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An update on atmospheric ice estimates from observations and reanalyses

David I. Duncan
Patrick Eriksson

Department of Space, Earth, and Environment
Gothenburg, Sweden

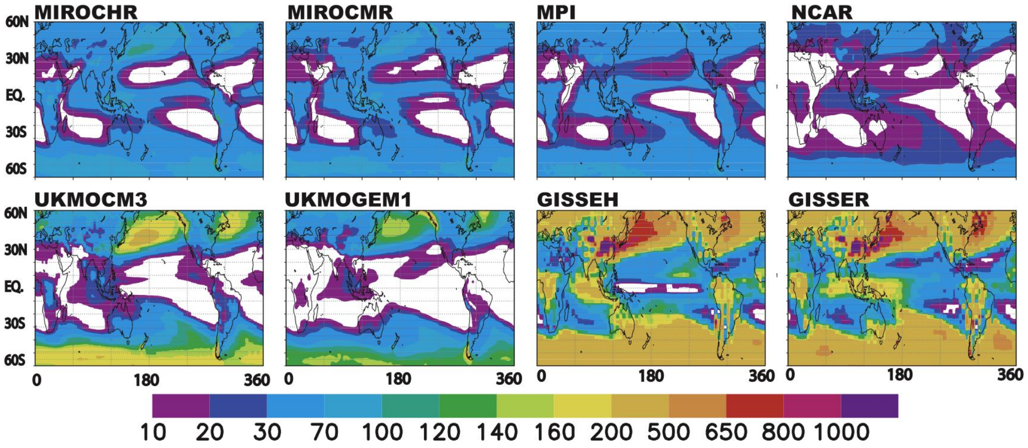
Clouds, circulation, and remote sensing

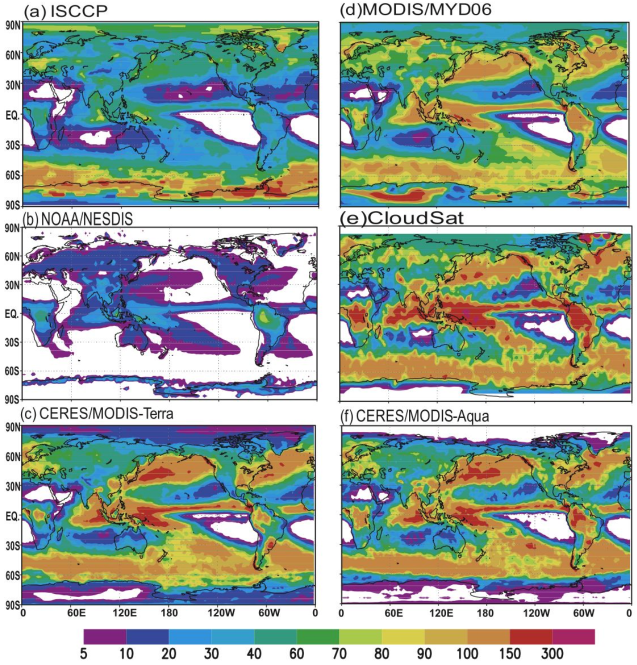
Active sensors provide vertical information and greater constraints applicable to models and passive retrievals

- What do passive and active satellite sensors tell us about ice clouds and thereby the atmospheric circulation?
- How well do estimates match for atmospheric ice?
- What can we learn about circulations on various scales?

Clouds, circulation, and remote sensing

Waliser et al. (2009) explored ice water path (IWP) variations between GCMs and observations in the early days of CloudSat -- huge differences!





Observing atmospheric ice

The global observing system for atmospheric ice is fragmented and not ideal – *because it was not designed for this*

- CloudSat/Calipso
- MODIS
- GPM radar
- Geostationary Vis/IR
- Microwave radiometers >85GHz
  - GPM constellation
  - Ice Cloud Imager on MetOp-SG (launch 2022)

Observing atmospheric ice

We ask two questions of the current knowledge:

1. What is the *consensus* on atmospheric ice mass from state-of-the-art satellite observations and reanalyses?
2. What is its relation to atmospheric *circulations* on short and long timescales?

