Co-investigators
J. W. Strapp[1], P. Liu[1], J. Verlinde[2], Z. Boybeyi[3], D. Lubin[4], D. Cziczo[5], J.P. Blanchet[6], P. A. Kucera[7], J. Sloan[8], T. Kuhn[9], E. Girard[6], D. Mitchell, S. Brooks[10], J. E. Cherry[11] , M. Wendisch[12] , P. Minnis[13], A. Zelenyuk[14] and K. Dethloff[15], J. Milbrandt[16], Xiaohong Liu[17]

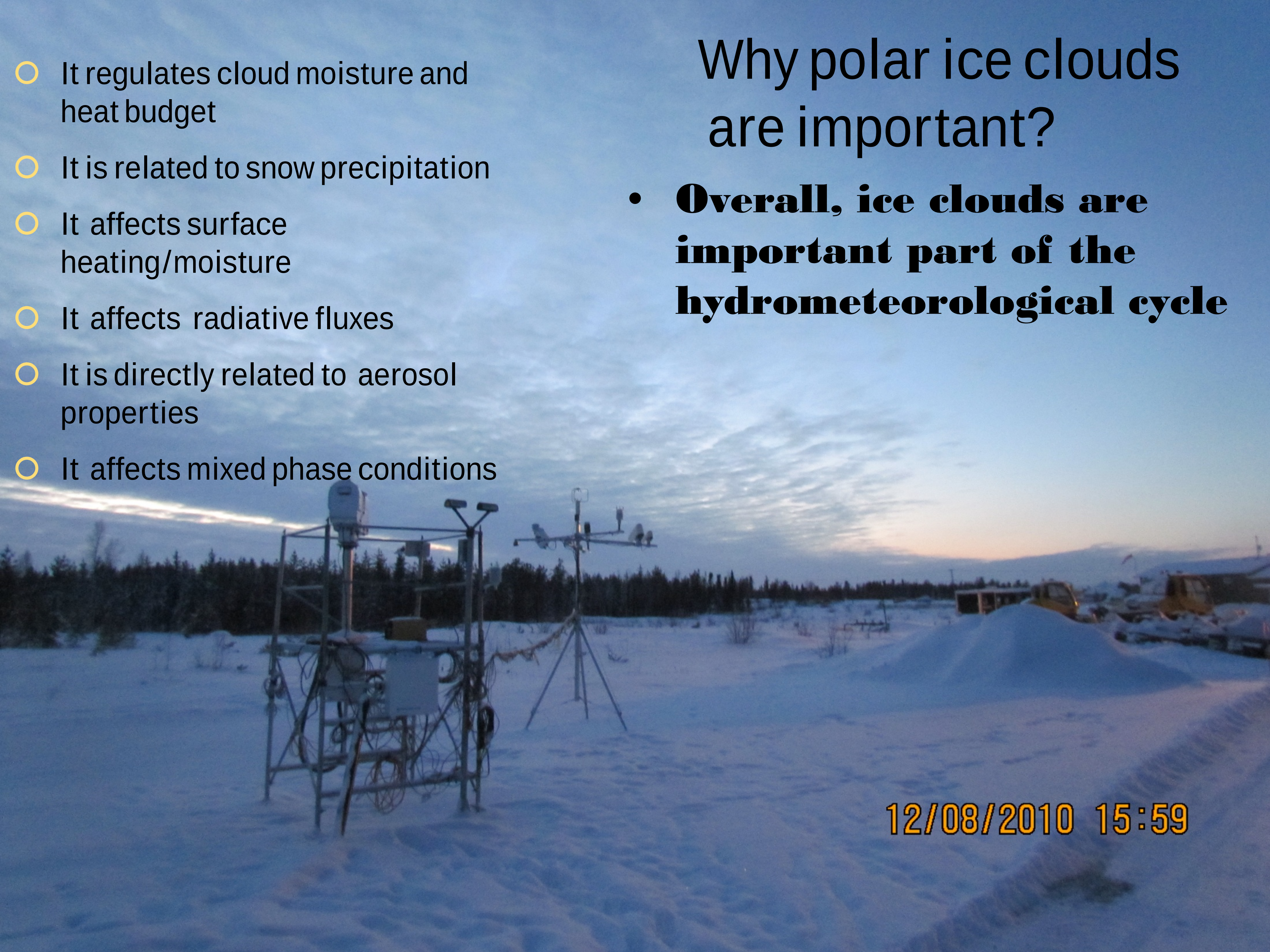
POLAR ICE CLOUDS AND CLIMATE CHANGE (PIC3)

EC
PSU
GMU
MIT
UQAM
NCAR
UW
LUT
DRI
TA&M
UA
UL
NASA LANGLEY
PNNL
AWI

Why polar ice clouds are important?

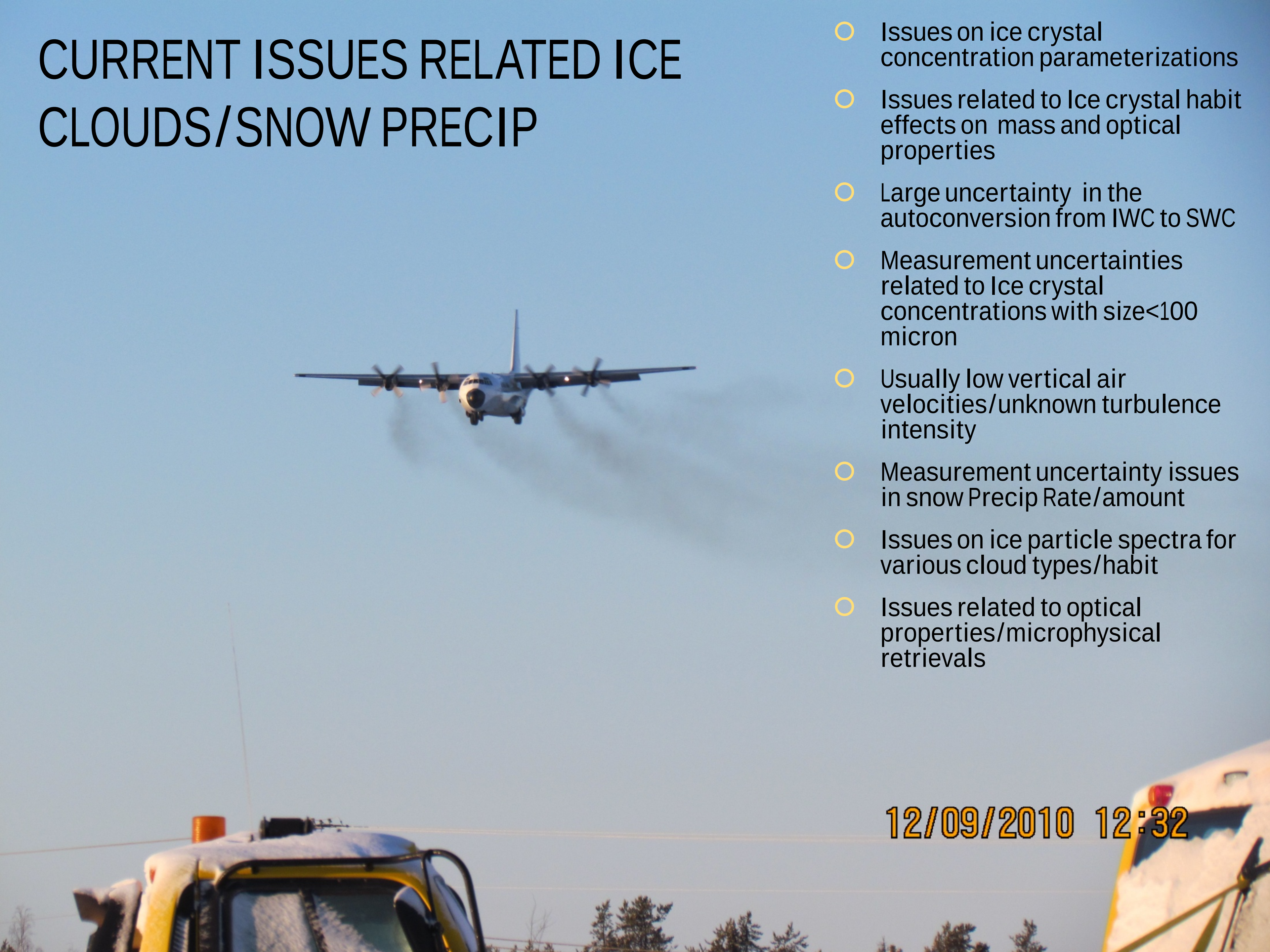
- It regulates cloud moisture and heat budget
- It is related to snow precipitation
- It affects surface heating/moisture
- It affects radiative fluxes
- It is directly related to aerosol properties
- It affects mixed phase conditions

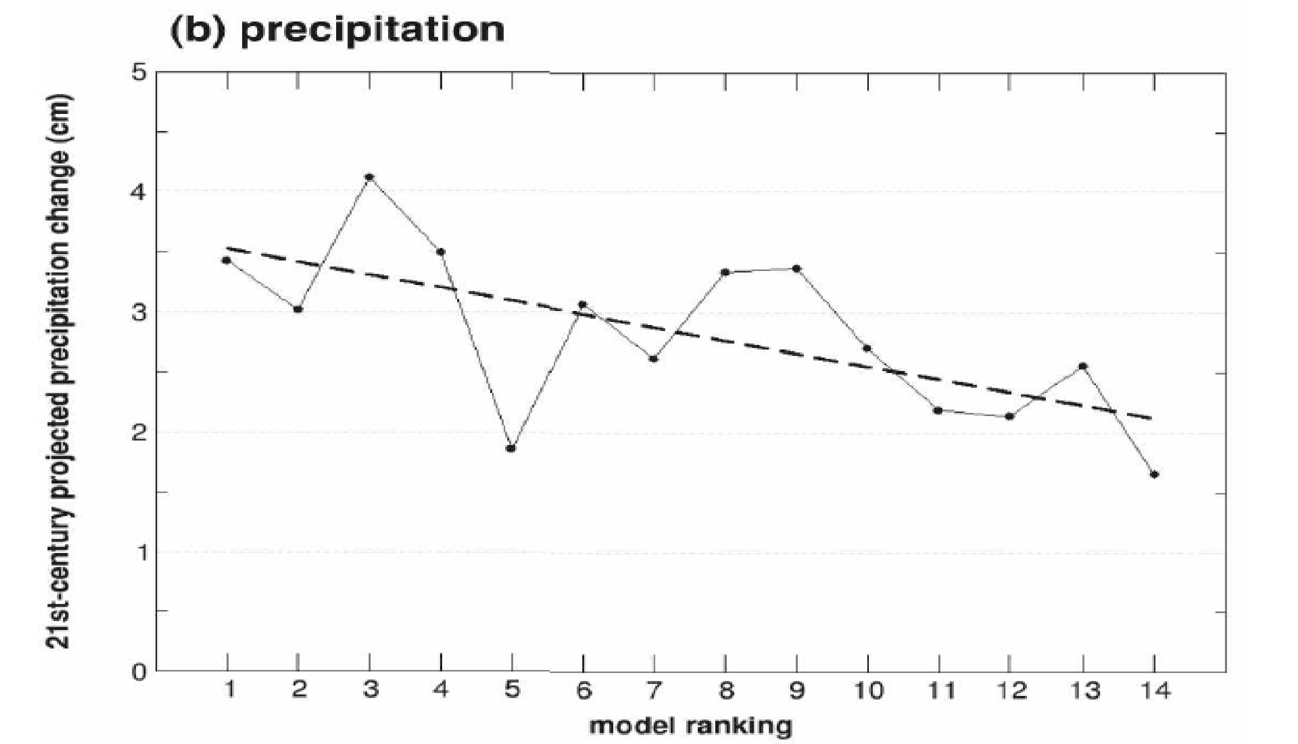
- **Overall, ice clouds are important part of the hydrometeorological cycle**



