

Northern Alaska Site Science: Surface energy forcing from low-level Arctic clouds and the changing environment supporting their development



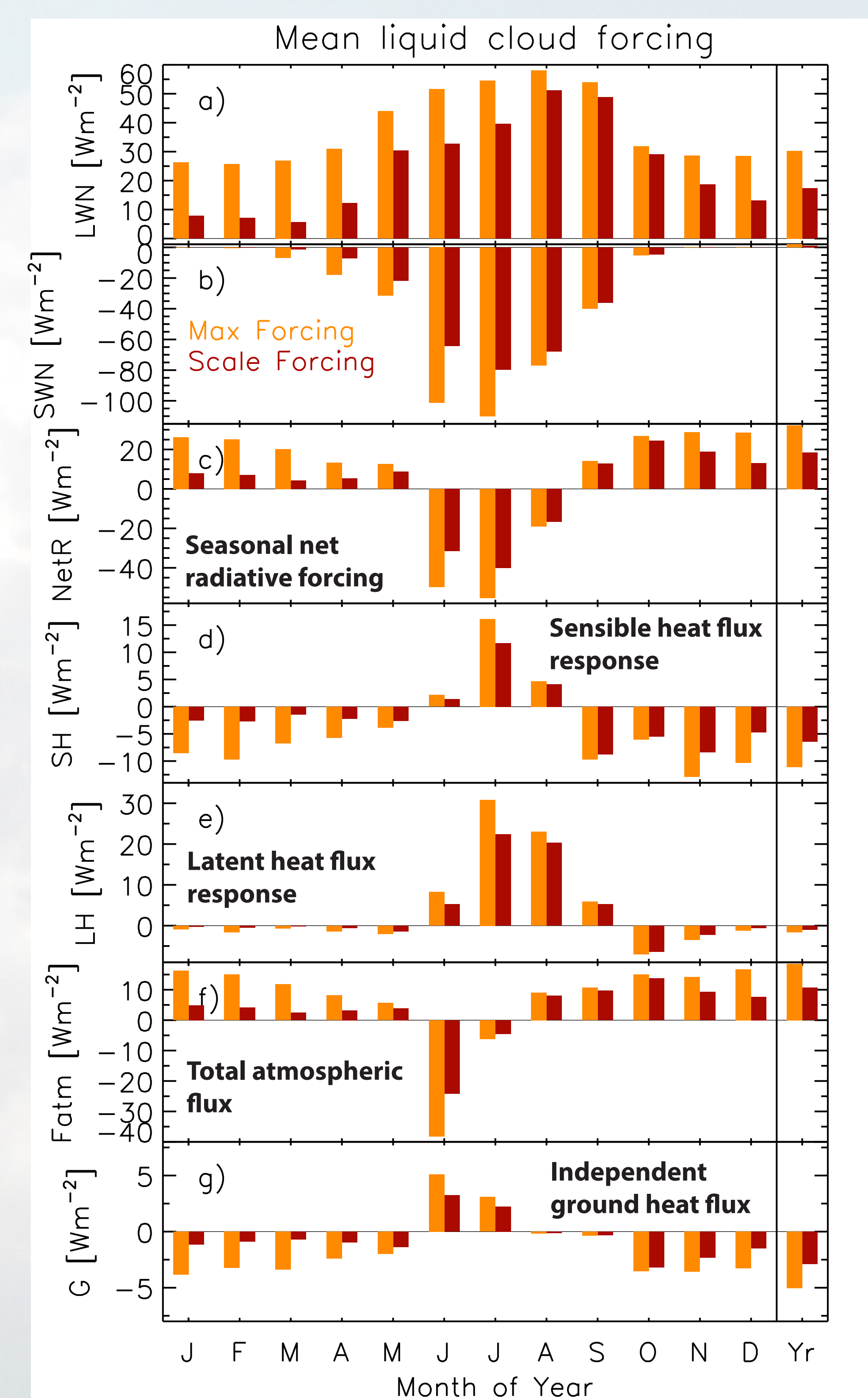
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Introduction

