Propagation of tropical heating perturbations to the midlatitudes and the role of orography

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Outline

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- Medium-term response to tropical heating
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Motivation

Tropical processes strongly influence midlatitude weather processes in the medium-range and longer forecasts

At the same time, analysis uncertainties and short-range forecast errors are largest in the tropics. They are shown to be associated with both balanced and unbalanced circulation across all spatial scales.

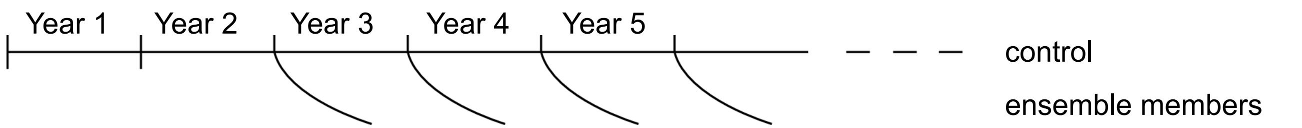
Little is known about the impact of the tropical analysis uncertainties on the growth of forecast errors in the mid-latitudes.

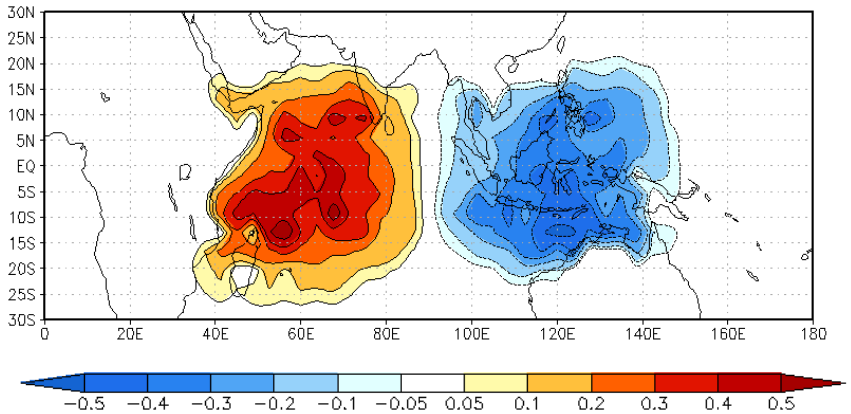
Perturbations in diabatic heating in the tropics have long-term impact on forecasts of the midlatitude circulation. We aim to quantify the role of unbalanced component of the large-scale circulation response to these perturbations in the tropics and their propagation outside the tropics.

Experiment set-up

- The model: ICTP AGCM (SPEEDY), version 41, T30 (Molteni 2003, Clim Dyn; Kucharski et al. 2006, Clim Dyn)

- Experiment set-up:
  - Continuous unperturbed control run for 32 years
  - Every 1st January from the third year on, the model was restarted with continuous additional heating perturbation, and run for 3 months. 30 ensemble members in northern hemisphere winter.



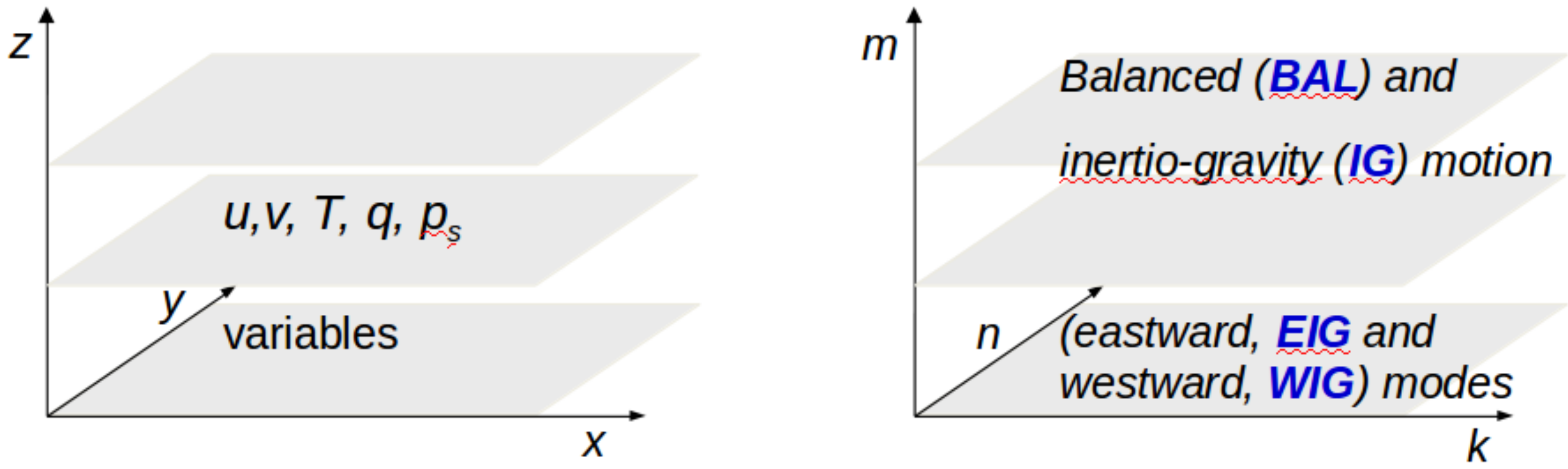


Heating perturbation in one ensemble member at 500 hPa, averaged over 90 days [K/day]

  - Heating perturbation from Molteni and Kucharski.
  - Daily means were analyzed with MODES decomposition.

