NASA's sea ice program: present and future

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What is NASA doing?

Observations

- **Satellites**
- **Airborne**
- **Field studies**

Tool development for remote sensing

- **New algorithms to interpret satellite data**

  Improvements to long term satellite record

- **New remote sensing applications**

  Infer properties such as sea ice thickness from ICESat

Research

- What is happening right now and how does it compare with the last thirty years?
- How does sea ice respond to climate forcings?
- How is it linked to oceanic heat transport?
- What role does surface roughness play?

Scope of program

Researchers

- **Goddard**
- **JPL**
- **Academic institutions**

Resources used

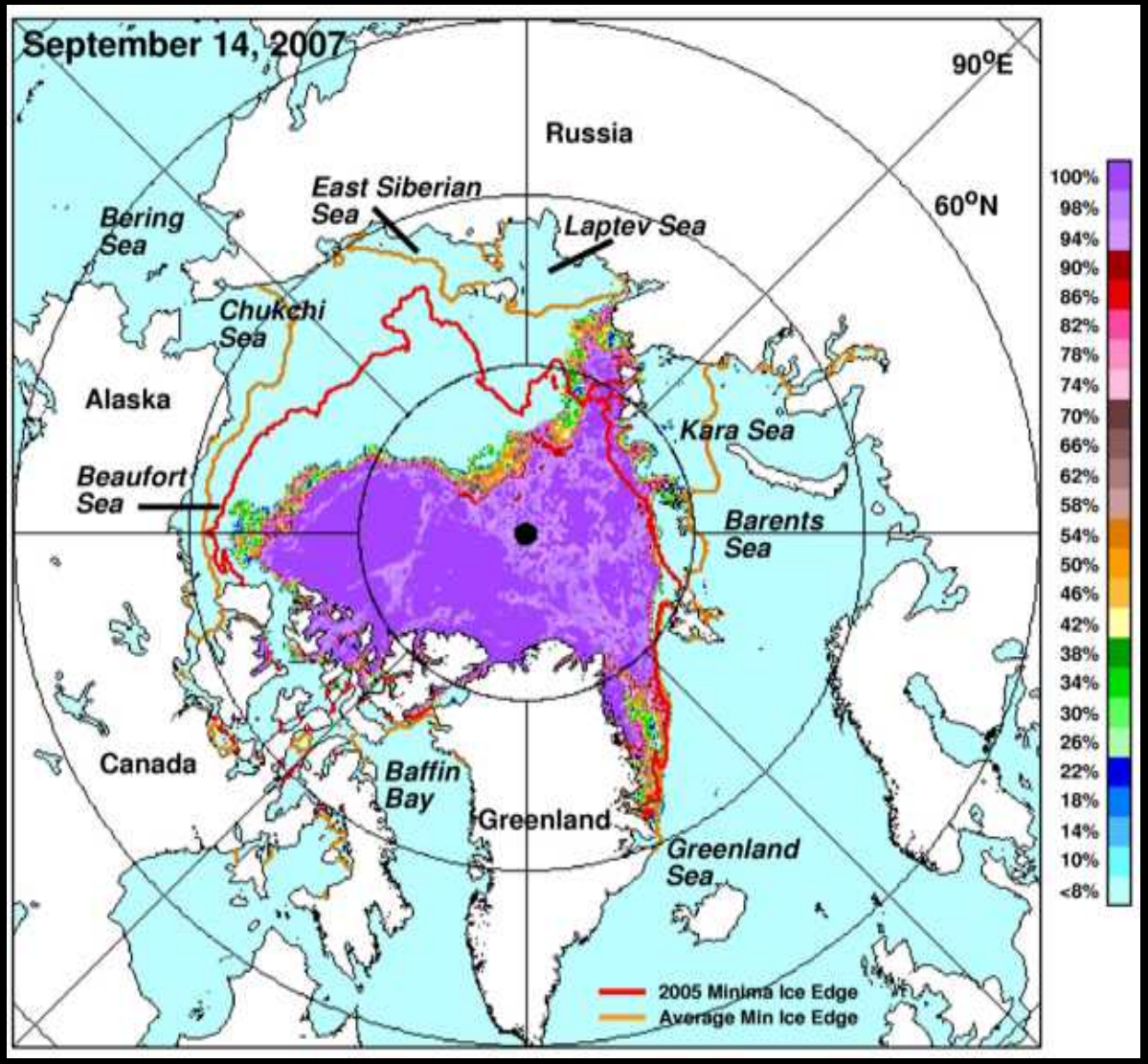
- **Satellites: DMSP, AMSR-E, QuikSCAT, MODIS, ICESat, GRACE**
- **NASA's manned and unmanned aircraft**

NASA funding sources

- **Cryosphere programs**
- **ICESat program**
- **IPY program**
- **Interdisciplinary science and modeling programs**
- **NASA Flight and DAAC programs**

Outreach/data/results delivery

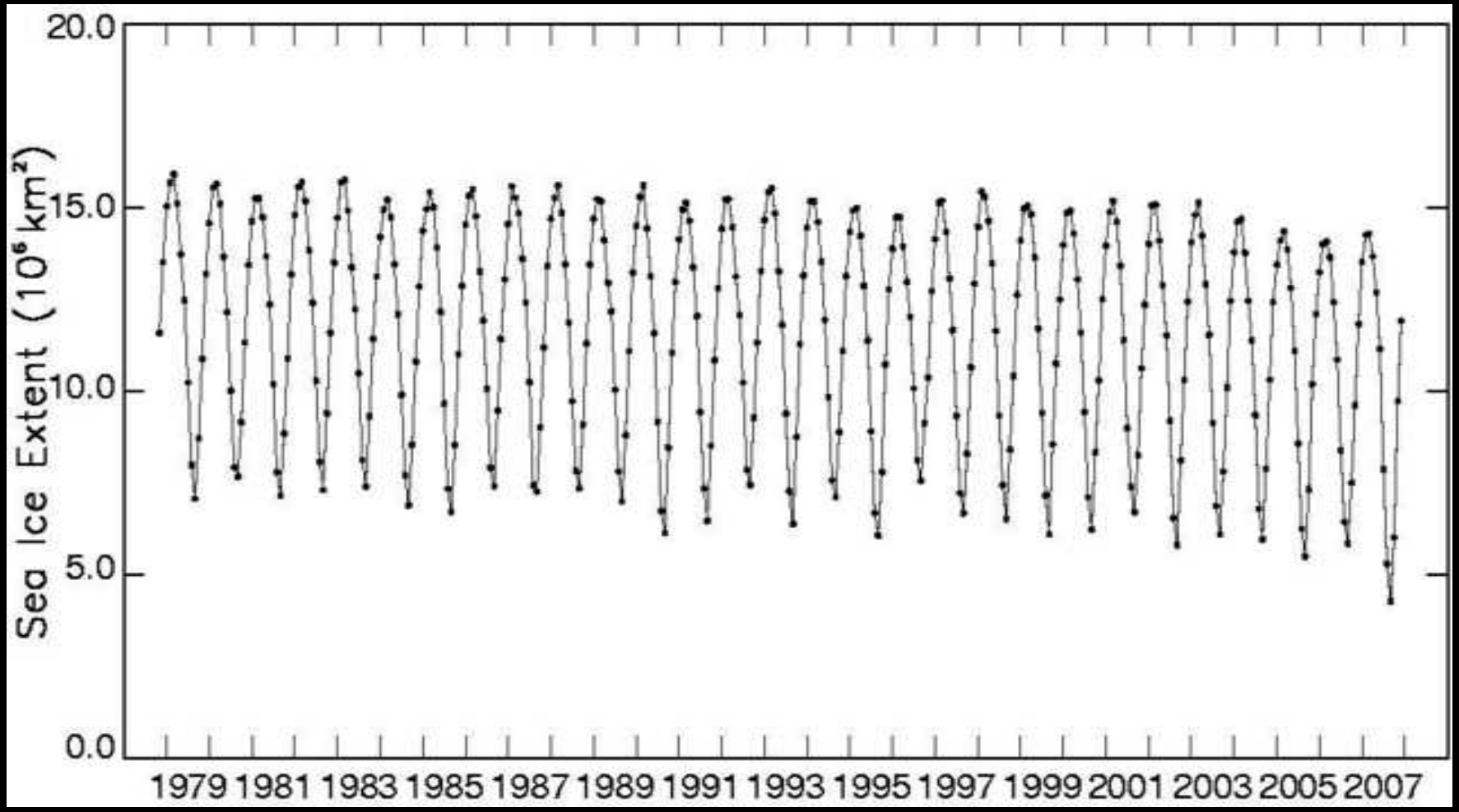
September 14, 2007 Arctic Sea Ice Distribution vs. Minima in 2005 and averaged over 1979-2006



