Arctic field experiments

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Prior International Polar Years

1982-1983: 12 countries participated; advances in meteorology and geographical exploration

1932-1933: 40 countries participated; jet stream, ionosphere, numerous permanent observing stations established

1957-1958 (IGY): emphasized new technologies; contributions to aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, precision mapping, meteorology, oceanography, seismology, solar activity.

What's been going on since the IGY?
(not much meteorology)

Arctic:

1960s -1980s: sea ice and oceanography, surface meteorology and radiation (Russians)

1980s-present: atmospheric chemistry

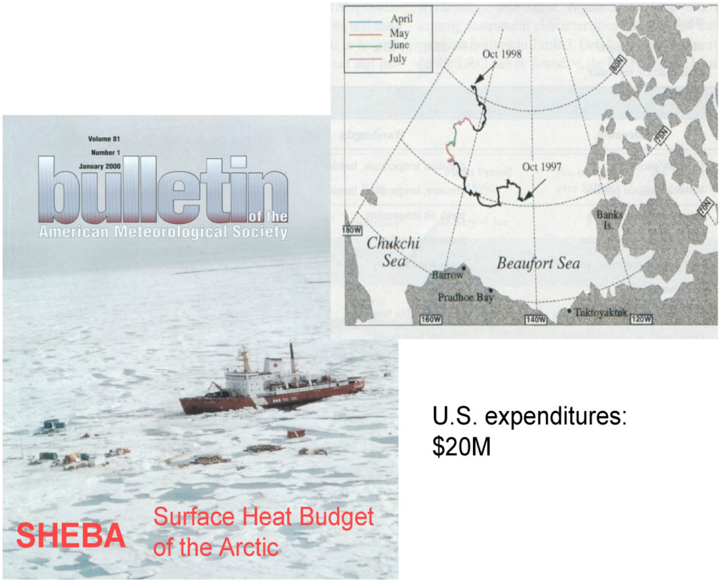
1995 - present: clouds and radiation

1990s-present: interdisciplinary research, climate change, social and biological sciences

Major field expeditions since the IGY
(of some relevance to NWP)

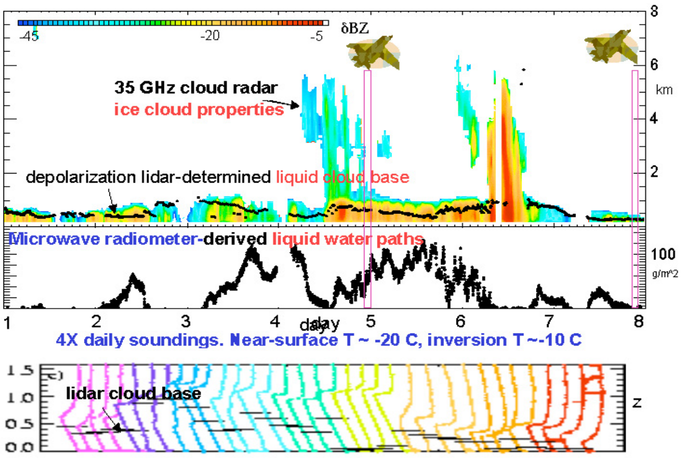
POLEX (FGGE; 1976-1977): Arctic ice dynamics (surface pressure buoys)

SHEBA (1997-1998): Arctic Ocean surface energy balance, clouds, radiation, sea ice thermodynamics, ocean mixed layer



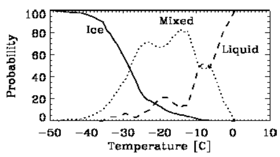
U.S. expenditures:
$20M

Surface-based Instrumentation: May 1-8 time series



Arctic Mixed-Phase Clouds

- Dominate cloud fraction of Arctic throughout year, occurring ~ 60% of the time clouds were present at SHEBA
- Persist on average for 12 hrs, but often last for several days.
- Much larger cloud radiative forcing compared to ice clouds
- Within mixed-phase clouds, liquid dominates ice in terms of radiative impact
- Common at temperatures down to -30° C.



Percent of time during SHEBA that clouds were classified as all-ice, mixed-phase, or all-liquid as a function of minimum in-cloud temperature (from Morrison et al. 2005, GRL).

What did SHEBA accomplish?

Test bed for:

- Radiative transfer models
- Cloud microphysics models
- Sea ice models
- Surface heat flux models

Evaluation of satellite products

Process studies

What did JC learn from SHEBA?

