Confronting Global Models with Observations of Clouds and Precipitation

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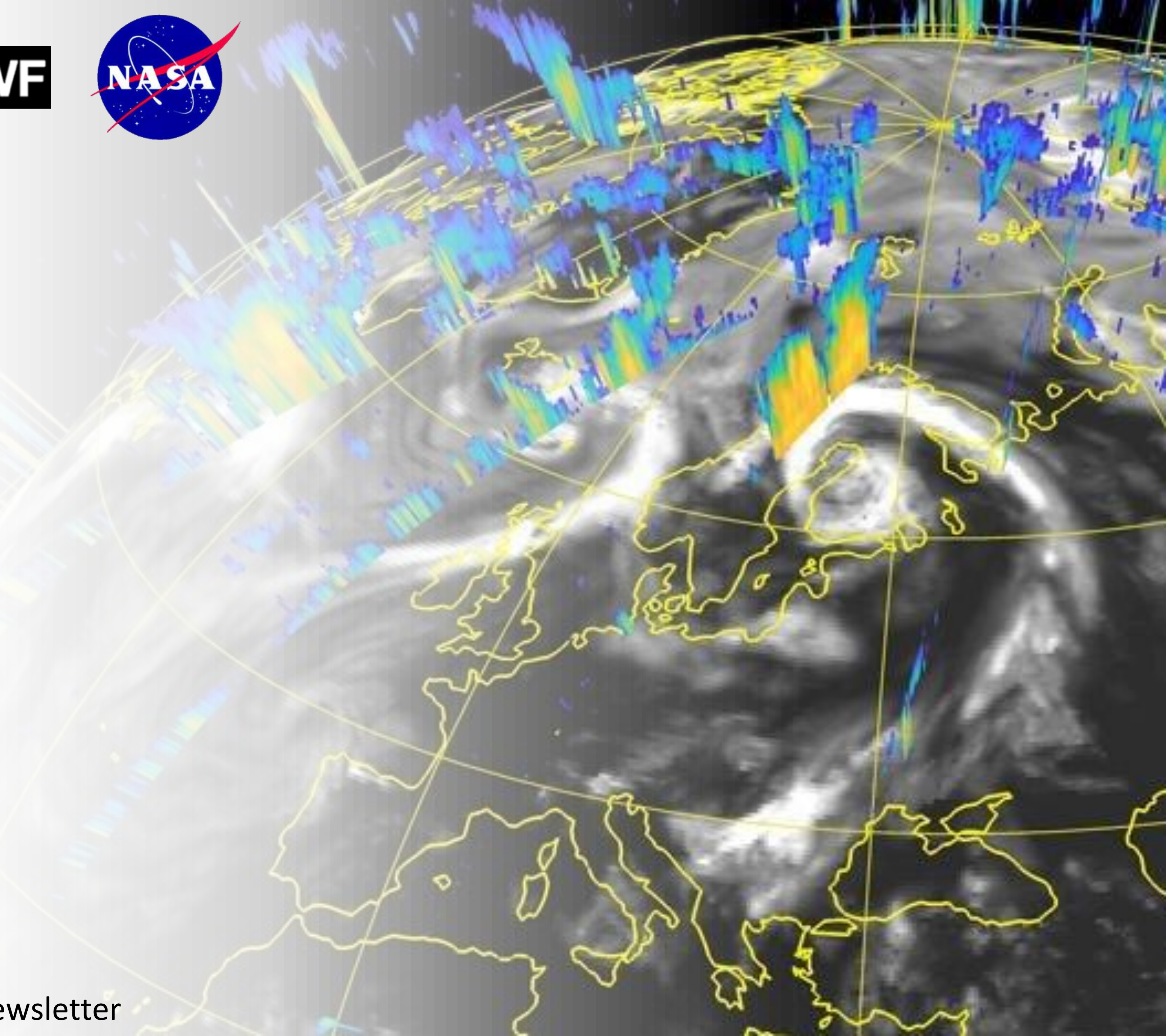