CURRENT ISSUES RELATED ICE CLOUDS/SNOW PRECIP

- Issues on ice crystal concentration parameterizations
- Issues related to Ice crystal habit effects on mass and optical properties
- Large uncertainty in the autoconversion from IWC to SWC
- Measurement uncertainties related to Ice crystal concentrations with size<100 micron
- Usually low vertical air velocities/unknown turbulence intensity
- Measurement uncertainty issues in snow Precip Rate/amount
- Issues on ice particle spectra for various cloud types/habit
- Issues related to optical properties/microphysical retrievals





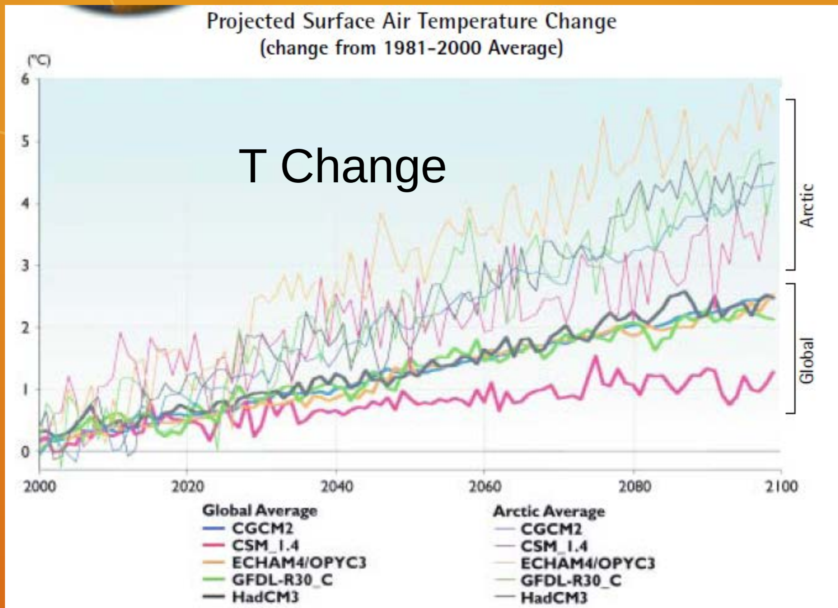
Rawlins et al 2006

- **1 mm precip amount approximately equals to 25 W m-2**
- **For snow,**

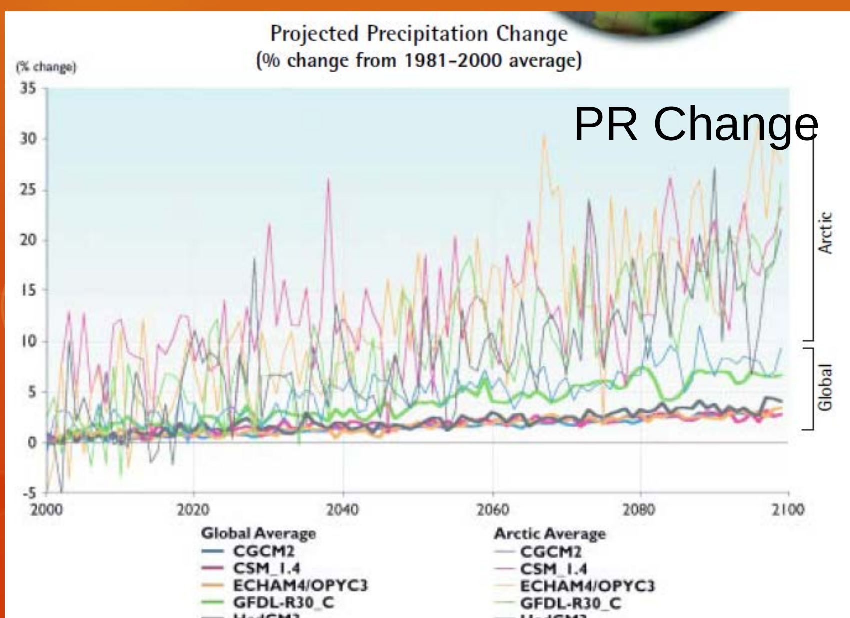
  1 mm SWE =1 cm snow depth (10% density)
- **We cannot measure precip rate better than 0.5 mm/hr.**
- **This results in ~ 12.5 W m-2 error in the heat budget cal.**
- **This is comparable larger than aerosol direct or indirect effects, and it is strongly related to cloud IWC and IN**

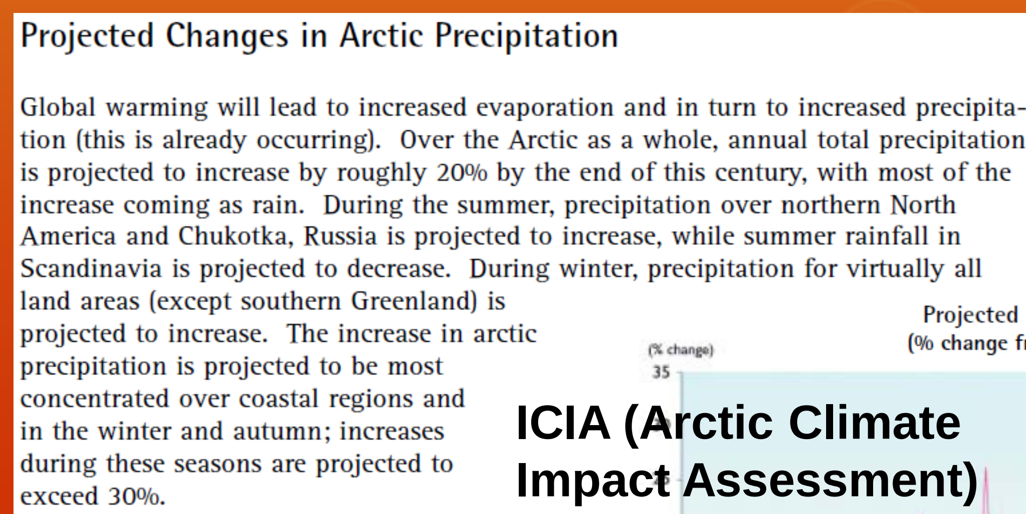
Why snow precip is important?

IPCC PR and T TRENDS



At latitudes poleward of 40° in winter, positive correlations between T and PR dominate as the water-holding capacity of the atmosphere limits precipitation amounts in cold conditions and warm air advection in cyclonic storms is accompanied by precipitation (IPCC Fourth Assessment Report: Climate Change 2007)