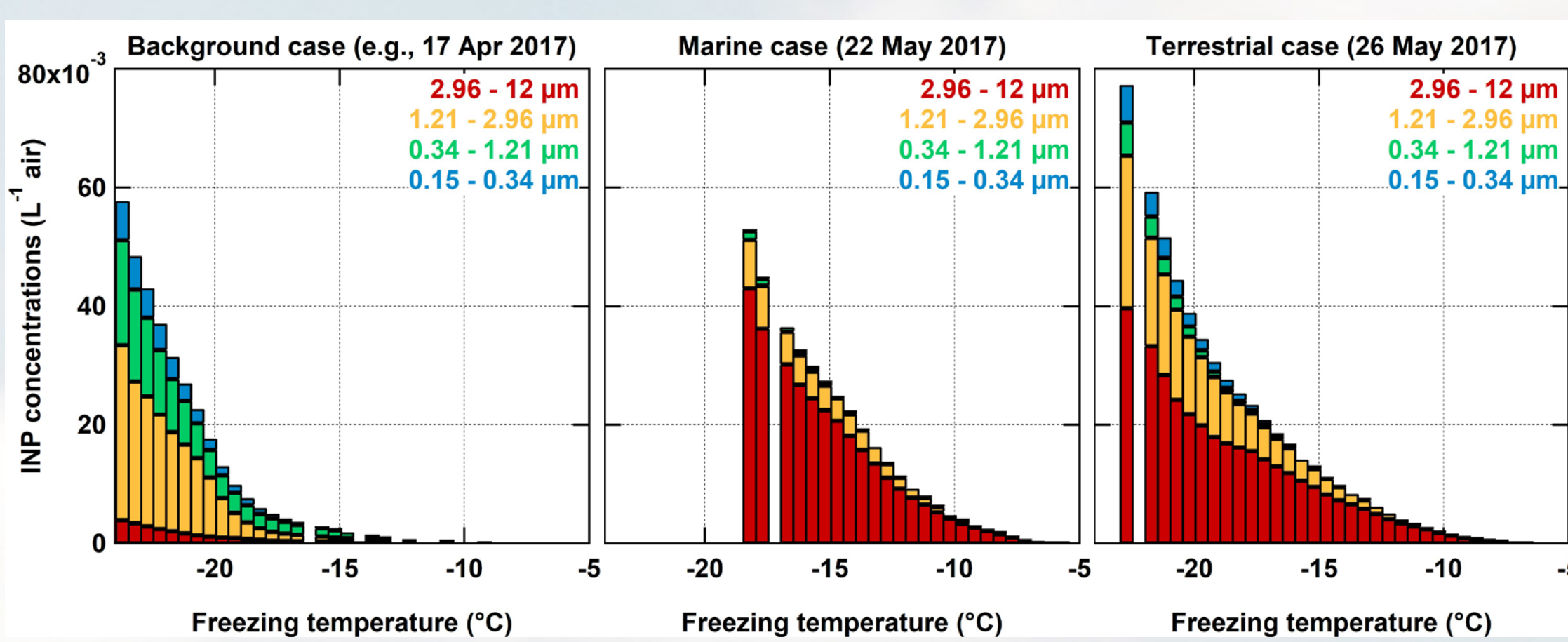
Clouds play a critical role in the Arctic climate system, seasonally warming or cooling the surface through radiative forcing. Ultimately cloud impacts on the surface energy budget are determined by various factors, including large-scale meteorological patterns, surface properties, and aerosol conditions. Low clouds are of particular climatological importance. These clouds are more likely to contain liquid and therefore have larger positive or negative cloud radiative forcing values. We believe that lower-tropospheric Arctic cloud properties may be particularly sensitive to variability in sea ice coverage and southerly advection patterns, in part because of the aerosol properties associated with those conditions. Here, we offer various perspectives on low clouds observed over northern Alaska, providing insight on how they influence the surface energy budget and how they may respond to changes in atmospheric and surface states.

