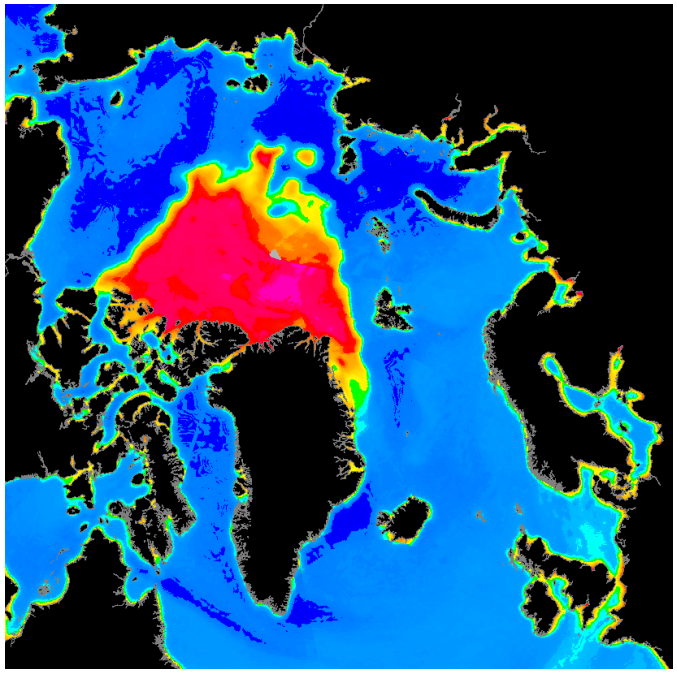
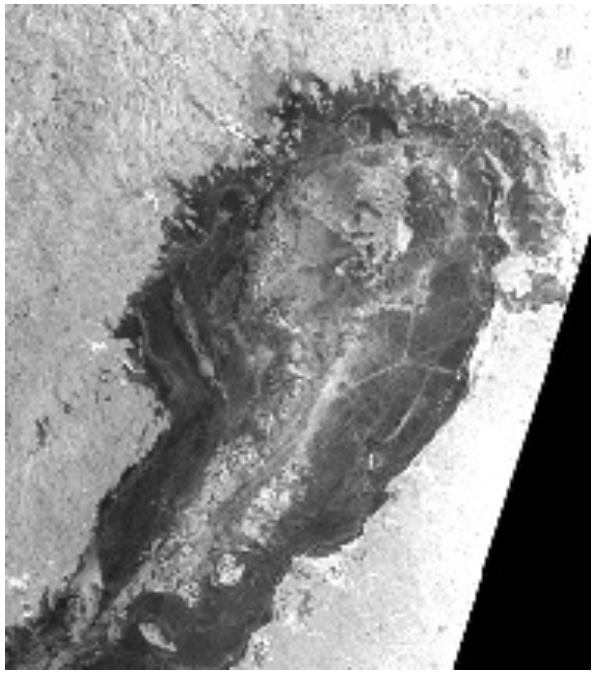
Sea Ice of the Arctic and Antarctic: How Remote Sensing Specialists See It

Wolfgang Dierking

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

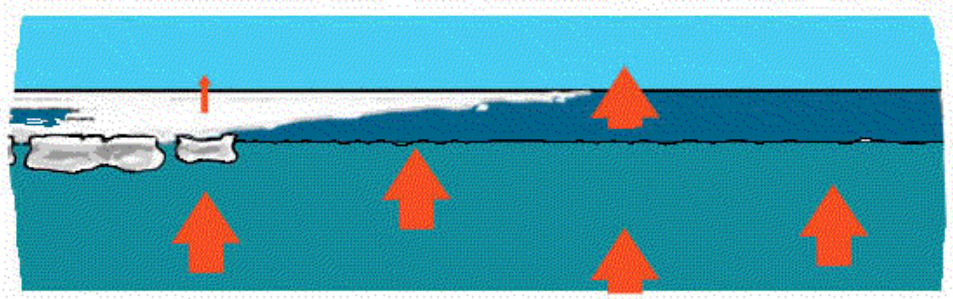


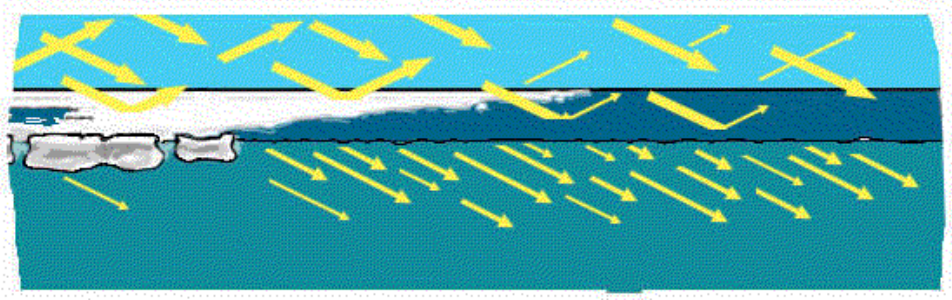


December 2014

Why are we interested in sea ice?

- …regulates exchanges of heat, moisture, momentum and matter between the ocean and the atmosphere
- …has a much higher reflectivity than the open ocean surface.
- …affects marine traffic and offshore operations, settlements, economy, biological habitats…





Ice properties can vary rapidly in response to weather and climate.

The New Zealand Herald

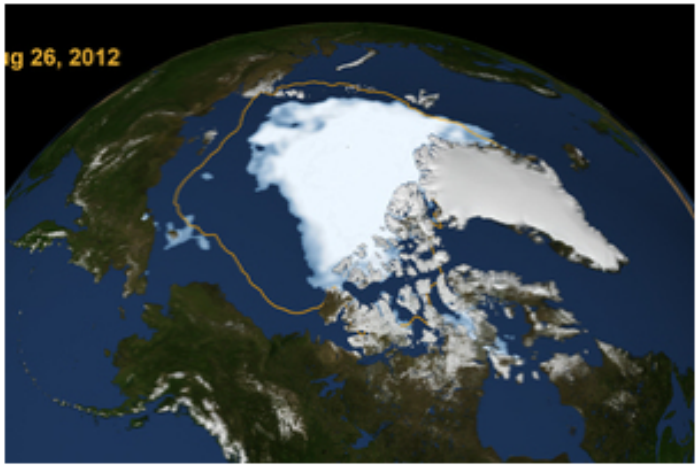
Record Arctic ice melt 'like a giant slushie'