MODES decomposition

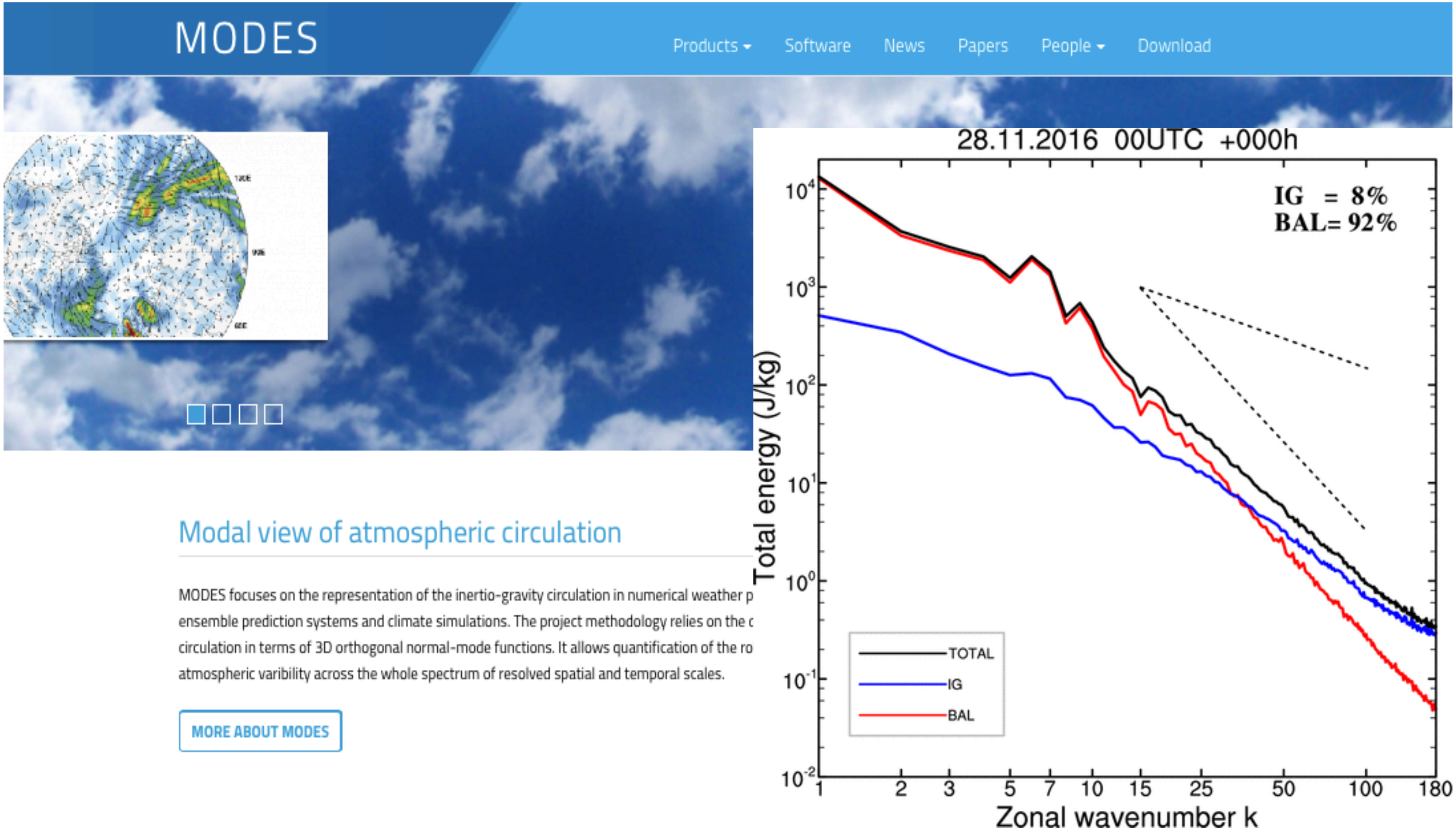
Physical space (*x,y,z,t*) → **Modal space (*k,n,m,t*)**



- Circulation is split in balanced and unbalanced components defined in terms of eigensolutions of the linearized primitive equations.
- The balanced part consists of the Rossby (quasi-geostrophic) waves. The unbalanced part projects onto the inertio-gravity eigensolutions that propagate eastward (EIG modes) or westward (WIG modes).
- Inertio-gravity modes → unbalanced modes (UBAL)

