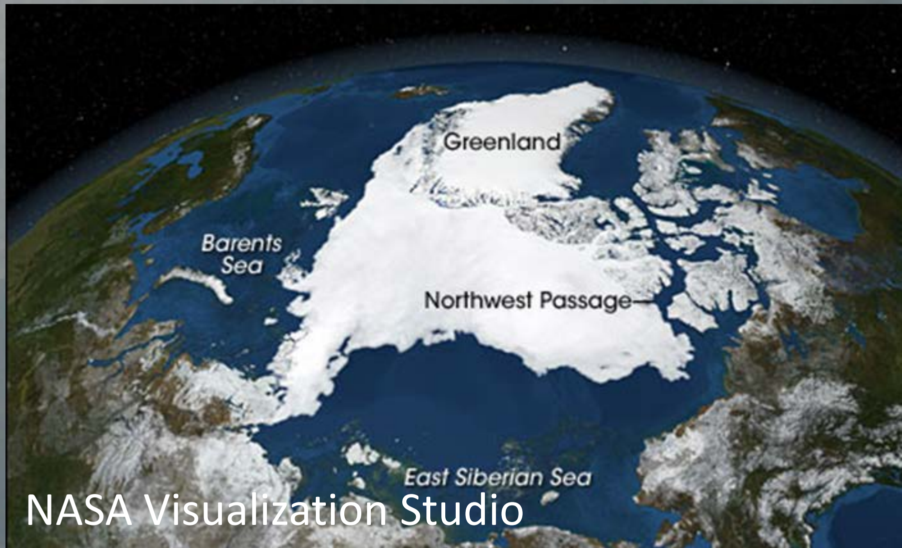
# Where are we I the Arctic?

- Drastic changes in Arctic
  - Summer sea-ice extent
  - Perennial sea-ice loss
  - Temperature rise at twice rate rest of world
- Not captured by models
  - Ice-albedo feedback
  - Aerosol (Sulfate/BC)
  - Cloudiness
  - Sea-ice loss + variability
  - Inflow warmer water



