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Mid-latitude response to stationary and non-stationary tropical heating.

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Mid-latitude Response to stationary and non-stationary Tropical Heating

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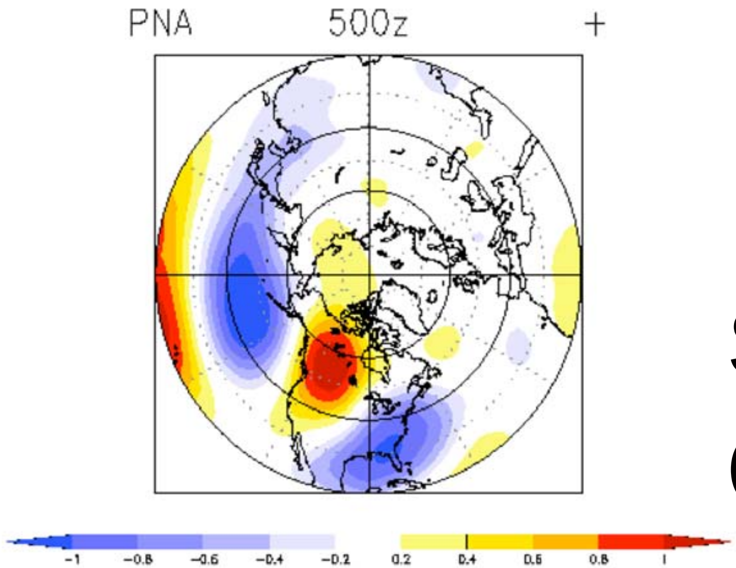
Motivation

Understanding impact of tropics/subtropics on weather in mid-latitudes

Medium range predictability



http://www.cdc.noaa.gov/map/wx/images/pna.cmp.gif

Storm damage by Lothar 1999

Seasonal variability

(Teleconnection patterns [PNA, NAO ...])

Key Questions

Highly asymmetric initial state:

- Wave propagation?
- Characteristics of mid-lat response?
- Sensitivities of interaction?
- Impact of migration of forcing?