Confirmed qualitatively many of my preconceived notions; firmed up quantitative understanding

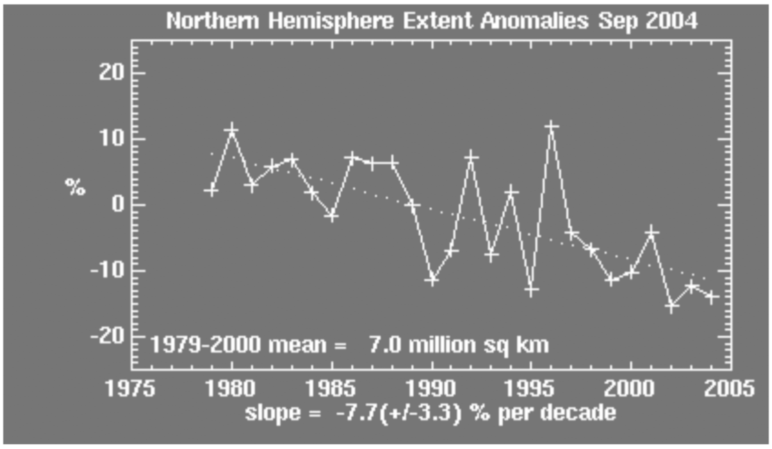
1998 different from 1980; different phase of the AO and thin ice

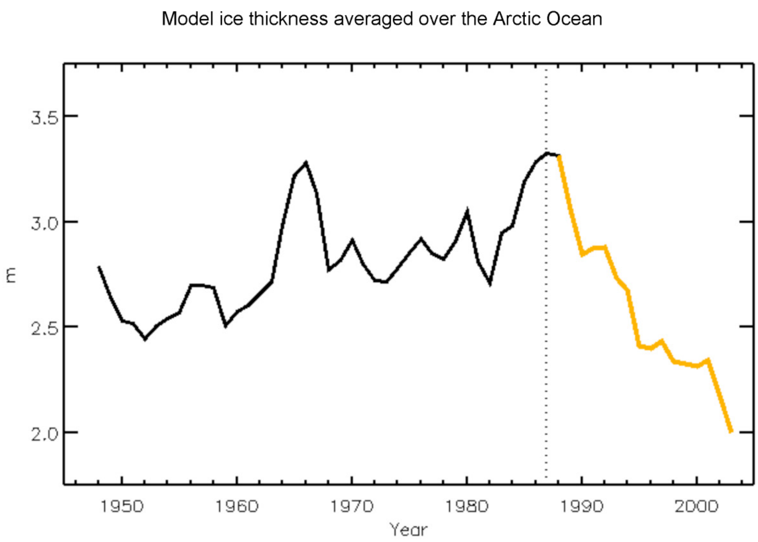
Feedbacks are complex interplay of hemispheric circulation patterns and local thermodynamics

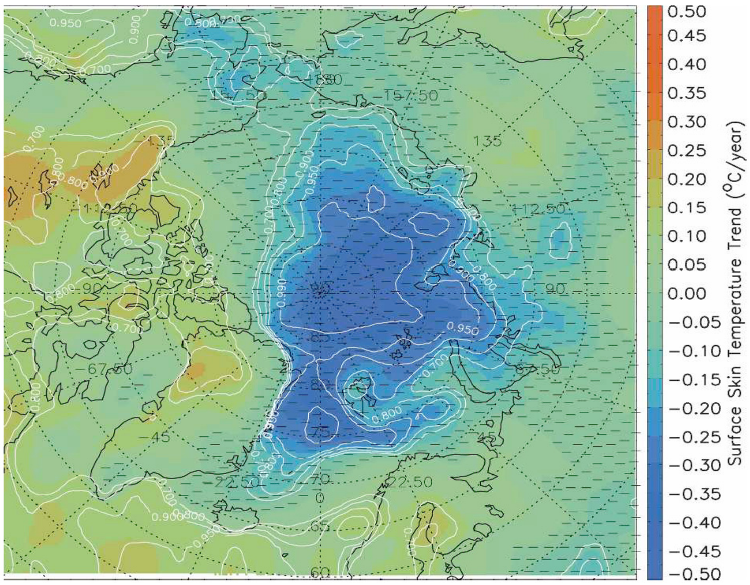
- Example: onset of spring melt associated storm in late May that had liquid precipitation

Mixed phase clouds are ubiquitous and cloud phase varies substantially with temperature

