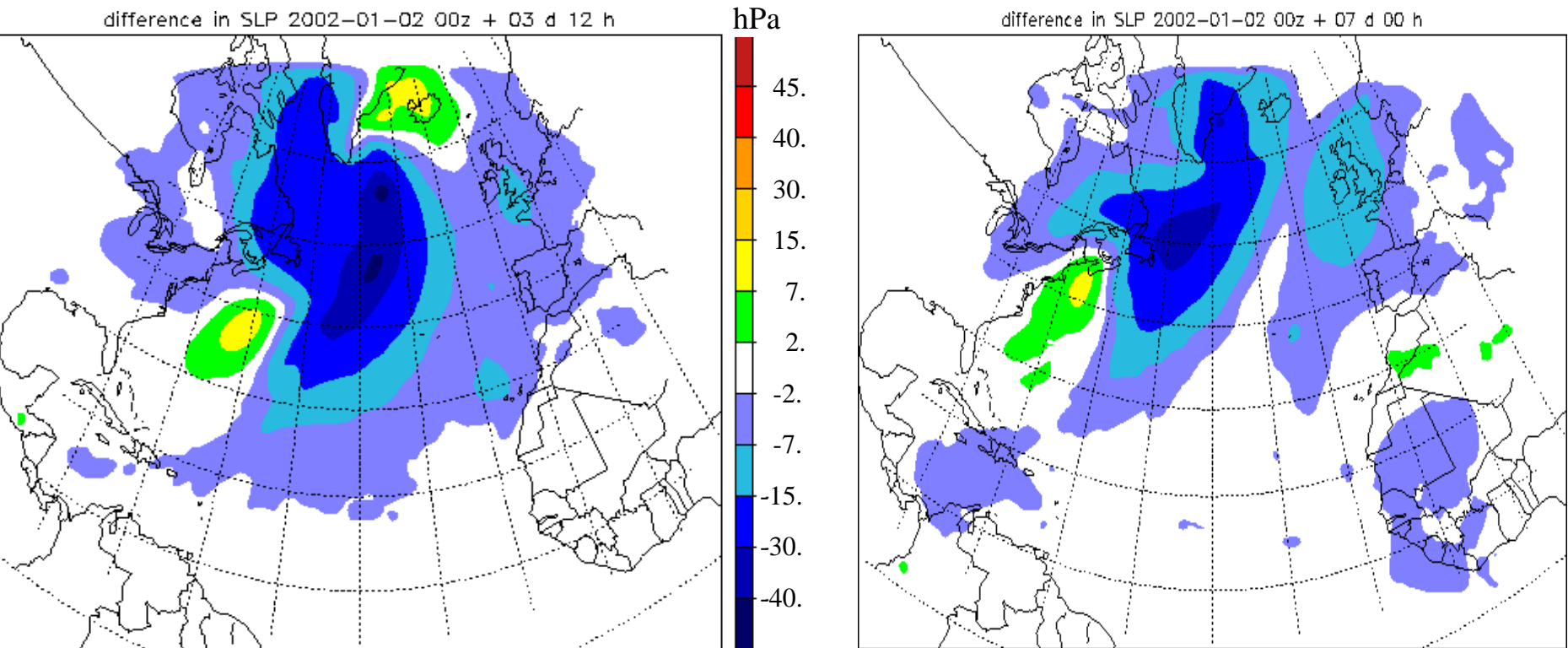
ThetaE on 850 hPa and SLP 2002-01-02 00z + 03 d 12 h



experiment

(T-tendencies =0)

5th January 2002 12UTC



differences in sea-level pressure in hPa

difference full physics - experiment

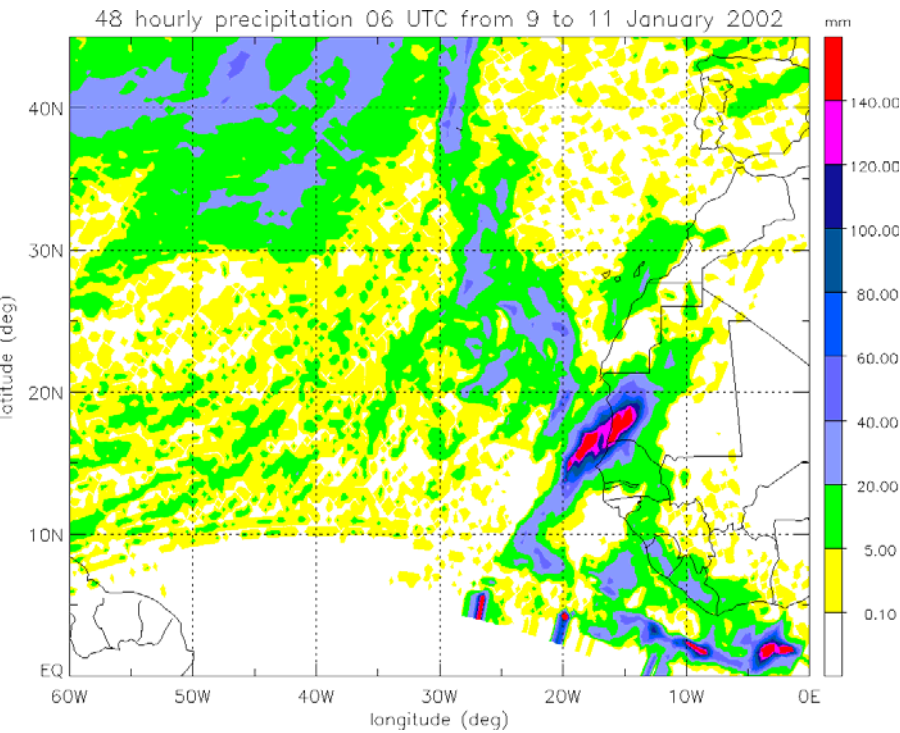
5th January 2002 12 UTC

9th January 2002 00 UTC

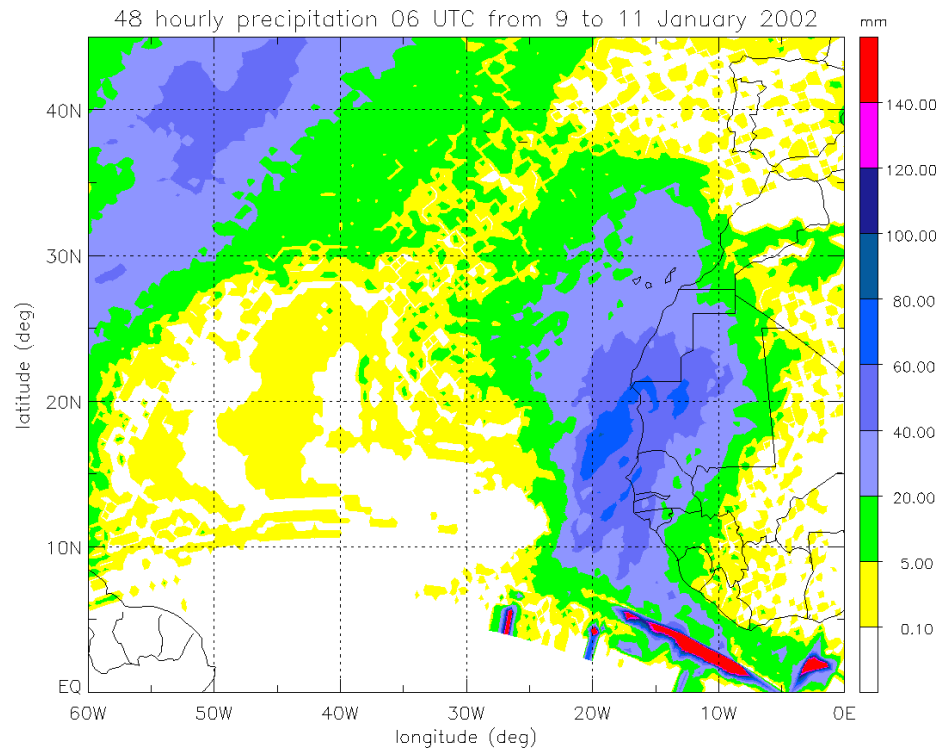
First summary

- deeper cyclones in the extratropics with latent heating
- stronger PV-anomalies in the extratropics and near the African coast
- differences more obvious on 5th January
- effect on the precipitation quantity?