(from J. Comiso, C. Parkinson, R. Gersten, and L. Stock 2008)

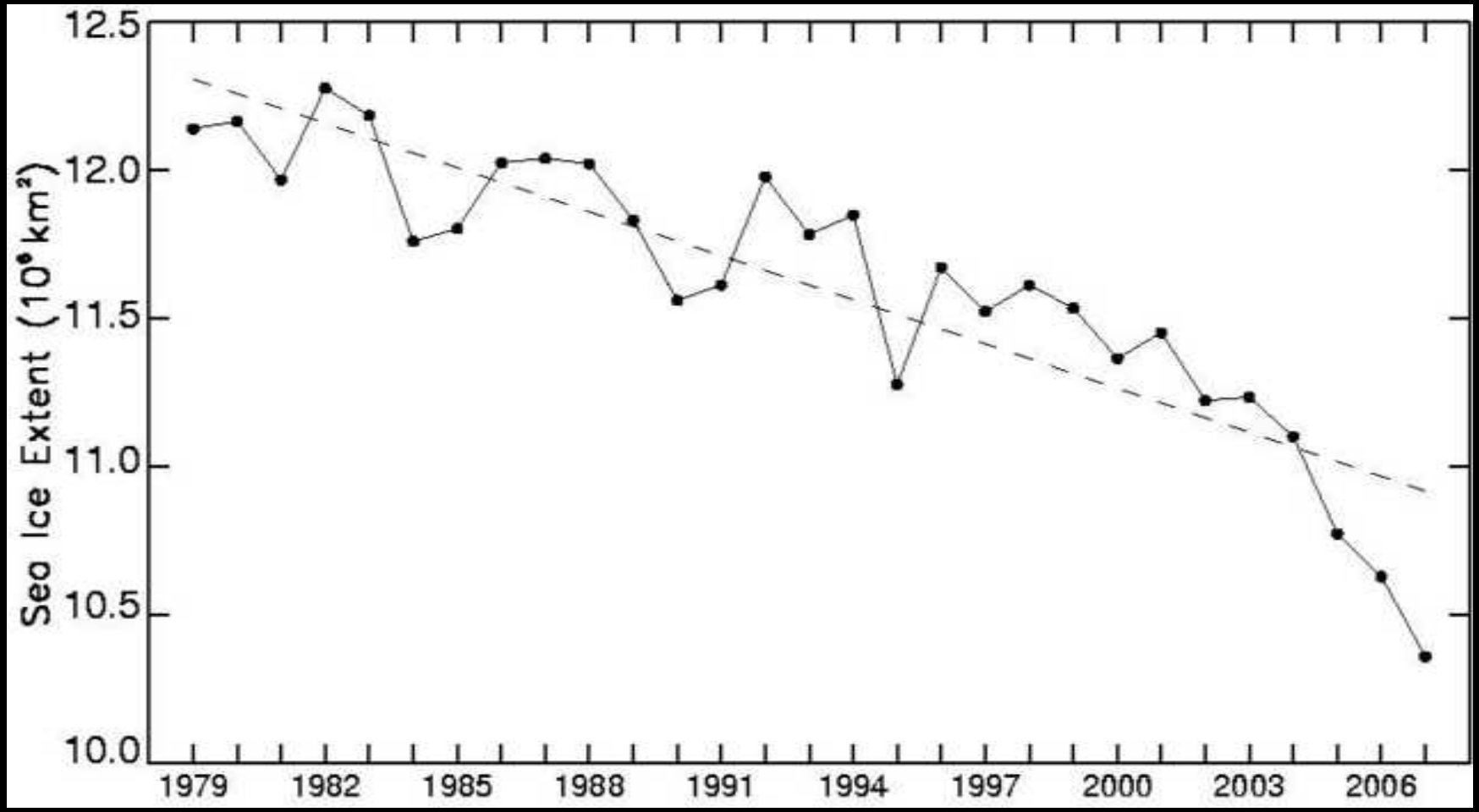
Monthly Arctic Sea Ice Extents
November 1978 – December 2007

from Nimbus 7 Scanning Multichannel Microwave Radiometer (SMMR) and DMSP SSMI data



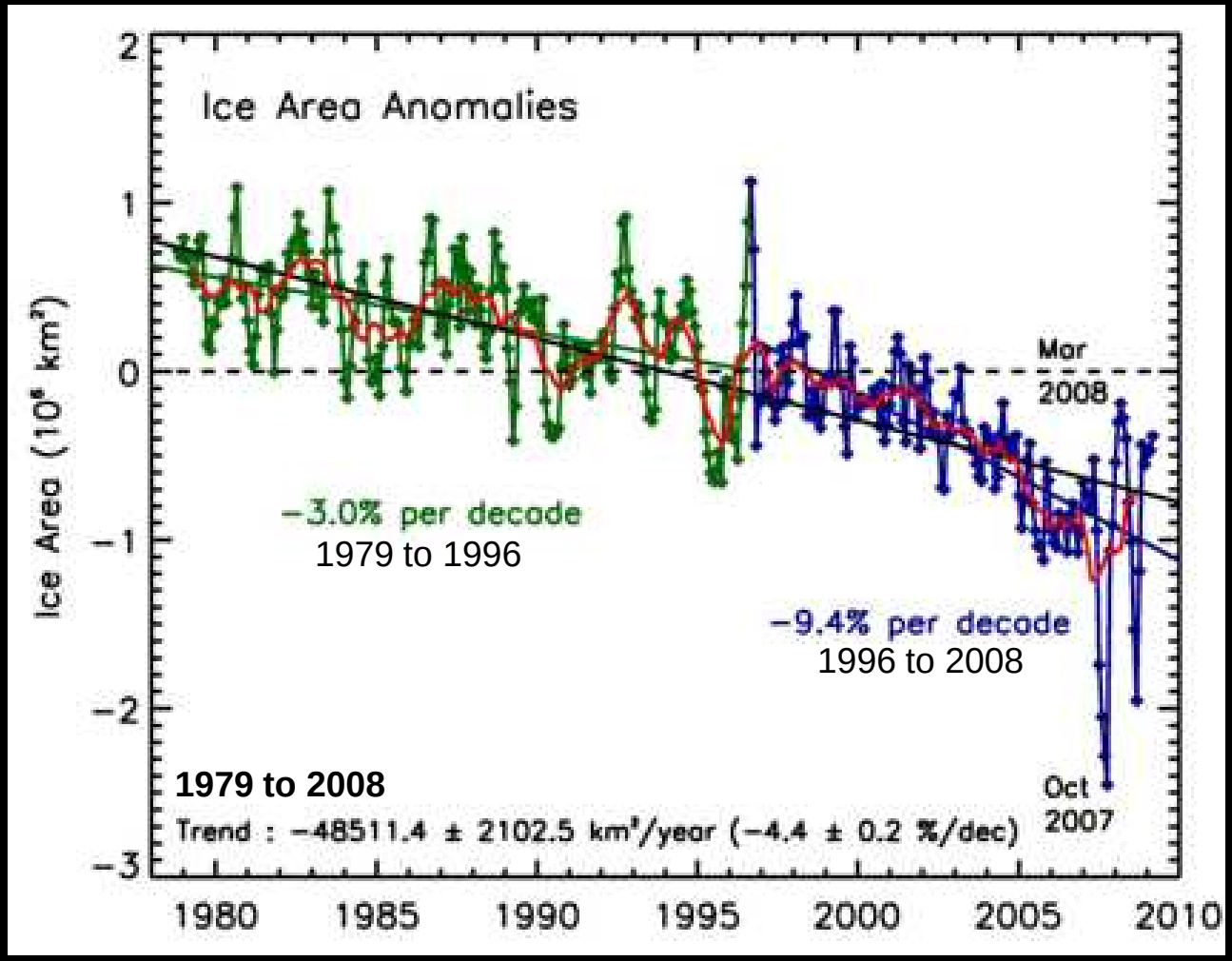
(extended from C. Parkinson, D. Cavalieri, P. Gloersen, J. Zwally, and J. Comiso, *J. Geophysical Research*, 1999 and from the update in Parkinson and Cavalieri 2008)

Yearly Arctic sea ice extent 1979 – 2007
SMMR & SSMI (working on AMSR)



