Pan-Arctic surface radiation measurements capture atmospheric preconditioning of sea ice melt season

Christopher J. Cox[1,2], Taneil Uttal[1], Chuck Long[2,3], Matthew D. Shupe[1,2], Janet Intrieri[1], Sandy Starkweather[1,2], Elena Konopleva[1,4],
Sara Crepinsek[1,2], Diane Stanitski[3], Robert Stone[2], and Allison McComiskey[3]

[1] NOAA Earth System Research Laboratory (ESRL) Physical Science Division (PSD), [2] Cooperative Institute for Research in Environmental Sciences,
[3]NOAA Earth System Research Laboratory (ESRL) Global Monitoring Division (GMD), [4]Science and Technology Corporation (STC)

I. Abstract

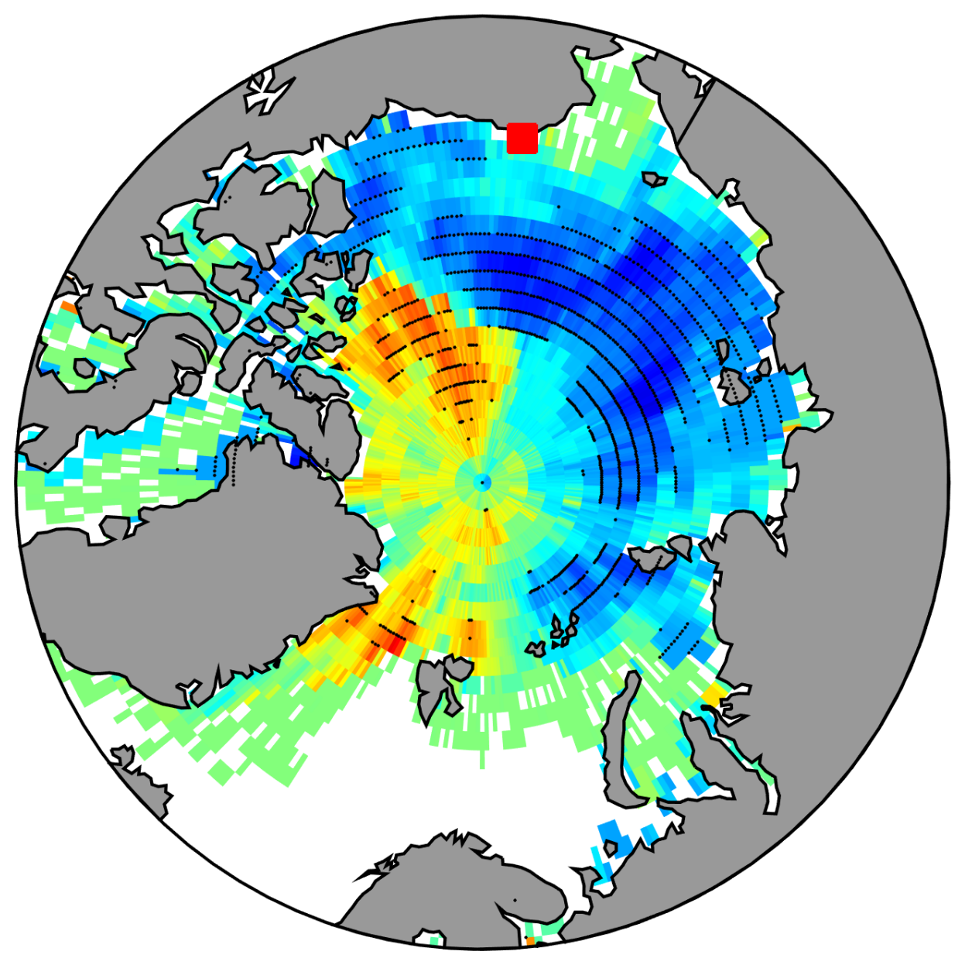
Recent changes in the Arctic climate involve surface-atmosphere energy exchange processes and feedbacks associated with clouds, surface albedo, and the atmospheric state. The Arctic is comprised of regional climate regimes, which exhibit unique sensitivities and responses to climate change.

The surface radiation budget is monitored from several stations in the pan-Arctic region. Thus far, most studies have focused on individual locations, reporting significant changes in the surface radiation budget. Spatial analyses are lacking and a coordinated analysis of these measurements is needed to improve understanding of the processes involved in the changing Arctic climate. The International Arctic Systems for Observing the Atmosphere (IASOA) (http://www.iasoa.org) Radiation Working Group is collectively analyzing these observations. The focus locations are Tiksi (Siberia), Ny-Ålesund (Svalbard), Barrow (Alaska), and Alert (Canadian Archipelago). These stations have long records of quality measurements, enabling analyses to be conducted focusing on variability in the surface radiation budget over the past 10 to 20 years, a time period during which the Arctic has experienced dramatic changes.