48h accumulated precipitation 9th January 06 UTC

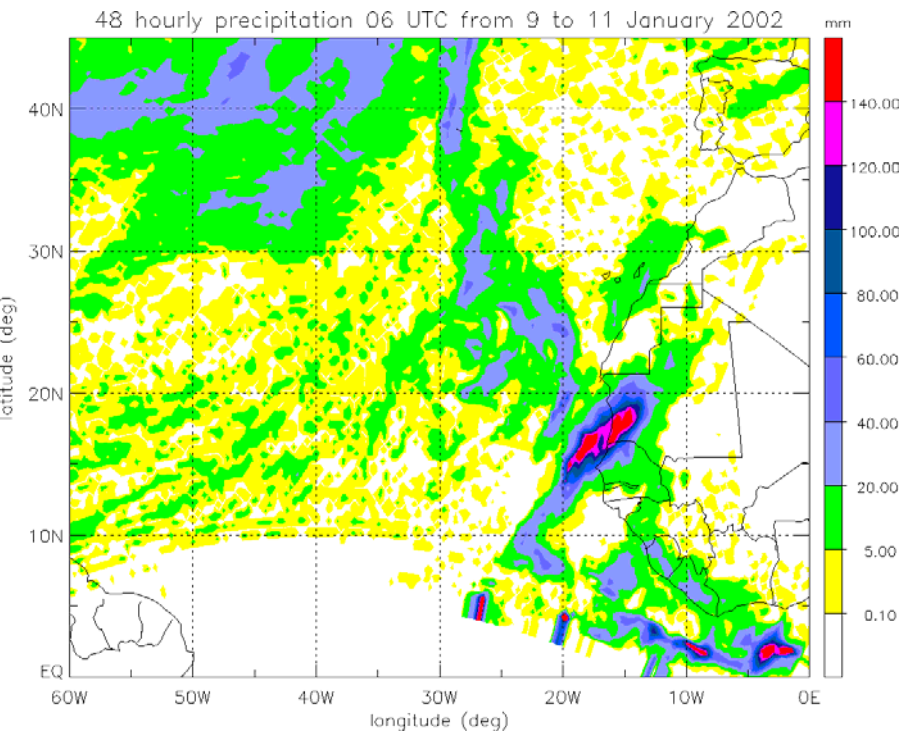


full physics

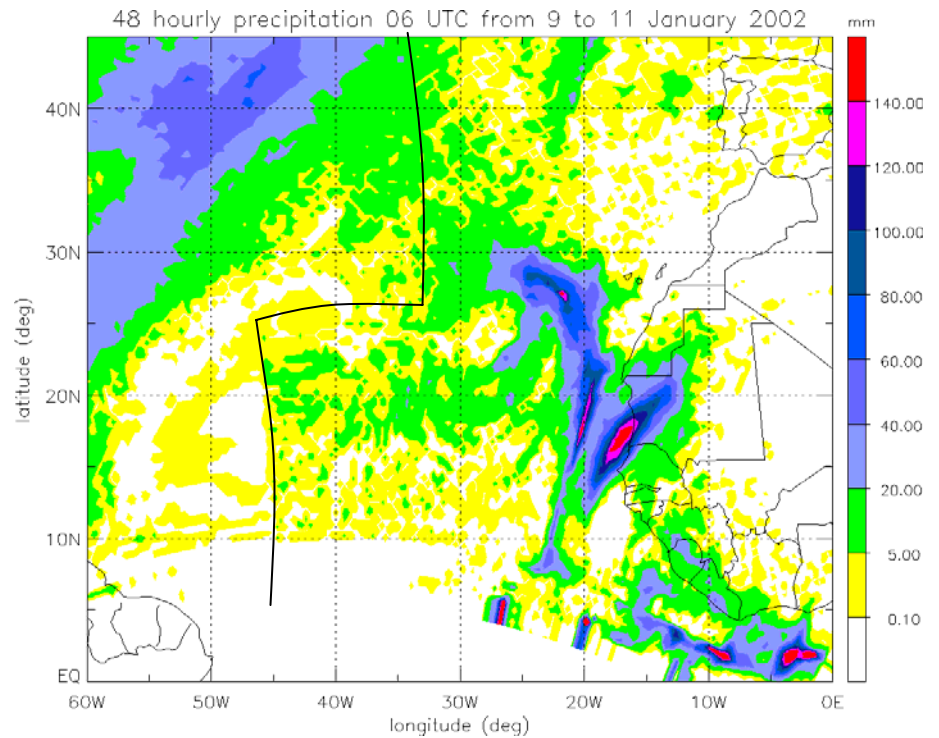


experiment

48h accumulated precipitation 9th January 06 UTC

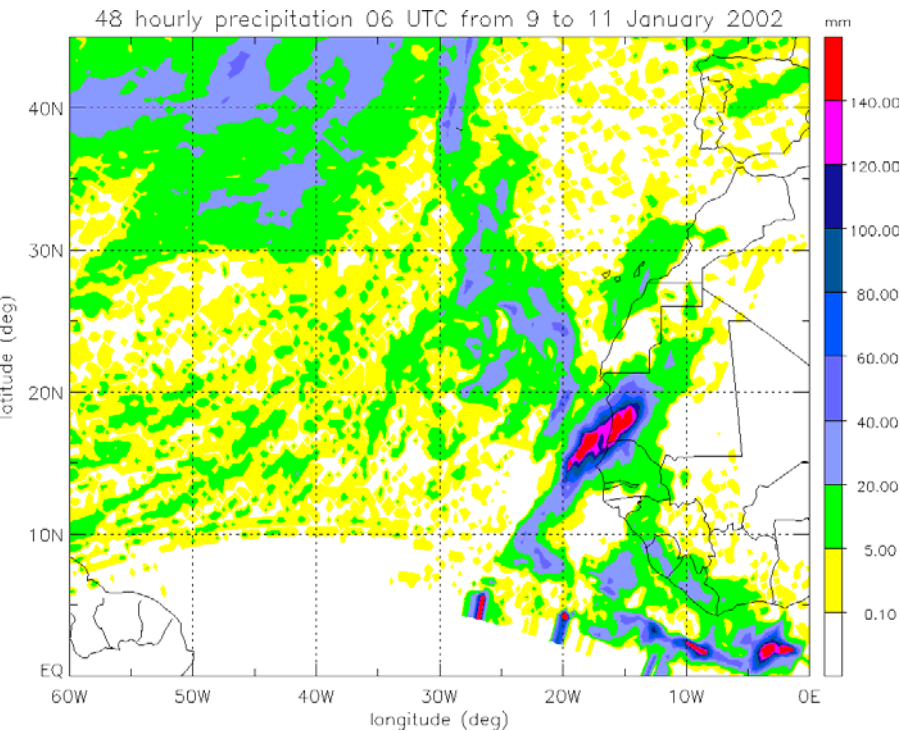


full physics run

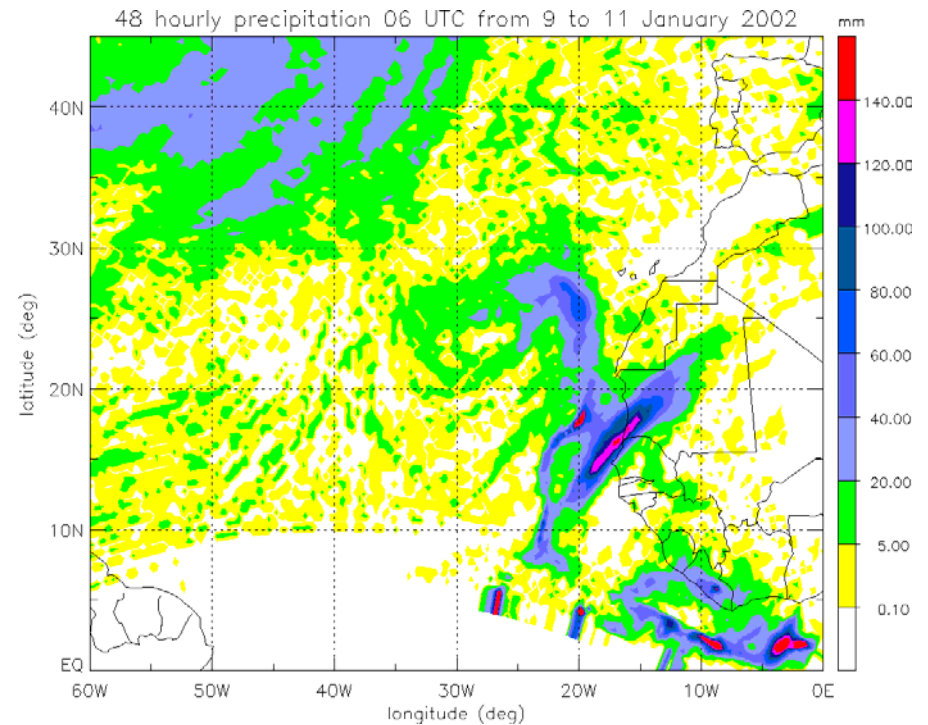


latent heating suppressed only in
parts of the domain

48h accumulated precipitation 9th January 06 UTC



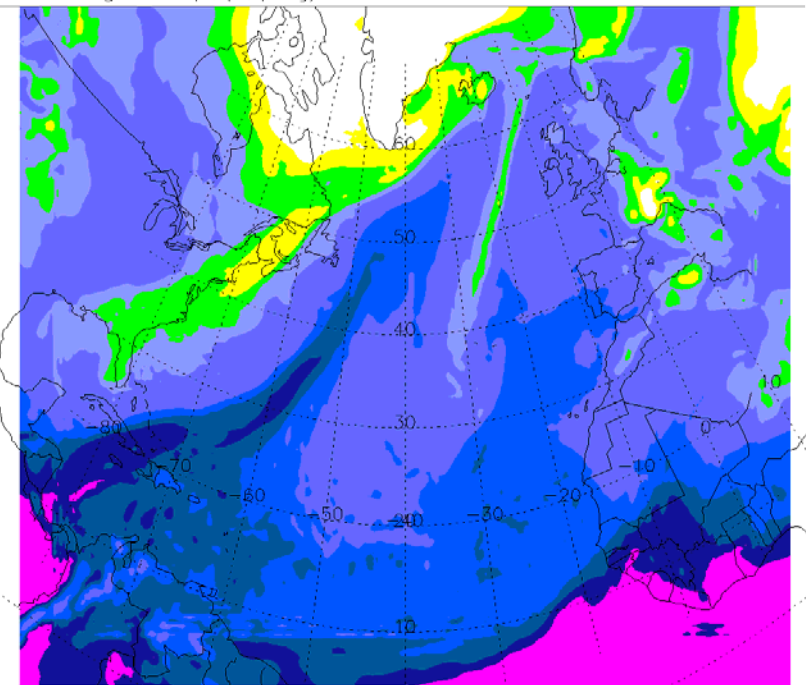
full physics run



latent heating started after first
PV-anomaly had passed

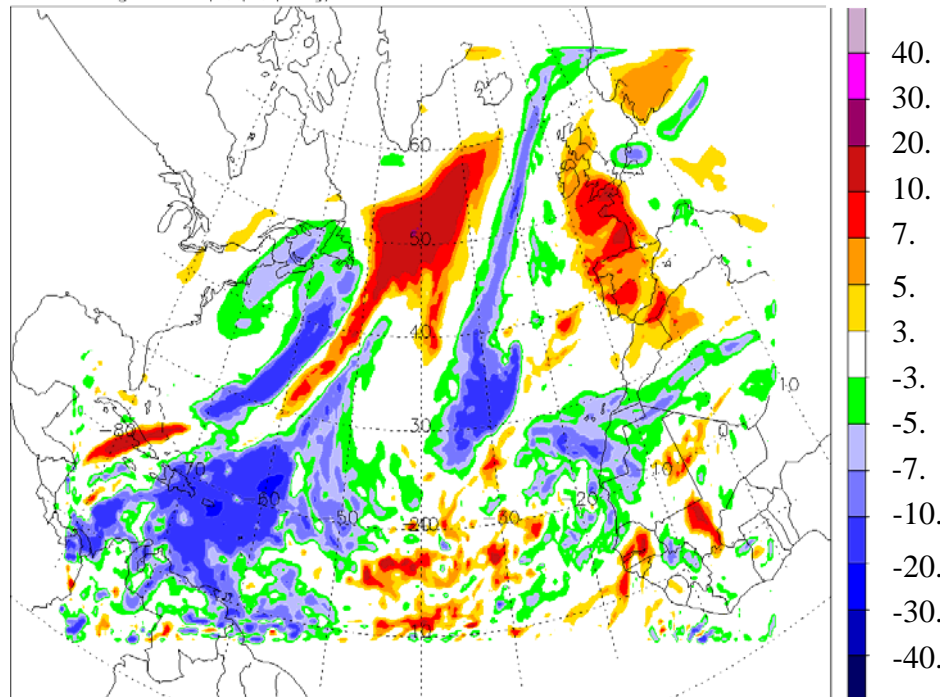
Only weak influence of latent heating on simulated precipitation quantity

Integrated q_v, q_c, q_i kg/m^2 2002-01-02 00z + 07 d 00 h kg/m^2



full physics

Integrated q_v, q_c, q_i kg/m^2 2002-01-02 00z + 07 d 00 h kg/m^2

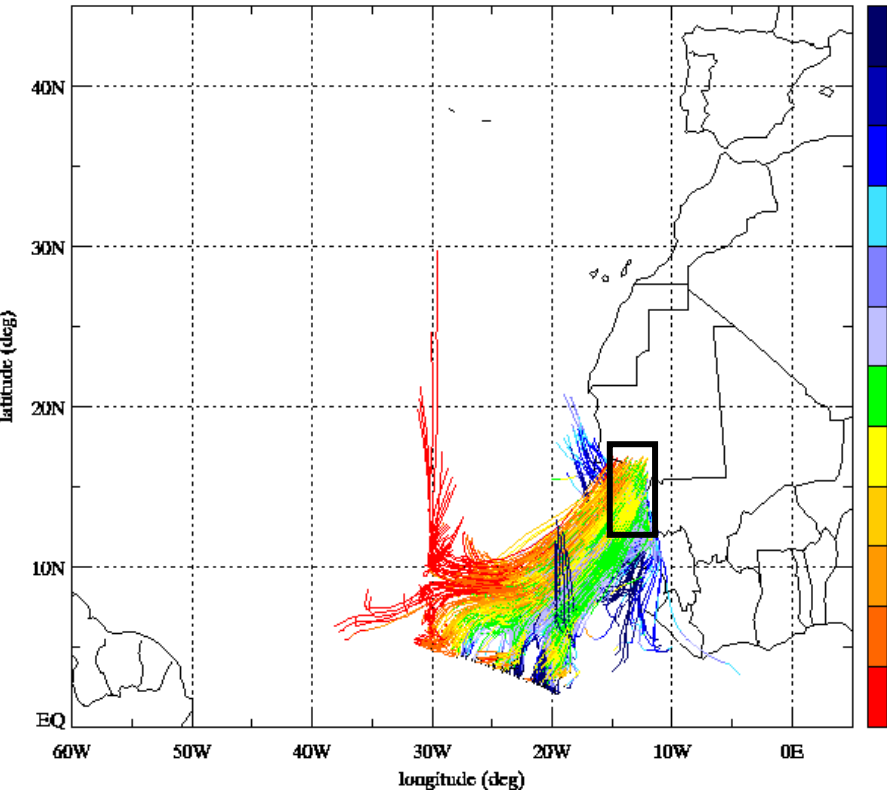


full physics - **experiment**

vertically integrated water vapor, cloud-water,
cloud-ice in kg/m^2

9th January 2002 00 UTC

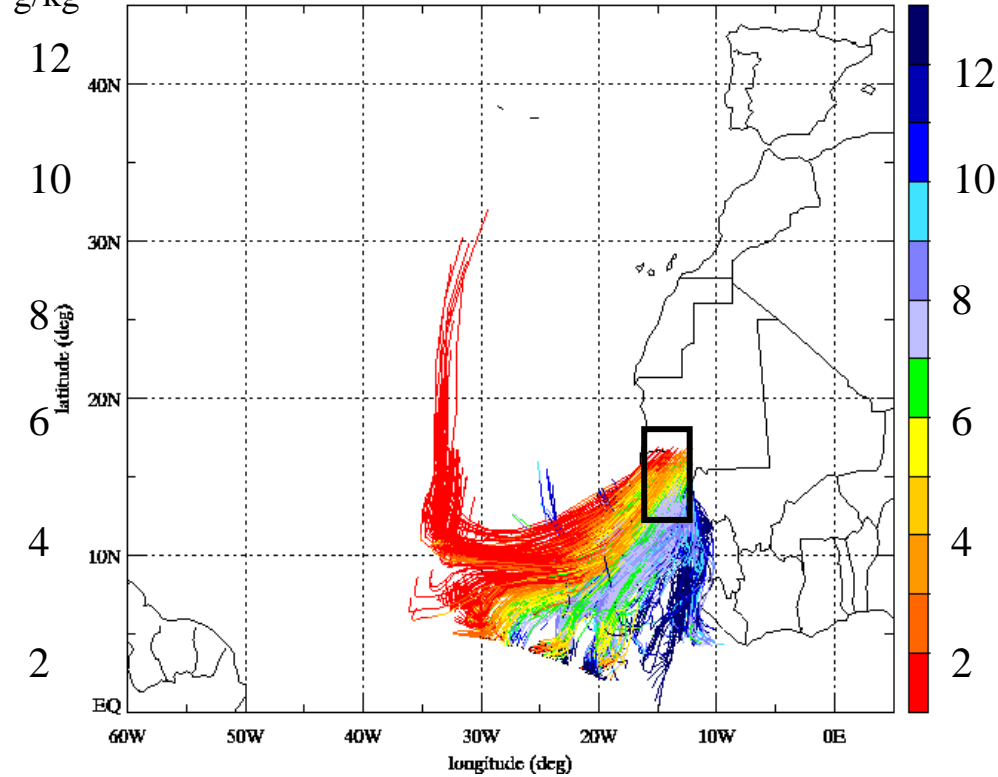
QV along trajectories from 200201090600 to 200201060000 UTC



full physics

g/kg

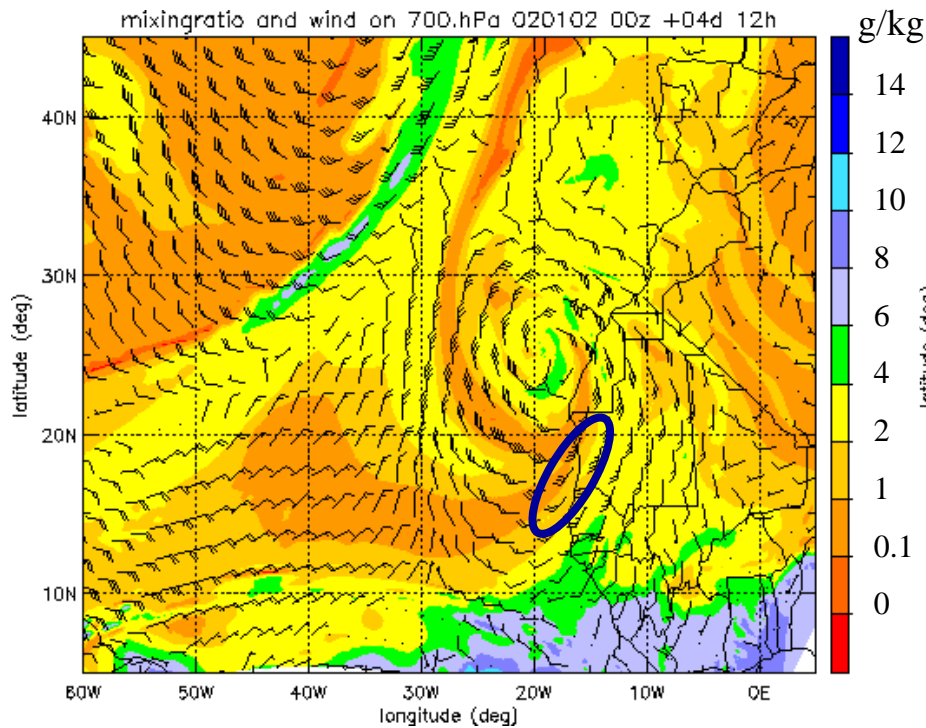
QV along trajectories from 200201090600 to 200201060000 UTC



