

Regime-dependent ERF_{aer} for different types of clouds in GCMs

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Contributors: Steve Ghan, Minghuai Wang, Xiaohong Liu (AeroCom indirect3 experiment design)

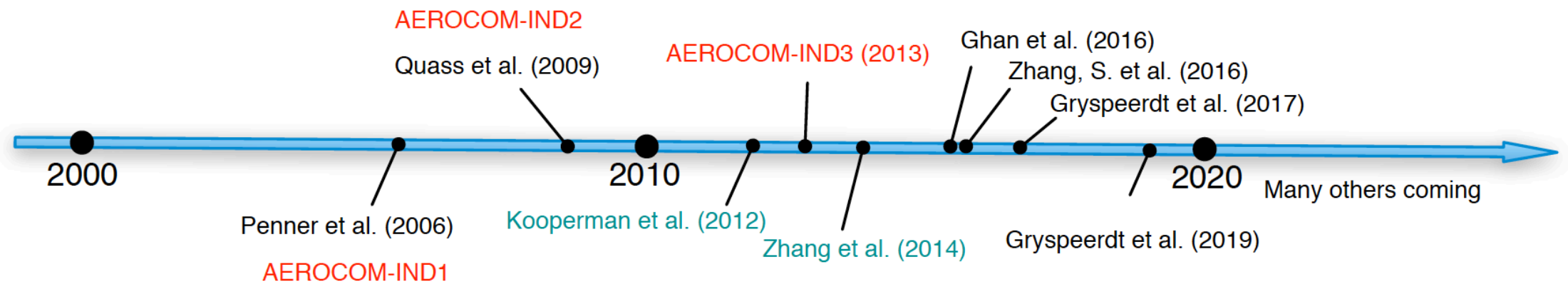
Phil Rasch, Hui Wan (composite analysis and hindcast approach)

AeroCom modelers and coordinators (model data providers)



Recap: AeroCom IND3 experiments

- ▶ Experiments designed to look at ERF_{aero} for both **liquid and ice clouds**
- ▶ **10+** global aerosol-climate models (CH/DE, JP, UK, USA)
- ▶ Horizontal winds **nudged** towards reanalysis (Zhang et al., 2014)
- ▶ **High-frequency data** available for cloud (e.g. LWP, IWP) and aerosol (e.g. CCN, IN) properties, as well as microphysics process rate.



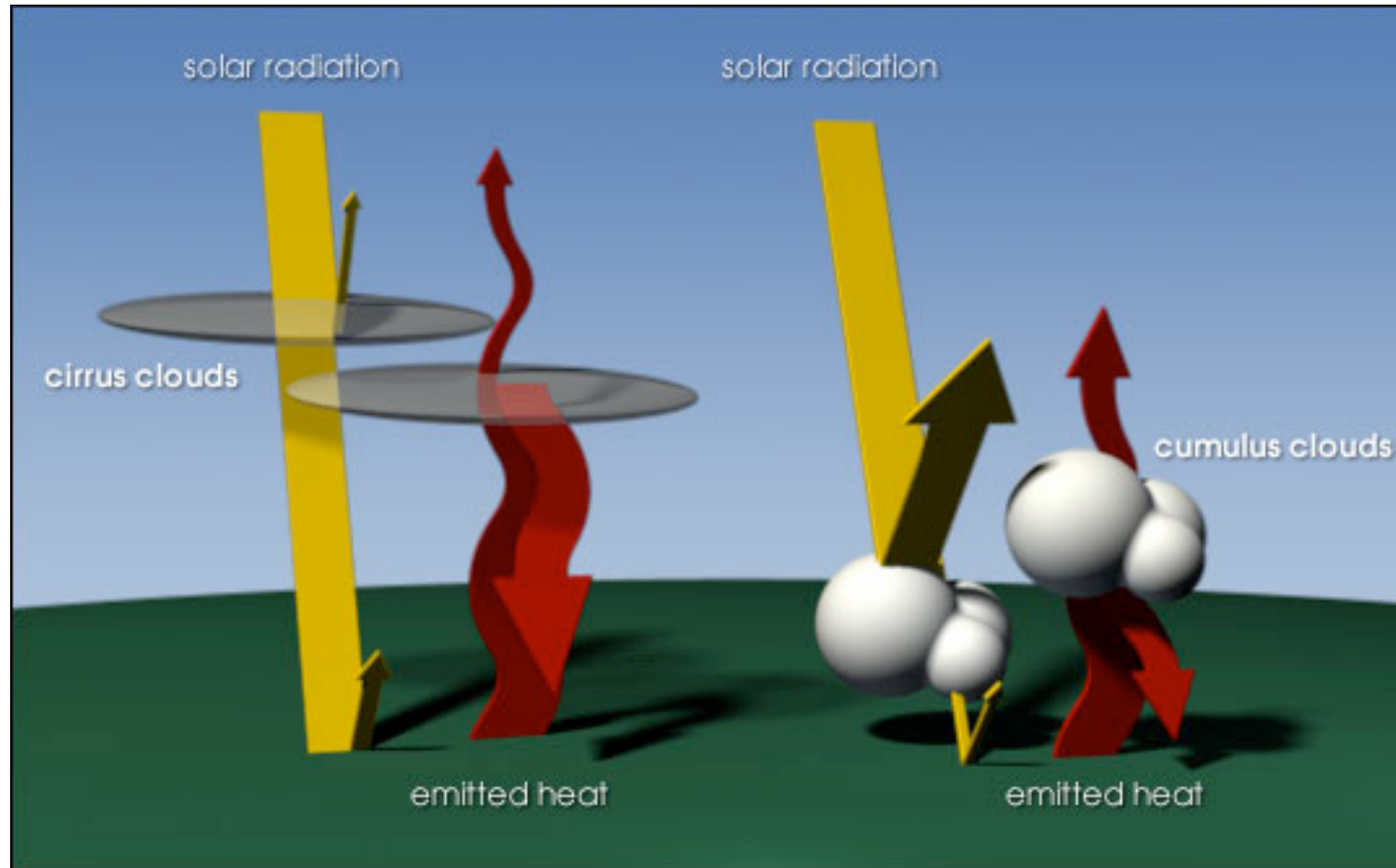
Cloud type/phase and associated dynamical regimes



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Modified from : <https://earthobservatory.nasa.gov/Features/DelicateBalance>

Optically
thin ice
clouds



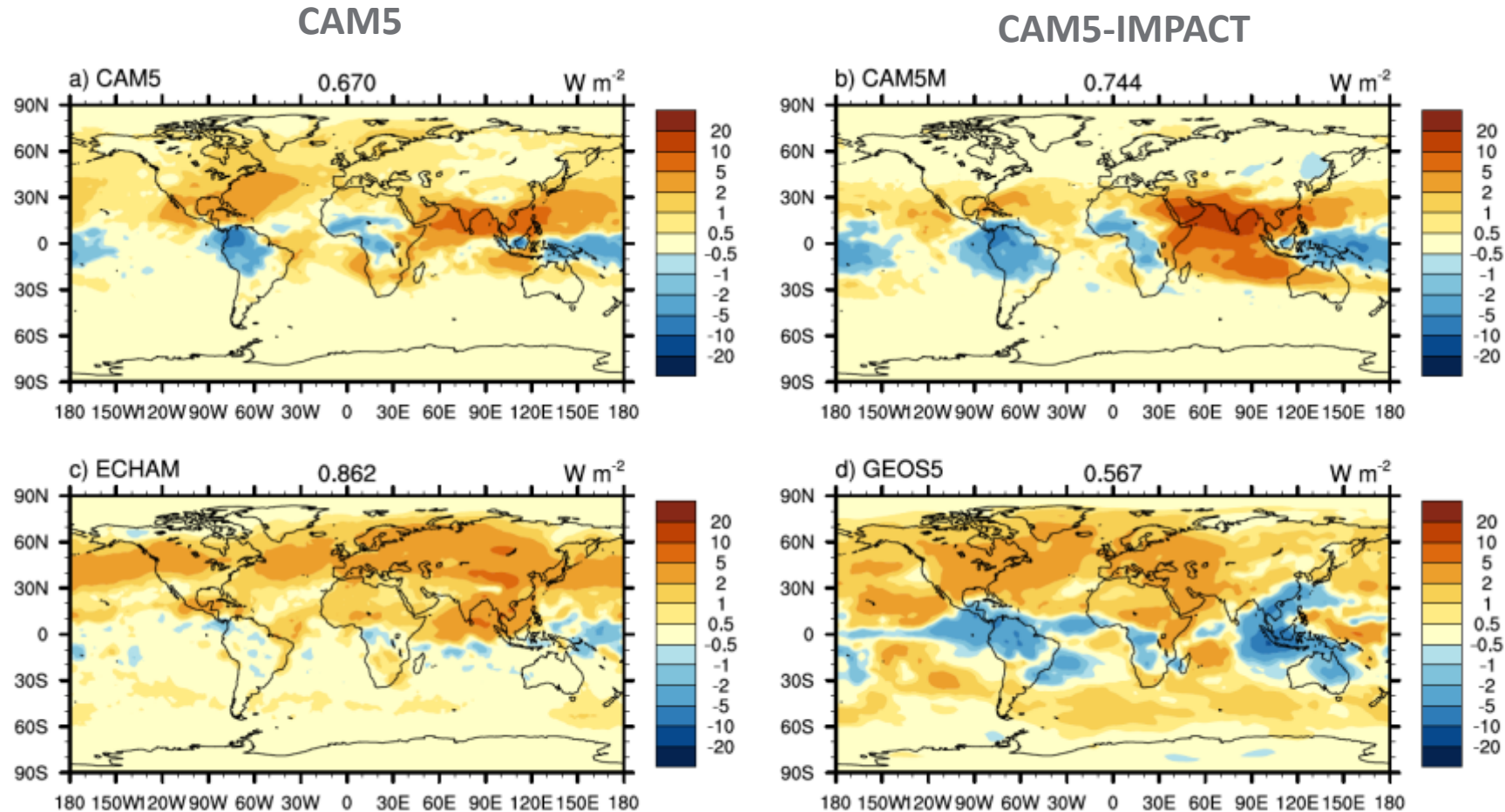
Optically
thick liquid
and ice
clouds

Absorb **longwave** radiation
heat the atmosphere

Reflect **shortwave** radiation
cool the atmosphere

ERF_{aer} : TOA LW Flux Change (PD-PI)