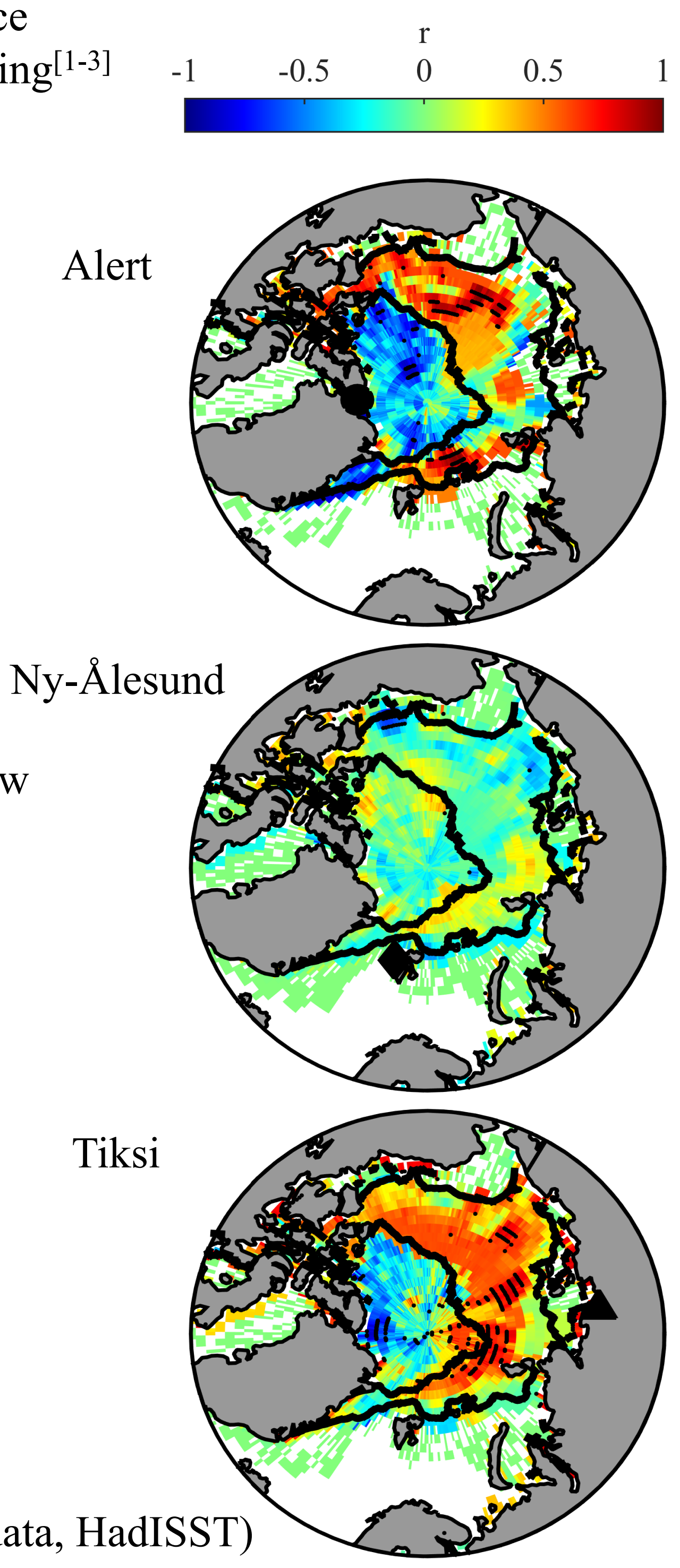
In this study, radiative fluxes and cloud properties in spring (April – June) are investigated to improve understanding of atmospheric preconditioning of the sea ice melt season. In addition to direct observations from broadband radiometers, the Radiative Flux Analysis (RFA) value-added product is used. The RFA provides quality control and higher order metrics, such as cloud radiative forcing, cloud fraction, and optical depth.