11:52 AM Tuesday Aug 28, 2012

Arctic | Science

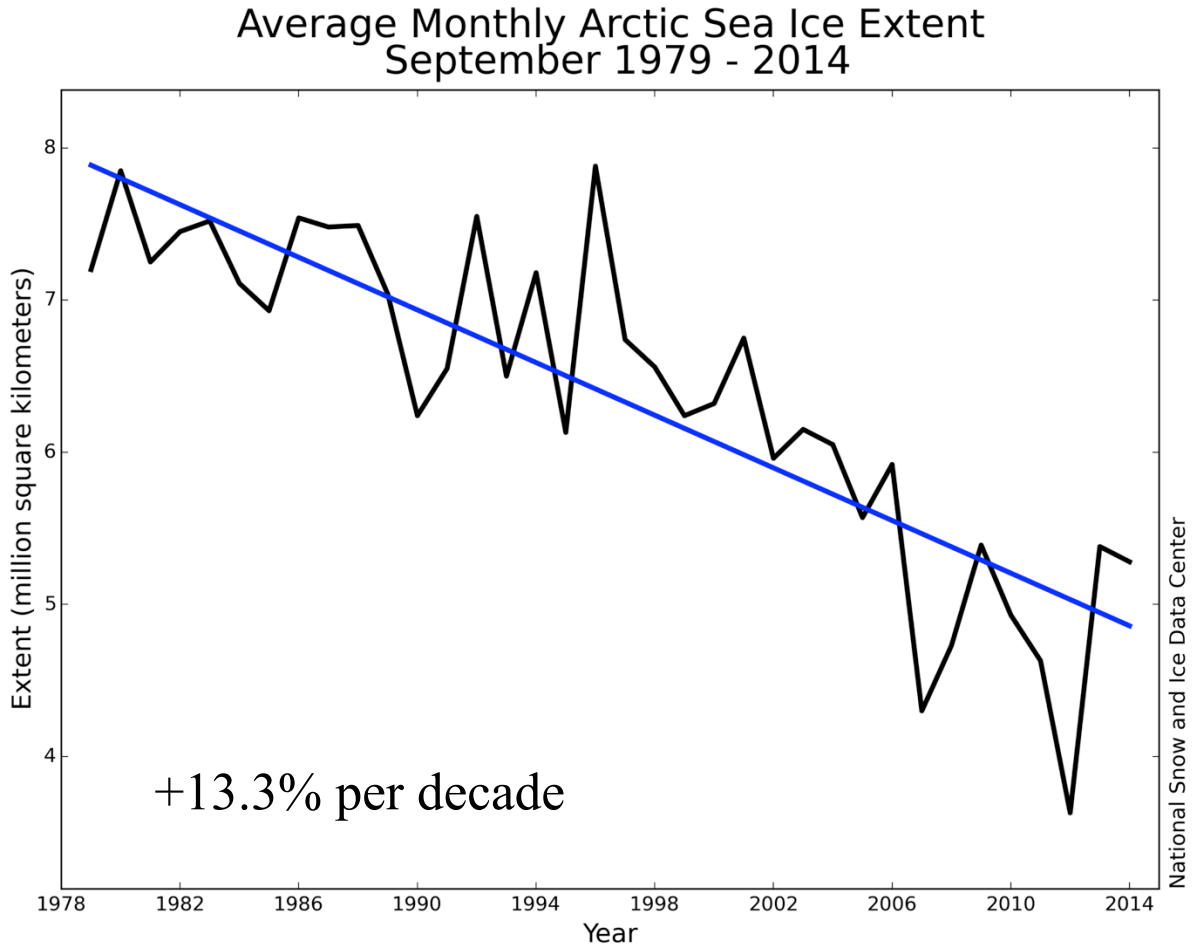
The sea ice in the Arctic Ocean has melted to its smallest point ever in a milestone that may show that worst-case forecasts on climate change are coming true, US scientists said today.

The extent of ice observed at the weekend broke a record set in 2007 and will likely melt further with several weeks of summer still to come, according to data from the National Snow and Ice Data Center and the Nasa space agency.



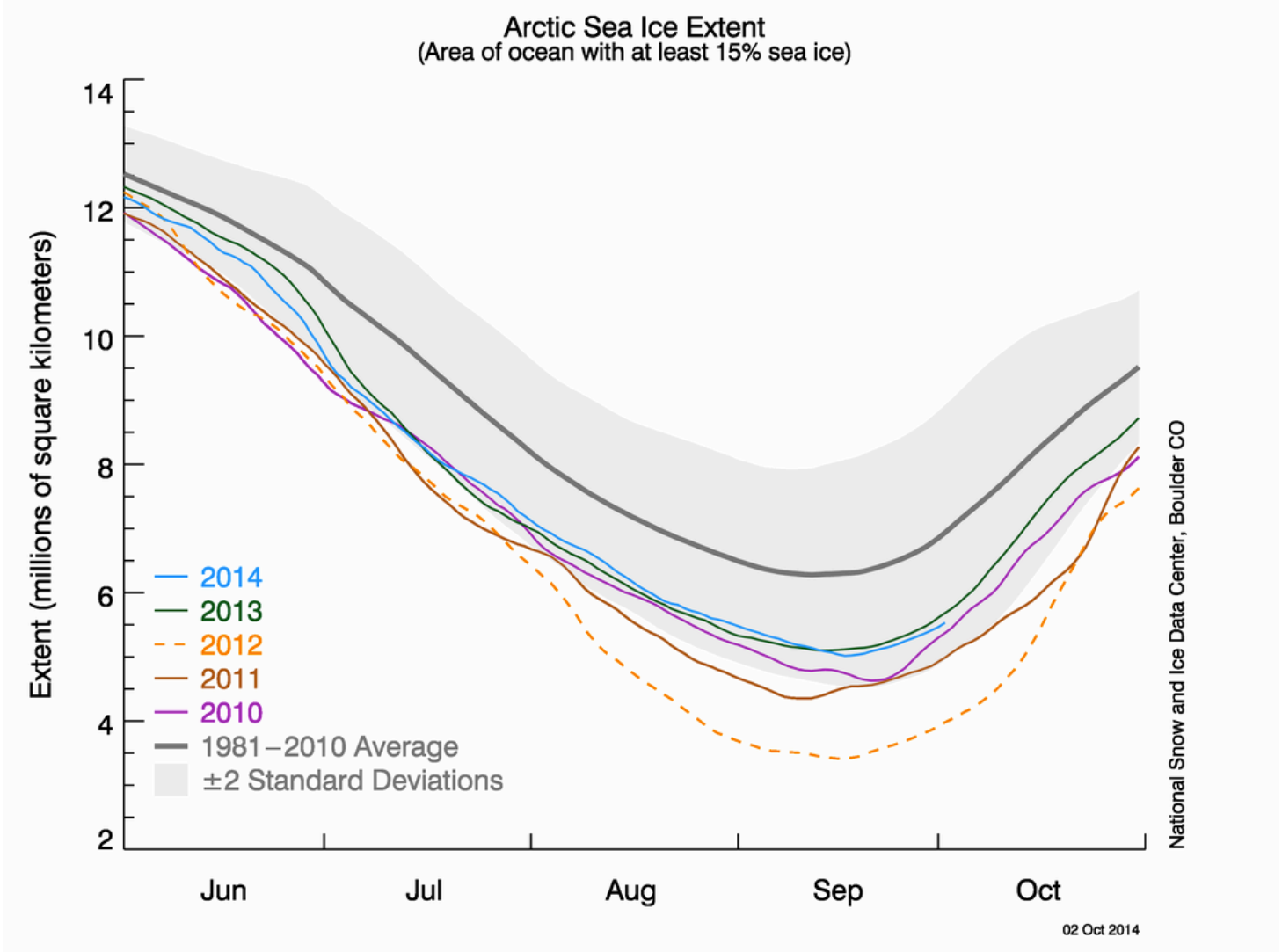
The extent of Arctic sea ice on Aug. 26, 2012, the day the sea ice dipped to its smallest extent ever recorded in more than three decades of satellite measurements. Photo / NASA

