New radar simulator-based precipitation diagnostics for CESM

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CESM | COMMUNITY EARTH SYSTEM MODEL

Evaluation of CESM1 Rain Frequency

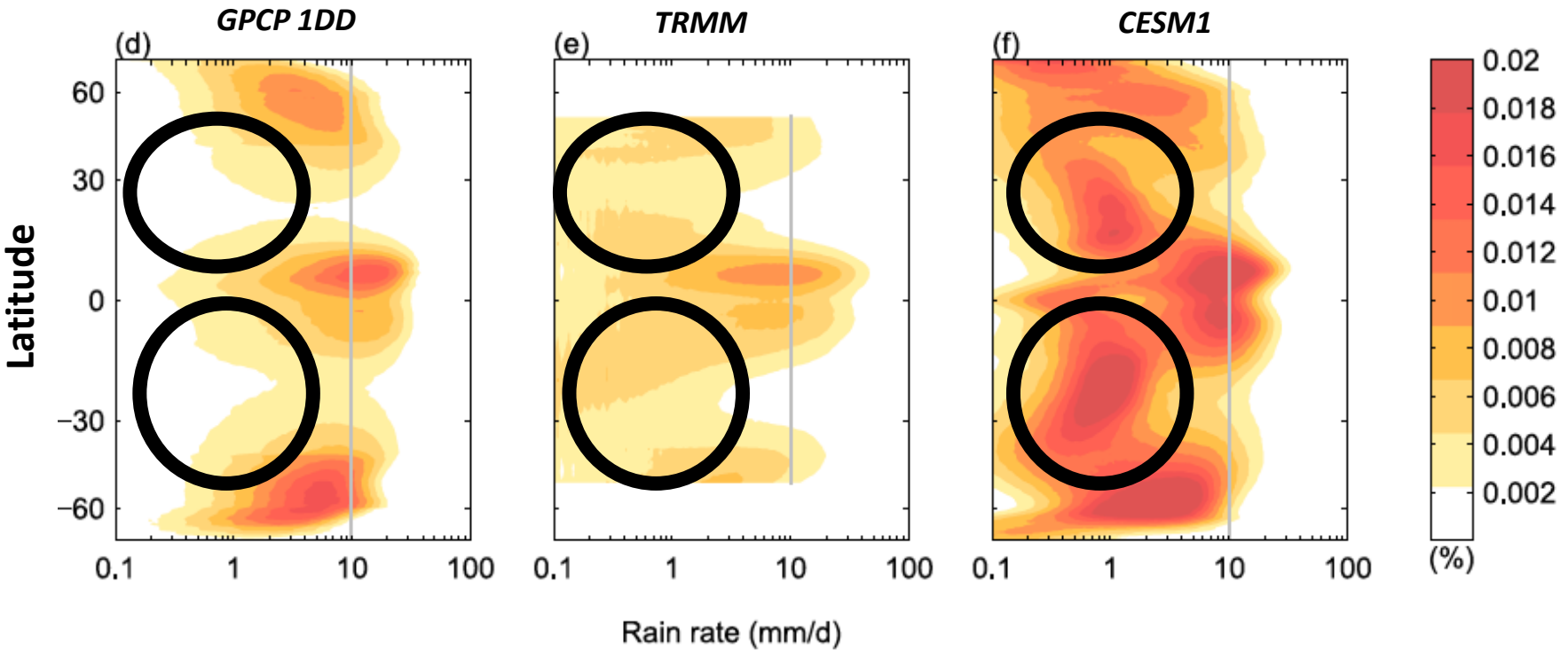


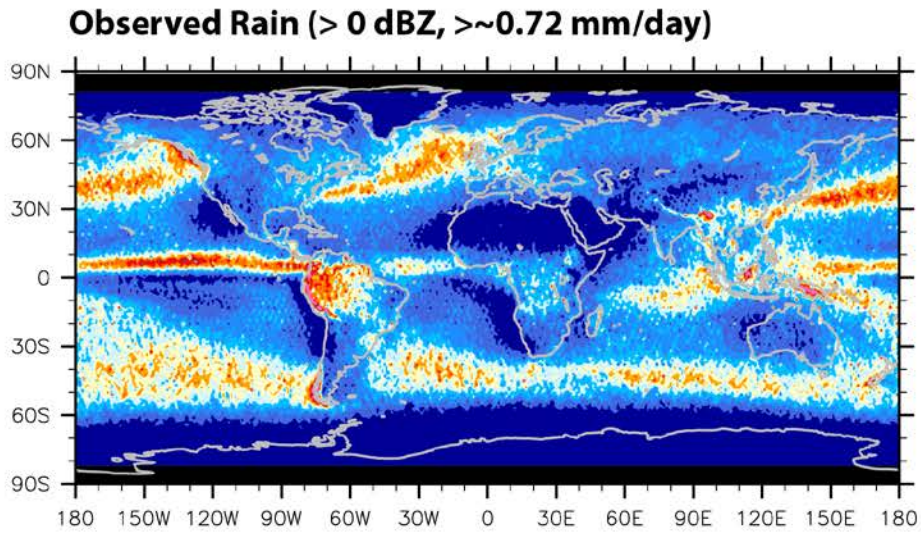
Figure adapted from Pendergrass and Deser (2017)

