How does sea ice loss affect clouds? A story about stability in a warming Arctic

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MODIS

Outline

1. Arctic clouds and climate
2. Interest in atmospheric stability
3. Data and approaches – annual means vs. monthly means
4. Stable vs. unstable regime
5. Relationship between stability and clouds
6. Future work

Motivating questions

- Does atmospheric stability control Arctic clouds?
- What are the most important process relationships between clouds, atmospheric circulation, and sea ice concentration?
- What are the relative controls from large- and regional-scale processes?

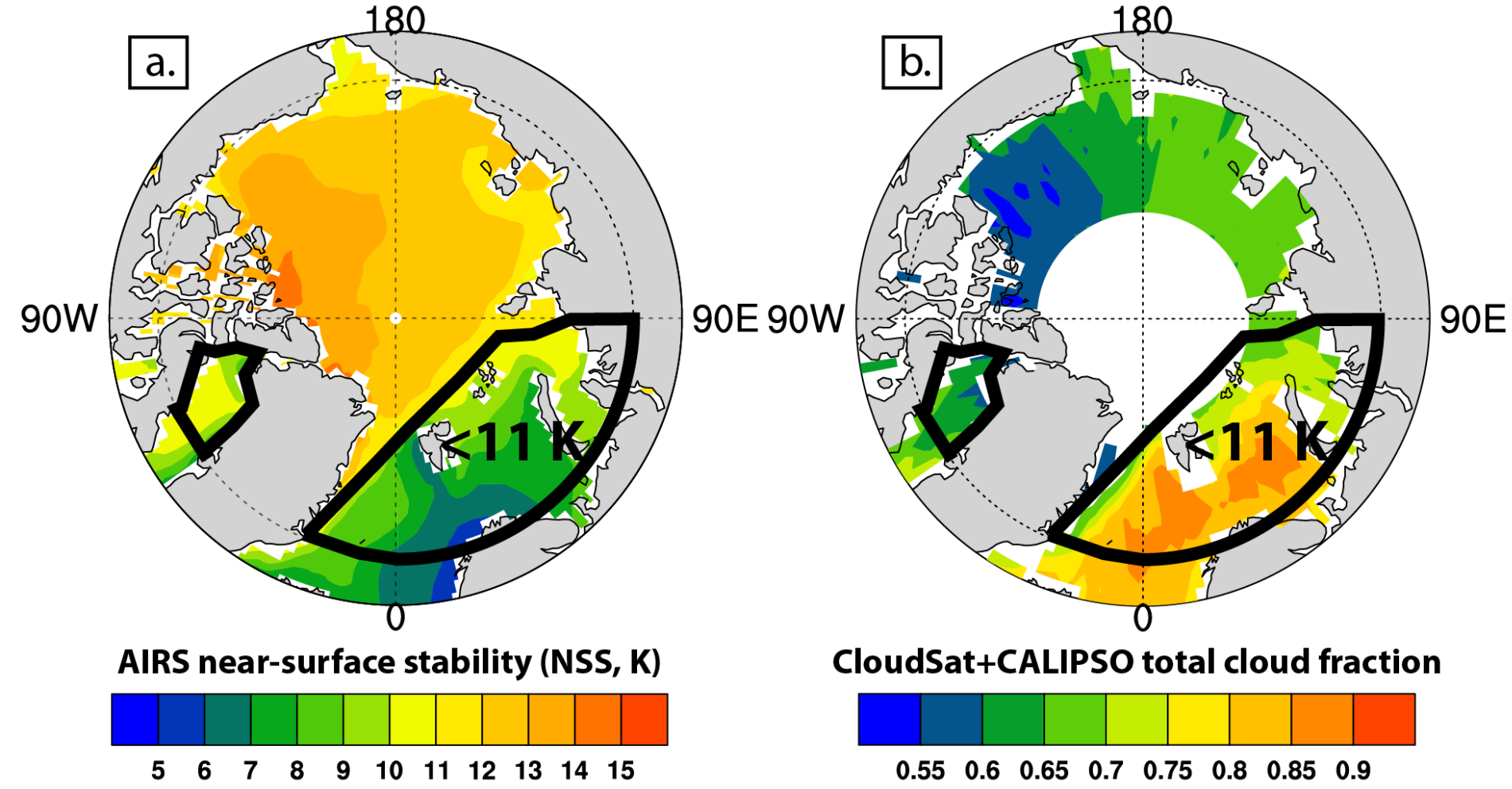
Data

- All monthly means 2006-07 – 2013-12
  - GOCCP – CALIPSO cloud fraction
  - AIRS – temperature profiles (near surface stability)
  - ERA-Interim – sea level pressure
  - HadISST – sea ice concentration
  - CERES-EBAF – TOA net radiation

First approach

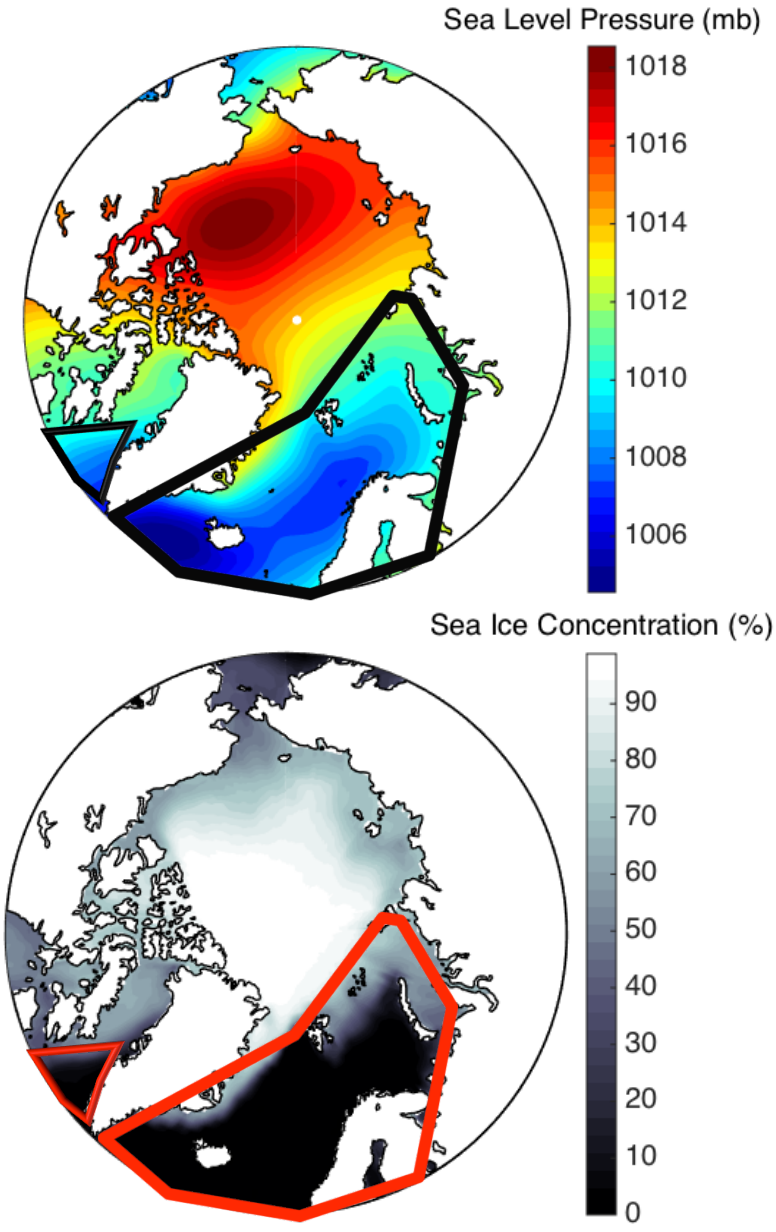
- Strategy:
  - Look at annual means for geographic distribution

How does stability vary across the Arctic?



