The Western Pacific Monsoon

Results from climate simulations of present and future wet seasons

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Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

Overview of talk

Description of general features of the WPM and how they are simulated by AOGCM such as from CMIP3:

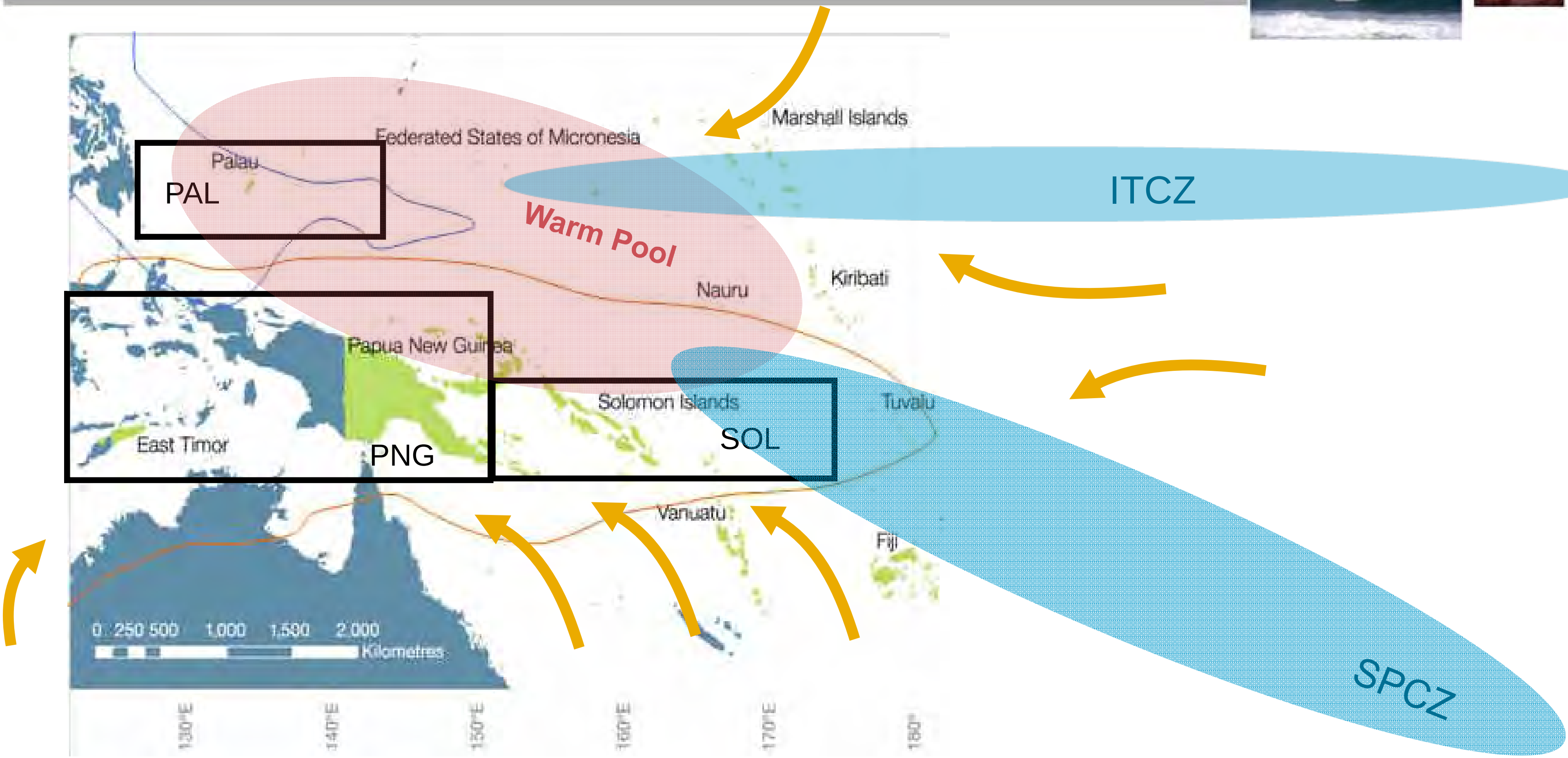
- **Climatology of rainfall and winds**
- **Annual cycles of rainfall**
- **Easterly extend of the monsoon domain.**

Data sources:
OBS (CMAP, GPCP)
Reanalysis (NCEP, ERA40)
CMIP3 GCM simulations

For individual countries: see posters from PCCSP partner countries

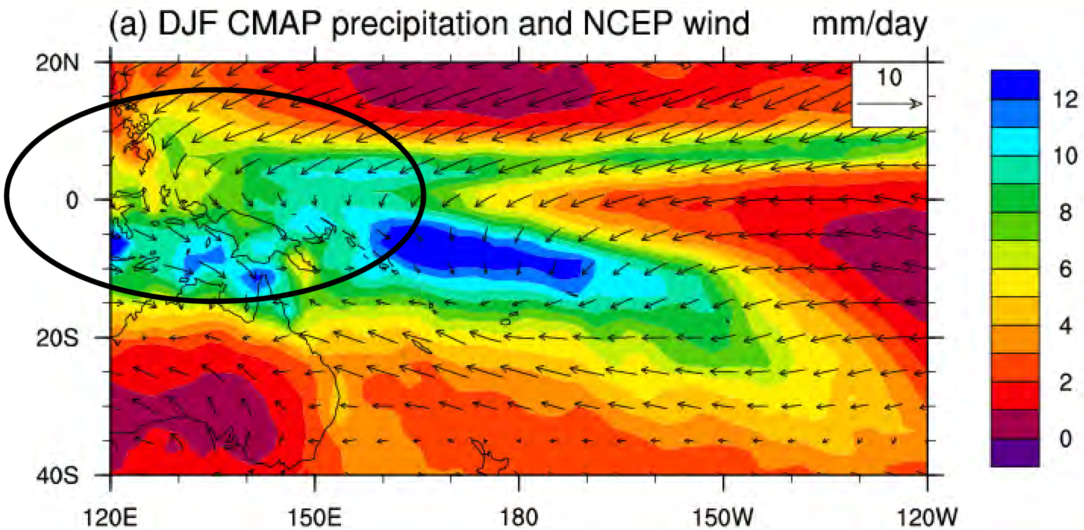
I.N. Smith, A. Moise and R. Colman (2011) An assessment of climate model simulations of the climate of the Western Pacific monsoon region. (in preparation)

