Quelles configurations de modèles (globaux) de climat pour quelle science ?

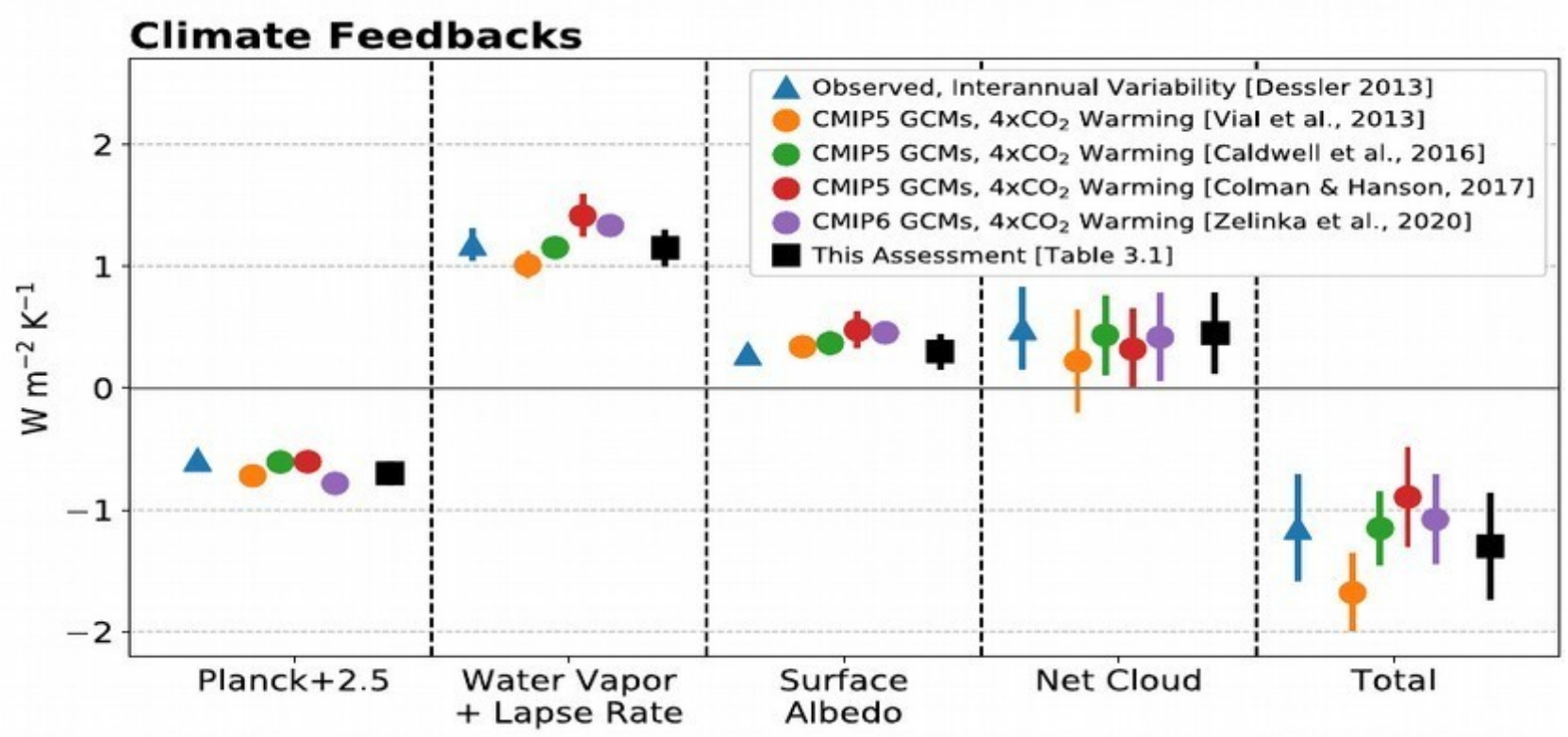
Nuages et cycle de l'eau

Sensibilité climatique et rétroactions

Jean-Louis Dufresne

Climate sensitivity

WCRP report on climate sensitivity. « An Assessment of Earth's Climate Sensitivity Using Multiple Lines of Evidence », *Rev. of Geophy.*, S. Sherwood et al. 2020



[Sherwood et al., RG, 2020]

Assessment based on multiple lines of evidence:

