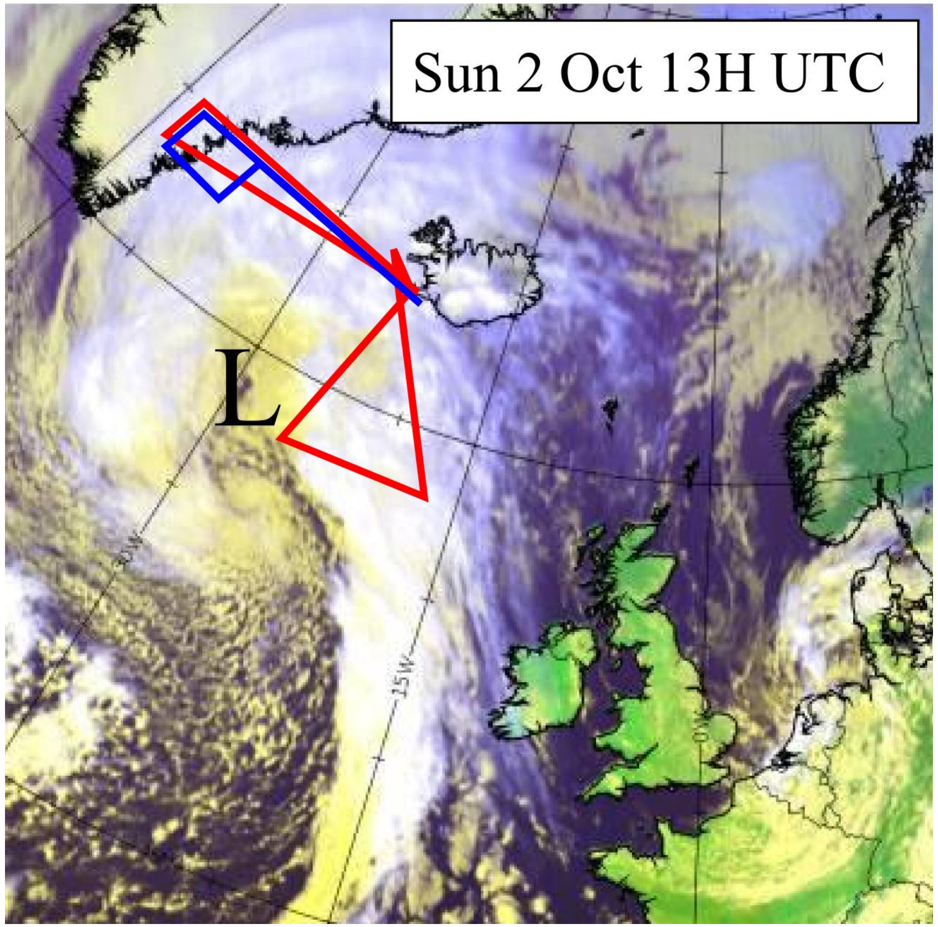
Representation of the Stalactite Cyclone in LMDZ and ARPEGE-Climat



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4. LATMOS

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Transpose AMIP experiments

- We need climate models to be able to accurately depict current cyclones to be able to determine future cyclones with any confidence
- One method to help ‘diagnose’ problems with parametrizations in climate models is Transpose – AMIP style experiments
  - Run a climate model in “weather forecasting” mode (i.e. run it out for 10—15 days) and compare short-term biases with long-term biases in the ‘fast’ physics variables (Williams et al., 2013).

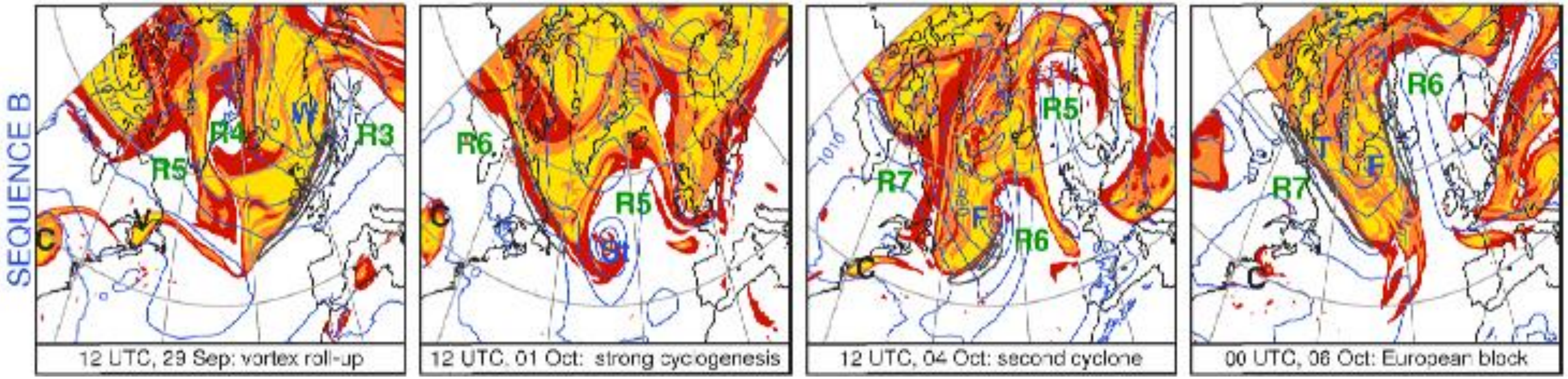
Project Aims

- Determine the relative role of diabatic and dynamical processes in the development of extra-tropical cyclones in climate models
- Determine the importance of cyclones for ridge formation and maintenance in climate models

    - Use 2 climate models (IPSL and CNRM)
    - Use observations from NAWDEX field campaign

The Stalactite Cyclone: Key Characteristics

- 2 stages of intensification
  - Initial cyclogenesis: small-scale vortex roll-up
  - 2nd deepening stage: Interaction with large-scale upper-level trough
- Steepest decline 24.4 hPa in 24h
- Important for the setup of the Scandinavian blocking event that followed



Schäfler et al (2018)

Models

LMDZ

- 1.1 degree resolution
- Hindcasts initiated at 0000 UTC on 29 Sept and 2 Oct
- Initialised from ECMWF analysis
- Length: 10 days

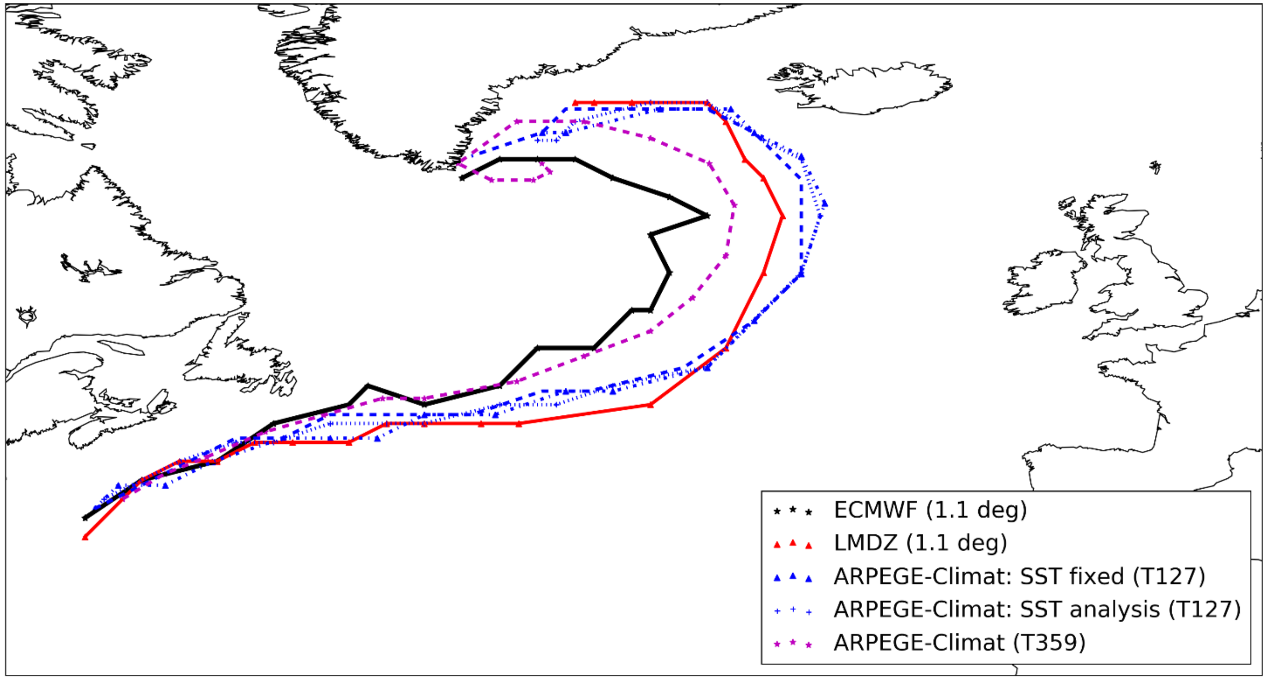
Both models used are setup as for CMIP6

ARPEGE-Climat

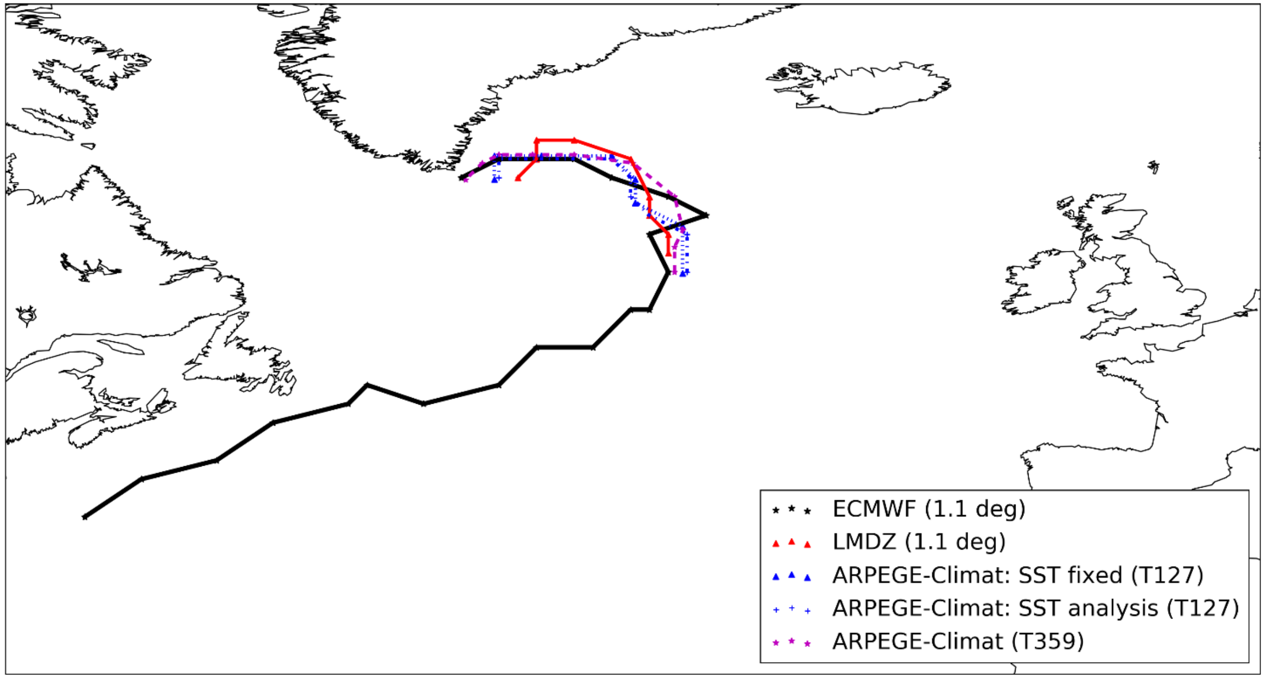
- T127 ~1.4 degree
- T359 ~0.5 degree
- Hindcasts initiated at 0000 UTC on 29 Sept and 2 Oct
- Initialised from ECMWF analysis and ARPEGE analysis
- Length: 10 days

Cyclone Track

Initialised at 0000 UTC 29 September 2016

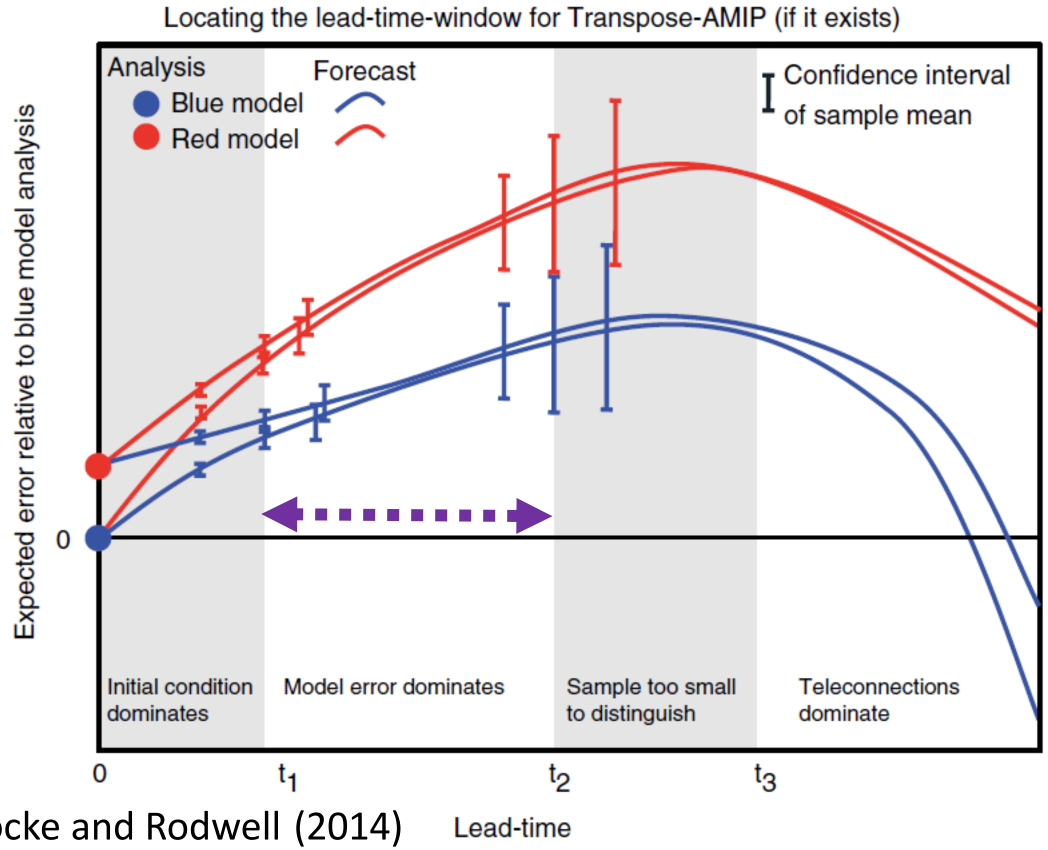


Initialised at 0000 UTC 2 October 2016

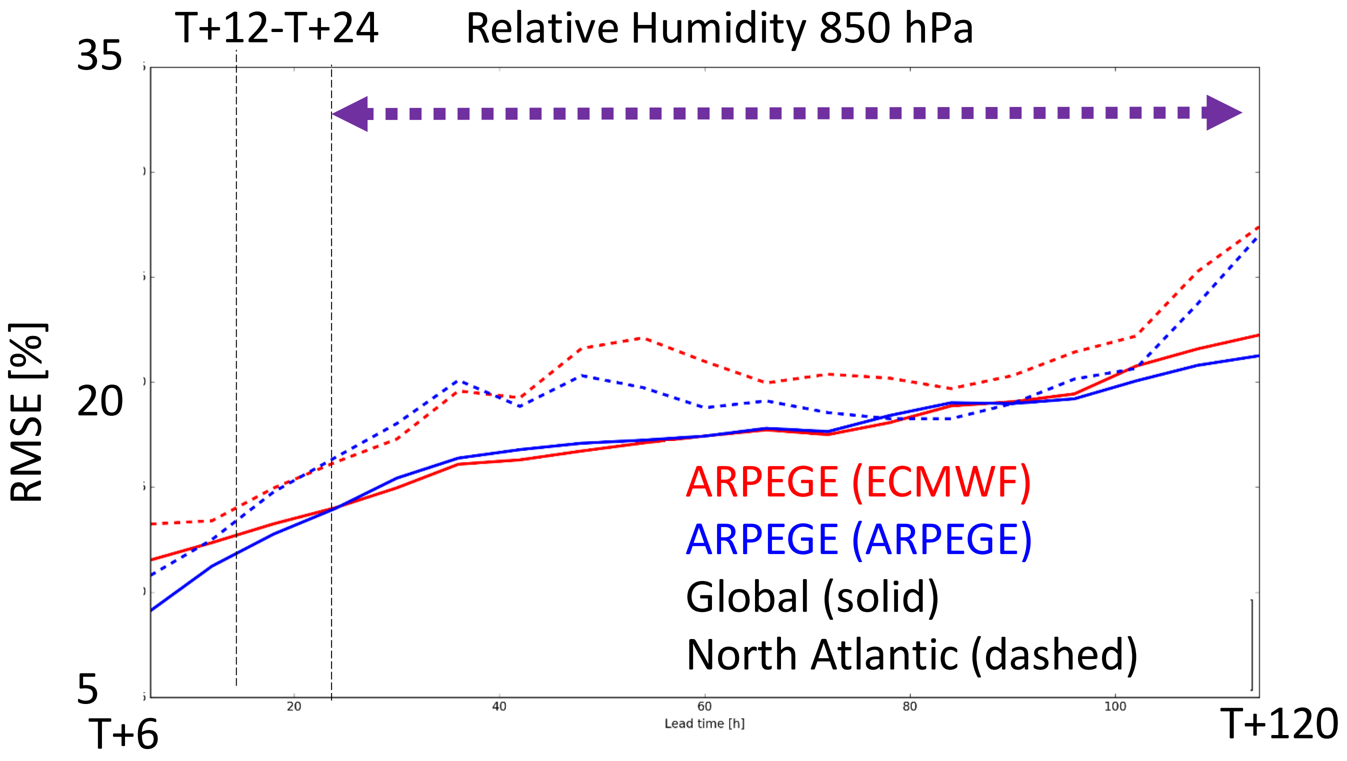


Initial Shock: The Theory

- Models initiated with a non-native initial set-up will take a while to adjust back to their own trajectory