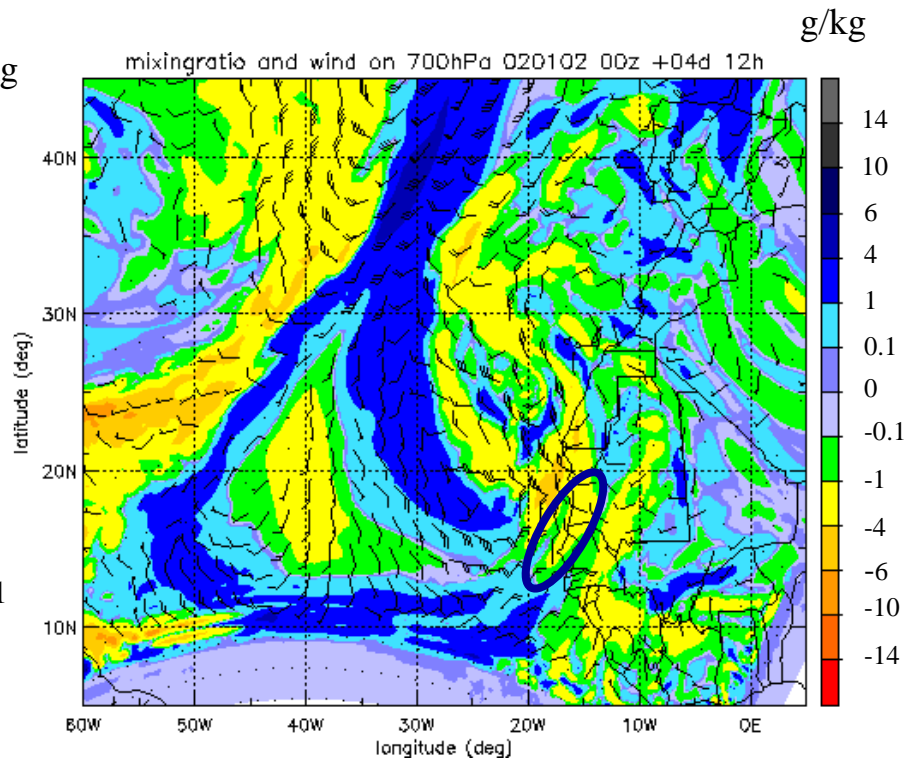
experiment

78h backward trajectories – specific humidity along trajectories

9th January 2002 06 UTC - 6th January 2002 00 UTC -

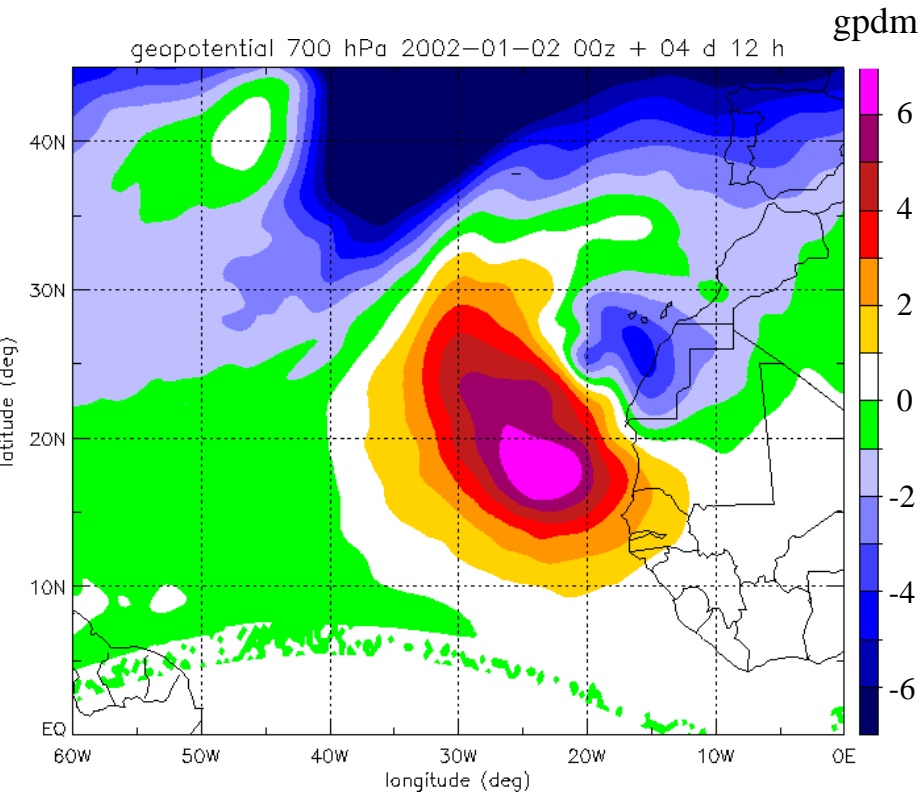


full physics



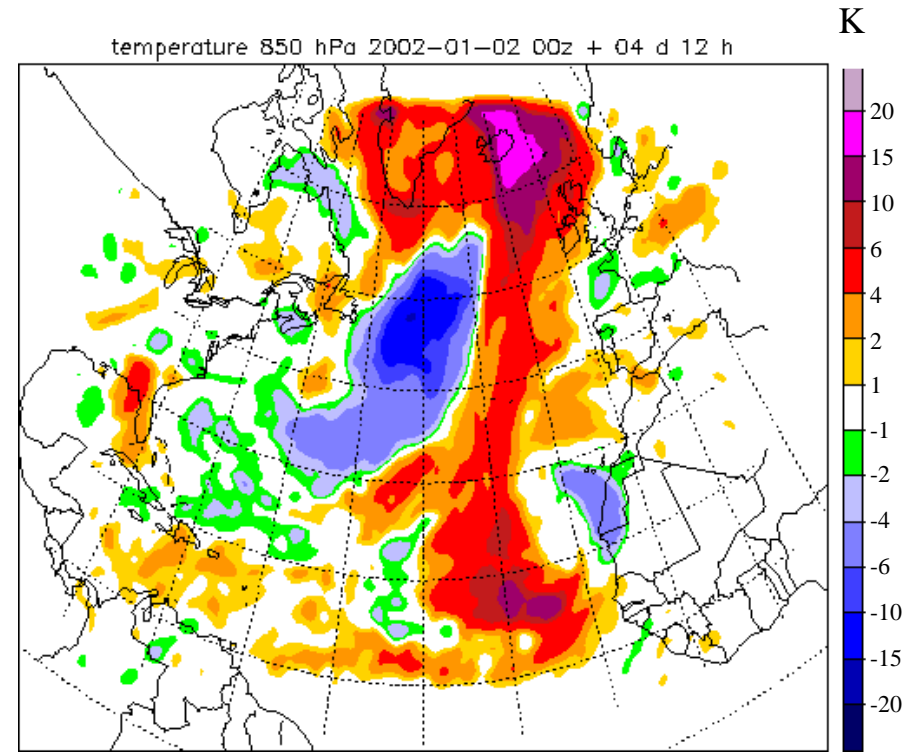
full physics - **experiment**

mixingratio g/kg and wind 700hPa



full physics - **experiment**

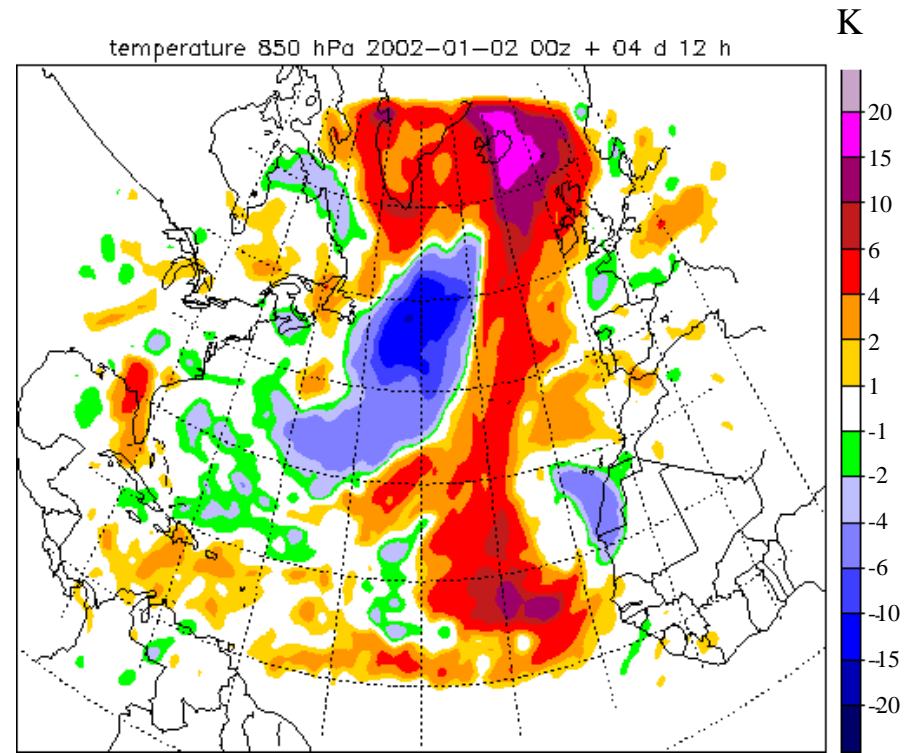
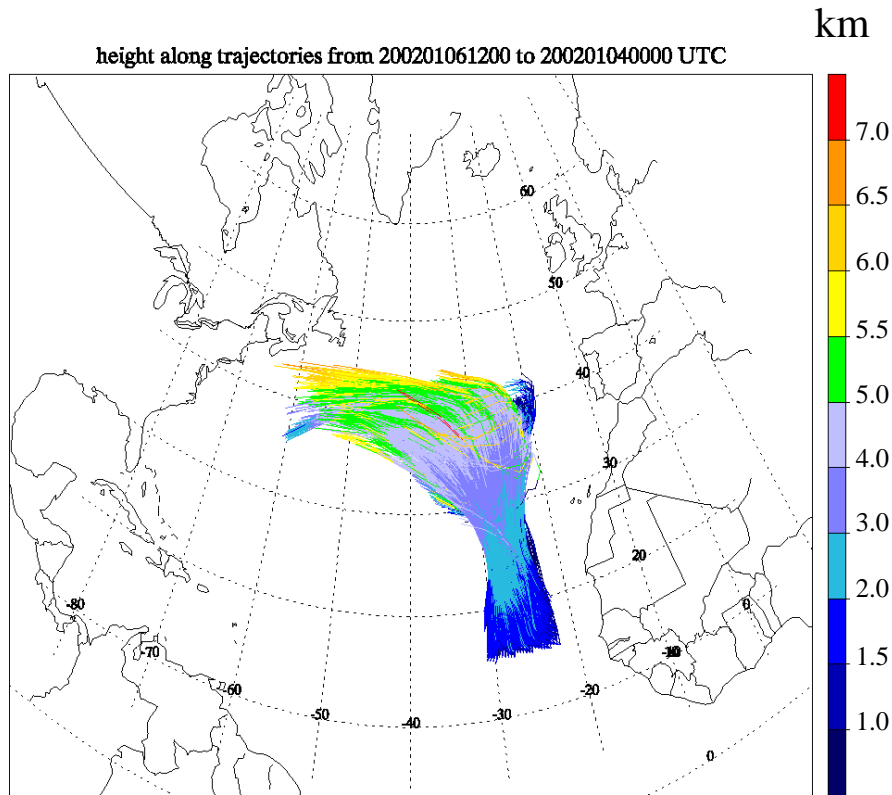
Δ geopotential 700hPa in
gpdm



full physics - **experiment**

Δ T 850 hPa in K

6th January 2002 12 UTC



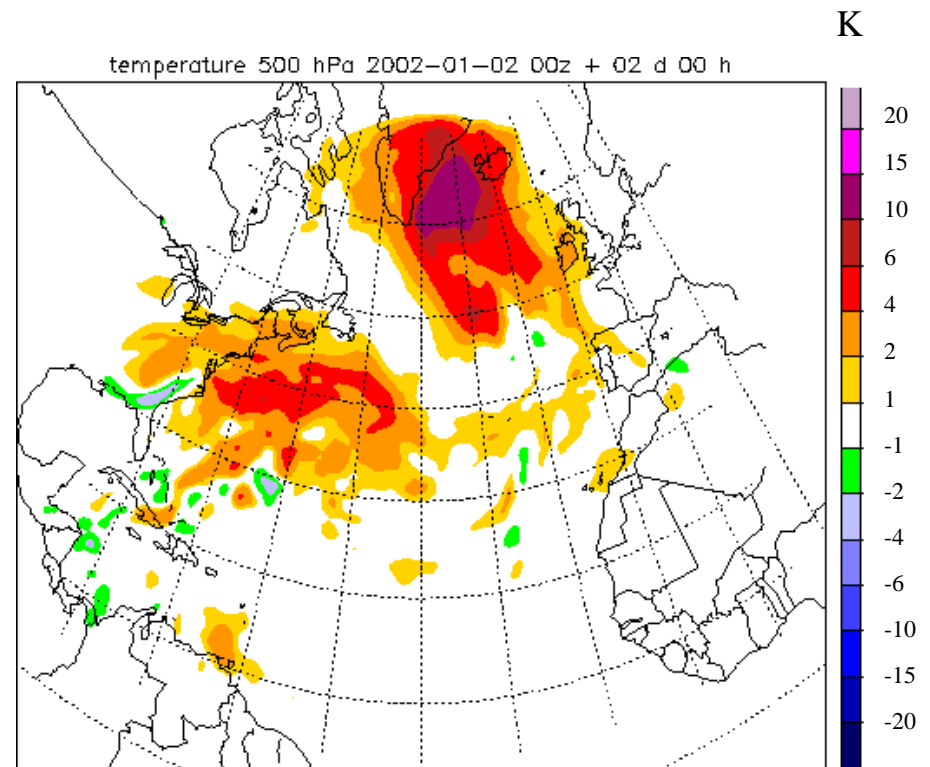
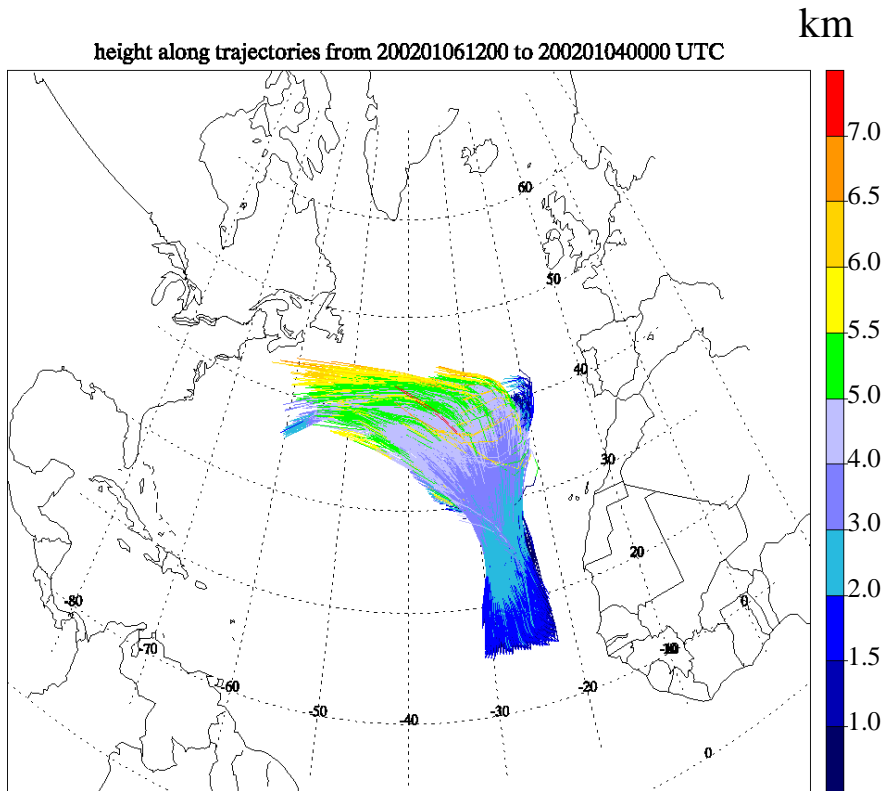
full physics run