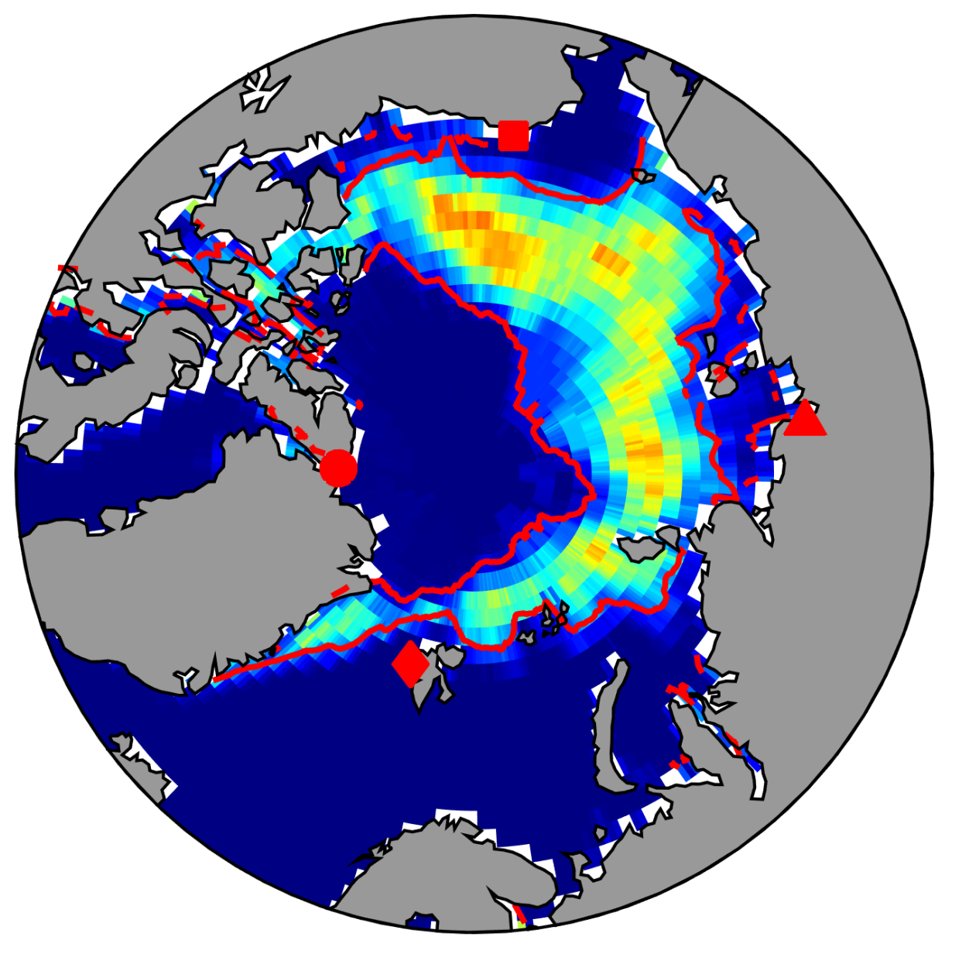
II. Spatial representation of observatories: Lagged-correlative links to sea ice

- April-May downwelling shortwave (SW$_d$) and downwelling longwave (LW$_d$) radiation anomalies correlated with September sea ice concentrations (SIC) in region of interannual variabilty in sea ice
- The signal of atmospheric preconditioning[1-3]