Domains

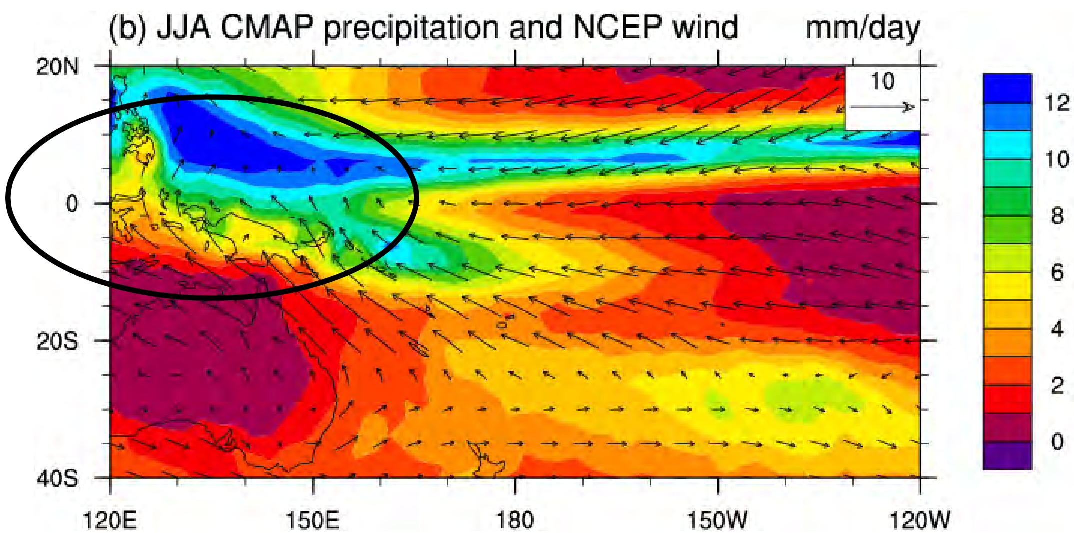


Marshall Islands
Federated States of Micronesia
Palau
PAL
ITCZ
Warm Pool
Nauru
Kiribati
Papua New Guinea
Solomon Islands
Tuvalu
SOL
East Timor
PNG
Vanuatu
Fiji
SPCZ
0 250 500 1,000 1,500 2,000
Kilometres
130°E
140°E
150°E
160°E
170°E
180°

Climatology of Rainfall and Winds in WPM



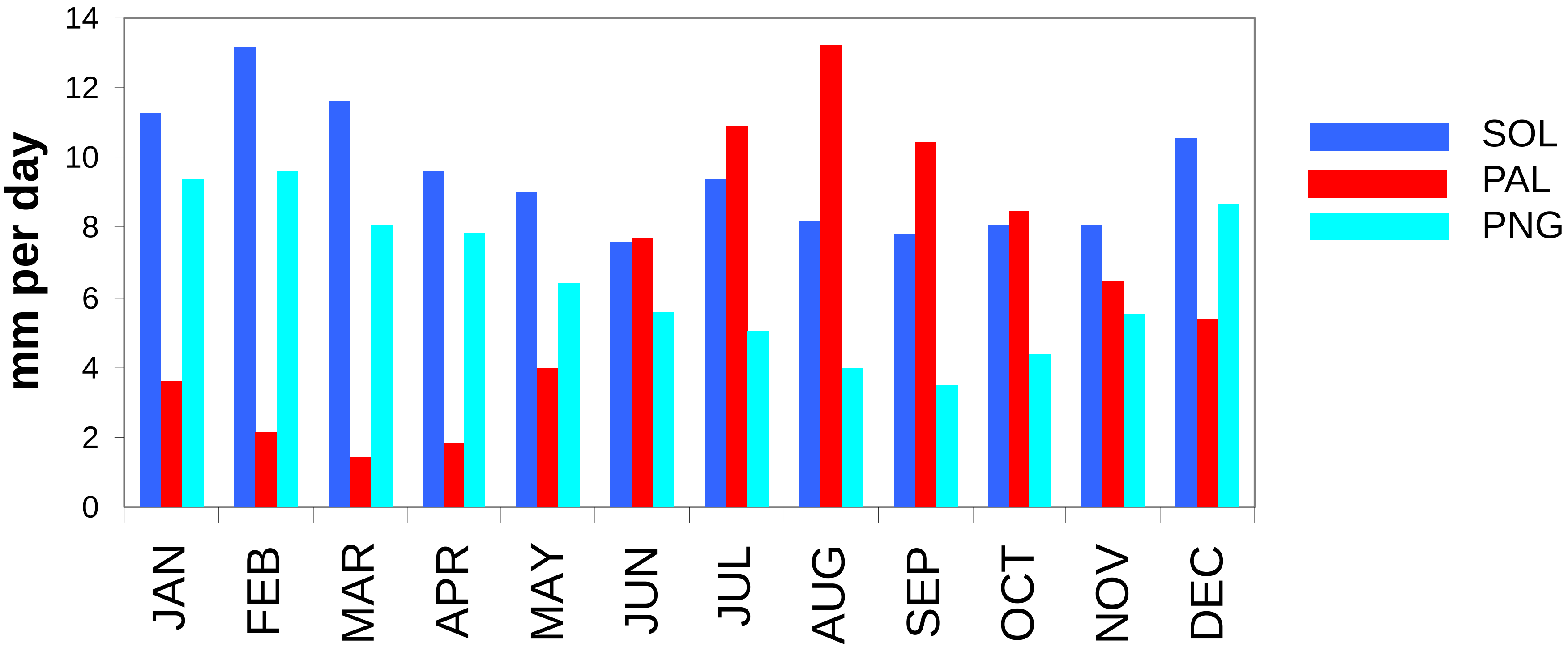
SH - wet season:
Monsoon westerlies
High rainfall
NH – dry season:
Trade North-easterlies bring enhanced rainfall



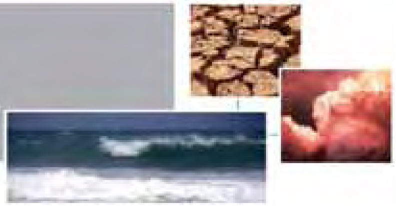
SH – dry season:
Westerlies replaced by trade south easterlies.
Reduced rainfall in central WPM region.
Still enhanced rainfall along eastern WPM region.
NH – wet season:
Strong monsoonal rainfall

