Properties of Arctic Clouds from Multiple Atmospheric Observatories

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Acknowledgments

- NOAA SEARCH program - Eureka
- NSF Arctic Natural Science - International Polar Year
  - University of Idaho - ARC 0632177
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- NSF Arctic Observing Network (AON)
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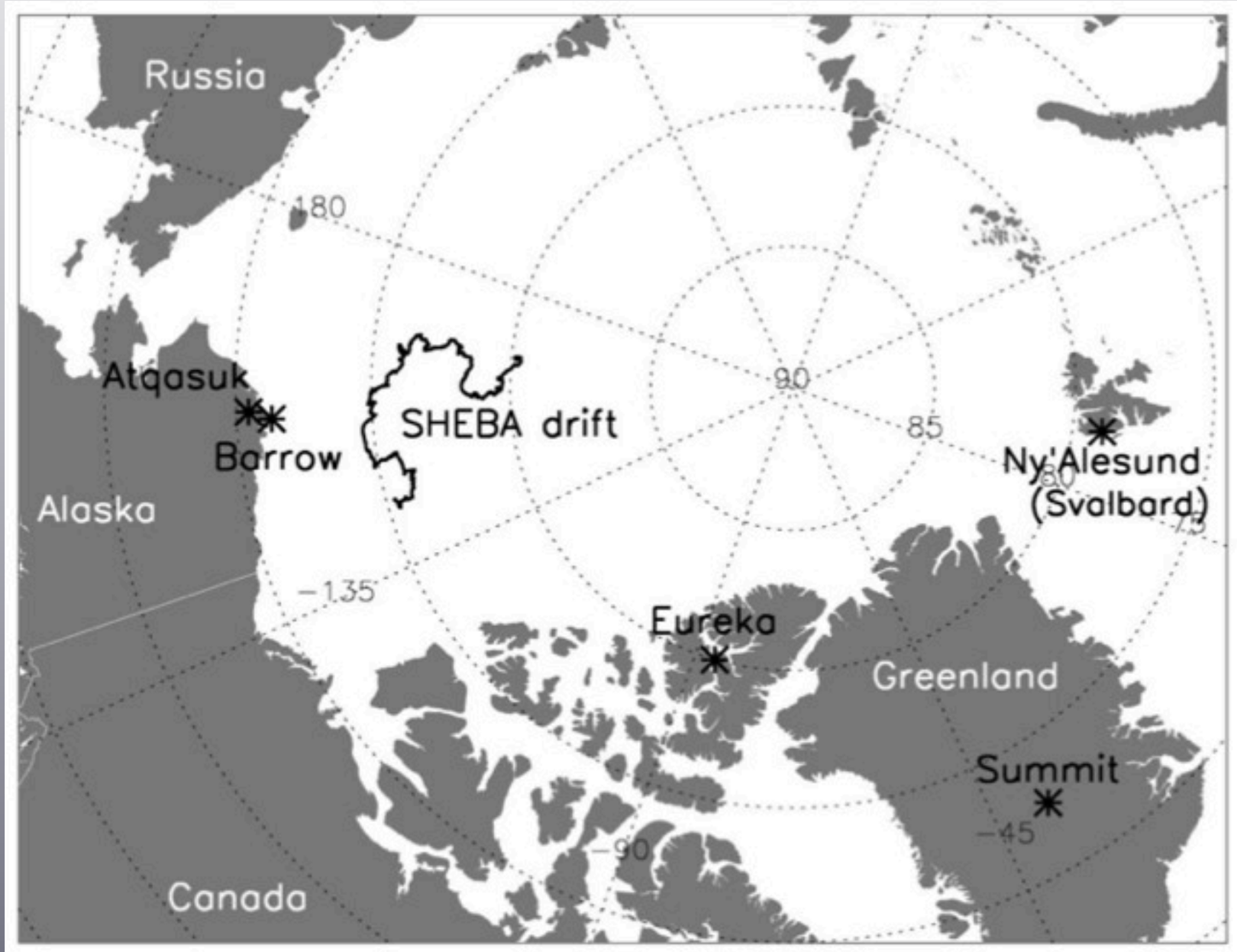
  - University of Colorado - ARC 0856559
  - University of Wisconsin-Madison - ARC 0904152
- Significant long-term investments in instrumentation development and facilities.

Goals and Objectives

- Understand both the *temporal* and *spatial* variability of cloud properties across the Arctic.
    - From *surface-based* instruments
        - Complement to satellite studies
- Study *macrophysical* and *microphysical* cloud properties, plus their *radiative* impact.

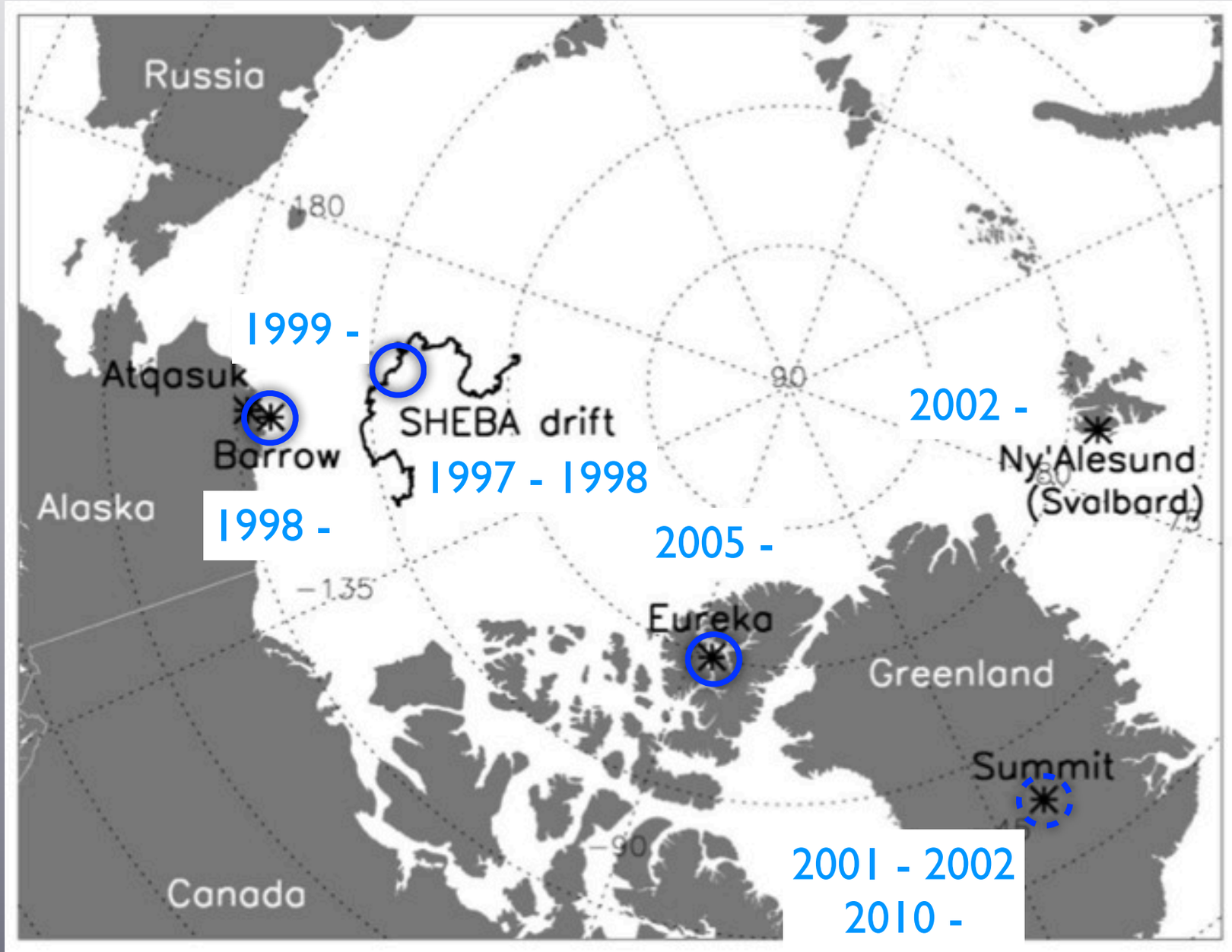
Arctic Observational Sites



- Stations are mainly in the Western Arctic

Arctic Observational Sites

= "Super Site"