Spring LW$_d$+SW$_d$ anomaly at Barrow correlated with September SIC

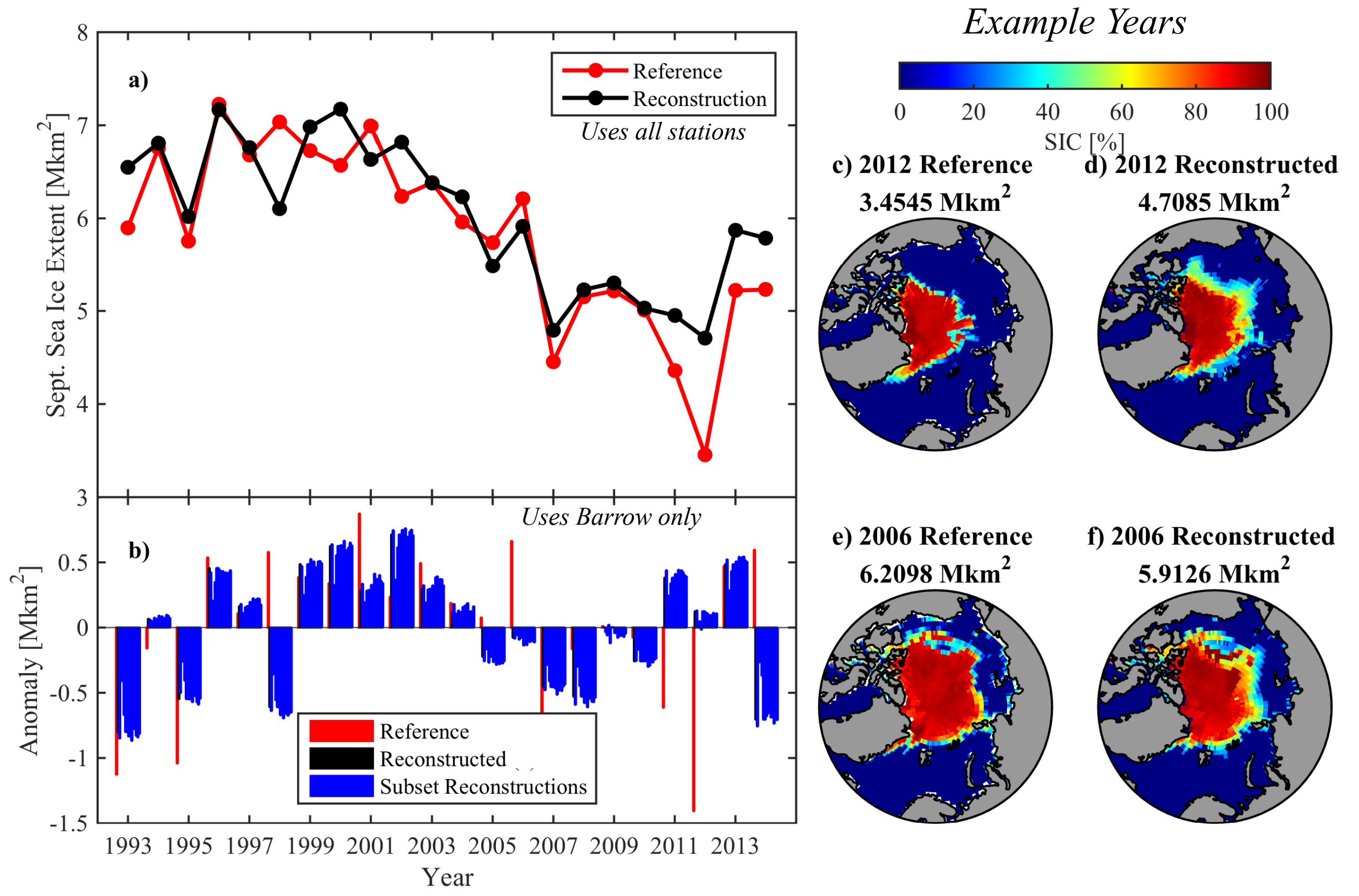




Variance in September SIC 1993-2014 (data, HadISST)

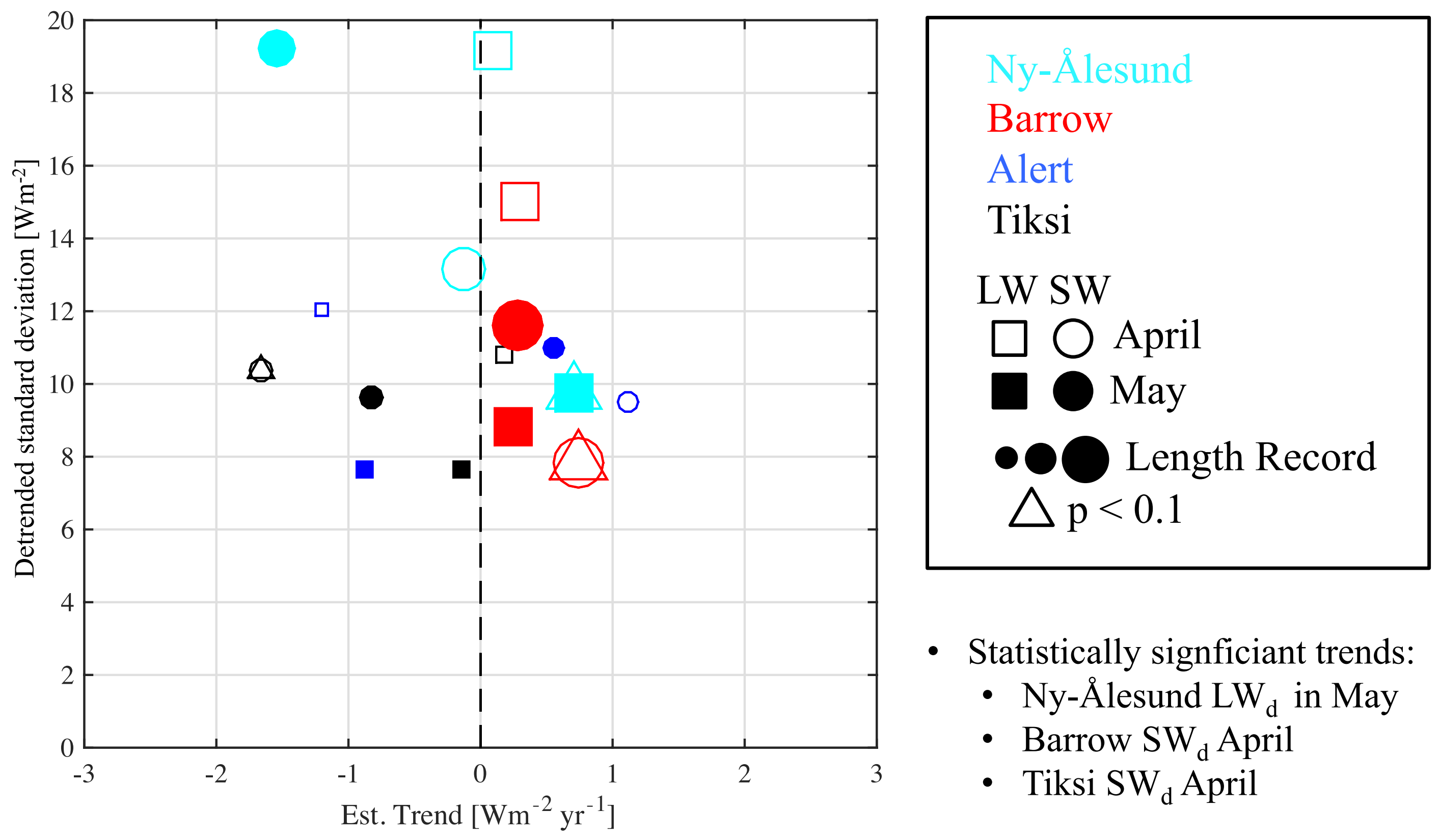
III. Towards a seasonal sea ice forecast