Mark Fielding, ECMWF Newsletter

Outline

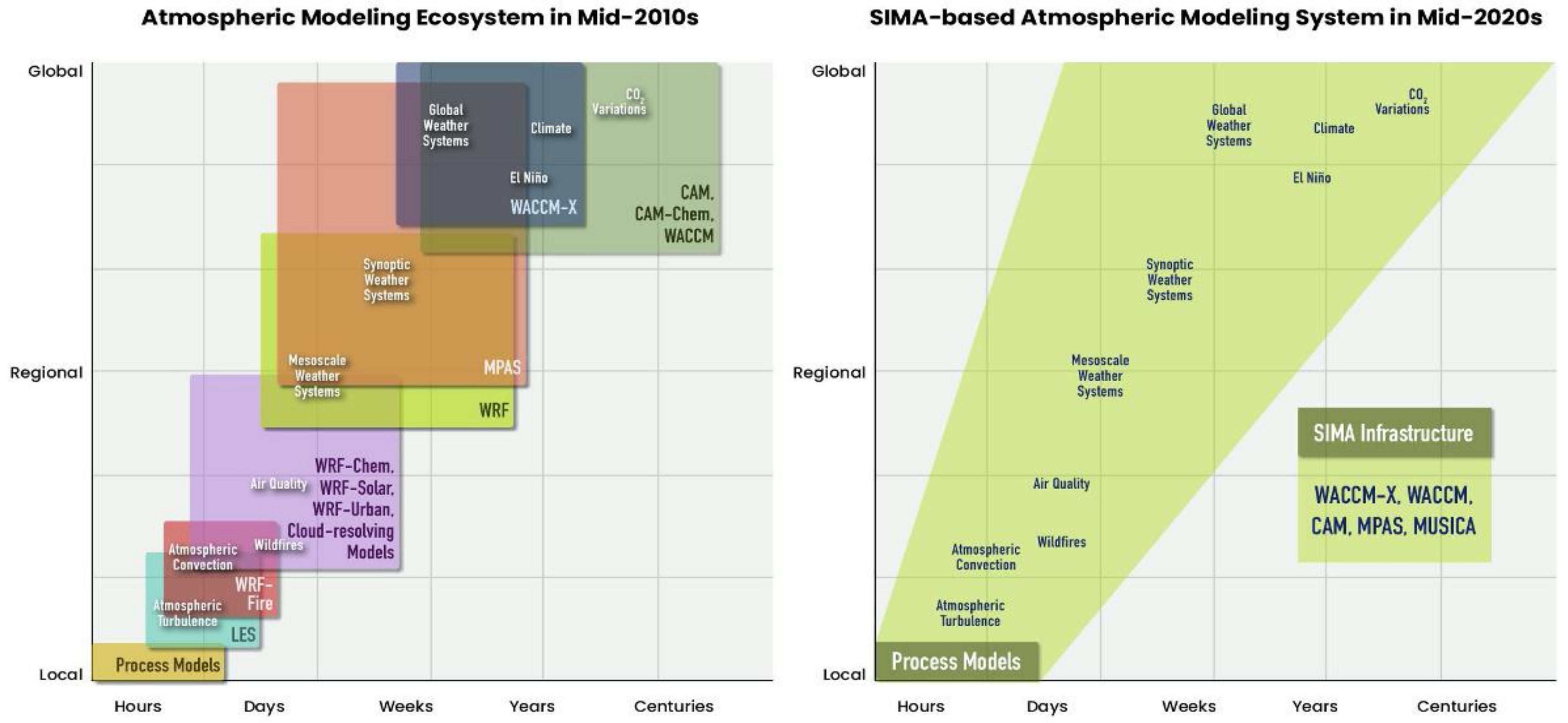
- Where are ESMs going?
- What are major issues for Clouds and Precipitation?
- How can EarthCARE Help?
- Larger vision: Model-Data Fusion

Where are ESMs Going?

- One path forward: GSRMs
- But: also want them traceable to lower resolution Global, Regional
  - Merging with mesoscale models (especially cloud processes)
  - Scalable (cross-scale) complexity: chemistry, aerosols, cloud processes (e.g. rimed ice)
- New methods
  - Emulators, Machine Learning (new generation of 'empirical' parameterizations)
- Better analysis, optimization methods
  - Satellite Simulators
  - Data Assimilation for Climate (especially for clouds)

NCAR's vision…similar to others

System for Integrated Modeling of the Atmosphere (SIMA)

