

Surface Winds along Eastern Boundary Upwelling Systems in Future Climate Scenarios

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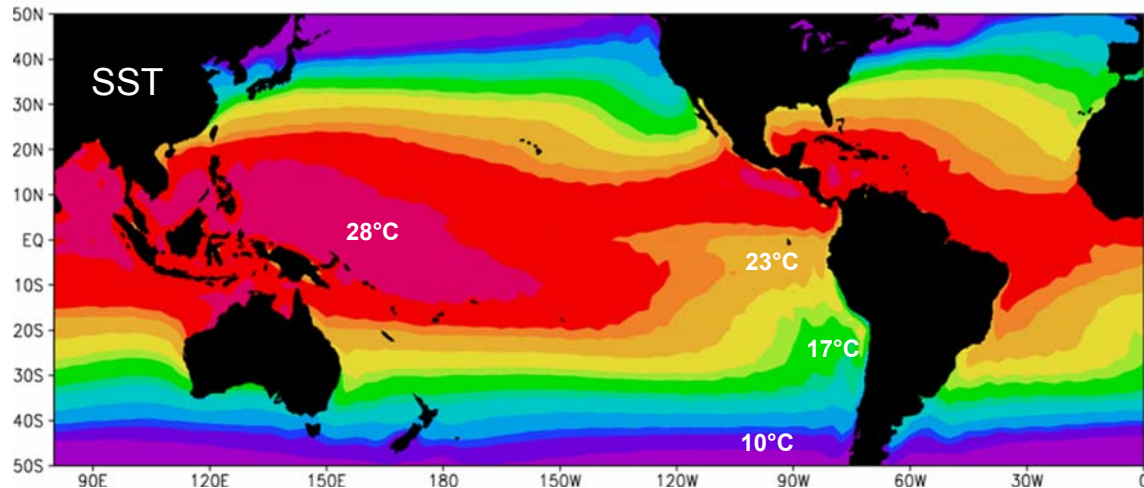
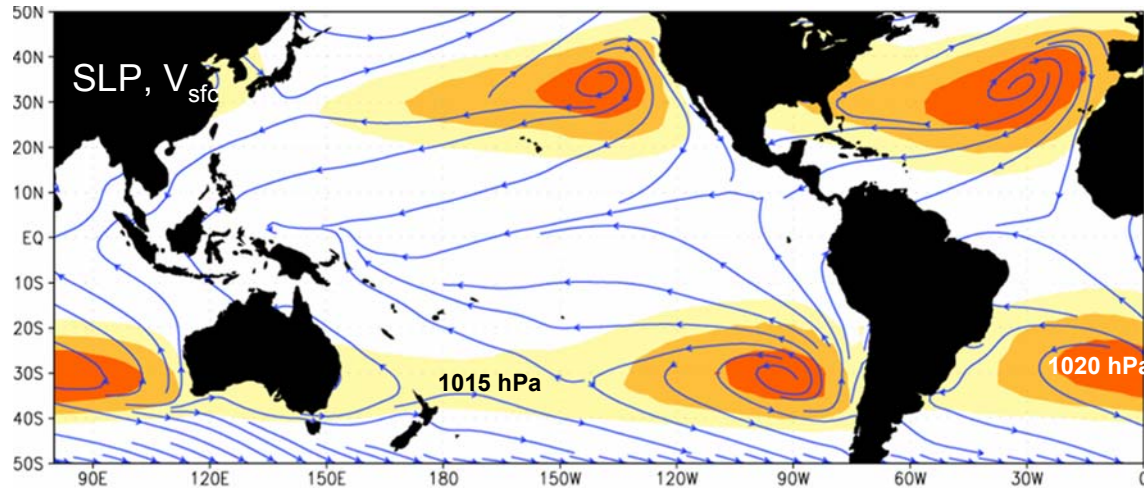
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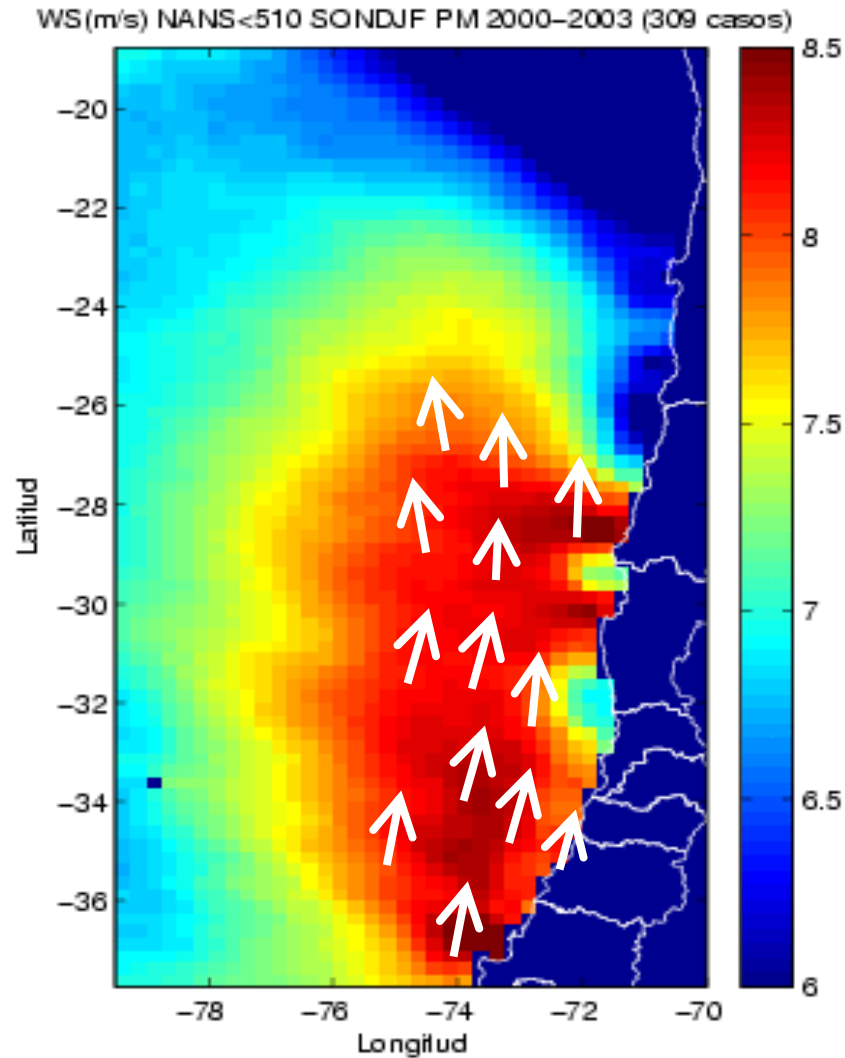
Outline

- EBUS Climate background
- Future (end of 21st century) climate: atmos + ocean
- (Humboldt) EBUS cooling already occurring

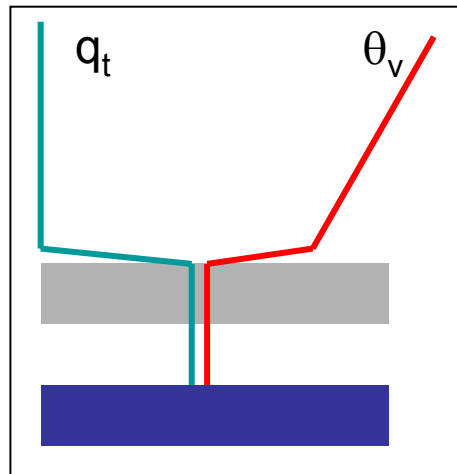
EBUS: Subtropical anticyclones, equatorward flow and cold SST



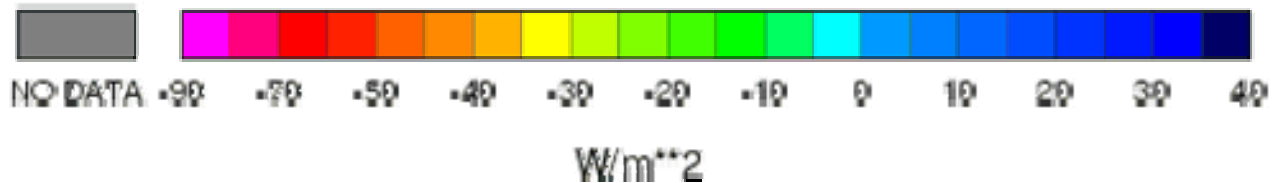
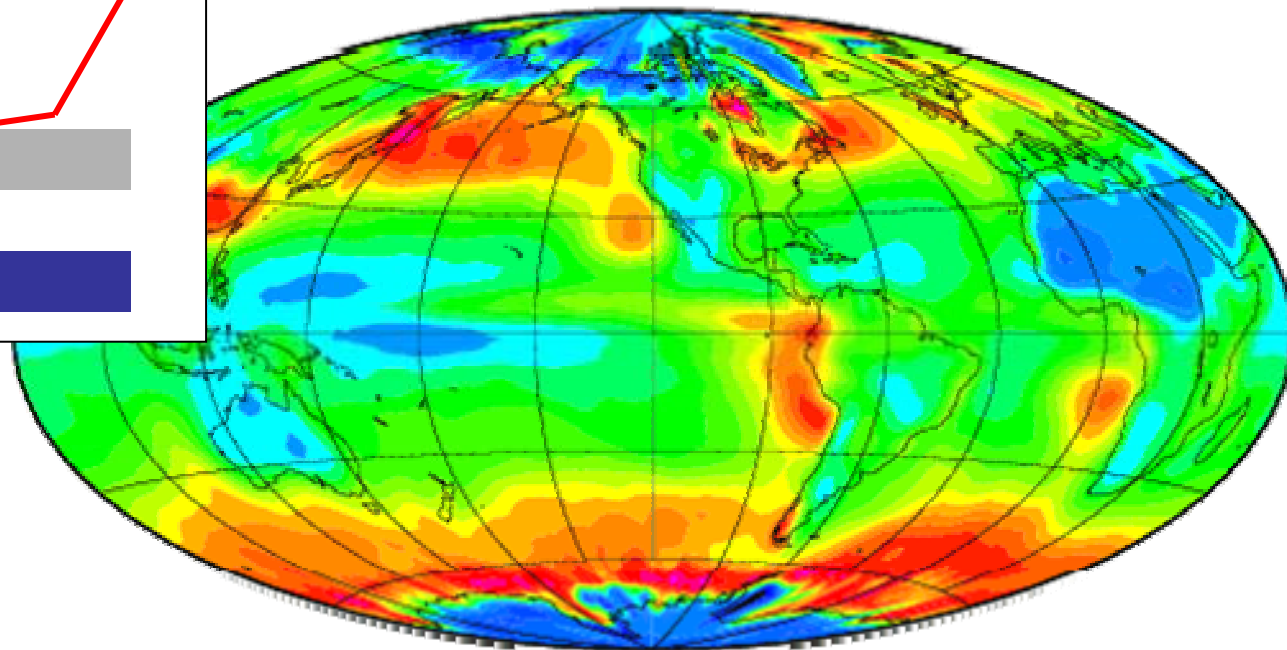
Equatorward flow often exhibits a coastal jet structure



