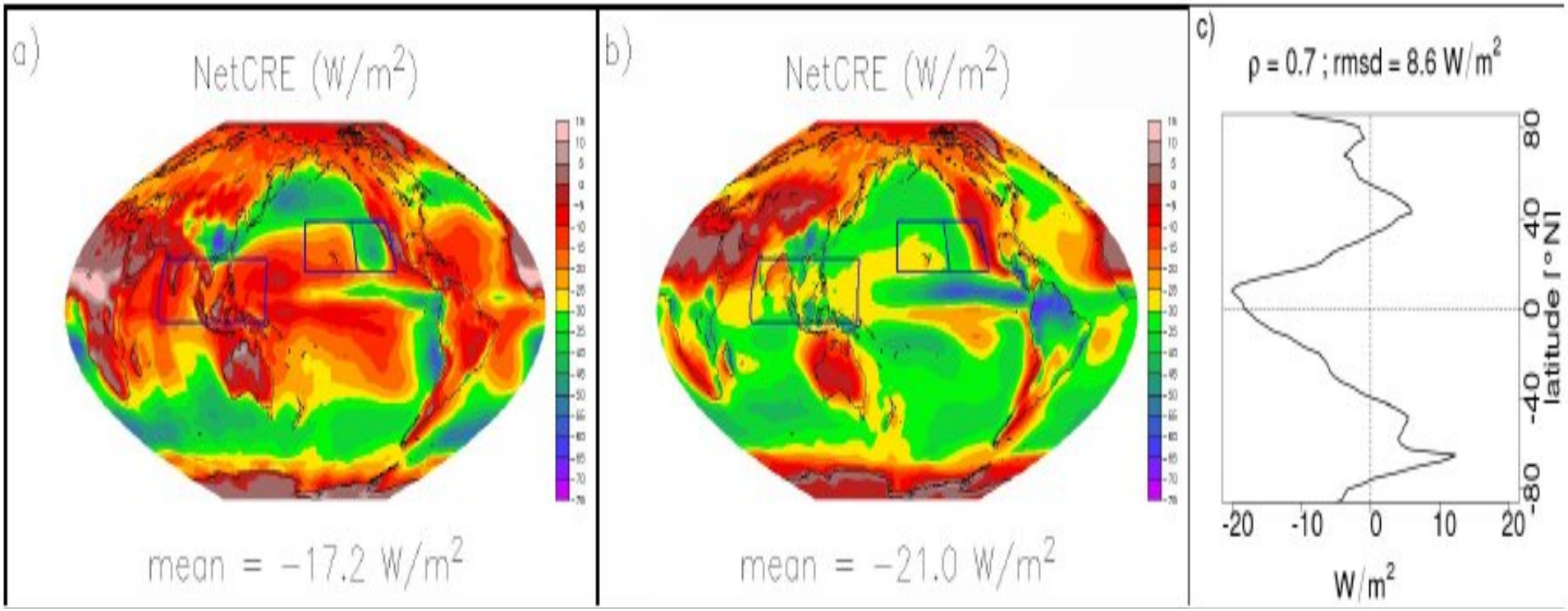
CLOUD BIASES IN EC-EARTH: FOCUS ON THE TROPICAL BELT

Carlo Lacagnina and Frank Selten

KNMI

Impact of clouds on the Earth Radiation Budget



OBSERVATIONS EC-EARTH BIAS

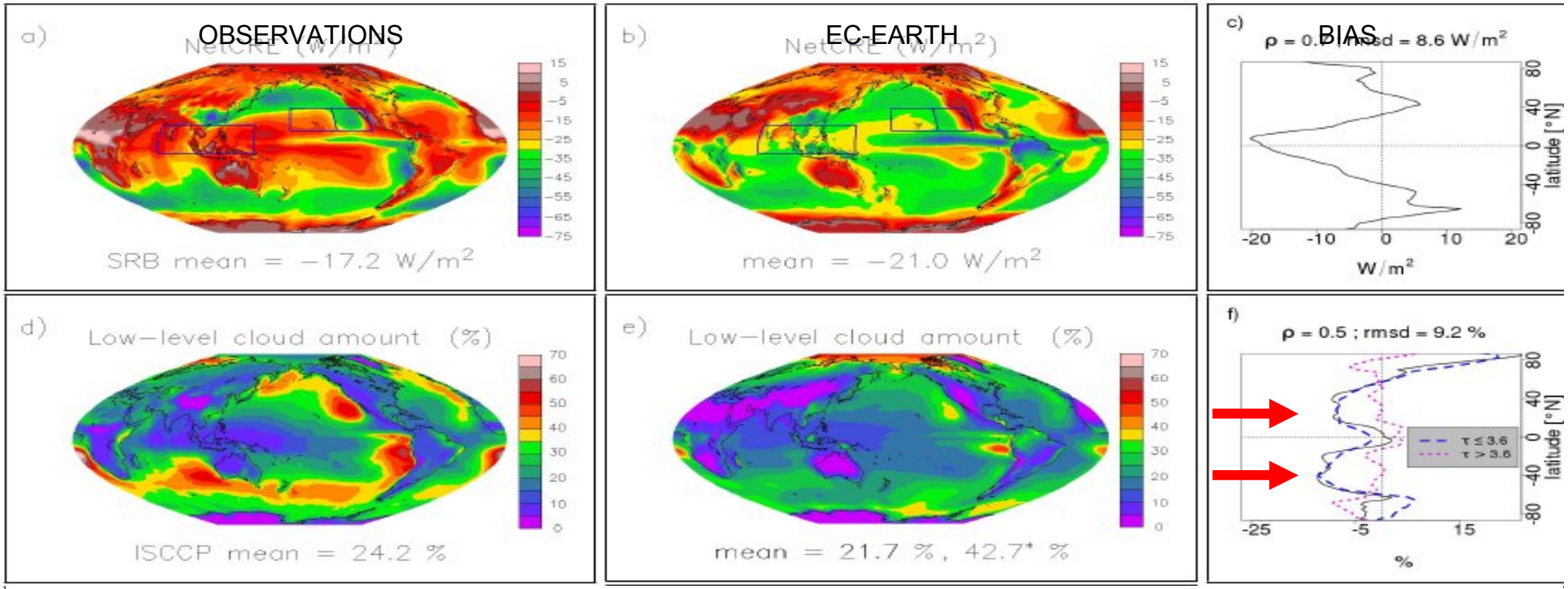
EC-EARTH based on cycle 31R1 of ECMWF IFS:

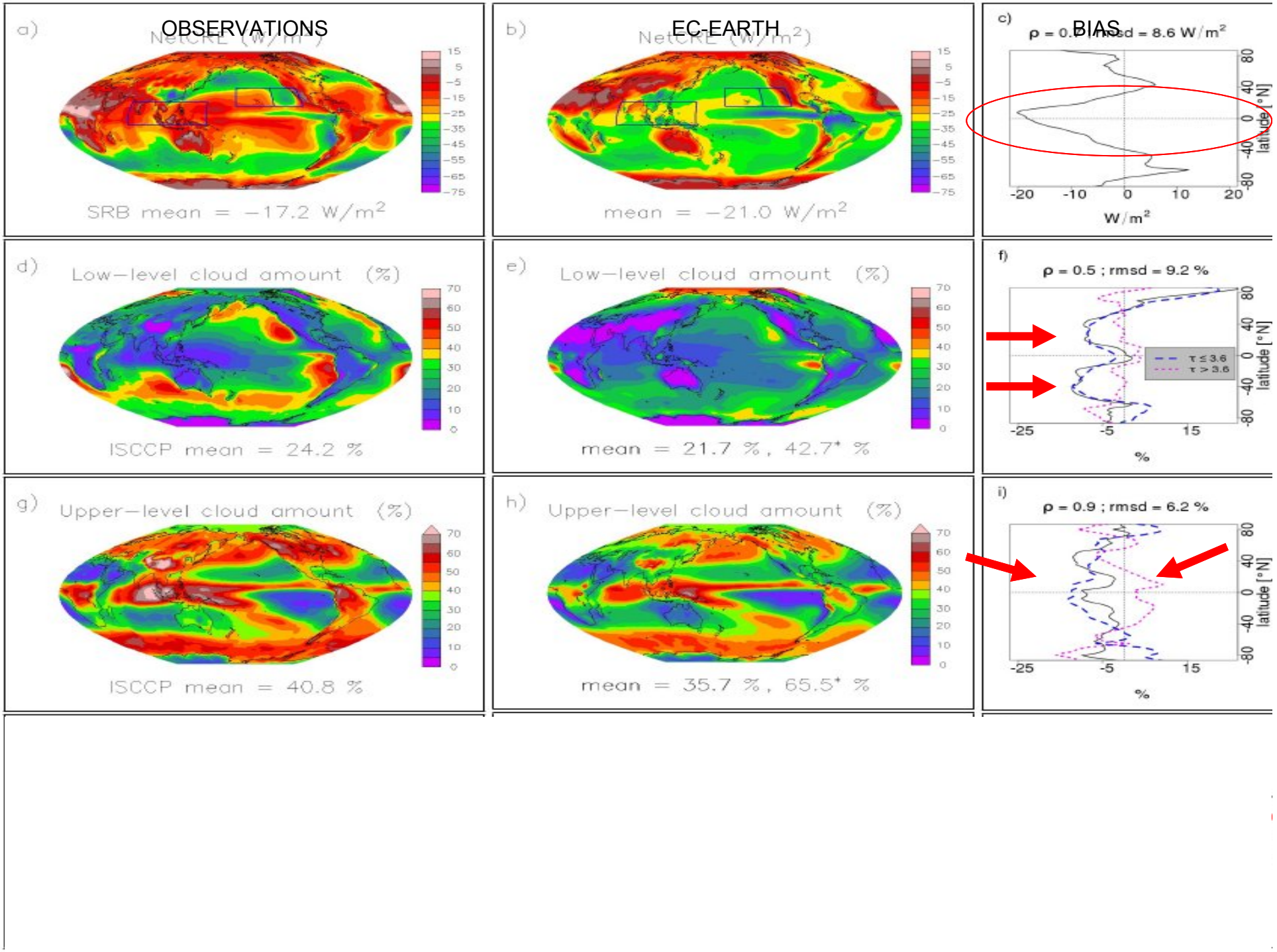
- AMIP simulation
- ISCCP simulator embedded

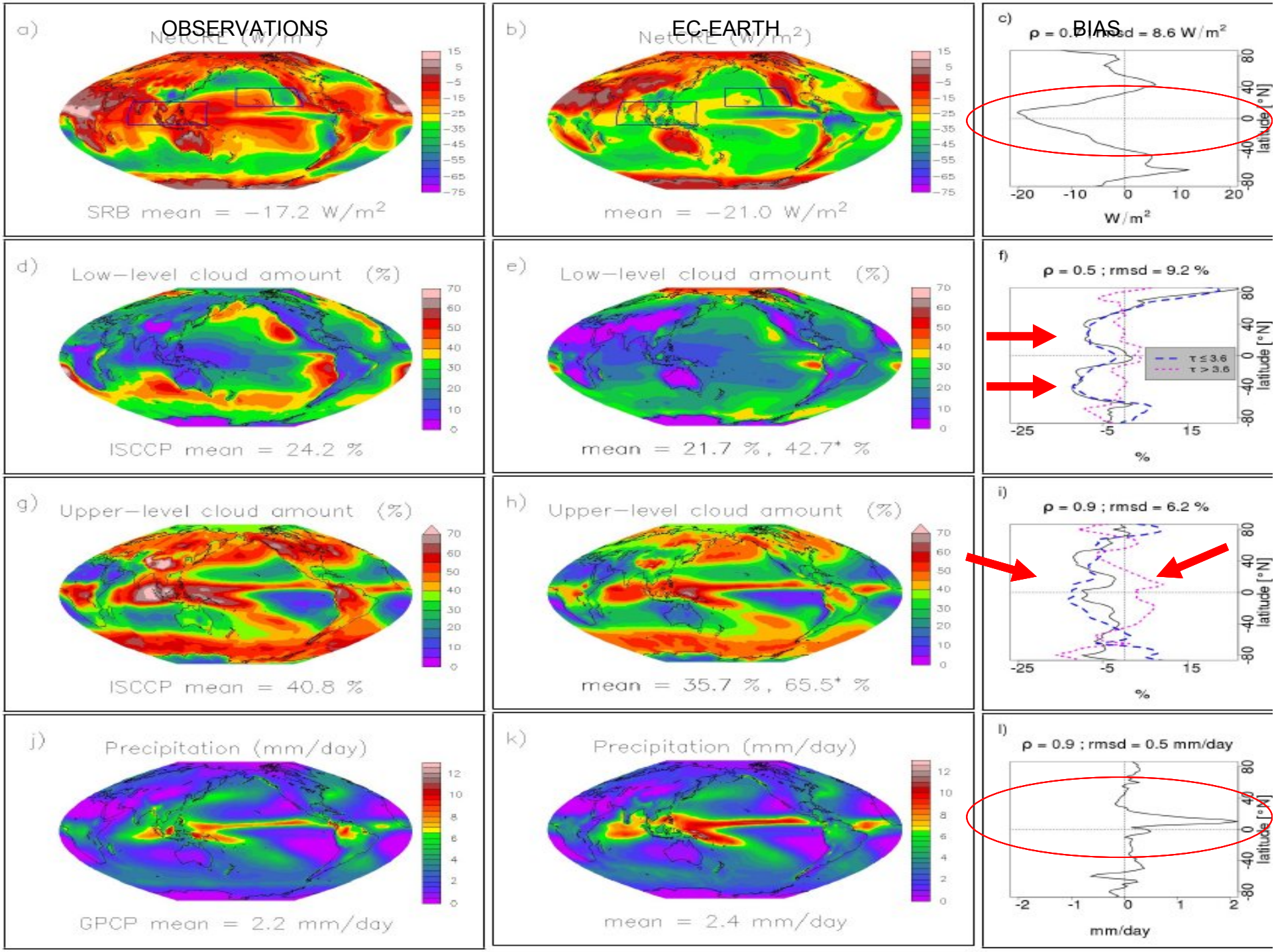
OBSERVATIONS

EC-EARTH

BIAS




OBSERVATIONS
EC-EARTH
BIAS
a)
SRB mean = −17.2 W/m²
b)
mean = −21.0 W/m²
c)
ρ = 0.7 ; rmsd = 8.6 W/m²
W/m²
d)
Low−level cloud amount (%)
ISCCP mean = 24.2 %
e)
Low−level cloud amount (%)
mean = 21.7 %, 42.7* %
f)
ρ = 0.5 ; rmsd = 9.2 %
τ ≤ 3.6
τ > 3.6
%
g)
Upper−level cloud amount (%)
ISCCP mean = 40.8 %
h)
Upper−level cloud amount (%)
mean = 35.7 %, 65.5* %
i)
ρ = 0.9 ; rmsd = 6.2 %
%
latitude [°N]


