Tristan L'Ecuyer

CloudSat's Radiative Fluxes and Heating Rates Dataset: Highlights from a Decade of Development and Analyses

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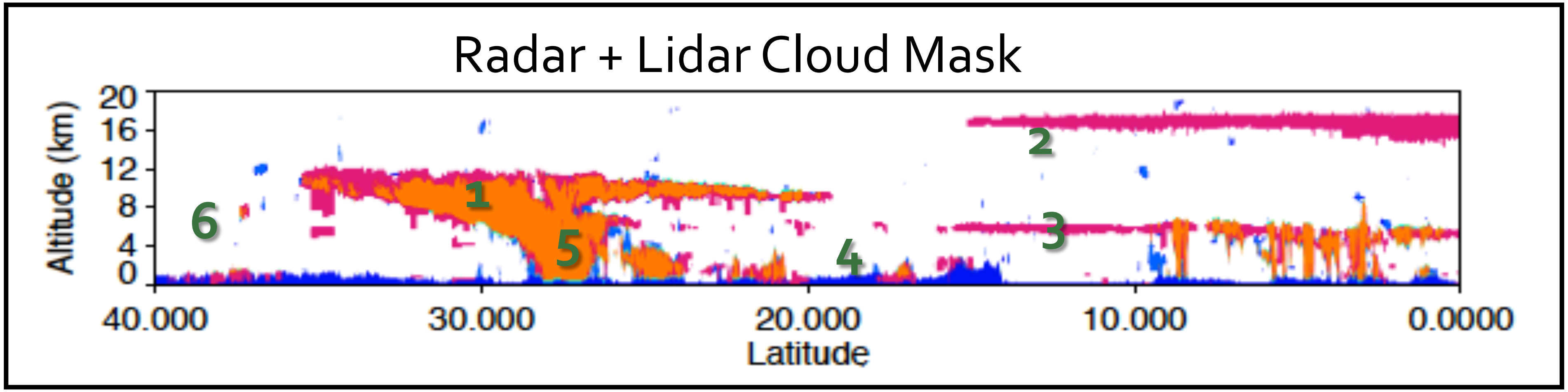
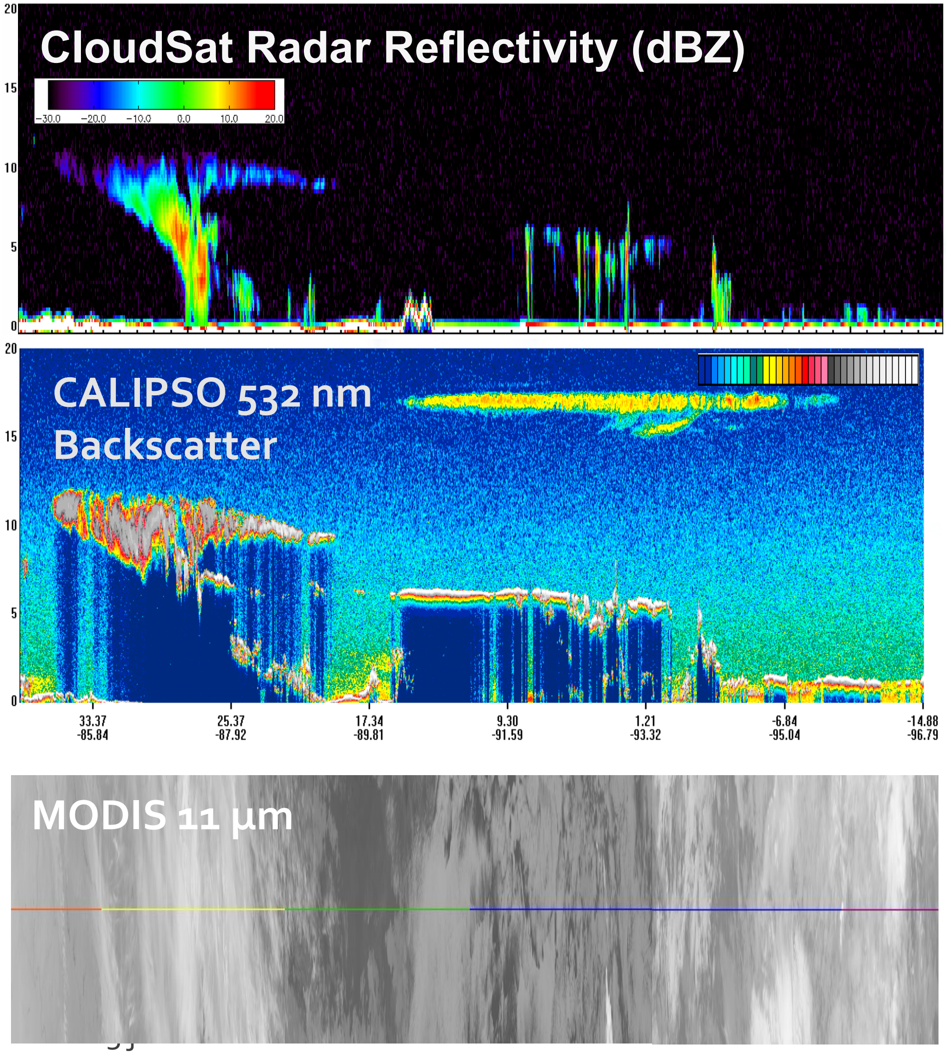
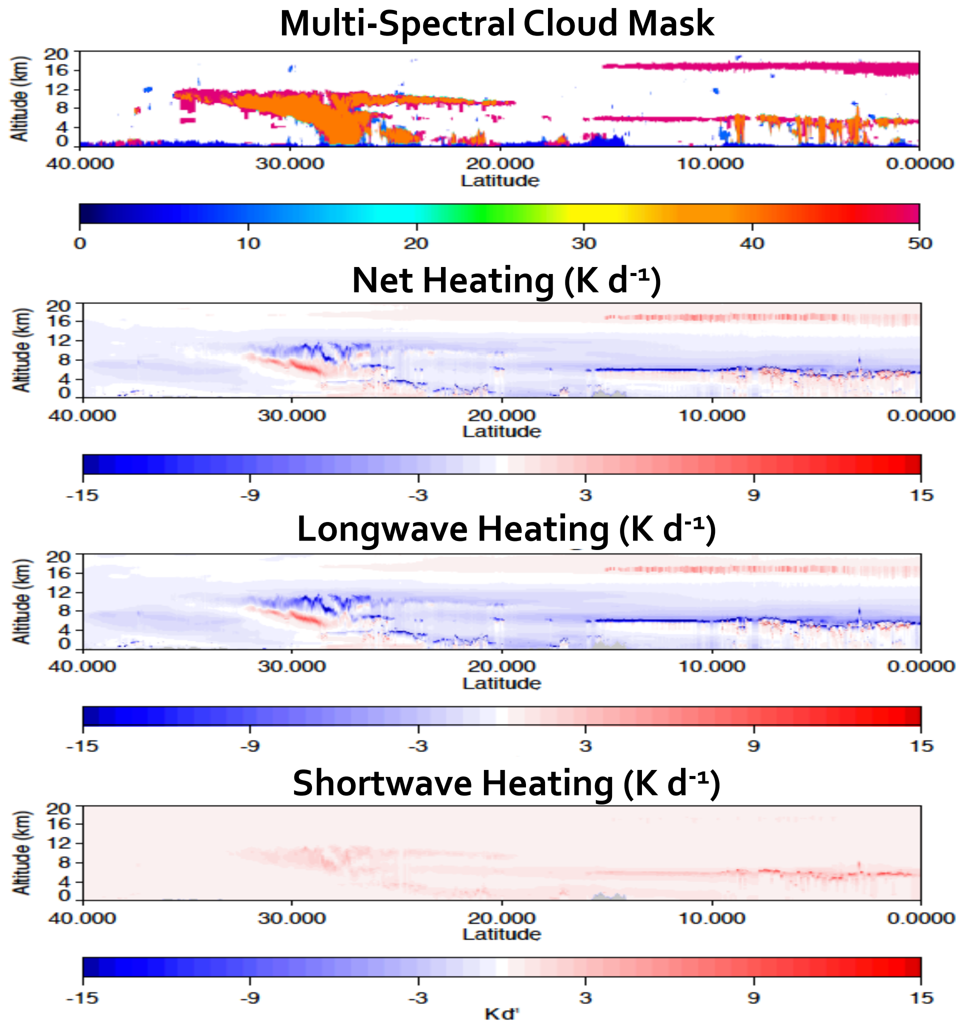
Radiative Fluxes and Heating Rates



2006	• R03 RO	1. Clouds – CloudSat CPR + MODIS optical depth
2016	• R05	2. Sub-visual Cirrus – CALIPSO (5 km Cloud Layer Product)
2016	• R04 R05	3. Stratus/mixed-phase – CALIPSO (identification) + MODIS (microphysical properties)
2009	• R04	4. Aerosol – CALIPSO (5 km Aerosol Layer Product)
2009	• R04	5. Precipitation – explicit rainfall DSD and CloudSat 2C-PRECIP-COLUMN (identification/LWP)
2006	• R03 RO	6. Temperature & Humidity – ECMWF/AIRS (in progress)