Low Cloud Forcing

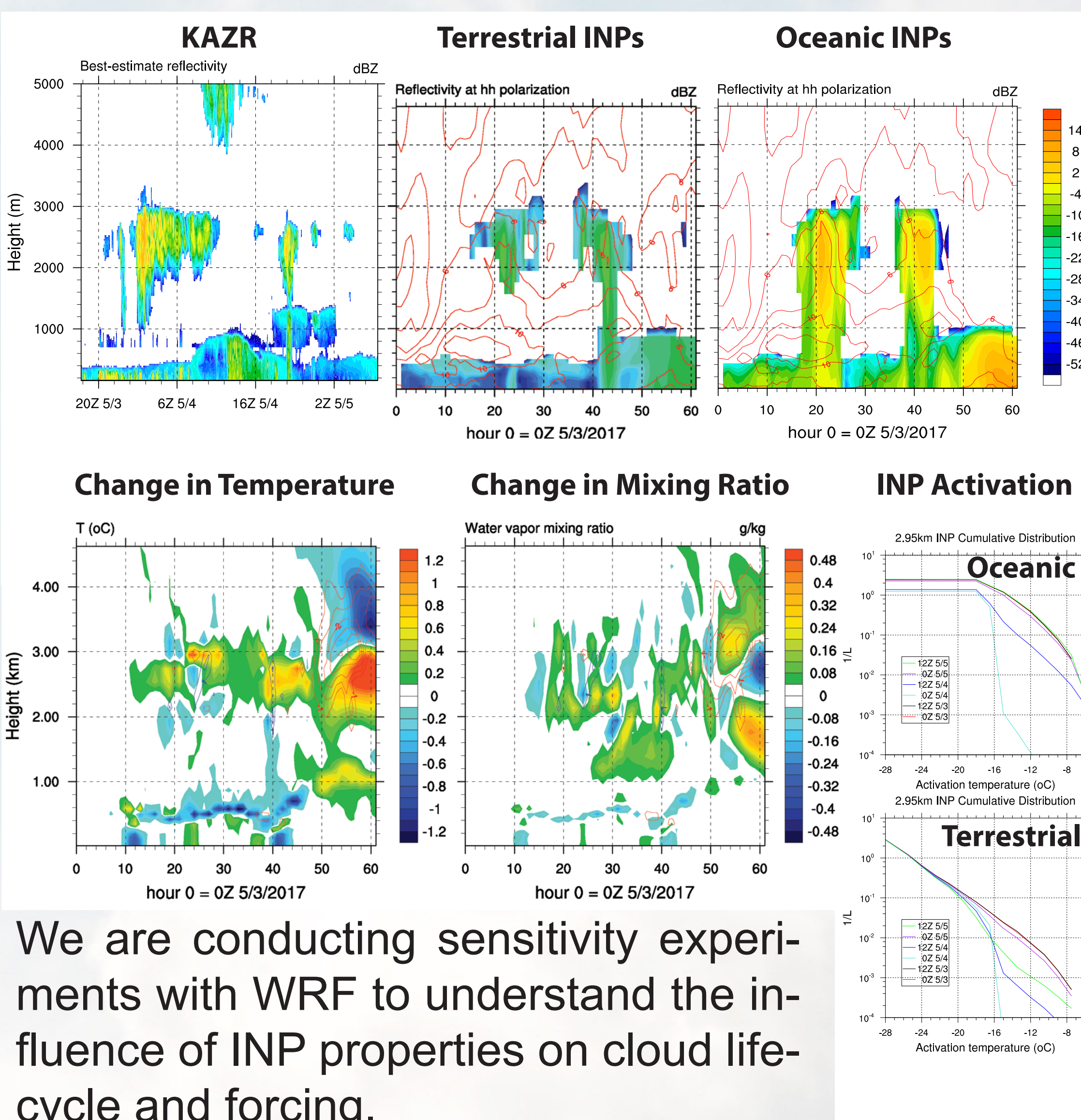


Using NSA data, we document the overall influence of clouds on the different terms of the surface energy budget. **Max Forcing** is the difference between opaquely cloudy and radiatively clear sky states of the atmosphere. **Scale Forcing** is **Max Forcing** scaled by the fractional occurrence of liquid clouds.