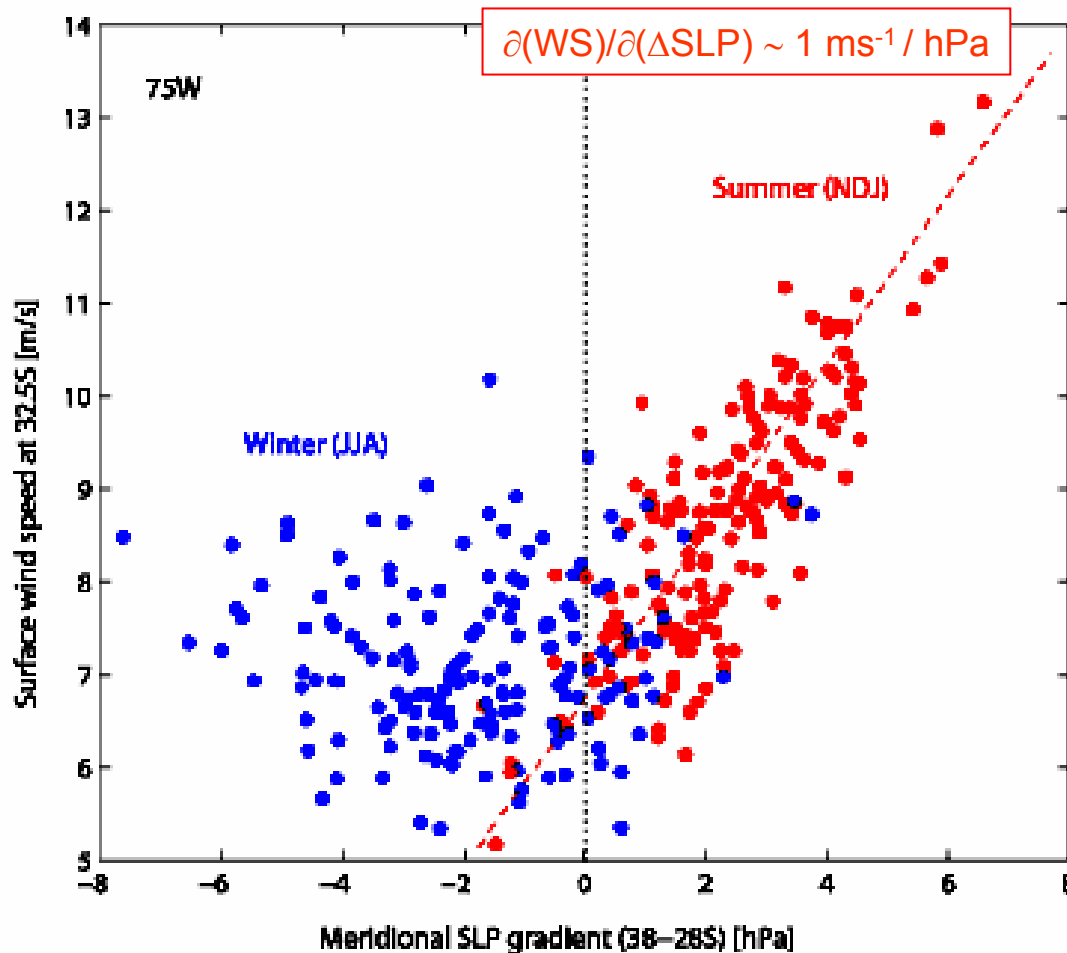
EBUS also “under” cloudy skies (stratocumulus deck)



Annual ERBE Net Radiative Cloud Forcing

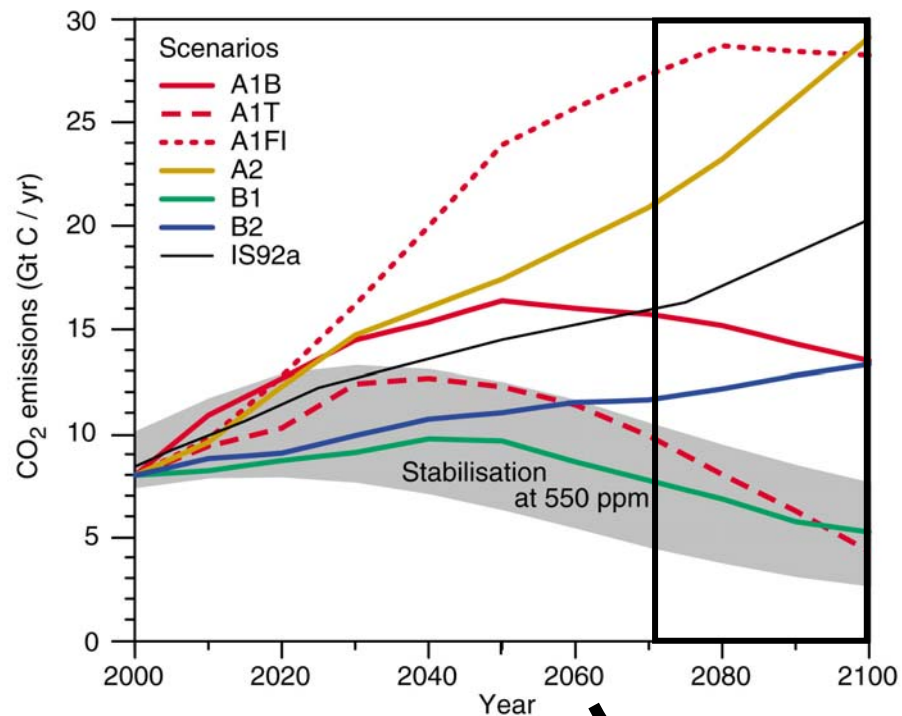


Year-to-year changes in subtropical equatorward flow forced by variations in *along-shore* pressure gradient

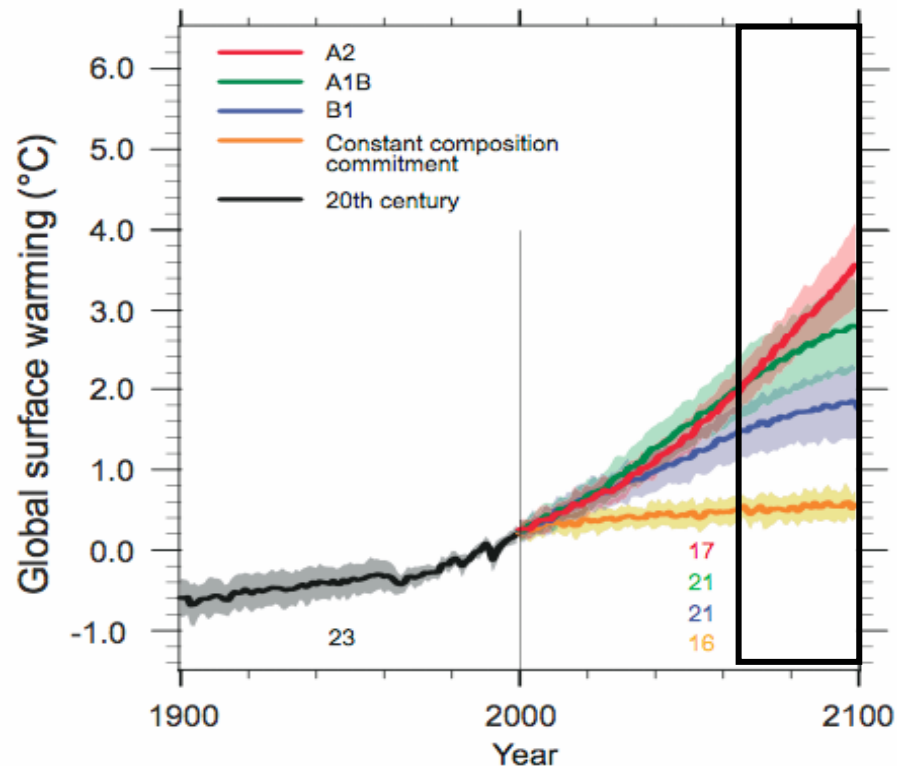


Future Climate Scenarios

GHG (CO₂,...) emissions projections + GCMs

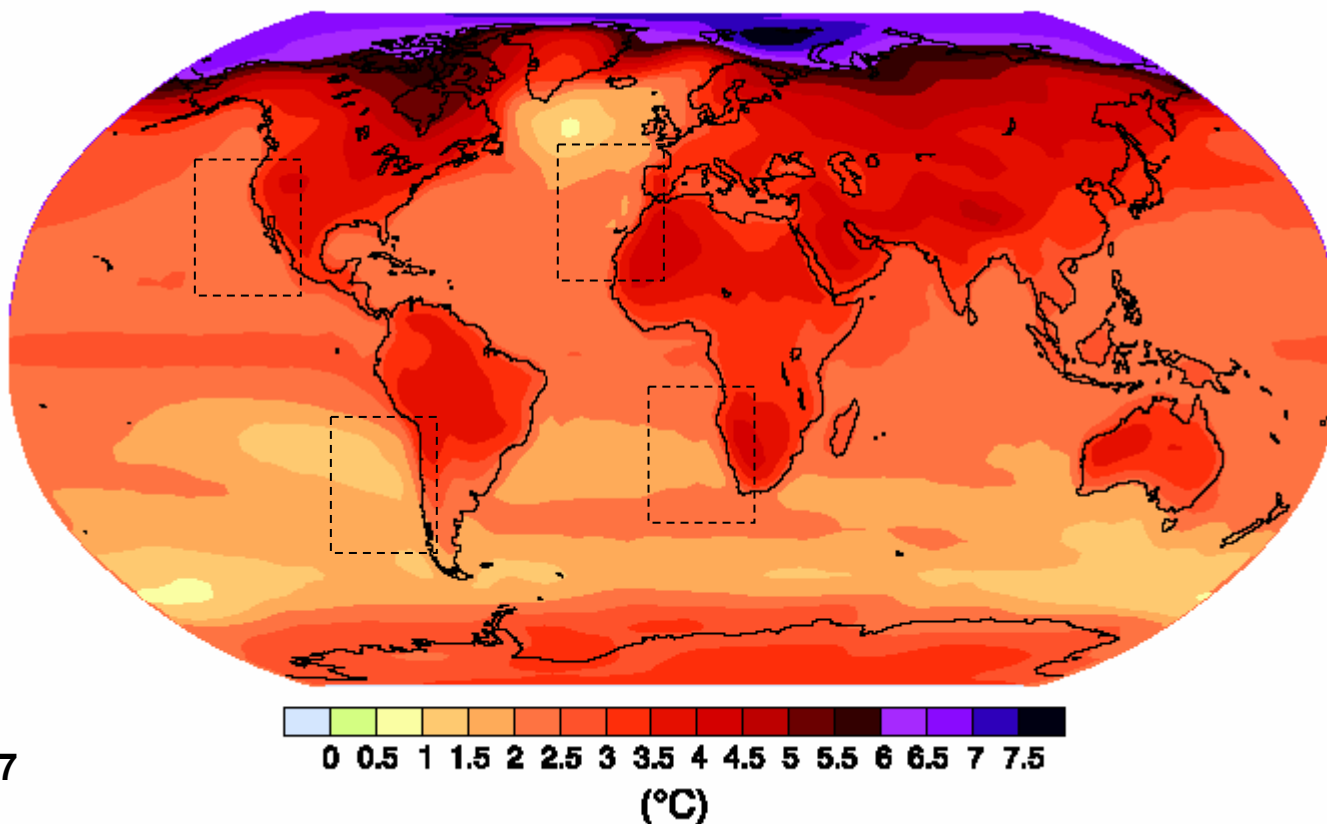


20+ GCMs
CMIP3/IPCC AR4



Multimodel average surface air warming A2-BL (future-present)

