UNIVERSITY OF CAMBRIDGE
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CP and EP ENSO teleconnections in an idealised atmospheric GCM

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NERC SCIENCE OF THE ENVIRONMENT

Aim

Explore dynamical processes and pathways linking the tropics and extratropics in Central Pacific (CP) and East Pacific (EP) ENSO events.

Method

Use a simplified atmospheric model to limit and control the processes in idealised experiments, with heating in the tropical 'Pacific' troposphere to represent ENSO events with various magnitudes and locations.

Atmospheric model

Reading GCM1 dry dynamical core, spectral T42 L40
Primitive equations, no land

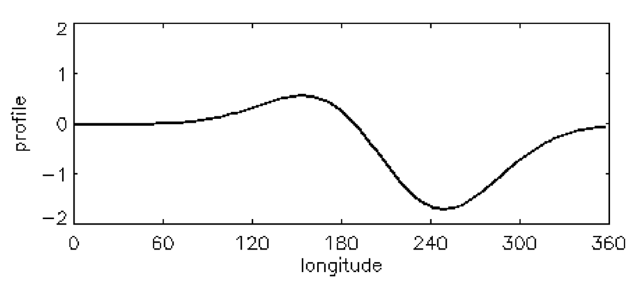
Only simple thermal forcing:
relaxation toward prescribed Tref(long, lat, σ, t)

$$dT/dt = \dots + (\text{Tref} - T)/\tau$$

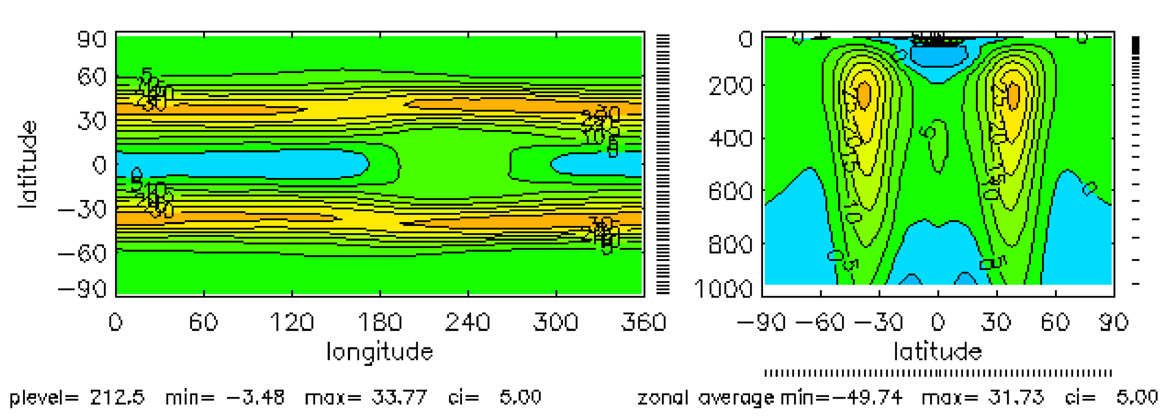
Background state:

start with zonally uniform Tref(latitude, σ, t) (as in Held & Suarez, BAMS 1994)

add longitudinal structure to Tref in the tropics ('warm pool' and 'cold tongue') to obtain a Walker circulation in the 'Pacific'



Longitudinal modification of Tref

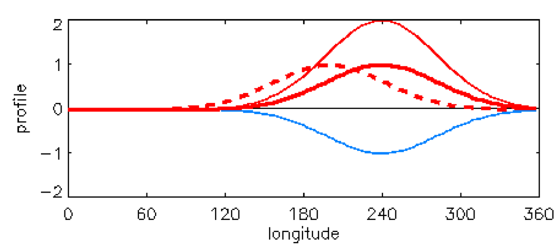


Zonal winds in the zonally asymmetric basic state

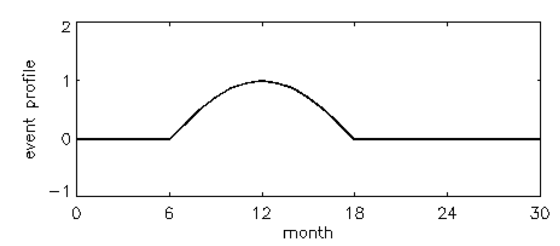
ENSO design

For El Niño, add extra heating by altering Tref in a patch in the tropical east (EP event) or central (CP) Pacific in the troposphere.
For La Niña, similarly decrease Tref .