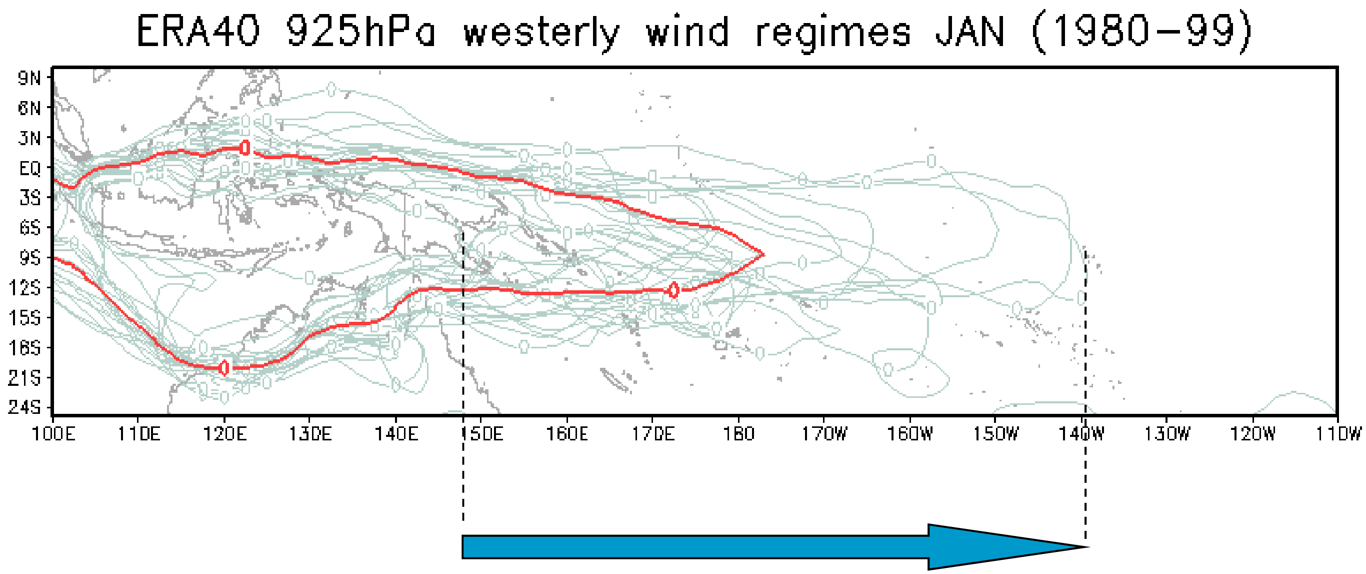
1980-1999 averages

Annual Cycle of precipitation (CMAP)



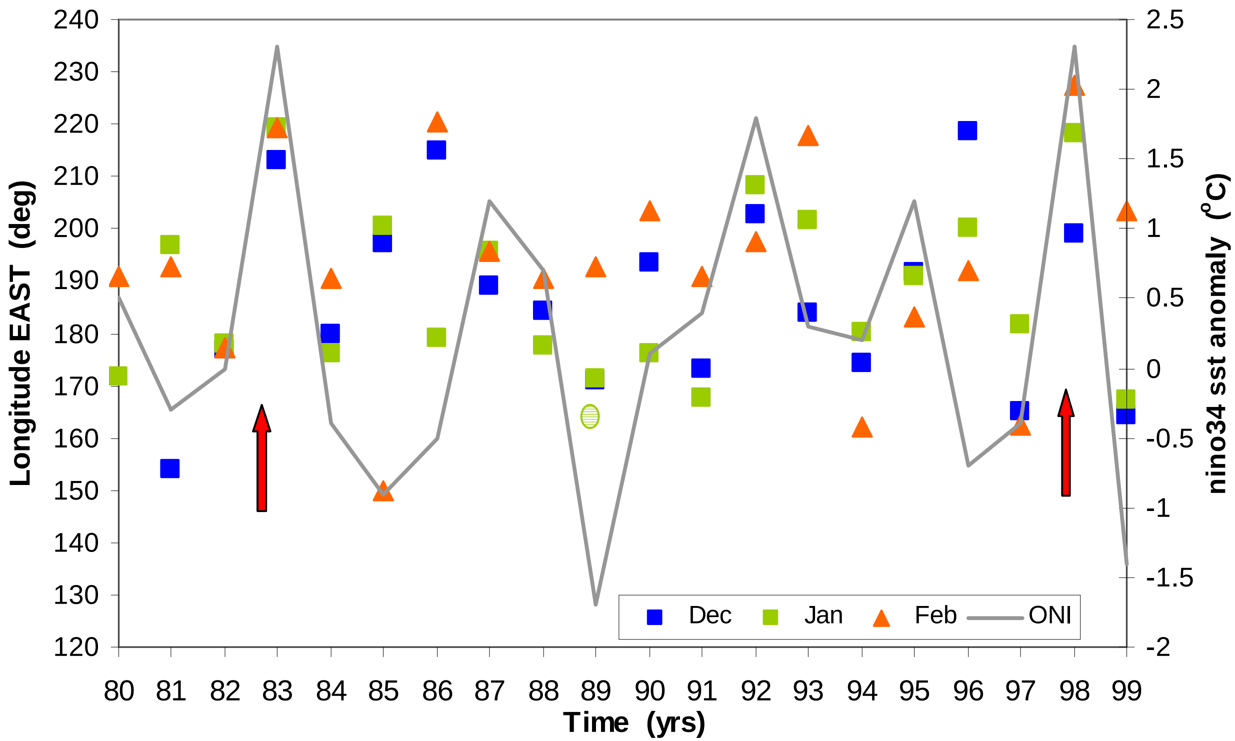
Inter-annual Variability: westerly winds