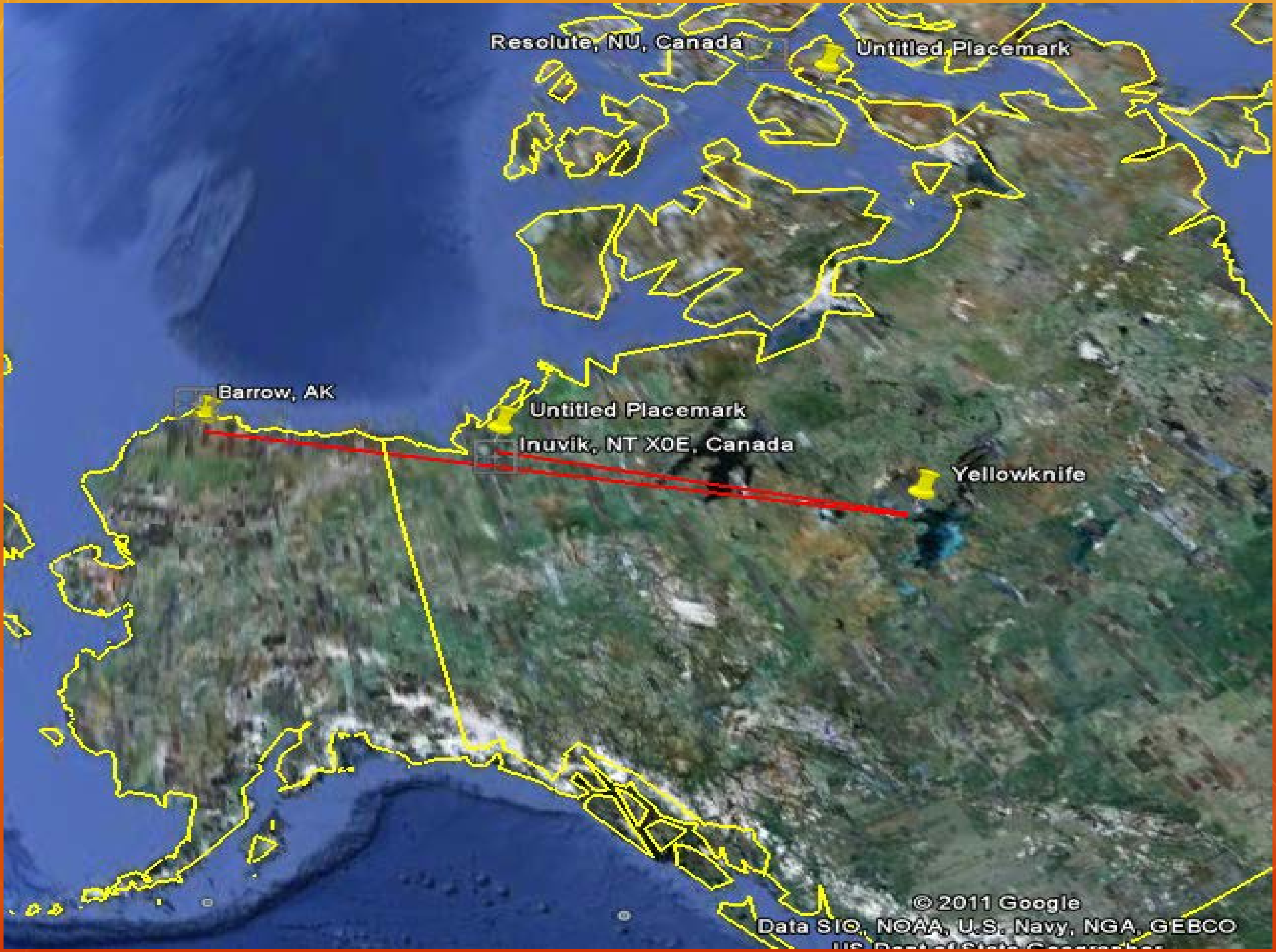


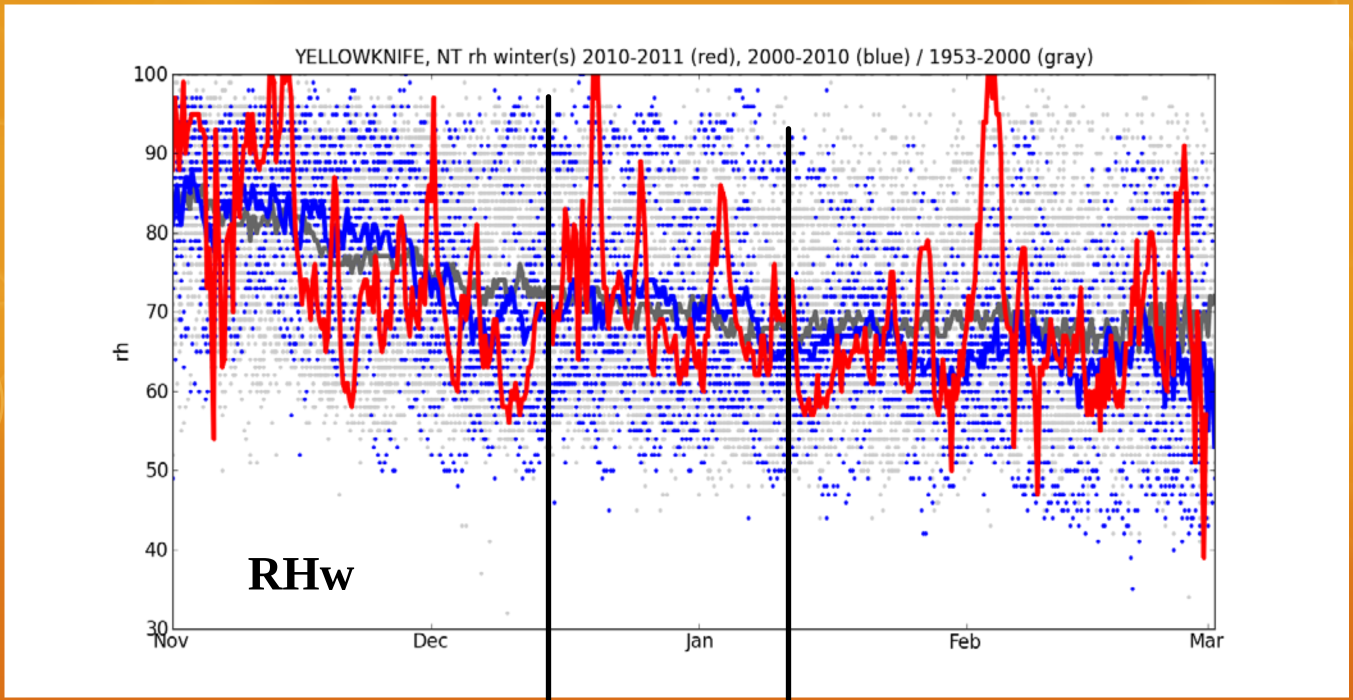
Projected Changes in Arctic Precipitation

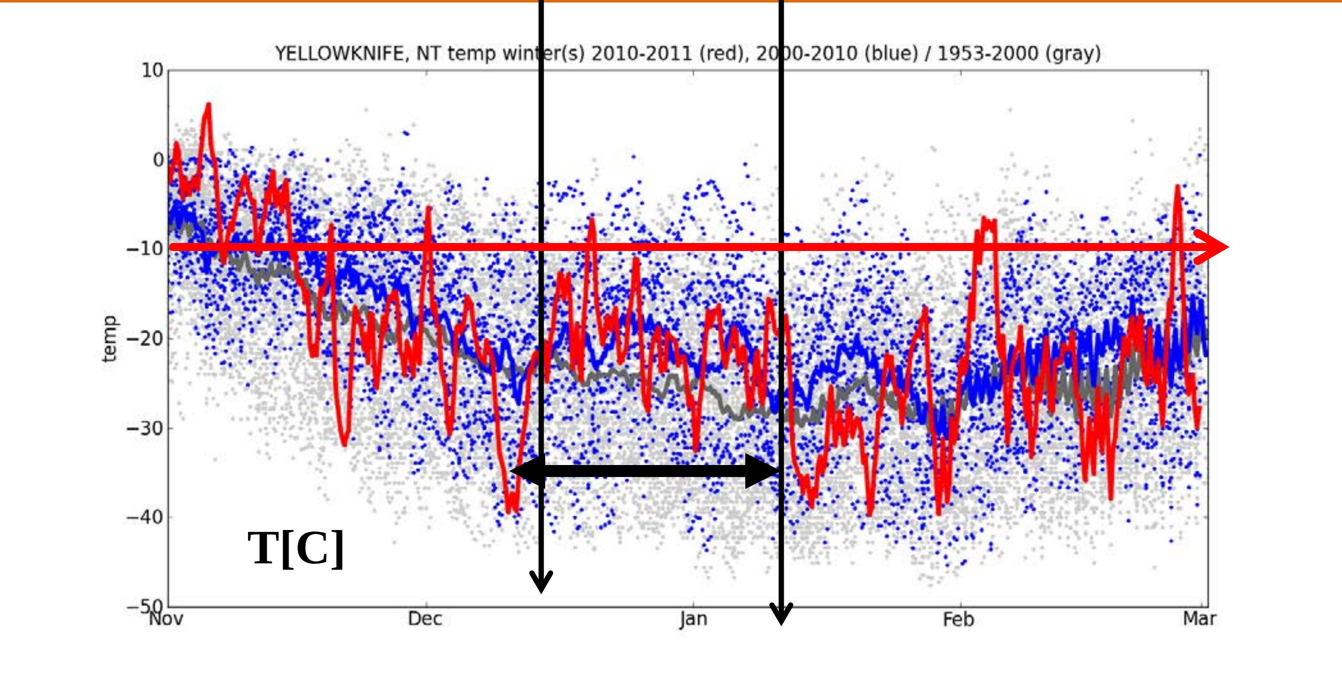
Global warming will lead to increased evaporation and in turn to increased precipitation (this is already occurring). Over the Arctic as a whole, annual total precipitation is projected to increase by roughly 20% by the end of this century, with most of the increase coming as rain. During the summer, precipitation over northern North America and Chukotka, Russia is projected to increase, while summer rainfall in Scandinavia is projected to decrease. During winter, precipitation for virtually all land areas (except southern Greenland) is projected to increase. The increase in arctic precipitation is projected to be most concentrated over coastal regions and in the winter and autumn; increases during these seasons are projected to exceed 30%.

ICIA (Arctic Climate Impact Assessment)