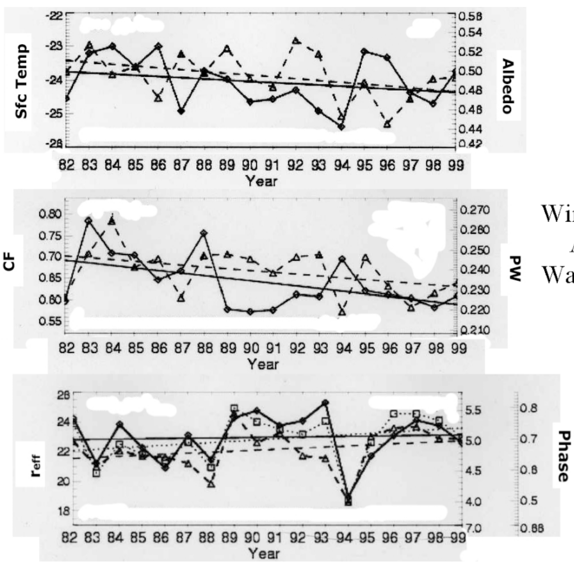
Greatest impediment to testing cloud parameterizations is inadequate dynamics (boundary layer, synoptic)



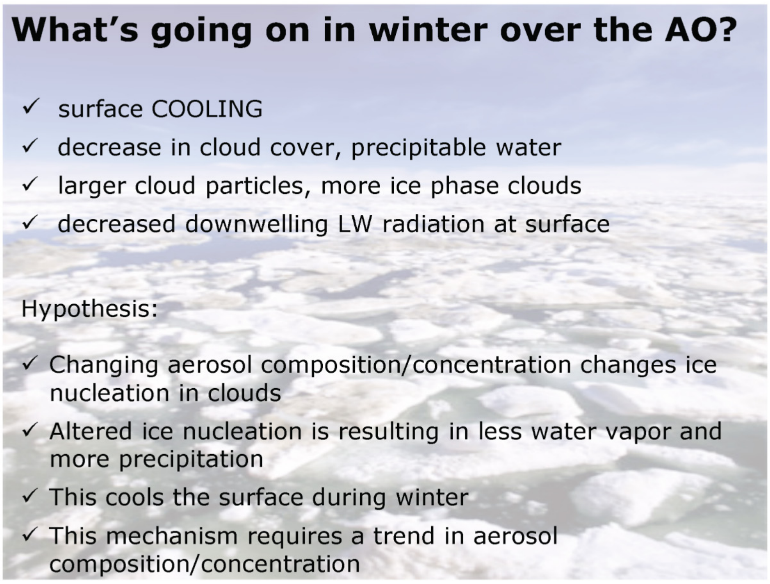


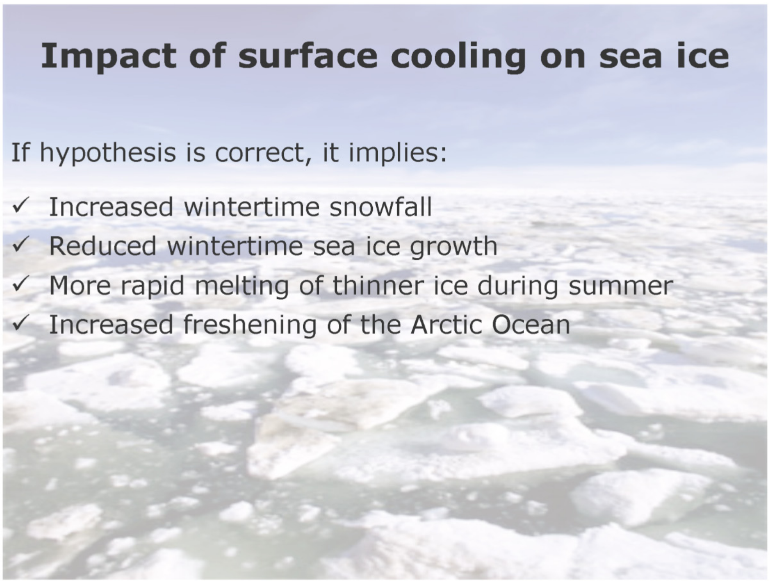


DJF trends 1982-1999 Wang et al. 2005



Wintertime Trends
Arctic Ocean
Wang et al. (2005)





Looking ahead to IPY 2007-2008

Improved observations to support meteorological analysis (data assimilation and model evaluation)

New technologies:

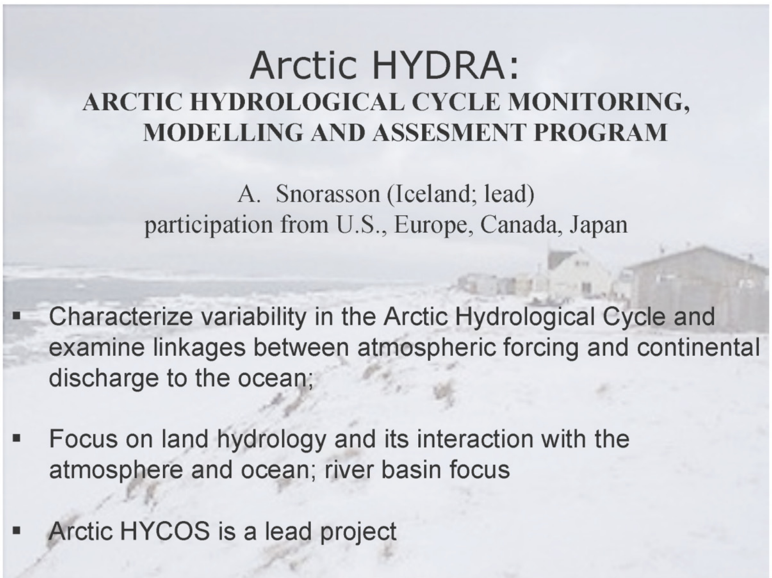
CLOUDSAT and CALIPSO (space radar & lidar)