OBSERVATIONS
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ρ = 0.9 ; rmsd = 6.2 %
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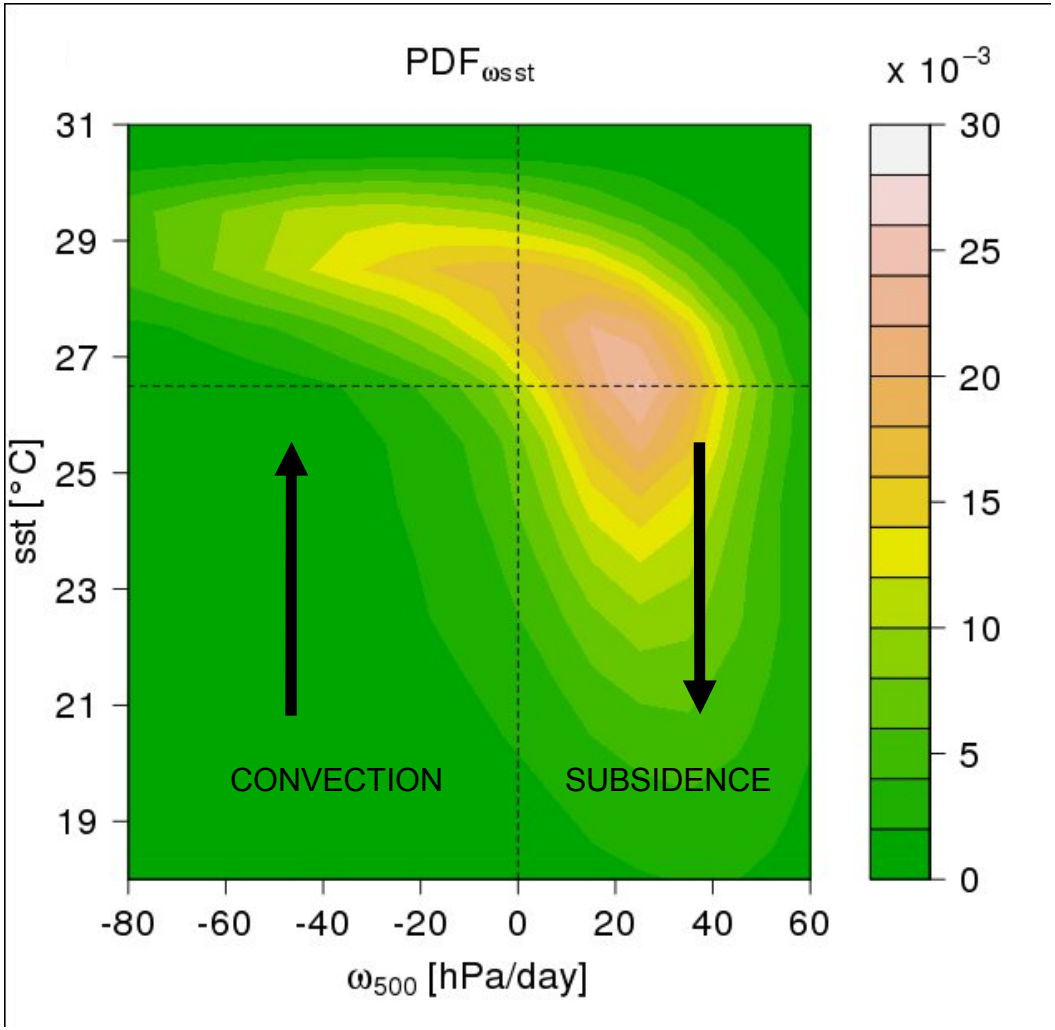
latitude [°N]
j)
Precipitation (mm/day)
GPCP mean = 2.2 mm/day
k)
Precipitation (mm/day)
mean = 2.4 mm/day
l)
ρ = 0.9 ; rmsd = 0.5 mm/day
mm/day
latitude [°N]

Tropical belt

Bivariate approach

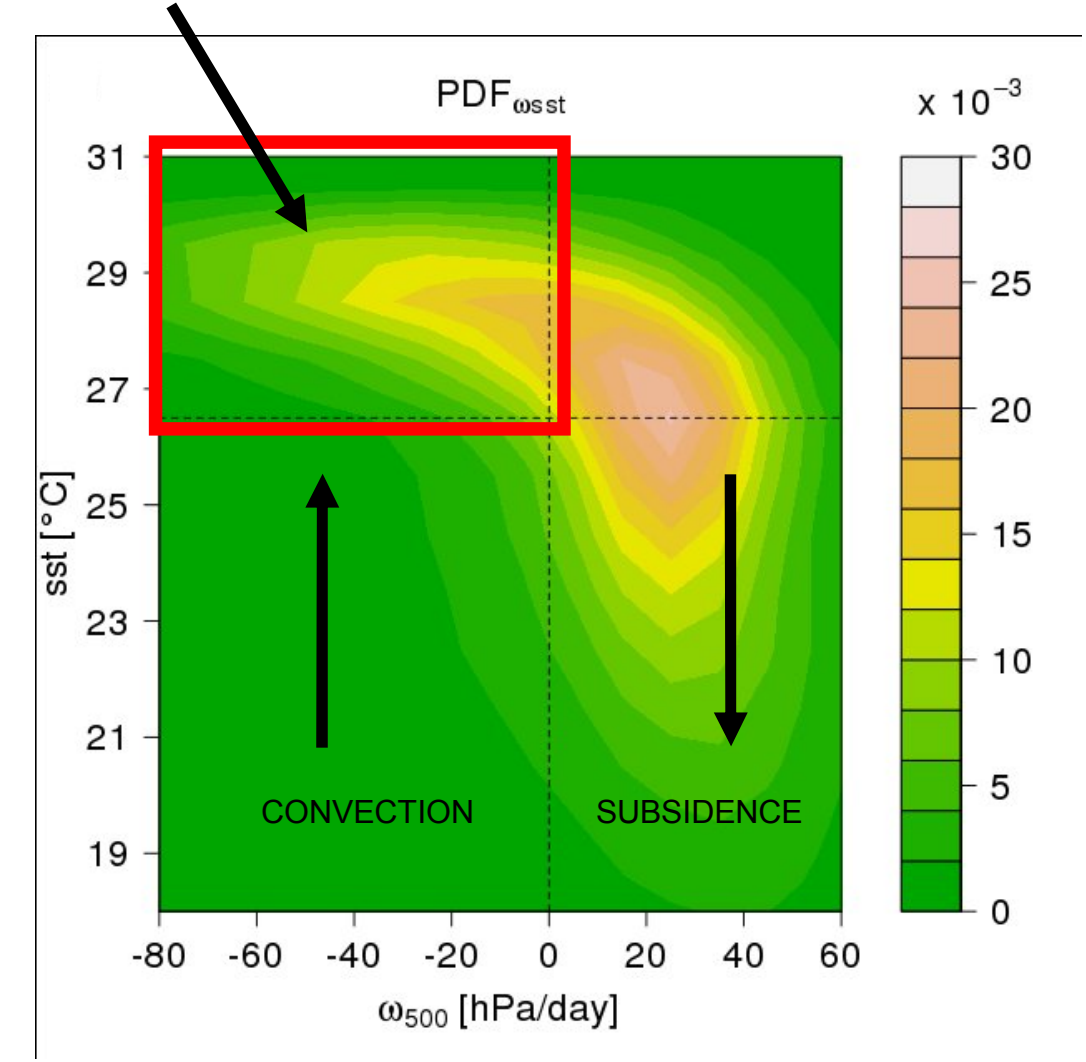


- Decomposition of the Walker-Hadley circulation over the tropical oceans (35ºN-35ºS) into ω - SST regimes

- ω is the vertical pressure velocity at 500 hPa, a proxy for large-scale vertical motions

- Here is plotted the number of occurrences of each ω-SST bin (PDF)

Bivariate approach



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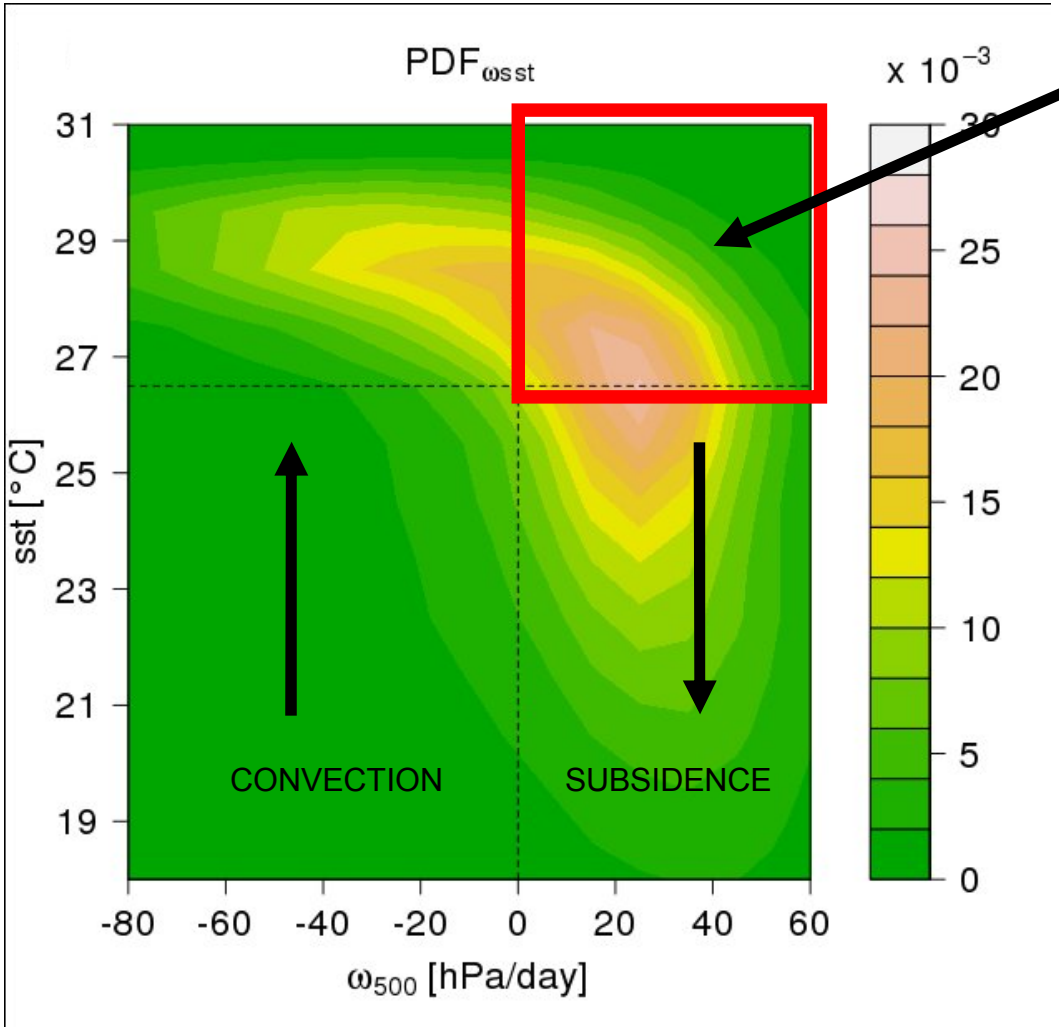

Low cumulus clouds (e.g., trade-wind cumulus)

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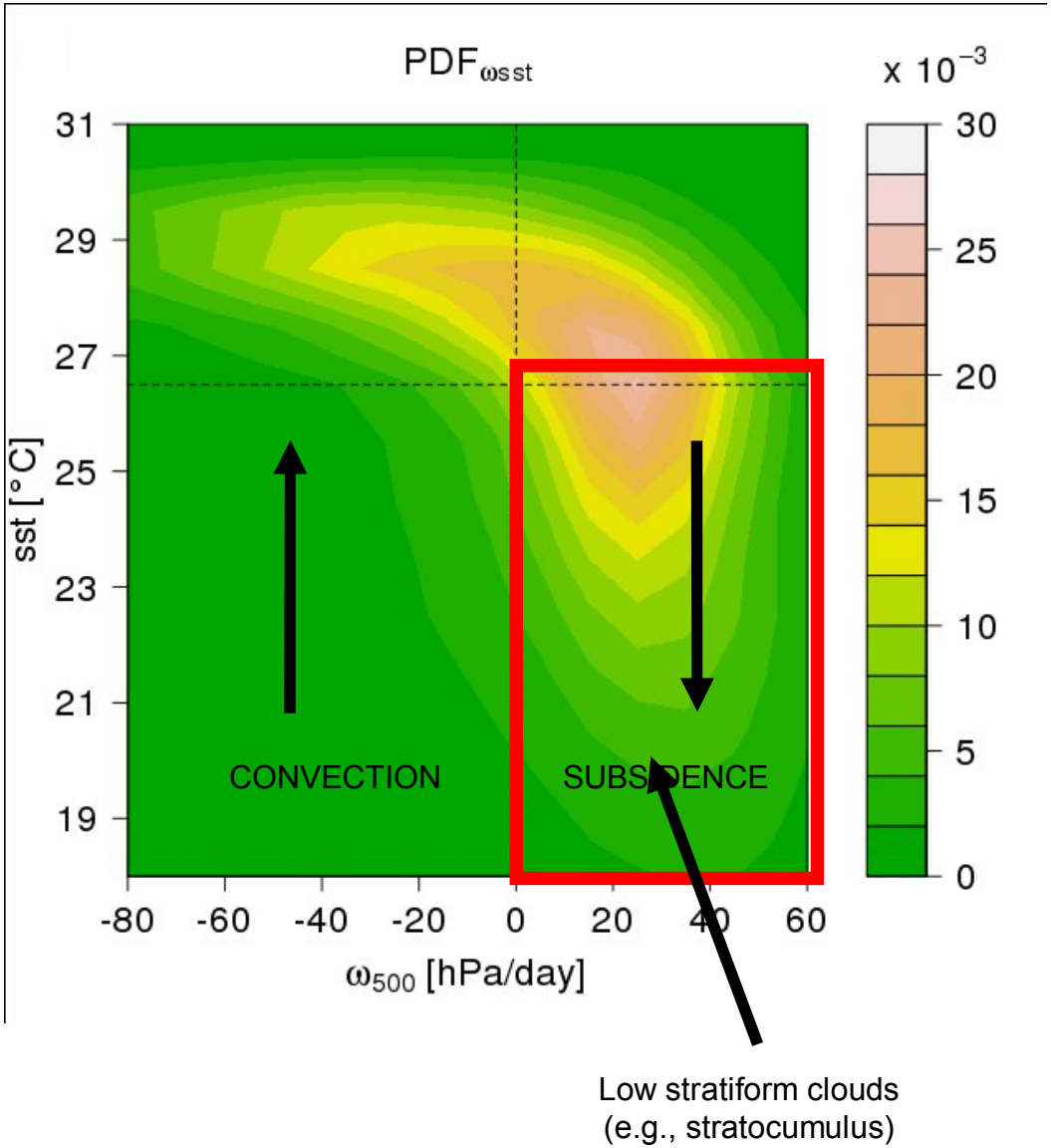