PROJECT SITES

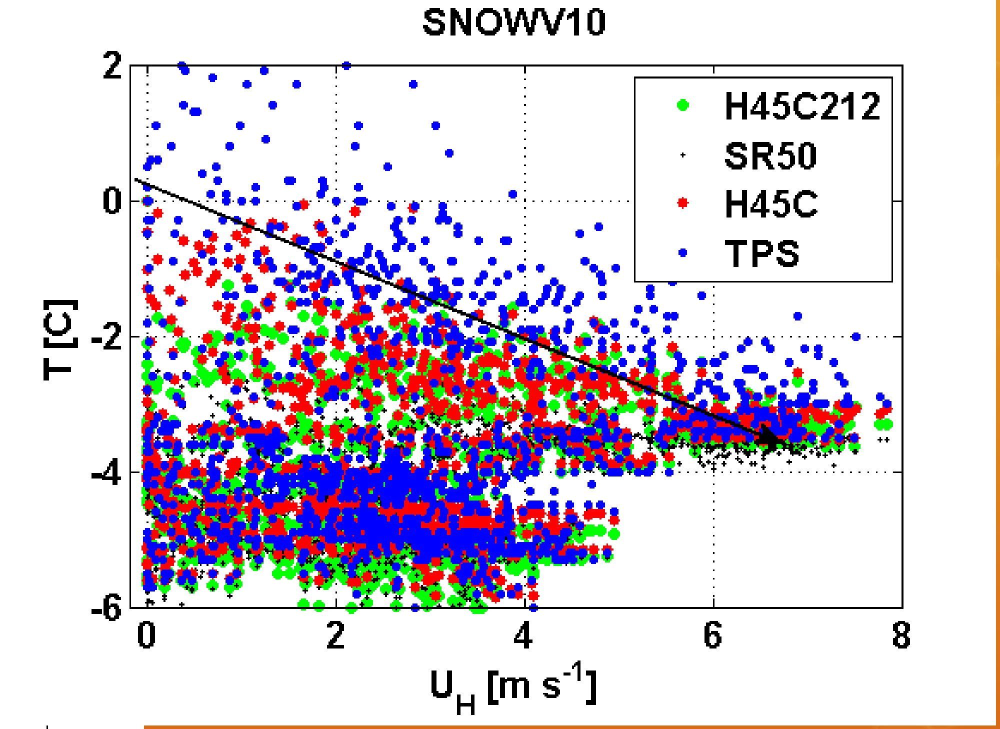


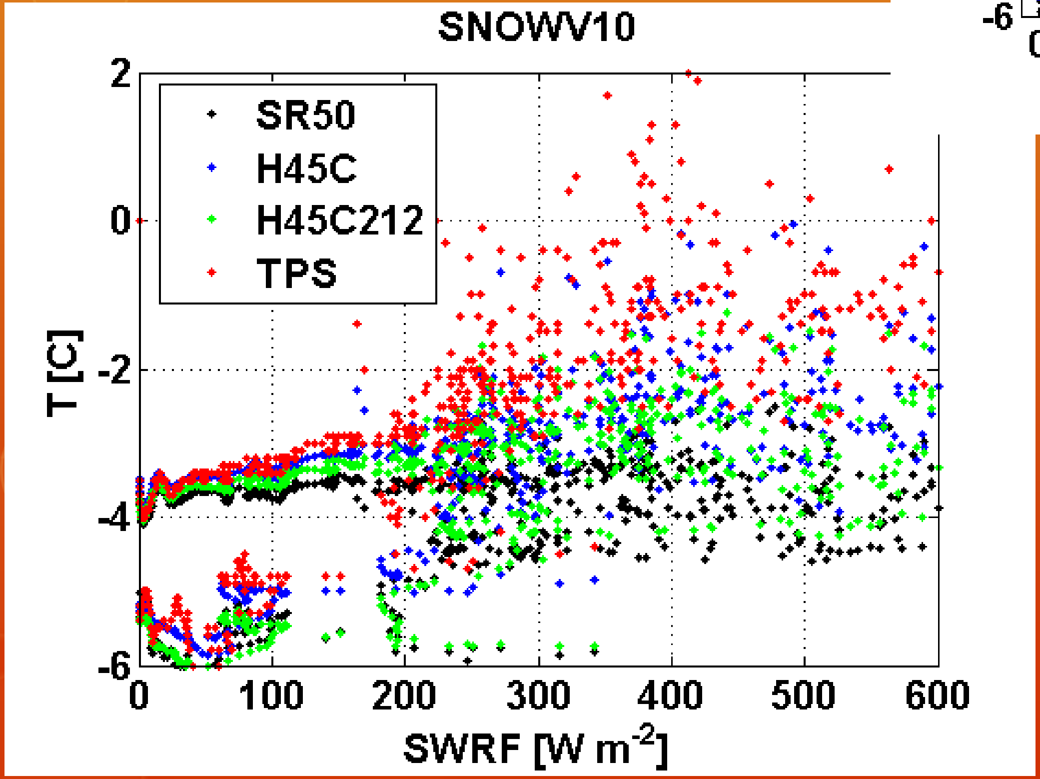


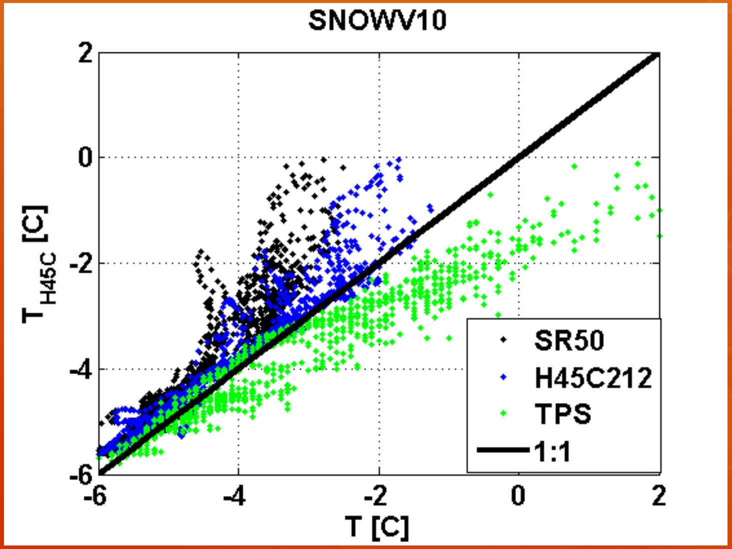


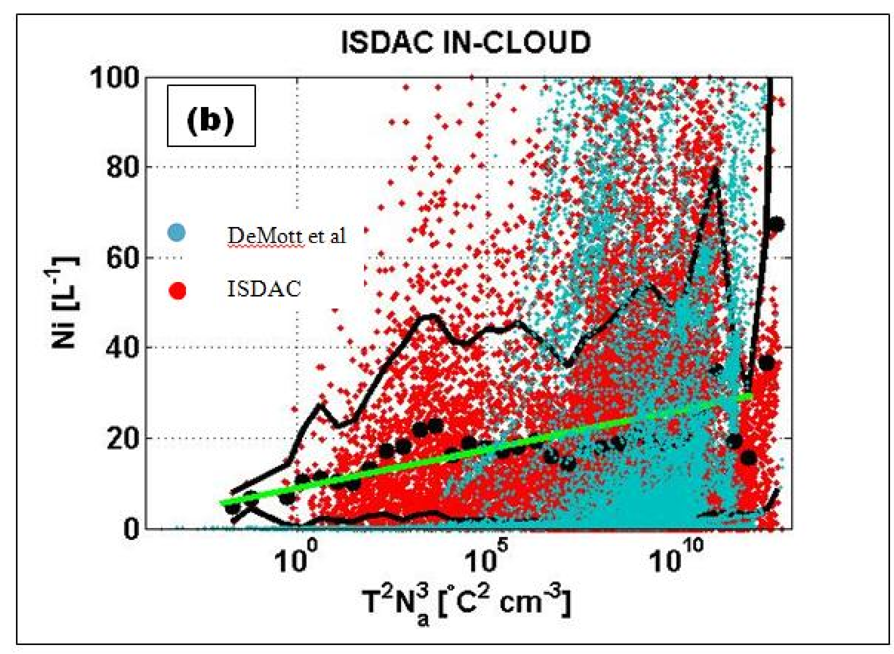
Yellowknife
NWT, Canada

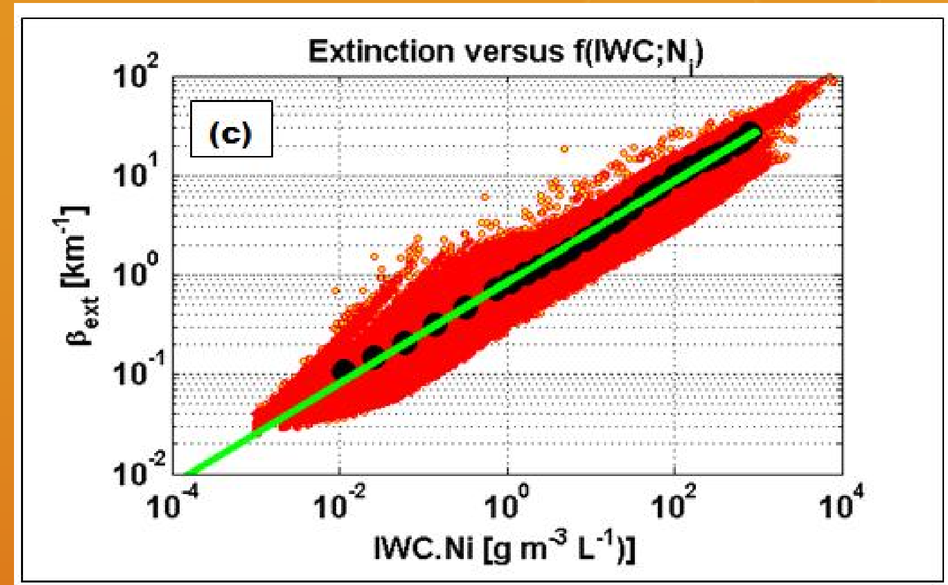
T vs radiative fluxes and hor. wind speed

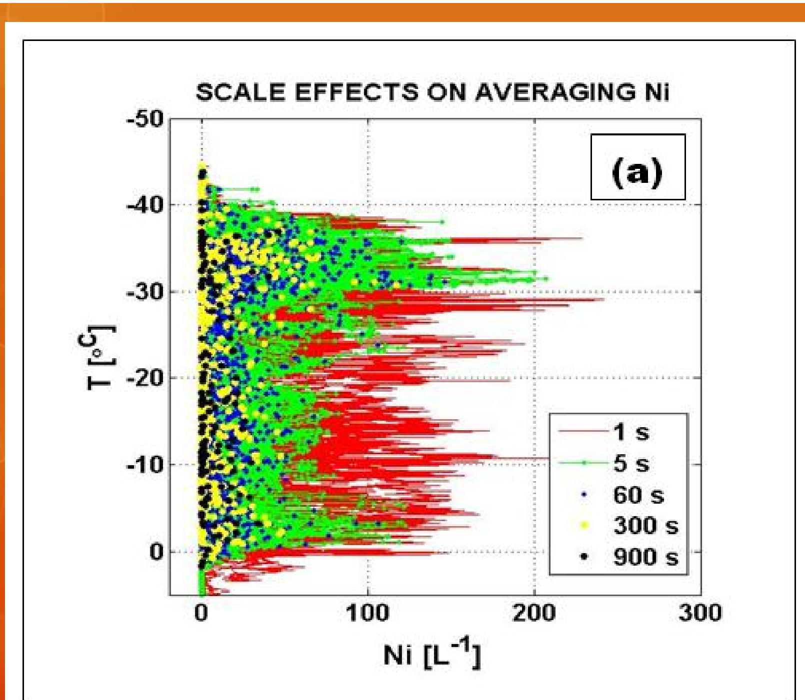


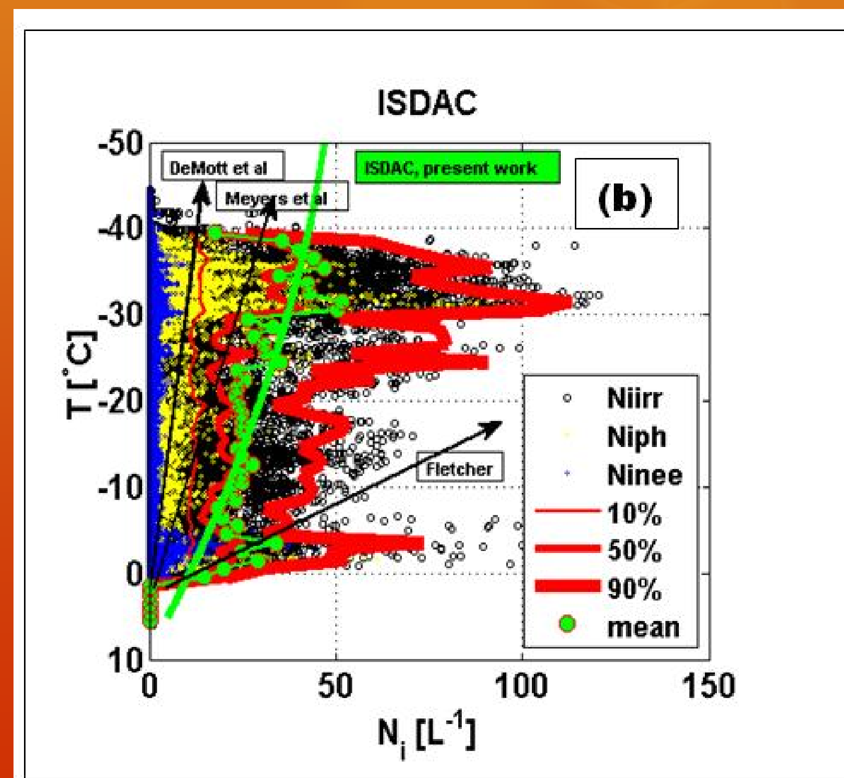


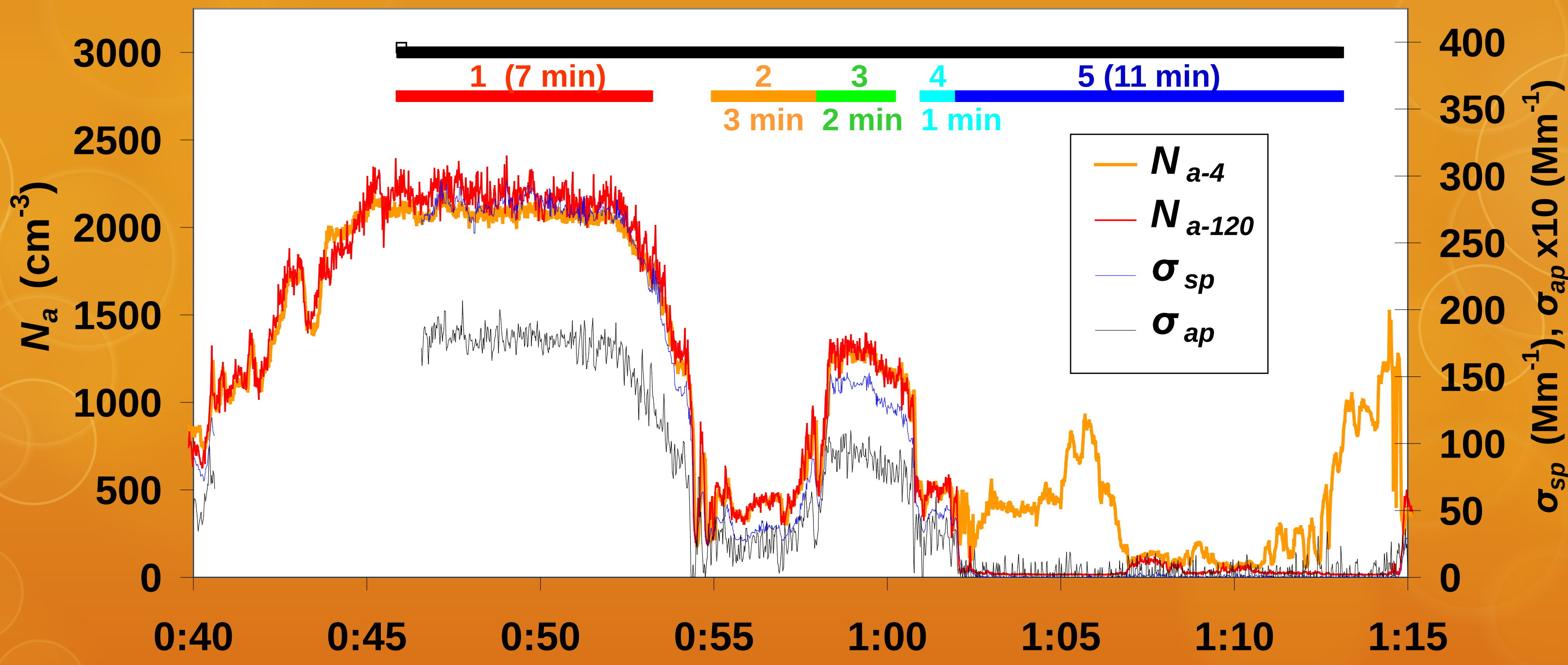


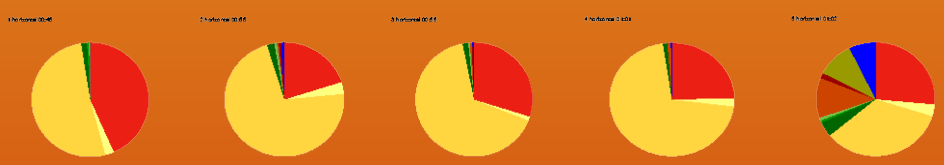

ISDAC IN-CLOUD
(b)
DeMott et al
ISDAC
Ni [L^-1]
T^2N_a^3 [°C^2 cm^-3]