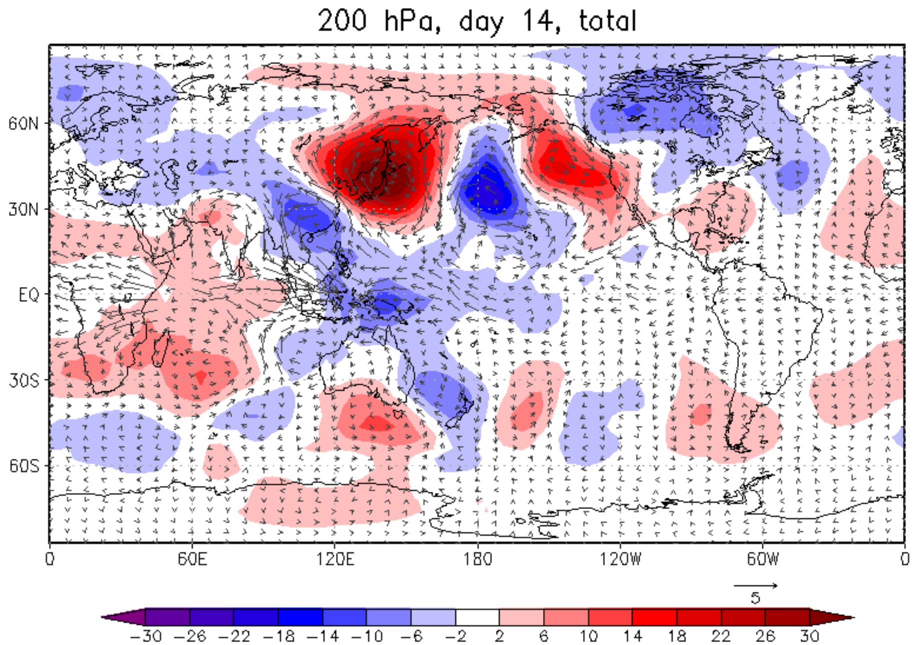
MODES decomposition

http://meteo.fmf.uni-lj.si/MODES



MODES decomposition

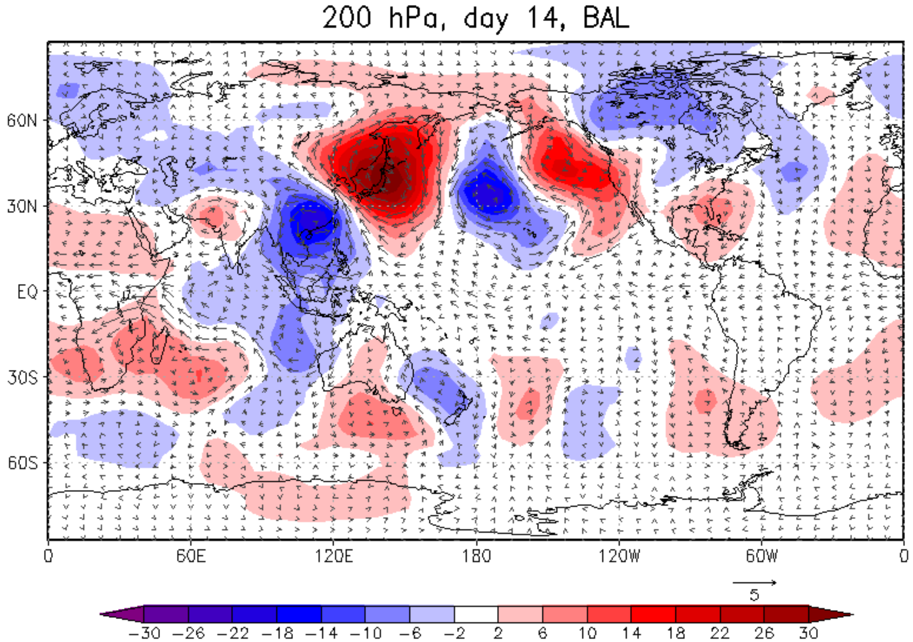
Total

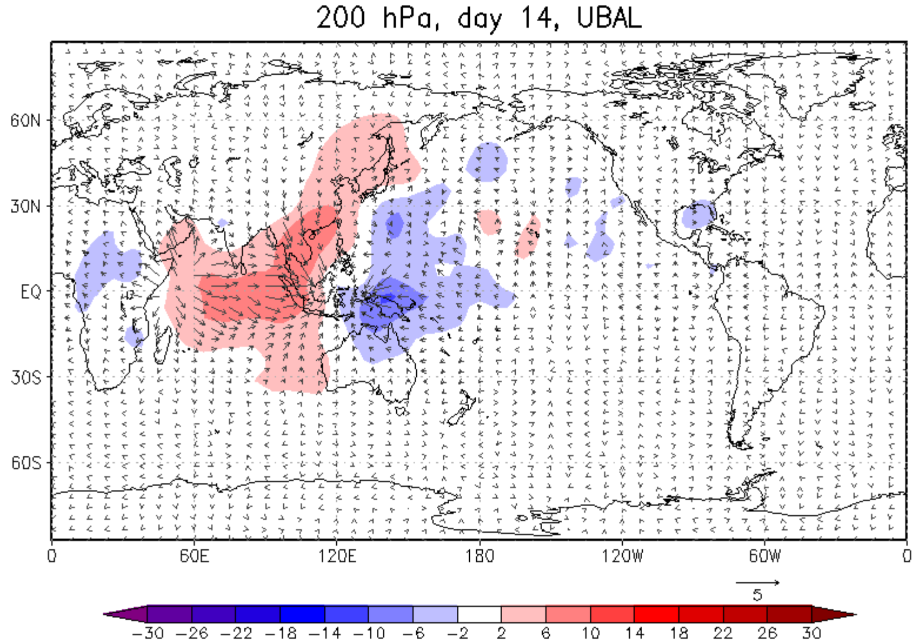


Geopotential height perturbation (m) in color & wind vectors (m/s)

