

# Climate implications of longwave scattering by clouds

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Xianglei Huang<sup>2</sup>, and Eli J. Mlawer<sup>3</sup>

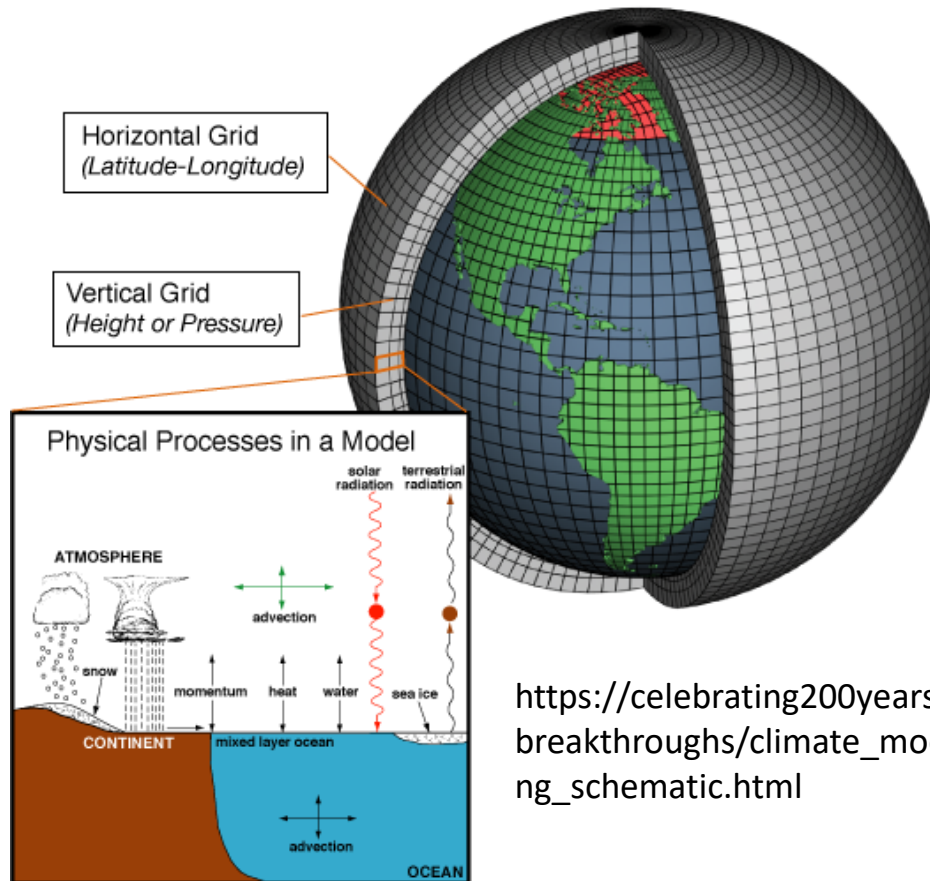
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<sup>2</sup>University of Michigan, Ann Arbor, MI

<sup>3</sup>Atmospheric and Environmental Research, Cambridge, MA

# Introduction

## General Circulation Models (GCMs)

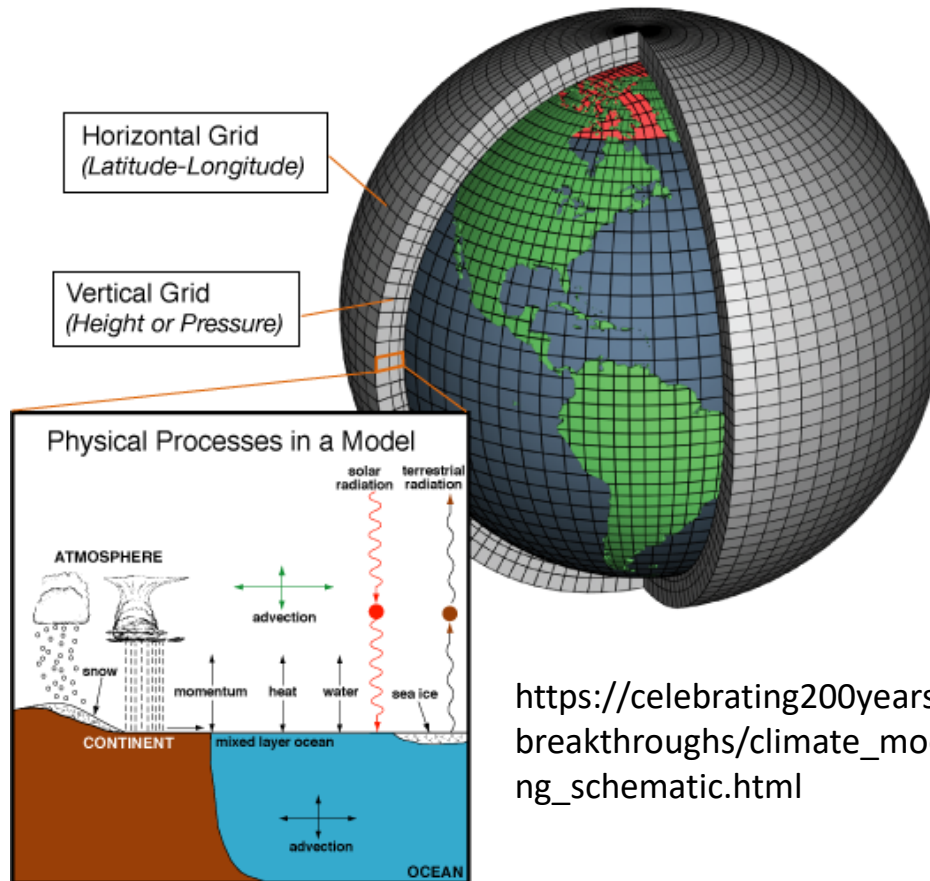


[https://celebrating200years.noaa.gov/breakthroughs/climate\\_model/modeling\\_schematic.html](https://celebrating200years.noaa.gov/breakthroughs/climate_model/modeling_schematic.html)

