Updates on unified turbulence and convection parameterization: CLUBB+MF

AMWG 2025 Winter Working Group Meeting

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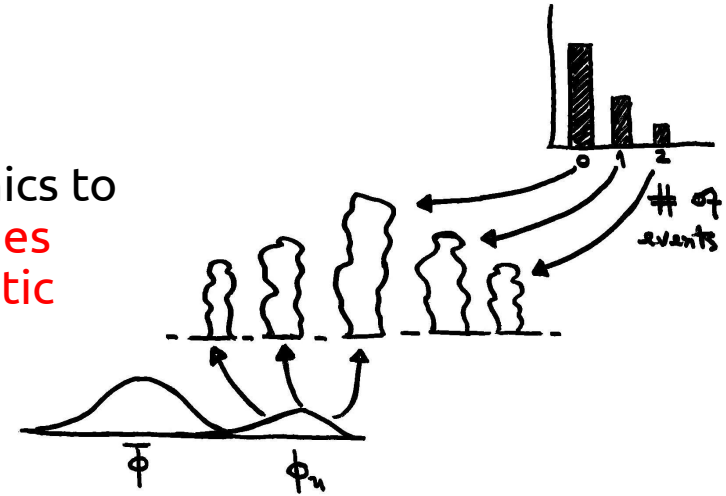
EDMF and moist convection

- Eddy Diffusivity represents mixing by small scale turbulence
  - Downgradient diffusion
- Mass Fluxes represent mixing due to asymmetric turbulence (plumes)
  - PDF of surface layer thermodynamics to initialize explicit ensemble of plumes
  - Individual plumes undergo stochastic lateral entrainment

ED MF

$$\overline{w'\varphi'} = -k\frac{\partial\bar{\varphi}}{\partial z} + M(\varphi_u - \bar{\varphi})$$



$$\varepsilon_{u_n}(\Delta z) = \frac{\varepsilon_0}{\Delta z}\mathcal{P}\left(\frac{\Delta z}{L_\varepsilon}\right)$$

Entrainment length scale

Suselj, Teixeira & Chung, JAS, 2013
Suselj, Kurowski & Teixeira, JAS 2019

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CLUBB+MF

- Eddy Diffusivity represents mixing by small scale turbulence
  - High-order turbulence model CLUBB
- Mass Fluxes represent mixing due to asymmetric turbulence (plumes)
  - PDF of surface layer thermodynamics to initialize explicit ensemble of plumes
  - Individual plumes undergo stochastic lateral entrainment

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CLUBB ED MF

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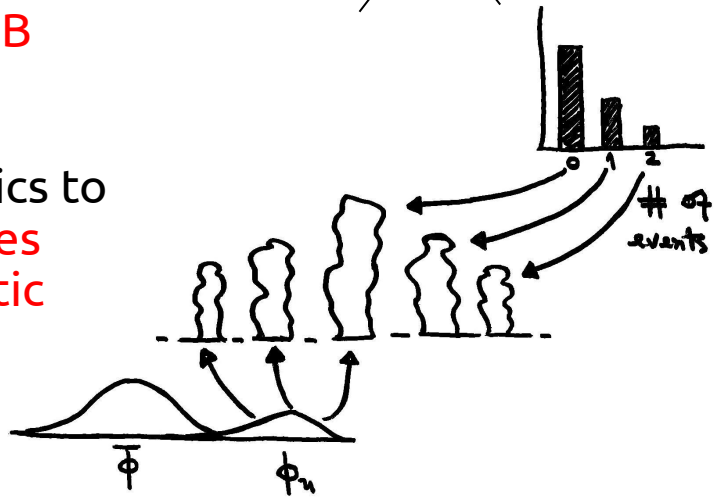

Suselj, Teixeira & Chung, JAS, 2013
Suselj, Kurowski & Teixeira, JAS 2019

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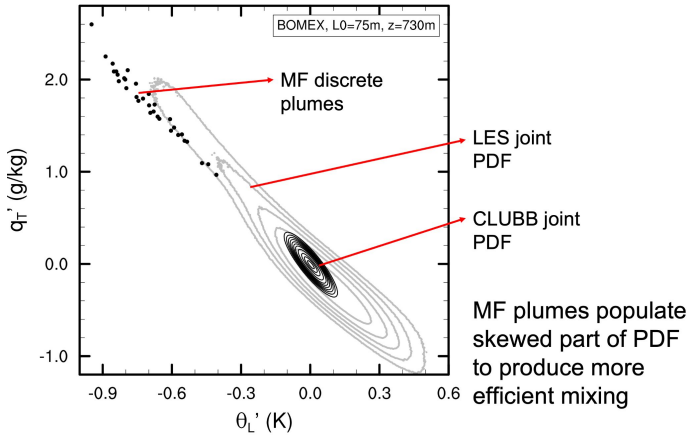
Version history