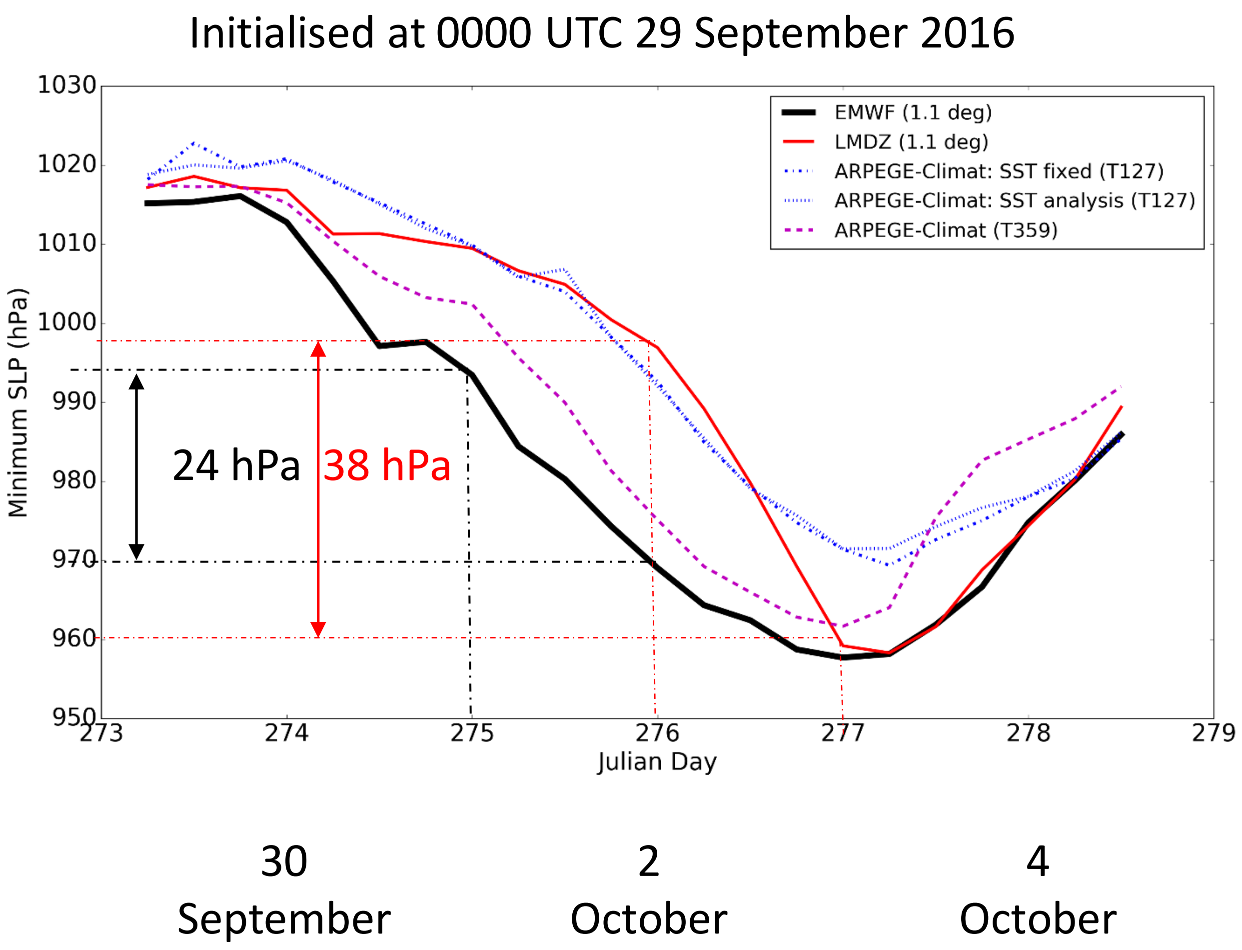


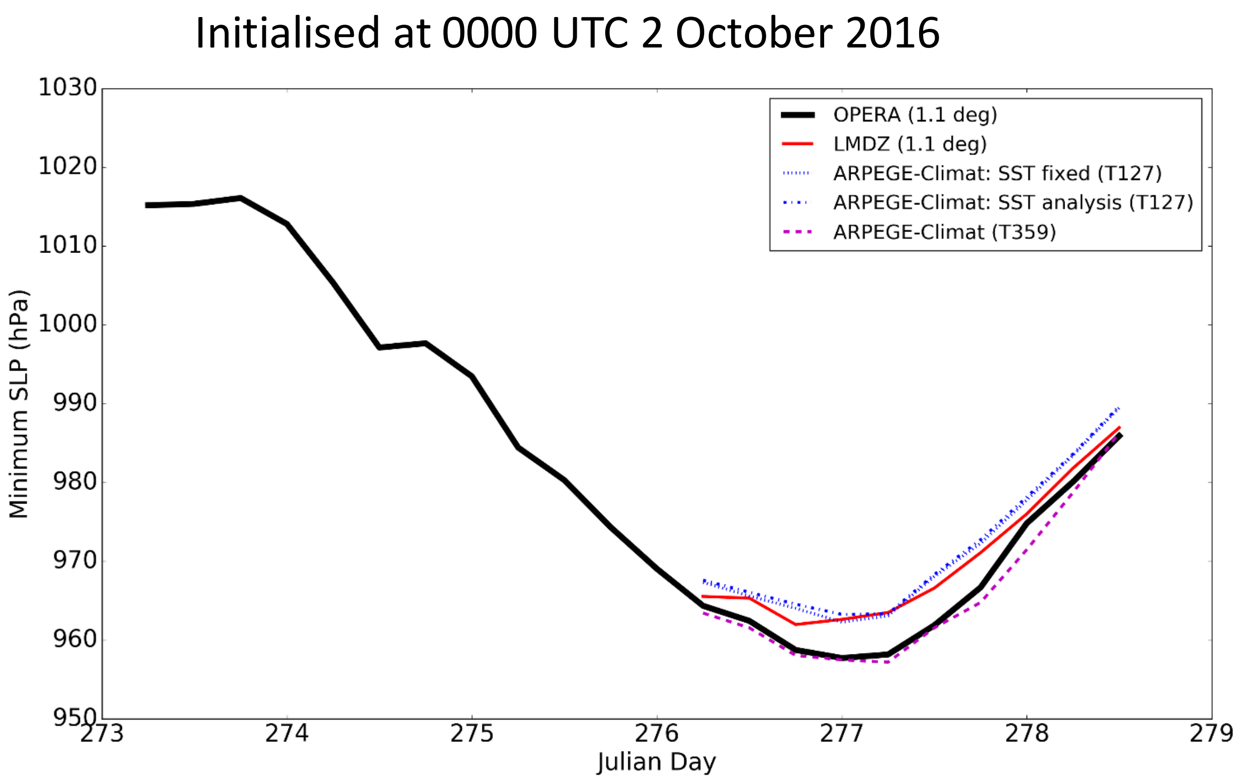
Klocke and Rodwell (2014)



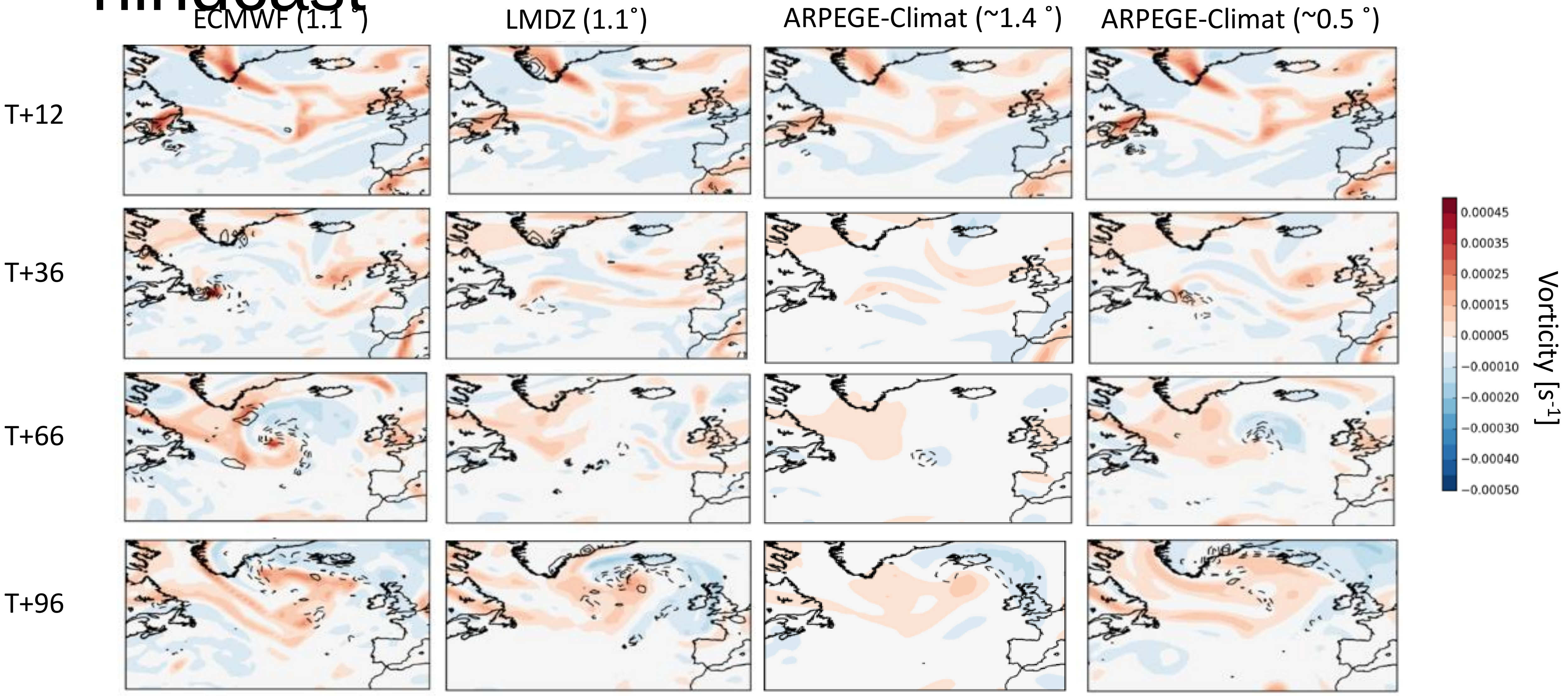
Transpose-AMIP experiments are viable

Cyclone Depth





Cyclone Development: 29 September hindcast



ω-equation budget

$$\sigma\nabla^2\omega + f_0\frac{\partial^2\omega}{\partial p^2} = -\frac{R}{p}\left(\nabla^2\left(-\overrightarrow{u_g}.T\right) + \nabla^2 J\right) - f_0\frac{\partial}{\partial p}\left(-\overrightarrow{u_g}.\nabla\left(\xi_g + f\right)\right)$$

Writing in the form of Q vectors and diabatic terms

$$\sigma\nabla^2\omega + f_0\frac{\partial^2\omega}{\partial p^2} = \underbrace{-2\nabla.\vec{Q}}_{\text{Dynamical contribution}} \underbrace{- \frac{R}{p}\left(\nabla^2\left(\left.\frac{\partial T}{\partial t}\right|_{mp}\right)\right)}_{\text{Diabatic contribution from the model physics tendencies microphysics, convection, radiation, turbulence, drag}} \underbrace{\cancel{- f_0\frac{\partial}{\partial p}\left(\frac{\partial}{\partial x}\left(\left.\frac{\partial v}{\partial t}\right|_{mp}\right) - \frac{\partial}{\partial y}\left(\left.\frac{\partial u}{\partial t}\right|_{mp}\right)\right)}}_{\text{Neglected as 10 times smaller than other terms}}$$

where

$$\vec{Q} = -\frac{R}{p}\begin{pmatrix} \frac{\partial\overrightarrow{v_g}}{\partial x}.\nabla T \\ \frac{\partial\overrightarrow{v_g}}{\partial y}.\nabla T \end{pmatrix}$$

Baroclinic Conversion

Inverting the omega-equation leads to the vertical motion being split into a dynamic and diabatic component:

$$\omega = \omega_{dynamic} + \omega_{diabatic}$$

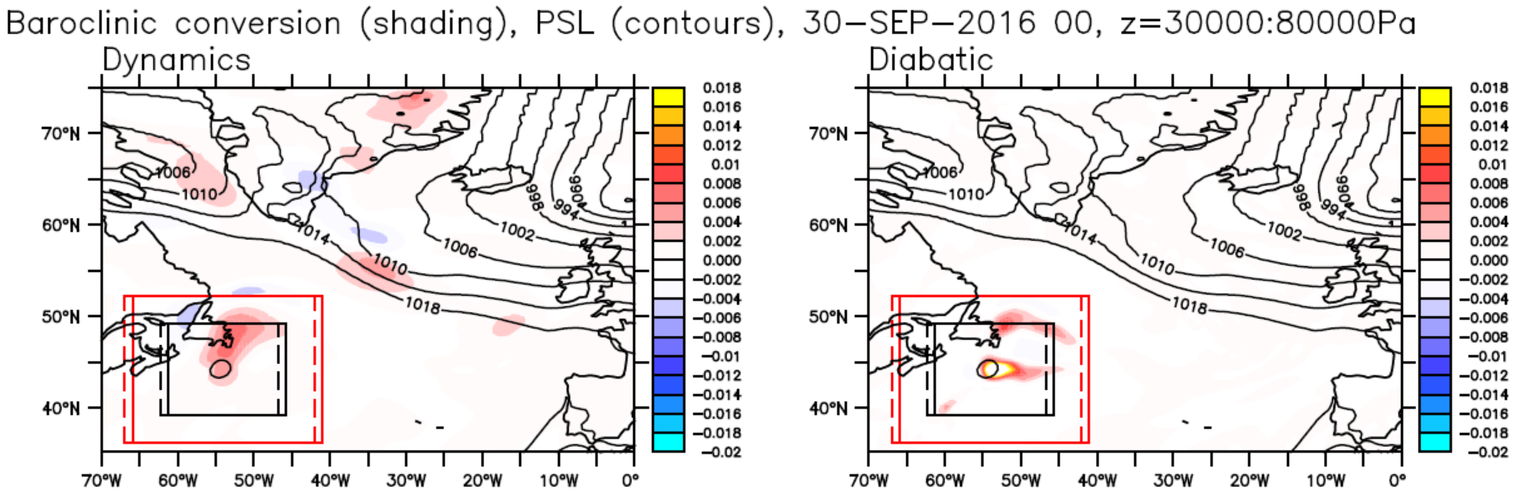
The diabatic component can then be split into the components from each of the model parametrizations:

$$\omega_{diabatic} = \omega_{conv} + \omega_{ls\ cond\ heat} + \omega_{rad} + \omega_{turb}$$

These values can be used to calculate the components contribution towards the baroclinic conversion:

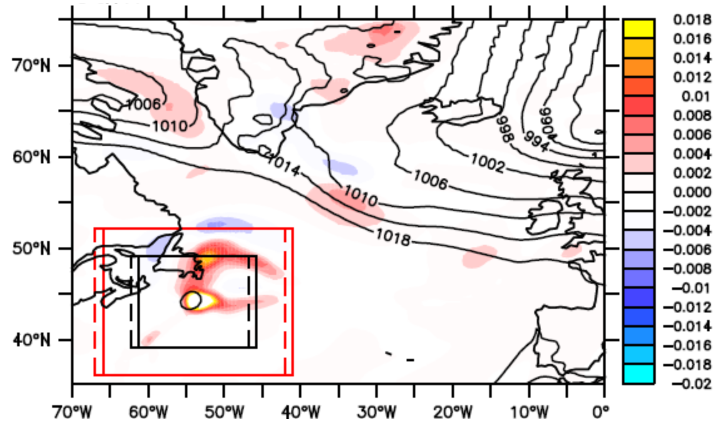
$$-\omega'\theta' = -\omega'_{dyn}\theta' - \omega'_{dia}\theta'$$