Δ FLNT



ECHAM6-HAM2

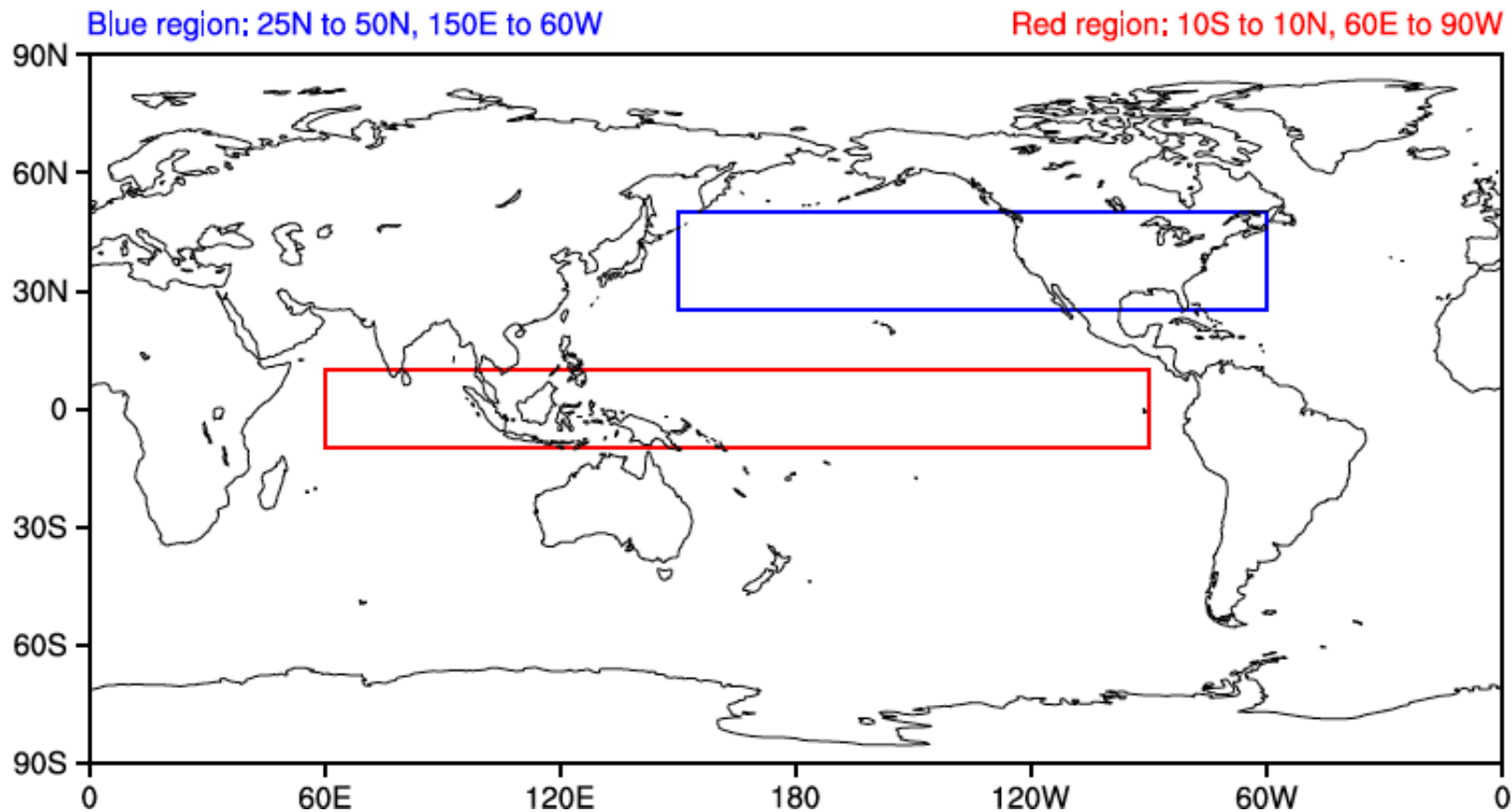
4

GEOS5

Liu et al. (in preparation)

A deep dive into the high-frequency data

Two regions defined for the Hovmöller diagram (time vs. longitude)

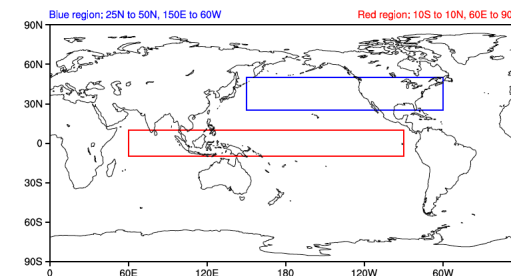
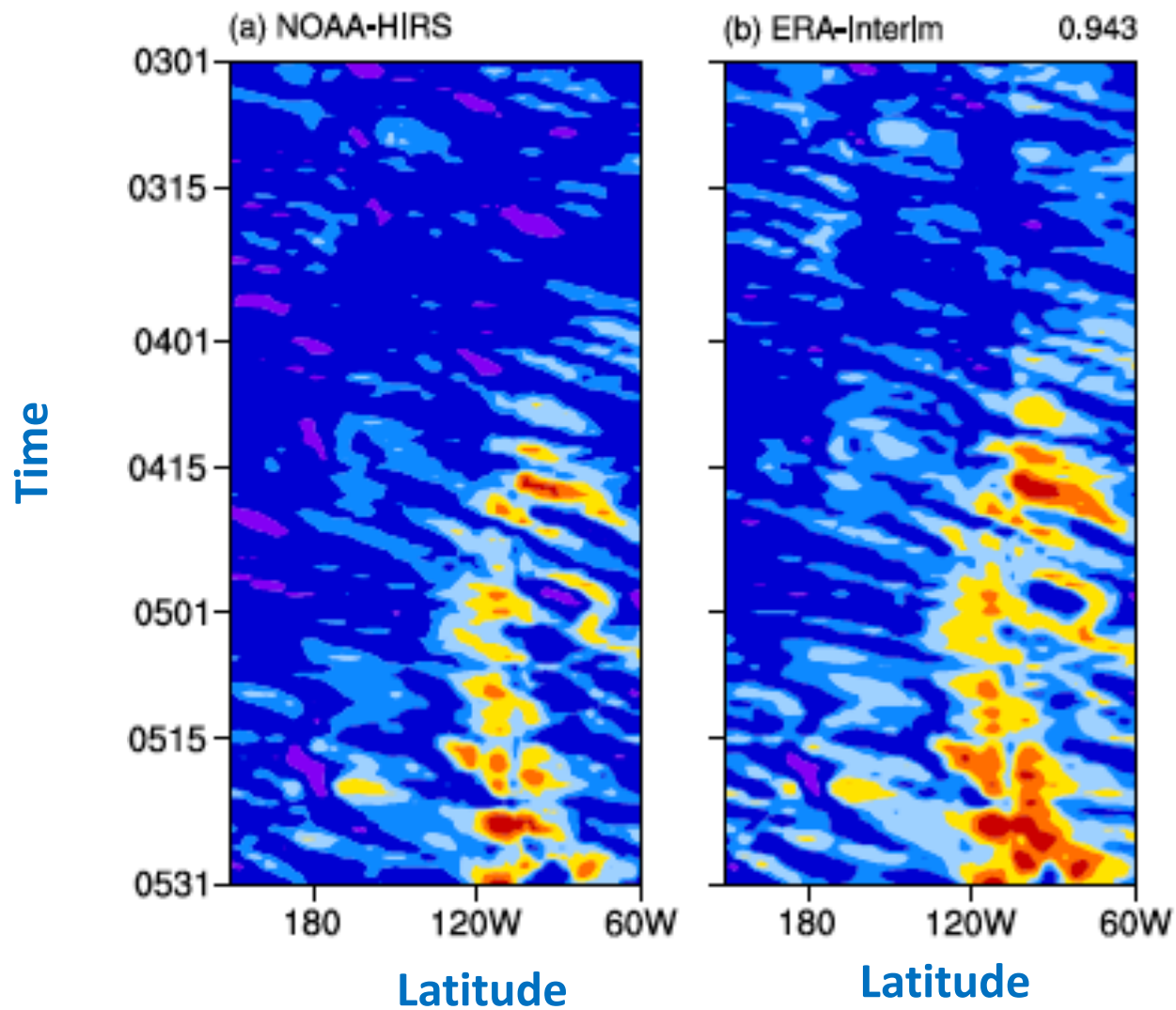