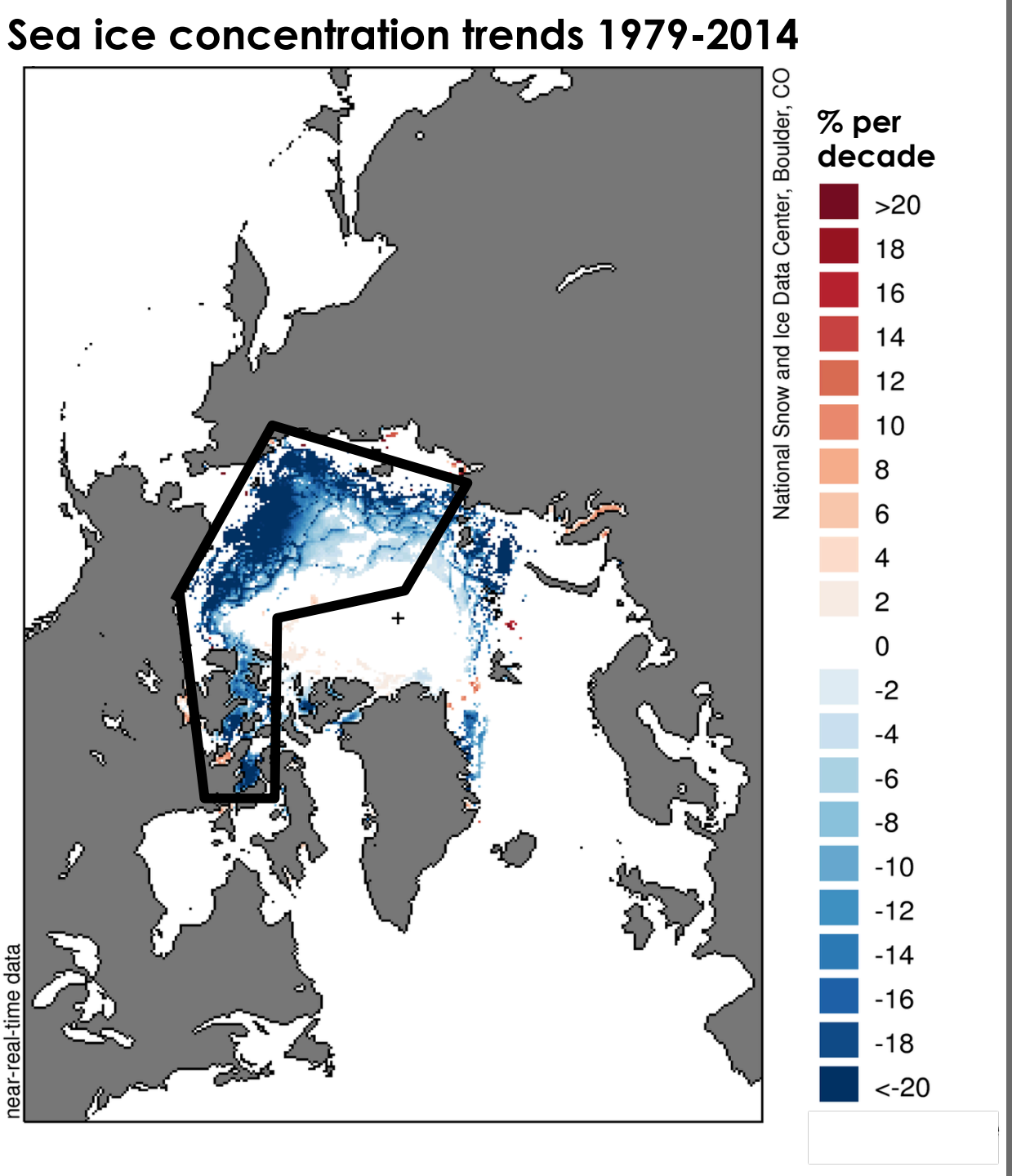
Kay and L'Ecuyer 2013

Annual mean – same geographic region has low stability, SLP, SIC, and high cloud fraction