Decrease of Arctic Summer Sea Ice Extent



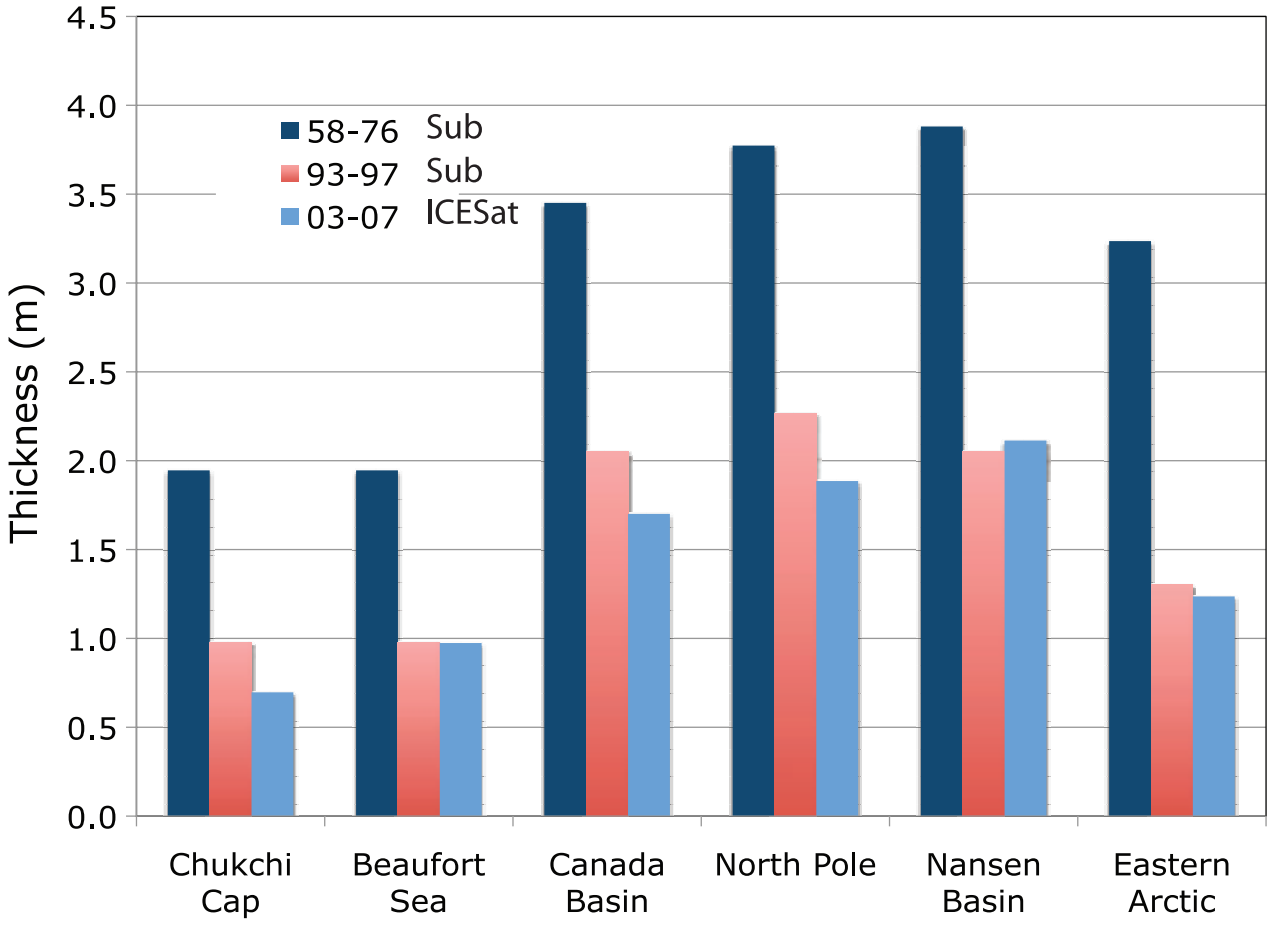
http://nsidc.org/

Arctic Sea Ice Seasonal Variations



http://nsidc.org/

Decrease of Arctic Sea Ice Thickness

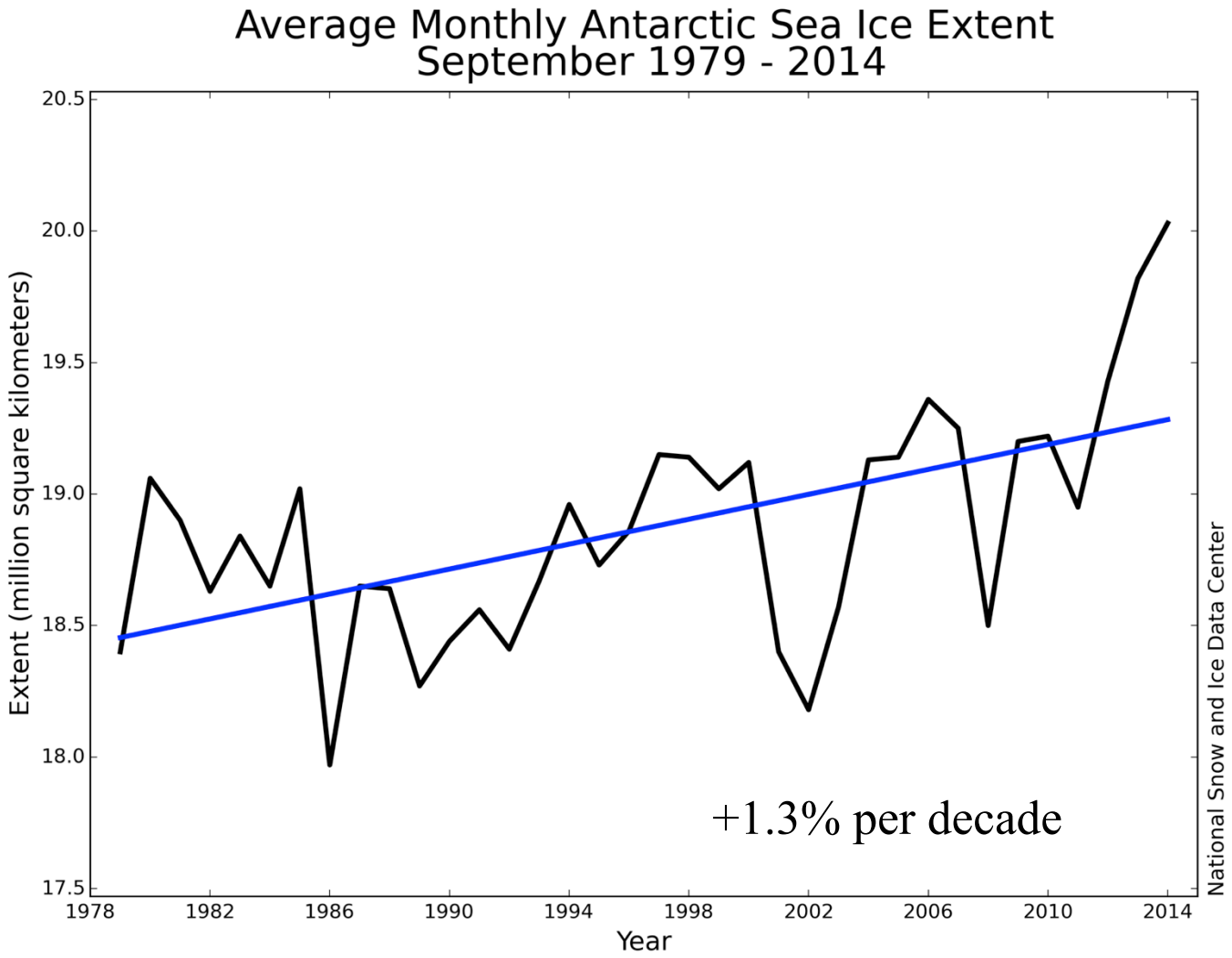


Source: Kwok&Rothrock, GRL, 2009

...and around Antarctica?

Reid, P., S. Stammerjohn, R. Massom, T. Scambos, and J. Lieser. 