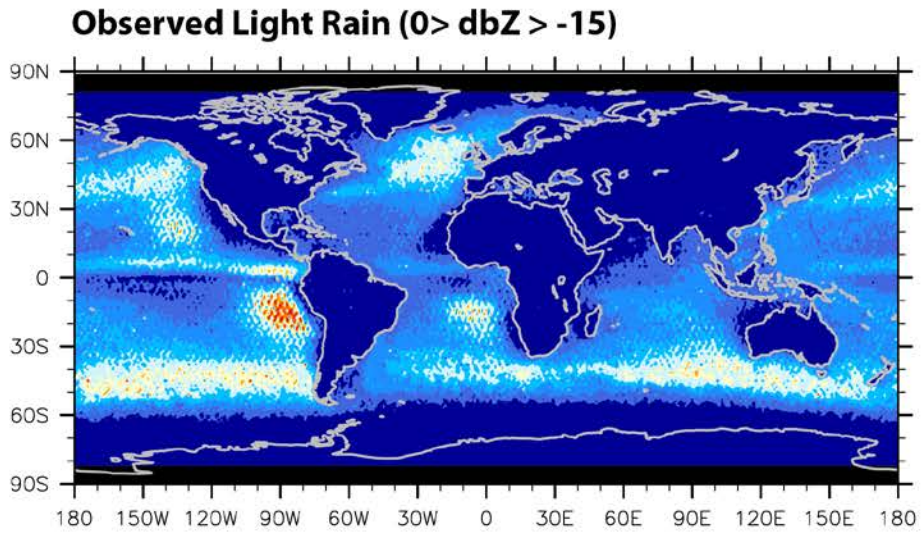
Problem: This evaluation is NOT "definition-aware".

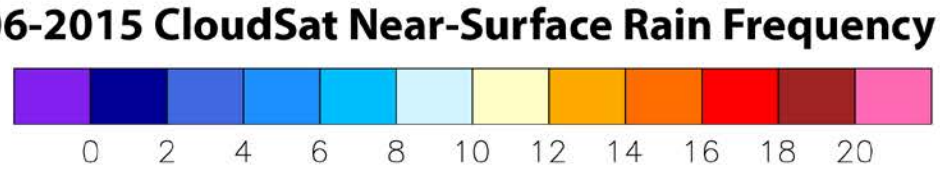
TRMM and GPCP do not detect "light rain" (< 1 mm/day)
(Berg et al. 2010; Behrangi et al. 2014)

How often does it rain?