Initial development: 30 September 00 UTC

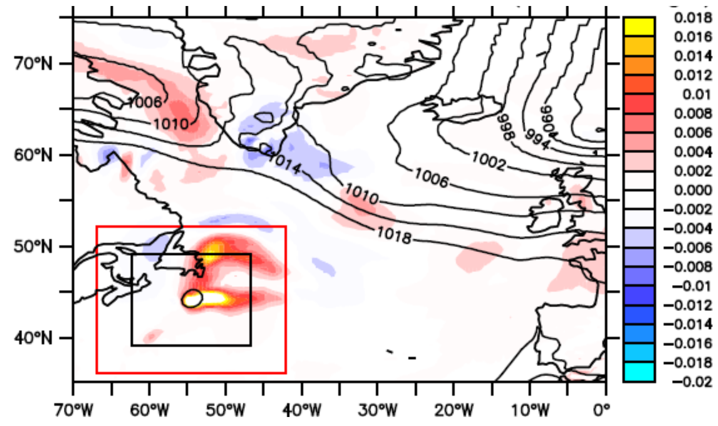


ARPEGE
(~0.5)

Baroclinic Conversion (ω-eqn)

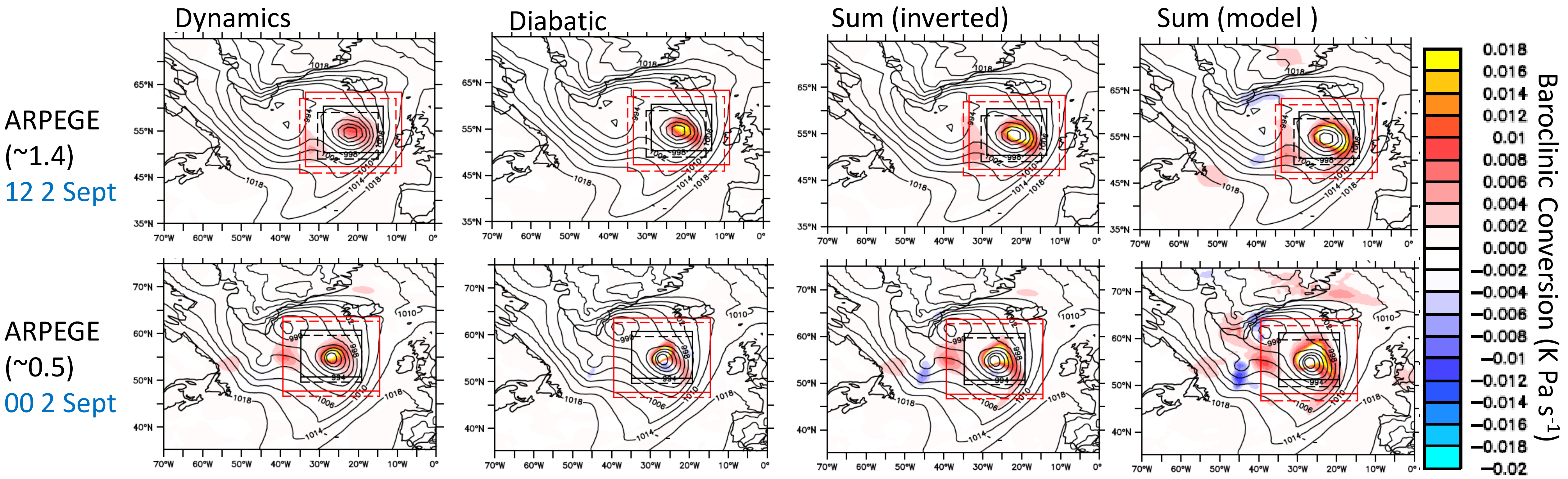


Baroclinic Conversion (model ω)



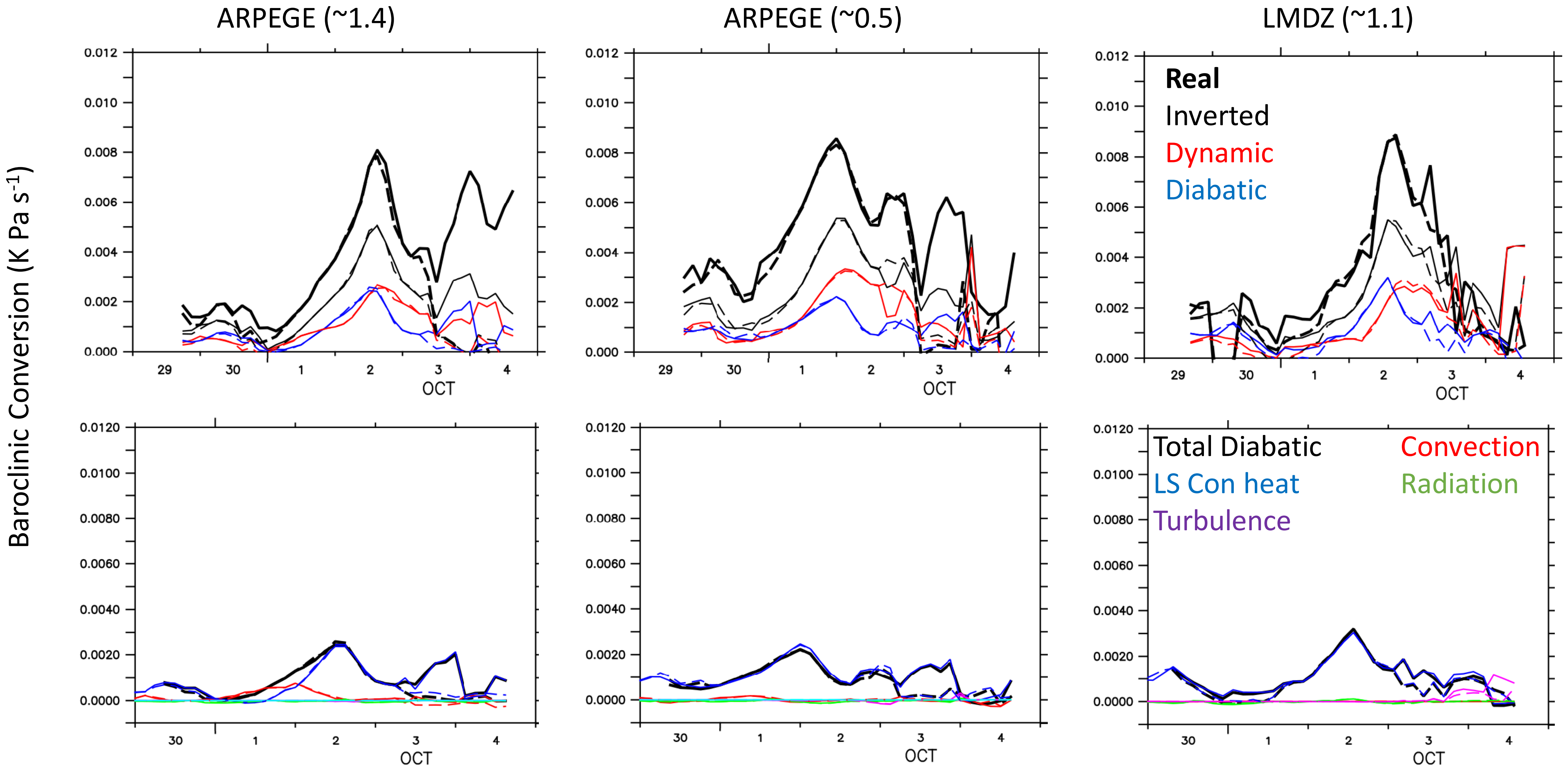
Baroclinic Conversion (K Pa s^{-1})

Maximum intensification



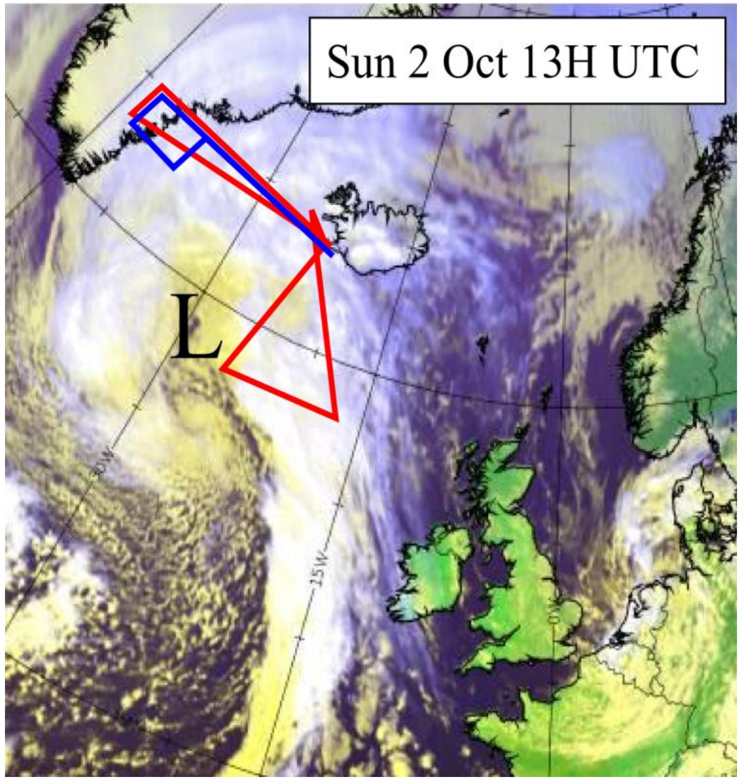
Average Baroclinic Conversion between 850 and 300 hPa