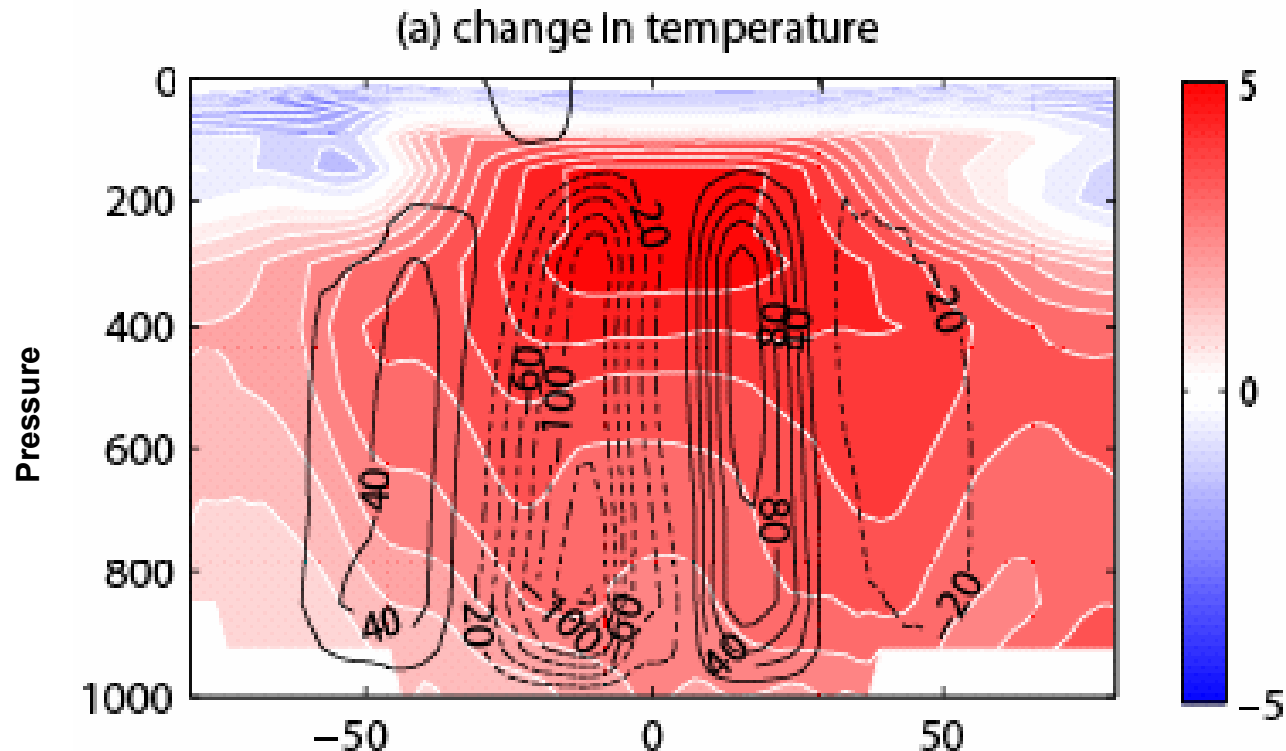
Geographical pattern of surface warming



IPCC 2007

Warming everywhere but with different magnitude
Ocean warming less than land warming, especially on EBUS!

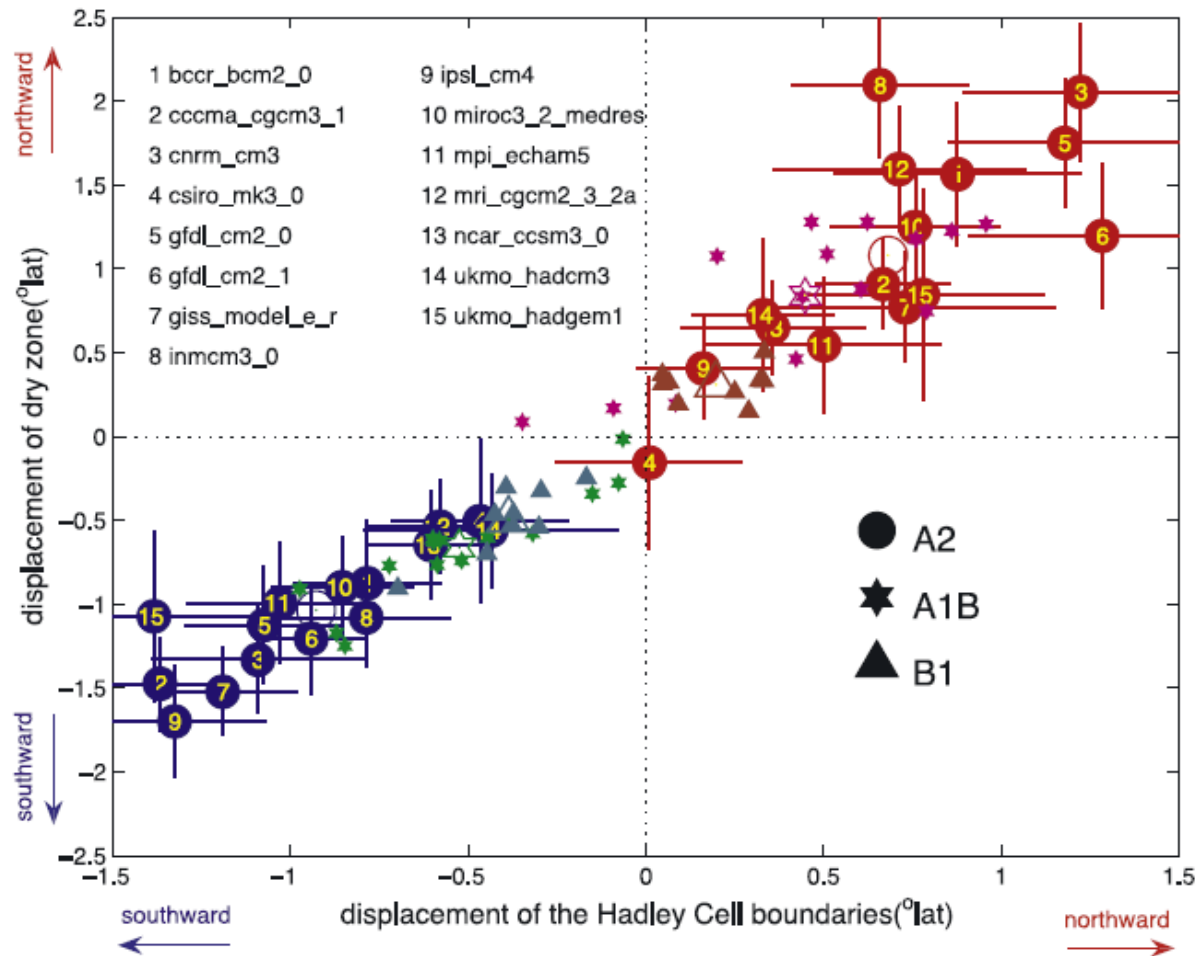
Multimodel average of difference in zonal mean air temperature between A2 and BL



