Cloud radiative forcing from pan-Arctic BSRN stations: Applications for climate monitoring and sea ice forecasting

Christopher J. Cox[1,2], Charles N. Long[1,2], Taneil Uttal[2], Sandy Starkweather[1,2], Sara Crepinsek[1,2], Marion Maturilli[3], Allison McComiskey[2], Nathaniel B. Miller[1,2], Elena Konopleva-Akish[4], Vasily Kustov[5], Matthew D. Shupe[1,2], Konrad Steffen[6], Diane Stanitski[2], Robert Stone[7], Von P. Walden[8]

[1] Cooperative Institute for Research in Environmental Sciences (CIRES), Boulder, CO

[2] NOAA Earth System Research Laboratory (ESRL) Boulder, CO

[3] Alfred Wegener Institute (AWI) Hemholtz Centre for Polar and Marine Research, Postdam

[4] Science and Technology Corporation (STC), Boulder, CO

[5] Arctic and Antarctic Research Institute (AARI), St. Petersburg

[6] Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Zürich

[7] Cooperative Institute for Research in Environmental Sciences (CIRES), retired

[7] Washington State University (WSU), Pullman, WA

christopher.j.cox@noaa.gov

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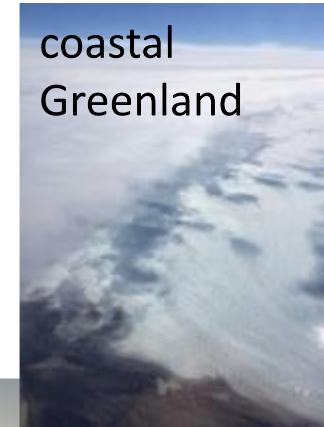
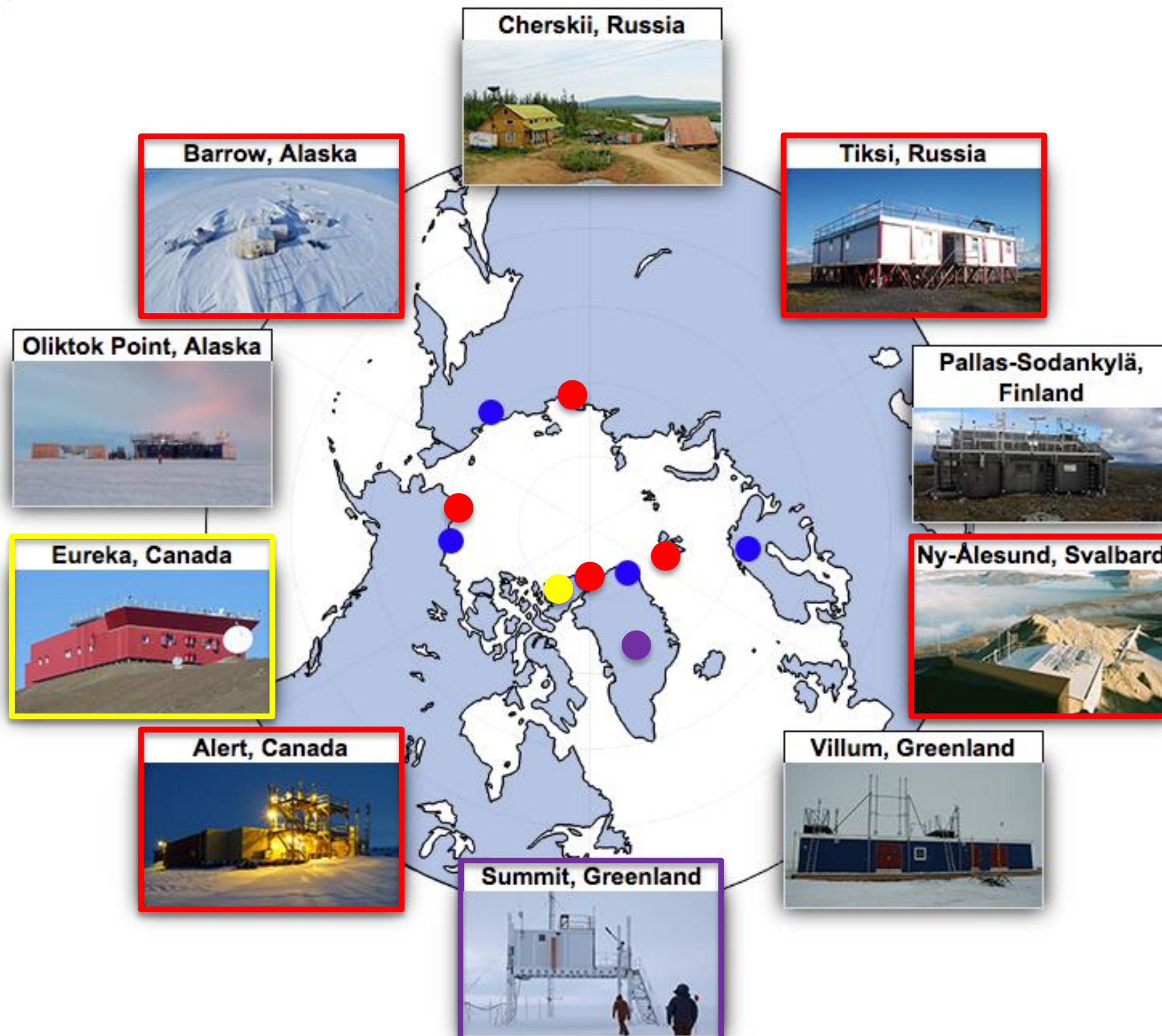
The Arctic looks like this…



International Arctic Systems for Observing the Atmosphere (IASOA)

http://www.esrl.noaa.gov/psd/iasoa/

Uttal et al. *in press* BAMS doi: 10.1175/BAMS-D-14-00145.1



BSRN status

BSRN

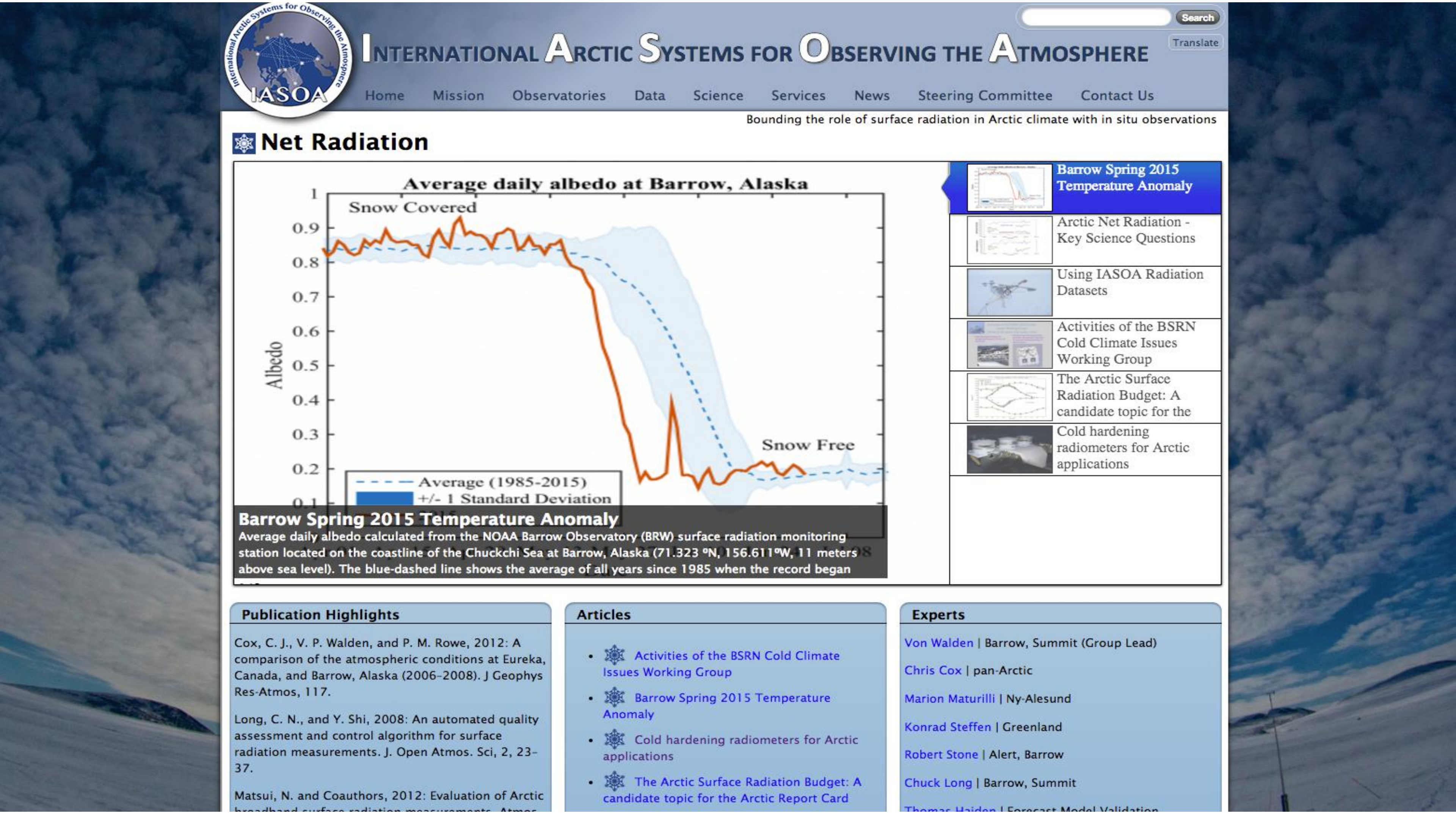
Closed (meas. continue)