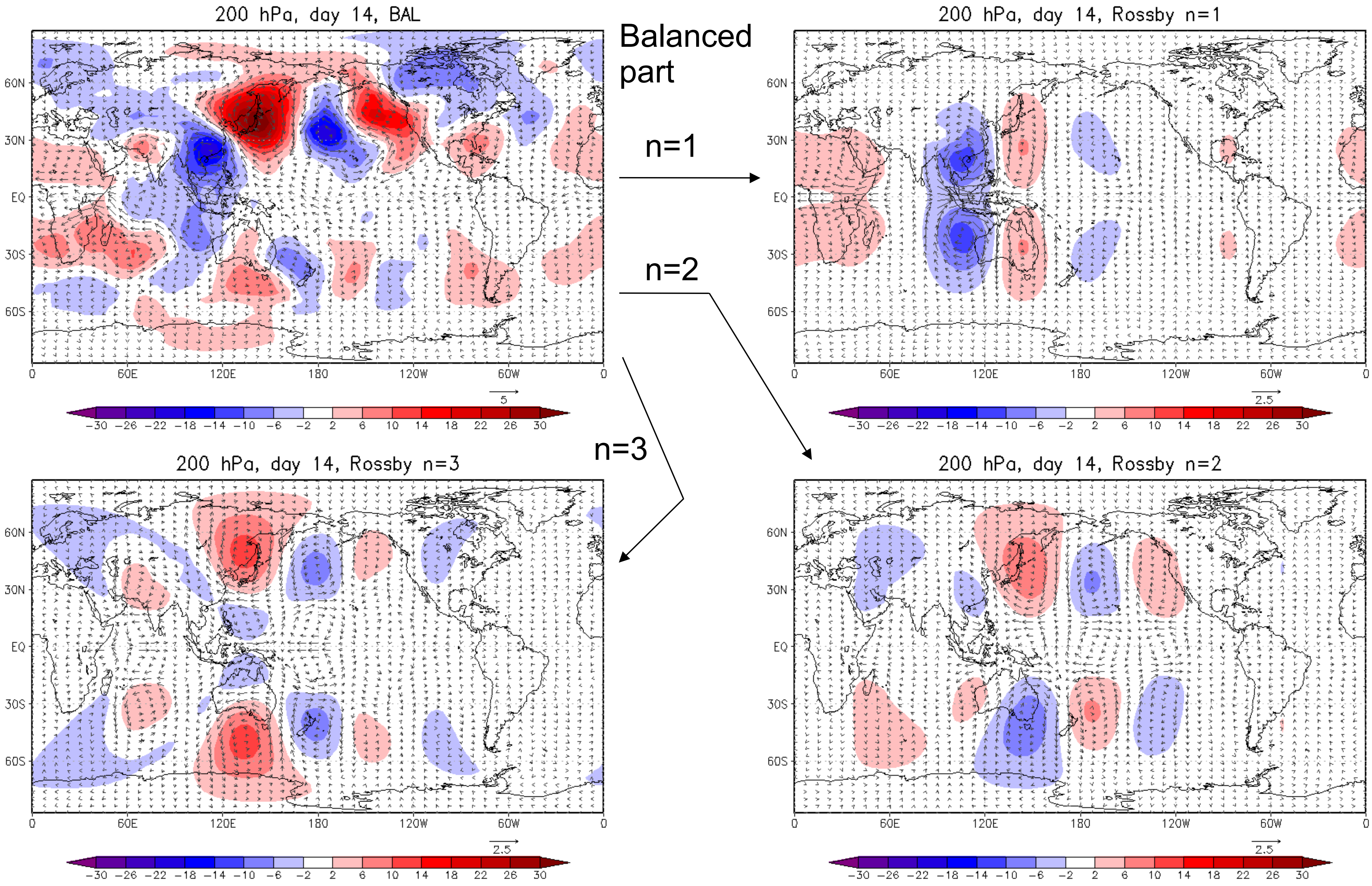
Balanced part

Unbalanced part



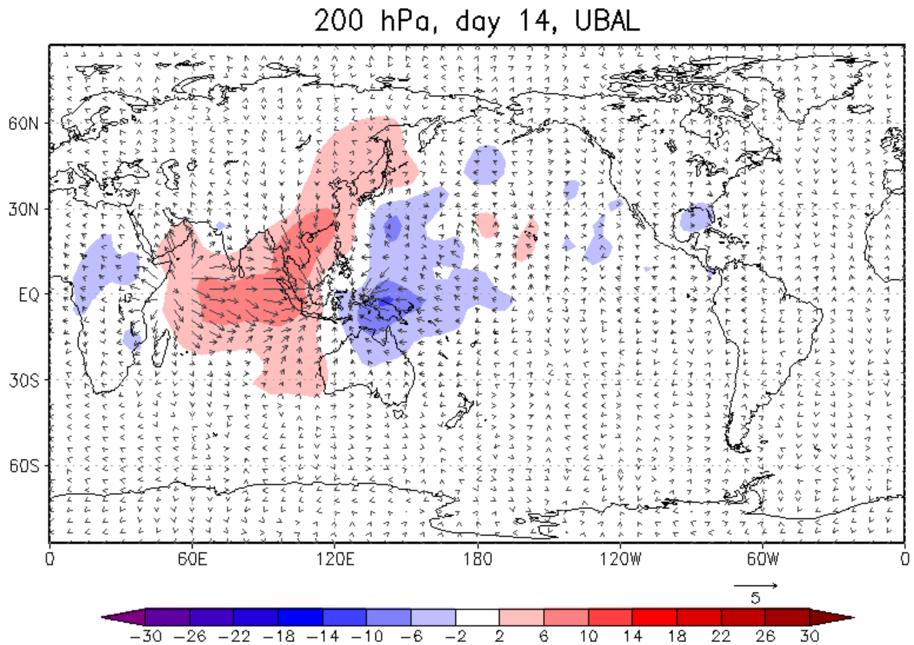


MODES decomposition



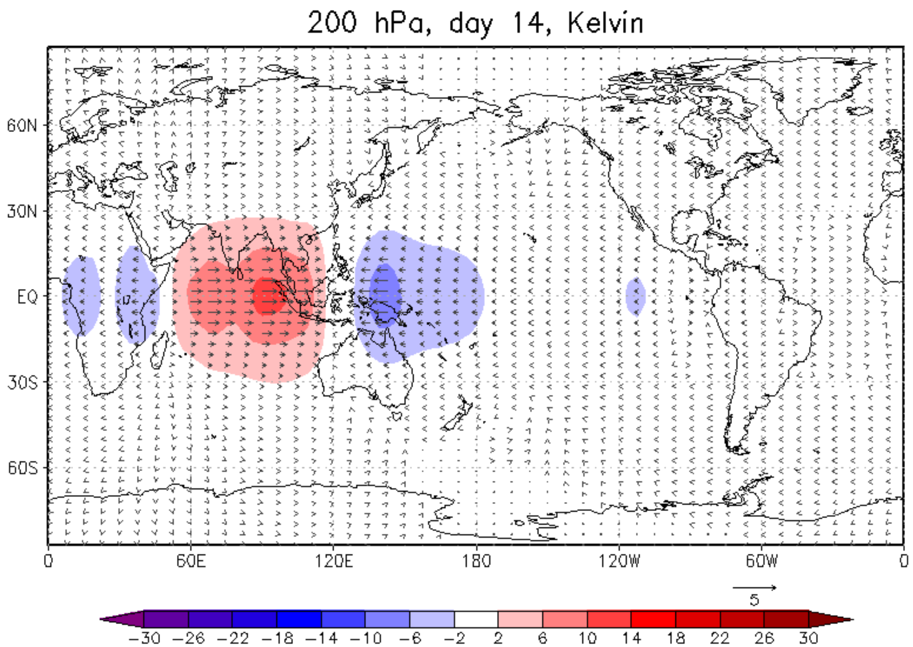