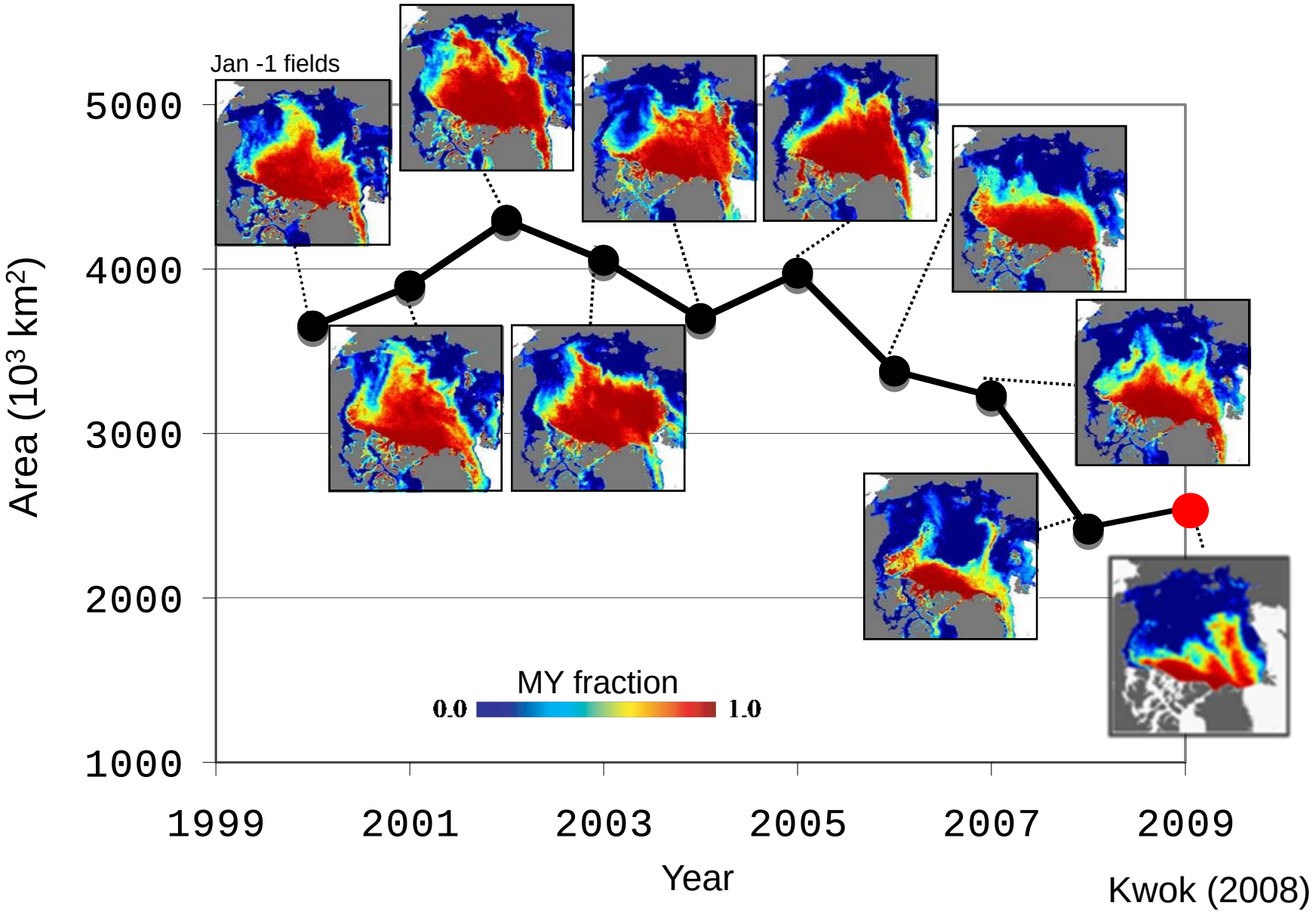
(extended from Parkinson et al. 1999 and Parkinson and Cavalieri 2008)

Accelerating trend in loss of total Arctic sea ice cover



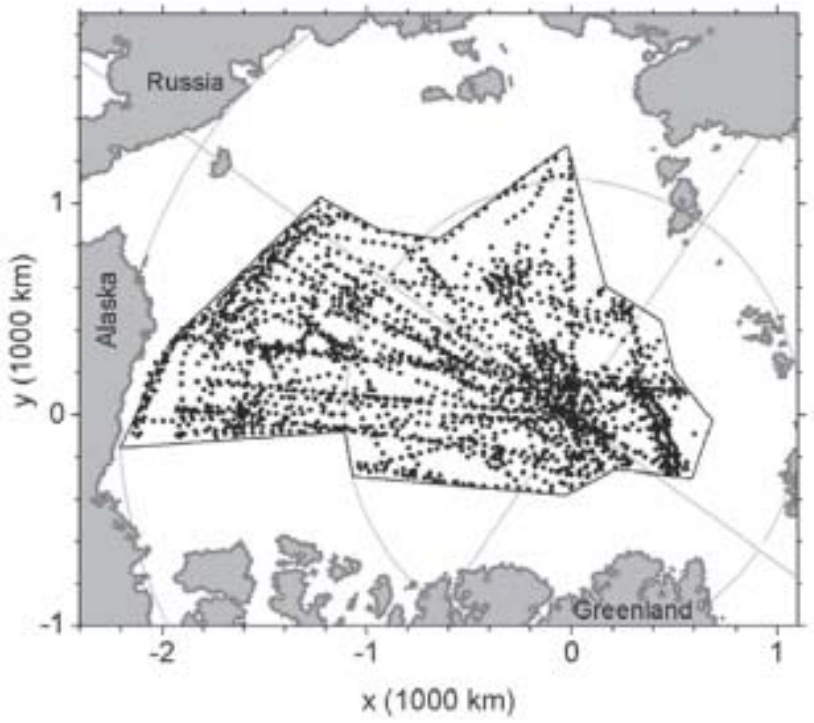
Comiso, J.C., C.L. Parkinson, R. Gersten, and L. Stock (2008), Accelerated decline in the Arctic sea ice cover, *Geophy. Res. Lett.* 35, L01703, doi:10.1029/2007GL031972.

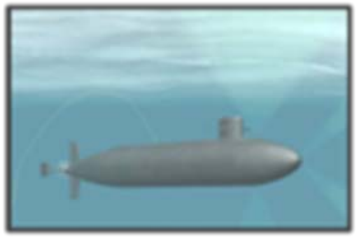
Decline in multiyear sea ice coverage from QuikSCAT



Quantifying ice thickness: New techniques using ICESat

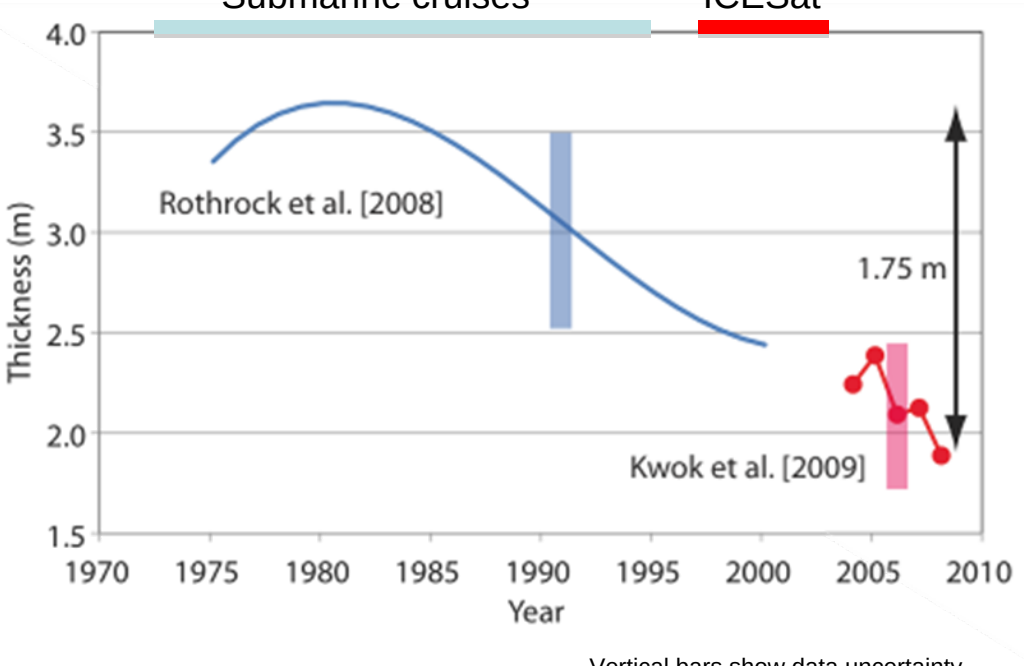
Submarine Data Release Area (DRA): 1975-2008