Let's look at CloudSat Observations

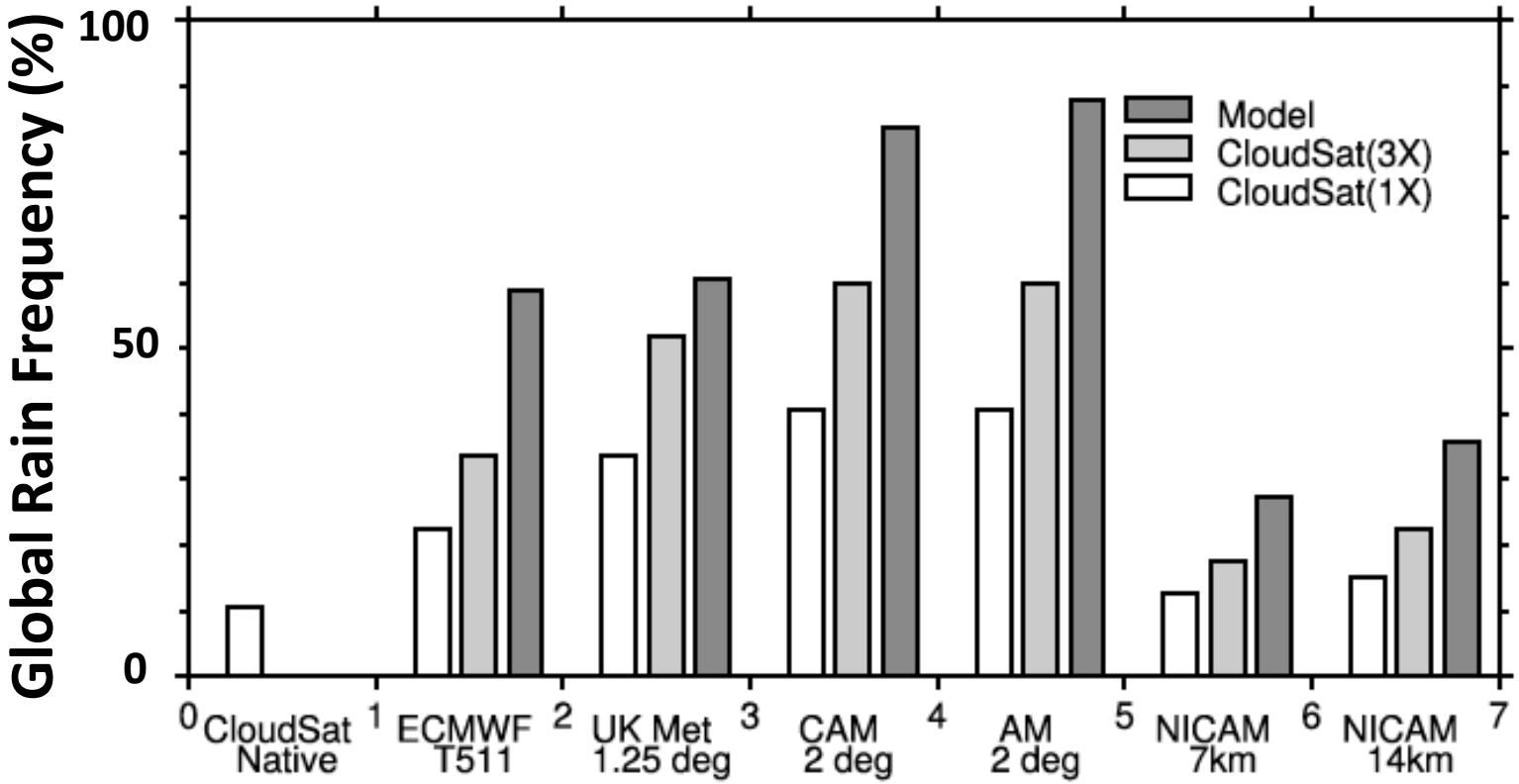






Data from Tristan L'Ecuyer (U. Wisconsin)
2C-PRECIP-COLUMN (Haynes et al. 2009)

Upscaling CloudSat observations to evaluate the "dreary state of models"!



Stephens et al. 2010

CONCLUSION: models overestimate rain frequency, but underestimate rain intensity.

This evaluation "scale-aware" but NOT "definition-aware".

Goal: Use CloudSat to make definition-aware and scale-aware precipitation frequency comparisons

*But **how**? And what is **new**?*

vs.

Model Gridbox Profiles

1) "Down-scale" using sub-column generator (COSP1.4)

Model Sub-Column Profiles

2) Apply satellite forward model (COSP1.4)

