The impact of deep convection schemes of a global atmospheric model on the warm conveyor belt and jet stream of NAWDEX IOP6

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Main questions

- How different are Warm Conveyor Belts between runs with parametrized deep convection and without ?

- How do distinct deep convection schemes differ in the representation of WCBs ?

- What is the impact of parametrized convection on jet stream in the WCB outflow region ?

- What are the forecast errors in the representation of the jet stream for the different runs with and without parametrized convection ?

Model and set up of the simulations

Model: global operational model Arpege

- Model resolution: T798 with stretching → 10km over France, 20km on Iceland
- Output resolution: lon x lat: 0.5° x 0.5°
- 3 simulations differing only on deep convection representation

Bougeault, 1985

B85

- Mass-flux scheme
- Closure in humidity

→ used in operational NWP version

Piriou et al, 2007

PCMT

- Mass-flux scheme
- Closure in CAPE
- Linked to microphysics and transport schemes
- Strong entrainment

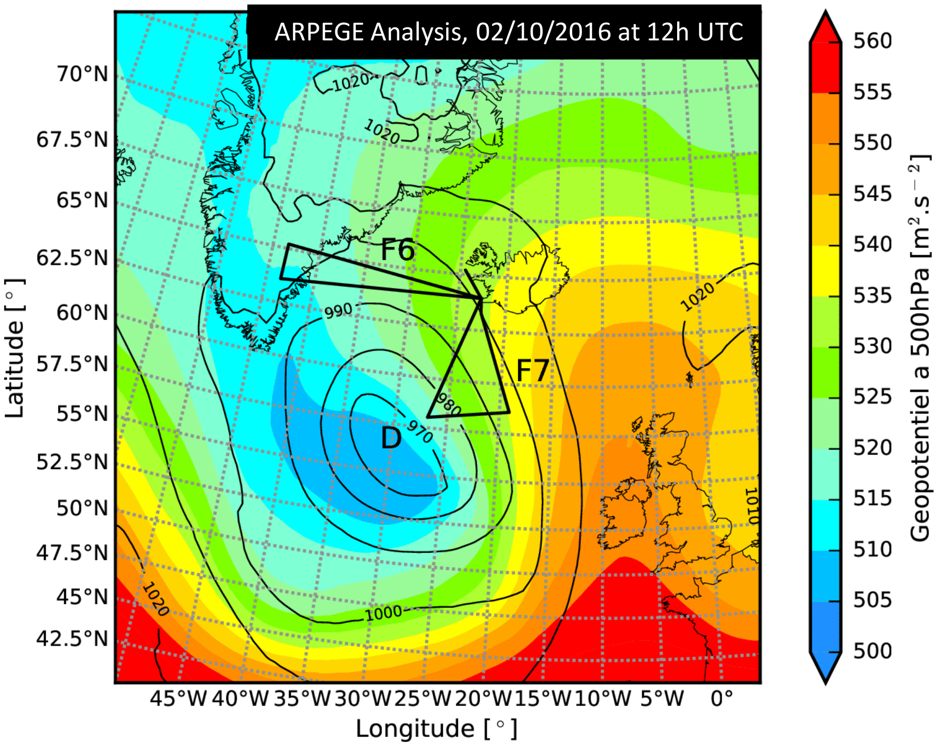
→ used in ARPEGE-CLIMAT

No parametrized deep convection

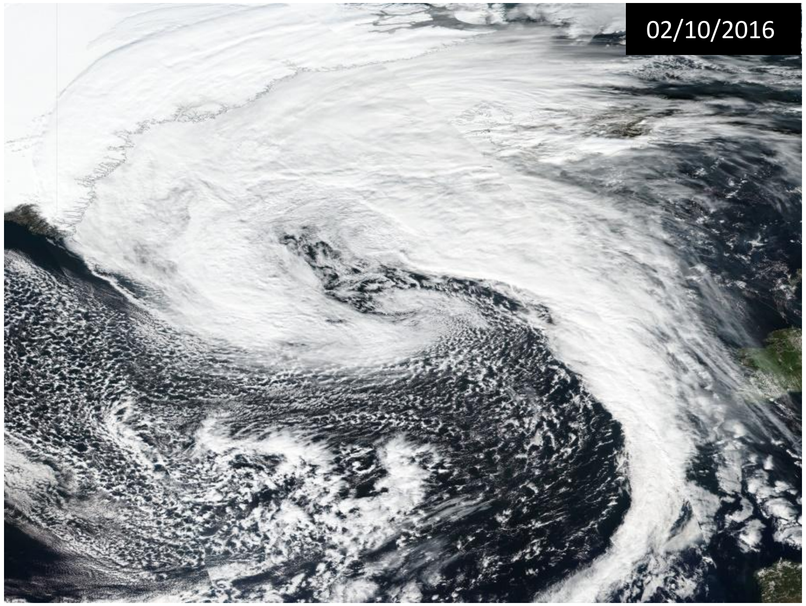
NoConv

Case study: IOP6 – Stalactite Cyclone

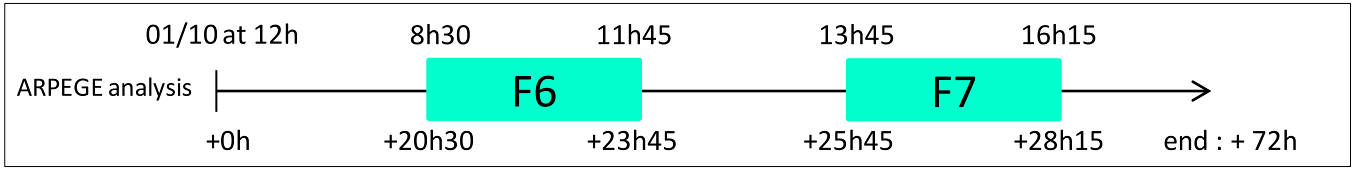
Geop 500 hPa (shadings) SLP (contour)



MODIS, Nasa Worldview Application



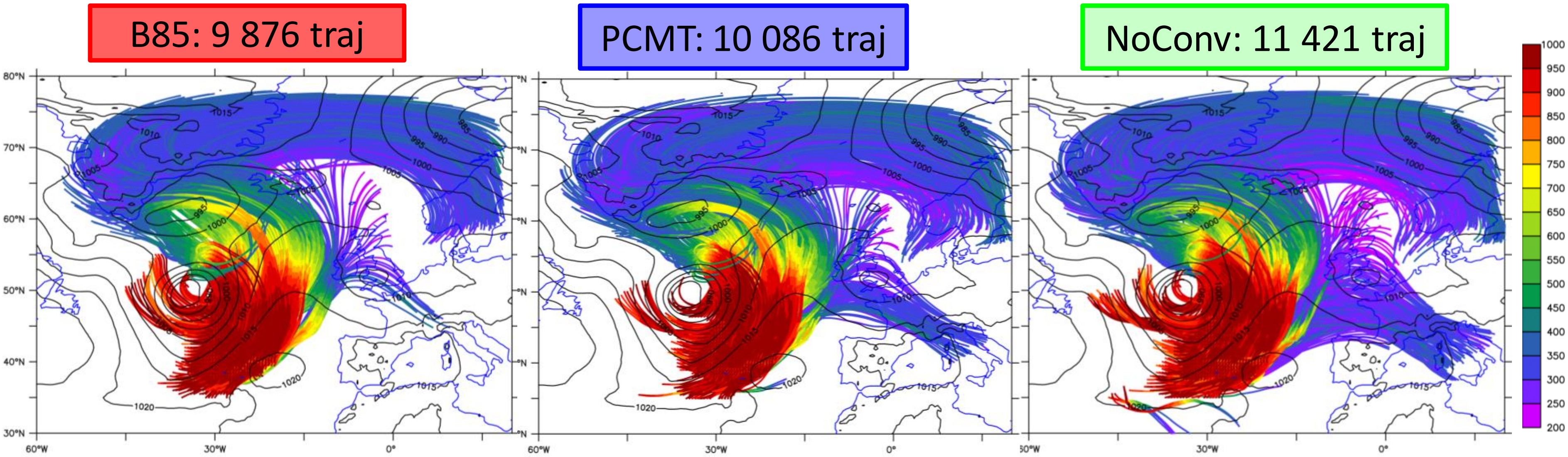
Timing of the runs vs flights:



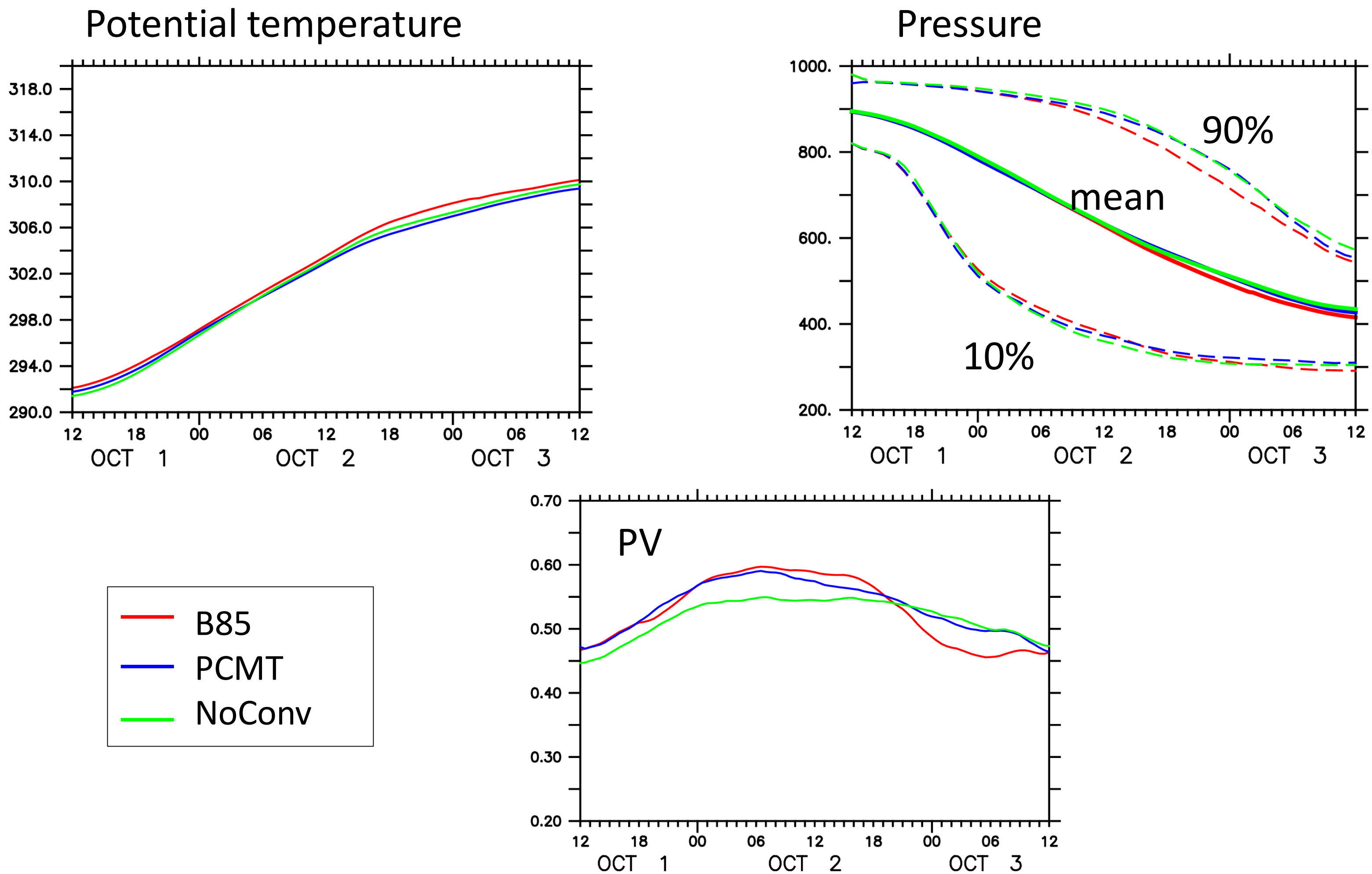
Computation of Lagrangian trajectories

Computation of Lagrangian trajectories starting in the warm sector at the initial time: 12h UTC 1 October