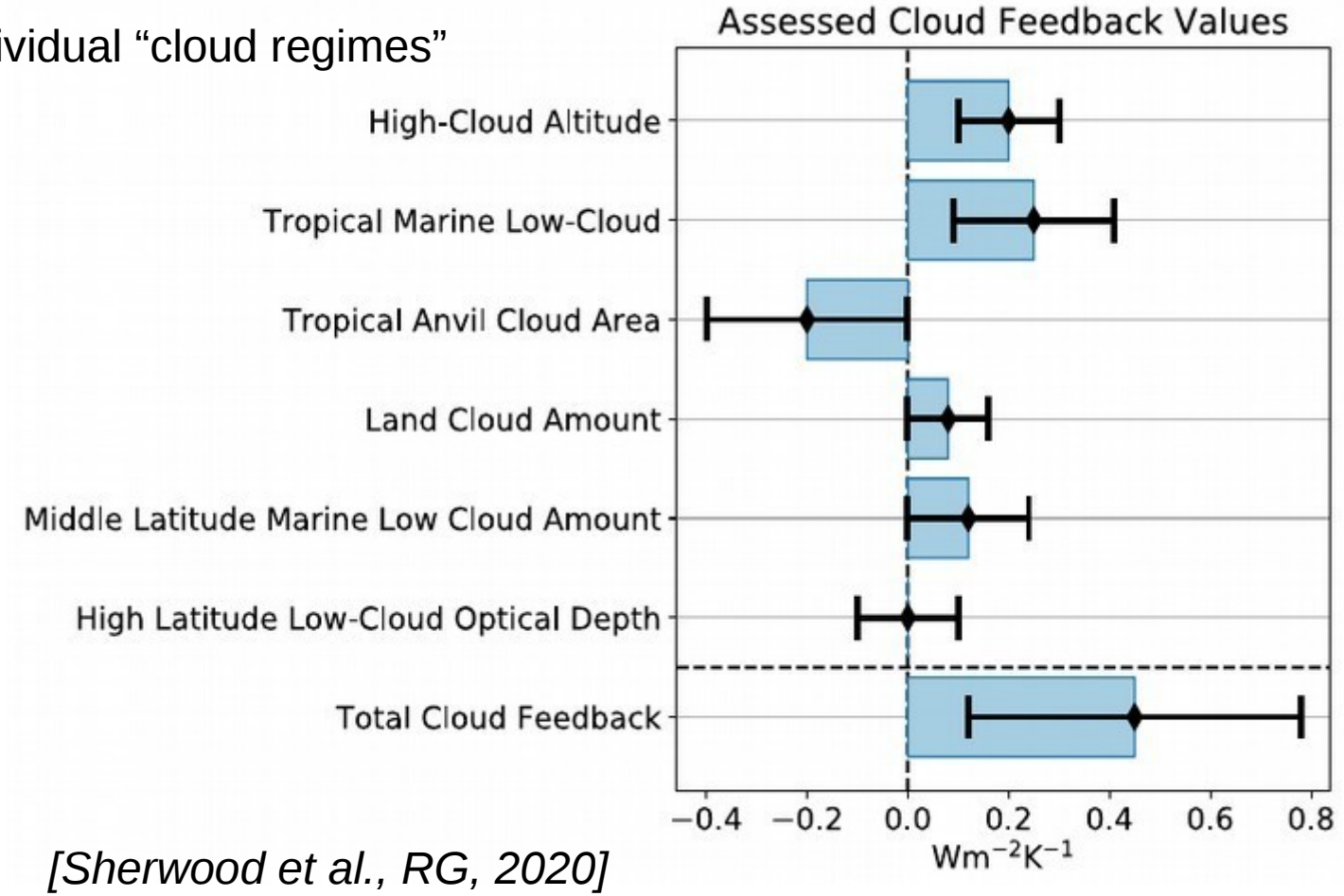
- Process understanding
- [Emergent constraints (empirical relationships between a present-day climate system variable and a future climate change)]
- Observations of global interannual radiation variability
- Historical climate record
- Paleoclimate records

Process understanding of feedbacks

The uncertainty on the forcing and on the Planck, water vapour, lapse rate and surface albedo are limited

… of cloud feedbacks

- Global climate models (GCMs), observations (short-term, inter-annual, paleo), process-resolving models (LES), theory
- Clouds feedback is the only feedback for which climate GCMs are not the main source of assessment
- Assessment of individual “cloud regimes”