Satellite-retrieved and reanalysis OLR



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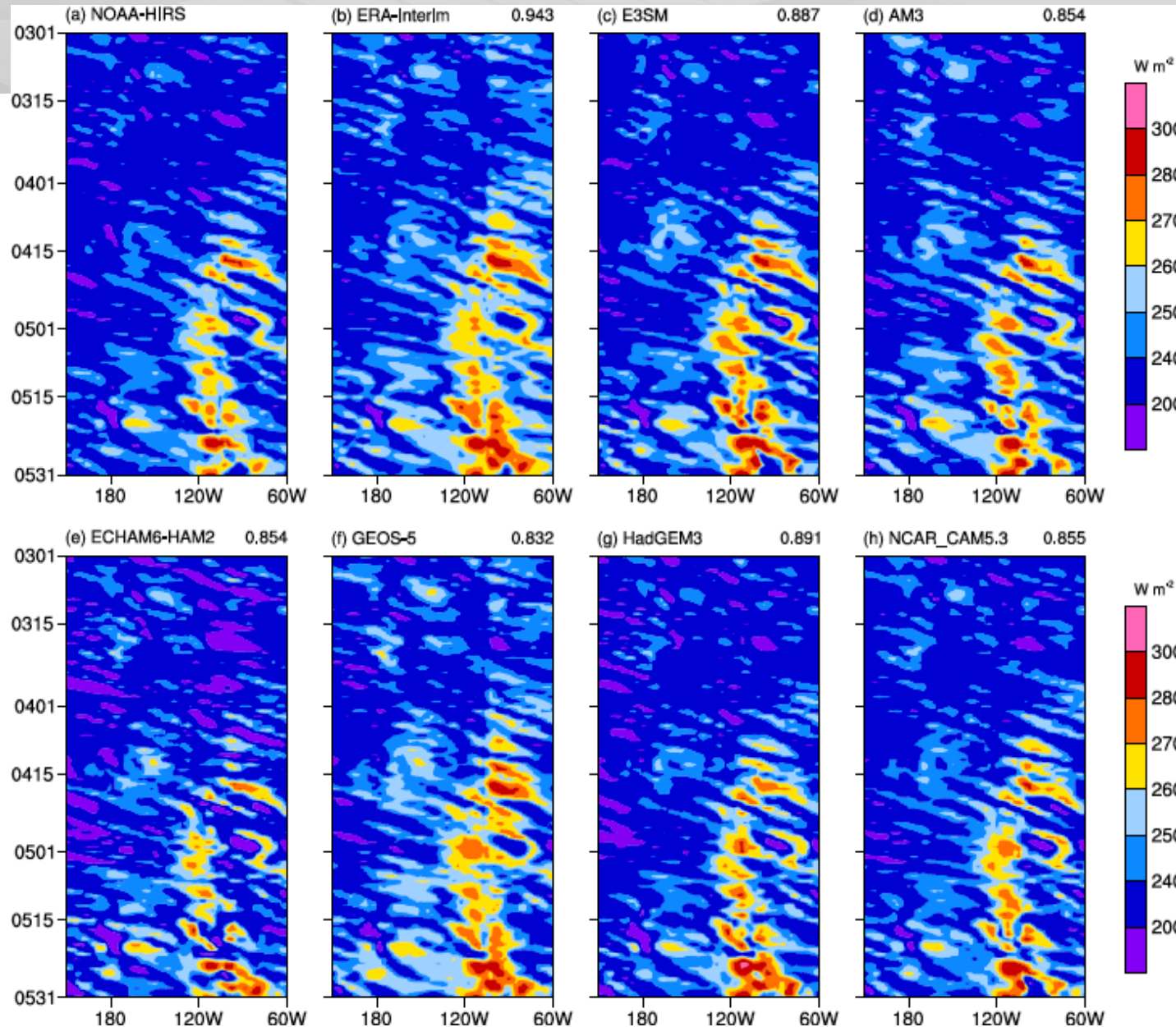
Mid-latitude

OLR: Mid-latitude (25N-50N, PD)



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- a) NOAA-HIRS
- b) ERA-Interim
- c) E3SMv1
- d) AM3

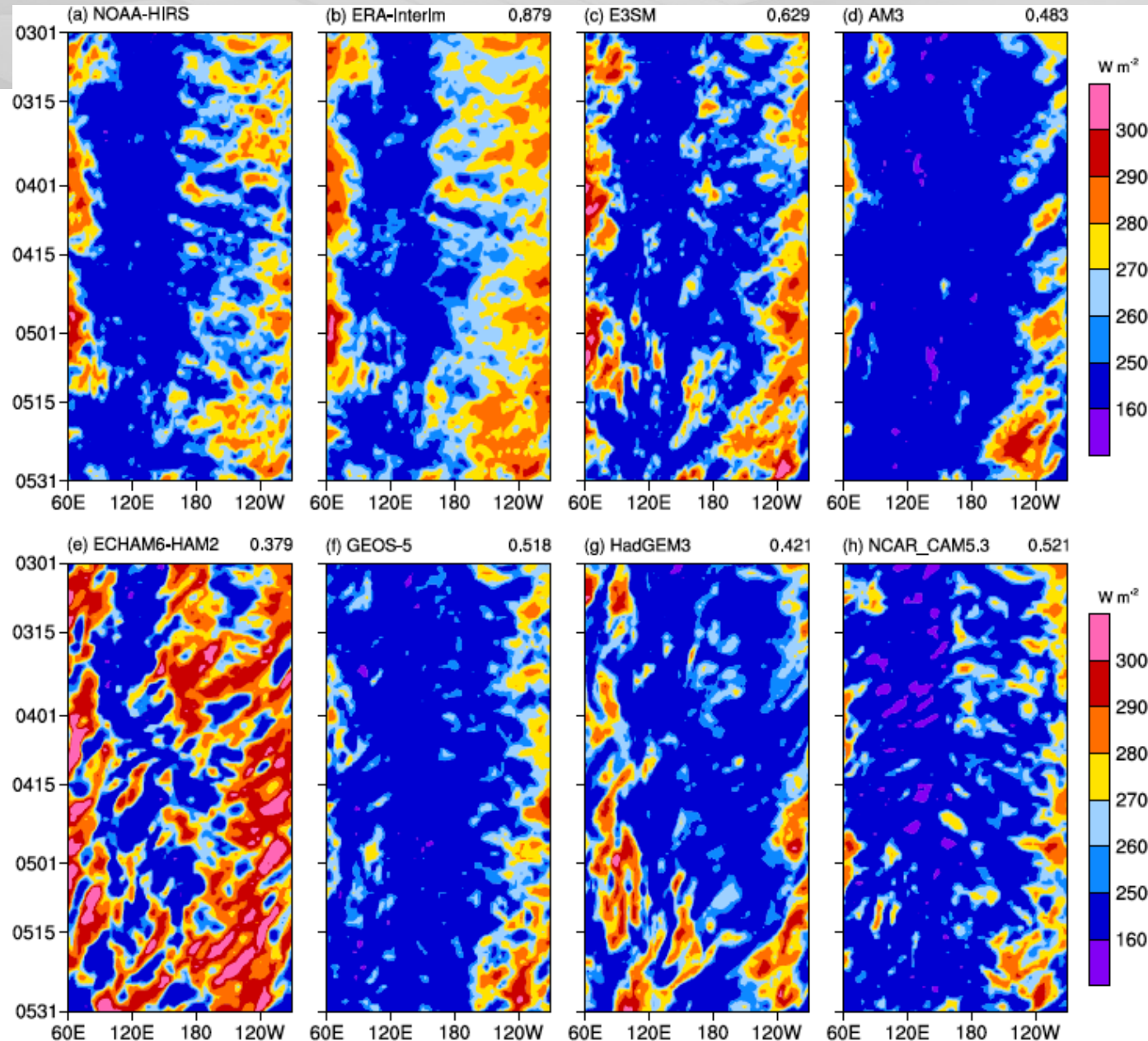
- e) ECHAM6-HAM2
- f) GEOS-5
- g) HadGEM3
- h) CAM5.3

OLR: Tropics (10S-10N, PD)



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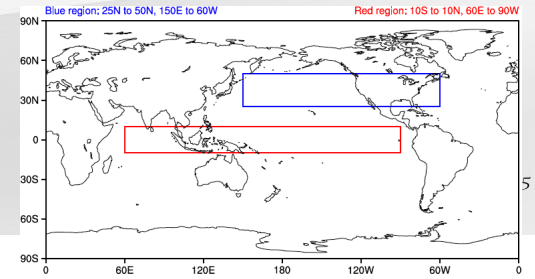
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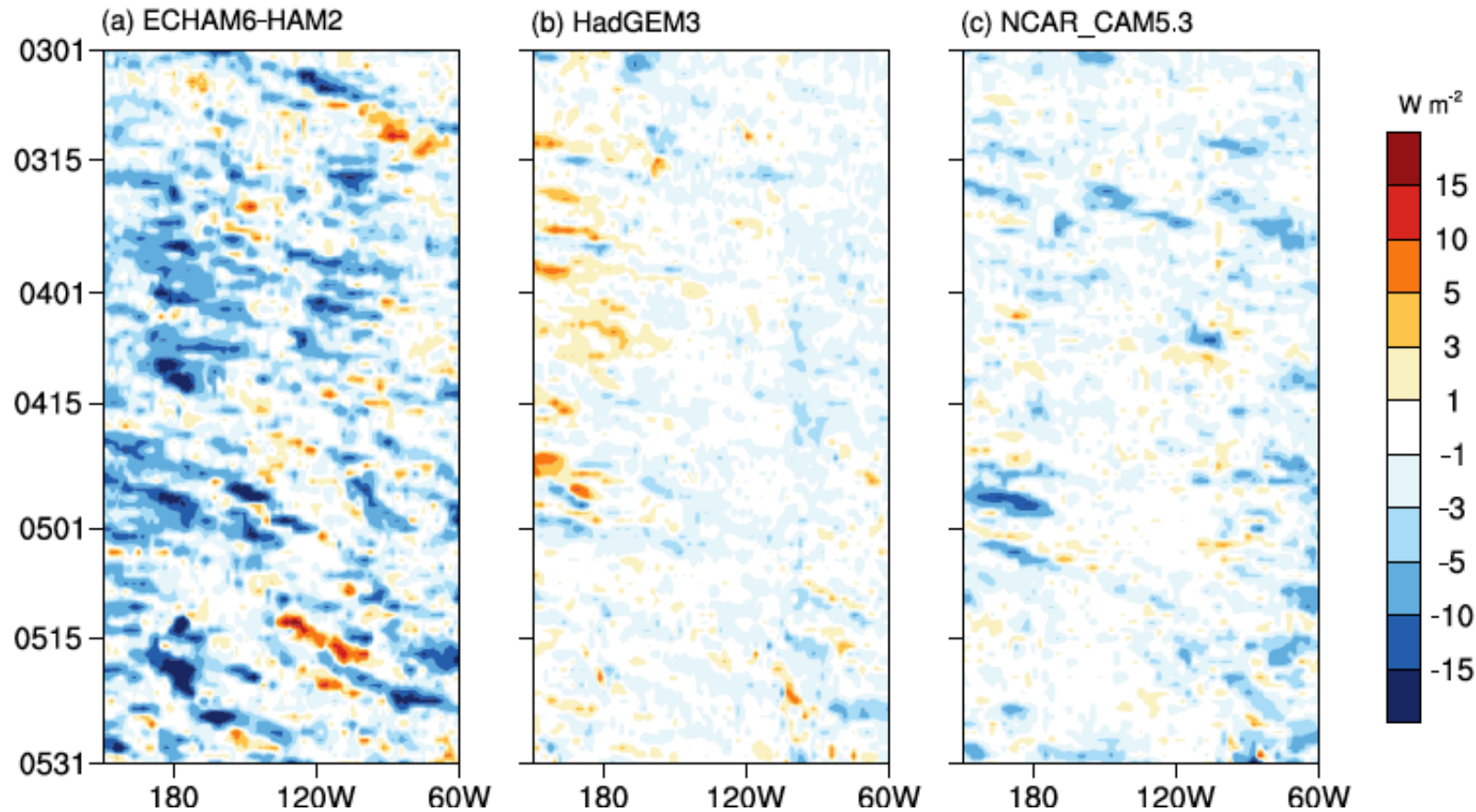
- a) NOAA-HIRS
- b) ERA-Interim
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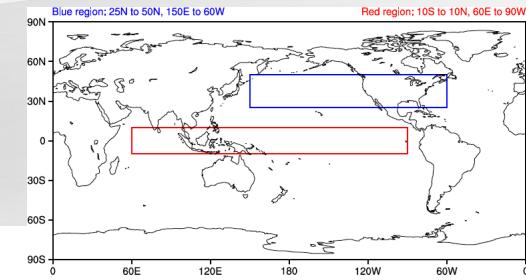
OLR_{PD} - OLR_{PI} : Mid-latitude