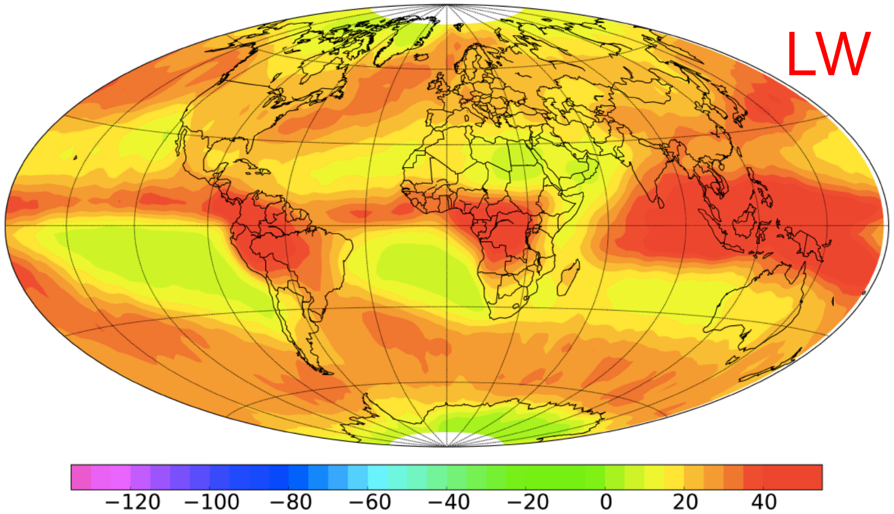
Example

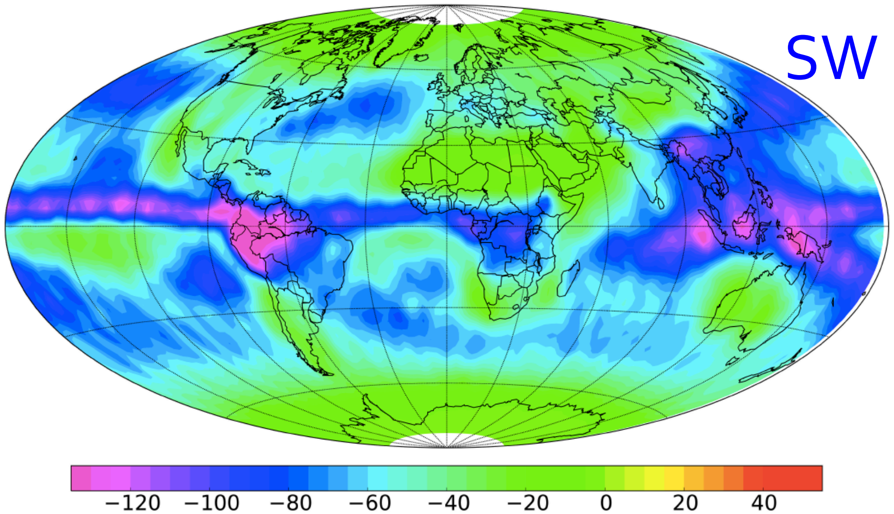


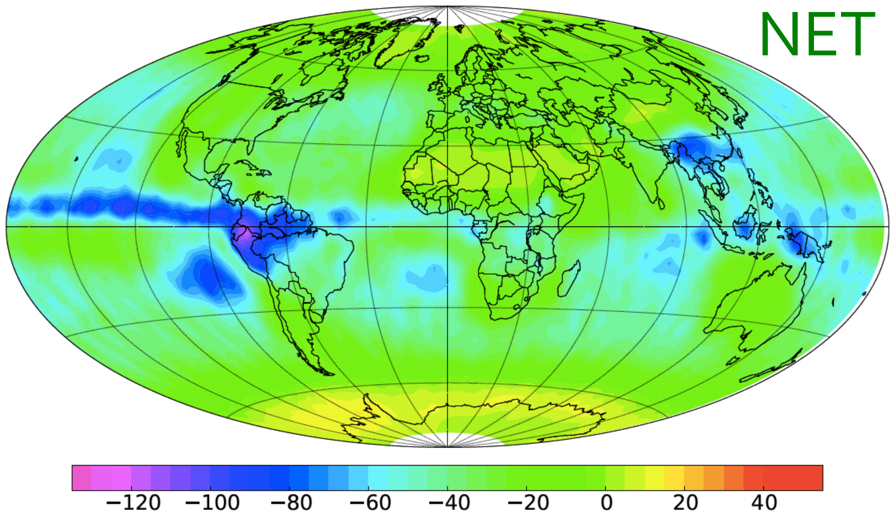


L'Ecuyer et al., *J. Geophys. Res.* (2008)

Estimates of Global CRE

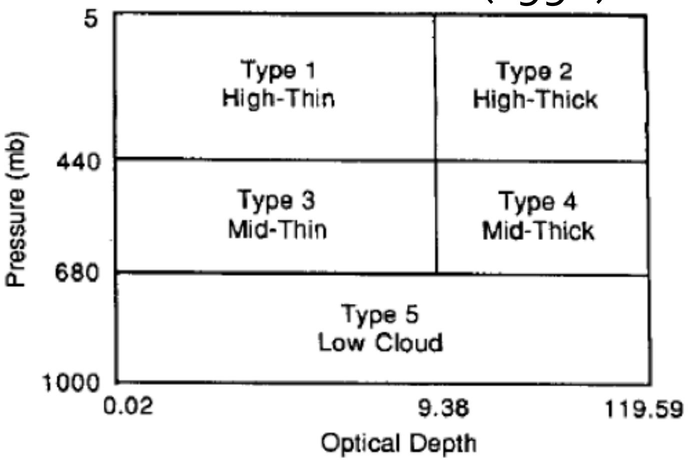




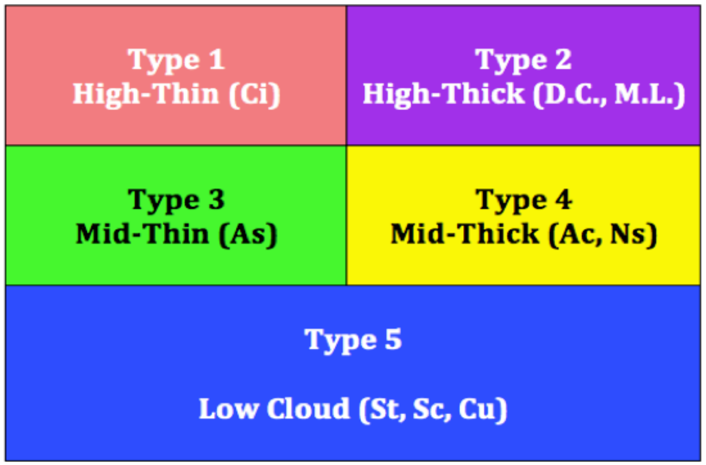


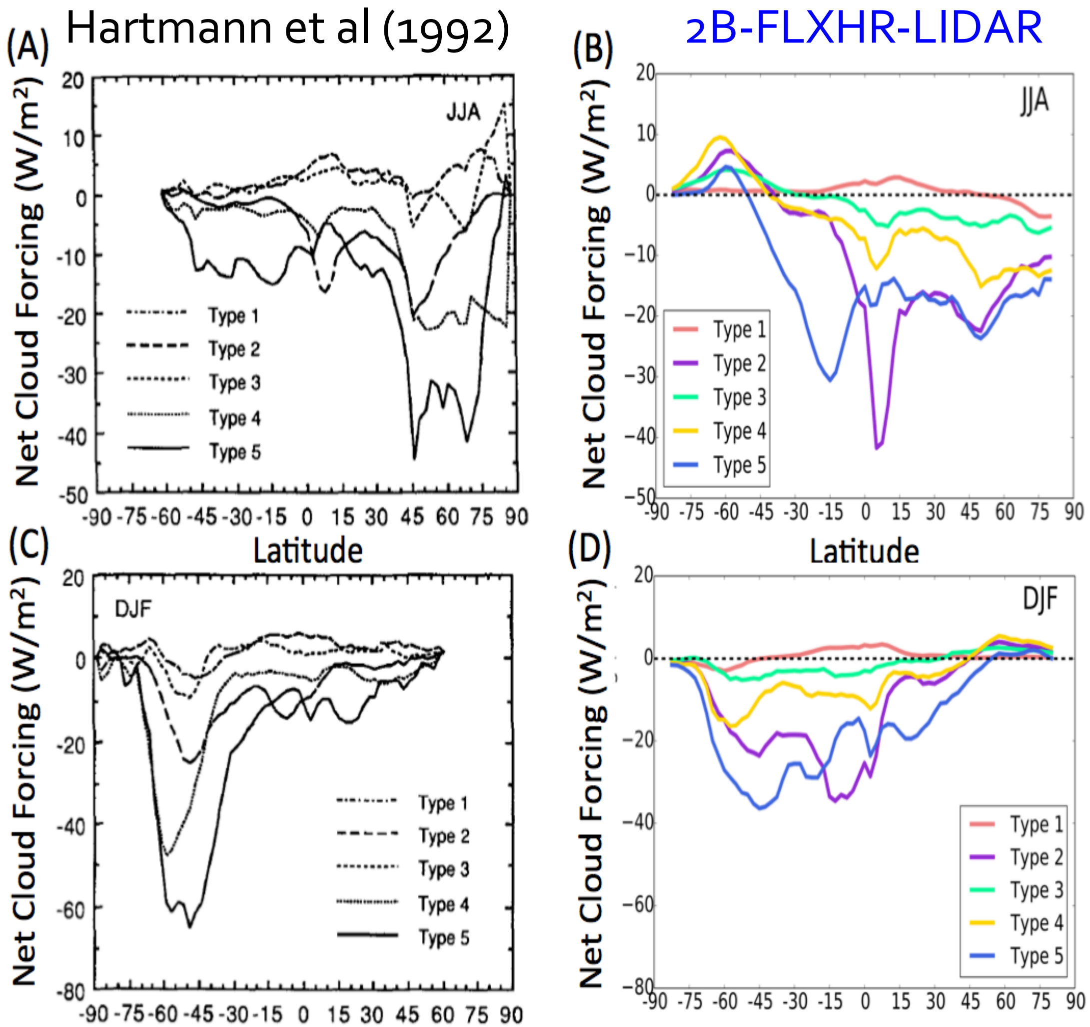
Revisiting Partitioning

Hartmann et al (1992)