Dashed = PSL min
Solid = BC max

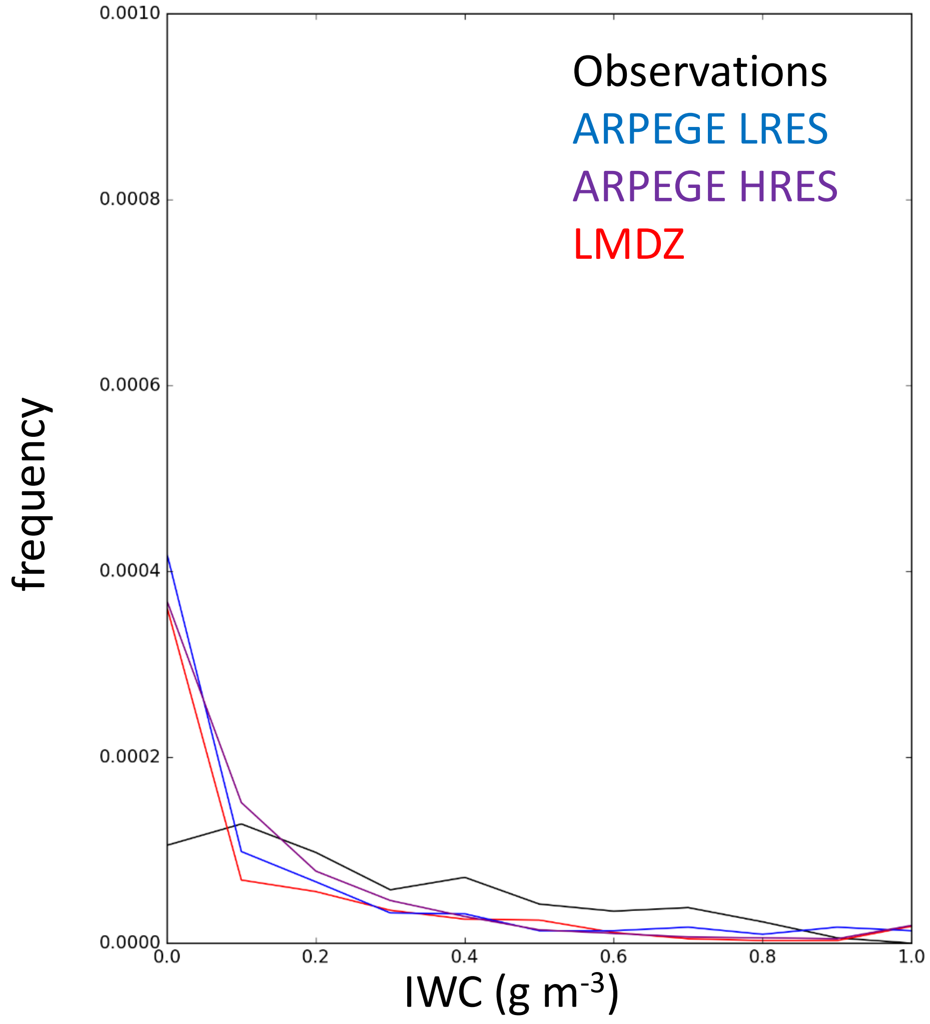


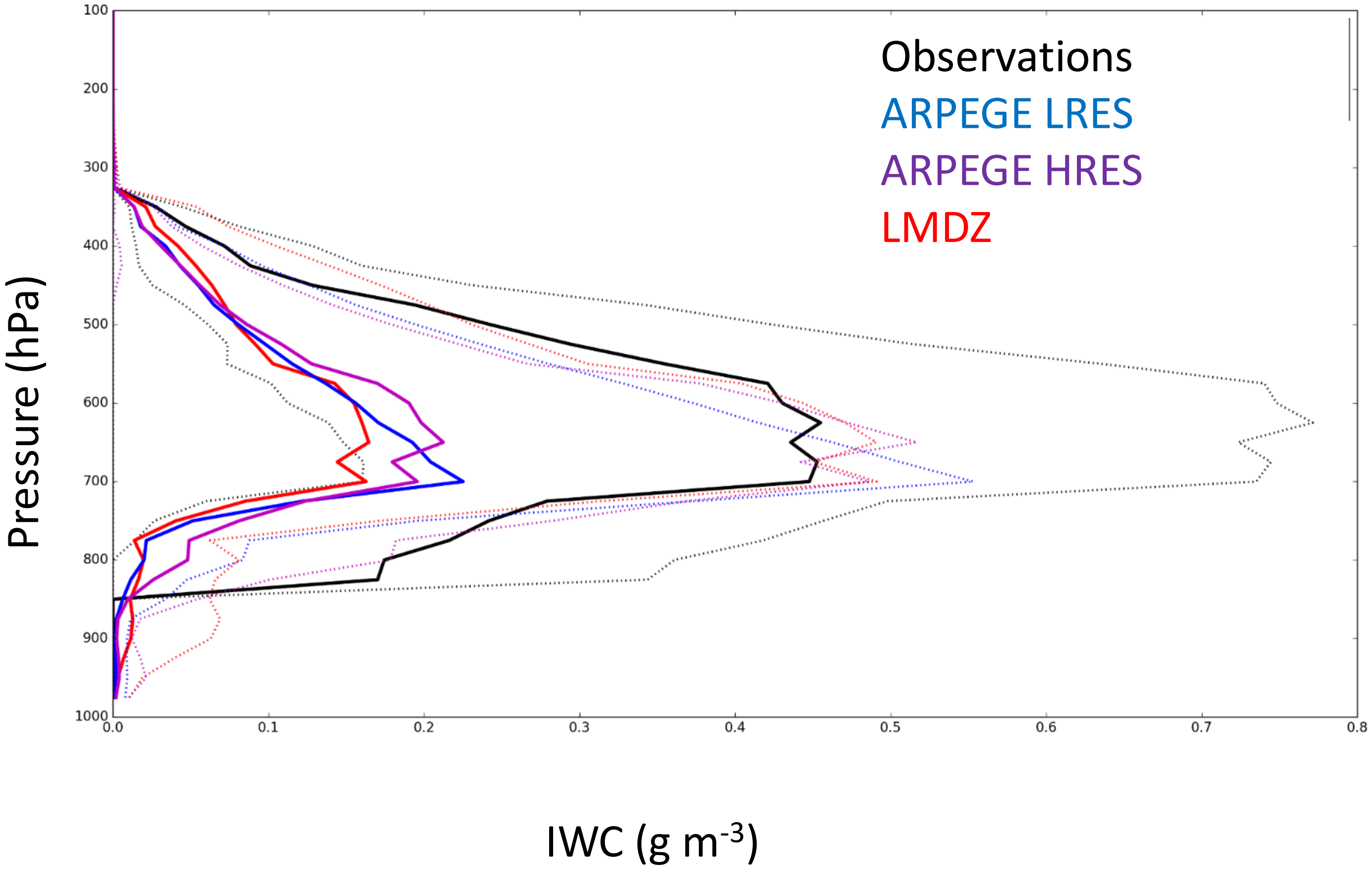
Observations

- Flight 7 – IWC content and retrieved wind speed

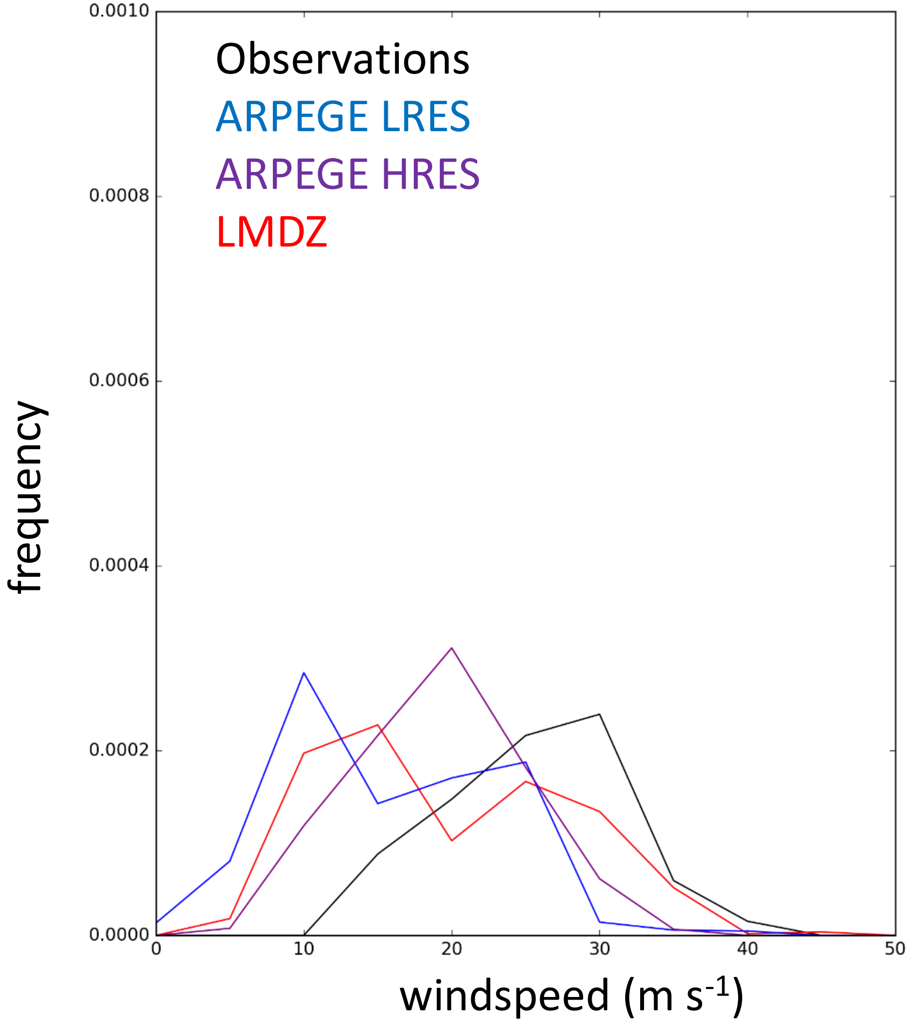


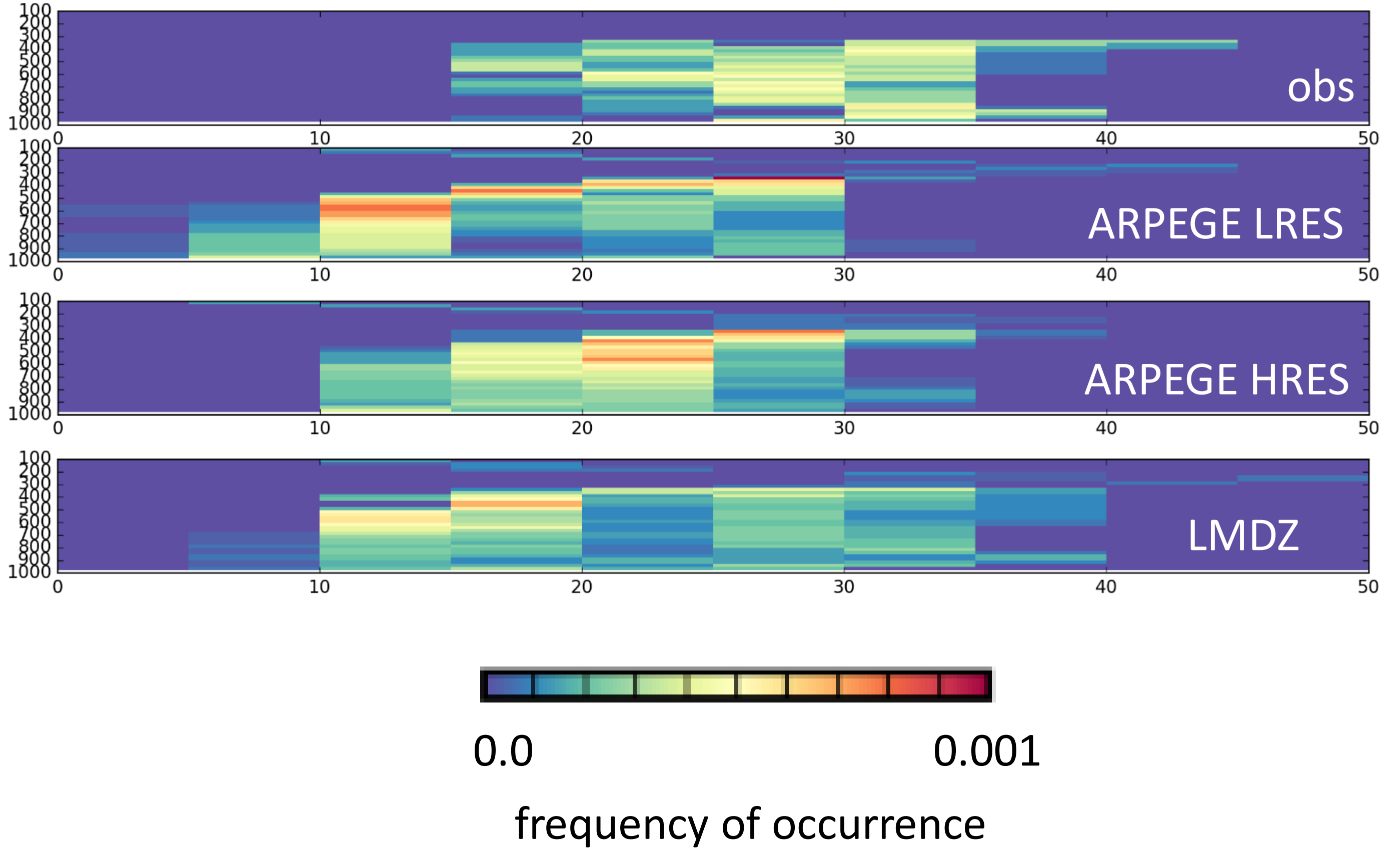
Ice Water Content Flight 7: 29 September hindcast



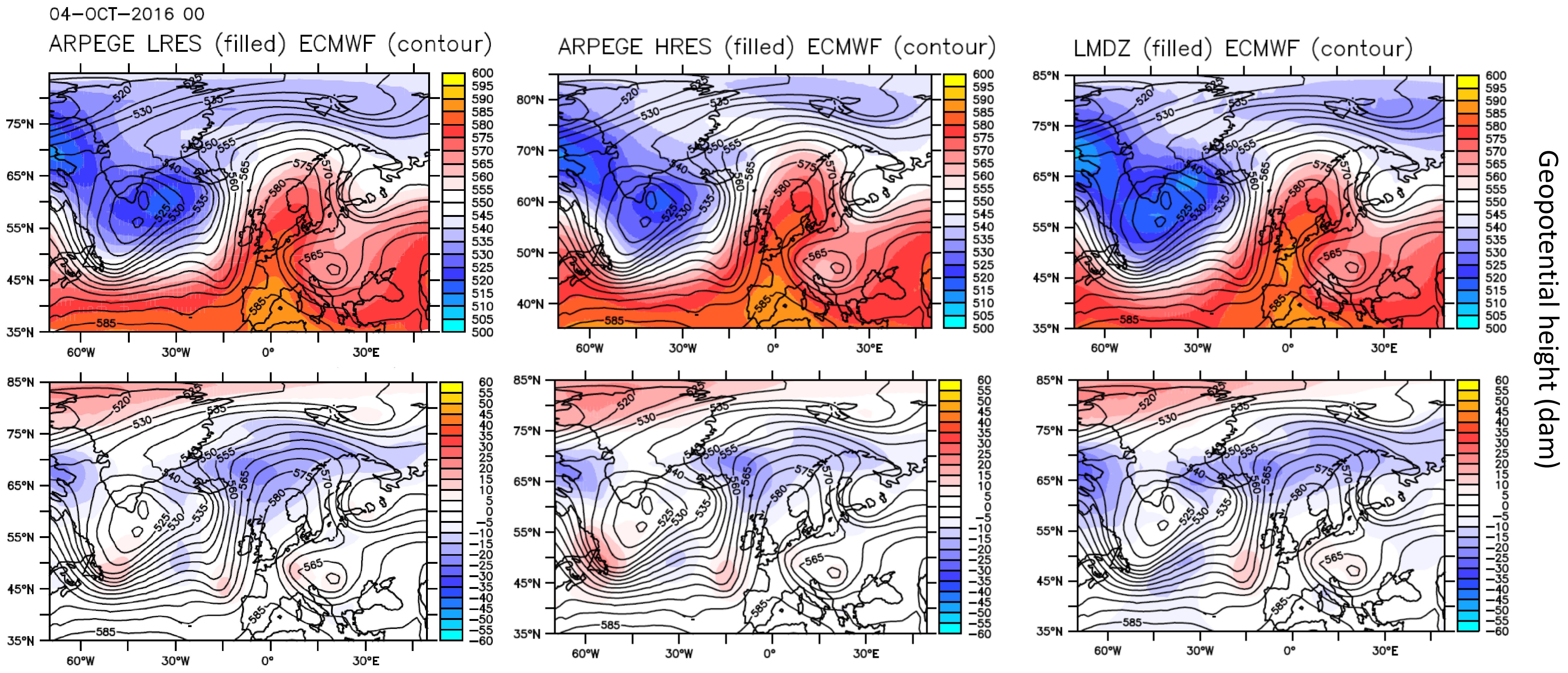


Windspeed Flight 7: 29 September hindcast



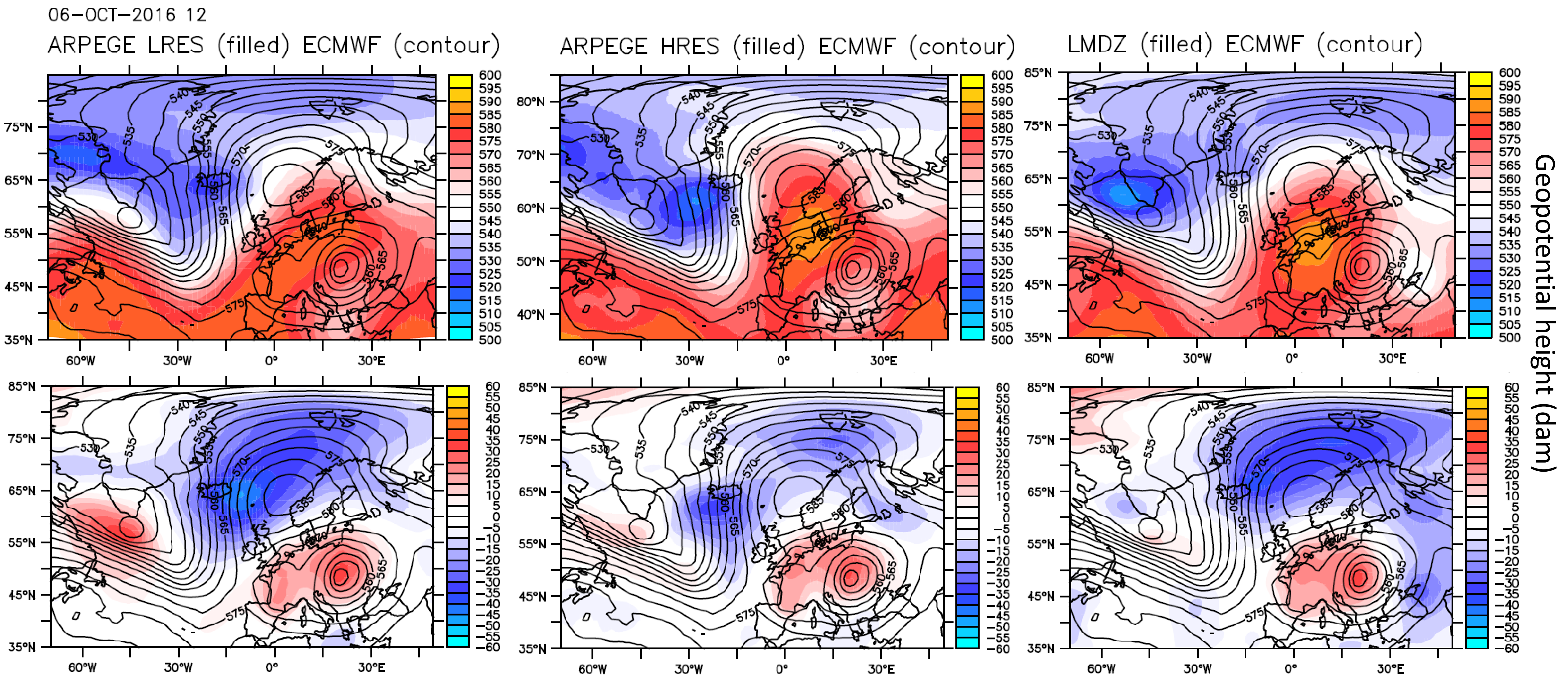


Impact on the ridge development



Model – ECMWF (solid) ECMWF (contour)

Ridge development



Model – ECMWF (solid) ECMWF (contour)

Summary

- Stalactite Cyclone
  - **HRES closer to analysis for development** (including timing)
  - **In all diabatic influence are similar to or slightly above dynamical processes before maximum deepening and dynamic processes dominate after (more so at HRES)**
  - **Diabatic processes are dominated by large-scale condensational heating** for all simulations (although convection important towards beginning for LRES)
  - There is no change in the average magnitude of diabatic influence on the cyclone development with resolution, unlike Willison et al. (2013) and Trzeciak et al. (2016).
  - Vertical structure improves with resolution compared to observations
  - Model distributions of windspeed and ice water content is shifted to lower values compared to observations
- Blocking
  - Too far S in all
  - **Improvement in representation with increase in resolution**

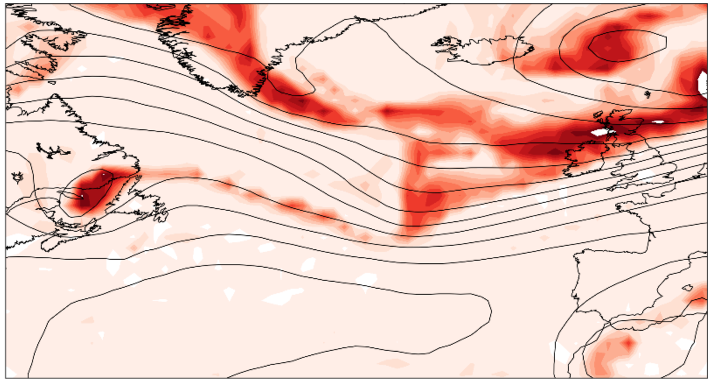
Future Work

- Look at higher and lower resolution LMDZ runs
- Look more into the ridge development
- Check consistency with the Frontal Wave Cyclone
  - Indications are results are consistent with Stalactite Cyclone
- See impact on ridge maintenance
  - Ridge appears to dissipate faster in HRES run
- Check results based on lead time