Cases:
0 no event
A moderate EP El Niño: thick red line below
B moderate CP El Niño (patch shifted 40 degrees westward): dashed
C large EP El Niño (patch doubled) thin red line
D moderate EP La Niña (patch sign reversed) blue



Longitudinal shape of Tref anomaly

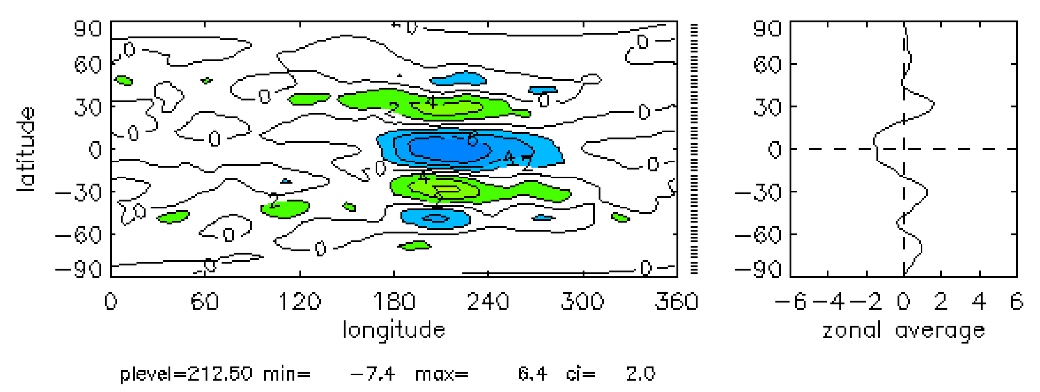


Event time profile

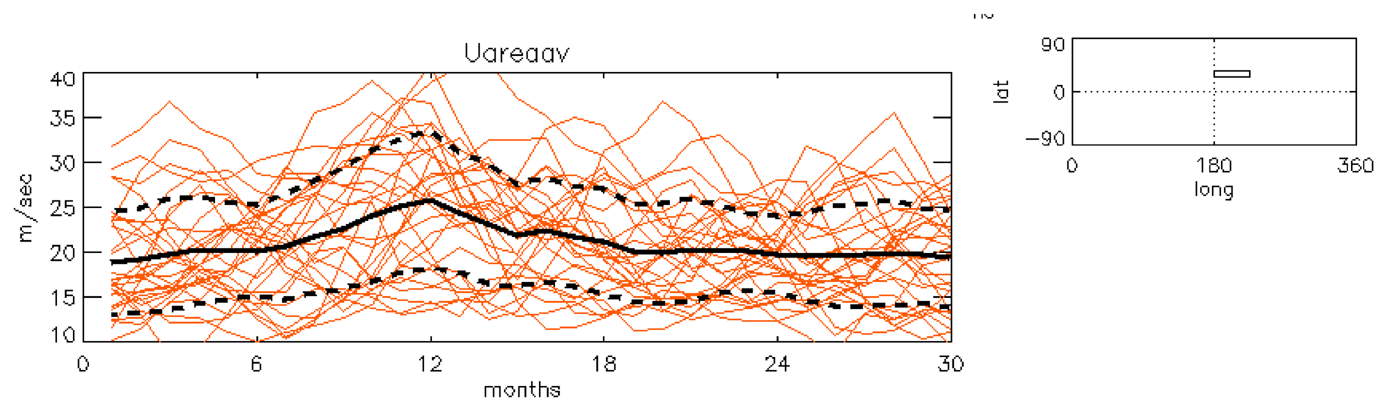
Time dependence:
events each last from month 6 to month 18, peak at month 12 ; repeating every 30 months to create a sequence (ensemble) of events in a long model run

Results: here we focus on the geopotential and subtropical jet behaviour in experiments with an equinox background state

Case (A) moderate EP event:

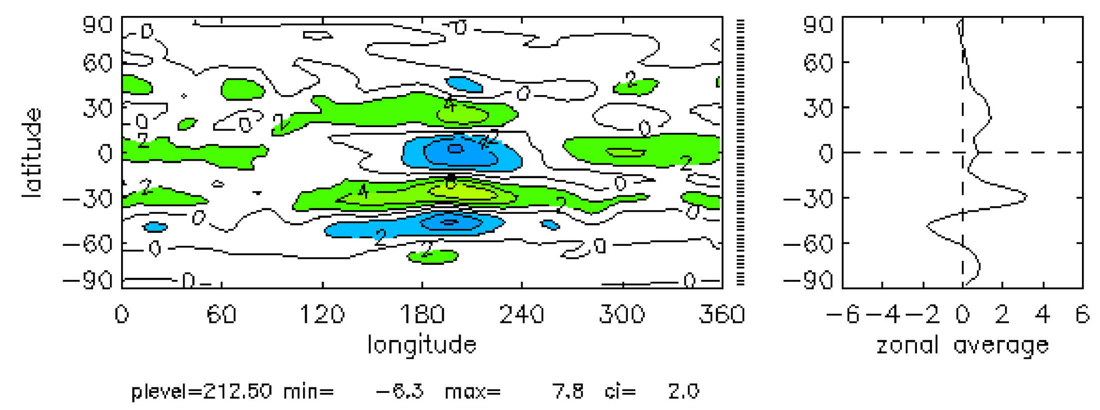


Zonal wind U at ~200hPa: difference [case(A)-case(0)] at peak of event ensemble mean
- equatorial easterly anomaly (Walker cell strength reduced)
- subtropical jet strengthens at heating longitude, shifts equatorward a bit



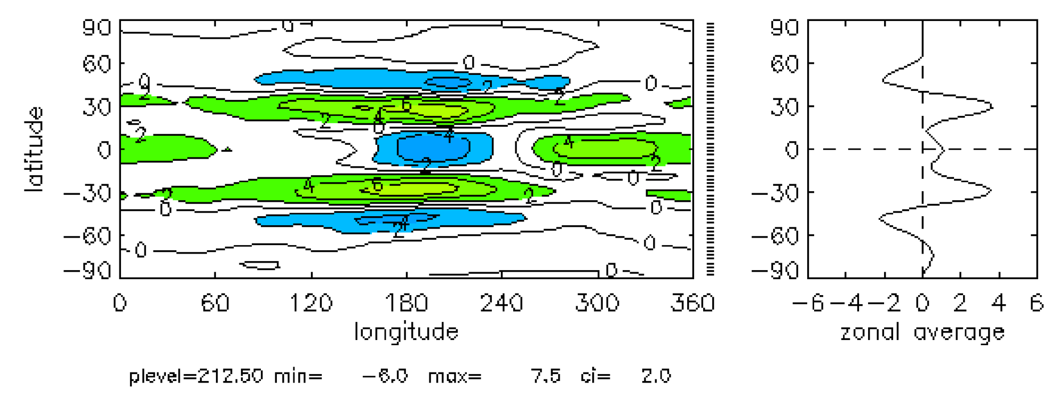
U at ~200hPa: area average for 30 sequences:
thick line is ensemble mean,
dashed lines +- 1 standard deviation; thin lines: individual sequences
- here U increases during event, returns quickly to normal, atmosphere is in quasi-equilibrium with forcing
- standard deviation increases slightly during event
- there is a lot of 'noise'

Case (B) moderate CP event: is response just shifted west by 40 degrees?



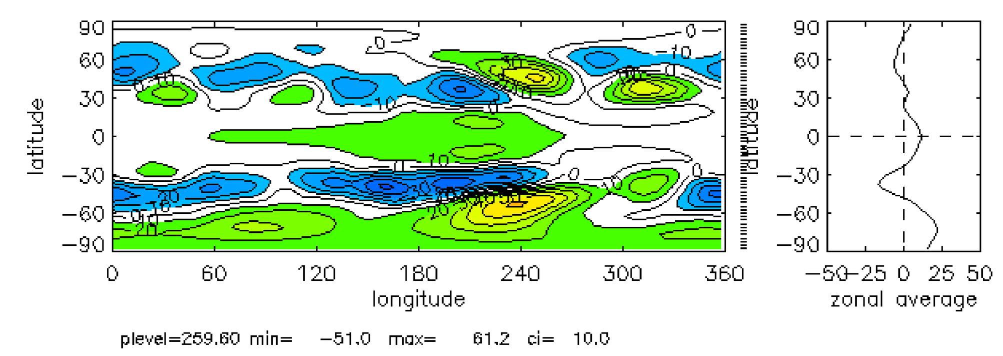
U at ~200hPa: difference [case(B)-case(0)] at peak of event, ensemble mean
- shift in response is less than 40 degrees
- but north-south asymmetry implies sample size issue