- CLUBB+MF (shlw)
  - Fixed entrainment length scale (L_e)
  - Witte et al. (2022)
- CLUBB+MF (shlw+deep)
  - Dynamic L_e – function of environ. RH
  - Paper in progress
- CLUBB+MF Aero
  - Dynamic L_e – function of plume history
  - Inclusion of downdrafts ensemble
  - Cold pool feedback on L_e
  - Cloud-aerosol interactions
  - Inclusion of tracer transport
  - Convective initiation aloft



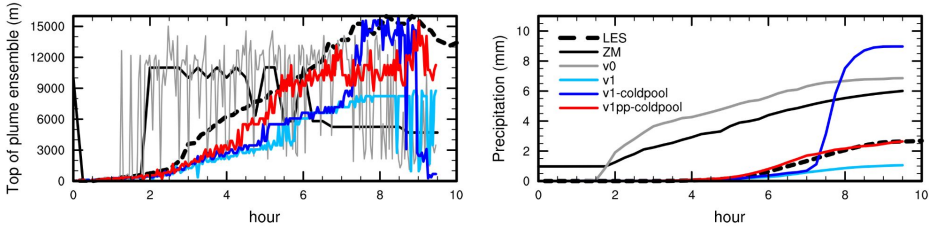


Figure 1. *CAM single column model experiments of the Large-Scale Biosphere-Atmosphere case (LBA), representing the diurnal cycle of moist convection over land. (Left) Top of the plume ensemble, and (right) cumulative precipitation rate. LES refers to large-eddy simulation reference, ZM refers to the operational deep convection scheme in CAM, whereas v0, v1, v1-coldpool and v1pp-coldpool refer to different configurations of CLUBB+MF discussed in the text.*

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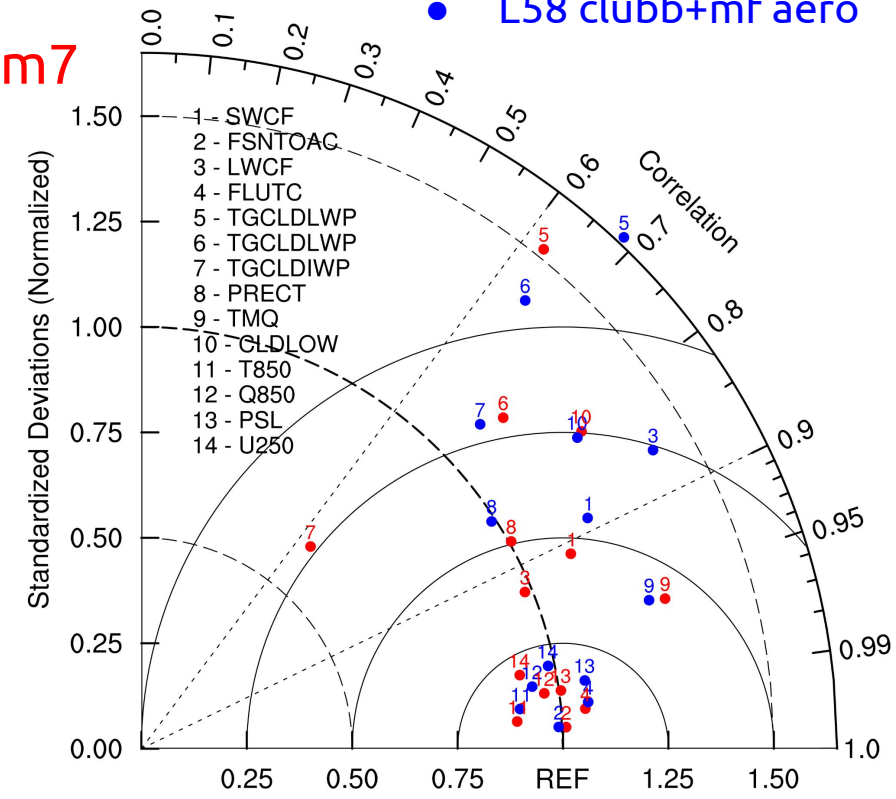
Climate skill (global)