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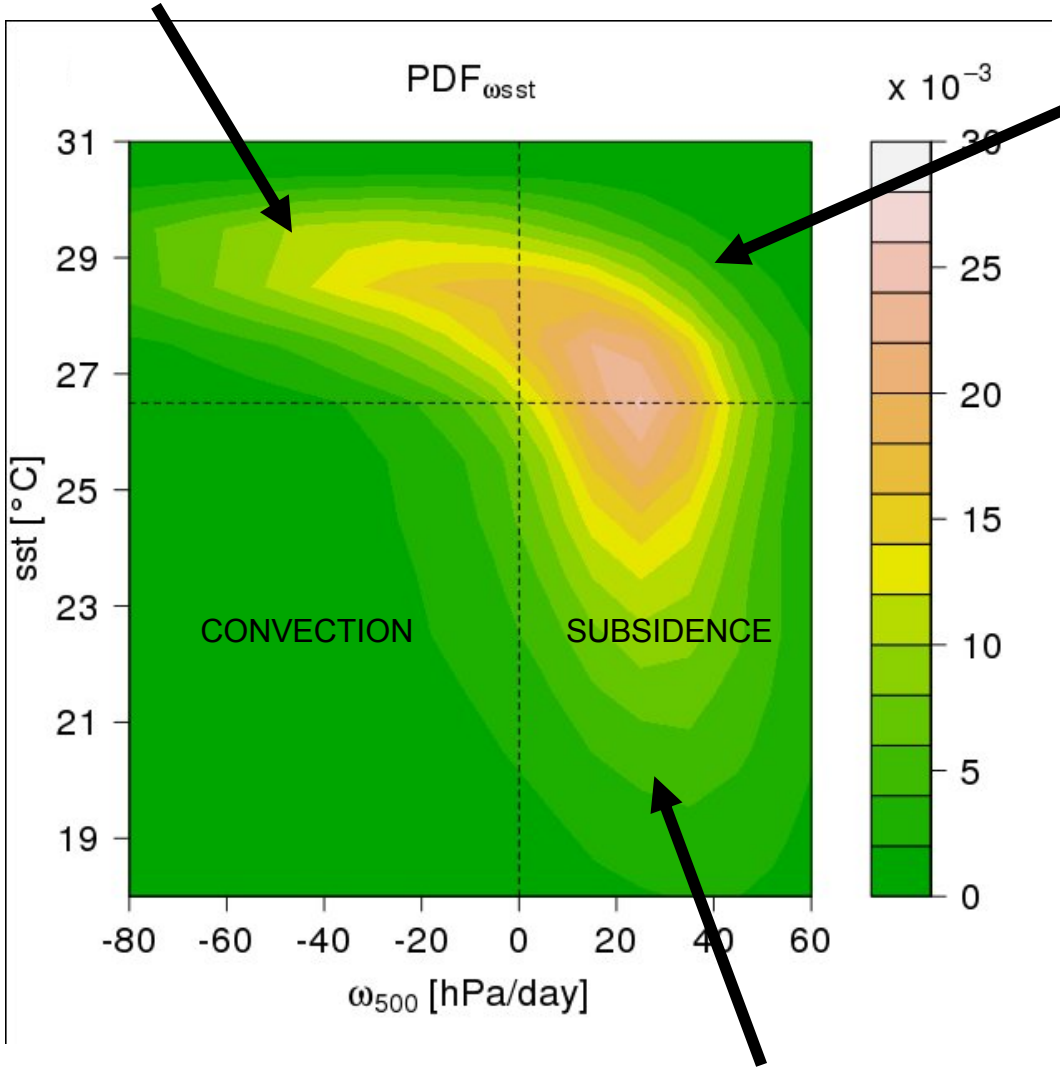
Bivariate approach

High clouds (e.g., cumulunimbus & cirrus)



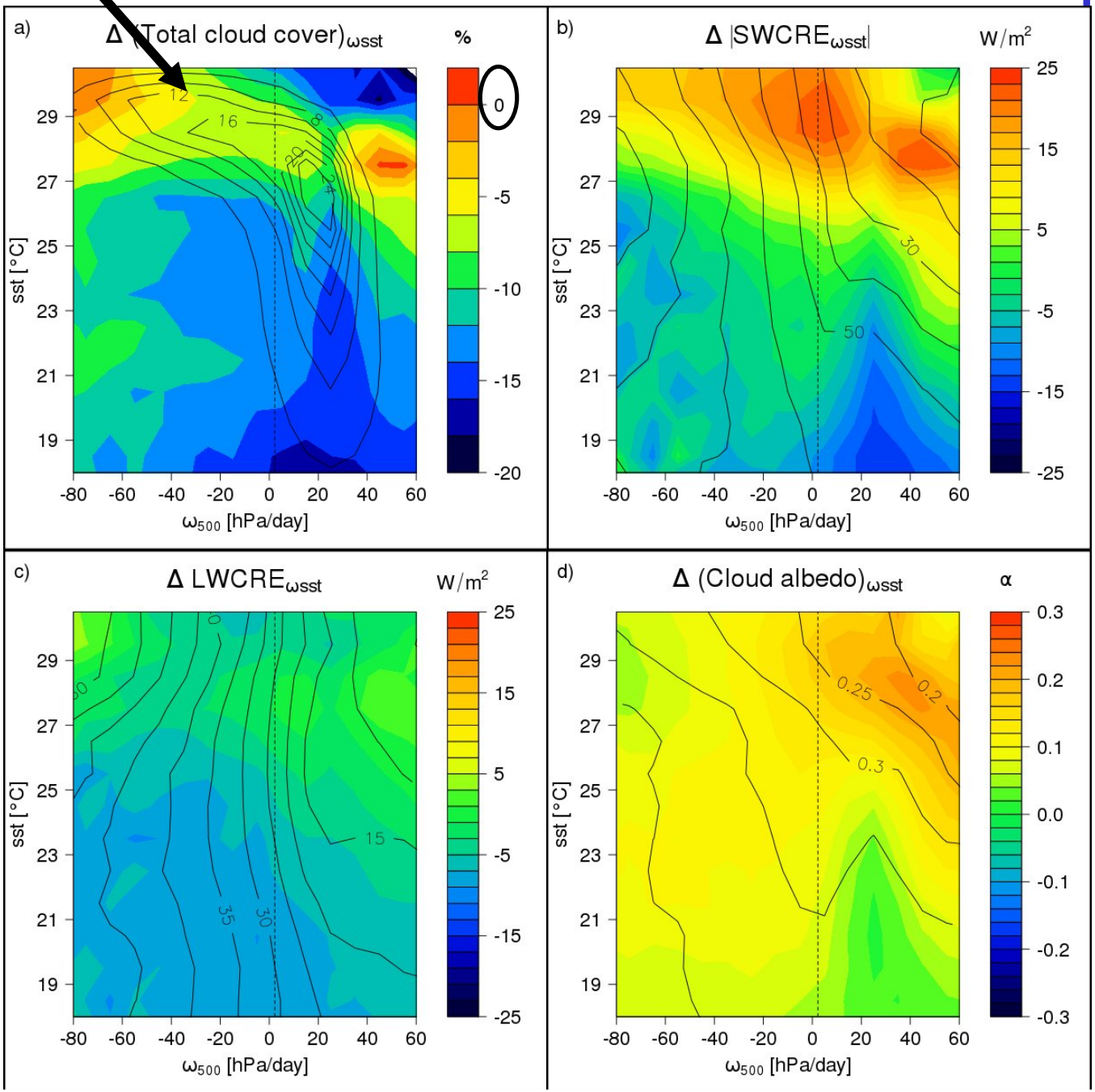
Low cumulus clouds (e.g., trade-wind cumulus)

Low stratiform clouds (e.g., stratocumulus)

- decomposition of the Walker-Hadley circulation over the tropical oceans (35ºN-35ºS)

- Advantages of this visualization:
  _disentangle different cloud types
  _relative contribution of the different cloud regimes to tropics-wide area

Cloud biases in the tropics



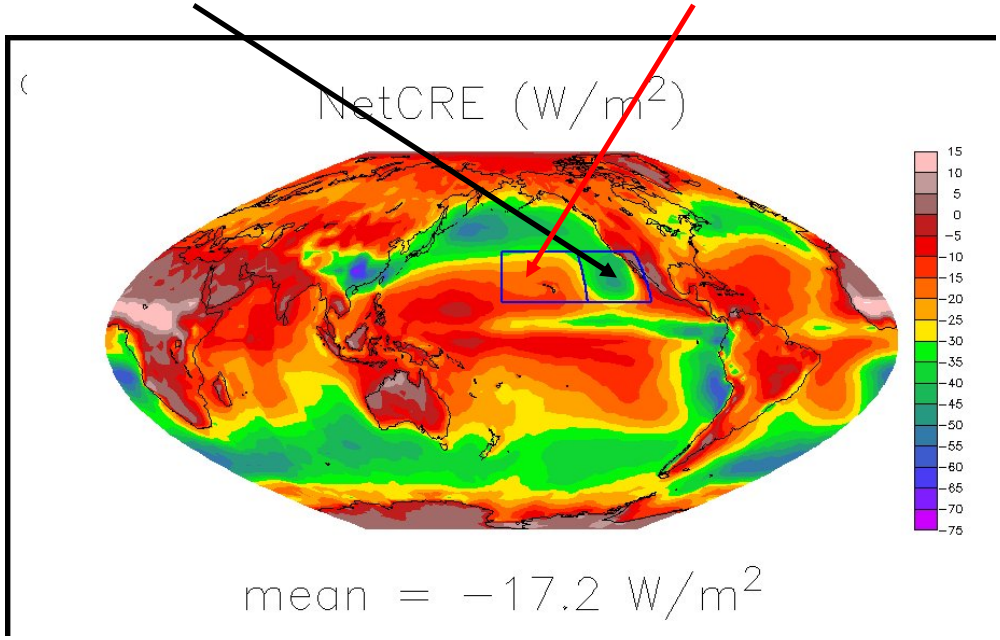
- Contour lines represent cloud field as in the observations, shadings are the biases (model – observations)
- Too few clouds, notably too few stratocumulus (Fig. a)
- SWCRE is the main source for cloud radiative biases (clouds cool too much, except for stratocumulus, Figs. b-c)
- Cloud albedo, unlike SWCRE, does NOT depend on cloud cover
- Stratocumulus albedo is about right, but too high for cumulus clouds (Fig. d)

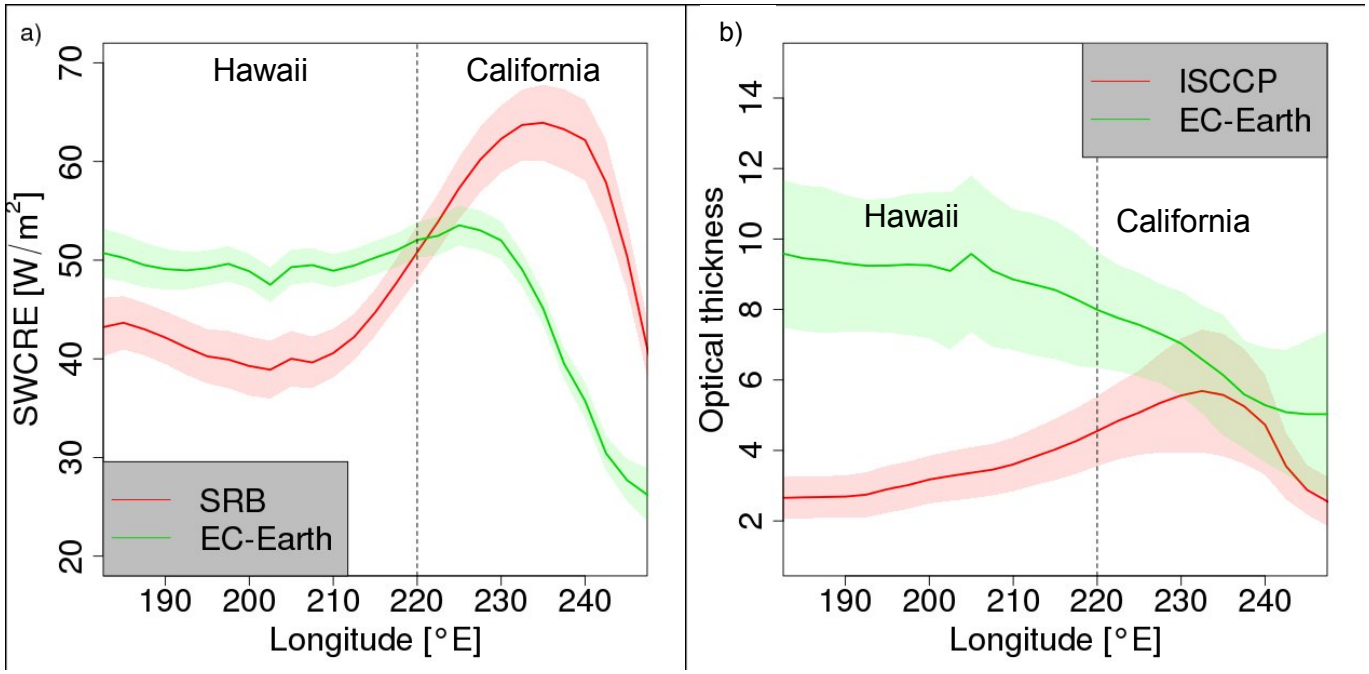
Why is the cloud albedo about right for stratocumulus, but too high for cumulus clouds?