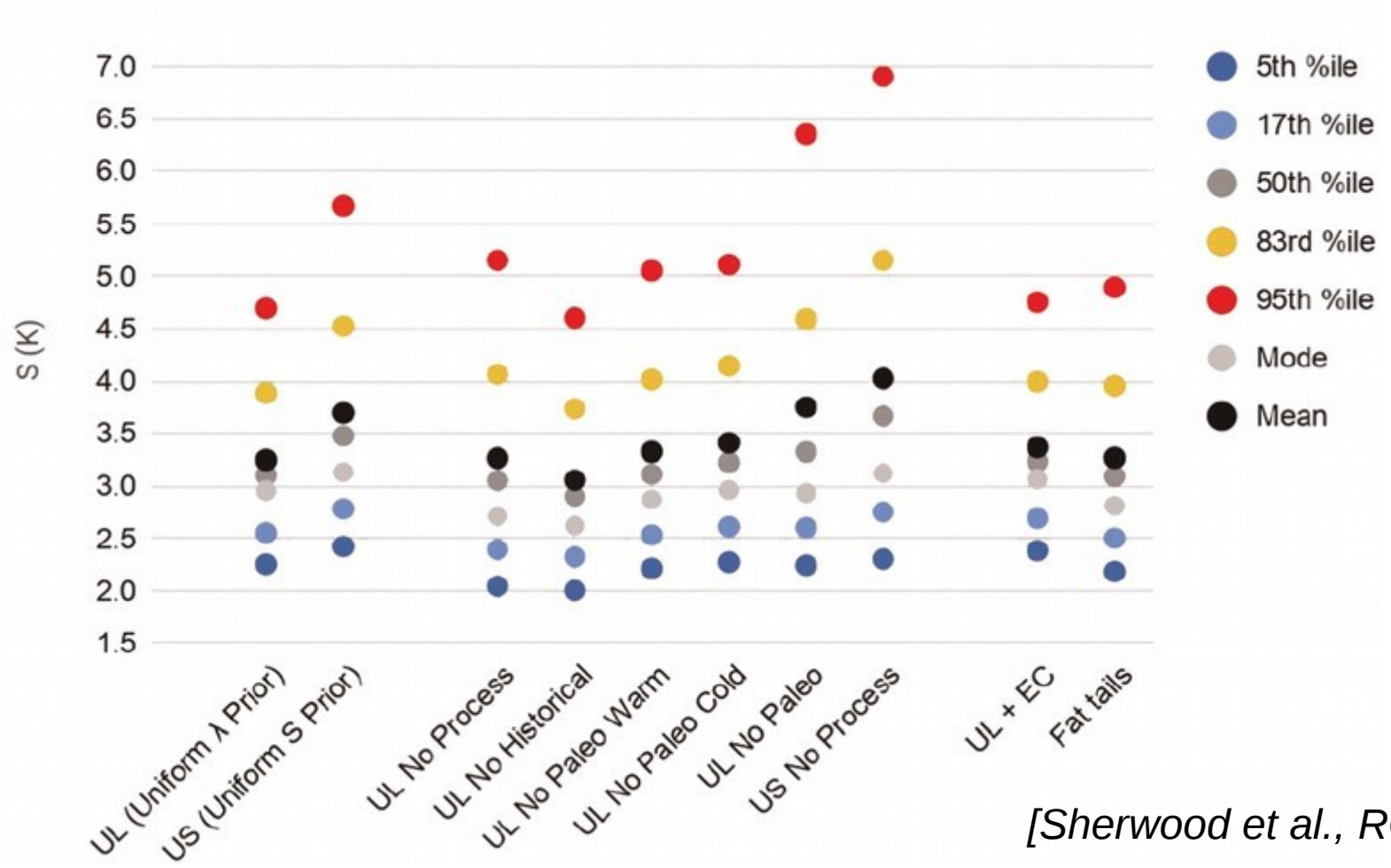


[Sherwood et al., RG, 2020]

Climate sensitivity

- The **low end** is well constrain by almost all the individual source of evidence
- Constraining the **high end** requires et combine various lines of evidence:

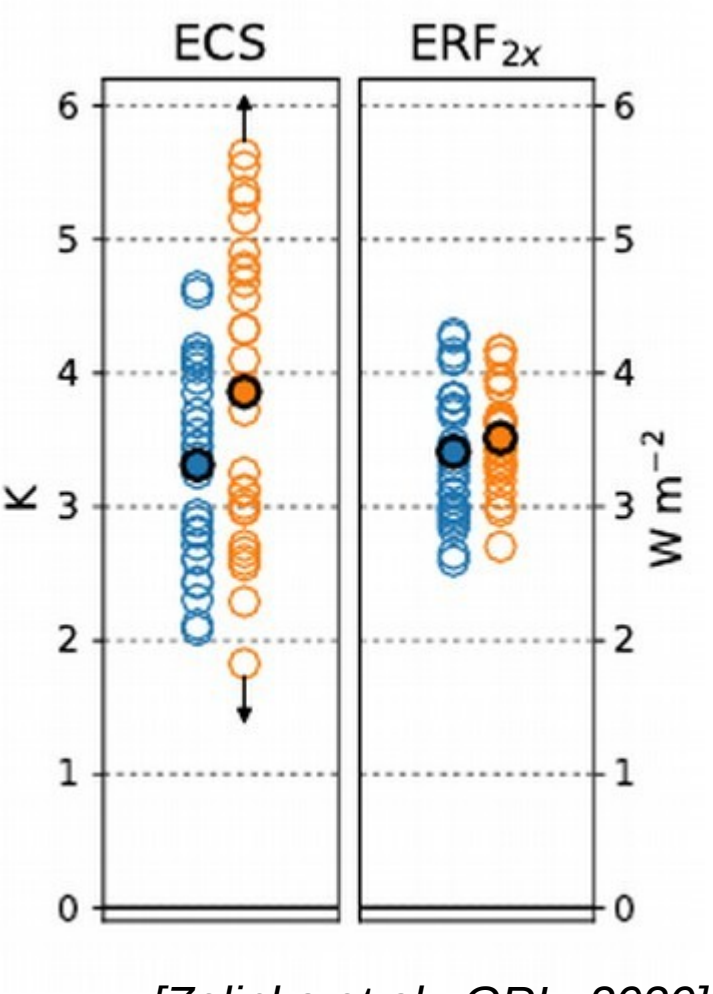
  => strength of the IPSL
-



[Sherwood et al., RG, 2020]

CMIP6 results

- a significant number of high sensitivity models (> 4.5K)
- larger intermodel spread than for CMIP5
- Higher global mean sensitivity… (less true with 40 CMIP6 models) than for CMIP5
- Higher sensitivity models: a combination of high individual feedbacks