Evaluating clubb+mf aero relative to cam7

1 - SWCF (CERES Ed4.1) OK
2 - FSNTOAC (CERES Ed4.1) OK
3 - LWCF (CERES Ed4.1) ❌
4 - FLUTC (CERES Ed4.1) OK
5 - TGCLDLWP (MAC-LWP) OK
6 - TGCLDLWP (ERA5) ❌
7 - TGCLDIWP (ERA5) ✅
8 - PRECT (GPM/IMERG) OK
9 - TMQ (AMSRv2) OK
10 - CLDLOW (CS/CAL) OK
11 - T850 (ERA5) OK
12 - Q850 (ERA5) OK
13 - PSL (ERA5) OK
14 - U250 (ERA5) OK

AMIP Runs (1998-2017)
- L58 cam7
- L58 clubb+mf aero



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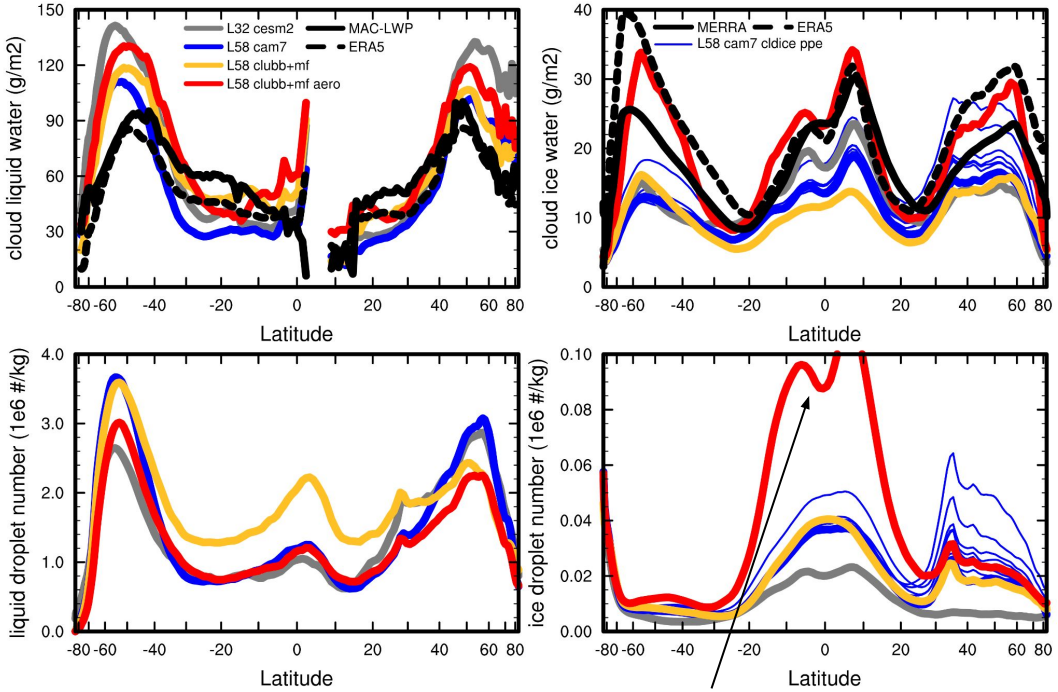
AMIP Runs

- L32 cesm2 (cmip6)
- L58 cam7
- L58 clubb+mf (shlw+deep)
- L58 clubb+mf aero

cloud water bias

- liquid water path – ERA5 & MAC-LWP (courtesy G. Elsaesser)
- ice water path –
  - large disagreement among remote sensing products (Duncan and Eriksson 2018)
  - ERA5 & MERRA only products that omit condensates
- clubb+mf aero better reproduces IWP magnitude in reanalysis



Due to coupling MF updraft velocity to ice nucleation

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AMIP Runs (1998-2017)