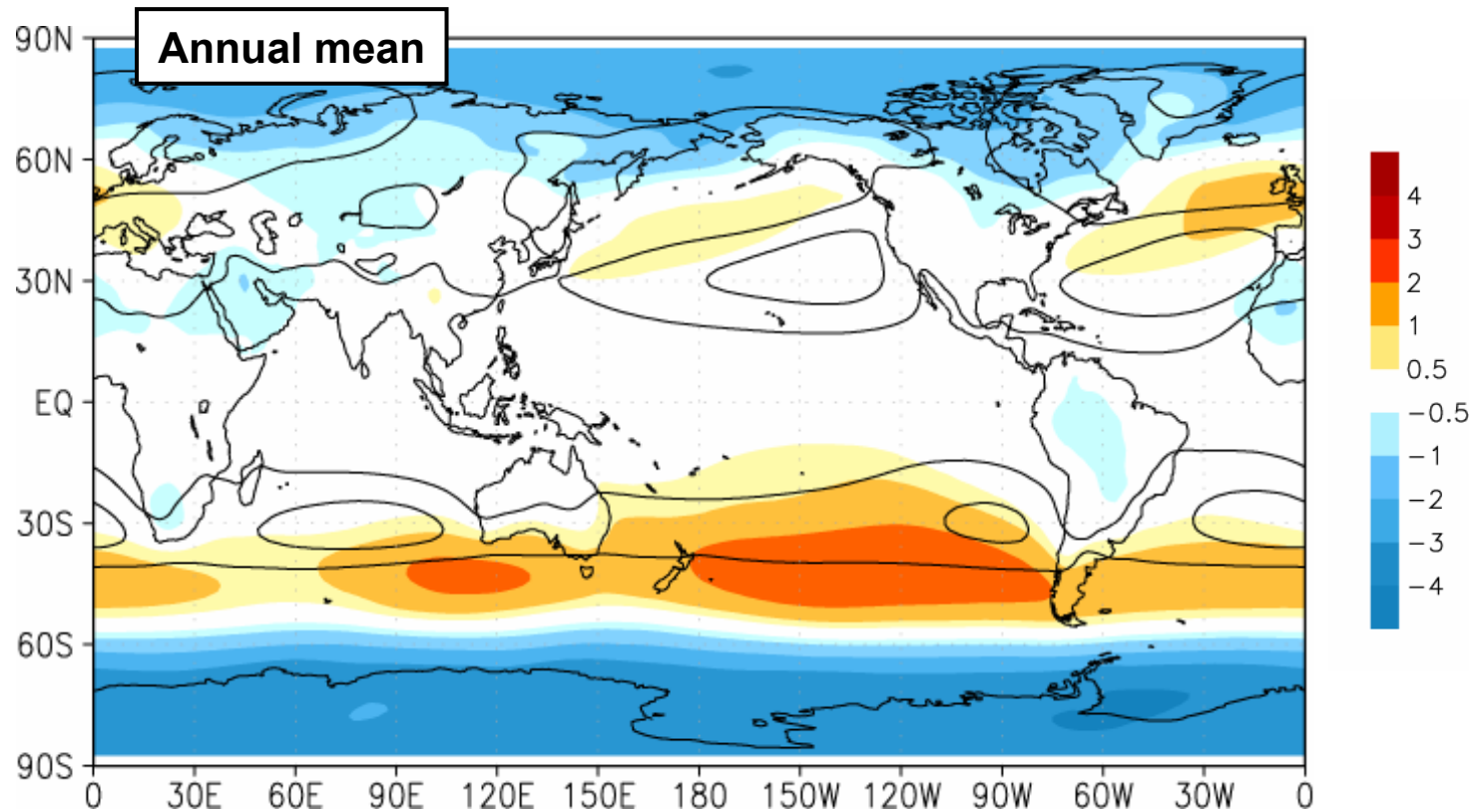
Lu et al. 2007

Warming of the tropical upper troposphere ► Increased static stability at subtropics and midlatitudes ► poleward expansion of the Hadley cell

Poleward expansion of the Hadley cell

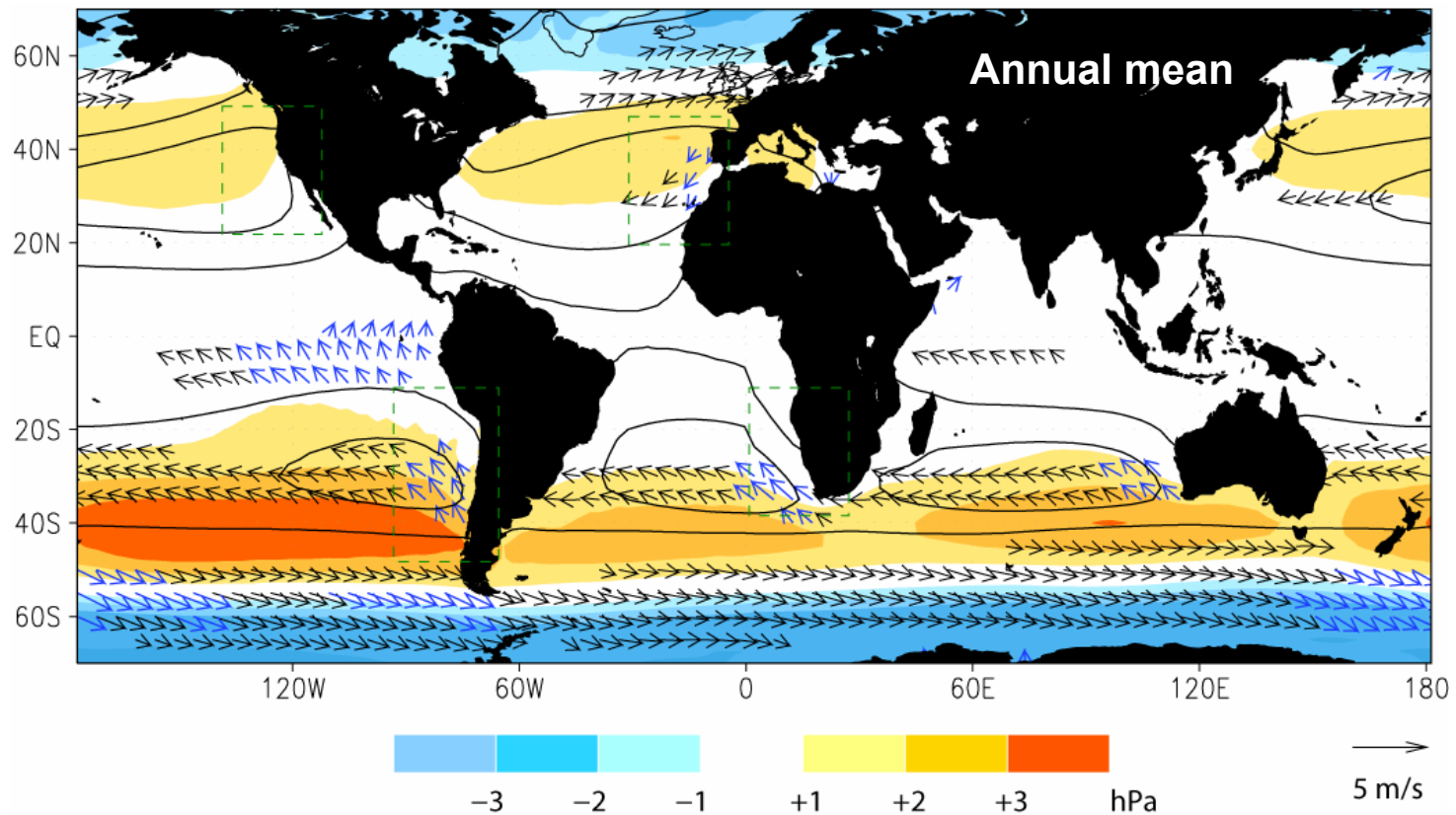


Multimodel average SLP difference between A2 (2070-2100) and BL (1970-2000)



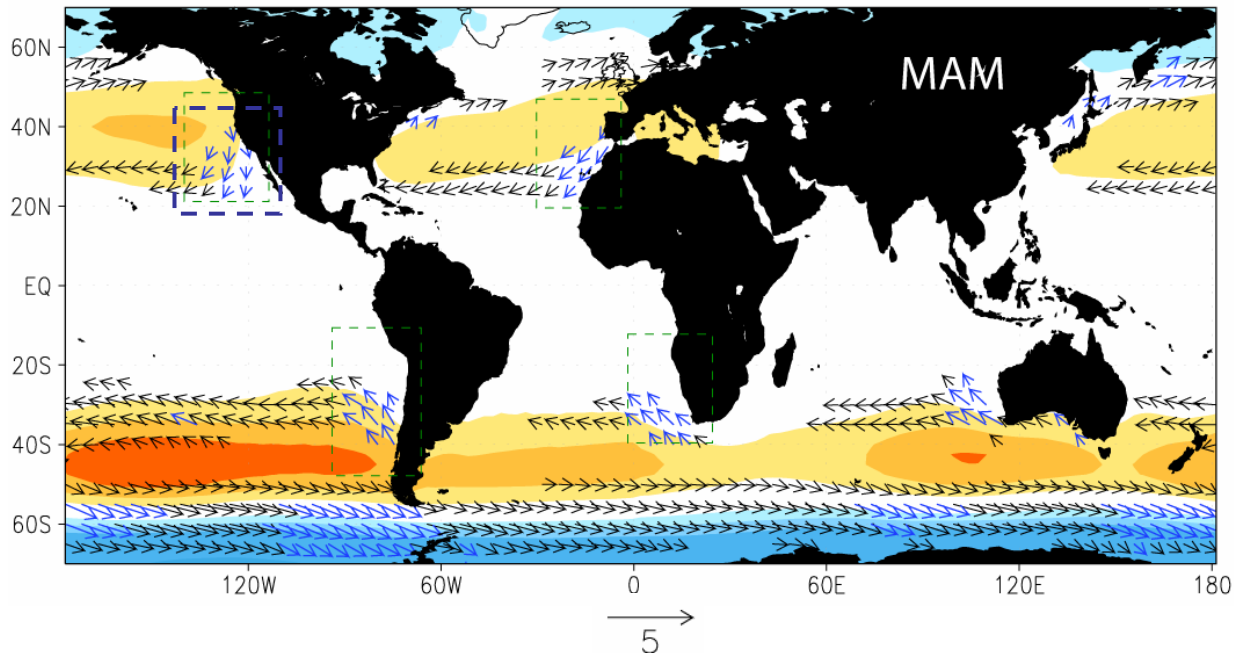
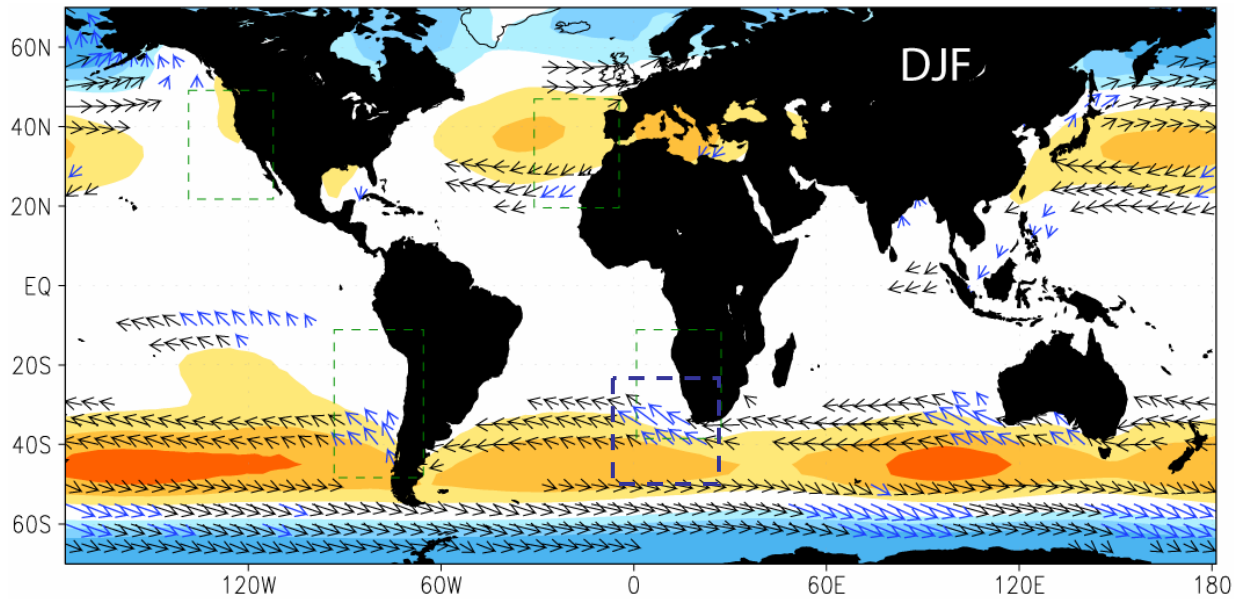
Strengthening of the poleward flank of subtropical anticyclones and poleward shift of the midlatitude storm track is very consistent among GCMs