Compare with response to constant forcing at peak of case (B):



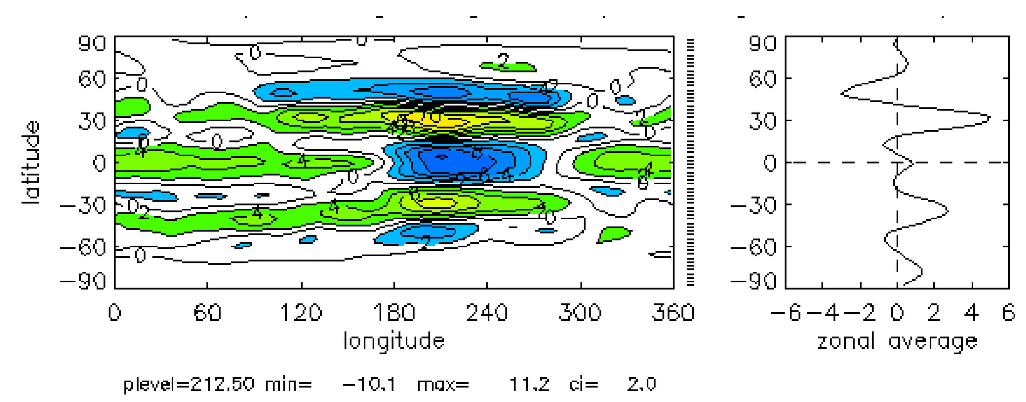
U at ~200hPa: large sample, peak case (B) forcing - case(0)
- has close north-south symmetry
- similar to tropics and southern extratropics in previous figure

Geopotential fields: shifted (B) minus (A):



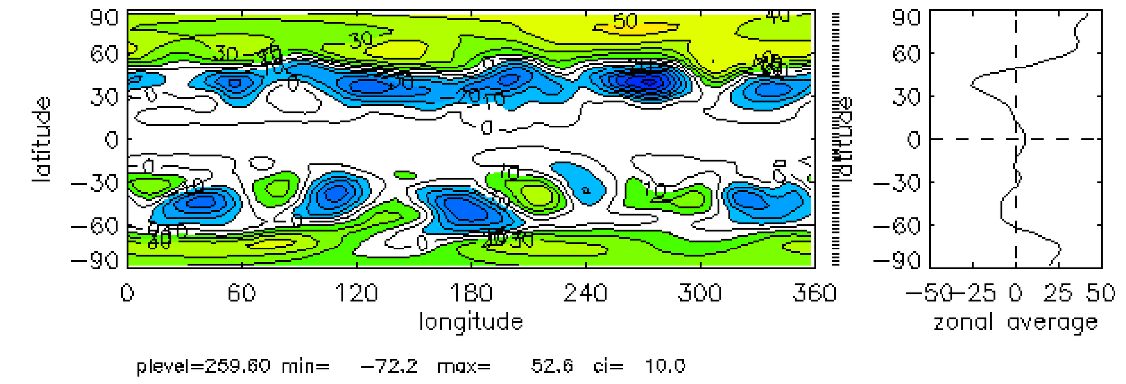
Geopotential height ~260hPa: at peak of event, ensemble mean
[case(B)-case(0)] shifted back 40 degrees east, minus
[case(A)-case(0)]
- is this just the difference in the linear response to forcing at different locations in a zonally varying background state?

Case (C) Strong EP event: is response just doubled?



