The Arctic Sea Ice Cover

- Frozen ocean
- 8-15 million km²
- Size of U.S.
- Meters thick
- Floating, moving ice
- Highly variable
- Large albedo

Interface, Impediment, Integrator
Why important

- **Exploration**
- **Economic**
- **Military**

**Climate change**
- Canary in a coal mine
- Amplifier of change

10m Air Temp Difference (K)
What are the major sea ice questions?

- How much ice is there?
  - areal extent
  - thickness
- How much snow is there?
- How does the ice move?
- What is its mass balance?
- Where does the sunlight go?
- What are its properties?
- How does it interact with other components?

- Is Arctic change related to the Arctic Oscillation?
- Is Arctic change a component of climate change?
- Are feedbacks critical to Arctic change?
- Do physical changes greatly impact Arctic ecosystems and society?
- Which Arctic changes reflect basin-wide, decadal, and long-term processes?
- How are they coupled?
- Have Arctic feedbacks amplified these changes?
- What are the future Arctic change scenarios?
- Determine the extent of the ice cover
- Determine the redistribution of the ice cover due to dynamics and thermodynamics
- Measure the export of ice from the Arctic basin
- Determine the snow depth and the ice thickness
- Assess large-scale Arctic environmental change.
- Conduct scientific exploration of polar frontiers.
- Observe polar regions in depth.
- Understand human-environmental dynamics.
- Create new connections between science and public.

How are these quantities changing?
What do we need to measure?

- Ice extent
- Thickness distribution
- Snow depth distribution
- Ice motion
- Temperature
- Mass balance
- Albedo and transmission
- Environmental forcing (ocean and atmosphere)

Spatial and temporal variability make it difficult
What tools do we have?

- Archived data
- Field experiments
  - camps
  - cruises
  - submarines
- Remote sensing
  - IPS
  - aircraft
  - satellites
- Models
  - process
  - discrete element
  - large-scale ice
  - GCM

*Ice tethered buoys!*
What is the ice extent?

*Satellites*

Ice extent is decreasing
How thick is the ice?

- Rothrock et al. show thinning everywhere!
- Average decrease was 40% from 3 m to under 2 m
- Tucker et al. show similar results for spring

Sea ice is thinning everywhere
How much snow is there?

- Surface obs
- Buoys
- Satellites?

Seasonal evolution and large spatial variability
How does the ice move?

Variations due to changes in forcing

- Buoys
- Satellites
What is the mass and heat budget?

- Surface obs
- Buoys

Large variability: spatial and interannual
Where does the sunshine go?

• Surface obs
• Buoys

Seasonal variability, melt ponds are the key.
What are the ice properties?

- Surface obs
- Buoys
- Satellites

Ice properties impact all parameters
How does it interact?

- Surface obs

Much work to do.
Ice tethered systems: ice measurements

1. Air temperature
2. Ice temperature
3. Upper ocean temperature
4. Snow depth
5. Ice thickness
6. Ice mass balance
7. Surface conditions
8. Solar partitioning
9. Ice position

1. Thermistors
2. Thermistors
3. Thermistors
4. Acoustic sensor
5. Acoustic sensor
6. Acoustic / thermistors
7. Web cams – above,below
8. Spectroradiometers
9. GPS

Ice tethered systems can make major contributions
Sample ice buoy results

Almost as good as being there.
Spatial variability

Snow depth, ice thickness, ice conditions
What good is a point measurement?

Pretty good if... you carefully select location
Snow-ice interface temperature tells all
Installation measurement festival

Explore spatial variability

- Aerial photographs
- Snow depth
- Pond depth
- Ice thickness
- Surface types

Characterize area during buoy installation
Remember outreach

Classroom visits, media outreach, web cams and pages
Integration coordination, and synthesis

3 levels of coordination and integration

- Integrate all buoy elements (ice, ocean, atmosphere, biology, geochemistry).
- Integrate tethered buoys with other components of an Arctic Ocean observing system (satellites, moorings, stations).
- Coordinate with other studies (process studies, field studies, models).

- Collaborate with other efforts
- Synthesize results

Integration is the key
Summary

- How much ice is there?
  - areal extent
  - thickness – Yes!
- How much snow is there? – Yes!
- How does the ice move? – Yes!
- What is its mass balance? – Yes!
- Where does the sunlight go? – Yes!
- What are its properties? – Yes!
- How does it interact with other components? – Yes!

Can ice tethered buoys help answer the questions – YES!
SEARCH ice mass balance activities

- Sponsored by NOAA and NSF
- Ice mass balance buoys
- Deployments defined by
  - Maximum coverage
  - Models and observations
- Eight buoys this year
- Expected life 1-3 year
- Coordinated with moorings
  - Ocean instruments
  - Ice profiling sonar
- Collaboration with other efforts

Location, location, location
Mass balance observations

Beaufort Sea

North Pole

Autonomous field experiment in a box