- Based on (II), observations of fluxes from stations may be suitable for seasonal sea ice forecasting of the pan-Arctic and sub-regions (a,c,d,e,f)
- (b) detrended anomalies similar to (a), but uses Barrow only. Shows consistency in reconstruction of all years developed from subsets of Barrow data record



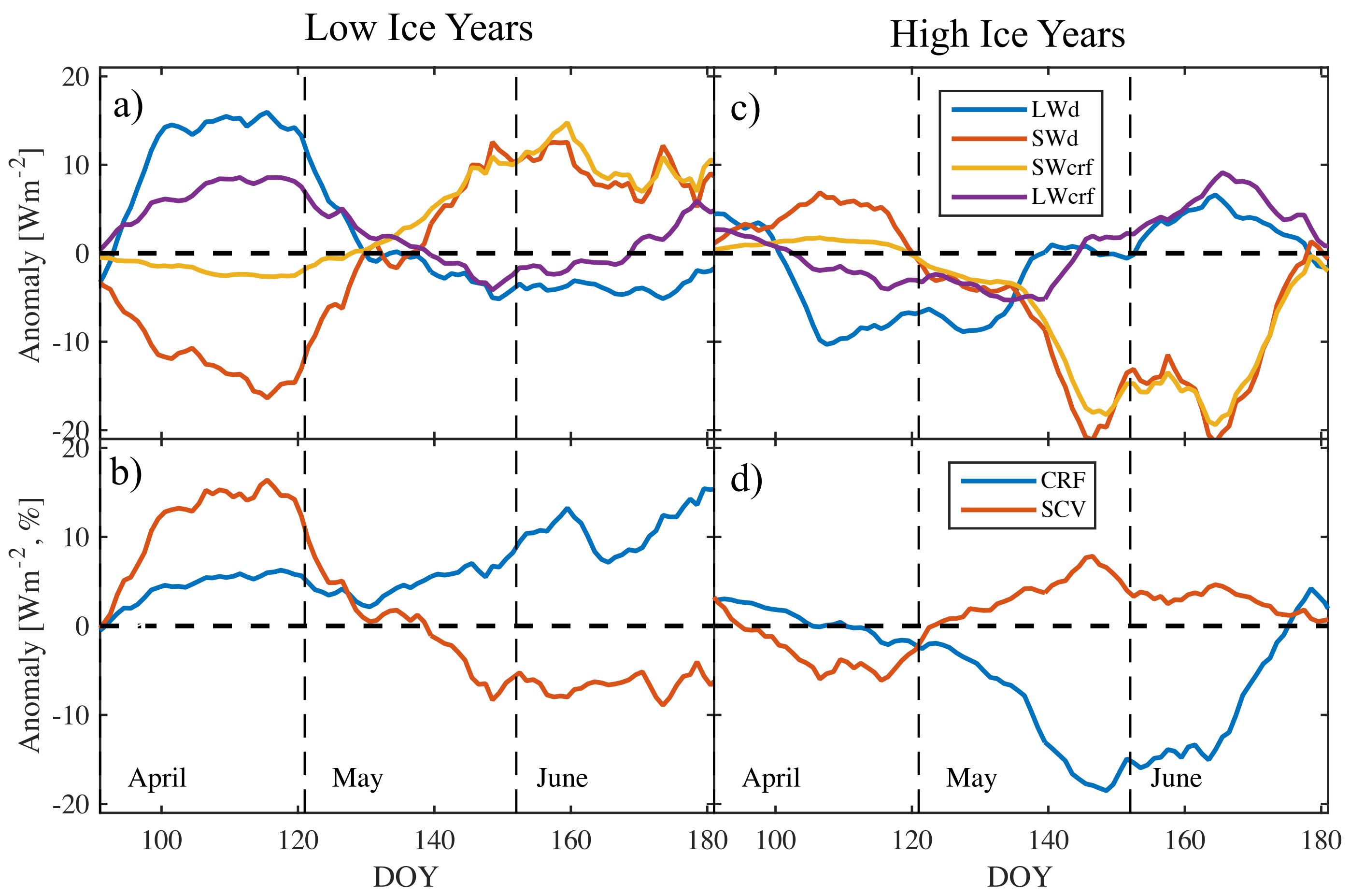
IV. April & May SW$_d$ LW$_d$ Trends

- Interannual variability is generally large compared to trends

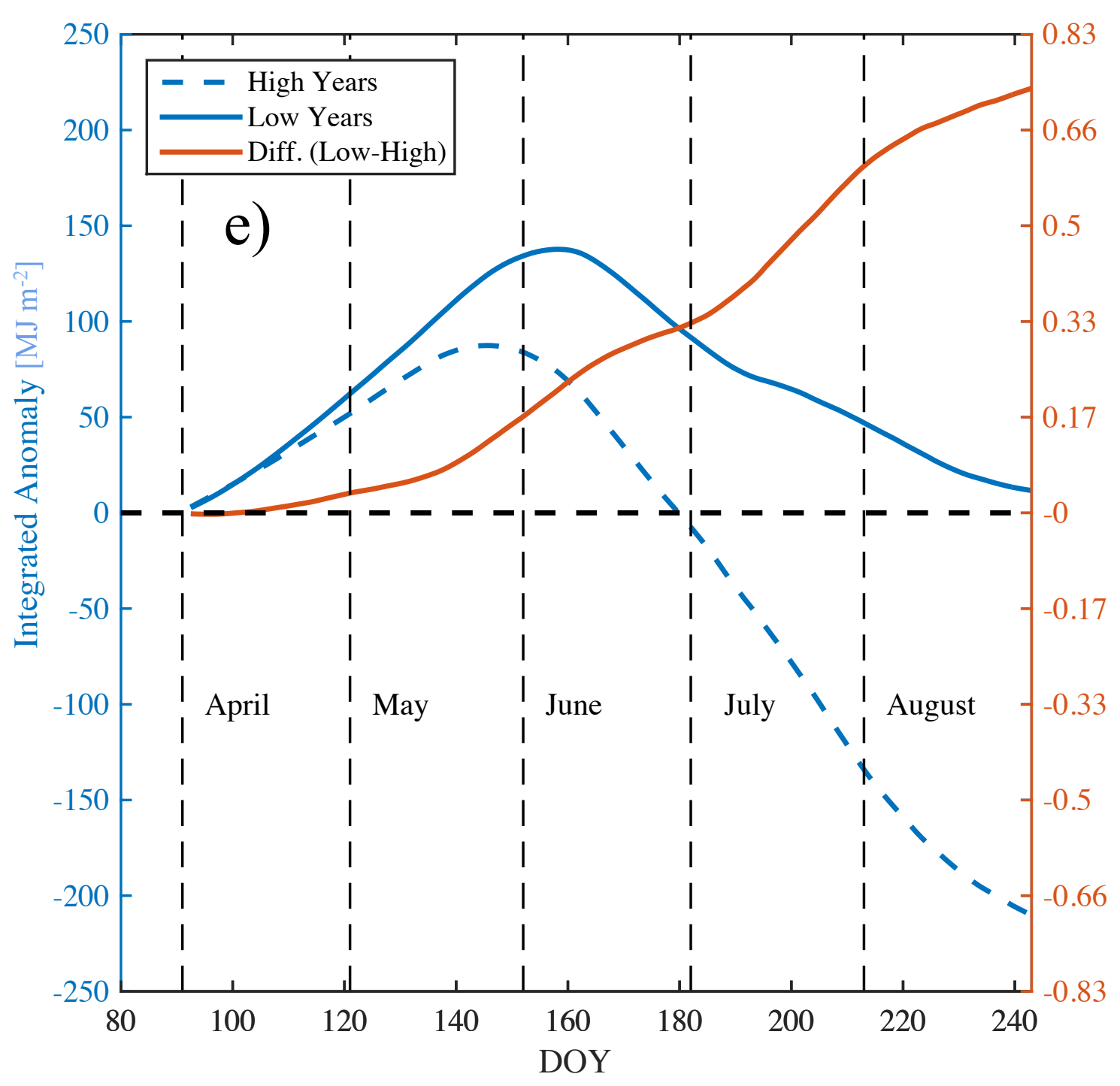


- Statistically signficiant trends:
  - Ny-Ålesund LW$_d$ in May
  - Barrow SW$_d$ April
  - Tiksi SW$_d$ April