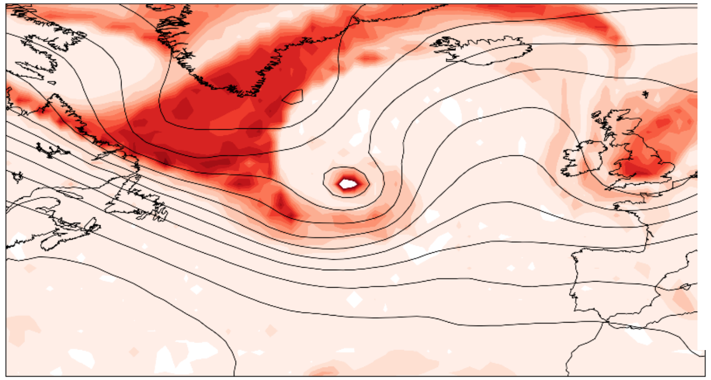
Extra Slides if required

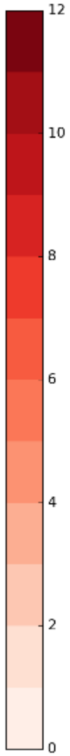
The Stalactite Cyclone

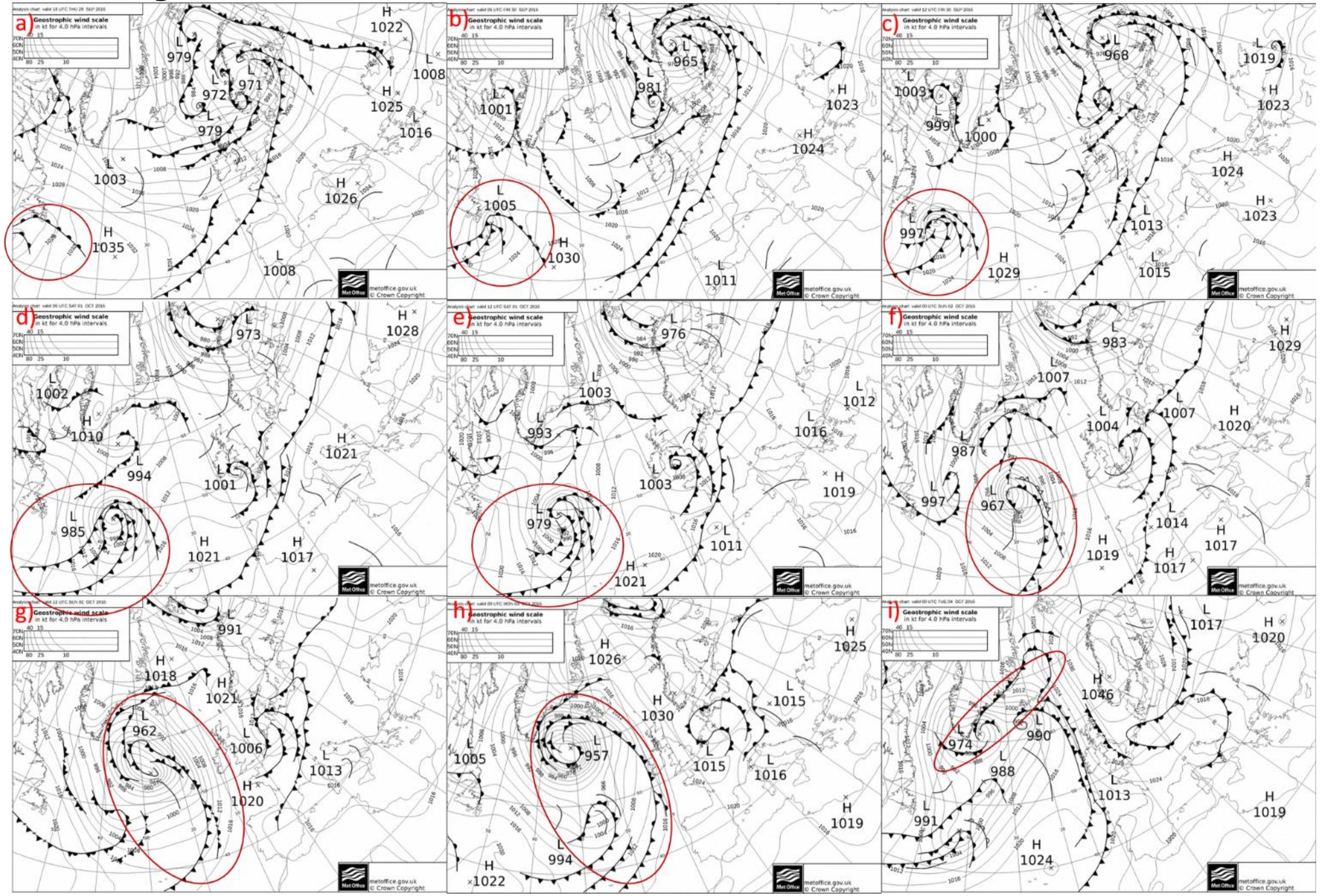
1200 UTC 29 September 2016



0600 UTC 2 October 2016



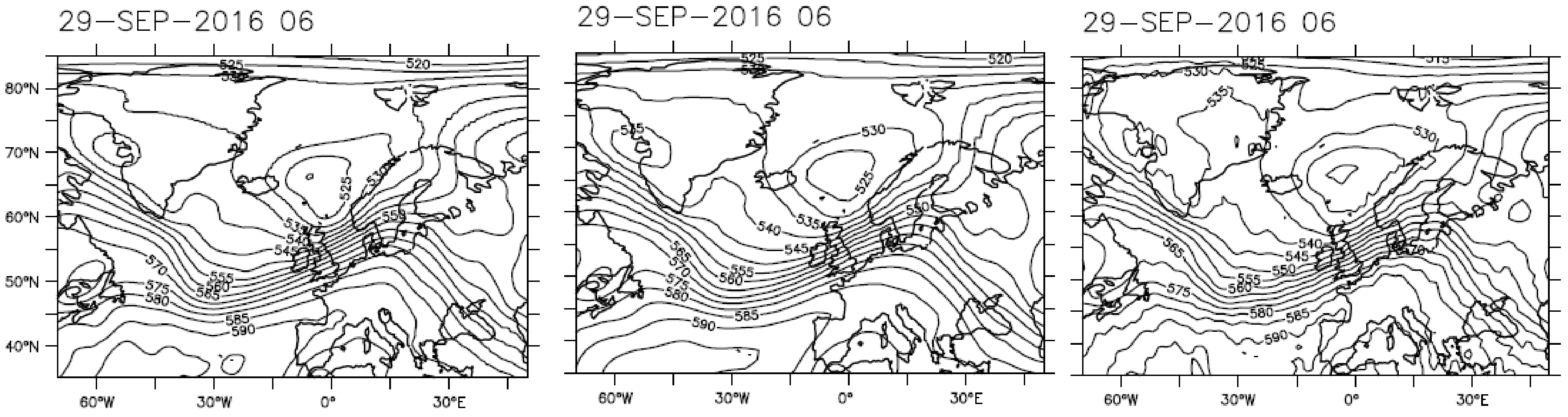




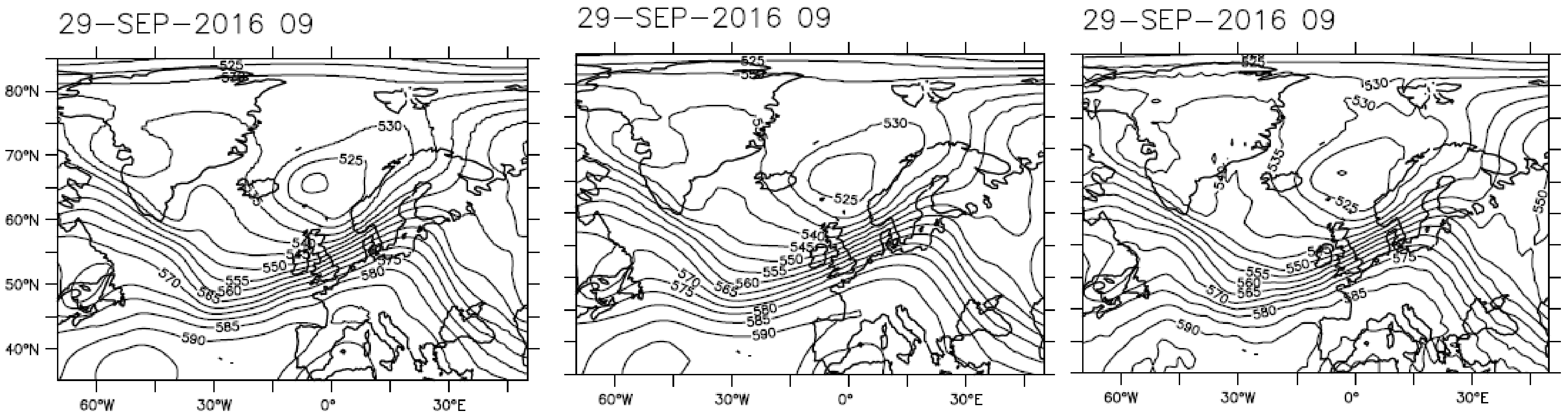
PV at 320 K and 500 hPa
Geopotential height

Initial Shock: 29 September 2016

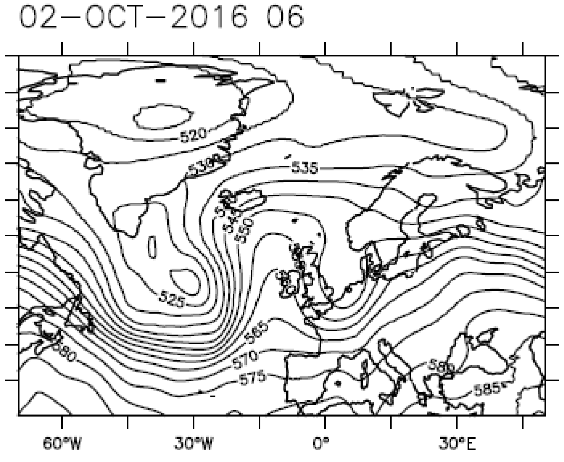
- Models initiated with non-native initial conditions will take a while to adjust back to their own trajectory.
- This adjustment is the “initial shock” and can be seen through initiation of gravity waves right at the start of the run.

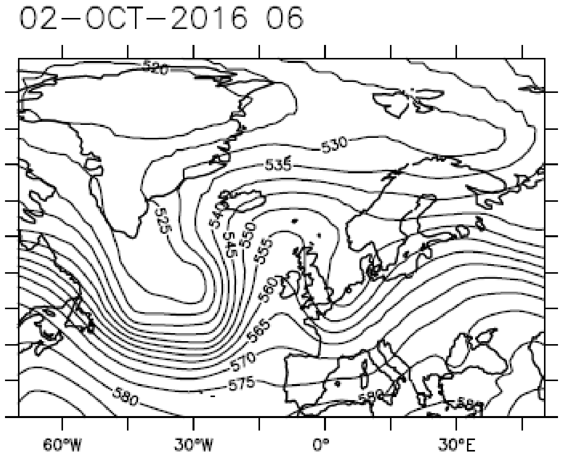


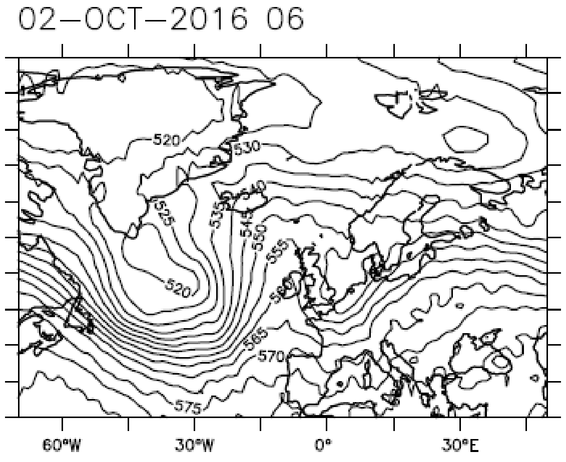
ARPEGE LRES (~1.4) **ARPEGE HRES (~0.5)** **LMDZ (1.1)**



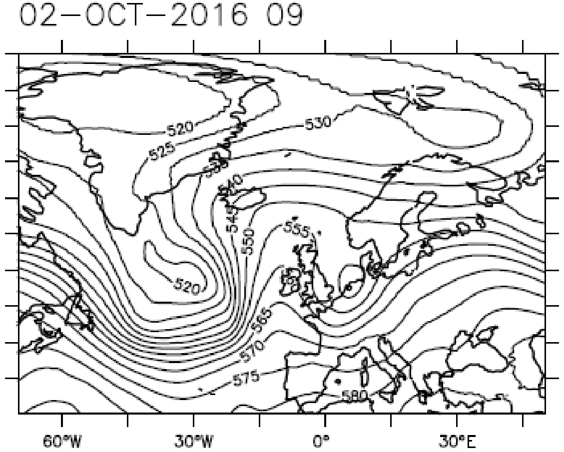
Initial Shock: 2 October 2016

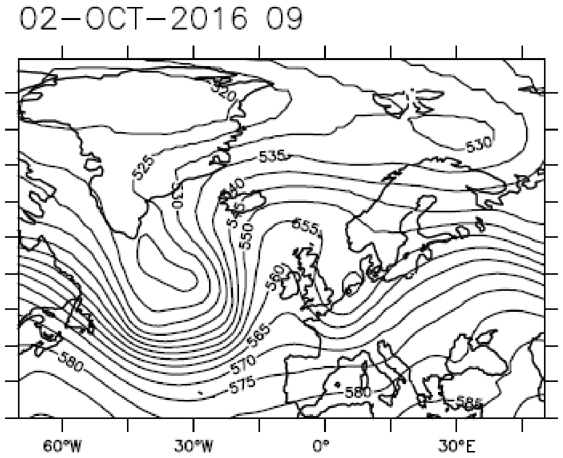


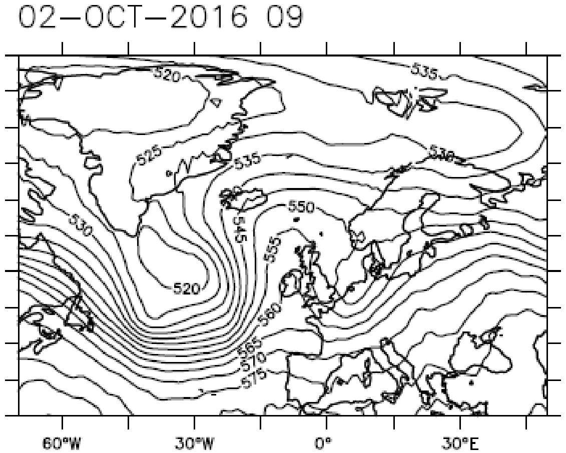




ARPEGE LRES (~1.4) **ARPEGE HRES (~0.5)** **LMDZ (1.1)**







Cyclone Development: 29 September hindcast

ECMWF (1.1 ˚) | LMDZ (1.1˚) | ARPEGE-Climat (~1.4 ˚) | ARPEGE-Climat (~0.5 ˚)

T+12

T+36

T+66

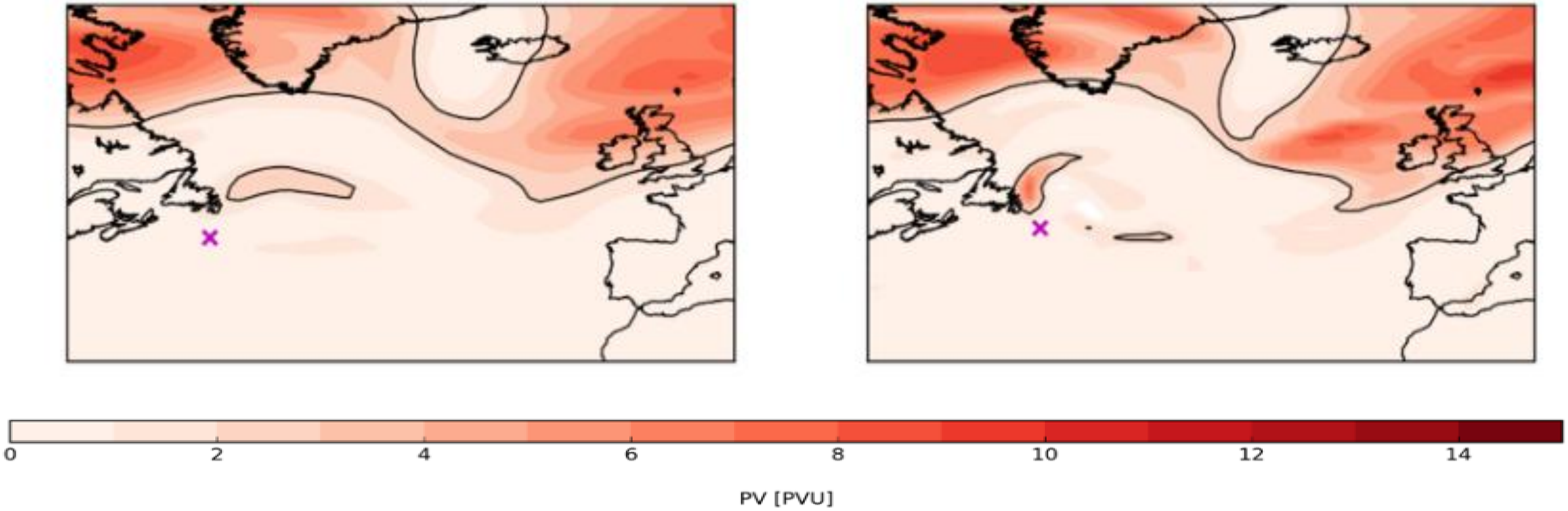
T+96

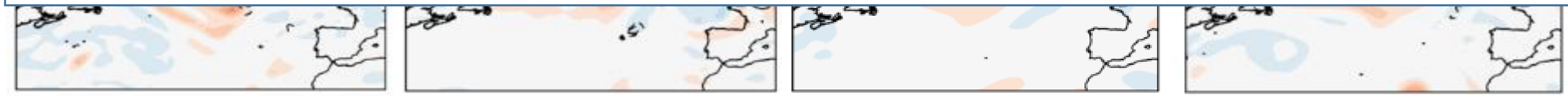
Vorticity [s-1]