Methods

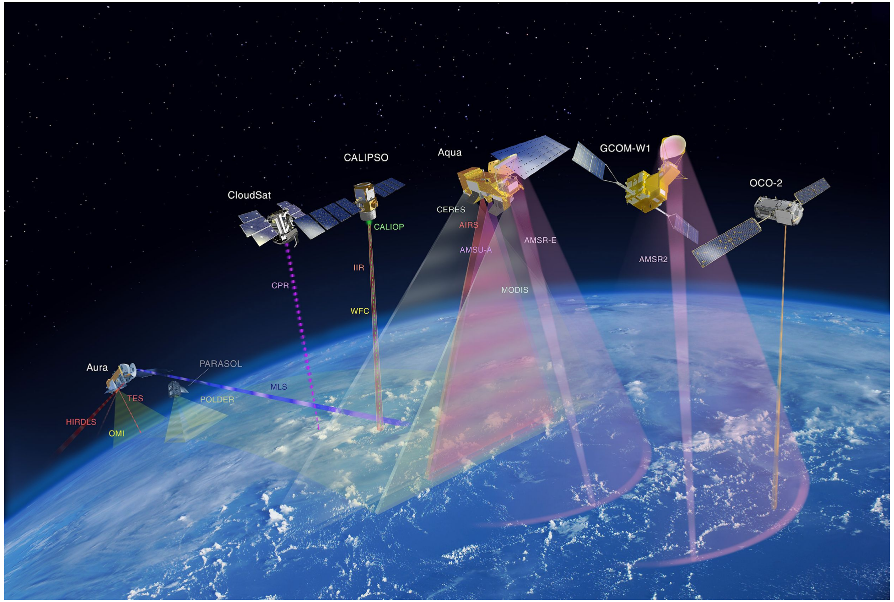
- ❑ Match all datasets to A-Train observation times since CloudSat/Calipso is the effective reference
- ❑ Average pixel-level satellite data to a common grid to lessen impact of differing footprints
- ❑ Use day/night A-Train crossing times to investigate diurnal variability
- ❑ Use EOF analysis to examine seasonal scale variability

Data: A-Train Centered

CloudSat/Calipso
- ❑ DARDAR
- ❑ 2C-ICE

Reanalyses -- subset to A-Train
- ❑ ERA5
- ❑ MERRA

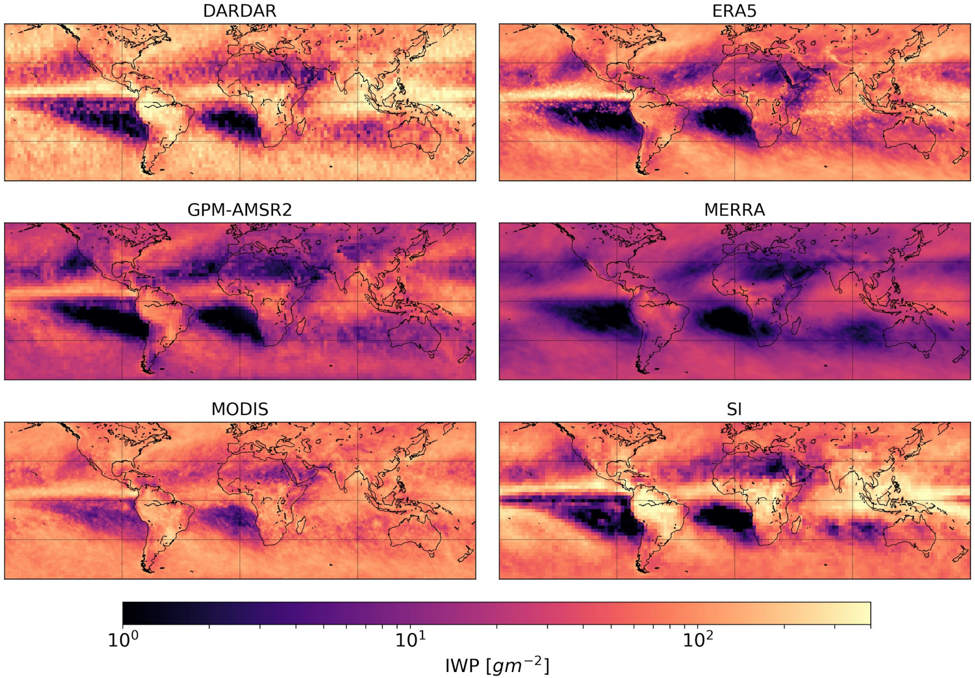
Passive satellite
- ❑ GPM (AMSR2)
- ❑ MODIS (Aqua)
- ❑ Spare-ICE (N18)



