An Early-Term Report Card for CESM1.5 Energy and Water Budgets

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Goals

To compare CESM1.5 to current "best estimate" obs

To provide context versus CMIP5 models

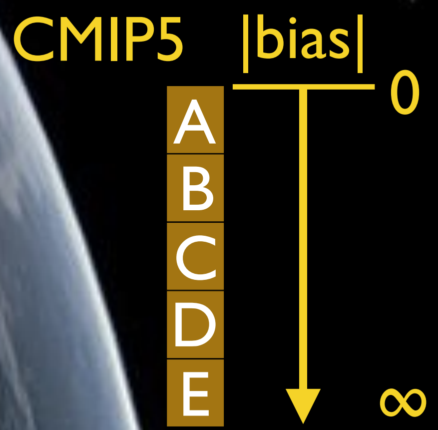
To provide context against CCSM4 / CESM1-CAM5

… while distinguishing between issues related to initialization/drift and model physics.

CESM Winter Working Group Meetings, 11 Feb 2016

Simulations/Methods Used

- 100-yr control and historical (1850-2005) #28, #31(energy-balanced)
- obs include CERES EBAF 2.8, ERA-Interim, ECMWF ORAP5, GPCP, GISTEMP
- "grades" vs CMIP5 are determined by bias quintile (A-E)
- grades only given for terms where model biases >> uncertainty in obs and internal variability



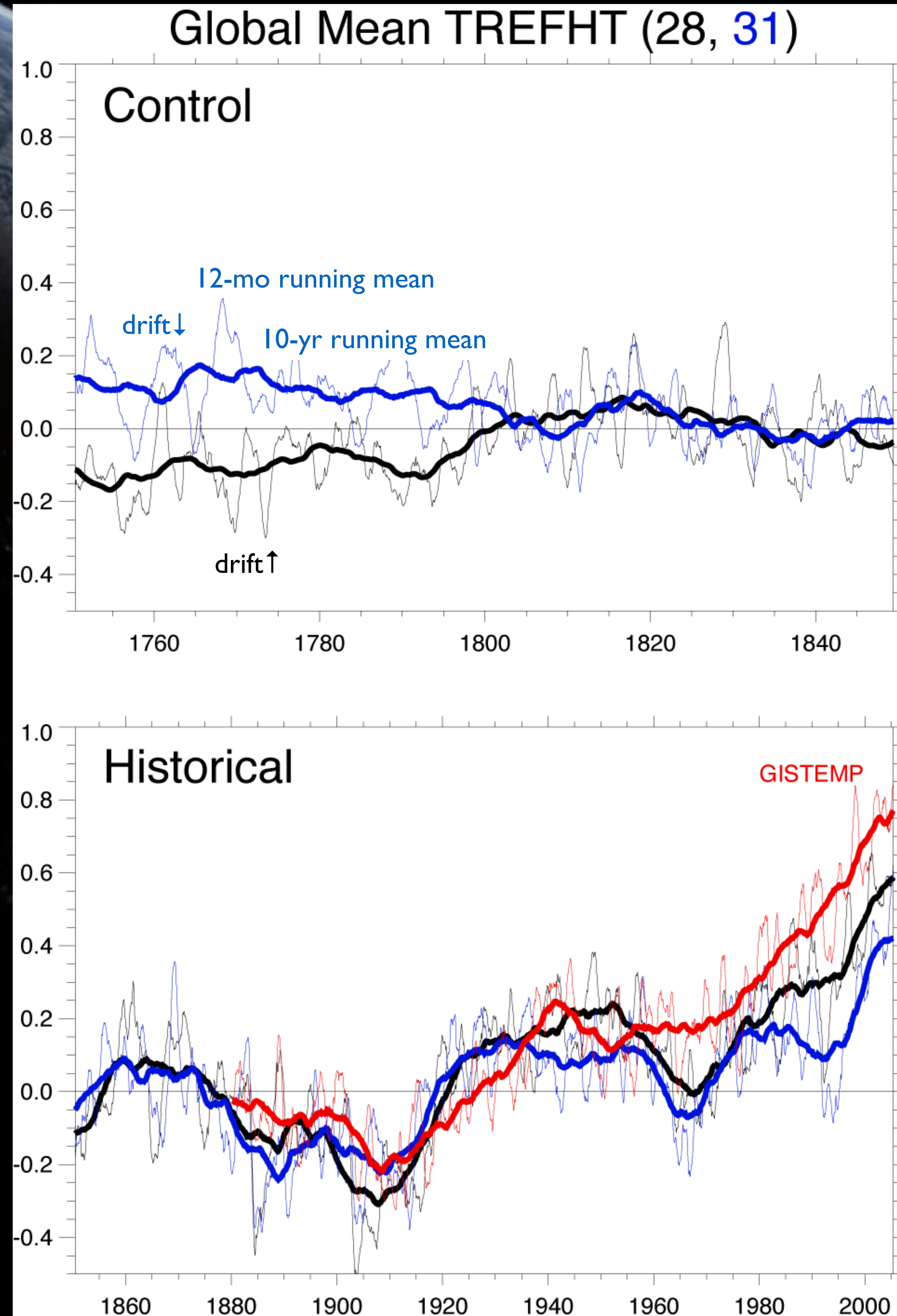
Outline

- Control runs and drift; 20th Century Budgets
- Global annual mean energy budget; Trenberth et al. 2009, BAMS
- Global annual mean water cycle; Trenberth et al. 2007, JHYMET
- Seasonal, zonal mean, and regional features

Surface Temperature Control Runs

Global mean surface temperature warms in control run of 28 and cools in 31 (more than 28 warms, despite being energetically balanced, why?)

Both runs fail to warm as much as observed during the 20th C. *Why? Is 28 or 31 more characteristic of CESM 1.5? Answers are nontrivial.*



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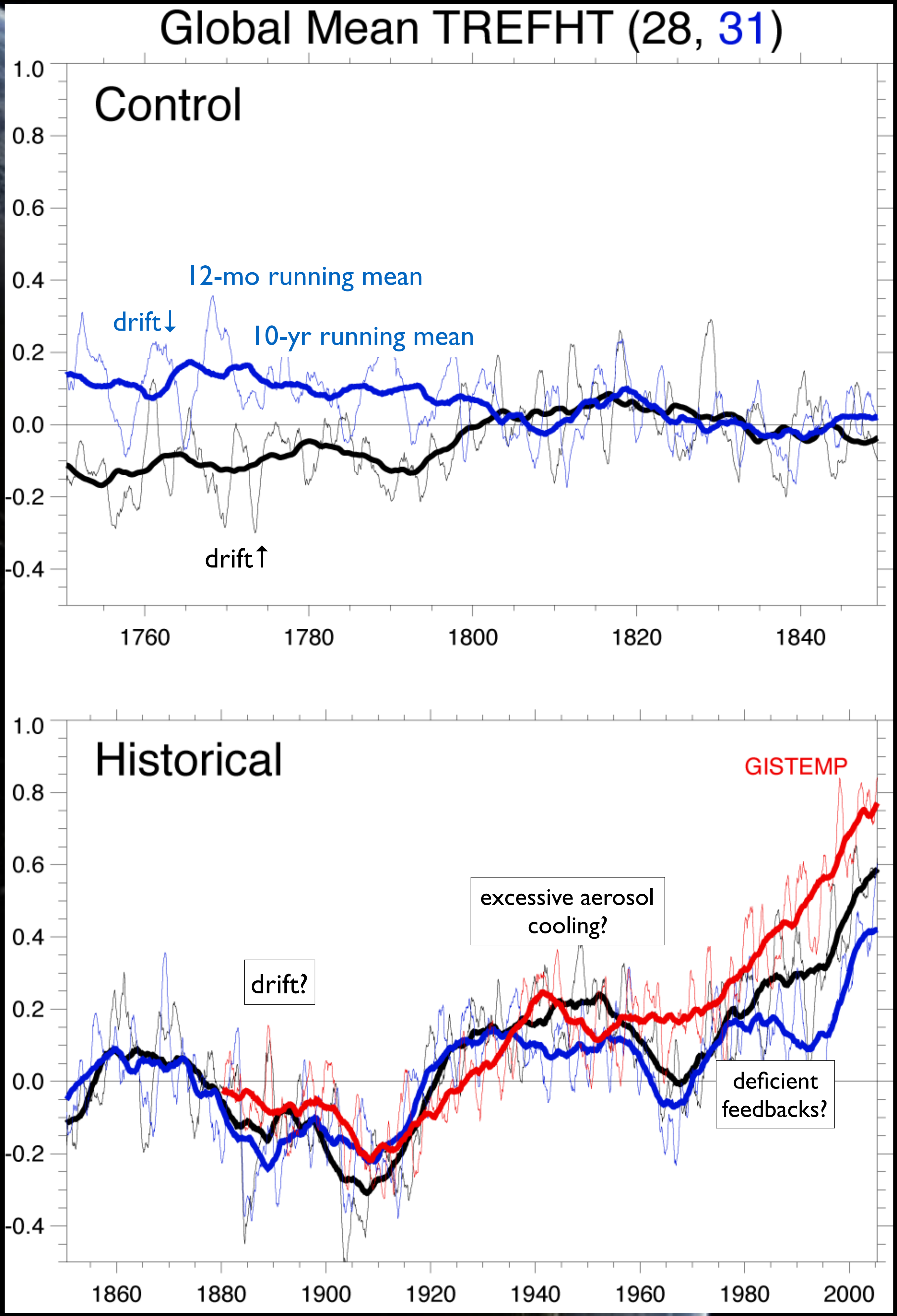