Multimodel average SLP and sfc wind difference between A2 (2070-2100) and BL (1970-2000)

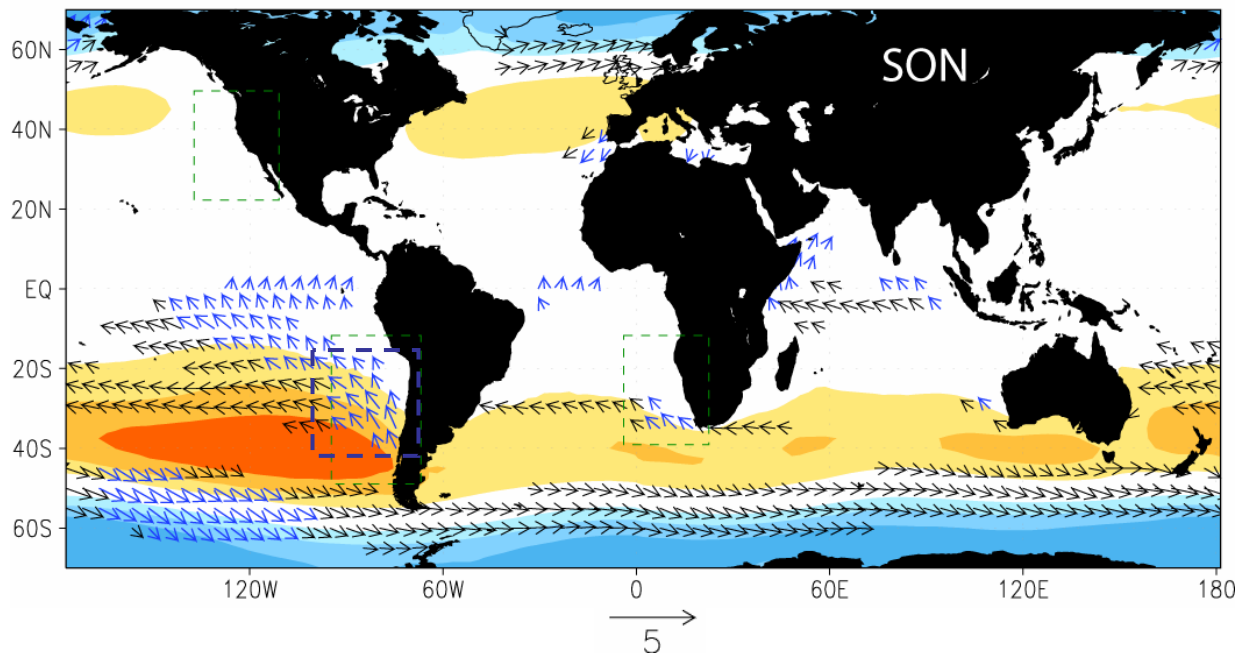
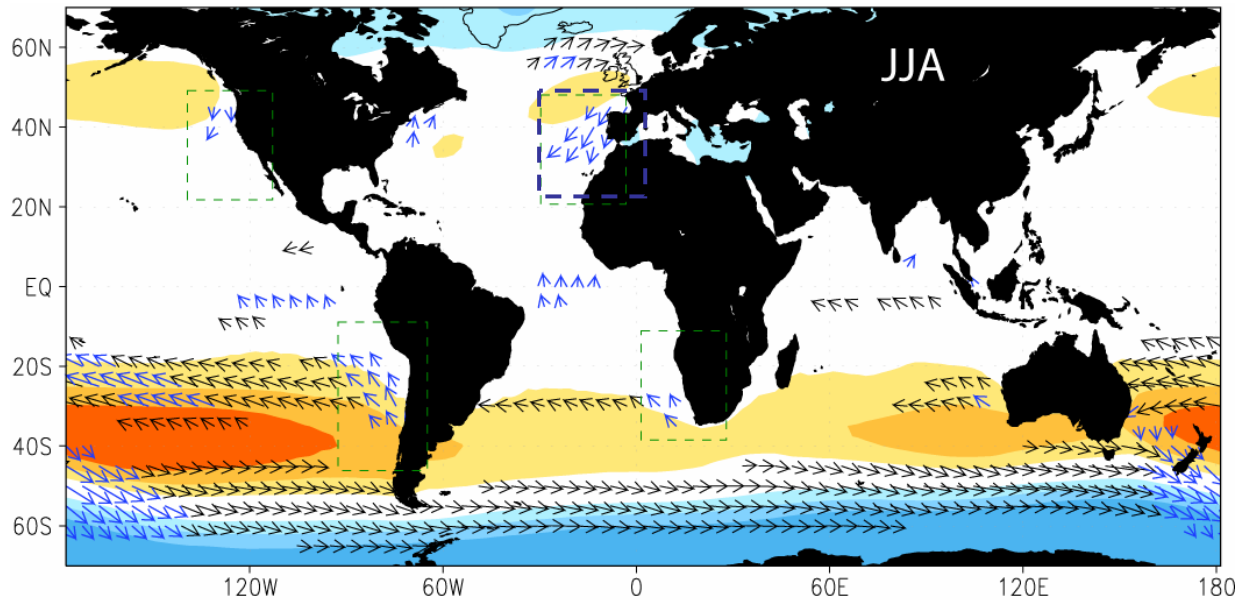


Over open ocean Δv in geostrophic balance with ΔSLP .
Near the coast Δv more controlled by along-coast ΔSLP

Multimodel average SLP and sfc wind difference between A2 (2070-2100) and BL (1970-2000)



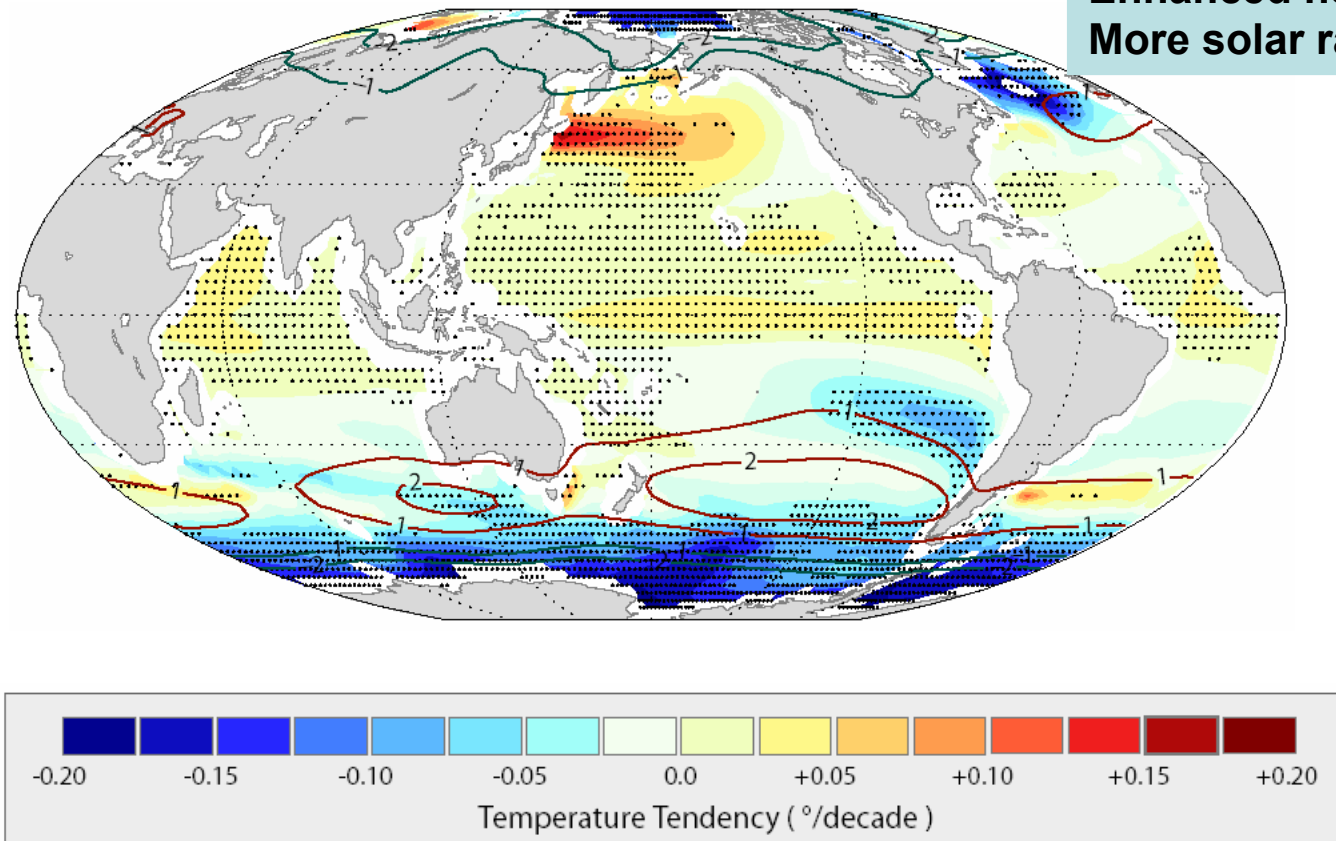
Multimodel average SLP and sfc wind difference between A2 (2070-2100) and BL (1970-2000)