Model Sub-Column CloudSat dBZ

Model Near-Surface Precipitation Frequency

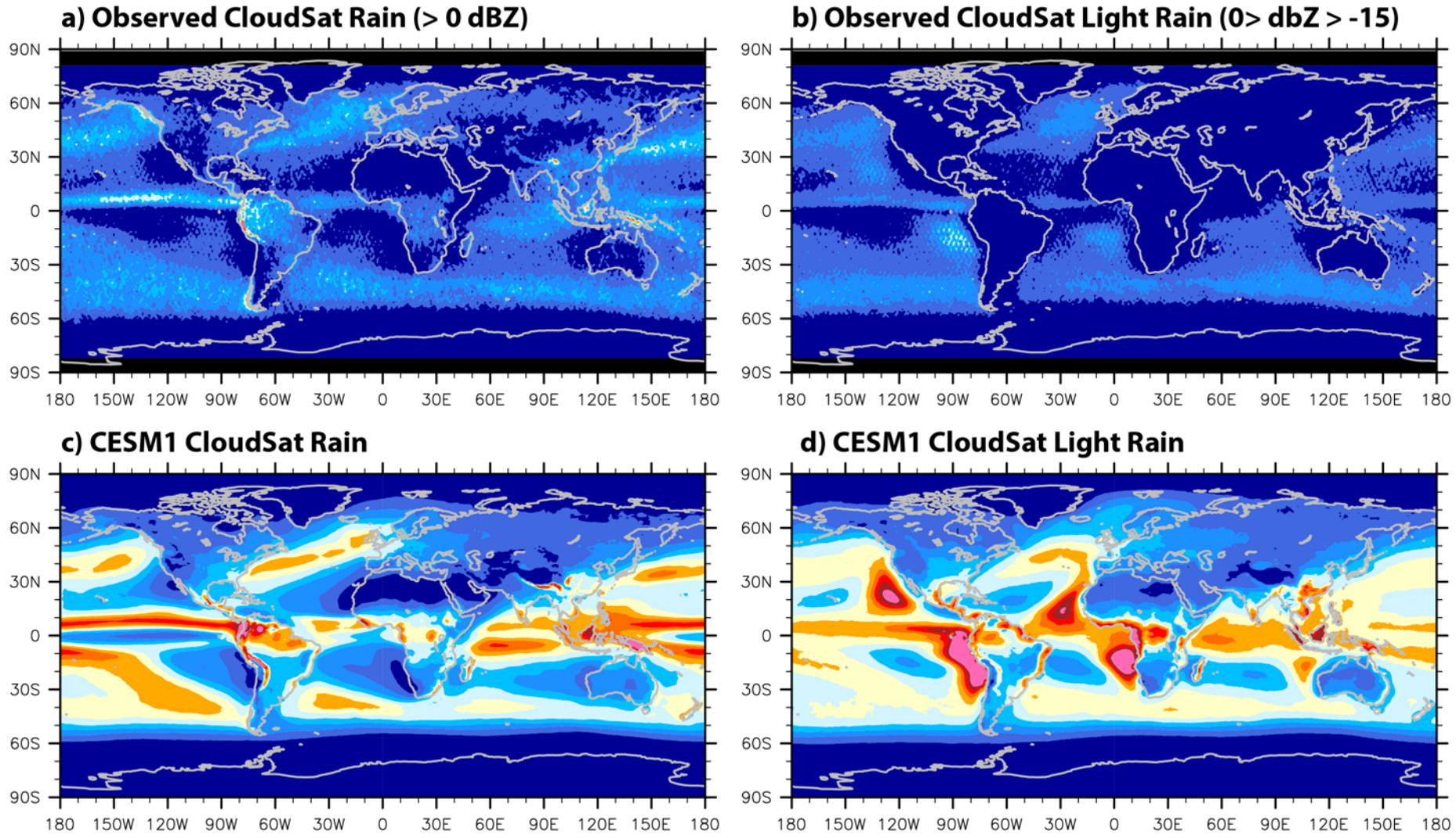
3) Apply 2C-PRECIP-COLUMN algorithm (Haynes et al.. 2009)

vs.