Candidate

Also, DOE-ARM obs. at Oliktok and Barrow

IASOA Radiation Working Group (RWG)

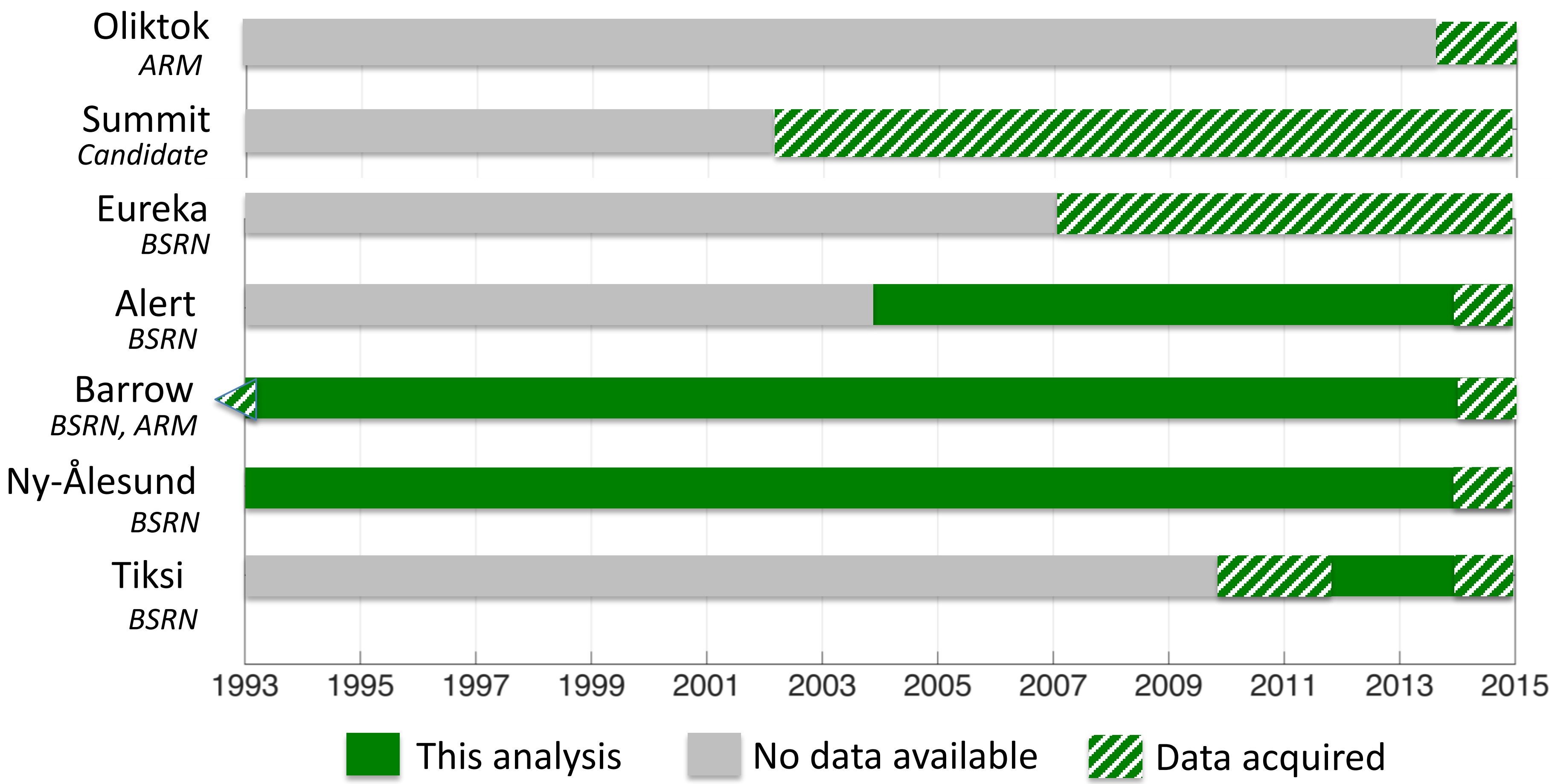
Sandy Starkweather (CIRES), Taneil Uttal (NOAA), Matthew Shupe (CIRES), Diane Stanitski (NOAA), Thomas Haiden (ECMWF), Von Walden (WSU), Allison McComiskey (NOAA), Rigel Kivi (FMI), Marion Maturilli (AWI), Elena Konopleva-Akish (STC), Sara Crepinsek (CIRES), Joseph Sedlar (Stockholm), Amy Solomon (CIRES), Janet Intrieri (NOAA), Ola Persson (NOAA), Robert Stone (NOAA, retired), Jeff Key (NOAA), Charles Long (CIRES), Christopher Cox (CIRES), Vasily Kustov (AARI), Hironori Yabuki (JAMSTEC), Yoshihiroo Iijima (JAMSTEC), Nathaniel Miller (CIRES)



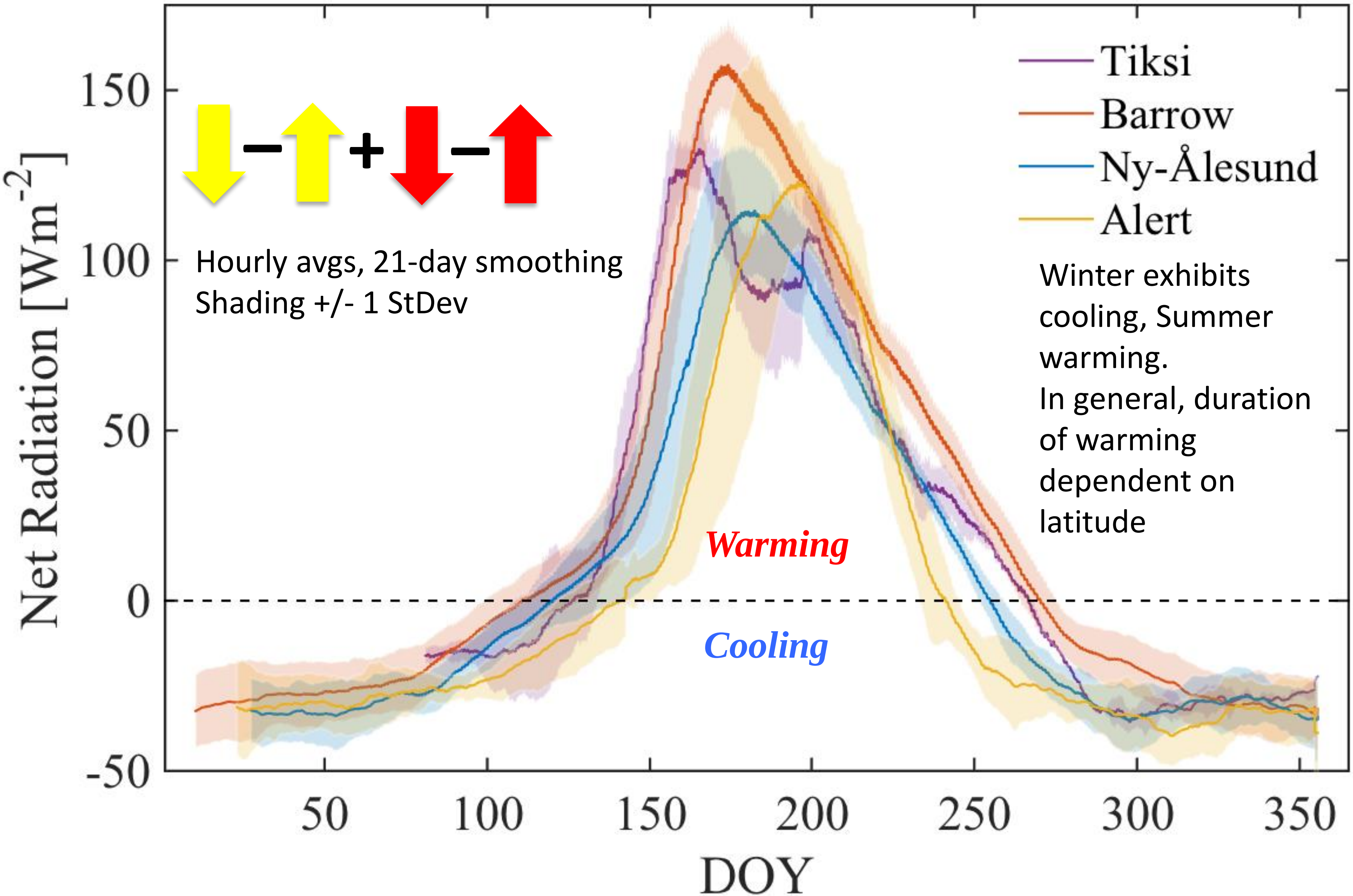
Cherskii, Russia
Barrow, Alaska
Tiksi, Russia
Oliktok Point, Alaska
Pallas-Sodankylä, Finland
Eureka, Canada
Ny-Ålesund, Svalbard
Alert, Canada
Villum, Greenland
Summit, Greenland
This analysis
Forthcoming