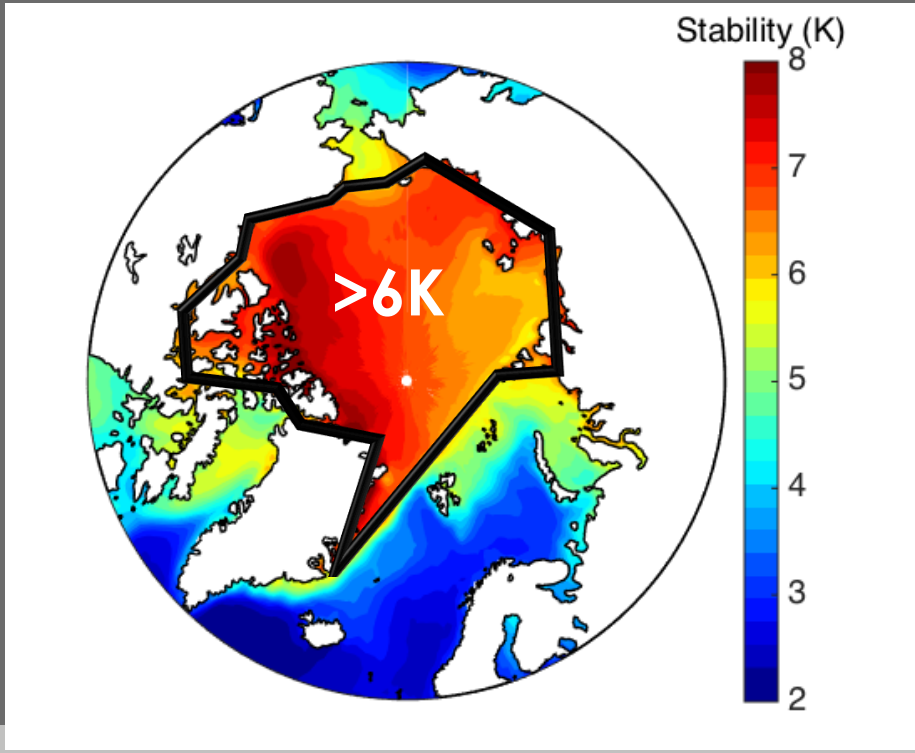
What controls clouds in the stable regime?

Region of fastest sea ice loss!