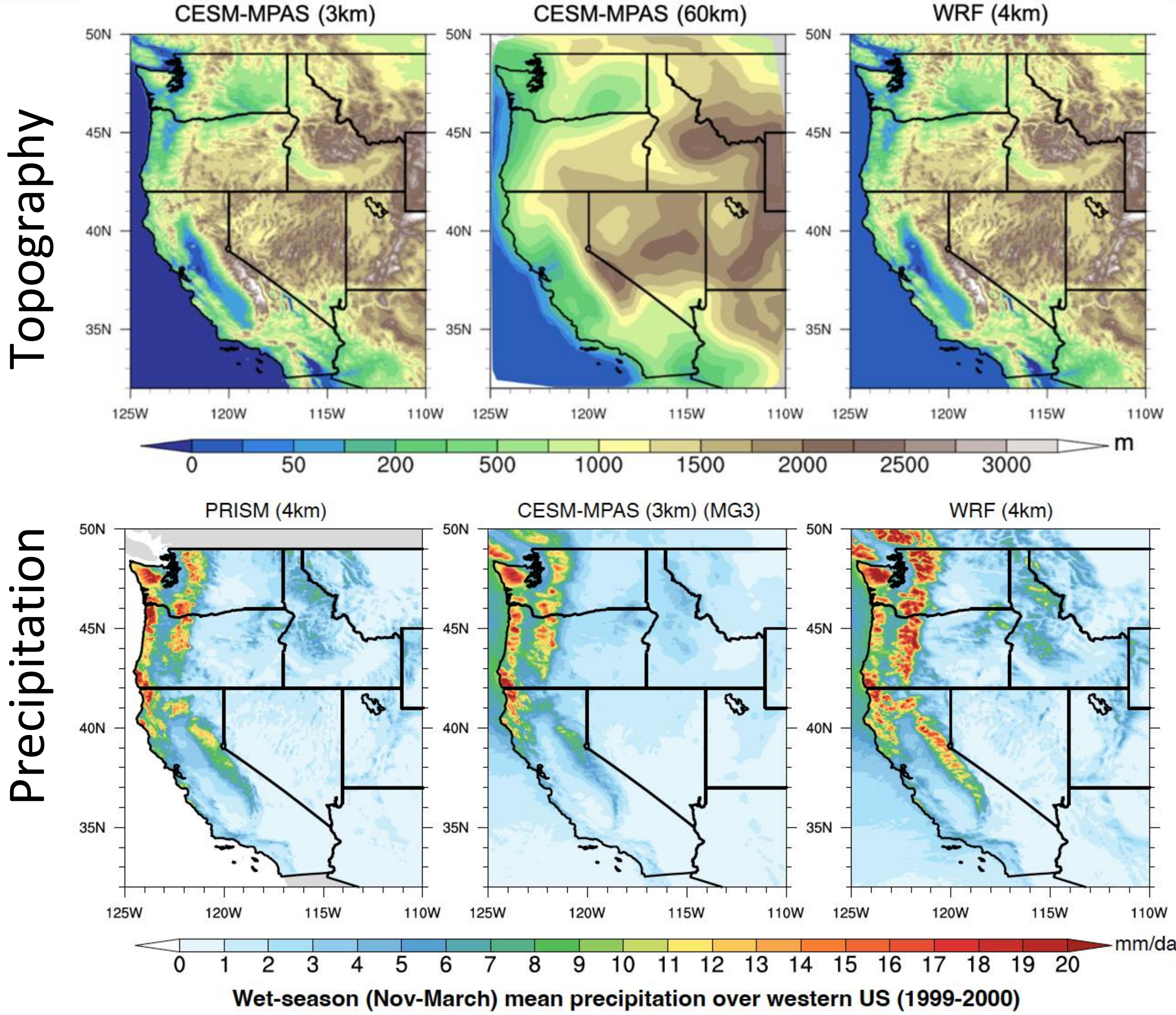


Climate Extremes: Variable-Resolution (60→3 km)

- Observational dataset: PRISM 4km (Daly et al., 2017)
- Global Model: CESM-MPAS: 3km regional, non-hydrostatic dynamics. Global model physics (2-moment microphysics with graupel)
- Regional climate model: WRF (CONUS) 4km (Rasmussen et al., 2021)

W. USA Wet-season (Nov-Mar) precipitation (1999-2004)

- CESM-MPAS results are compare well to observations
- Smaller biases than WRF mesoscale model



X. Huang, NCAR

Major Issues for Clouds, Precip and Aerosols (IMHO)

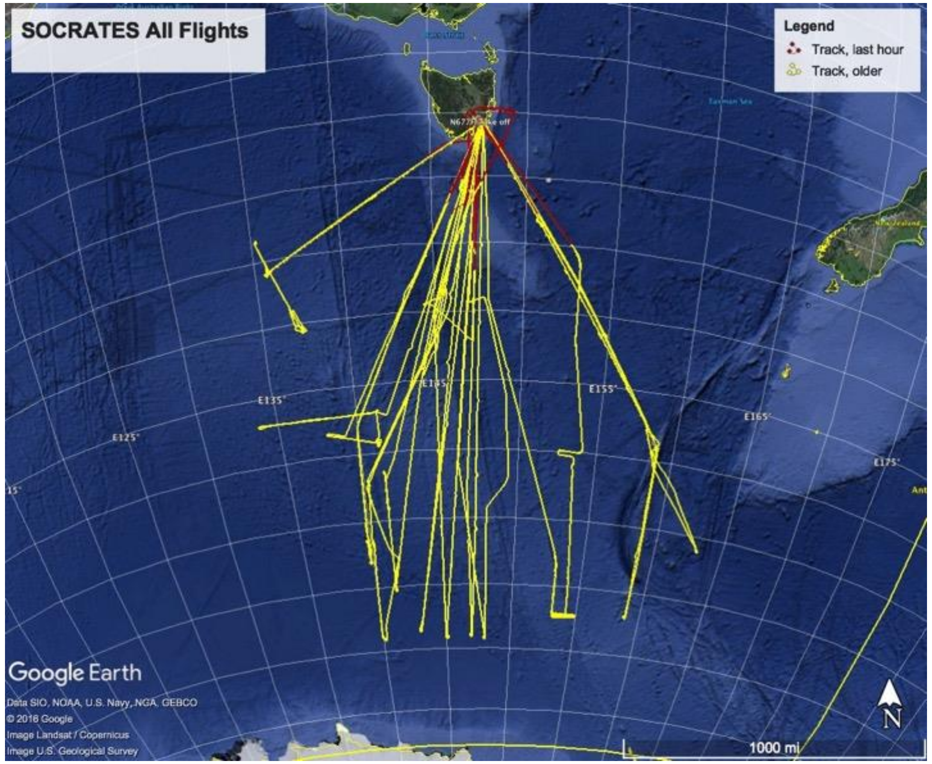
Heard lots about warm clouds. Let’s talk about cold clouds