Stratocumulus to trade cumulus transition

Cloud albedo is proportional to optical thickness:

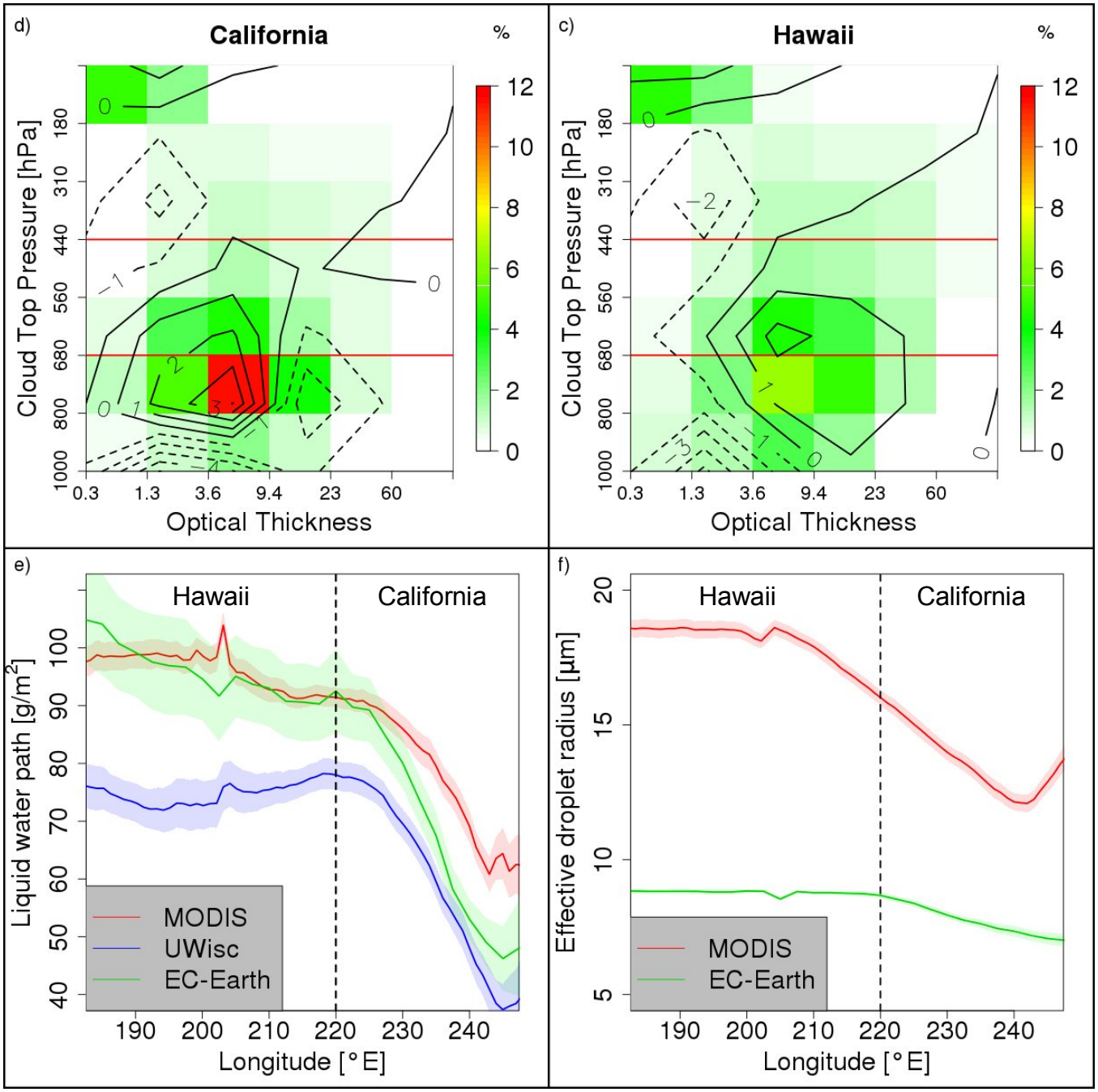
$\alpha \propto \tau$





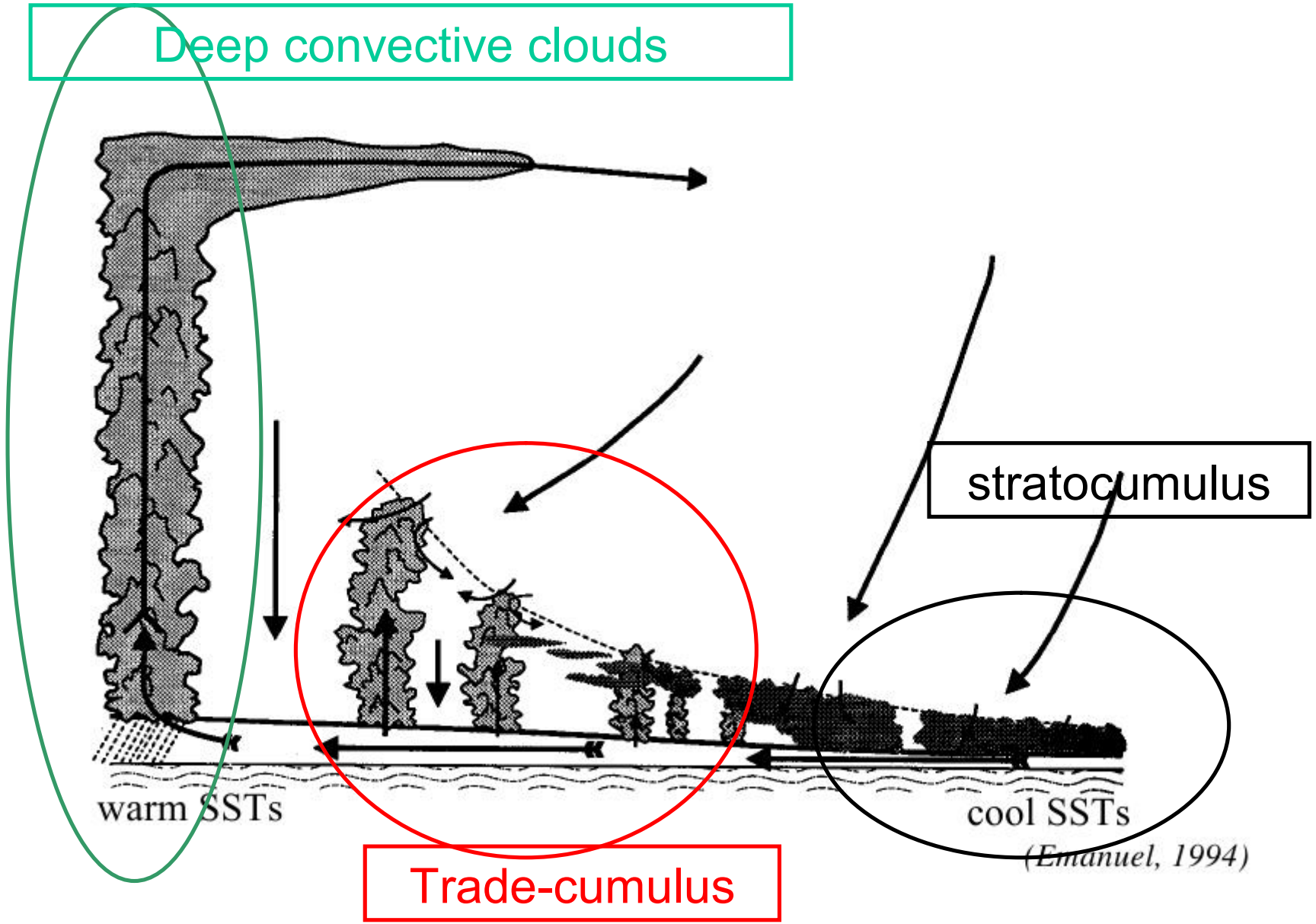
- what was observed at the large-scale can be also found at the regional scale (off coasts of California)
- about right distribution of optical depth for stratocumulus, but too high for trade-cumulus (Fig. b)

Stratocumulus to trade cumulus transition

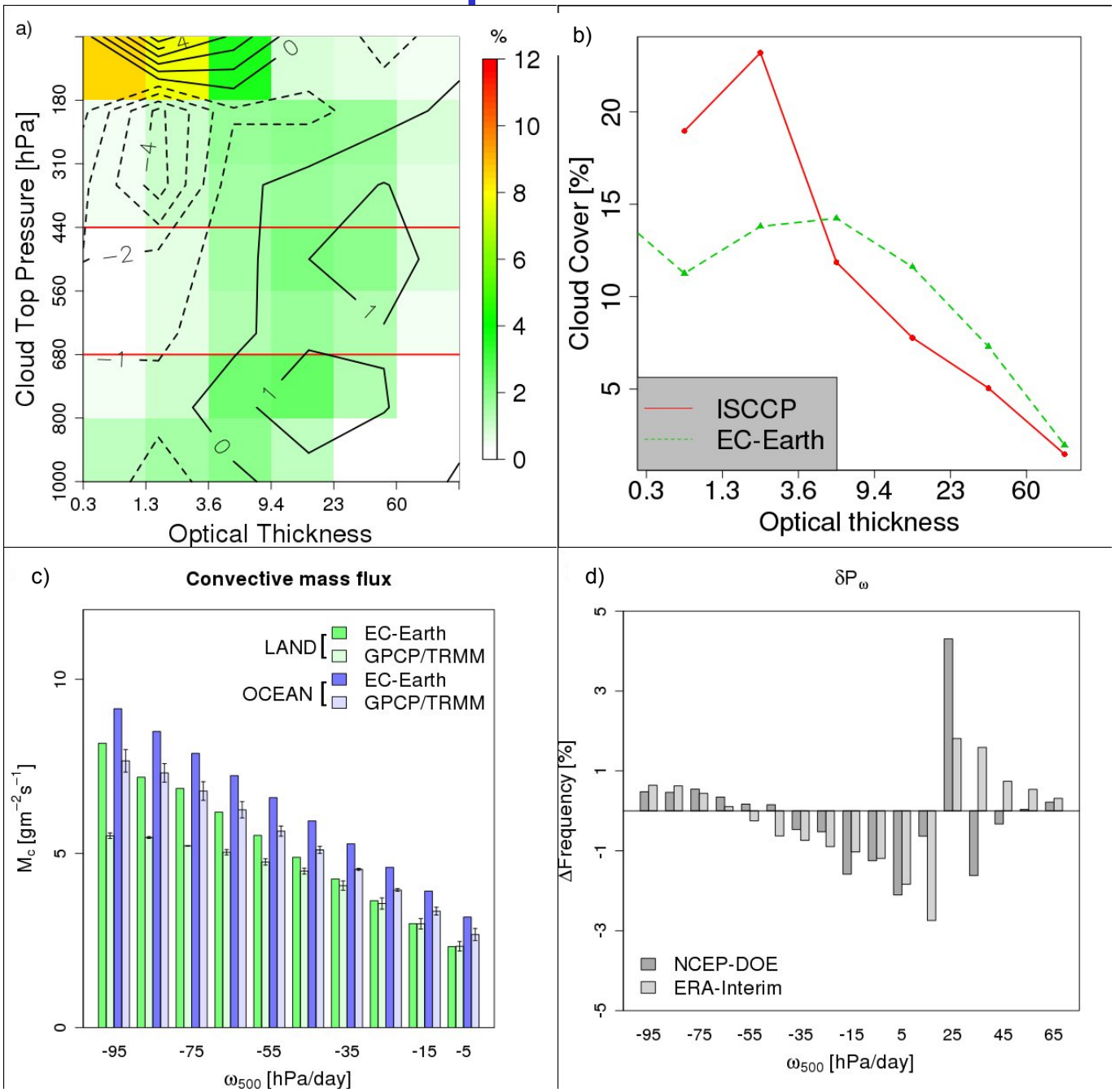


- 3D cloud distribution on California and Hawaii
- compensating errors give an about right averaged optical depth over the Californian region (Fig. c)
- too few thin and too many thick clouds leads to overestimation of cloud albedo in the Hawaiian region (Fig. d)
- <u>relationship</u>: $\alpha \propto \tau$
  $\tau = k * LWP / r_{eff}$
- too high optical depth may be due to too small droplets radius (r_{eff}) (Fig. f)

What about the deep convective clouds?


Deep convective clouds
stratocumulus
warm SSTs
cool SSTs
(Emanuel, 1994)
Trade-cumulus

Tropical Western Pacific



- also in the deep tropics EC-Earth predicts too many thick clouds and too few thin clouds (Figs. a-b)
- as a result the |SWCRE| and the precipitation are overestimated (shown before)
- <u>why too thick high clouds in the deep tropics?</u>
- overestimated mass-flux (Fig. c), confirmed by enhanced extremes of ω PDF (vertical pressure velocity, Fig. d)
- convective scheme may be the source of cloud biases in the deep tropics