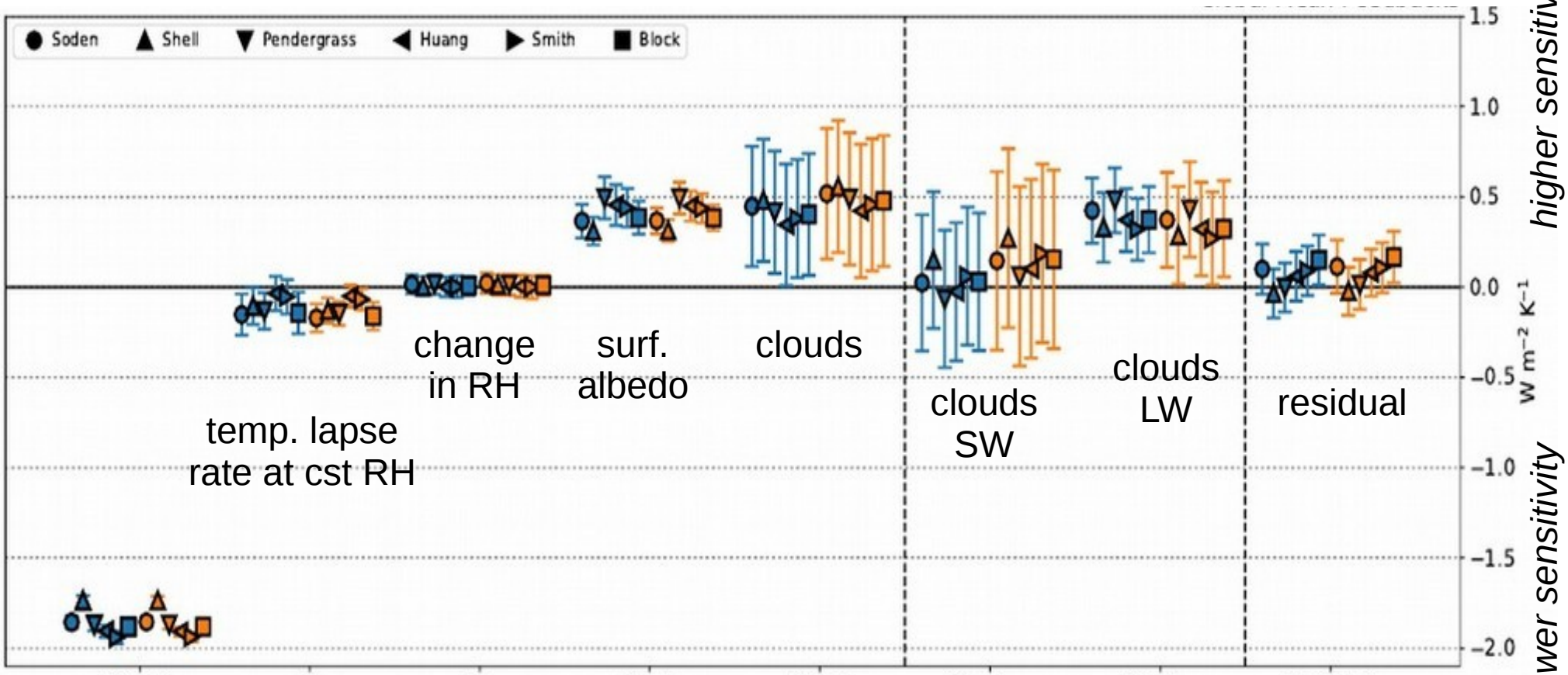


[Zelinka et al., GRL, 2020]

CMIP5
CMIP6

Multi-model feedback parameters

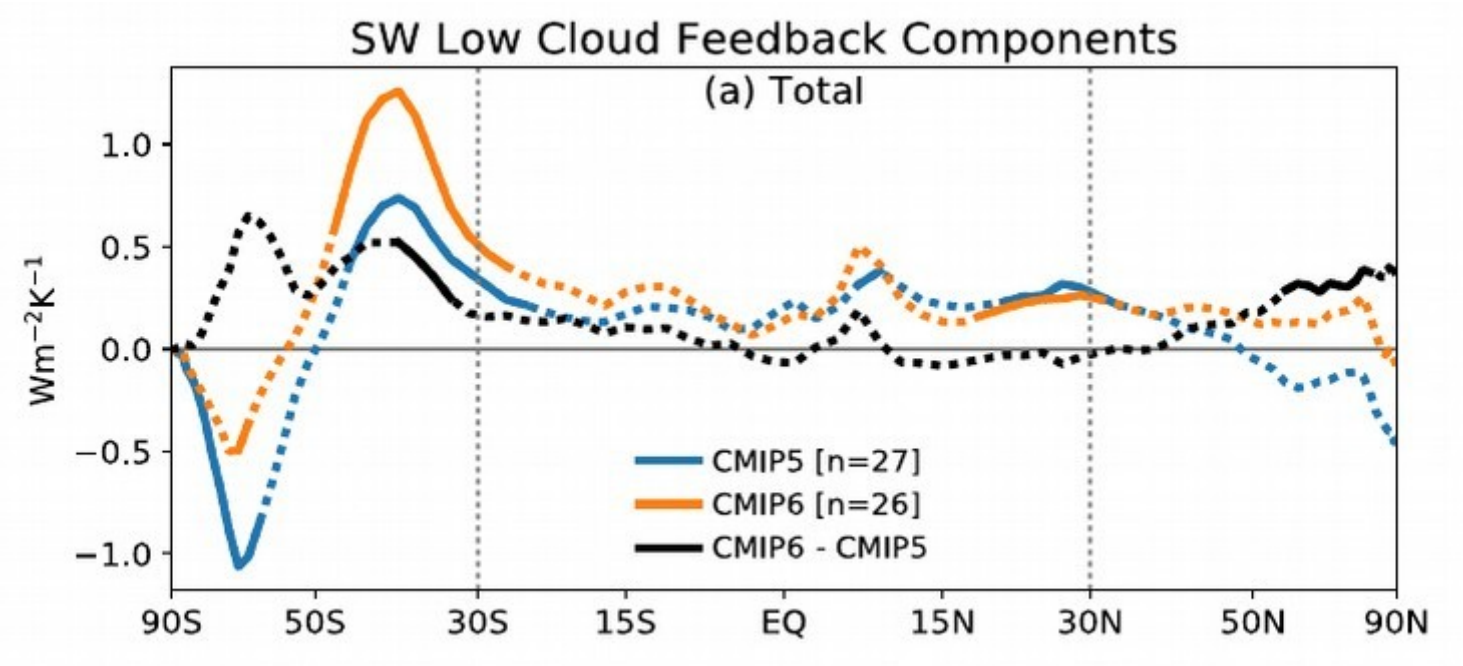
- **CMIP5** and **CMIP6**
- different kernels
- mean a spread



[Zelinka et al., GRL, 2020]

- Cloud feedbacks are still the main source of spread among models
- The inter-model spread is unchanged or has decreased (albedo) for non-cloud feedbacks.
- It has increases for clouds, especially in the SW