Criterion : if exceeds 300 hPa ascents within 24h

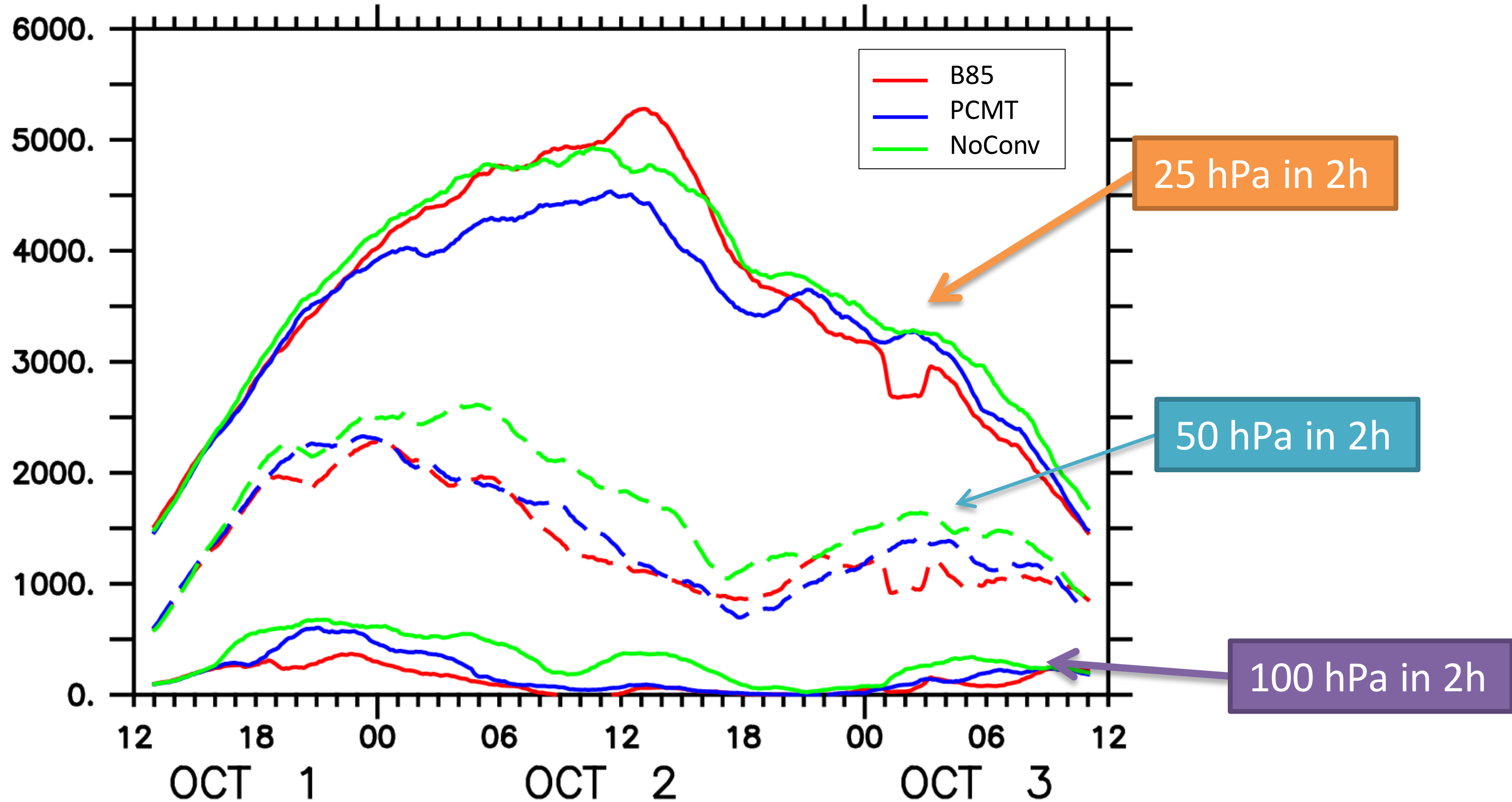


Averaged quantities along trajectories



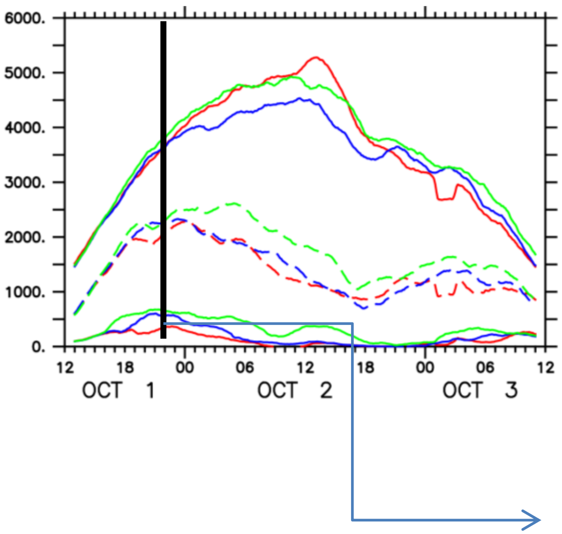
- Slightly more WCBs in NoConv than in runs with parametrized convection
- No drastic differences in the mean pressure or potential temperature
- PV shows more differences: B85 has a more important PV decrease at the end

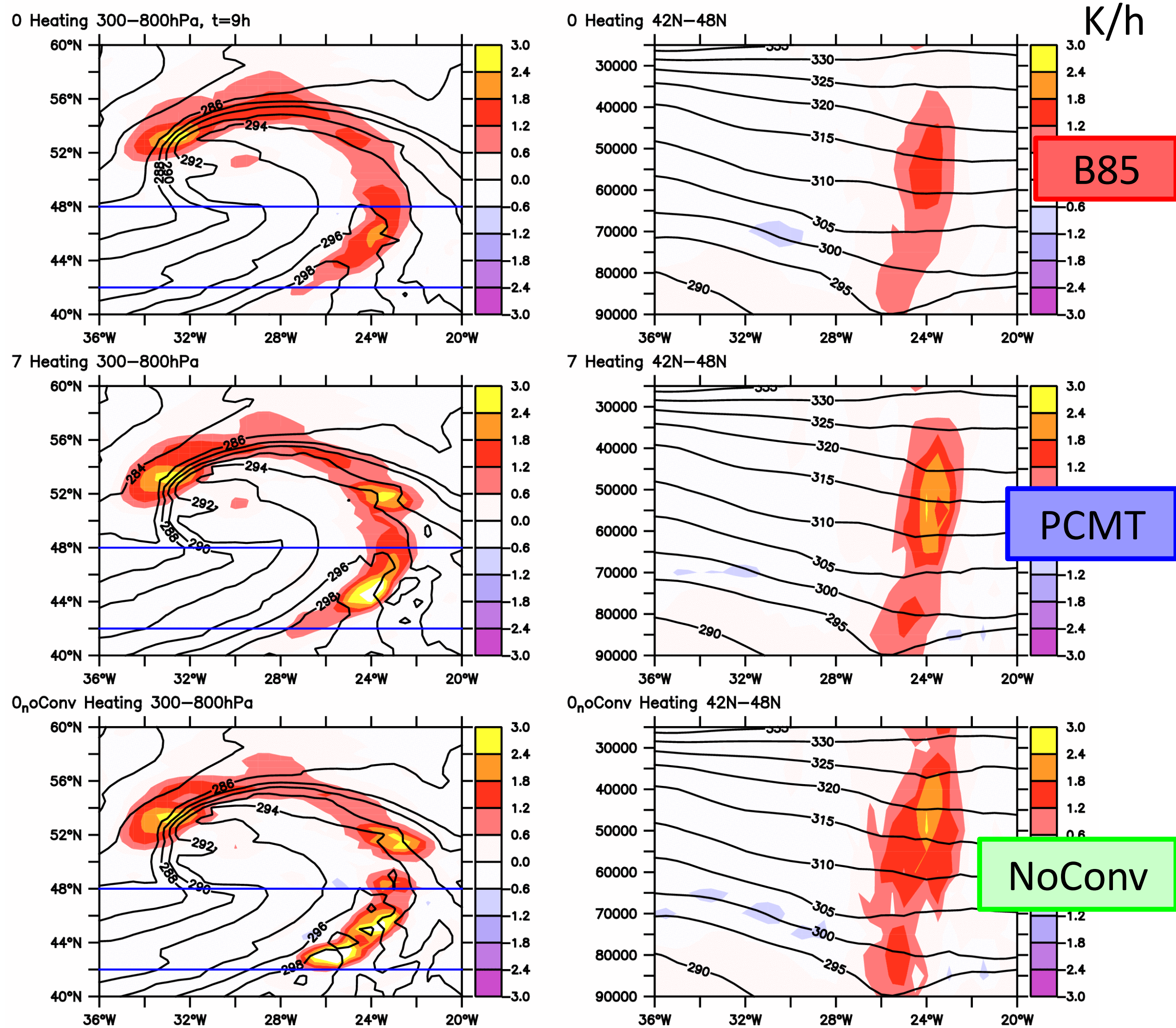
Nber of trajectories satisfying a criterion on ascents



Fastest ascents for the run without convection scheme

Early times (t0+9h) and fast ascents (100 hPa/2h)



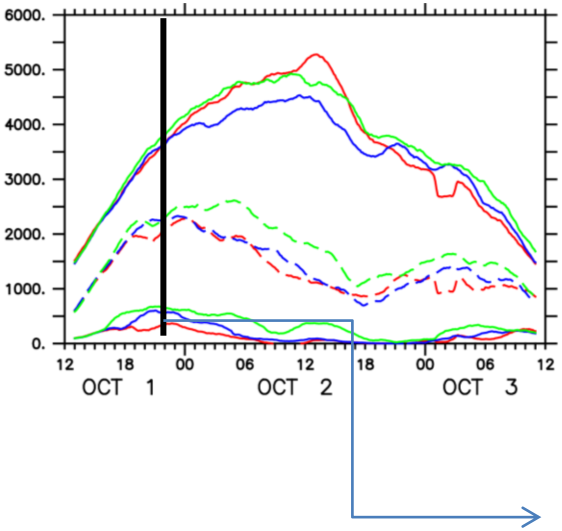


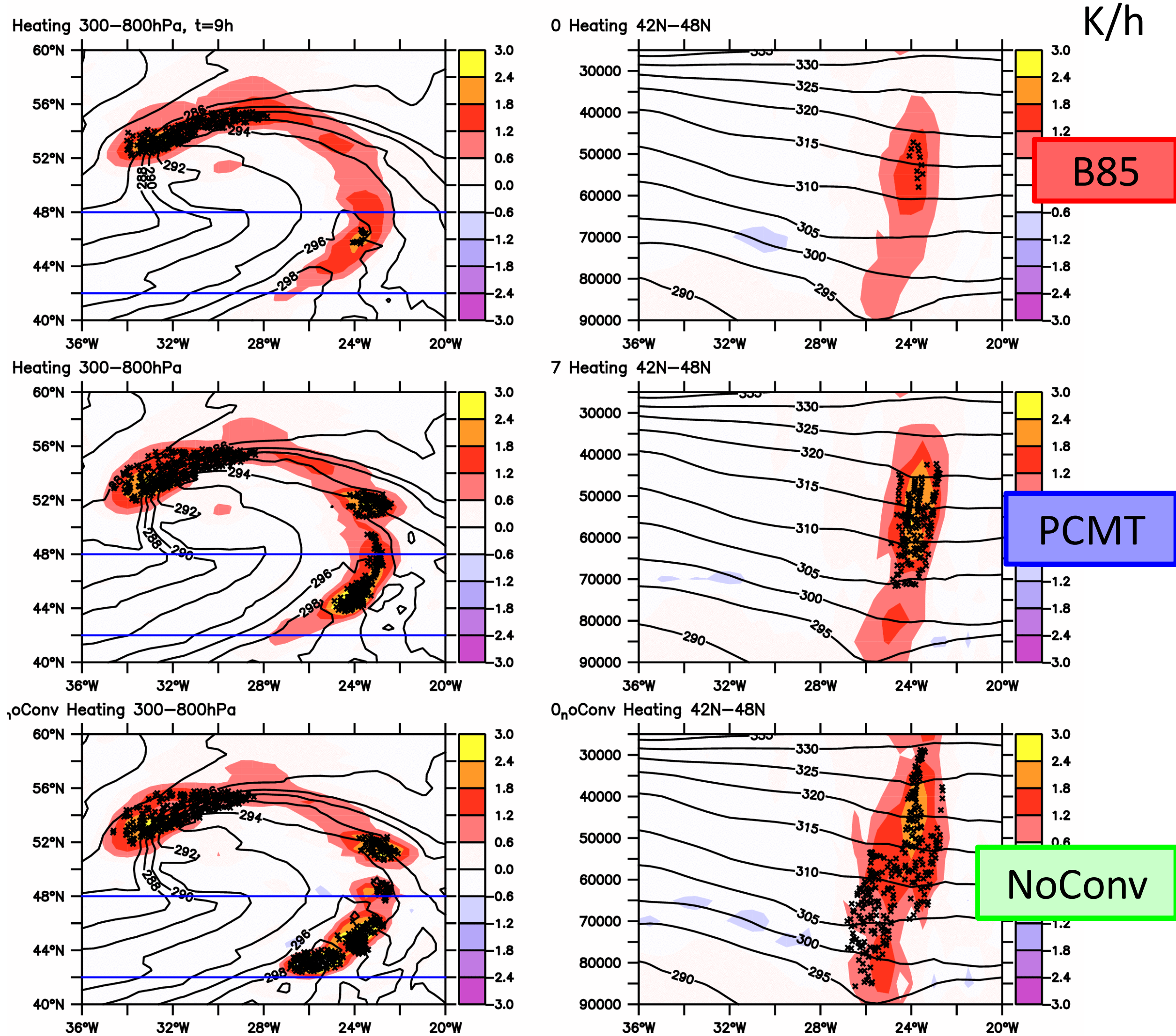
Shadings: vertically averaged heating rate $\dot{\theta}$

Contours: 850-mb θ

Stronger, less homogeneous heating rate without convection scheme

Early times (t0+9h) and fast ascents (100 hPa/2h)





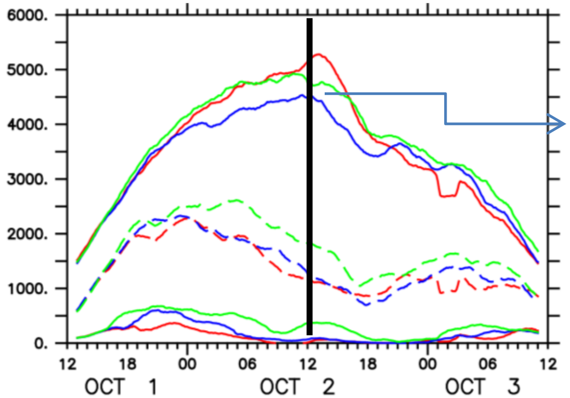
Shadings: vertically averaged heating rate $\dot{\theta}$

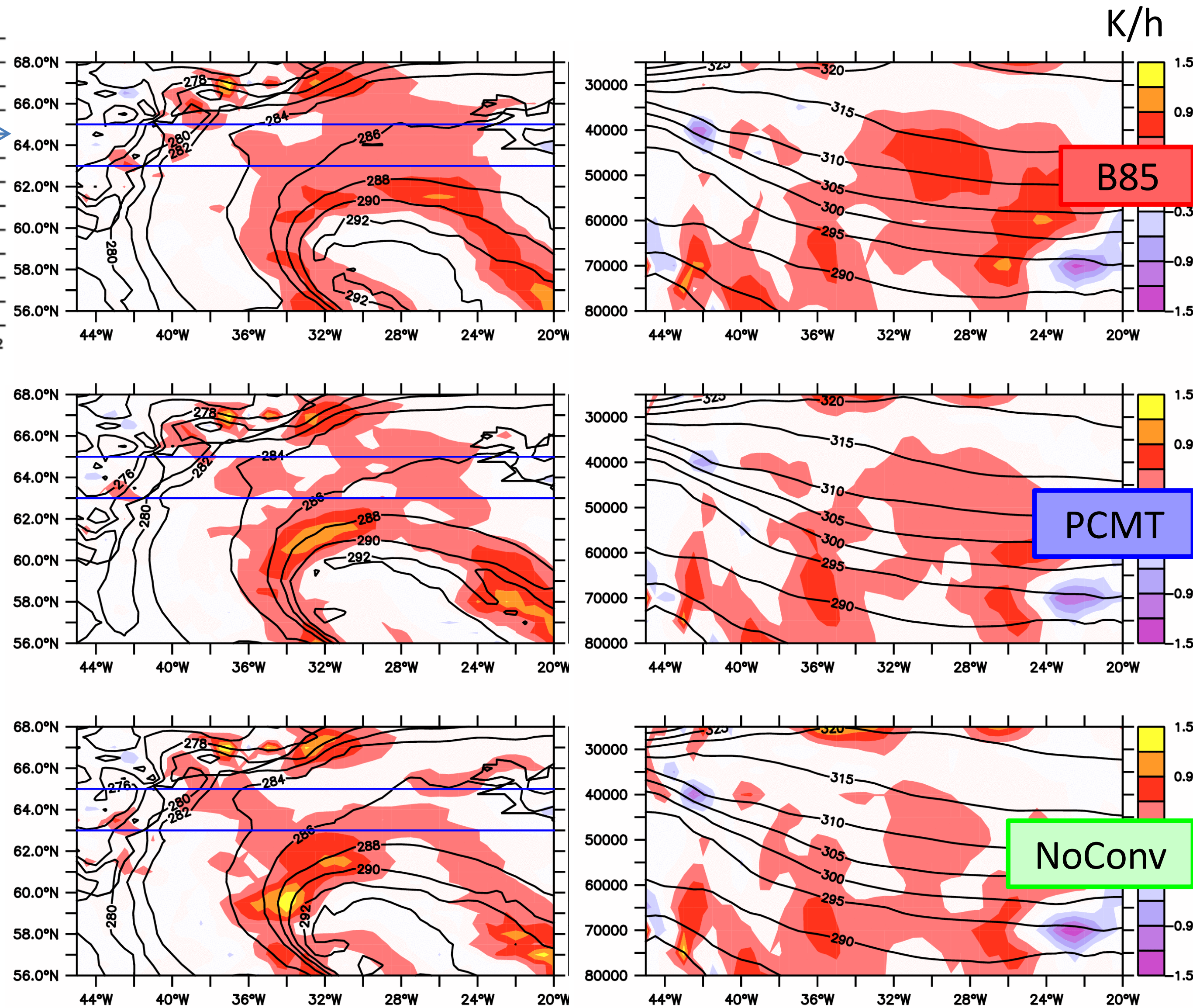
Contours: 850-mb θ

WCB with ascents 100hPa/2h

Stronger, less homogeneous heating rate without convection scheme

Later times (t0+24h) and moderate ascents (25 hPa/2h)





