Properties of Arctic Clouds from Multiple Atmospheric Observatories

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Acknowledgments

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  • 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

- Stations are mainly in the Western Arctic

= “Super Site”
<table>
<thead>
<tr>
<th>Instruments</th>
<th>MWR</th>
<th>AERI</th>
<th>Ceilometer</th>
<th>MPL</th>
<th>DARE</th>
<th>HSRL</th>
<th>MMCR</th>
<th>Instrument Measurements</th>
<th>Sites</th>
<th>Pertinent Specifications</th>
<th>Derived Parameters</th>
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<tbody>
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| MVR       | T<sub>8</sub> | IR radiance T<sub>8</sub> | Backscatter | Backscatter | Backscatter | Backscatter | Backscatter | Reflectivity, | Barrow, | 45-90 m | Presence, |
|           | T<sub>8</sub> | IR radiance T<sub>8</sub> | Backscatter | Backscatter | Backscatter | Backscatter | Backscatter | Reflectivity, | Barrow, | 45-90 m | Presence, |
| SHEBA     | Eureka | Barrow, Summit | Eureka | Barrow, SHEBA | Barrow, NY, Alesund | Barrow, SHEBA | Eureka | Eureka | SHEBA | SHEBA | SHEBA |
| Δt = 30 s | Δt = 15 s | Δt = 30 s | Δt = 5 m | Δt = 2 s | Δt = 5 s | Δt = 5 s | Δt = 5 s | Δt = 5 s | Δt = 5 s | Δt = 5 s | Δt = 5 s |
| (support) | presence | base | presence, cloud | presence, boundaries | presence, boundaries | presence, boundaries | presence, boundaries | presence, boundaries | presence, boundaries | presence, boundaries | presence, boundaries |
Macrophysical Properties

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

- **a)** BARROW
- **b)** EUREKA
- **c)** SHEBA

- **Height [km, AGL]**
- **Month of Year**
- **Fraction [%]**

Legend:
- Red: 50%
- Orange: 40%
- Yellow: 30%
- Green: 20%
- Light Green: 10%
- White: 5%
- Light Blue: 1%
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

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

Cox (2009)
Longwave Cloud Radiative Forcing

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