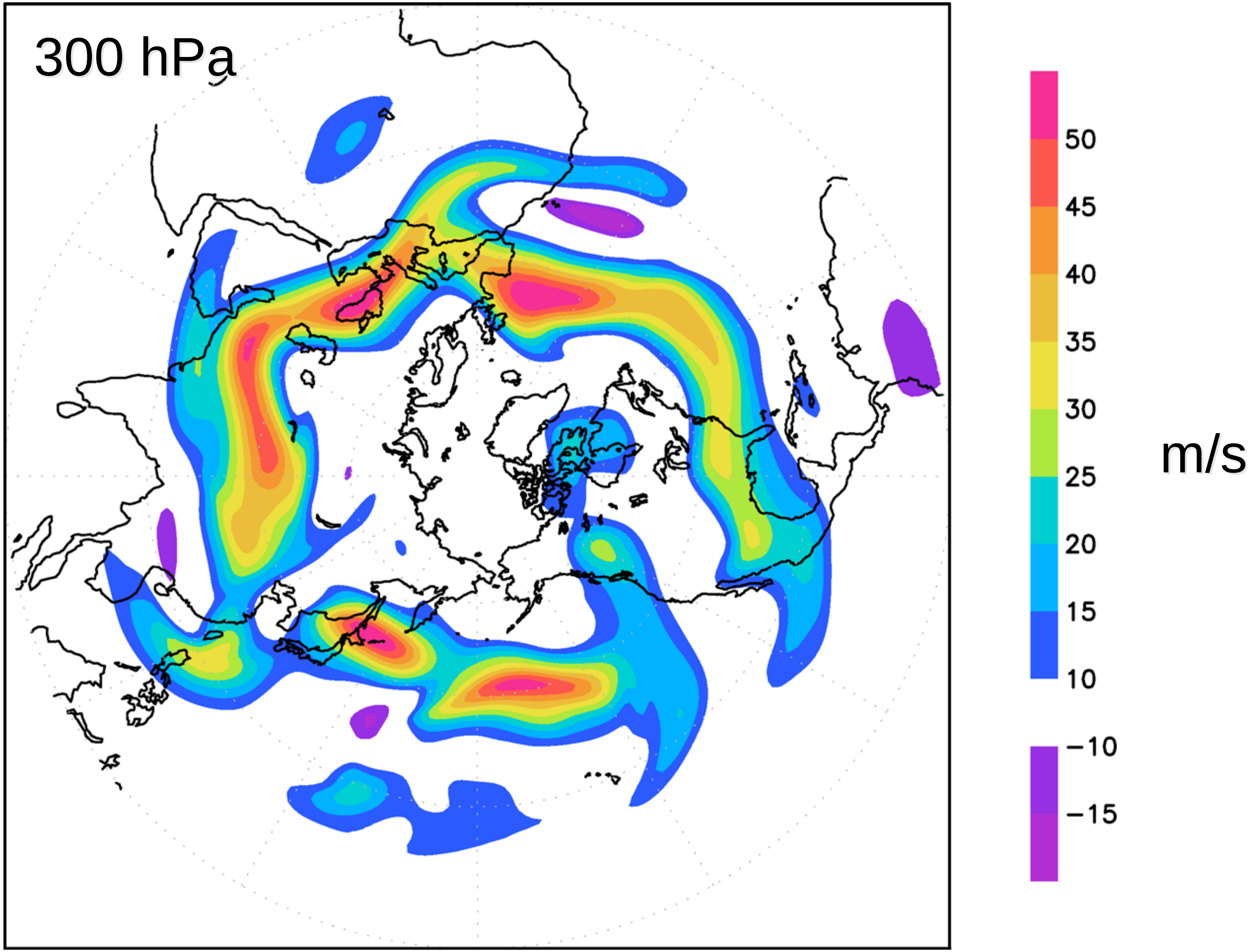
Numerical model

- ECMWF IFS (Integrating Forecasting System)
- Global spectral-Model with hybrid-levels
- Horizontal resolution T159
- 60 levels in vertical
- Idealised version: pure dynamical Core
  (T, LNSP, U, V, Z)

Zonally asymmetric basic state

Zonal

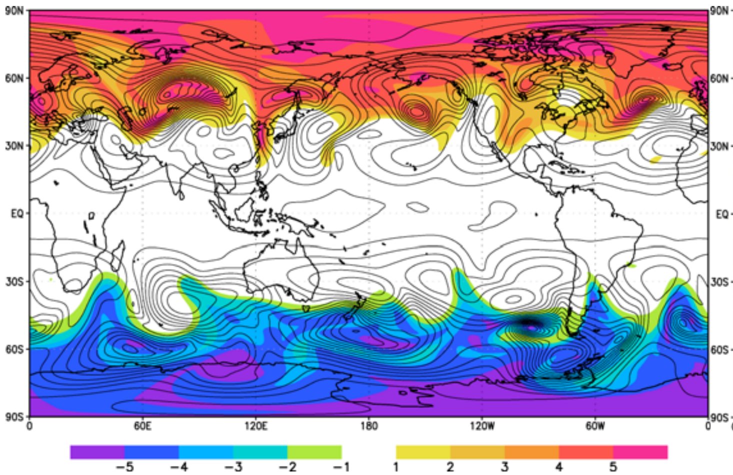
Wind



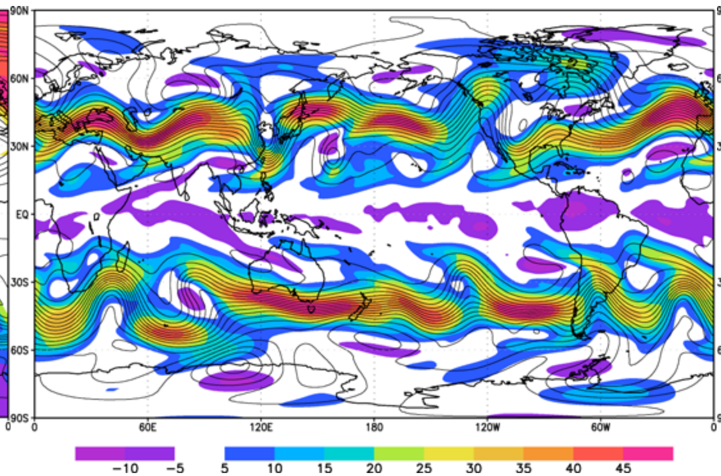
Initial fields

- Initial data from idealized setup (Held-Suarez)
- Temperature-relaxation: sustaining idealized midlatitude tropospheric jet in each hemisphere
- Jet time varying and zonally asymmetric
- No orography