Shadings: vertically averaged heating rate $\dot{\theta}$

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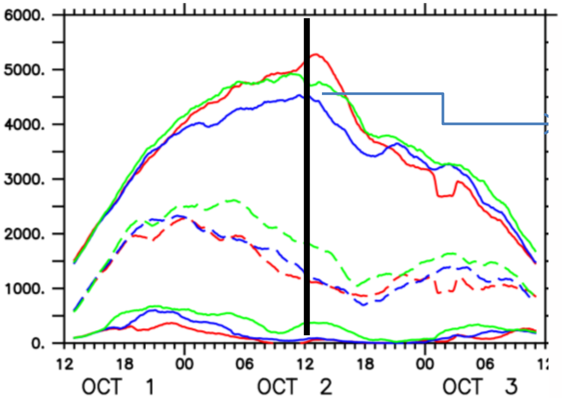
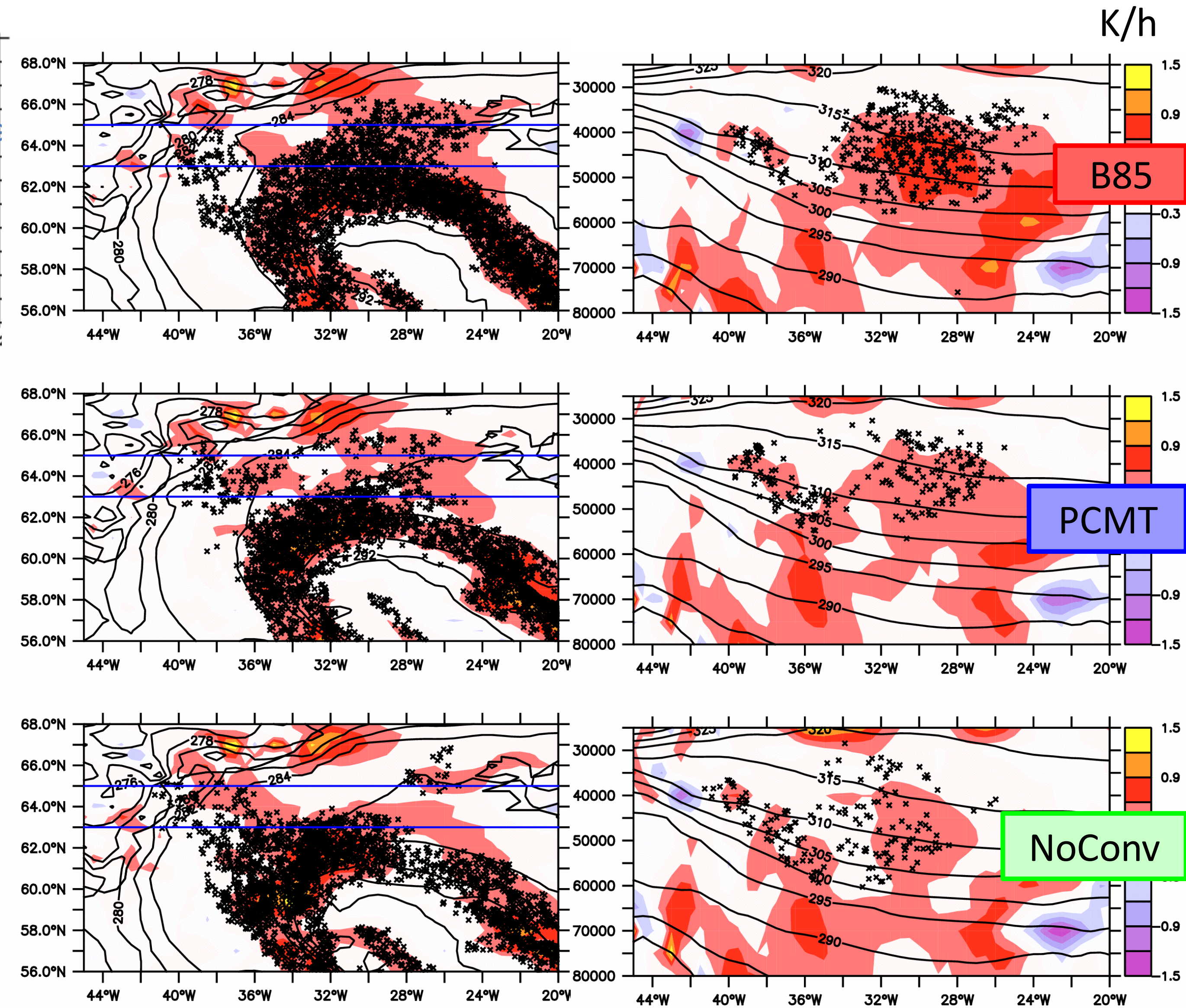
Later times (t0+24h) and moderate ascents (25 hPa/2h)