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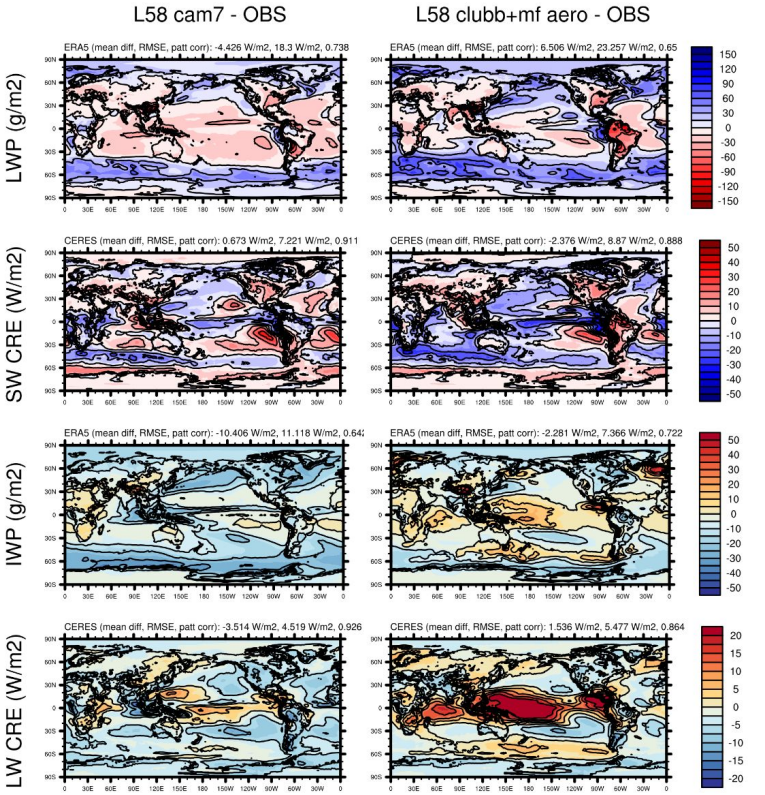
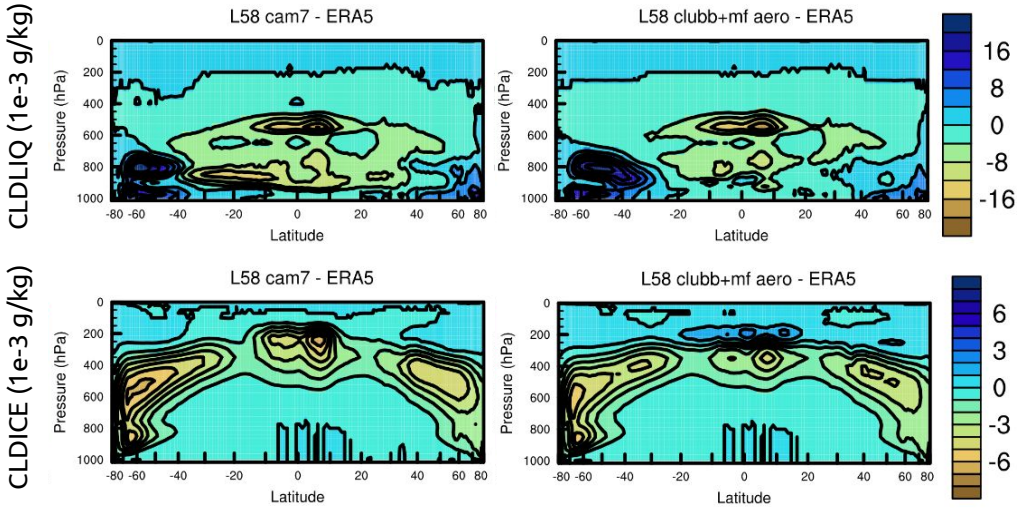
- L58 clubb+mf aero