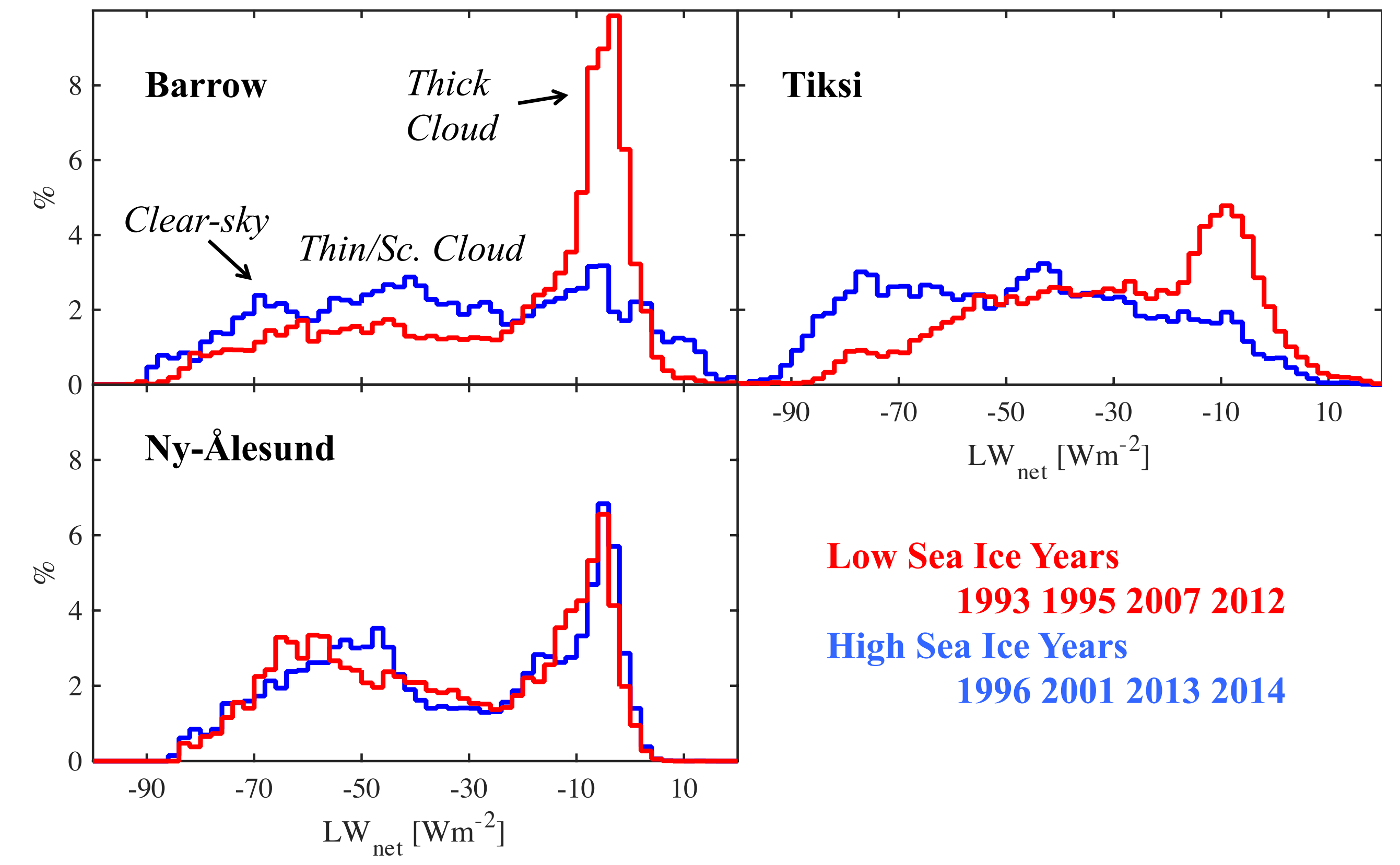
V. The role of clouds



- Cloudier early spring (April) followed clearer late spring (May-June) in low sea ice years (a,b). The opposite is true in high sea ice years (c,d), though the signal is weaker.
- In low years (a,b), cloud radiative forcing maximized: increases LW warming before seasonal cycle in SW dominates and minimizes SW cooling after.
- (e) From April 1, clouds support additional melted ice in low ice years vs. high ice years of 0.16 m (by June 1) and 0.74 m (by Sept 1).