Submarine cruises

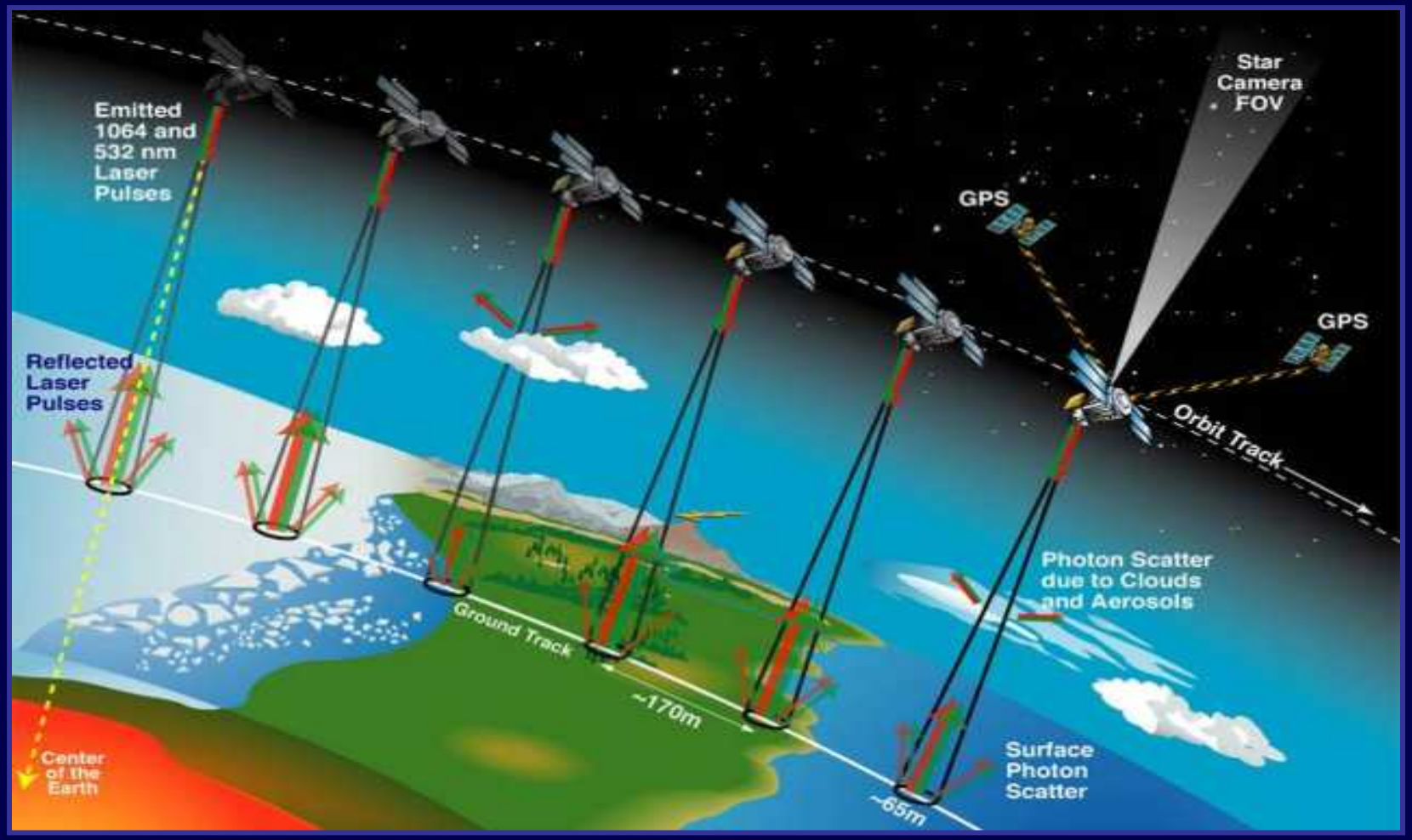
ICESat



Vertical bars show data uncertainty

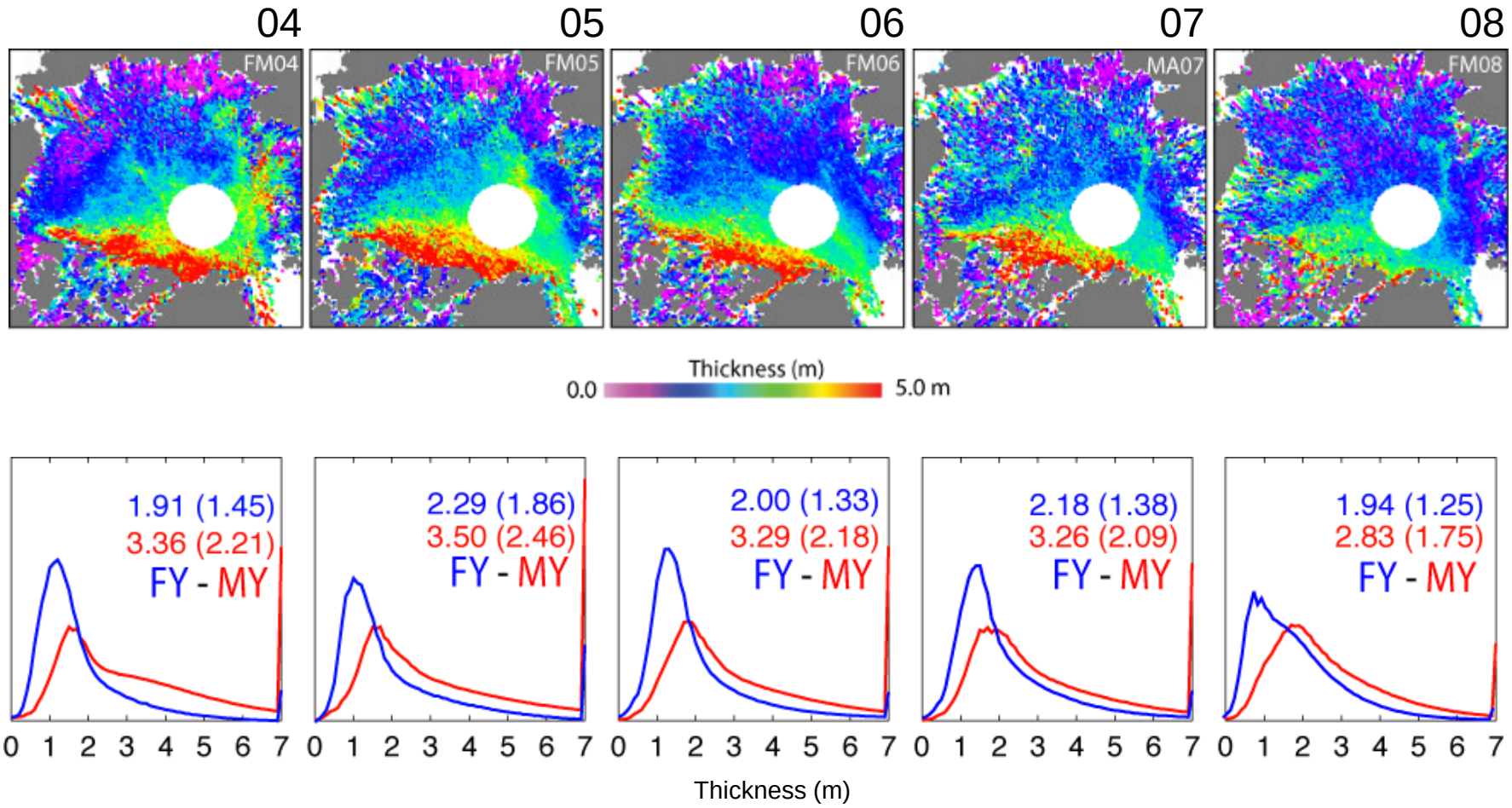
Kwok & Rothrock (2009)

Laser Altimetry from the Ice, Cloud, and Land Elevation Satellite (ICESat)

