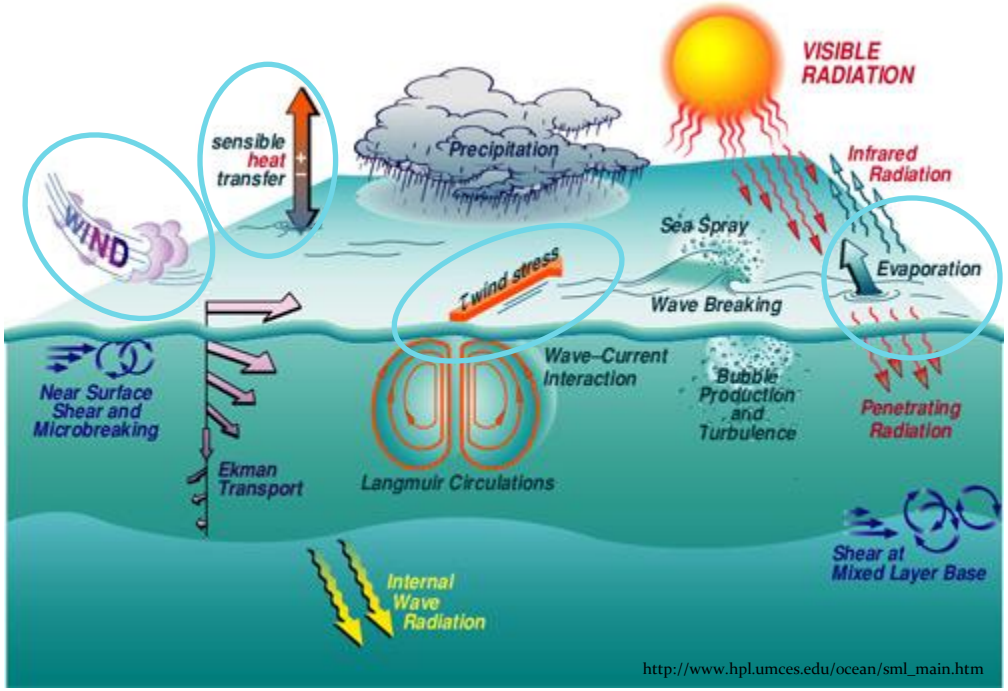
Evaluation of the IPSL-CM5 Earth System Model turbulent air-sea fluxes in tropical regions



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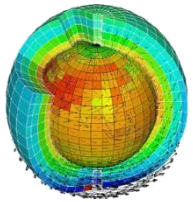
LSCE cea Institut Pierre Simon Laplace

Data

5 historical simulations

5 types of 'OBS'
→ 14 data sets

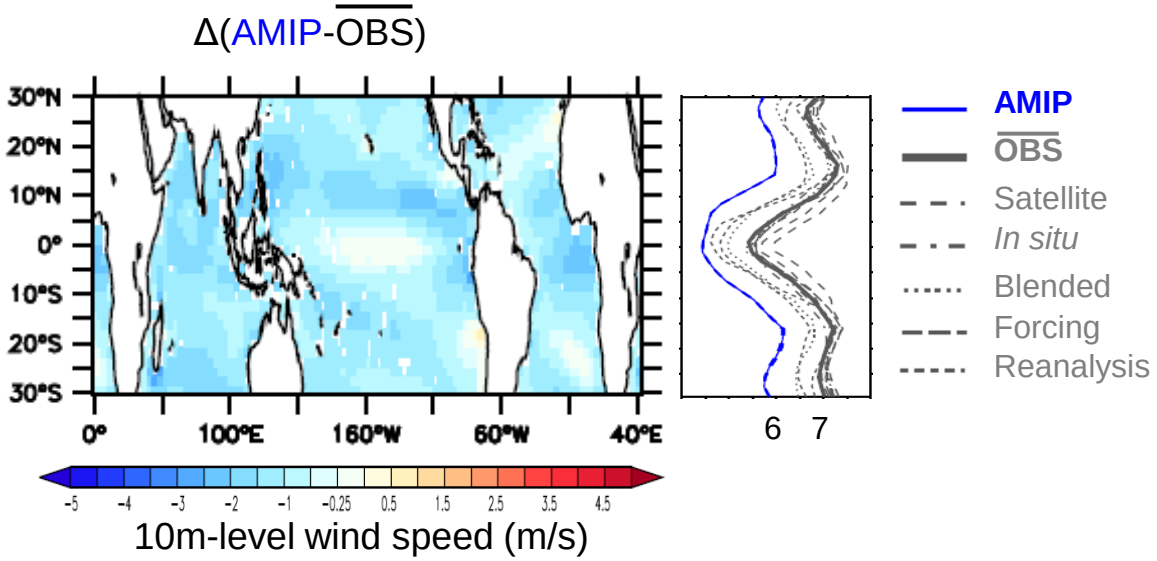


Models	"Validation" data sets
IPSL-CM5A	3 *in situ*
LMDZ5A → "AMIP"	3 satellite-based
IPSL-CM5AMR	3 hybrid
IPSL-CM4	3 reanalyses
IPSL-CM5B	2 ocean model forcing