Annual Mean

Daytime only data at
A-Train crossing times

Averaged over 2015,
except DARDAR (6 years)



Note:

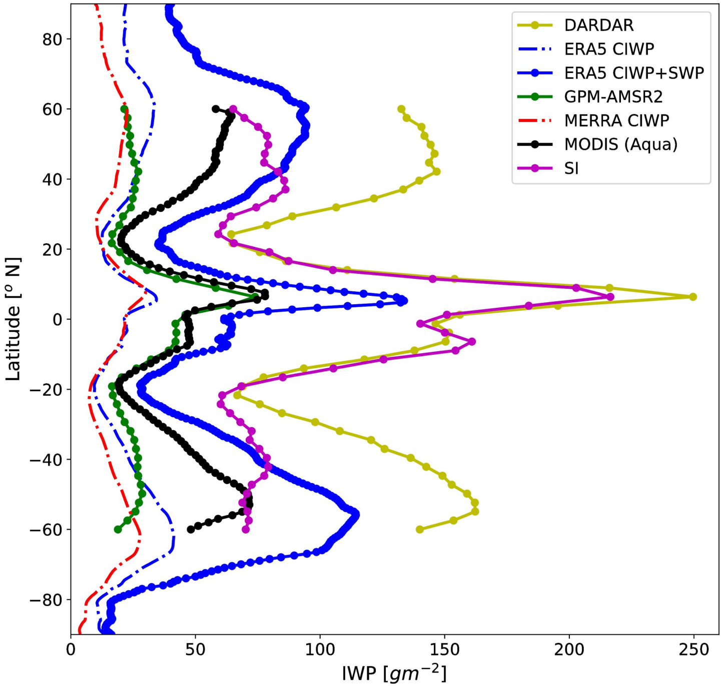
ERA5 is CIWP+SWP

MERRA IS CIWP only

Zonal Means

Daytime only data at
A-Train crossing times

Averaged over 2015,
except DARDAR (6 years)