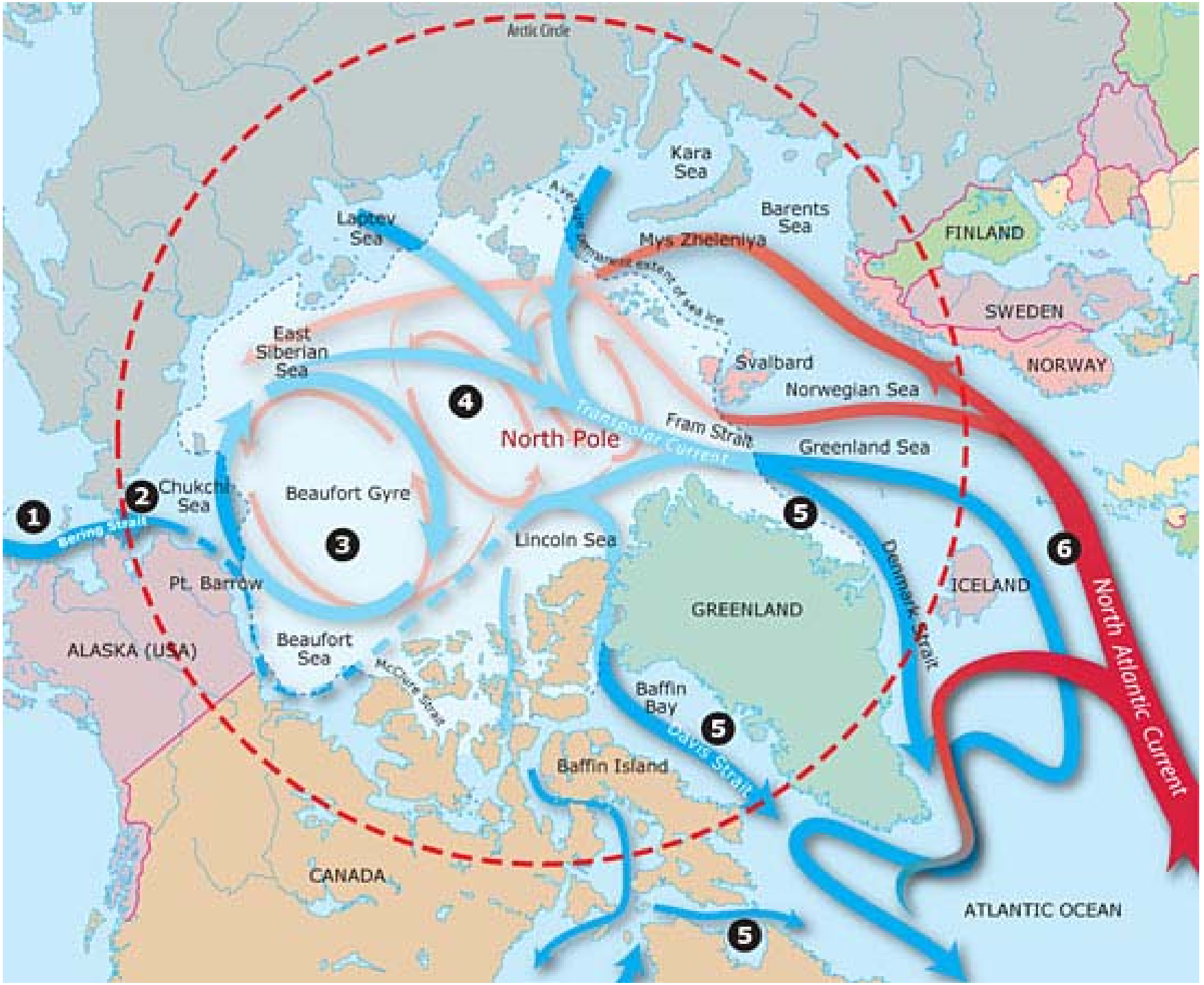


(schematic from the ICESat Science Team)

Winter sea Ice thickness from ICESat



(Kwok et al., 2009)


Arctic Circle
Kara Sea
Laptev Sea
Barents Sea
Mys Zhelaniya
FINLAND
SWEDEN
NORWAY
East Siberian Sea
Svalbard
Norwegian Sea
North Pole
Transpolar Current
Fram Strait
Greenland Sea
Chukchi Sea
Beaufort Gyre
Bering Strait
Lincoln Sea
Pt. Barrow
ICELAND
GREENLAND
Denmark Strait
North Atlantic Current
ALASKA (USA)
Beaufort Sea
McClure Strait
Baffin Bay
Davis Strait
Baffin Island
CANADA
ATLANTIC OCEAN
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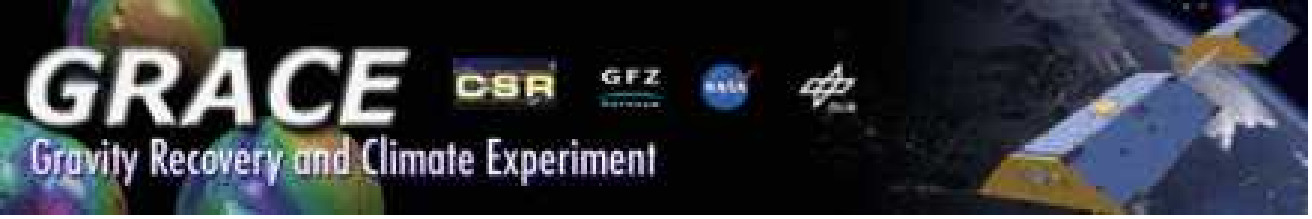
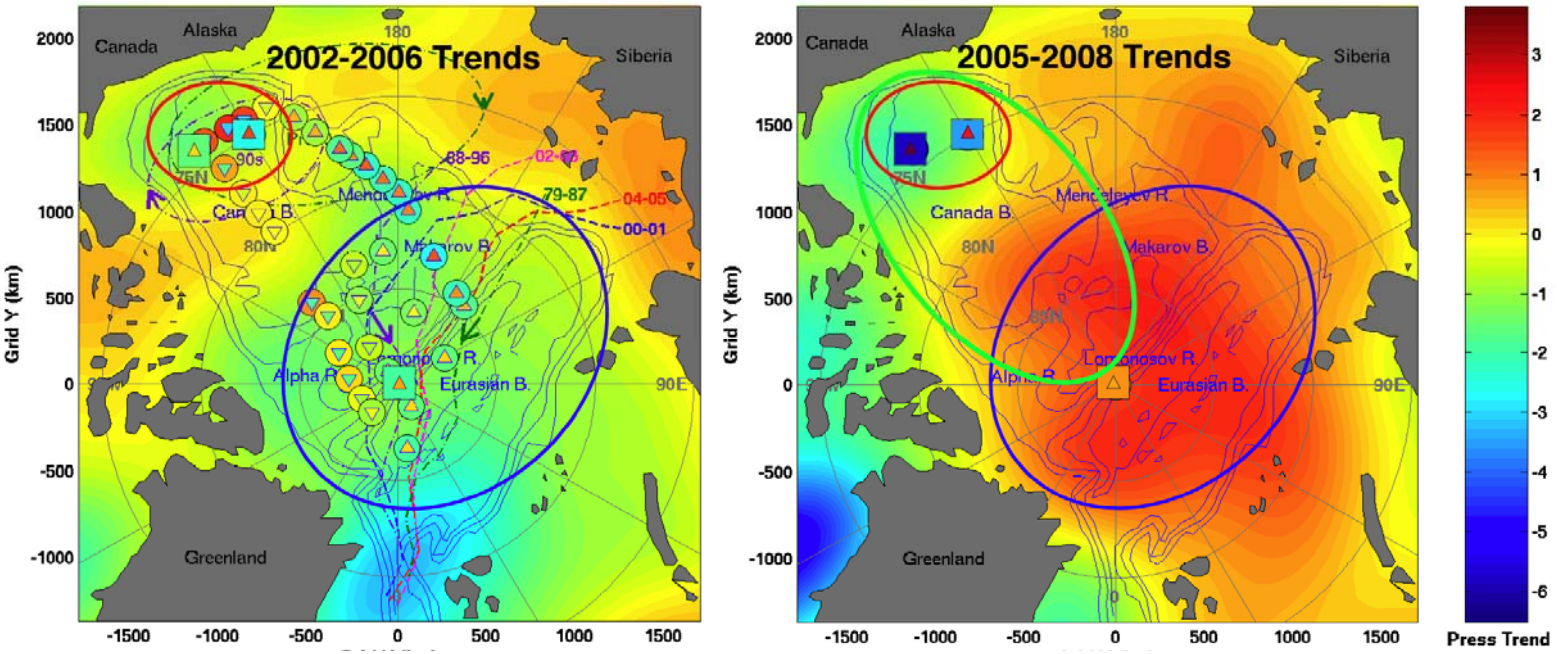




GRACE Release 4 bottom pressure trends, 2002-06 (left) and 2005-08 (right), in the Arctic Ocean. Colored circles (left) represent trends associated with a hypothesized return to climatology from conditions of the 1990s [from Morison et al., 2007]. Also shown are the steric trends from hydrographic observations (colored squares) and the sea surface height trends (colored triangles) calculated as the difference between the bottom and steric pressure trends. The declining bottom pressure trend, 2002-06, in the central Arctic (blue ellipse) illustrates the anticyclonic advance of relatively fresh (light) Pacific-derived water across the basin, and the rising trend, 2005-08, is associated with a cyclonic advance of salty Atlantic-derived water. Declining trends in bottom pressure in the Beaufort Sea (red ellipses) due to declining salinity persist throughout and in 2007-08 accelerated to produce a growing lens of low salinity surface water in the eastern Canada Basin (green ellipse). From Morison et al. [2007 & 2008].