8 variables: latent heat flux **LHF,** sensible heat flux **SHF,**
zonal wind stress τ_x, meridional wind stress τ_y,
near-surface wind speed **wind10m,**
surface temperature **SST,**
ocean-atmosphere temperature gradient **SST-T2m,**
near-surface air specific humidity **Q2m**

Period of reference: **1979-2005** Spatial coverage: **oceans 30°S-30°N**

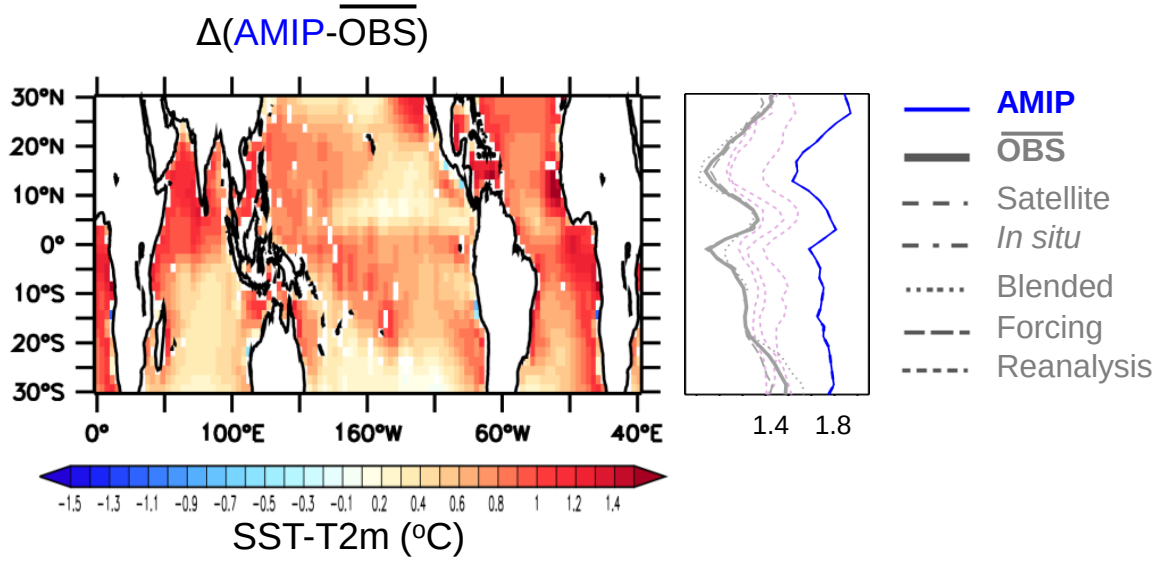
1. AMIP vs. OBS: Given correct SSTs, what does the model represent well, and what biases already appear?



Map and zonal means comparing the simulated climatological annual mean near-surface wind speeds with the observations.

Significant weak surface wind bias!

1. AMIP vs. OBS: Given correct SSTs, what does the model represent well, and what biases already appear?

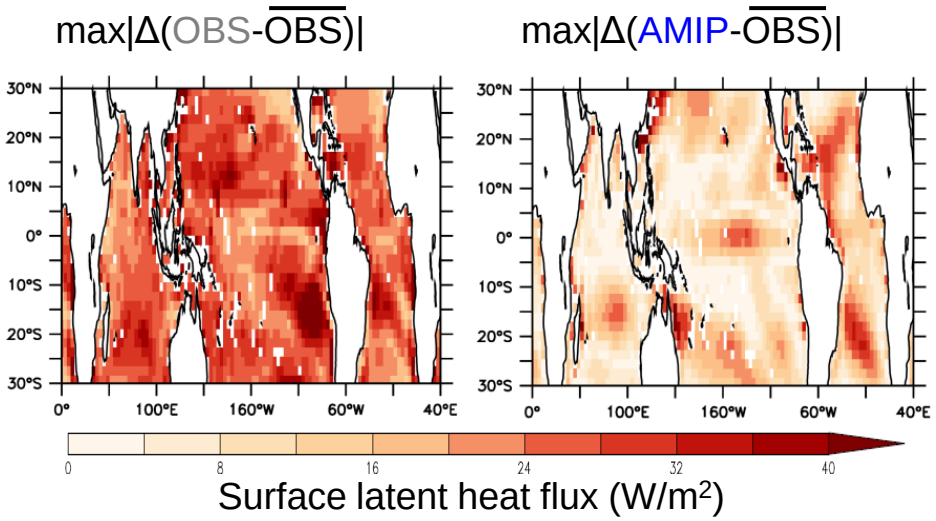


Map and zonal means comparing the simulated climatological annual mean sea-air temperature contrast with the observations.