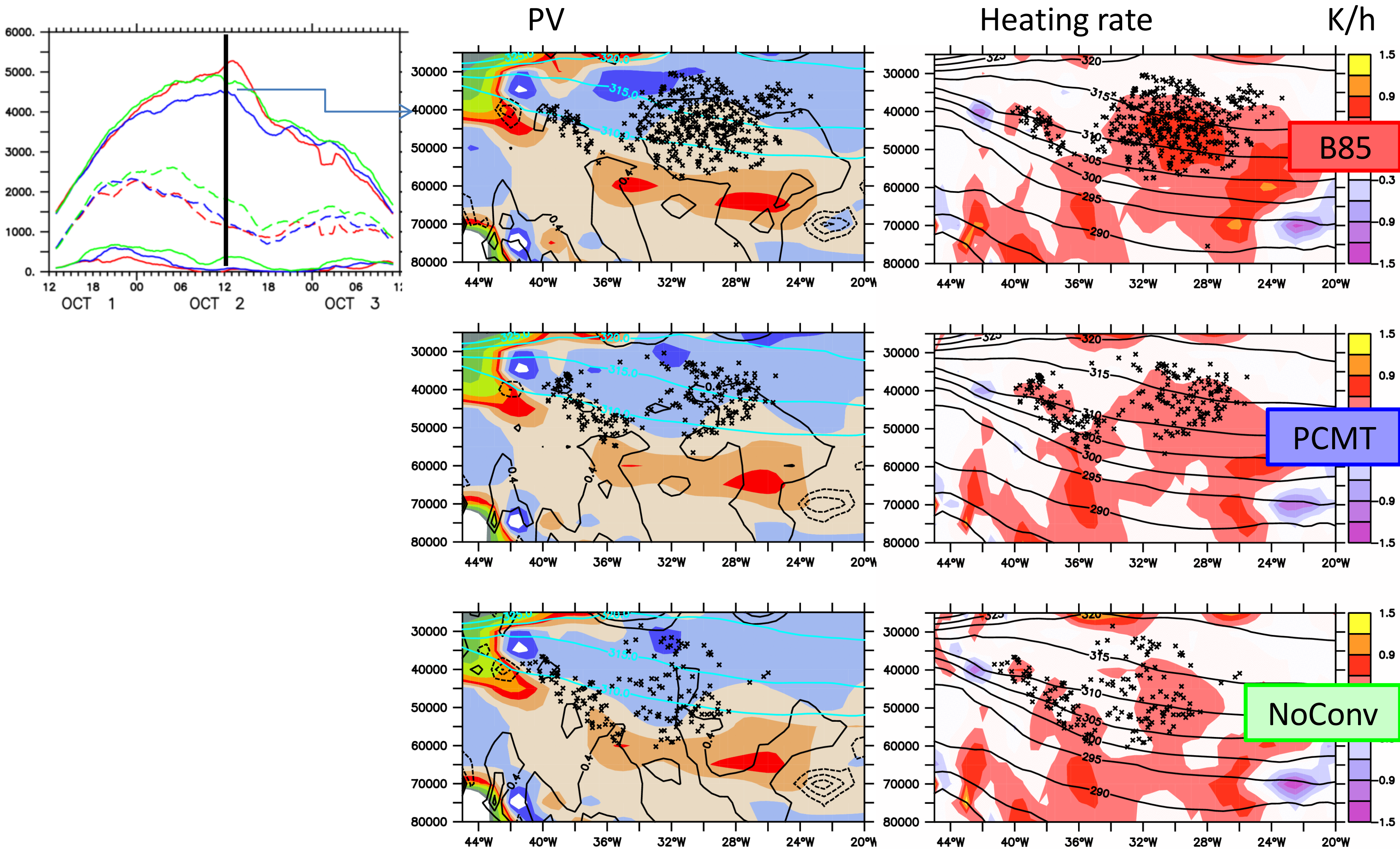


Shadings: vertically averaged heating rate $\dot{\theta}$

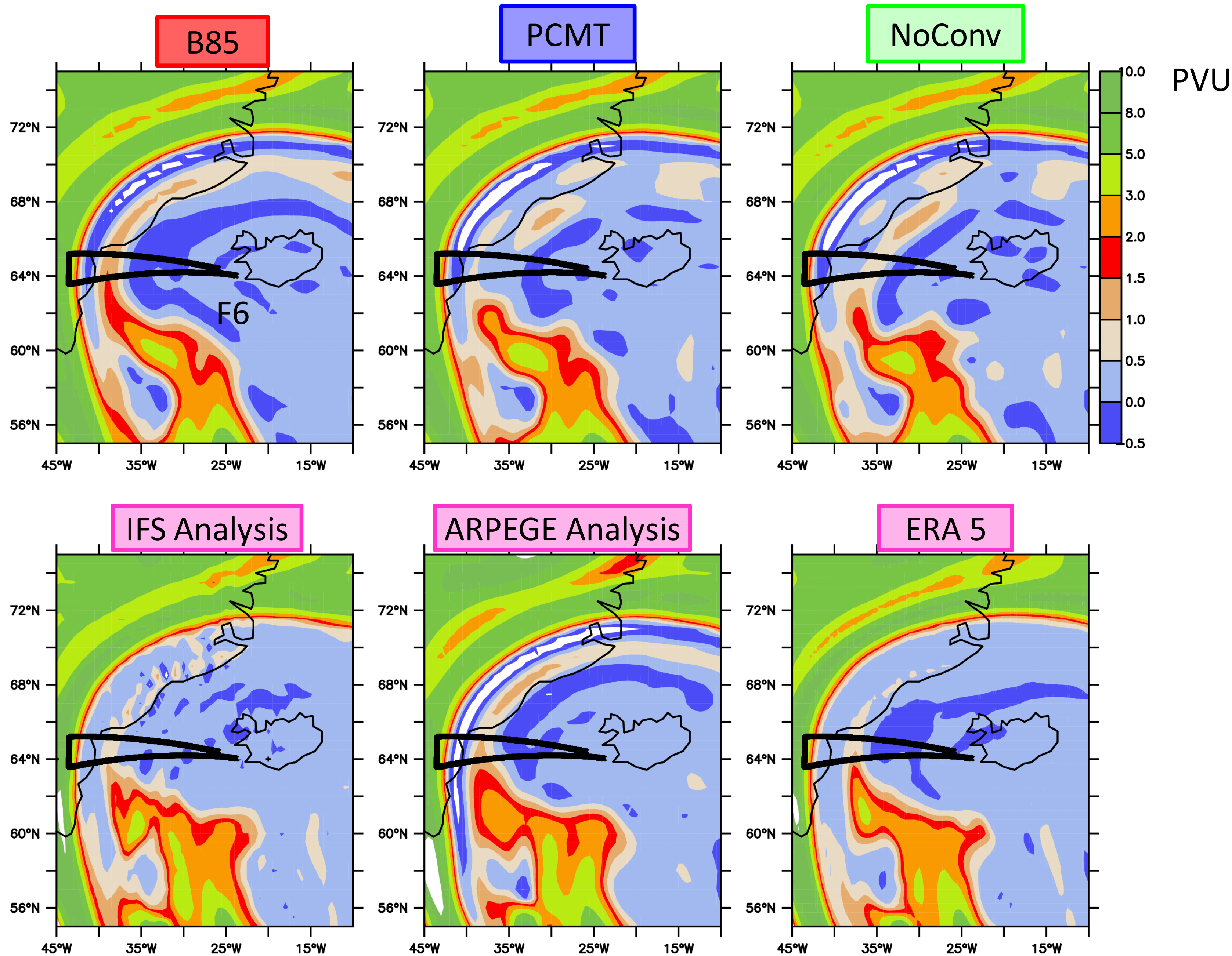
Contours: 850-mb θ

WCB: 25hPa/2h

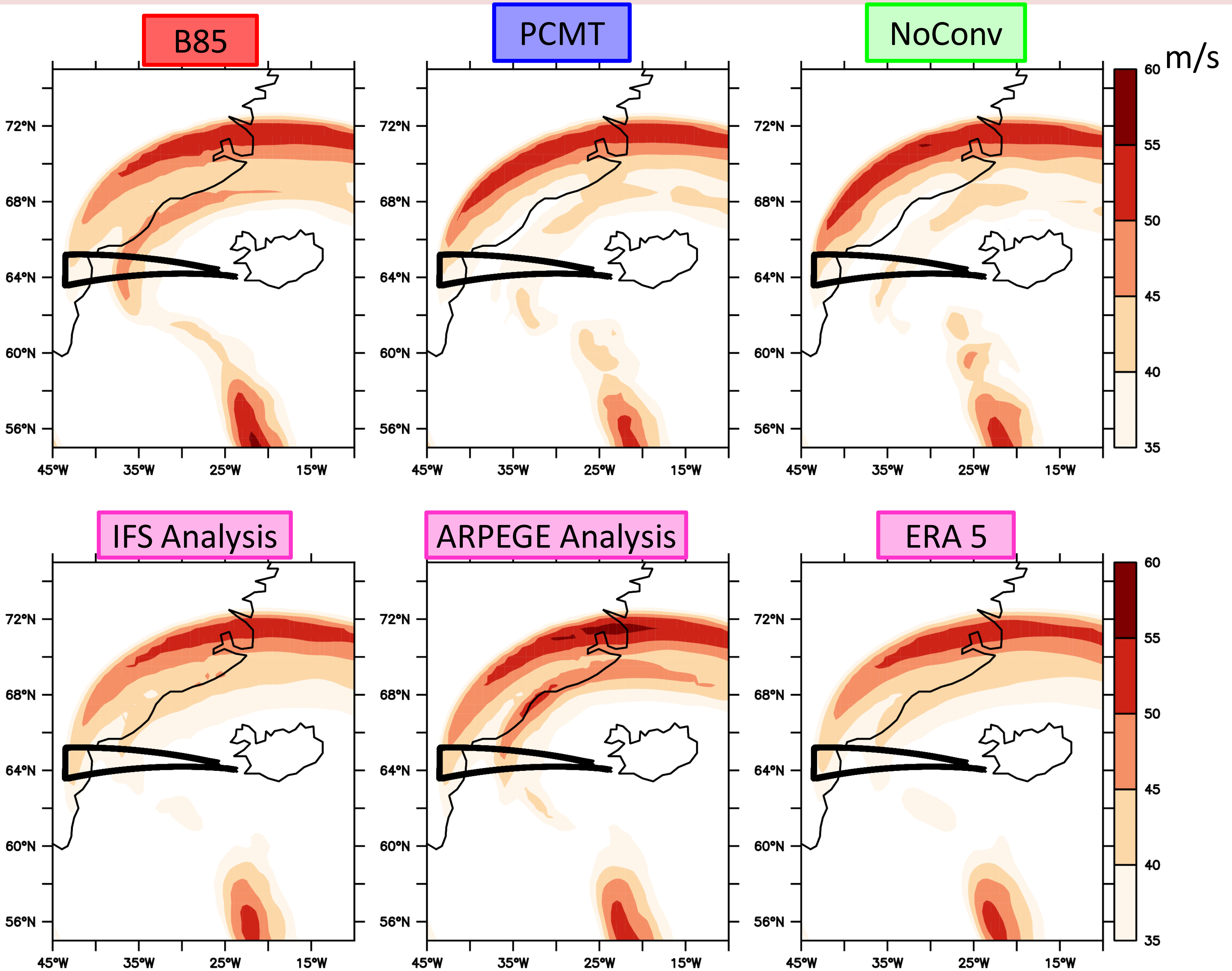
Later times (t0+24h) and moderate ascents (25 hPa/2h)