cloud water and radiation



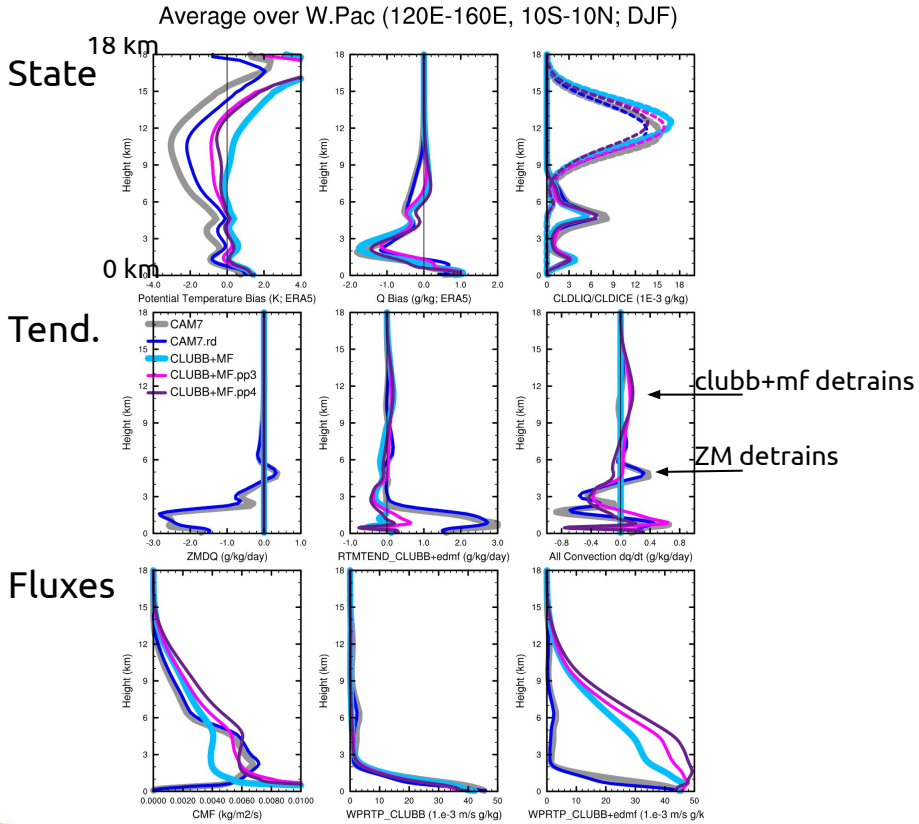
cloud water in the vertical



clubb+mf convection vs. cam7 convection

clubb+mf:

- ❏ Warms & moistens the tropical atmosphere compared to CAM7
- ❏ Deep Cu is deeper; detrainment occurs much higher than in CAM7
- ❏ Magnitude of Deep Cu mass fluxes similar to ZM
- ❏ Competitive tropical variability (AMIP)

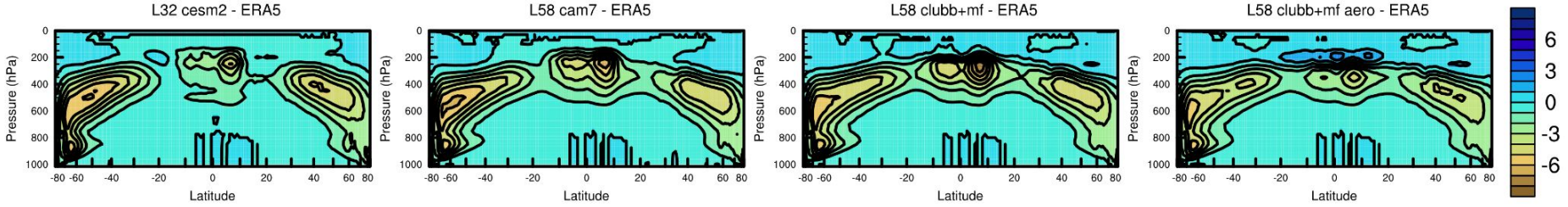


Questions?

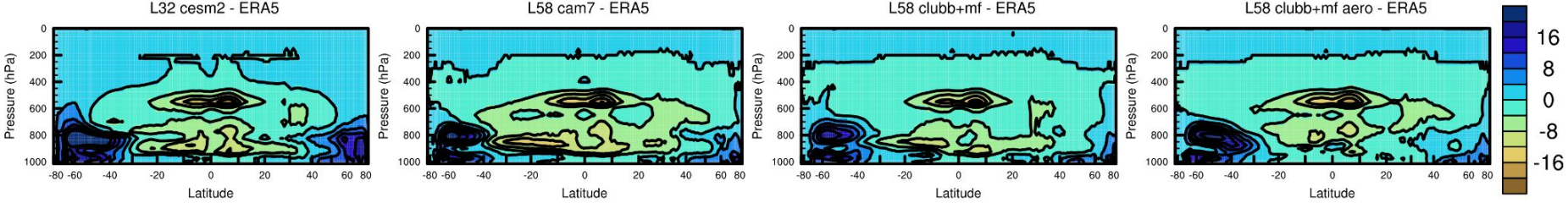
CGD
Climate & Global Dynamics
a laboratory of NCAR

cloud water bias in the vertical

cloud ice (1e-3 g/kg)



cloud liquid (1e-3 g/kg)