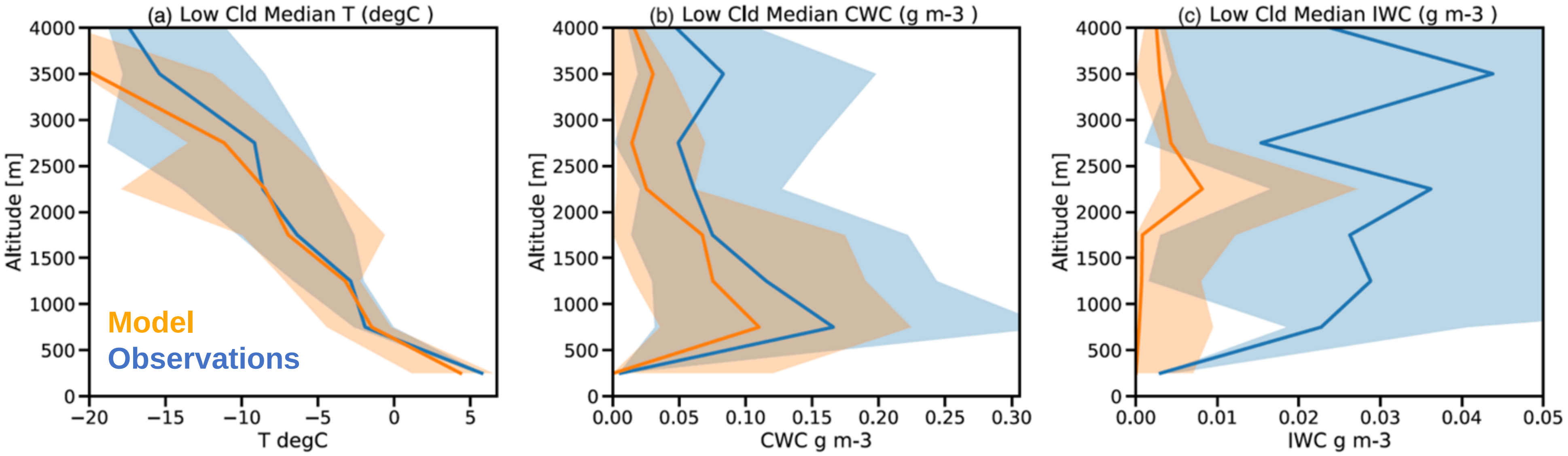
- Cloud Phase: critical for radiative effects at high latitudes AND for cloud feedbacks. Also weather impacts
- Cloud Microphysics: size distributions govern process rates
- Aerosol activation (cloud-aerosol interactions). Vertical velocity
  - Issue: shallow velocity may be more important.
- Precipitation Intensity: weather impacts

Cloud Phase

SOCRATES in-situ flights over the S. Ocean used to understand & improve models

CAM6: Too little ice. This contributes to high climate sensitivity.



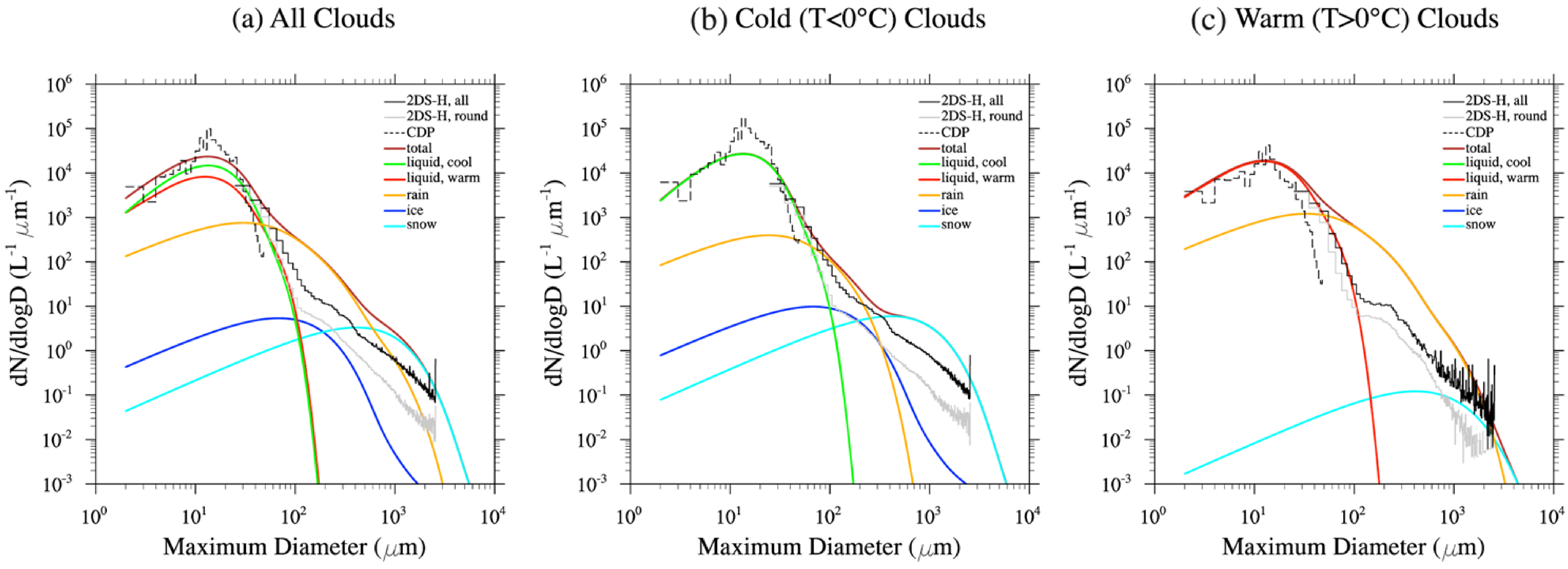


Gettelman et al 2020

Microphysics, Size distributions

Advanced GCMs/GSRMs can be compared directly to cloud microphysical size distributions (here from SOCRATES).