MODES decomposition

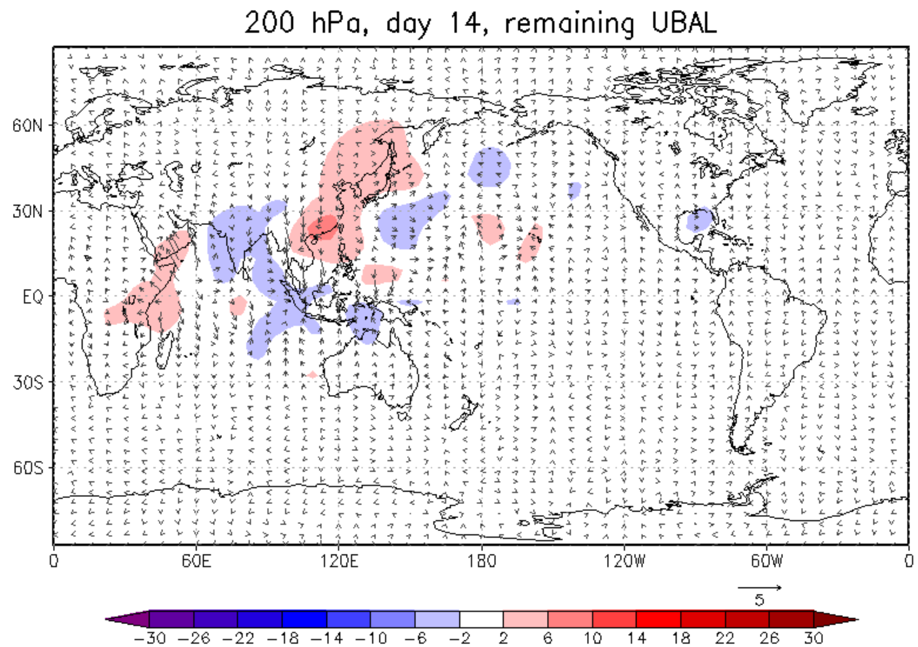
Unbalanced part



Kelvin mode

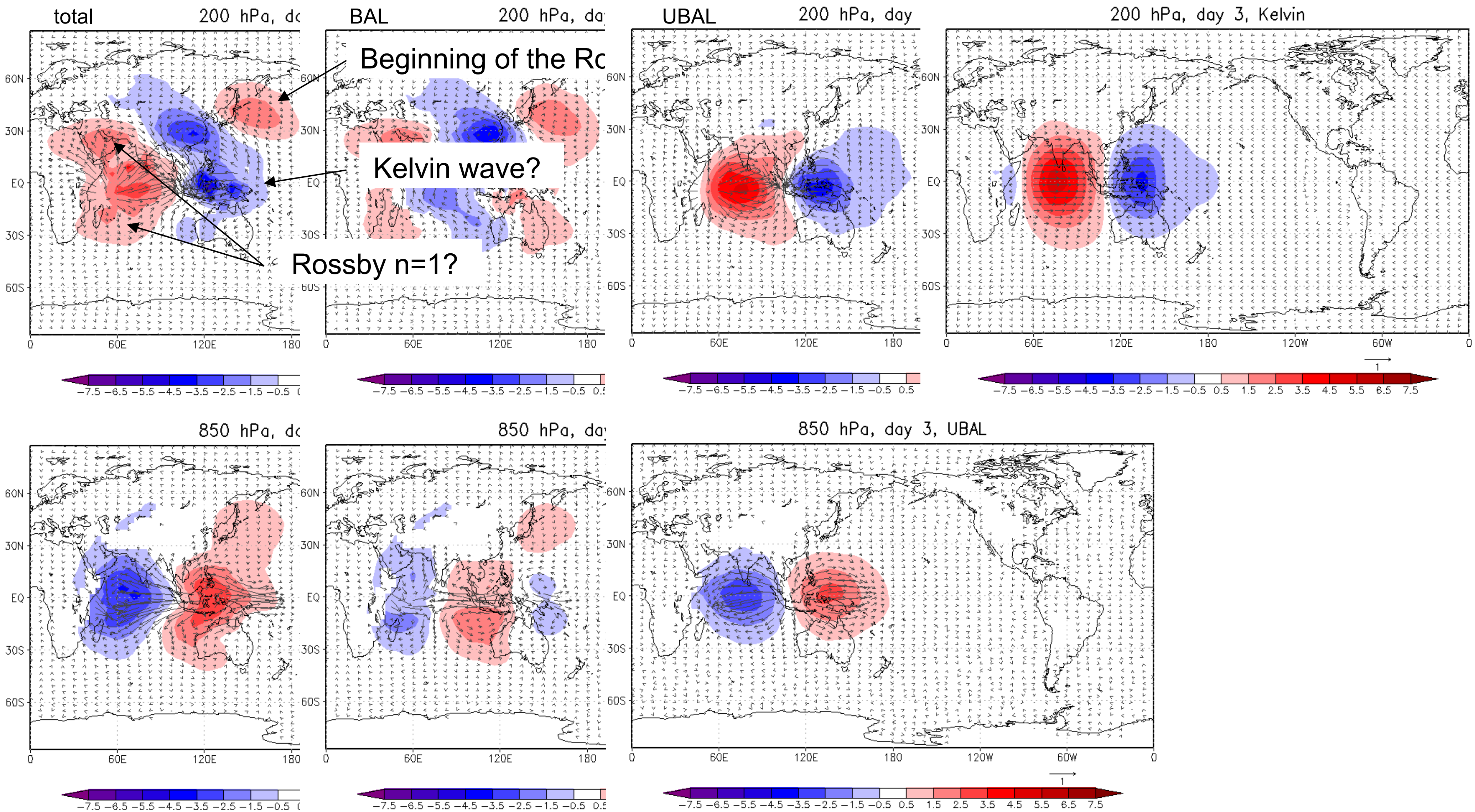
remaining unbalanced modes