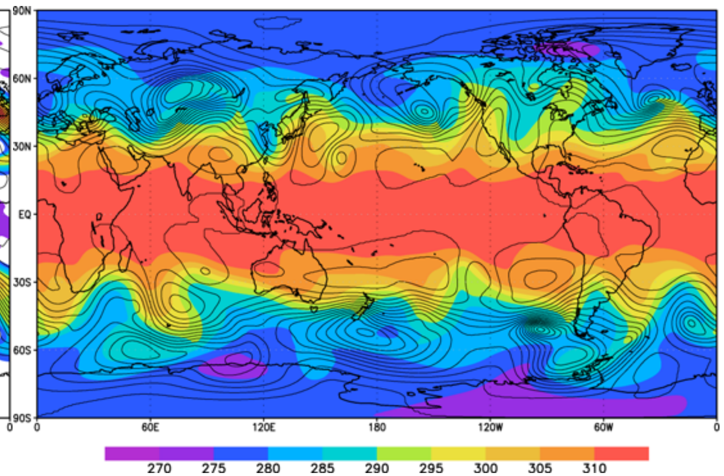
PV and SLP on 320 K



U and Z on 200 hPa



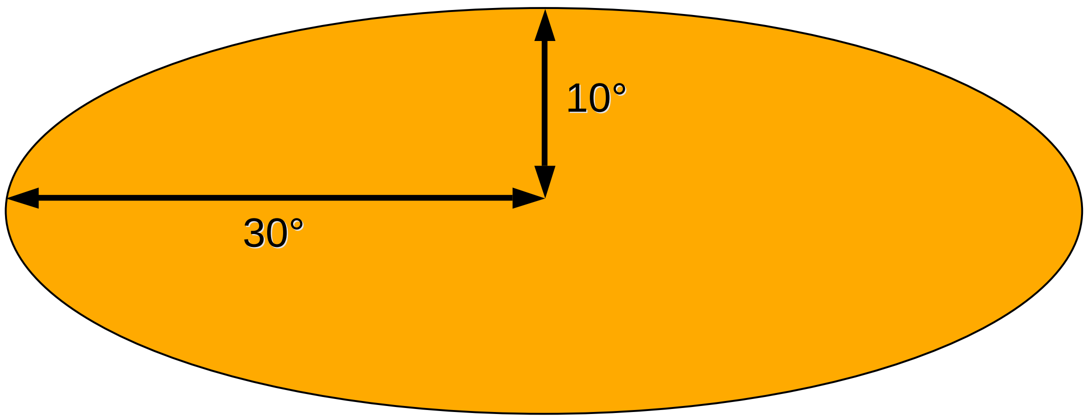
T and Z on 850 hPa



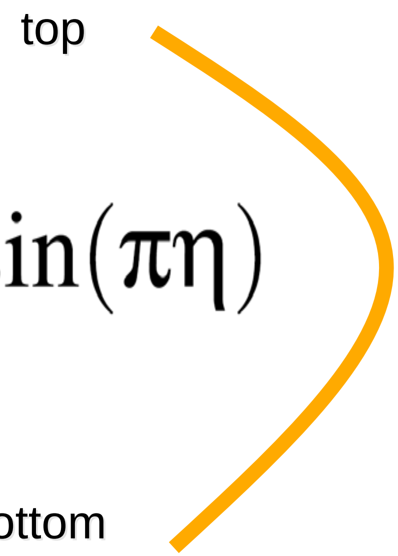
Experiment setup

- Impact of 3D non-linear varying background state
- Forcing (5 K/day) in tropics / subtropics

  lat [-15°, 0°, 15°] lon [0°, 30°,...,330°]