PV at T+30

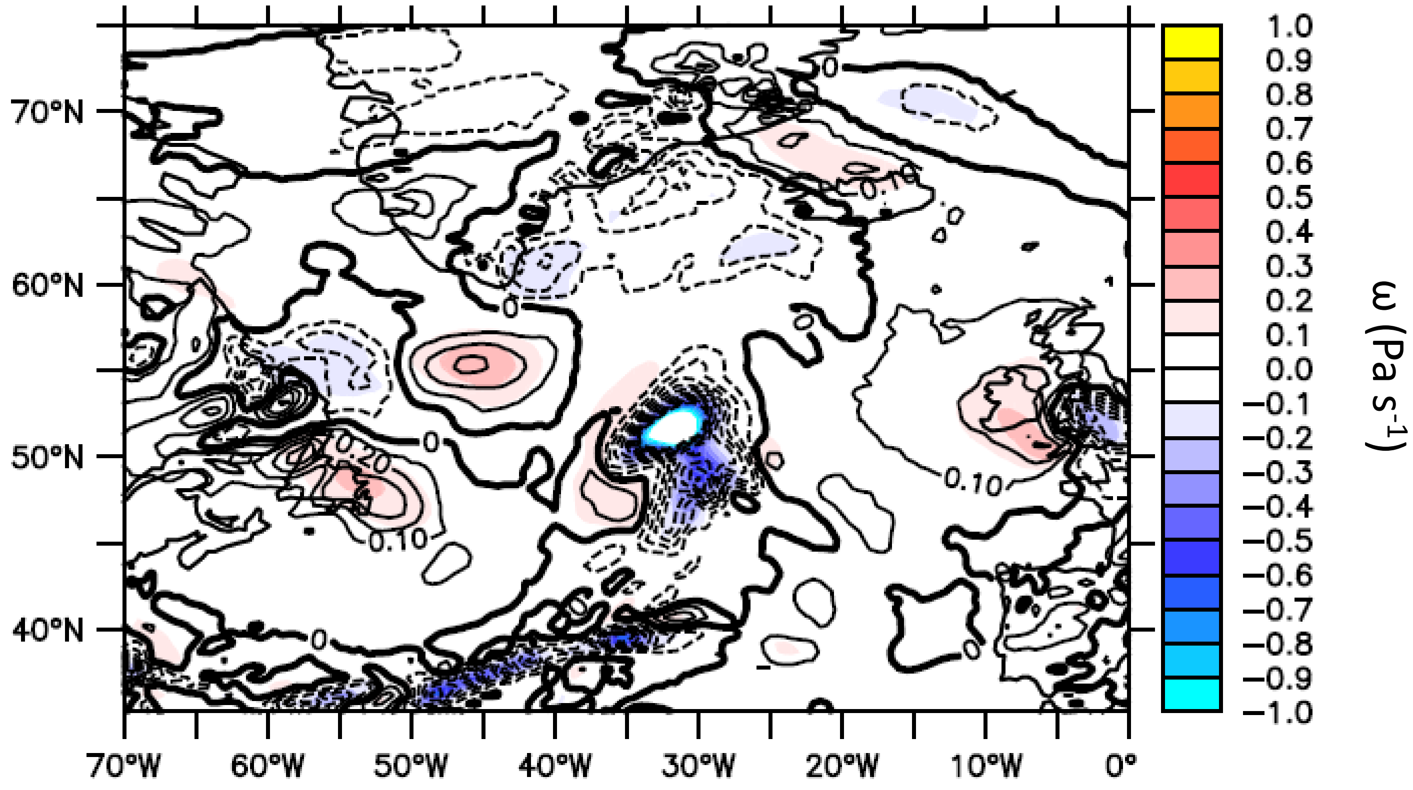
ARPEGE-Climat (~1.4 ˚)

ARPEGE-Climat (~0.5 ˚)





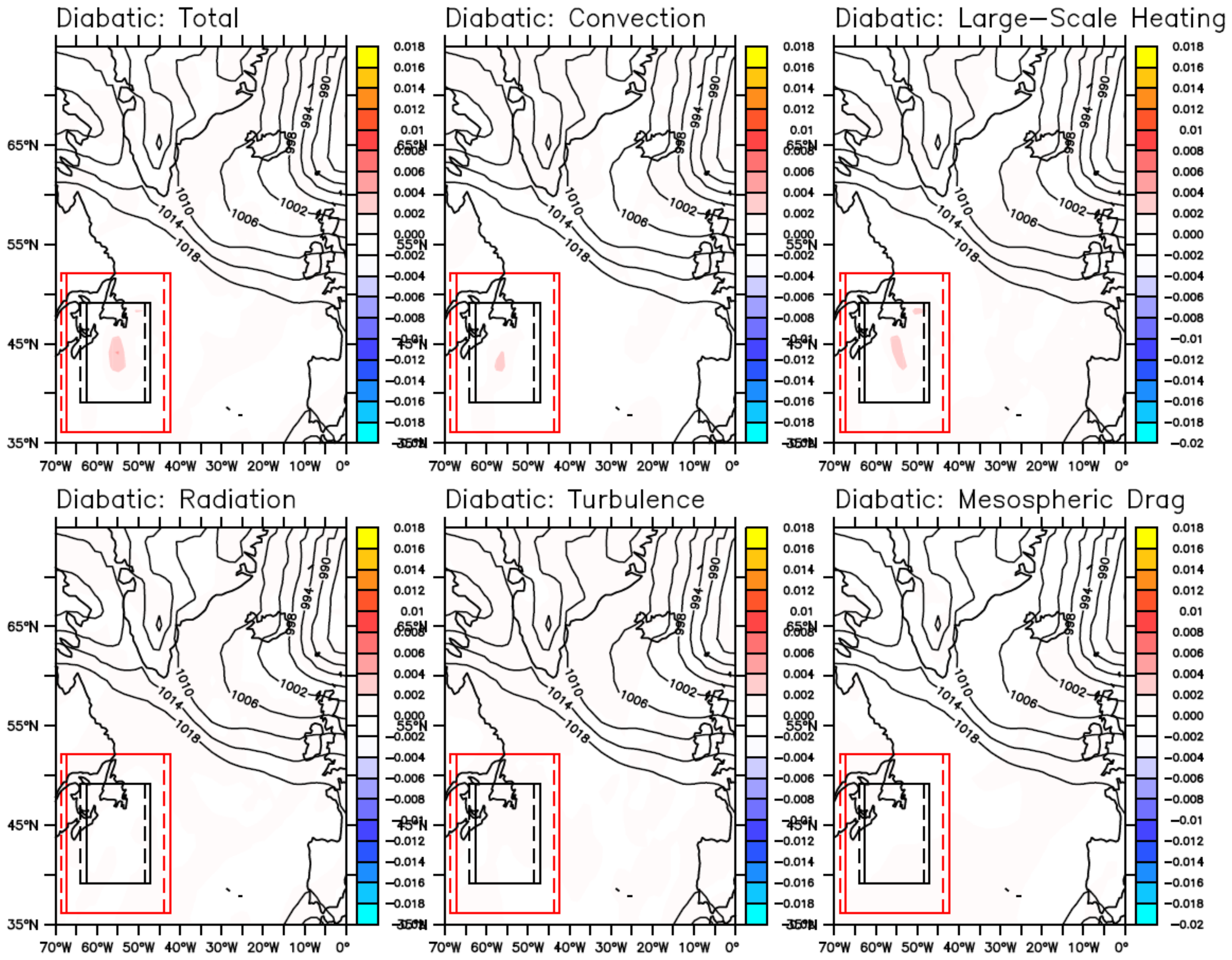
Inversion of the omega equation



ARPEGE

LRES

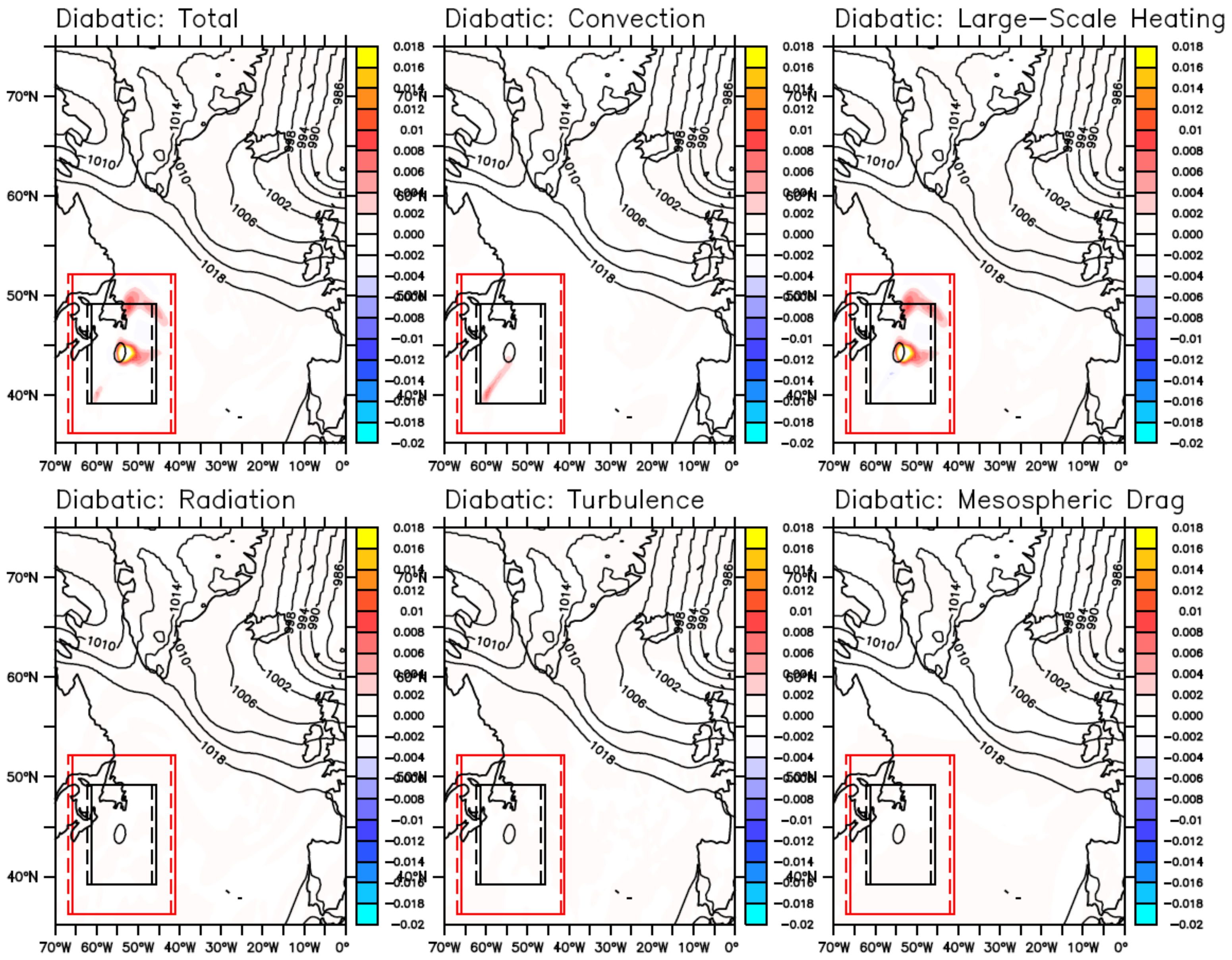
T+18



ARPEGE

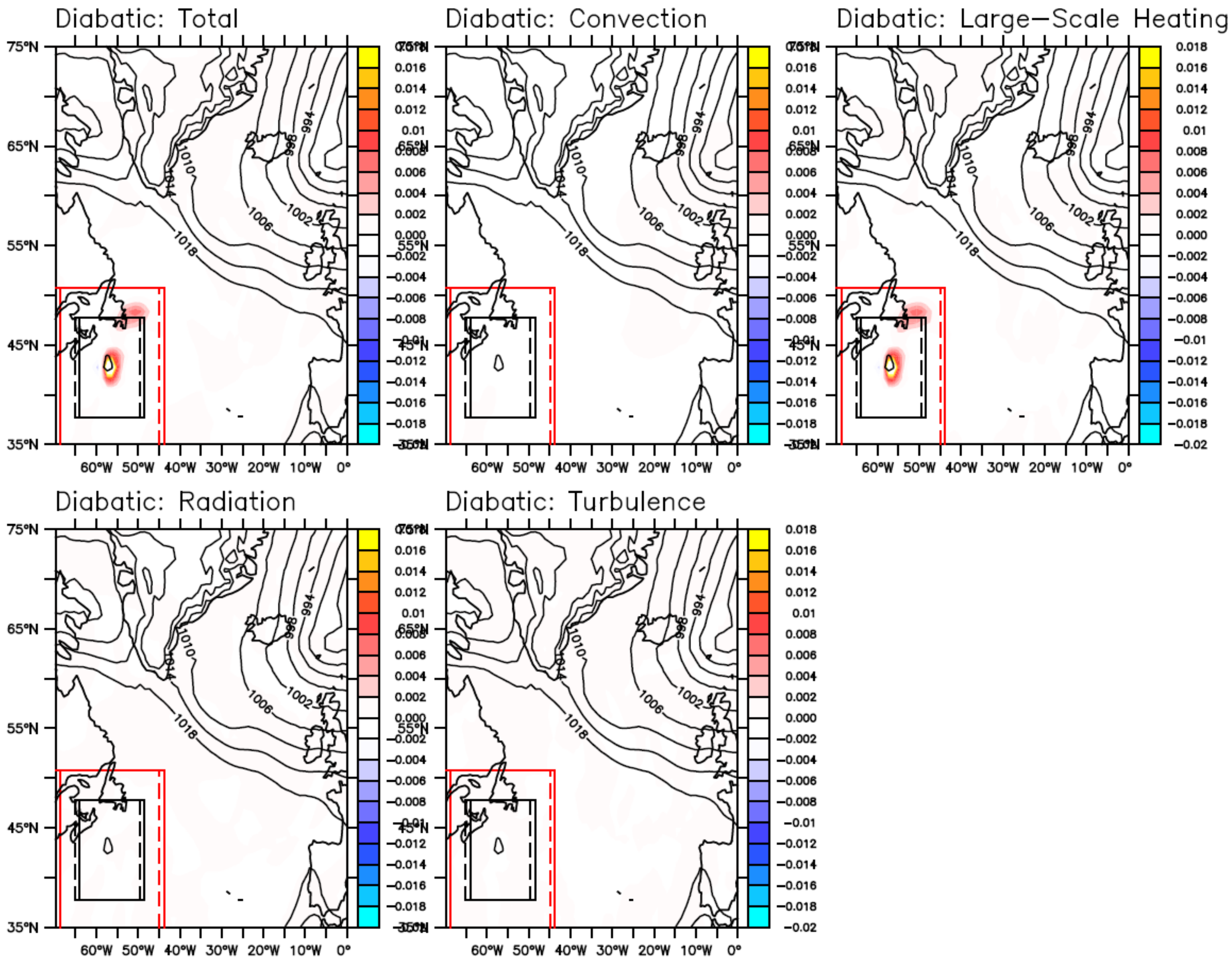
HRES

T+18



LMDZ

T+18



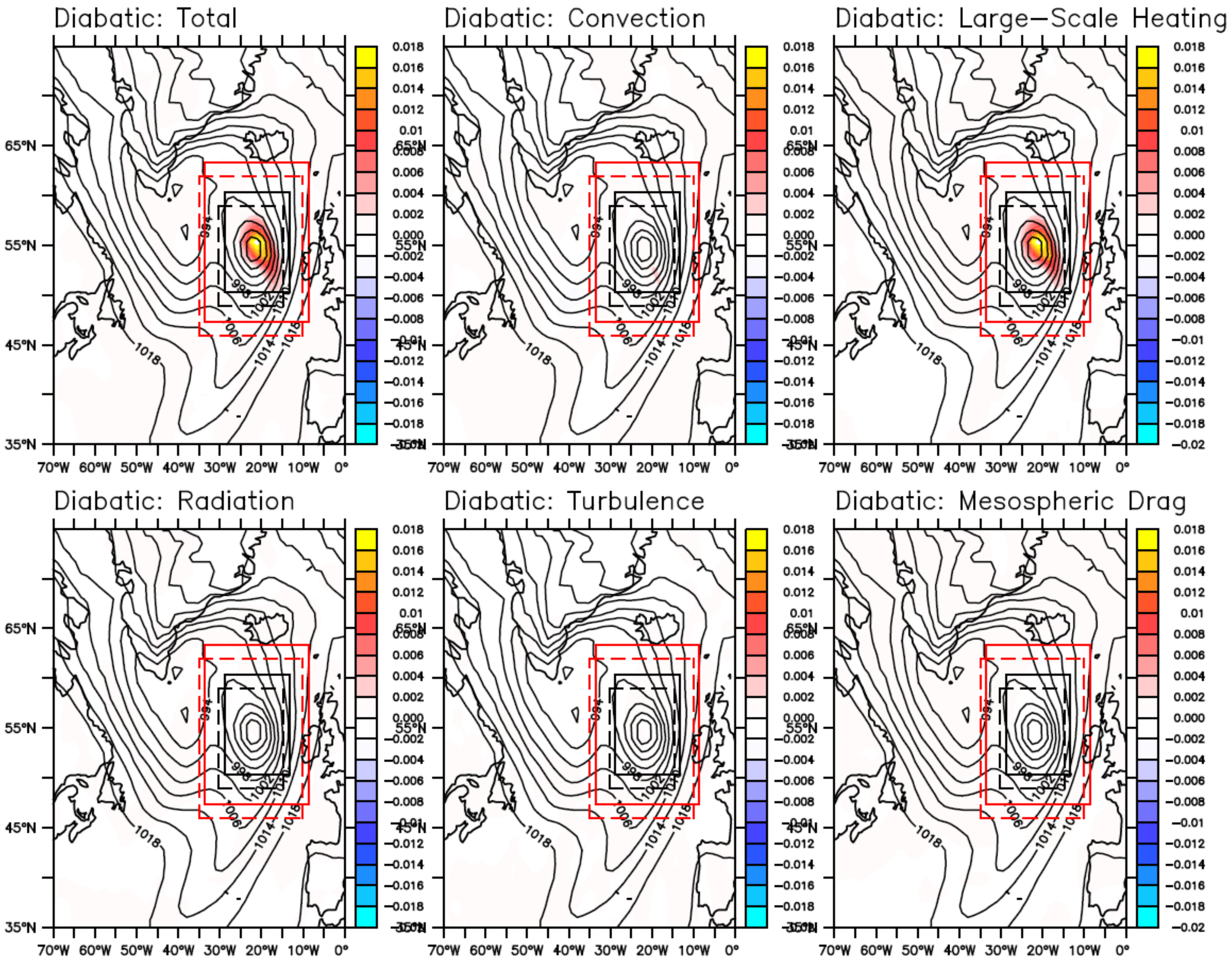
Diabatic: Total
Diabatic: Convection
Diabatic: Large-Scale Heating
Diabatic: Radiation
Diabatic: Turbulence