GRACE Data and Bottom pressure trends 2002-06 and 2005-08

How have changes in the Arctic sea ice affected other properties and its stability?

Courtesy J. Maslanik

Physical properties that change with age and deformation:

- thickness
- total ice volume (ice contained in ridges, rubble fields)
- salinity/strength (resistance to ridging, significance for shipping)
- surface topography (with effects on wind drag, snow trapping and albedo during melt)

CASIE: Characterization of Arctic Sea Ice Experiment

July 2009

Objectives: Quantify relationships between thickness, roughness, age, and life history.

Location: Fram Strait and East Greenland Sea, with flights from Ny-Alesund, Svalbard.

Platform: NASA's SIERRA; UAV with long-range, "low and slow" flight with substantial payload)

Instrumentation: LIDAR, synthetic aperture radar, digital cameras, spectrometers, skin temperature sensors, anti-icing instrumentation

New sea ice programs at NASA

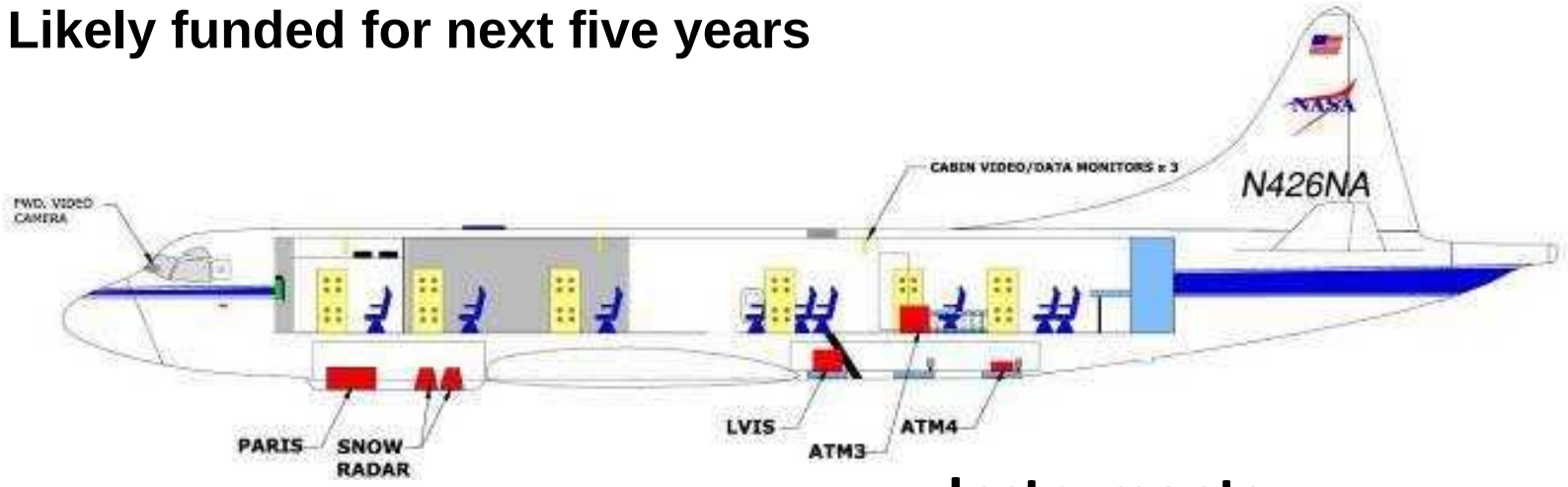
New suborbital mission: IceBridge

Objectives

- **Bridge gap between current ICESat and next LIDAR mission**
- **Likely funded for next five years**

Aircraft

P-3, DC-8, UAVs?