60h backward trajectories –
height along trajectories

full physics - **experiment**

ΔT 850 hPa in K

6th January 2002 12 UTC



full physics run

60h backward trajectories –
height along trajectories

6th January 2002 12 UTC

full physics - **experiment**

ΔT 500 hPa in K

6th January 2002 12 UTC -60h

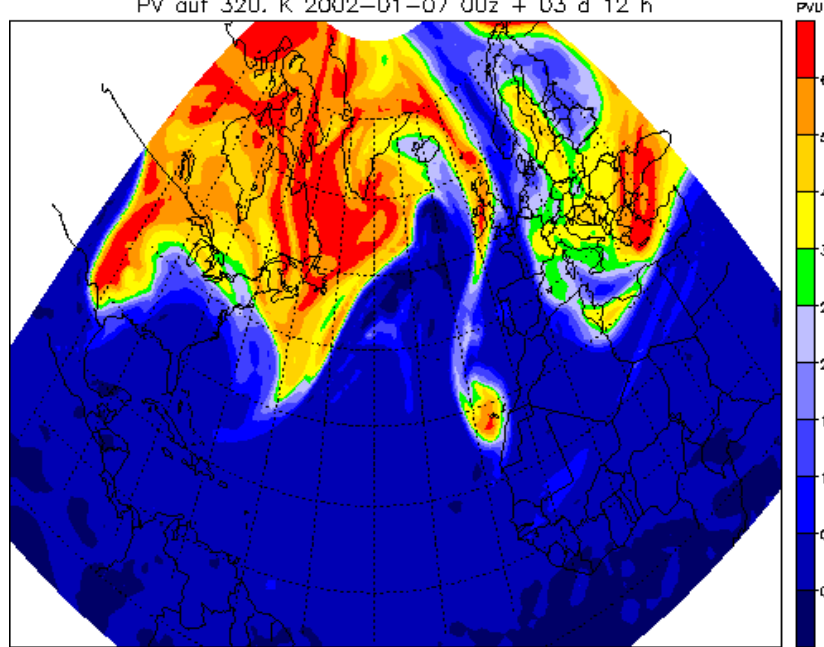
Conclusions

- Strong influence of latent heating in the extratropics (cyclogenesis, fronts, PV-structures)
- Stronger PV-anomalies near West Africa
- Weak changes in the precipitation quantity
 - Higher atmospheric water content in sensitivity experiment
 - Weaker moisture transport in the control run due to compensating geopotential modification


```
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ECMWF-
analysis

Runge Kutta



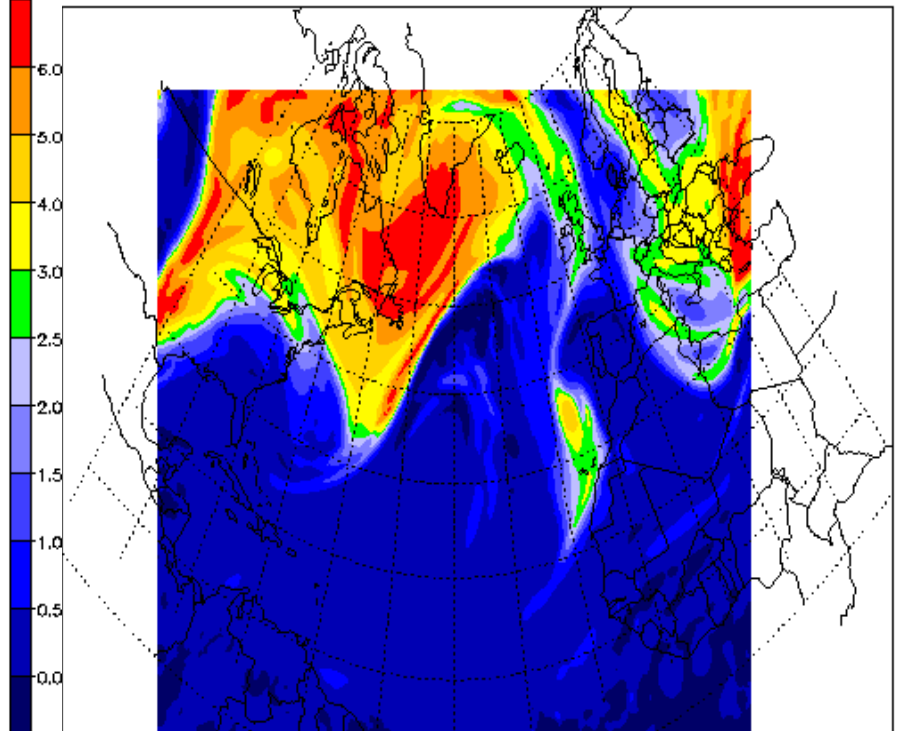
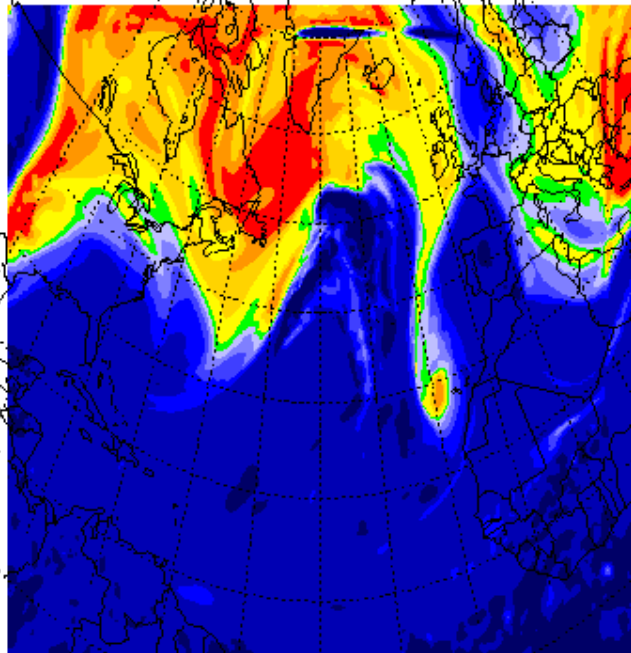
Leapfrog

PV auf 320. K 2002-01-02 00z + 03 d 12 h

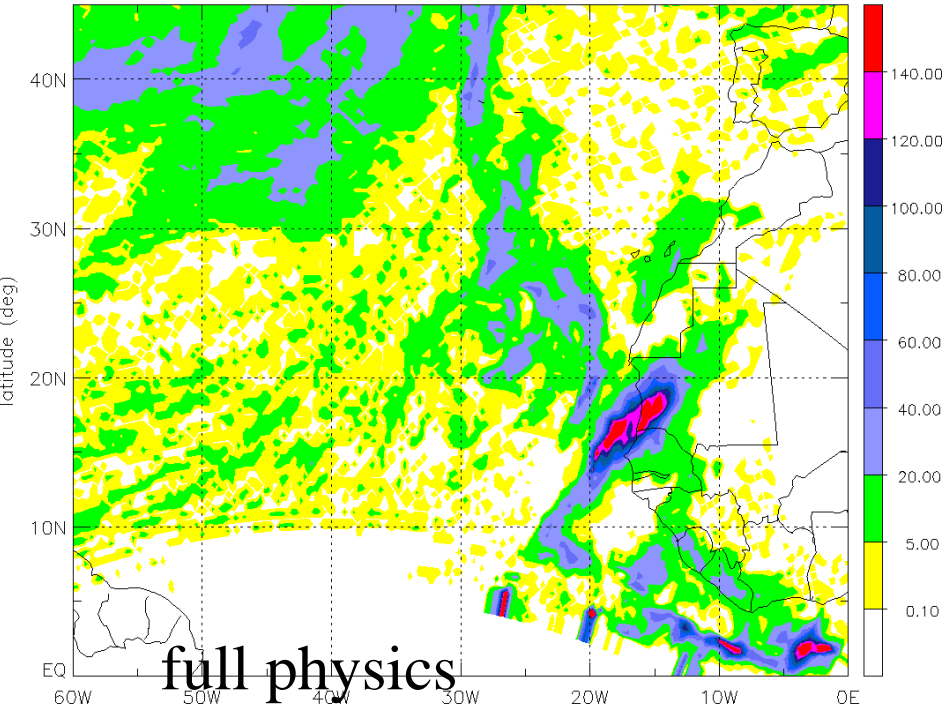
PVU

PV auf 320. K 2002-01-02 00z + 03 d 12 h

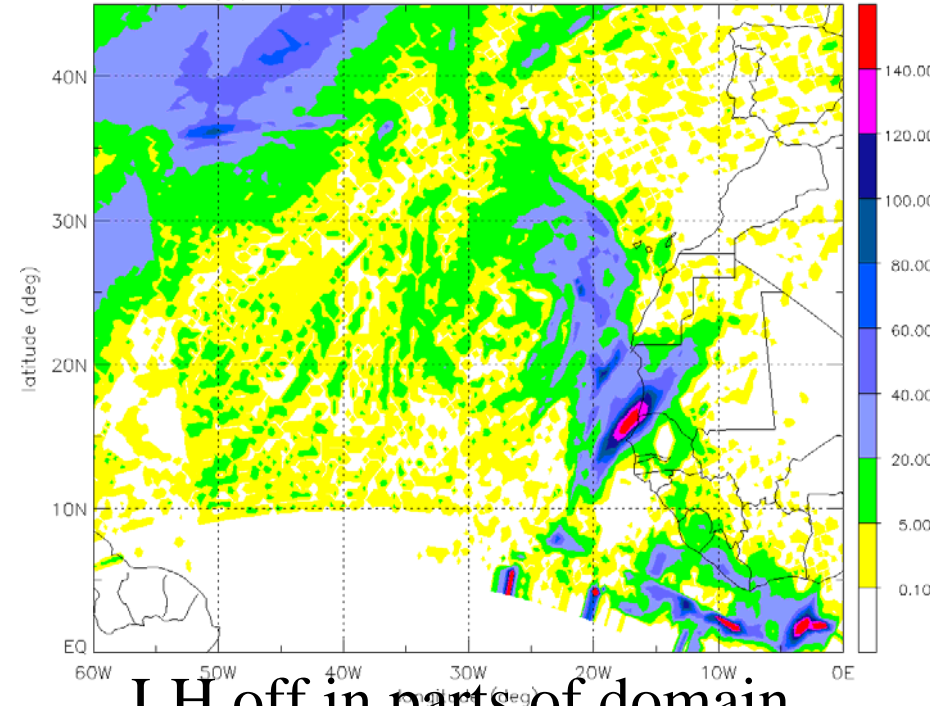