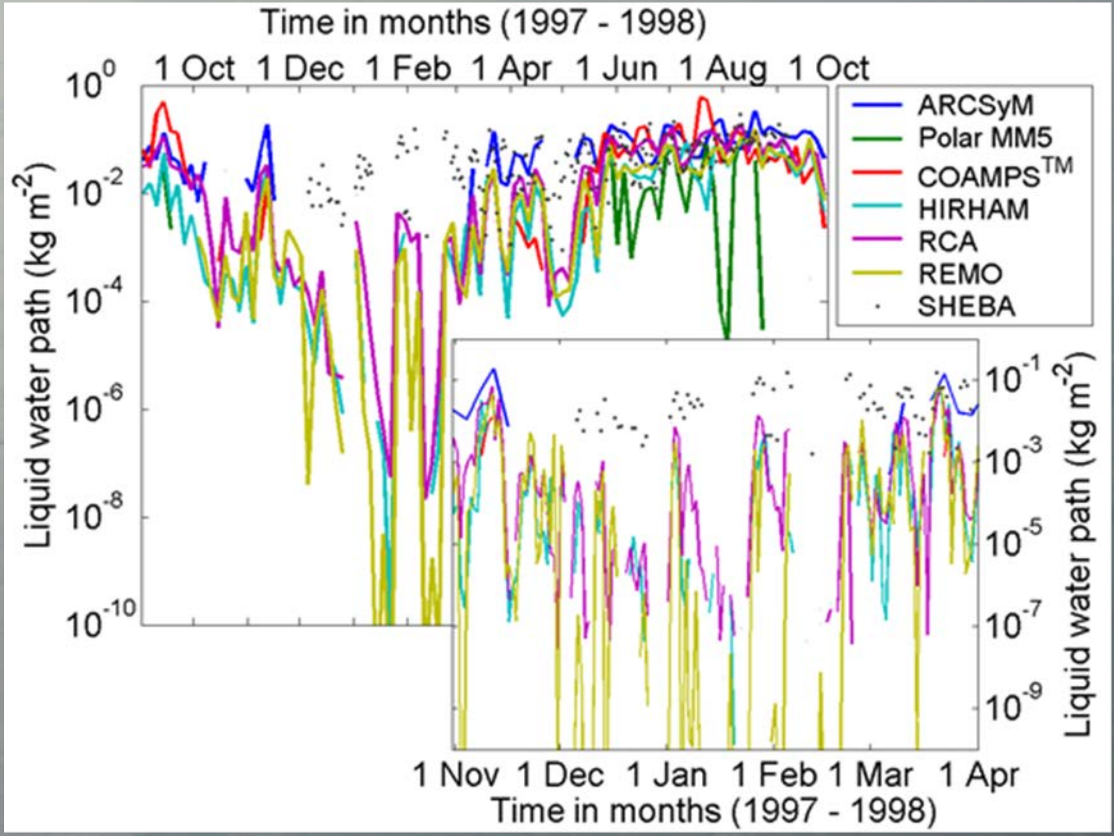
NASA Visualization Studio

# Where are we in the Arctic?

- Likely all factors contribute to and interact in non-linear ways with sea-ice loss
  - Predicted climate change variability great (30 to 100 years to ice-free summers)
  - Ice-albedo feedback strongly coupled to arctic cloud processes
- All climate models underestimated sea-ice loss over last decade
- Arctic vast stores of GHG reservoirs ($CO_2$, methane)
- Climatologically important region

# Clouds in the Arctic

- SHEBA revealed mixed-phase clouds common
- Regional models perform poorly, particularly in cold season
- Arctic stratiform clouds differ from mid-latitudes
- Sensitive to aerosol