Observed Near-Surface Precipitation Frequency

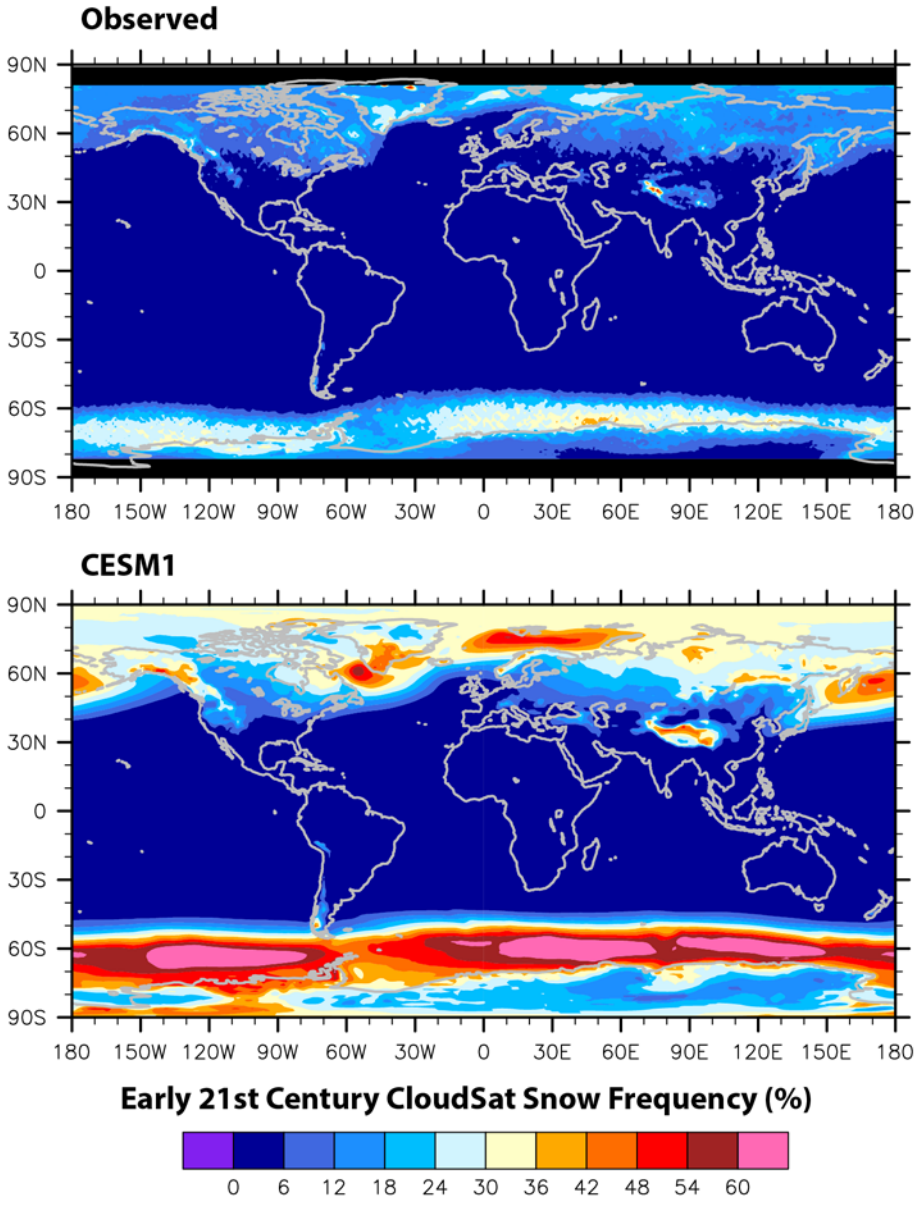
4) Apply 2C-PRECIP-COLUMN algorithm (Haynes et al.. 2009)

Global Rain and Light Rain



Kay et al. (2018)