CanCM4  
CAM4  
CAM5  
CFSR  
CFSv2  
ECHAM5  
ECHAM6  
HadCM3  
LMDZ4  
LMDZ-B  
GFDL AM2  
GFDL AM3  
GISS ModelE  
GISS ModelE2

# Introduction

## General Circulation Models (GCMs)



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**CanCM4**

**CAM4**

**CAM5**

**CFSR**

**CFSv2**

**ECHAM5**

**ECHAM6**

**HadCM3**

**LMDZ4**

**LMDZ-B**

**GFDL AM2**

**GFDL AM3**

**GISS ModelE**

**GISS ModelE2**

**What if LW scattering of clouds is ignored in the simulations?**

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**1. Satellite observations**

**2. CAM5**

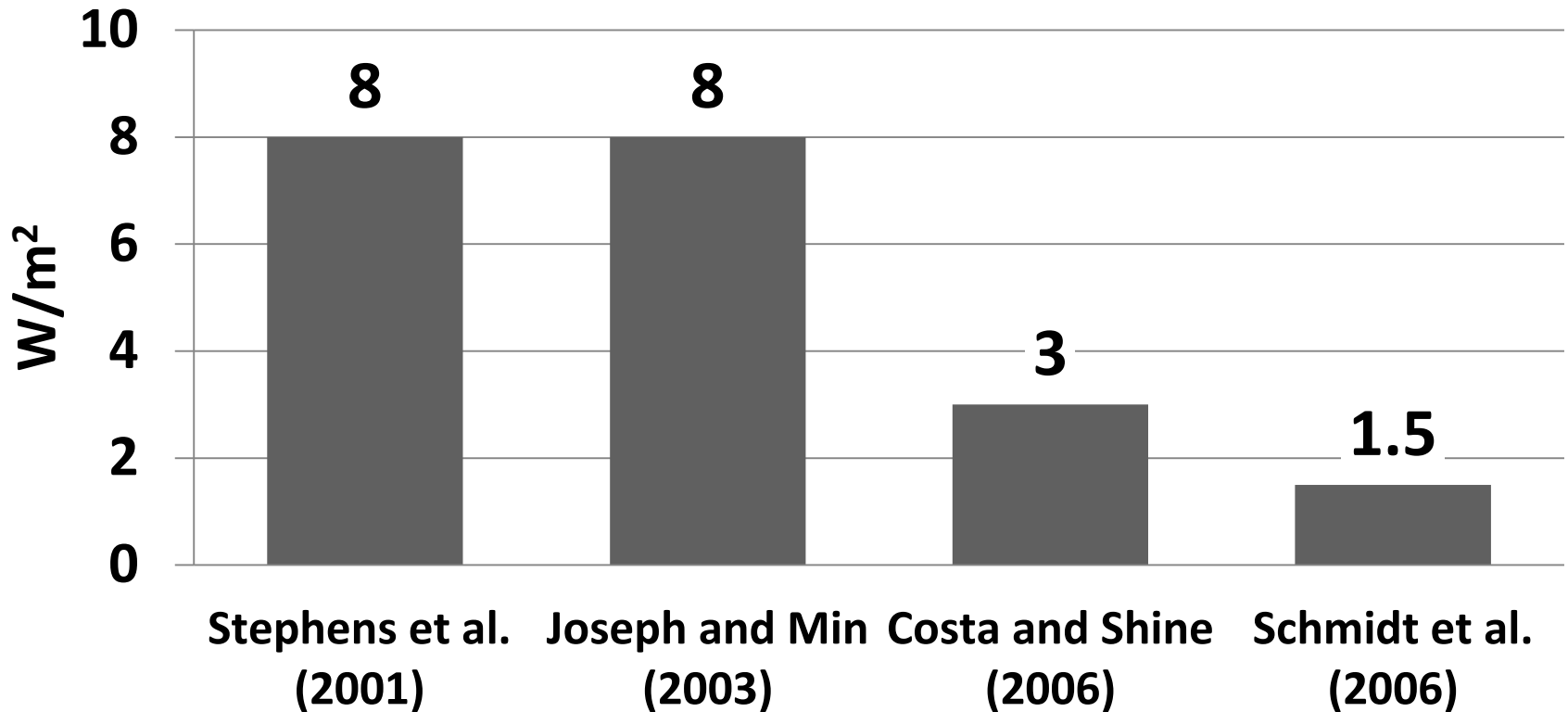
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**1. Satellite observations**