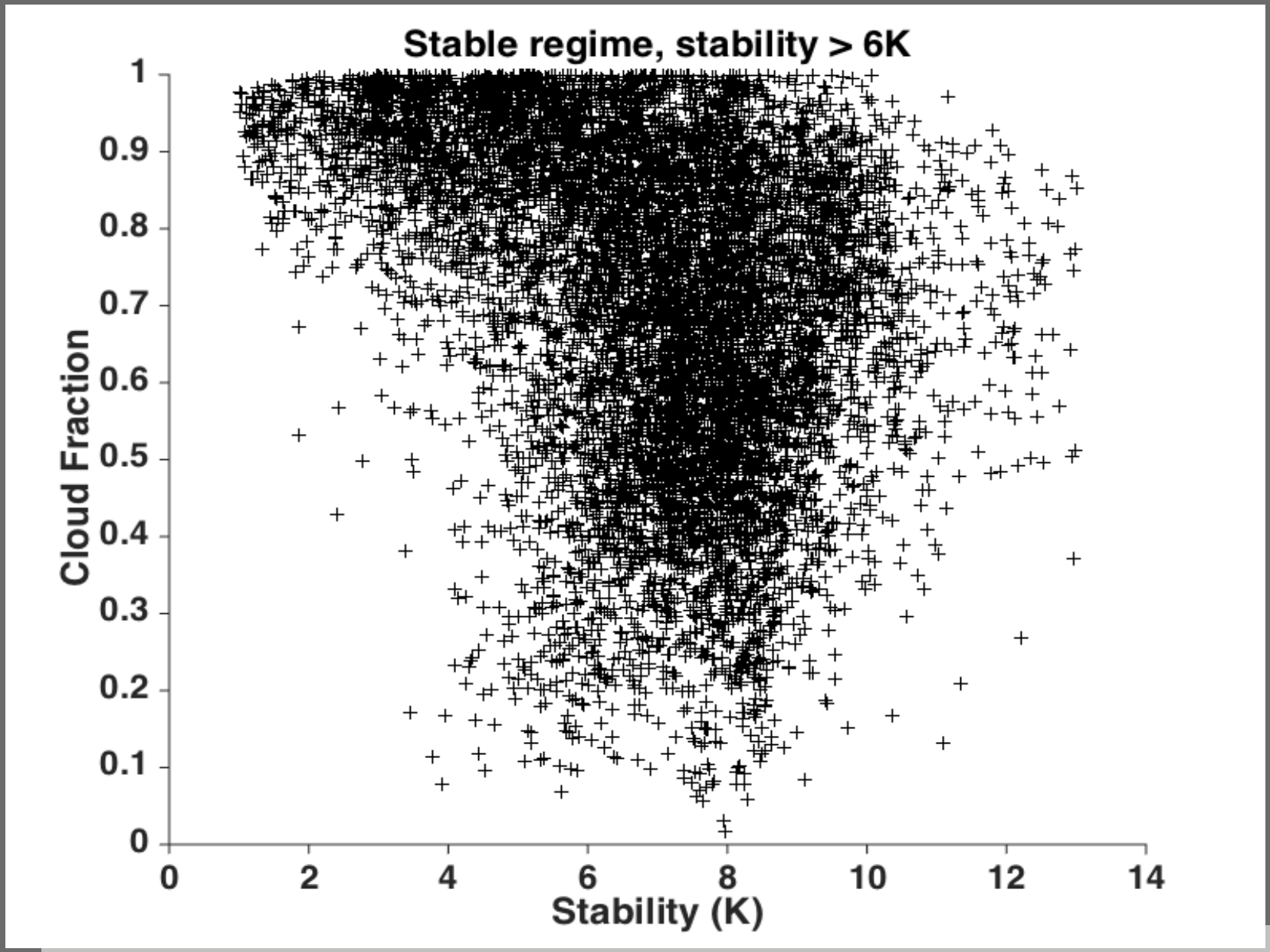


Next approach

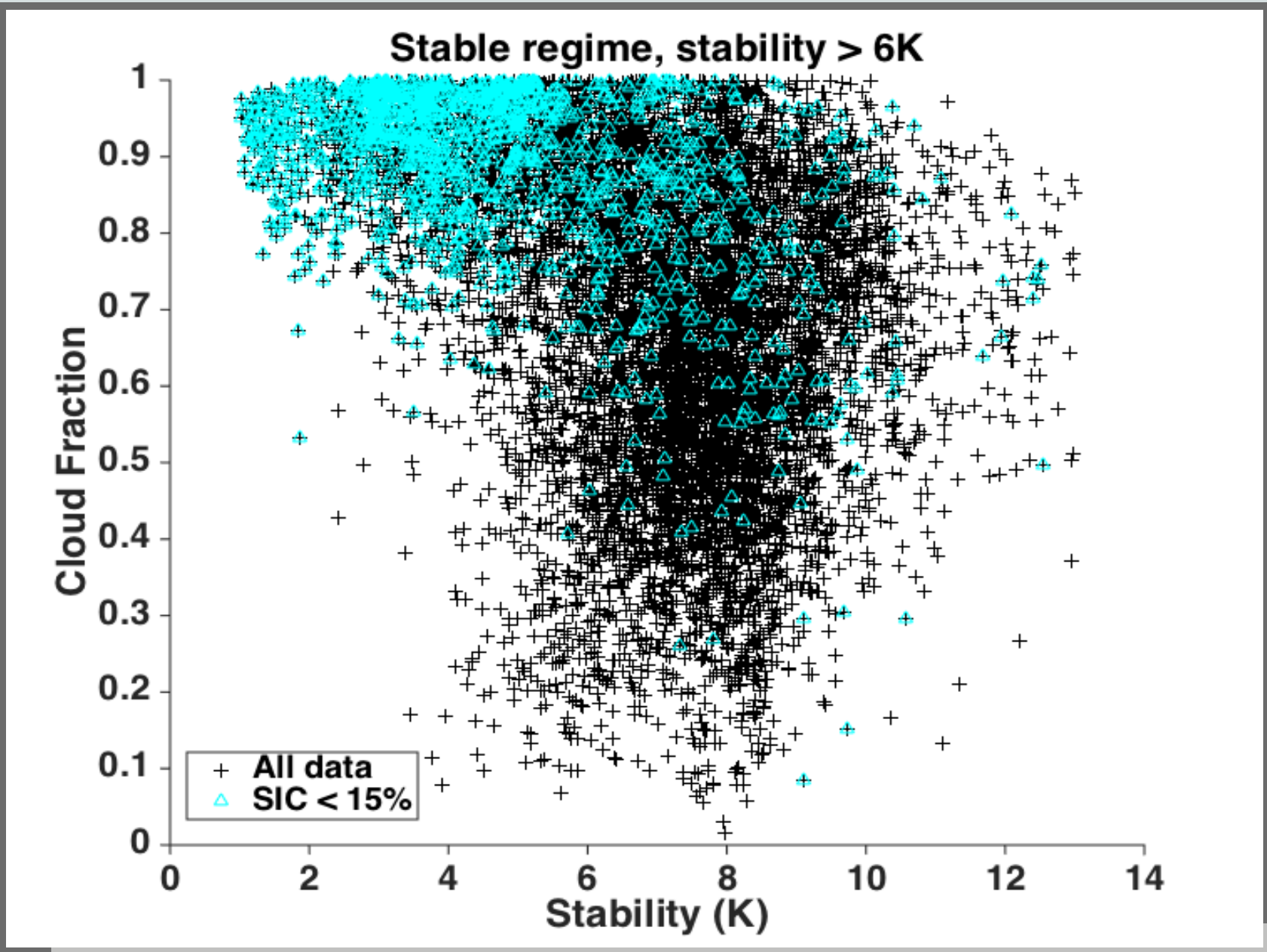
- Strategy:
  - Assess relationships between variables with scatterplots of monthly means in the stable regime
  - "Time-independent" relationships