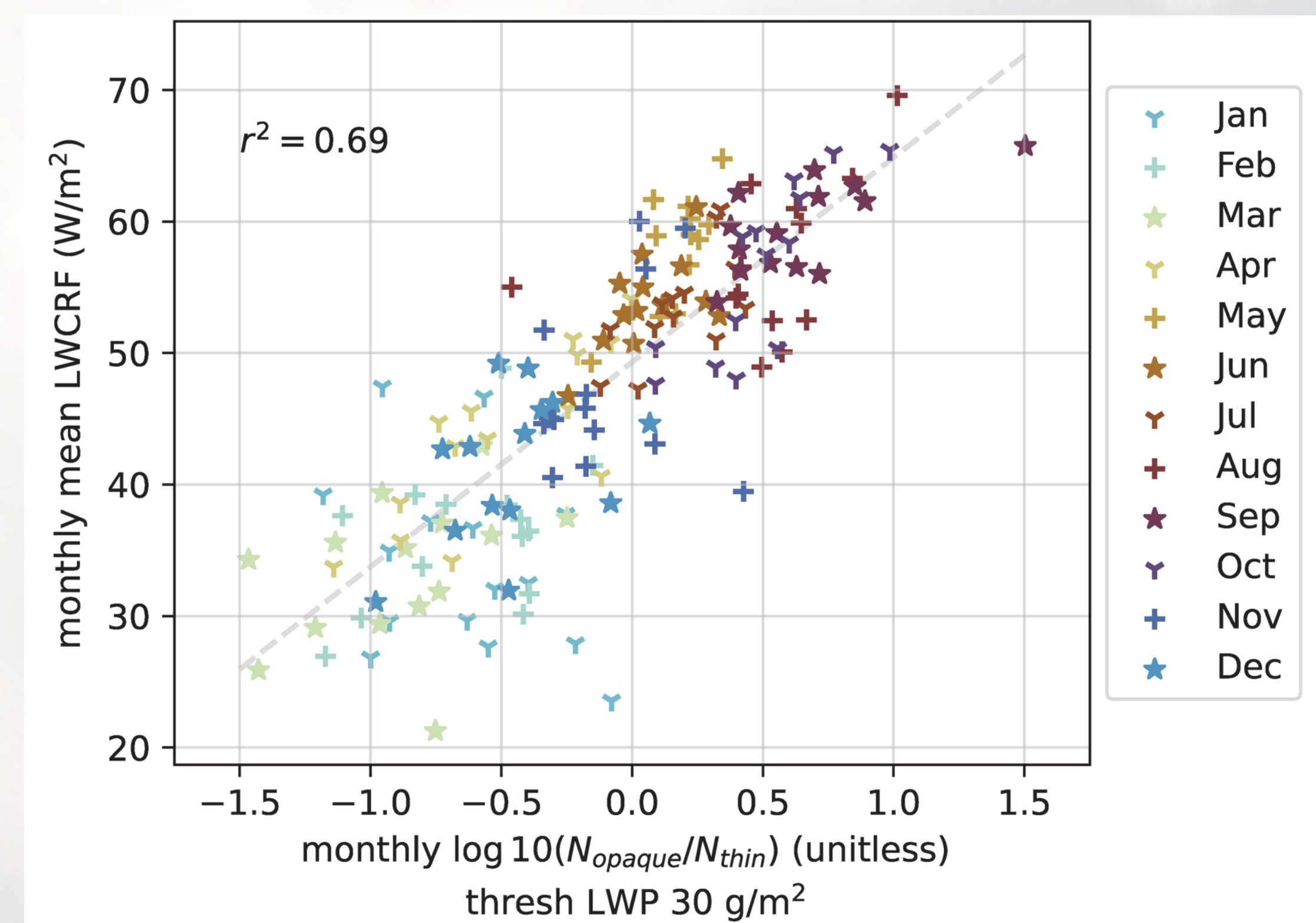
Importance of INP Source



Ice nucleating particles (INPs) modulate the liquid water content of Arctic clouds, and thereby, their radiative forcing. Measurements from Oliktok Point demonstrate significant differences in the activation temperatures for INPs originating from open oceanic (center) versus exposed terrestrial surfaces (right). Both are different from "Arctic background" conditions (left) from snow and ice covered time periods.