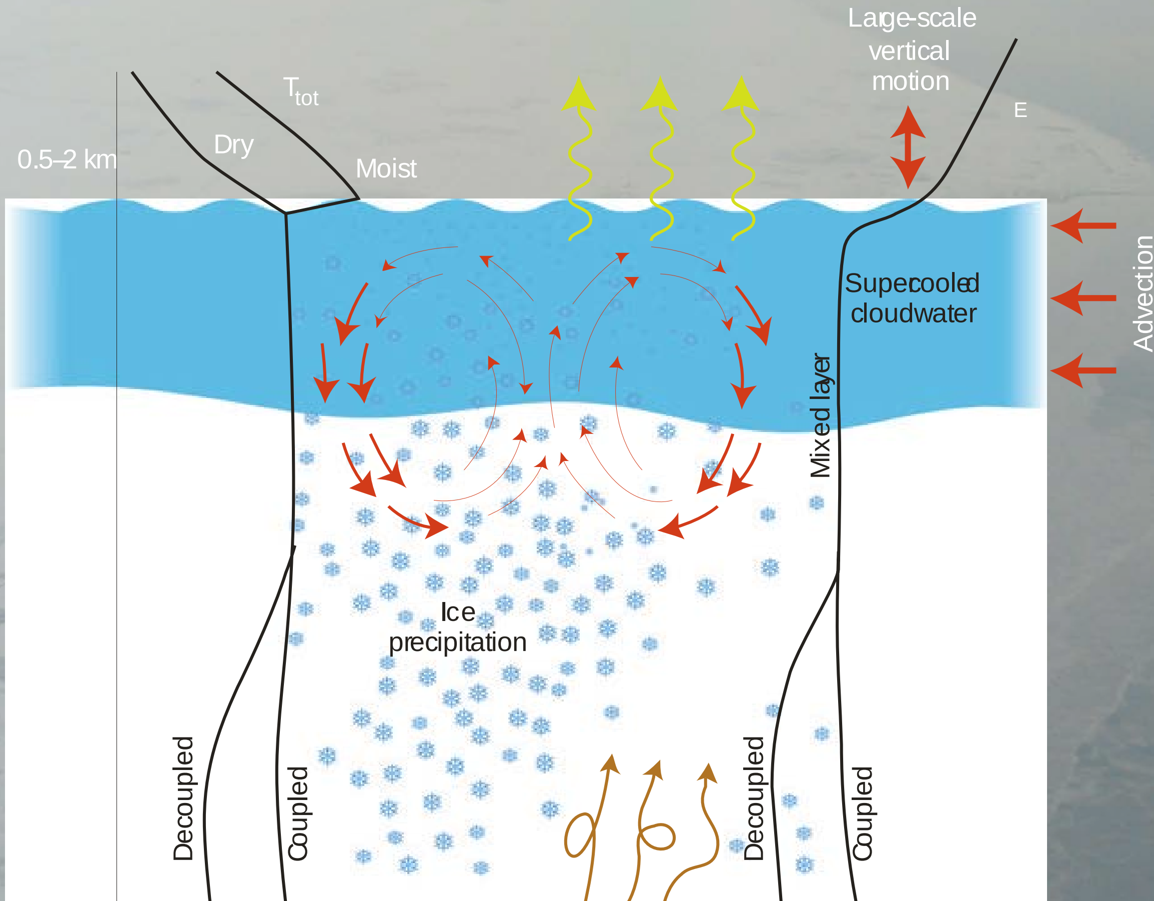



Prenni et al. 2007

# Clouds in the Arctic

- Processes not well understood
  - Complex thermodynamic environment
  - Strong function of microphysical processes
  - Tightly coupled to radiation/dynamics
  - Cloud fractions over-predicted by NWP models
- Difficult to observe
  - Mixed-phase dangerous for aircraft (expensive)
  - Microphysics/thermodynamics highly variable
  - Over the sea-ice (expensive or dangerous)
  - Remote sensing

# Mixed-phase cloud processes




**Radiative Cooling**
- Drives buoyant production of turbulence
- Forces direct condensation within inversion layer
- Requires minimum amount of cloud liquid water

**Microphysics**
- Liquid forms in updrafts and sometimes within the inversion layer
- Ice nucleates in cloud
- Rapid ice growth promotes sedimentation from cloud

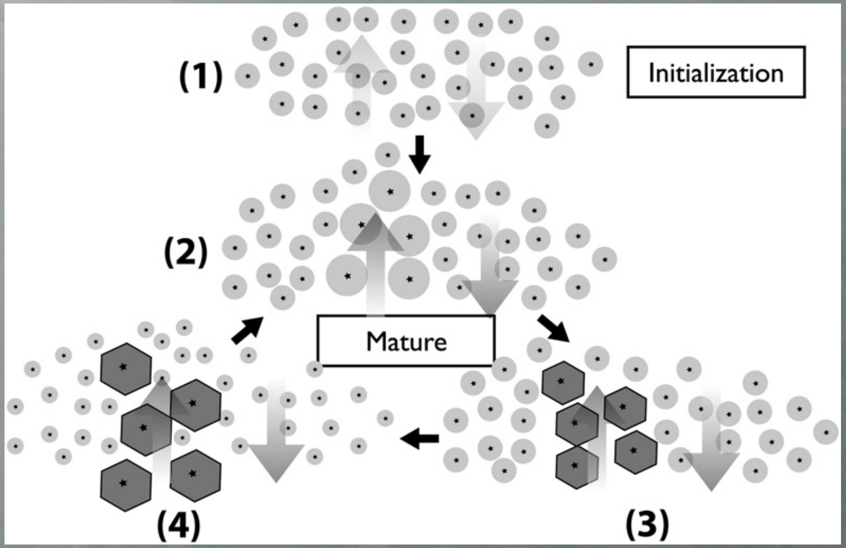
**Dynamics**
- Cloud-forced turbulent mixed layer with strong narrow downdrafts, weak broad updrafts, and $T_{tot}$ and E nearly constant with height
- Small-scale, weak turbulence in cloudy inversion layer
- Large-scale advection of water vapour important