Comparison is GCM cloud microphysics along aircraft flight tracks with in-situ data

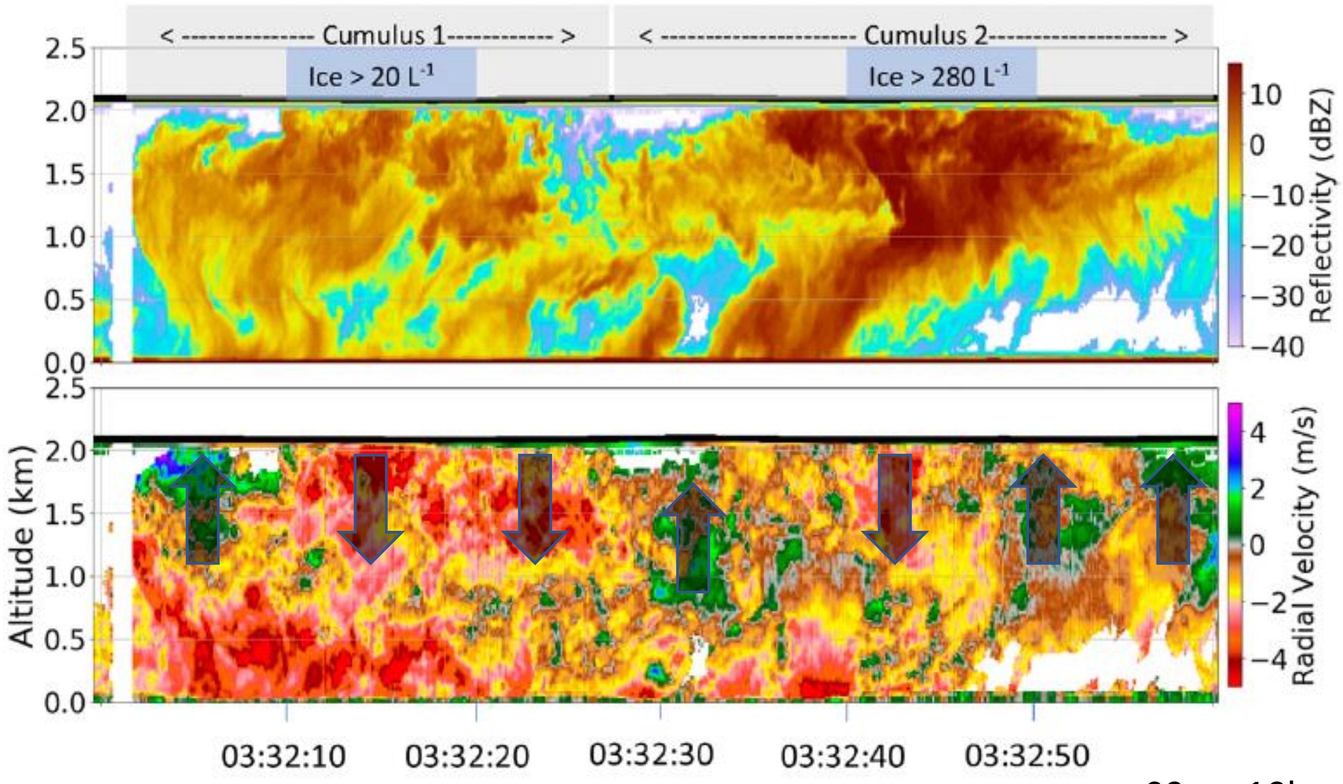


Note potential issue with too large rain sizes

Gettelman et al 2020

Cloud Dynamics & Microphysics

- Cloud dynamics (velocity) influences/controls cloud microphysics & aerosol activation
- Leads to different cloud drop/crystal number, precipitation & radiative effects
- S. Ocean SOCRATES example