PV anomalies at 300 hPa at t=24h

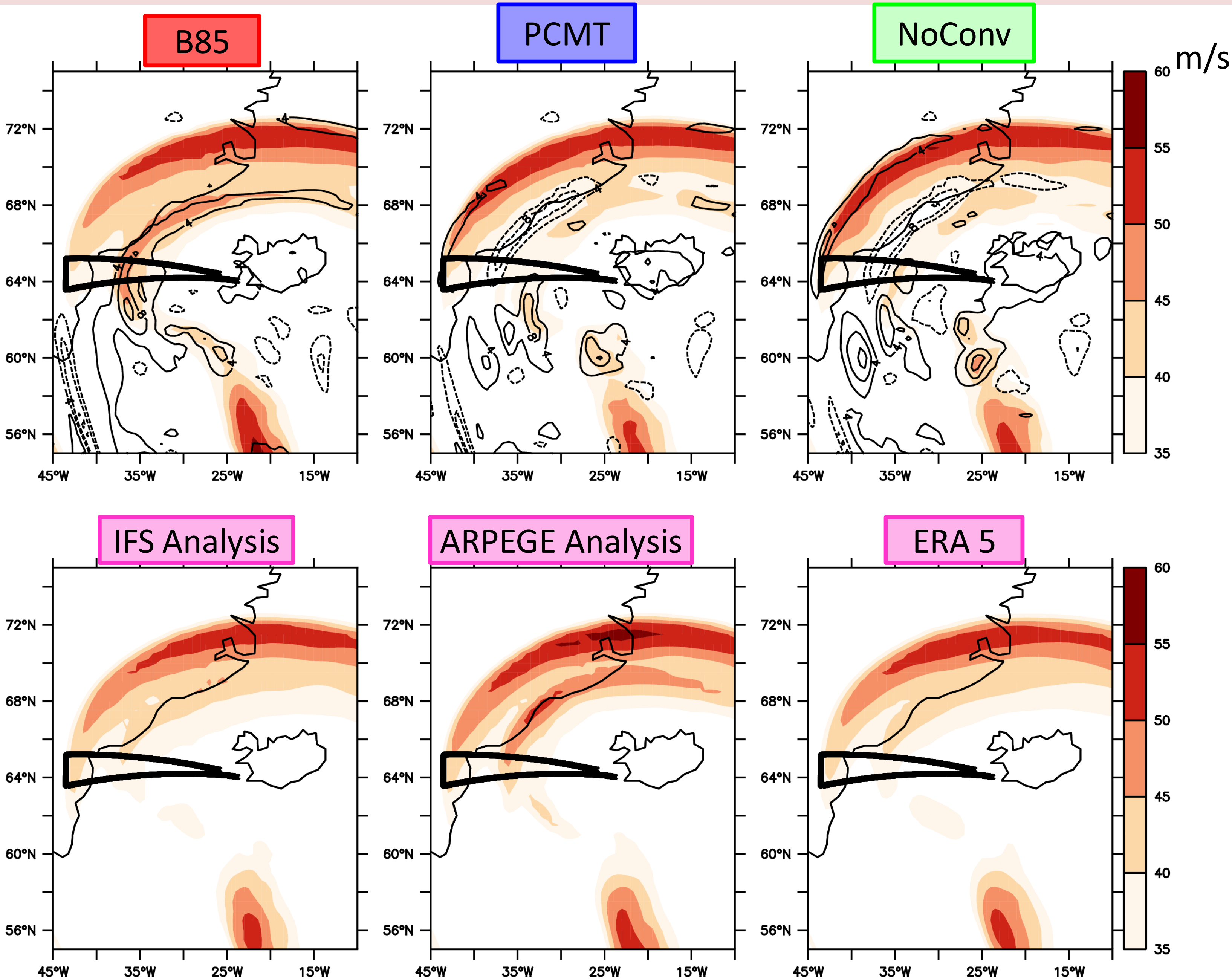


Wind speed at 300 hPa at t=24h

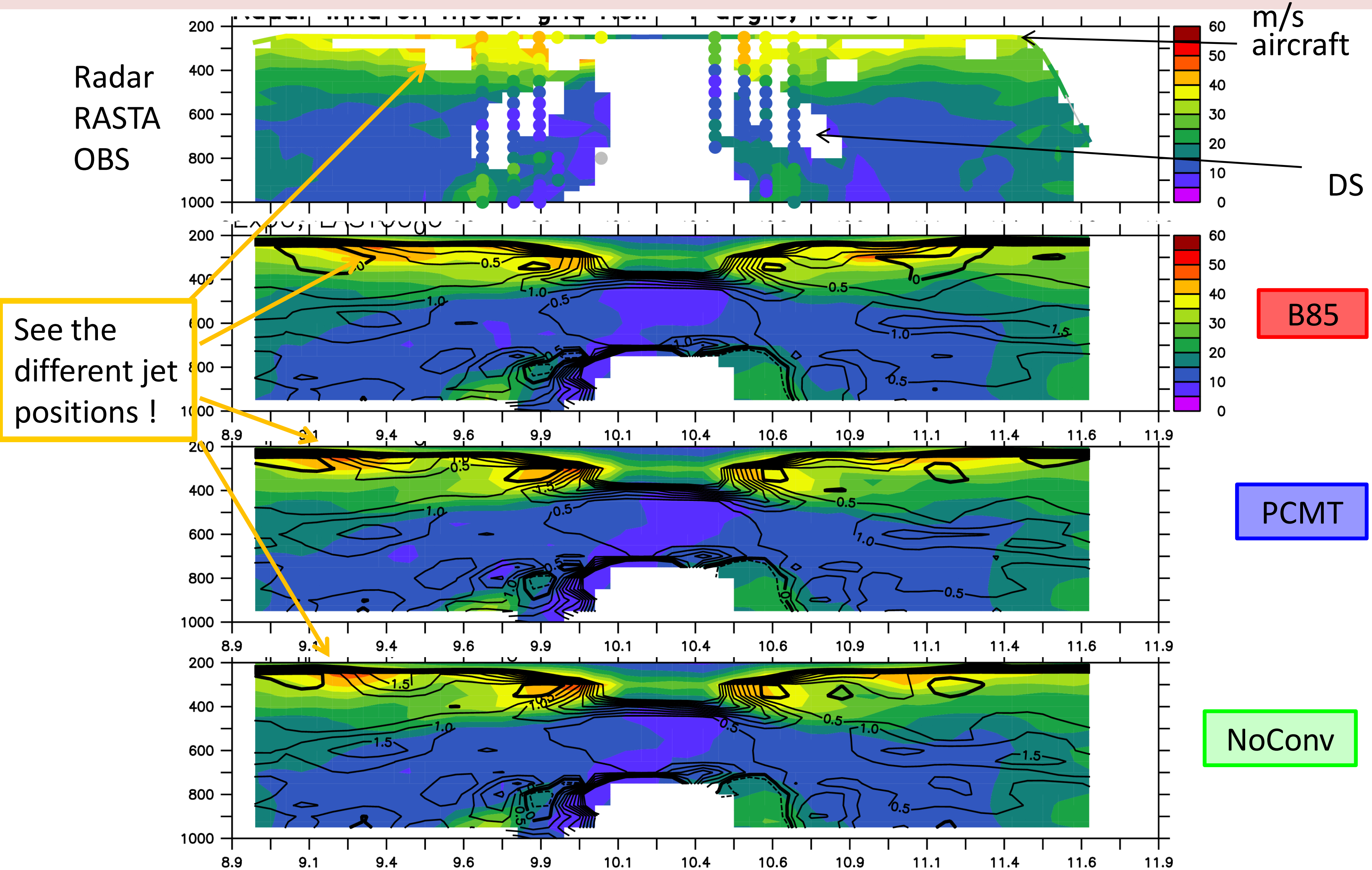


Wind speed at 300 hPa at t=24h

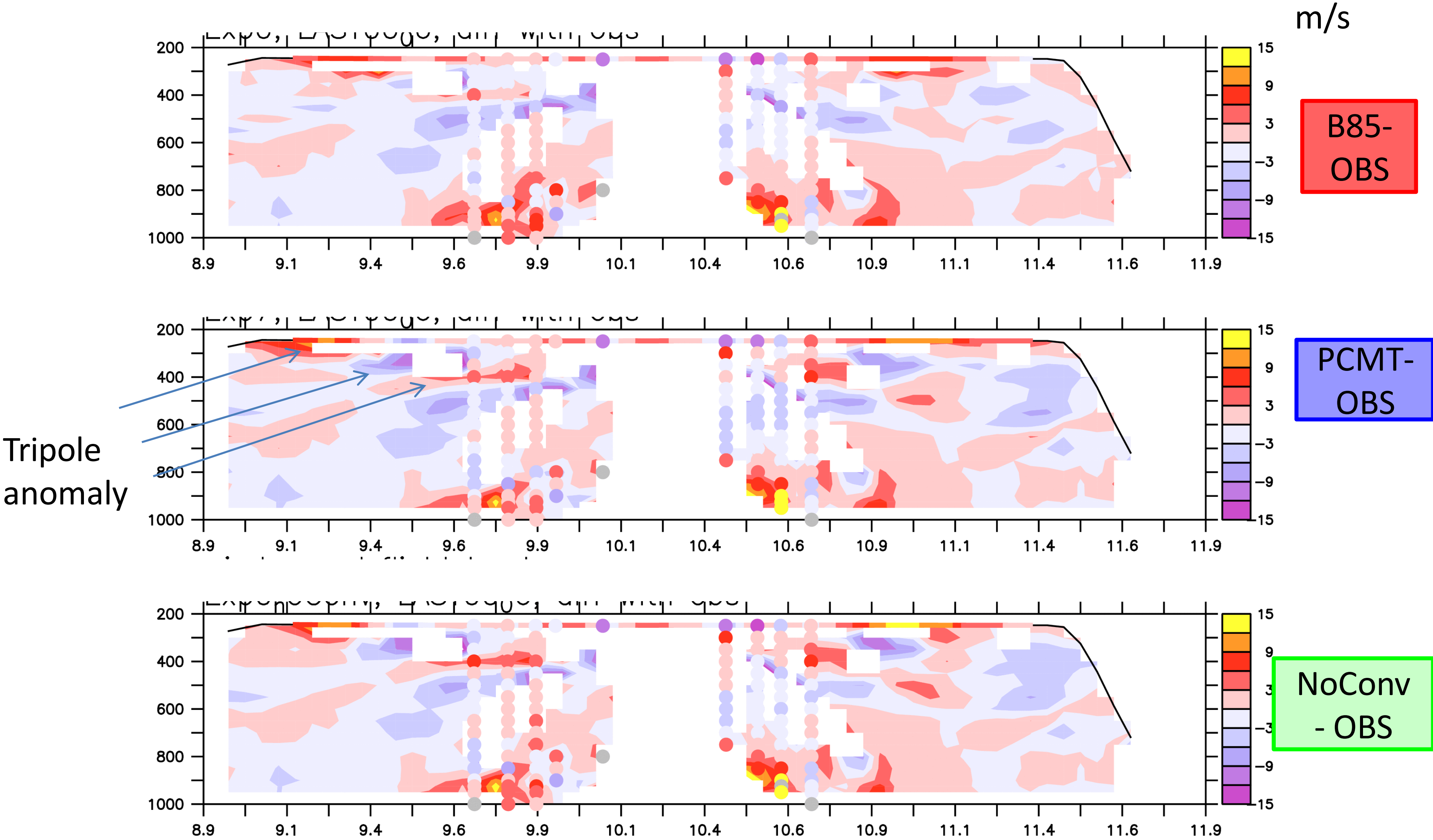
Contours: difference with IFS



Wind speed vertical profiles along Flight 6

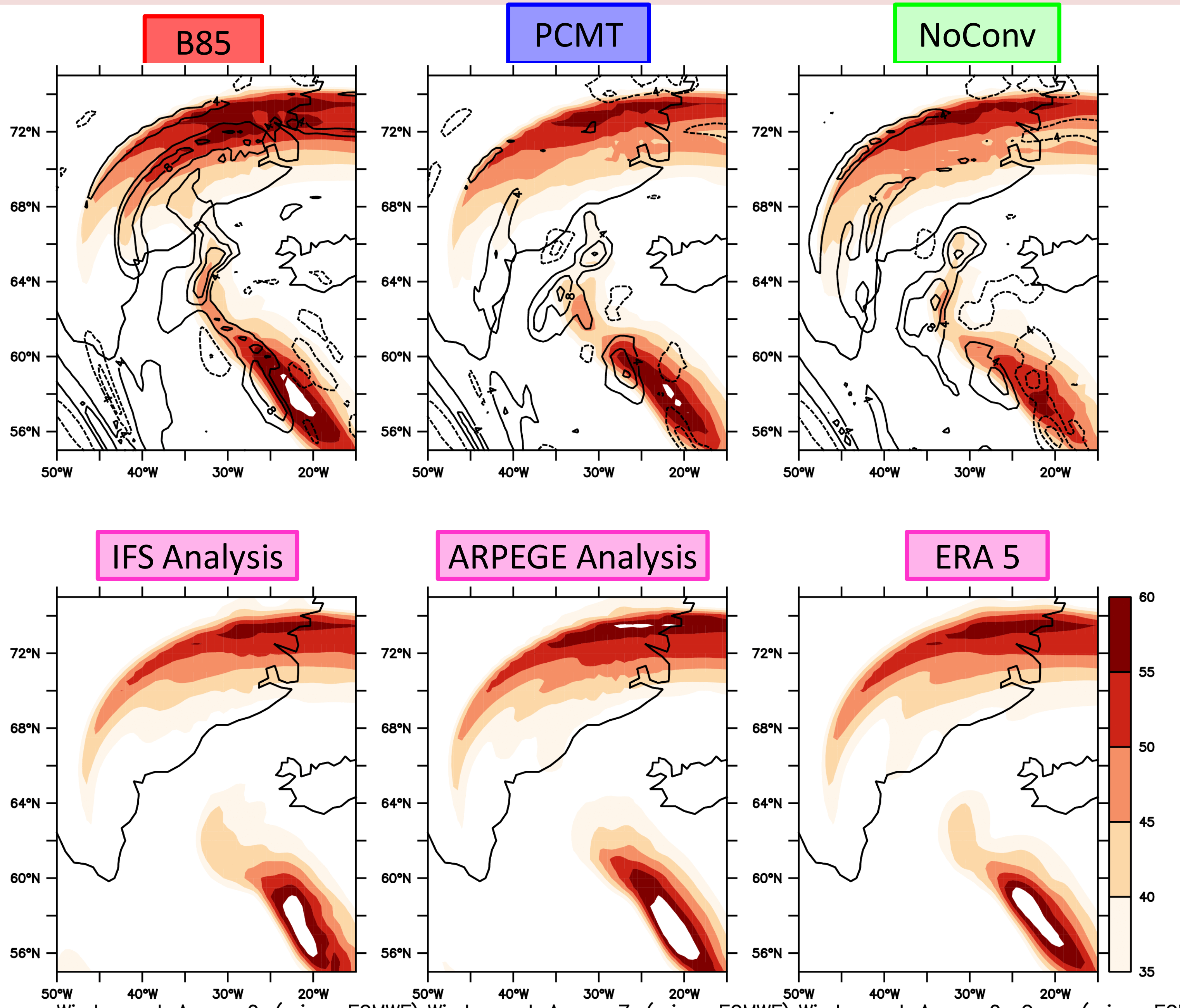


Wind speed anomalies with respect to observations



Wind speed forecast error after 30h

Contours: difference with IFS



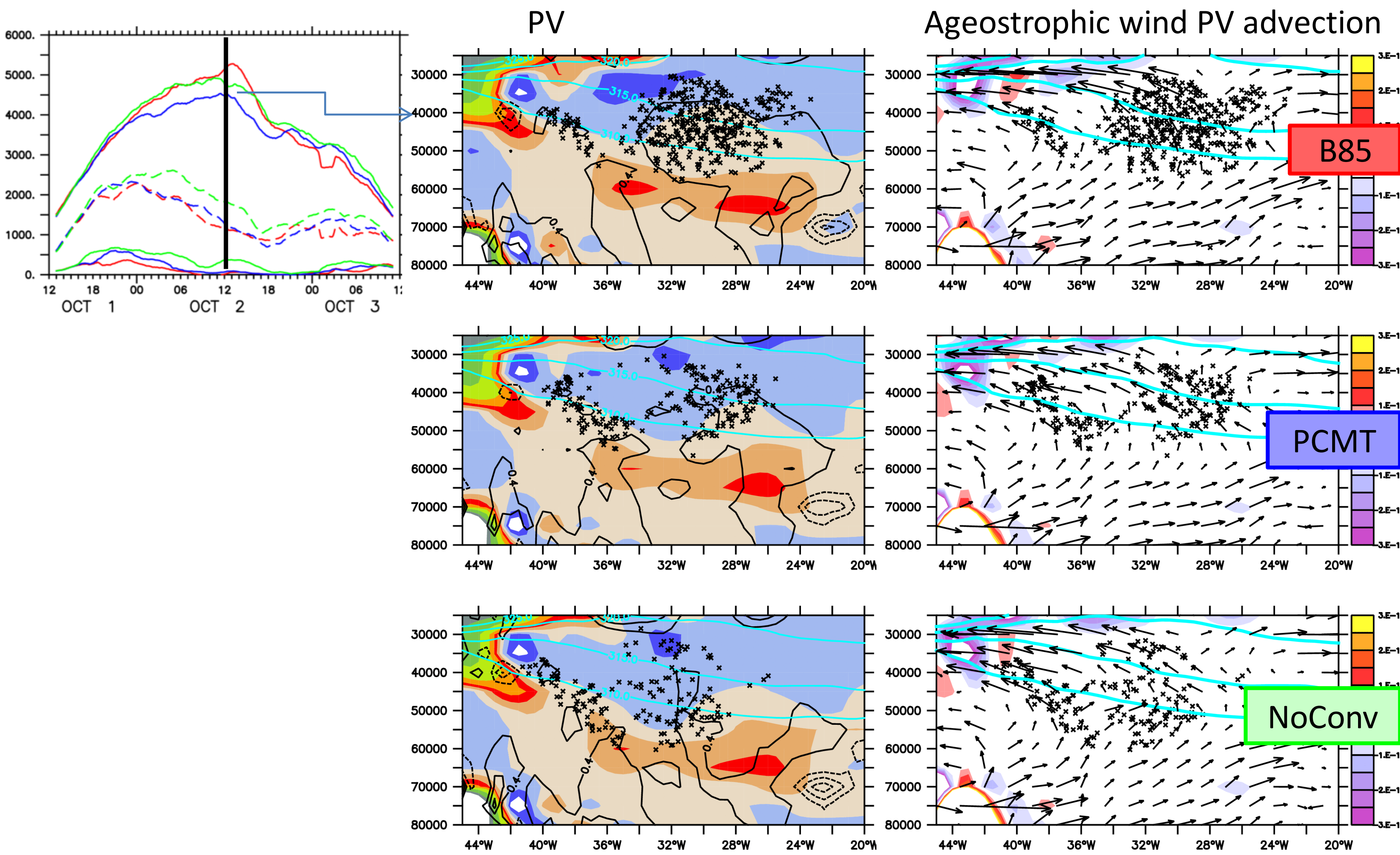
Conclusion

- NoConv: sooner stronger heating, more isolated regions, more rapid ascents than B85 and PCMT ahead of the cold front
- More sustained ascents in B85 than PCMT and NoConv
- PCMT has an intermediate behavior between B85 and NoConv.
- More PV desctruction in WCB outflow region in B85 than PCMT and NoConv.
- The more active dynamics in the upper troposphere in B85 is consistent with observations and (re)-analysis but too strong (consistent with IWC observations, not shown).

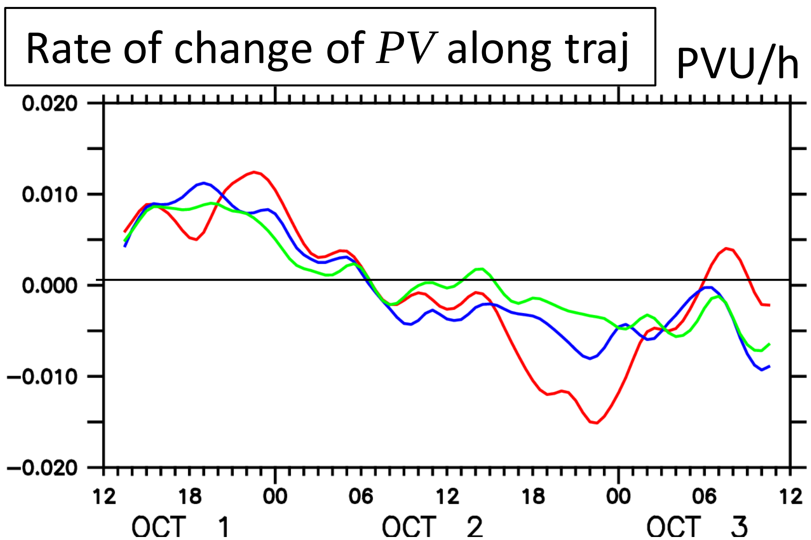
Outlook: Comparison with Tiedtke (1993) scheme used in IFS

Additional slides

Later times (t0+24h)