PVU



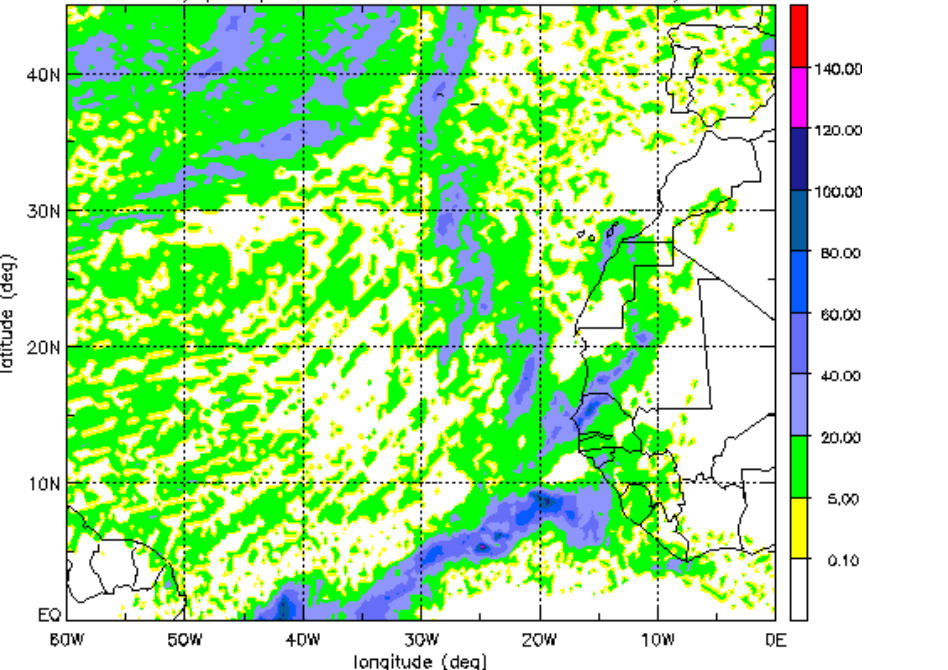
48 hourly precipitation 06 UTC from 9 to 11 January 2002



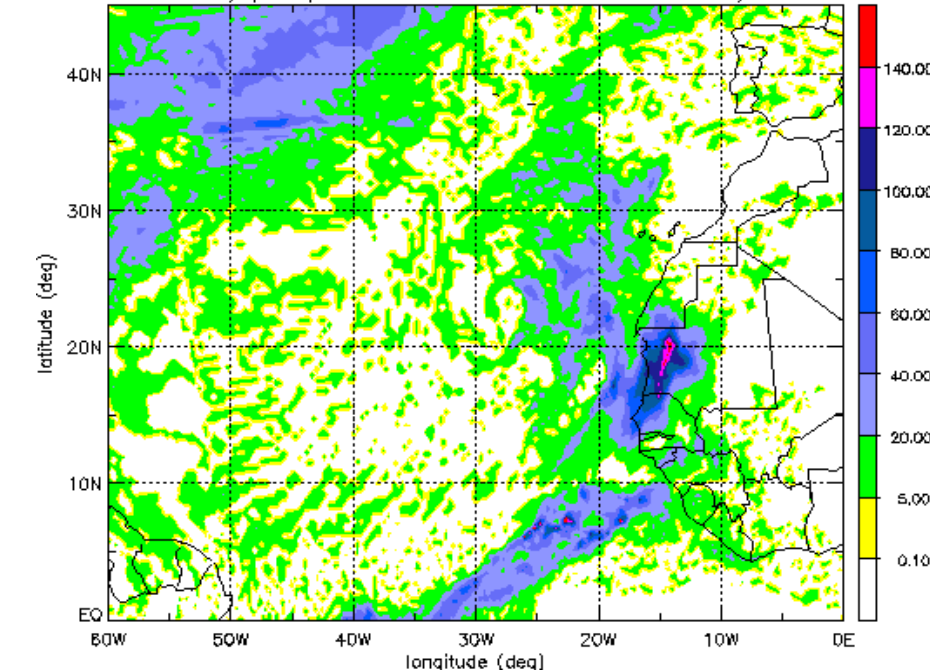
48 hourly precipitation 06 UTC from 9 to 11 January 2002



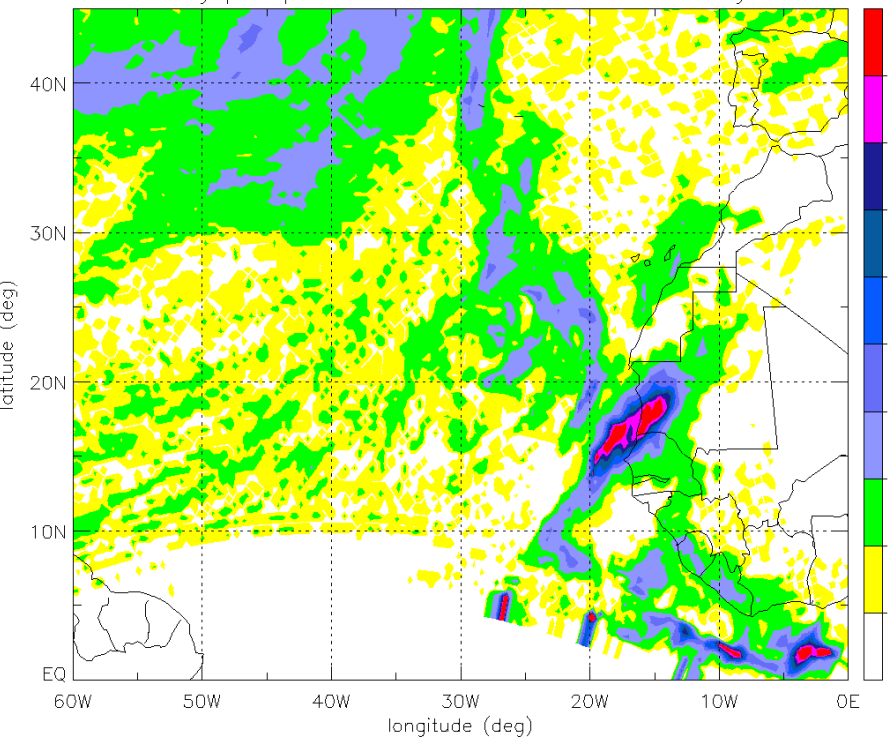
48 hourly precipitation 06 UTC from 9 to 11 January 2002



48 hourly precipitation 06 UTC from 9 to 11 January 2002

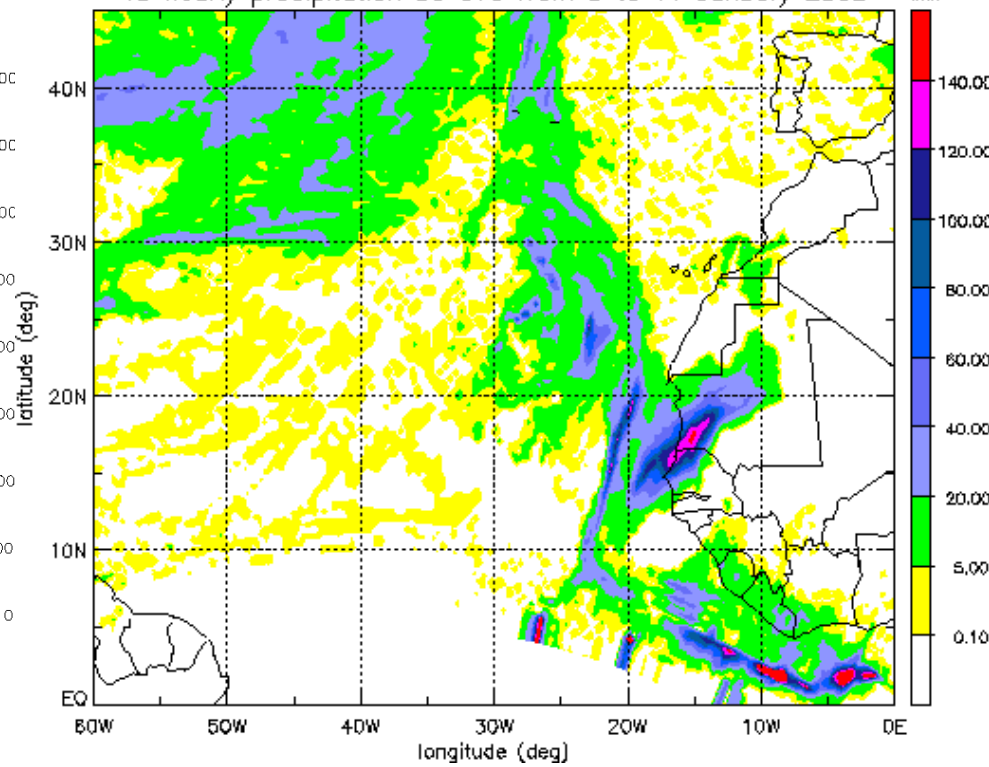


48 hourly precipitation 06 UTC from 9 to 11 January 2002

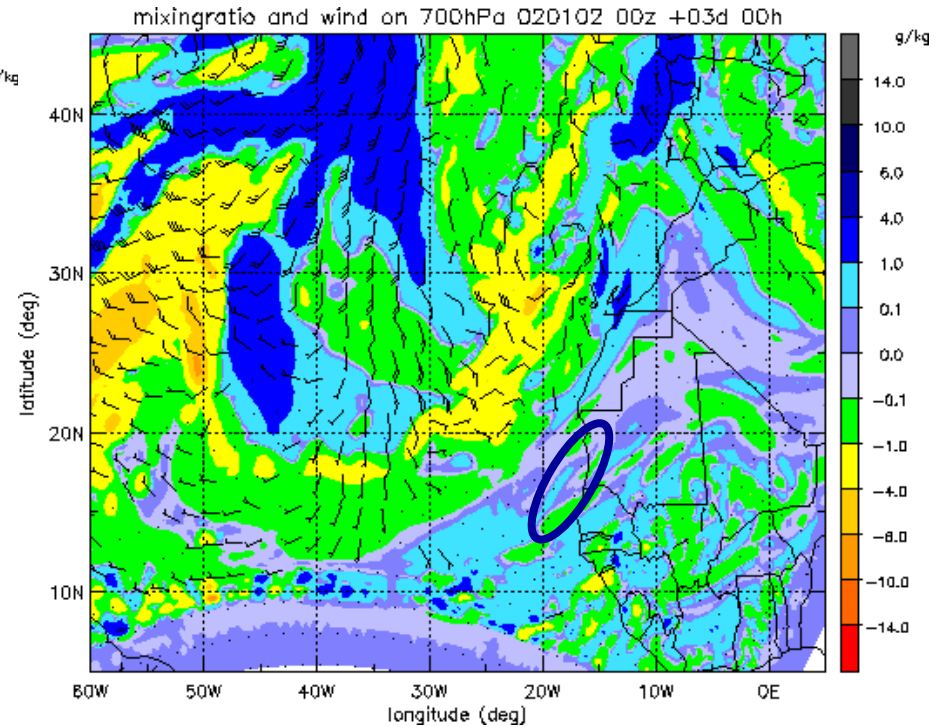
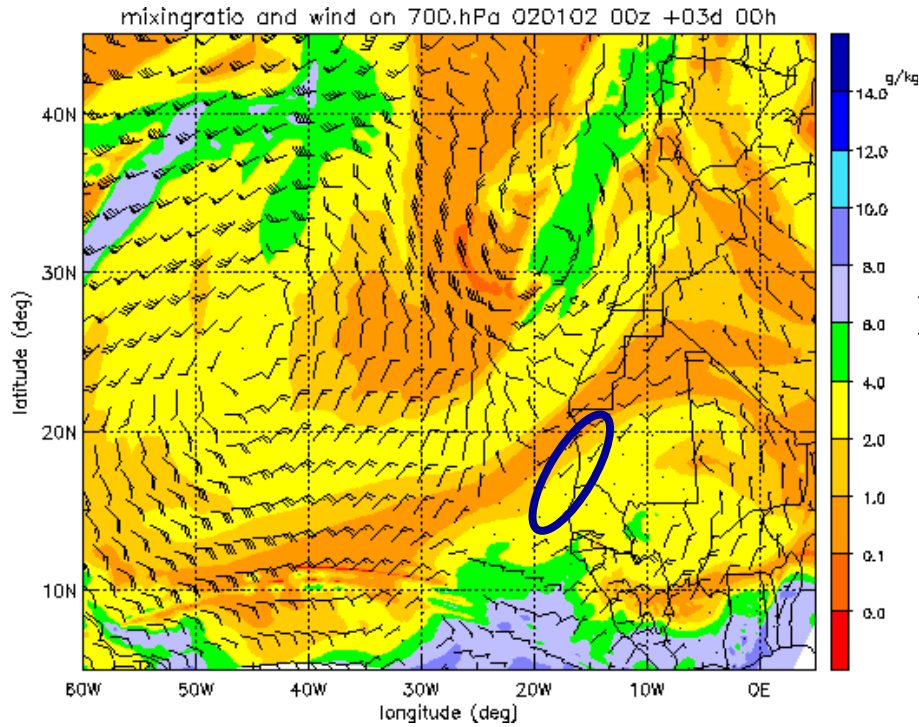


Kain-Fritsch

48 hourly precipitation 06 UTC from 9 to 11 January 2002



Tiedtke



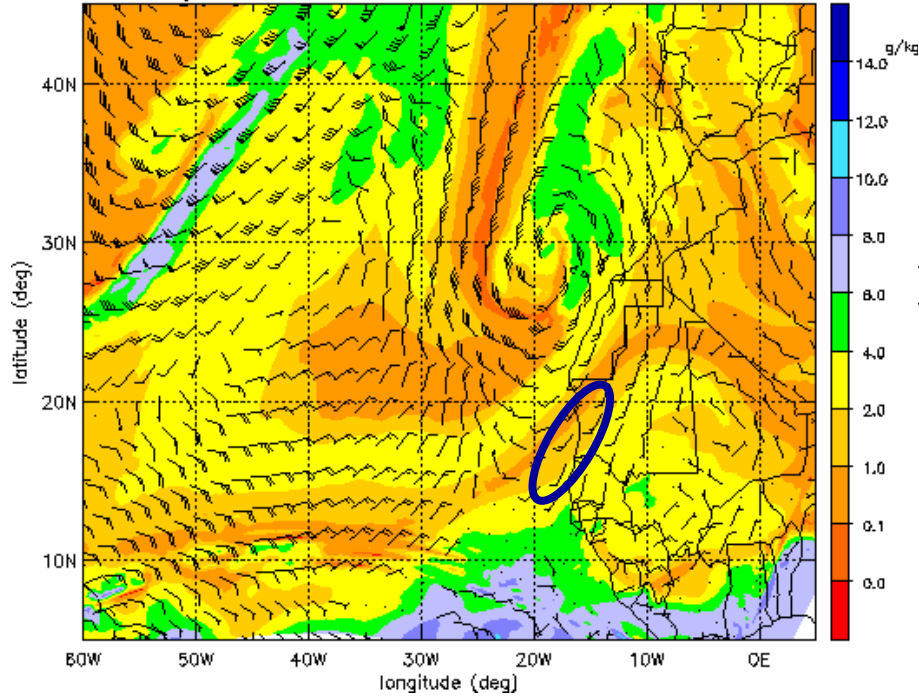
5th January 2002 00 UTC

full physics

full physics - **experiment**

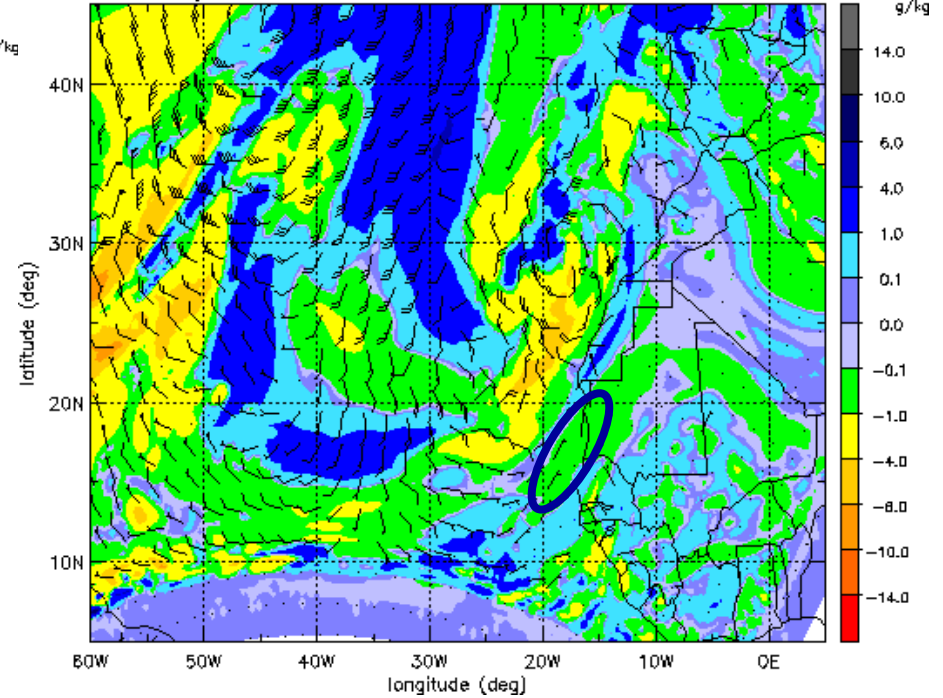
mixingratio g/kg and wind 700hPa

mixingratio and wind on 700.hPa 020102 00z +03d 12h



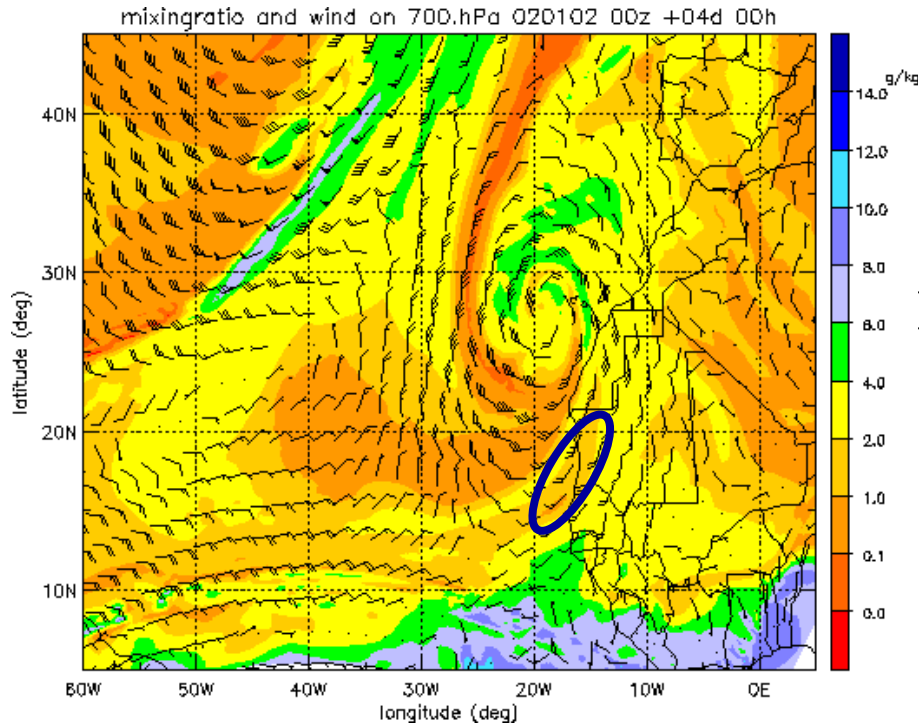
full physics

mixingratio and wind on 700hPa 020102 00z +03d 12h

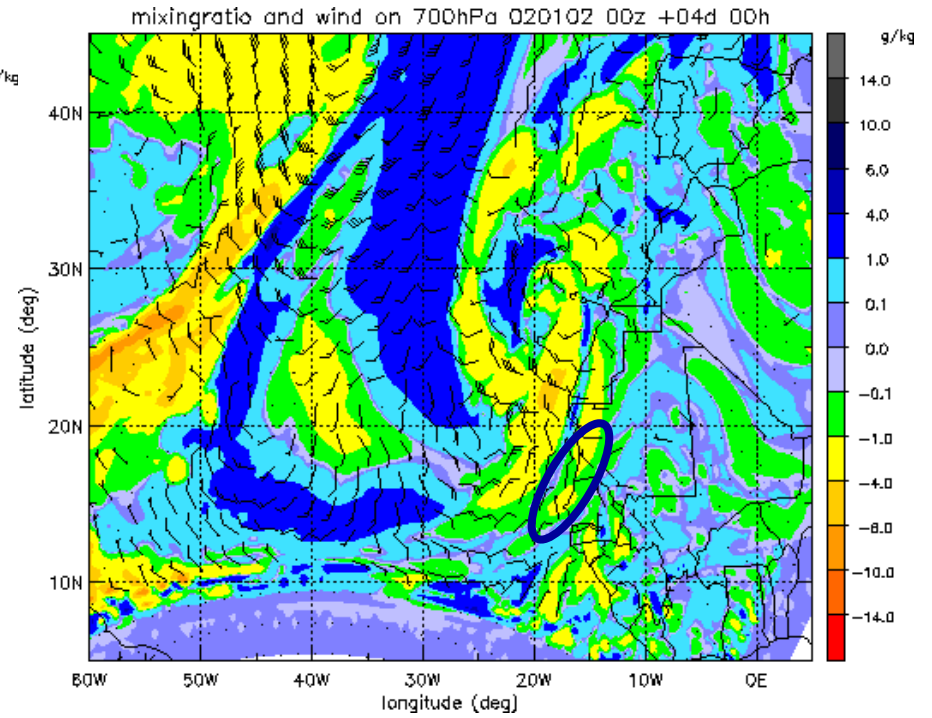