unmanned vehicles

Aerosol/cloud/precipitation interactions


International Polar Year (IPY) Activity
International Arctic Systems for Observing the Atmosphere (IASOA)
NOAA/SEARCH Arctic Atmospheric Observatories Program


Barrow, Alaska
Tiksi, Russia
Eureka, Canada
Ny-Alesund, Svalbard
Arctic Ocean
North Pole
Alert, Canada
Summit, Greenland
Establishing Intensive Atmospheric Observatories In the Arctic is the component of NOAA/SEARCH being directed by ESRL


Arctic HYDRA:
ARCTIC HYDROLOGICAL CYCLE MONITORING, MODELLING AND ASSESMENT PROGRAM
A. Snorasson (Iceland; lead)
participation from U.S., Europe, Canada, Japan
Characterize variability in the Arctic Hydrological Cycle and examine linkages between atmospheric forcing and continental discharge to the ocean;
Focus on land hydrology and its interaction with the atmosphere and ocean; river basin focus
Arctic HYCOS is a lead project

Hydrological Impact of Arctic Aerosols: HIAA

J. Curry (lead)
GEWEX project to integrate clouds/radiation with land surface hydrology

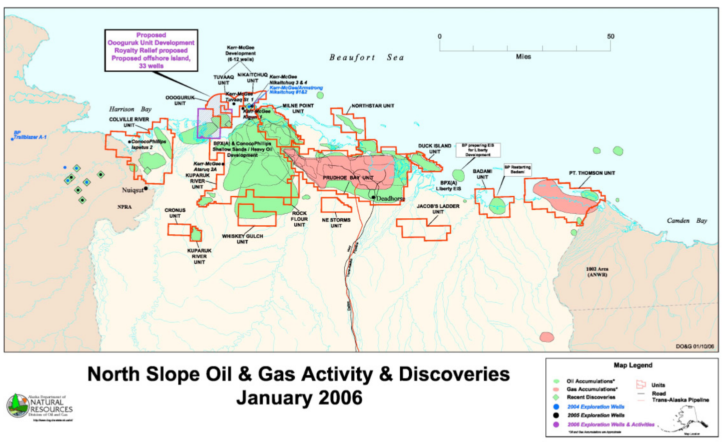
Sources of Arctic aerosols:

Biomass burning in northern forests
Pollution aerosol
Biogenic aerosol
Desert dust

Motivation

– Changes in the Arctic hydrological cycle likely arise from a complex interplay between natural modes of climate variability and anthropogenic activity; what is the relative role of aerosols in the recent warming observed in the Arctic.
– Variations in aerosol characteristics potentially modulate the Arctic climate through impact on *precipitation, radiation fluxes, and surface albedo*
– Atmospheric aerosols influence the nucleation of cloud particles, in turn the cloud cover and precipitation processes, and hence river runoff, snow cover, permafrost, glacial accumulation, and surface temperature

Proposed deployment of ARM Mobile Facility In Alaskan Oil Fields (Prudhoe/Kuparuk)



Prudhoe Bay is the largest oilfield in North America

• Permanently altered more than 400 square miles of formerly pristine wilderness

• Hosts one of the world's largest industrial complexes

• Provides an opportunity to investigate the impact of pollution aerosol from resource extraction activities) on clouds, radiation, and precipitation

New satellite observations:
- Calipso: lidar
- CloudSat: cloud radar (attempt snowfall rate retrievals)

Relevant IPY aircraft obs:
- POLar study using Aircraft, Remote sensing, surface measurements and modelling of Climate, chemistry, Aerosols and Transport (POLARCAT)
- Indirect and Semi-Direct Aerosol Campaign (ISDAC)
- Unmanned Aerial Vehicles (UAVs)

Indirect and Semi-Direct Aerosol Campaign (ISDAC)