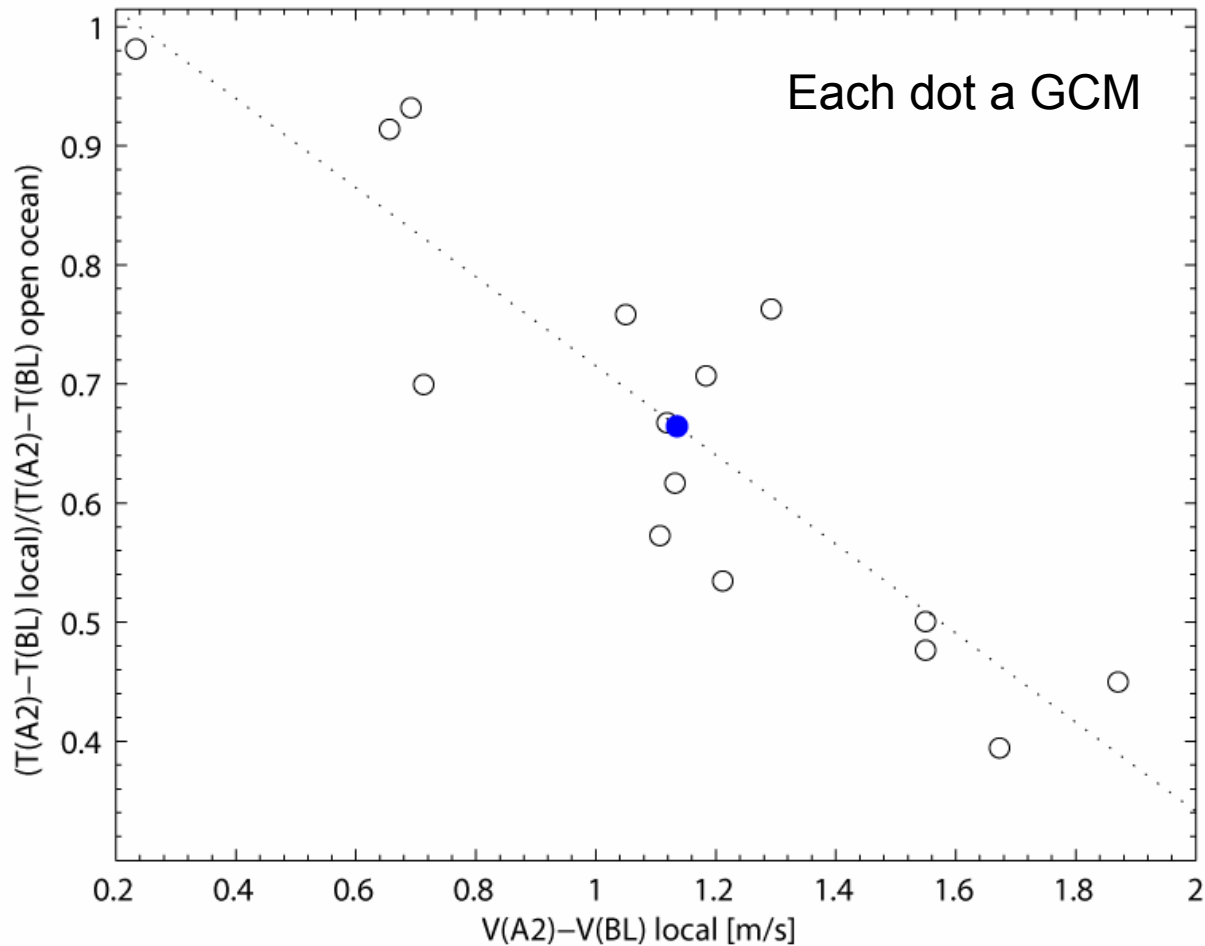
Multimodel average regional surface air warming A2-BL (Also shown dSLP)

Global mean: +3.3°

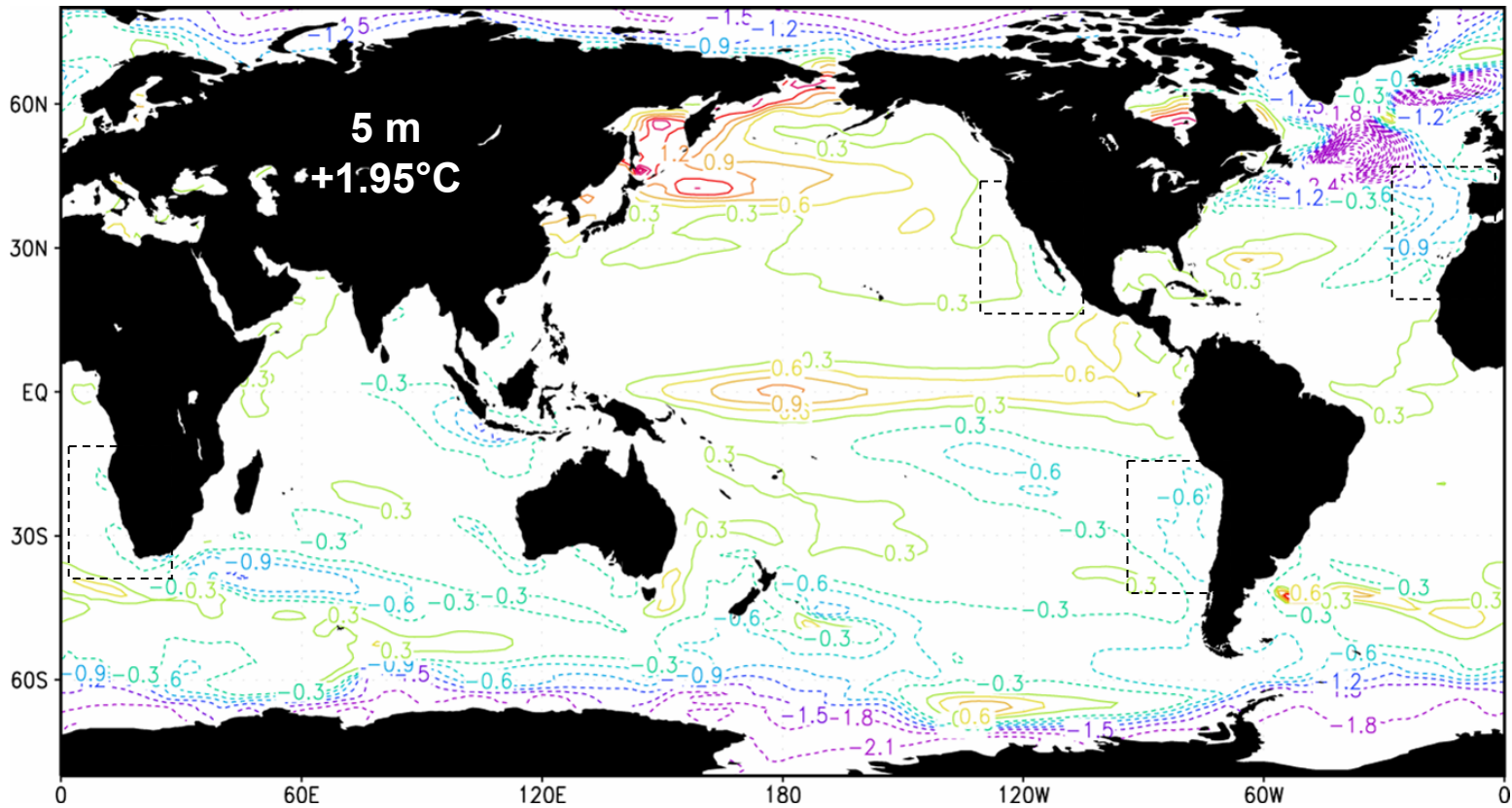
Stronger upwelling
Enhanced heat fluxes
More solar radiation



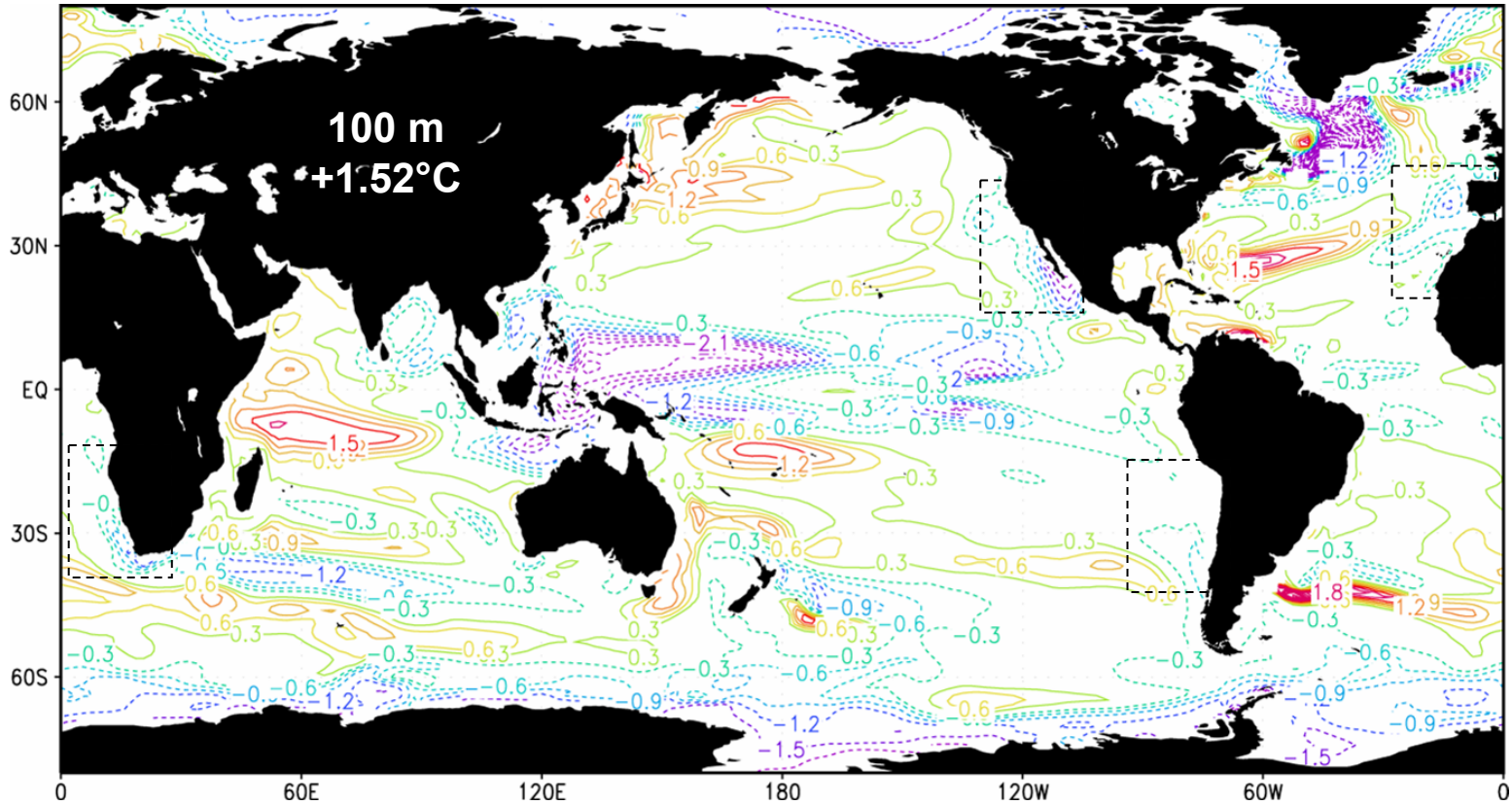
Multimodel average regional surface air warming A2-BL as a function of sfc. wind