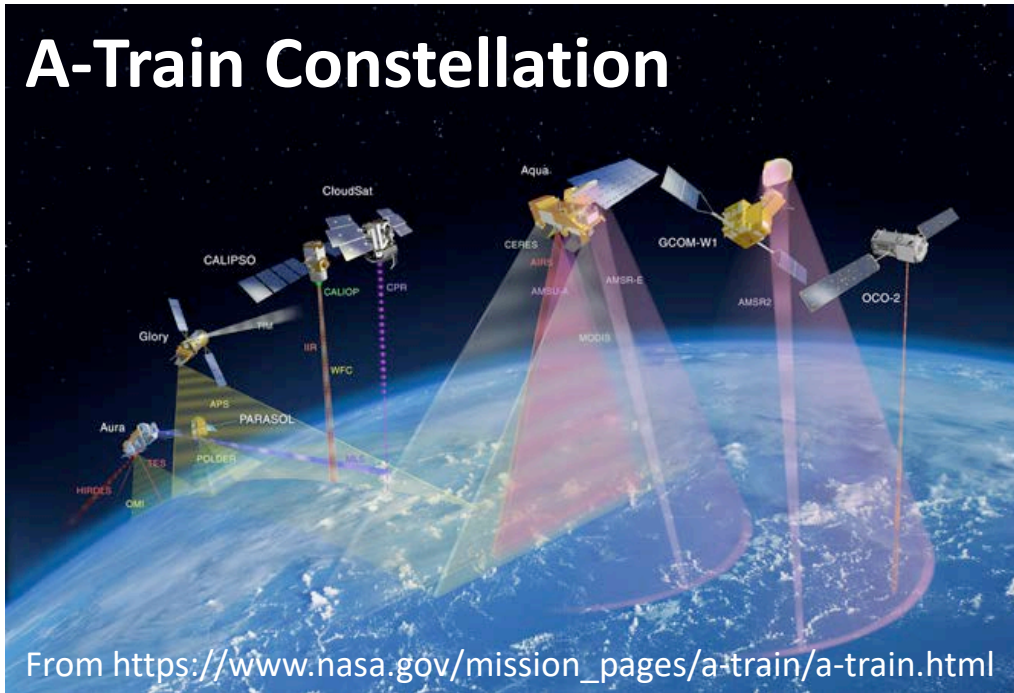
**2. CAM5**

## When LW scattering by clouds is neglected:

The global mean outgoing longwave radiation (OLR) is overestimated



## A-Train Constellation



**CCCM:** (Kato et al., 2014)

- CALIPSO
- CloudSat
- CERES
- MODIS

CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation

CERES: Clouds and the Earth's Radiant Energy System

MODIS: Moderate Resolution Imaging Spectrometer



# RTM Configurations

## 2010 Global Observations (CCCM) (Kato et al., 2014)

### Clouds

Microphysical and  
Optical Properties

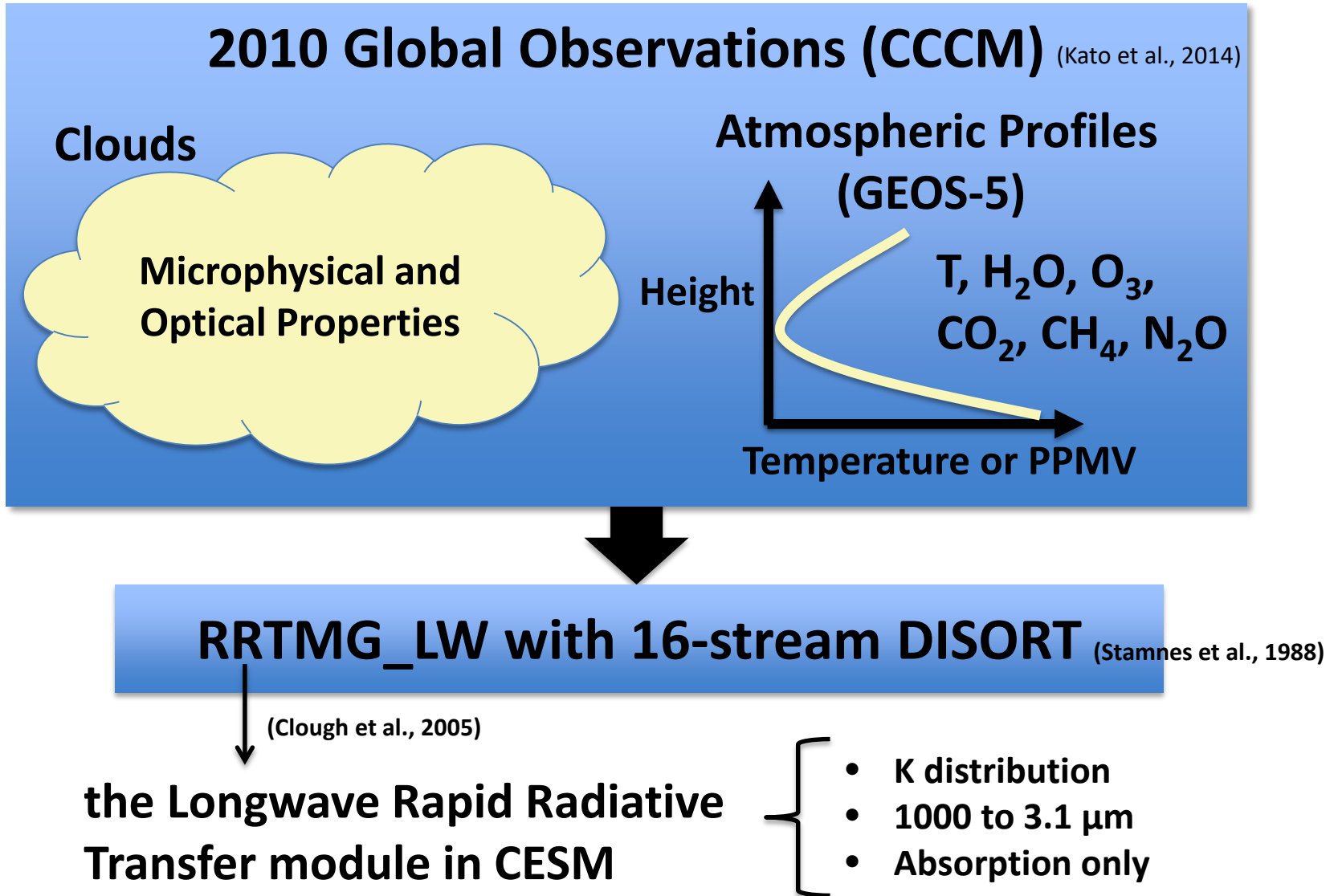
### Atmospheric Profiles (GEOS-5)

