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Investigating effects of latent heating on midlatitude cyclone intensification with potential vorticity diagnostics

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Introduction

Features of midlatitude cyclones

- Midlatitude cyclones are often associated with weather extremes like wind, precipitation, and floodings
- Adiabatic energy source: baroclinic instability [1]
- Diabatic energy source: latent heating (LH) during cloud formation → can have a significant contribution to cyclone intensification [2,3,4,5,6]

Motivation: Global warming → higher atmospheric moisture content → more LH → effect on midlatitude cyclone intensity and tracks?

Potential vorticity (PV)

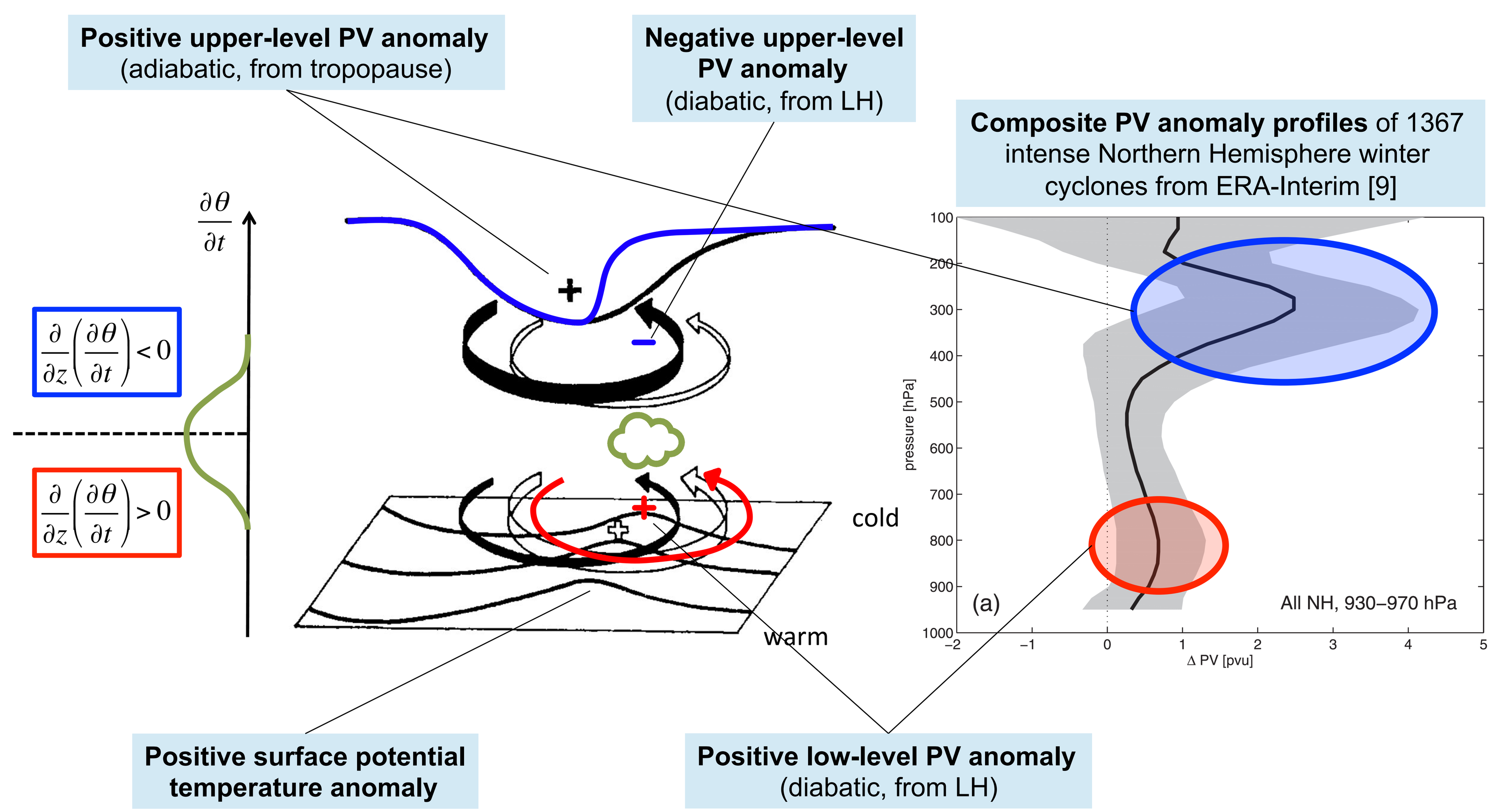
- Key variable for investigation of cyclone dynamics [7]:

$$Q = \frac{1}{\rho} \cdot \boldsymbol{\eta} \cdot \nabla\theta$$

- Conserved under adiabatic conditions but can be changed through frictional and diabatic processes:

$$\frac{DQ}{Dt} = \frac{1}{\rho}(\nabla\theta \cdot \nabla \times \boldsymbol{F}) + \frac{1}{\rho}(\boldsymbol{\eta} \cdot \nabla\dot{\theta})$$