Tropical Western Pacific

- thin upper-clouds → warm

  Too few

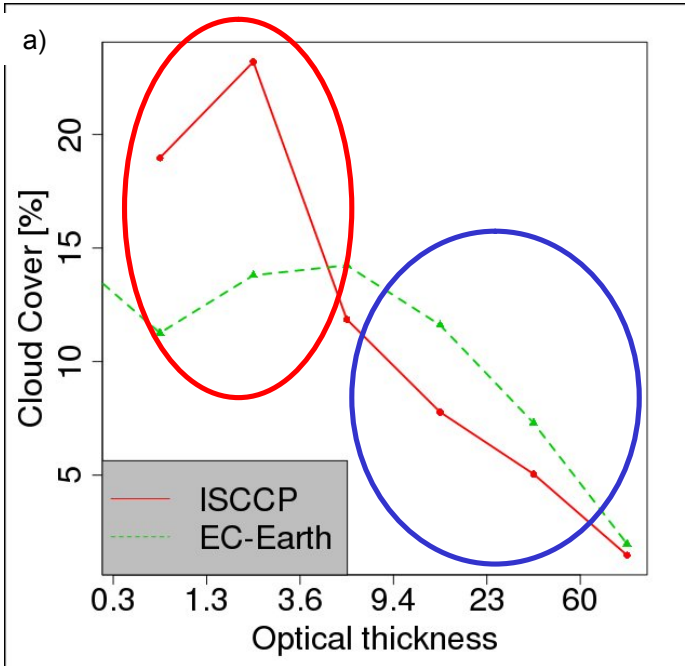
  ↘

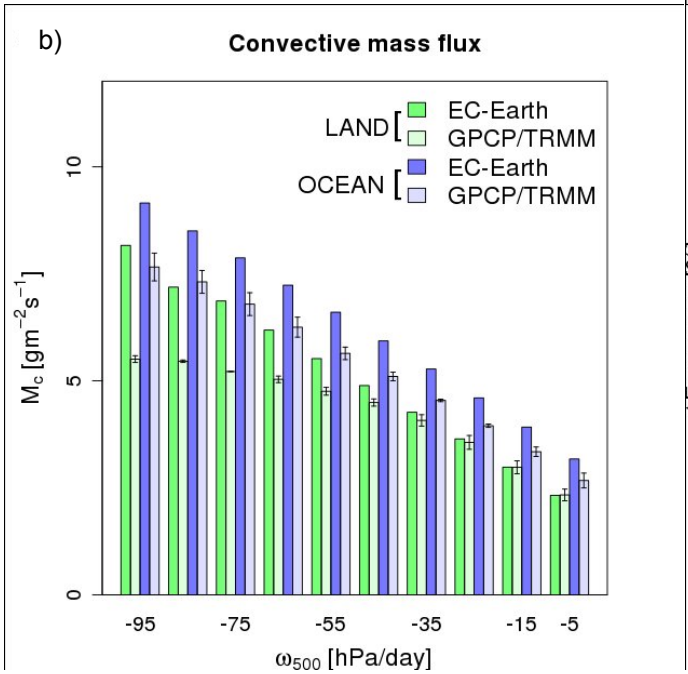
  NetCRE too strong → too cold

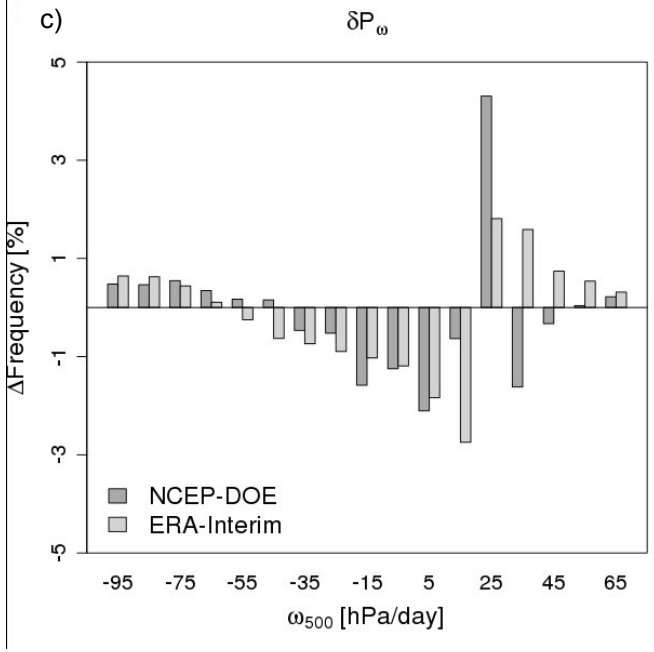
  ↖

  Too many

- thick upper-clouds → cool







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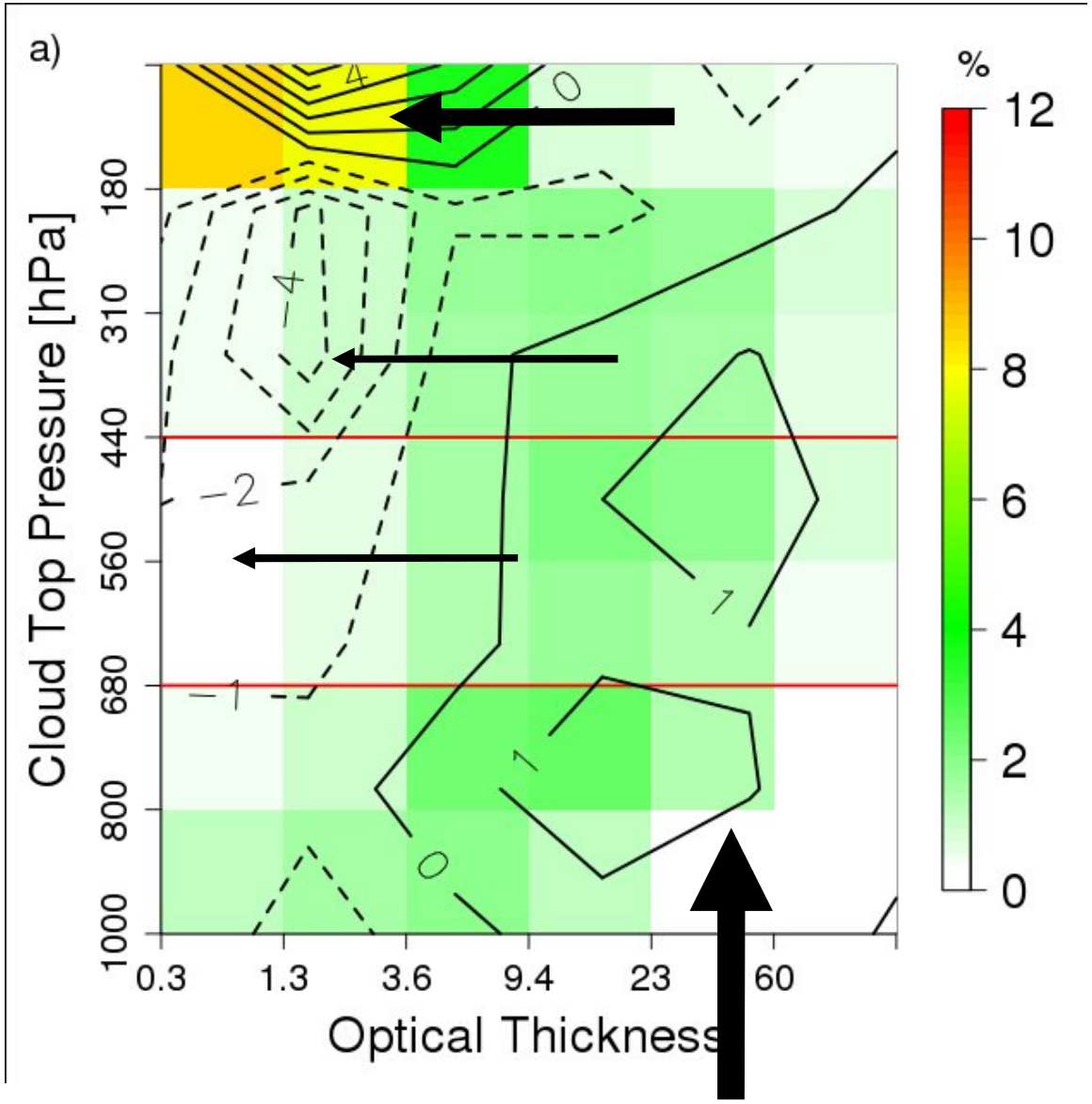
Tropical Western Pacific



Hypothesis:

- too strong convective activity → too water vapor can penetrate deeper in the atmosphere
- not enough detrainment in mid-troposphere → anvil clouds insist on the same area continuing to precipitate
- because of the tropopause, the anvil clouds stretch generating thin clouds (e.g. cirrus)
- biases in the convective scheme (known bias in ECMWF IFS) and detrainment parameterization

Conclusions

Summary

- Clouds exert a too high cooling effect in EC-Earth, notably in the tropics

- This is mainly due to biases in the SWCRE from different cloud types and every cloud type has its own specific bias

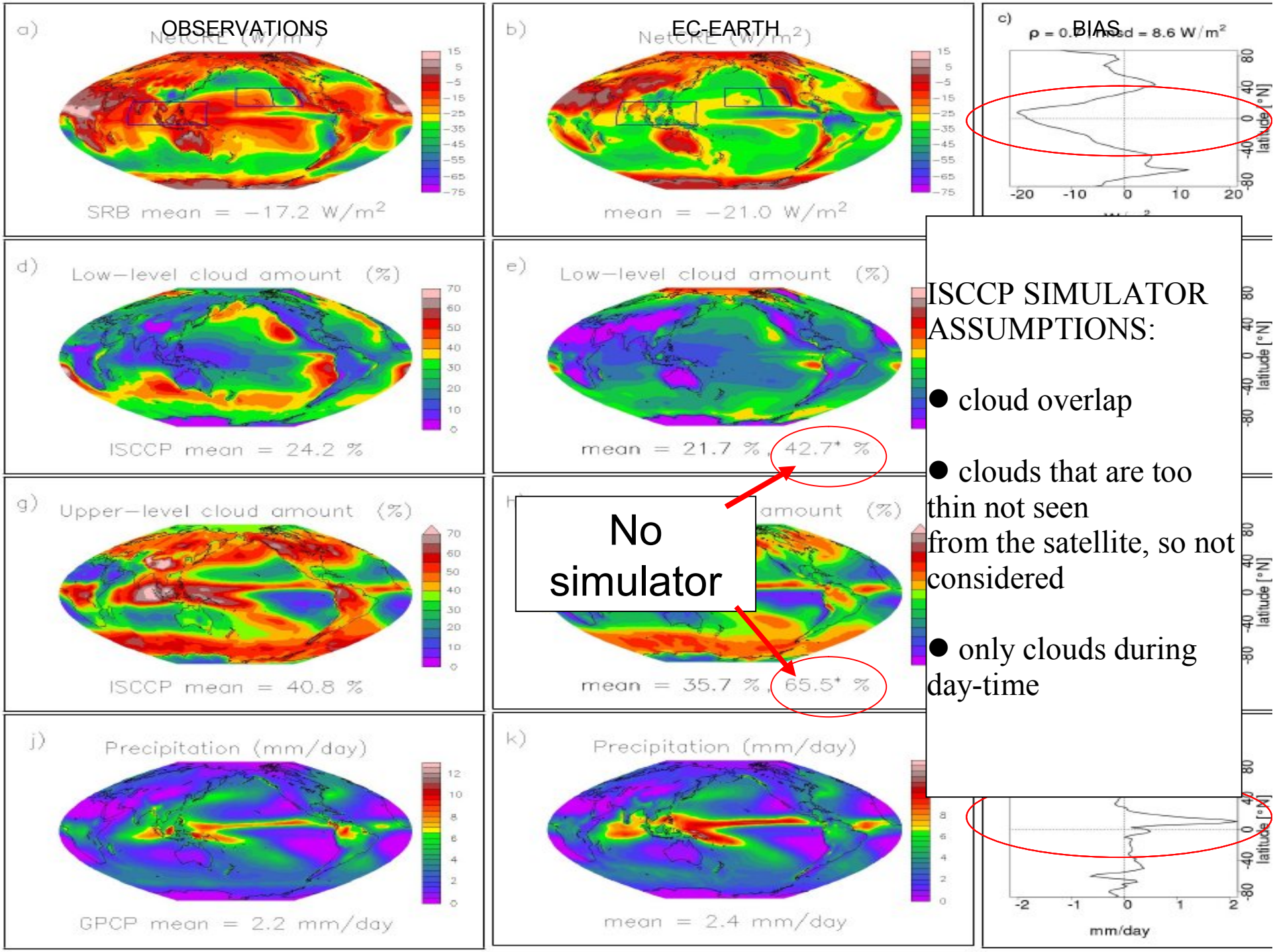
- Stratocumulus do not cool enough because they are too few; trade-cumulus cool too much because they are too thick (probably because the cloud droplets are too small)

- Deep convective clouds are too thick and precipitate too much, probably because the mass-flux in EC-Earth is too strong

- There are several other possible sources of bias: in the cloud scheme, radiative s., turbulence s., entrainments, mixed-phase clouds, precipitation efficiency, …

Thank you!

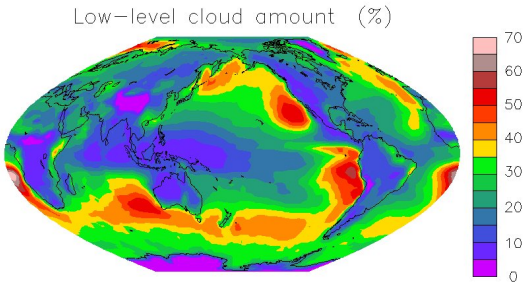
Questions ?



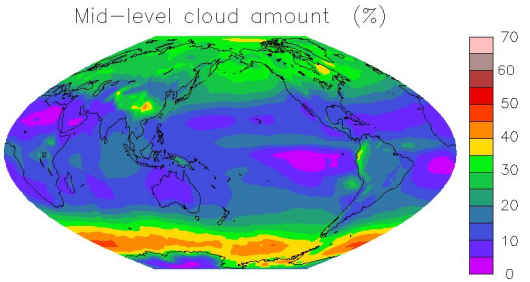
ISCCP SIMULATOR ASSUMPTIONS:

- cloud overlap
- clouds that are too thin not seen from the satellite, so not considered
- only clouds during day-time