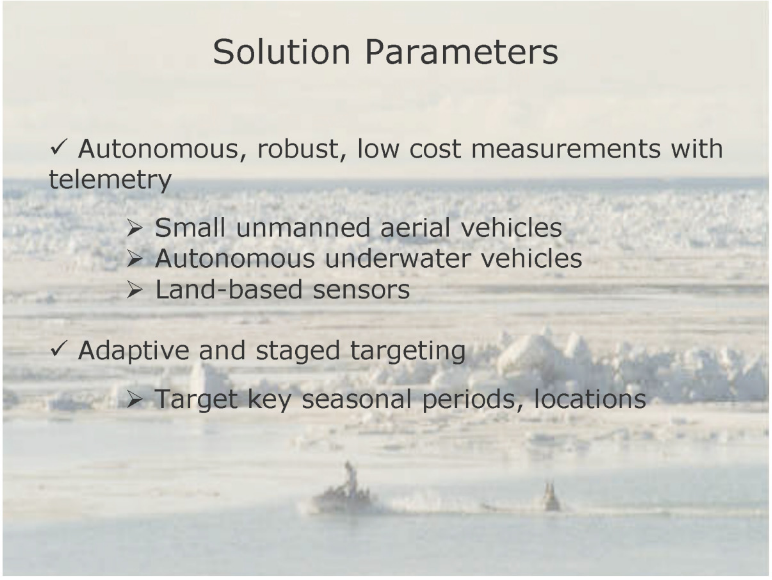
Primary Motivation

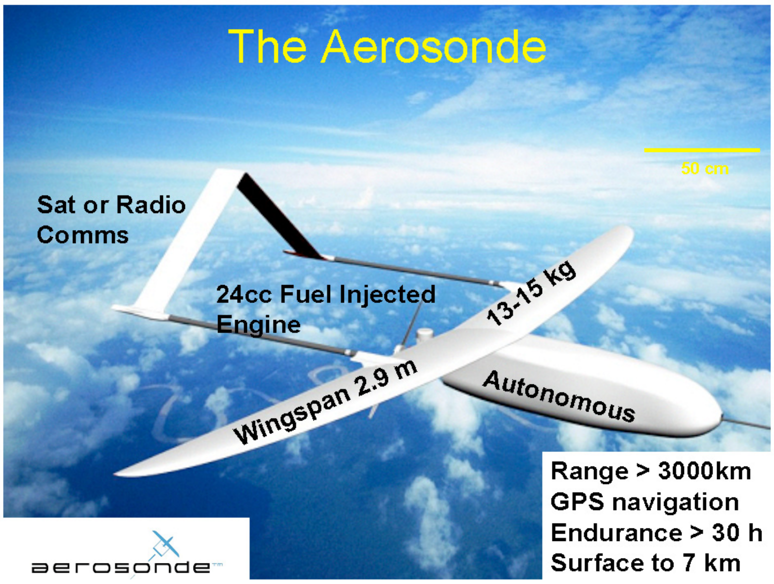
- Well known that anthropogenic aerosols are advected into Arctic in springtime
- Indirect effect: more aerosols à smaller droplets à longer cloud lifetime and enhanced cloud albedo
- Semi-direct effect: more absorbing aerosols à more local heating à shorter cloud lifetime
- Impacts on surface fluxes/properties and melting rates, as well as atmospheric heating rate profiles