**Surface Layer**
- Turbulence and T contributions can be weak or strong
- Sink of atmospheric moisture due to ice precipitation
- Surface type (ocean, ice, land) influences interaction with cloud

Morrison et al., 2012

# Cloud Resolving Models

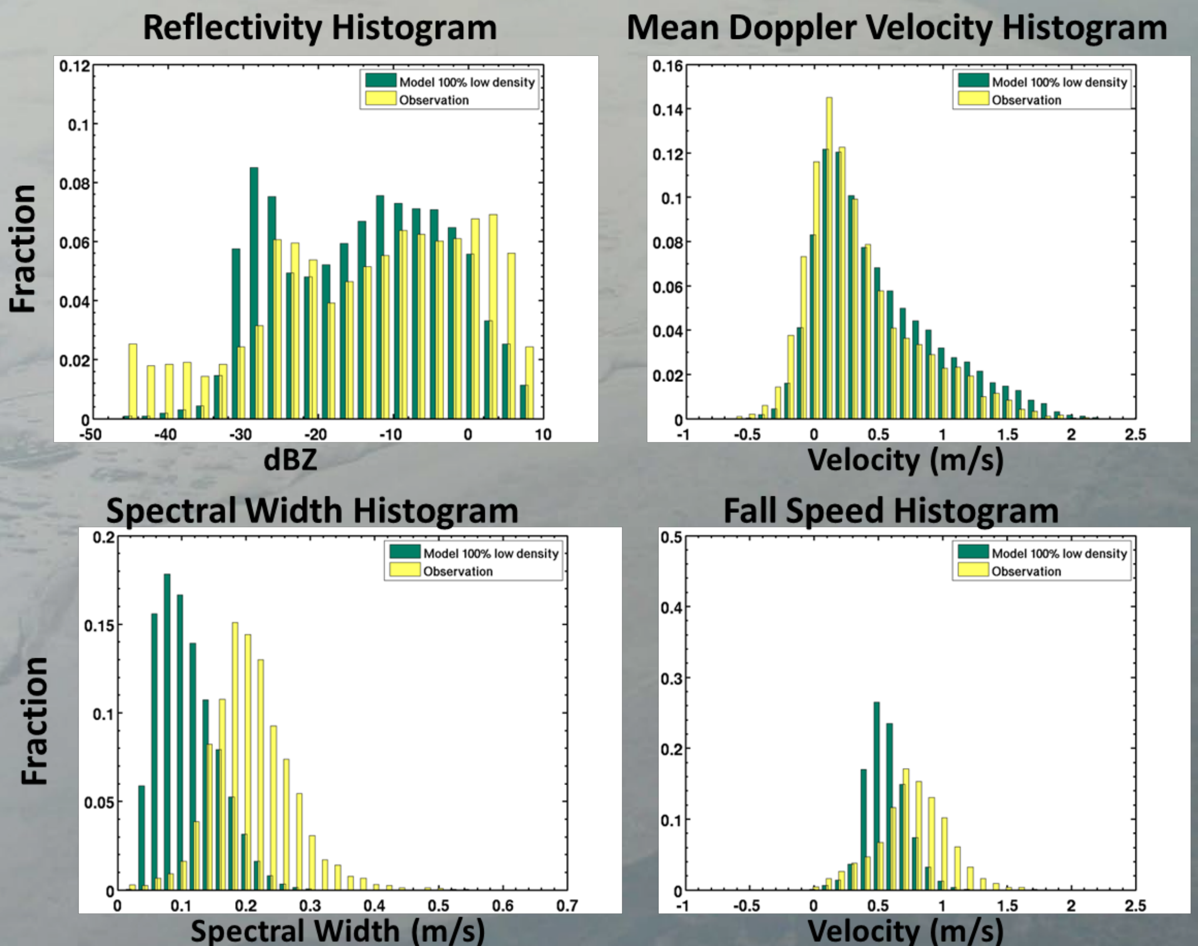
- Simulations by different groups:
  - Ice nuclei concentrations
  - Evaporation freezing
  - Immersion freezing
  - Ice habit impacts
    - Mass growth rate
    - Fall speed
- Many degrees of freedom
- Differing conclusions