Height

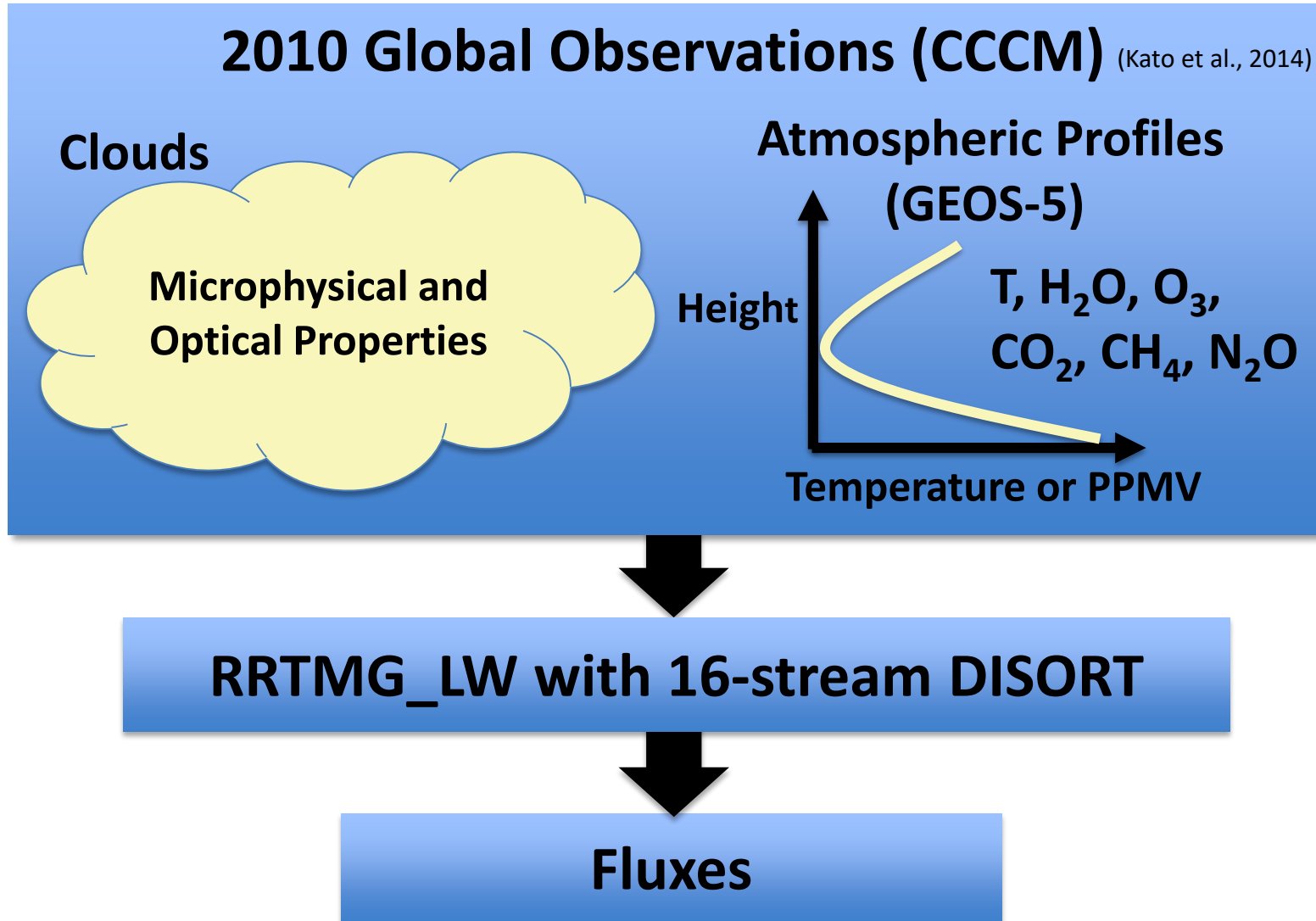
T, H<sub>2</sub>O, O<sub>3</sub>,  
CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