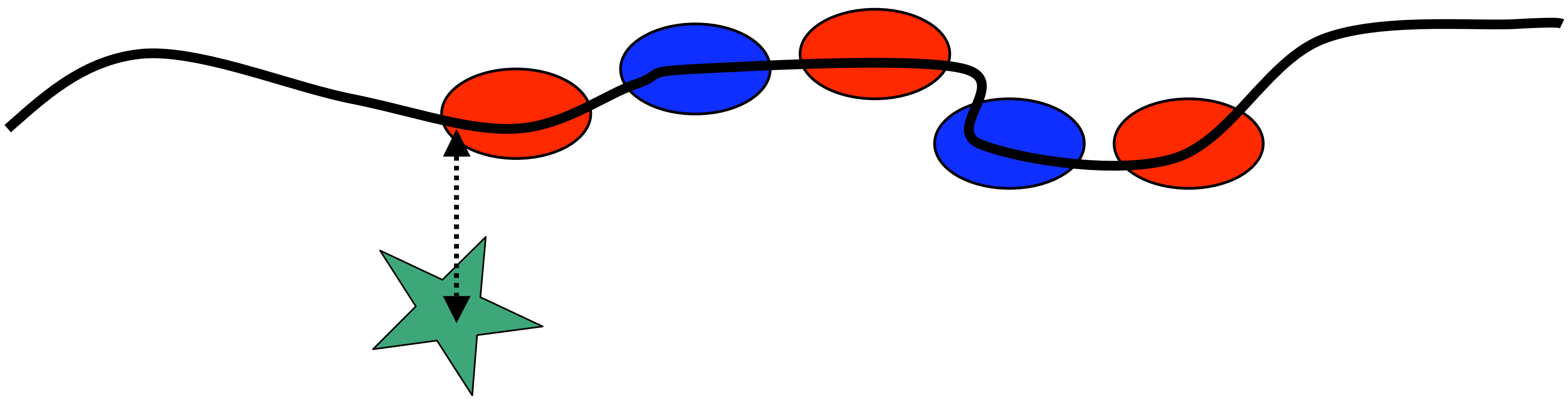
$$V(\eta) = \sin(\pi\eta)$$



$$H(\lambda,\Phi) = \begin{cases} \cos^2\left(\pi\frac{\lambda-\lambda_0}{2\Delta\lambda}\right)\cos^2\left(\pi\frac{\Phi-\Phi_0}{2\Delta\Phi}\right) & \text{if } |\lambda-\lambda_0| \leq \Delta\lambda,\ |\Phi-\Phi_0| \leq \Delta\Phi \\ 0 & \text{if } |\lambda-\lambda_0| > \Delta\lambda,\ |\Phi-\Phi_0| > \Delta\Phi \end{cases}$$

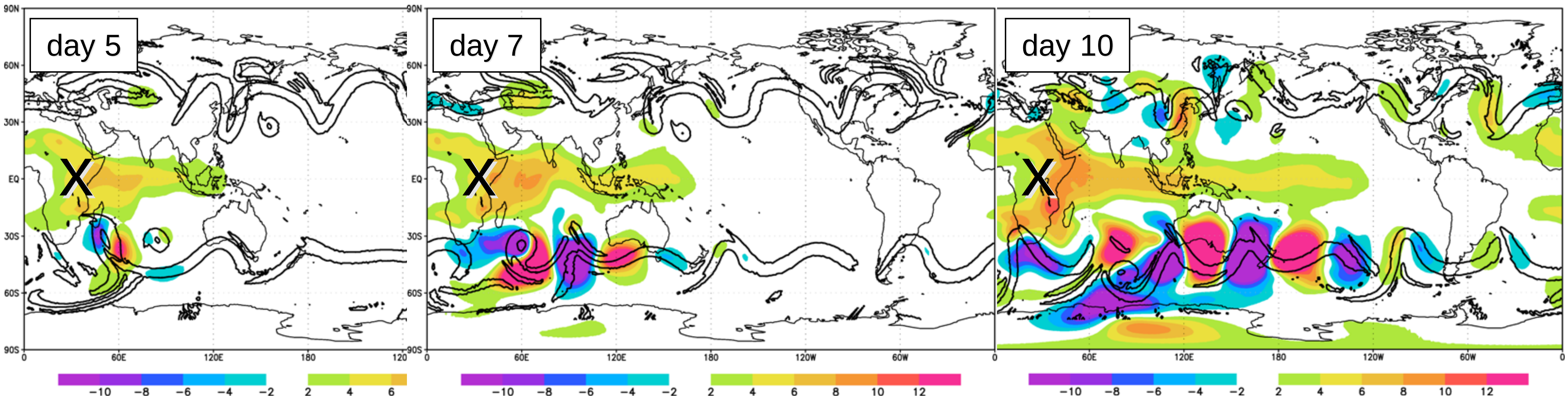
Method

- Integrating forced and unforced model runs
- Difference forced - unforced forecasts
- Diagnosing Geopotential height Z [dam] on 200 hPa
- ∇PV on 200 hPa exceeding 4 PVU/1000 km



Horizontal evolution

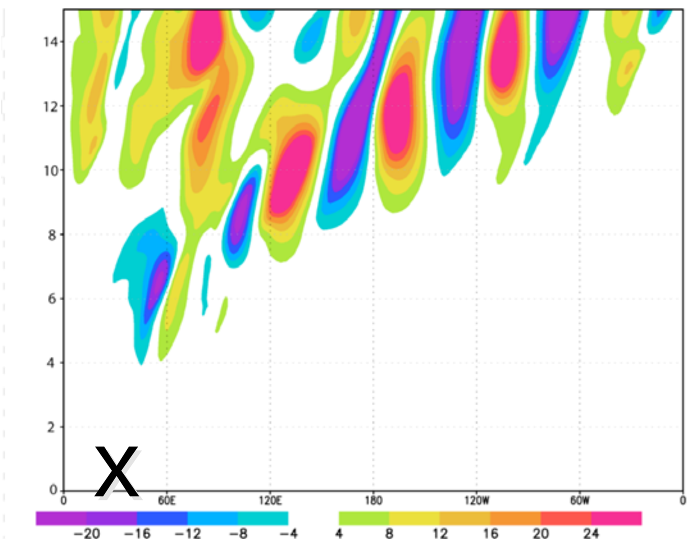
- Equatorial Kelvin-Rossby response
- Wave development along wave guide
- Asymmetry in hemispheric extent due to relative distance of forcing to wave guide