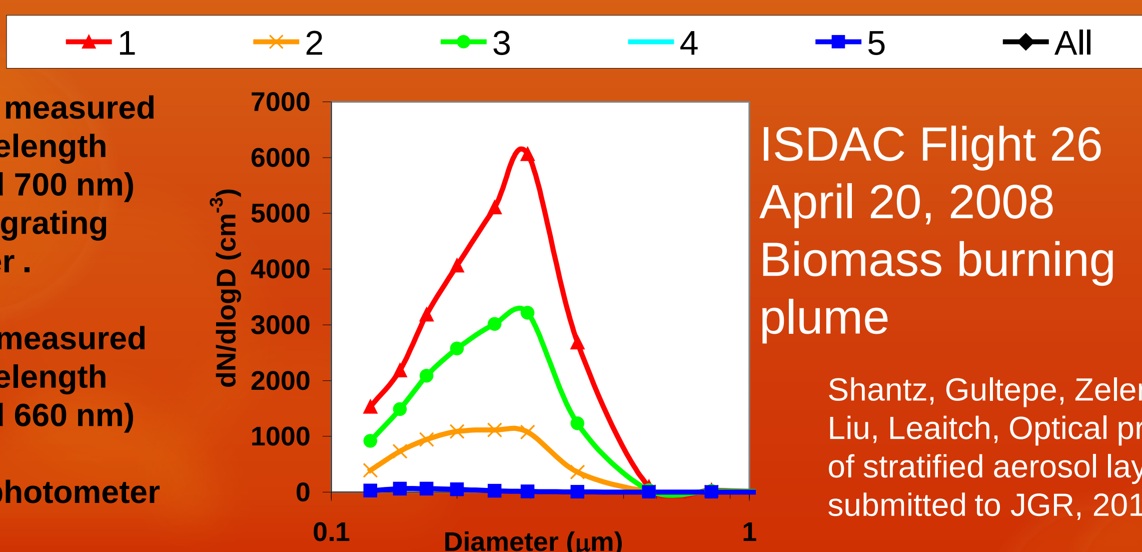

Extinction versus f(IWC;N_i)
(c)
β_ext [km^-1]
IWC.Ni [g m^-3 L^-1)]

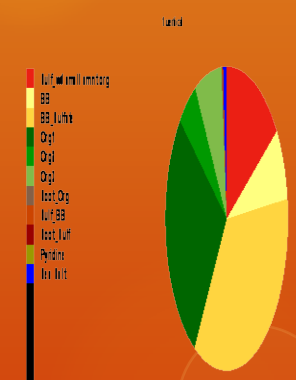

SCALE EFFECTS ON AVERAGING Ni
(a)
1 s
5 s
60 s
300 s
900 s
T [°C]
Ni [L^-1]


ISDAC
DeMott et al
Meyers et al
ISDAC, present work
(b)
Fletcher
Niirr
Niph
Ninee
10%
50%
90%
mean
T [°C]
N_i [L^-1]









The σ_{sp} was measured with a 3-wavelength (450, 550 and 700 nm) TSI 3563 integrating nephelometer .

The σ_{ap} was measured with a 3-wavelength (467, 530 and 660 nm) Particle Soot Absorption photometer (PSAP)

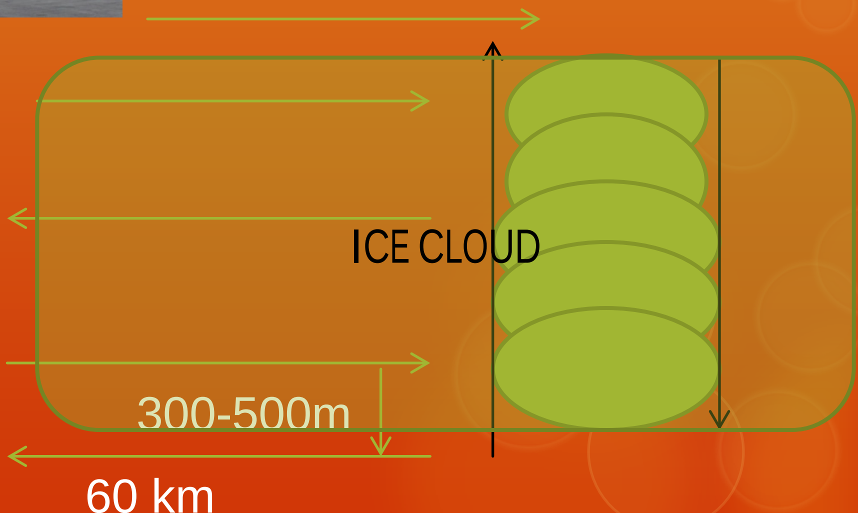
ISDAC Flight 26
April 20, 2008
Biomass burning plume

Shantz, Gultepe, Zelenyuk, Andrews, Earle, Macdonald, Liu, Leaitch, Optical properties and chemical composition of stratified aerosol layers in the springtime Arctic, submitted to JGR, 2011.

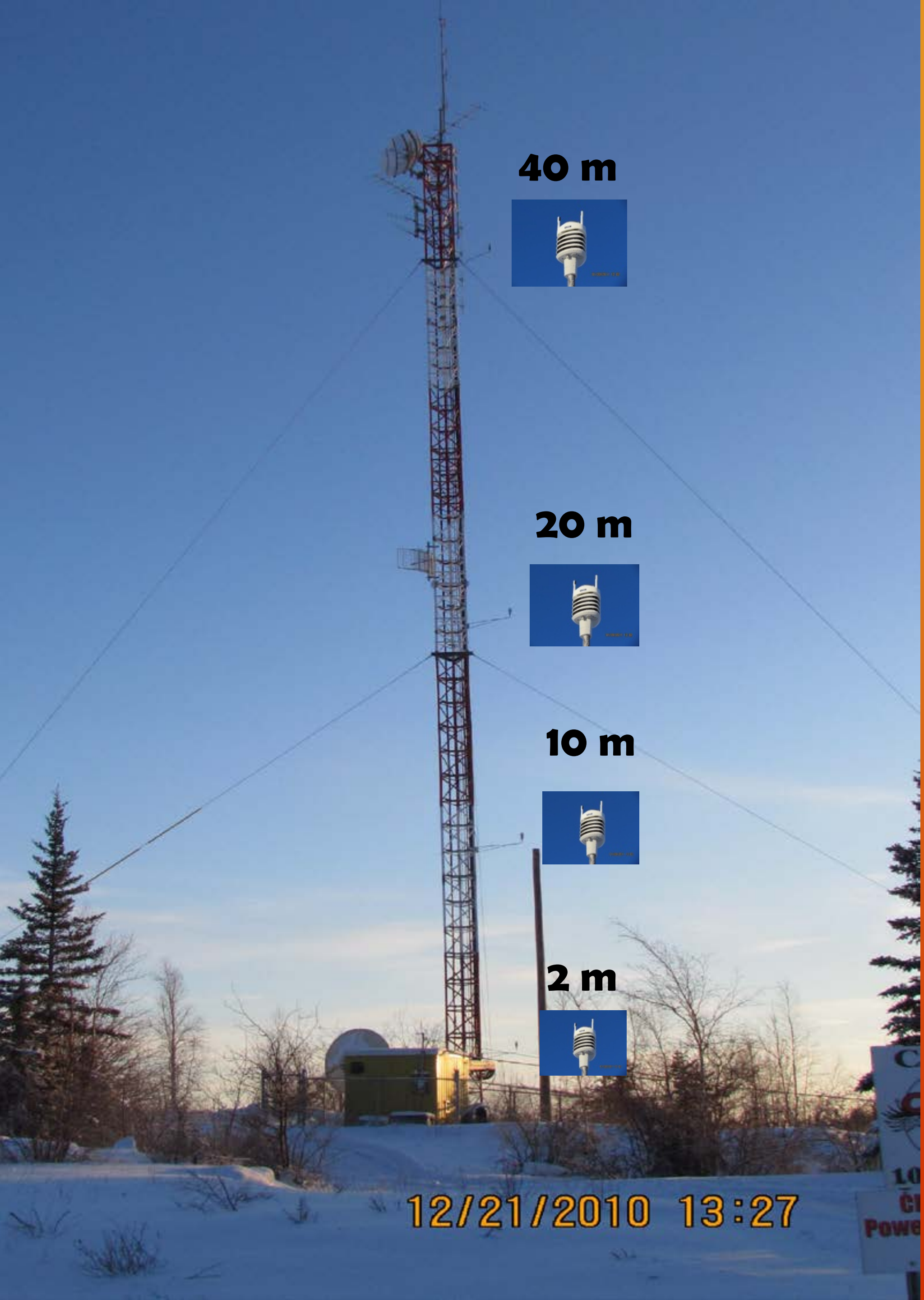
YK site hanger for aircraft (AWI-Polar 5)

Yellowknife, NWT
to
Barrow, Alaska

SU/SD/CFL



Yellowknife, NWT, Canada



JACK FISH TOWER measurements

- RH
- T, Td
- Pressure
- Wind Speed
- Turbulence
- Rain/hail/ice pellet

Aircraft observations

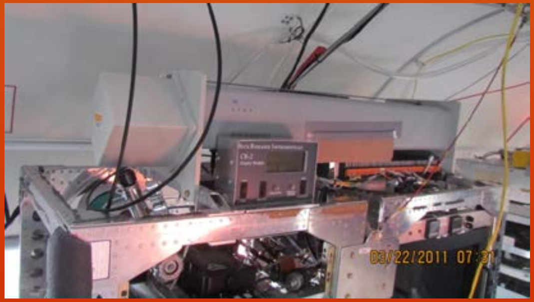
AWI Polar-5:

Many flight hours experience over the Arctic that include PAM-ARCMIP (Pan-Arctic Measurements and Arctic Climate Model Inter comparison Project).