Data Record

(Need SW Total, diffuse and direct components)



Net All Wave Radiation



Radiative Flux Analysis (RadFlux)

Measured Variables

$LW\downarrow$ $LW\uparrow$ $SW_{GLOB}\downarrow$ $SW_{DIFF}\downarrow$ $SW_{DIR}\downarrow$ $SW\uparrow$
Relative Humidity, Temperature

Quality Control

Remove suspect data, IR loss correction
Long and Shi 2008

Calculated Variables

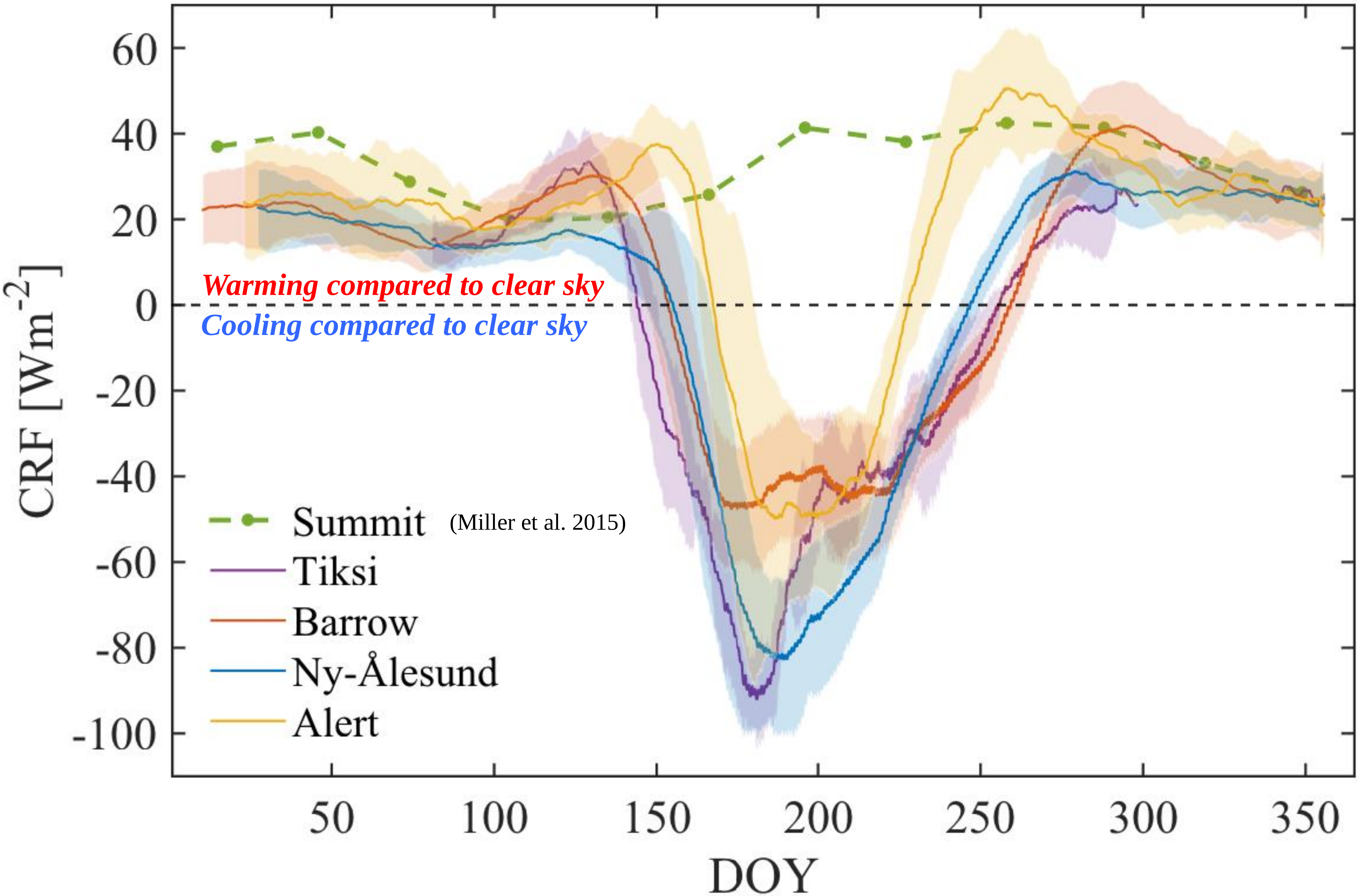
Clear-sky SW & LW, total sky cover, LW effective sky cover, cloud optical depth, cloud transmissivity, sky brightness temperature, cloud radiative temperature, LW clear sky emissivity
Long and Ackerman 2000, Long and Turner 2008, Long 2005, Barnard and Long 2004, Barnard et al. 2008, Long et al. 2006, Durr and Philipona 2004, Marty and Philipona 2000

Radiative Flux Analysis (RadFlux)

- RadFlux methodology
  - Time series analyses of surface broadband radiation and meteorological measurements (T/RH)
    - Need at least 5-minute resolution
  - Detect clear-sky (cloud free) periods
  - Use detected clear sky data to fit functions
  - Interpolate coefficients to produce continuous estimate of clear-sky irradiances
  - Use clear-sky and measured irradiances to infer cloud forcing and cloud properties

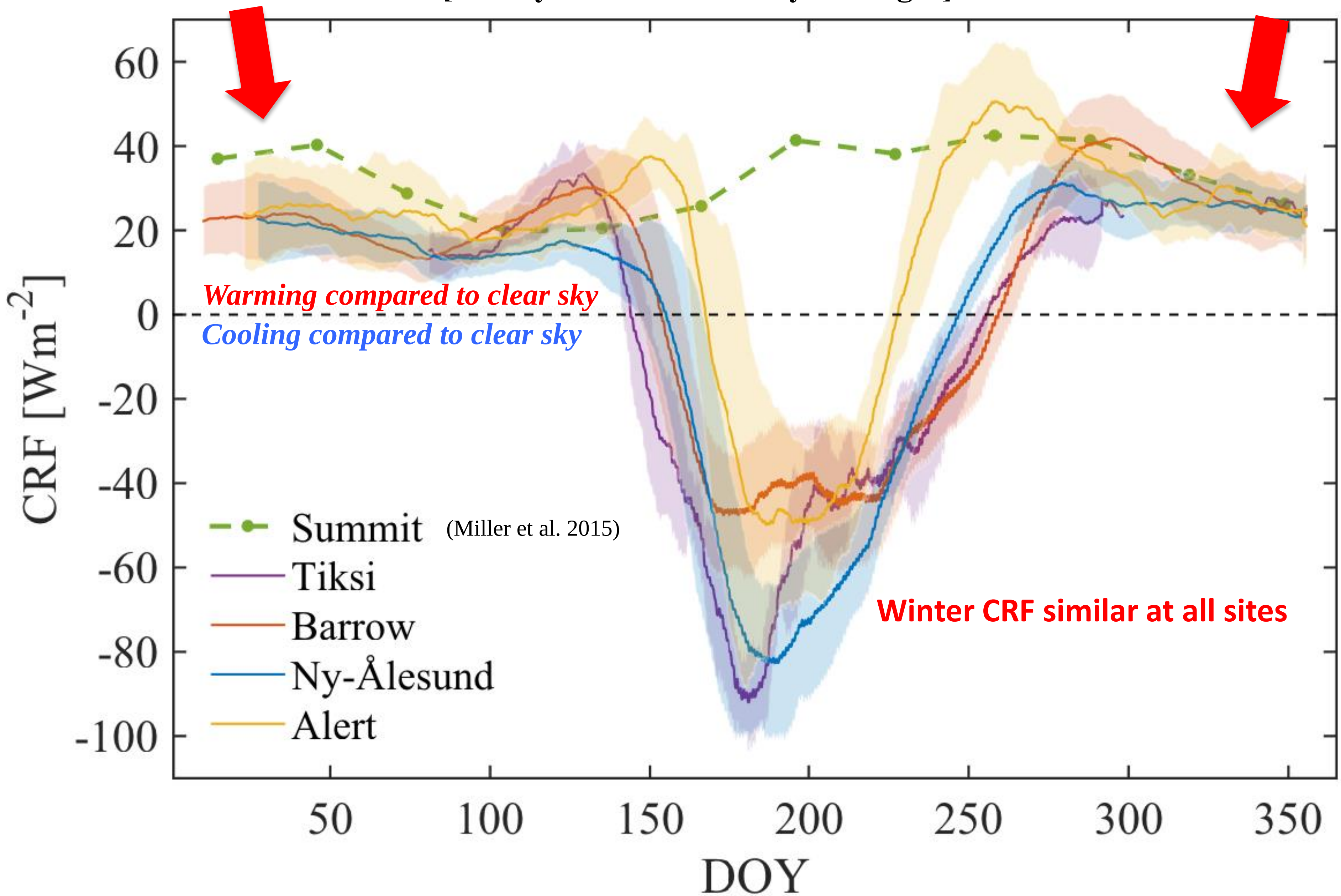
Cloud Radiative Forcing (CRF) Seasonal Cycle