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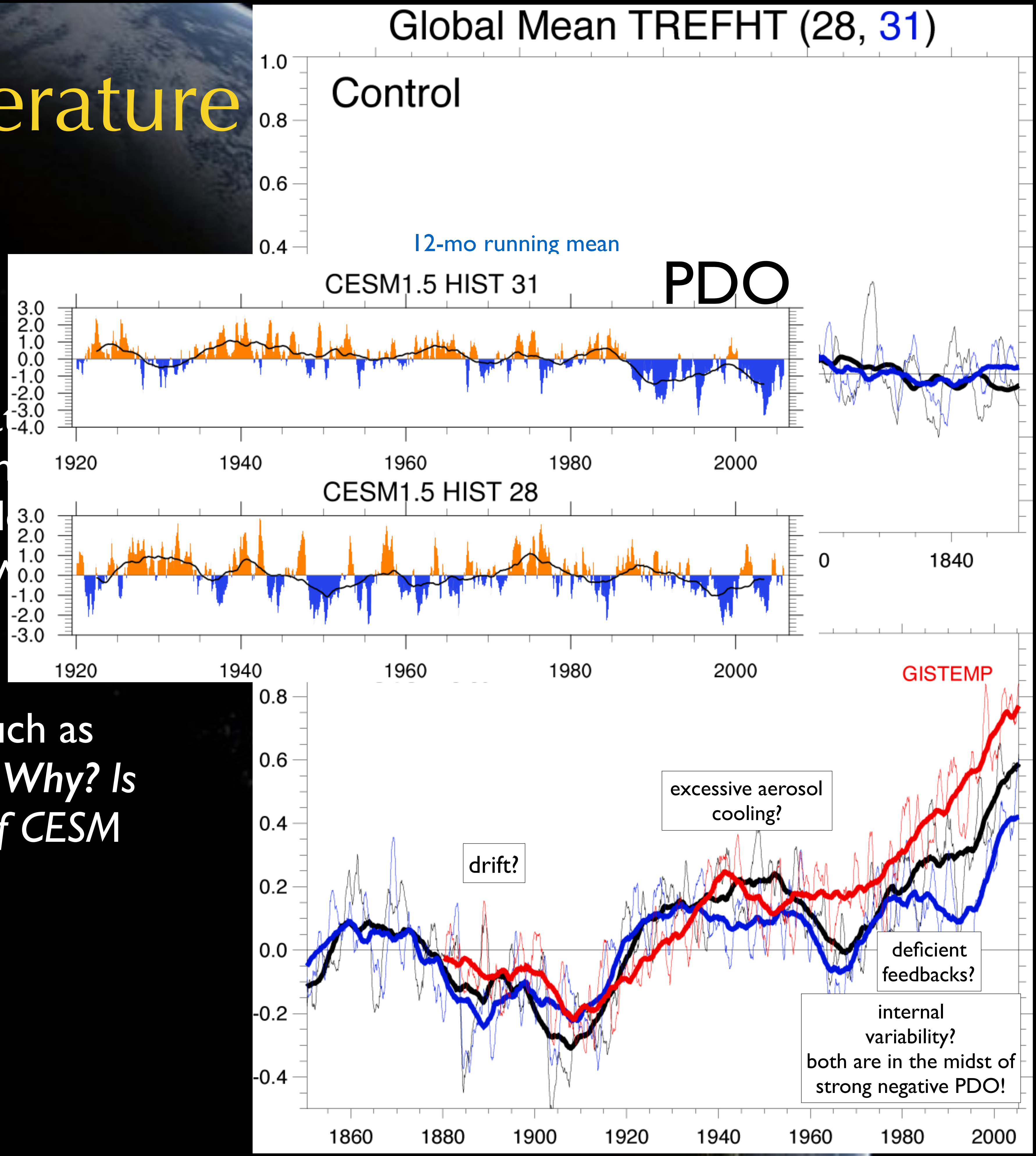

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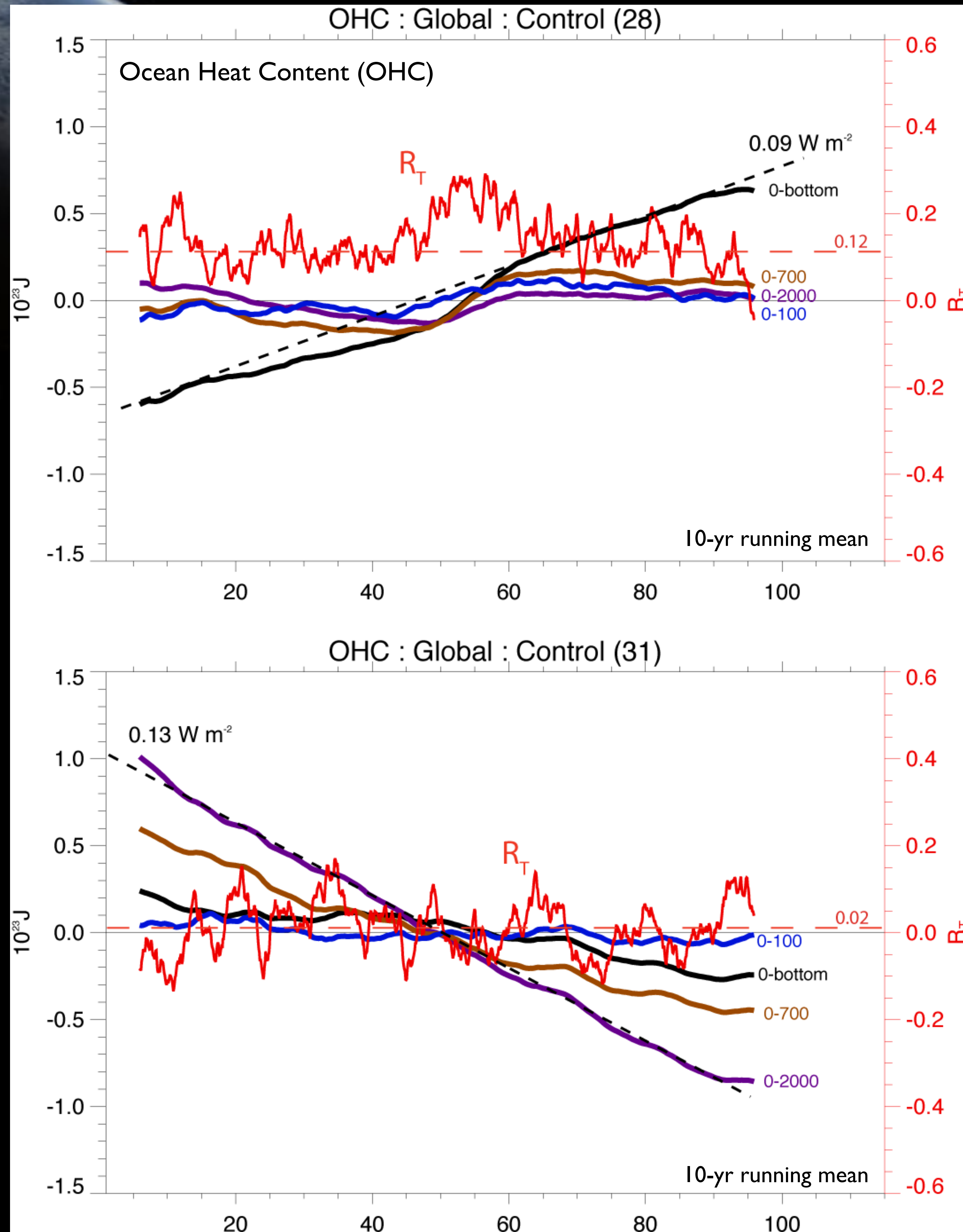
Global Energy: Control Runs

The TOA imbalance in #28 of 0.12 Wm^{-2} BUT - the drift is confined to depths below 2000m. ∴has only marginal influence on surface T.

The TOA imbalance in #31 is near zero, yet drift in the ocean's upper 2000m is considerable (larger than #28's total) and likely contributes to spurious cooling in #31's historical simulation.