↑

Exaggerated sea-air temperature gradient

1. AMIP vs. OBS: Given correct SSTs, what does the model represent well, and what biases already appear?

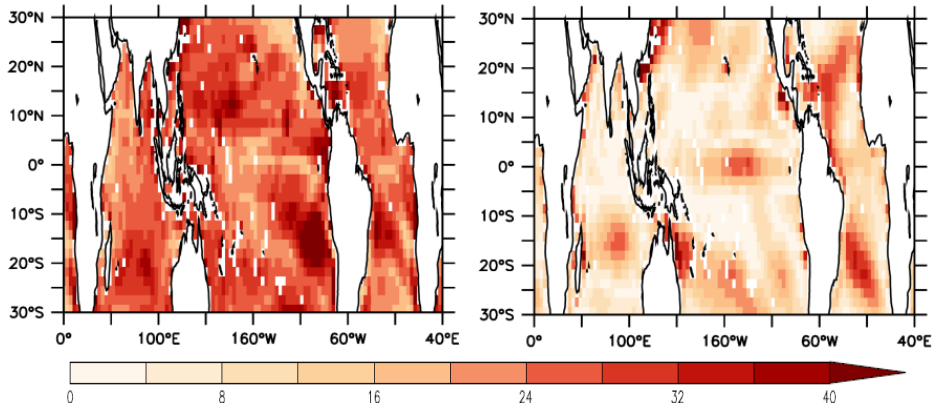


Maps of maximum absolute differences between the observational mean and: the individual observations (left); the individual AMIP simulations (right). The figure is based on climatological annual means.

Very large uncertainties in observational data;
Simulated latent heat flux within observational range

1. AMIP vs. OBS: Given correct SSTs, what does the model represent well, and what biases already appear?

max|Δ(OBS-$\overline{\text{OBS}}$)|

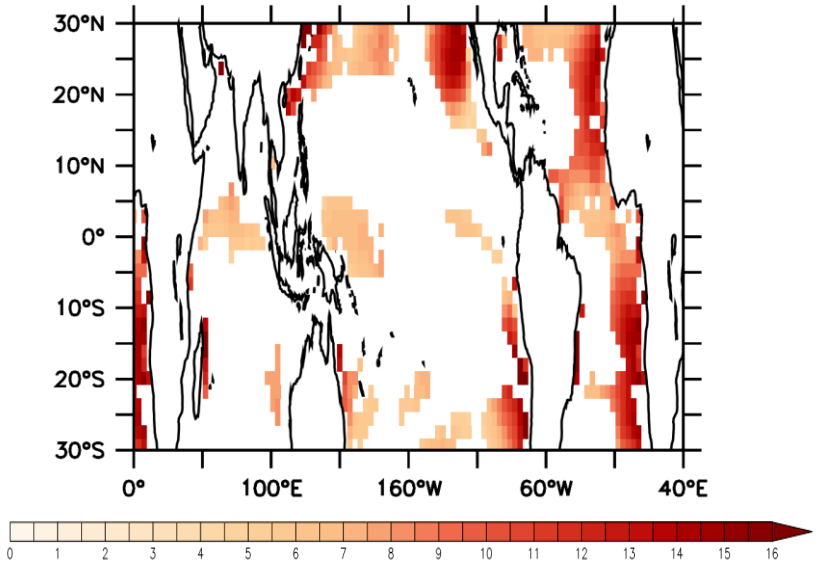


max|Δ(AMIP-$\overline{\text{OBS}}$)|

Surface latent heat flux (W/m^2)

Maps of maximum absolute differences between the observational mean and: the individual observations (left); the individual AMIP simulations (right). The figure is based on climatological annual means.

Signif. Δ(AMIP-$\overline{\text{OBS}}$)

