



MINISTÉRIO DA CIÊNCIA E TECNOLOGIA  
**INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS**

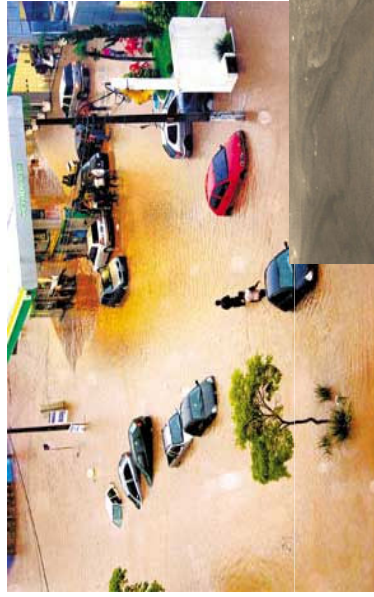
# **LARGE-SCALE CHANGES IN PRECIPITATION AND TEMPERATURE IN SOUTH AMERICA UNDER CLIMATE CHANGE - ENSEMBLE CLIMATE MODEL PROJECTIONS AND UNCERTAINTY ASSESSMENTS**

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Kay, Chou Sin Chan**

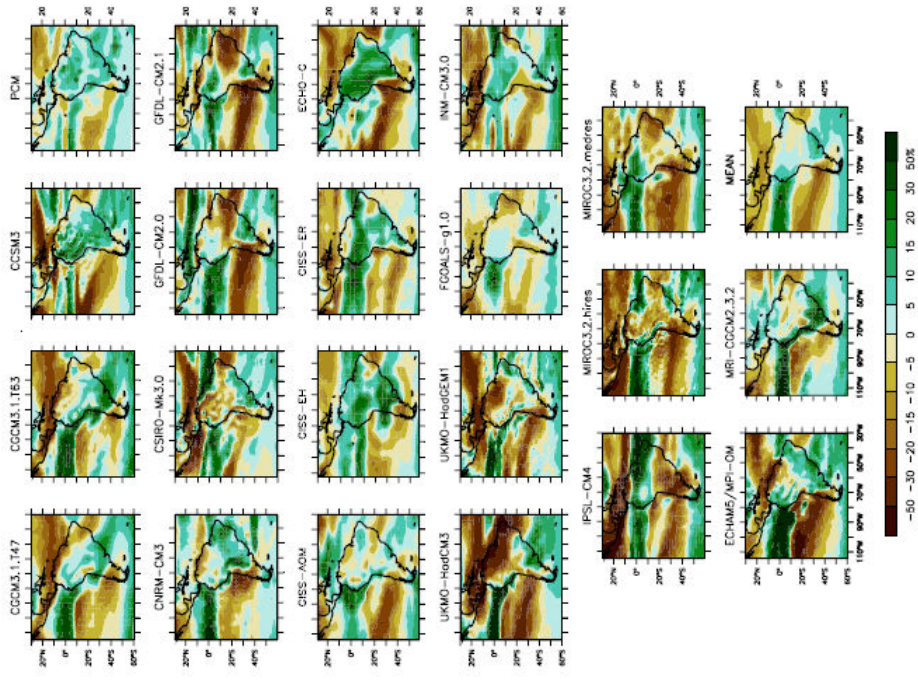
II Entrenamiento en Modelado Numérico de Escenarios de Cambio Climático  
Cachoeira Paulista - São Paulo - Brazil  
**02/Set/2009**

# MOTIVATION

Direct Observations



IPCC AR4  
Climate Change Projections



# Outline

- Uncertainty on uncertainty
- Perturbed Physics Ensembles ("QUMP")
- Ongoing work

# The uncertainty "cascade"

## Predicting the impacts of climate change

### Emissions

Scenarios from population, energy, economics models

### Concentrations

CO<sub>2</sub>, methane, sulphates, etc.

Carbon cycle and chemistry models

### Global climate change

Temperature, rainfall, pressure, etc.

Coupled global climate models

### Regional detail

Mountains, coasts, extreme weather, etc.

Regional climate models

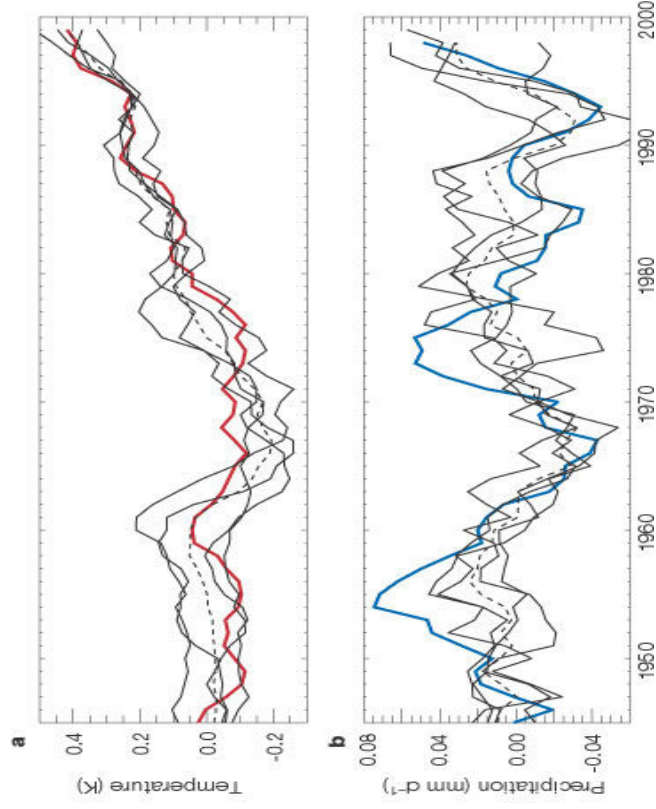
### Impacts

Flooding, drought, food supply, etc.