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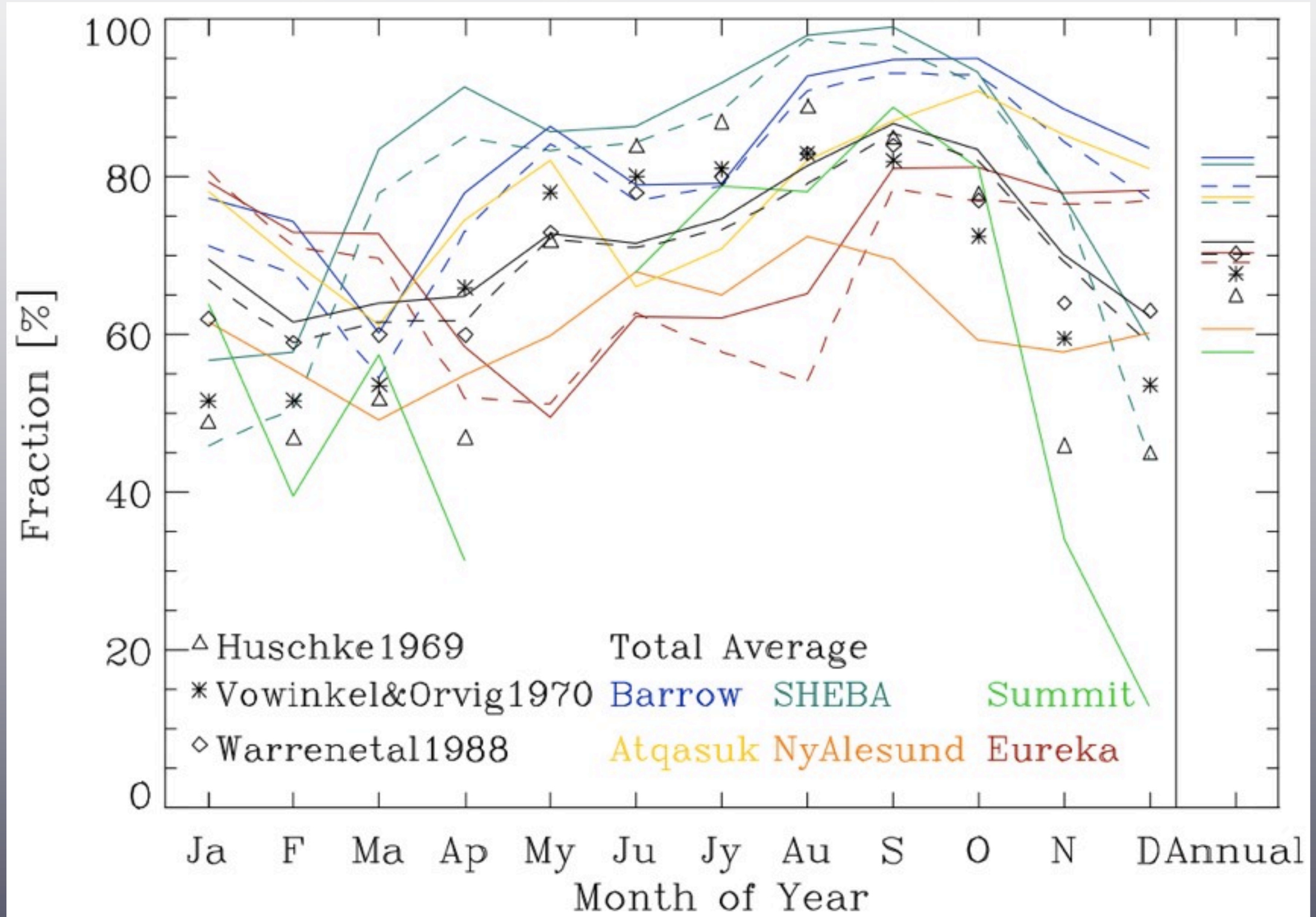
List of Instruments

Instrument	Measurements	Sites	Pertinent Specifications	Derived Parameters
MMCR (Radar)	Reflectivity, Signal-to-Noise Ratio	Barrow, Eureka, SHEBA	Δz = 45-90 m Δt = 4-10 s	presence, boundaries
HSRL (Lidar)	Backscatter, depolarization ratio	Eureka	Δz = 30 m Δt = 30 s	presence, boundaries
DABUL (Lidar)	Backscatter, depolarization ratio	SHEBA	Δz = 30 m Δt = 5 s	presence, boundaries
MPL (Lidar)	Backscatter, depolarization ratio (Barrow-only)	Barrow, Ny'Alesund	Δz = > 5 m Δt = > 2 s	presence, boundaries
Ceilometer (Lidar)	Backscatter	Atqasuk, Barrow, SHEBA, Summit	Δz = 15 m Δt = 15 s	presence, cloud base
AERI (Infrared Spectrometer)	IR radiance/T_B	Barrow, Eureka, SHEBA	Δt = 30 s	presence
MWR (Microwave Radiometer)	T_B	Barrow, Eureka, SHEBA	Δt = 30 s	presence (support)