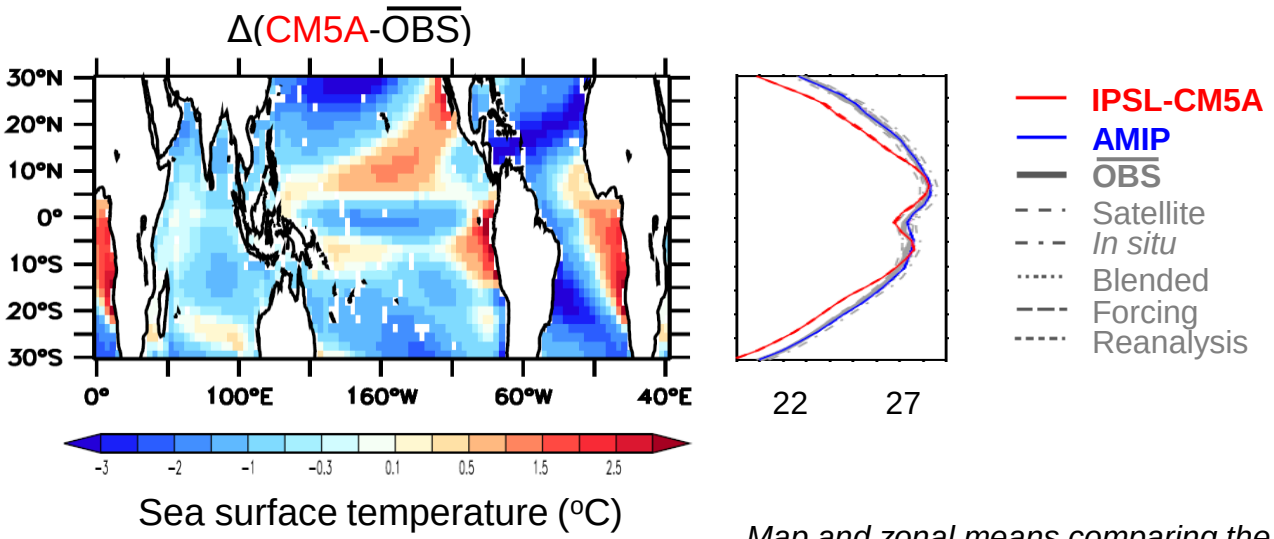


Surface sensible heat flux (W/m^2)

Map of significant model bias. The figure is based on simulated and observational climatological annual means.

Very large uncertainties in observational data;
Simulated heat flux mostly within observational range

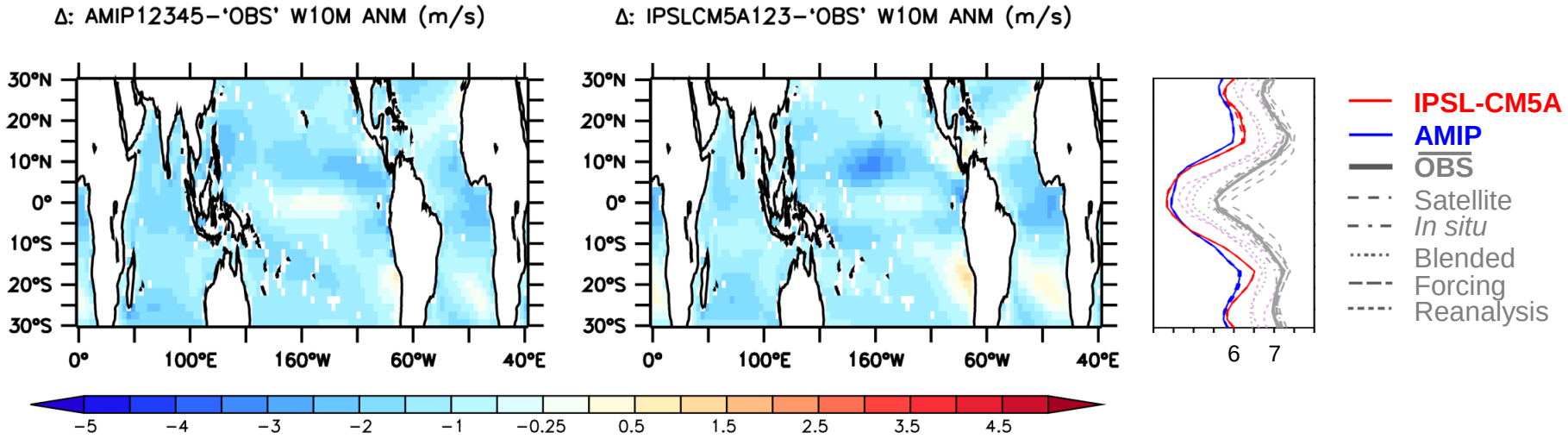
2. CM5A vs. AMIP vs. OBS: What are the effects of ocean-atmosphere coupling? What improves, what new biases appear, what stays the same?



Map and zonal means comparing the simulated climatological annual mean sea surface temperature with the observations.

Ocean-Atmosphere coupling => significant underestimate of the sea surface temperature in most tropical regions.

2. CM5A vs. AMIP vs. OBS: What are the effects of ocean-atmosphere coupling? What improves, what new biases appear, what stays the same?