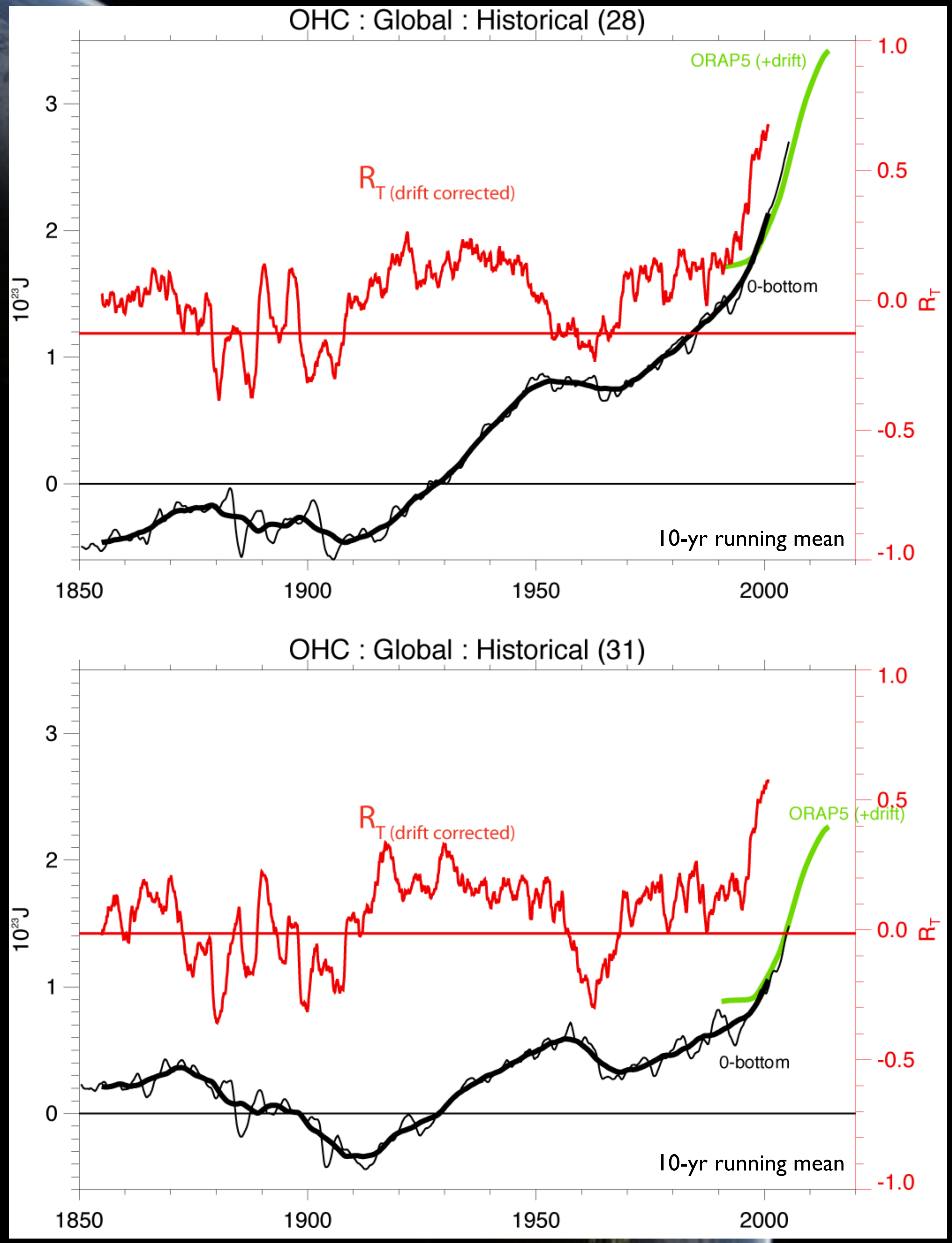


Global Energy Historical Runs

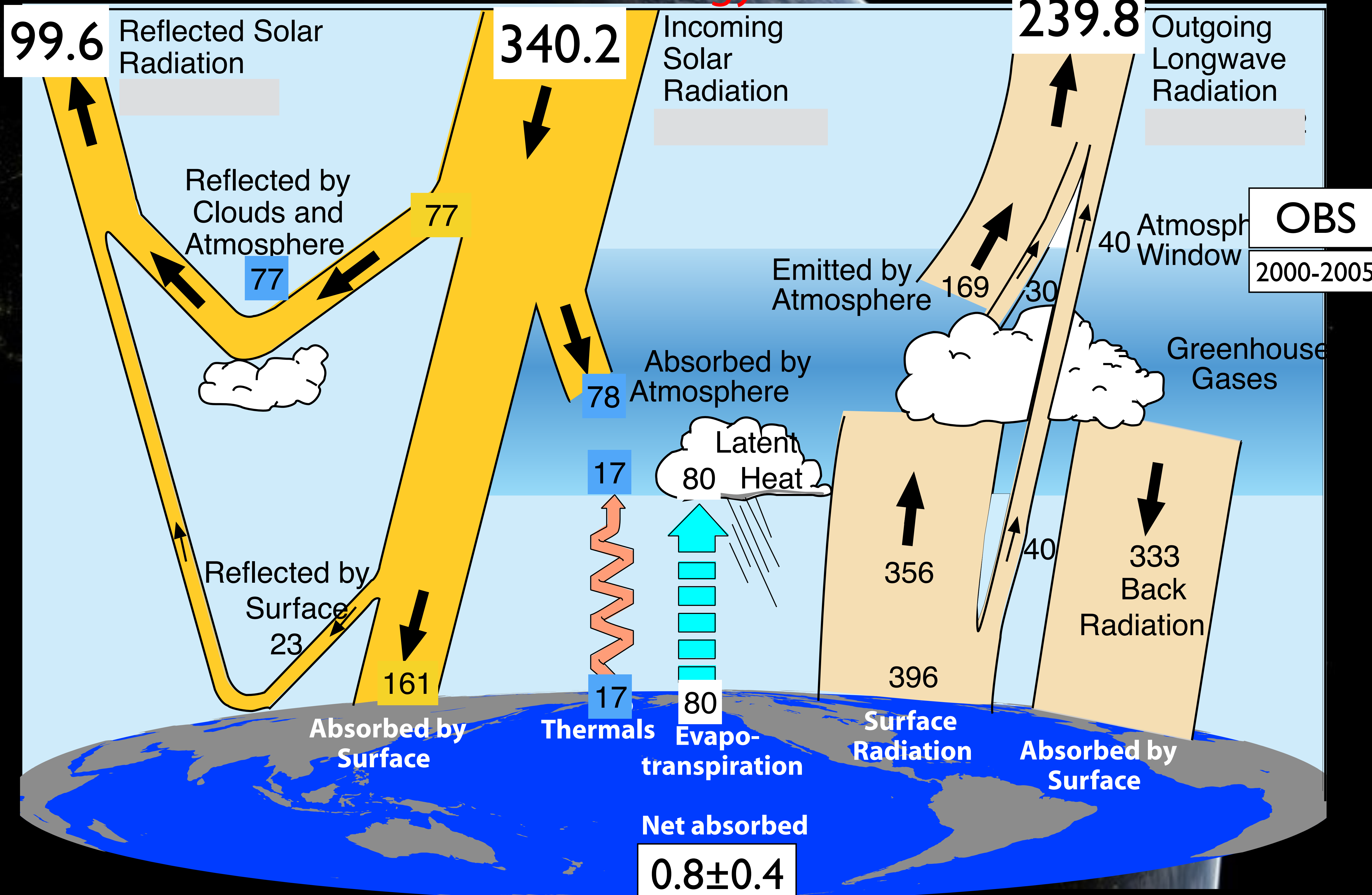
Compared to observed OHC (ECMWF ORAP5), and accounting for drift, agreement in ↑OHC is good.

The TOA imbalance at 2005 for each run is also very similar once the drift is removed. ∴ Differences between #28 and #31 historical runs likely due to contrasting drift / int. var.

∴ #28 is likely more representative of CESM1.5 and used hereafter.



Global Energy Flows W m^{-2}



*drift adjusted; no grade since obs uncertainty on par with model spread

adapted from Trenberth et al. 2007

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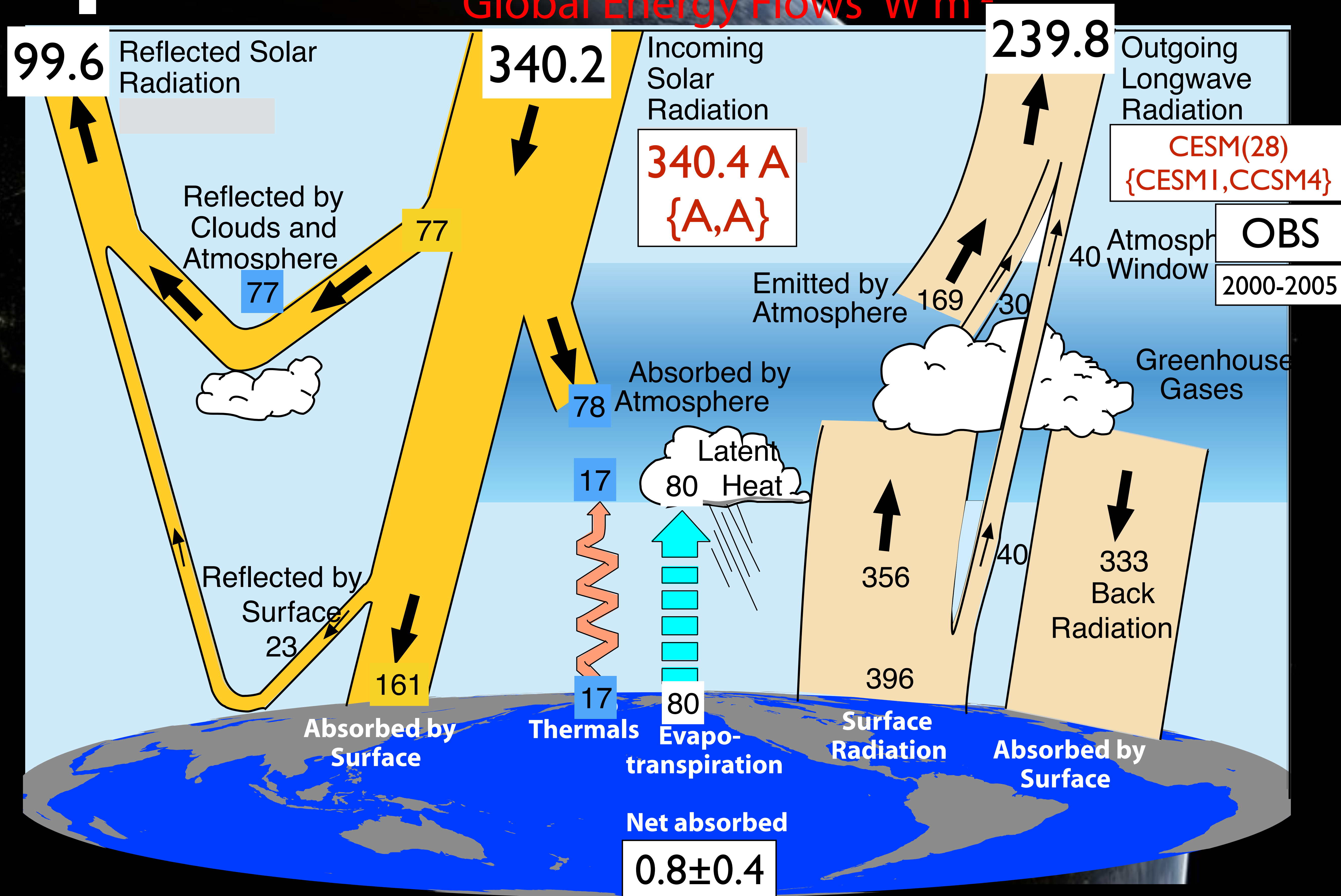