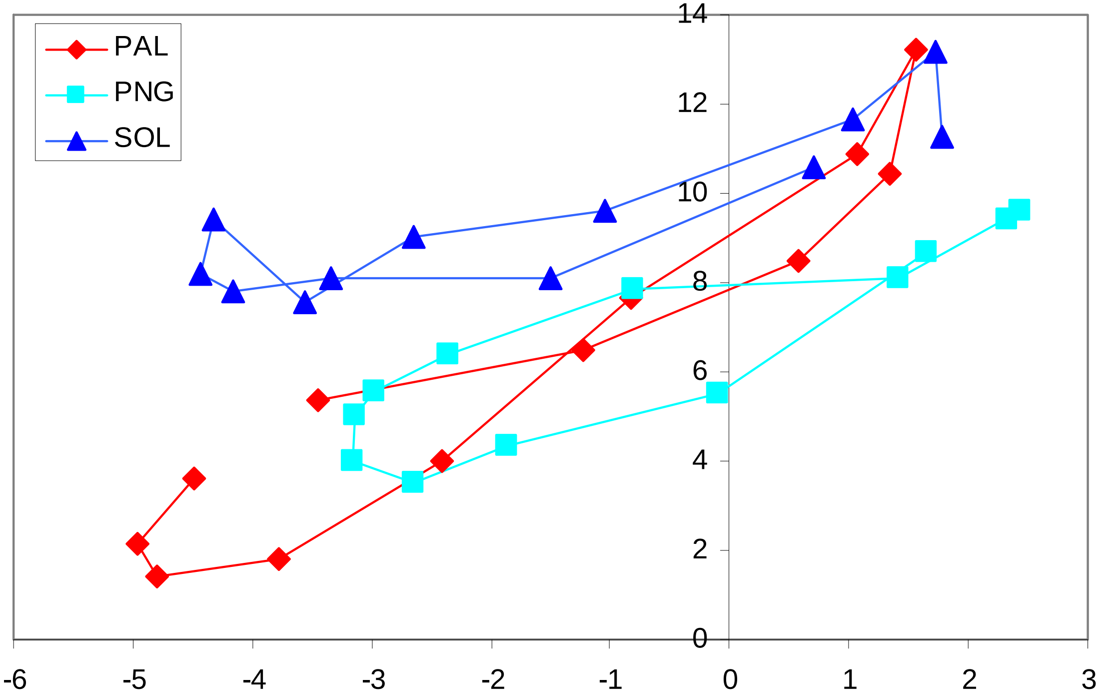
Inter-annual variability of the extent of the monsoon westerly wind domain during January. The extent for each **individual January** during 1980-1999 is shown in blue, whilst the **mean** January extent during 1980-1999 is shown in red. (Based on ERA40 zonal winds at the 925 hPa level).

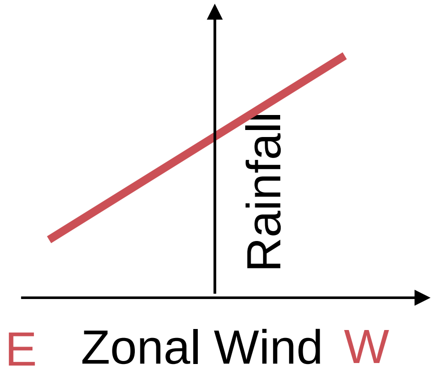
Inter-annual variability: westerly wind regime



Position of the **eastern edge** of the monsoon westerly wind domain in **December** (blue), **January** (green) and **February** (orange) between 1980 and 1999. The seasonal (December-February) mean Nino3.4 sea-surface ocean temperature index is also shown (grey), with the major El Niño's of 1983/84 and 1997/98 denoted by red arrows.

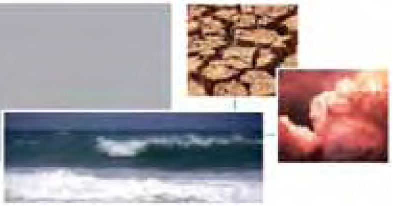
Rain-Wind relationship: NCEP and CMAP





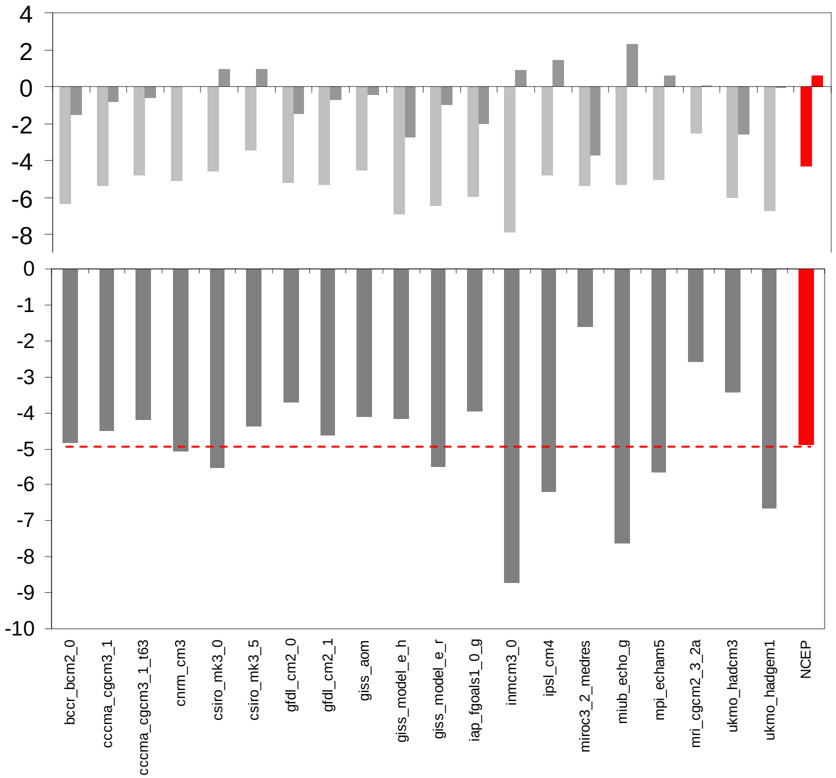
Positive slope

The relationship between average monthly rainfall totals (CMAP data) and average monthly surface zonal winds (NCEP data) for the **PAL** region (red), the **PNG** region (light blue) and the **SOL** region (dark blue).



How do GCMs simulate these features?

GCM simulations of seasonal wind reversal

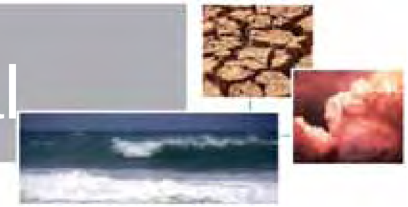


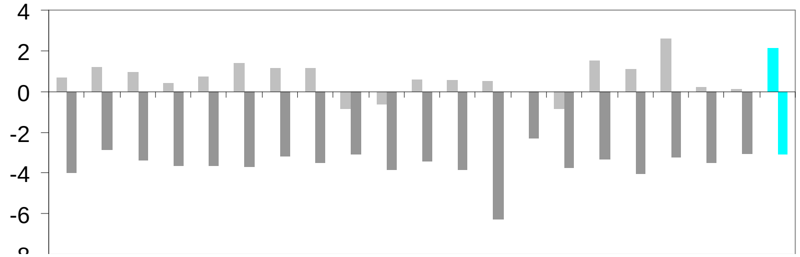
zonal surface winds during DJF (light grey bars) versus JJA(dark grey bars).

the difference (DJF)-(JJA). The observed values (NCEP data) are shown by the coloured bars.