Instruments

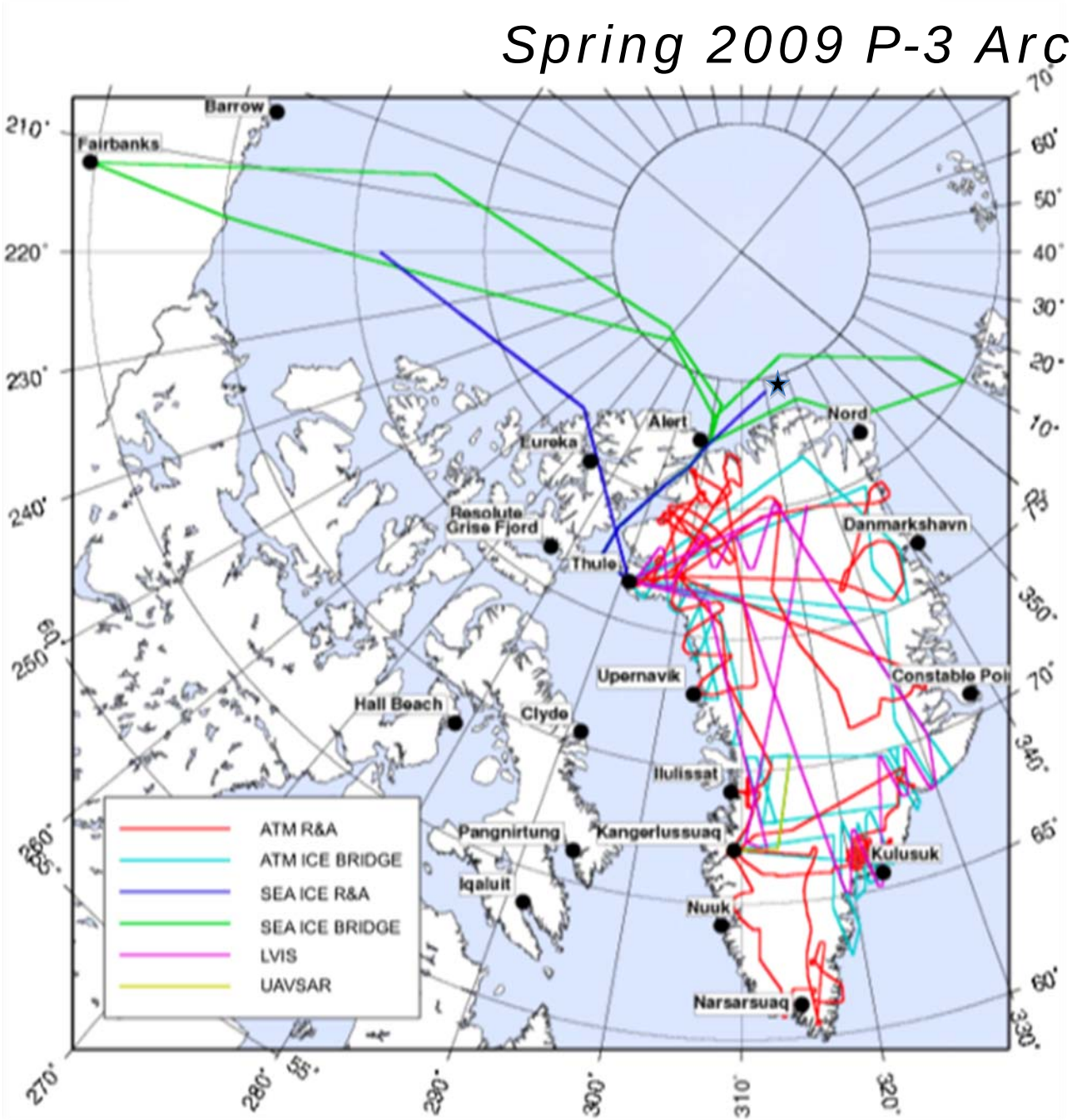
ATM : Airborne Topographic Mapper

PARIS: Pathfinder Airborne Radar Ice Sounder

LVIS: Laser Vegetation Imaging Sensor

KU Snow Radar: Snow depth radar

Spring 2009 P-3 Arctic Flight Lines



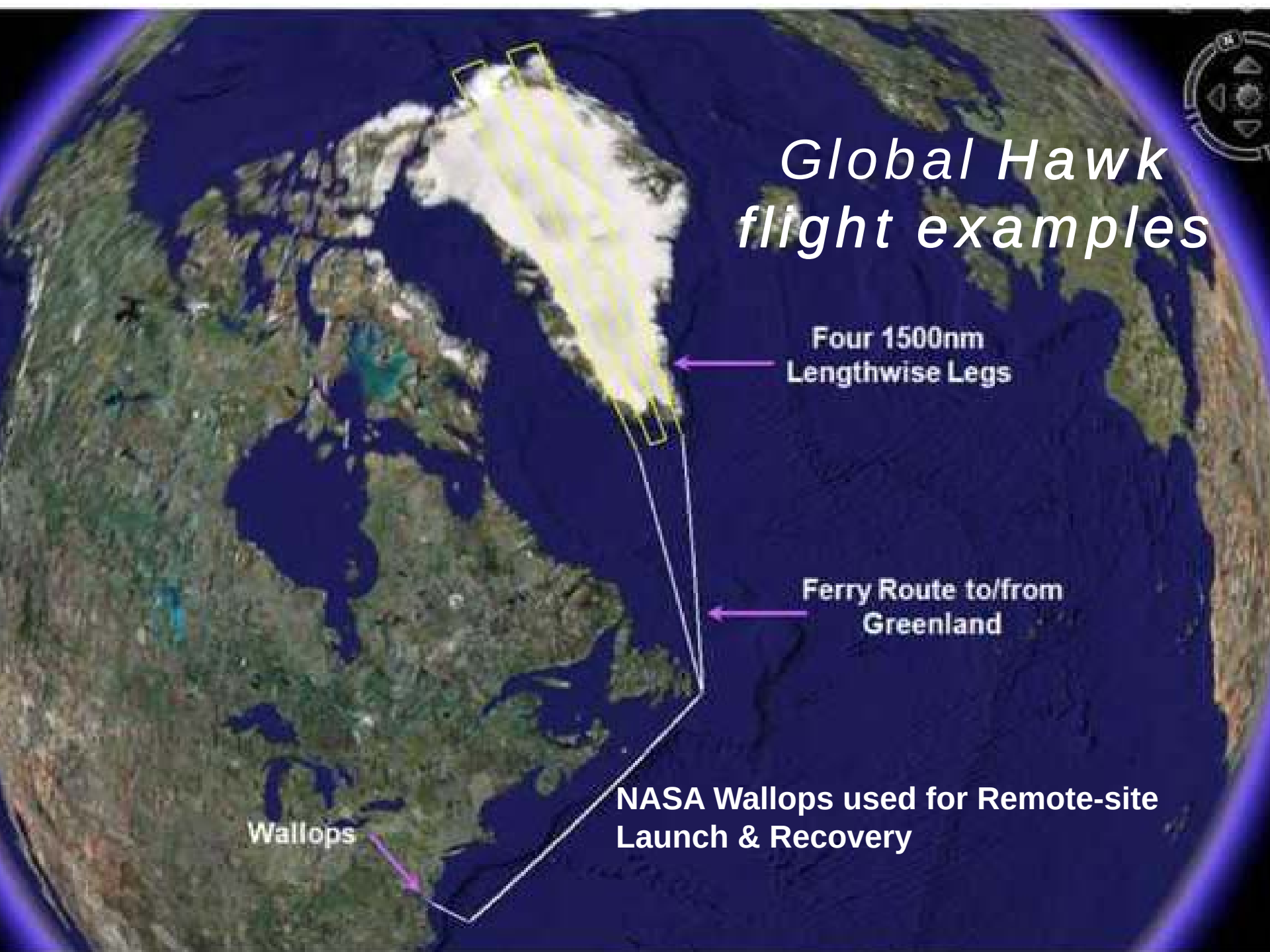
- Green coincident with ICESat
- Blue coincident with ENVISAT
- Final line over the Danish camp (blue star)

ICESat-2
LIDAR mission
Launch in 2015?
Sea ice freeboard

DESDynI
InSAR radar and LIDAR mission
Launch in 2019?
Sea ice motion and freeboard

NASA Global Hawk

- 20+ hr flight times
- Multiple instrument pods
- Fantastic tool for polar work


Global Hawk
flight examples
Four 1500nm
Lengthwise Legs
Ferry Route to/from
Greenland
Wallops
NASA Wallops used for Remote-site
Launch & Recovery

NASA Arctic field program: Ecologic impacts of shrinking ice

Research cruise in 2010/2011 to Beaufort and Chukchi seas

Goal: Correlate field observations with remote sensing to understand ocean productivity

- Field work, data synthesis, and modeling
- Details ROSES 2009 - http://nspires.nasaprs.com/

Supported by NASA's Ocean Biology & Biogeochemistry and Cryospheric Sciences programs

SeaRISE

Sea-level Response to Ice Sheet Evolution

- Community-wide effort to inform IPCC-AR5 of reasonable ice sheet contributions to sea level
- Goal is quantitative estimates for the 21st century that consider dynamic ice movement and the question: How bad could it get?
  - Identify upper bound and work toward increasing likelihood
  - Remove all Antarctic ice shelves
  - Activate retreat/thinning of all Greenland outlet glaciers
- Complements Ice2Sea (EU effort)
- Led by NASA Goddard (Bindschadler)
- *Do we need a similar effort for Arctic sea ice?*

Getting results out

- Scientific papers
- Sea ice atlas (Goddard)
- Daily MODIS mosaic of Arctic
  - http://rapidfire.sci.gsfc.nasa.gov/
- NSIDC: NASA DAAC/On-line sea ice report for general public

But who is using these resources?

Please don't hesitate to contact me with ideas and collaborations

Final points consider:

- **Permafrost--will it go with the sea ice?**
- **Encouraging next generation of scientists**

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How Has Sea Ice Changed, and What Does This Imply for the Future?

Questions:

1). How has the fundamental nature of the Arctic sea ice (not just ice extent) changed in recent years?

2). Why has the sea ice loss occurred faster than predicted?

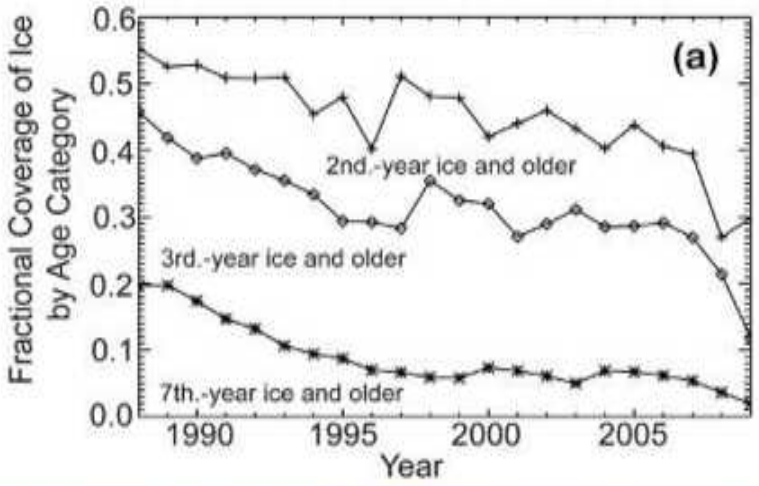
3). Can the Arctic ice cover stabilize and recover, or has a tipping point truly been reached?

3). Why have ice models underestimated the rate of ice loss? Are there basic aspects of the ice cover that climate models are not treating sufficiently?

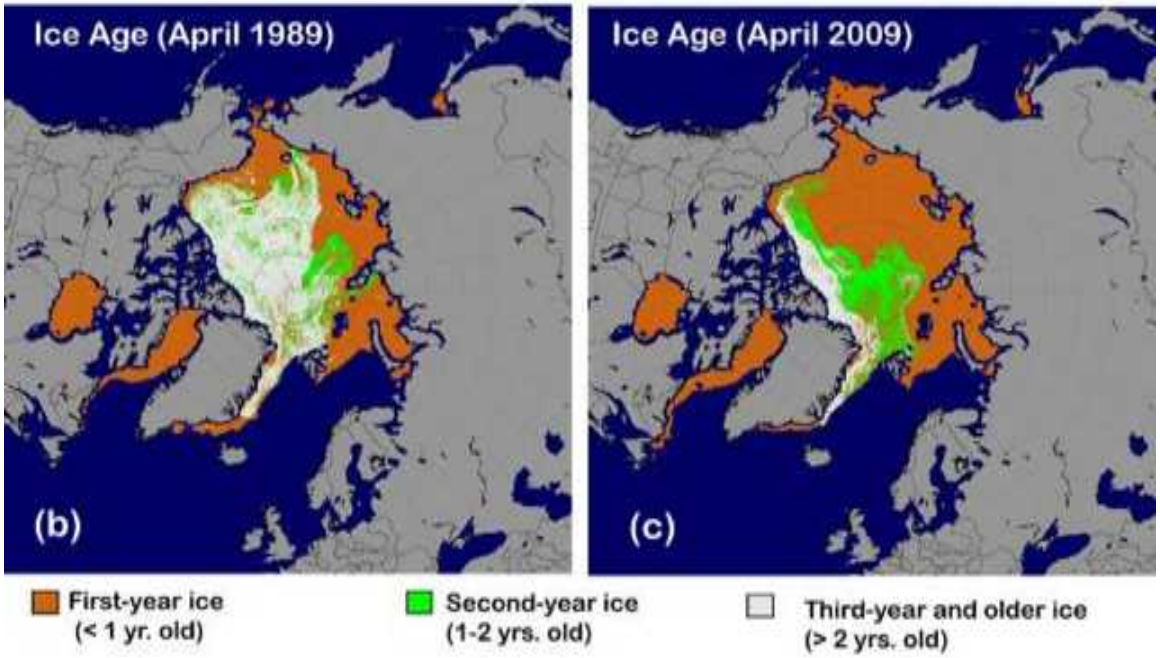
Problems: Insufficient knowledge about how the ice has changed, in terms of ice ridging, volume, and physical properties. Treatments in models are based on pre-1990s ice conditions.