Impacts models

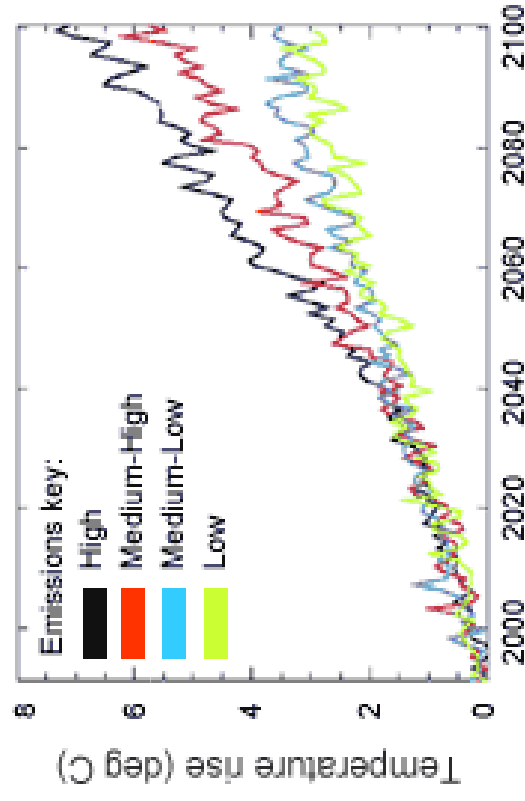
# Ensemble simulations

- Enable exploration of the different uncertainties
  - Initial conditions (chaos)



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  - Boundary conditions (response to external forcings)

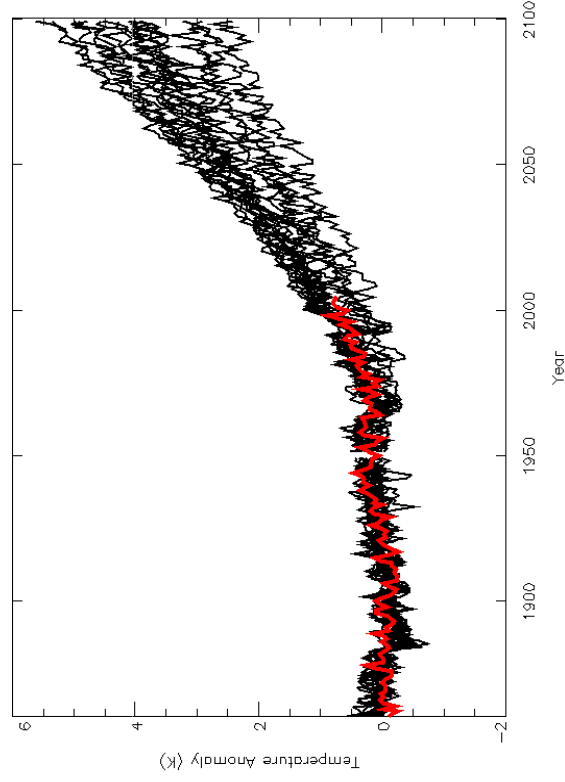




# Ensemble simulations

- Enable exploration of the different uncertainties

Global mean temperature change



- Initial conditions (chaos)
- Boundary conditions (response to external forcings)
- Different model structures ("ensembles of opportunity")
- Different process representations (perturbed physics)

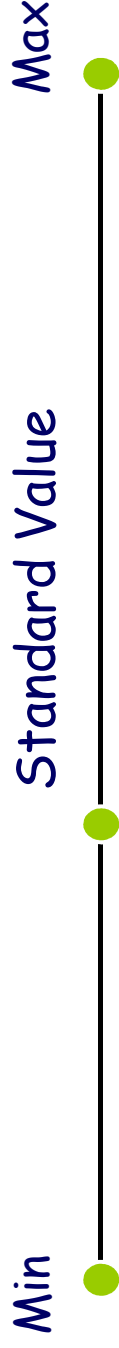


# Perturbed physics approach

- The perturbed physics approach allows uncertainties (in various components of the model) to be systematically explored.
- This is done by:
  - Identifying parameters in the model which are both uncertain and important for the model response
  - Using an ensemble of models to explore the implications of these parameter uncertainties

The QUMP ensemble

# Parameter Perturbations



- 29 parameters, 300+ ensemble members (some parameters are switches)
- Parameters and their ranges determined by expert elicitation

# Parameter Perturbations

## Large Scale Cloud

Ice fall speed  
Critical relative humidity for formation  
Cloud droplet to rain: conversion rate and threshold  
Cloud fraction calculation

## Convection

Entrainment rate  
Intensity of mass flux  
Shape of cloud (anvils) (\*)  
Cloud water seen by radiation (\*)

## Radiation

Ice particle size/shape  
Cloud overlap assumptions  
Water vapour continuum absorption (\*)

## Boundary layer

Turbulent mixing coefficients: stability-dependence, neutral mixing length  
Roughness length over sea: Charnock constant, free convective value

## Dynamics

Diffusion: order and e-folding time  
Gravity wave drag: surface and trapped lee wave constants  
Gravity wave drag start level