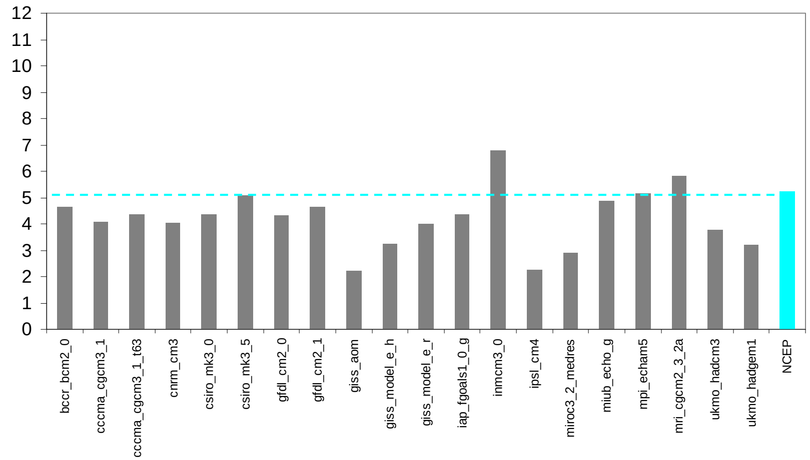
For northern hemisphere monsoon region **PAL**

GCM simulations of seasonal wind reversal





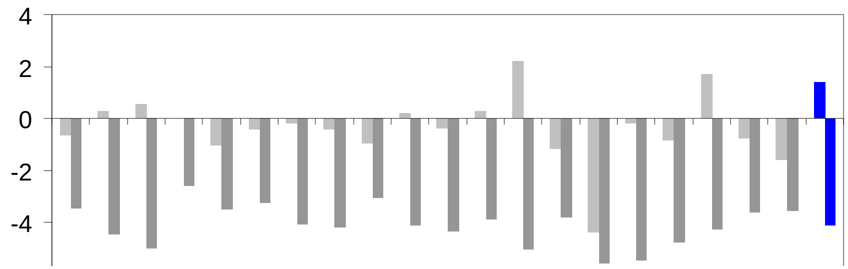
zonal surface winds during DJF (light grey bars) versus JJA(dark grey bars).



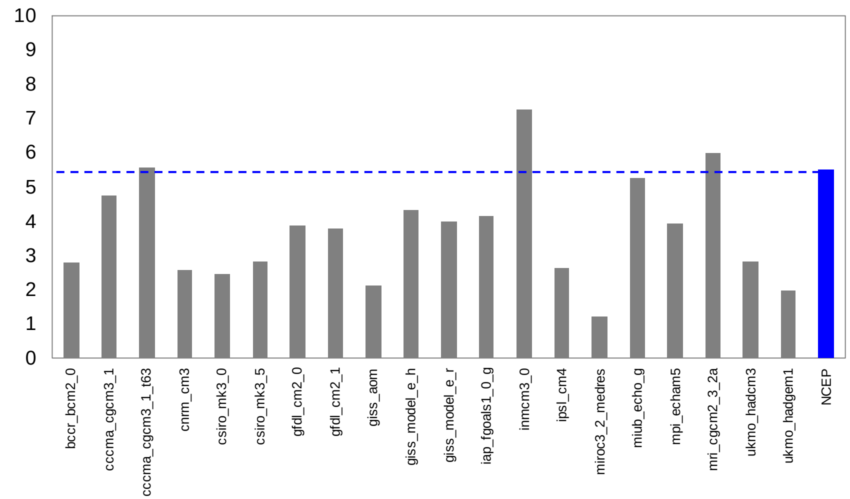
the difference (DJF)-(JJA). The observed values (NCEP data) are shown by the coloured bars.

For Southern Hemisphere monsoon region **PNG**

GCM simulations of seasonal wind reversal



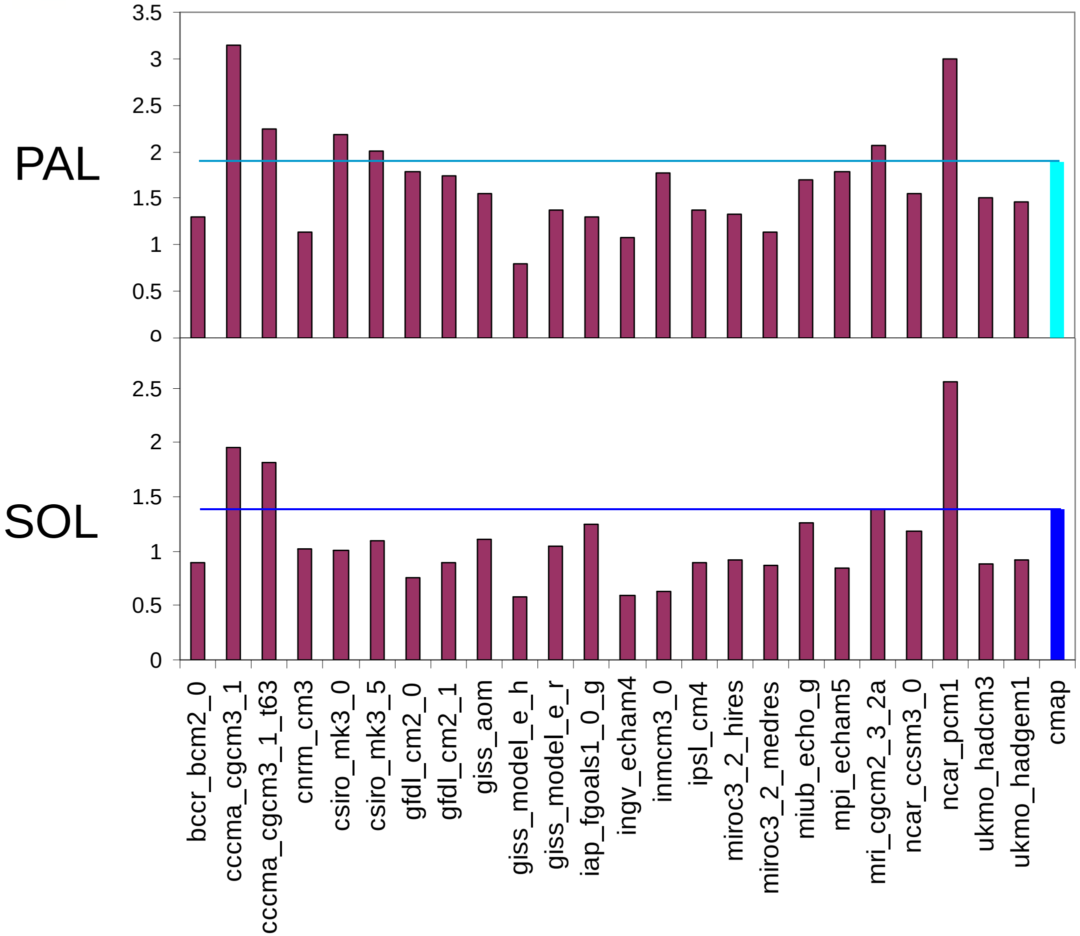
zonal surface winds during DJF (light grey bars) versus JJA(dark grey bars).