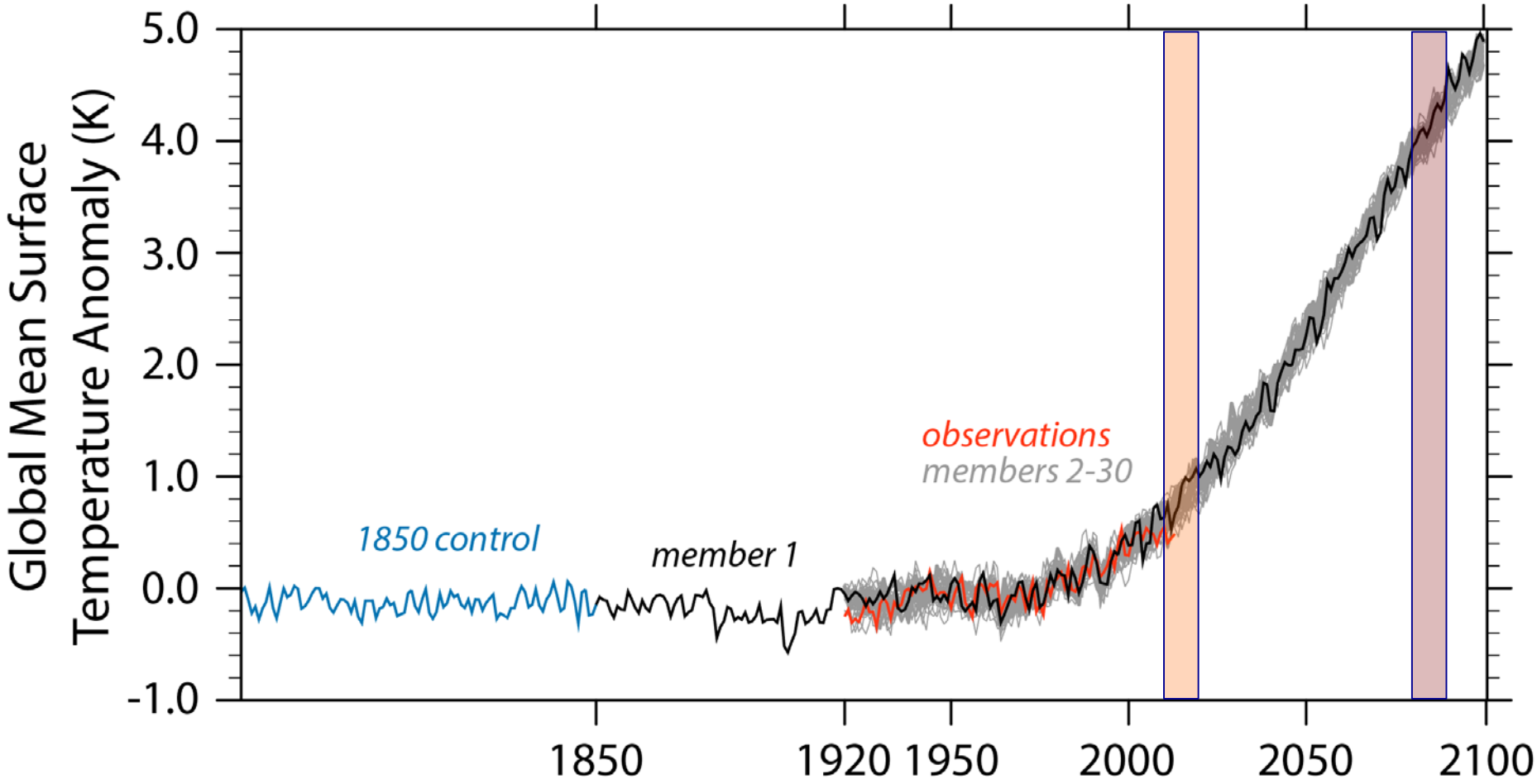
Global Snow



Kay et al. (2018)

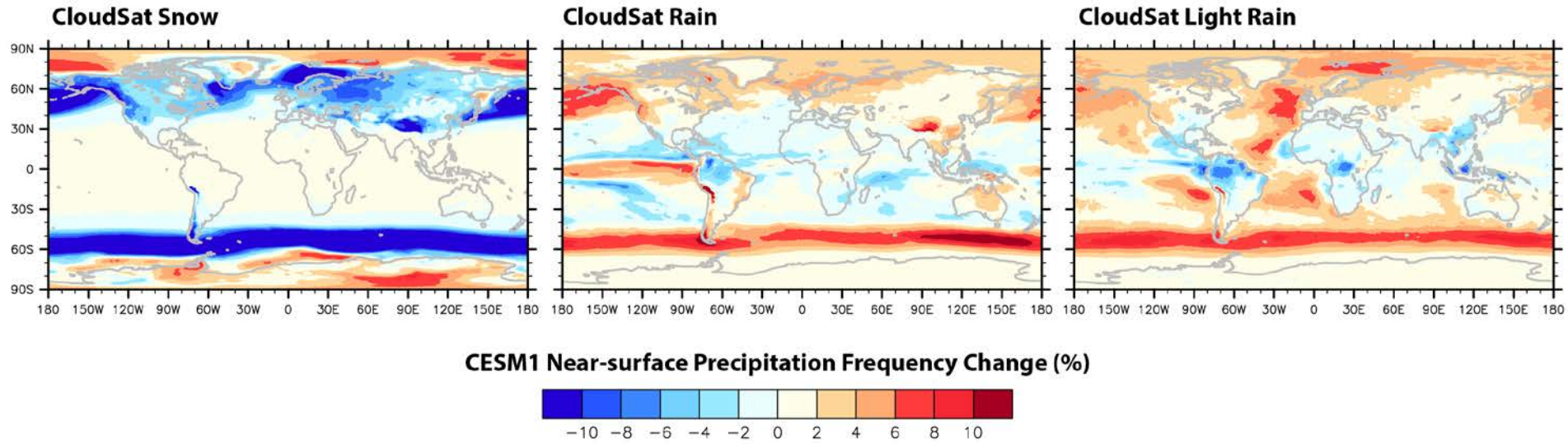
What about future near-surface precipitation changes projected by CESM1?

Let's compare 2010s with 2080s!



CESM1 Large Ensemble, (Kay et al. 2015)

CESM1-Projected 21st Century Change: What would CloudSat Observe?