ARPEGE

LRES

Max. intensification

1200 UTC 2 Sept

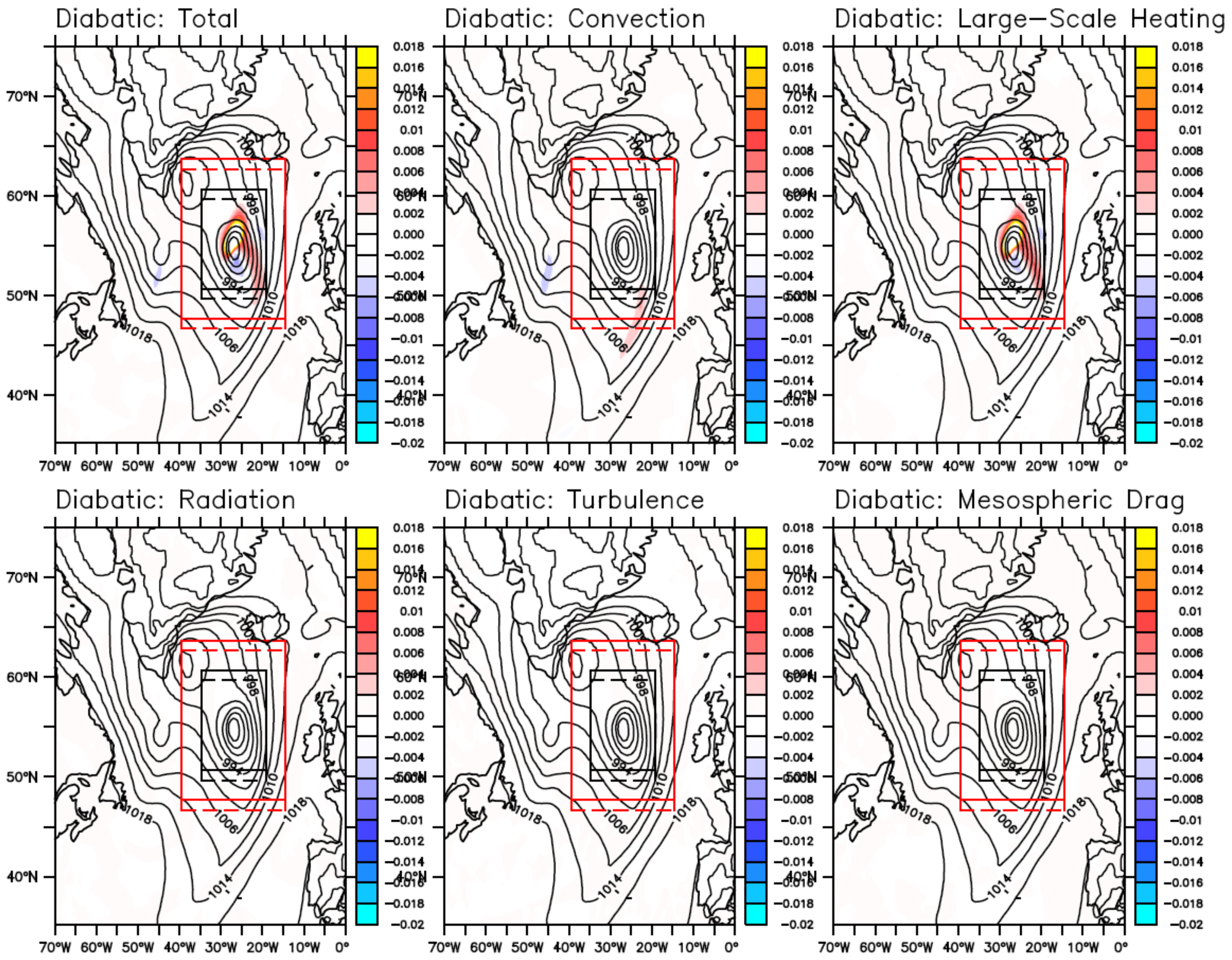


ARPEGE

HRES

Max. intensification

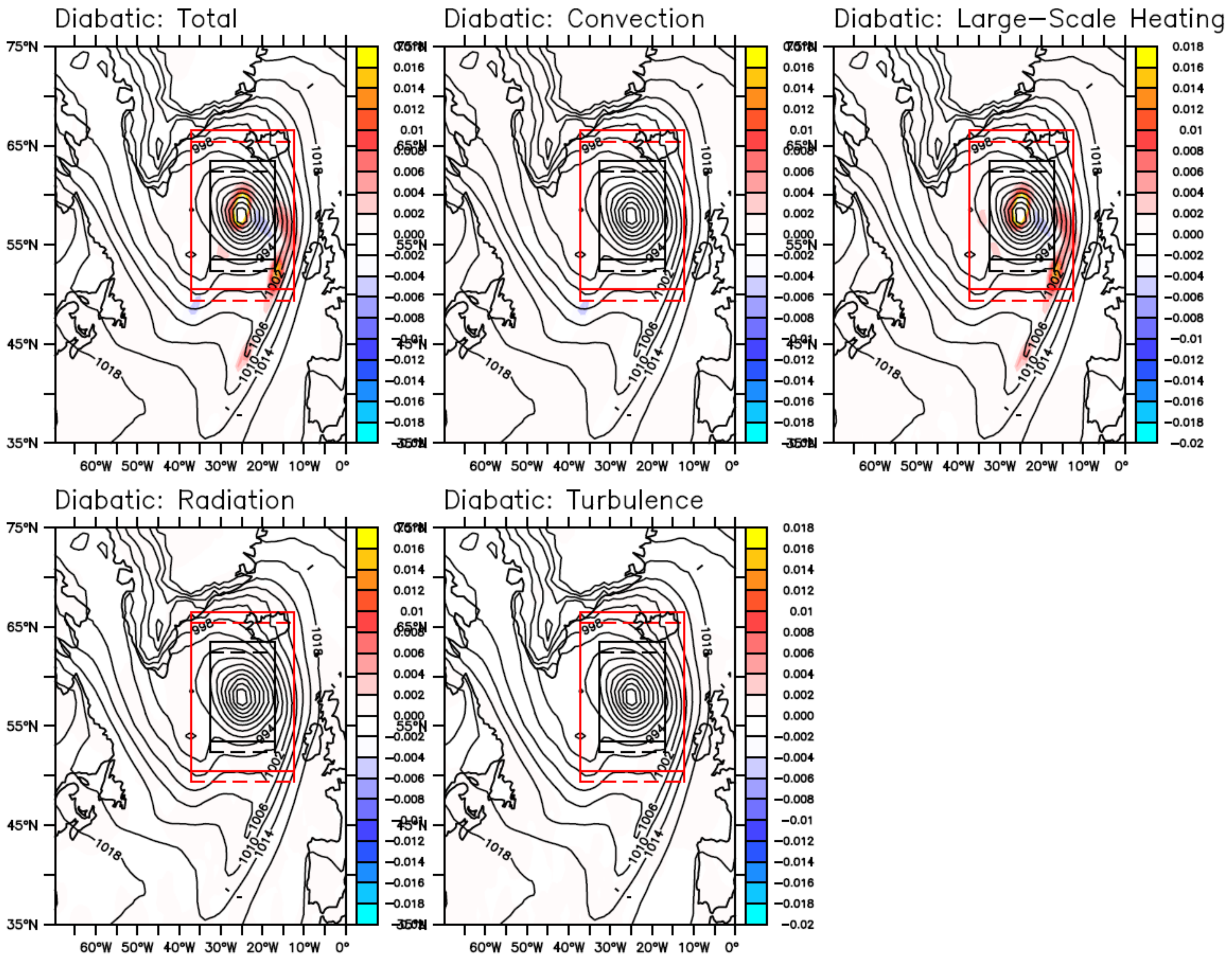
0000 UTC 2 Sept



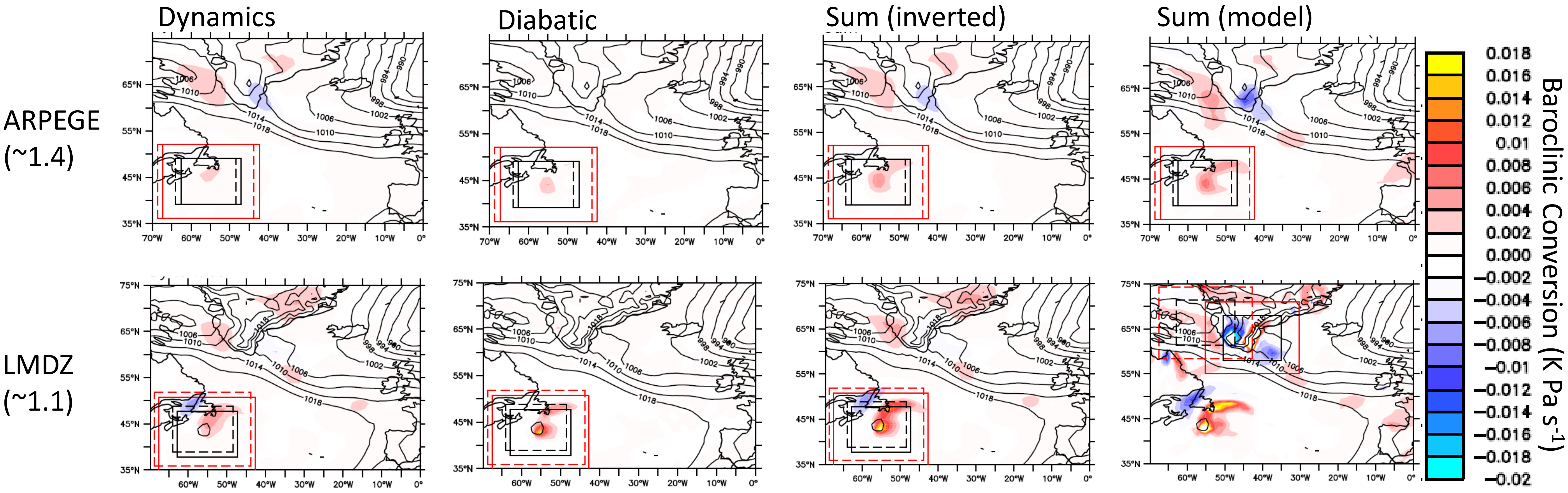
LMDZ

Max. intensification

1800 UTC 2 Sept

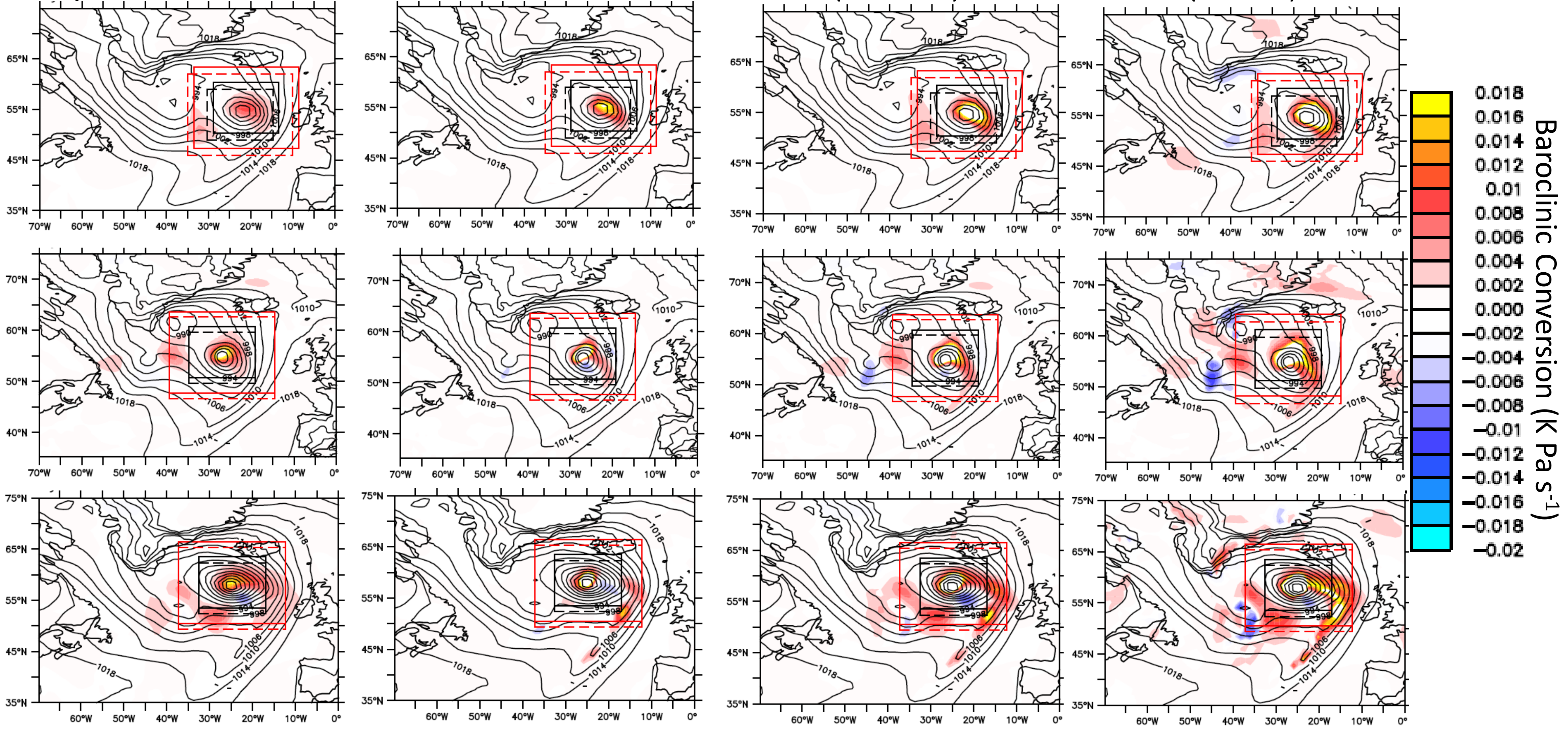


Initial development: 30 September 00 UTC



Maximum intensification

Dynamics | Diabatic | Sum (inverted) | Sum (model)

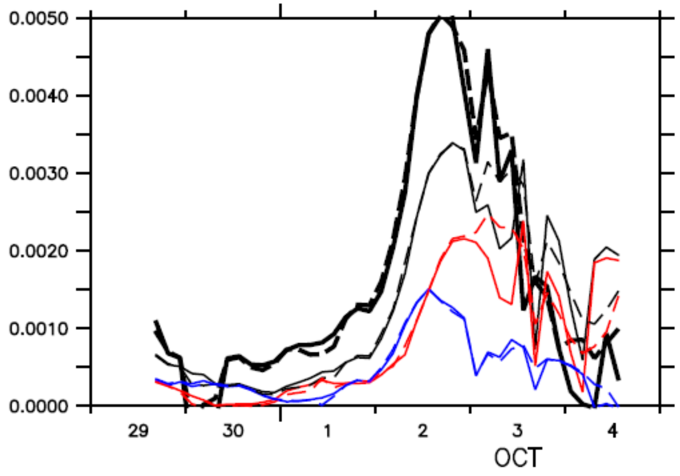


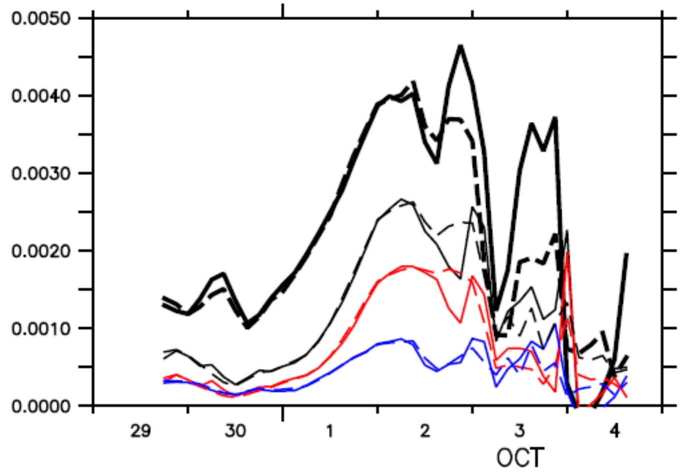
ARPEGE (~1.4) 12 2 Sept

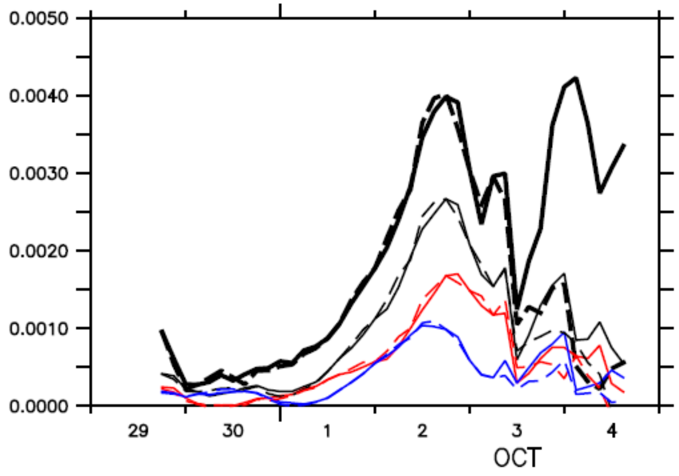
ARPEGE (~0.5) 00 2 Sept

LMDZ (~1.1) 18 2 Sept

Larger area (10x10 degrees)