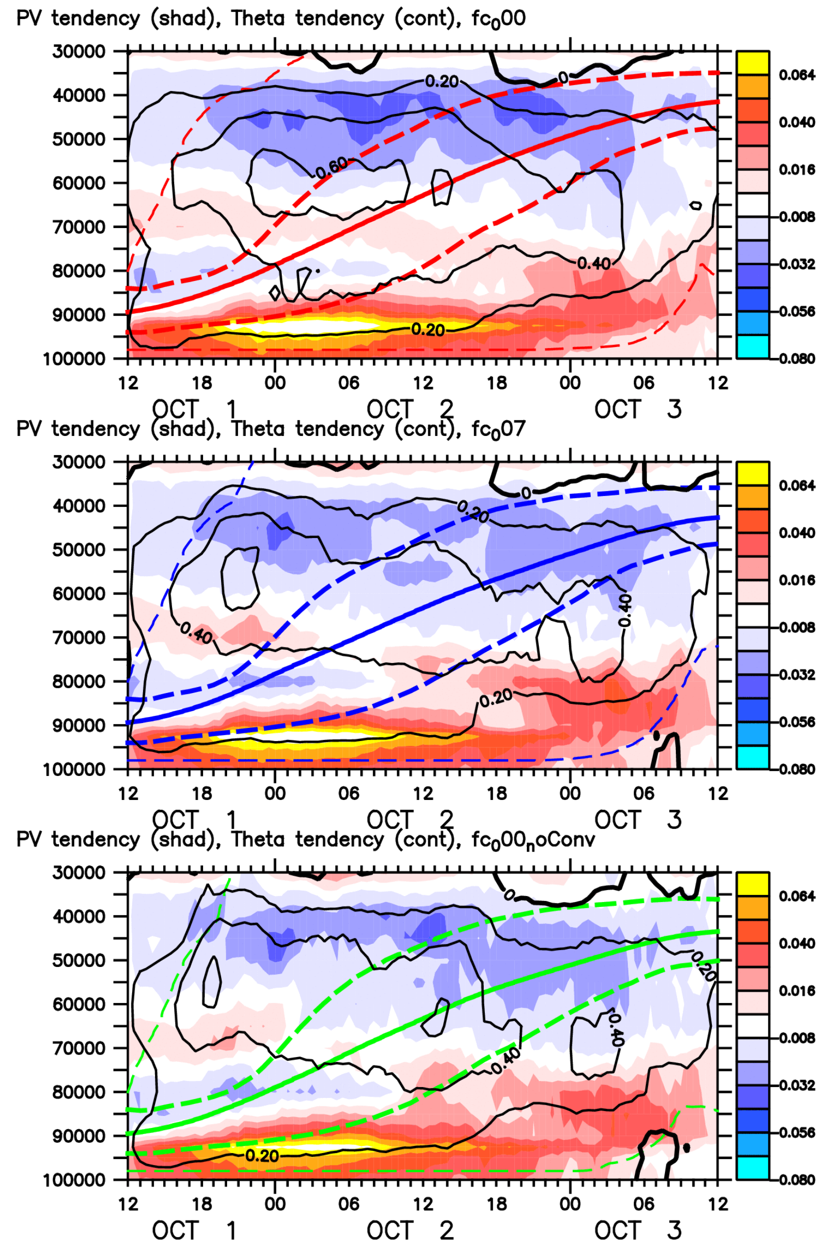
PV tendencies along trajectories



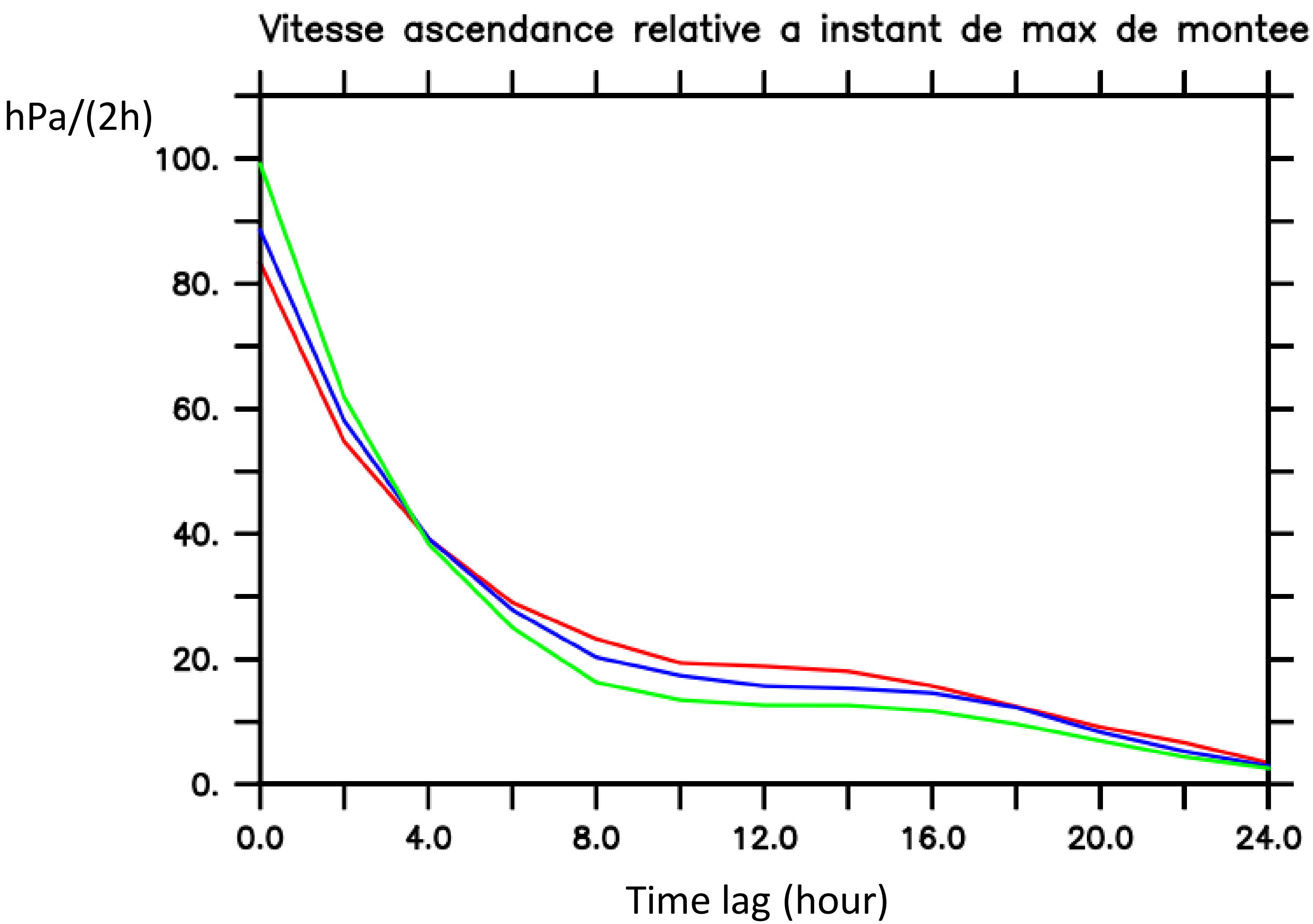
B85

PCMT

NoConv



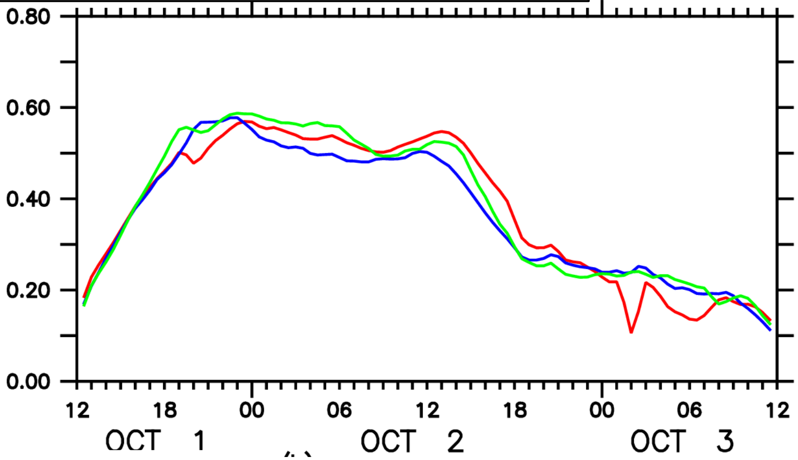
Ascending velocities



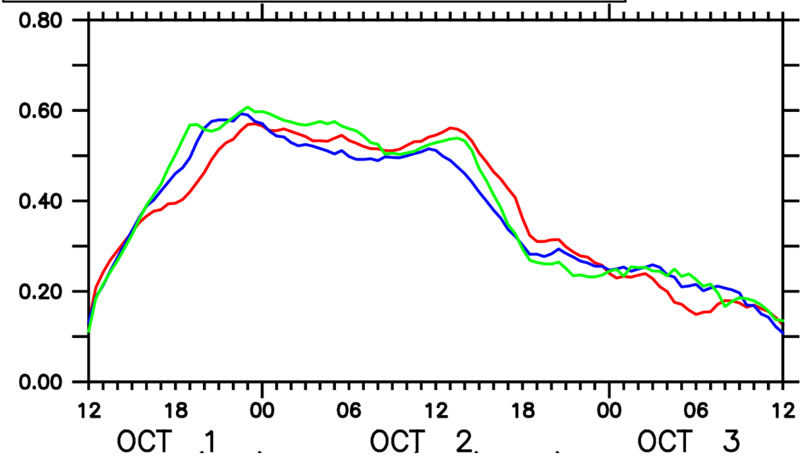
More rapid ascents in **NoConv** than **B85** at the time of maximum ascents but more sustained ascents in B85. **PCMT** is in between.

Heating and PV tendencies along trajectories

Rate of change of θ along traj K/h



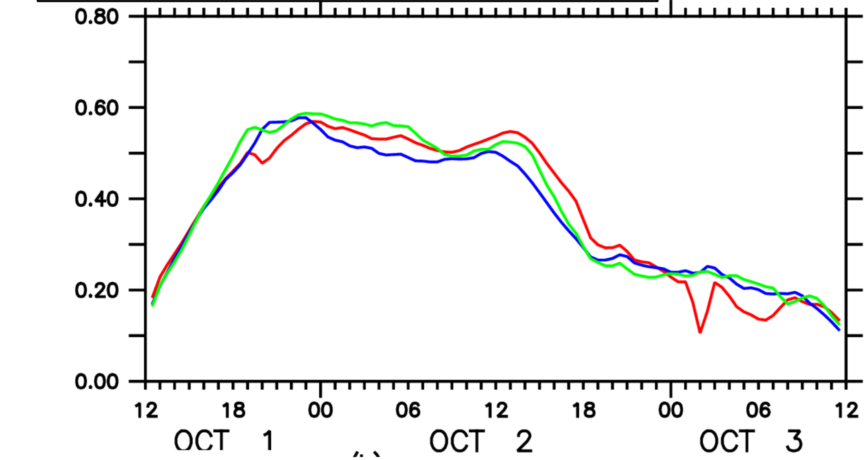
$$\dot{\theta} = \frac{\theta(t + 30\ \text{min}) - \theta(t - 30\ \text{min})}{\Delta t} + \mathbf{u} \cdot \nabla \theta(t)$$ K/h



Consistency between heating rate fields computed with finite differences and variations in potential temperature along trajectories

Heating and PV tendencies along trajectories

Rate of change of θ along traj K/h



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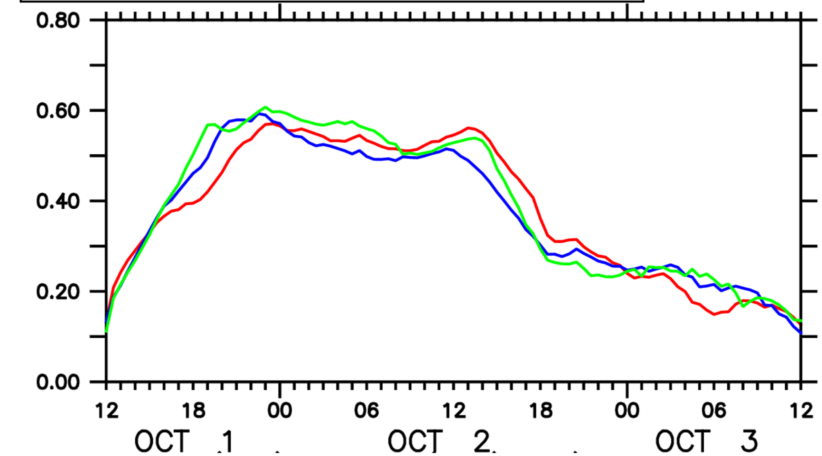
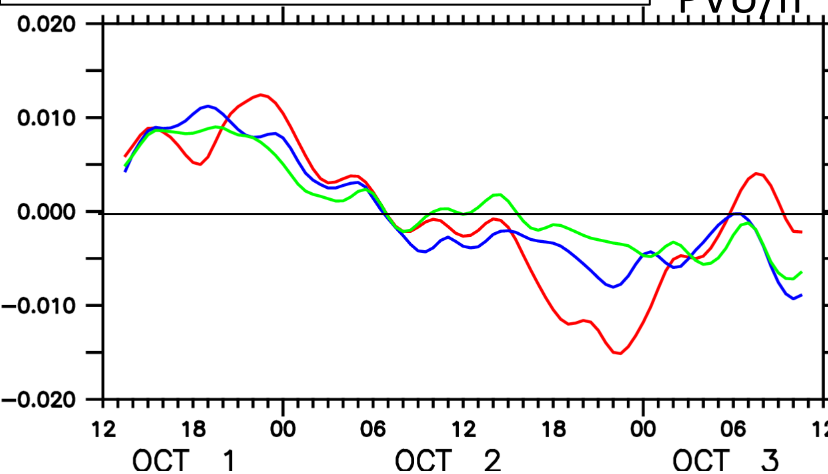
K/h

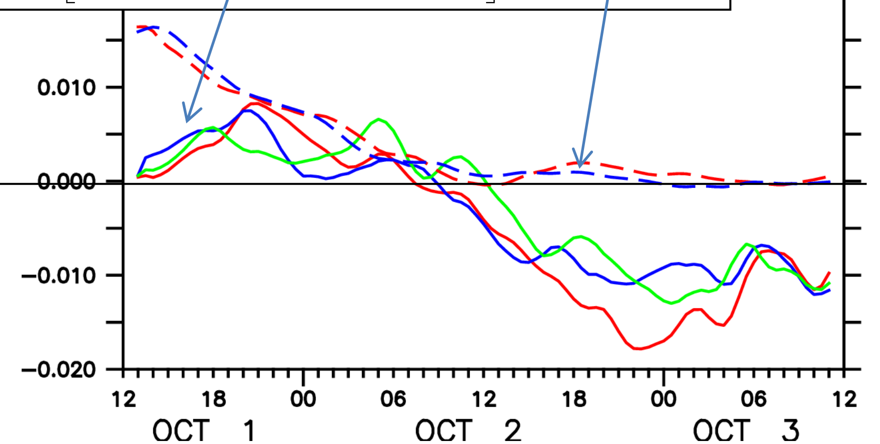


Rate of change of PV along traj PVU/h

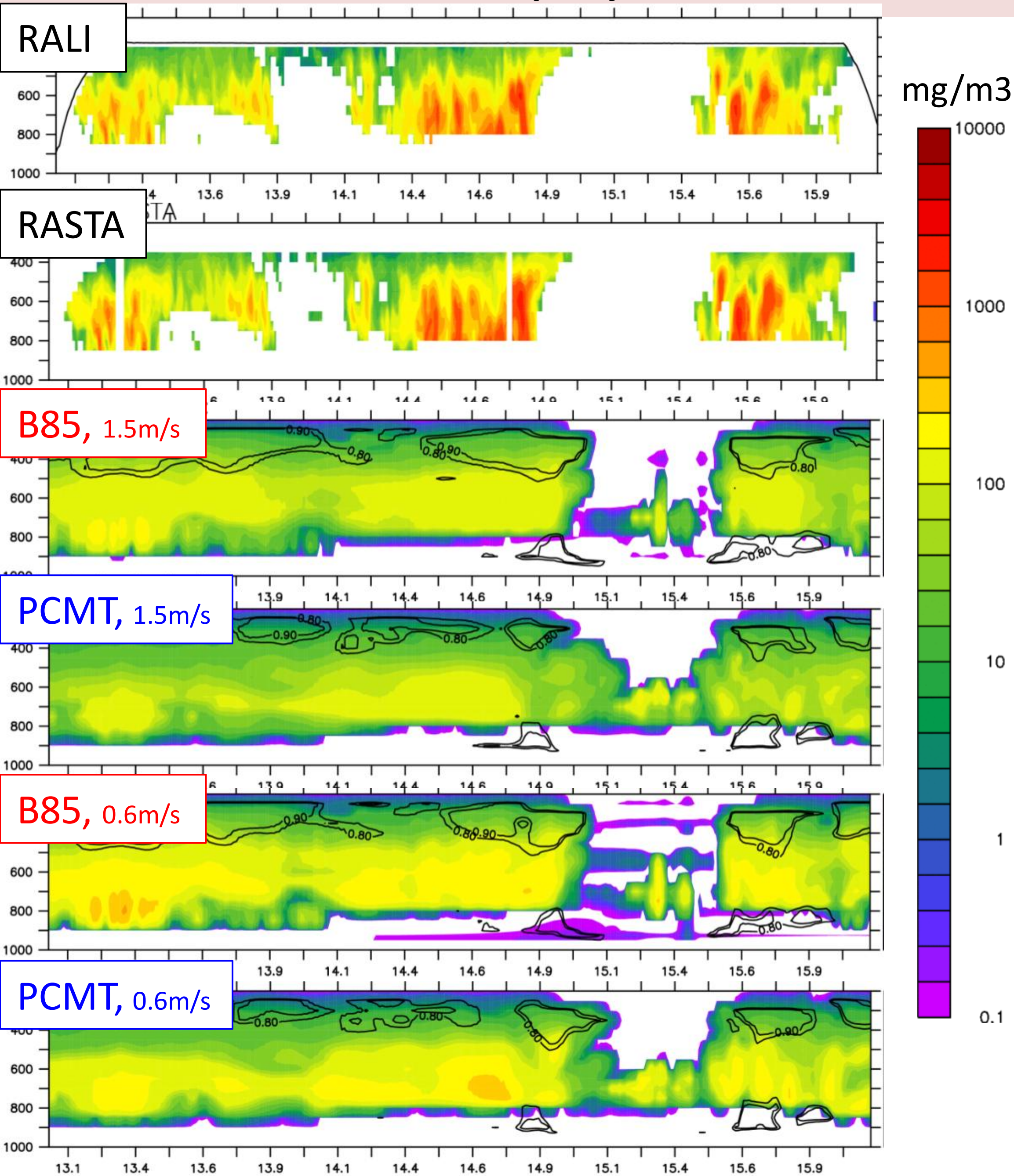


$$\frac{DPV}{Dt} = -g\left[(\varsigma + f)\frac{\partial \dot{\theta}}{\partial p} + \frac{\partial u}{\partial p}\frac{\partial \dot{\theta}}{\partial y} - \frac{\partial v}{\partial p}\frac{\partial \dot{\theta}}{\partial x}\right] - g(\nabla \wedge \mathbf{F}) \cdot \nabla \theta$$