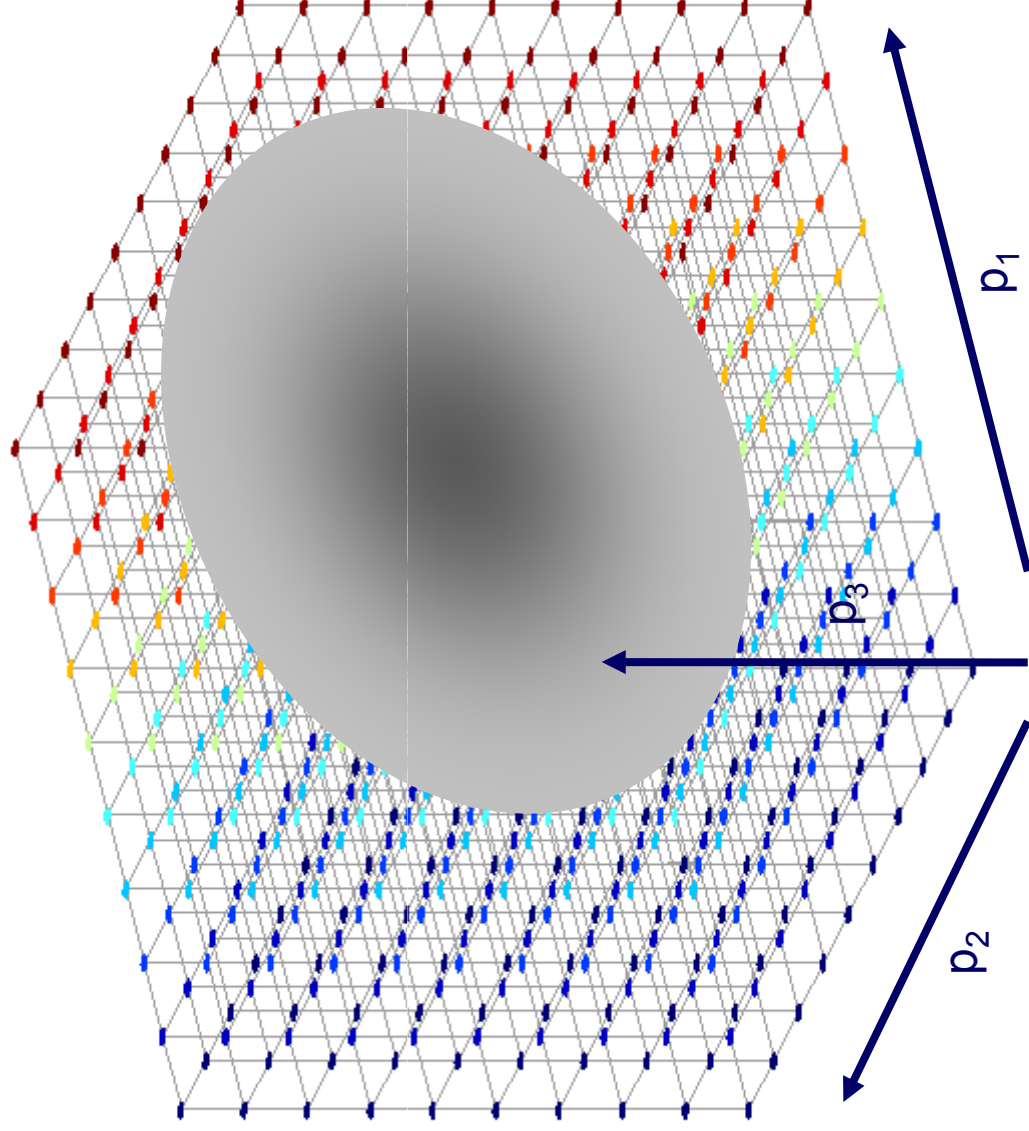
## Land surface processes

Root depths  
Forest roughness lengths  
Surface-canopy coupling  
CO<sub>2</sub> dependence of stomatal conductance (\*)