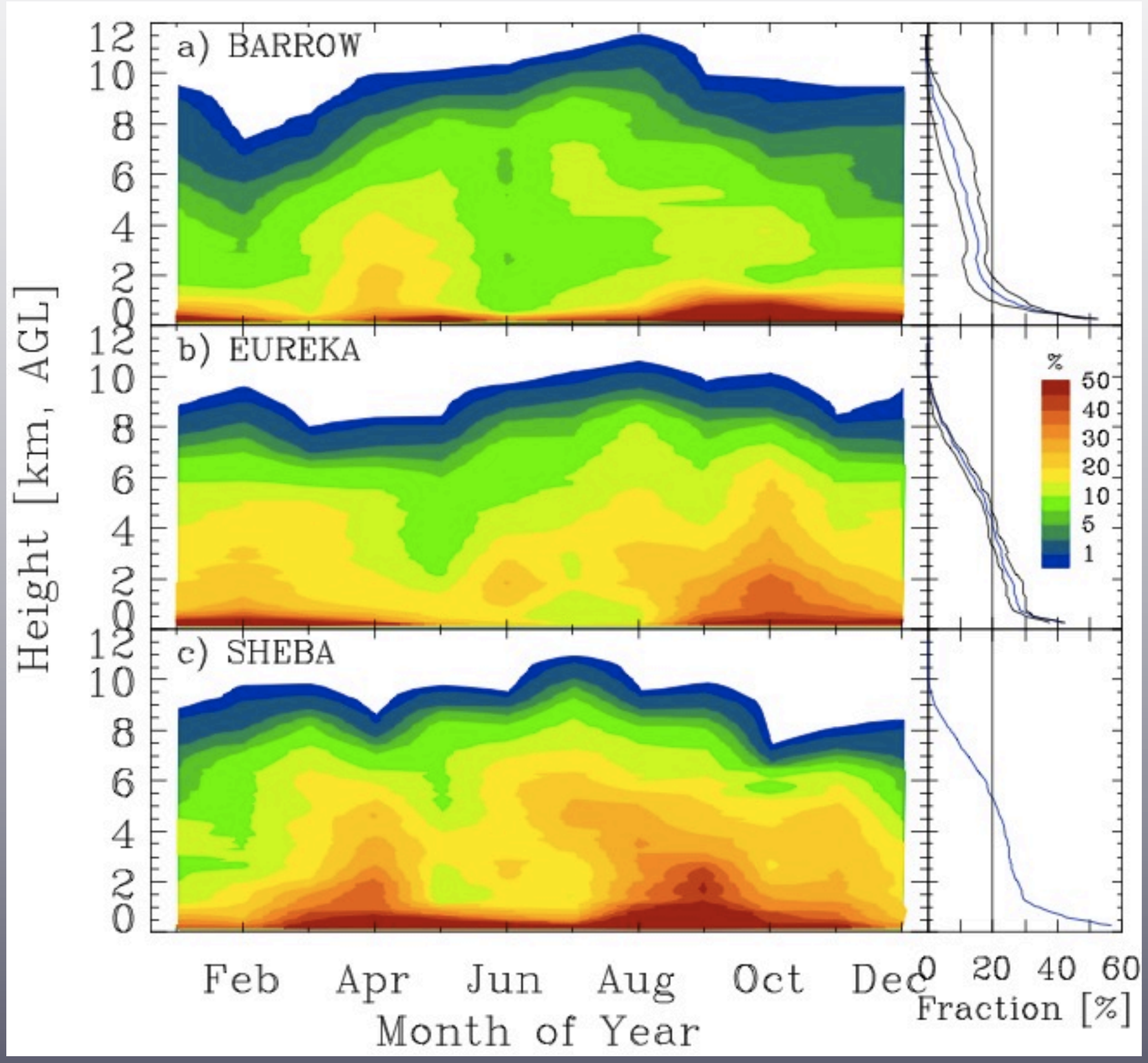
Macrophysical Properties

- *From Shupe et al, 2010, submitted to JAMC*
  - Cloud Fraction
  - Cloud-Height Distribution
  - Inter-annual and Inter-site Variability

Cloud Fraction



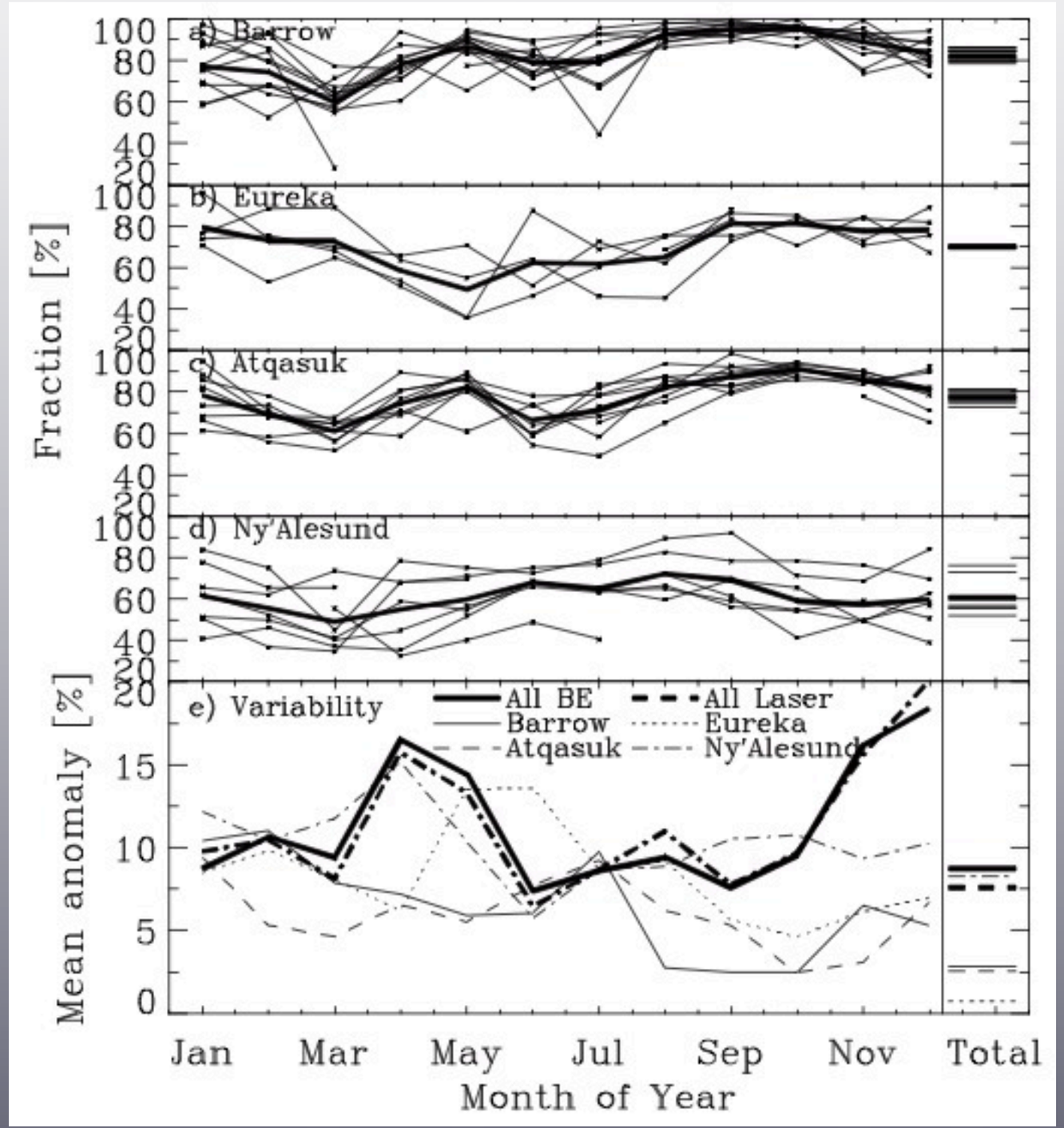
Distribution of Cloud Heights



Variability

- Inter-site monthly variability is typically within 10 – 15% of the all-site averages

- Interannual variability at specific sites is less than 15% for any given month, and typically less than 3% for annual cloud fractions