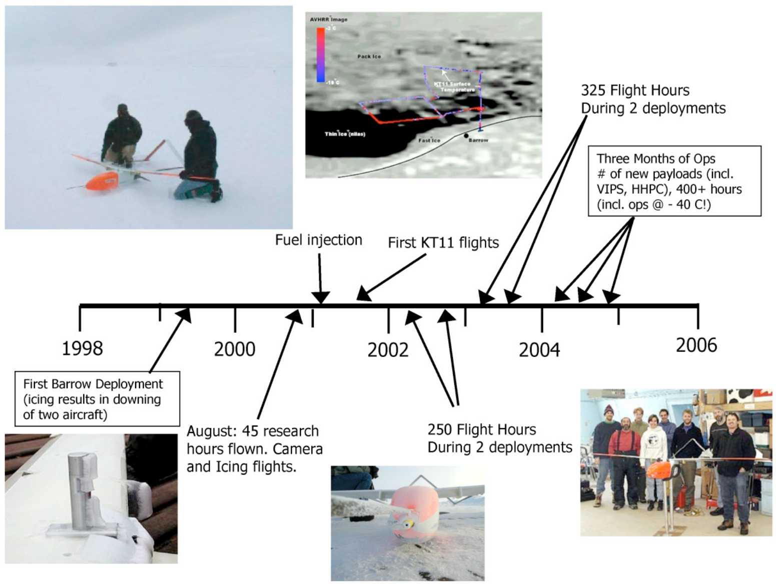
Proposed ISDAC Observations

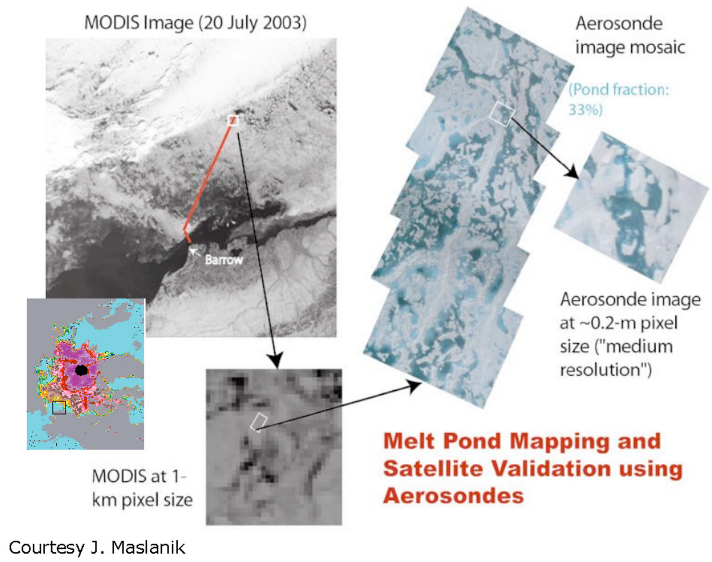
- Aircraft with 50-60 flight hours for science
  - Full suite of aerosol in-situ observations, including size distributions
  - Full suite of cloud microphysical instruments
  - CCN and IN observations
- Additional radiosondes (at least 4/day)
- 90 GHz MWR
- Molecular lidar (Raman or HSRL)
- Additional surface aerosol observations,
- Chemical composition of aerosols at surface and aloft

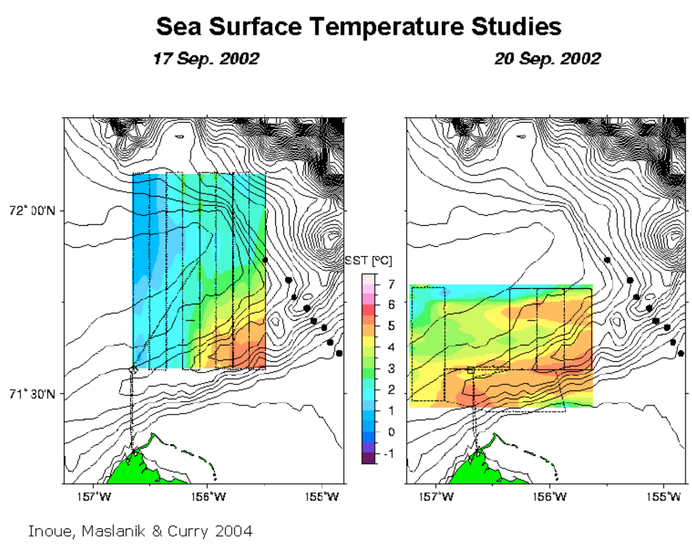

Logistical Issues in Polar Observations
✓ Harsh, dangerous environment
✓ Observations are expensive
✓ Manpower shortage
✓ Satellite remote sensing is confounded by snow/ice surface

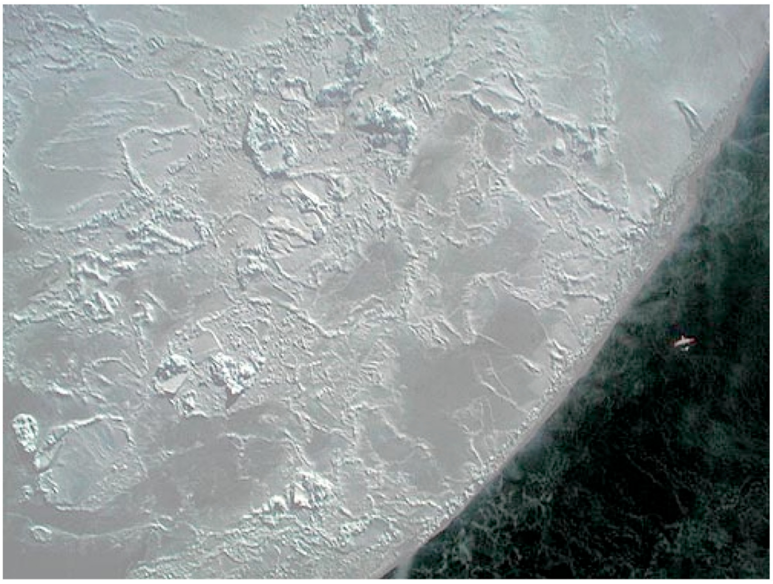

Solution Parameters
✓ Autonomous, robust, low cost measurements with telemetry
➢ Small unmanned aerial vehicles
➢ Autonomous underwater vehicles
➢ Land-based sensors
✓ Adaptive and staged targeting
➢ Target key seasonal periods, locations