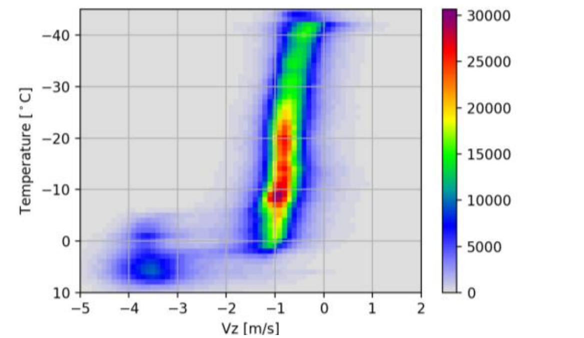
PVU/h



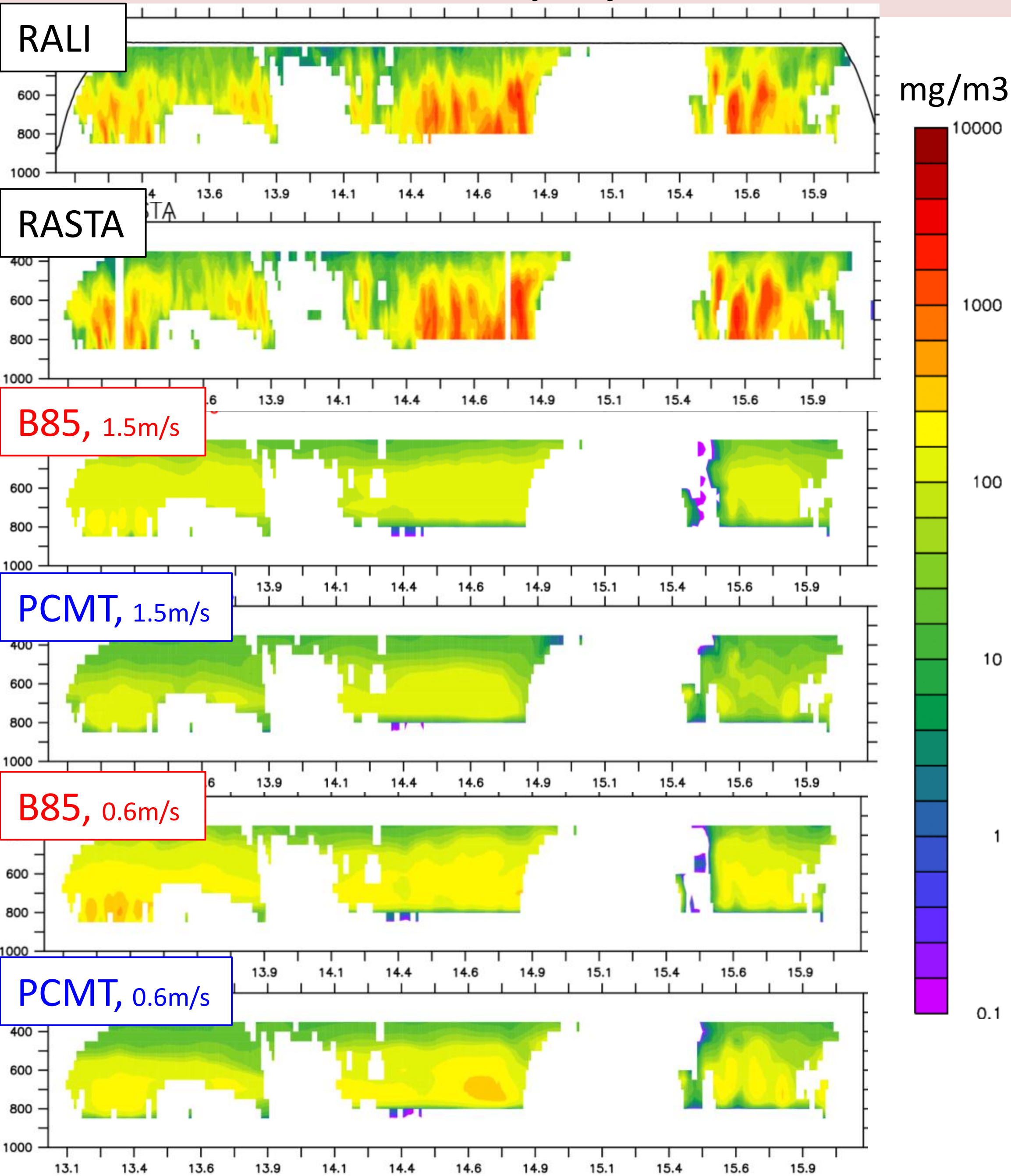
Microphysics: Ice water content F7



RASTA statistics of fall speed (Vt+w)



Microphysics: Ice water content F7



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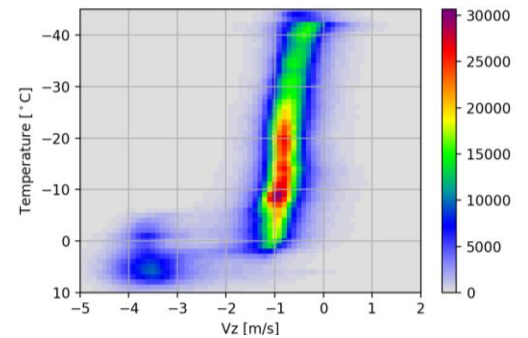

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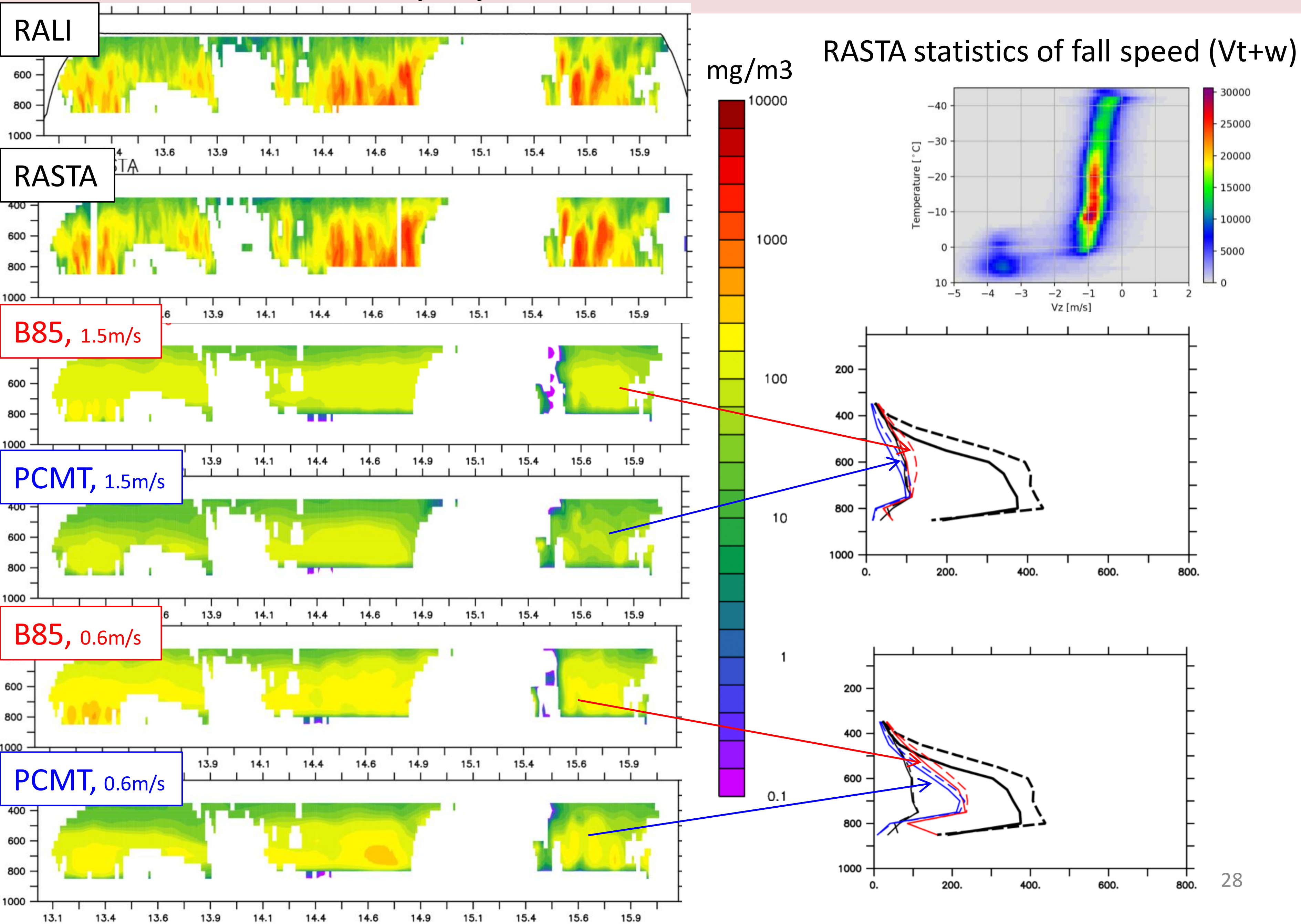

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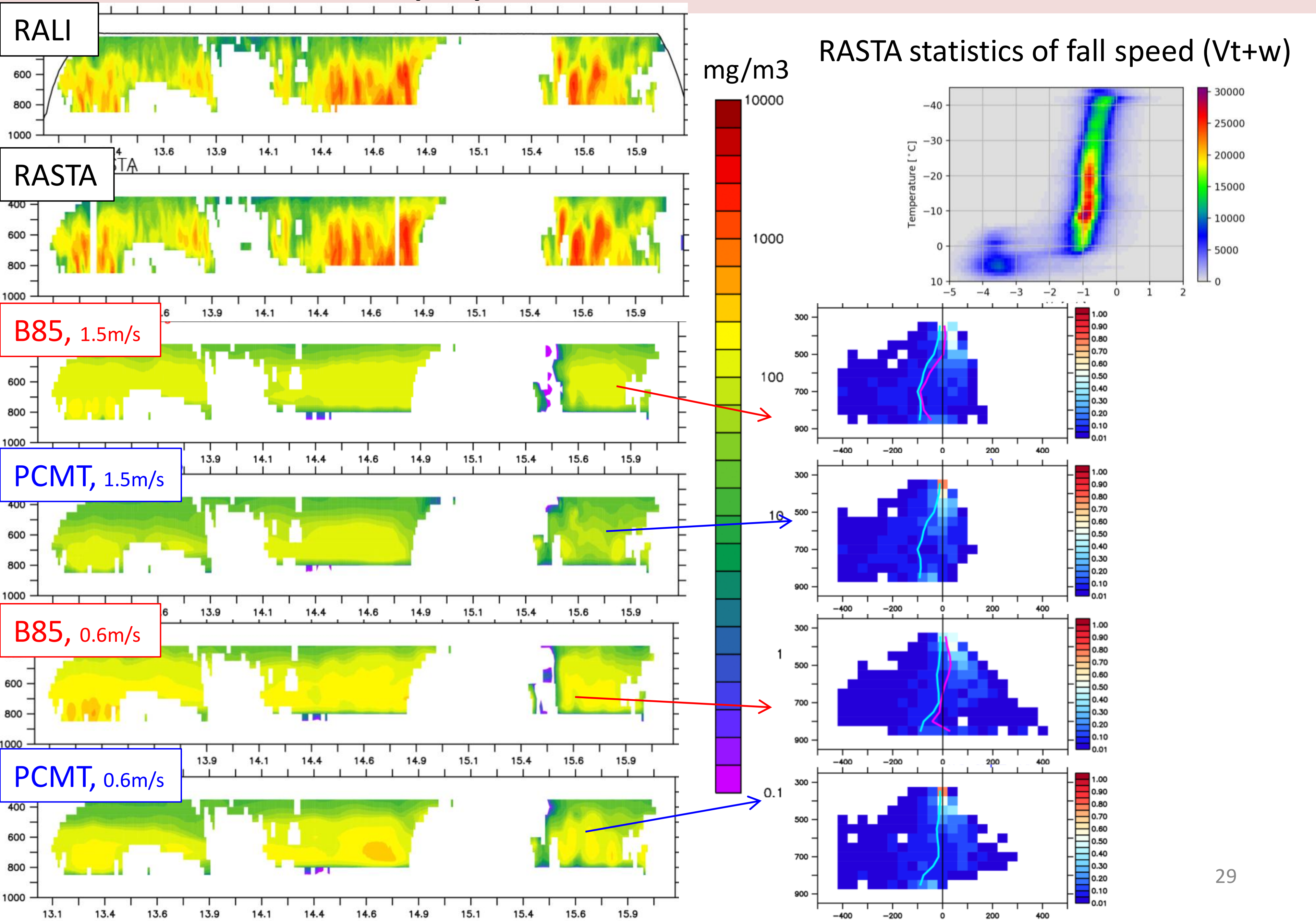
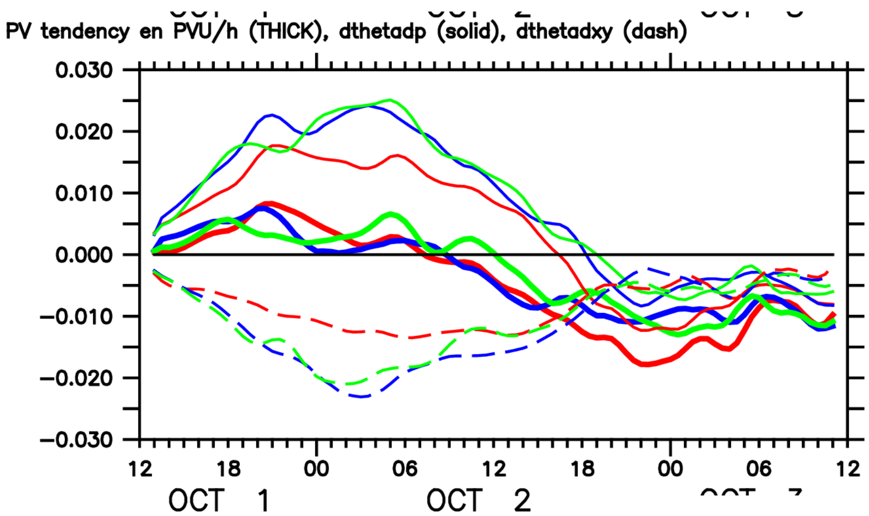
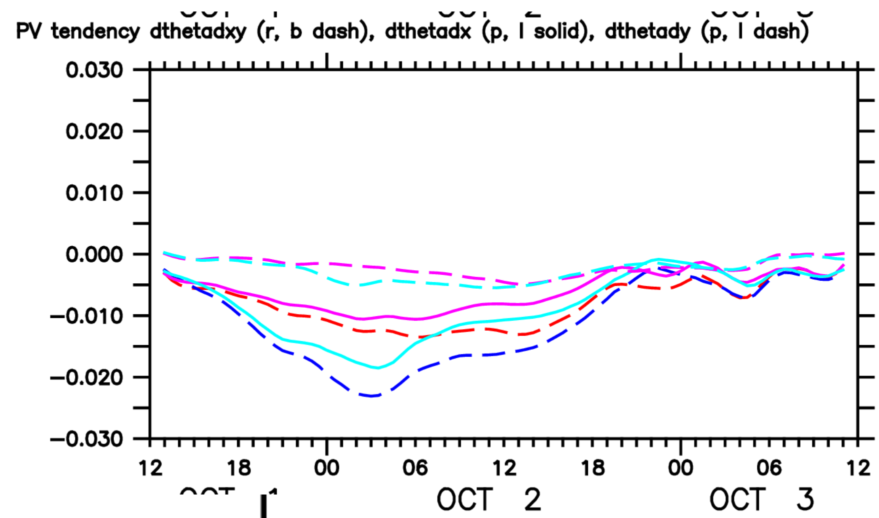
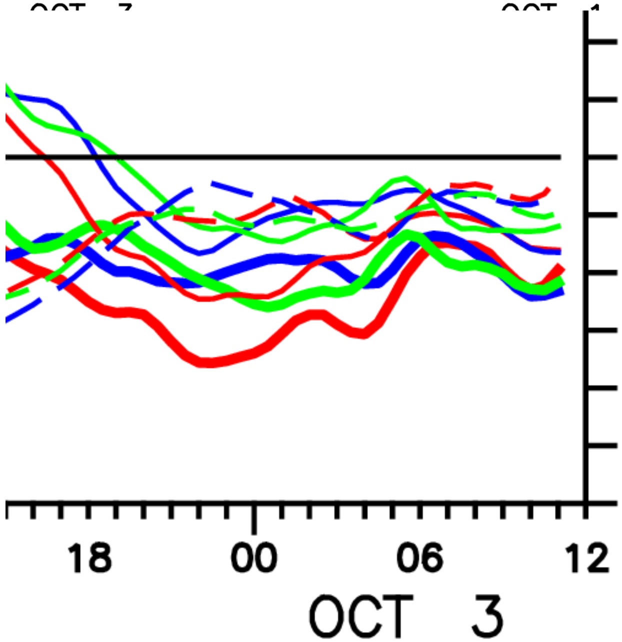