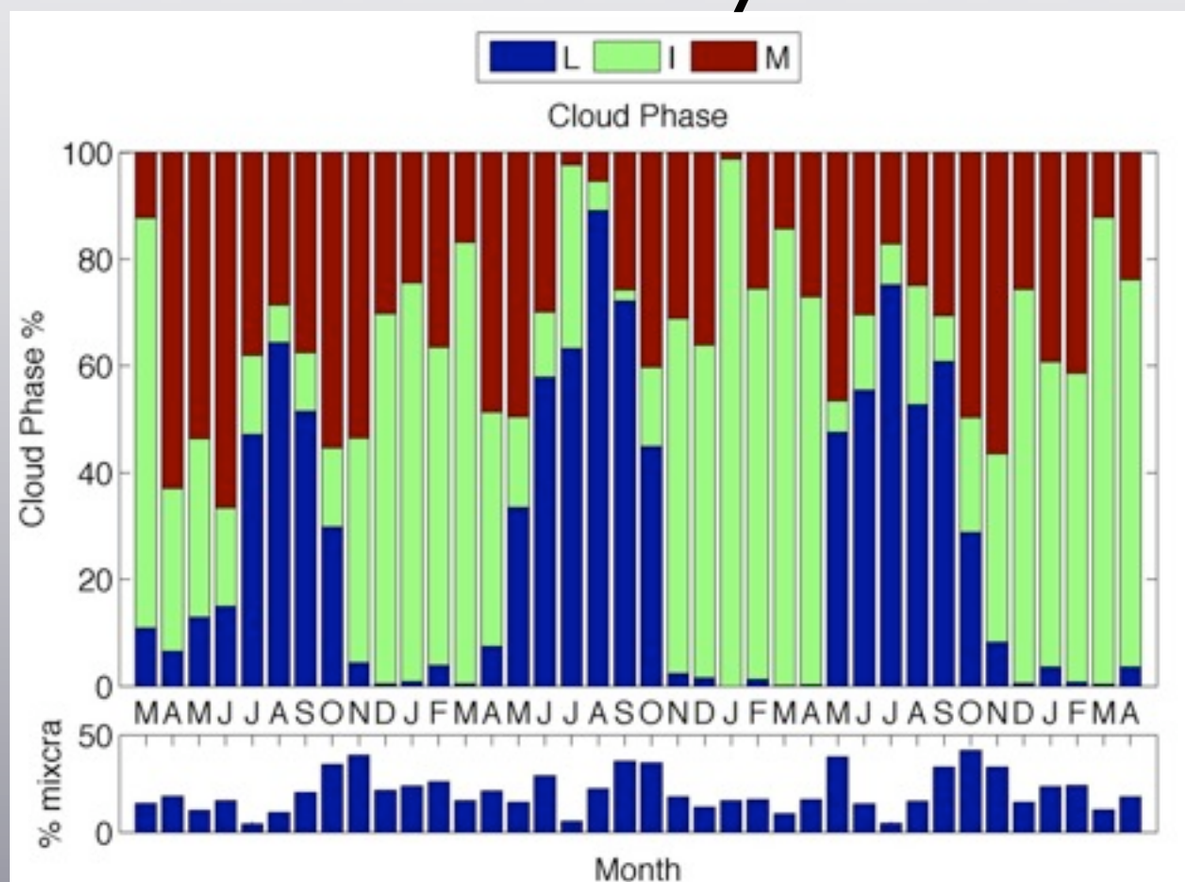


Microphysical Properties

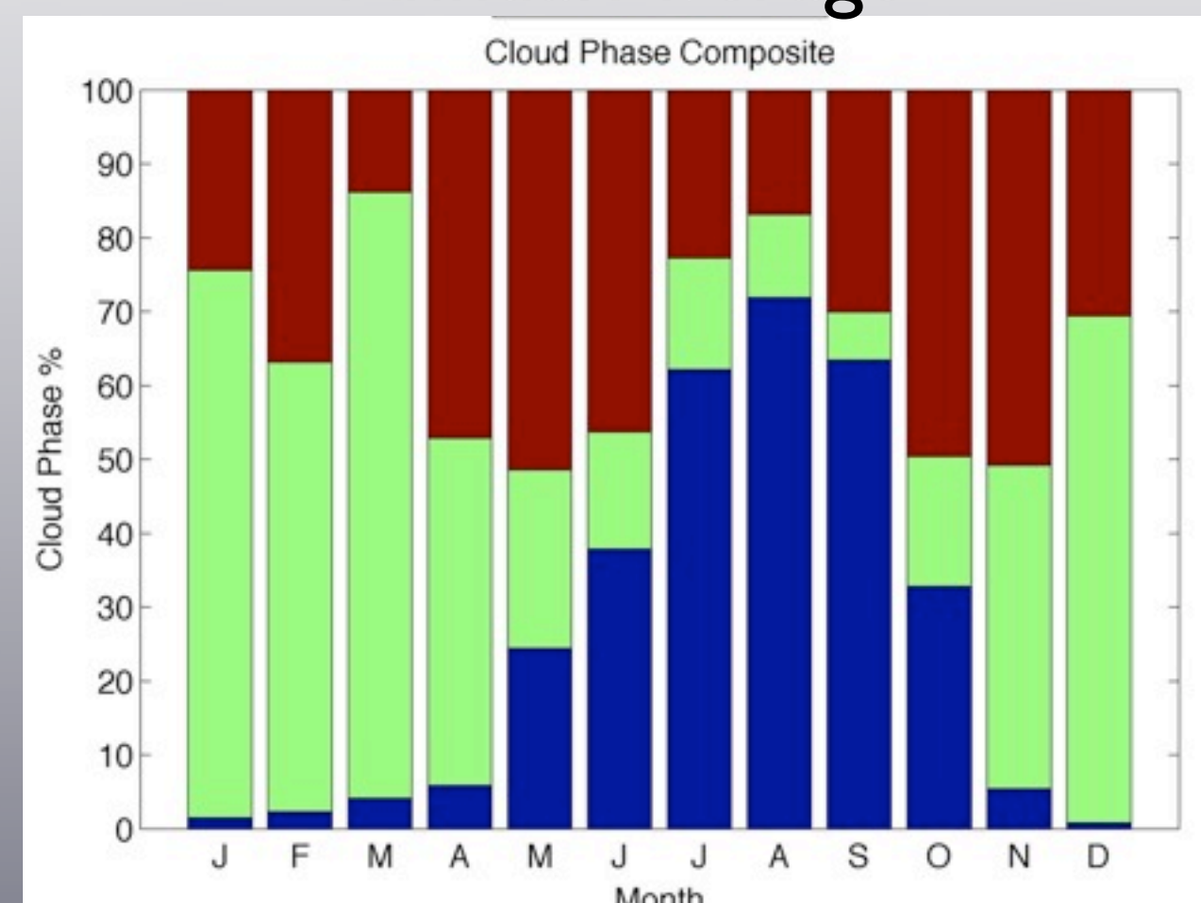
- Examples from Eureka (2006-2009)
  - From MIXCRA retrievals (Turner 2005)
- Preliminary comparisons to SHEBA (1998)
- Long time series at Barrow (up to 2005)