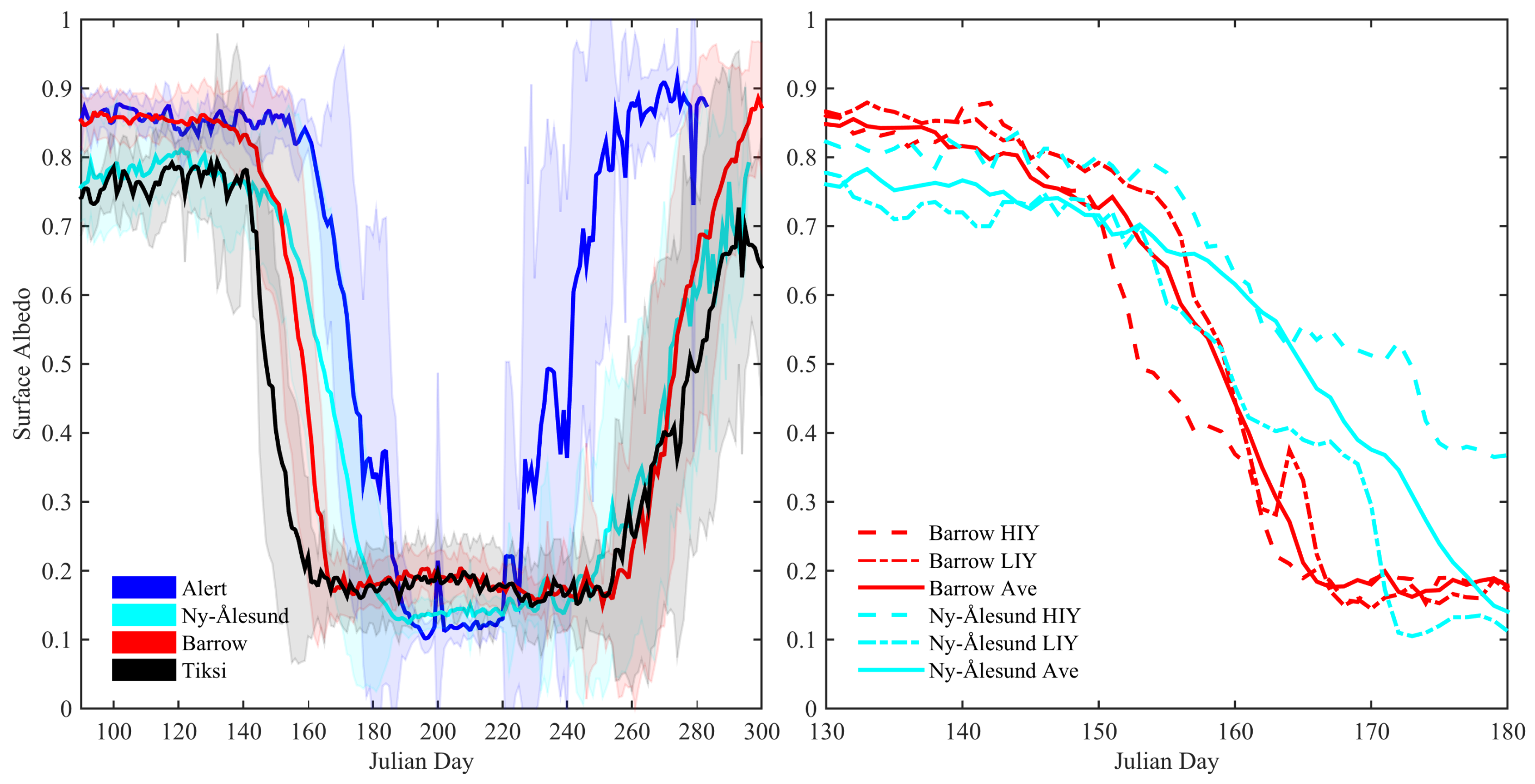


VI. LW$_{net}$ mid to late April



- Bimodal distributions in LW$_{net}$ (clear and cloudy modes) common in the Arctic
- April cloud anomalies in low sea ice years reduce surface cooling
- Consistent with (II), signal is seen at Barrow and Tiksi, but not Ny-Ålesund

VII. Snowmelt Dates



- Different locations have different snow-in, snow-out dates
- Snow melt in low ice years (LIY) is later at Barrow and earlier at Ny-Ålesund
- Barrow: also later snow onset in autumn in LIY (not shown)

VIII. Conclusions

- Radiative fluxes observed at coastal Arctic land stations carry information relevant to the sea ice zone where climate monitoring from the surface is impractical.
- Anomalies in SW$_d$ and LW$_d$ radiative fluxes in spring capture atmospheric preconditioning of sea ice – a seasonal scale forecast is possible.
- Trends in the fluxes in spring are found, but are small compared to interannual variability.
- Cloud radiative forcing is transitioning in spring from dominant LW warming (winter) to SW cooling (summer)[4]. Clouds enhance melt season when positive cloud anomalies appear in April followed by negative anomalies in May/June. This maximizes longwave warming and minimizes shortwave cooling at critical times.
- The cloud anomaly in April substantially reduces LW cooling of the surface in early spring during low sea ice years.
- The spring snowmelt season is also influenced by these anomalies, though in more complex ways.

References & Acknowledgements

This work was funded by the NOAA Climate Program Office. We are grateful for contributions from M. Maturilli (AWI), Y. Iijima (JAMSTEC), and V. Kustov (AARI)

[1] Kapsch et al. (2013) *Nature Clim. Ch.* **3**, 744-748 doi 10.1038/nclimate1884. [2] Kapsch et al. (2014) *GRL* **41**, 5288-5296 doi: 10.1002/2014GL060826. [3] Choi et al. (2014) *JGR* **119**, 11087-11099 doi: 10.1002/2014 JD022013. [4] Dong et al. (2010) *JGR* **115**, D17 doi: 10.1029/2009JD013489.