Temperature or PPMV

# RTM Configurations



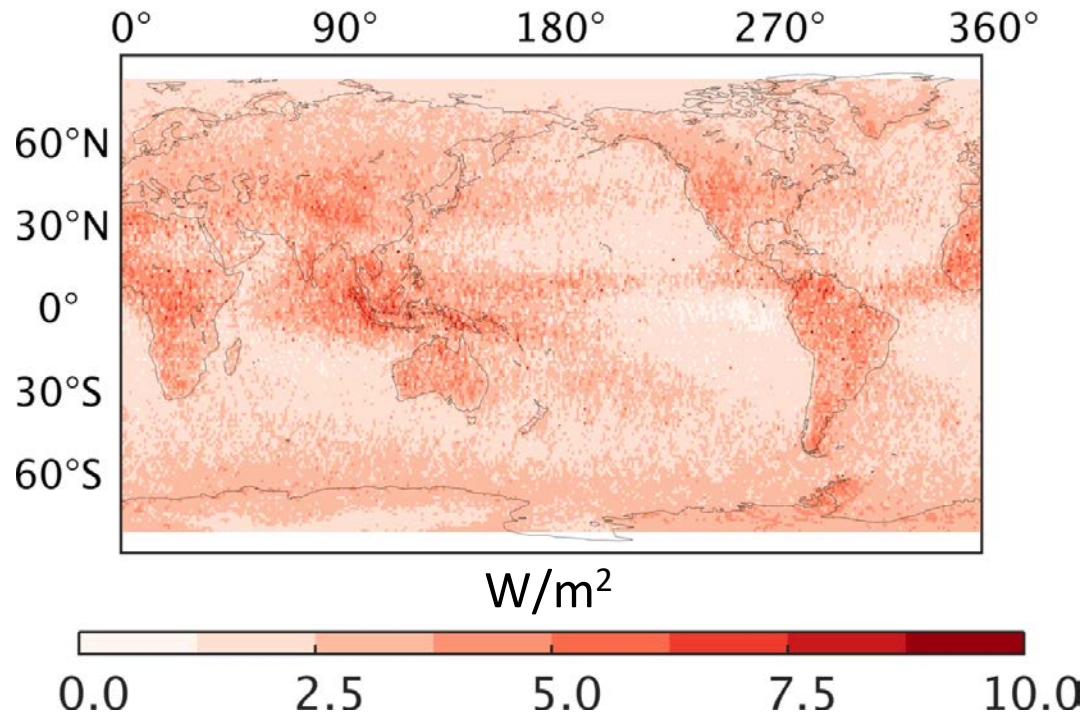
# RTM Configurations



- 2 Runs
  - Absorption only
  - Absorption + Scattering



# TOA Upward Flux Biases



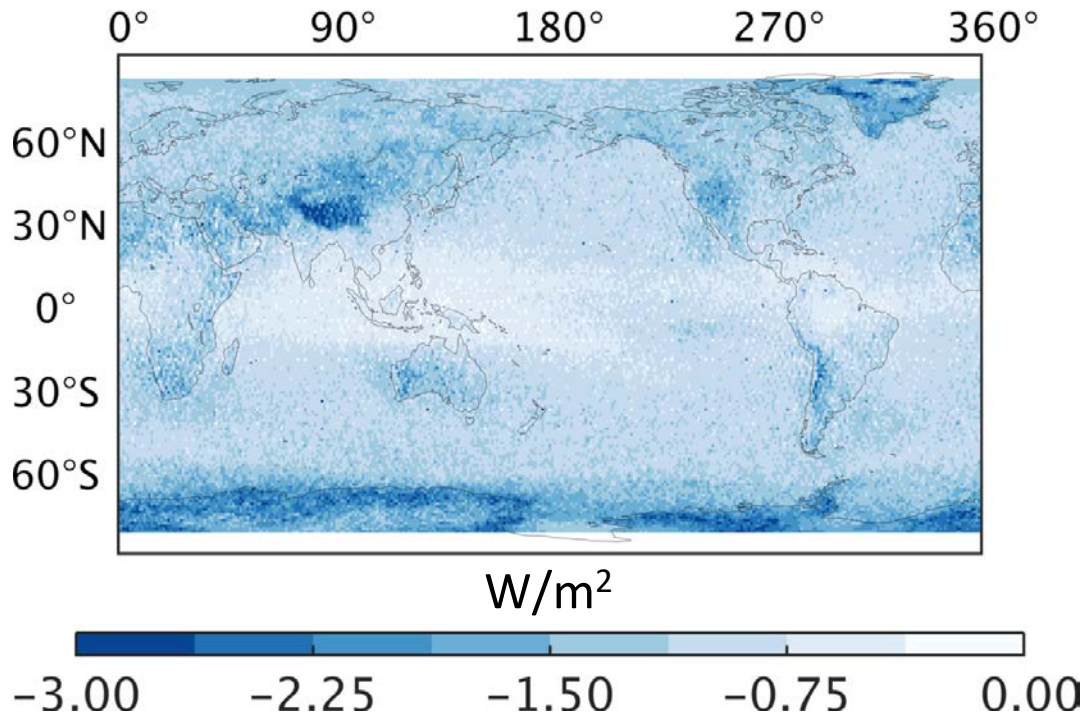
**Areas containing large biases**

- **Intertropical Convergence Zone (ITCZ)**
- **Pacific warm pool**
- **Tibetan Plateau**