Cloud Phase

Seasonal Cycle



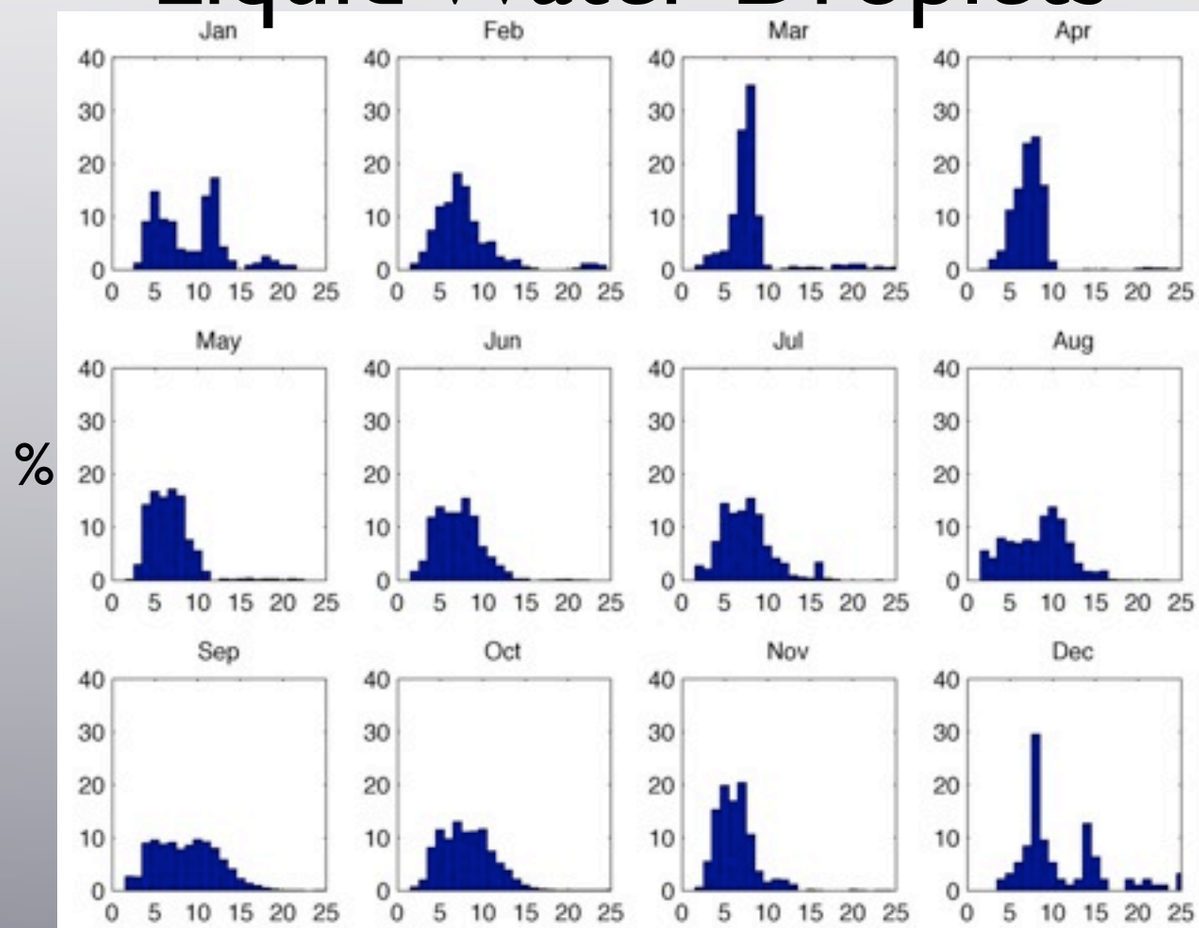
Annual Average



From Eureka

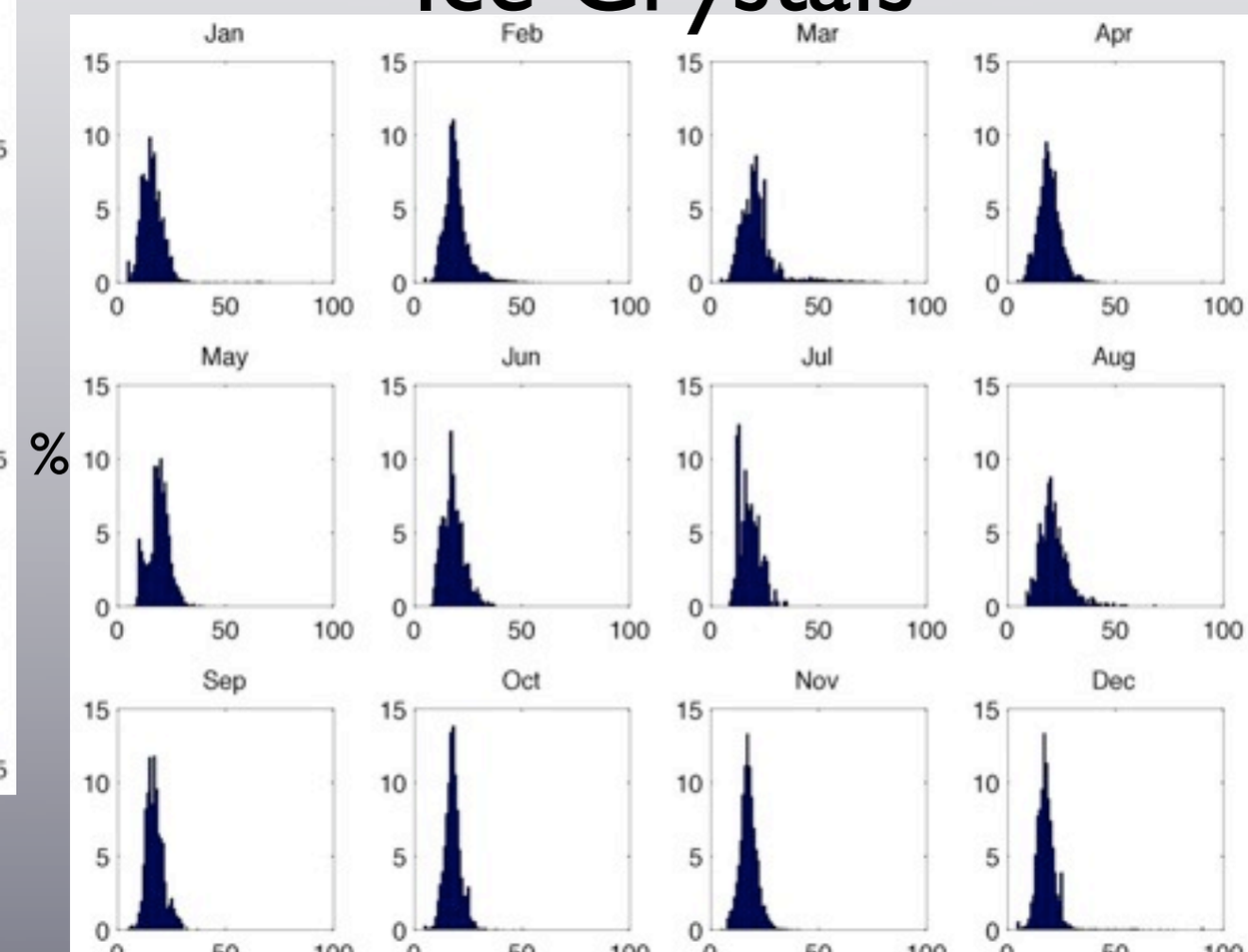
Effective Radius

Liquid Water Droplets



Effective Radius (um)