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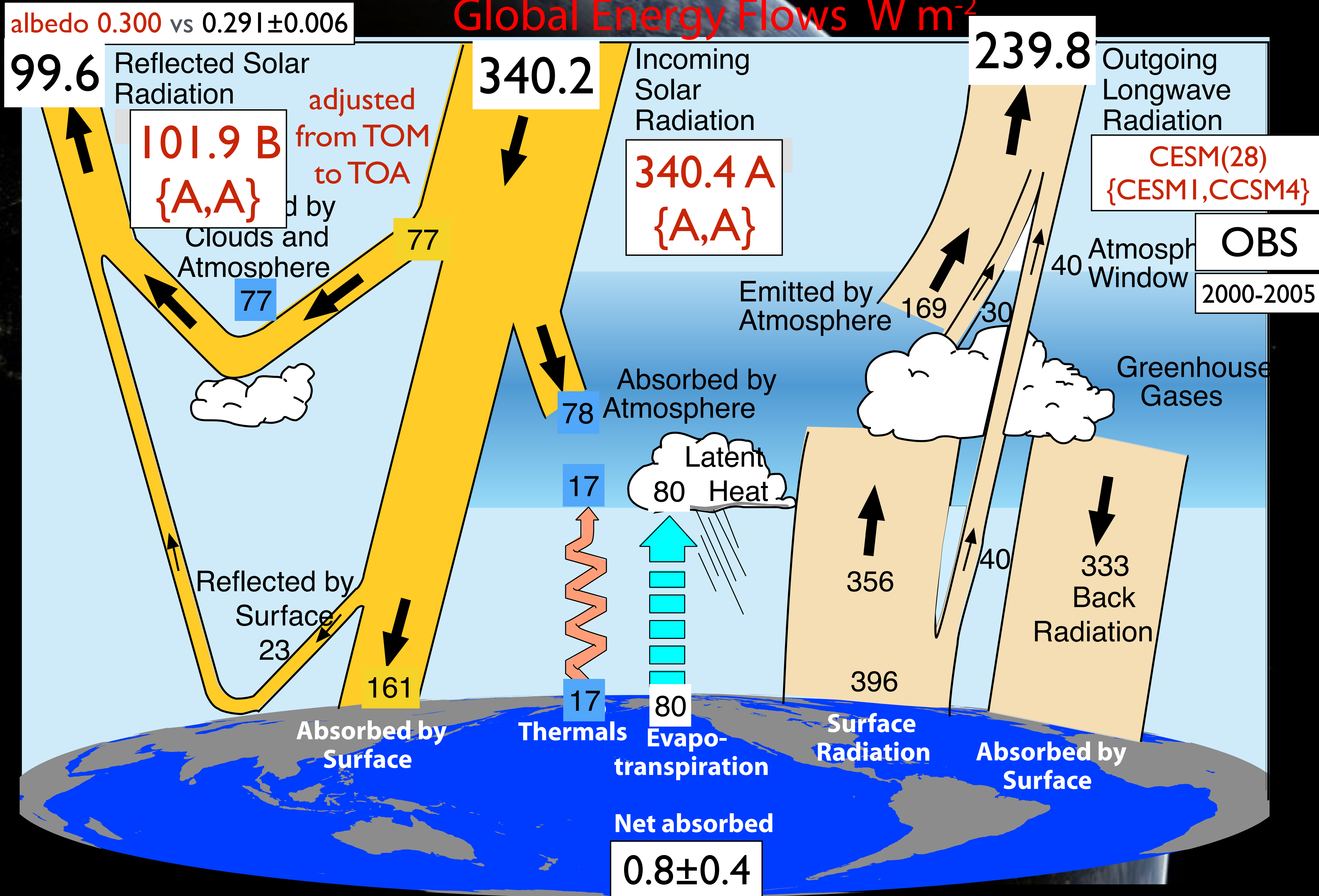

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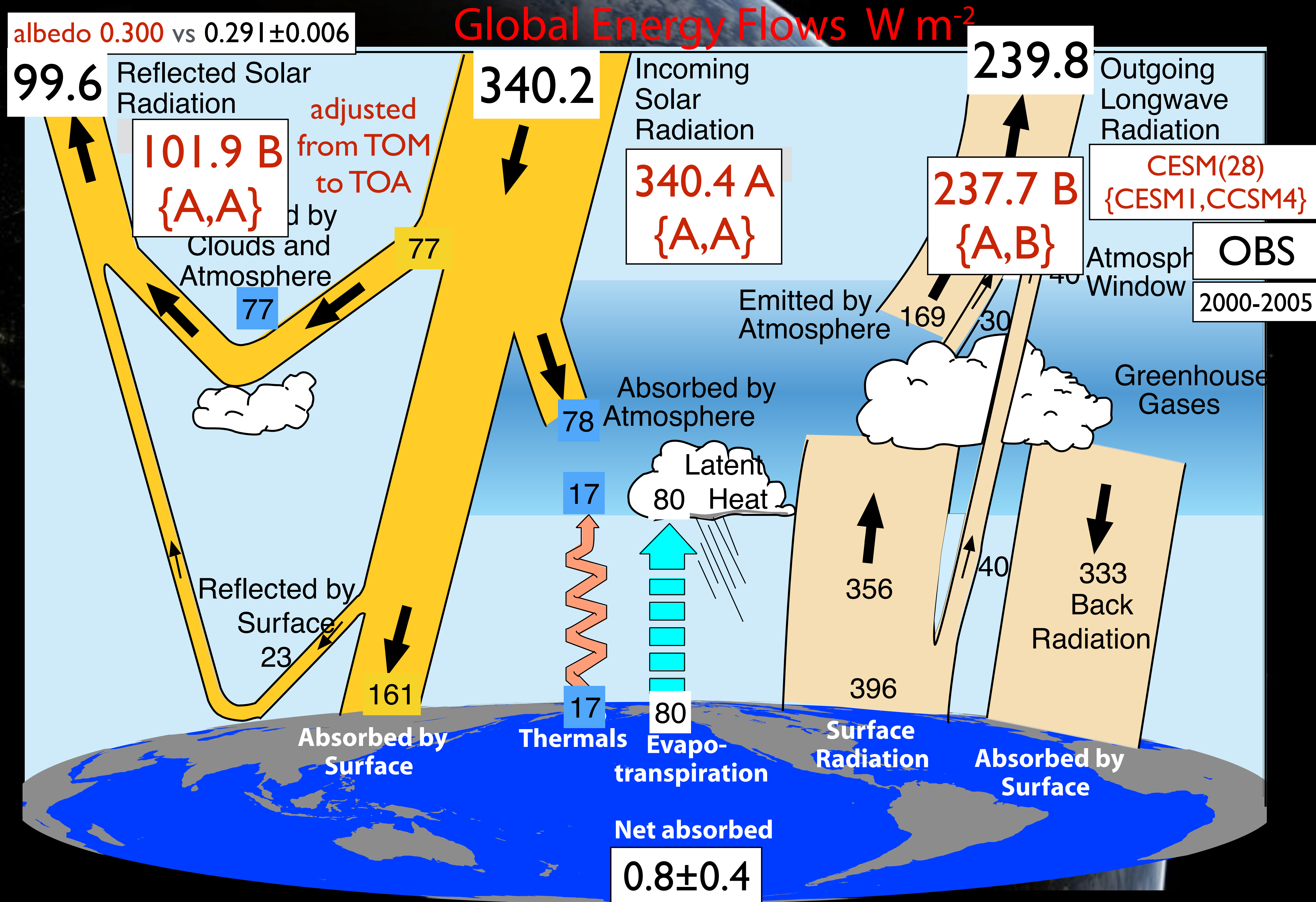

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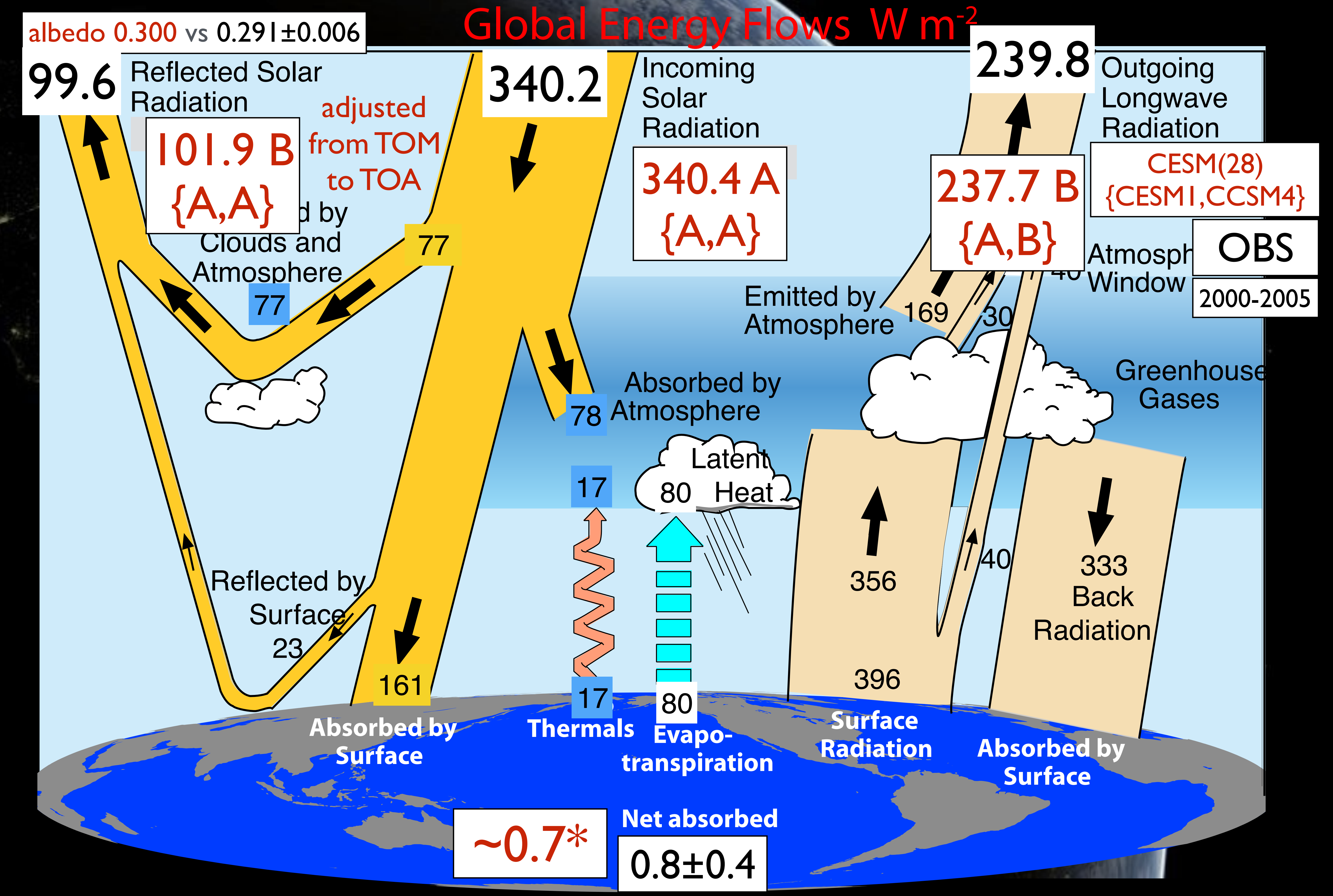