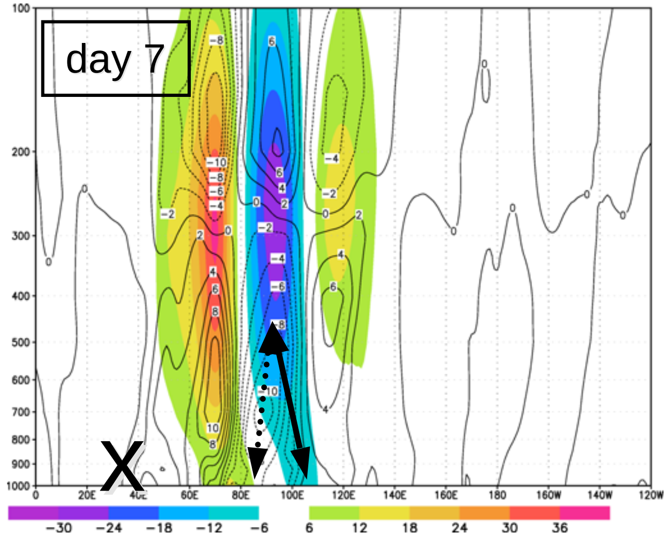
Vertical / Horizontal evolution

- Downstream development
- Westward tilt with height below 500 hPa
- Maximum perturbation at tropopause level
- C_{ph} = 9 m/s; C_g = 30 m/s

Hovmöller diagram ($Z_{30°\text{-}60°}$)



Vertical cross-section $(Z;T)_{45°}$



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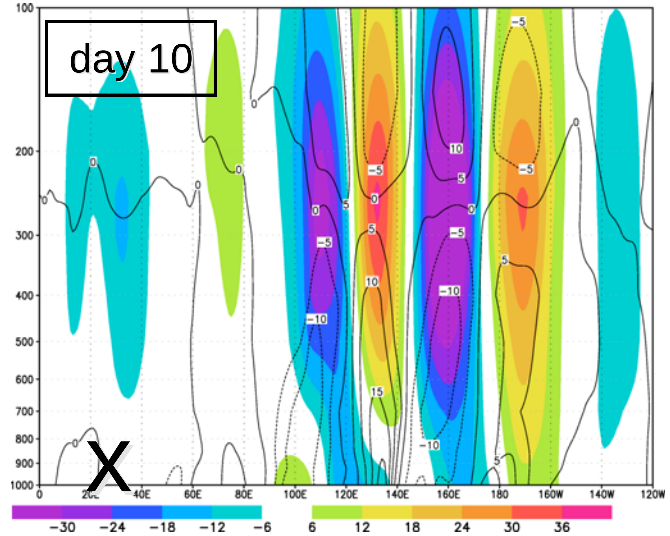
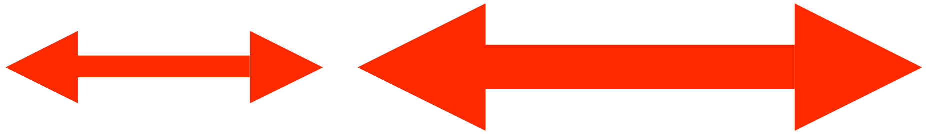


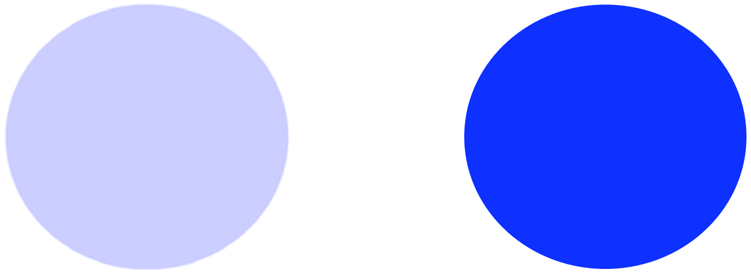
Sensitivities of response

Amplitude of response is depending linearly on:

Size of the forcing



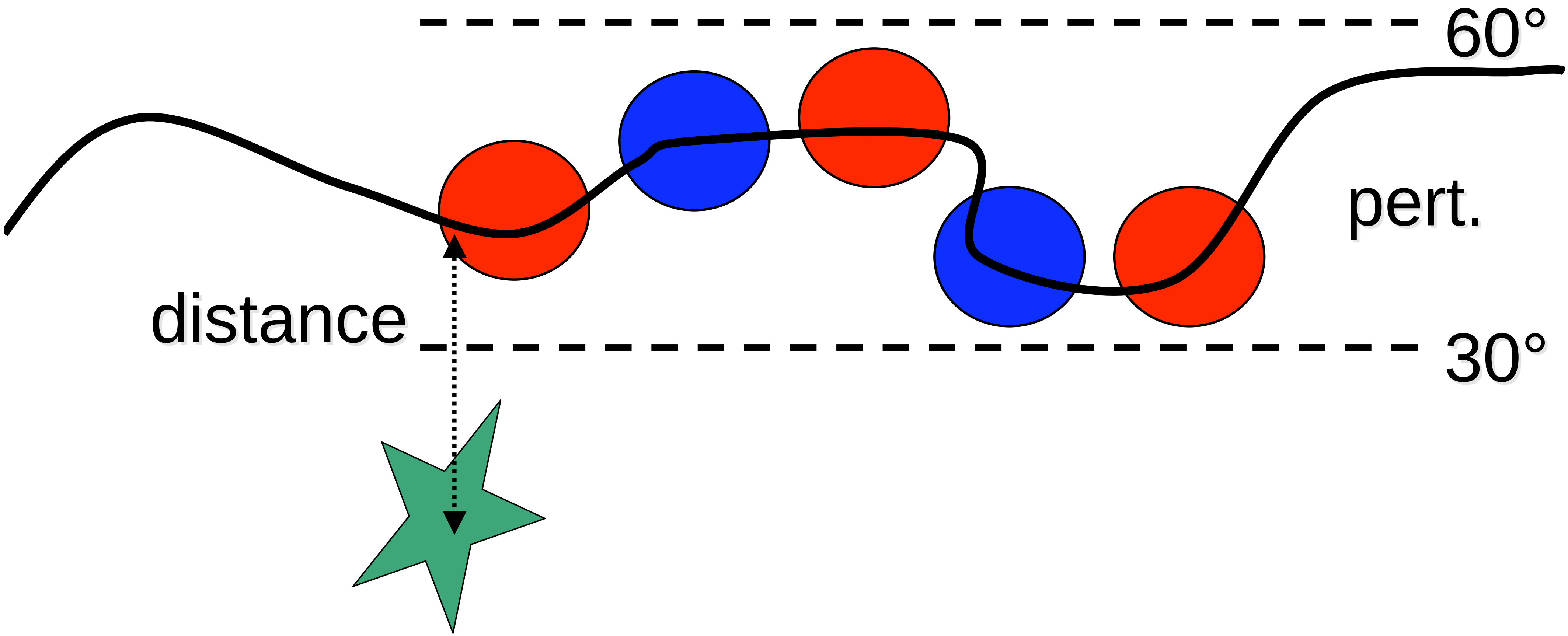
Amplitude of the forcing



Sensitivities of response

Distance of perturbation

Time of first detection/Amplitude of response

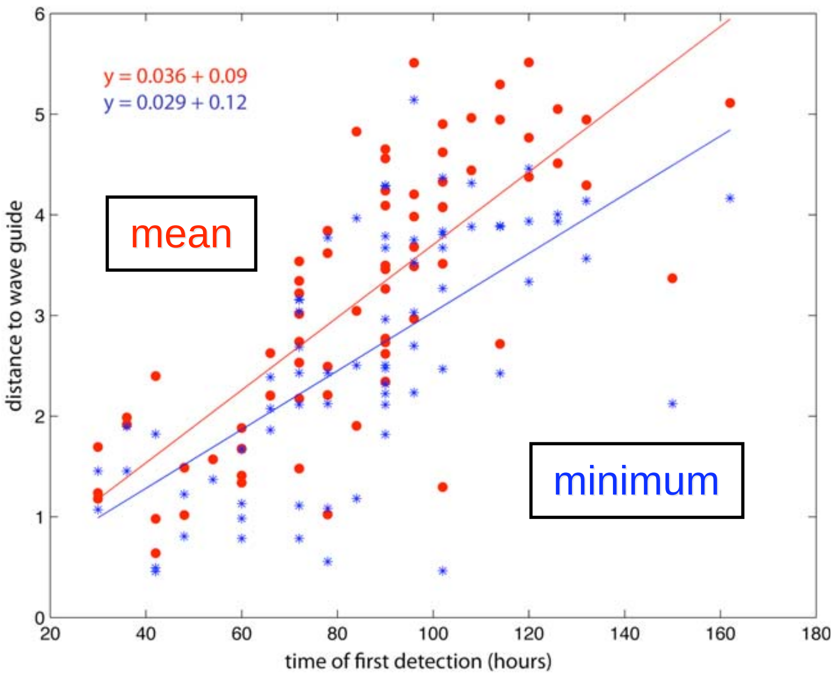


Sensitivities of response

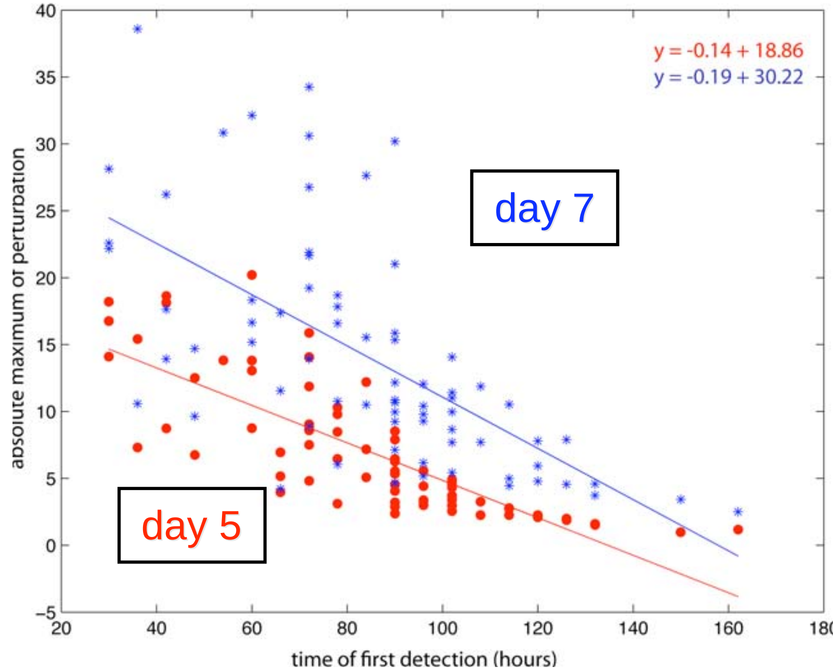
Quasi-linear Relationships:

- Distance of perturbation to wave guide
- Time of first detection/Amplitude of response