full physics - **experiment**

mixingratio g/kg and wind 700hPa



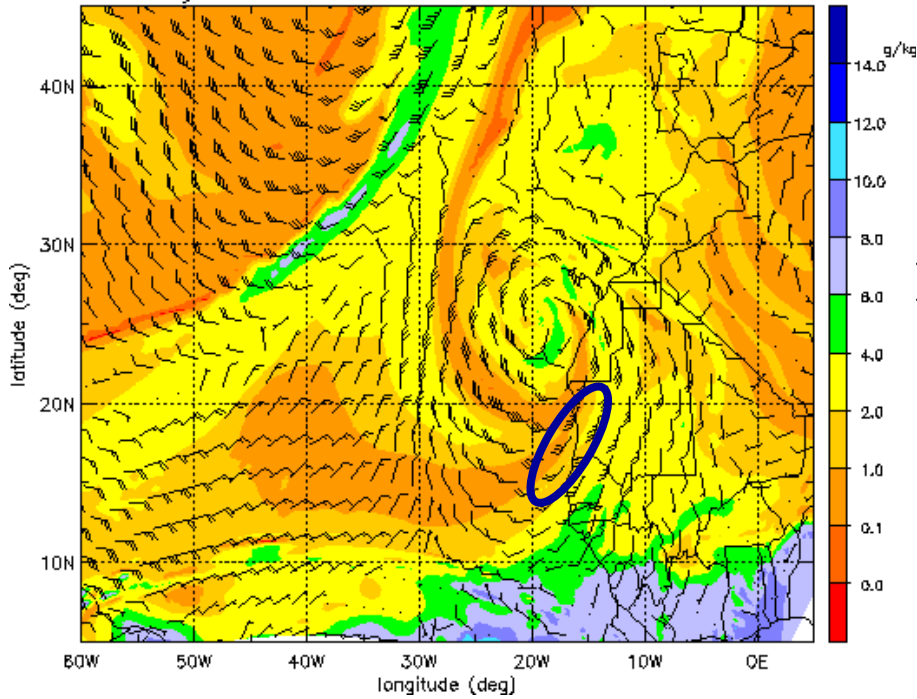
full physics



full physics - **experiment**

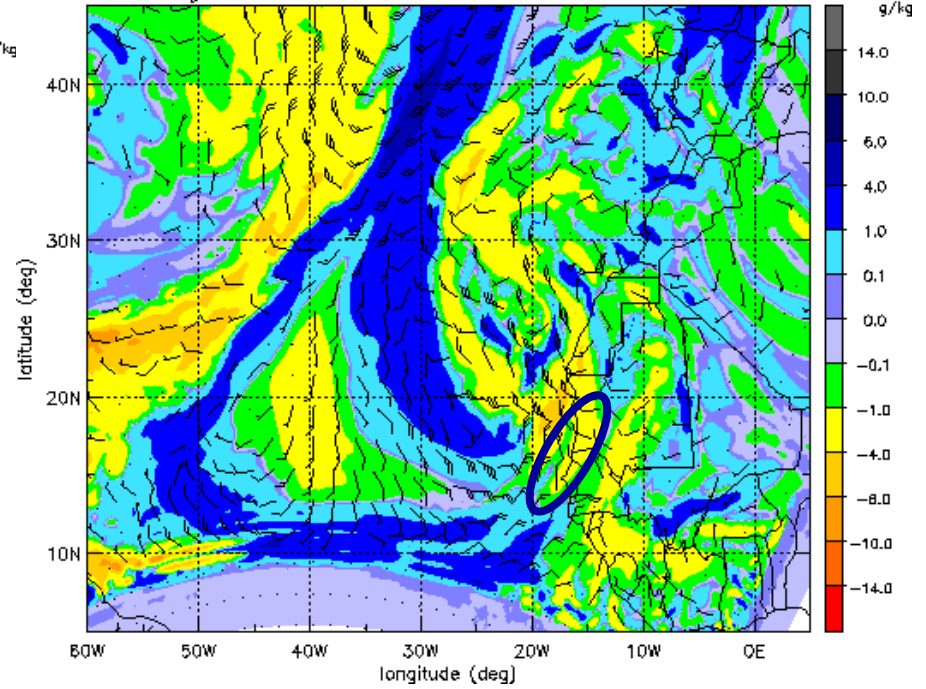
mixingratio g/kg and wind 700hPa

mixingratio and wind on 700.hPa 020102 00z +04d 12h



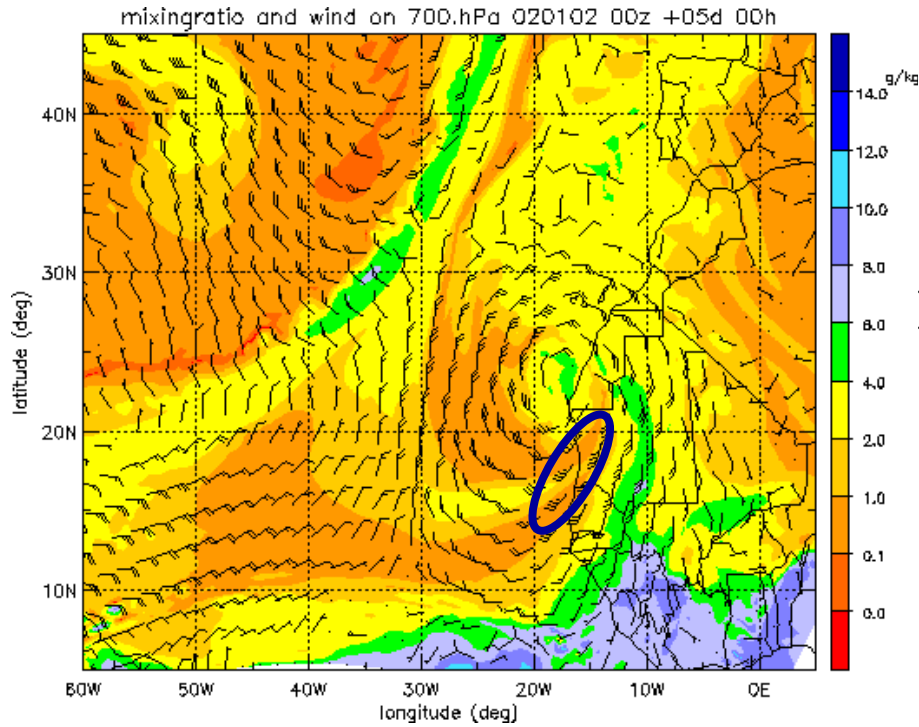
full physics

mixingratio and wind on 700hPa 020102 00z +04d 12h

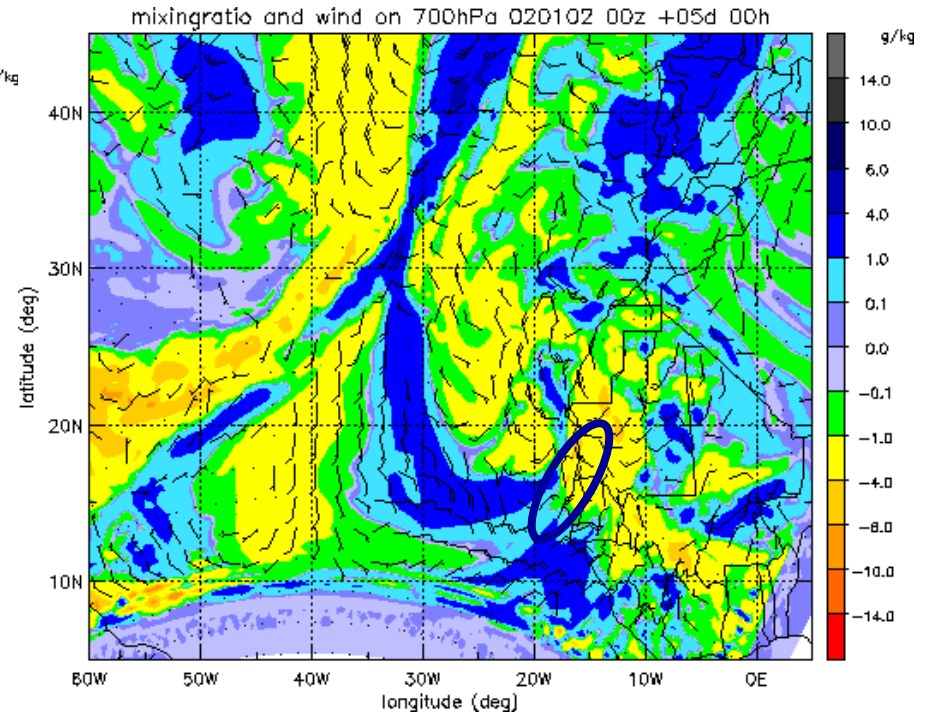


full physics - **experiment**

mixingratio g/kg and wind 700hPa



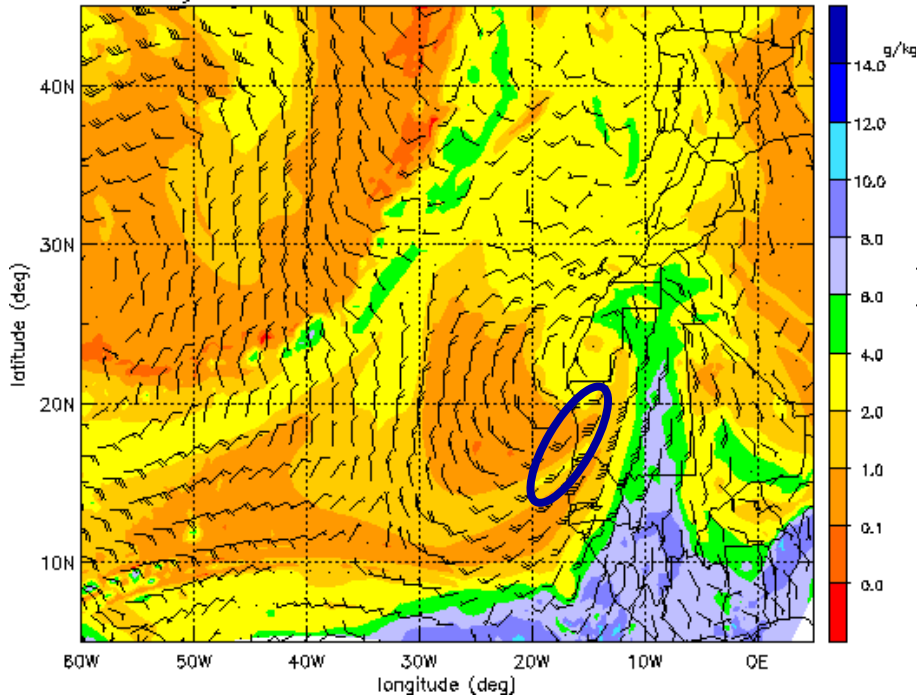
full physics



full physics - **experiment**

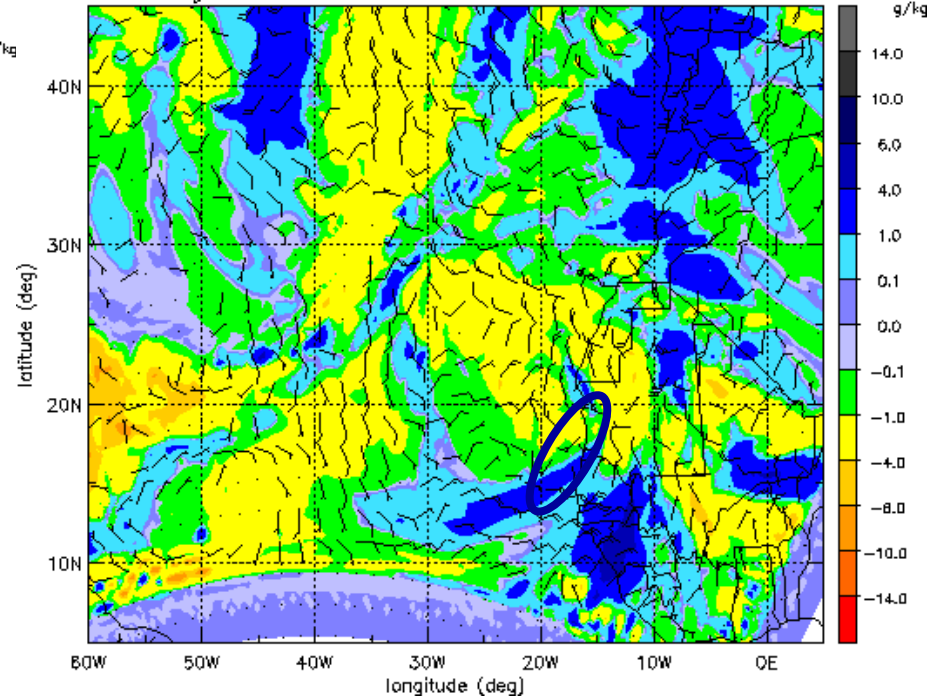
mixingratio g/kg and wind 700hPa

mixingratio and wind on 700.hPa 020102 00z +05d 12h



full physics

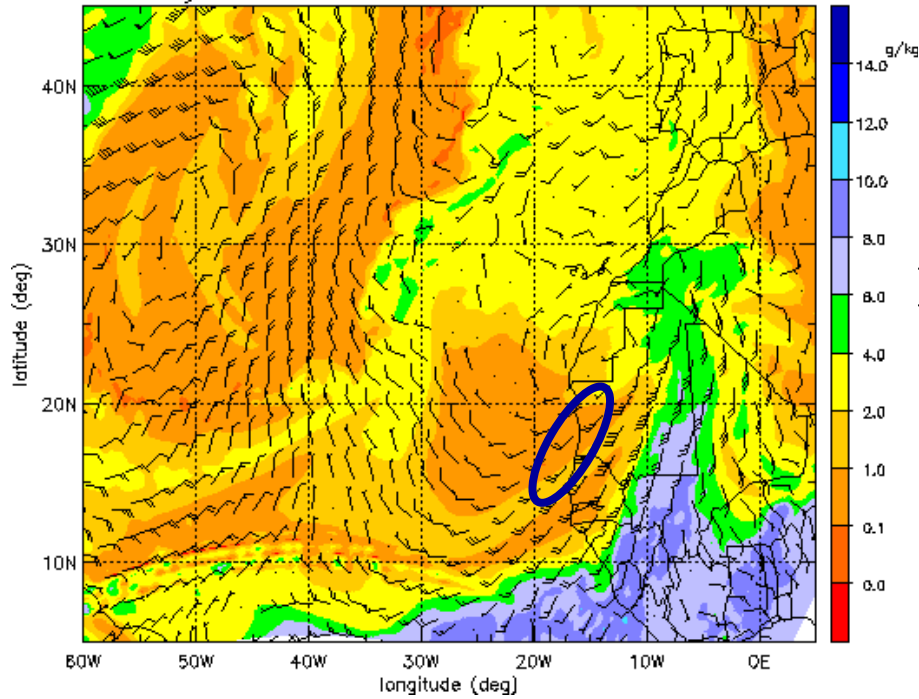
mixingratio and wind on 700hPa 020102 00z +05d 12h



full physics - **experiment**

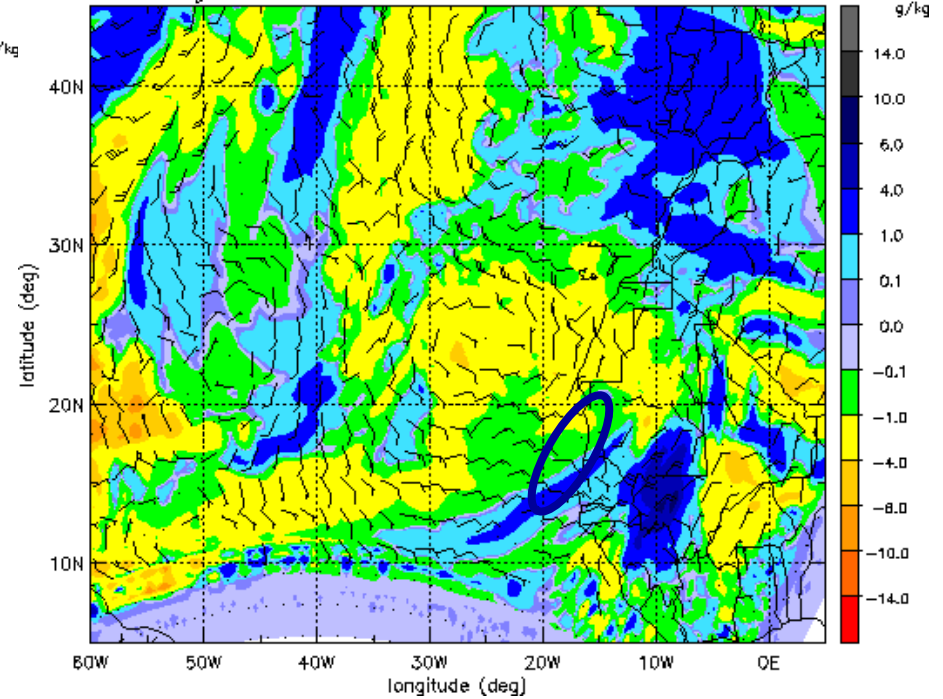
mixingratio g/kg and wind 700hPa

mixingratio and wind on 700.hPa 020102 00z +06d 00h



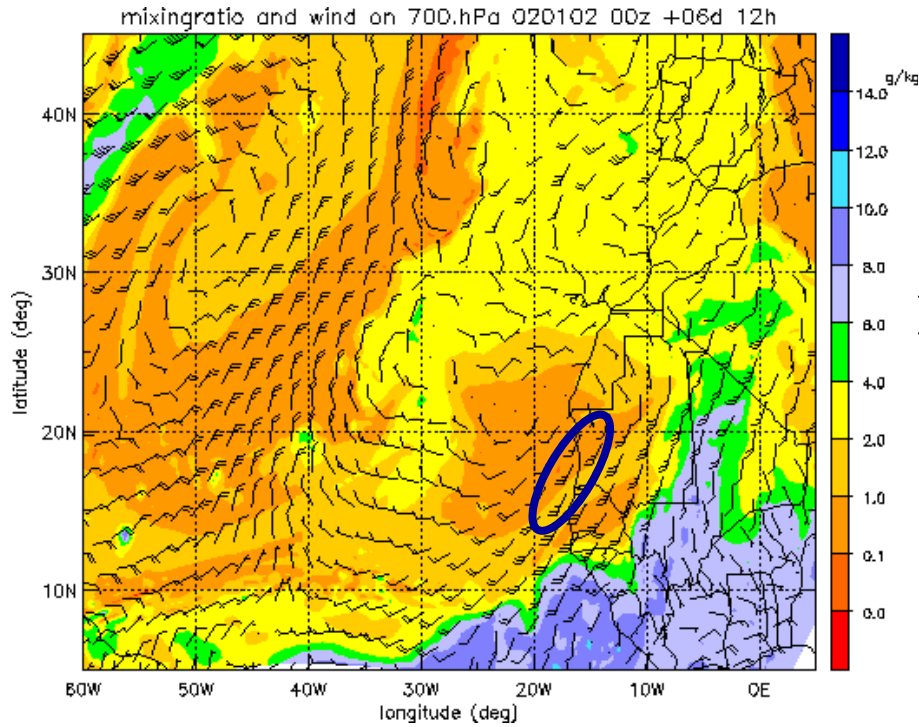
full physics