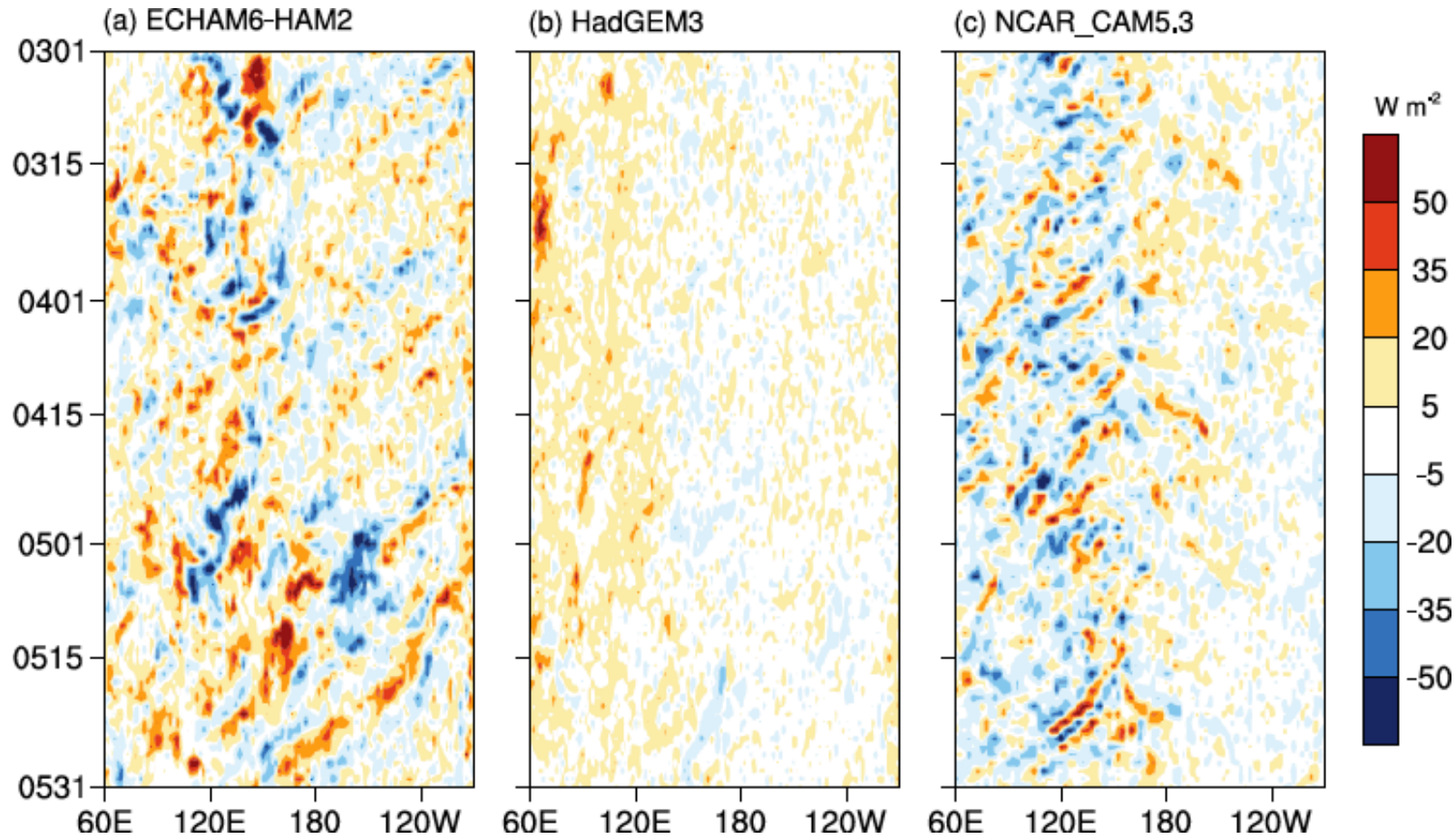
year 2006



OLR PD-PI: Tropics



year 2006



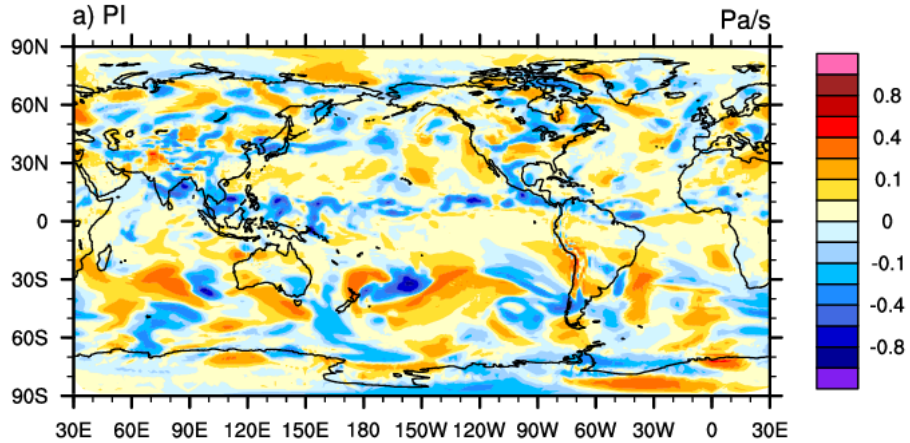
ω_{500} is overall well constrained, but less well in tropics



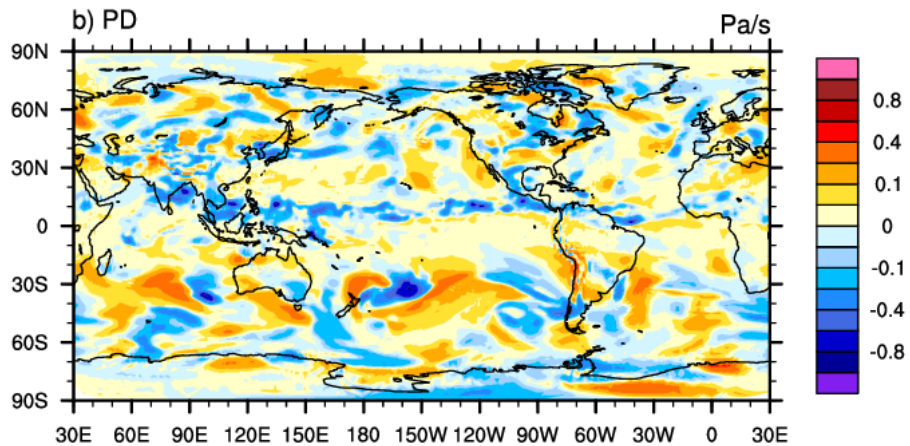
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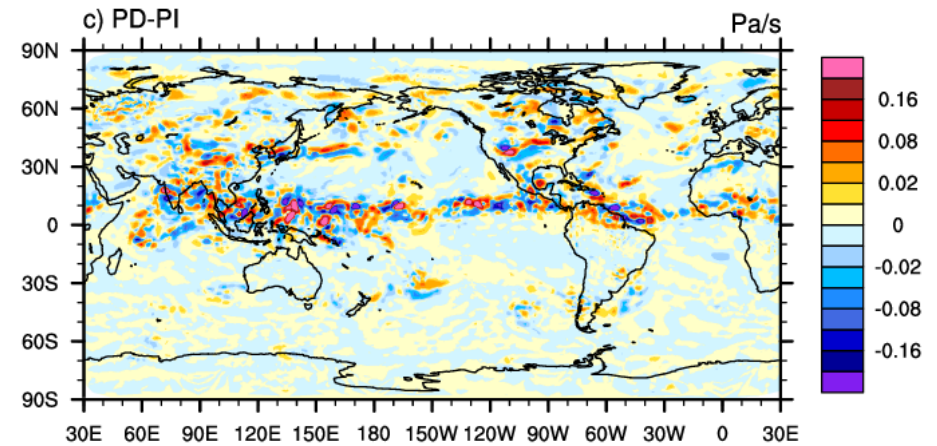
PD