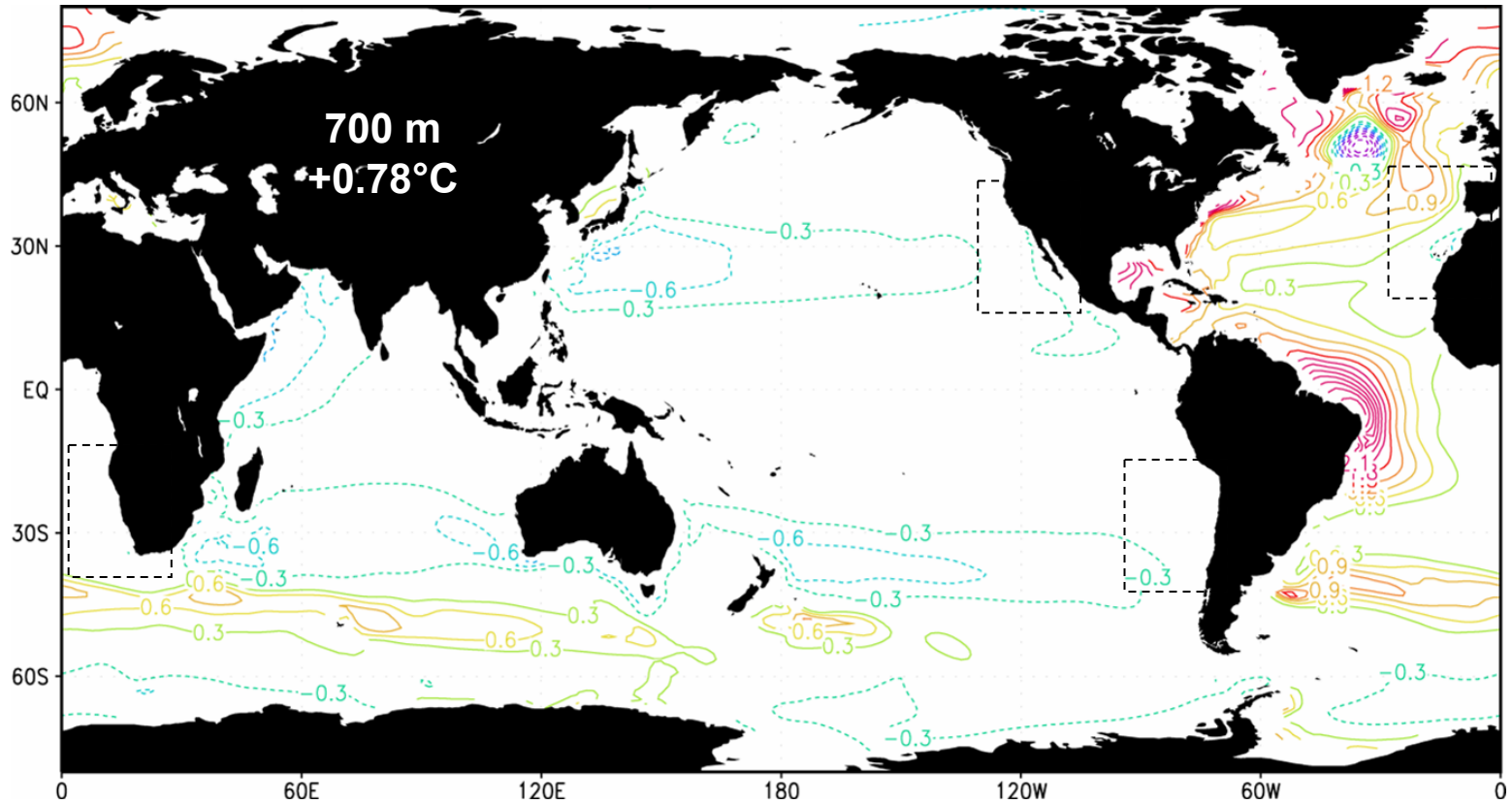
Multimodel average regional ocean warming A2-BL



Multimodel average regional ocean warming A2-BL



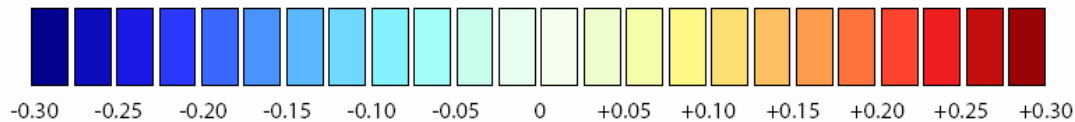
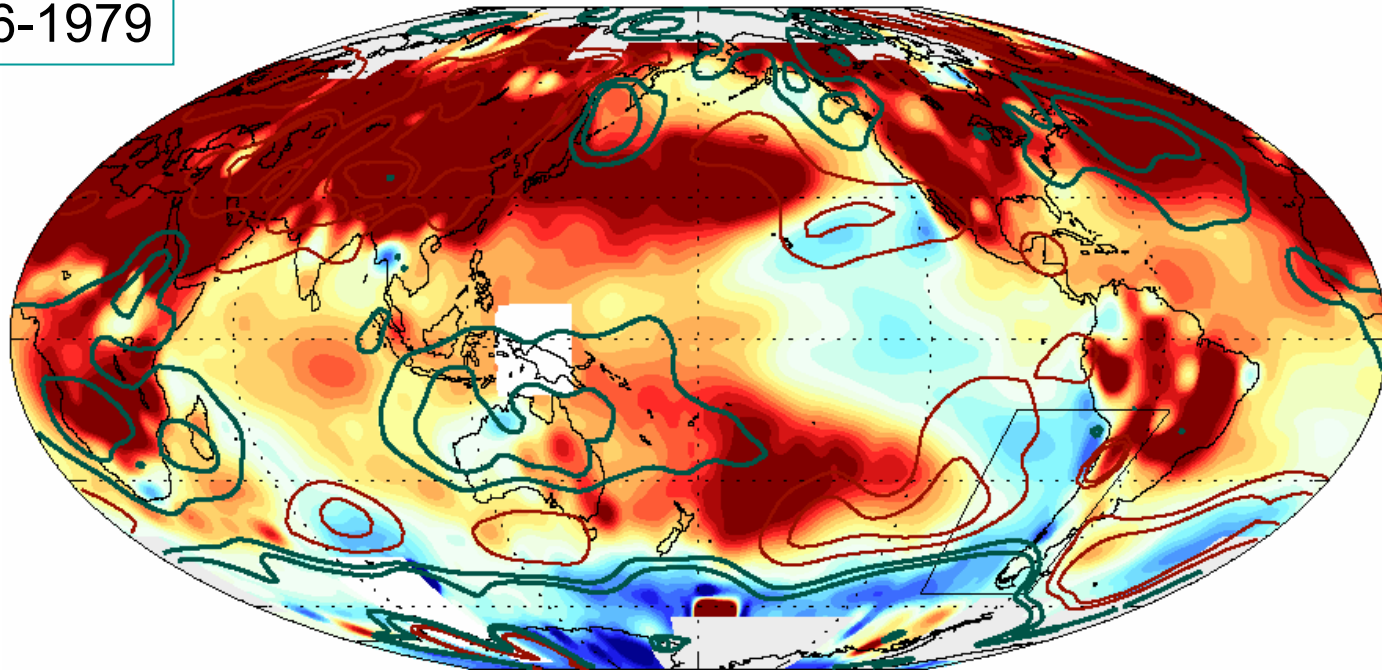
Multimodel average regional ocean warming A2-BL



Is the regional cooling of the Humboldt EBUS already taking place?

2006-1979

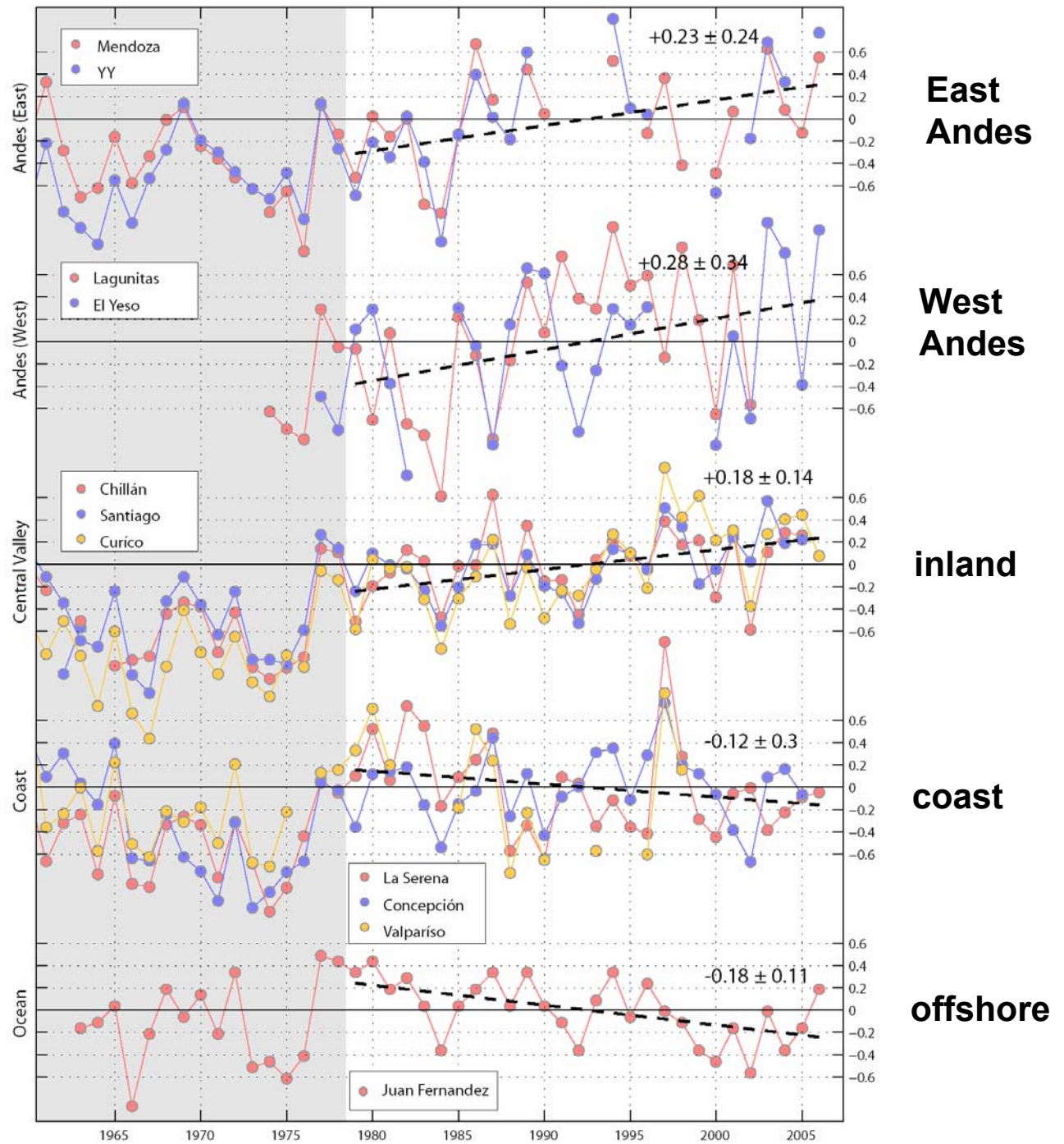
Surface Air Temperature and SST (NCDC)