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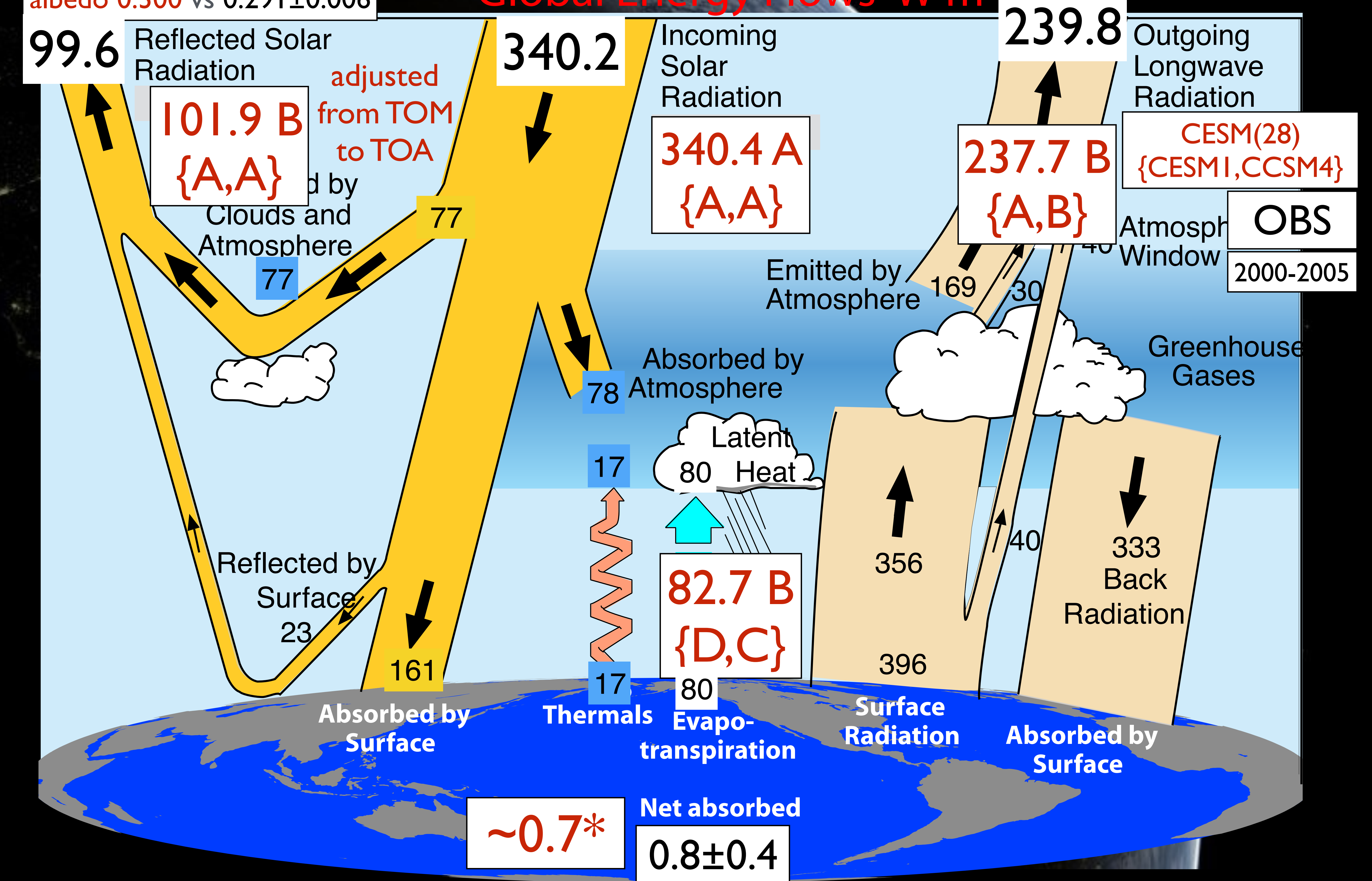
Global Energy Flows W m-2



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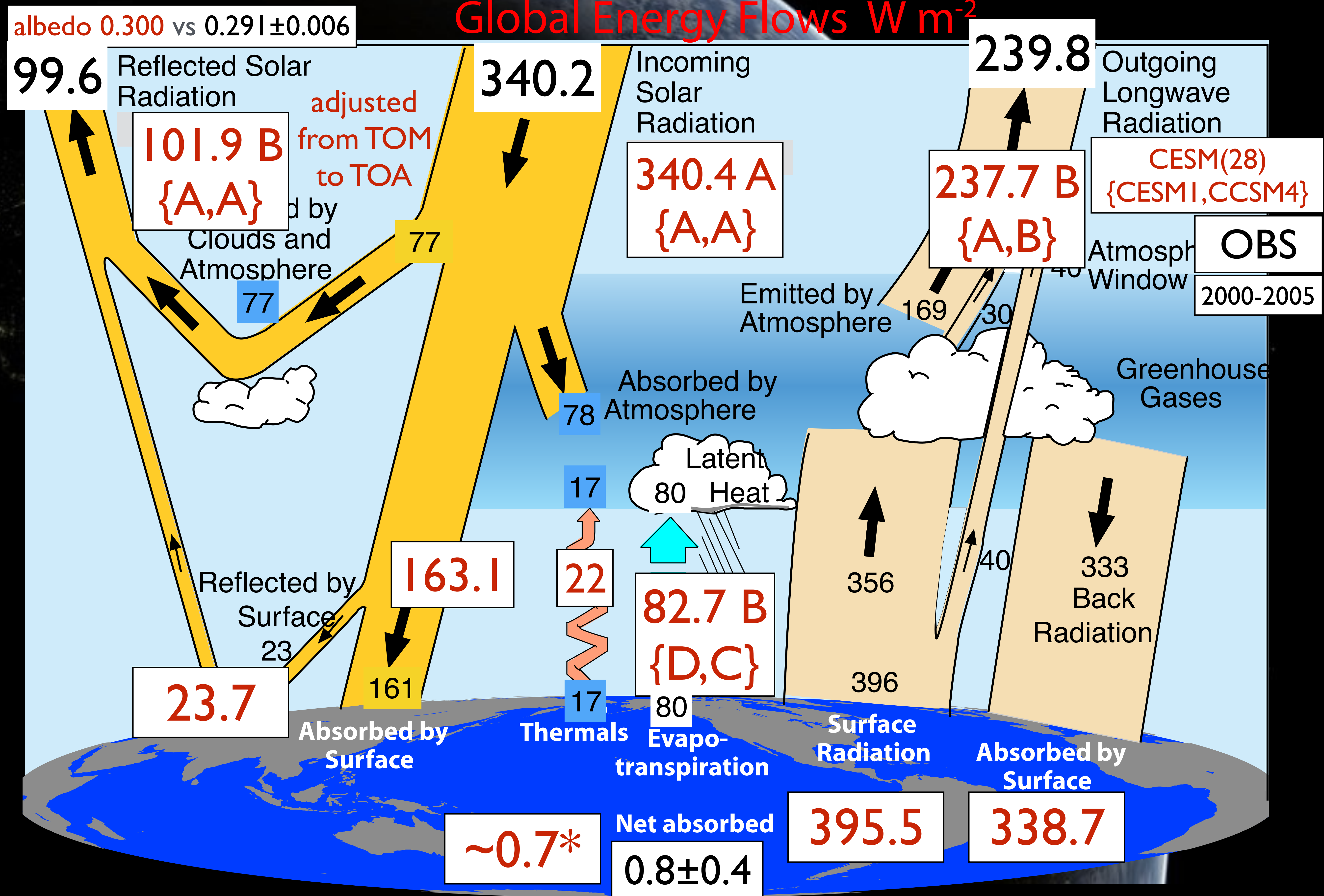