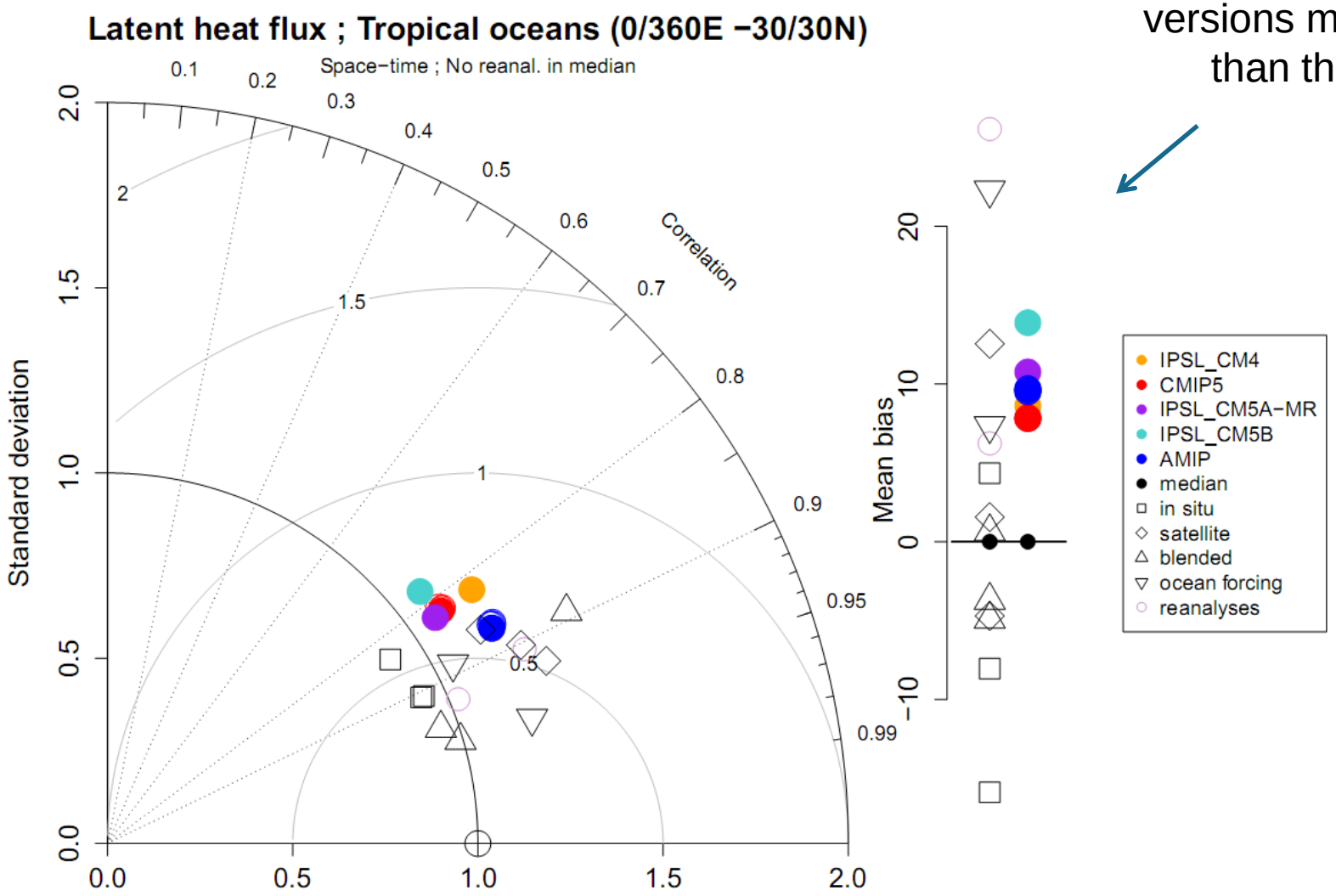
10m-level wind speed (m/s)

Increase in wind speed,
Change of structures in Pacific low latitudes

3. CM4 vs. CM5A vs. CM5A-MR vs. CM5B vs. OBS:

How do different versions of the coupled model compare?

Spread between model versions much smaller than the inter-OBS spread



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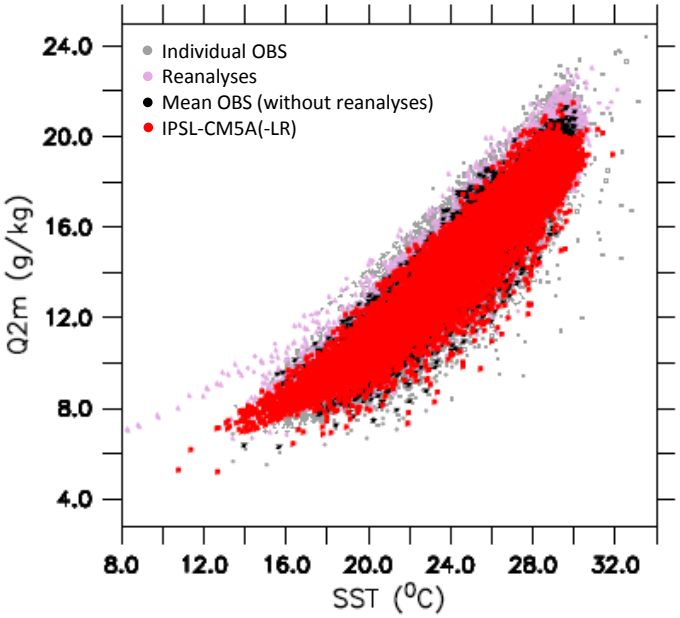
How do different versions of the coupled model compare?