Zonally averaged SW low cloud feedback



CMIP5
CMIP6
diff

[Zelinka et al., GRL, 2020]

- Multimodel model mean at **high southern latitudes** larger in CMIP6
- Due to both **cloud amount** and **cloud scattering**
- Change in **supercooled liquid fraction** to better match observations (in HadGEM3, CESM2)
- Strong and negative extratropical response in CMIP5 is reduced in CMIP6
- Warming induced by cloud feedbacks: **CMIP5** 0.7K, of which 0.1K from the extra-tropics

  CMIP6 1.0K, of which 0.4K from the extra-tropics

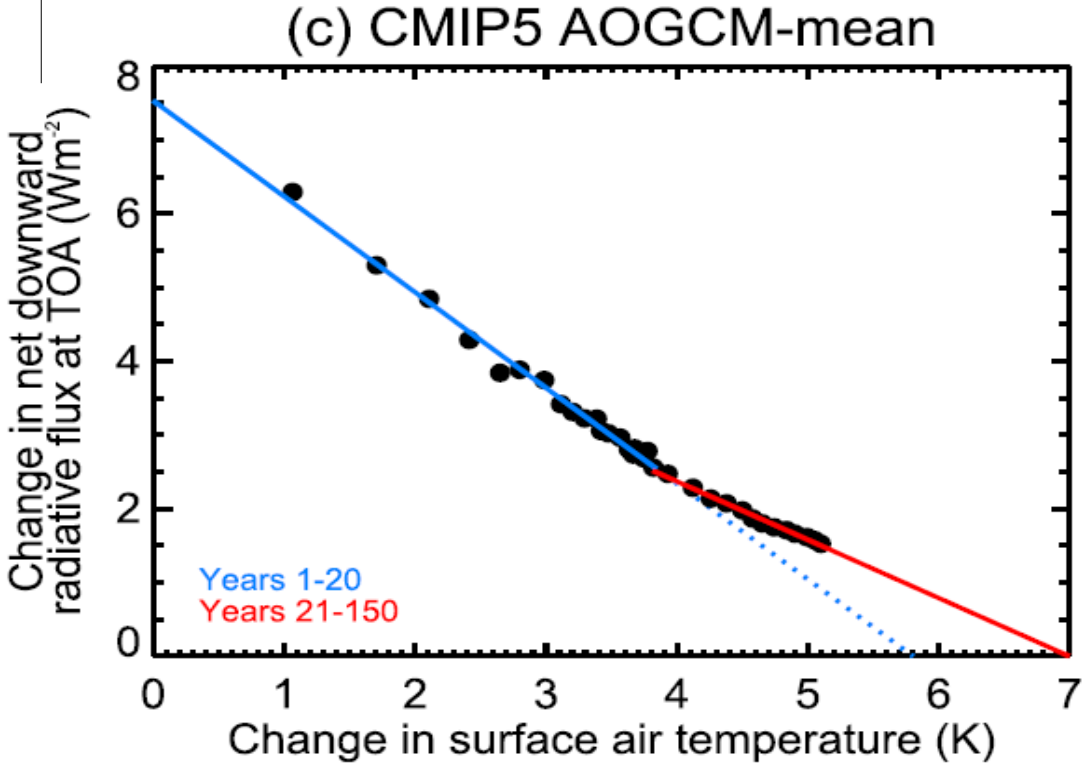
Tropical SW low cloud amount feedback is positive in all but one CMIP6 model

Pattern effect

- Why is climate sensitivity as estimated from the recent past always lower than that estimated from simulations of future climate change projections?
- Why is climate sensitivity changing with time in abrupt 4xCO2 experiments?

Radiative forcing 4xC02 ($W.m^{-2}$)