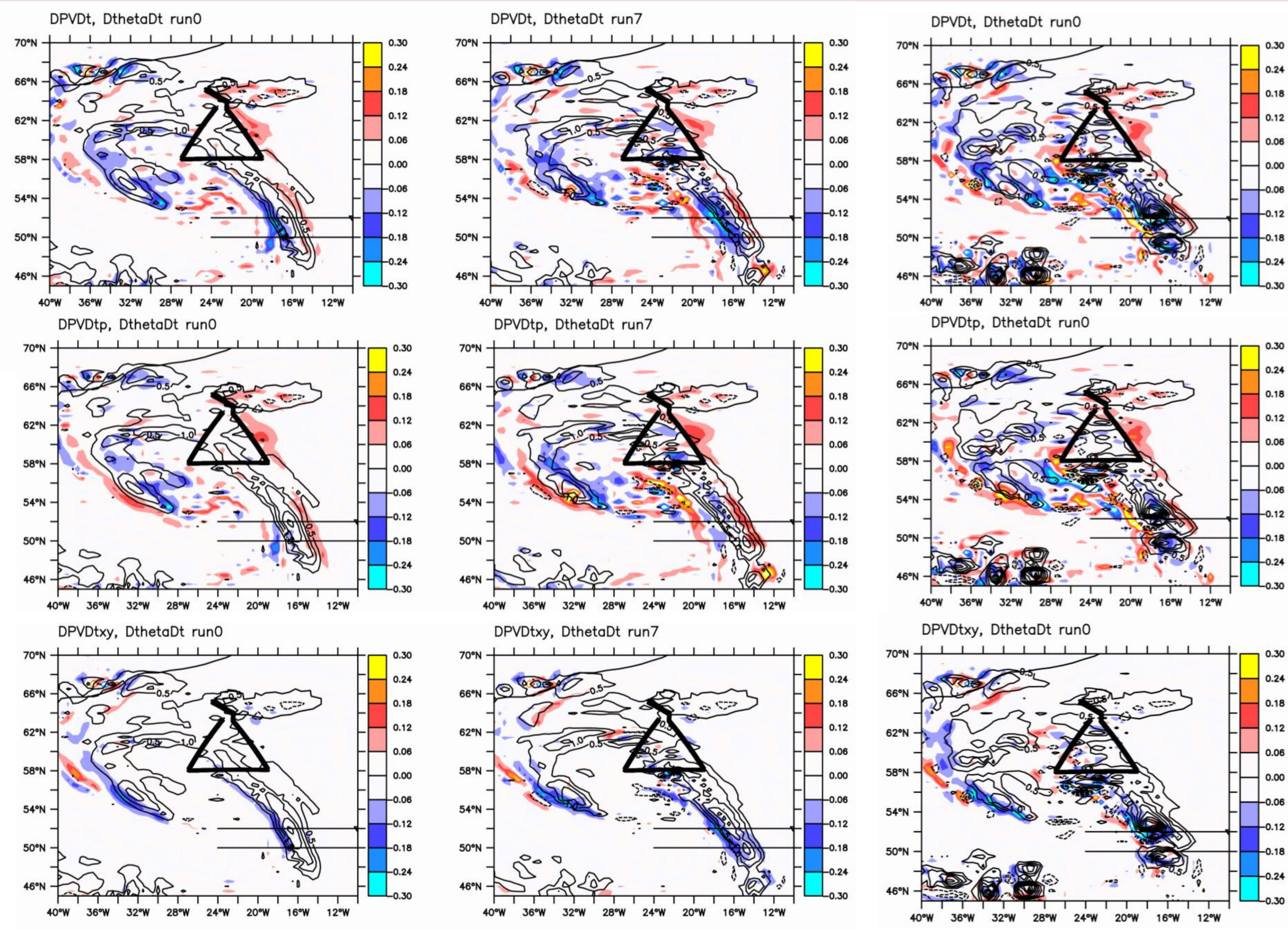
Heating and PV tendencies budgets



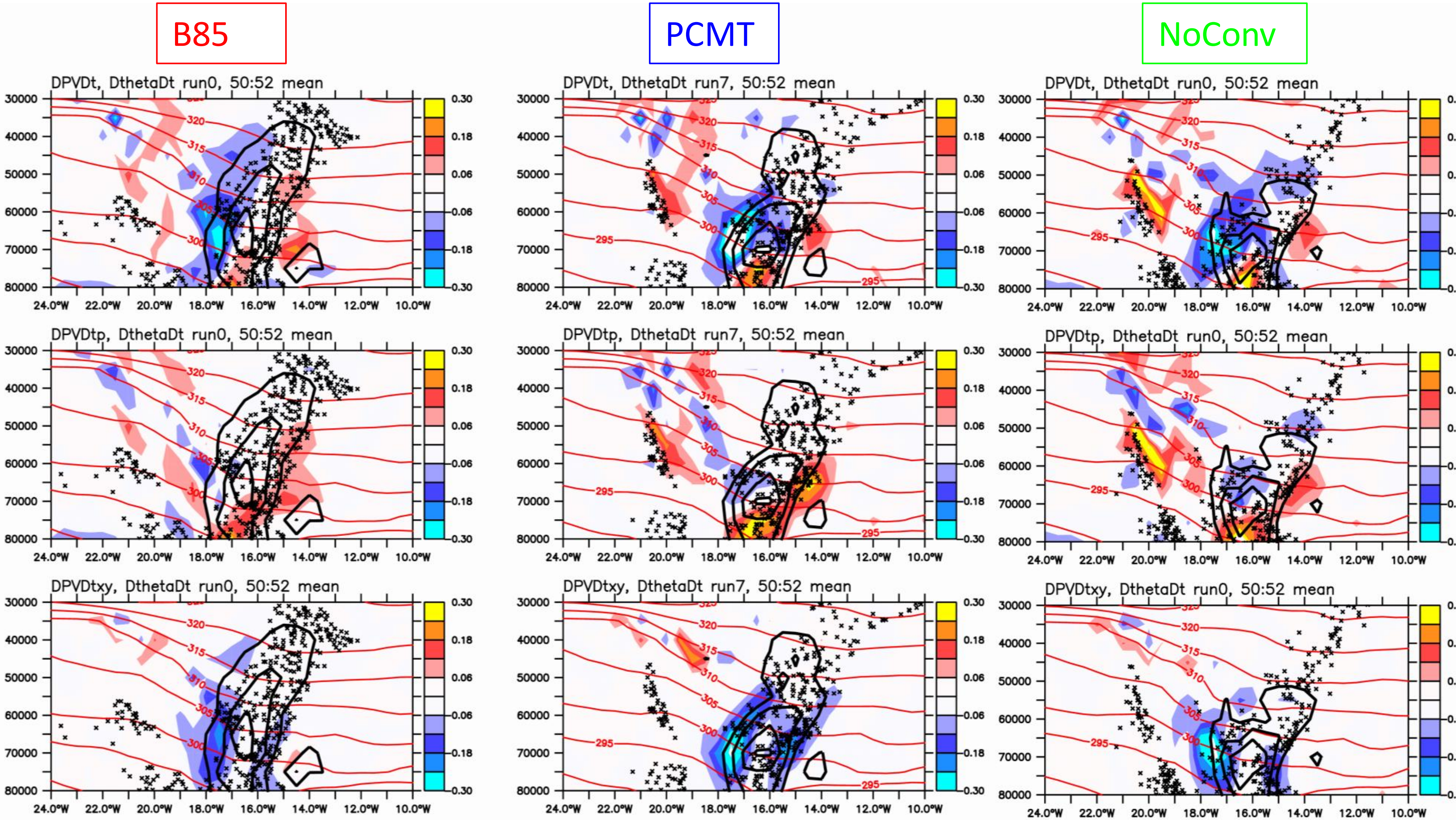




Heating and PV tendencies budgets (t0+24h)



Heating and PV tendencies budgets (t0+24h), 50N-52N



Understanding the negative PV tendency due to horizontal gradient of heating rate along the cold front

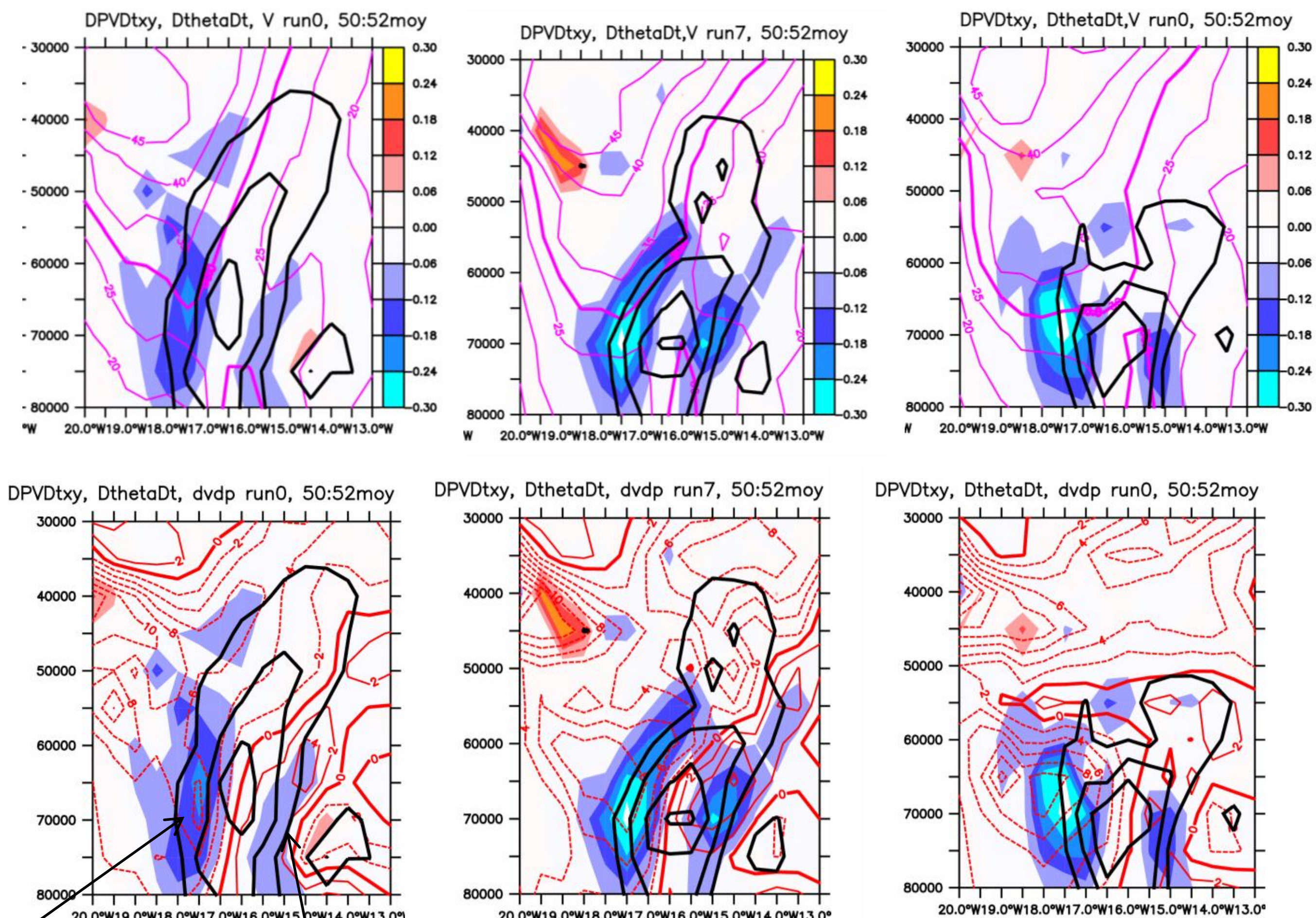
B85 | PCMT | NoConv

v

$$\frac{DPV}{Dt} = \ldots + g\,\frac{\partial v}{\partial p}\,\frac{\partial \dot{\theta}}{\partial x}$$

$$\frac{\partial v}{\partial p}$$

$$\frac{DPV}{Dt} = \ldots + g\,\frac{\partial v}{\partial p}\,\frac{\partial \dot{\theta}}{\partial x}$$



$$\frac{\partial v}{\partial p} < 0;\ \frac{\partial \dot{\theta}}{\partial x} > 0 \qquad \frac{\partial v}{\partial p} > 0;\ \frac{\partial \dot{\theta}}{\partial x} < 0$$

Eulerian Heating rate budget after 24h