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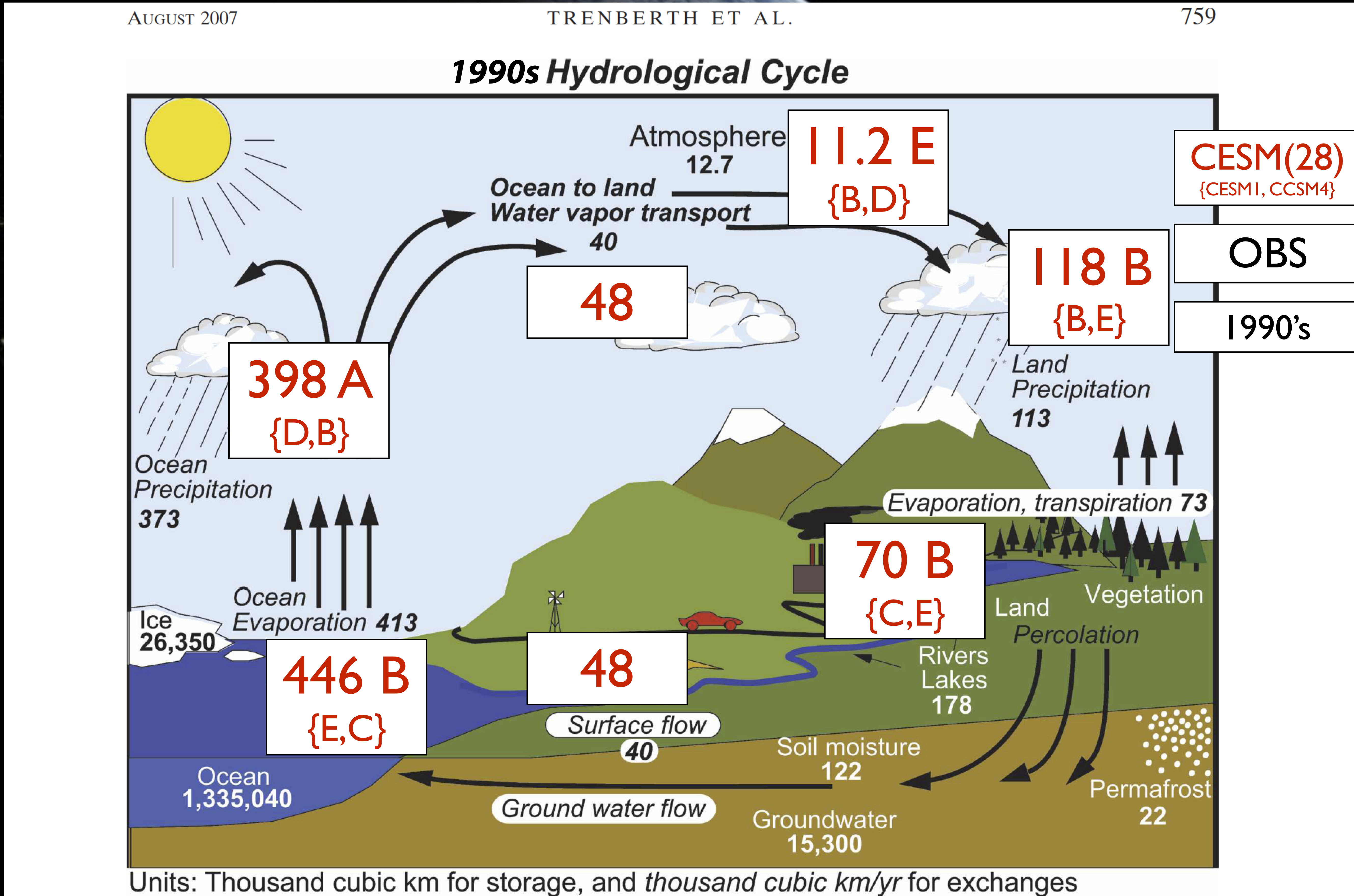
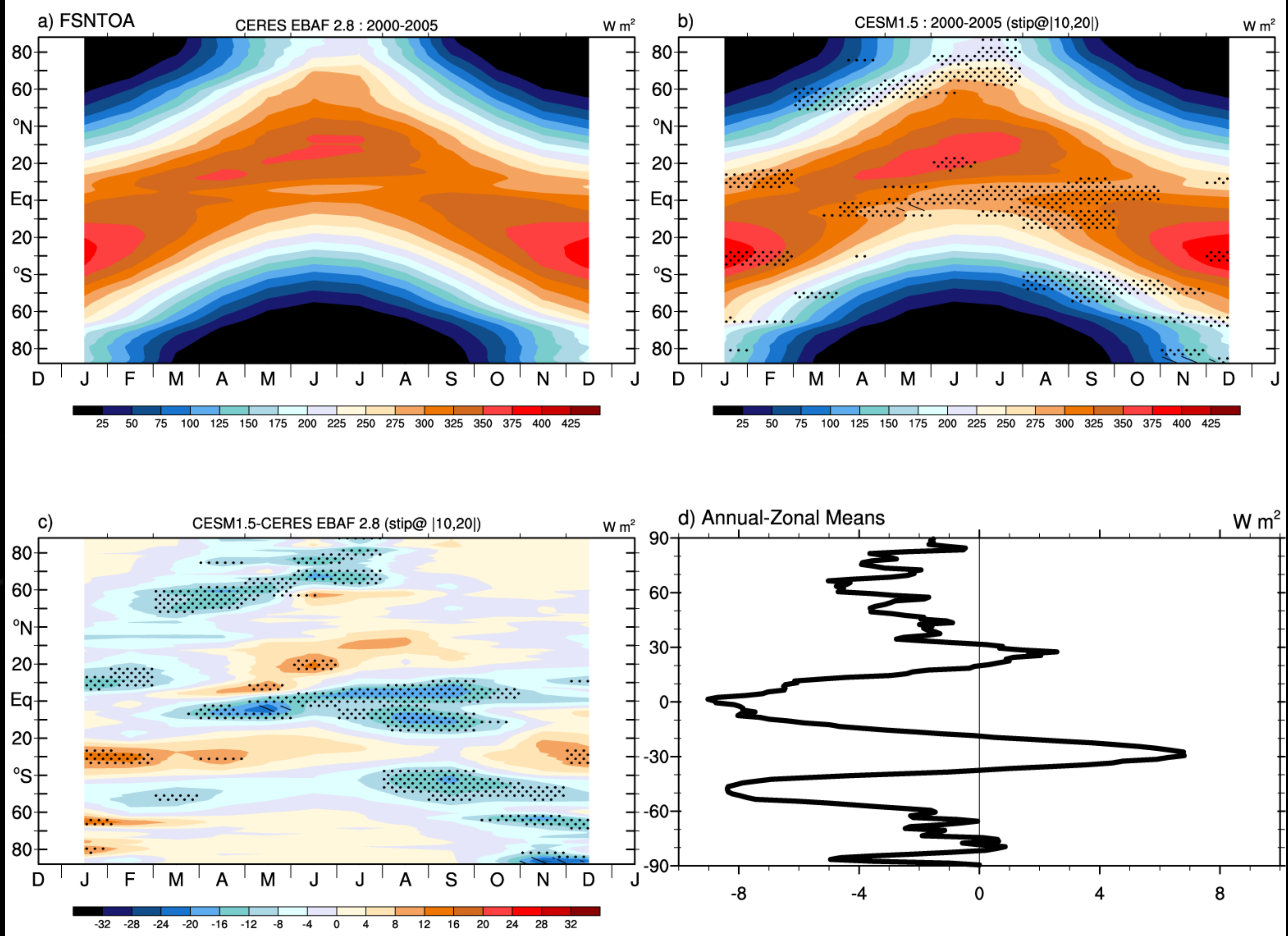


PW: too dry, P and E (not bad); residual too large yet obs uncertain

Zonal Mean Annual Cycle FSNTOA

Too little absorbed in polar regions in spring/ summer (~3 W/m2)

Too little absorbed in tropics. (~8 W/m2)



grades based on area-weighted rms error

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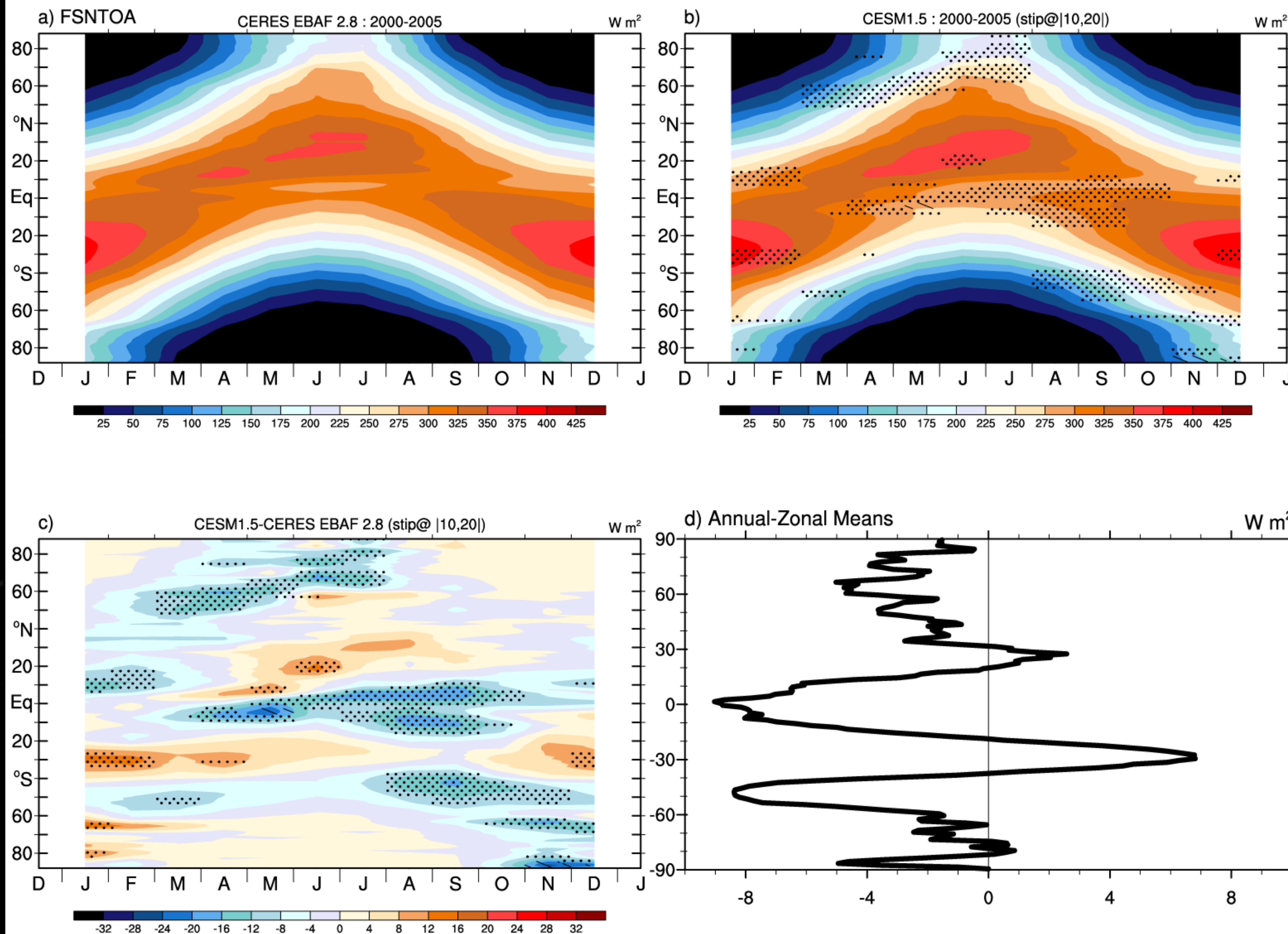