De Boer et al. 2009

# Cloud Resolving Models

## Low Density Ice Particles

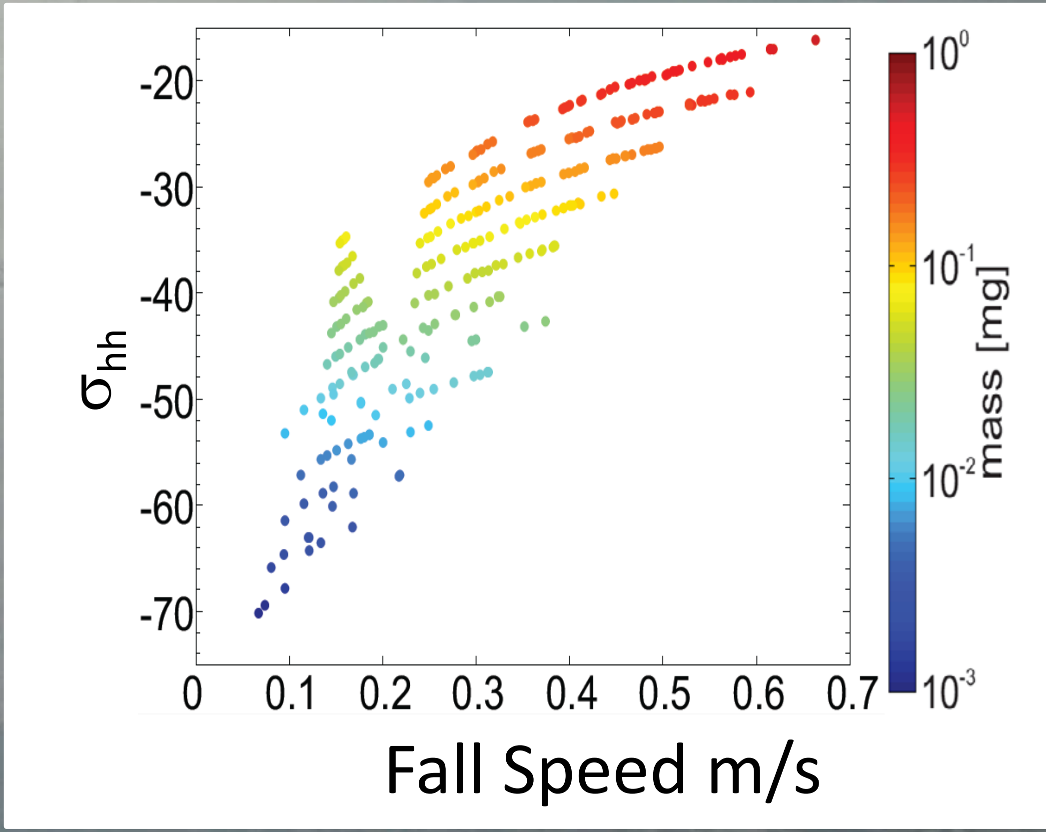



Simulations of
Avramov et al. 2011

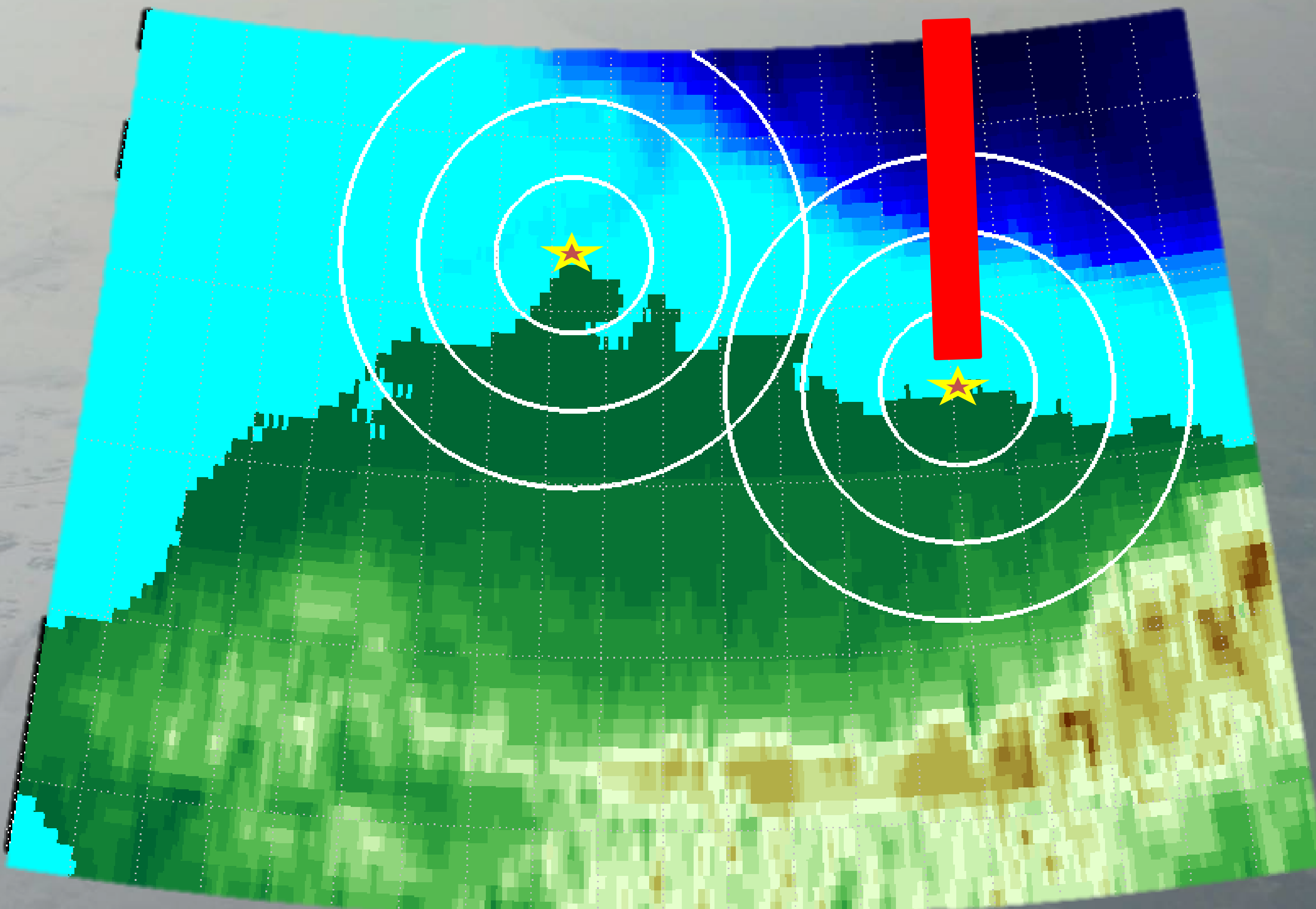
# Radar remote sensing

- Potential to constrain CRM models
  - Must understand scattering by ice
  - Must have some knowledge of cloud scatterers
- Scanning radars provide spatial information