mixingratio and wind on 700hPa 020102 00z +06d 00h

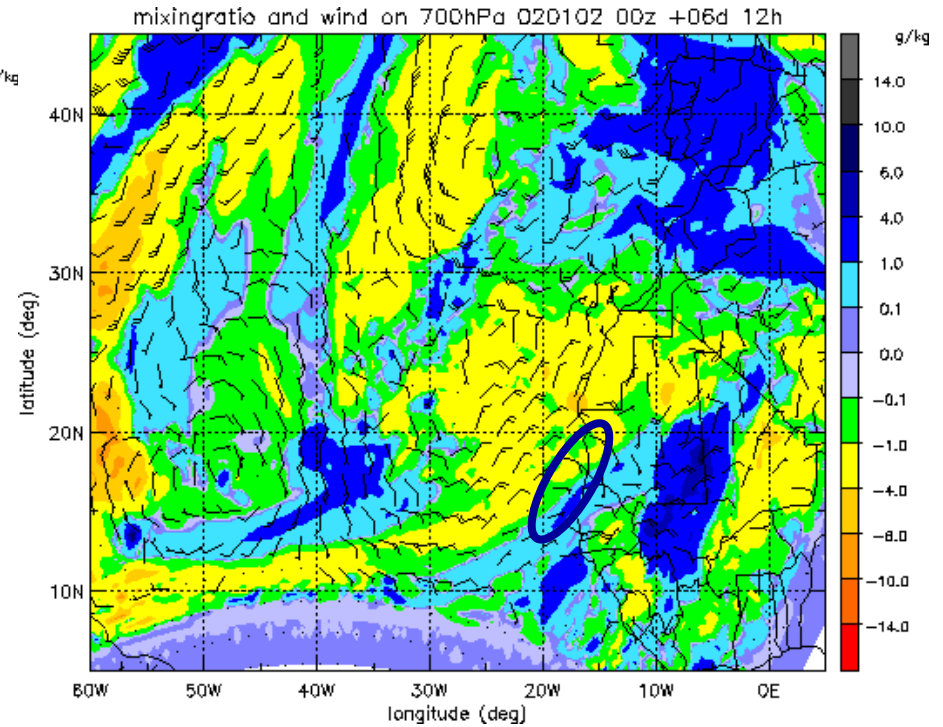


full physics - **experiment**

mixingratio g/kg and wind 700hPa

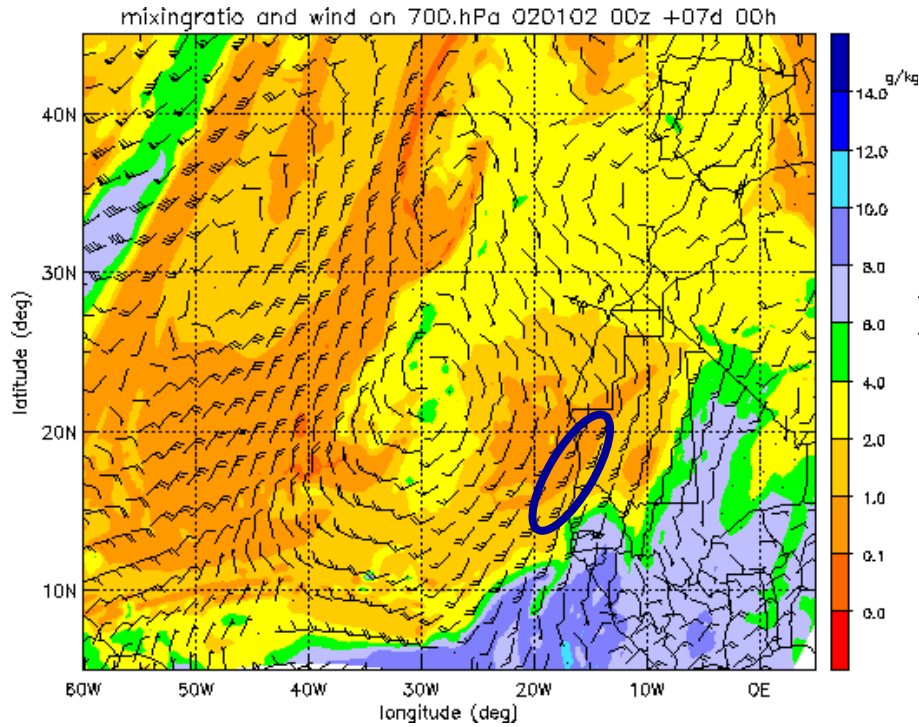


full physics

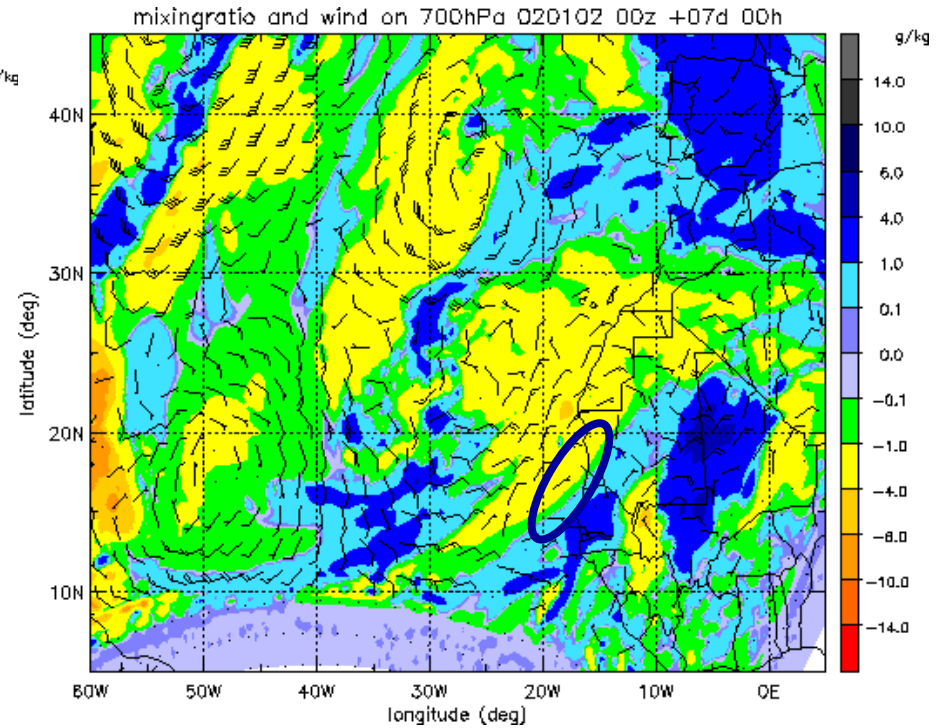


full physics - **experiment**

mixingratio g/kg and wind 700hPa



full physics



full physics - **experiment**

mixingratio g/kg and wind 700hPa

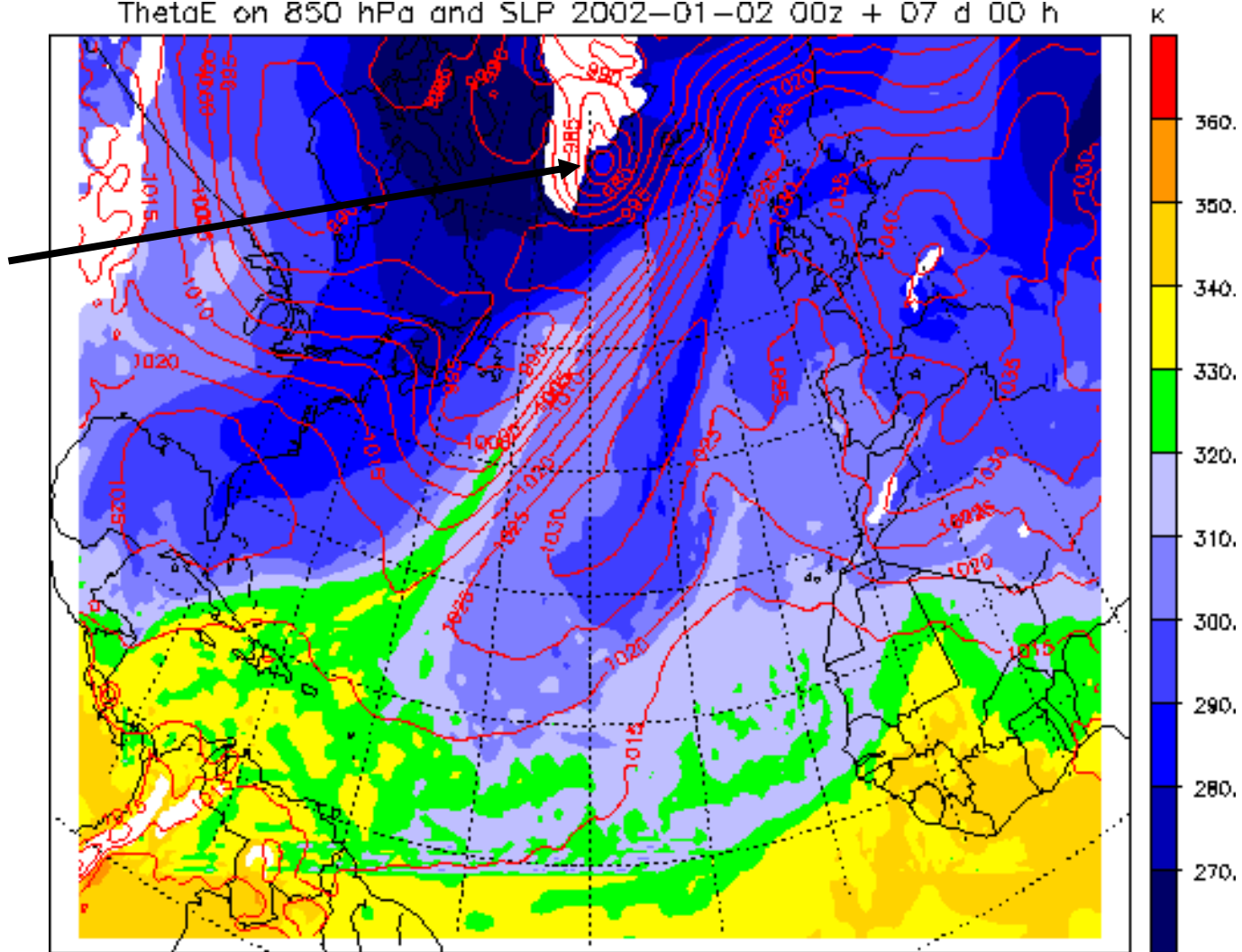
Conclusions

- Strong influence of latent heating in the extratropics (cyclogenesis, fronts, PV-structures)
- Stronger PV-anomalies near West Africa
- Weak changes in the precipitation quantity
 - Higher atmospheric water content in sensitivity experiment
 - Weaker moisture transport in the control run due to compensating geopotential modification

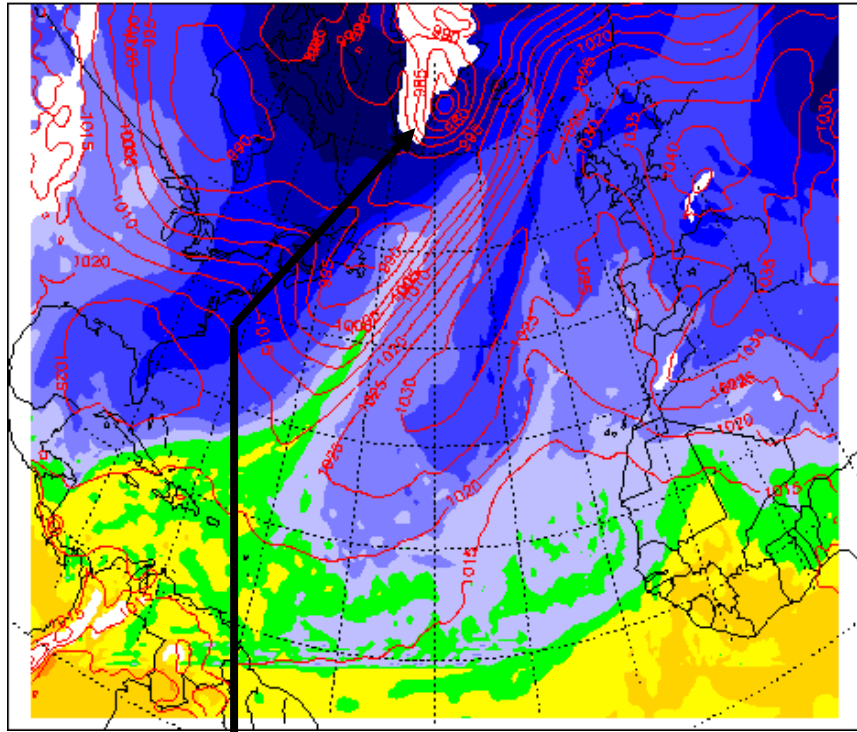
Equivalent potential temperature on 850 hPa and sea-level pressure

ThetaE on 850 hPa and SLP 2002-01-02 00z + 07 d 00 h

975hpa



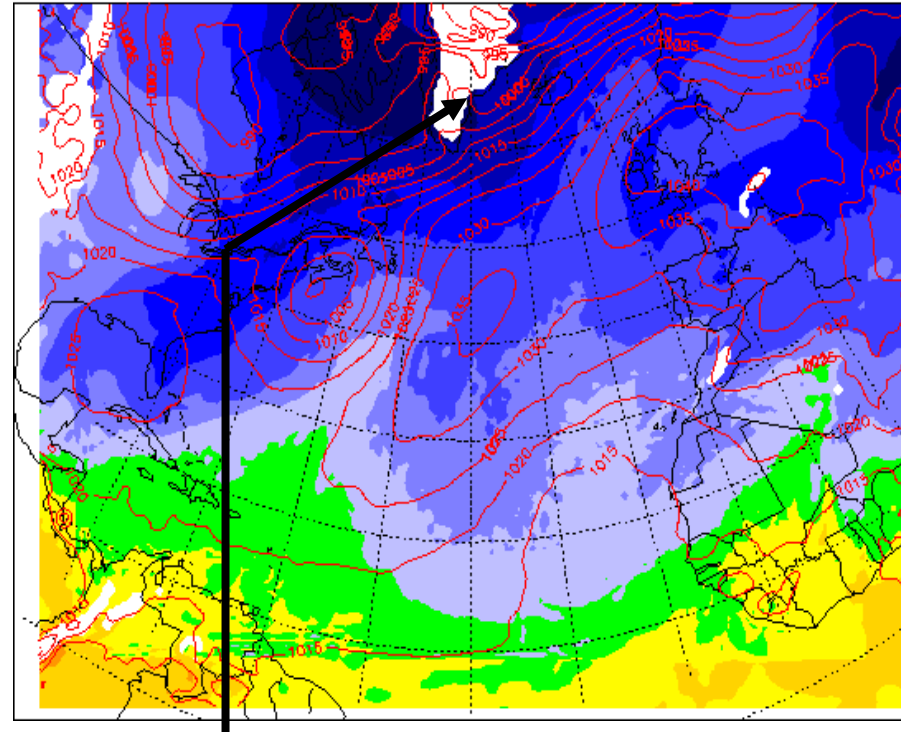
ThetaE on 850 hPa and SLP 2002-01-02 00z + 07 d 00 h