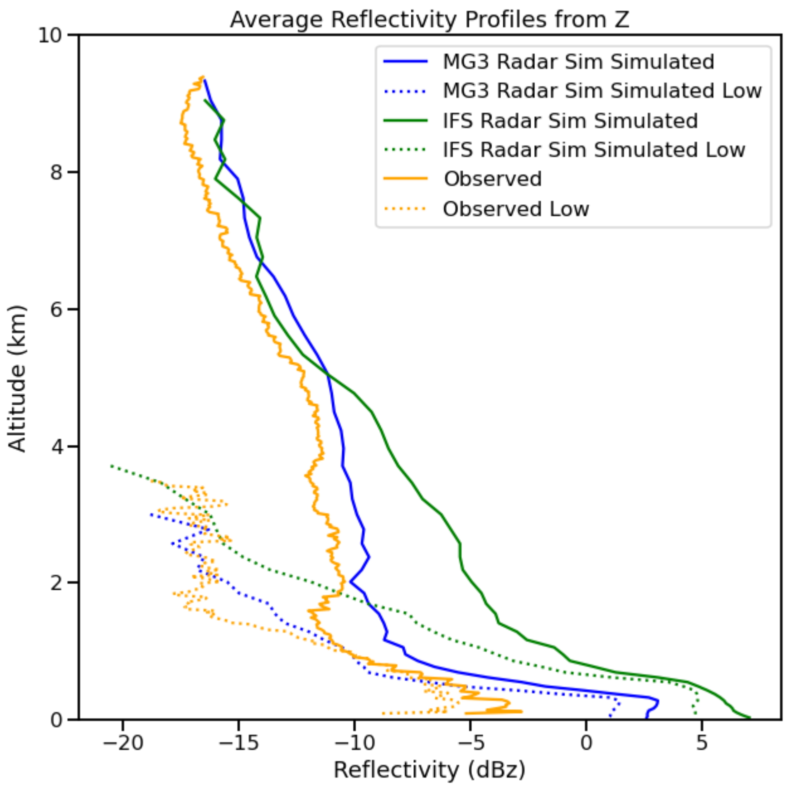


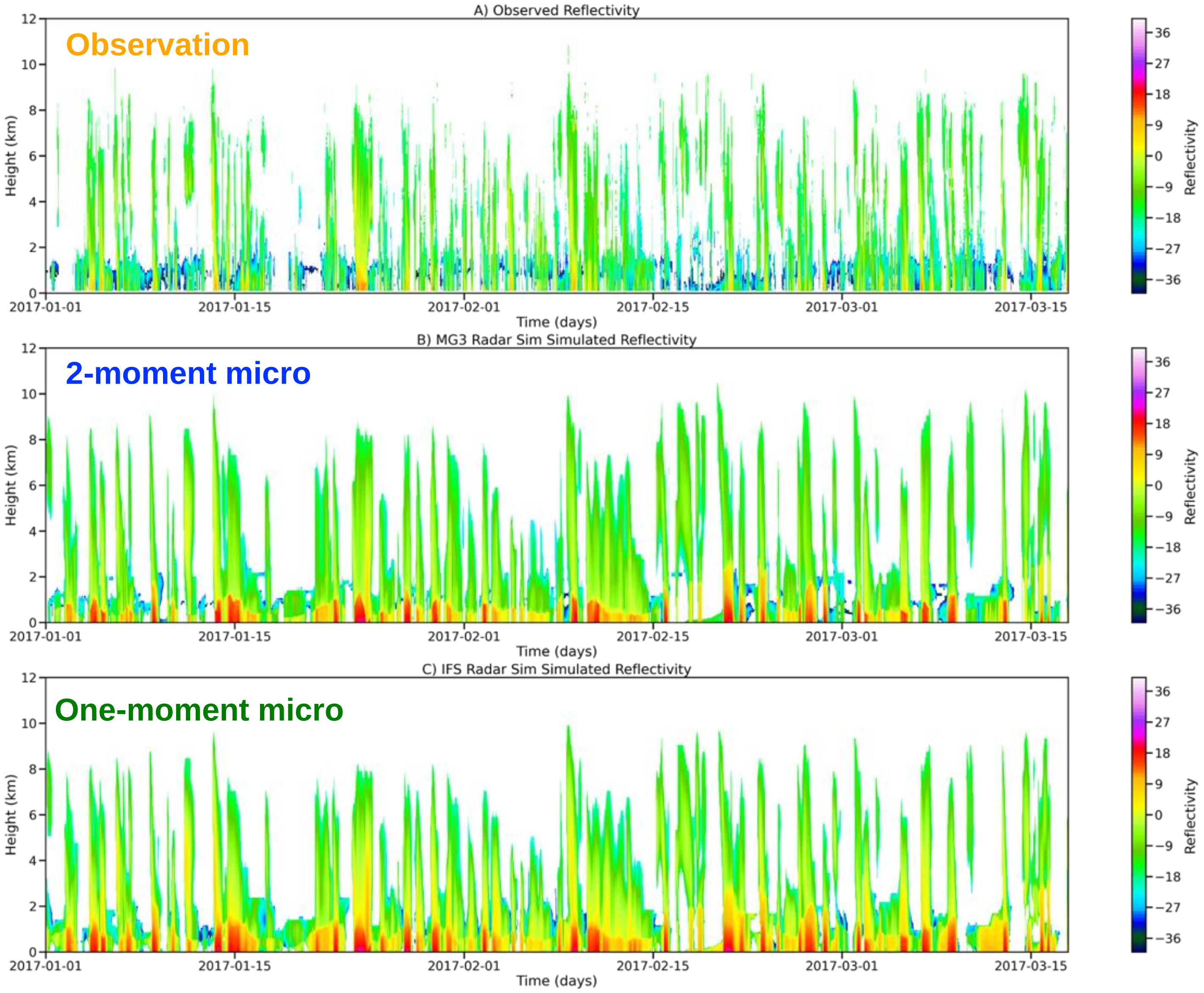
60s ~ 10km

McFarquhar et al 2020

Microphysics: Comparing to Reflectivity

Comparisons over Macquarie Island in S. Ocean between a **precipitation radar** and single column simulations with **one-moment** and **2-moment** microphysics in the ECMWF-IFS SCM.