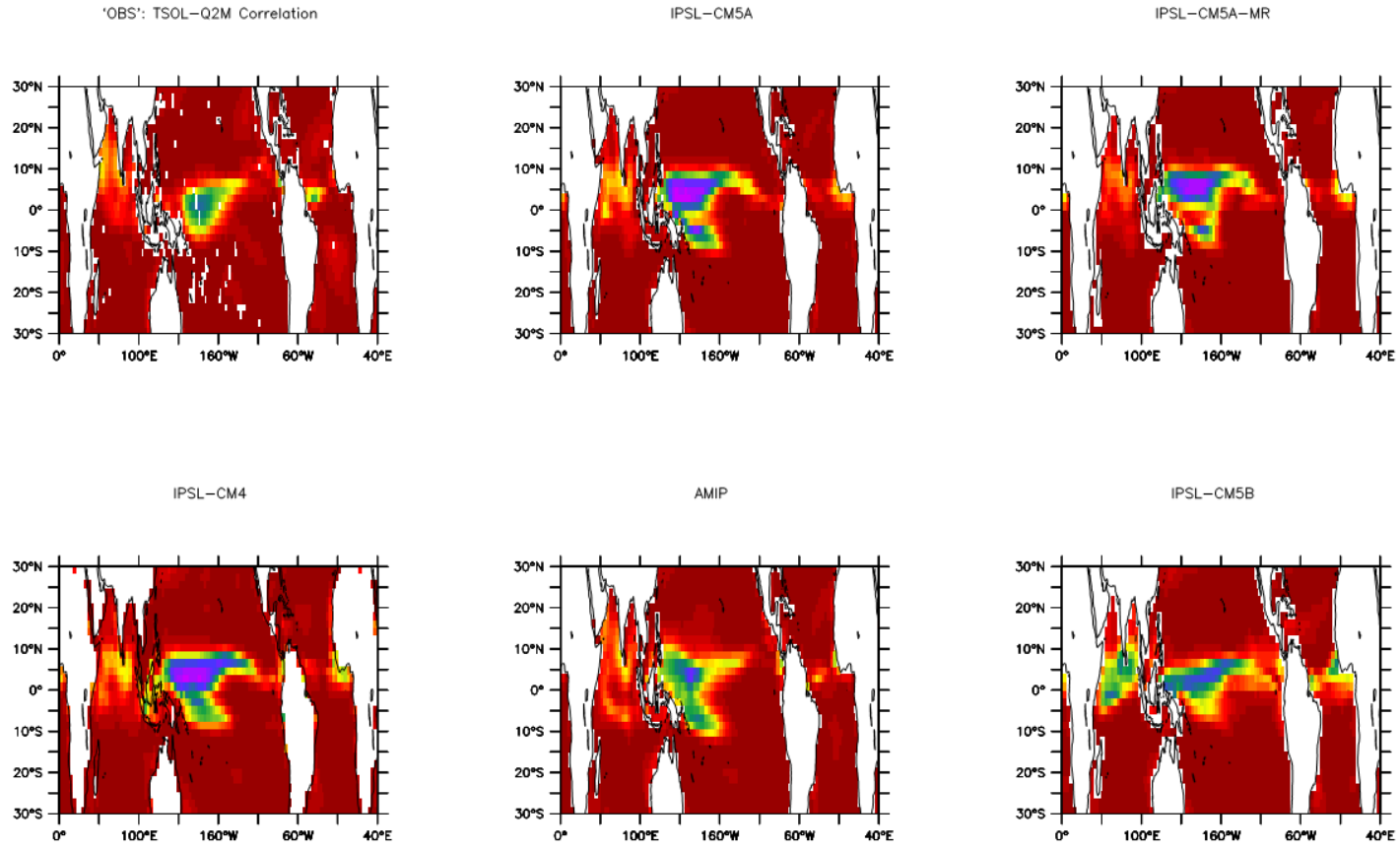


Well-constrained Q2m-SST relationship

Relationship stable in all model versions, but...