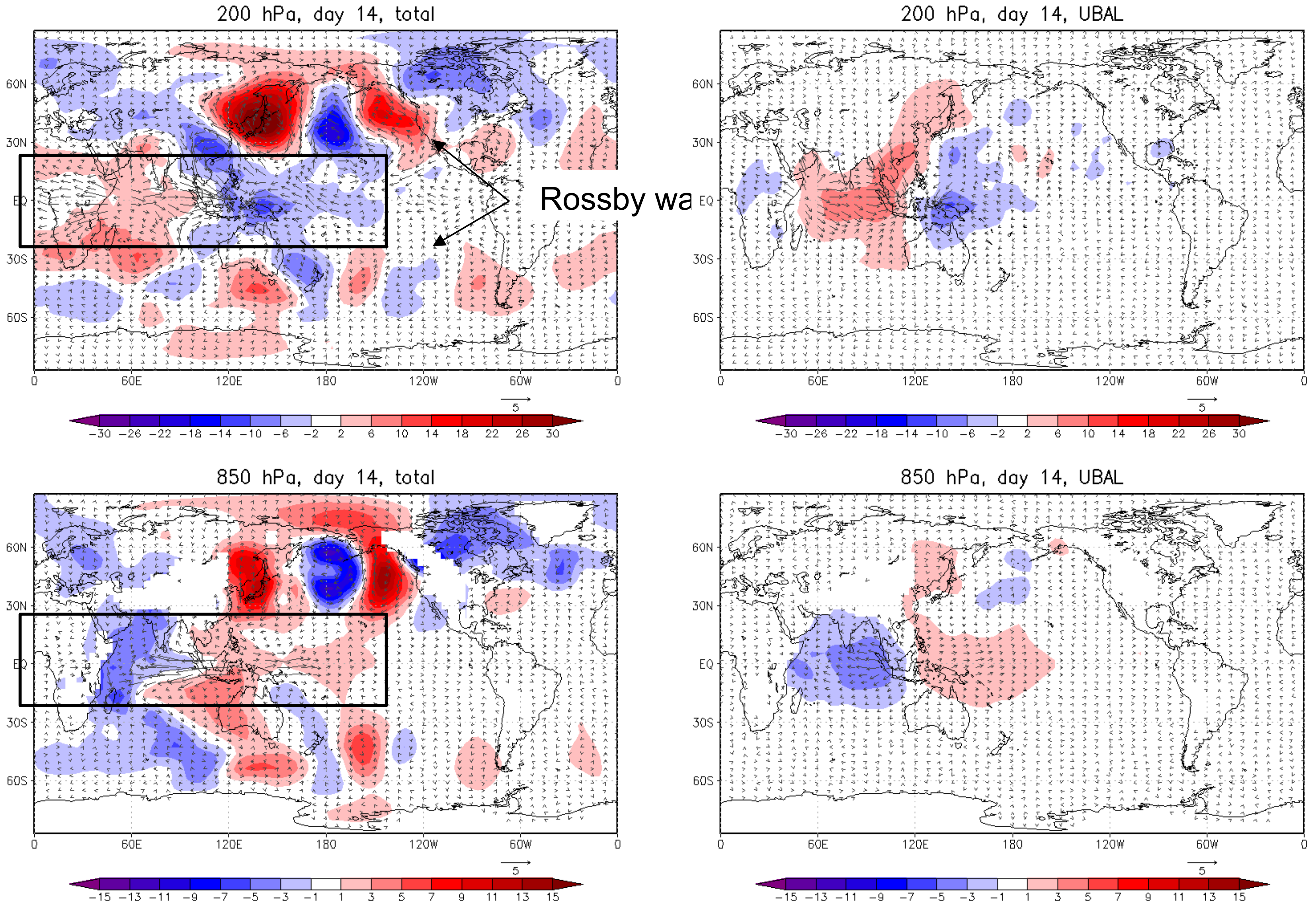
Short-term response

- Short-term response → mostly confined to tropics
- Medium-term response → Rossby wave train in midlatitudes