Three CESM1-projected Changes:

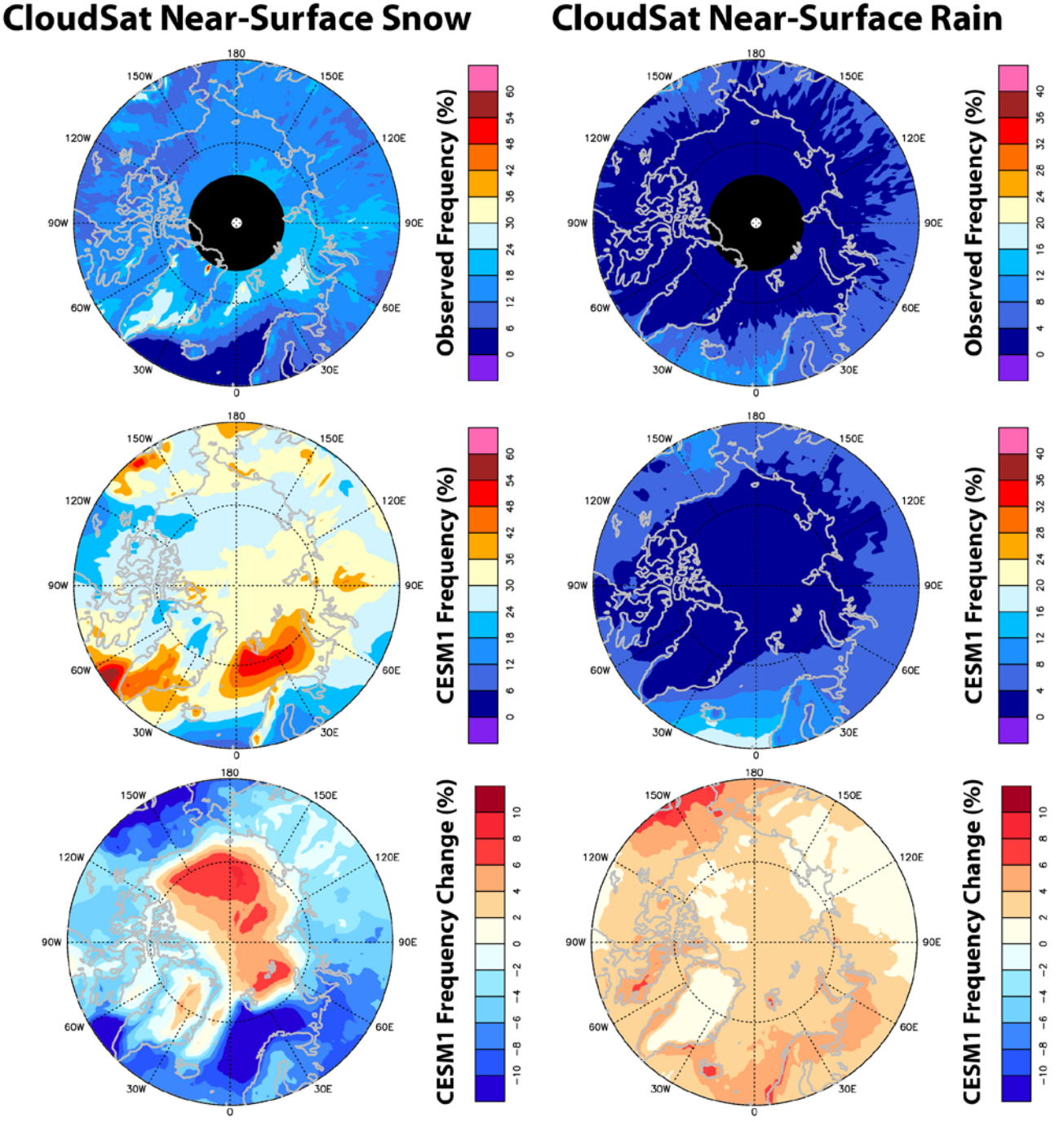
1) Snow becoming Rain (esp. in mid-latitude storm tracks)
2) Less Off-Equatorial Rain, More Equatorial Rain (esp. in Pacific)
3) Increase in Sub-tropical Light Rain Frequency

Kay et al. (2018)

Arctic Snow and Rain Maps

CESM1-projected 21st century changes:

1) More Snow in High Arctic and Over Greenland
2) More Rain Except over Greenland and Central Russia



Conclusions – Kay et al.