**Large biases (up to 12 W/m<sup>2</sup>)**

**Positive biases mean TOA upward fluxes are overestimated when LW scattering is ignored**

# Surface Downward Flux Biases



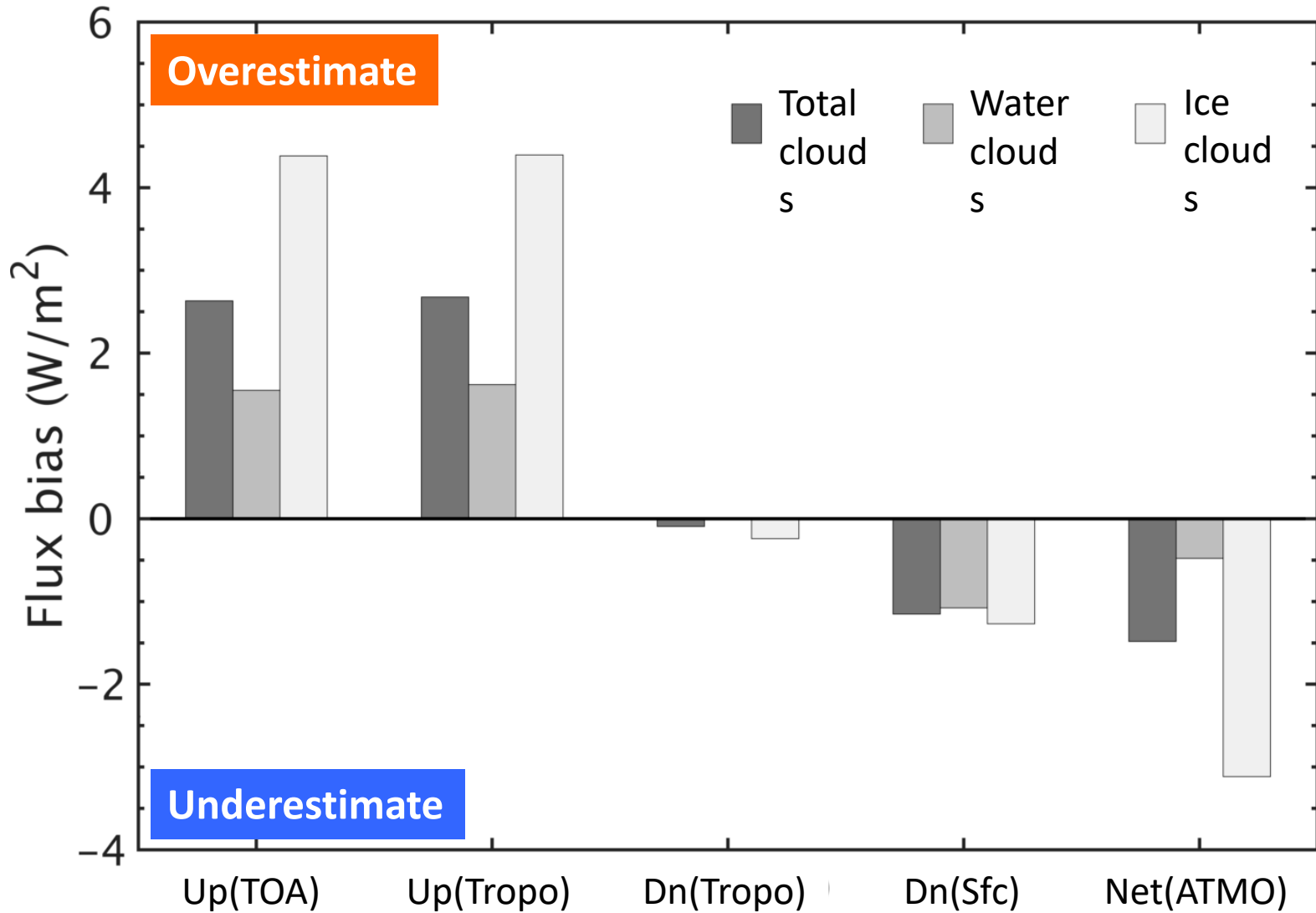
## Areas containing large biases

- Dry and high regions
- Tibetan Plateau
- Antarctic
- Greenland

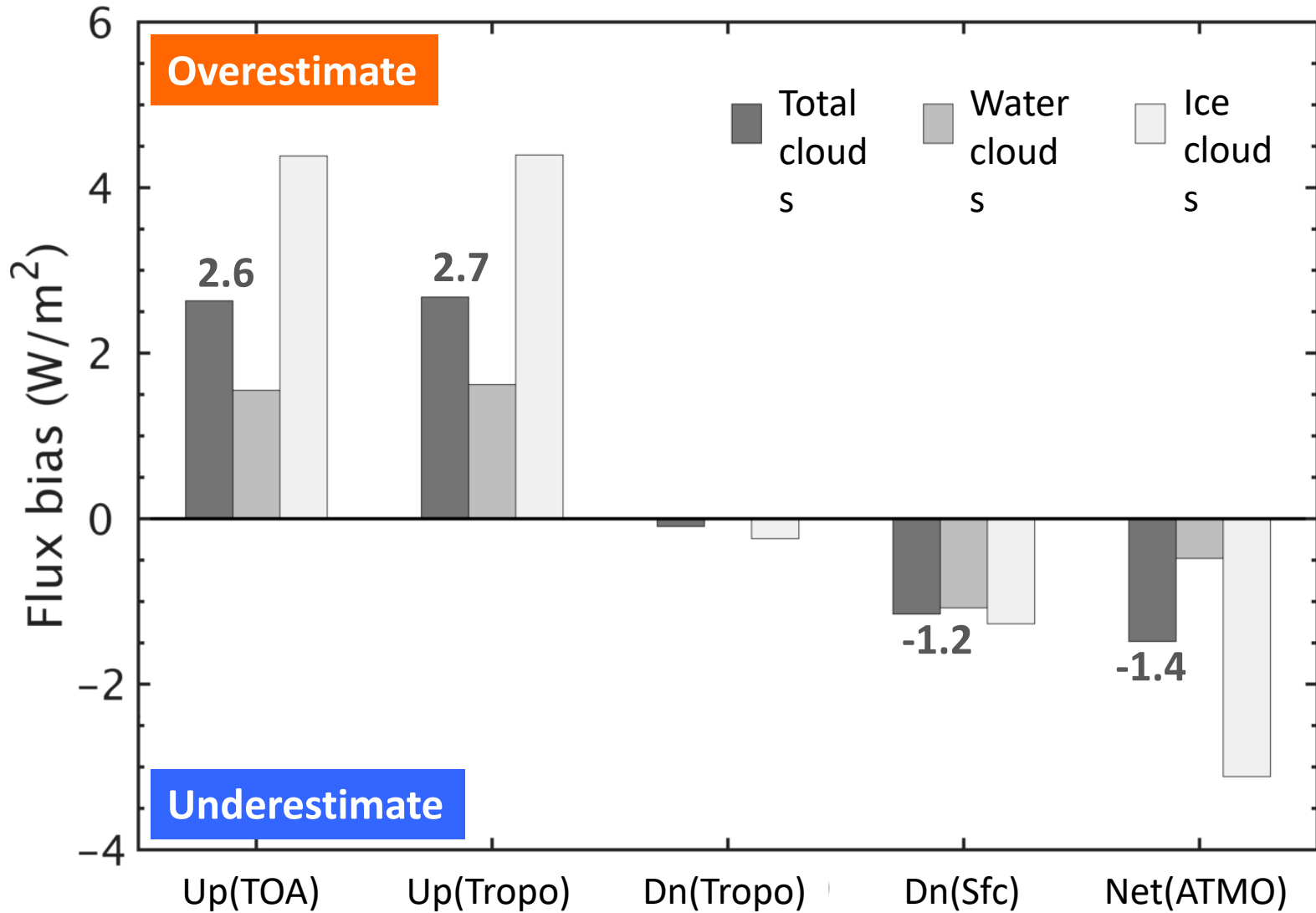
Large biases (about 3.6 W/m<sup>2</sup>)