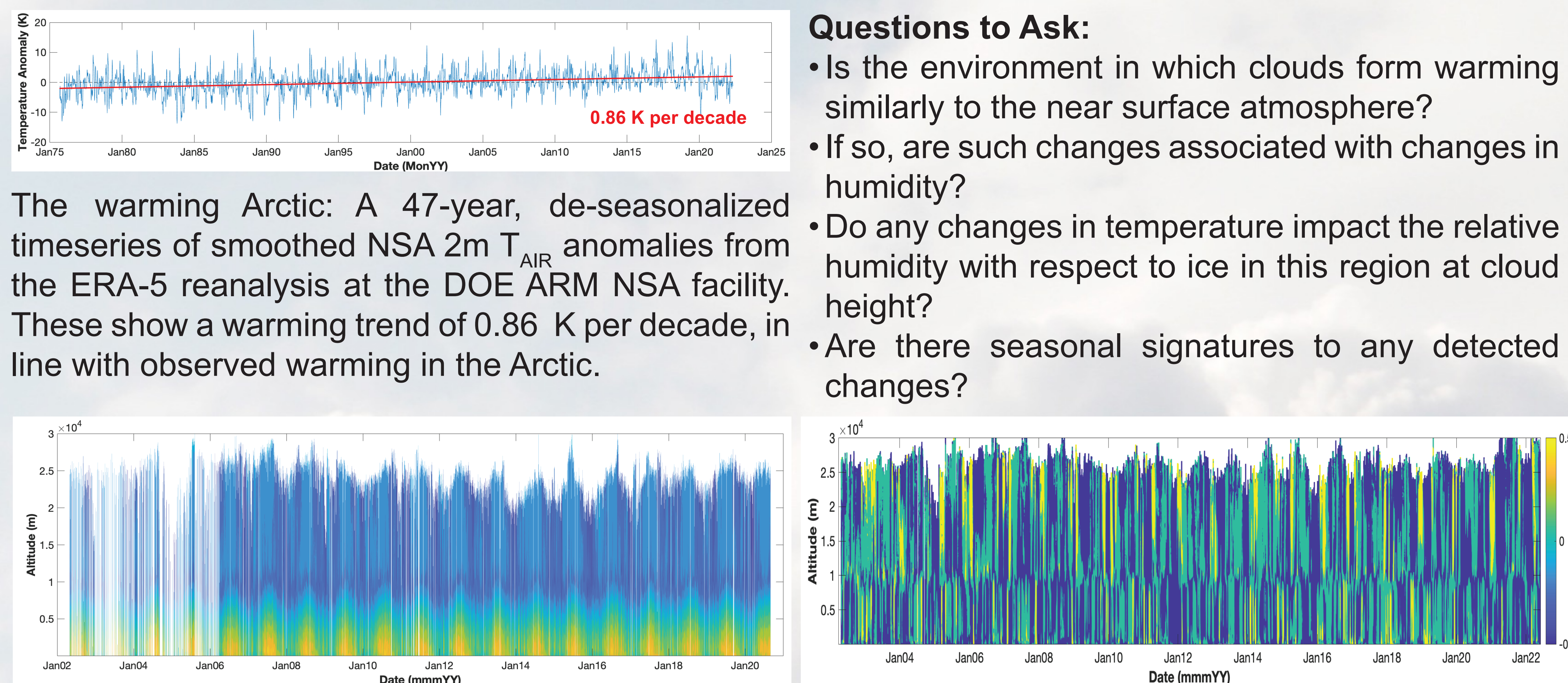
We are conducting sensitivity experiments with WRF to understand the influence of INP properties on cloud life-cycle and forcing.



Using NSA data, we demonstrate the seasonal relationships between cloud liquid water path and monthly mean longwave cloud forcing. Changing INP populations can potentially shift the positions of points on this graph as ice forms more/less readily.

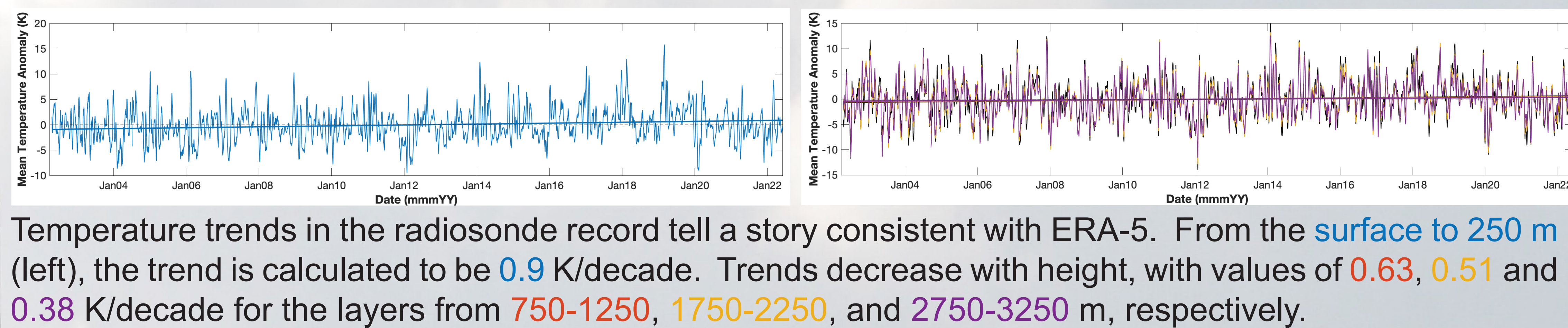
The Changing Environment Sustaining Low Clouds