PI



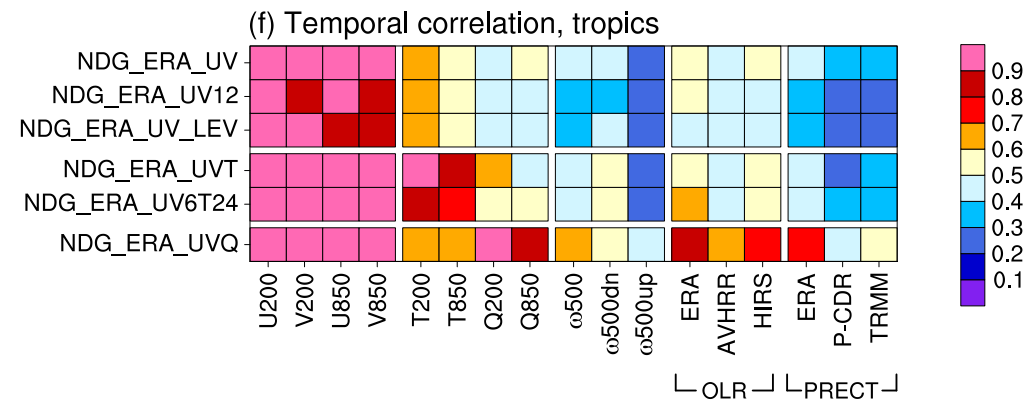
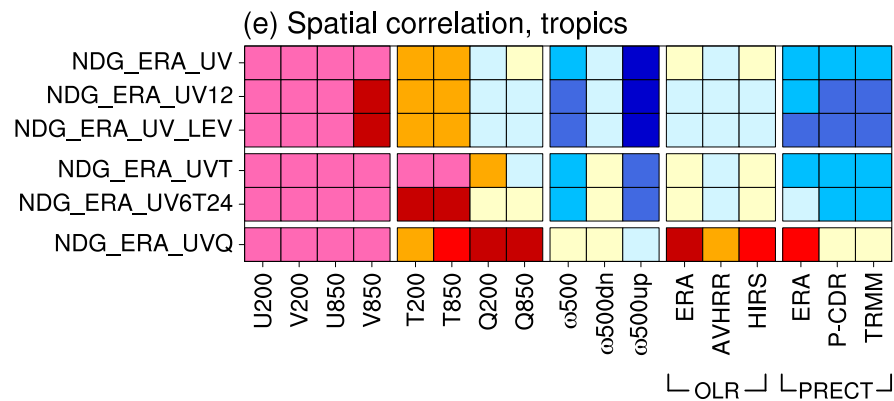
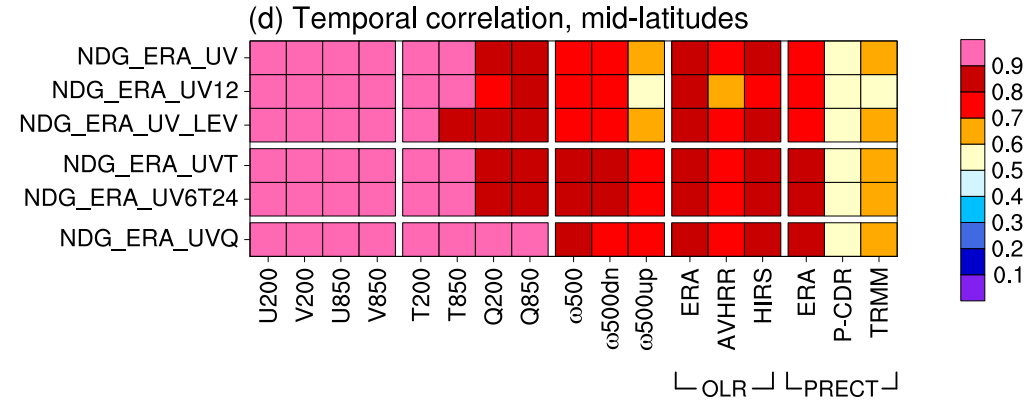
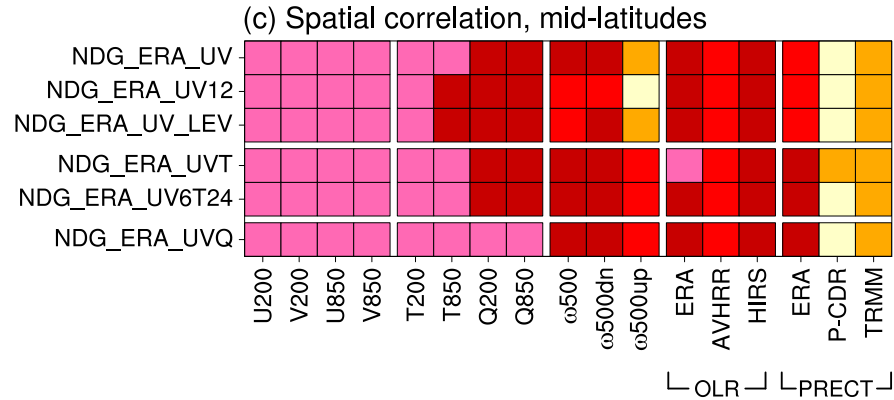
PD - PI



Daily mean snapshots

A consistent picture (E3SM_{v1} as an example)

Mid-latitudes



Tropics

Sun and Zhang et al. (2019)
JAMES under revision

Dynamical regimes and decomposition

$$\bar{C} = \int_{-\infty}^{\infty} P_{\omega} C_{\omega} d\omega$$

$$\overline{\delta c} = \int_{-\infty}^{+\infty} C_{\omega} \delta P_{\omega} d\omega + \int_{-\infty}^{+\infty} P_{\omega} \delta C_{\omega} d\omega + \int_{-\infty}^{+\infty} \delta P_{\omega} \delta C_{\omega} d\omega$$

dynamic

thermodynamic

co-variation

Bony et al. (2004)

Dynamical regimes and decomposition

$$\bar{C} = \int_{-\infty}^{\infty} P_{\omega} C_{\omega} d\omega$$

$$\overline{\delta c} = \int_{-\infty}^{+\infty} C_{\omega} \delta P_{\omega} d\omega + \int_{-\infty}^{+\infty} P_{\omega} \delta C_{\omega} d\omega + \int_{-\infty}^{+\infty} \delta P_{\omega} \delta C_{\omega} d\omega$$

dynamic

thermodynamic

co-variation

Expected in this study

**small
due to nudging**

dominant

negligible

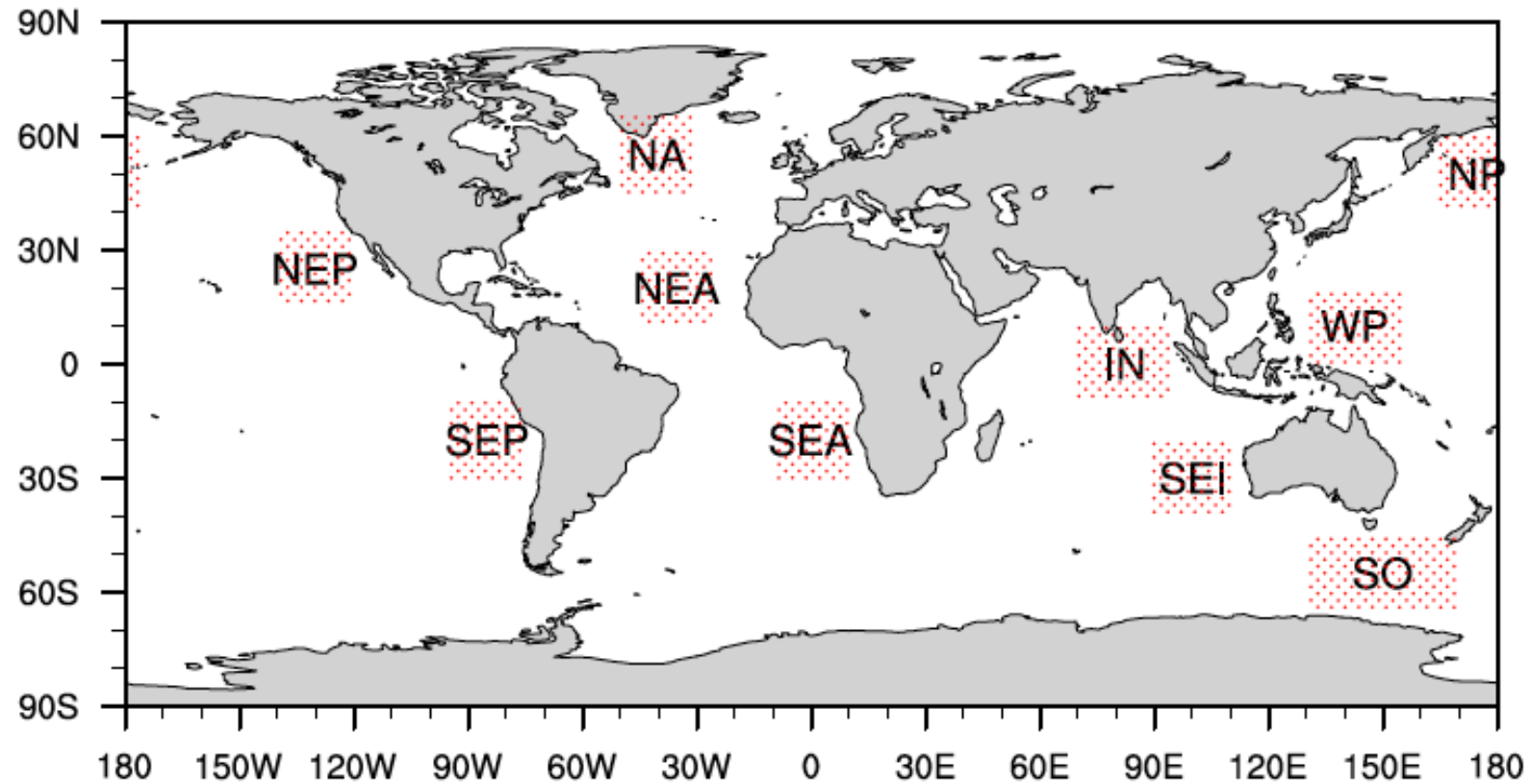
Bony et al. (2004)