Negative biases mean surface downward fluxes are underestimated when LW scattering is ignored

# Flux Biases

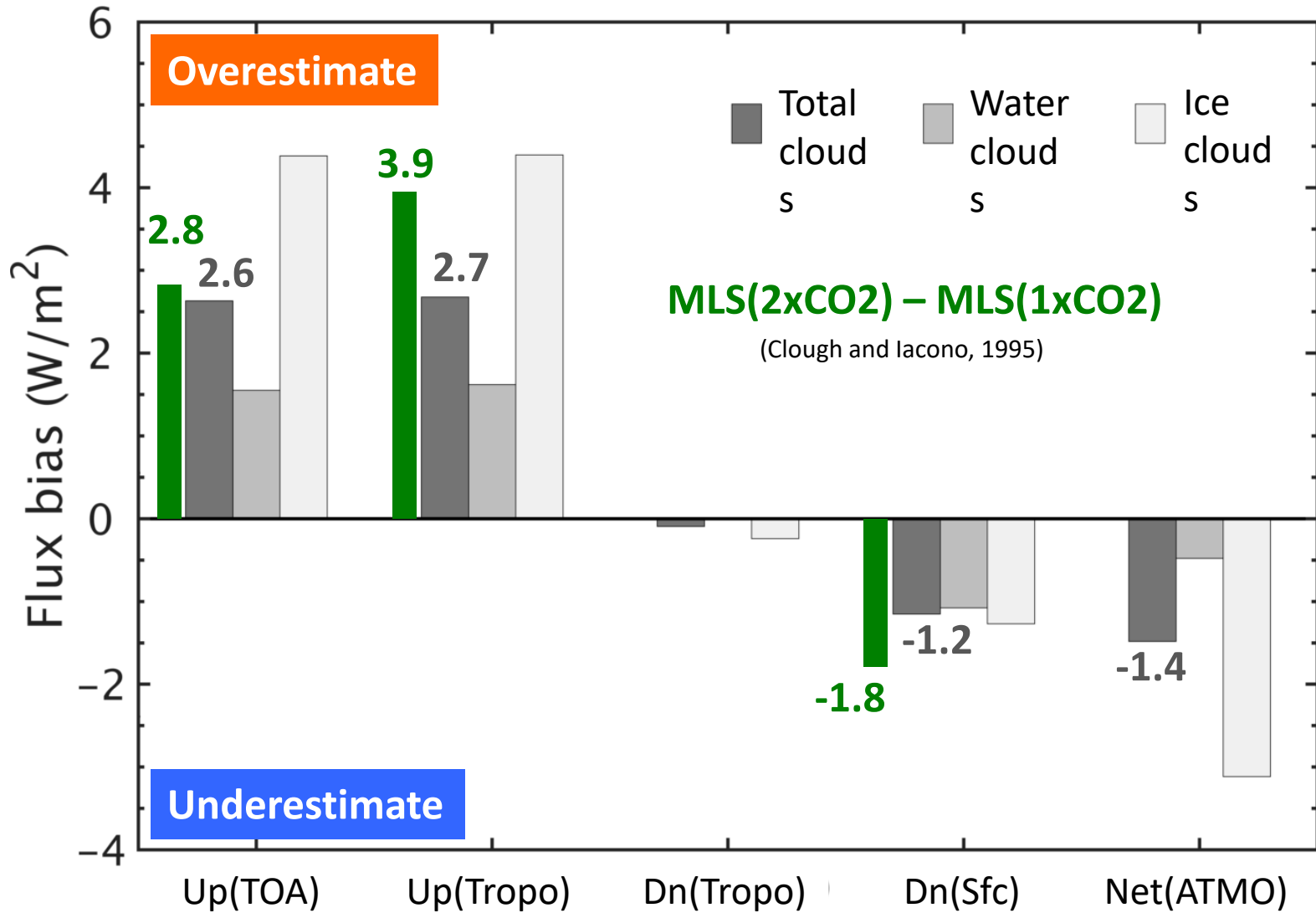


# Flux Biases





# Flux Biases



**What if LW scattering of clouds is ignored in the simulations?**

**1. Satellite observations**

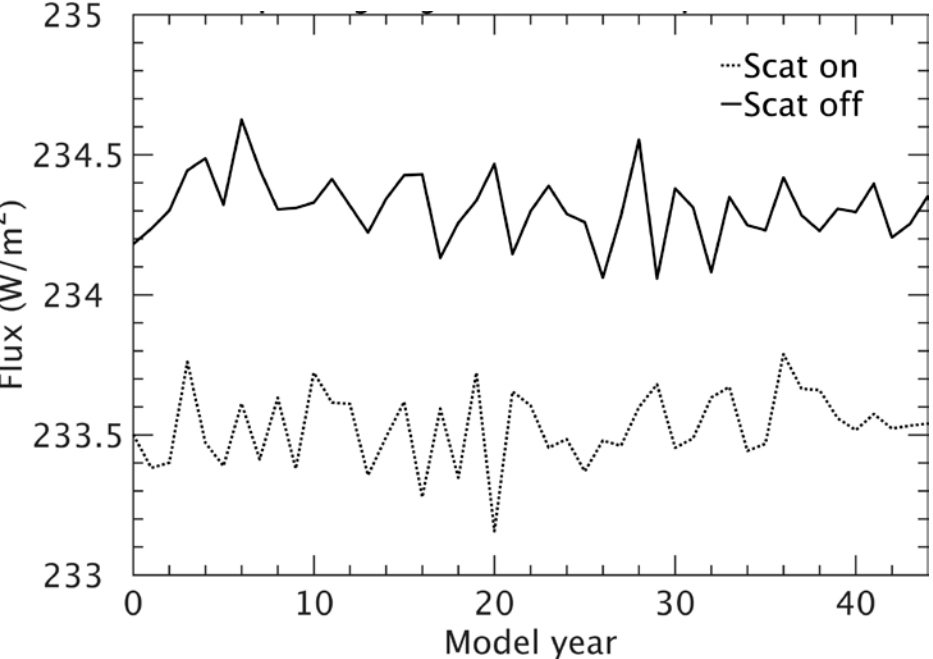
**2. CAM5**

# CAM5 Sensitivity Tests

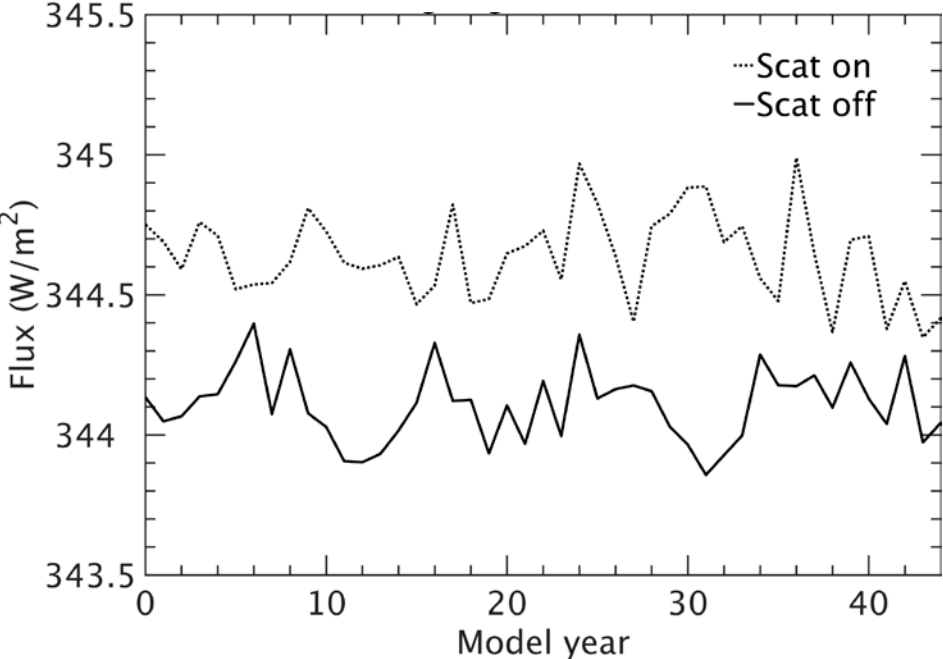
- CESM version 1.2 (Hurrell et al., 2013)
- F\_2000\_CAM5
  - Greenhouse gas concentrations of 2000
  - Prescribed sea surface temperature and sea ice fractions (climatology of 1982 - 2001; Hurrell et al., 2008)
- 1.9° x 2.5° horizontal resolution
- Scattering and No Scattering by Ice Clouds
- 2 Runs
  - LW Scattering on
  - LW Scattering off

# CAM5 Sensitivity Tests

### Upward LW flux at the top of model



### Downward LW flux at the surface



- LW scattering is important.
- Radiative effects of neglecting LW and doubling CO<sub>2</sub> are comparable.
- Using satellite observations and CAM5 simulations, when LW scattering is neglected
  - TOA upward flux is overestimated.
  - Surface downward flux is underestimated.

Kuo, C.-P., Yang, P., Huang, X.L., Feldman, D., Flanner, M., Kuo, C., & Mlawer, E. J. (2017). Impact of multiple scattering on longwave radiative transfer involving clouds. *Journal of Advances in Modeling Earth Systems*, 9(8), 3082–3098. doi:10.1002/2017MS001117