[21-day smoothed hourly averages]



Cloud Radiative Forcing (CRF) Seasonal Cycle

[21-day smoothed hourly averages]



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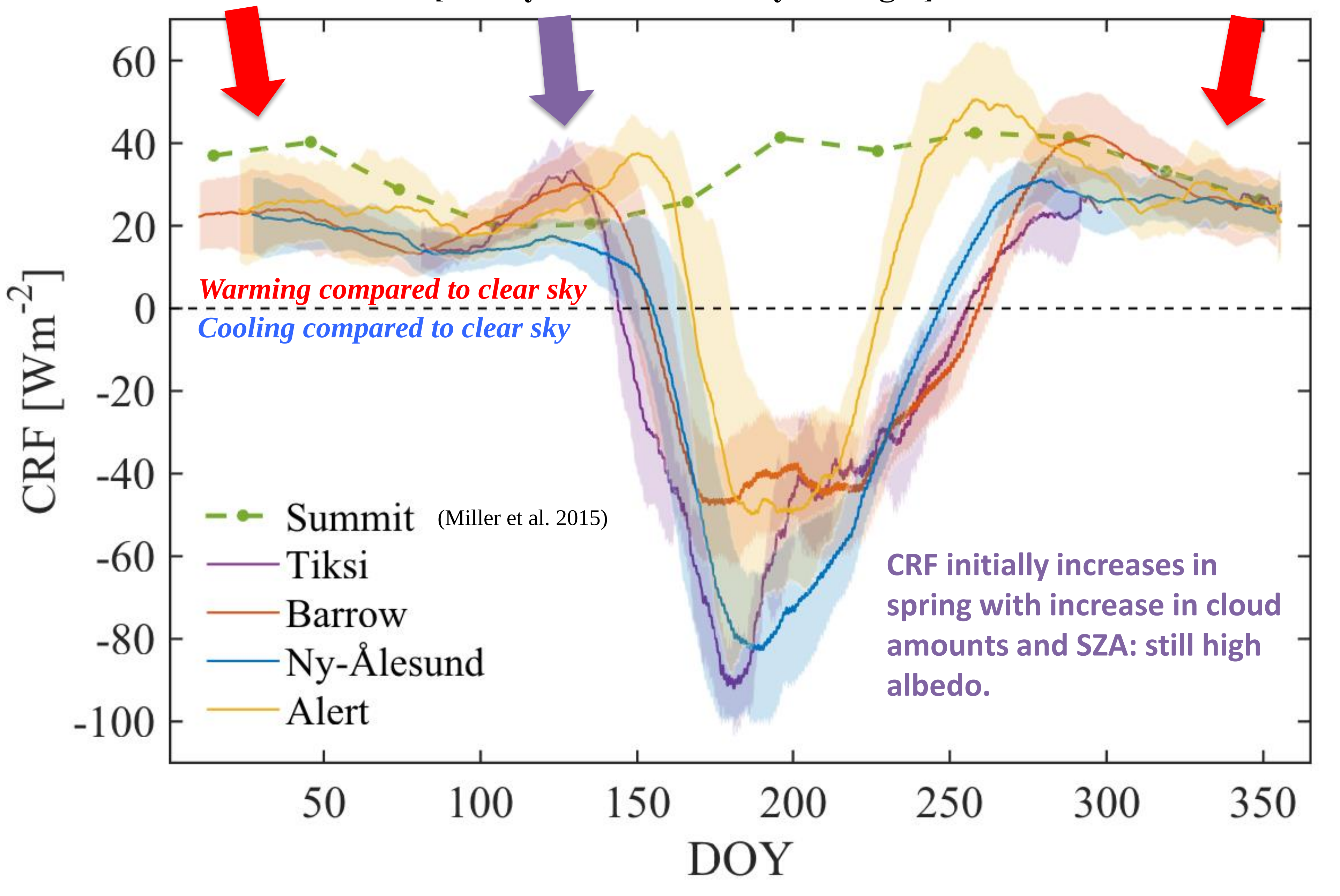

Cloud Radiative Forcing (CRF) Seasonal Cycle

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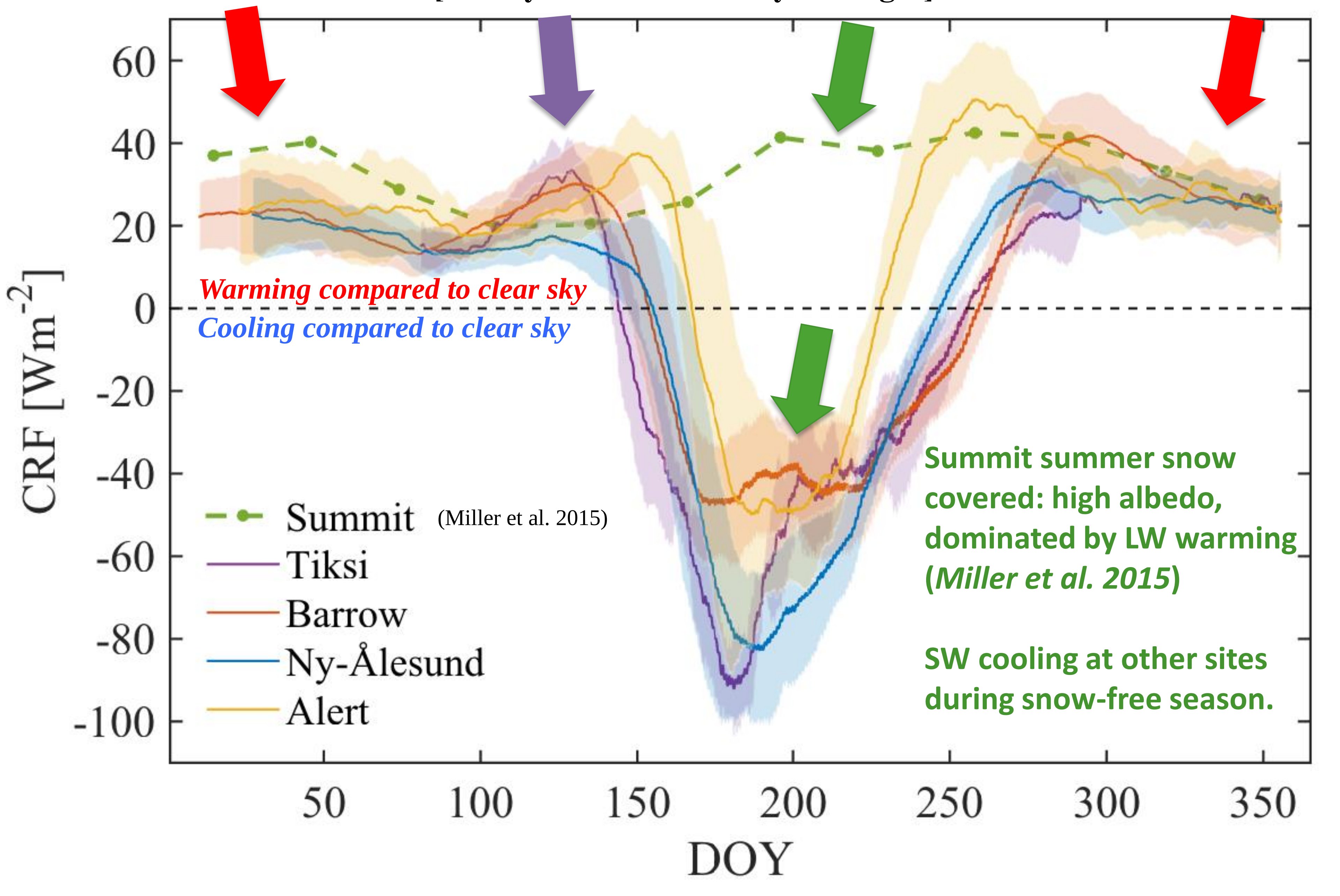