< 970hPa

full physics

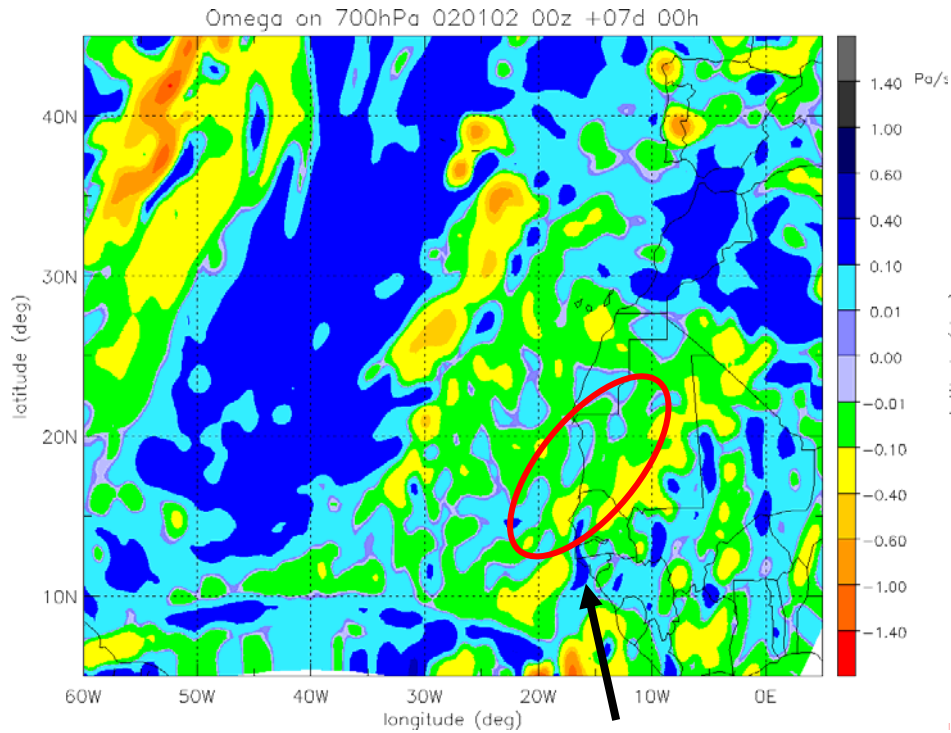
ThetaE on 850 hPa and SLP 2002-01-02 00z + 07 d 00 h



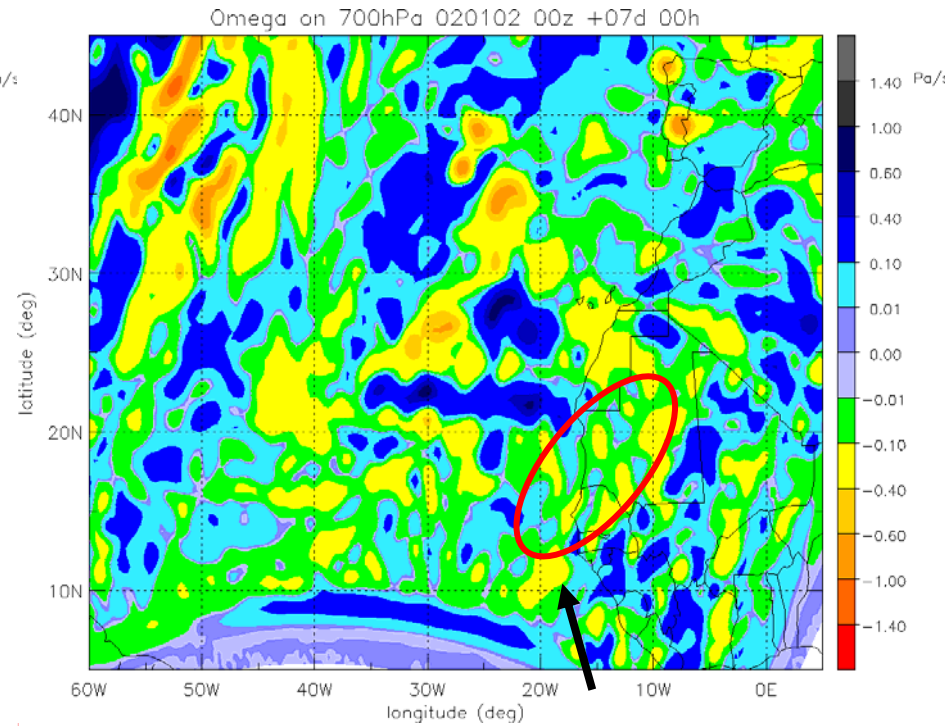
< 1000hPa

experiment

9th January 2002 00UTC



full physics run

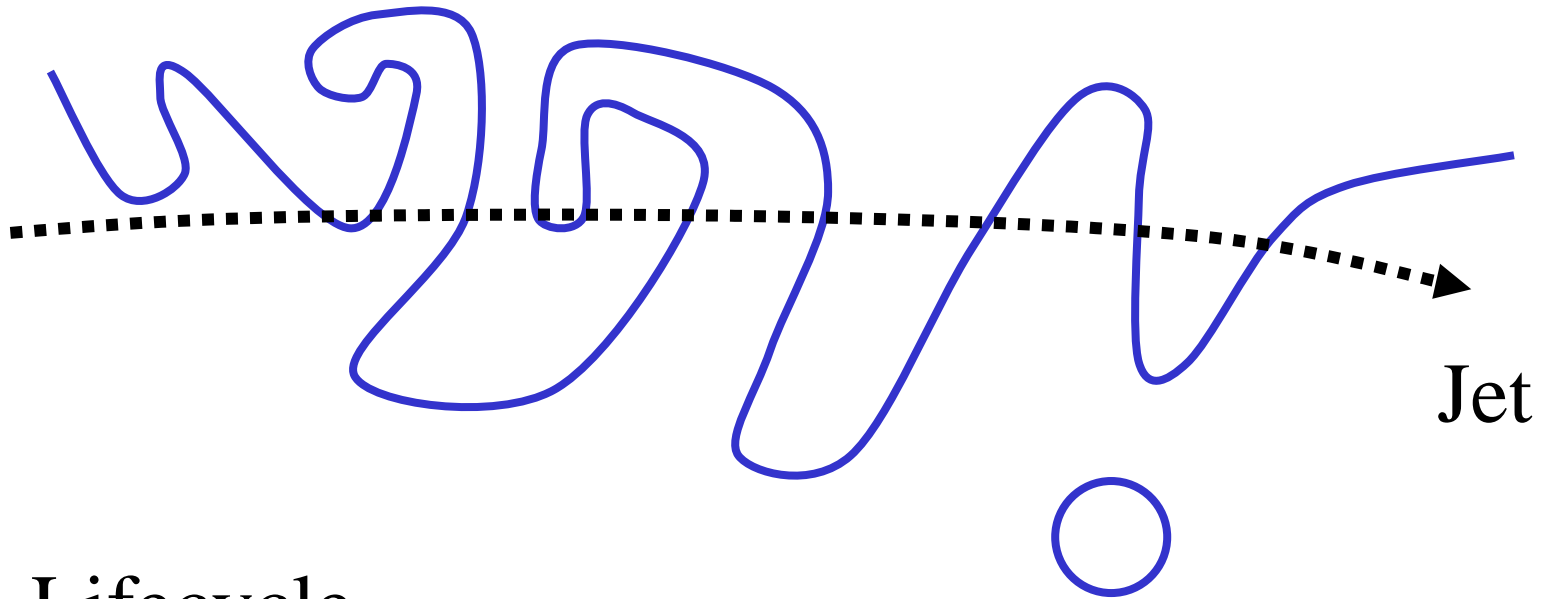


full physics - **experiment**

vertical motion on 700hPa in Pa s^{-1}

9th January 2002 00 UTC

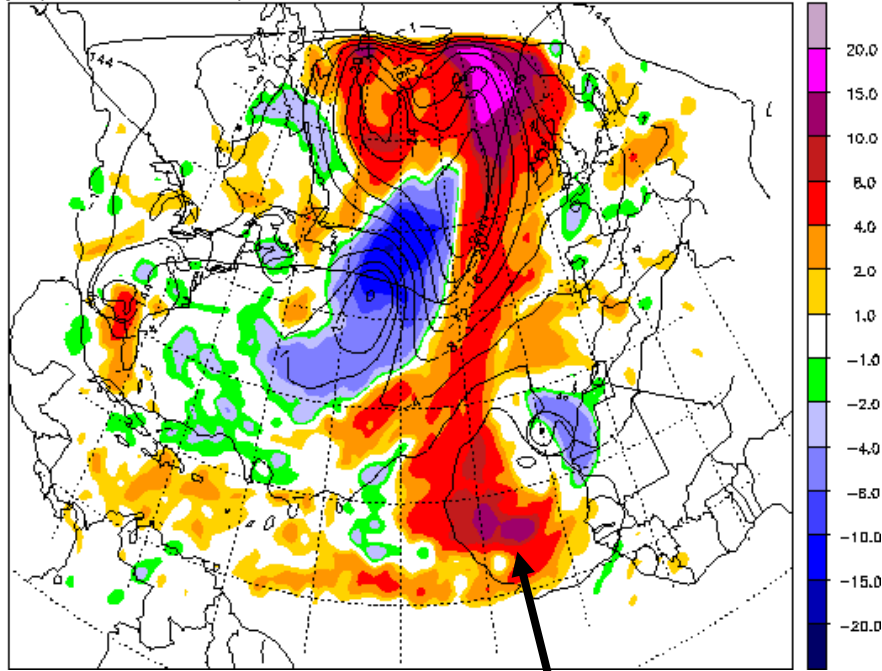
cyclone development in dry dynamics



Lifecycle
(LC) 1

after Thorncroft et al. 1991

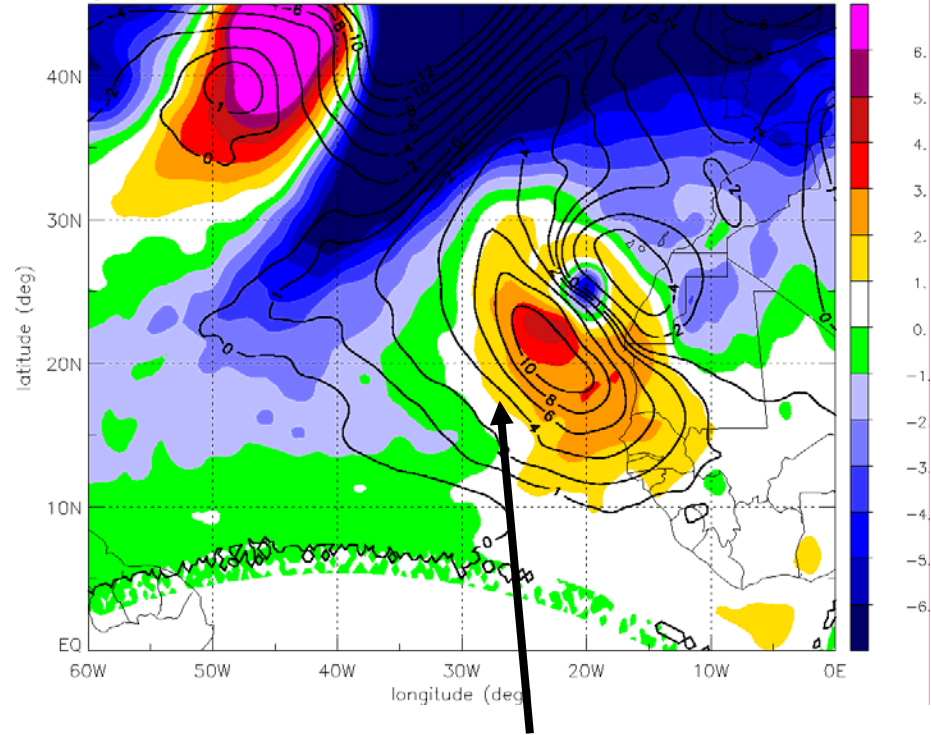
geopotential and temperature 850 hPa 2002-01-02 00z + 04 d 12 h κ



full physics - **experiment**

ΔT 850 hPa in K
and Δ geopotential
850hpa in gpdm

geopotential 500 hPa and SLP 2002-01-02 00z + 04 d 12 h hPa

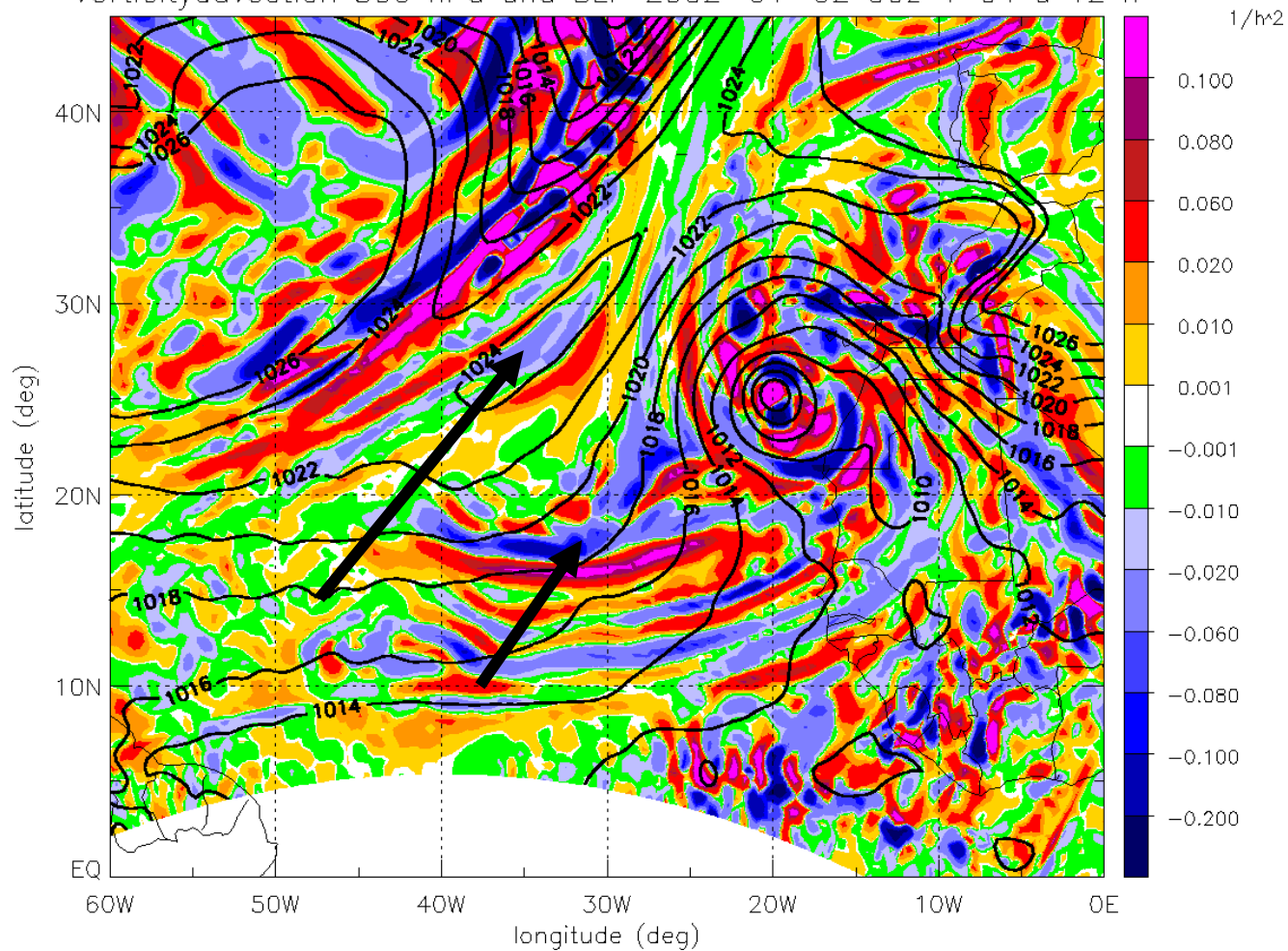


full physics - **experiment**

Δ SLP in hPa and
 Δ geopotential 500hPa in
gpdm

6th January 2002 12 UTC

Vorticity advection 500 hPa and SLP 2002-01-02 00z + 04 d 12 h



abs. vorticity advection and SLP 6th January 2002
12 UTC
full physics run