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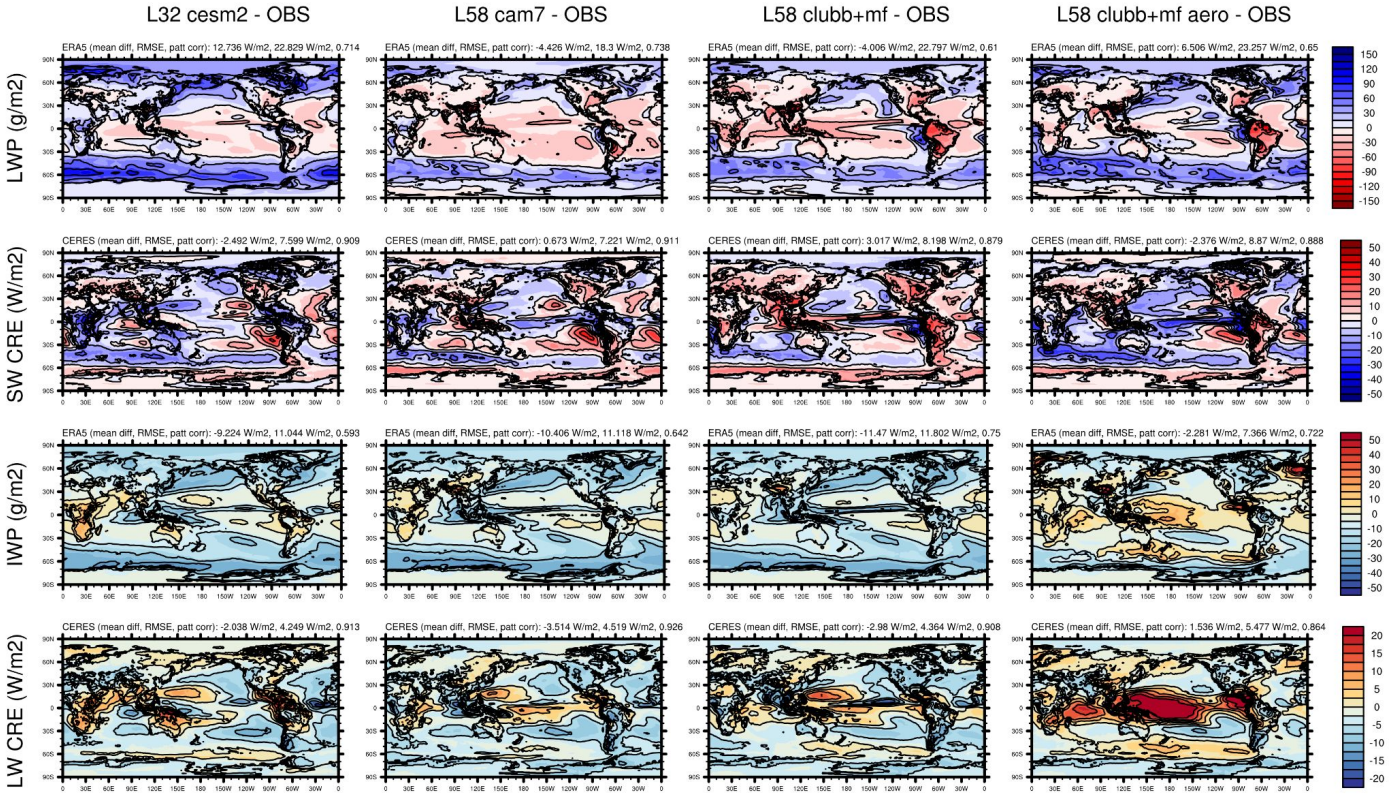
cloud water and radiation

Larger cloud radiative forcing coincides with larger cloud water



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