the difference (DJF)-(JJA). The observed values (NCEP data) are shown by the coloured bars.

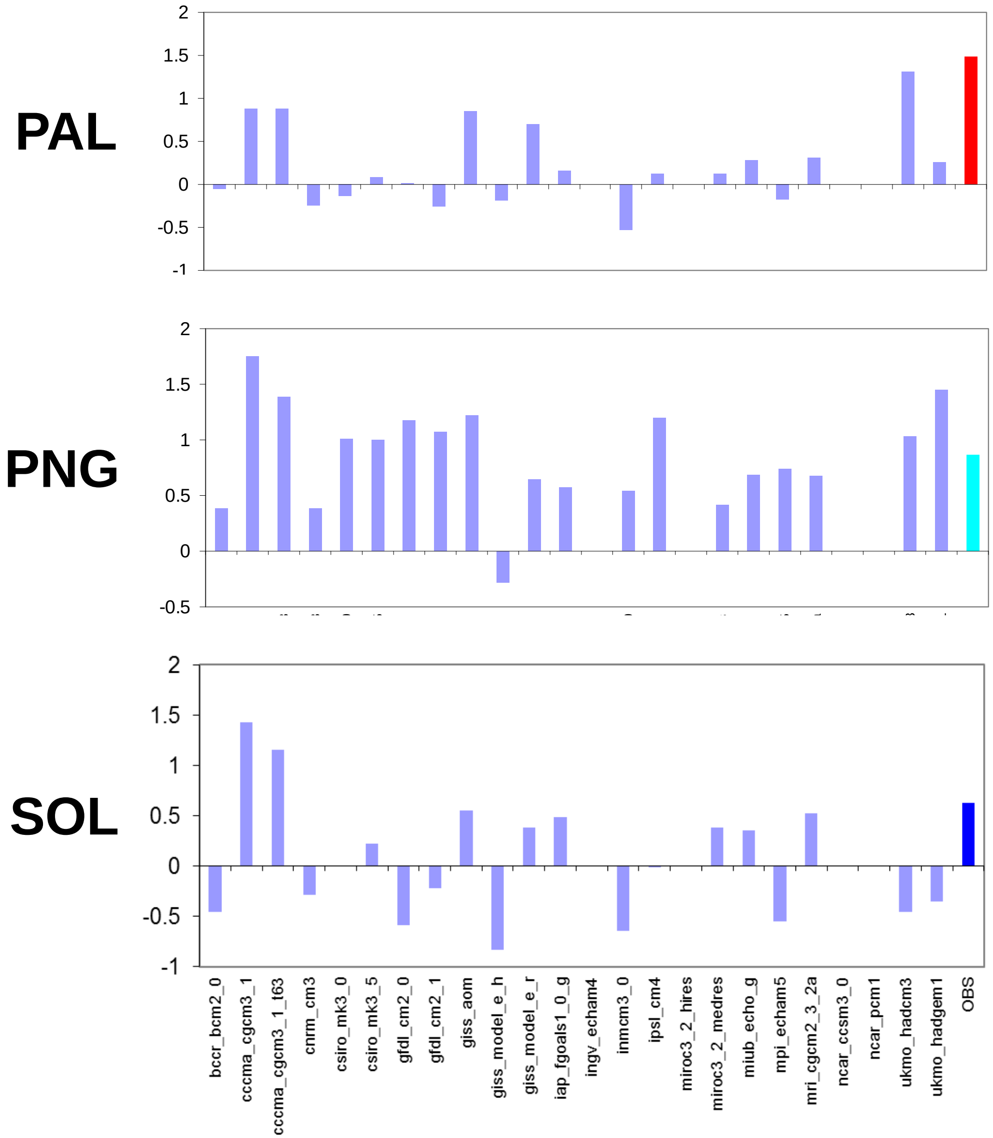
For Southern Hemisphere monsoon region **SOL**