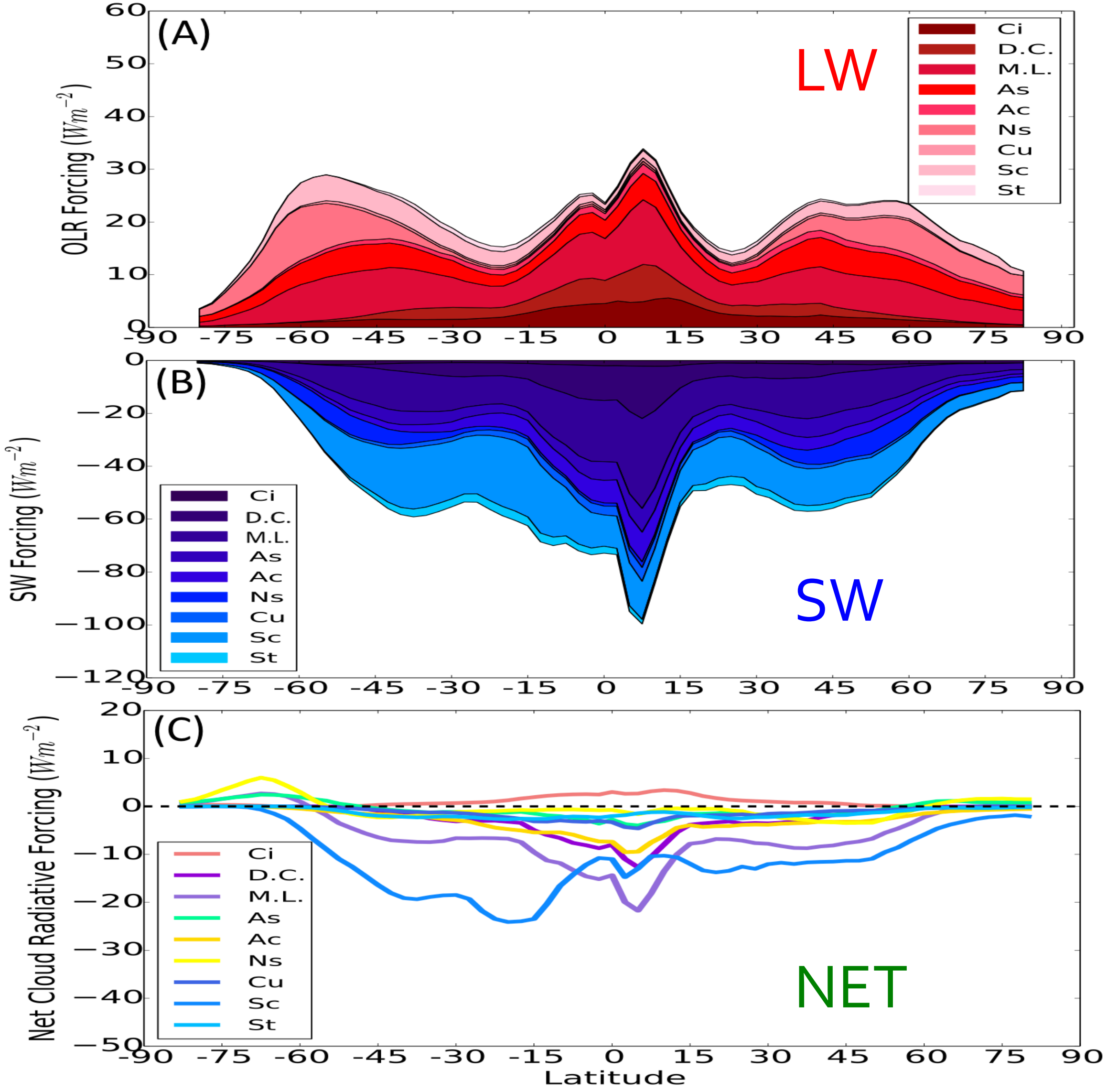


2B-FLXHR-LIDAR

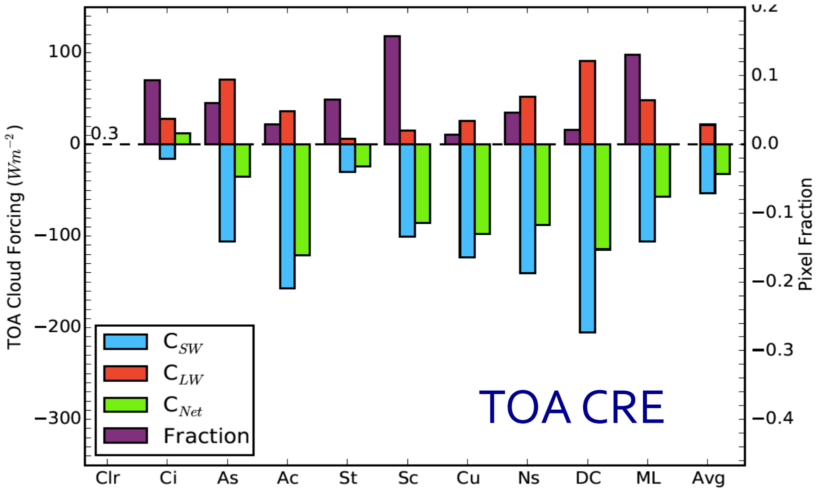


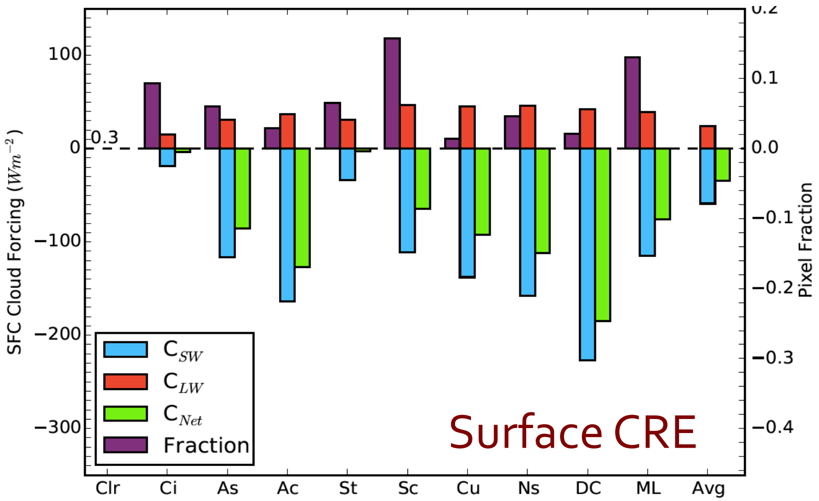


Full Decomposition

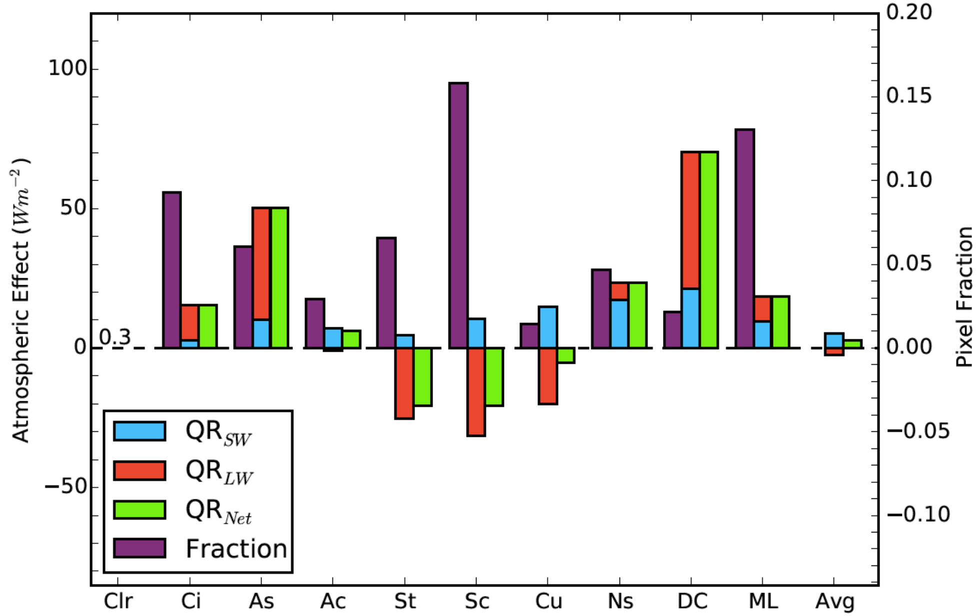


New Insights into Surface and Atmospheric Impacts





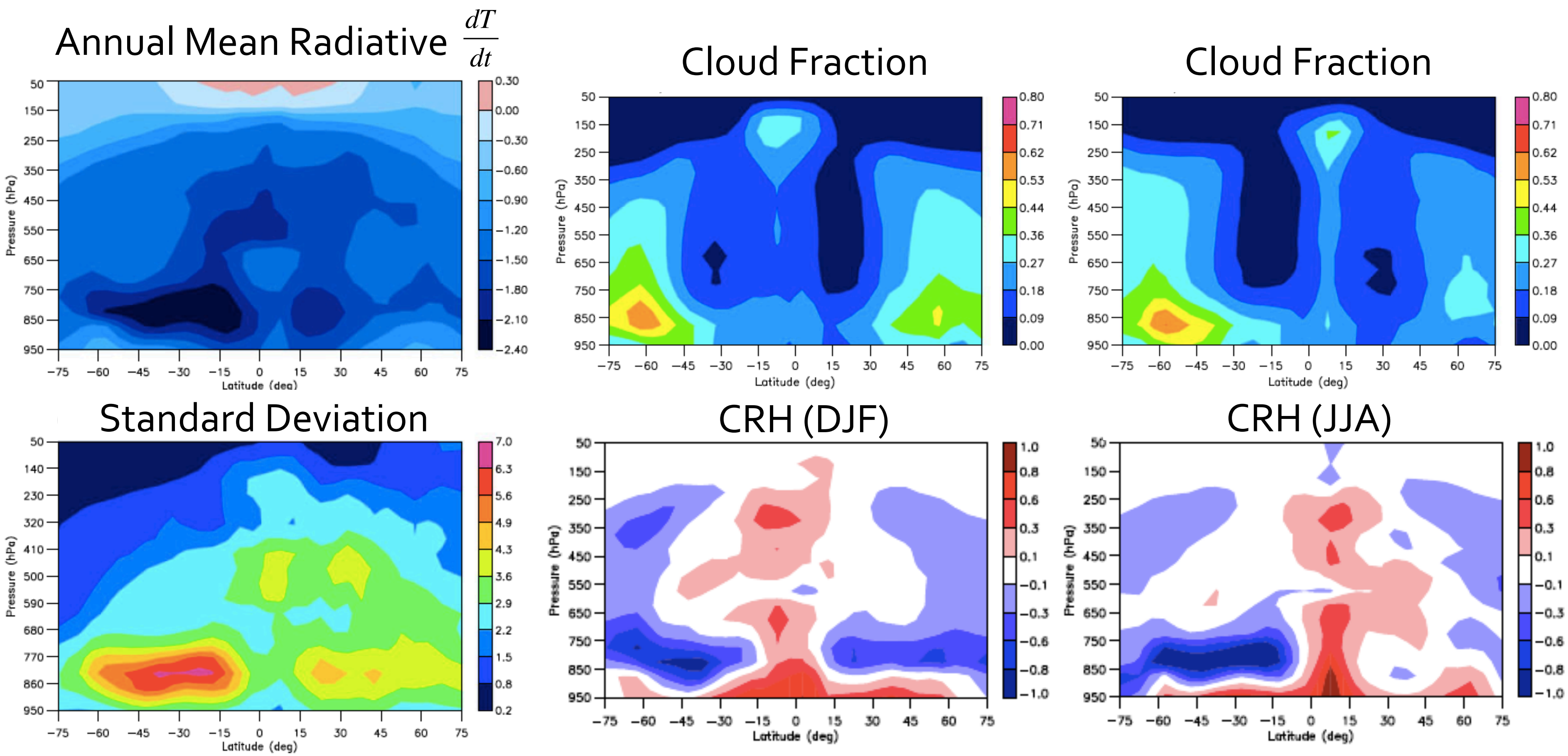