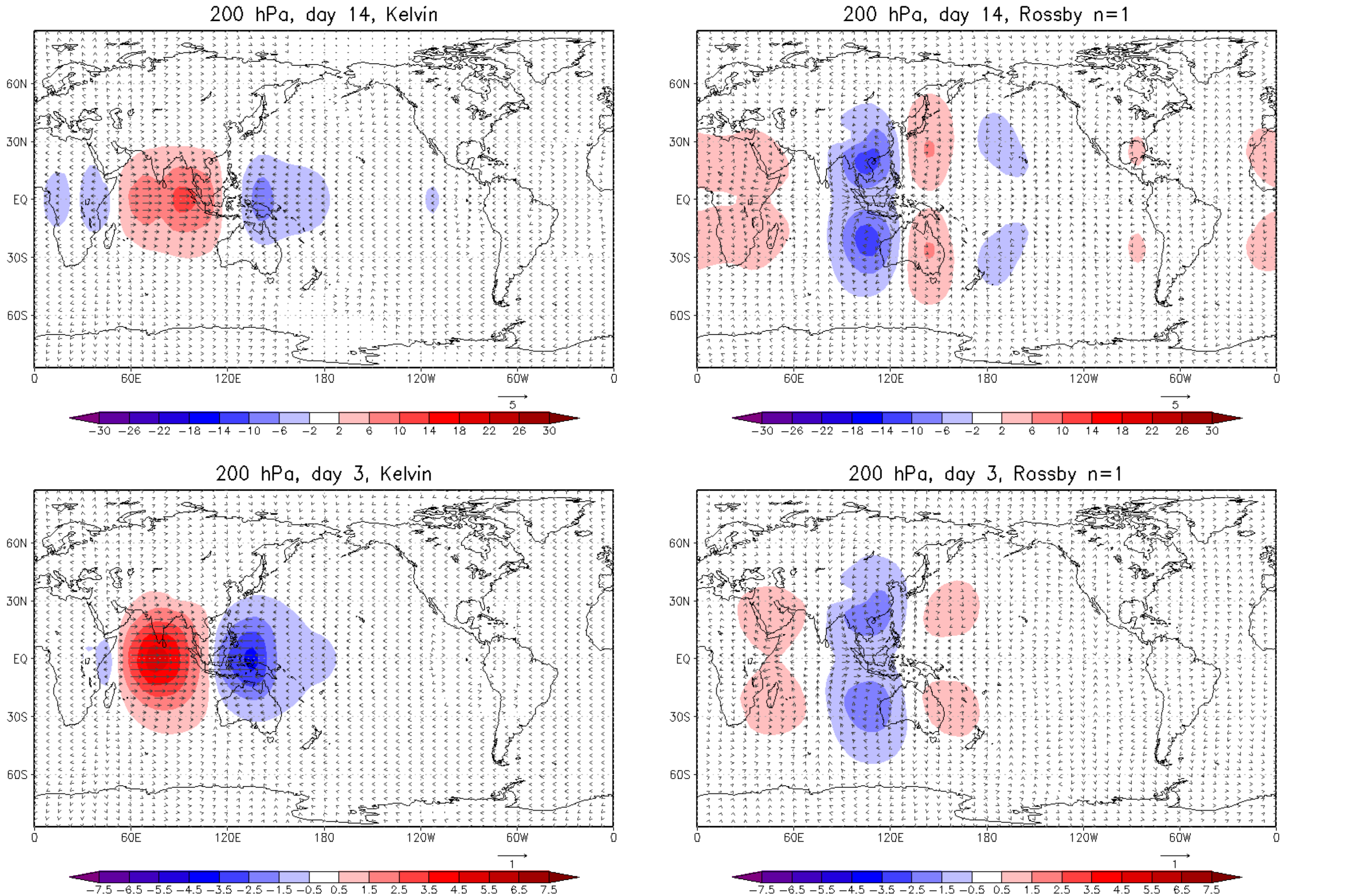


Medium-term response

- Short-term response → confined to tropics
- Medium-term response → Rossby wave train in midlatitudes



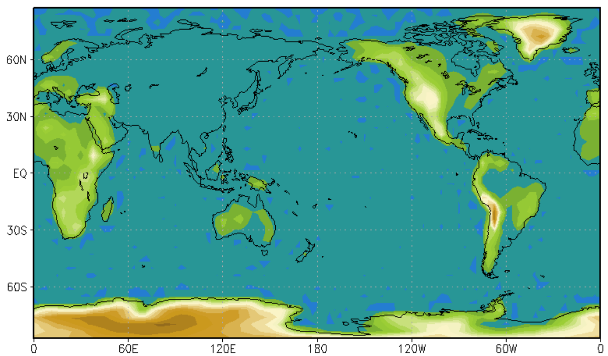
Kelvin and Rossby n=1 modes



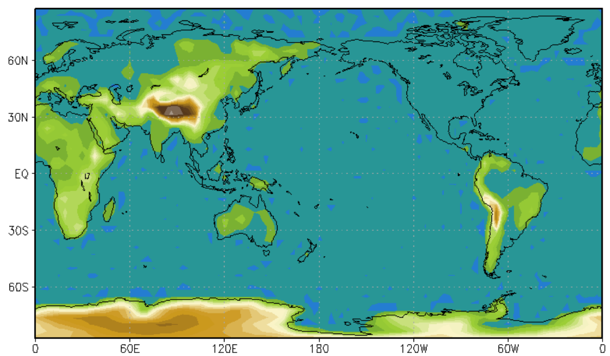
The role of orography

- 3 additional experiments, the only difference was that part of the northern hemisphere orography was lowered to maximum 100 m.
  - Himalayas and Tibet (no HT)
  - Rocky Mountains and Greenland (no RG)
  - Himalayas, Tibet, Rocky Mountains and Greenland (no HTRG)
- The question: what is dynamic effect of orography on growth and propagation of perturbations.