2015, in press. The record 2013 Southern Hemisphere sea-ice extent maximum. *Annals of Glaciology* 56 (69)

Increase of Antarctic Winter Sea Ice Extent



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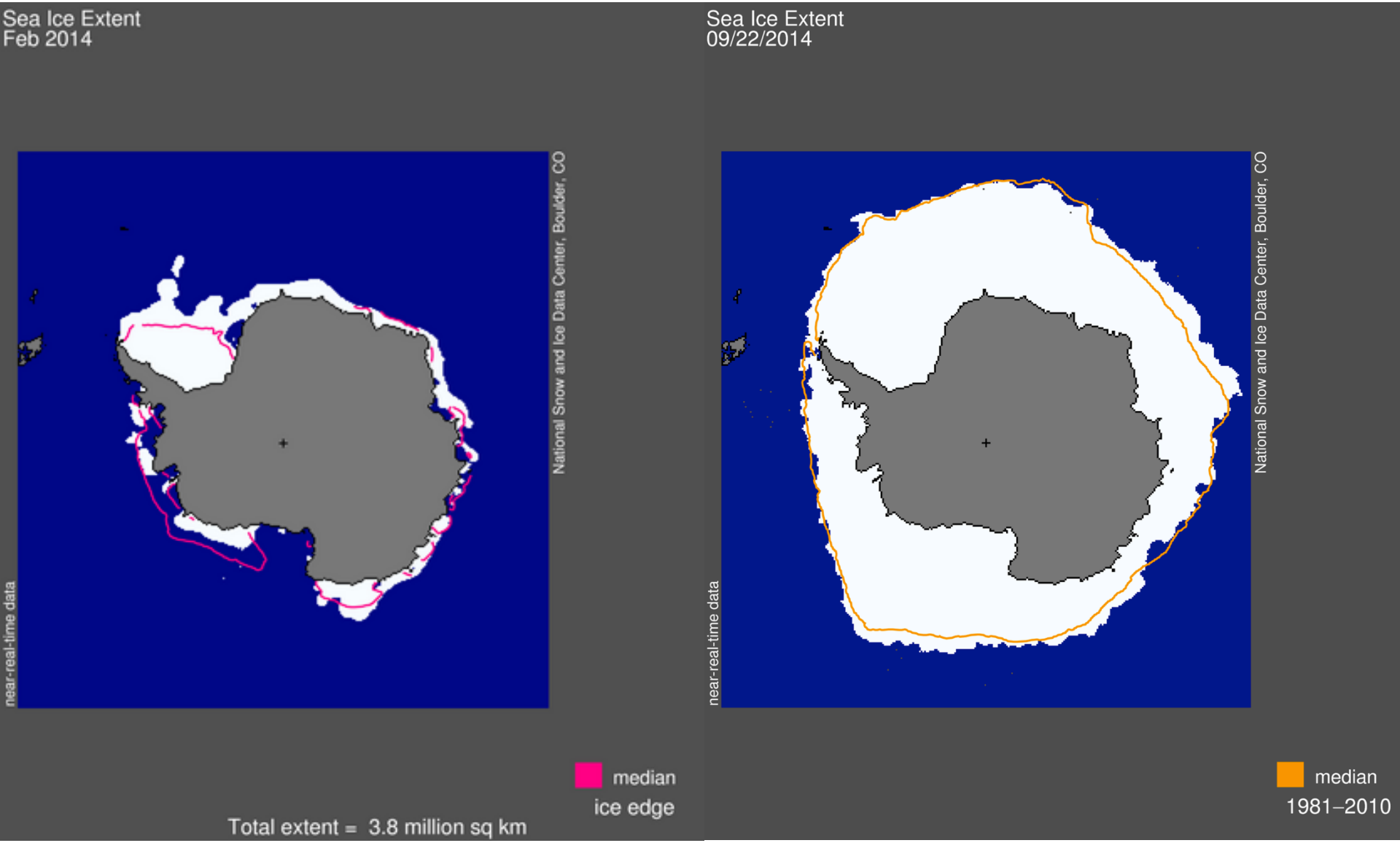
Antarctic: Sea Ice Extent Summer/Winter

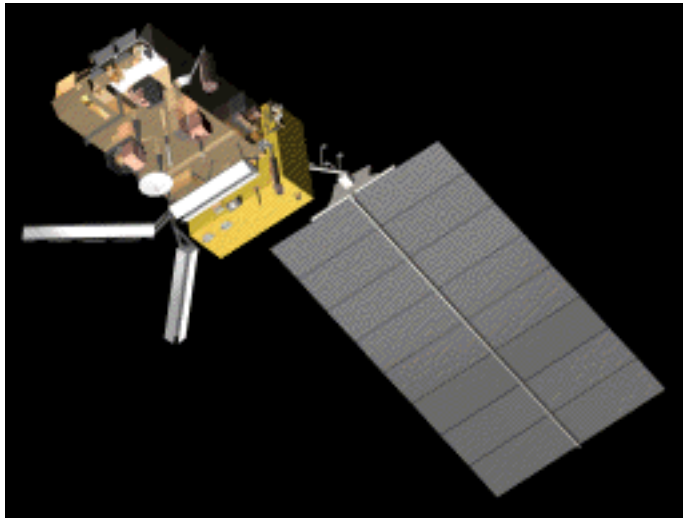


http://nsidc.org/

How did/do we get this information?