3. CM4 vs. CM5A vs. CM5A-MR vs. CM5B vs. OBS:
How do different versions of the coupled model compare?

...but not everywhere

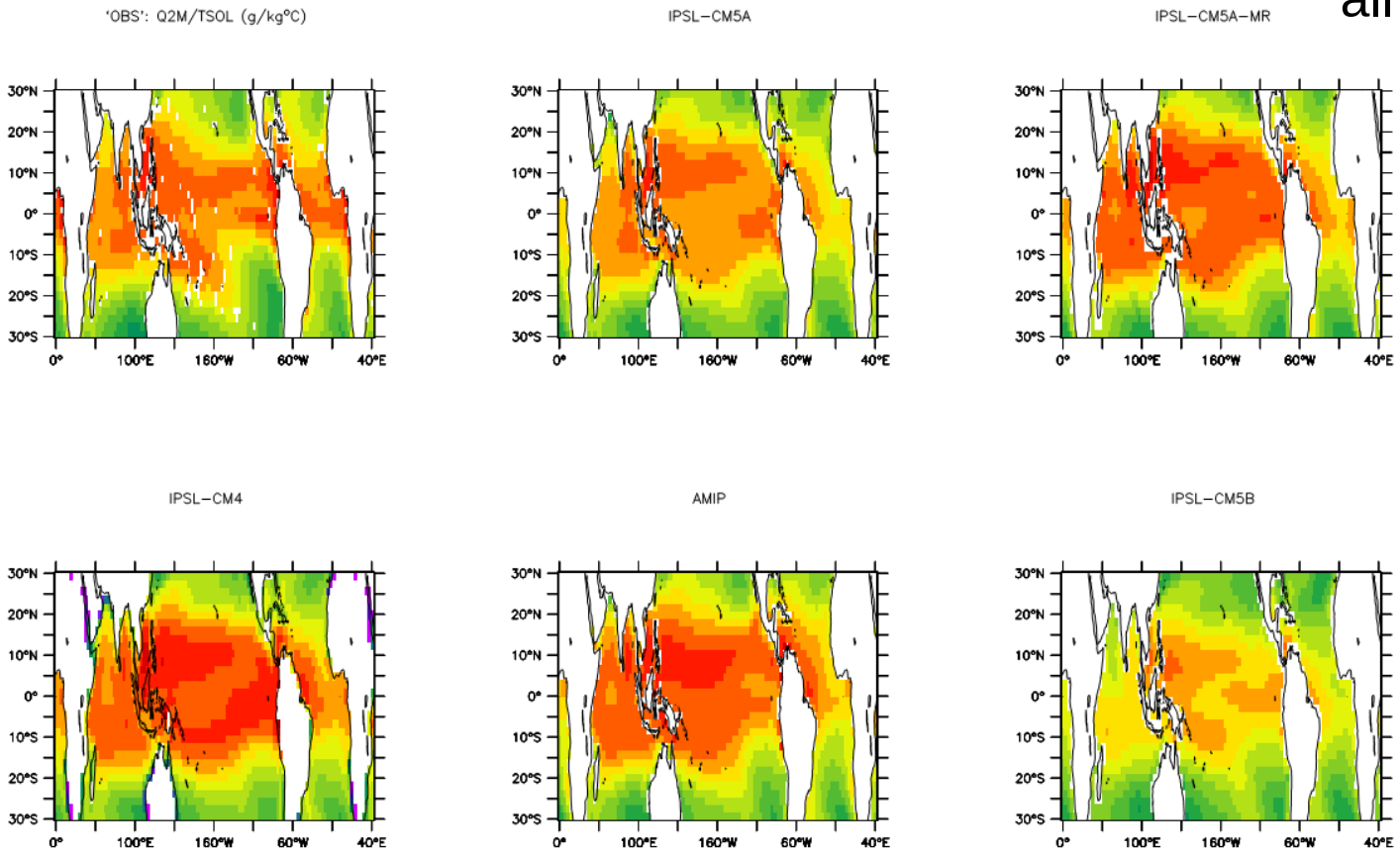


← Q2m-SST correlations
(from climatological seasonal cycles)

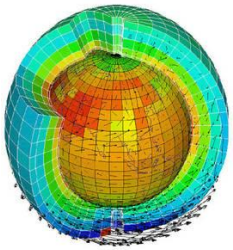
3. CM4 vs. CM5A vs. CM5A-MR vs. CM5B vs. OBS:

How do different versions of the coupled model compare?

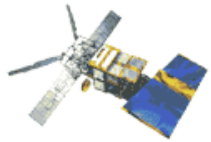
...and not the same in all model versions



Q2m / SST



Conclusions

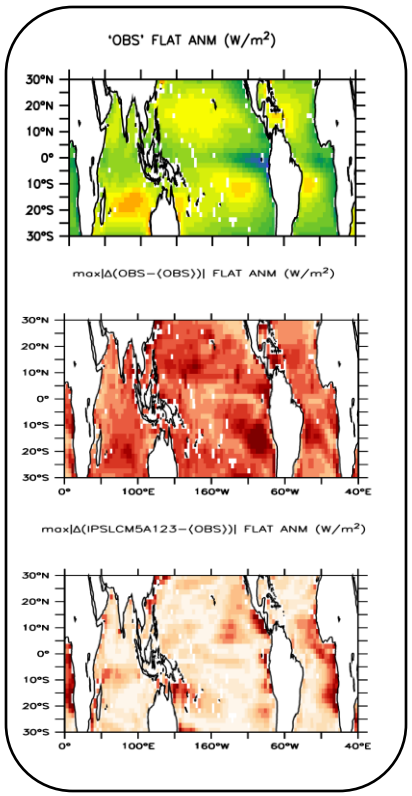


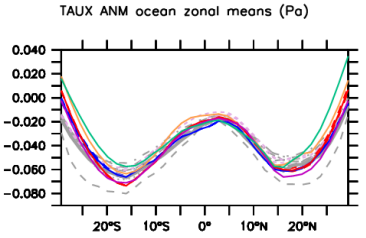
- Large observational uncertainties, especially in the surface heat fluxes – need to be addressed by the observational community
- When evaluating model results, we need to account for these uncertainties