Cloud Impact on Atmospheric Heating



Hang and L'Ecuyer, 2016, *in preparation*

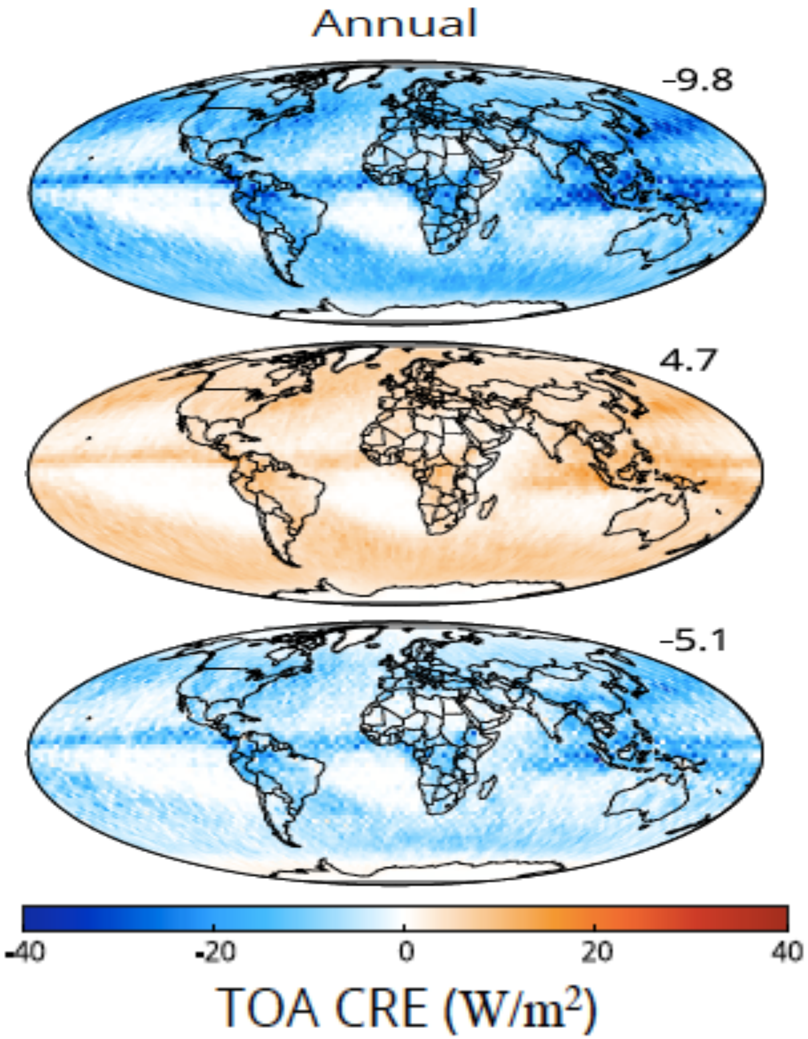
Also: Stephens et al, *J. Climate* (2012)

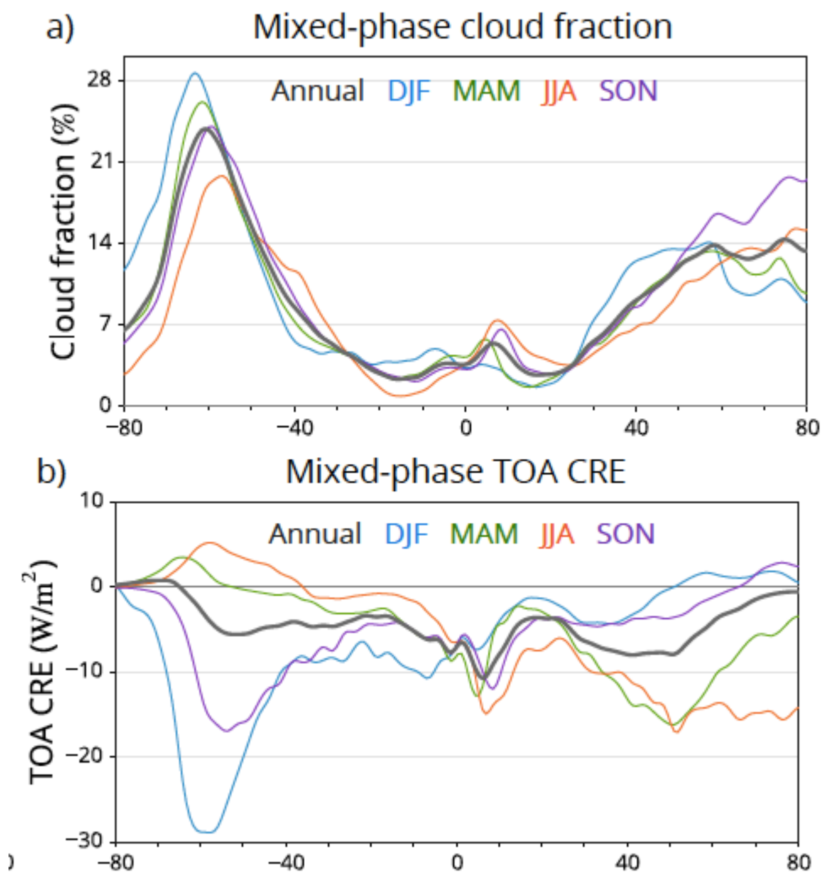
Adding The Vertical Dimension



Haynes et al., *Geophys. Res. Letters* (2013)