Satellite Sensors

Examples:



ASCAT on MetOP

SIRAL on Cryosat-2

TerraSAR-X

AMSR2 on GCOM-W1

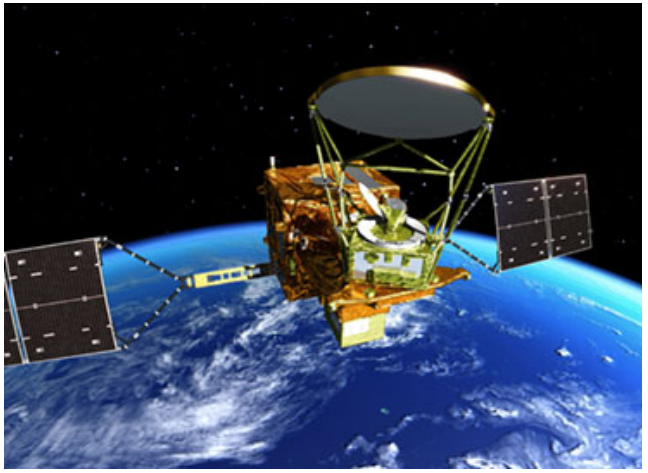
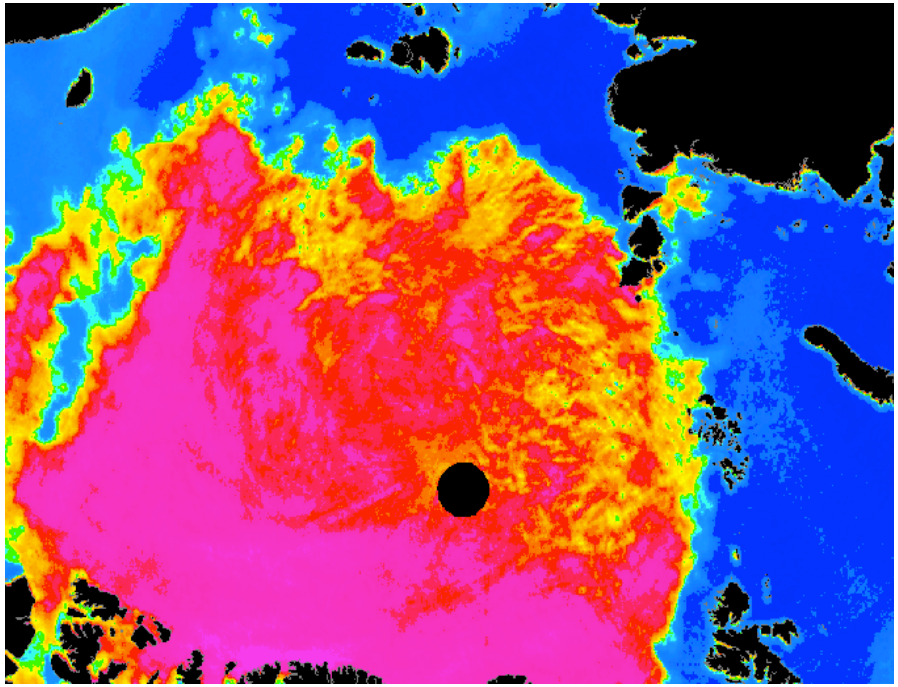
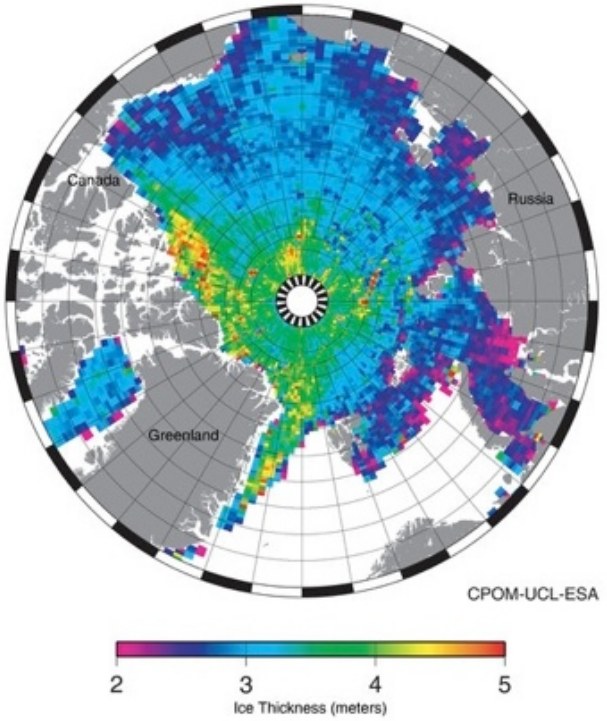