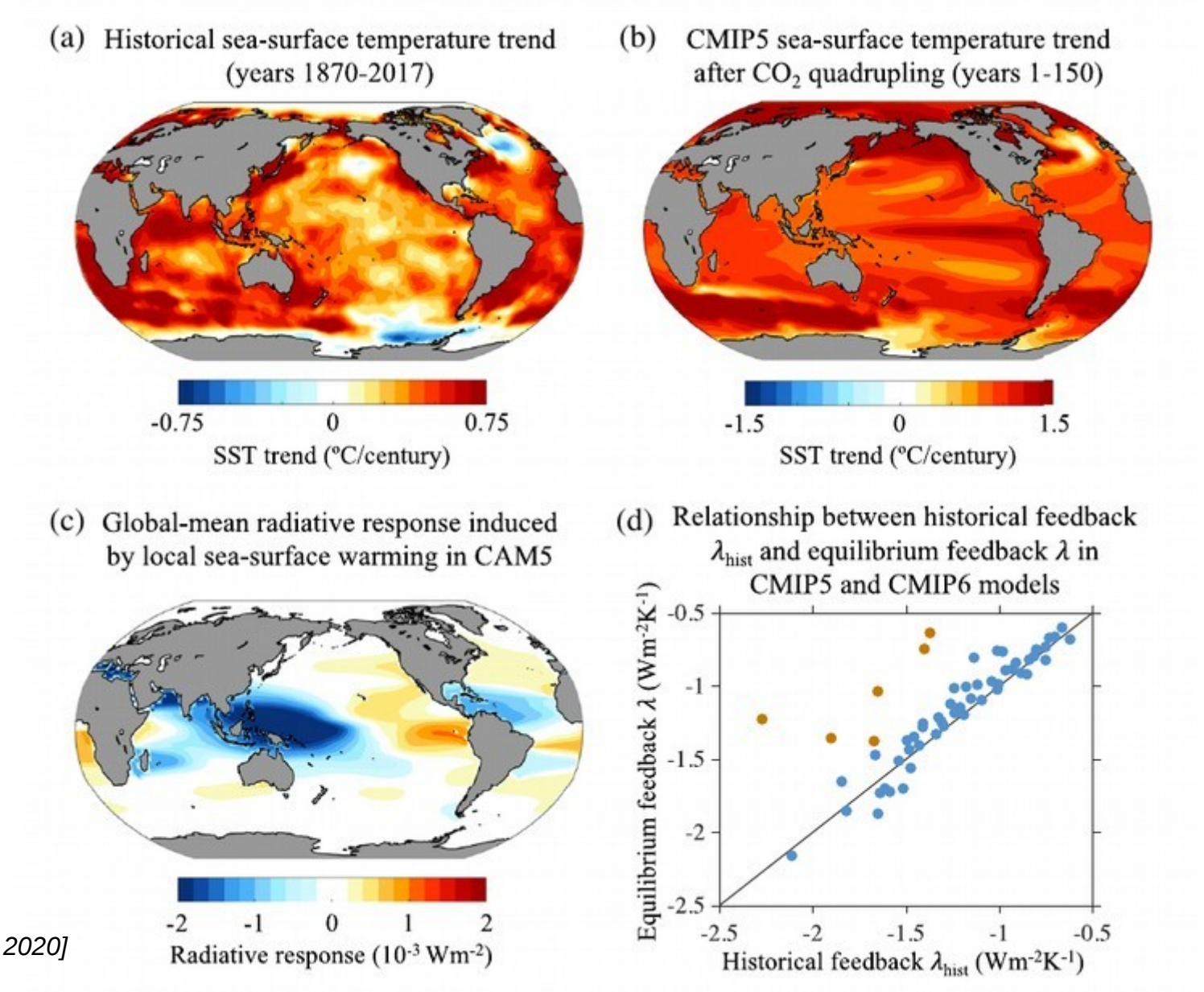
$$N = F - \alpha T$$



[Andrews et al. 2015]

=> Climate sensitivity depends on the pattern of SST changes

Pattern effect



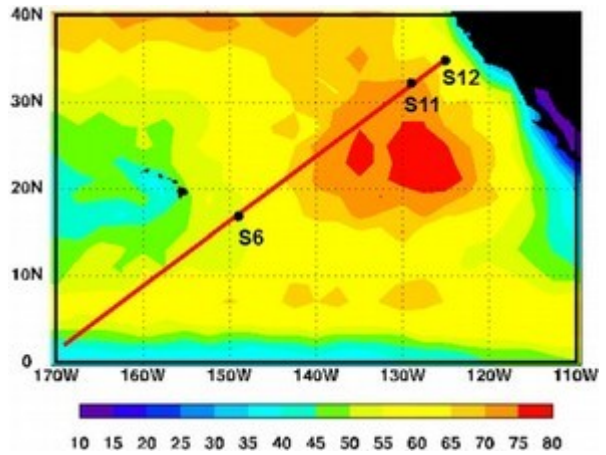
[Sherwood et al., RG, 2020]