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ARTICLE

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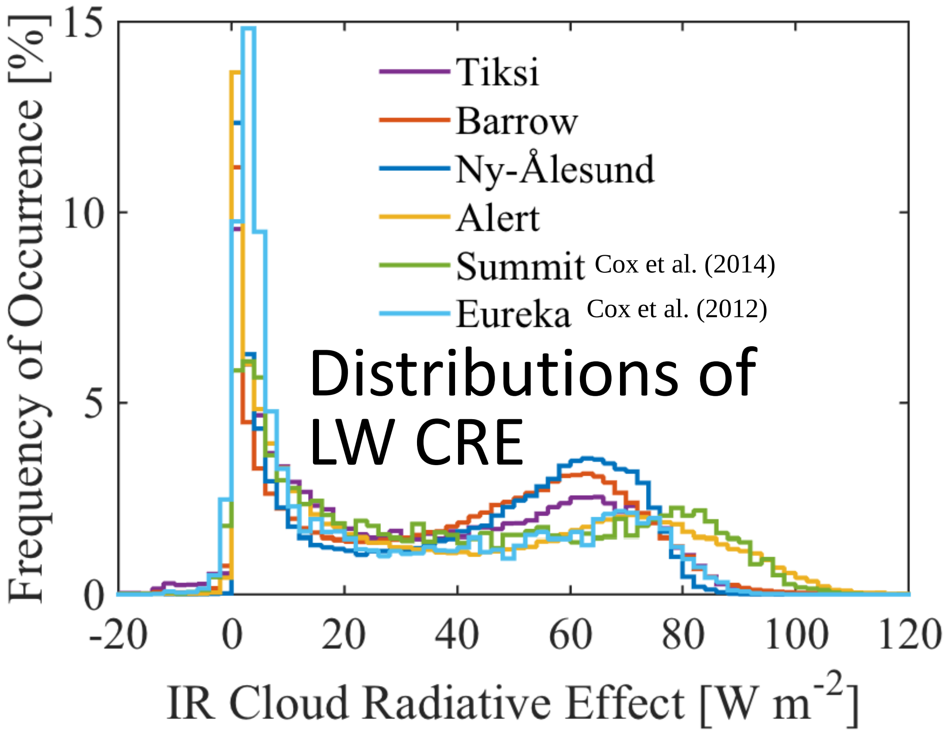
Humidity trends imply increased sensitivity to clouds in a warming Arctic

Christopher J. Cox[1,2], Von P. Walden[3], Penny M. Rowe[4,5] & Matthew D. Shupe[1,2]



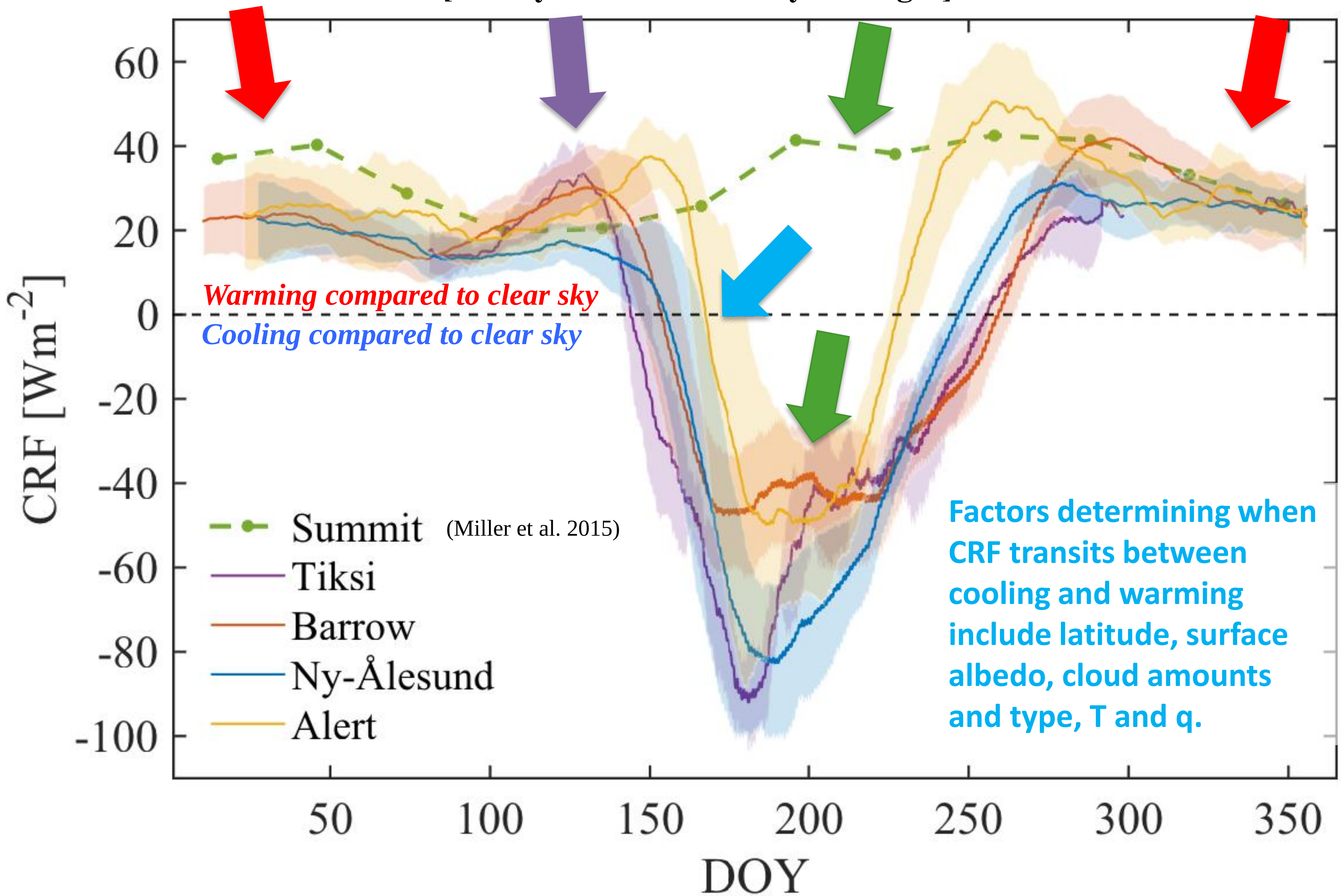
The longwave analogue to the affects of albedo on SW CRF…

Distributions of cloud radiative effect are different at some sites because of different T/PWV climates

CRE in far-IR and atmospheric window compensate at constant RH

Cloud Radiative Forcing (CRF) Seasonal Cycle

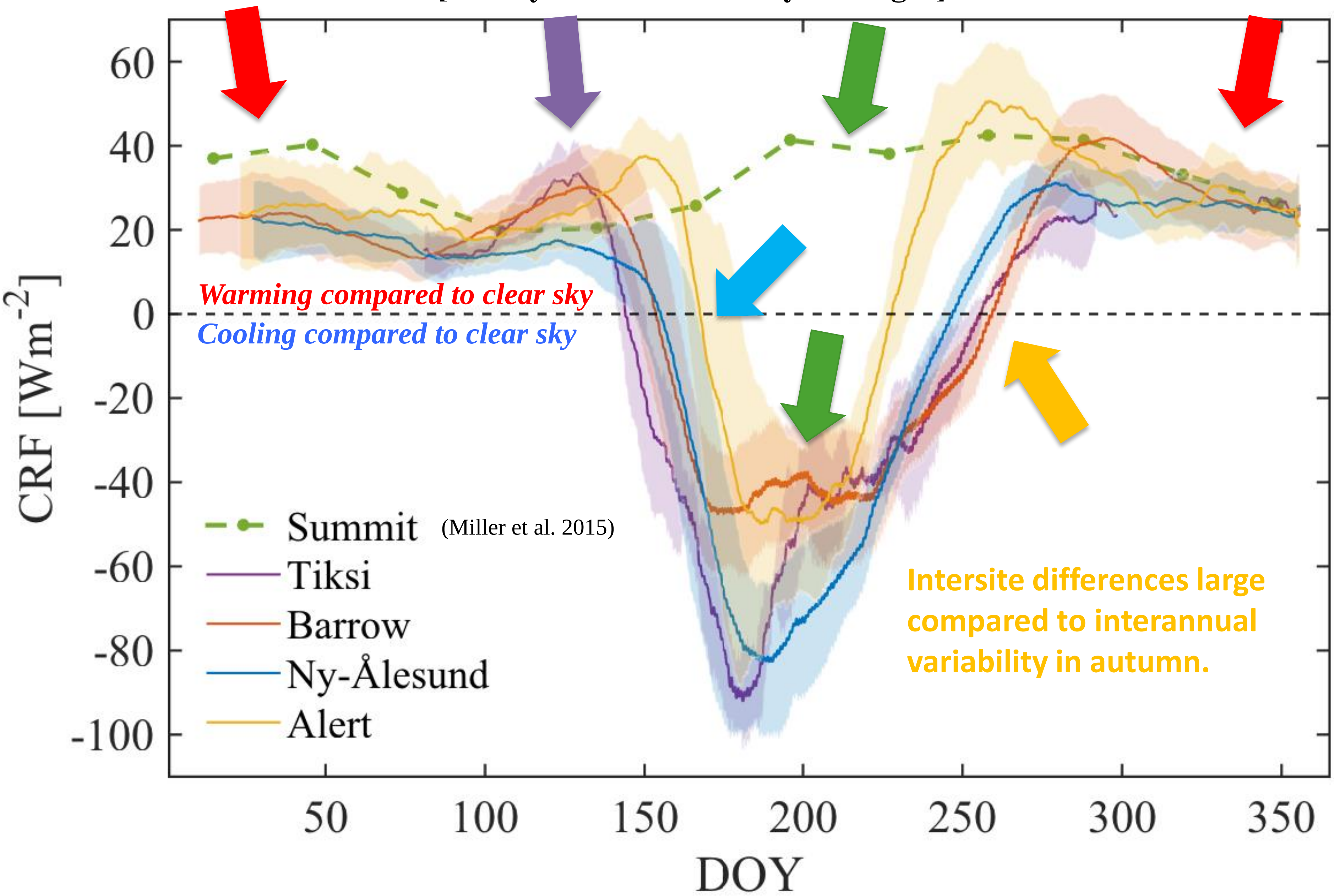
[21-day smoothed hourly averages]