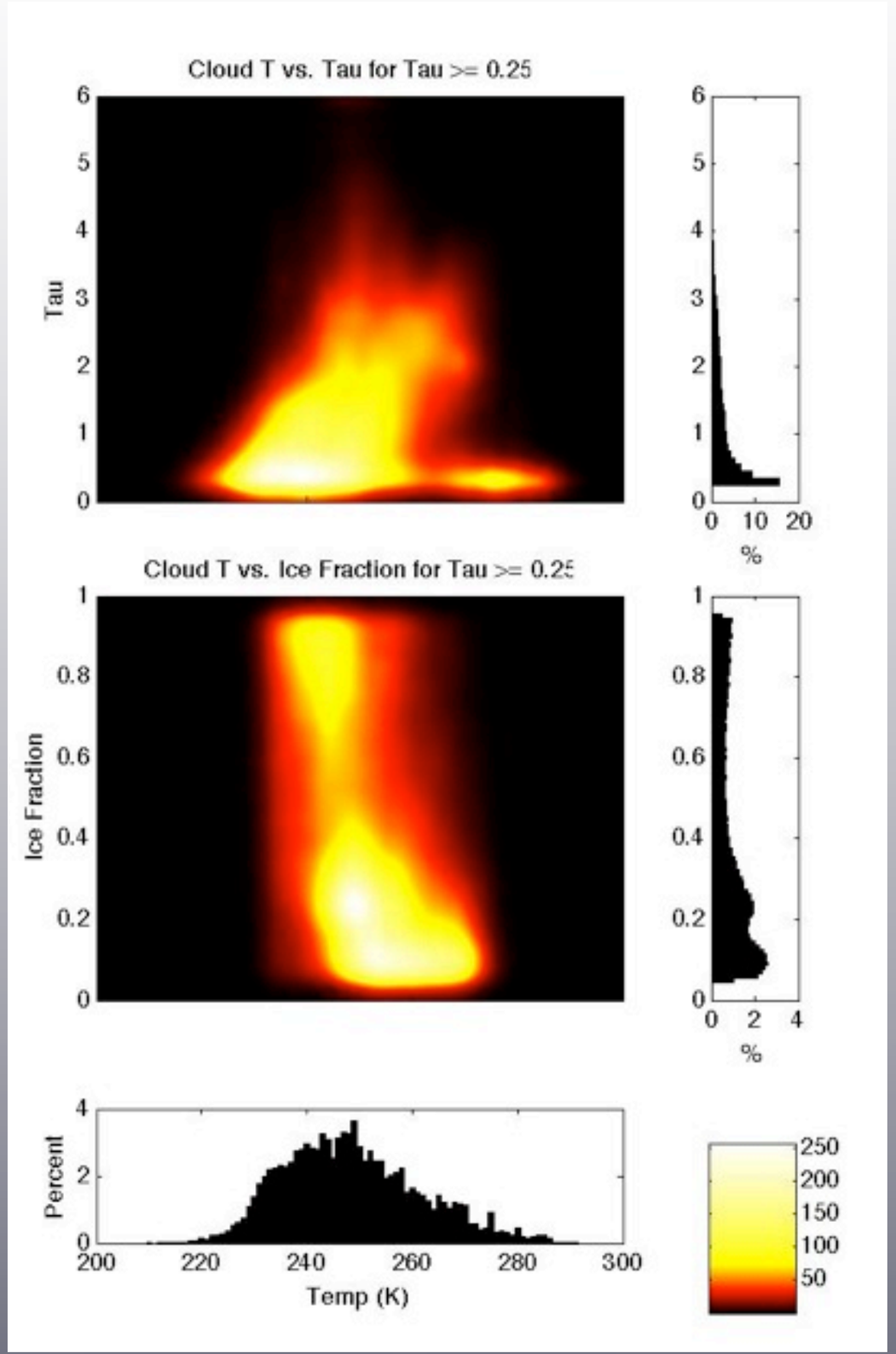
Ice Crystals



Effective Radius (um)

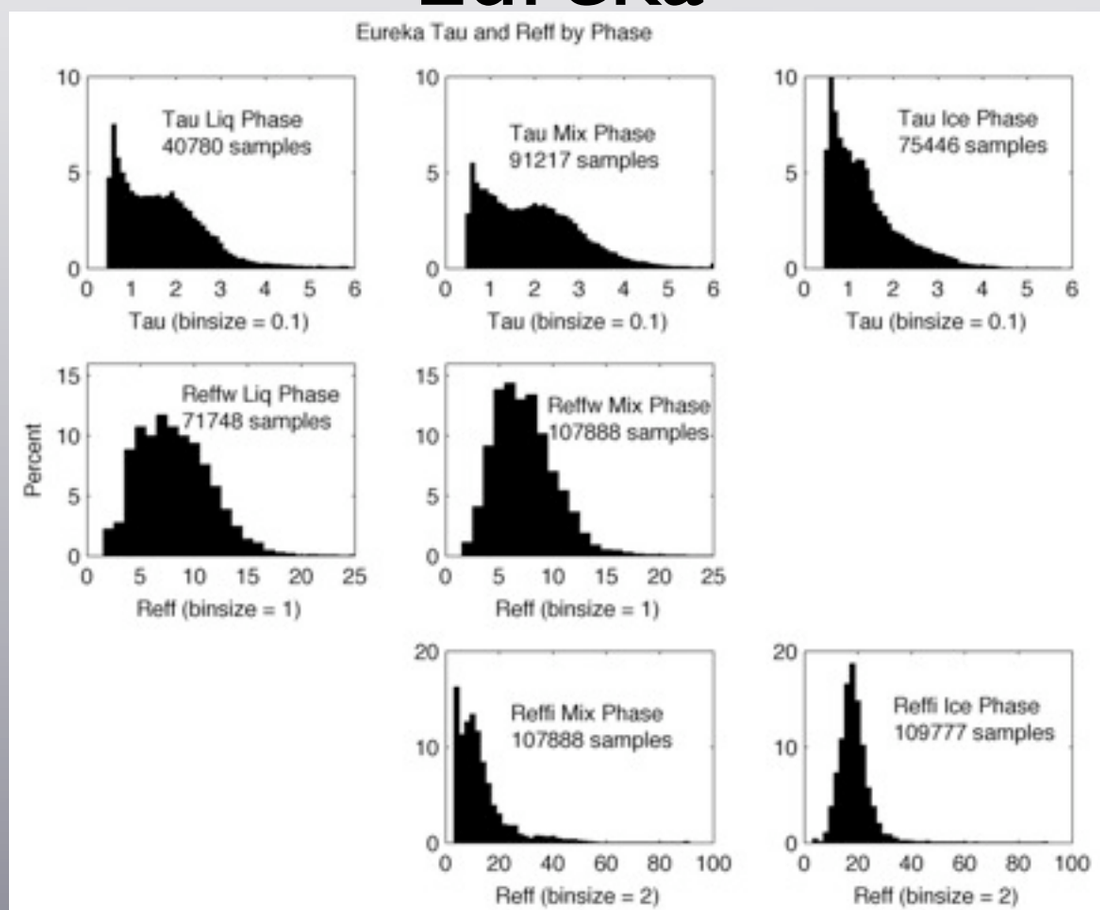
T-dependence

- Optical depths are generally < 1 (thin)
- Some dependence of tau and cloud fraction on temperature

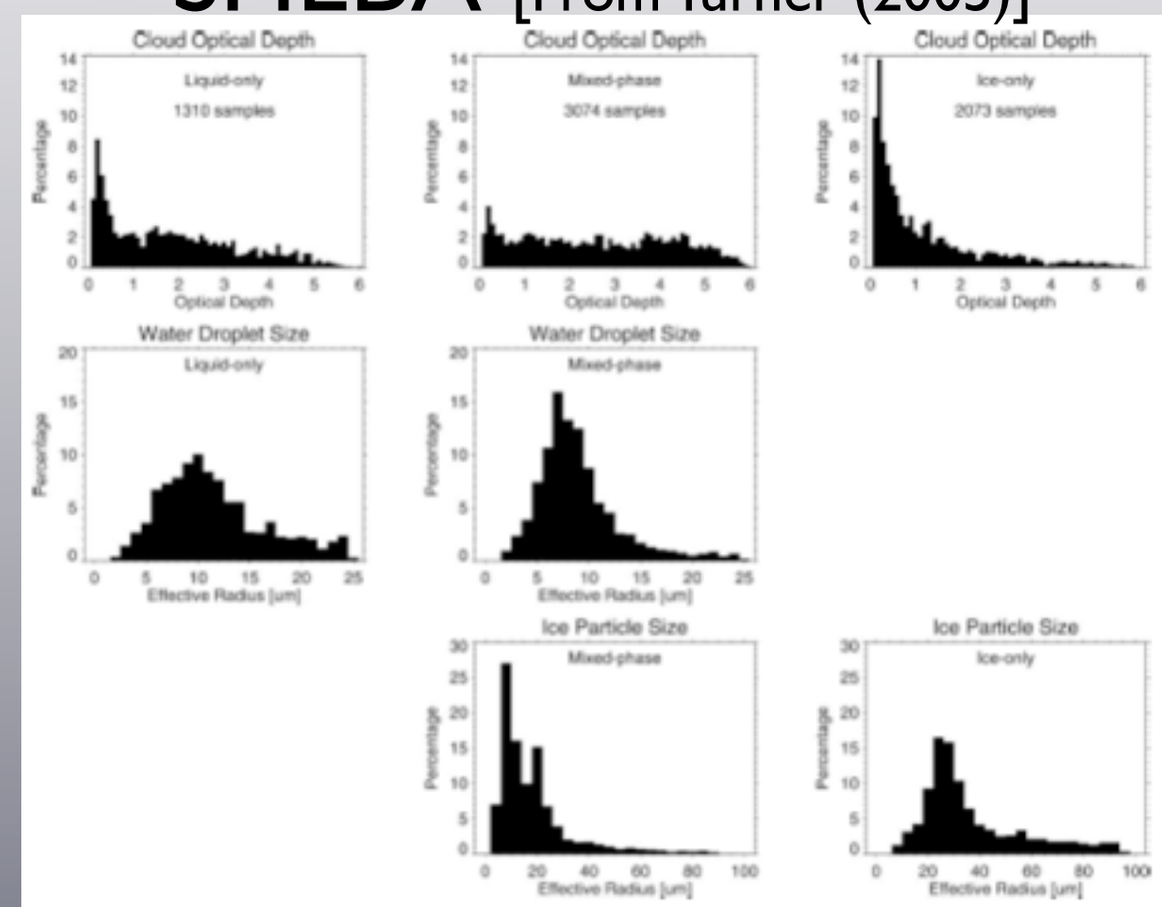


Site comparison

Eureka



SHEBA [From Turner (2005)]