Approach: Exploit satellite data sets to extract sea ice information that provides new insights into ice age, thickness, and roughness; key factors in assessing ice volume and the survivability of the ice cover.

Ice Age Data Estimated from Satellite-Derived Ice Motion Show Rapid and Extreme Loss of the Oldest Ice



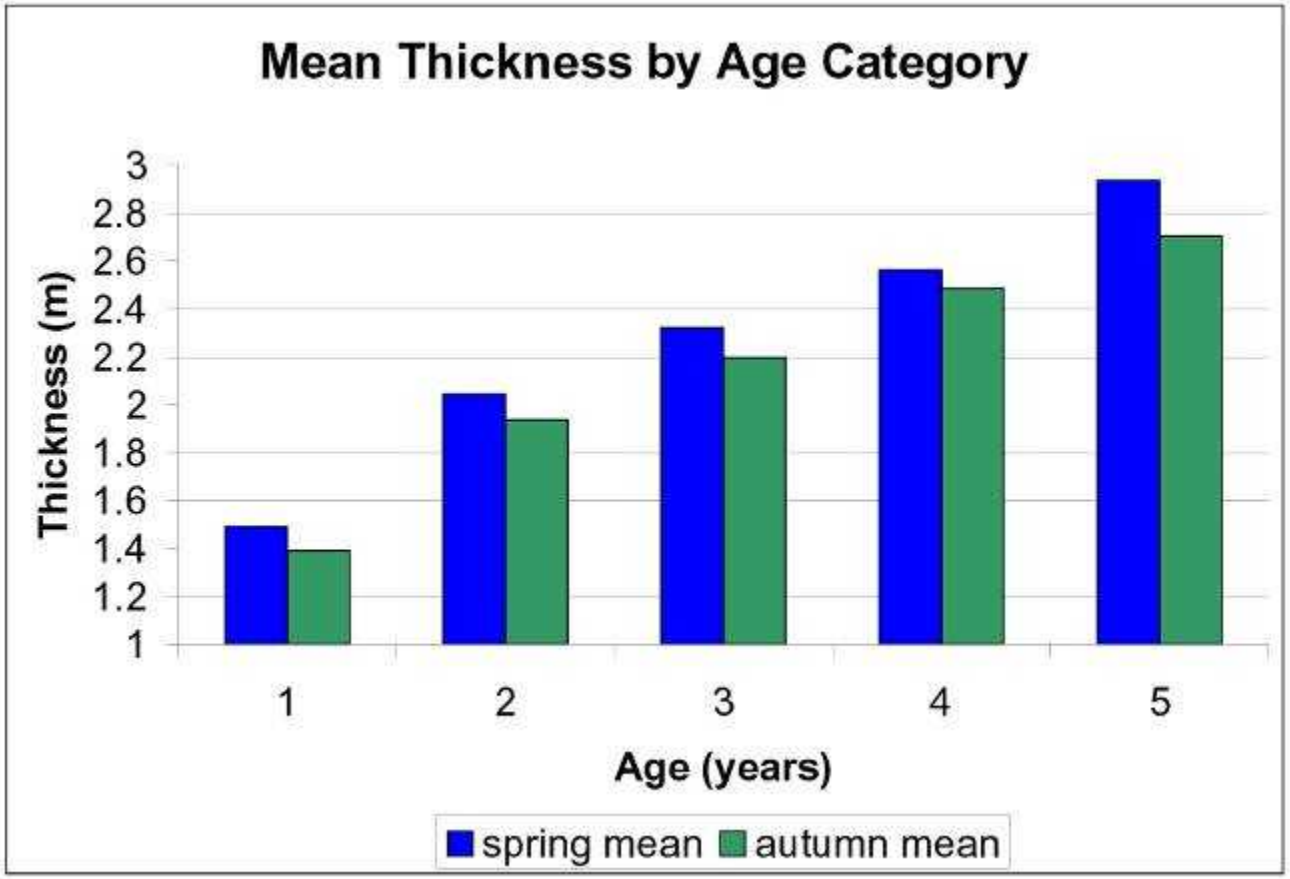
Approach uses NASA data sets to track ice movement and to estimate how many melt seasons the ice has survived.



Most of the Arctic is now first-year ice. Older ice types have declined by 74% since 1988.

Areas in orange are areas that were ice-free in summer.

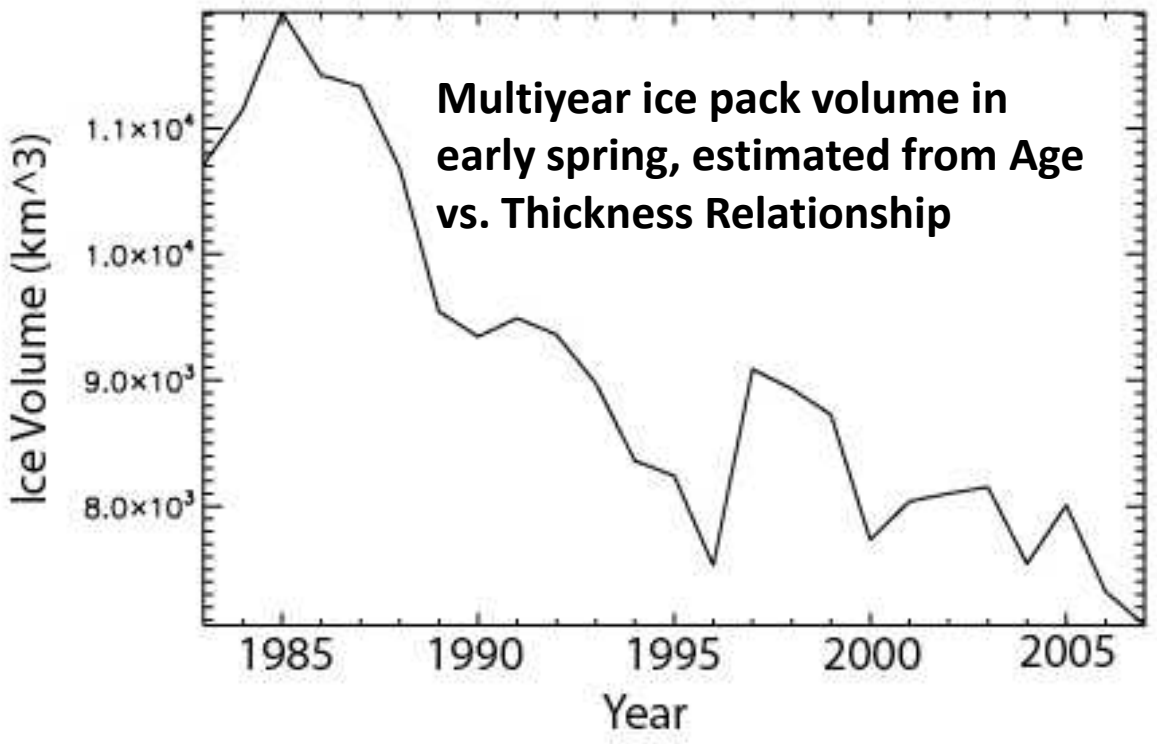
Can Age Data be a Proxy for Ice Thickness? Merging Ice Age with ICESat Ice Thickness Allows Us to Estimate Thickness as a Function of Age



- Thickness increases nearly linearly with age within the multiyear ice pack
- Ice age therefore can as a proxy for ice thickness

Means averaged over thickness/age for 2003-2006

Age-Derived Thicknesses Can Then Provide a 26-Year Estimate of Ice Volume Loss Due to the Transition to Younger Ice



<u>Suggests a 41% total loss in ice volume within the multiyear pack from 1985-2007 due to transition to younger ice types.</u>

CASIE Study Area