Mixed-Phase Clouds

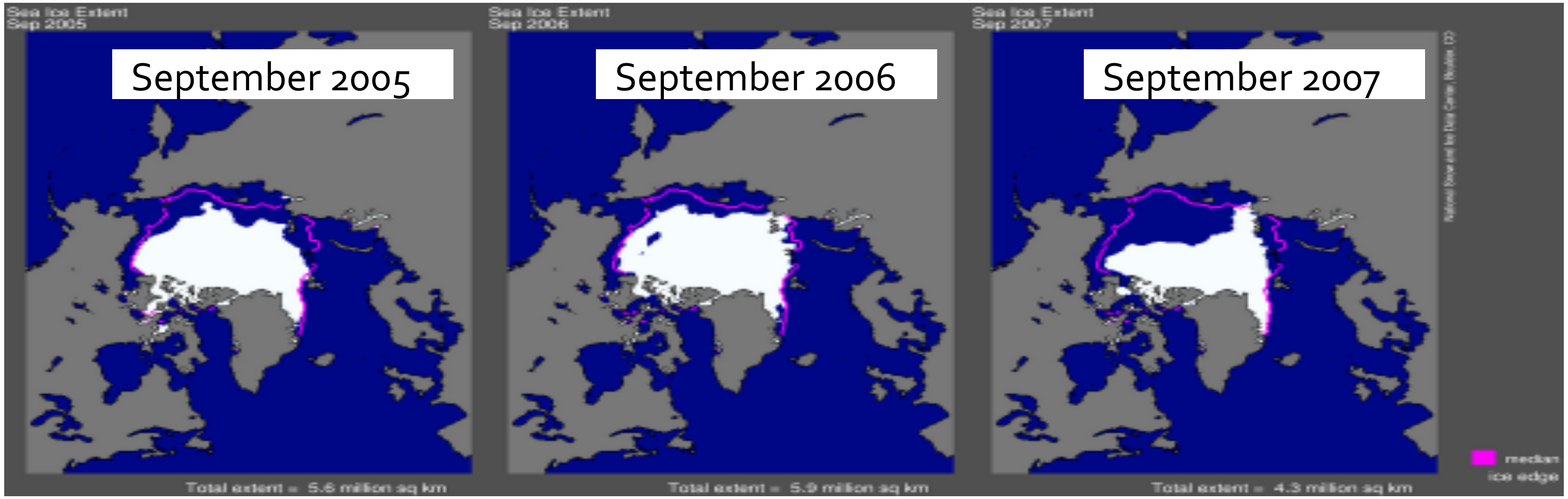


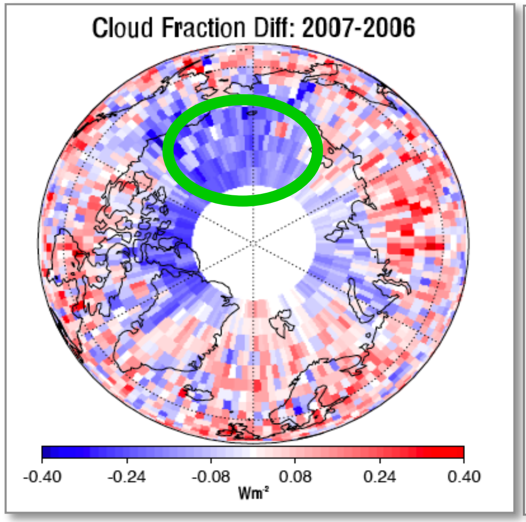


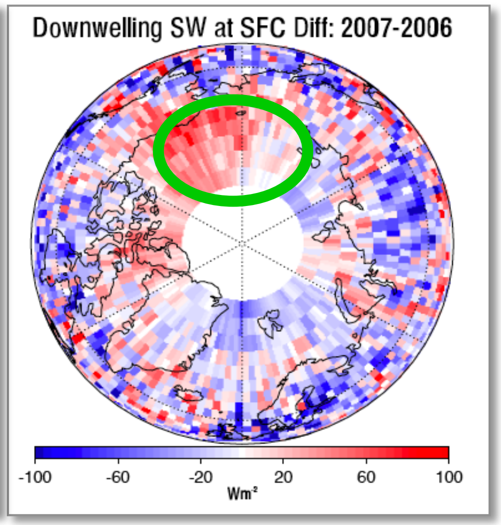
Matus et al., 2016, *in preparation*


Cloud Influences in The Arctic
PHOTOGRAPH BY PAUL NICKLEN, National Geographic

Summertime Clouds and Sea Ice



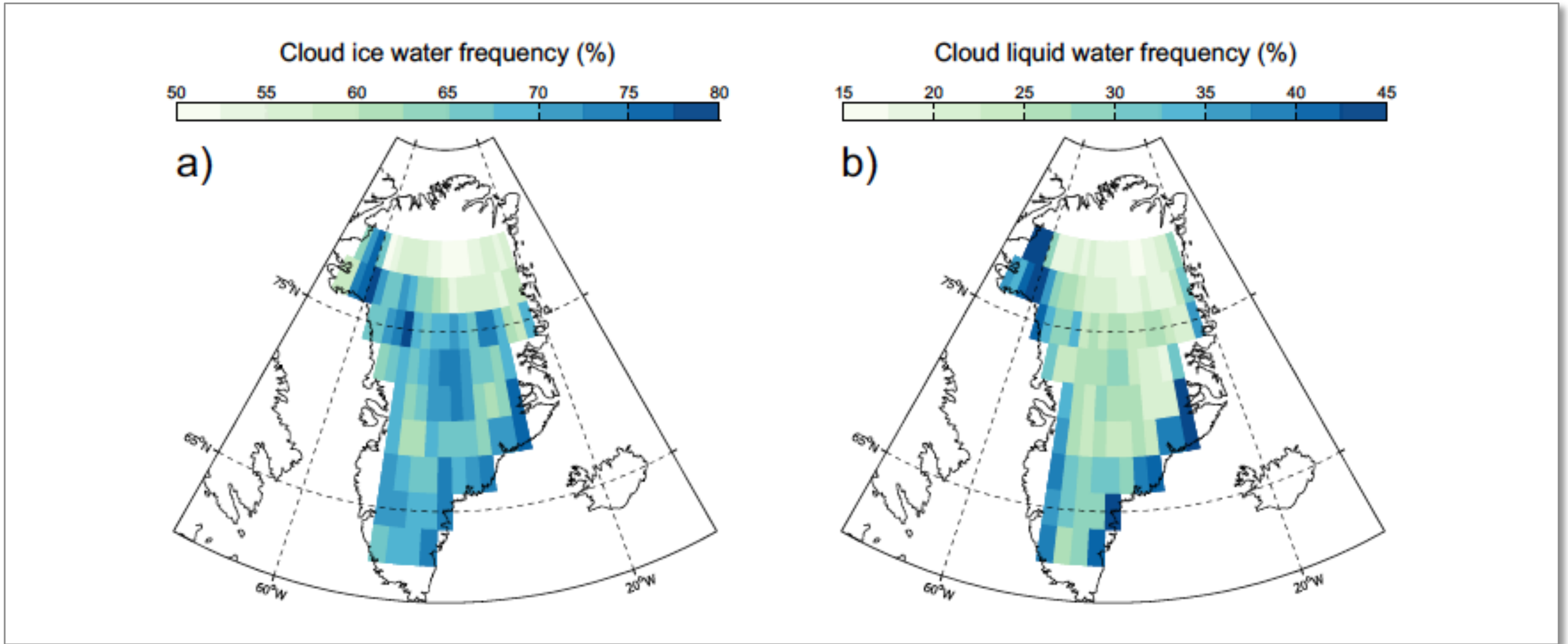




- 30 Wm^{-2} over 3 months is enough energy to melt about 0.3 m of sea ice or warm the ocean mixed layer by 2.5 K.

Kay et al., *Geophys. Res. Letters* (2008)

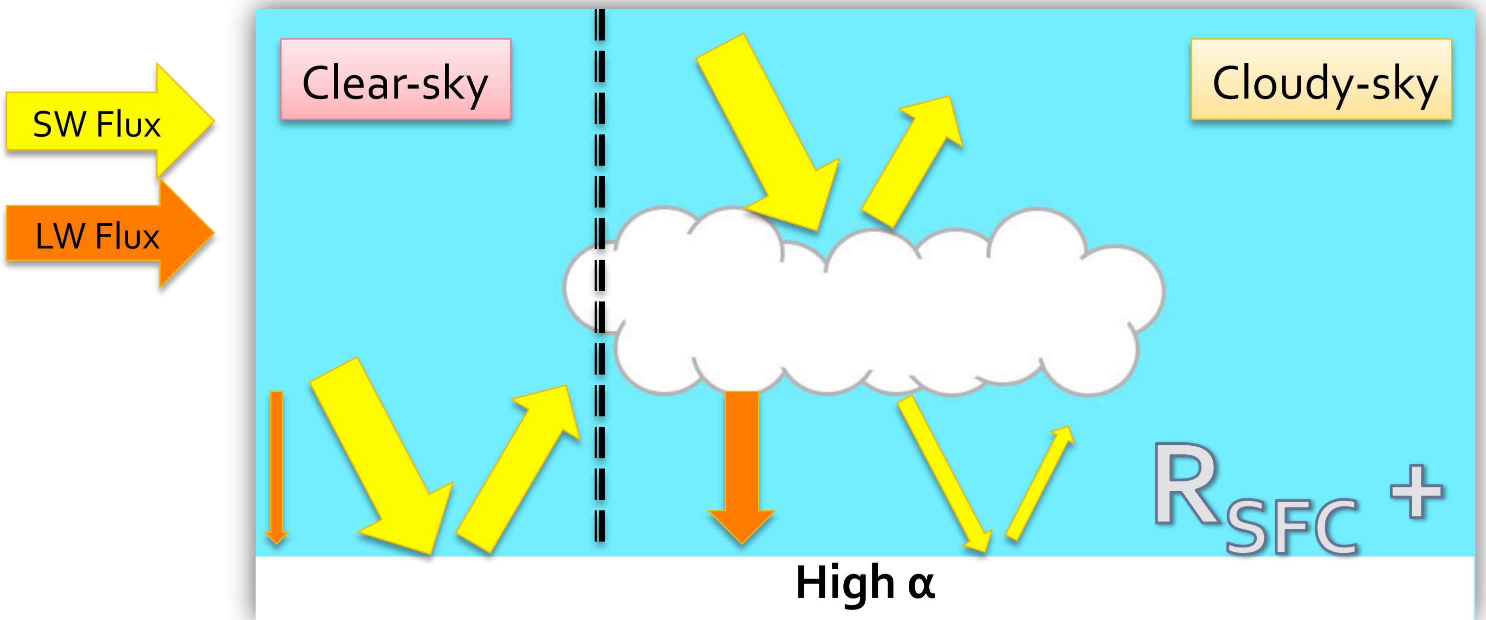
Role of Clouds in Ice Sheet Melt



- On average, more than 40% of the clouds over the Greenland Ice Sheet contain super-cooled liquid water (70% in summer, 25% in winter).