Image Products *Retrieved* From Satellite Data





sea ice extent, concentration

- **passive microwave radiometer**
- **(extent: scatterometer)**

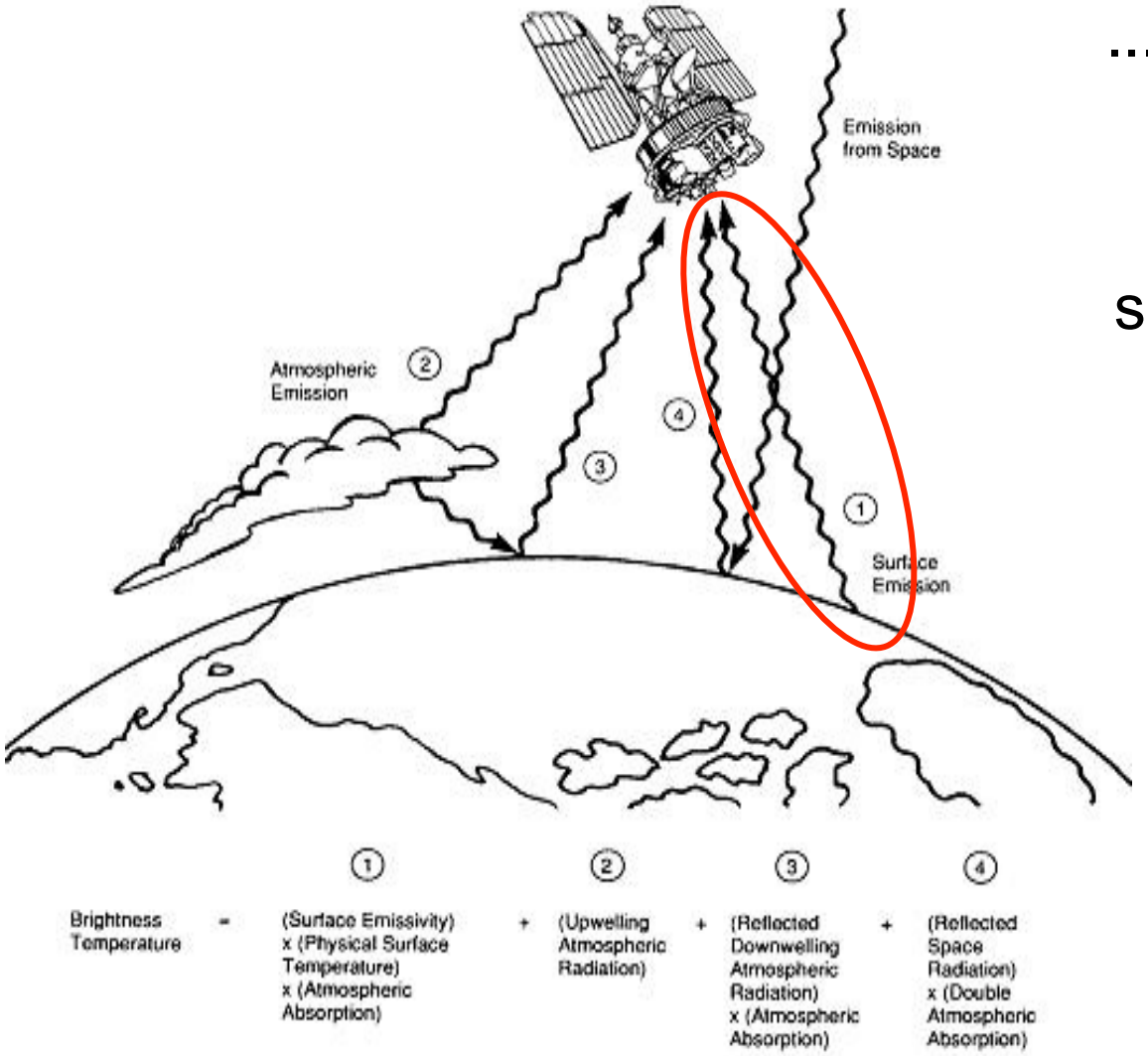
http://www.seaice.dk/N/

sea ice thickness

- **altimeter (≥ 1m)**
- **passive microwave radiometer**

http://spaceinimages.esa.int/Images/2011/06/Arctic_sea-ice_thickness

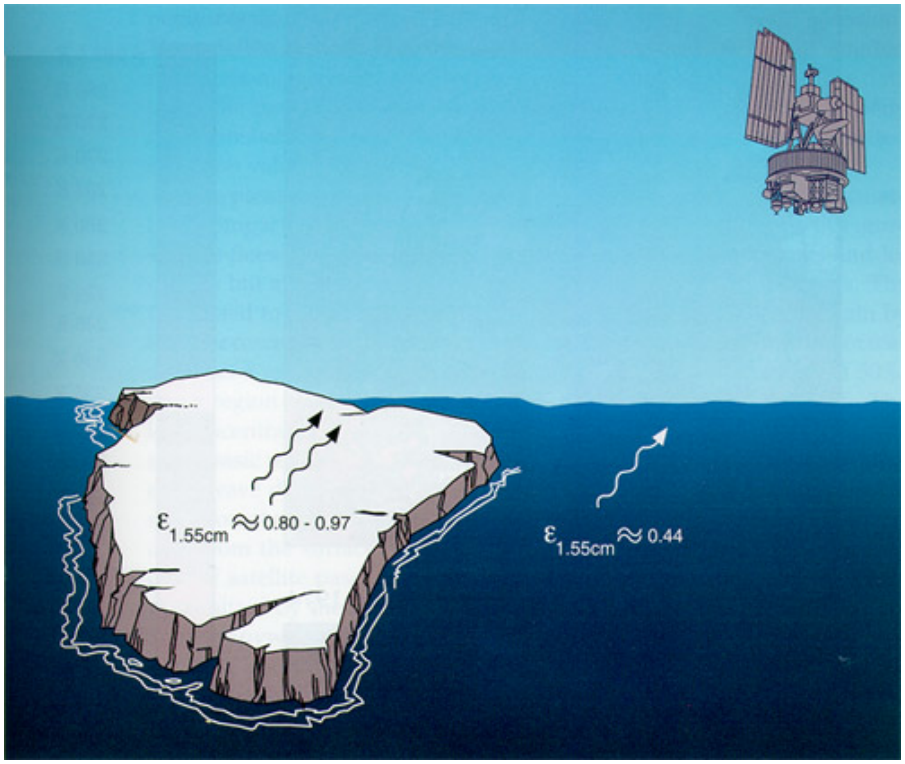
Passive Microwave Radiometer



Source: Carsey, 1992

... measures thermal radiation of the Earth ‘s surface in the range 1-100GHz

Passive Microwave Radiometer



emissivity – “relative ability” to emit energy by radiation

...ice concentration is *retrieved* using mixture formulas:

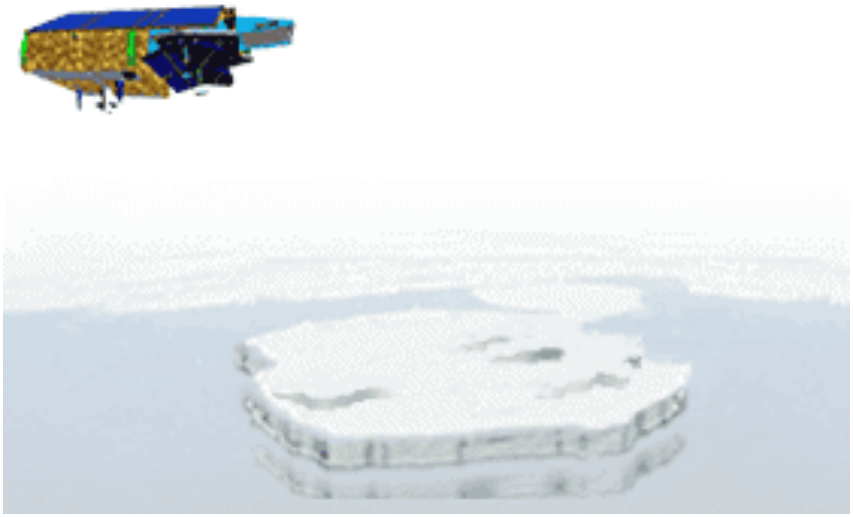
$T_B=(1-C)\varepsilon_w T_w+C\varepsilon_i T_i$

➔ *combination of different channels*

Problems:

- melting conditions
- unknown ice type composition
- unknown snow cover properties