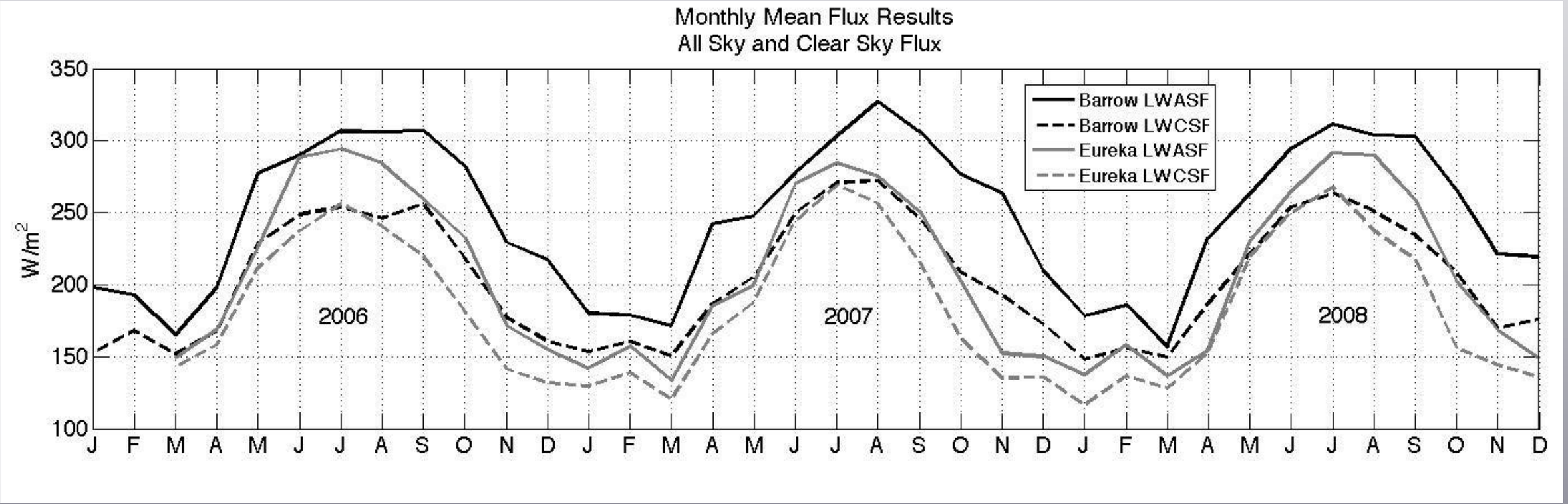


Microphysical properties are similar at Eureka and SHEBA

Longwave Radiative Effect

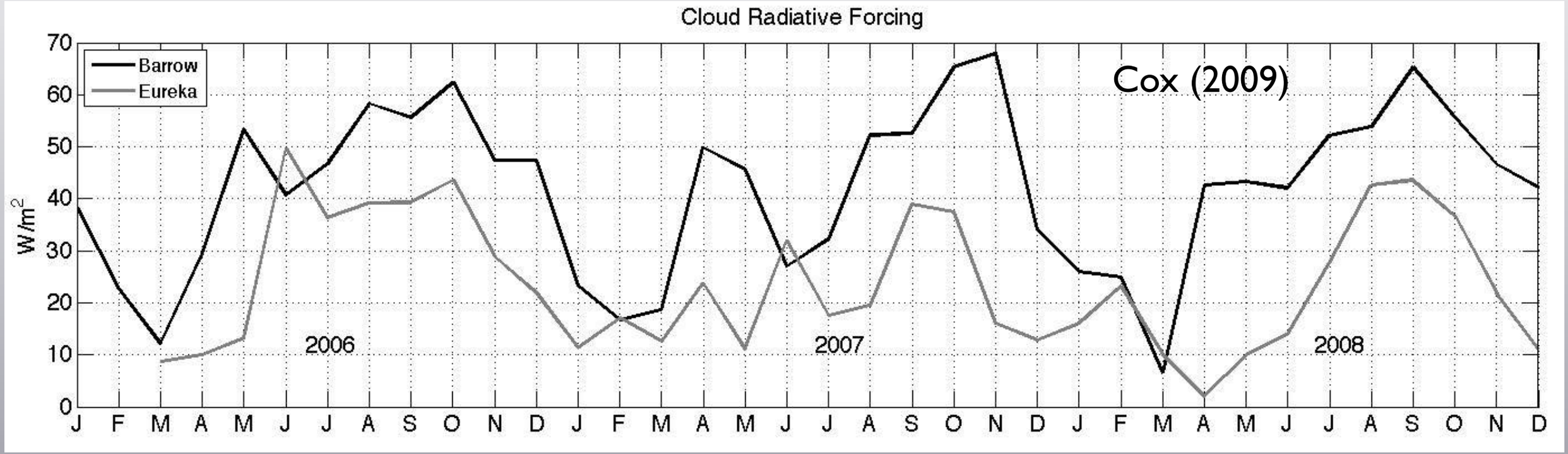
- Comparison of Barrow and Eureka
  - No broadband shortwave data at Eureka for this time period.