Time *vs* distance wave guide

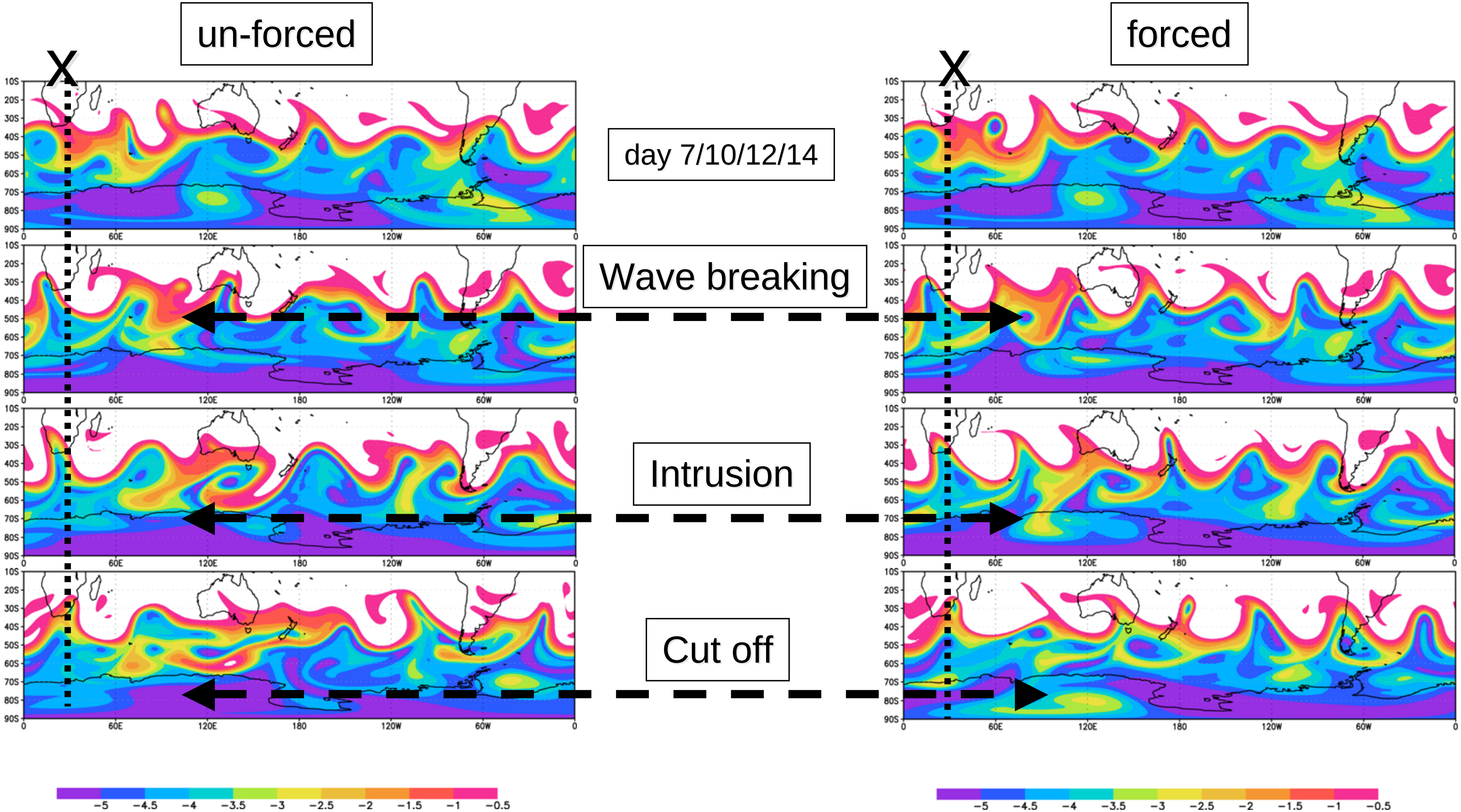


Time *vs* max amp. of pert.



Case of non-linear evolution

- Non-linear character of interaction



Non-stationary heating

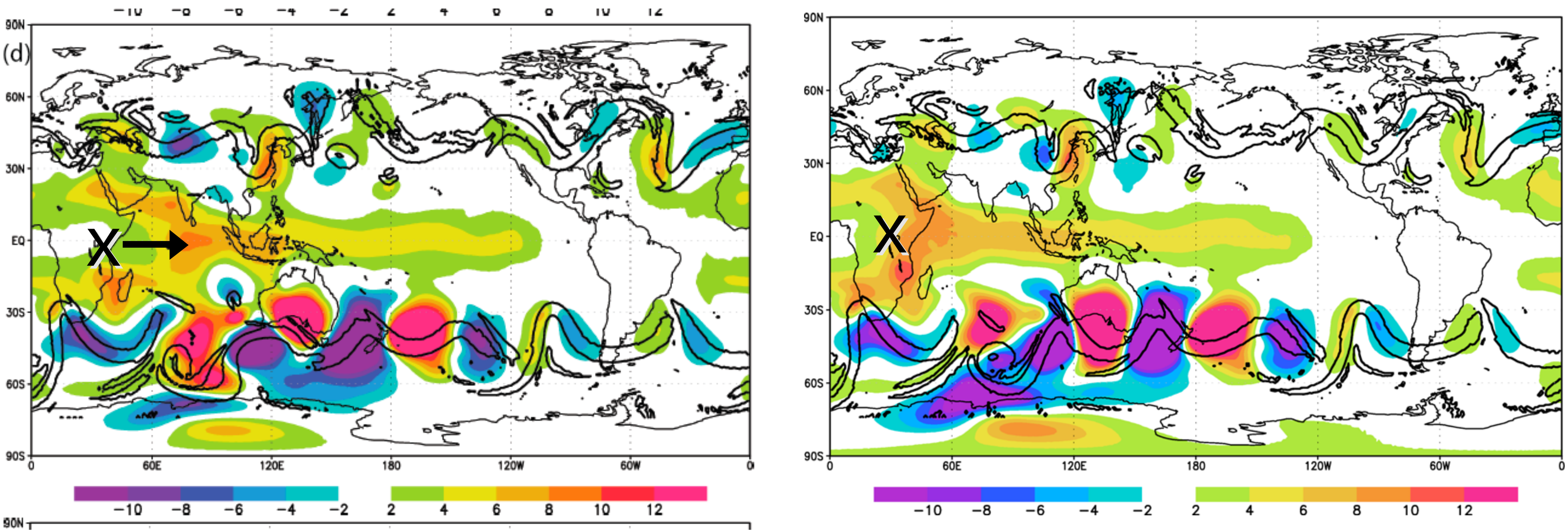
- Same experimental setup as before
- Heating is identical but moving (5 m s^{-1})
- Only 12 experiments centred at equator

- Compare results to stationary counterparts

Non-stationary heating

- Large qualitative agreement in response
- Amplitude varies depending on distance to wave guide

day 10



Summary

- Tropical heating initiates baroclinic downstream development along wave guide (Jet)
- Quasi-linear sensitivity to size and amplitude of forcing
- Sensitivity to the distance forcing <=> wave guide
- Migratory forcing results in similar response
- Character of pole-ward perturbations often non-linear