Cloud Impacts on the Ice Sheet

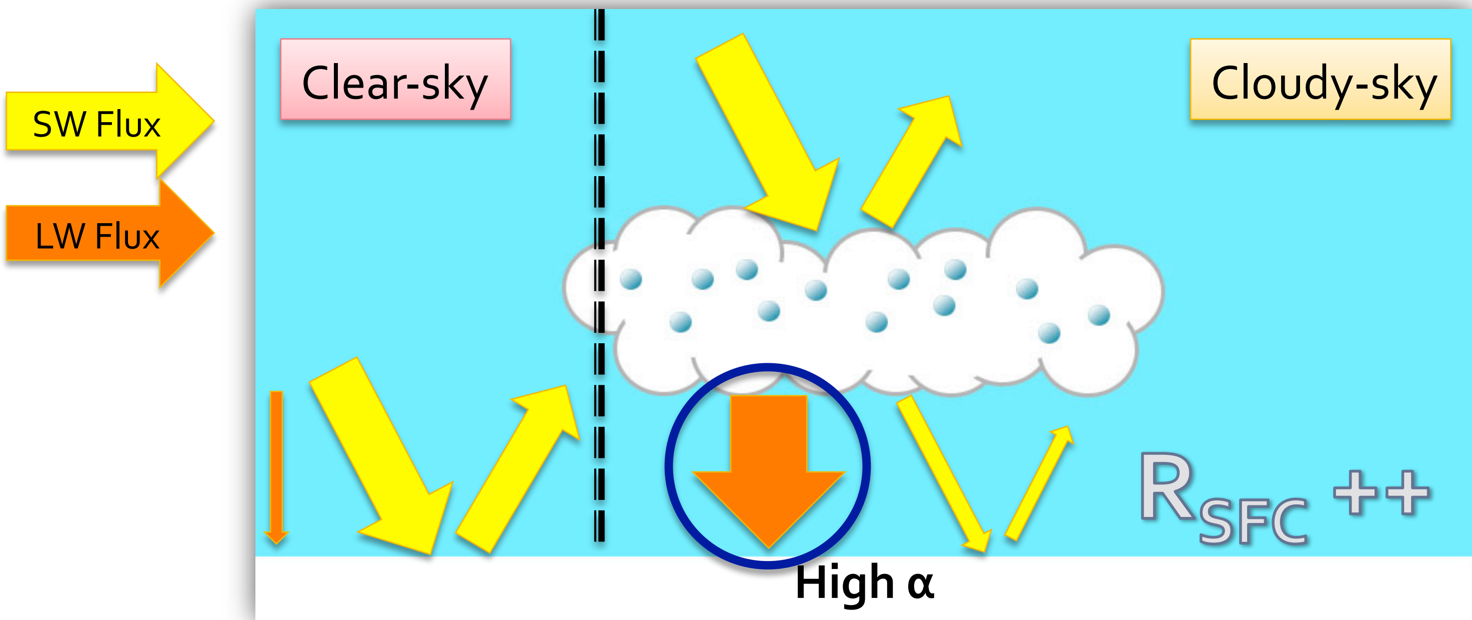
$$R_{sfc} = F_{LW}^{\downarrow} + F_{SW}^{\downarrow} - F_{LW}^{\uparrow} - F_{SW}^{\uparrow} \approx (\varepsilon_{atm} - 1)\sigma T_{sfc}^{4} + (1 - \alpha)F_{SW}^{\downarrow}$$



Over bright surfaces, enhanced ε_{atm} is the dominant cloud effect

The Role of Super-cooled Liquid

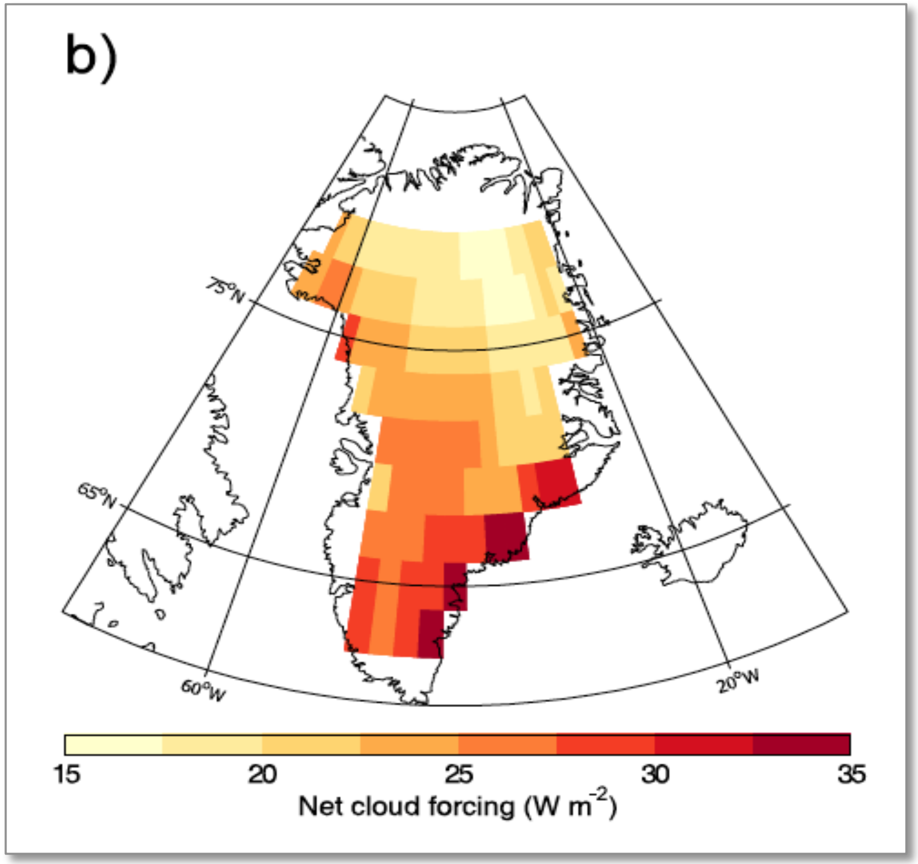
$$R_{sfc} = F^{\downarrow}_{LW} + F^{\downarrow}_{SW} - F^{\uparrow}_{LW} - F^{\uparrow}_{SW} \approx (\varepsilon_{atm} - 1)\sigma T^{4}_{sfc} + (1-\alpha)F^{\downarrow}_{SW}$$



The presence of super-cooled liquid enhances the cloud effect on ε_{atm}

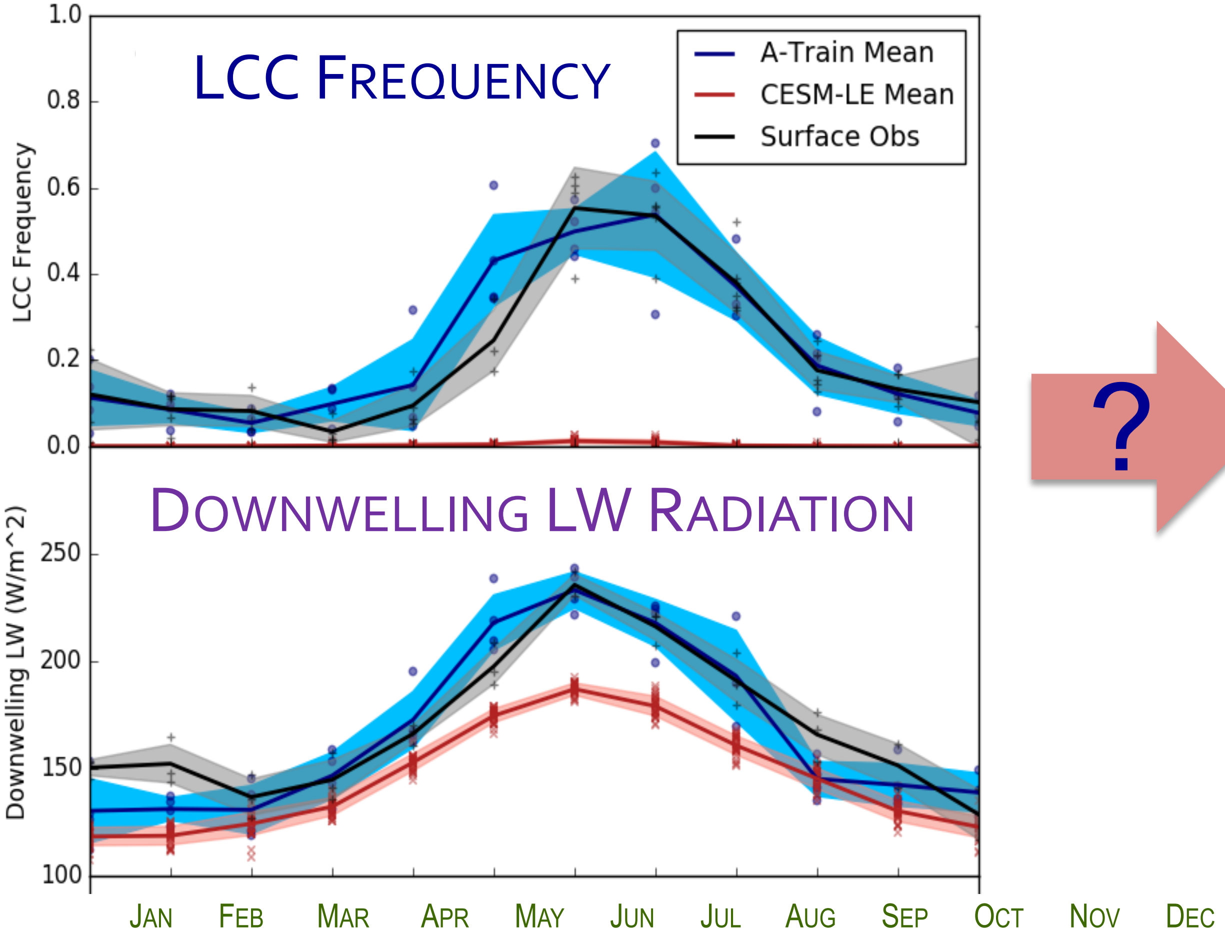
Implications for Sea Level Change

- Clouds enhance the net surface radiation on the ice sheet by an average of nearly 30 ± 6 Wm^{-2} relative to clear conditions.
- Unfrozen liquid droplets account for HALF of this forcing.
- This is enough energy to melt up to 90 Gt of ice each year.
- Surface modeling suggests that this effect results in about 25 Gt of additional runoff each year after warming and sublimation are accounted for.