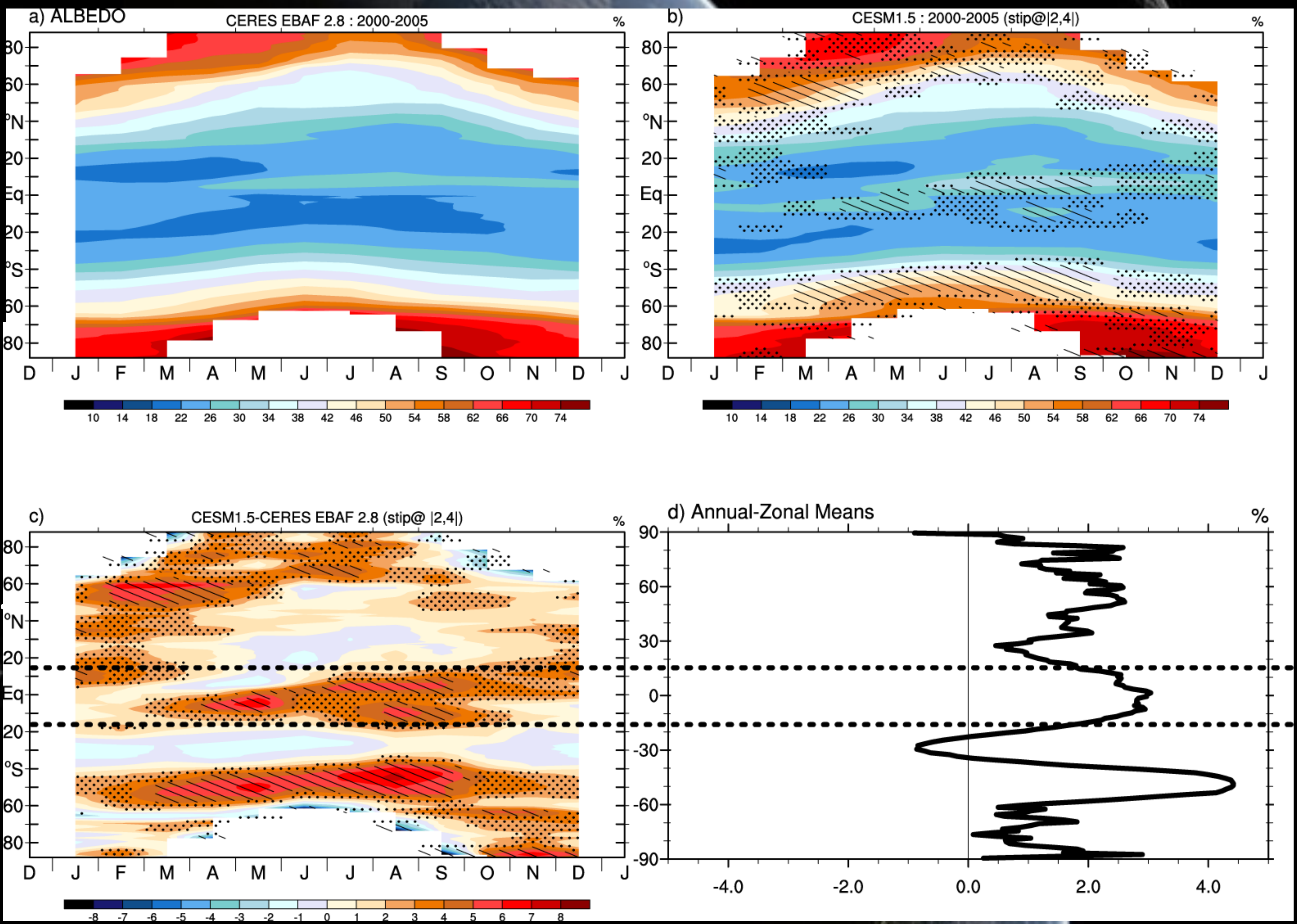
A {A,B} grades based on area-weighted rms error

Zonal Mean Annual Cycle ALBEDO

FNSTOA biases that appear to be seasonal at high latitudes are more perennial in albedo.

Tropical albedo is too high.

Emergent constraint literature suggests that deficient low latitude gradients relate to underestimated feedbacks.



Relevant Emergent Constraint Literature

Klein, S.A., and A. Hall, 2015: Emergent constraints for cloud feedbacks. Current Climate Change Reports, 1, 276-287, doi: 10.1007/s40641-015-0027-1.
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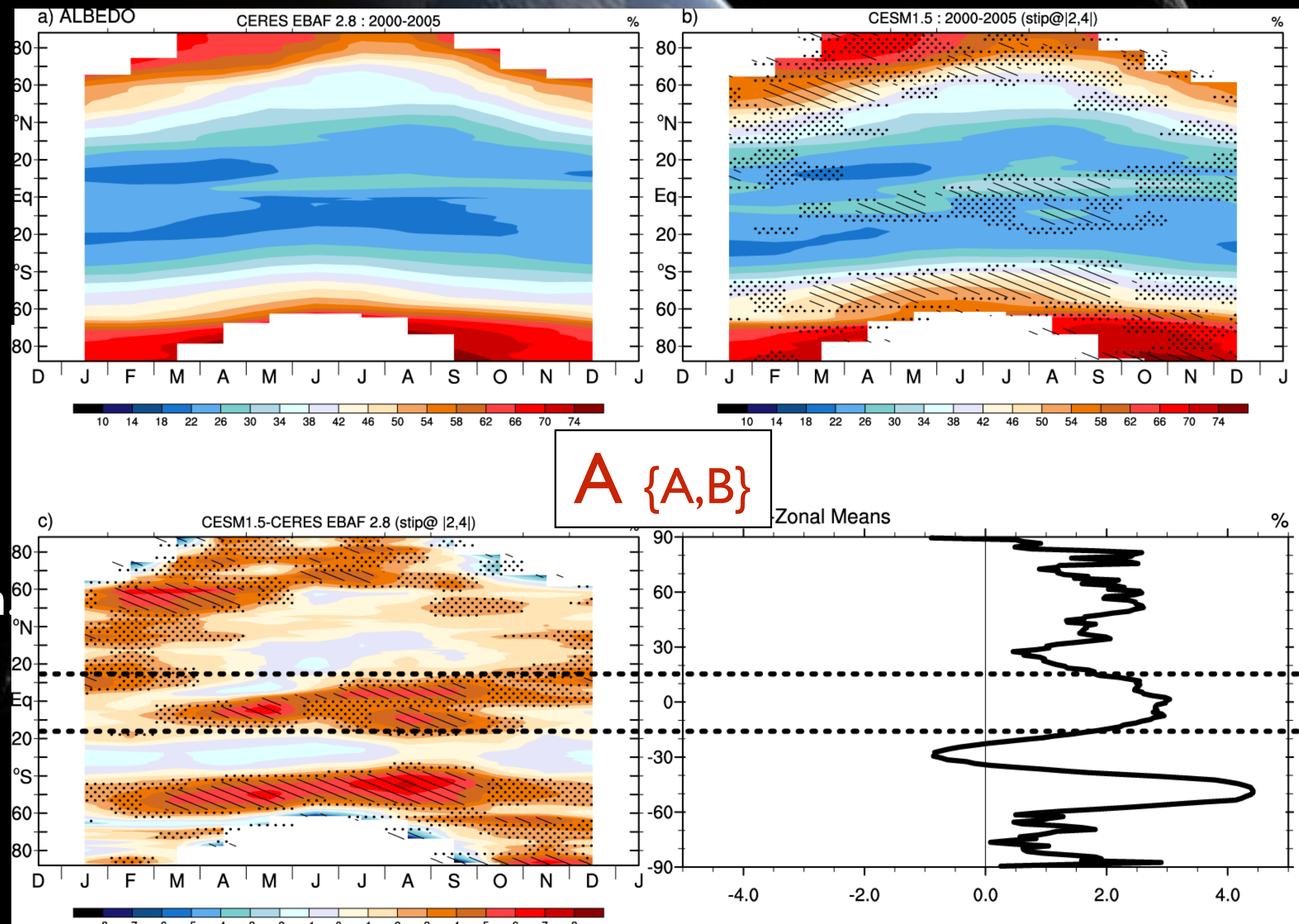

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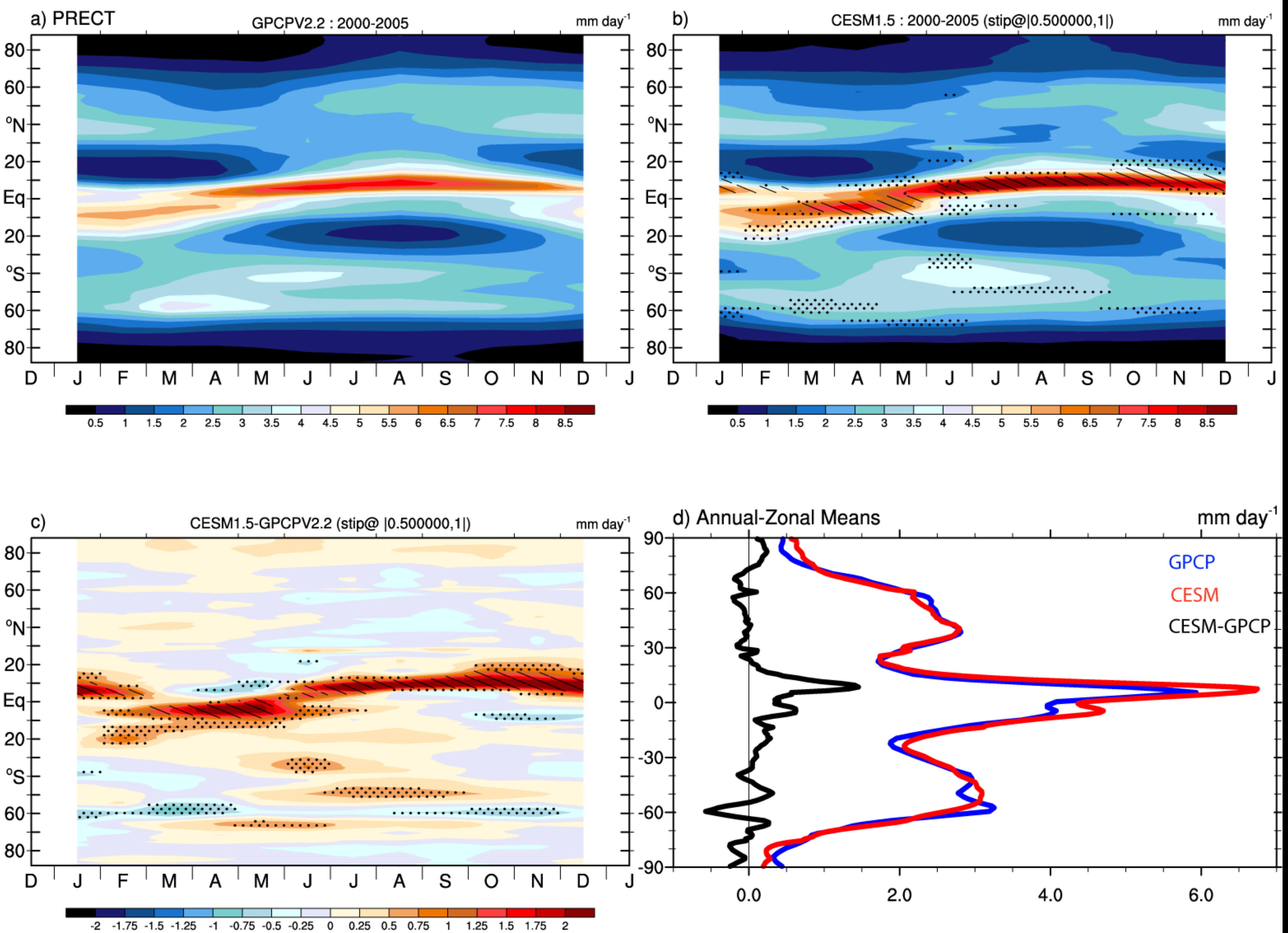
Zonal Mean Annual Cycle PRECT

+Rainfall biases are evident in all regimes. Wet are too wet and dry are too wet.