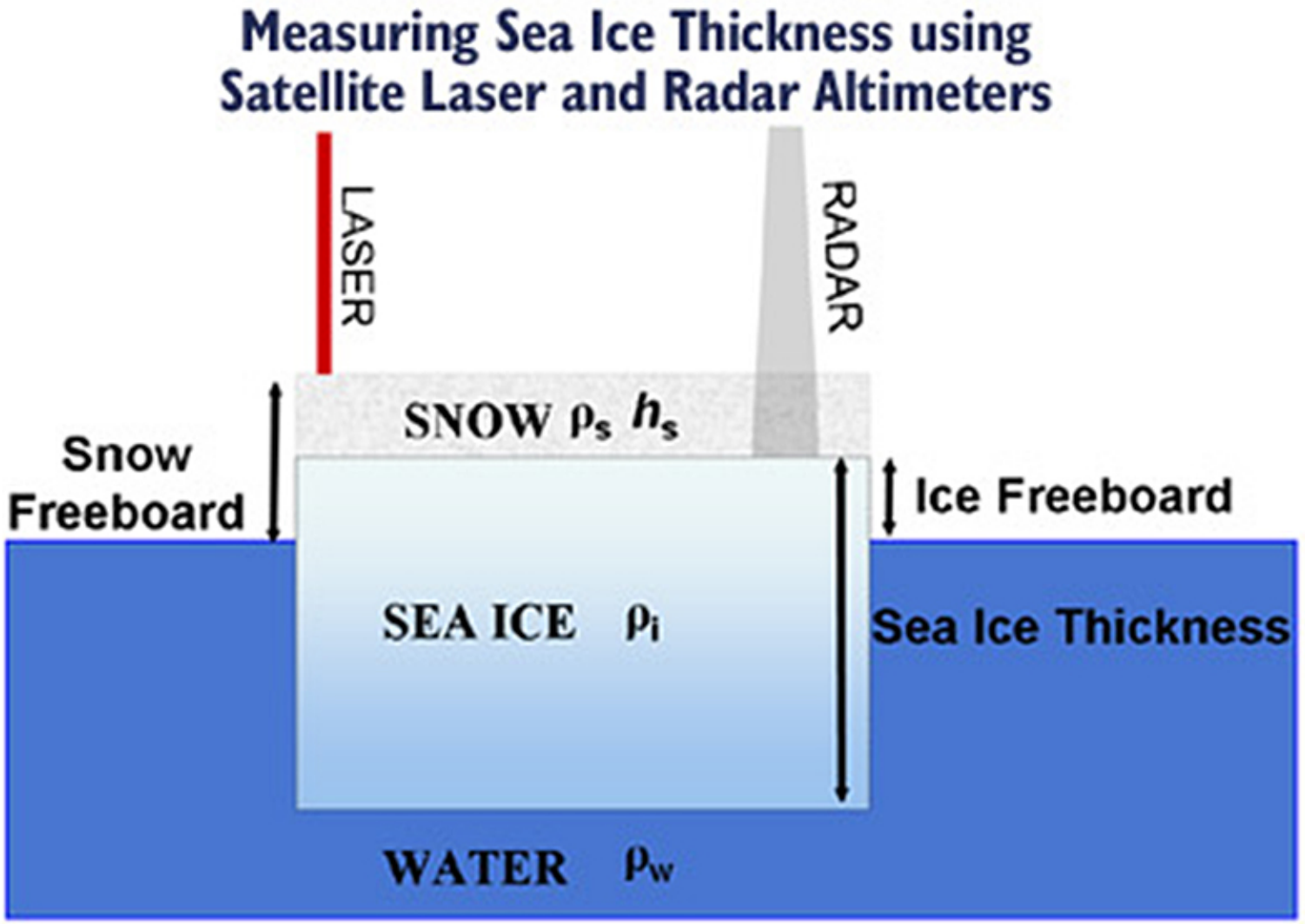
Altimeter (Laser, Radar)



Courtesy: AWI Cryosat Project Office

www.universetoday.com

	Cryosat-2	ICESAT
spatial resolution	250 m along track 1.5 km across track	170 m
accuracy	≈ 20-70 cm thickness	1-3 cm freeboard



www.star.nesdis.noaa.gov

Altimeter: *Retrieval* of Sea Ice Thickness

- separate radar echos : “FY- and MY-ice“ versus
  “open water and thin ice“
- freeboard: subtract travel times over water from travel times over ice
- conversion of freeboard into thickness
  (hydrostatic equilibrium, required: ice and water densities, snow mass)

Thickness t_E of ice with snow load of mass m_S per unit area:

$$t_E = \frac{\rho_W}{\rho_W - \rho_E} f_E + \frac{1}{\rho_W - \rho_E} m_S$$

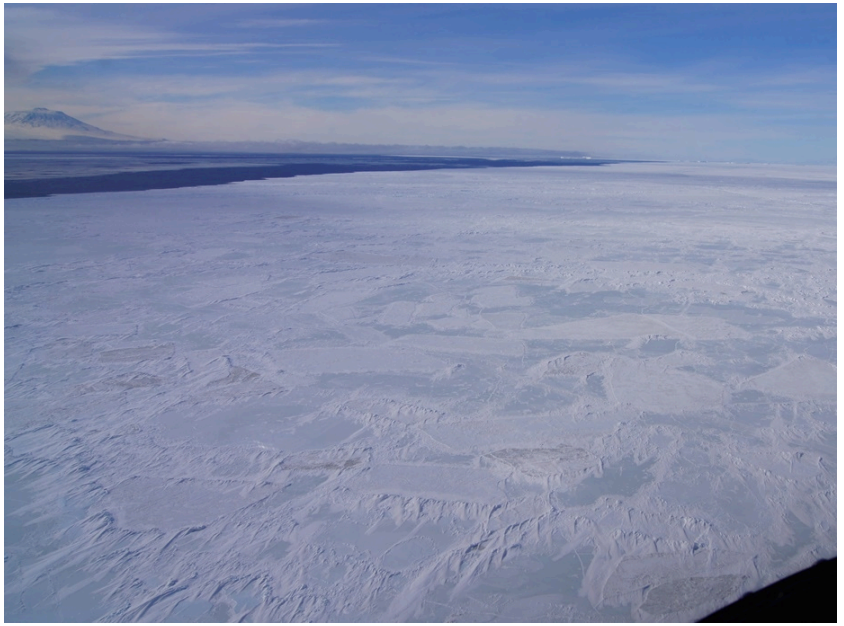
ρ_E, ρ_W - ice and water density

How strong are variations of the ice parameter (to be retrieved) reflected in the signal that is received by the satellite instrument?
(sensitivities…)

Which additional parameters (aside from the one of interest) do influence the measurements?
(meteorological conditions, snow and ice properties)

How accurate are the retrieval algorithms?

We Need to Measure On the Ice!!