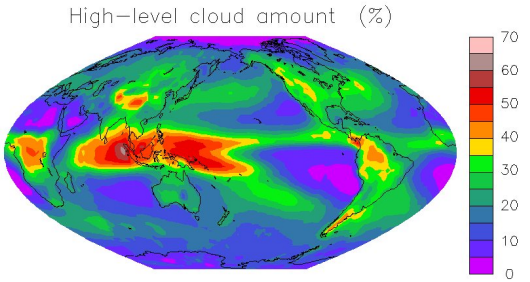
OBSERVATIONS:
ISCCP



ISCCP mean = 24.2 %

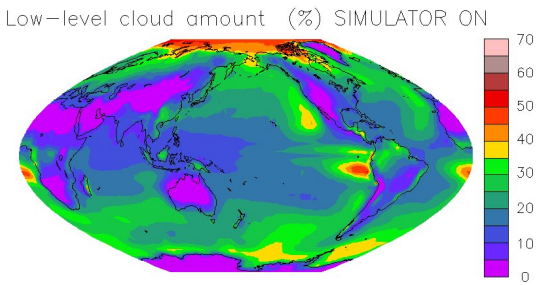


ISCCP mean = 22.4 %

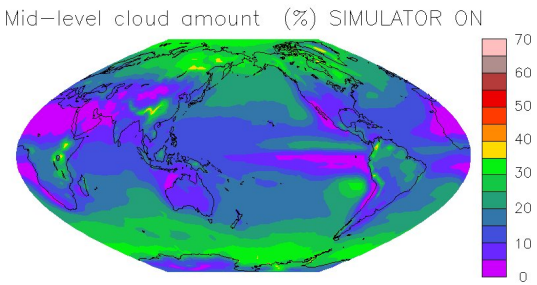


ISCCP mean = 18.4 %

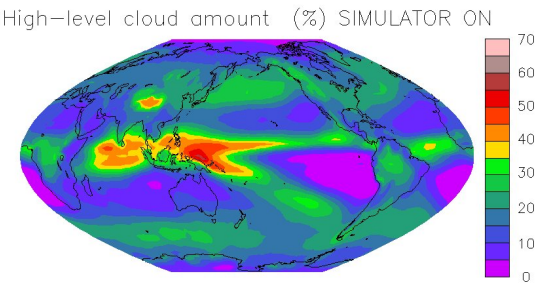
EC-EARTH:
SIMULATOR ON



EC−EARTH mean = 21.7 %

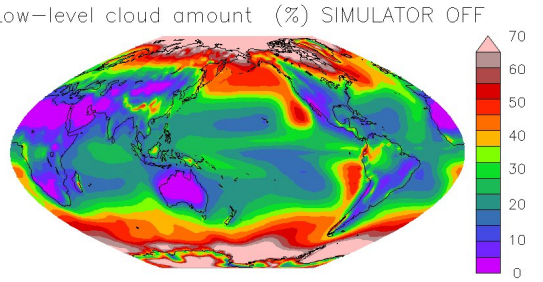


EC−EARTH mean = 19.6 %

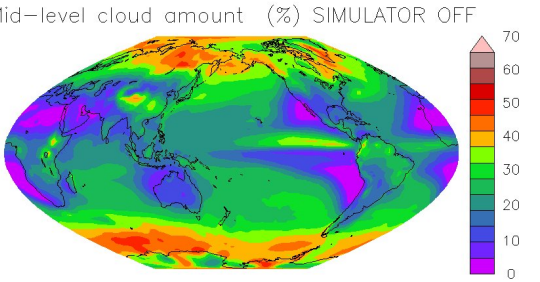


EC−EARTH mean = 16.1 %

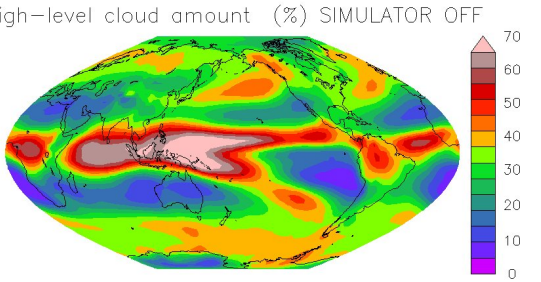
EC-EARTH:
SIMULATOR OFF



EC−EARTH mean = 42.7 %



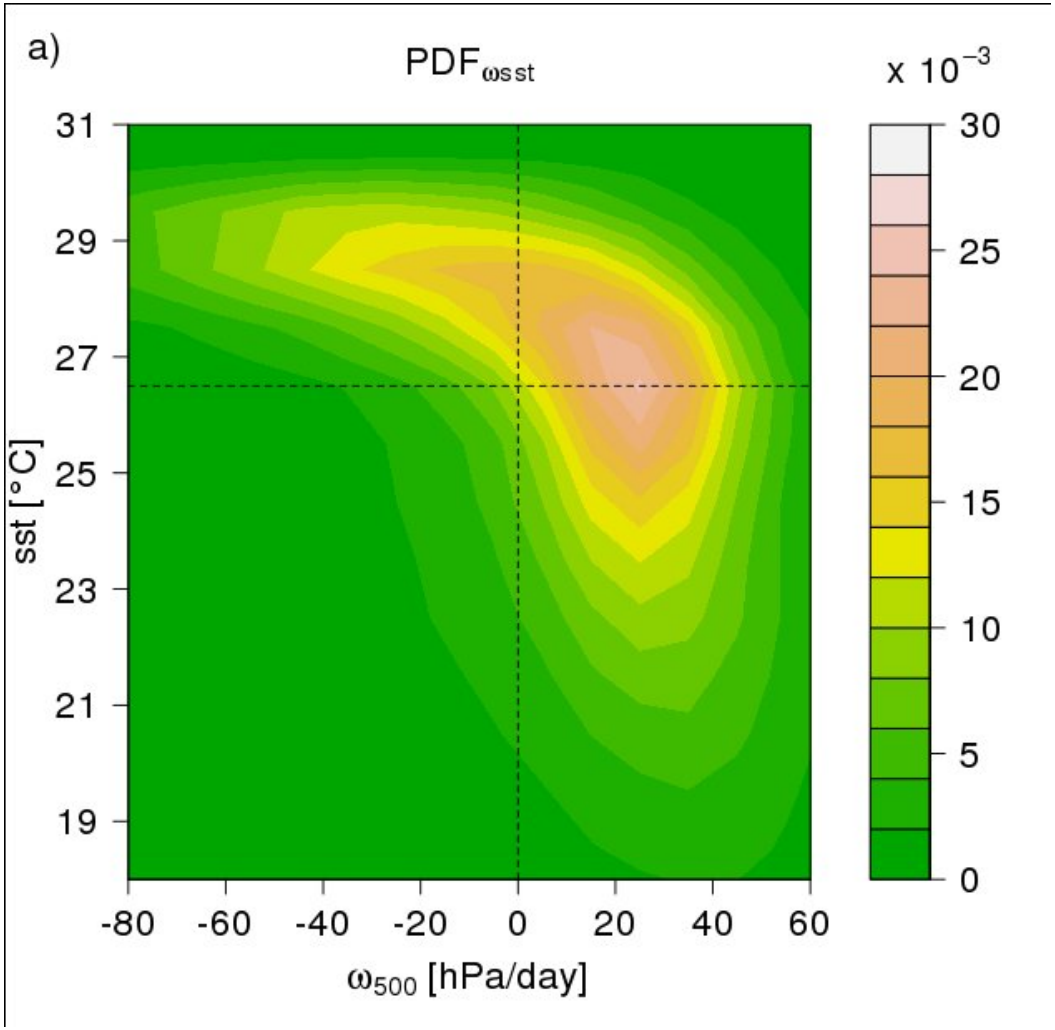
EC−EARTH mean = 30.6 %



EC−EARTH mean = 34.9 %

(Lacagnina and Selten, submitted)

Bivariate approach



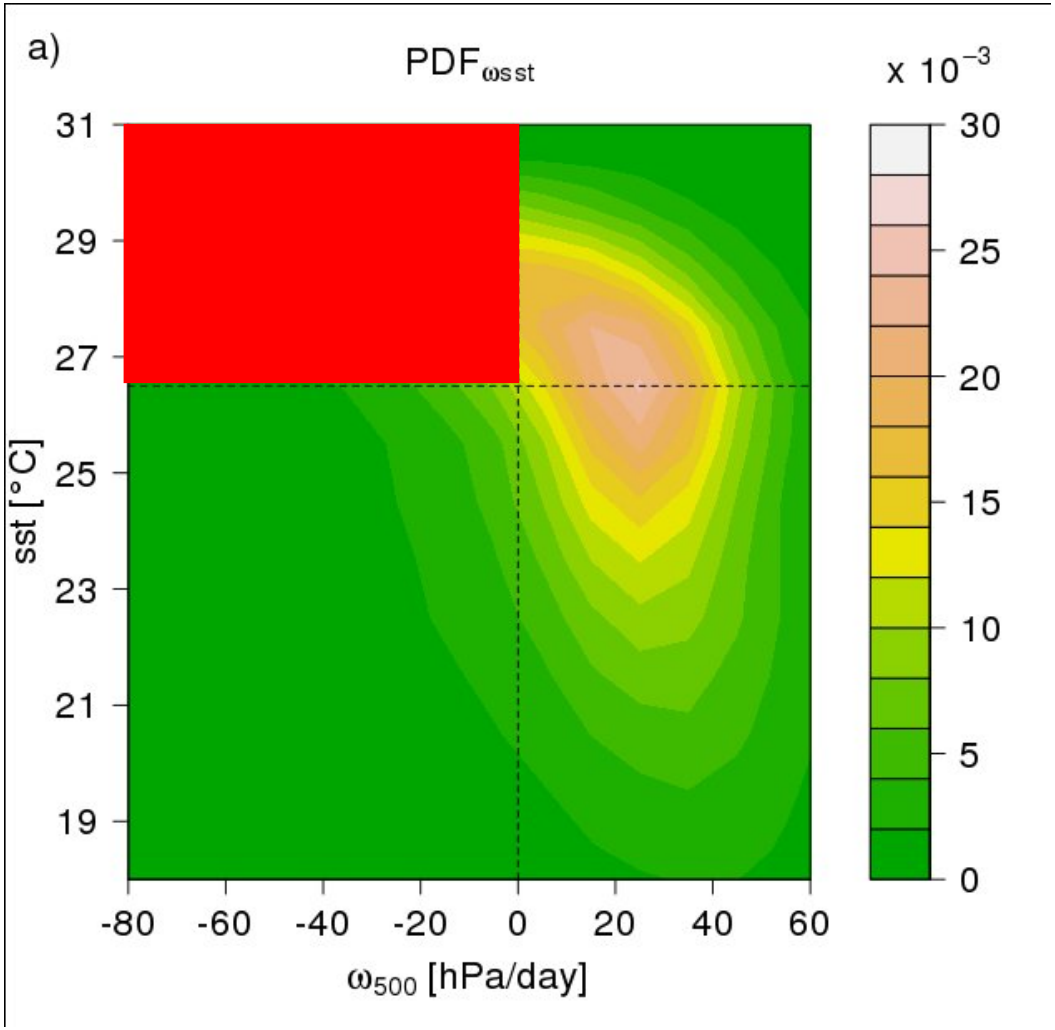
ERA-40 vs ERSST data

period: 1985-2001

- decomposition of the Walker-Hadley circulation over the tropical oceans (30ºN-30ºS)

- This novel composite technique shows that using ω and SST together allows to better distinguish cloud regimes and CRFs

Bivariate approach



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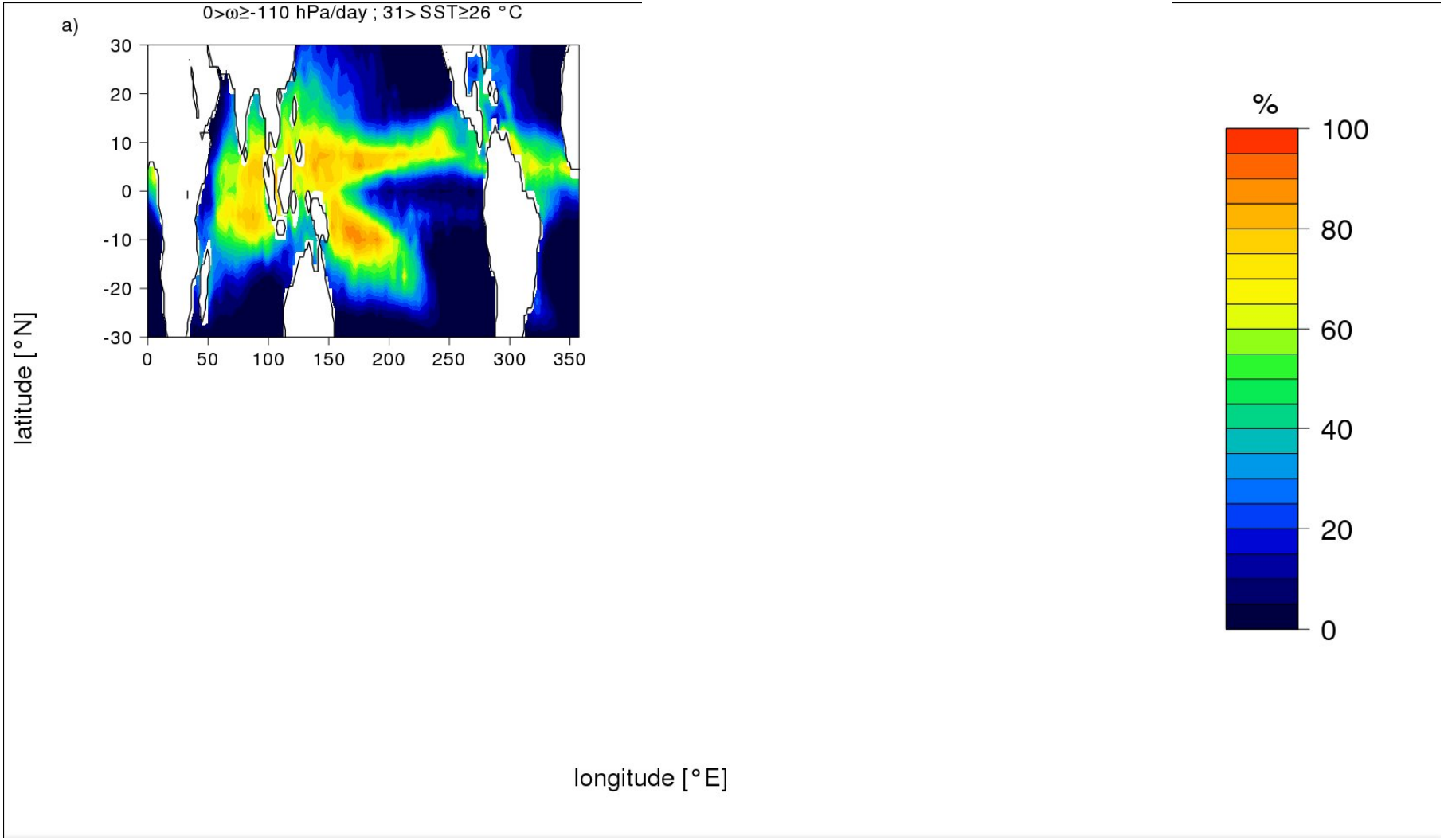
Occurrences