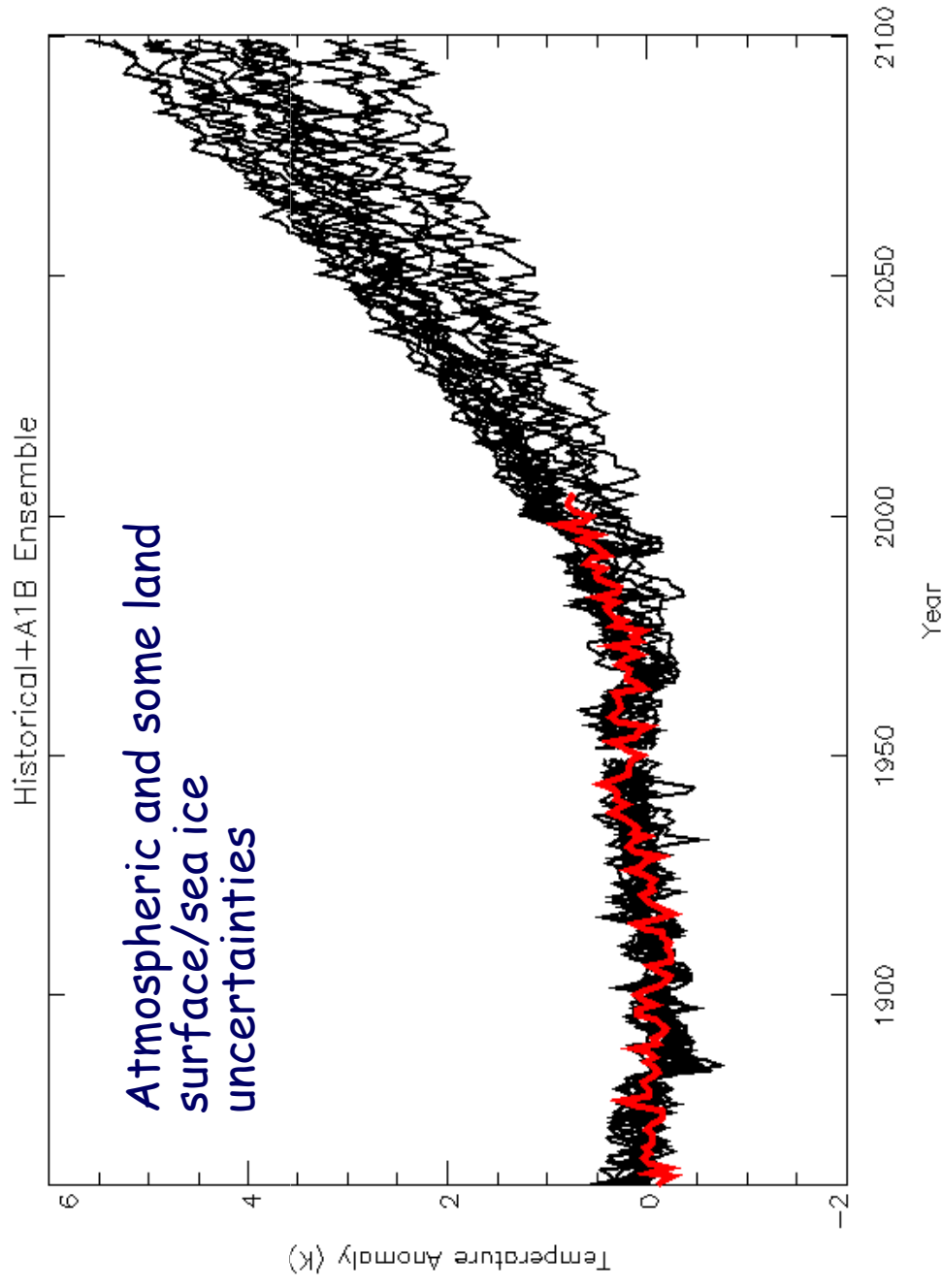
## Sea ice

Albedo dependence on temperature  
Ocean-ice heat transfer

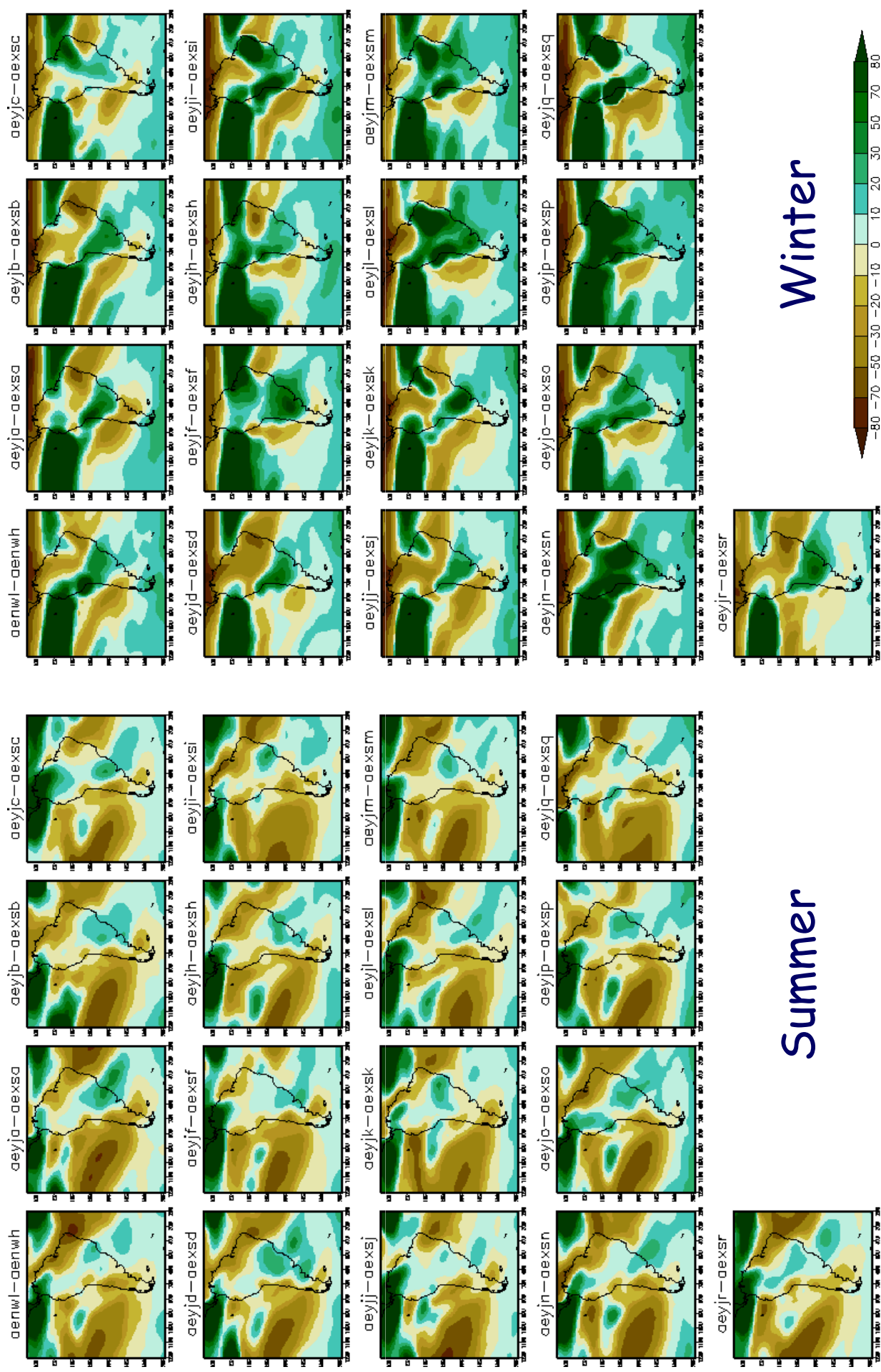
# Effect of physics perturbations on climate