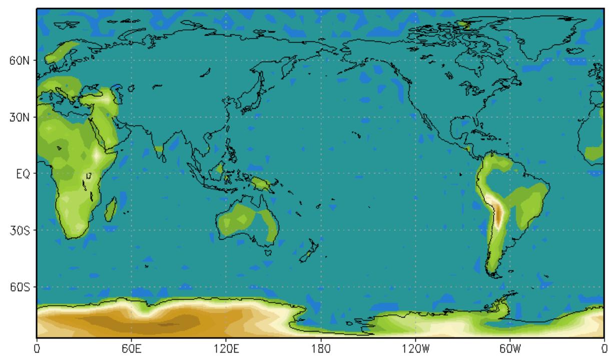
No HT



No RG



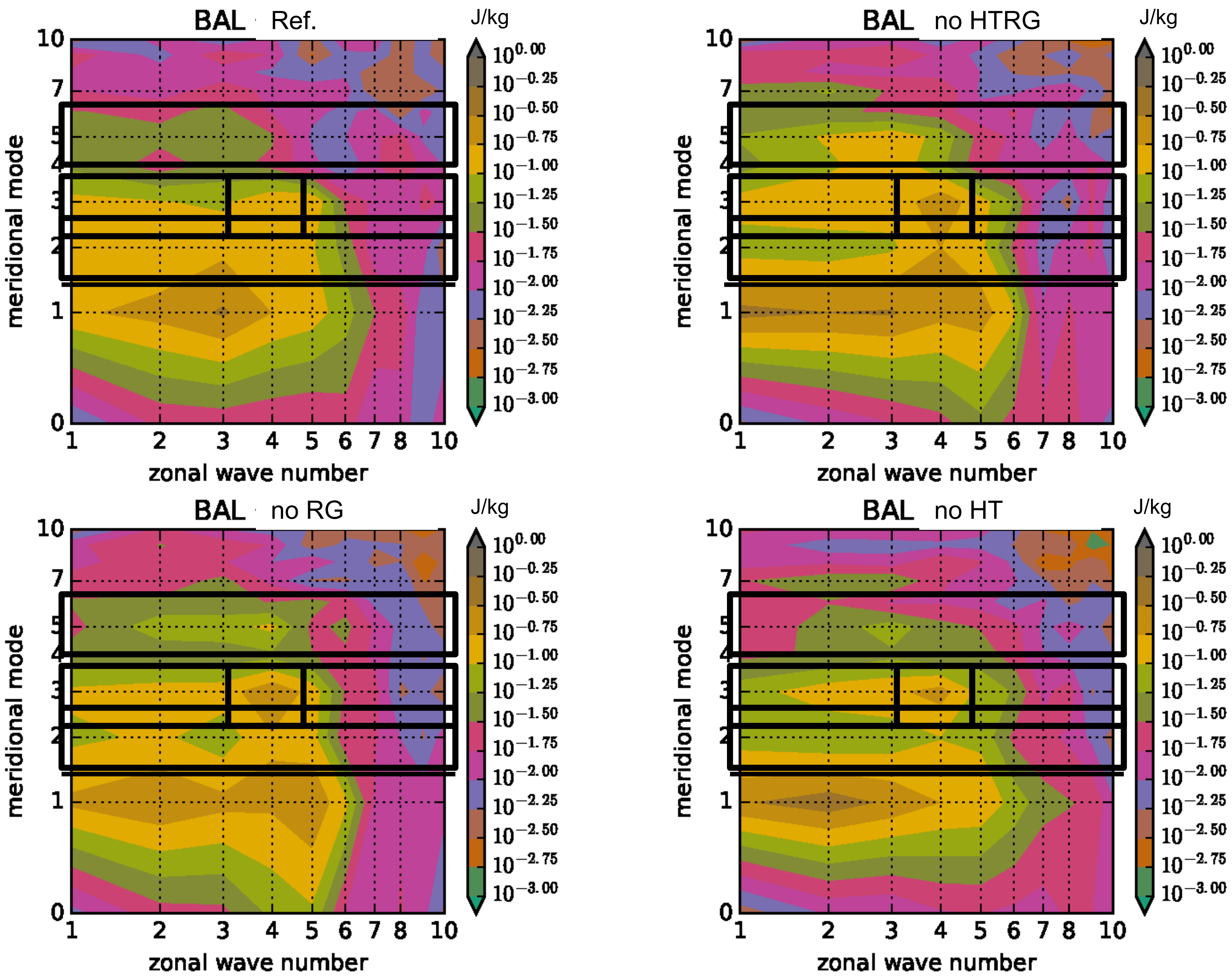
No HTRG



- In midlatitudes the intensity and propagation of Rossby wave train are affected by the large-scale orography.

The role of orography

Balanced part, day 14



Summary

- A novel method for the decomposition of 3D global circulation to the balanced and unbalanced components, MODES, has been applied to diagnose the global response to tropical heating perturbation
- In the tropics, the balanced and unbalanced components of the response have comparable amplitudes.
- Circulation response in tropics is confined close to the heating source (possibly due to the dipole structure of the heating)
- The midlatitudinal response consist of the (balanced) Rossby wave train.
- Removal of orography increases the variability in odd (symmetric) Rossby modes. The largest variability appears in Rossby n=3, at zonal wavenumber 4.

The role of orography

Hovmöller diagrams at 50 °N

Midlatitudes →BAL part