IWP Frequency

Daytime only data at
A-Train crossing times

Averaged over 2015,
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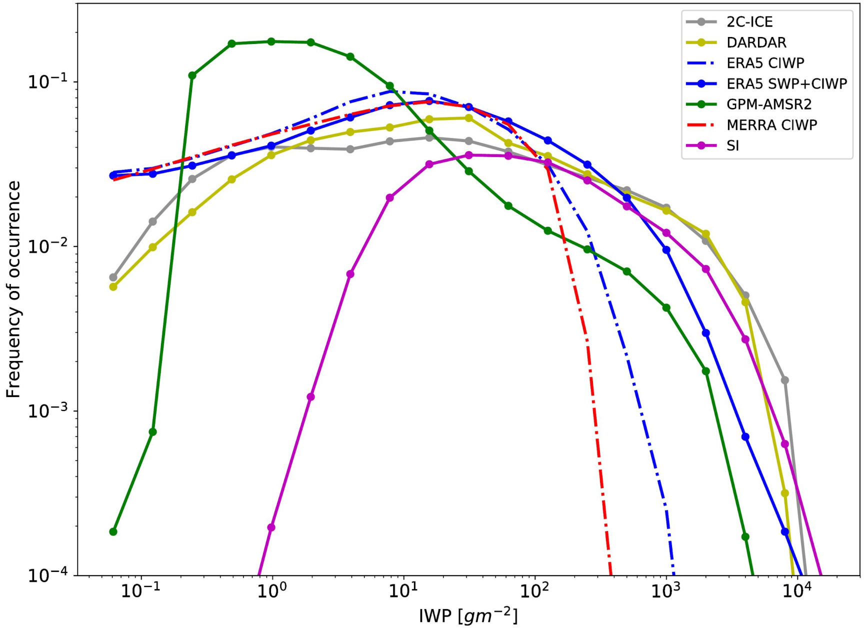
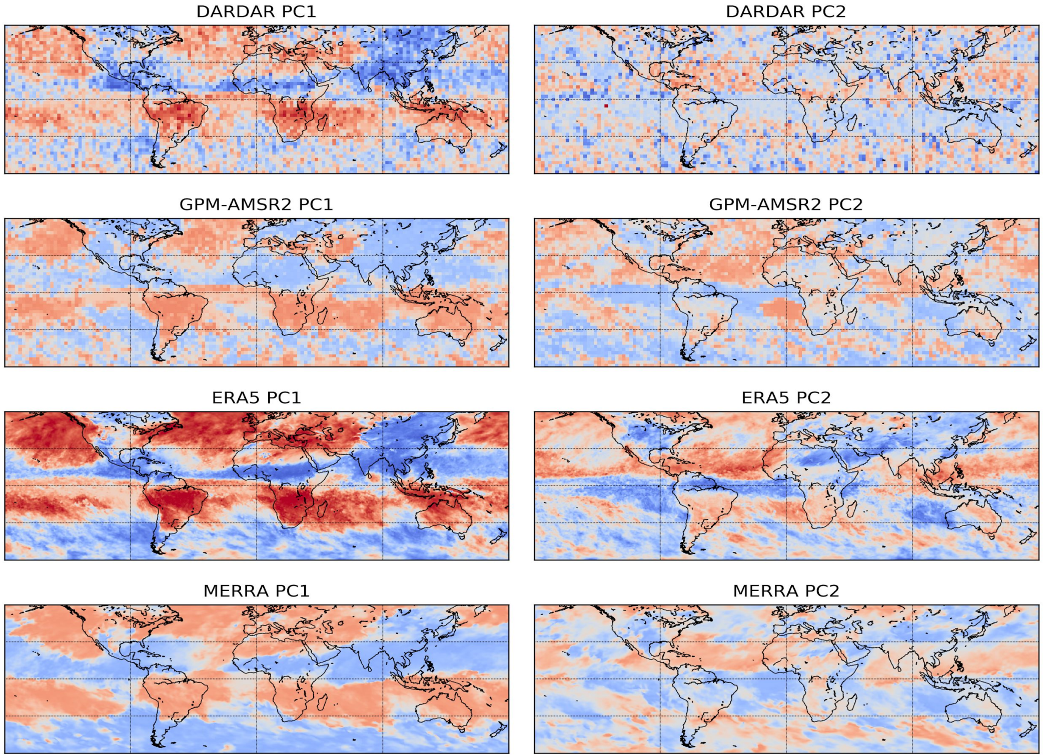


Seasonal Variability

First two principal components of seasonally averaged IWP (DJF, MAM, JJA, SON)