Instrument List:

•Various aerosol measurements:
-SP2, UHSAS, CPC, PCASP, SMPS,
CLAP (Continuous Light Absorption Photometer), Nephelometer,
•Lidar
•Spectral radiance and BBF measurements
•Cloud Microphysical Sensors:
FSSP, CDP, 2DS, 2DC/2DP, CIPs etc.

AWI POLAR-5



TECHNICAL PARAMETER	
Wing span	29.00 m
Length of fuselage	12.85 m
Width of fuselage	2.34 m
Height of fuselage	2.00 m
Maximum take off weight	13,039 kg
Maximum payload	3,900 kg
Fuel consumption	500 kg/hr
Endurance for ferry*	2,600 km
Endurance 1,000 kg	2,000 km
Endurance 1,500 kg	1,700 km
Number of passengers	18 PAX
Maximum service ceiling	7,600 m
Lowest cruising speed	185 km/hr.

Snow precipitation in Arctic regions





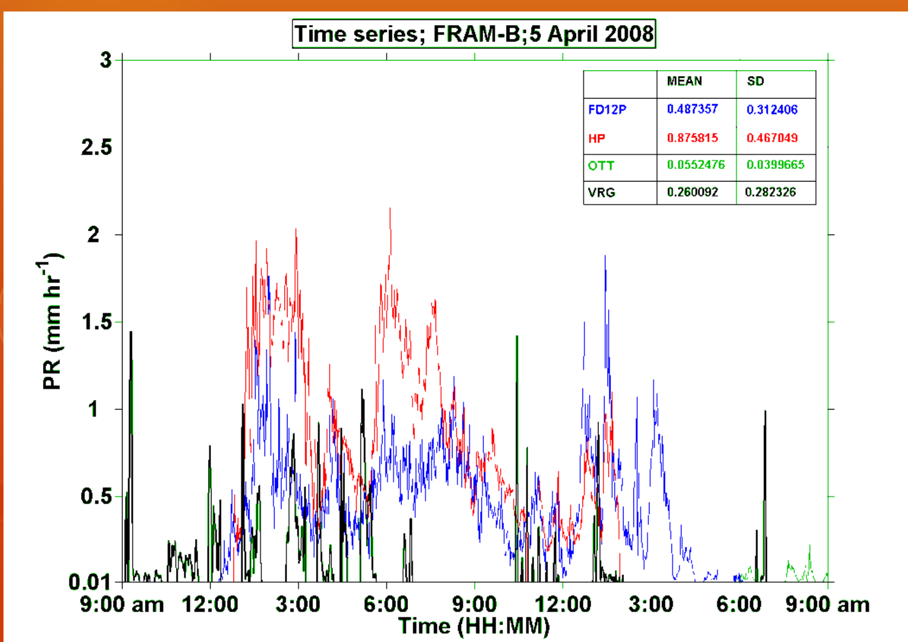




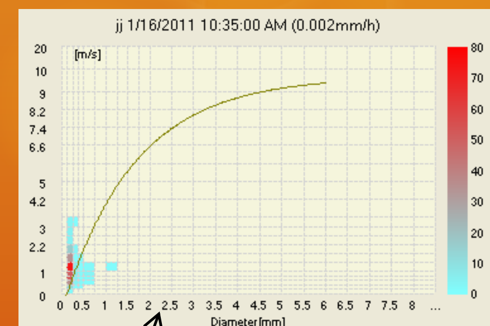

- Precip rates cannot be measured accurately if it is less than 0.5 mm/hr
- Weighing gauges do not work accurately in the Arctic regions because of their sensitivity to particle size and density, and wind effects
- Optical gauges are better than weighing gauges because their sensitivity is directly related to individual particle in a sampling volume
- Snow density is not well known during the precipitation to obtain accurate SWE.
- Hot plates (or capacitance sensors) can work better than others but no particle density info is provided

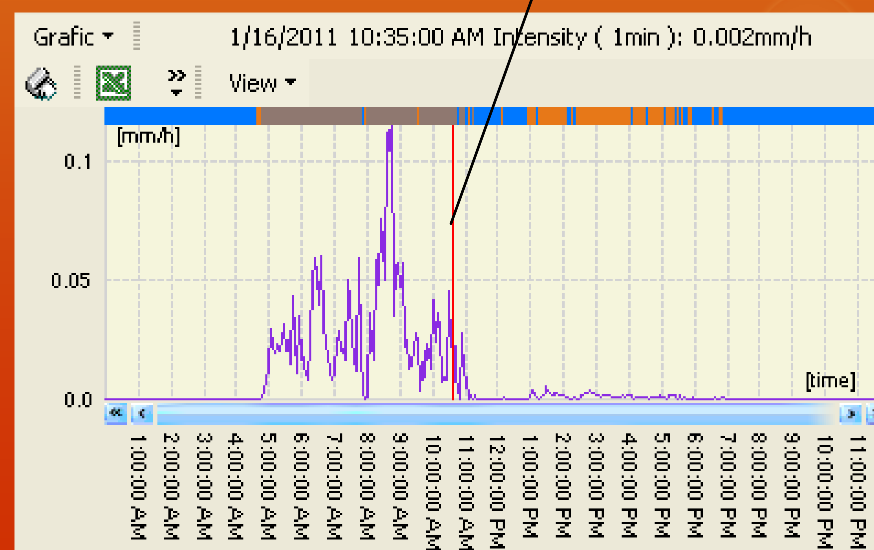
SNOW PRECIPITATION

BARROW NSA SITE



YELLOWKNIFE SITE





2D Snow Precip Measurements

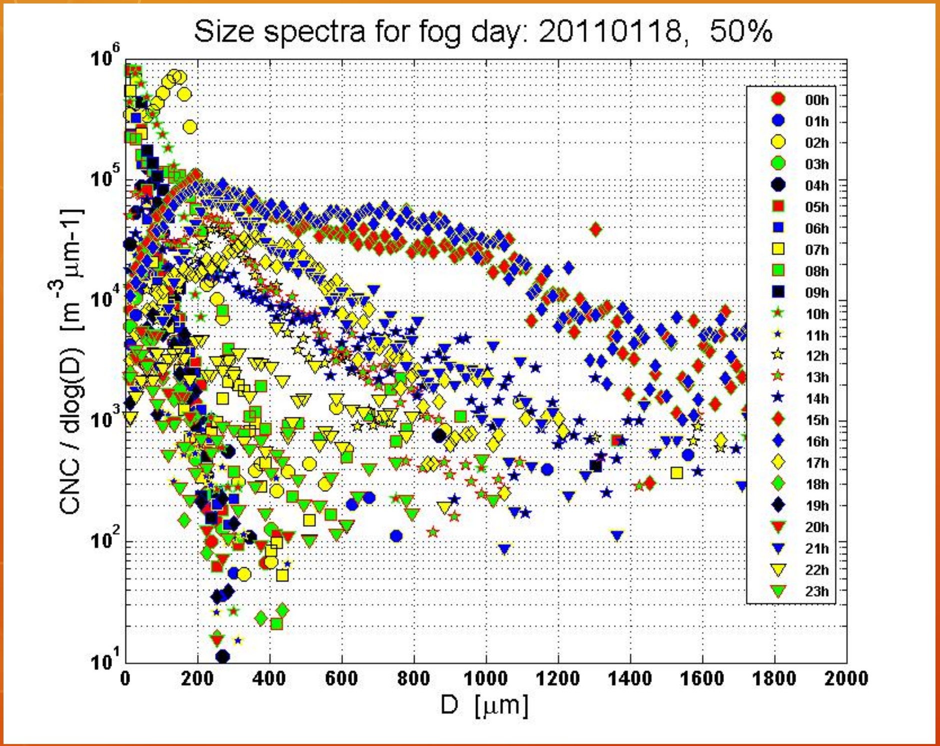
- FMD (fog device, similar to FSSP) (2-50)
- GCIP (similar to Aircraft CIP probe) (15-1000)
- SVI (snow video imaging sensor) (>500)
- SIP (snow particle photography) (>50)
- 2D video images (>500)

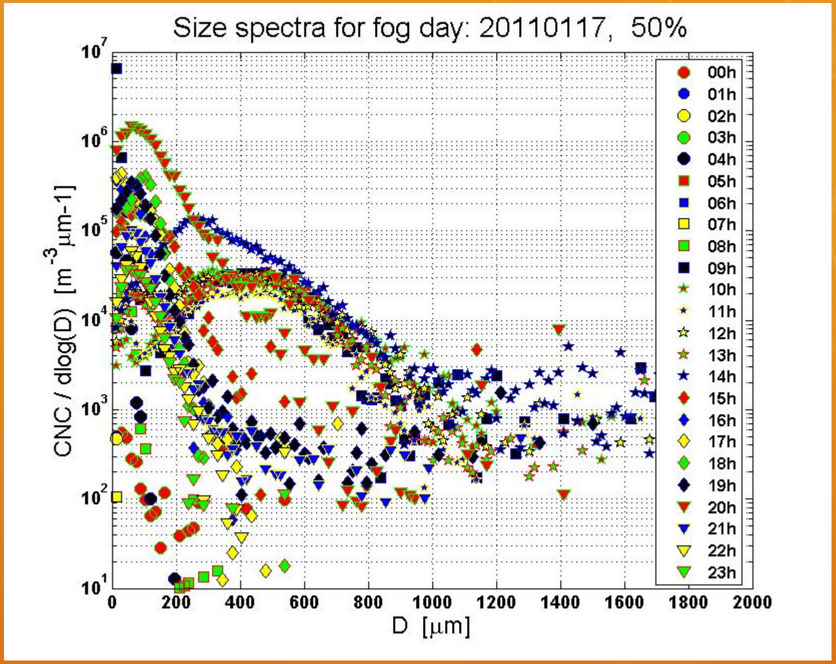
GCIP

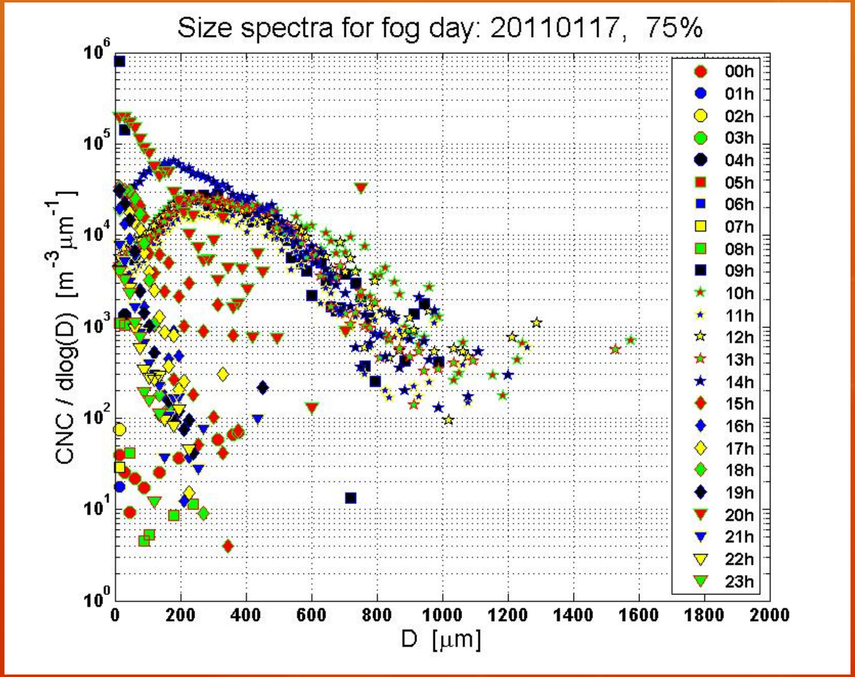
LTU SIP

NCAR SVI

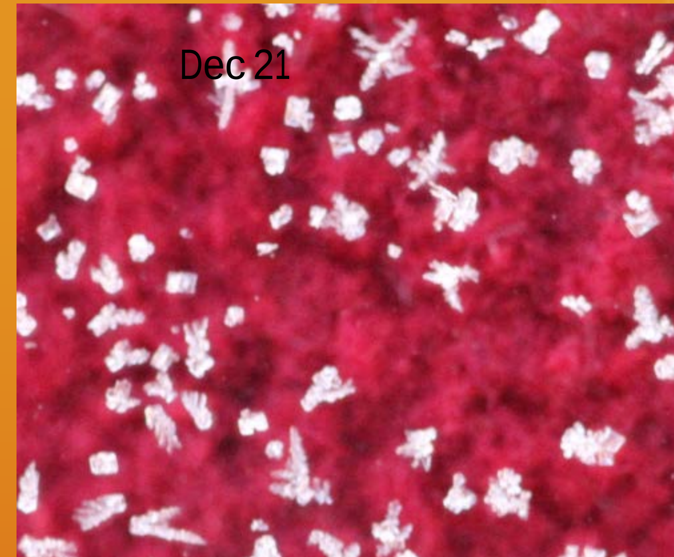
SNOW SPECTRA IN ARCTIC CONTINENTAL CLIMATE (YK surface observations)