- PV distribution in midlatitude cyclones [3,8,9]:



Data & Method

- Simulation of the historical European winter storm *Klaus* in 2009 [10]
- COSMO model setup:
  - North Atlantic / European domain
  - Spatial resolution: 0.125° x 0.125° (horizontal), 40 levels (vertical)
  - Initial and boundary conditions from ECMWF analysis
- Sensitivity simulations: scale specific latent heat constants in the model (lh_v, lh_f, lh_s) with a constant α
  - Reference (**REF**): α = 1.0
  - Reduced / enhanced LH (**L05**, **L15**): α = 0.5, α = 1.5
  - No LH (**L00**): α = 0.0
- Analyze 6h-heating-rates due to microphysics (TMPHYS) and convection (TCONV)
- Cyclone area definition:
  - Radius of 200 km around SLP minimum (for PV budget)
  - Rectangular box including SLP minima at times t_0 and t_{-6} (for heating rate budgets)

Klaus, 2009

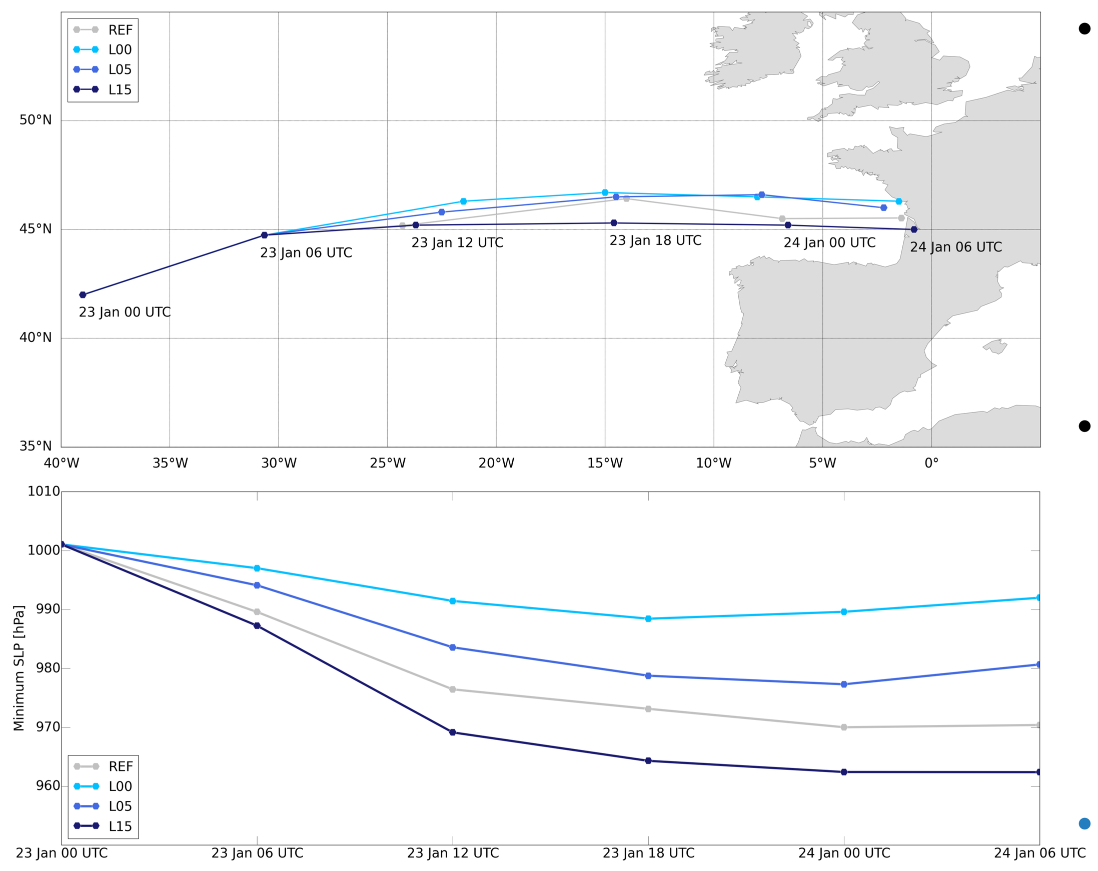
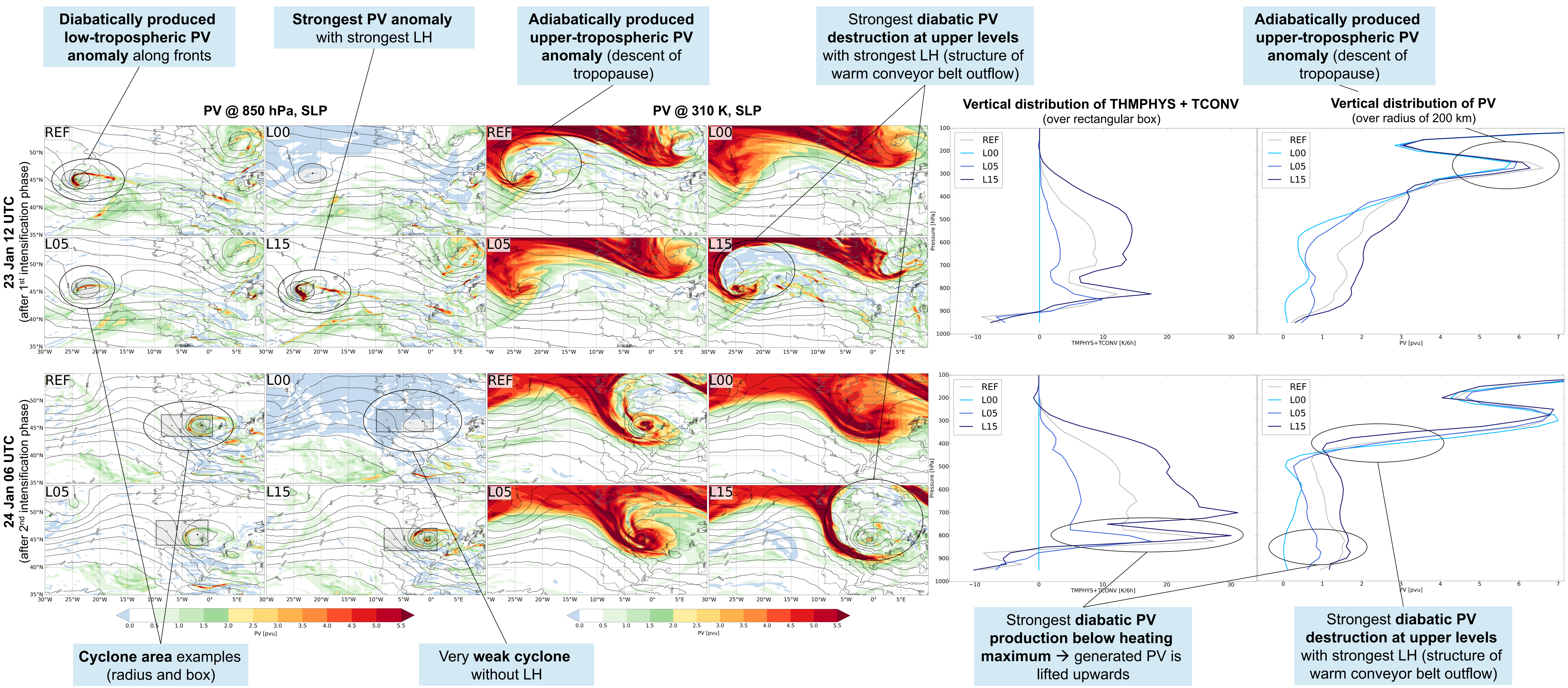


Figure: Tracks (top) and development of minimum SLP (bottom) for the four sensitivity simulations (REF, L00, L05, L15)

- One of the most damaging storms for Northern Iberia and Southern France with extreme winds and heavy precipitation [10]
- Explosive deepening after crossing a region of strong upper-level divergence (left exit region of jet streak) [10]
- LH strongly contributed to the intensification [11]

Results



Conclusions & Outlook

- The dynamic contribution of LH was significant during the explosive intensification of *Klaus*
- Both the diabatically produced positive low-tropospheric and negative upper-tropospheric PV anomalies of *Klaus* scale approximately linearly with intensified LH
- With more intense LH, the track of *Klaus* shifts slightly southward during the intensification phase
- The vertical PV distribution is a good diagnostic metric to investigate the effect of different LH conditions on the intensity and dynamics of midlatitude cyclones
- The result of this study motivates to use the PV budget to further investigate the LH sensitivity of midlatitude cyclones both on a case-to-case and climatological basis

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