Data were standardized before analysis, so PC magnitudes are directly comparable

Color scale is linear and dimensionless

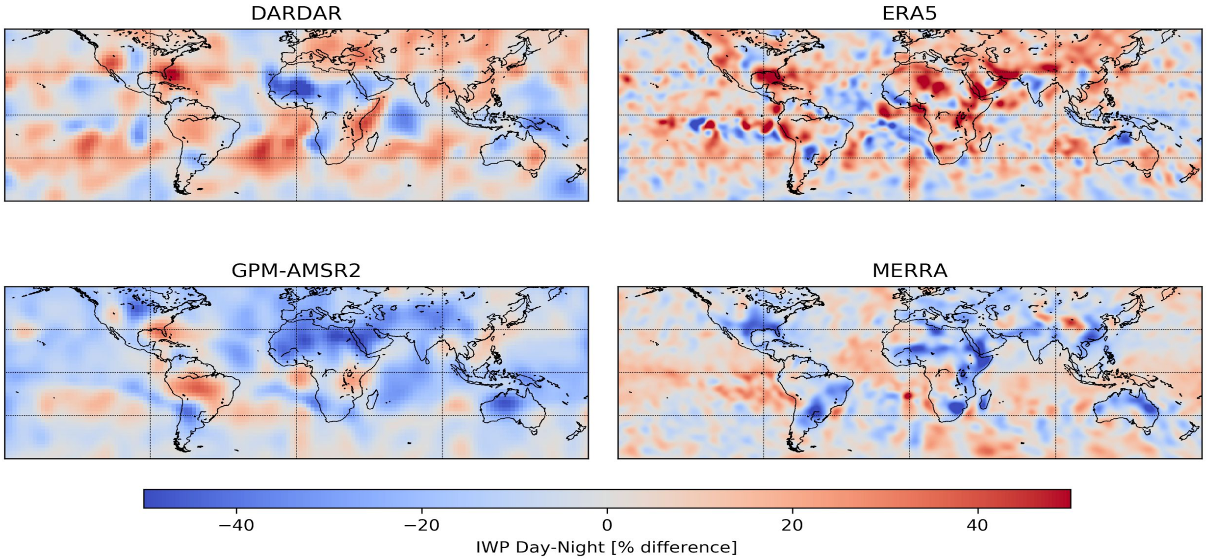


Diurnal Variability

Diurnal variability in IWP is judged by differencing day and night A-Train observation times

Data are smoothed to aid interpretation

ERA5 signal is dominated by large IWP values at tail of distribution



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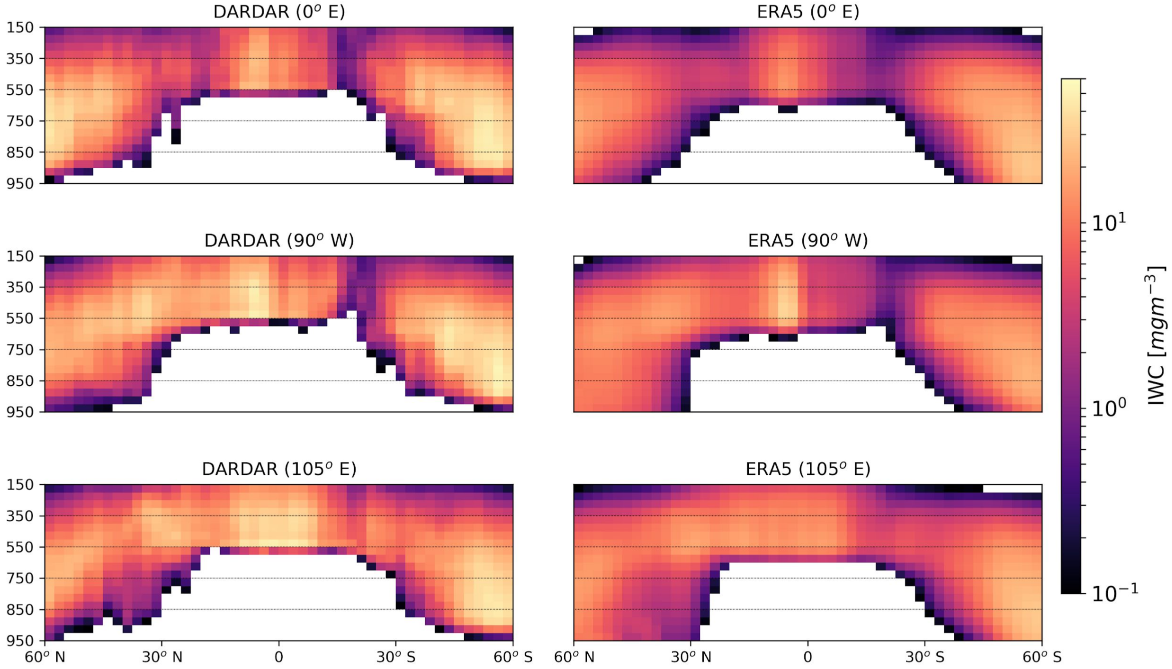
Profiles of Ice