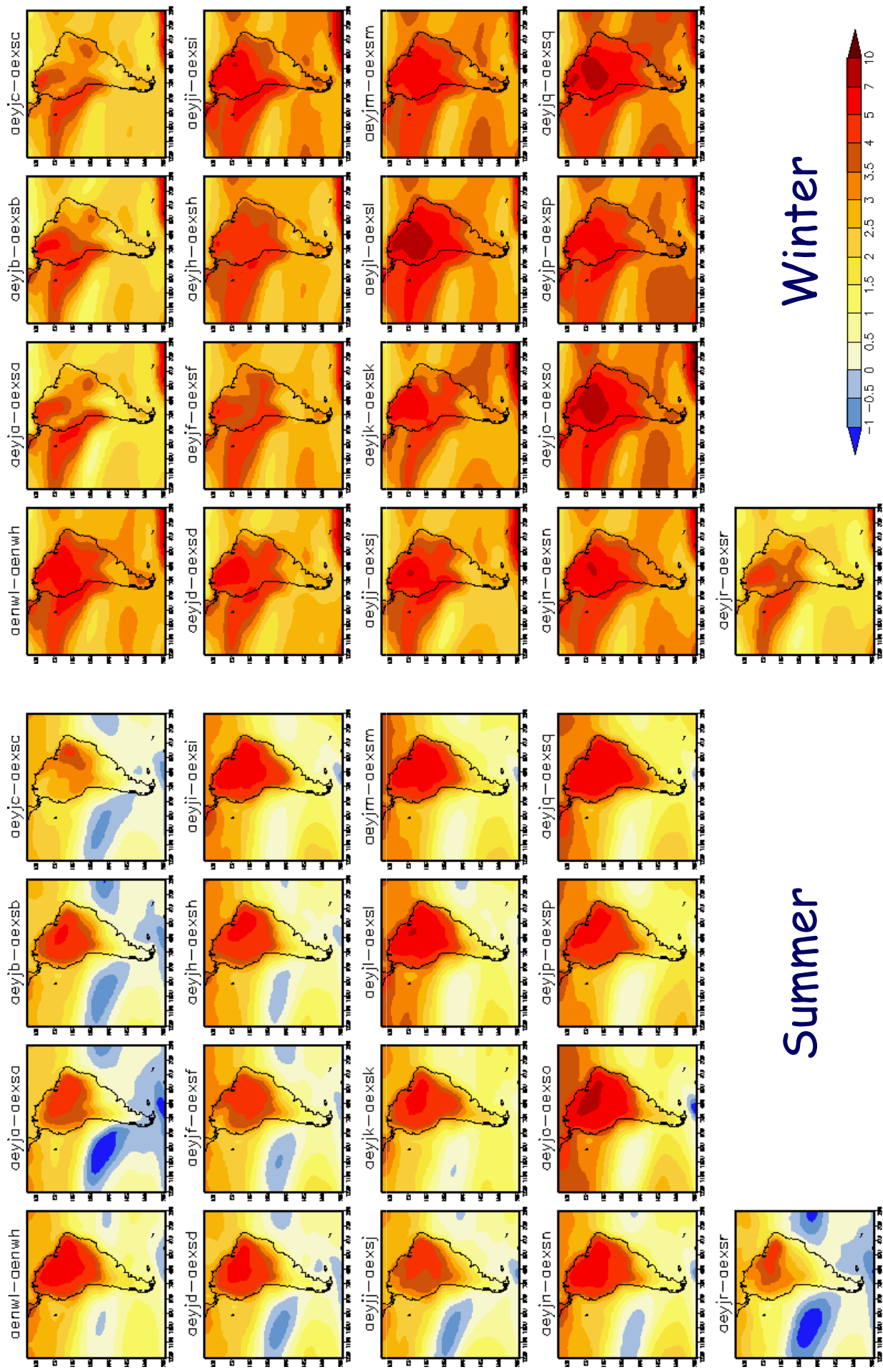
# Global mean temperature rise over 21<sup>st</sup> century