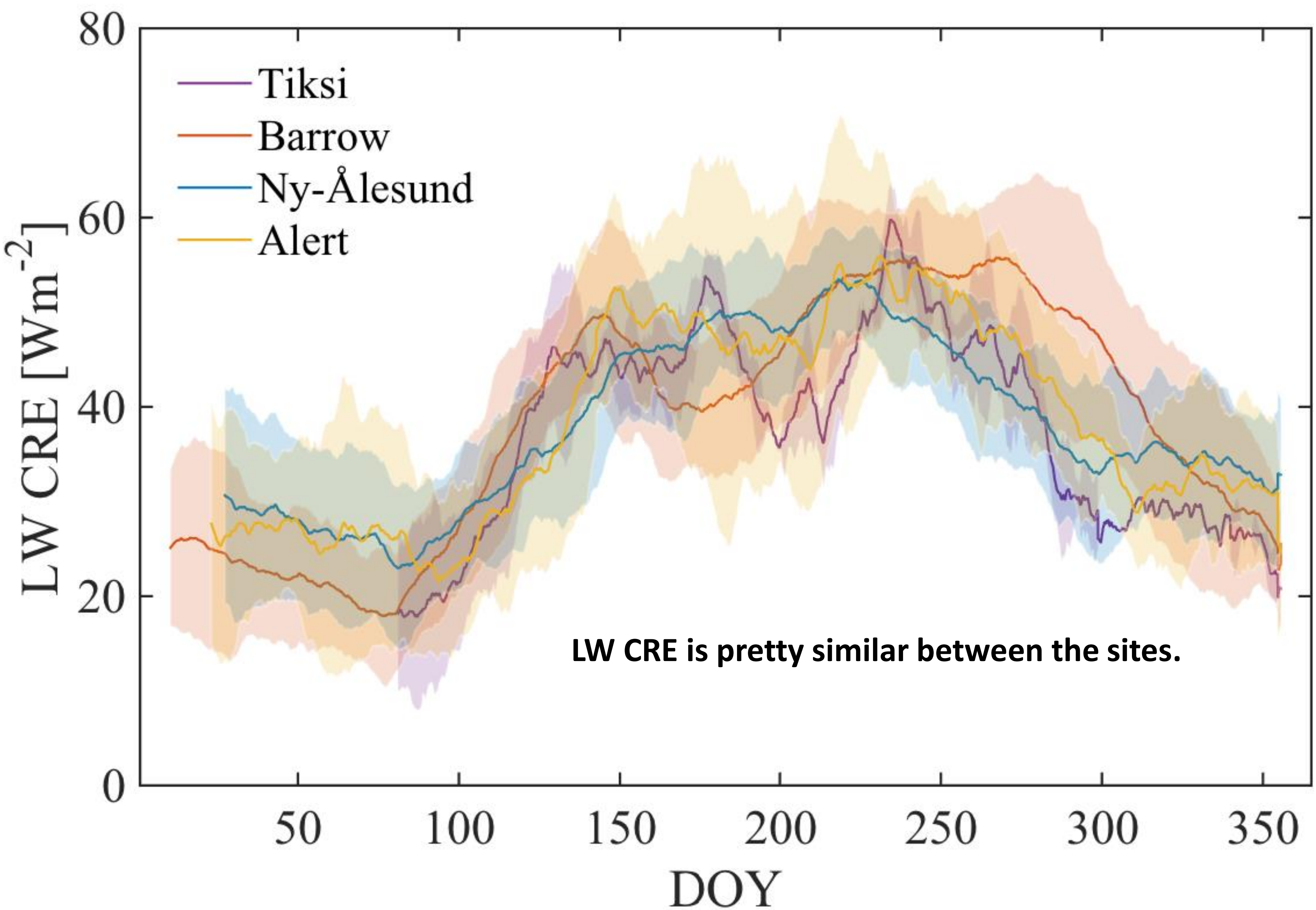
Factors determining when CRF transits between cooling and warming include latitude, surface albedo, cloud amounts and type, T and q.

Cloud Radiative Forcing (CRF) Seasonal Cycle

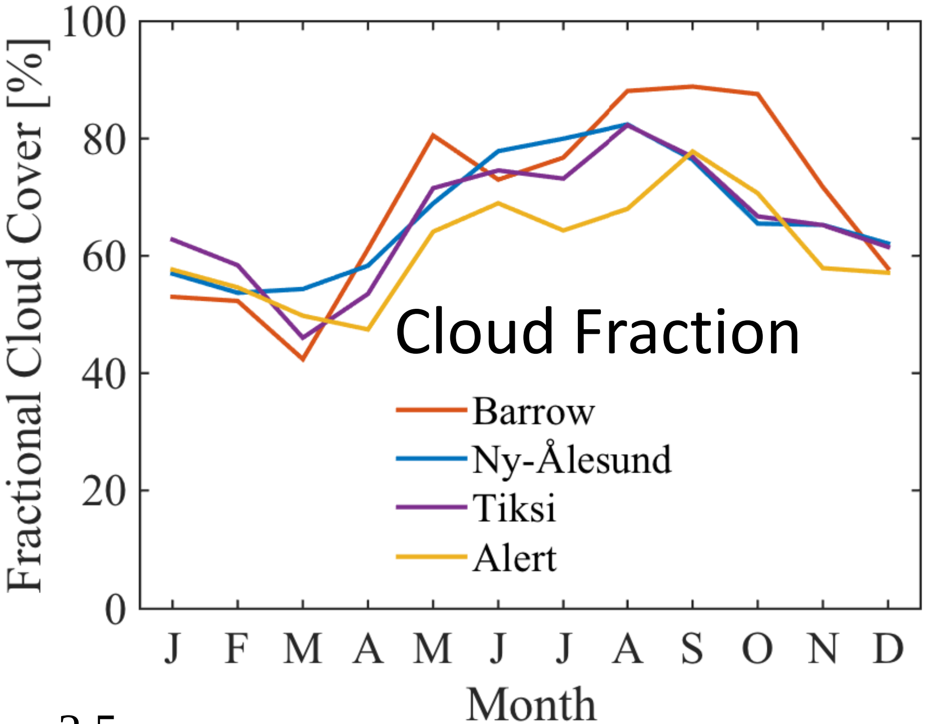
[21-day smoothed hourly averages]

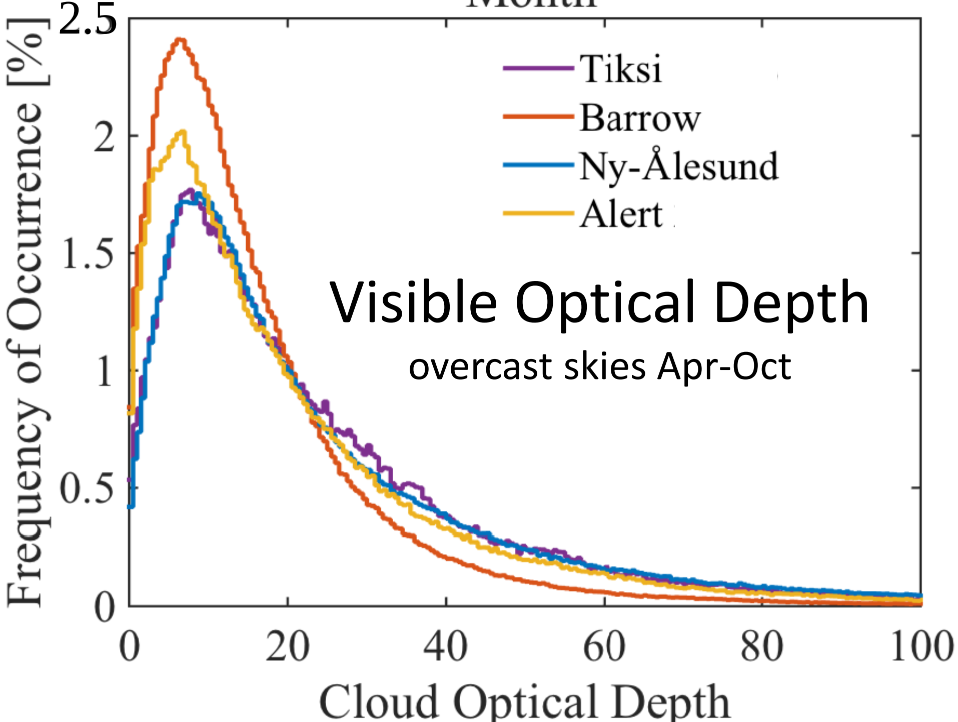


Longwave Cloud Radiative Effect (LW CRE)



LW CRE is pretty similar between the sites.