Regions with low/high cloud appearance



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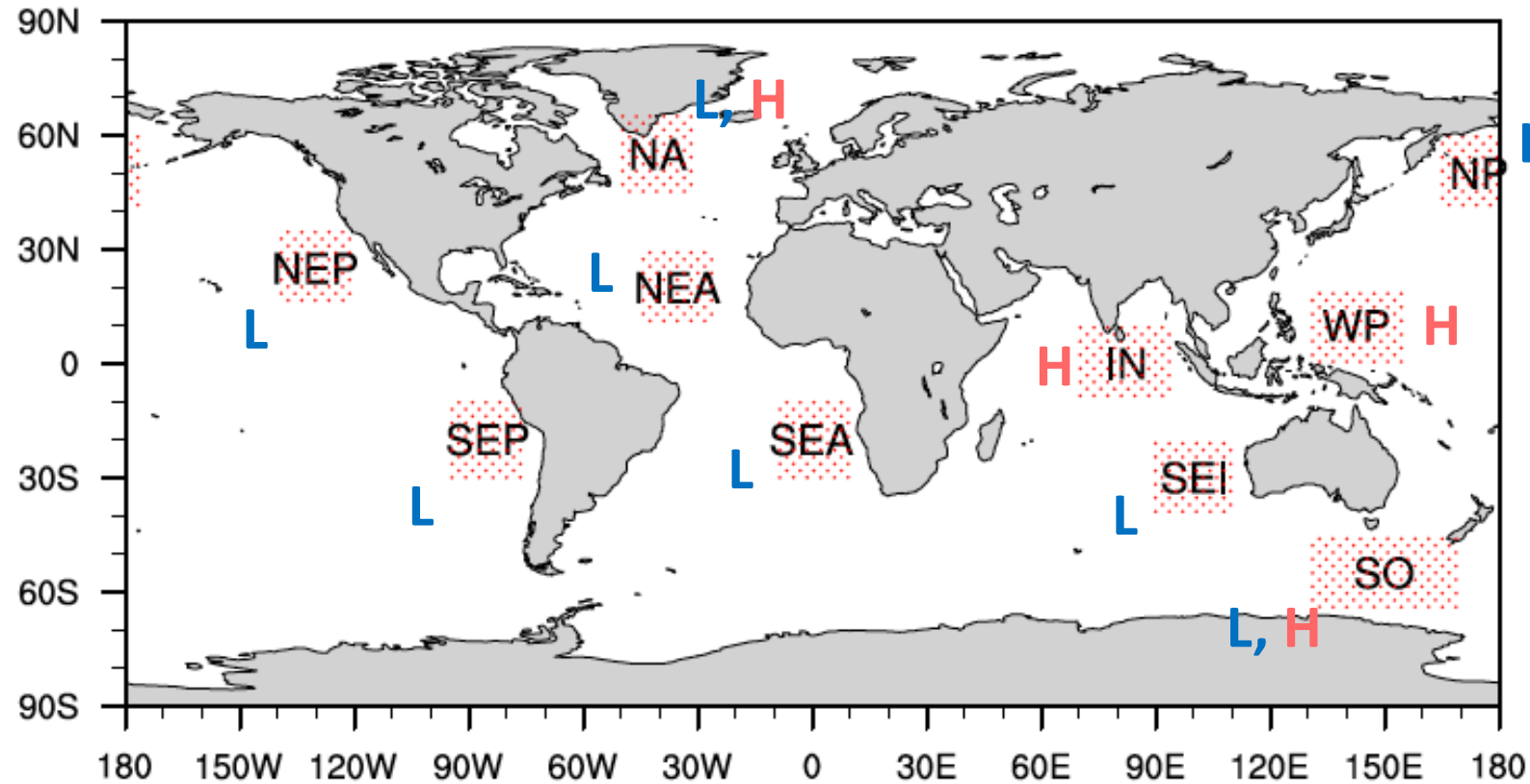


Regions with low/high cloud appearance



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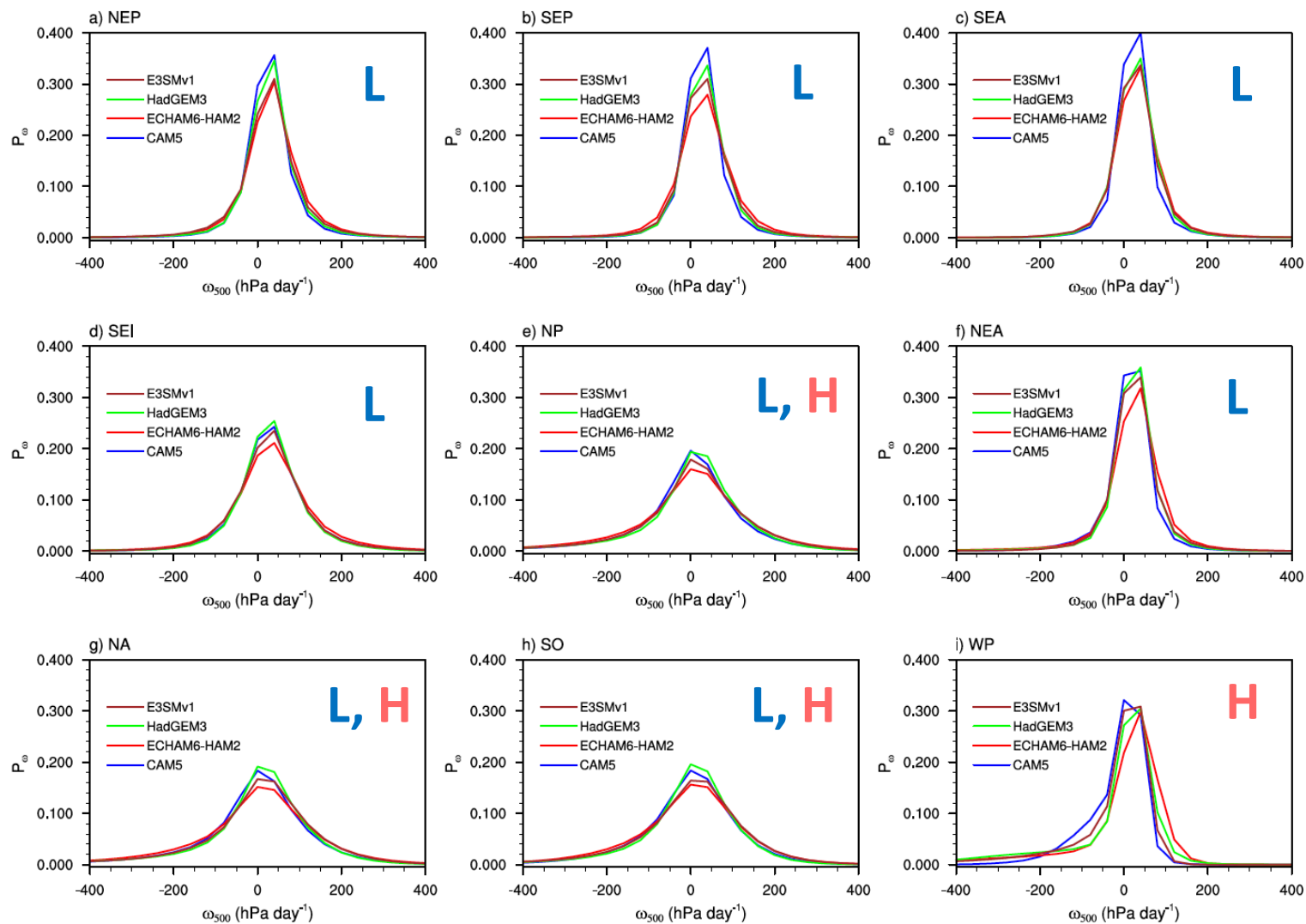


L: low clouds
H: high clouds



Pw: PDF of ω_{500} (PD)