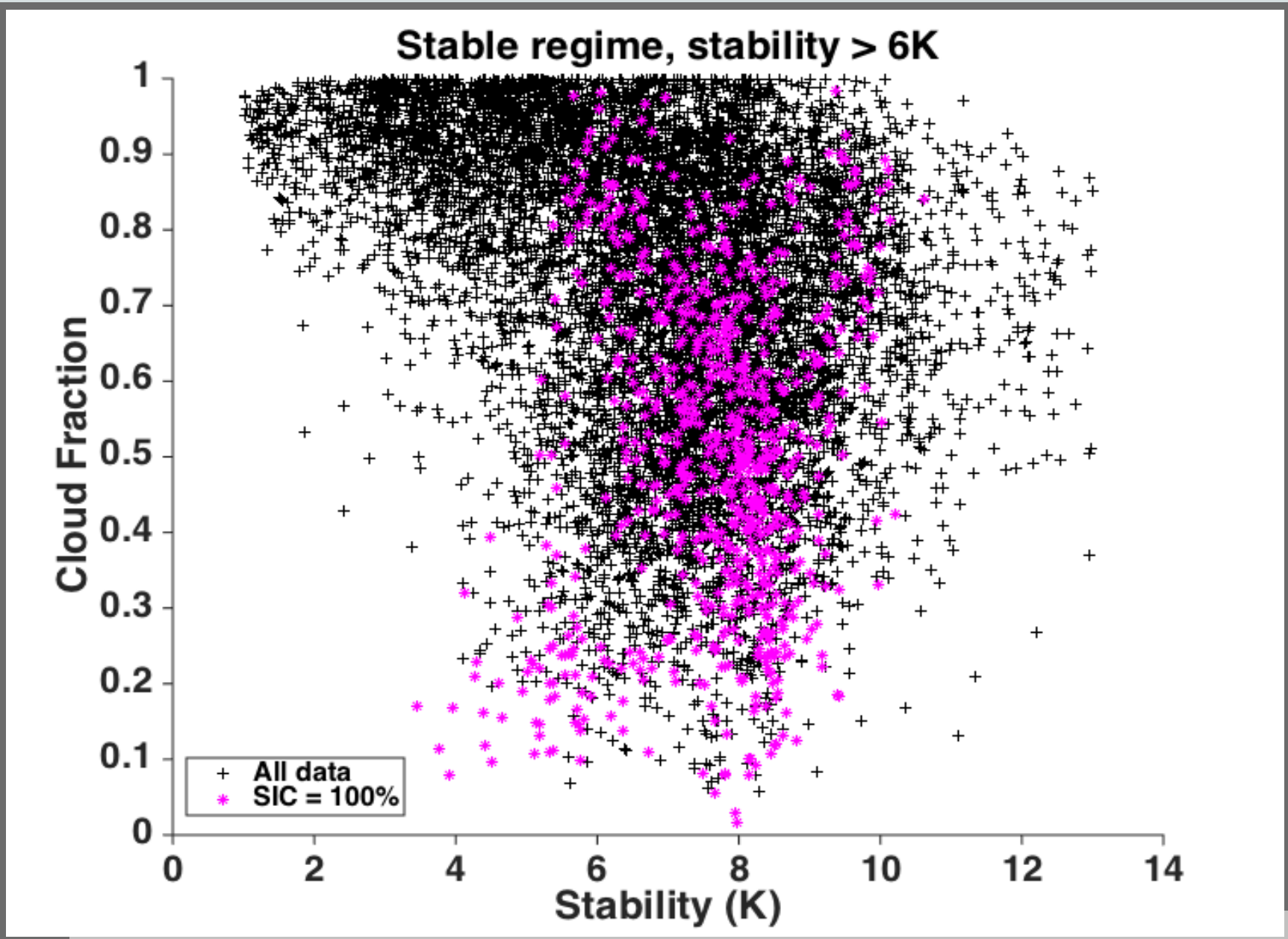
Low stability = large cloud fraction
High stability = large range of cloud fraction