The few negative biases that exist appear to be related to late onset of seasonal transitions (perhaps monsoon).



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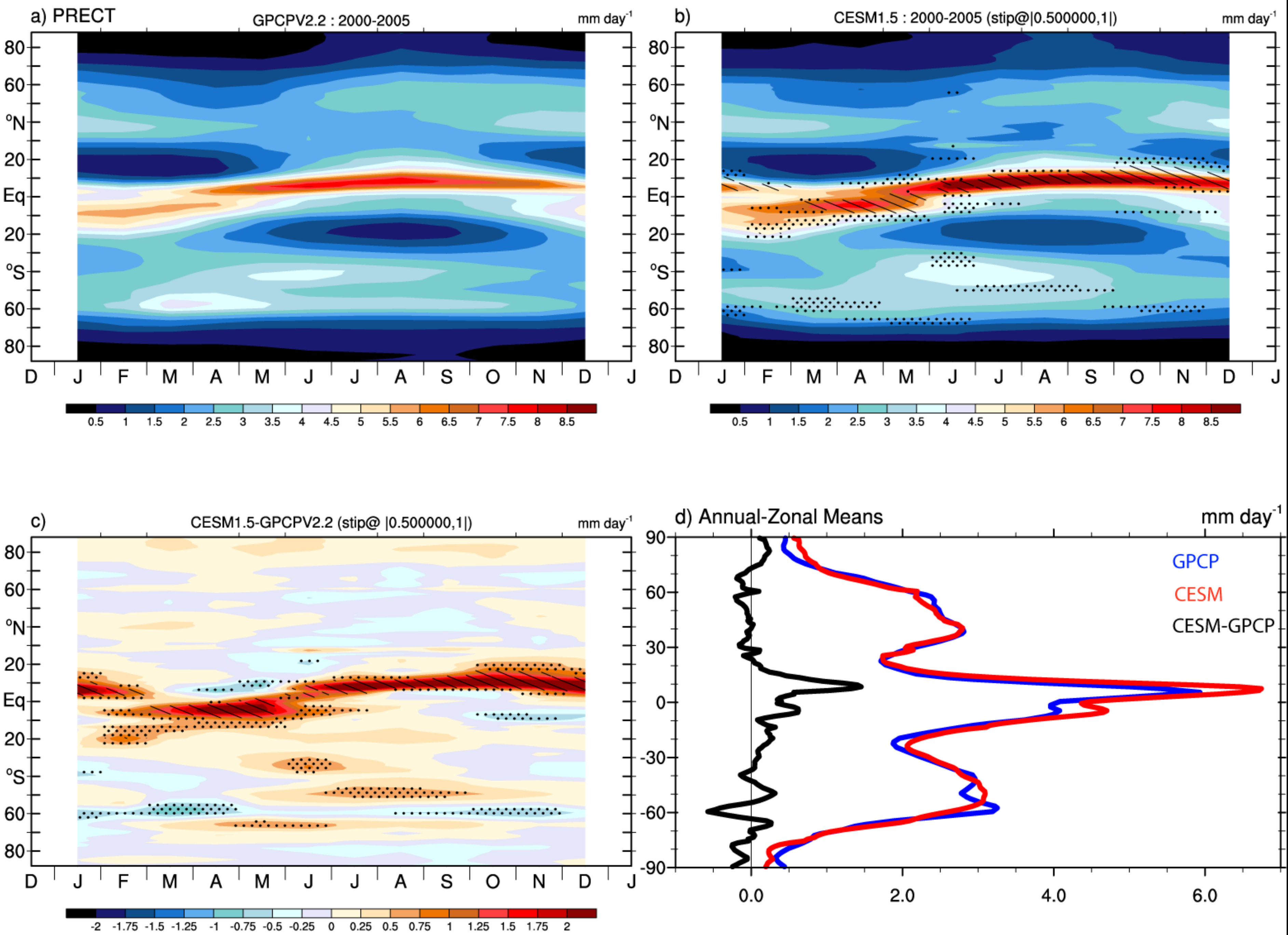


A {B,B}

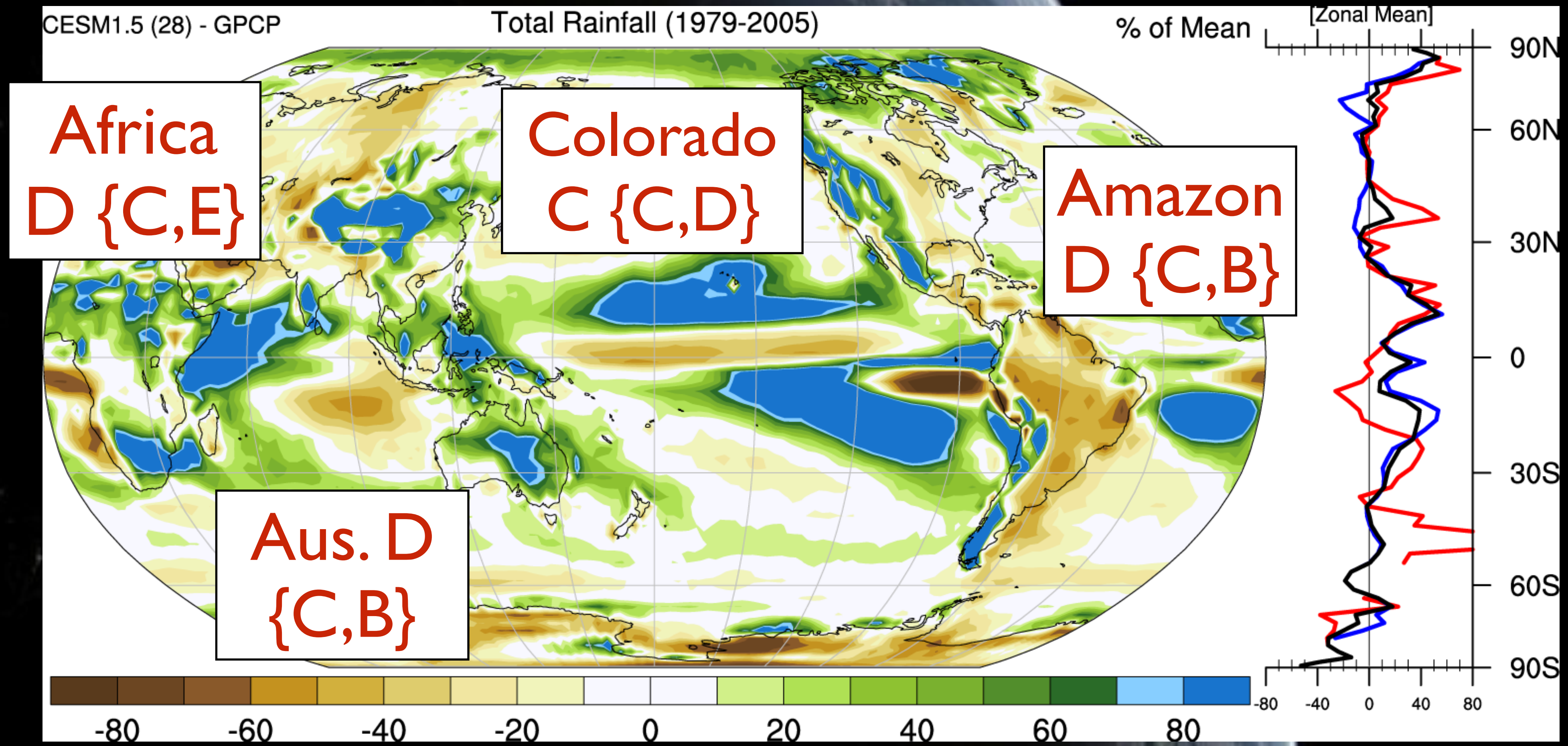
Basin-Scale Rainfall

Amazon is deficient (should be increased by PDO). Major model bias - getting worse.

Colorado basin is too wet (PDO should dry).

Africa is too wet.

Australia is in excess (*perhaps related to PDO*).



Caveat: Larger sensitivity to internal variability.

Report Card

1) Energy Budget: Global / annual means…………..B+
2) Water Cycle: Global / annual means……………B+
3) Energy Budget: seasonal / meridional structures.A
4) Water Cycle: seasonal / meridional structures…A
5) Regional Rainfall … incomplete awaiting more runs

Main Points

- There is a reasonable case to be made that deficient warming of the 20th C in runs #28, 31 arises from 1) drift, 2) internal variability, 3) aerosol forcing, and 4) feedbacks.

- Both #28 and #31 control runs have strong drifts; #31 has a smaller planetary imbalance while #28 has smaller drift in 0-2000m OHC; both *appear* to have strong negative PDOs in the late 20th C; aliasing aerosol effects? +runs needed; the drift-corrected TOA imbalance from 2000-2005 agrees closely with the observed range.

Main Points

- Irrespective of drift and TOA/TOM distinctions, the model's albedo is too high, particularly in the deep tropics (possible cause of cool surface and cool/dry atmosphere biases); subtropical / tropical albedo gradients are also too weak → emergent constraints suggest potentially deficient climate sensitivity.

- Decreasing CESM1.5's albedo (via cloud amount/albedo?) will likely increase the biases in surface radiative fluxes and water cycle (which are otherwise in good agreement with observations).

- Global water cycle intensity is better than most models but slightly too strong overall. It *appears to* have major regional biases, most notably dryness in South America and wetness in the Colorado River basin. More runs needed to quantify robustness to internal variability.