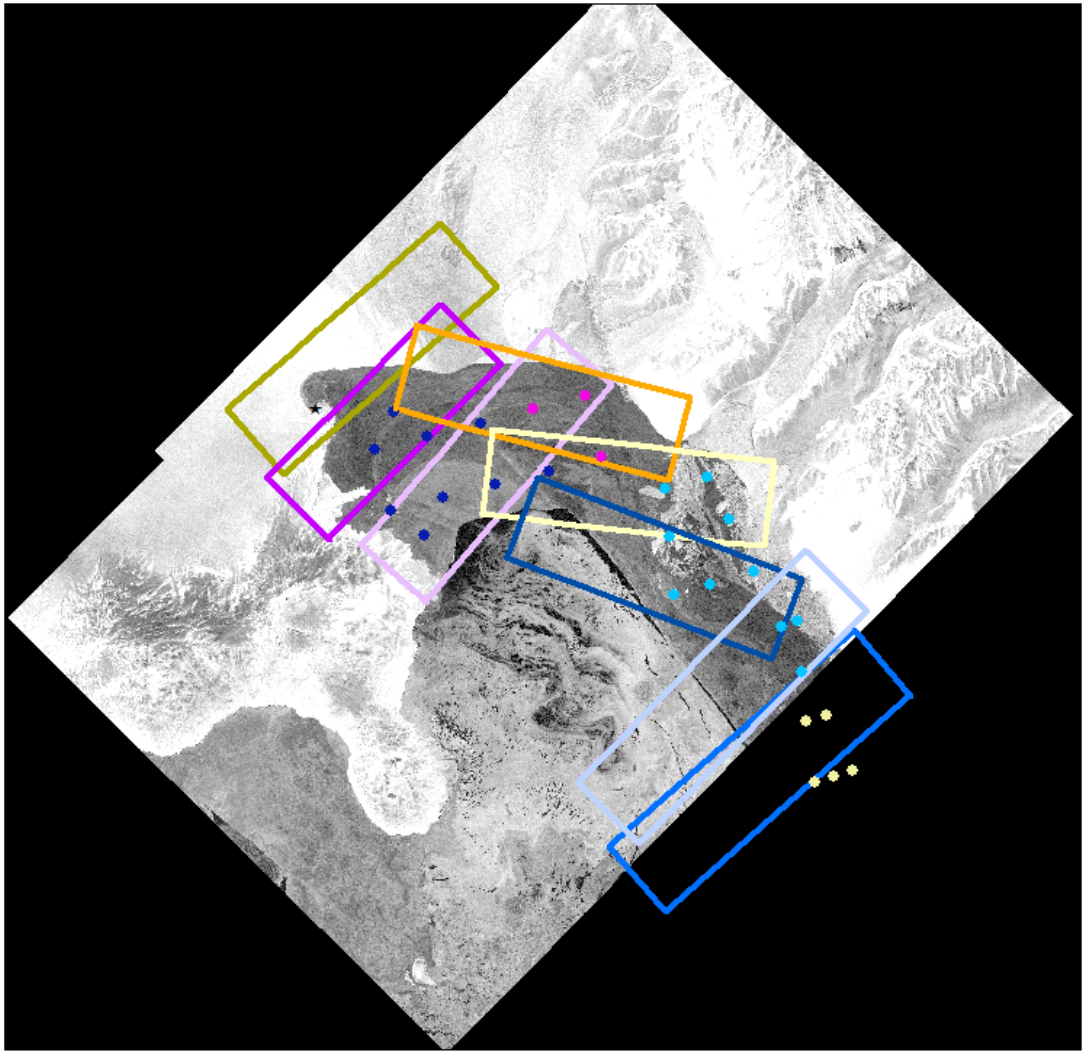


Field-Expedition 2013
(K063, W. Rack & co-workers)

Snow parameters determined:
- thickness
- density
- grain sizes
- stratigraphy
- hardness

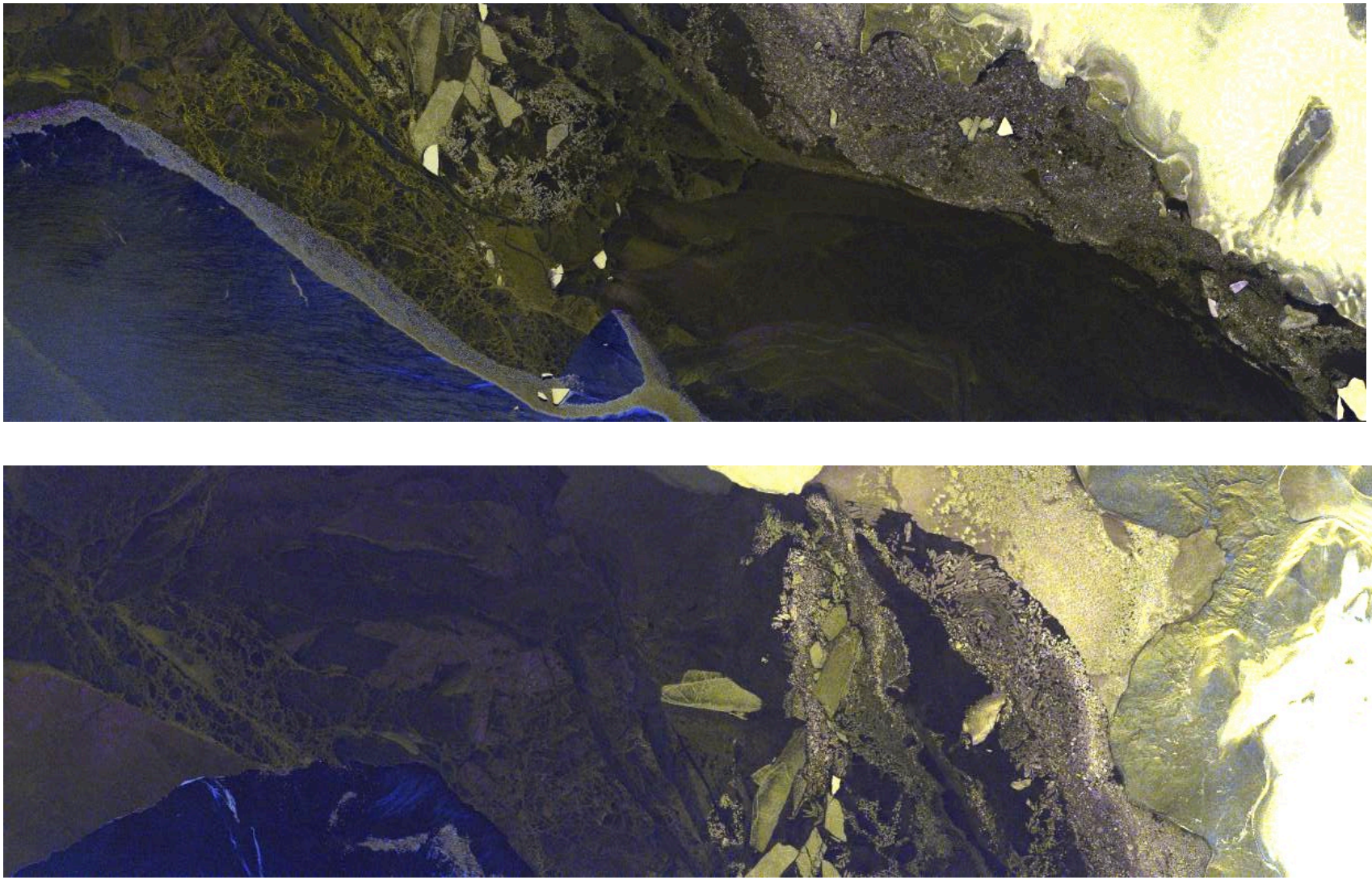
Photos: W. Rack, Gateway Antarctica

We Need The Regional View From Satellite!



Radar Image
TerraSAR-X (TSX)
ScanSAR Mode
100 km swath,
20 – 50 m resolution
Region:
McMurdo Sound / Ross Sea

... Sometimes at Even Higher Spatial Resolution



Color composites of TSX-images acquired at different polarizations
(stripmap-mode, swath width 15 km, resolution 5-20 m)

SNOWonICE

- Project funded by the New Zealand – Germany Science and Technology Programme
- Subject: Retrieving properties of sea ice snow cover from data of different satellite instruments
- Emphasis is on radar and optical sensors with high spatial resolution (25-100 m)


Be curious!
Thank you for your attention !