Seasonal difference in rainfall

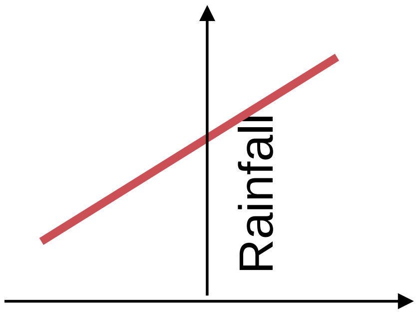


$$\frac{PR(djf)}{PR(jja)}$$

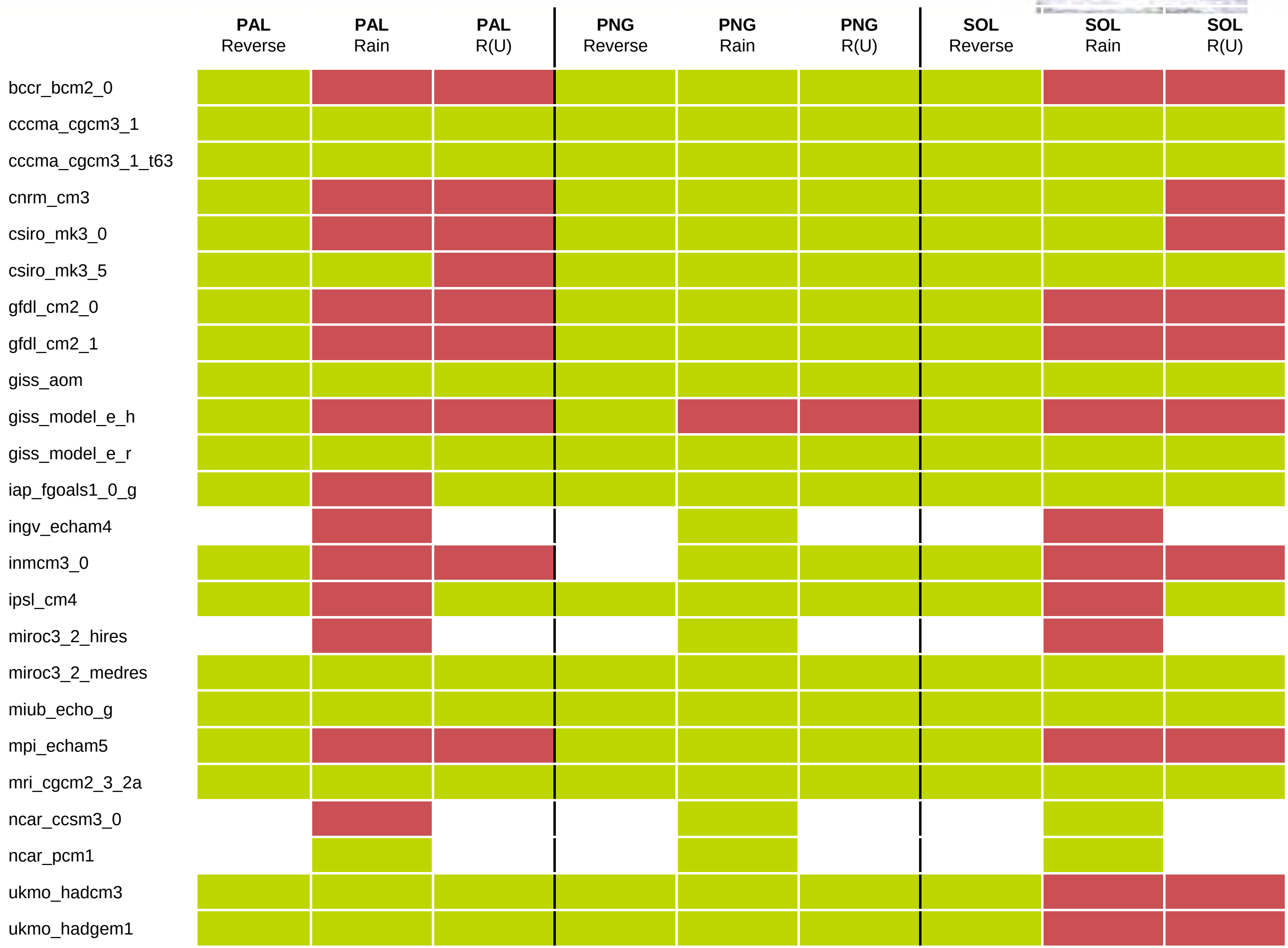
Rainfall – Wind relationship



Looking for **POSITIVE** slopes



Overview of GCM performance



Projections

From IPCC AR4 we know

General intensification of rainfall in deep tropics
Slowing down of the Walker circulation

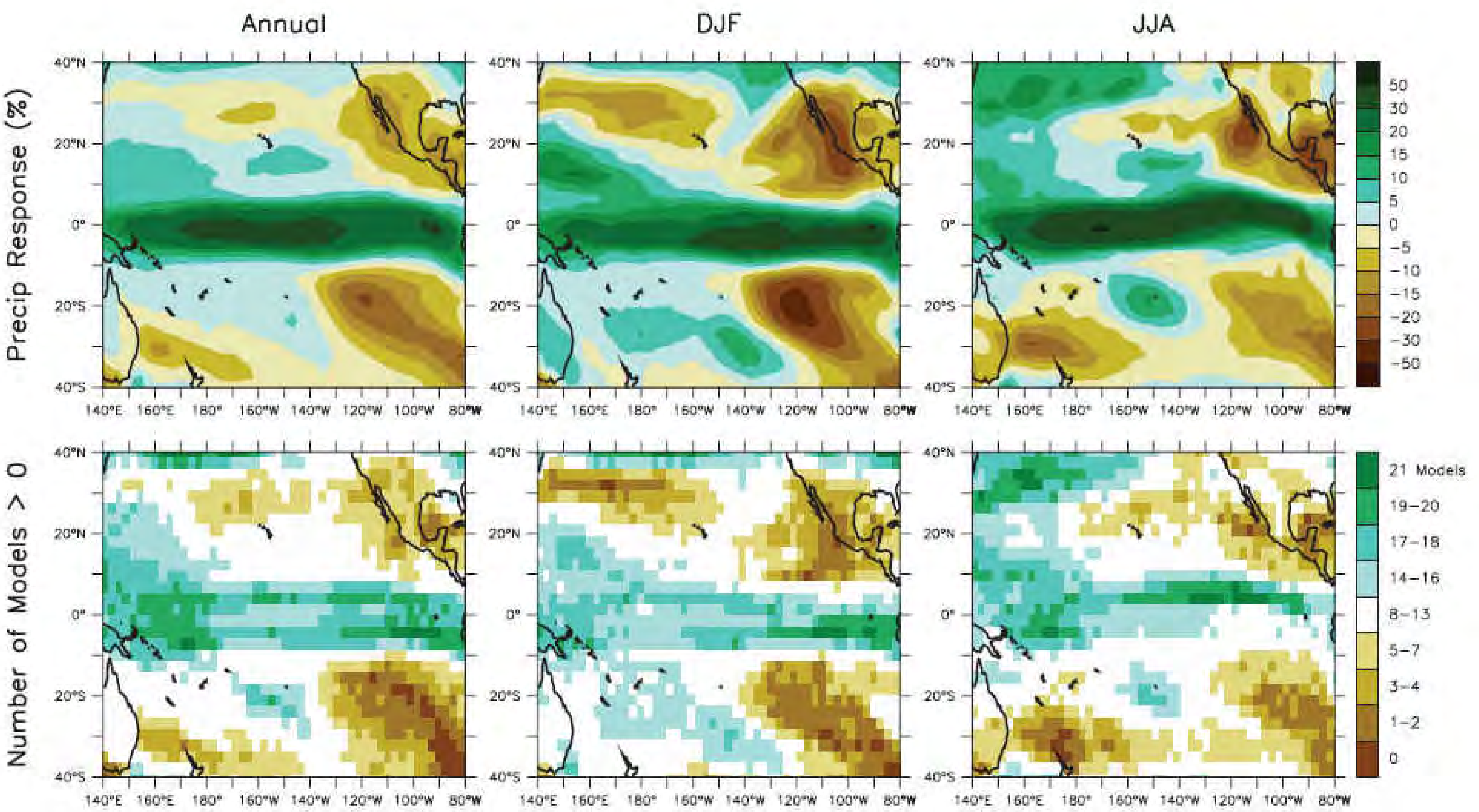
Temperature projections for the region:

(1) Broadly, simulated warming in the South Pacific closely follows the global average warming rate.
(2) Warming a little stronger in the central equatorial Pacific (North Polynesia) and a little weaker to the south (South Polynesia).
(3) for the period 2080 to 2099: increase in annual temperature of 1.8°C. The individual model values vary from 1.4°C to 3.1°C and at least half of the models project values very close to the mean.

Rainfall projections for the region:

(1) For the same period, annual precipitation increases over the southern Pacific when averaged over all models are close to 3%
(2) individual models projecting values from –4 to +11% and 50% of the models showing increases between 3 and 6%.

Rainfall Projections: pacific basin



Summary

- In general, the models adequately simulate the seasonal cycle of winds and rainfall, with the Inter-Tropical Convergence Zone migrating north and south as observed.
- However, the spatial pattern of rainfall and winds associated with the monsoon is not perfectly reproduced.
- As indicated by the IPCC Fourth Assessment Report, there is some consensus for an intensification of rainfall in the future.

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Thank you

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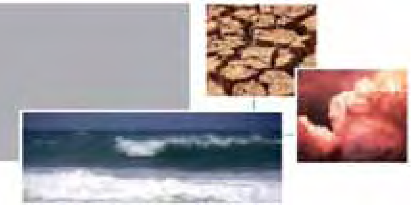
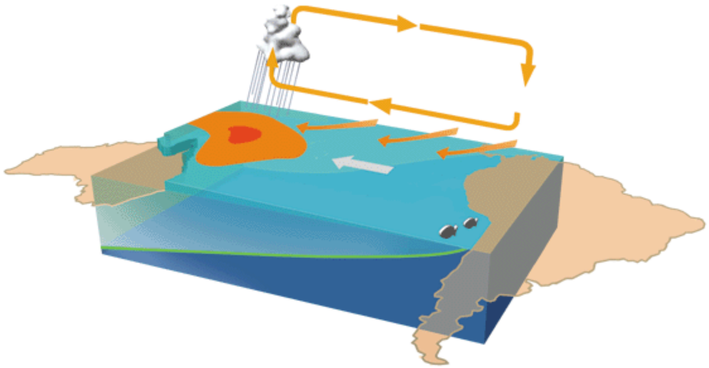
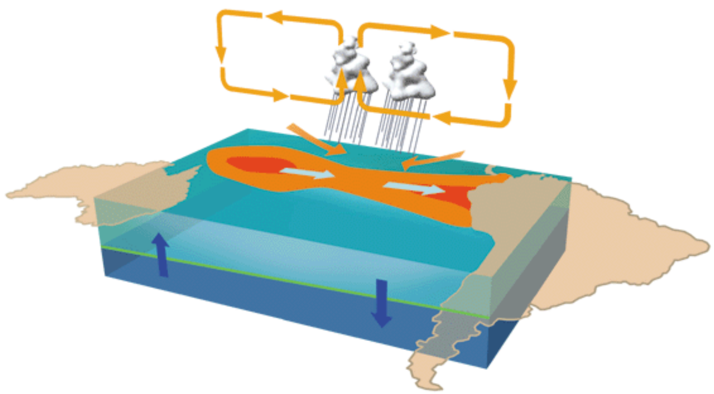
Western Pacific Warm Pool:





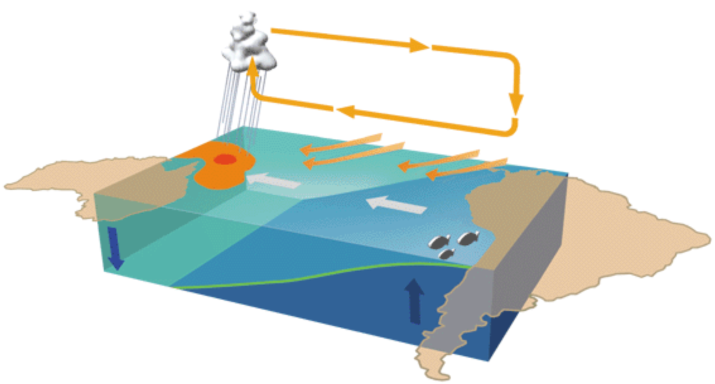
Normal pattern

1. The sea surface is higher in the west, in Asia, than in the east, along the coast of South America. The thermocline (the boundary layer between the warm surface waters and the colder underlying water) is, on the contrary, tilted up to the east. Easterly trade winds push surface waters in the Pacific towards Australia and the Philippines, **creating a warm pool at the western end of the basin** (in red on the illustration) with higher temperatures and sea level.
2. As the winds cross the ocean, they load up with moisture and release it as heavy rains in atmospheric convection over the warm pool.
3. Meanwhile, at the eastern end of the basin, nutrient-rich cold waters well up to the surface. This is favourable for anchovy, which abounds along the Peruvian coast.



El Niño pattern

1. Sea level and the thermocline flatten to near-horizontal. Westerly wind bursts at the eastern end of the basin allow the **warm pool to drift eastward** into the central Pacific. The trade winds weaken.
2. Atmospheric convection, and the storm zone, move eastward with the warm pool. Heavy rainfall floods coastal areas of western South America.
3. As the thermocline deepens, cold water no longer upwells off the coasts of Chile and Peru. The surface waters are warmer. Nutrients disappear; fish stocks dwindle.



La Niña pattern

Sea level tilt increases, rising more in the west and deepening in the east. The thermocline tilt also increases, most noticeably at the western and eastern ends of the basin.

1. The trade winds strengthen, **shrinking the warm pool** and cooling the Tropical Pacific. The climate is drier and colder off the coast of America.
2. Atmospheric convection is confined to the western end of the basin. Rain is abundant over Indonesia.
3. Cold waters upwells more strongly along the west coast of south America; anchovy is plentiful.