Calculated with
3-hourly data

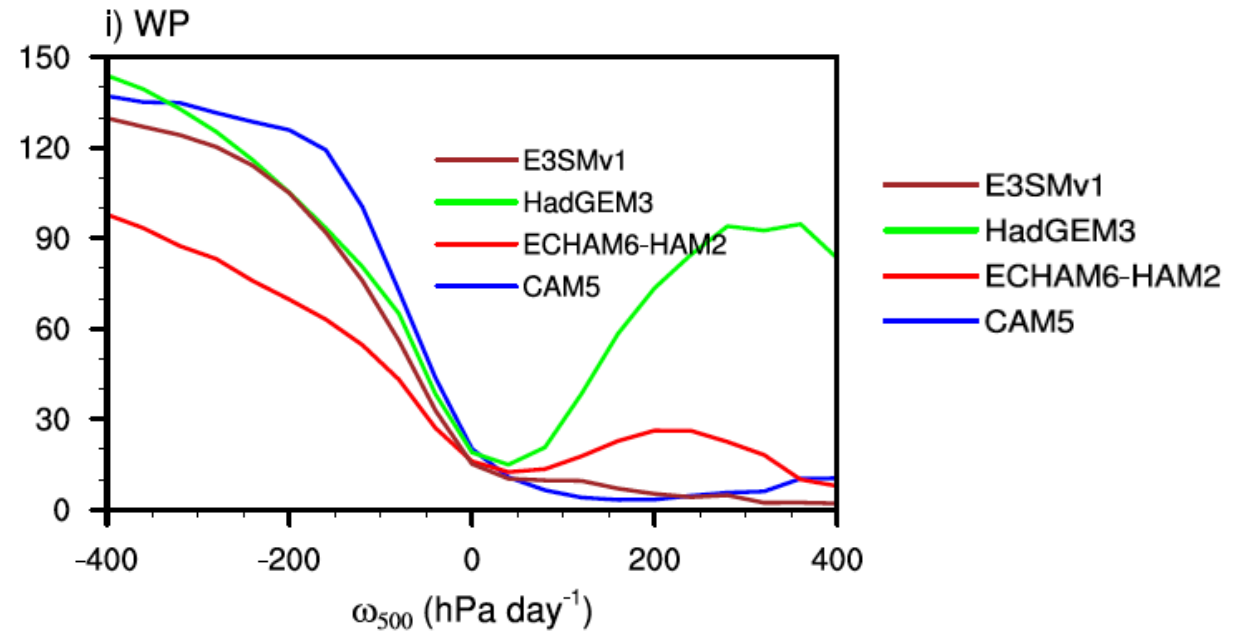
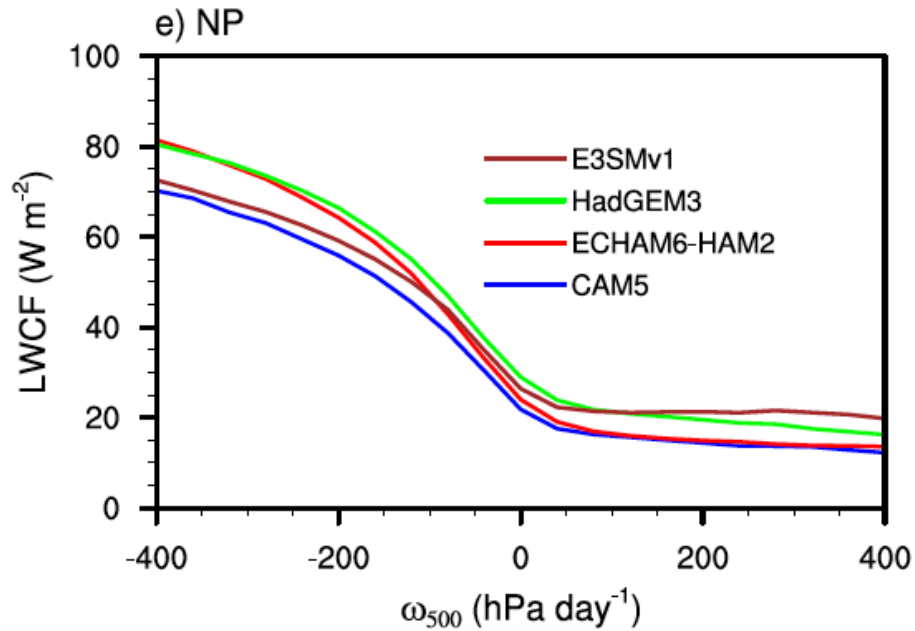


L: low clouds
H: high clouds

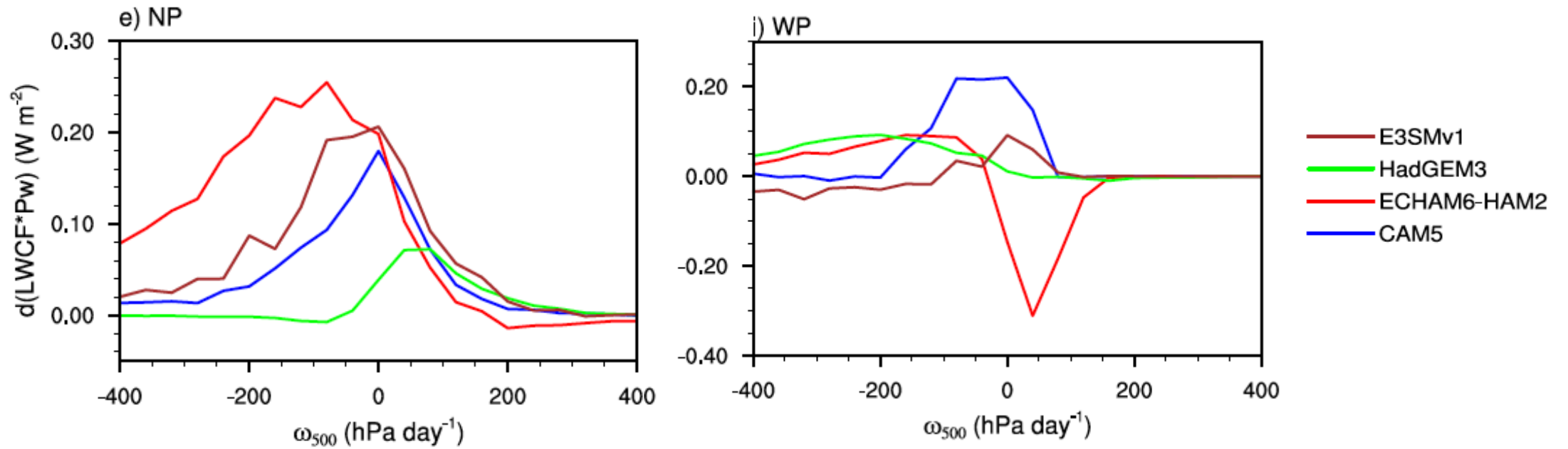
Conditionally sampled LWCF (at given ω_{500})



PD



Pw-weighted ERF_{aer}: d(LWCF*Pw)



Dynamical regimes and decomposition

$$\bar{C} = \int_{-\infty}^{\infty} P_{\omega} C_{\omega} d\omega$$

$$\overline{\delta c} = \int_{-\infty}^{+\infty} C_{\omega} \delta P_{\omega} d\omega + \int_{-\infty}^{+\infty} P_{\omega} \delta C_{\omega} d\omega + \int_{-\infty}^{+\infty} \delta P_{\omega} \delta C_{\omega} d\omega$$

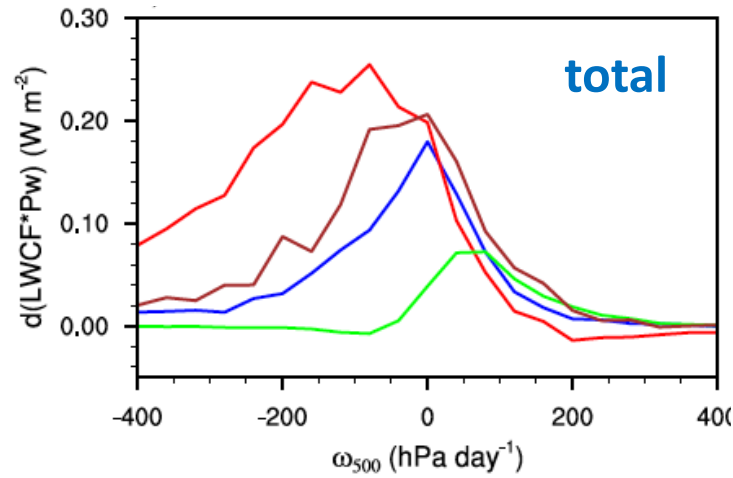
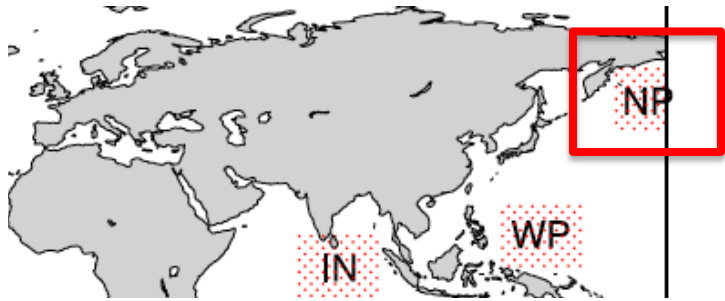
dynamic

thermodynamic

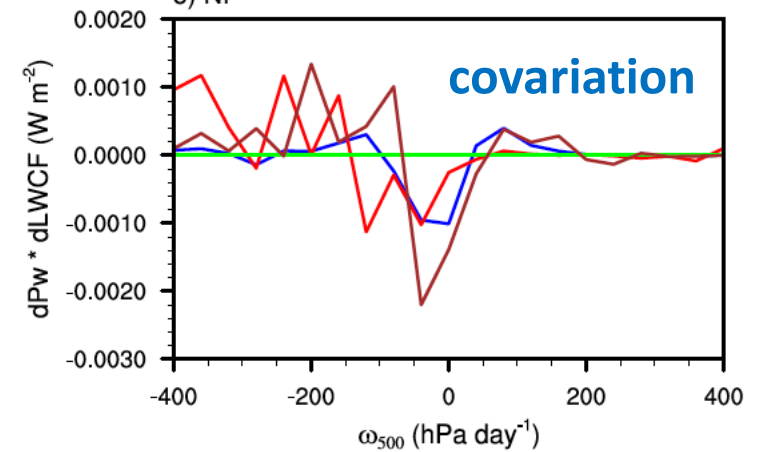
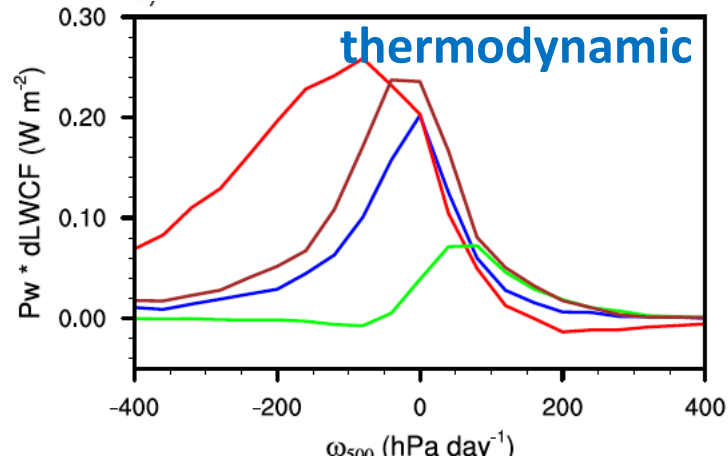
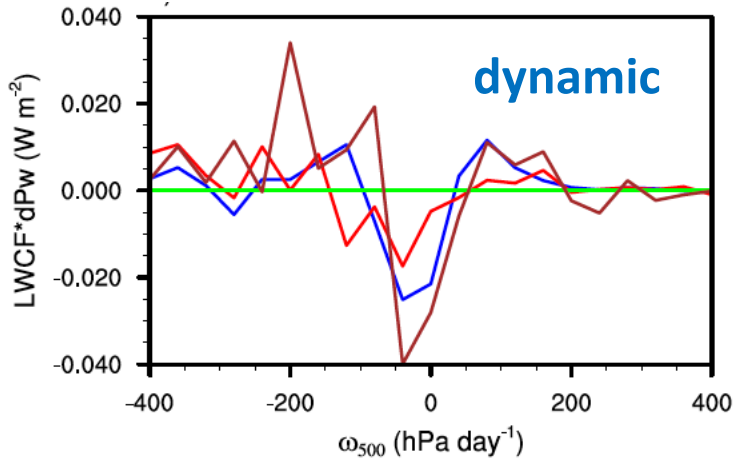
co-variation