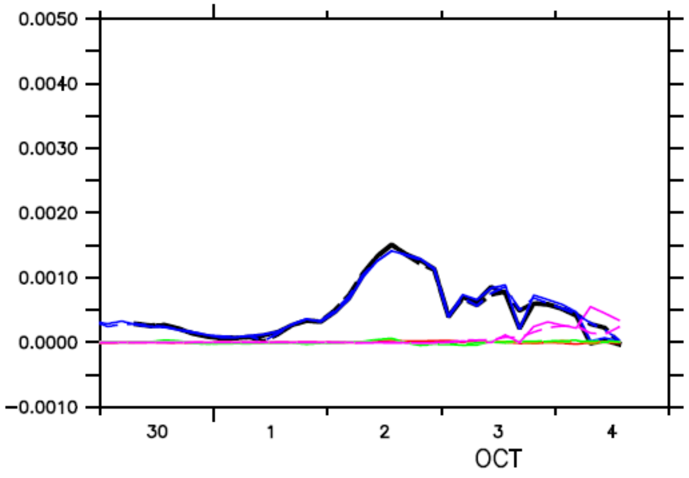


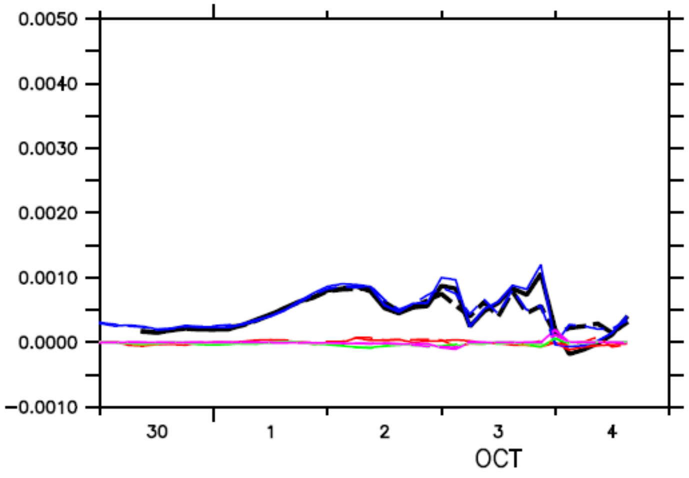


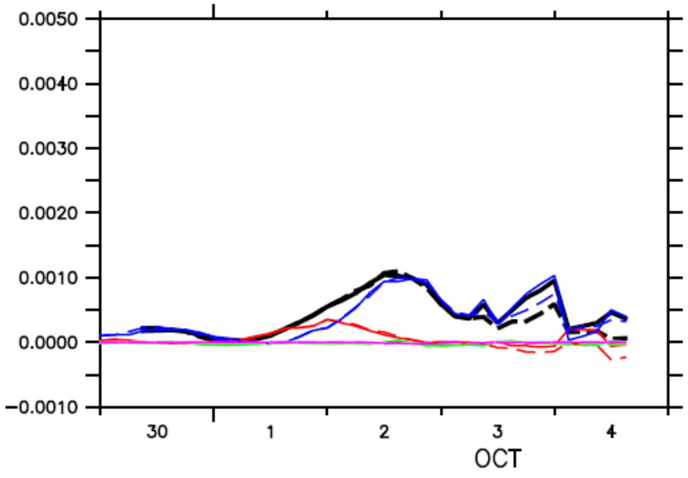
LRES ARPEGE

HRES ARPEGE

LMDZ



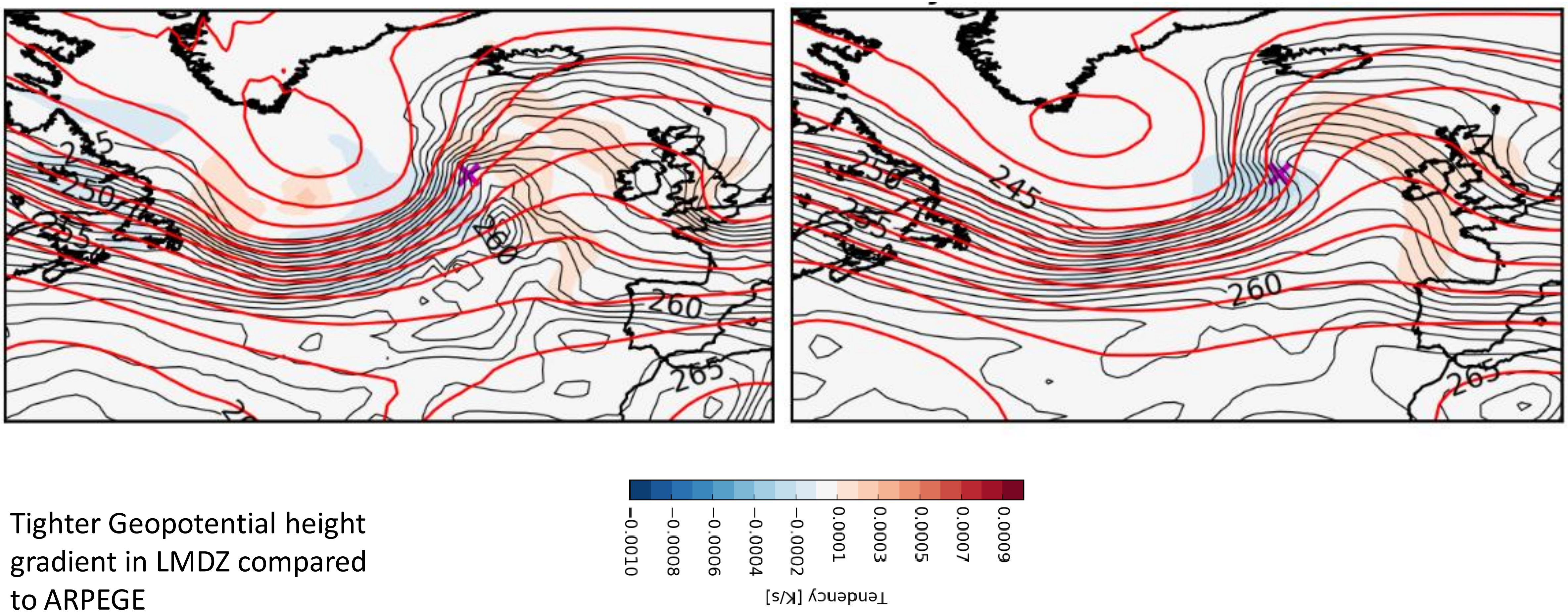




LMDZ vs. LRES ARPEGE deepening

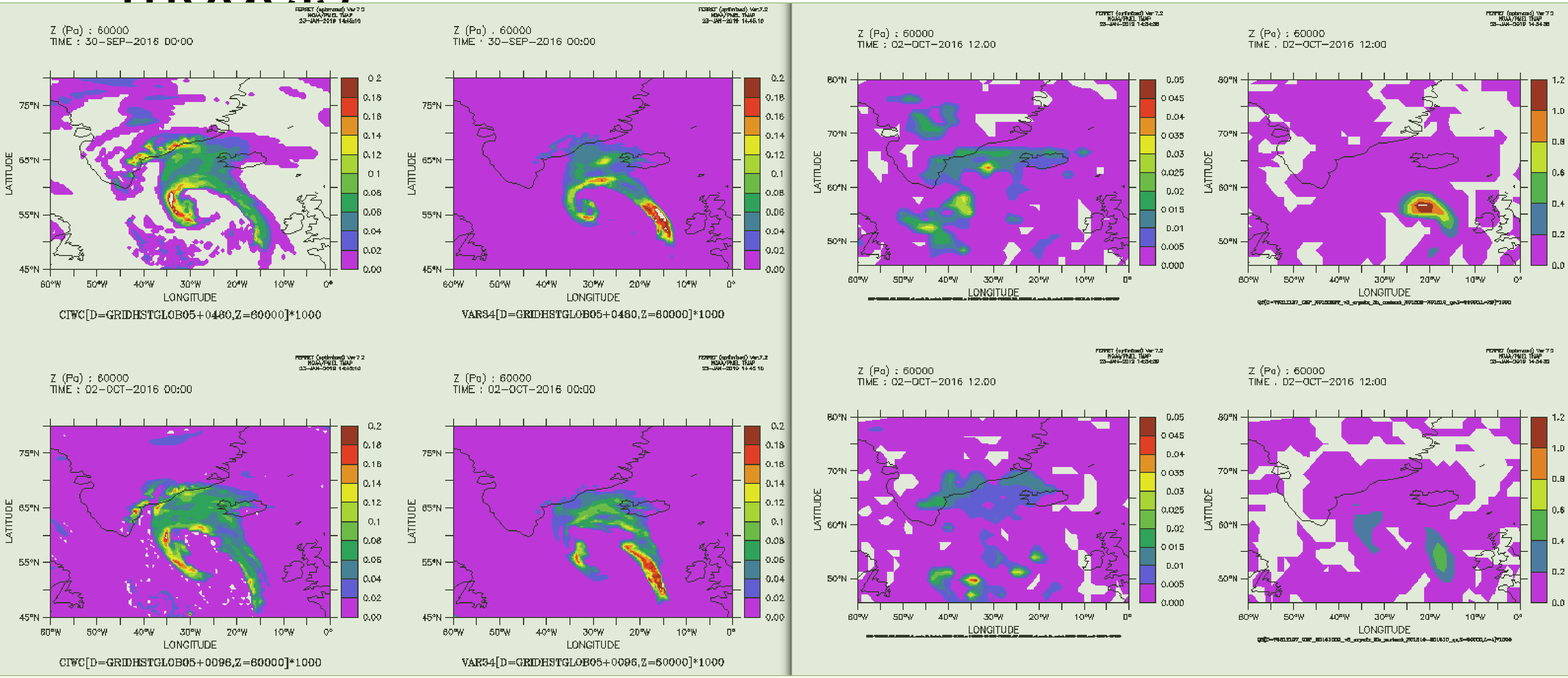
LMDZ T+84

ARPEGE T+84

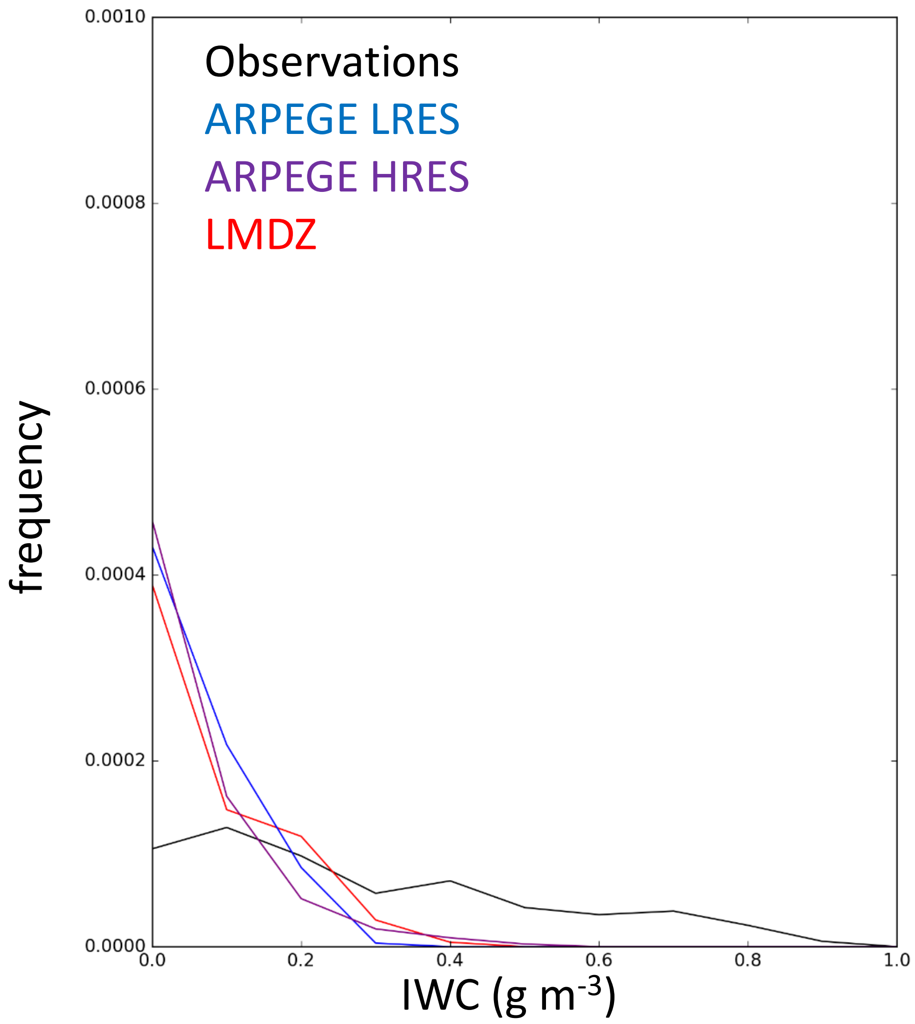


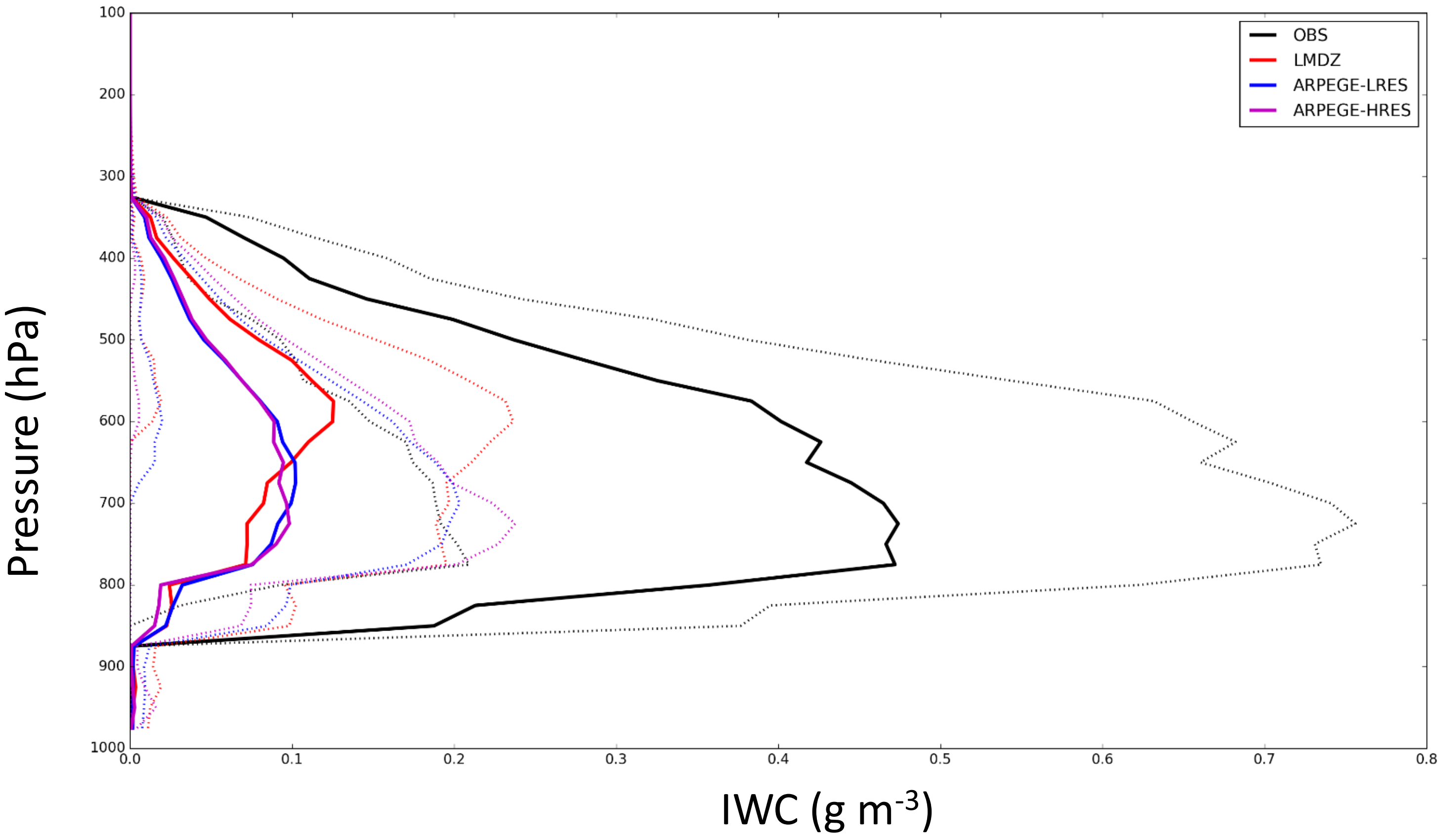
Tighter Geopotential height gradient in LMDZ compared to ARPEGE

Ice Water Content – raw output from models



Ice Water Content Flight 7: 2 October hindcast





Windspeed Flight 7: 2 October hindcast