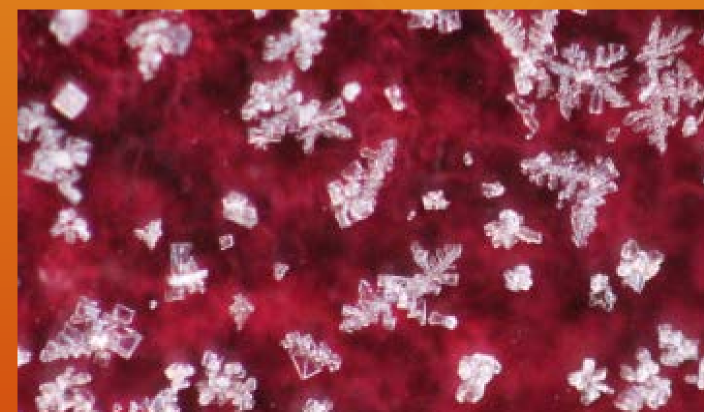




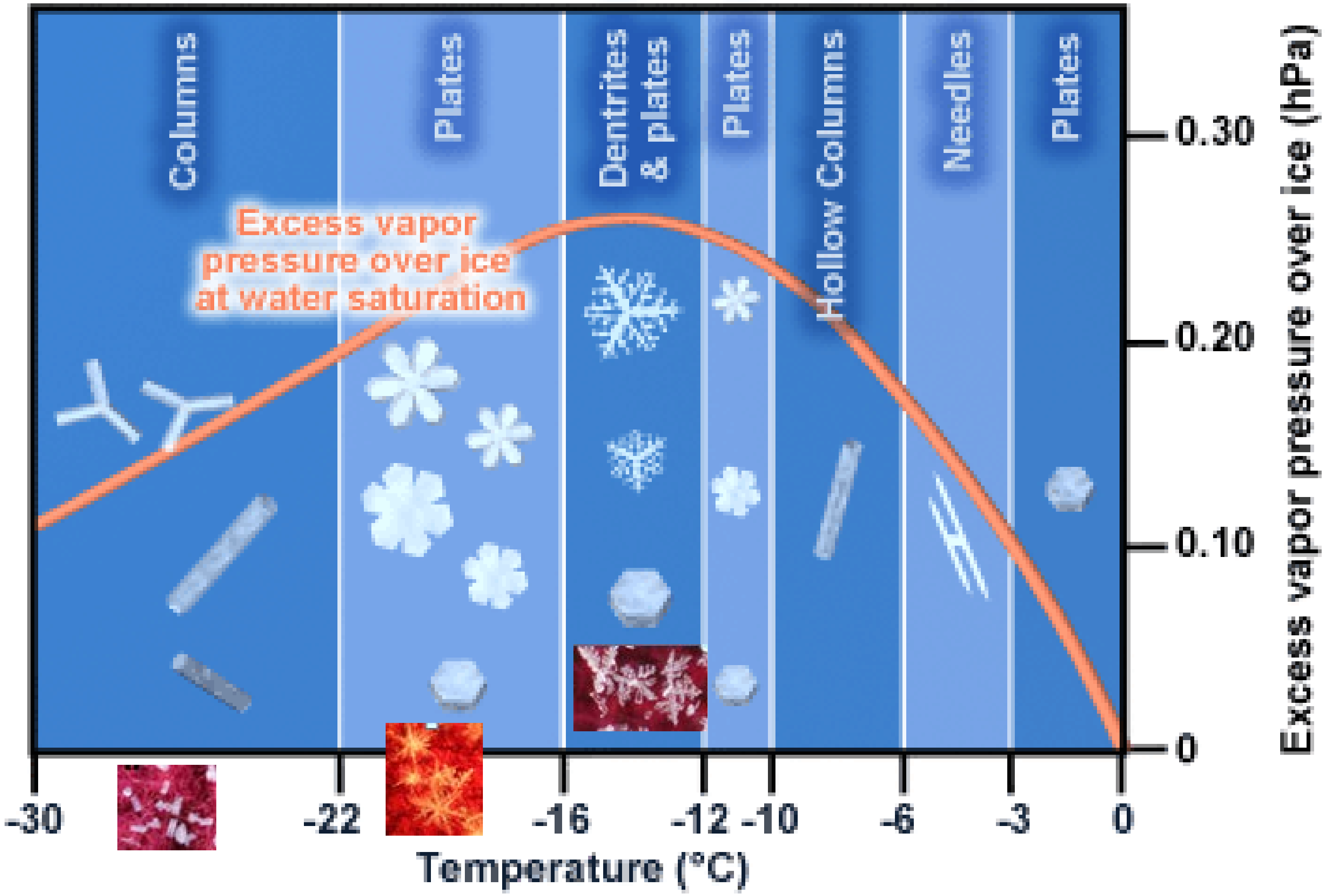


YK site surface snow measurements





Common Crystal Habits and Formation Conditions



Ice Nuclei (IN) characteristics

S. Brooks

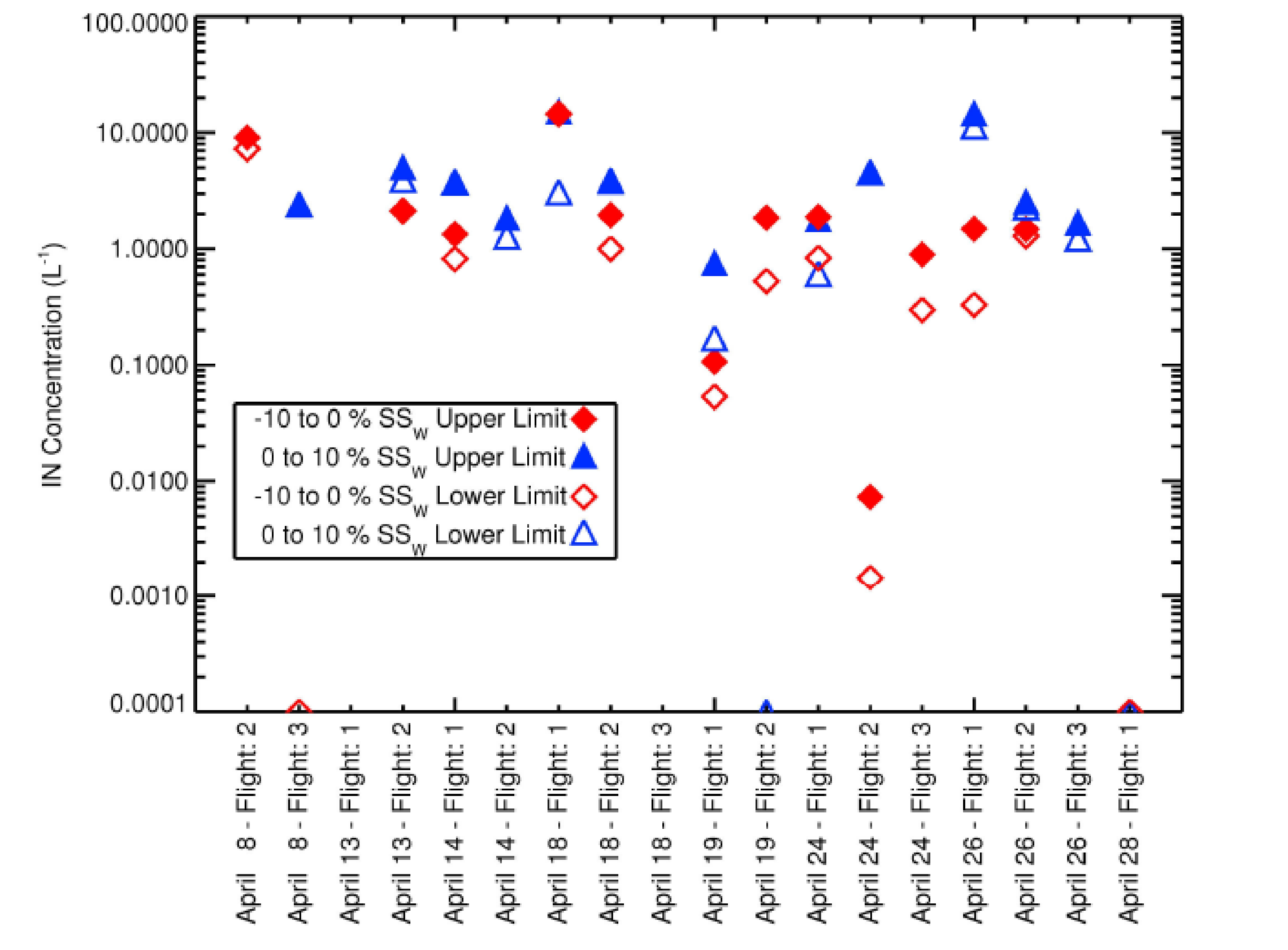
- Ice nucleation potential is determined by aerosol size, composition and morphology.
- Only 1 in 10^5 ambient particles acts as an IN
- Potentially effective heterogeneous IN:

Dust, sea salt, aged soot, marine biogenic aerosol

prepared by Sarah Brooks.

S. Brooks

IN parameterizations



SIP measurements (Thomas Kuhn)




Jan 14 2011 -YK site

AEROSOL-ICE CRYSTALS INTERACTIONS;
ISSUES RELATED TO FLIGHT PLANNING

ARM Mobile Facility (AMF2-SKIP) will be at YK site

Both NSA and YK sites will have similar surface instruments and remote sensing platforms; this will provide us state of art ground base measurements for model validations and comparisons of the observations in the different environmental conditions (including snow precip, aerosol properties, and cloud autoconversion processes].