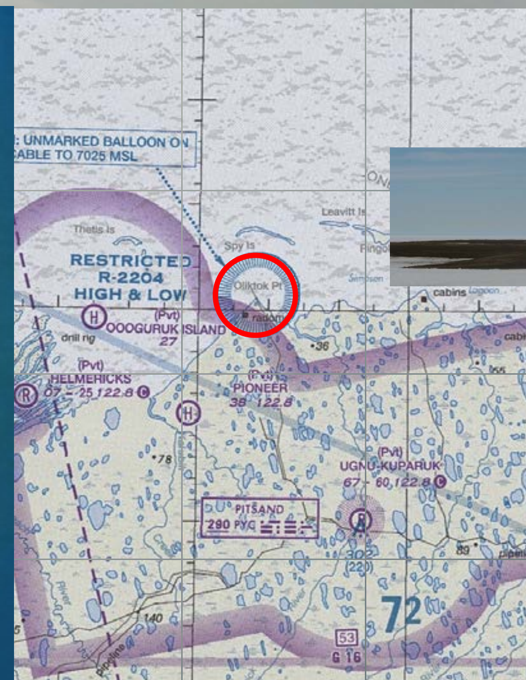
Dendrites



# Why Oliktok Point? I



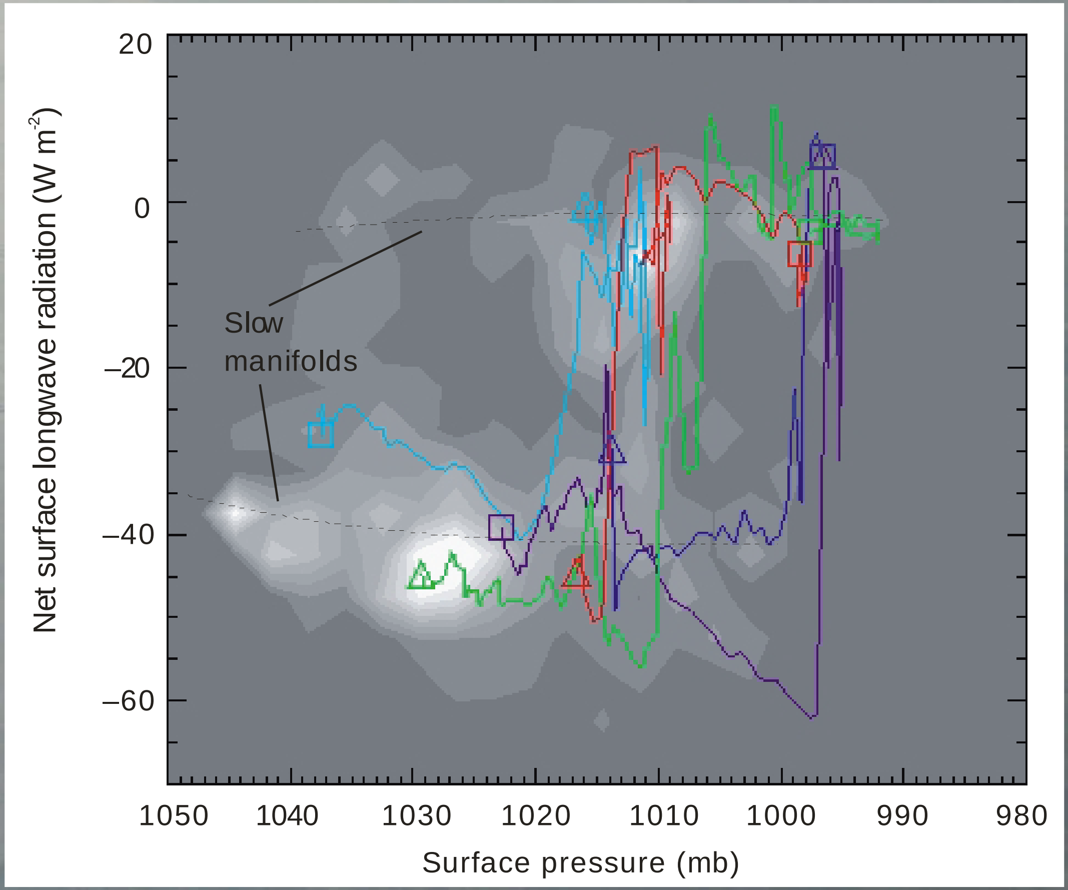
# Why Oliktok Point? II


Tether balloon facility

# Different Attractors
## Two-fold observational strategy

- Fast-timescale
  - Clouds processes
- Slow-timescale
  - Longer periods
  - Detailed profiles
- Atmospheric state
  - Advection
  - Sea-ice/Ocean
- Transitions