The warming Arctic: A 47-year, de-seasonalized timeseries of smoothed NSA 2m T_{AIR} anomalies from the ERA-5 reanalysis at the DOE ARM NSA facility. These show a warming trend of 0.86 K per decade, in line with observed warming in the Arctic.

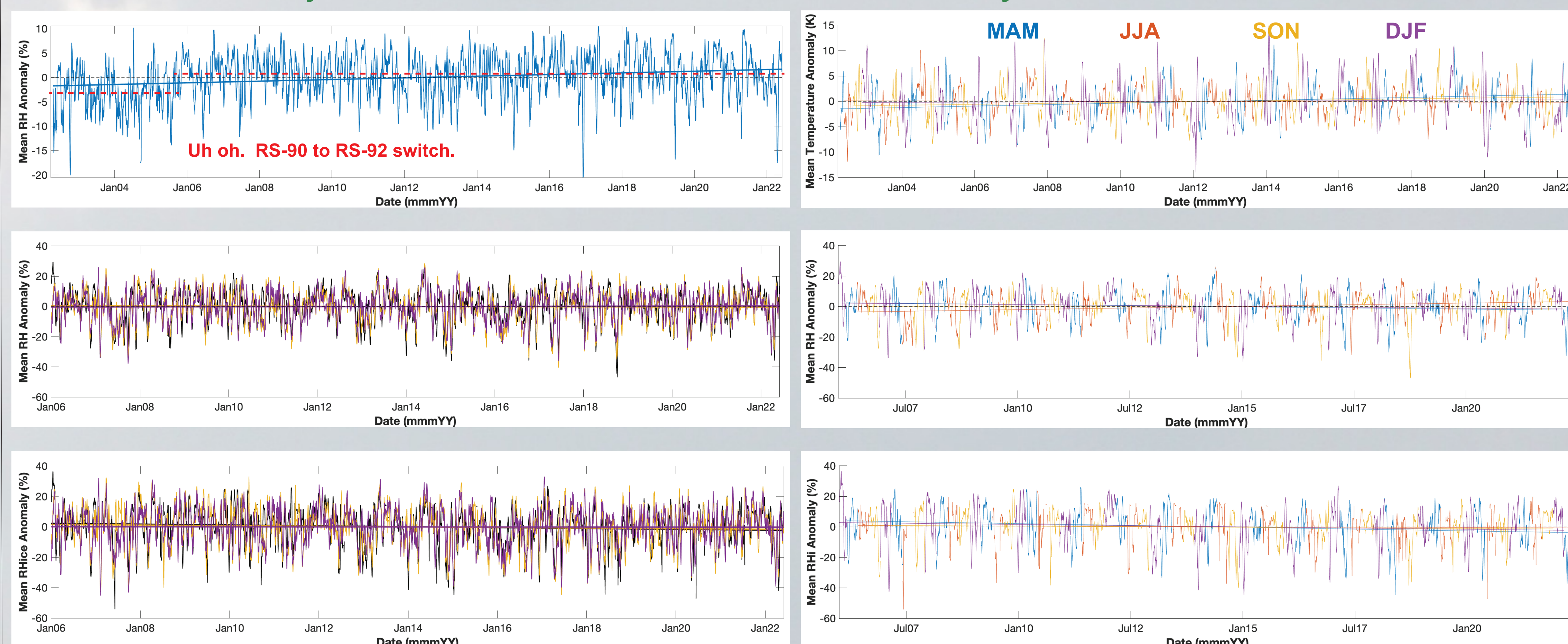


To answer these questions we use the 20-year radiosonde record from NSA. Temperatures from this record are shown above (left), along with the deseasonalized anomalies at every altitude (right).