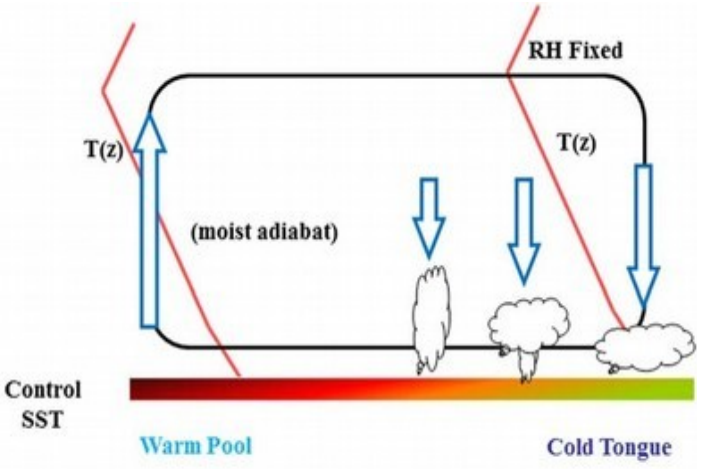
Importance of the pattern effect in paleoclimate studies ?

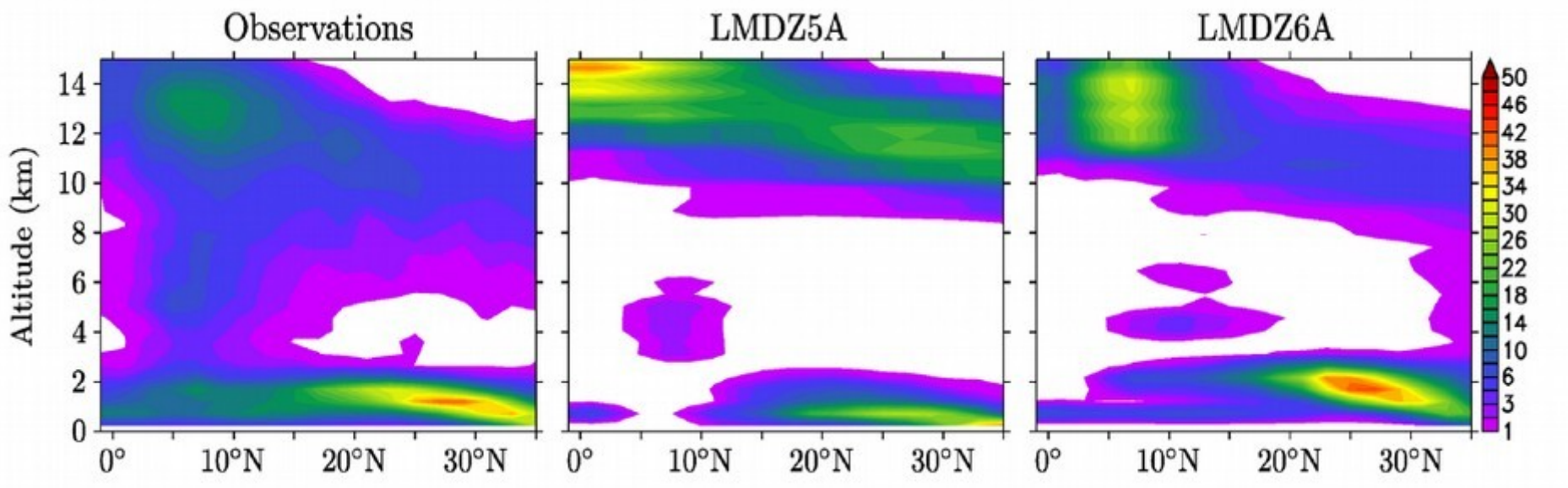
LMDZ6 results

Important developments of the parameterizations driving the clouds properties and better tuning of their parameters

Much better spatial and temporal simulated cloud fractions and cloud radiative properties… except for high clouds.







Cross section of the cloud fraction along the GPCI transect

[Madeleine et al., James, 2020]

Near and mid term evolutions

- **Ongoing developments in LMDZ:**
  - *Cloud overlap and sub-grid heterogeneity* (spatial structure of cloud and precipitation fields), coupling with *radiation* (new EcRad code)
  - Thermodynamics and microphysics, microphysical processes (freezing, supersaturation in relation to ice, sedimentation). High clouds and polar clouds
  - Convection and cloud turbulence, complex cloud systems associated with deep convection, turbulent transport by "descents", etc.

- **Exploiting the results of the Eurec4a field campaign:**
  - Campaign dedicated to study the coupling between clouds, convection and circulation in the subtropics
  - Quantifying how cloudiness in shallow cumulus layers responds to changes in the large-scale environment and how shallow clouds affect radiant energy transfer for different forms of convective organization.

- **Keep the possibility of a large variety of configuration and of use of LMDZ**