van Tricht et al., *Nature Comm.* (2016)

Identifying Model Biases



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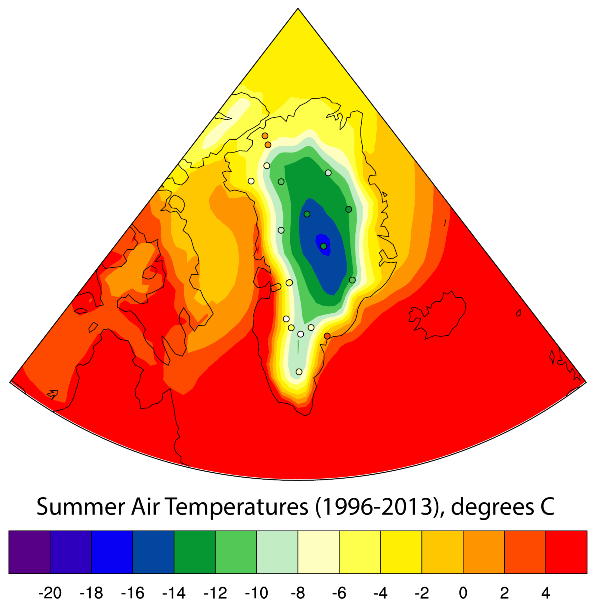
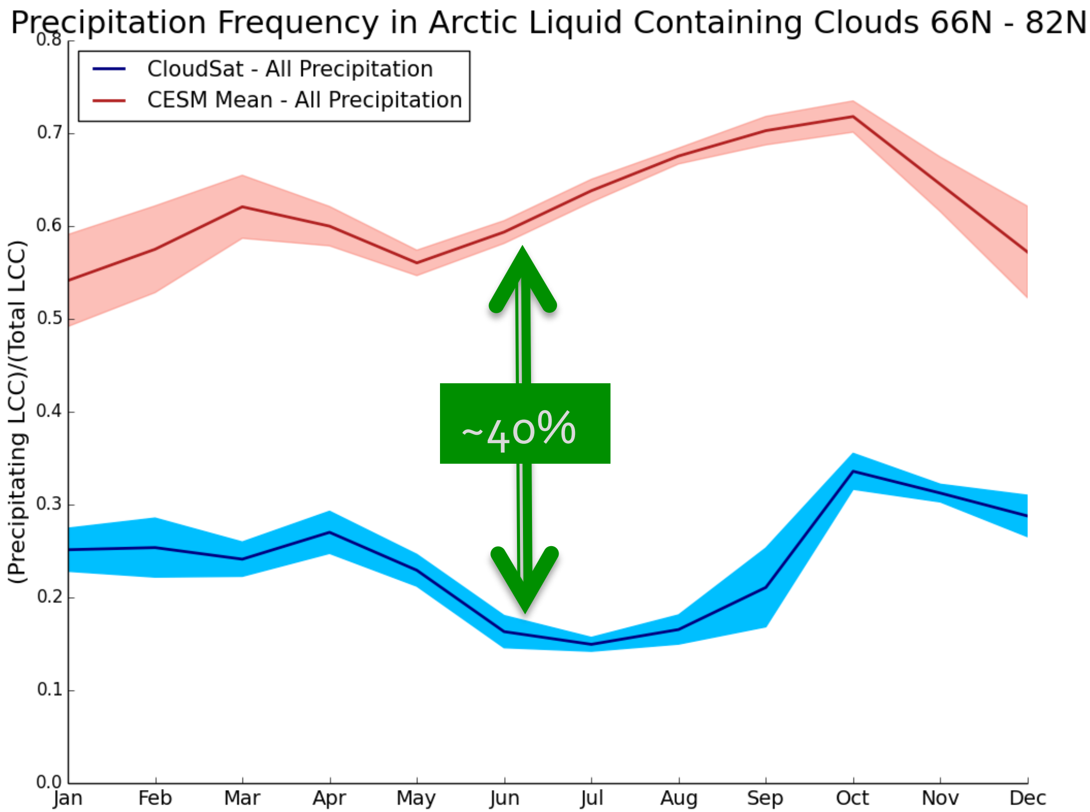
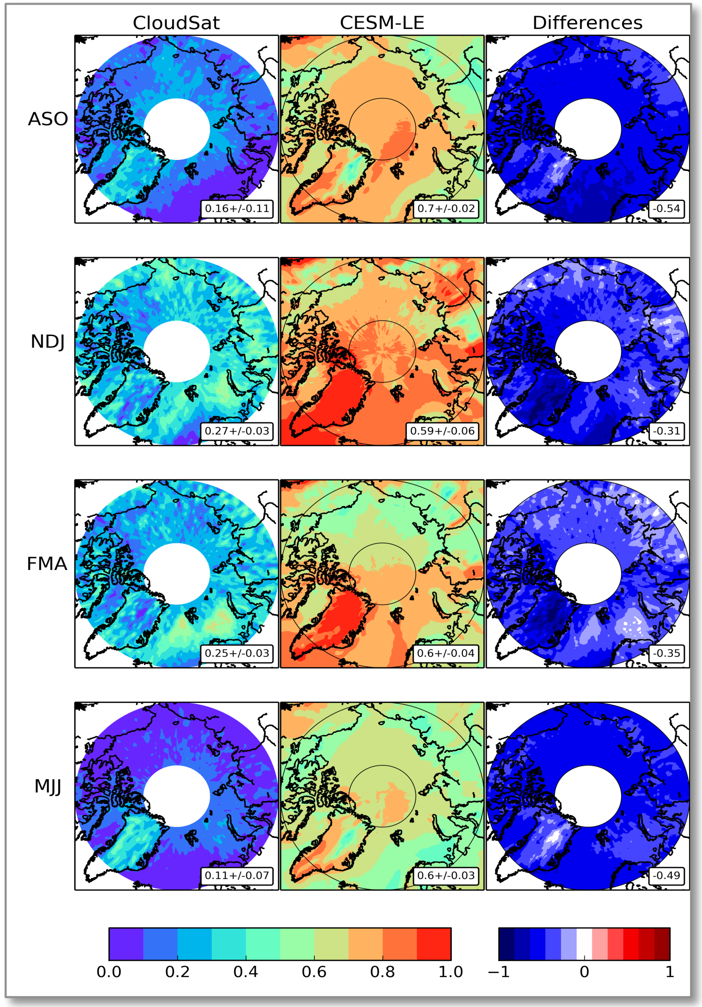


Greenland is too cold in CESM.