Available Instrumentation for Land-Based Deployments

Aerosols

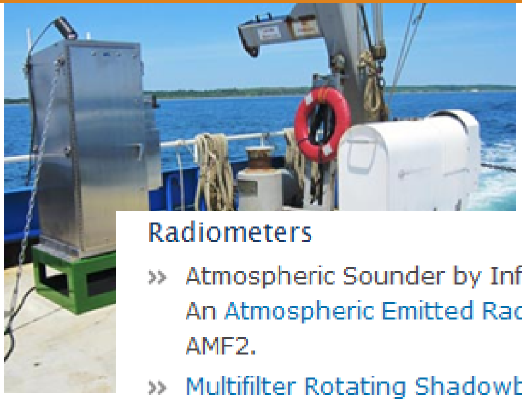
- Aerosol Observation System from ARM (AOSB)
- Cimel Sunphotometer (CSPHOT)

Atmospheric Profiling

- Balloon-borne Sounding System (SONDE)
- Microwave Radiometer, 3-channel (MWR3C)

Clouds

- Micropulse Lidar (MPL)
- Microwave Radiometer (MWR)
- High Spectral Resolution Lidar (HSRL) – coming soon
- Total Sky Imager (TSI)
- Vaisala Ceilometer (VCEIL)
- Scanning W-band (95 GHz) ARM Cloud Radar (WACR)
- Radar Wind Profiler at high frequency (RWP)
  Land-based deployments in the United States will include a standard 91
  and foreign deployments a 1290 MHz wind profiler is currently under de
- Ka-Band Scanning ARM Cloud Radar (KASACR) – coming soon
- W-Band Scanning ARM Cloud Radar (WSACR) – coming soon
  New dual-frequency scanning cloud radars for the AMF2 will operate at
  pedestal, dual antenna system which operates out of a dedicated 20-fo
- Ka ARM Zenith Radar (KAZR) – coming soon
  formerly known as the Millimeter Wavelength Cloud Radars (MMCR).



Radiometers

- Atmospheric Sounder by Infrared Spectral Technology (ASSISTII) – coming soon
  An Atmospheric Emitted Radiance Interferometer (AERI) like system manufactured
  AMF2.
- Multifilter Rotating Shadowband Radiometer (MFRSR)
- Upwelling Radiation (GNDRAD)
- Downwelling Radiation (SKYRAD)
- Portable Radiation Measurement Package (PRP2)
  The PRP2 is a test instrument that holds promise for relaxing some stability require
  deployment, potentially reducing the need for expensive, complex sun trackers. Wh
  instruments (SKYRAD and PRP2) will be operated for comparison and continuity wit

Surface Meteorology

- Meteorological Instrumentation at AMF (MET)
- Eddy Correlation System (ECOR)
- Surface Energy Balance System (SEBS)
- 2-Dimensional Video Disdrometer (2DVD) – coming soon
- Weighing Bucket Gauges – coming soon

Modeling studies

- **Parcel models (EC)**
- **LES models/Cloud Models**
- **Forecasting models (WRF; GEM-LAM)**
- **Regional climate models (WRF; GEM; GEM-LAM)**
- **GCM/CCM applications (NCAR-CAM, EC CCM)**

GEM simulations
January and February 2007

(Girard et al)

- Pan Arctic simulation domain
- Horizontal resolution: 0.25^o with 53 vertical levels
- Initial and boundary conditions: ERA-40 and AMIPII SST and sea ice cover

- **2 scenarios:**

  <u>Scenario B:</u>

  IN coated with sulfuric acid (contact angle of 26^o)

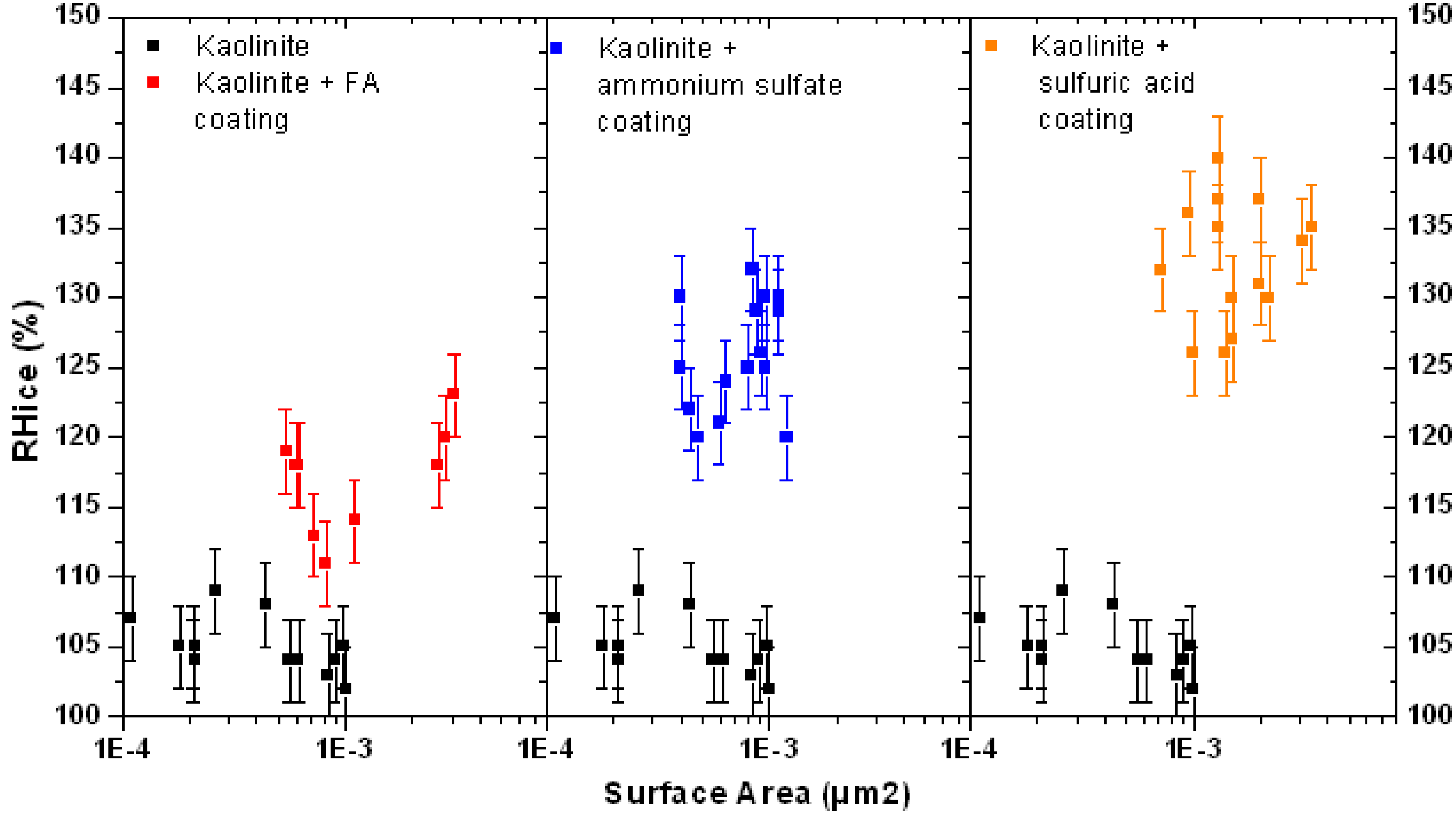
  <u>Scenario A:</u>

  Uncoated IN (contact angle of 12^o)

- Ensemble of 12 simulations for each scenario.
- An anomaly is defined as the difference between the coated scenarios and the uncoated scenarios (scenario B minus A).

Laboratory experiments of Eastwood et al. (2009) testing the ability of several dust particles (uncoated and coated with sulphuric acid and ammonium sulphate) to act as deposition nuclei:

T=-33^{0}C



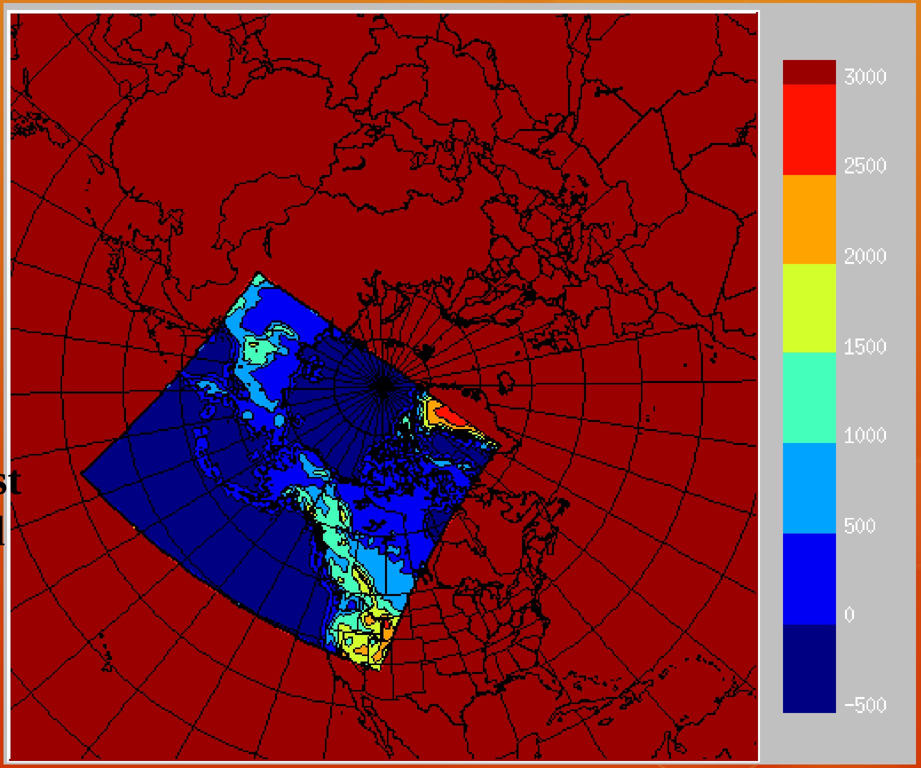
Similar results were obtained with other mineral dust particles

Model configuration

- Spin-up: 01/09/1996 – 31/08/1997
- Driven by ERA-40 re-analysis
- SST and sea ice: AMIP2 (monthly means)
- Horizontal resolution ≈ 50 km
- Time step: 30 min
- SHEBA run: 01/09/1997 - 31/08/1998

•Deposition-immersion ice nucleation based on Eastwood et al. lab experiments

SUN: Sundqvist (results shown previously)
MLO: Milbrand and Yau scheme (2 moments)
ML-AC: New parameterization for acid coating
ML-NAC: New parameterization for uncoated dust
ML-AC-test and ML-NAC-test: dust conc reduced by a factor 5



How to improve statistics on ice clouds?

- Large uncertainties occur due to aircraft quick turn angles and short flight legs; these need to be improved
- Mixed phase conditions result in icing that affects instrument accuracy and measurements.
- Radiative fluxes, extinction probes, and aerosol inlets can be affected by under-sampling issues e.g. time/space variability, shorter legs
- Better turbulent fluxes (e.g. 8hz) and dynamical parameters; they need to be collected over at least 60 km legs
- Precipitation/cloud particles should be measured away from inversion layers
- More constant altitude legs at the cold temperatures e.g. T<-15C and spiral downs
- Spectral radiance measurements above the cloud top

11/27/2010 10:41

Projected work related to PIC3

- **Continue to work on the proposal**
- **Increase collaborations on instrument deployment**
- **Integrate observational and modeling communities' interest on Arctic ice clouds and its conversion to snow**

11/28/2010 11:43

- **Sort out issues related field program**