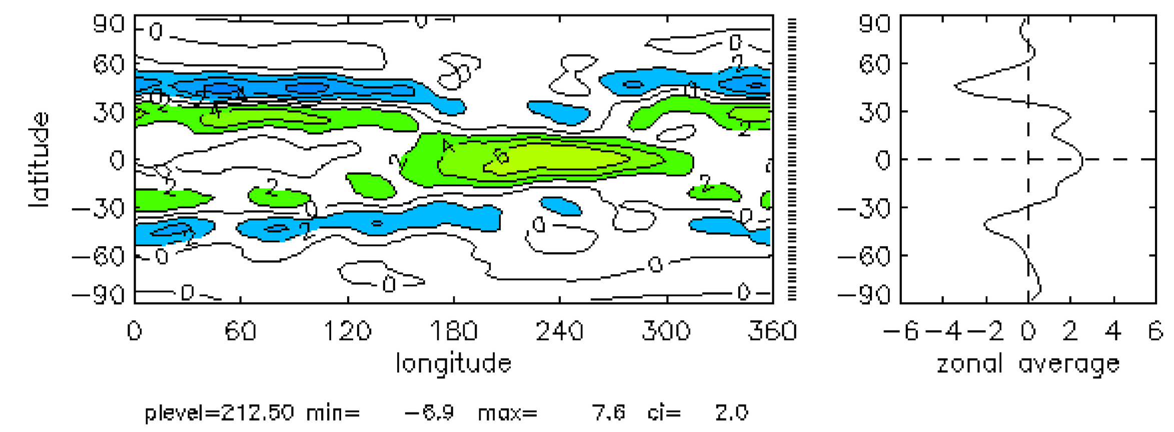
U at ~200hPa: difference [case(C)-case(0)] at peak of event, ensemble mean
- looks like stronger version of case (A)
- but note difference in equatorial zonal average

Case (C) continued:

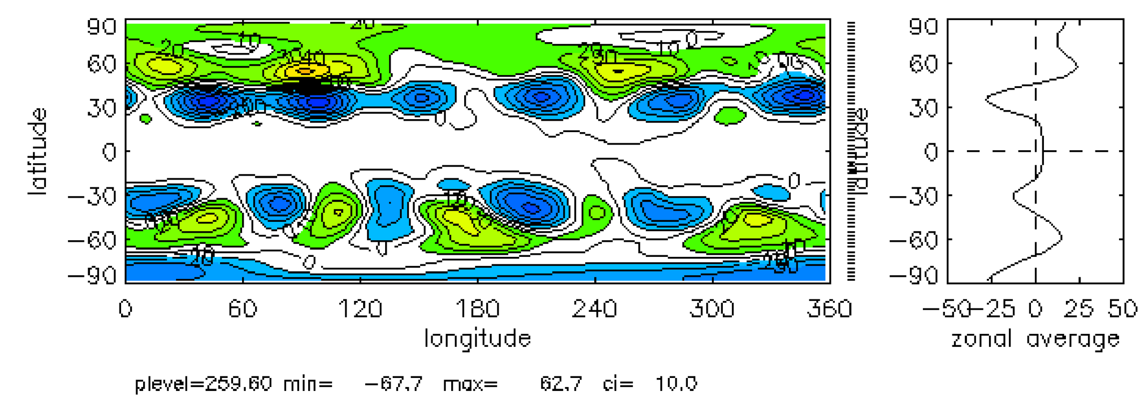


Geopotential ~260hPa: [case(C)-case(0)] minus twice [case(A)-case(0)] at peak of events, ensemble mean
- zero if linear
- cancellation in equatorial strip
- differences in extratropics: wave mean flow interaction

Case (D) moderate EP La Nina: is response just reversed?



U at ~200hPa: difference [case(D)-case(0)] at peak of event, ensemble mean: cf case A: different extratropical pattern



Geopotential at ~260hPa: case(D) plus case (A) at peak of event, ensemble mean: sum to zero if linear response to forcing
- cancellation in equatorial strip
- differences in extratropics: zonal mean and wavelike features, is k~5 robust?

Discussion: some emerging questions

The response to the ENSO-like forcing is a combination of zonally symmetric effects (cf Tandon et al. JClimate 2013), zonally asymmetric linear Rossby wavetrains, and wave mean flow interactions with longitudinal structure. The relative contribution of these effects needs to be quantified.

To what extent is the overall response to varying the forcing amplitude linear in this nonlinear system? Results suggest the extratropics are nonlinear in this respect for large variations: to be investigated further.

Results suggest a preferred wavelike structure in the extratropics (cf Branstator JClimate 2002): is this robust, and how might it relate to the tropical forcing structure?

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