1) Scale-aware and definition-aware comparisons of near-surface precipitation frequency show CESM1 rains and snows too frequently when compared to CloudSat observations.
2) 21st Century precipitation frequency change shows conversion of snow to rain, narrowing of the tropical overturning circulation, increased light rain in sub-tropics, more snow in high Arctic and over Greenland. ***If CESM1 realistic*** – all would be detectable by a future CloudSat launched in 2080 ☺.
3) Diagnostics implemented in CESM1 (and soon CESM2).

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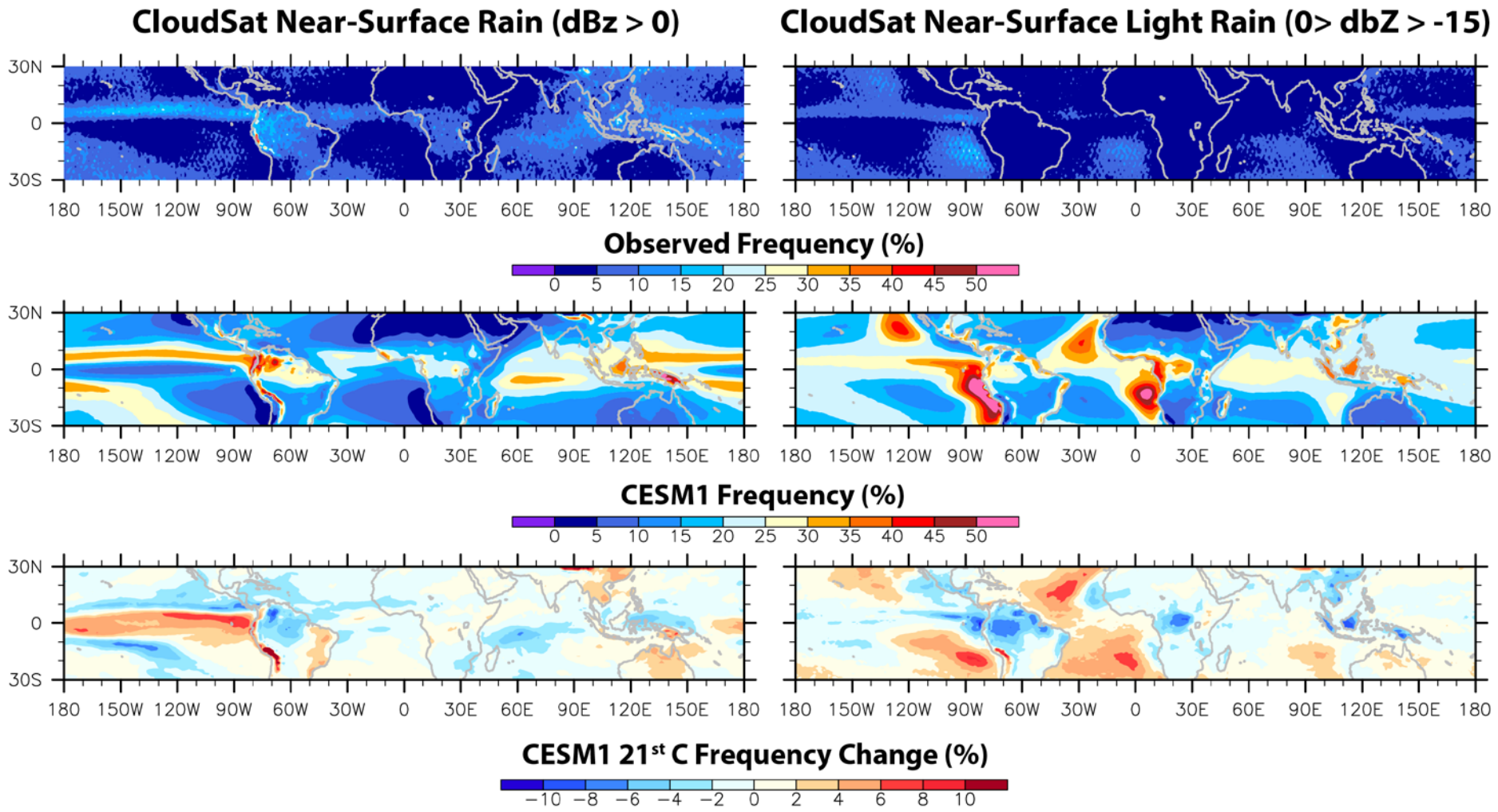
Tropical Rain and Light Rain Maps



Kay et al. (2018)