The Aerosonde
50 cm
Sat or Radio Comms
24cc Fuel Injected Engine
13-15 kg
Wingspan 2.9 m
Autonomous
aerosonde
Range > 3000km
GPS navigation
Endurance > 30 h
Surface to 7 km


325 Flight Hours
During 2 deployments
Three Months of Ops
# of new payloads (incl. VIPS, HHPC), 400+ hours (incl. ops @ - 40 C!)
Fuel injection
First KT11 flights
1998
2000
2002
2004
2006
First Barrow Deployment (icing results in downing of two aircraft)
August: 45 research hours flown. Camera and Icing flights.
250 Flight Hours
During 2 deployments


MODIS Image (20 July 2003)
Barrow
Aerosonde image mosaic
(Pond fraction: 33%)
Aerosonde image at ~0.2-m pixel size ("medium resolution")
MODIS at 1-km pixel size
Melt Pond Mapping and Satellite Validation using Aerosondes
Courtesy J. Maslanik


Sea Surface Temperature Studies
17 Sep. 2002
20 Sep. 2002
72° 00'N
71° 30'N
SST [°C]
7
6
5
4
3
2
1
0
-1
157°W
156°W
155°W
Inoue, Maslanik & Curry 2004



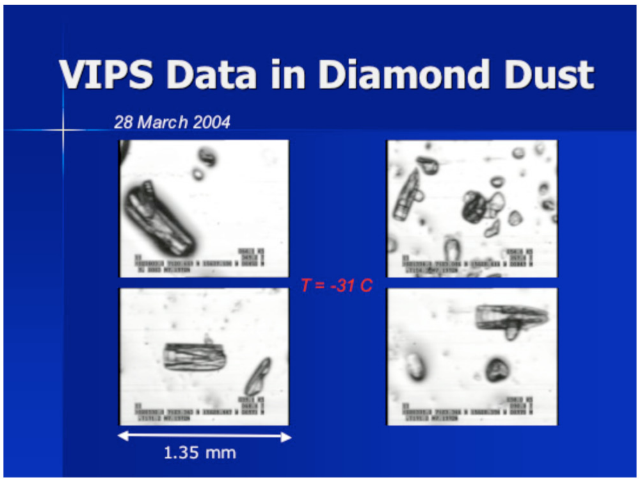
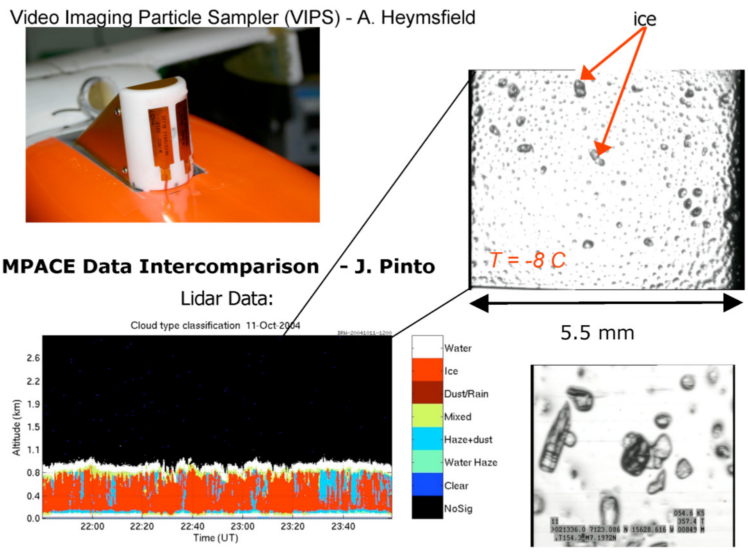
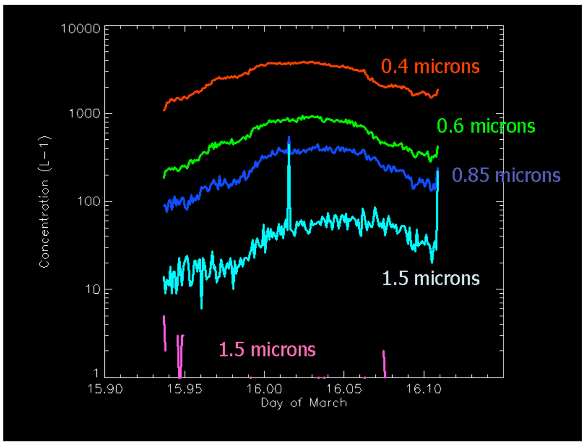


Figure 10. Examples of VIPS-acquired images showing ice particles, as observed within "diamond dust" (relatively low-density ice crystals in the lower polar atmosphere).