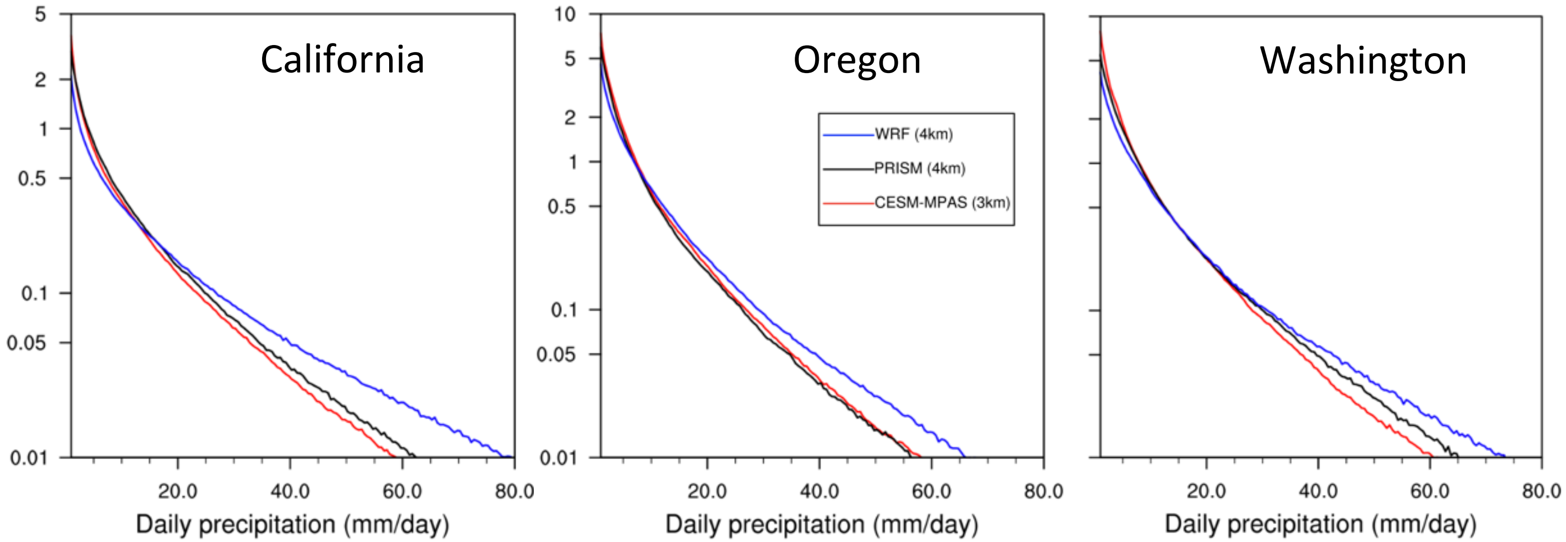




Gettelman, Forbes, Fielding, in Prep

Precipitation Intensity & Frequency

Daily precipitation Intensity PDF

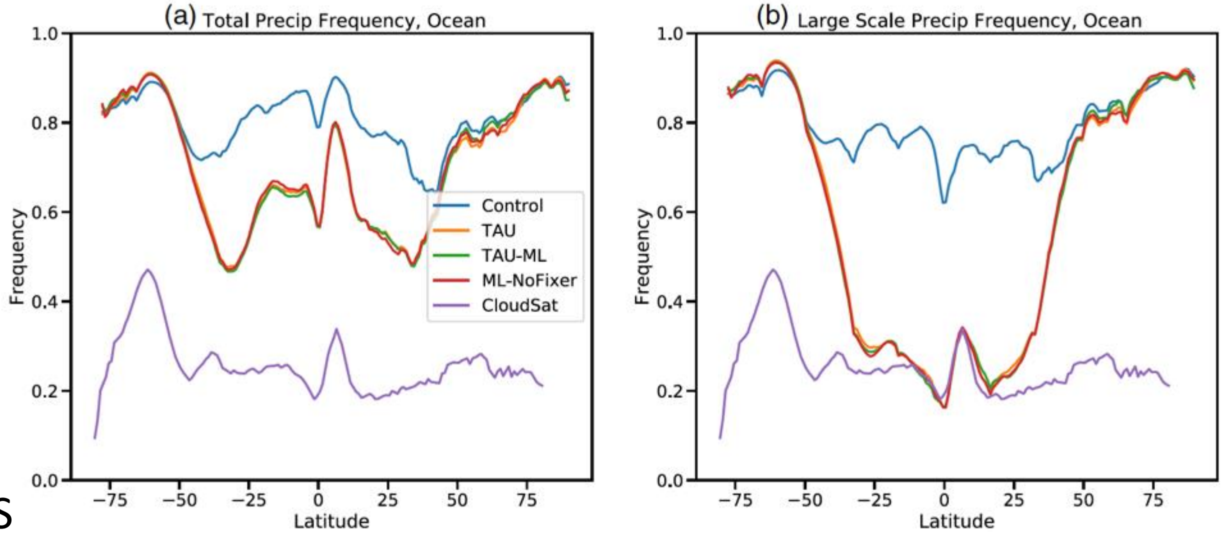


- Daily precip. Intensity from **4km Mesoscale Model (WRF)**, **3km Global Model (CESM)** and **4km Observations**
- **CESM** captures **observed PDF** better than **WRF**, especially for more extreme precipitation (upper tail)

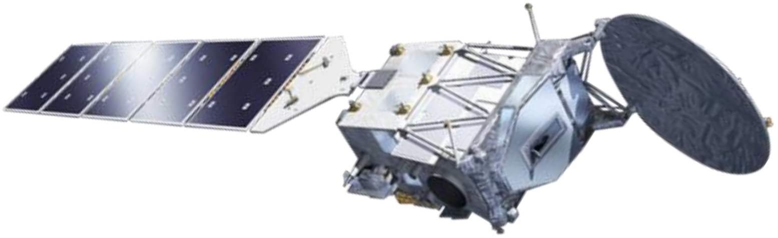
X. Huang, NCAR

Precipitation Frequency

Control v. **Observations** and
Bin precipitation and **ML Emulator.**
Using stochastic collection from a bin scheme improves large scale precipitation frequency in shallow clouds