Temperature Tendency 1979-2006 ($^{\circ}$ / decade)

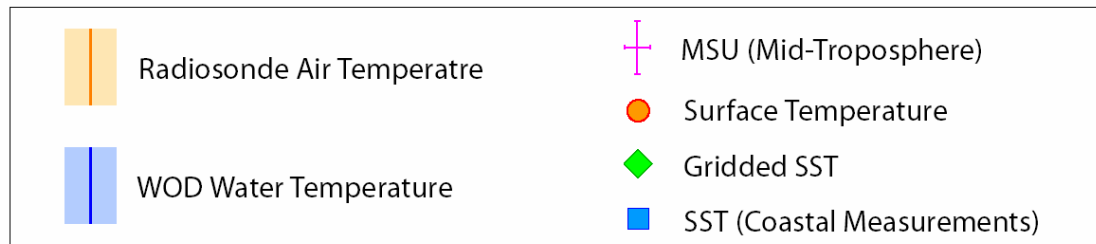
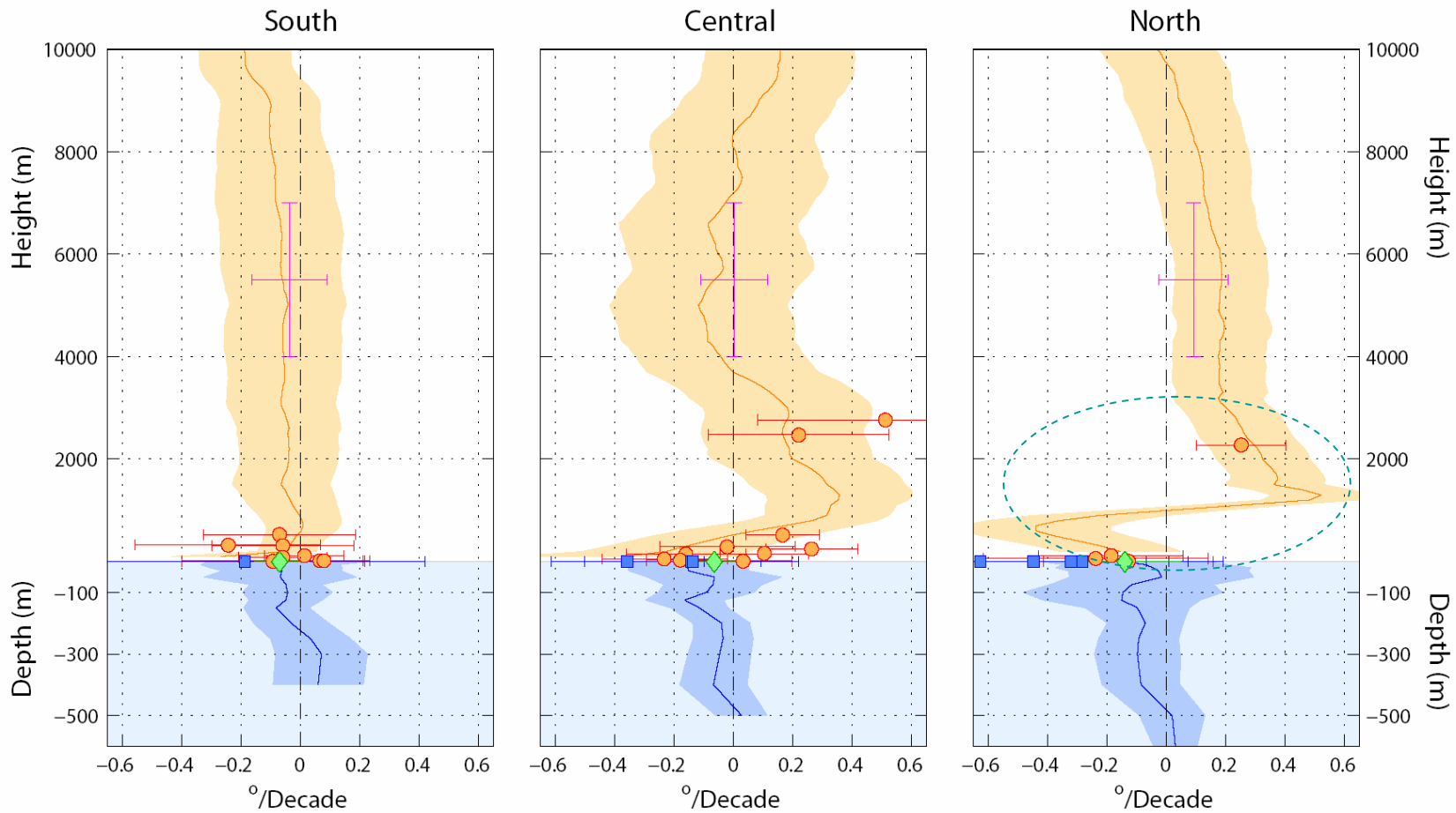
Over the Pacific SST trend looks very similar to the PDV patten

Is the regional cooling of the Humboldt EBUS already taking place?



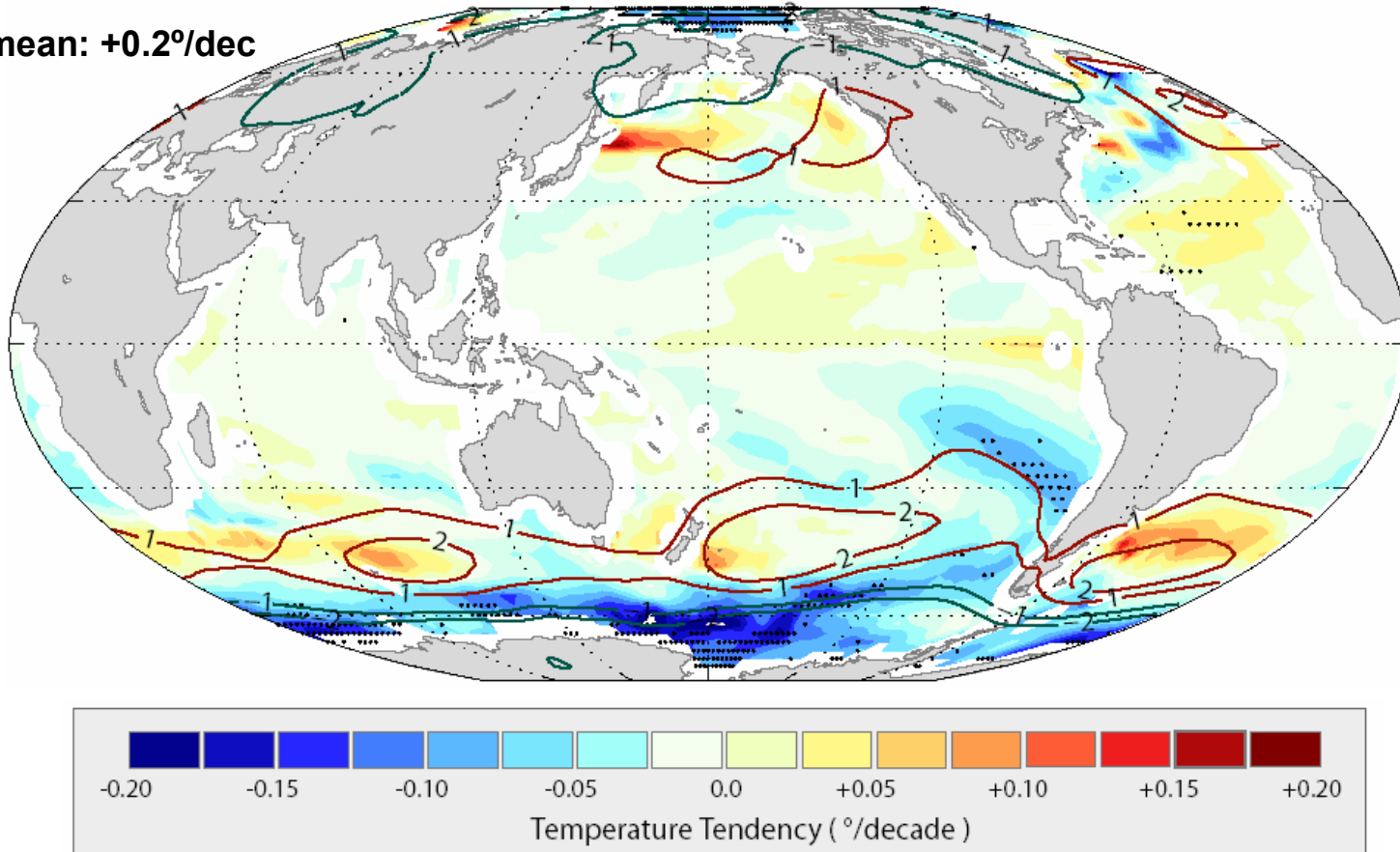
Is the regional cooling of the Humboldt EBUS already taking place?

Temperature trends 1979-2006



Is the regional cooling of the Humboldt EBUS already taking place?

Global mean: $+0.2^\circ/\text{dec}$



Multimodel mean Regional warming 1970-2000 (SST anomaly).
Also shown in contours SLP trend

Conclusions

- EBUS: complex interaction among atmospheric circulation (SLP, low-level winds), ocean processes (SST) and cloudiness.
- Interannual variations of upwelling favorable, equatorward flow driven by changes in the along-shore surface pressure gradient.

- GCMs consistently predict an expansion (and weakening) of the Hadley cell resulting in SLP increases at midlatitudes (largest @ SH).
- The increase in SLP results in a strengthening of the equatorward flow along the EBUS, most notable off Chile (subtropical Humboldt).
- Stronger flow leads to a regional cooling @ surface down to 200 m that superimpose to a global mean warming trend

- Cooling off Chile (-0.25° /decade) due to (2/3) PDV variability and (1/3) Anthropogenic climate change

References

- Garreaud, R. and M. Falvey, 2008: The coastal winds off western subtropical South America in future climate scenarios. *Int. J. of Clim.* (in press).
- Lu, G., P. Vecchi and R. Reichler, 2007: Expansion of the Hadley cell and climate change. *Geoph. Res. Lett.*
- Falvey, M. and R. Garreaud, 2008: Recent atmosphere and ocean temperature trends in Chile. Submitted to *JGR-Atmos.*

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