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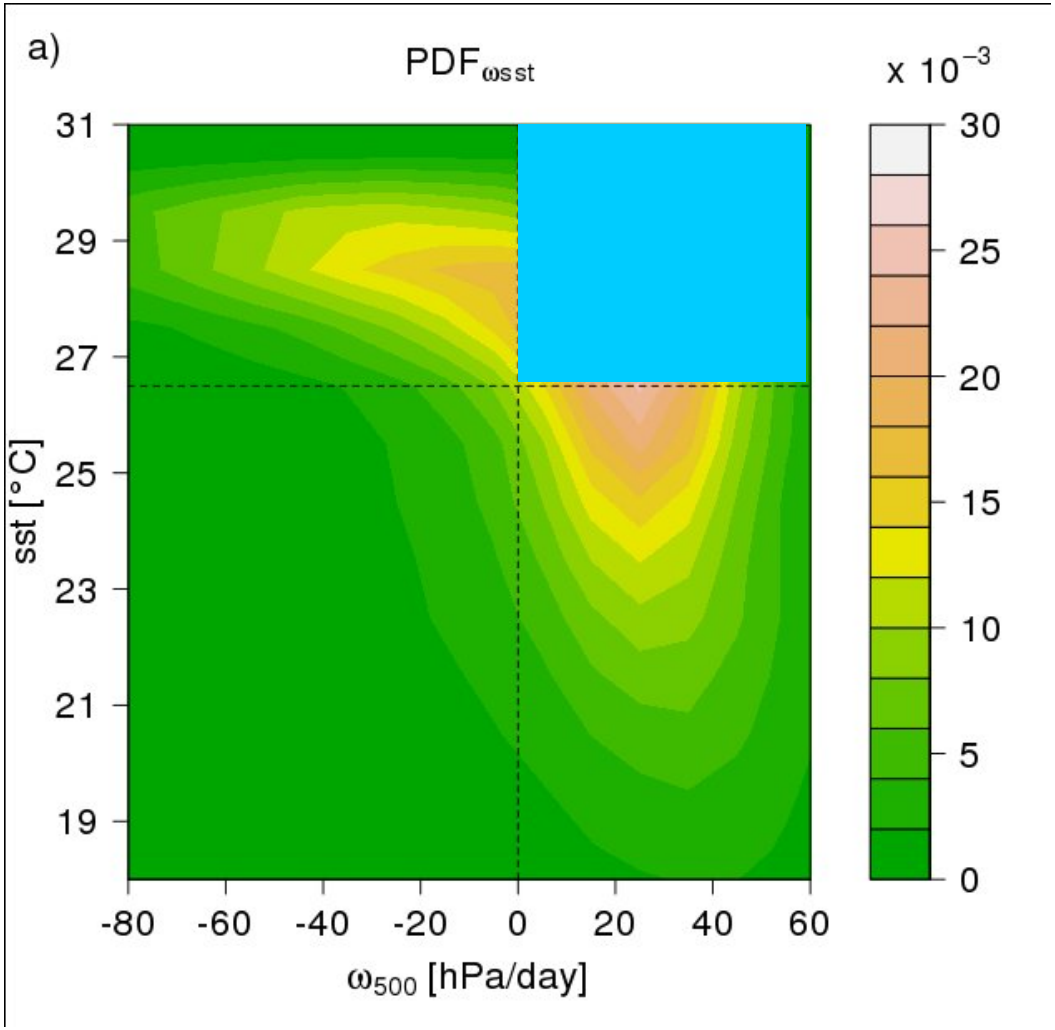

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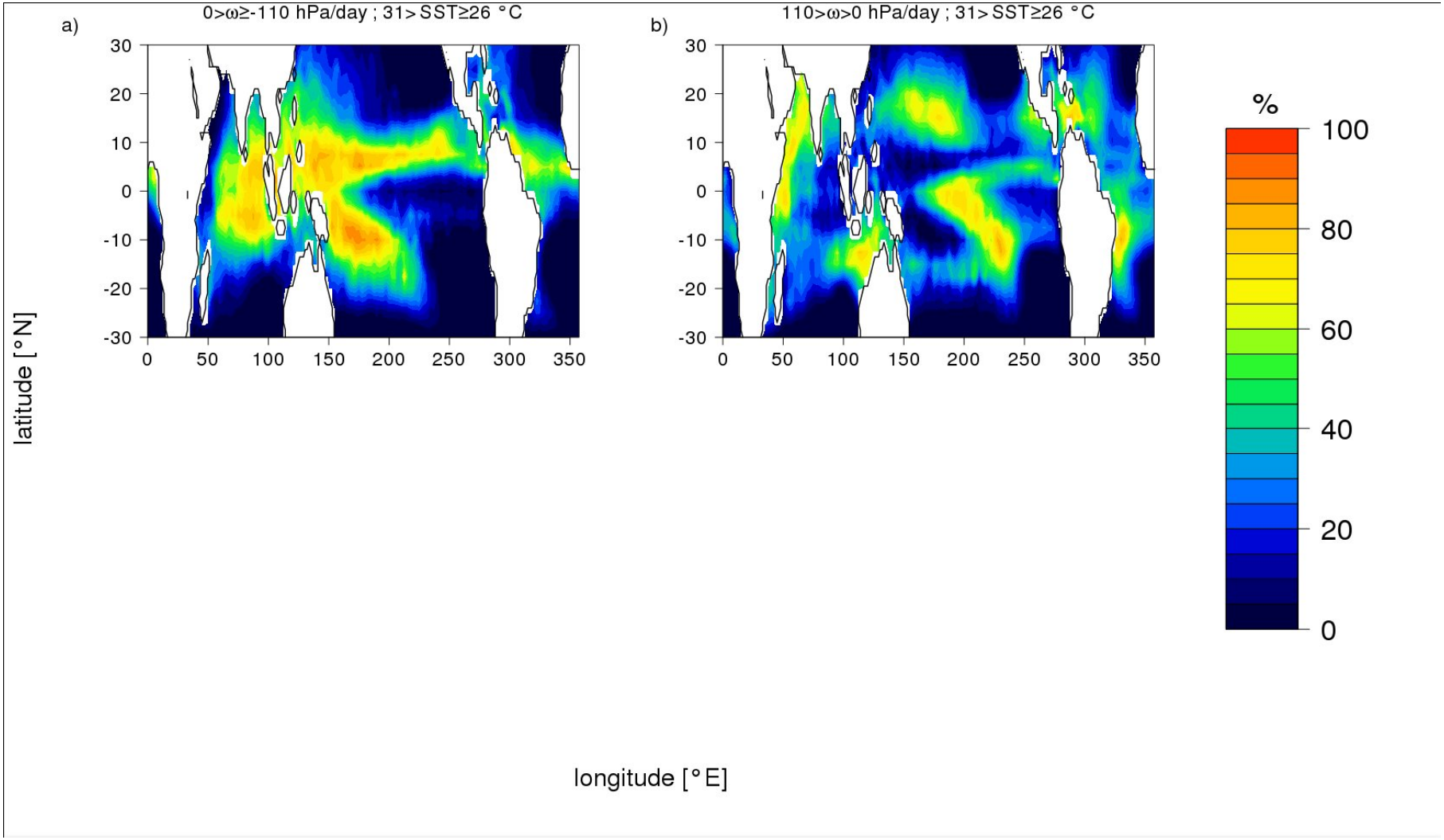

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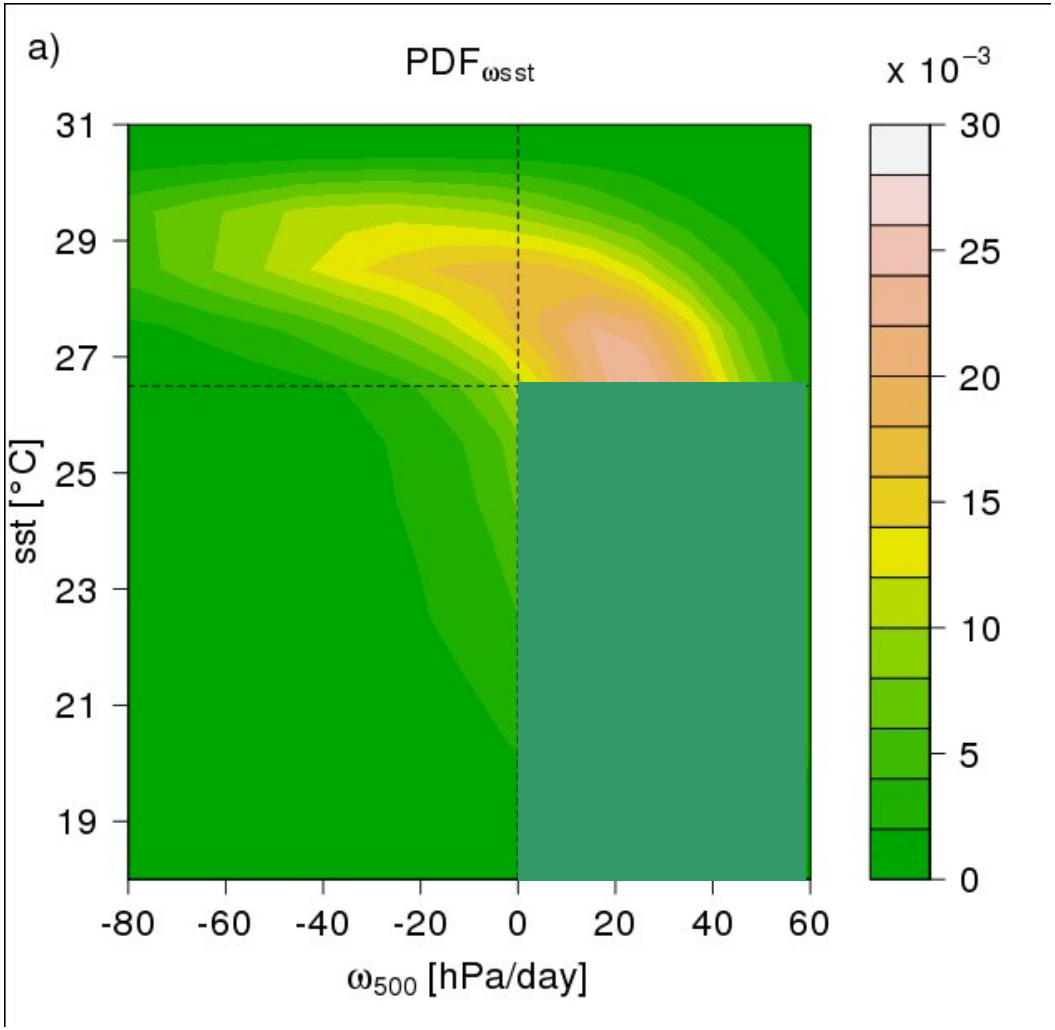

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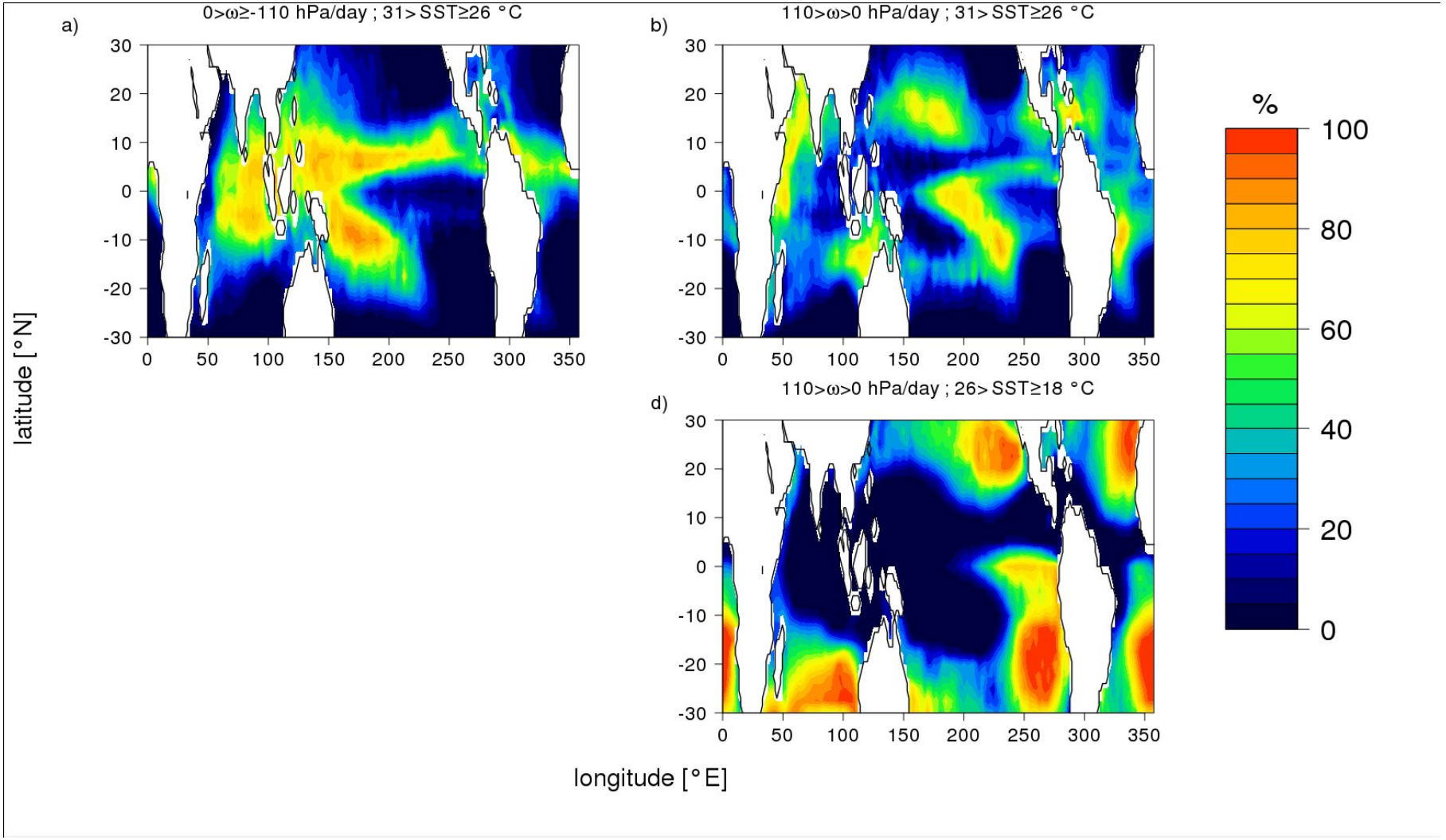