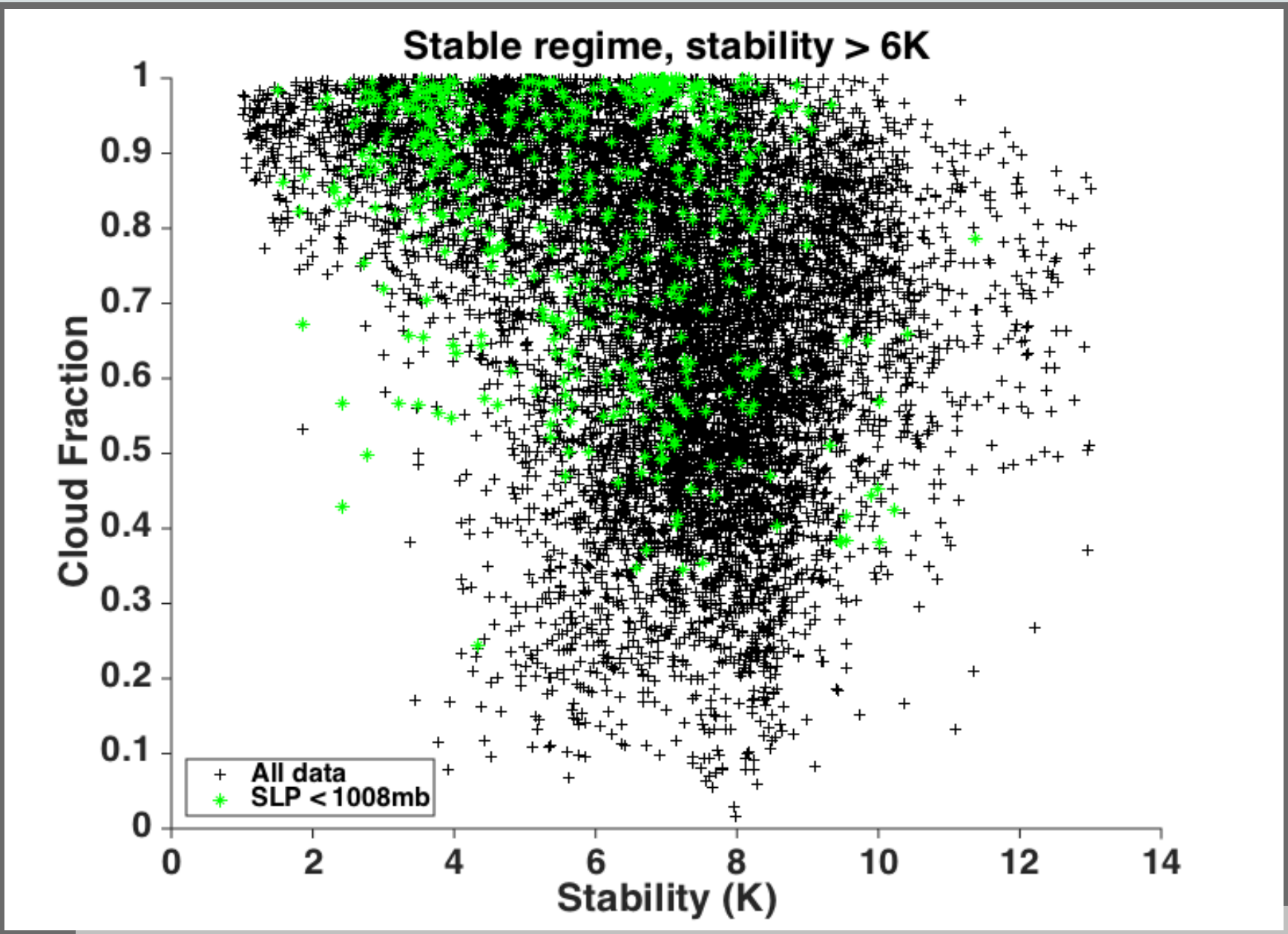
Cloudiest unstable points = open ocean, large cloud fraction from convective cloud formation