Profiles of ice water content (IWC) from DARDAR and ERA5

Shown at 3 longitude bands using 2 years of data

Directly comparable for total ice if using ERA5 cloud + snow



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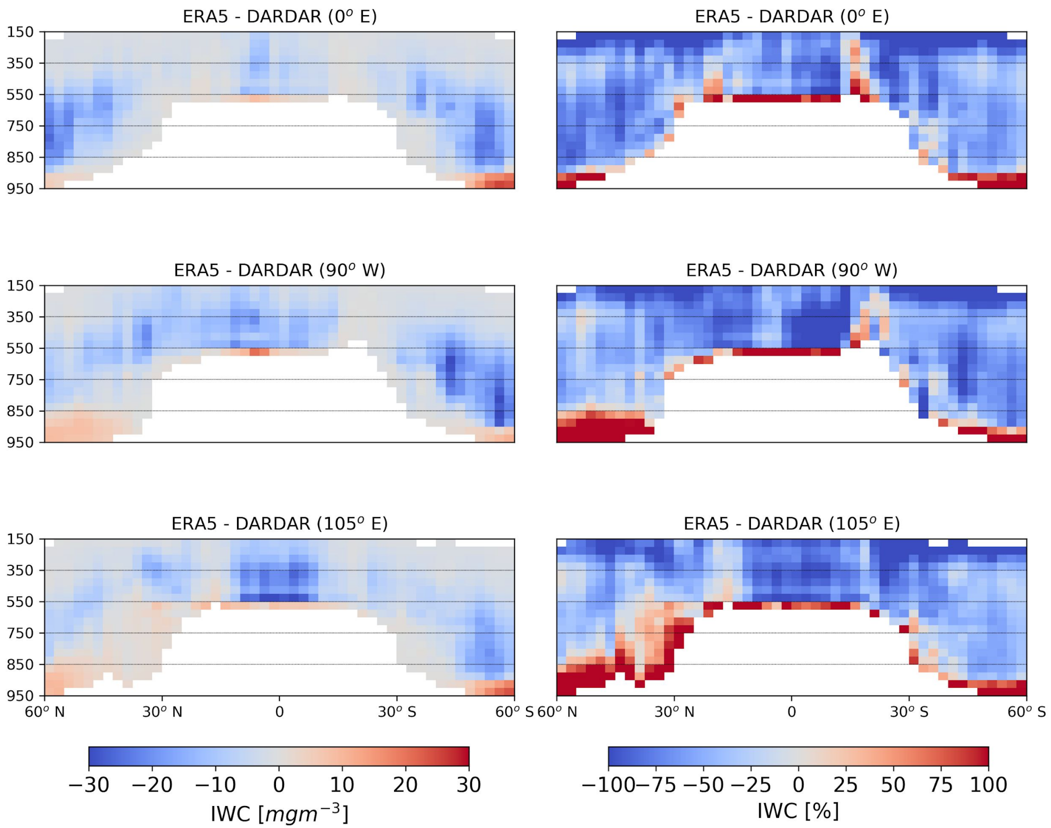

Conclusions

- ❑ Satellite estimates themselves show large discrepancies in IWP magnitude
- ❑ Differentiating precipitating vs. cloud ice is still an issue when comparing observations and models
- ❑ Large-scale variability matches well between datasets, speaking to global circulation of atmospheric ice
- ❑ Diurnal variability shows that smaller scale circulations are not captured well by observations or models
- ❑ Treatment of ice microphysics seems the leading culprit for the differences in magnitude