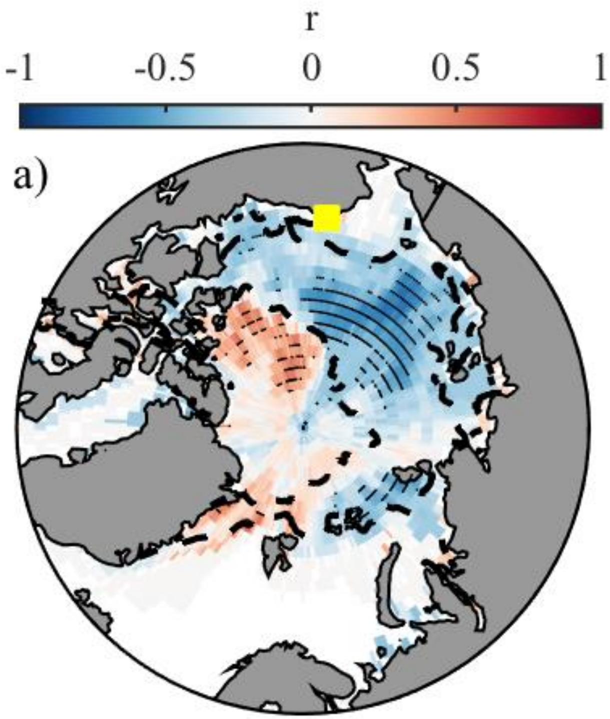


Cloud properties vary between sites

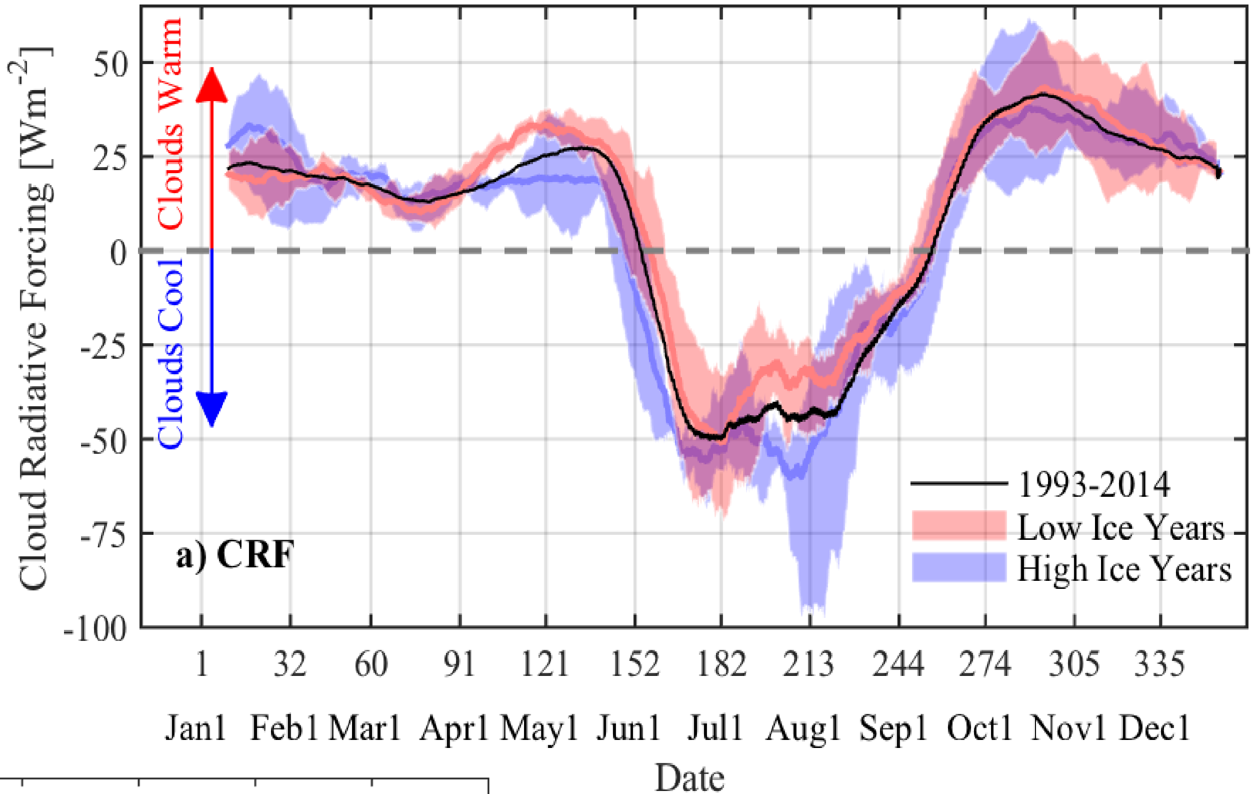
e.g.,

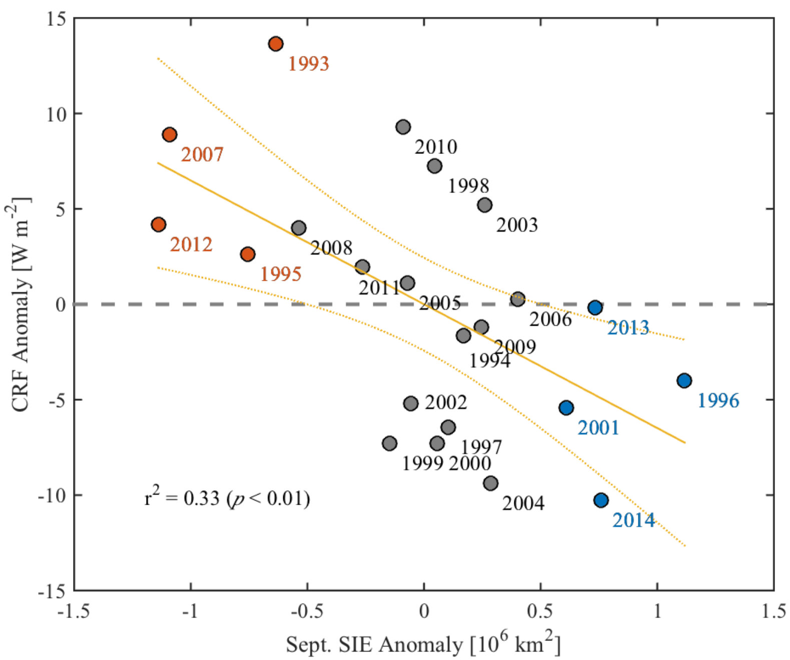
- **Cloud occurrence greater at Barrow than other sites in autumn.**

Applications – seasonal sea ice forecasting



- Autumn sea ice conditions are thought to be affected by radiative conditioning of the ice in spring.
- Springtime downwelling all-wave at Barrow, Alaska, well-correlated with autumn sea ice extent.





- The observed correlation is driven in part by clouds.
- Increased CRF during spring supported by positive cloud cover anomaly early followed by negative anomaly late.
- The subtleties of the CRF transition in spring appear to be important!

Cox et al. *submitted* J. Climate, 2016

Conclusions

- **Working to leverage Arctic BSRN observations collectively to advance process understanding.**
- **Properties of the environment that are not cloud properties (e.g., surface cover, T,q profiles) are among the largest sources of variability in CRF.**
- **Interannual variability in CRF is similar to differences between sites except in autumn. *Intra-site characterization is needed.***
- **On average, CRE_{LW} is similar between the sites, but this is from different combinations of cloud properties and interaction with T/q. Analyzing components of SEB and understanding how balance is reached through compensation is a priority.**
- **BSRN observations may be useful in advancing seasonal-scale sea ice forecasting. Working on a multi-site empirical-statistical methodology.**

Thanks!

References:

Cox, C.J., Walden, V.P., Rowe, P.M., & Shupe, M.D. (2015). Humidity trends imply increased sensitivity to clouds in a warming Arctic. Nature Comms., 6, 1-8.

Cox, C. J., Walden, V. P., Compo, G. P., Rowe, P. M., Shupe, M. D., & Steffen, K. (2014). Downwelling longwave flux over Summit, Greenland, 2010–2012: Analysis of surface-based observations and evaluation of ERA-Interim using wavelets. J. Geophys. Res., 119(21), 12-317.