Gettelman et al 2021, JAMES

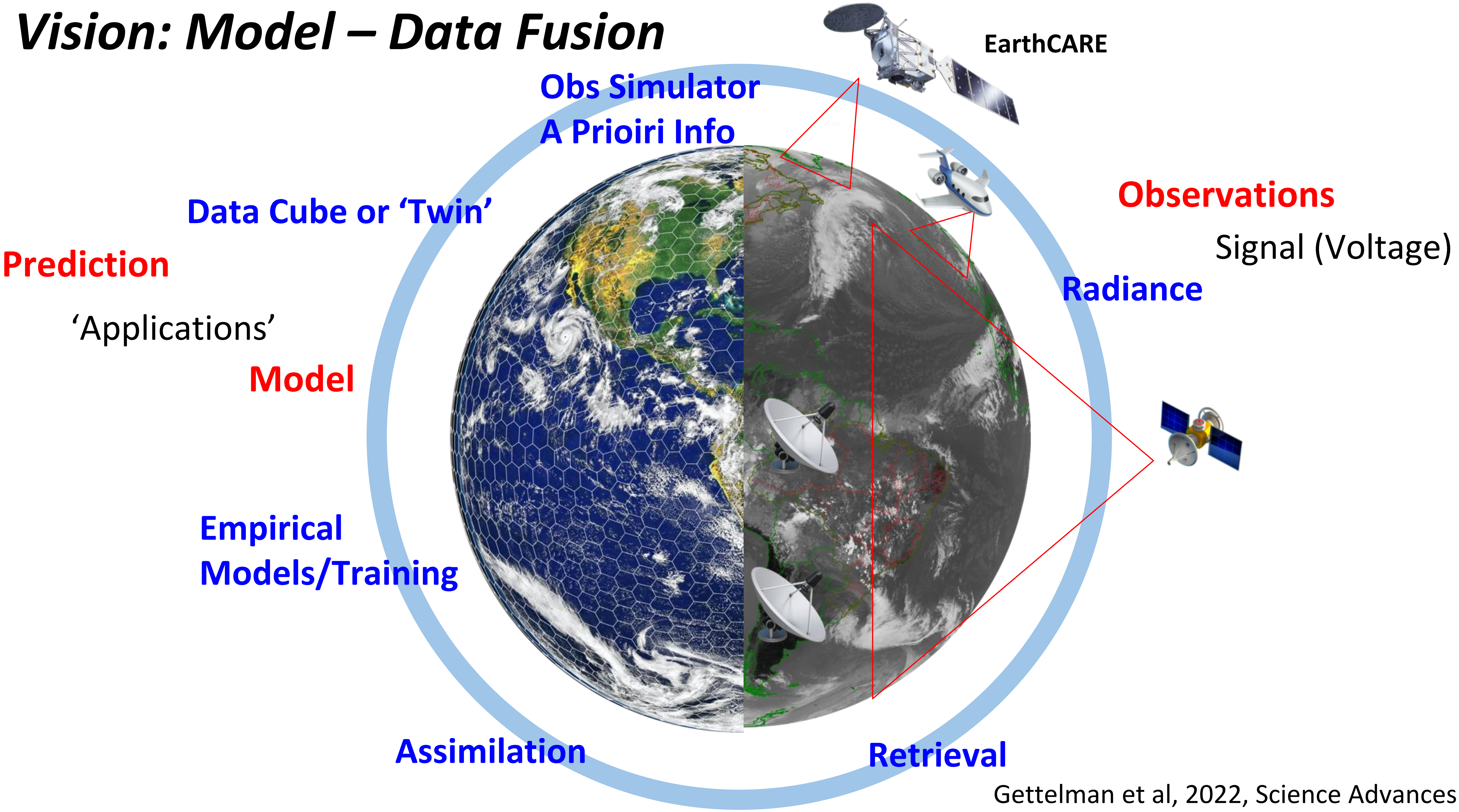
Where can  help?

- Doppler velocity: what are the intensity and scales of motion in shallow and deep clouds
- Reflectivity: solid measurement we can simulate in models and if the microphysics is wrong we will know it
- Better simulators. We aren't just trying to get means right we are using more integrated models from weather to climate, and want more direct process information
  - What simulator are we going to use? J-SIM? COSP? RTTOV?
  - Suggest maybe we take the COSP model interface and make it modular
- Assimilation of cloud information for model evaluation

Goal: Improving Prediction

- Improving prediction relies on models AND observations together
- A ‘model-data fusion’
- Better models
- Better observations
- Better techniques (assimilation, evaluation of models and obs)

Vision: Model – Data Fusion



Gettelman et al, 2022, Science Advances

Summary

- Key cloud microphysics problems:
  - Cloud Phase
  - Aerosol-Cloud Interactions (dynamics!)
  - Precipitation
- Key places to make progress with Earth Care
  - Vertical motion, reflectivity, cloud phase
- New methods: Model-Data Fusion
  - Simulators
  - Assimilation