# Precipitation change (%) for 2071-2099 relative to 1961-1989 over South America from the PPE (SRES A1B scenario)



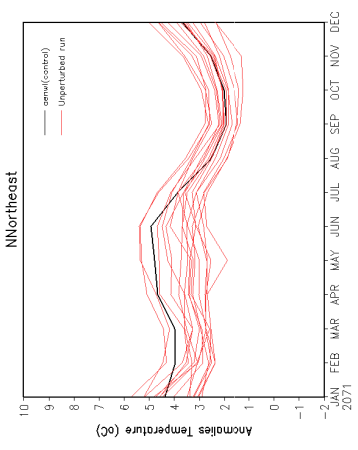
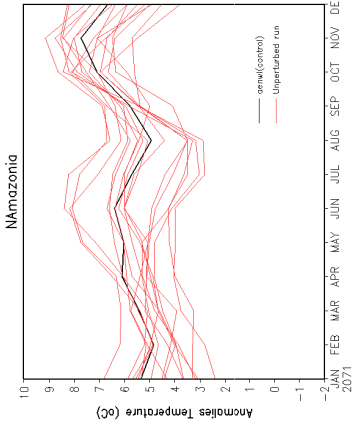
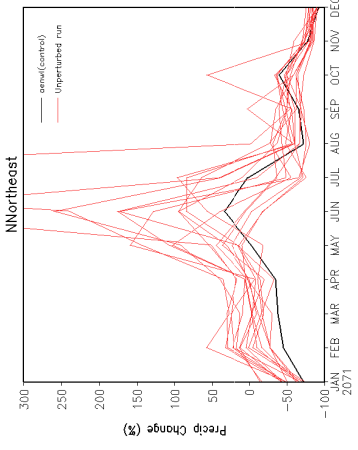
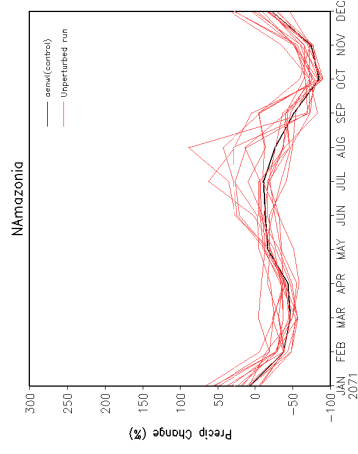
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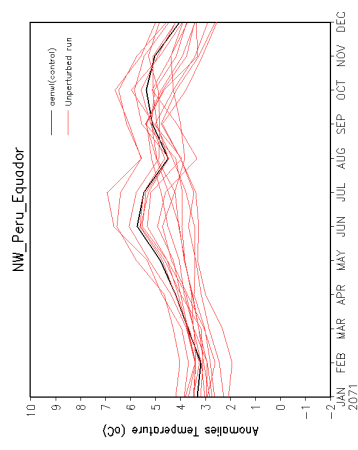
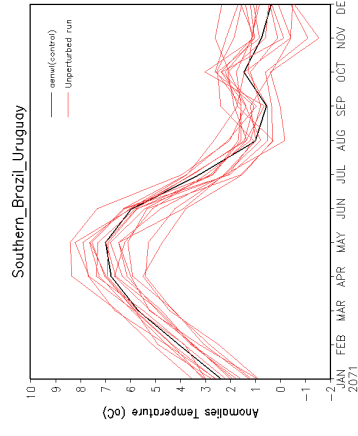
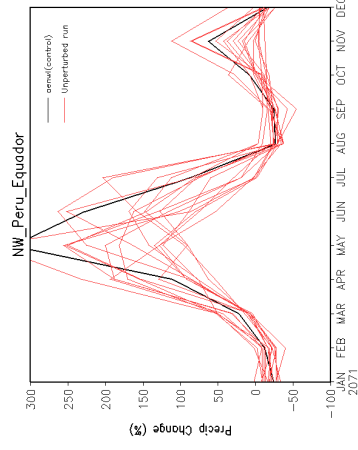
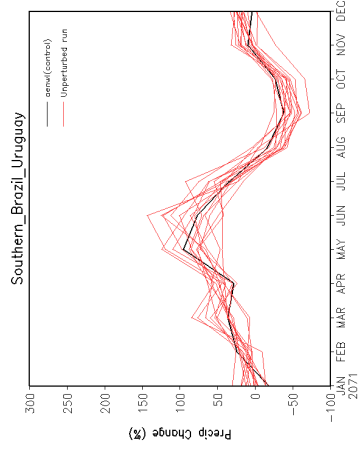


# Annual cycle from the PPE (SRES A1B scenario) for selected land regions over South America

precipitation change (%)