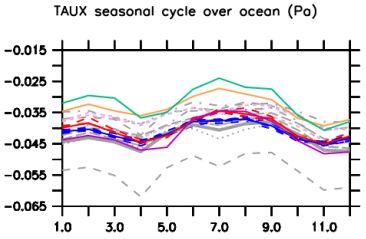
- Systematic model biases (cold sea surface, weak winds) do not transfer to the surface fluxes, because of compensation of effects

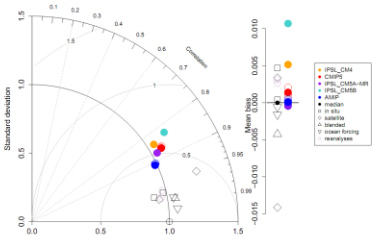
- Different model physics => “different world” (even when removing the mean bias)

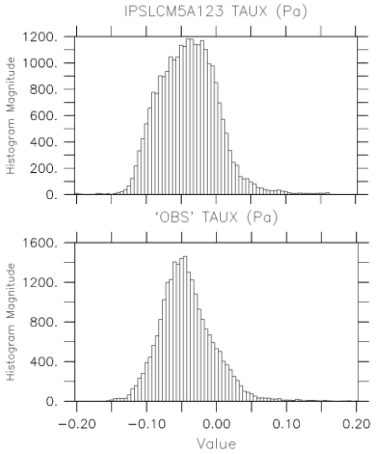
Analyses Atlas

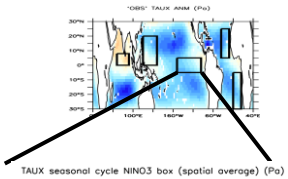








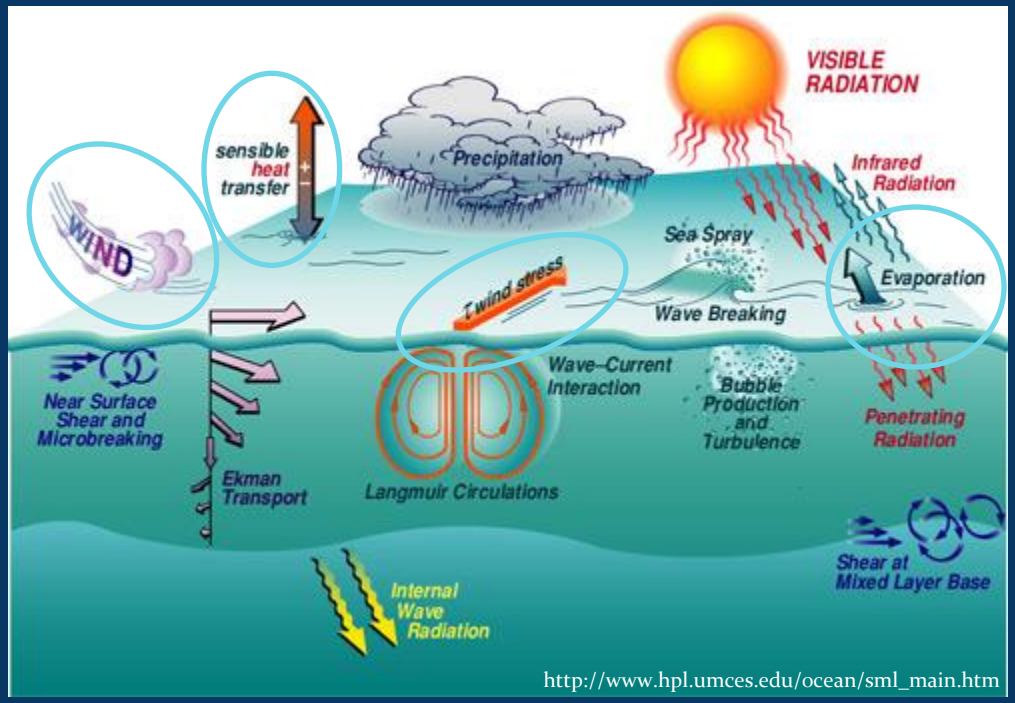




Turbulent fluxes

Sensible heat flux
$\rho C_p C_H (U-U_s) (T_s-T_a)$

Momentum flux = Wind stress
$\rho C_D (U-U_s)^2$



Latent heat flux
$\rho L_v C_E (U-U_s) (Q_s-Q_a)$

• SENS – lower in CM5B than in CM5A, despite higher ΔT2m AND higher WIND10M!! ← any modifications in the bulk formula? YES: f_cdrag=0.7 instead of 0.8 in CM5A.

• Change in the relative importance of the heat fluxes: SENS lower, but FLAT higher than in CM5A!

• FLAT – higher than in CM5A, because of higher SST and WIND10M but lower Q2M!