Ice-covered surface = smallest cloud fraction, moisture cap, large range from stratiform cloud formation?



Stratiform clouds over ice-covered ocean = forced lifting from low pressure

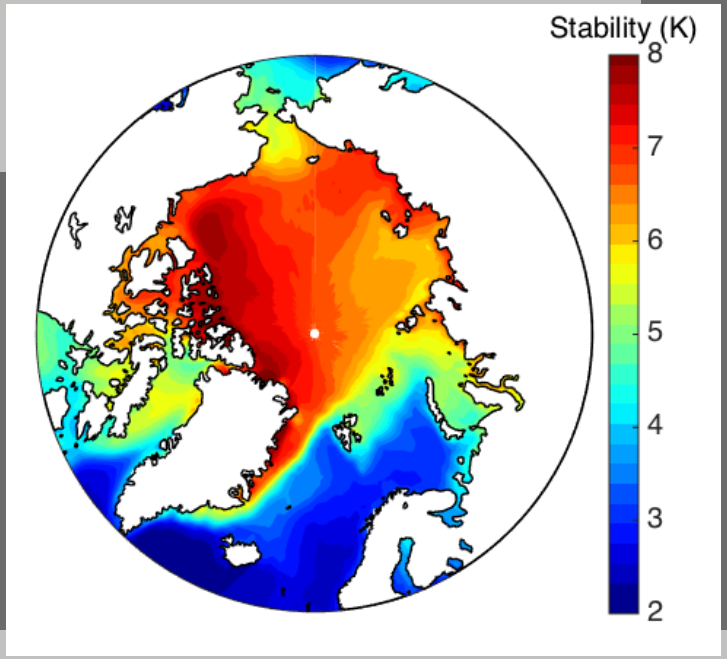


Initial results

- Annual mean geographic variations = two distinct regions
- Within stable regime:
  - Low stability = always more clouds?
    - Open water when air is cold
  - High stability = large range in cloud fraction
    - Low sea level pressure vs. capped ocean
  - Ice-covered = smallest cloud fraction
    - Possible forced lifting = stratiform clouds?
- Clouds controlled by both surface and atmosphere

Goals and future work

- Add more data, e.g. cloud phase, cloud top height, boundary layer depth
- Follow CloudSat swath for rapid changes in clouds/stability
- Look at seasonality of process relationships using TOA net radiation



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High stability, varied cloud fraction = air heated by solar radiation, surface still cold