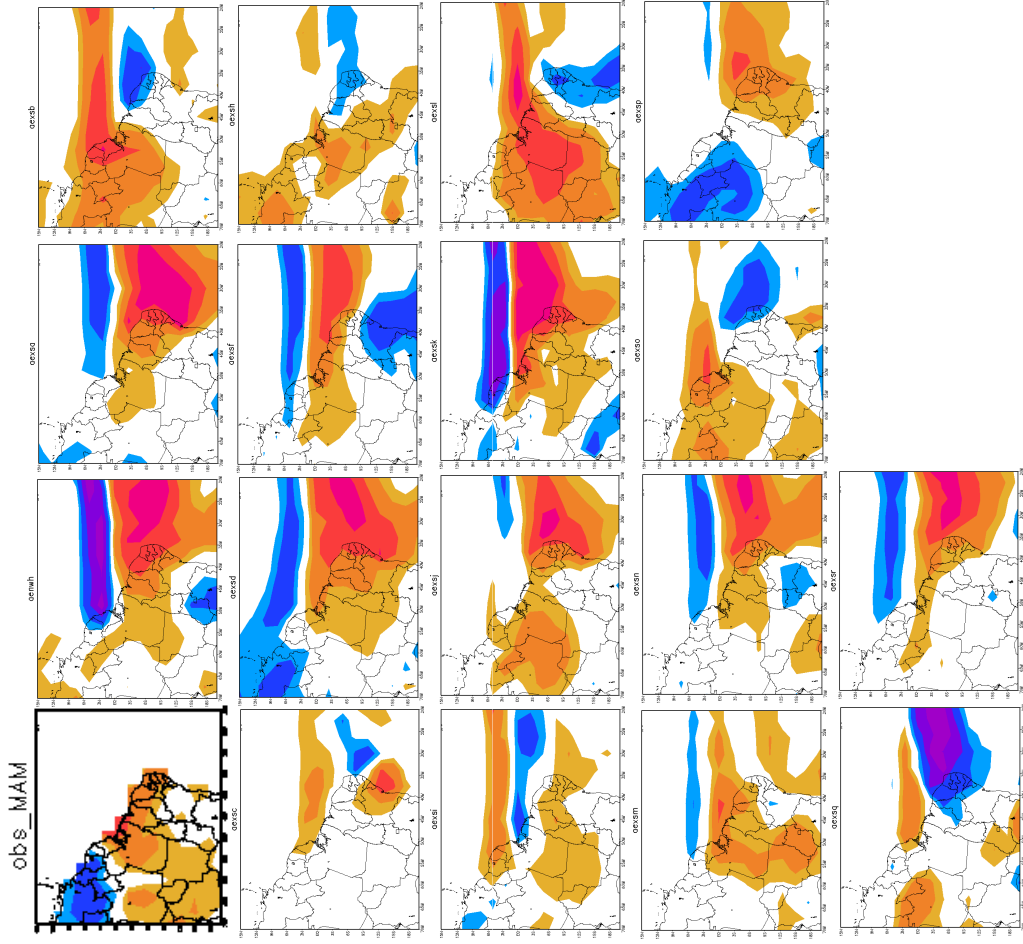
temperature anomalies (oC)