Connecting to Processes

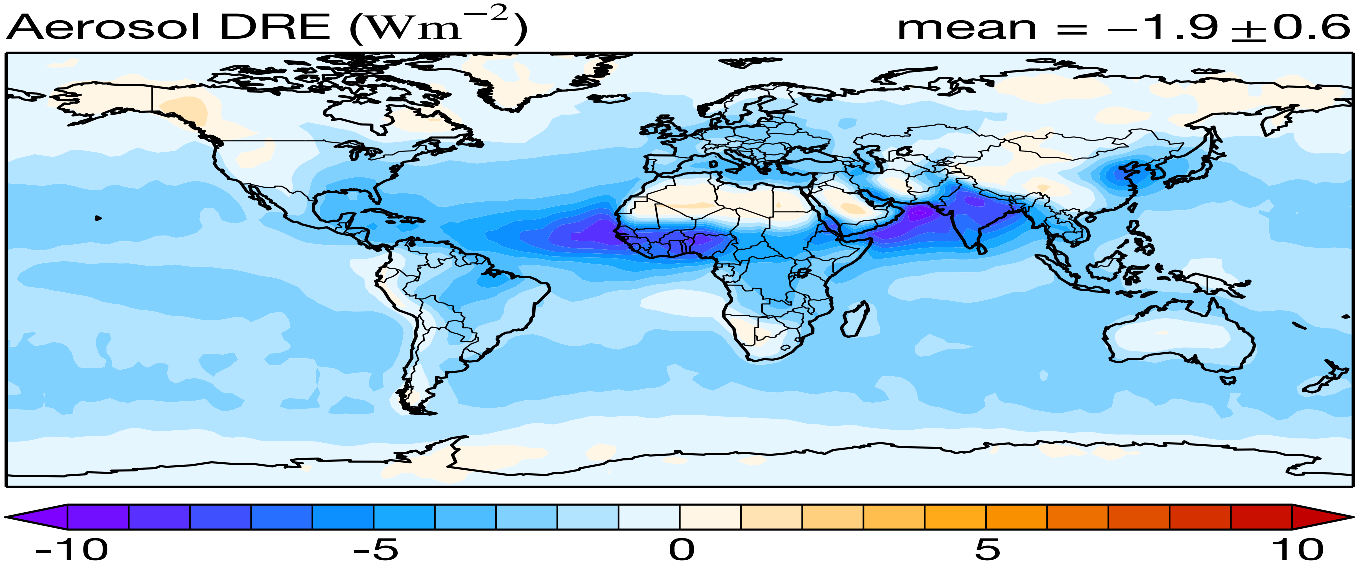
PRECIPITATION FREQUENCY OF ARCTIC LIQUID CONTAINING CLOUDS

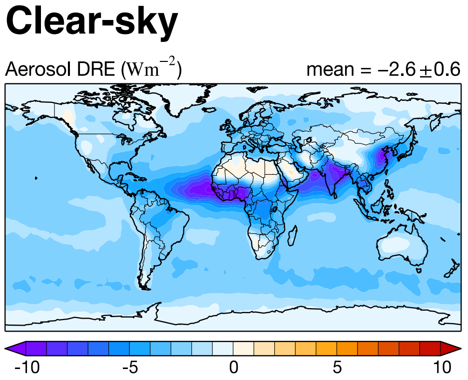


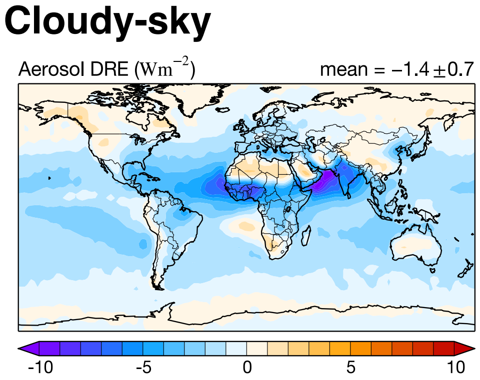


McIlhattan et al., in preparation

Impacts of Clouds on Aerosol Direct Effects

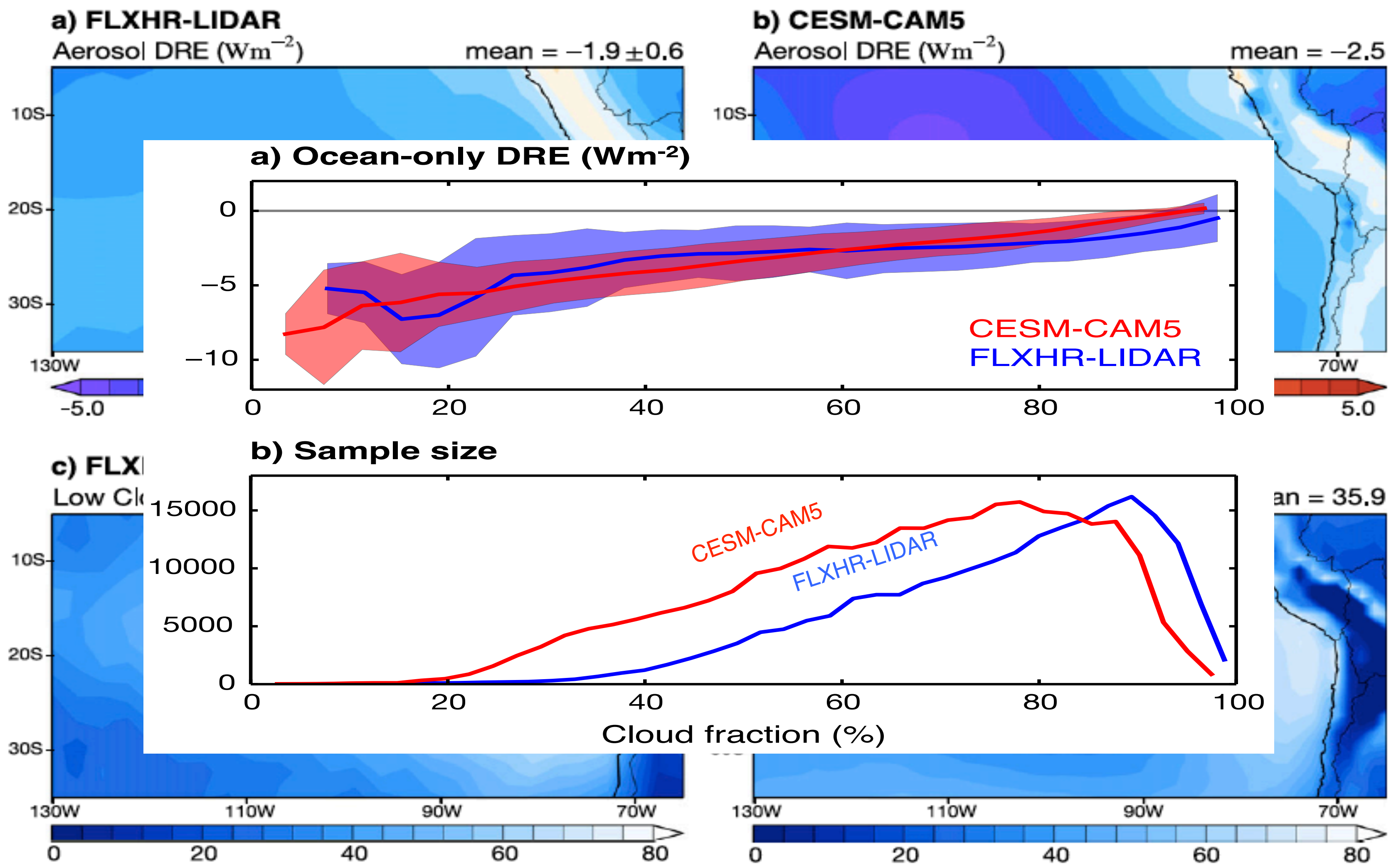






ADRE (Wm^{-2})	Clear sky	Cloudy sky	All-sky
Land	-2.2	-0.9	-1.5
Ocean	-2.6	-1.5	-2.0
Global	-2.6 ± 0.6	-1.4 ± 0.7	-1.9 ± 0.6

Impacts of Model Cloud Biases



Matus et al., *J. Climate* (2015)

Summary

- After 10 years in orbit, CloudSat and CALIPSO are shedding new light on the classical problem of establishing the role of clouds and aerosols in the Earth's radiation budget.
- Estimates of cloud radiative forcing, its vertical structure, and the relative contributions of individual cloud types need to be revised in light of these new active observations.
- Mixed-phase clouds exert a strong impact on mass balance of the Greenland Ice Sheet that appears to be under-represented in models.
- CloudSat and CALIPSO provide insights into the influence of clouds on aerosol direct radiative effects (ADRE) and have identiyfied a connection between model ADRE and cloud biases.

References

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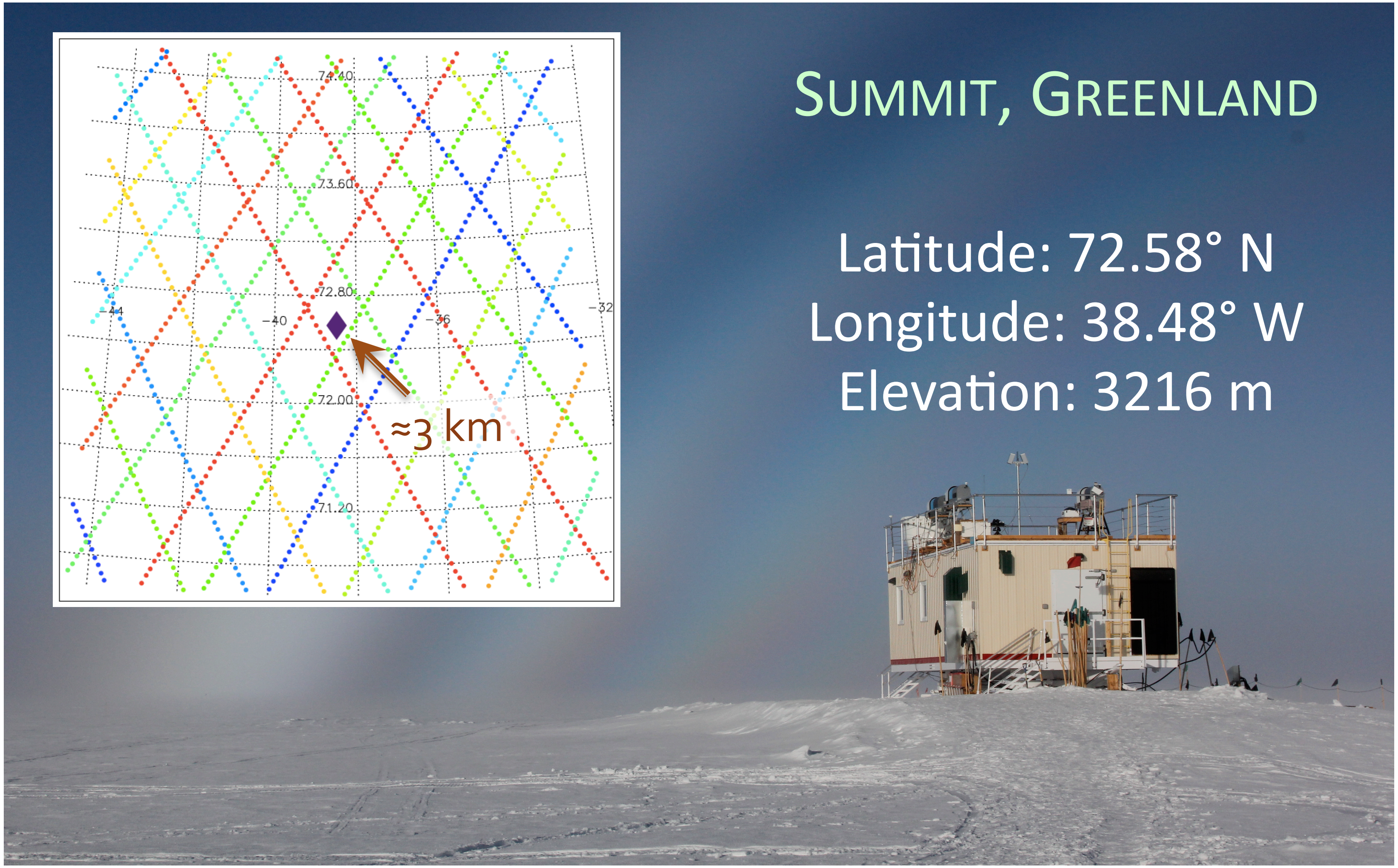
Extra Materials…

Summit Station Observations



Downward LW Flux Comparisons