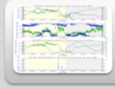



Morrison et al., 2012

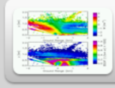
# Needs

- Routine (sustained) measurements through cloud layers
  - Thermodynamic profiles
  - Microphysical parameters (liquid)
  - Aerosol characteristics
- Larger scale environment
  - Surface conditions
  - Advection into limited domain
- Multi-scale modeling effort

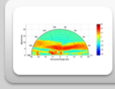
# Instrumentation for the New ARM Sites



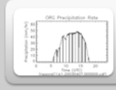
**Atmospheric and Boundary State**
- MET, PWD, TSI
- Sondes, ECOR, 915 RWP (NSA), 1290 RWP (ENA)



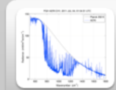
**Lidars**
- HSRL, MPL, Doppler



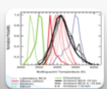
**Cloud and Precipitation Radars**
- Scanning Cloud, Scanning Precipitation
- Ka Zenith Pointing



**Precipitation**
- Parsivel , Video Disdrometer, Weighing Bucket, TPS



**Radiometry**
- Solar Broadband (Up/Down), IRT
- MFRSR, MFR , AERI or ER-AERI, MWR3C



**Aerosol Observation System**
- Scattering, Absorption, Size Distribution
- Trace Gases

**Oliktok**

Unmanned Aerospace Vehicles

**Oliktok Infrastructure**
- Instrument, Operations, and UAS Enclosures
- Electrical Power Generator Module

**Azores Infrastructure**
- Instrument Enclosures
- Operations Enclosure
- Electrical Power and Hydrogen Generators

***Azores Research Site***
**Kim Nitschke - Site Operations Manager**
**Los Alamos National Laboratory**

***Oliktok Point Research Site***
**Mark Ivey - Site Operations Manager**
**Sandia National Laboratory**

**Fundamentally New Arctic Measurements**


**Unmanned Aerospace Vehicles for Coordinated Multi-Sensor Measurements**

**Tethered Sonde and In-Situ Measurement Package**

- **Multiple UAVs' and Associated Infrastructure**
- **Instrument Suite Under Discussion Options Include;**
  - ✓ **Condensation Particle Counter**
  - ✓ **Optical Particle Counter**
  - ✓ **Aethalometer**
  - ✓ **Radiometry and Atmospheric State**
  - ✓ **Cloud Condensation Nuclei Counter**
  - ✓ **Stabilization Platform**

Issues under discussion include characteristics of Azores precipitation radar (X- or C-band) and characteristics of the UAS and associated payload.

From Jim Mather

# Ideas

- Start routine in situ measurements of lower troposphere clouds when remote sensing complement in place with tether balloon system
  - Thermodynamic state, microphysics, aerosol
- Routine sampling of spatial atmospheric state and ocean surface (UAV)
- Forcing data sets for large-scale environment
  - Scanning X-band radars (precip?)
- Multi-scale modeling effort using this much expanded data set
- Platform in the Arctic Ocean basin (need ice breaker: collaboration with other programs)

# The field is ripe

- New developments in microphysical parameterization offers hope for better phase partition
- Retrieval techniques & observing systems can get consistent parameters
- Clouds microphysical structure simpler than lower latitudes where more processes operate: hope for precipitation estimation from scanning radars