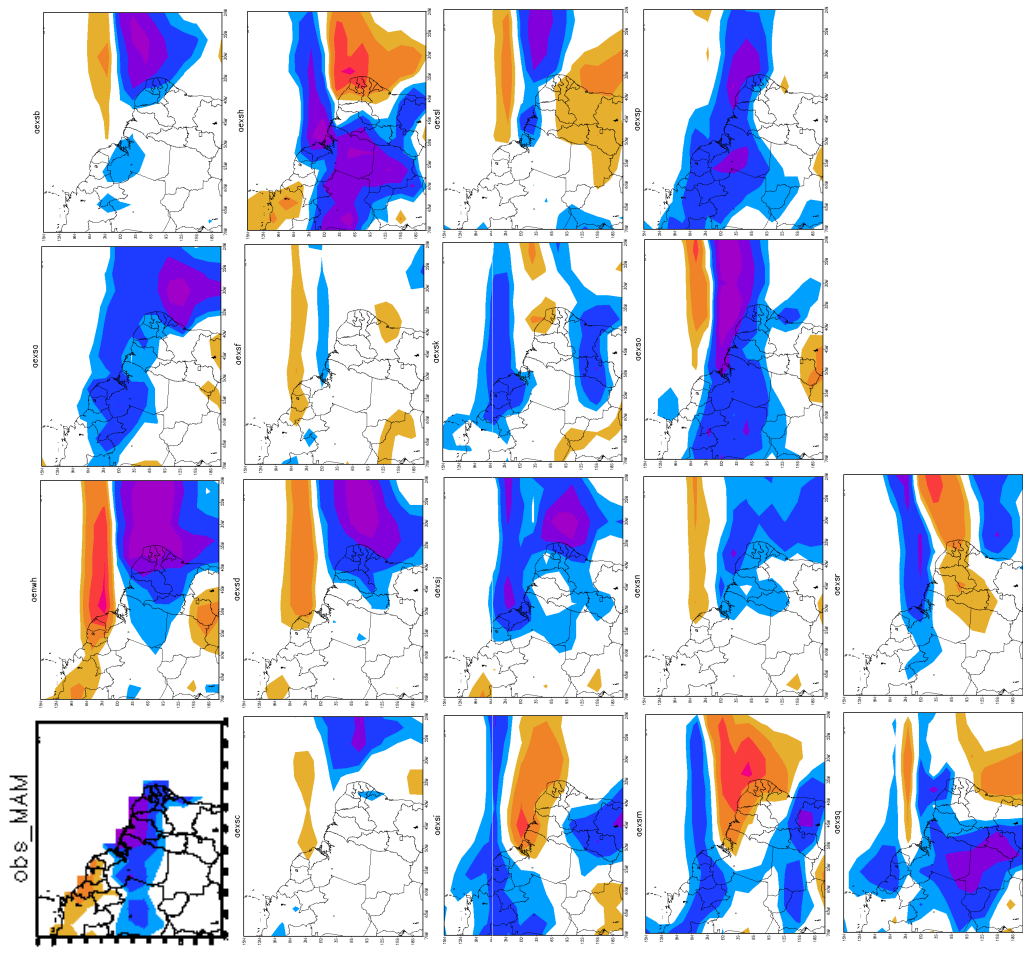
# ENSO Episodes

## EL NINO



Composite of several years:  
1963/65/68/69/72/83/87

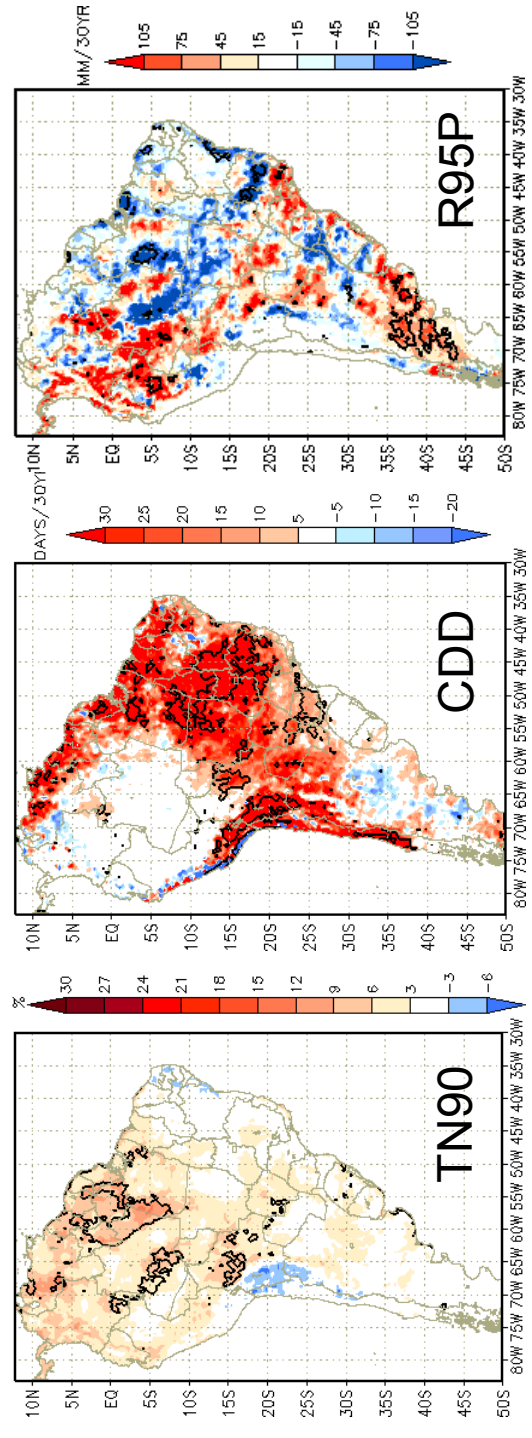
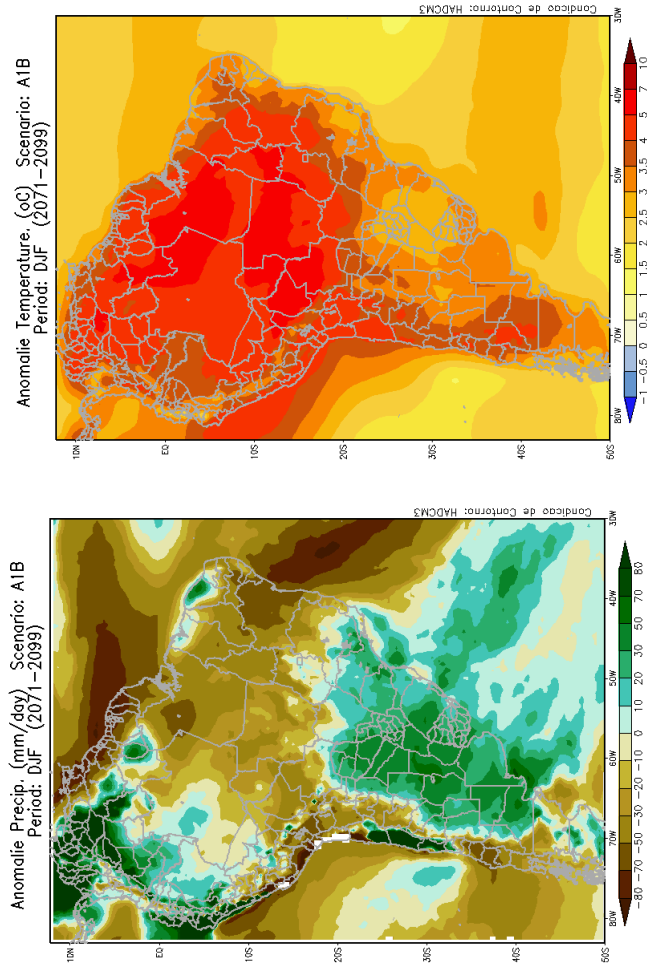
## LA NINA



Composite of several years:  
1962/64/71/74/85/89

Ongoing work...

# Precipitation and Temperature change over South America from A1B Eta simulation.



Projected trends of extreme climate indices for 2071-2099 relative do 1961-89. Panels a-f show projections for the A1B scenario

# SUMMARY

- The ensemble members share to a greater or lesser extent the tendency towards an enhanced El Niño-like state in the future
- In all of the PPE members warming is projected over the 21st century, with enhanced warming over land
- The ensemble produces a range of regional changes much wider than indicated by traditional methods based on scaling the response patterns of an individual simulation;
- The ensemble technique a necessary tool to reduce the effect of Boundary Conditions;
- There can be large differences between the PPE members in the projections of future climates over Brazil. These uncertainties in projections can be explored in finer detail using dynamical downscaling.
- Without appropriate regional projections of climate change, it is arguable whether regional adaptation strategies can be developed or implemented.

**Thank you! Obrigado! Gracias!**

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