All-sky vs Clear-sky Flux



Longwave Cloud Radiative Forcing

- LWCRF = All-sky flux - Clear-sky flux



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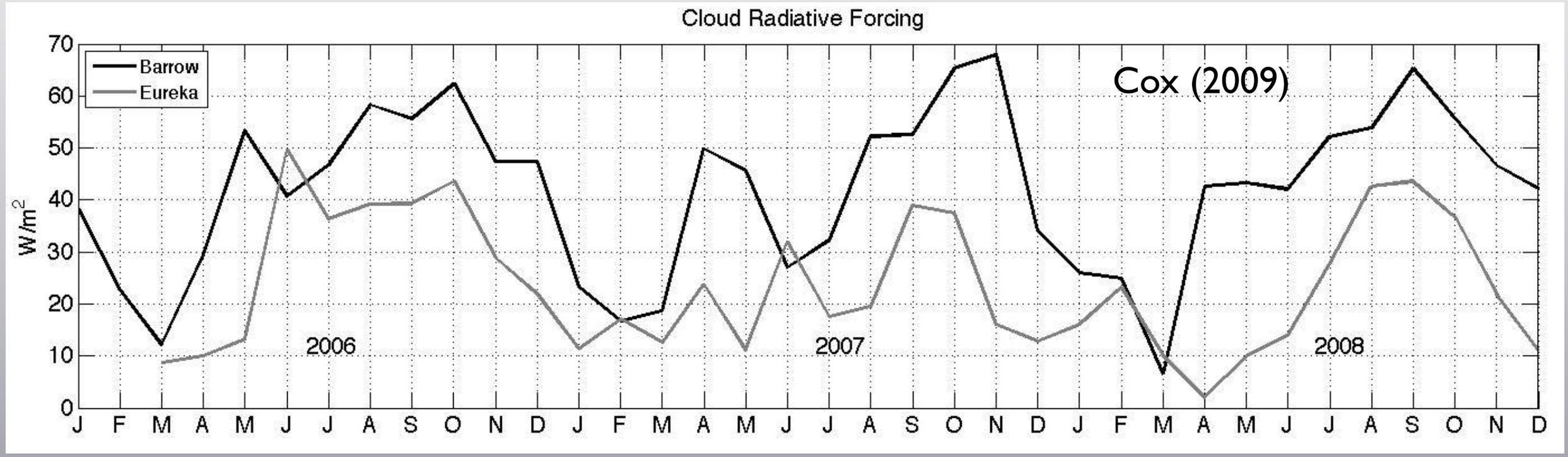
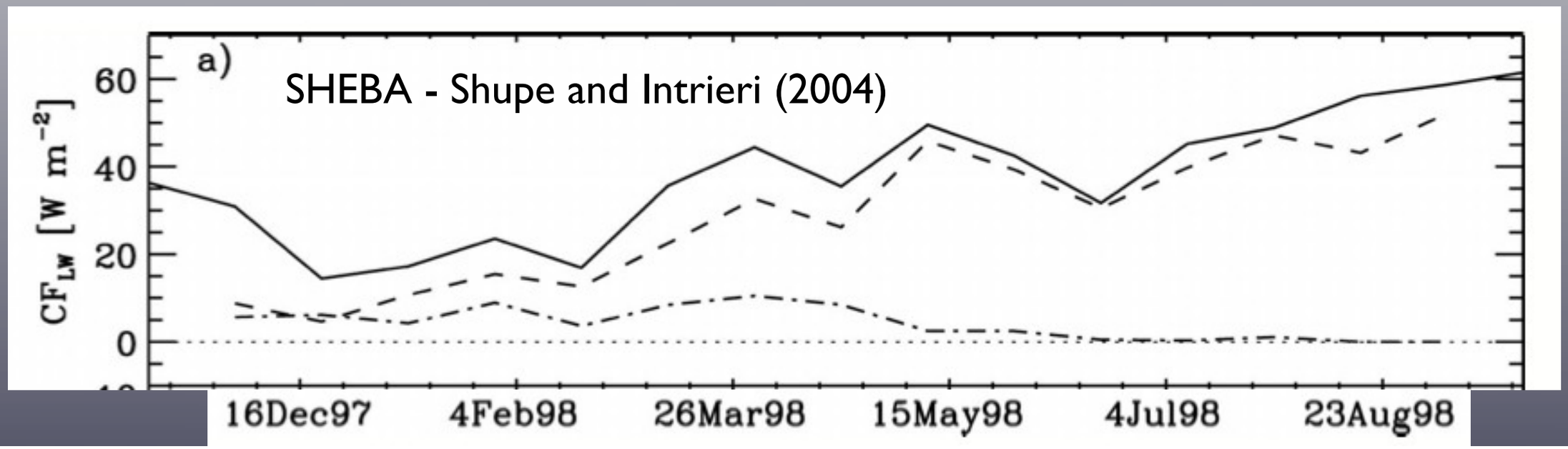
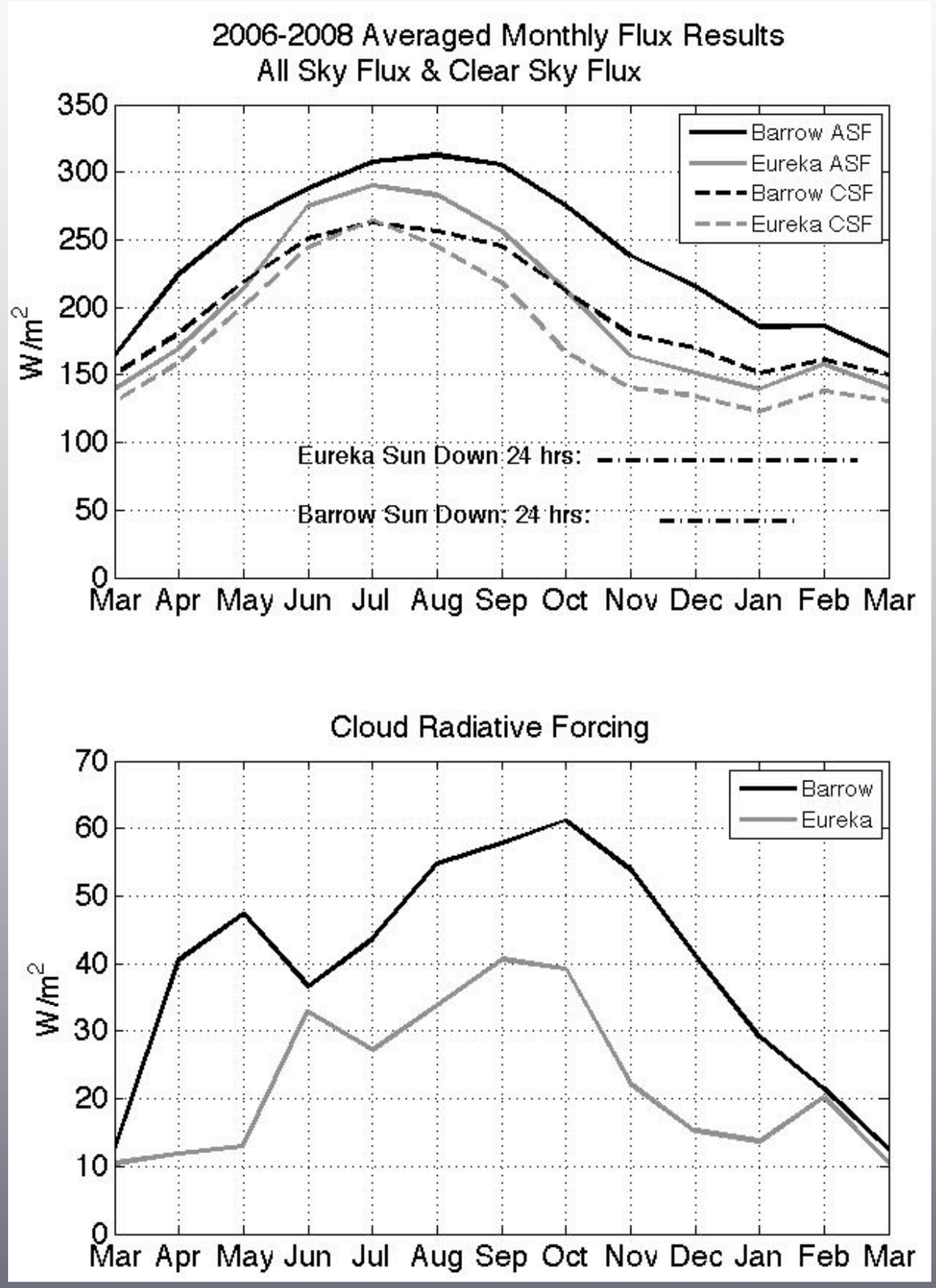




Multi-year Average

- Cloud Radiative Forcing in winter is 10 - 30 W m^{-2} (LW = Total)
- LW Forcing in summer at Barrow is almost twice that at Eureka



Conclusions

- Surface-based observations of Arctic clouds now yield information on spatial, as well as temporal, variations.

- These observations provide valuable comparisons to satellite retrievals and model calculations.

Macrophysical Properties (http://www.aoncadis.org/)

- Cloud fraction across the Western Arctic is high.

- Cloud fraction is highest in late summer and fall, lowest in winter at many sites.

- Arctic clouds primarily occur within the lowest few kilometers in the Western Arctic.

- Inter-annual and inter-site variability is less than about 15%.

Conclusions

Microphysical Properties

- Liquid-only and mixed-phased clouds are common (at Eureka).
- Liquid water droplets are small (7-10 um), while the effective size of the ice crystals are larger (20-30 um).
- There is some temperature dependence on ice fraction (and maybe optical depth).
- Microphysical properties SHEBA and Eureka are similar.

Longwave Radiative Effect

- The longwave CRF at Barrow and SHEBA is almost twice that at Eureka.

ICECAPS (2010-2014)

- ICECAPS = Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit
- New "super-site" at Summit
- Deployment in May 2010