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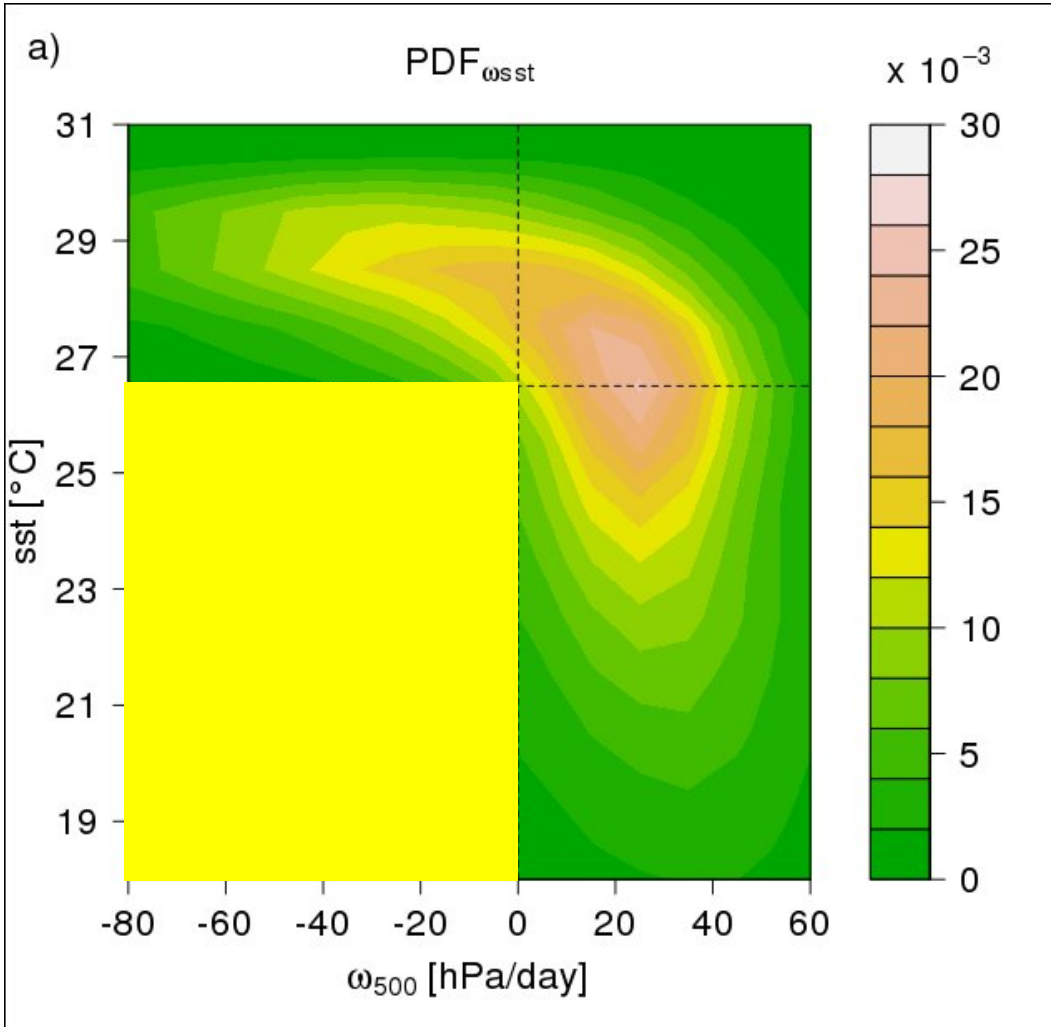

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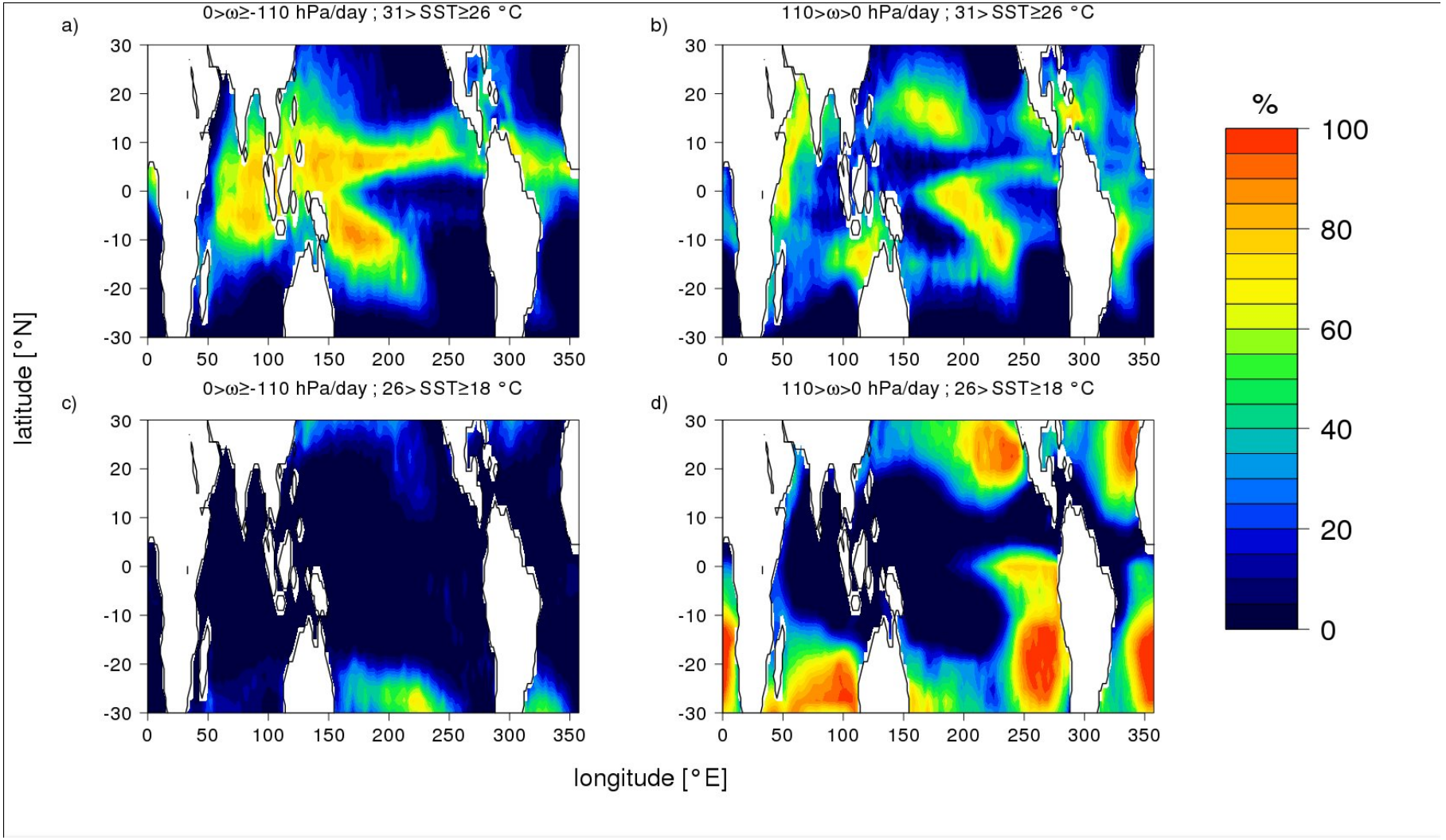
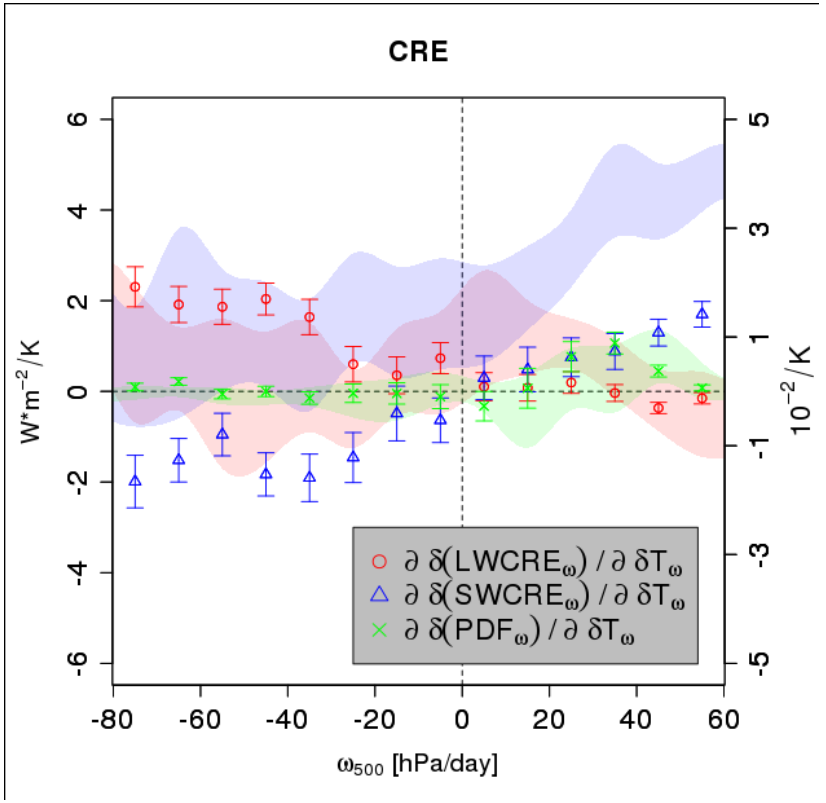
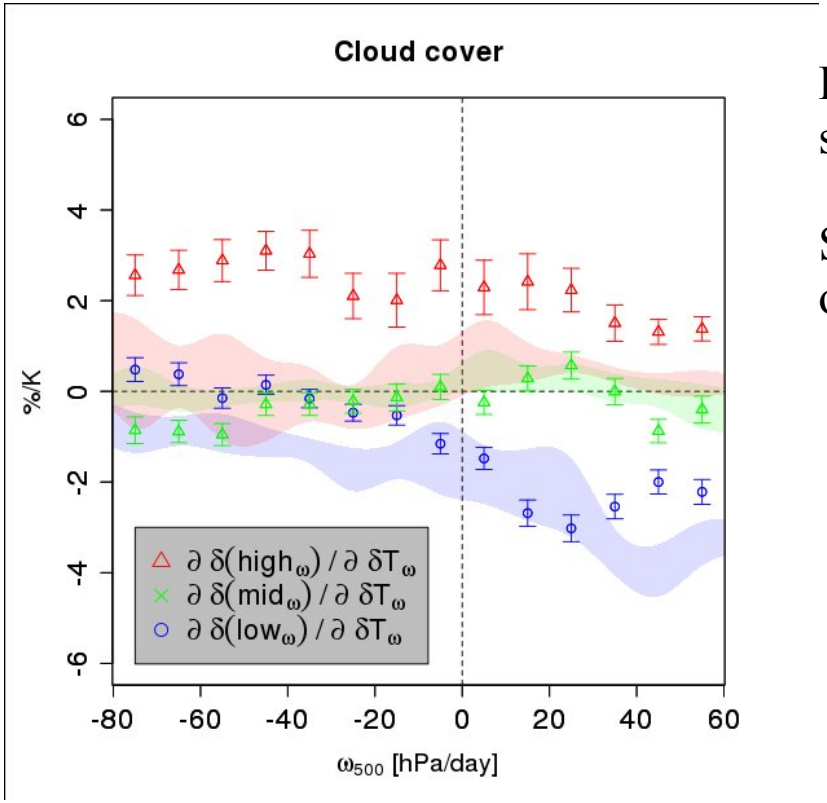


Interannual sensitivity

Linear regression between a cloud-related variable (C) and SST for each dynamical regime (ω)





Points: simulations;

Shades: observations

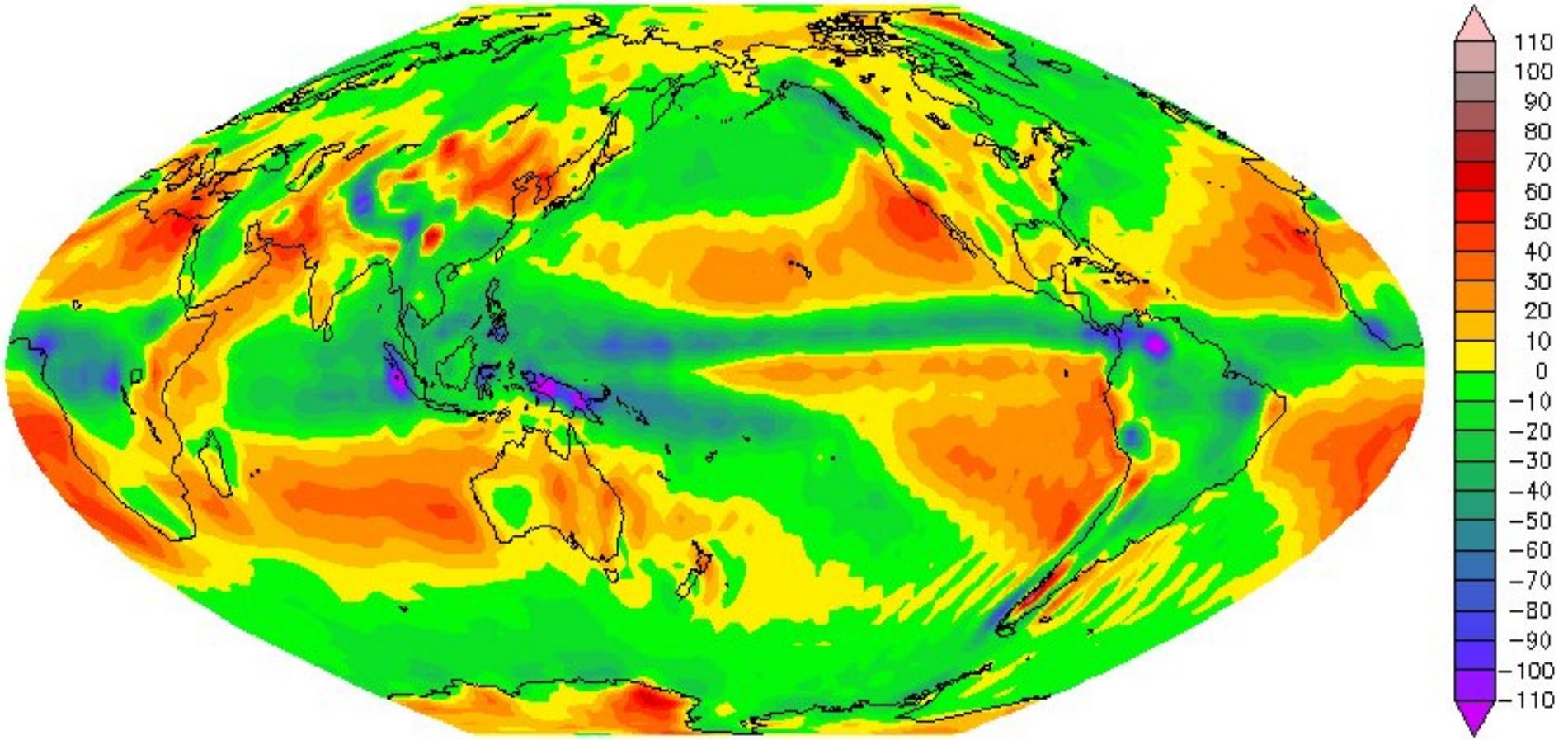
ISCCP; ERA-40; NCEP-DOE; SRB; ISCCP-FD data

period: 1985-2001

- Discrepancy between EC-EARTH and observations relative to the interannual sensitivity of CRE and cloud cover to a change in an external forcing (e.g. temperature)

- Are the low-clouds the main responsible for EC-EARTH CRE biases?

Pressure velocity



ERA−40 1985−2001: W (hPa/day)

Sea Surface Temperature