Cox, C. J., Walden, V. P., & Rowe, P. M. (2012). A comparison of the atmospheric conditions at Eureka, Canada, and Barrow, Alaska (2006–2008). J. Geophys. Res., 117(D12).

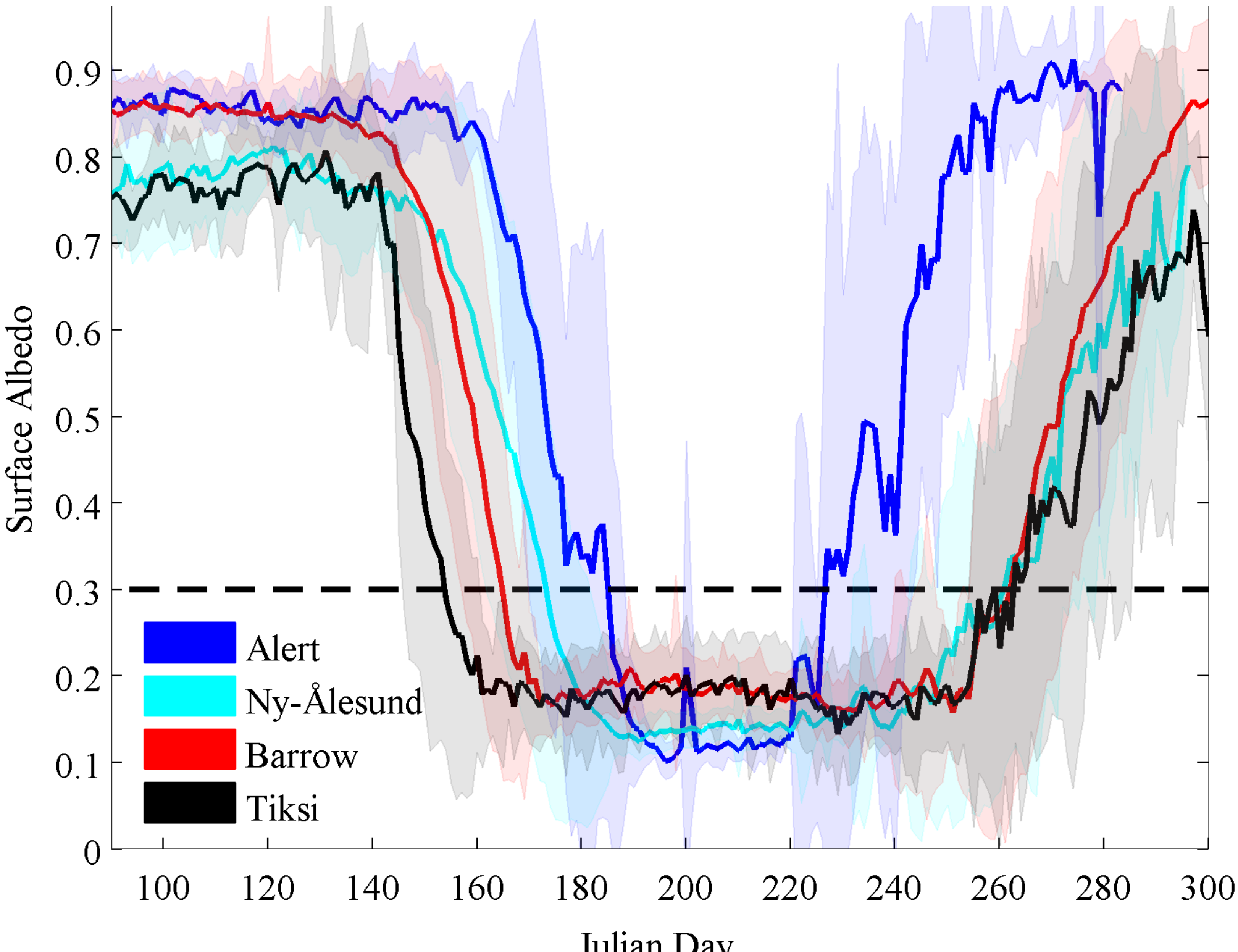
Long, C. N., & Shi, Y. (2008). An automated quality assessment and control algorithm for surface radiation measurements. Op. Atmos. Sci. J., 2(1).

Long, C. N., & Turner, D. D. (2008). A method for continuous estimation of clear-sky downwelling longwave radiative flux developed using ARM surface measurements. J. Geophys. Res., 113(D18).

Long, C. N., & Ackerman, T. P. (2000). Identification of clear skies from broadband pyranometer measurements and calculation of downwelling shortwave cloud effects. J. Geophys. Res., 105(D12), 15609-15626.

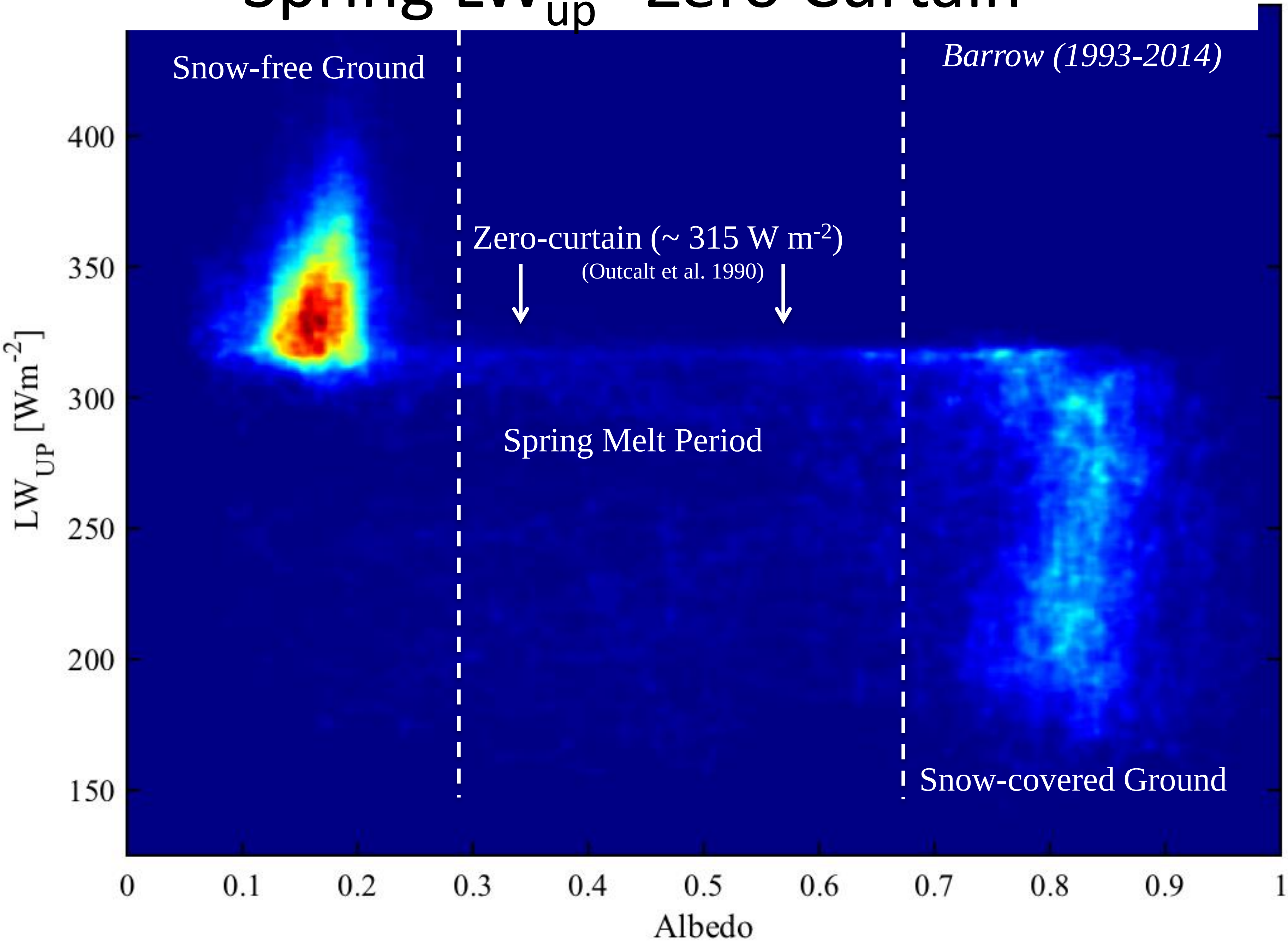
Miller, N. B., Shupe, M. D., Cox, C. J., Walden, V. P., Turner, D. D., & Steffen, K. (2015). Cloud radiative forcing at Summit, Greenland. J. Clim., 28, 6267-6280.

Albedo



Surface Albedo
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
120
140
160
180
200
220
240
260
280
300
Julian Day
Alert
Ny-Ålesund
Barrow
Tiksi

Spring LW_{up} "Zero Curtain"



Monthly Mean Cloud Radiative Forcing (CRF)