Bony et al. (2004)

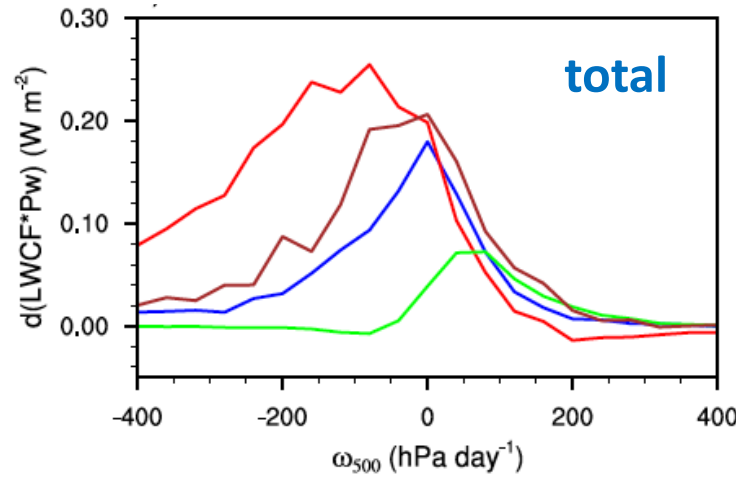
Dynamical, thermodynamical, and covariation terms



- E3SMv1
- HadGEM3
- ECHAM6-HAM2
- CAM5



Dynamical, thermodynamical, and covariation terms

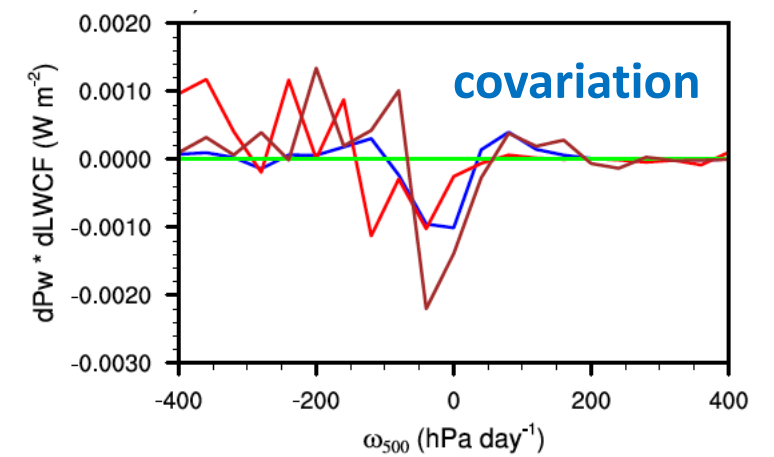
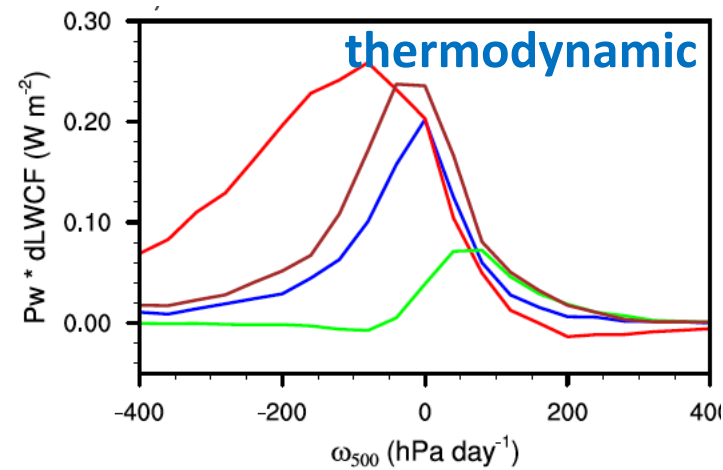
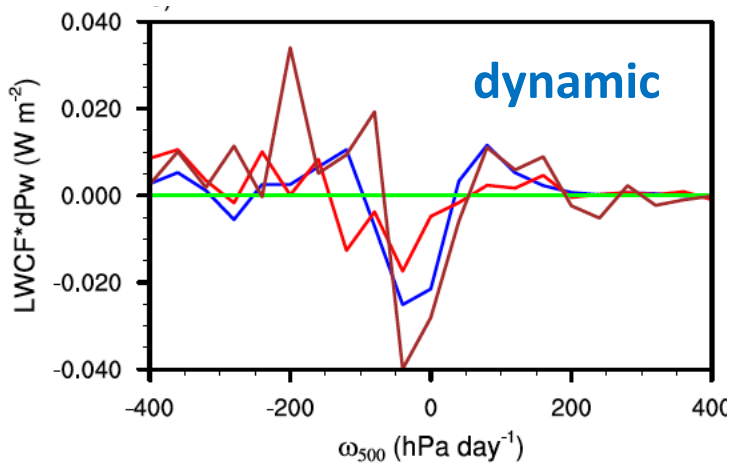


- E3SMv1
- HadGEM3
- ECHAM6-HAM2
- CAM5

small

dominant

negligible



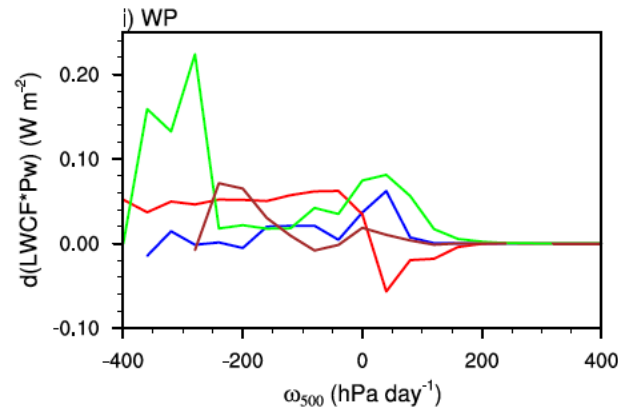
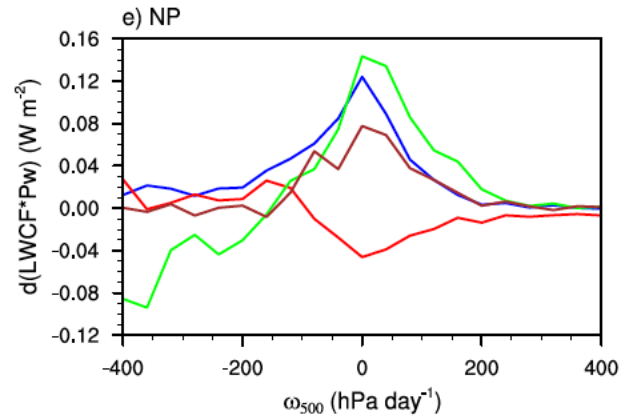
Further decomposition for different cloud phases



NP

WP

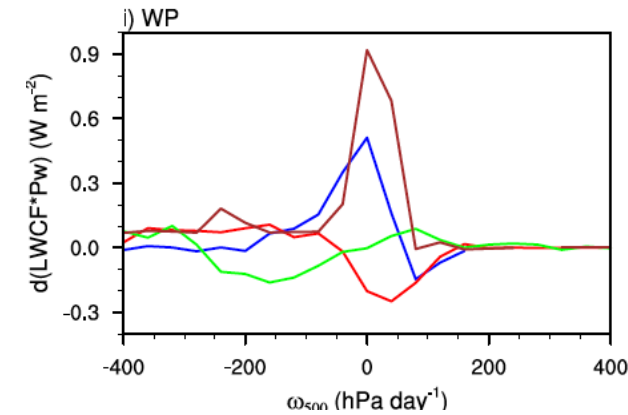
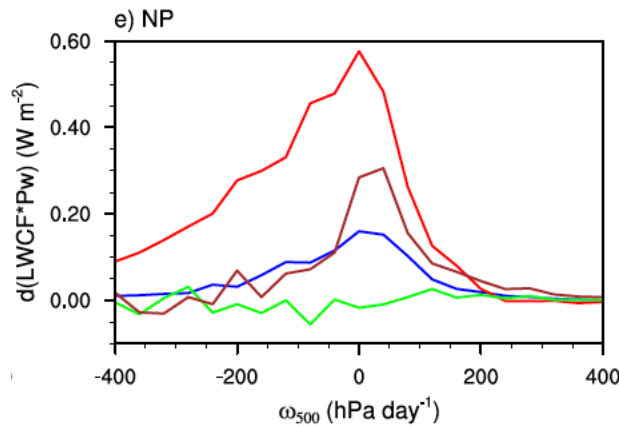
Liquid phase only



- E3SMv1
- HadGEM3
- ECHAM6-HAM2
- CAM5

Note that normalization for liq/ice contribution is NOT done for this figure

Ice phase only



Overlapped ice/liquid clouds are NOT considered here.



Summary

- ▶ Nudged IND3 simulations show **reasonable hindcast skill** over mid-latitude, but less well-constrained in tropics
- ▶ ERF_{aer} is highly dependent on **dynamical regimes and cloud phase**.
- ▶ Much more interesting (**some are weird**) results will be shared with co-authors soon.