Temperature



Relative Humidity

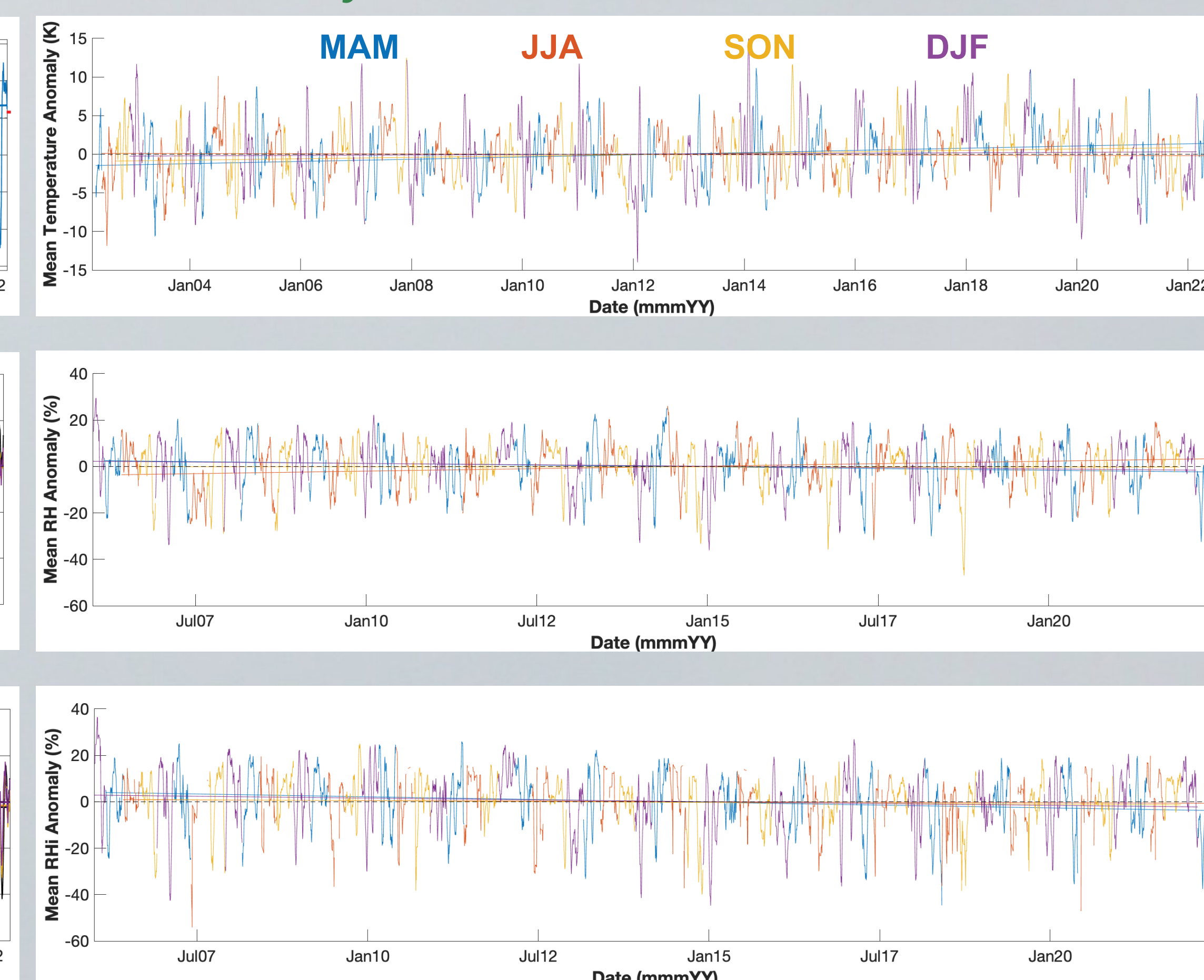


Relative humidity trends are impacted by a change from the RS-90 to the RS-92 radiosonde around January 2006. To account for this we calculate trends only from 2006 onwards. This reveals trends in RH of 0.14, -0.46, -0.59 and 0.45 %/decade and trends in RH_{ICE} of -1.42, -2.80, -1.97 and -0.11 %/decade for the layers from SFC-250, 750-1250, 1750-2250, and 2750-3250 m, respectively.

Questions to Ask:

- Is the environment in which clouds form warming similarly to the near surface atmosphere?
- If so, are such changes associated with changes in humidity?
- Do any changes in temperature impact the relative humidity with respect to ice in this region at cloud height?
- Are there seasonal signatures to any detected changes?

Seasonality



Acknowledgments

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