HHPC-6 large particle counter
Aerosol size distribution - M. Bergin



Integrated

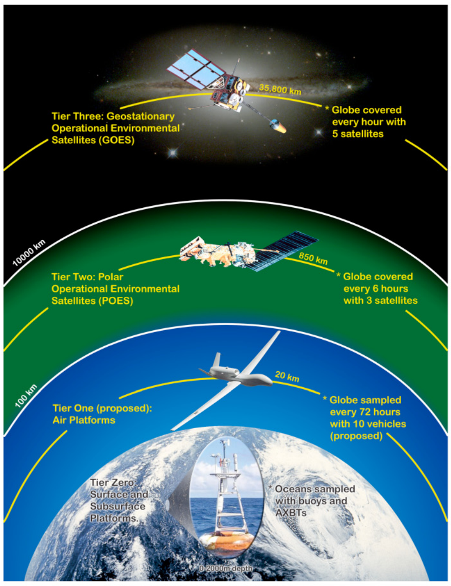
Global

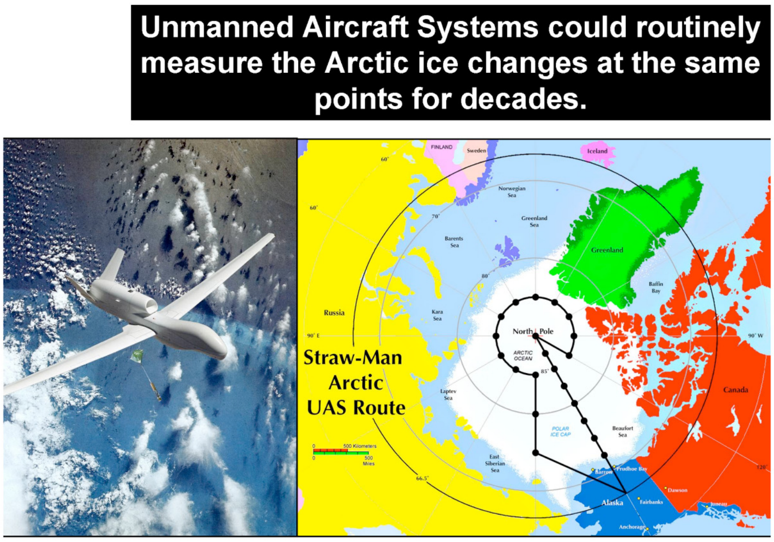
Observing

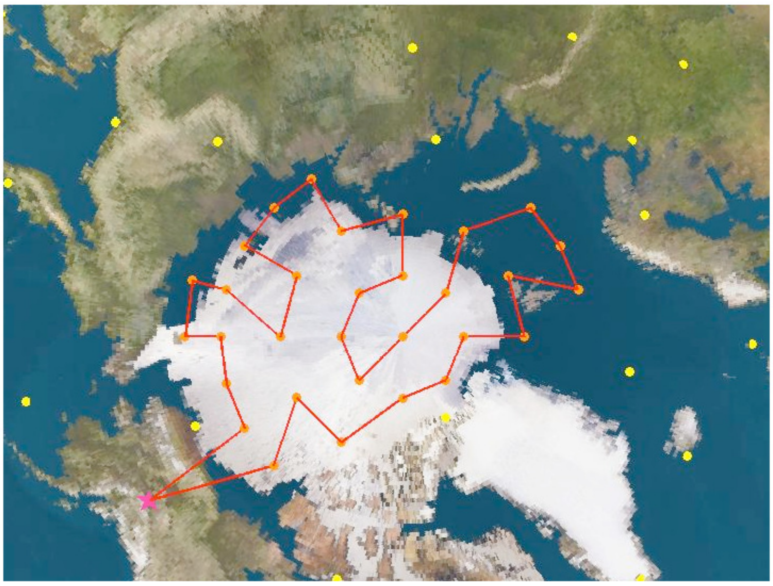
The global observing system must be designed to support the scientific questions inherent in long term climate diagnosis and prediction.

The strategic triad of global observing:

Satellites – UAVs - Buoys




Unmanned Aircraft Systems could routinely measure the Arctic ice changes at the same points for decades.
Straw-Man
Arctic
UAS Route
North Pole
Russia
Greenland
Canada
Alaska
Iceland




Challenges for IPY Arctic field experiments:
Coordination among projects, particularly across disciplines
Funding
Logistics
Technology readiness