Conference on Teleconnections in the Atmosphere and Oceans

17 - 20 November 2008

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

Seasonal variability

(Teleconnection patterns [PNA, NAO …])

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

Storm damage by Lothar 1999
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
  \((T, \text{LNSP}, U, V, Z)\)
Zonally asymmetric basic state

300 hPa

Zonal Wind

m/s

IAC ETH Institute for Atmospheric and Climate Science

Trieste 2008 Thomas Spengler
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

\[ \text{lat} [-15^\circ, 0^\circ, 15^\circ] \quad \text{lon} [0^\circ, 30^\circ,...,330^\circ] \]

\[ V(\eta) = \sin(\pi \eta) \]

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

- Integrating forced and unforced model runs
- Difference forced - unforced forecasts
- Diagnosing Geopotential height $Z$ [dam] on 200 hPa
- $\nabla PV$ 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
- \( C_{ph} = 9 \text{ m/s}; \ C_g = 30 \text{ m/s} \)
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

Distance

pert.

30°

60°
Sensitivities of response

Quasi-linear Relationships:

- Distance of perturbation to wave guide
- Time of first detection/Ampplitude of response
Case of non-linear evolution

- Non-linear character of interaction

un-forced forced

day 7/10/12/14

Wave breaking
Intrusion
Cut off
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
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 $\leftrightarrow$ wave guide
- Migratory forcing results in similar response
- Character of pole-ward perturbations often non-linear