Climate and Cryosphere (CliC) Update

Walt Meier
NASA Goddard Space Flight Center

WDAC Meeting, Asheville, NC
7 April 2016

Thanks to Sophie Nowicki, Dirk Notz, Greg Flato and the rest of CliC SSG for their contributions

CliC Structure

Limited Lifetime Targeted Activities
(Core and Grand Challenge)

- Arctic Freshwater Synthesis
- Antarctic Ice Sheet / Ocean Interactions
- ESM Snow Model Intercomparison
- ESM Ice Sheet Model Intercomparison
- Polar CORDEX Analysis / Arctic Regional Climate Scenarios
- Polar Jet Stream Variability and Extremes
- Improved Greenland Mass Balance Estimation
- Carbon cycle feedbacks in a changing Arctic climate

- *Glacier volume change monitoring*
- *Interactions between cryospheric elements*

ASPeCt
Joint with SCAR

Arctic Sea Ice Working Group

Ice Sheet Mass Balance and Sea Level

ISMASS
Joint with SCAR and IASC

Permafrost Carbon Network
Joint with IASC

Sea Ice and Climate Modelling Forum

Polar Climate Predictability Initiative (PCPI)
Joint with SPARC

Permafrost and Climate Modelling Forum

CliC Focus Areas

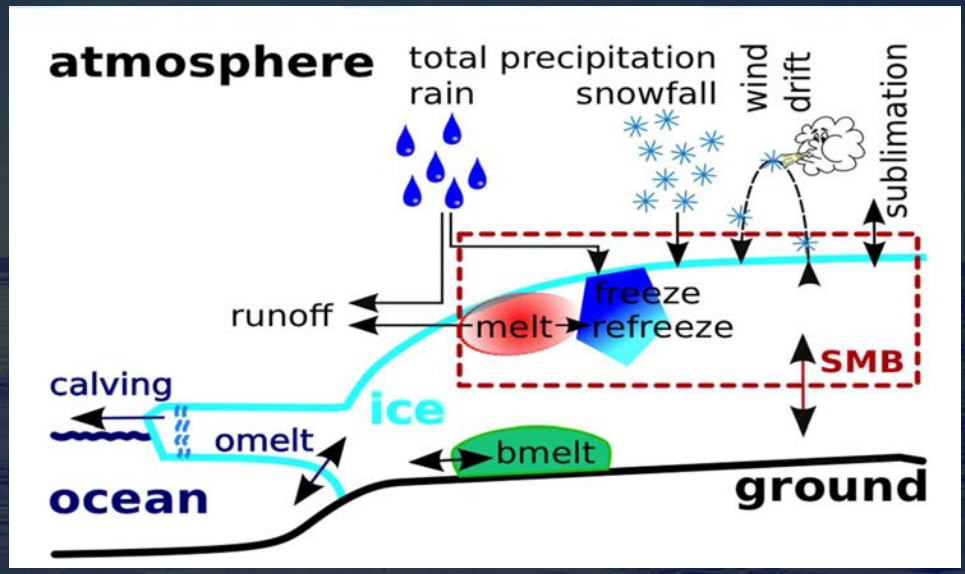
- Primary lead for the Cryosphere Grand Challenge, which was recently re-named: *Melting Ice – Global Consequences*
- Contributing to the Grand Challenge on Regional Sea Level Rise.
- The anticipated grand challenge on Decadal Climate Prediction will necessarily involve the WCRP Polar Climate Predictability Initiative (PCPI) which CliC co-organizes.
- These efforts will also have significant observational data needs spanning all aspects of the cryosphere (snow, sea-ice, frozen ground, glaciers, ice sheets).
- MIPs! MIPs! MIPs!

CliC and CMIP6

- Ice Sheet MIP (ISMIP)
- Marine Ice Sheet-Ocean MIP (MISOMIP)
- Sea Ice MIP (SIMIP)
- There will be a need for quality-controlled (ideally gridded) data sets, with quantified uncertainty, to be used in evaluating model output, improving model physics, and potentially integrating with models

Ice Sheet Model Intercomparison Project for CMIP6

- Ice sheets responding much faster than expected, major contributor of SLR and uncertainty in future SLR projections
- Accepted project within CMIP6, model runs starting
  - S. Nowicki, NASA Goddard, PI
  - Proposal approved, plans underway
- Data needed to constraint and validate models



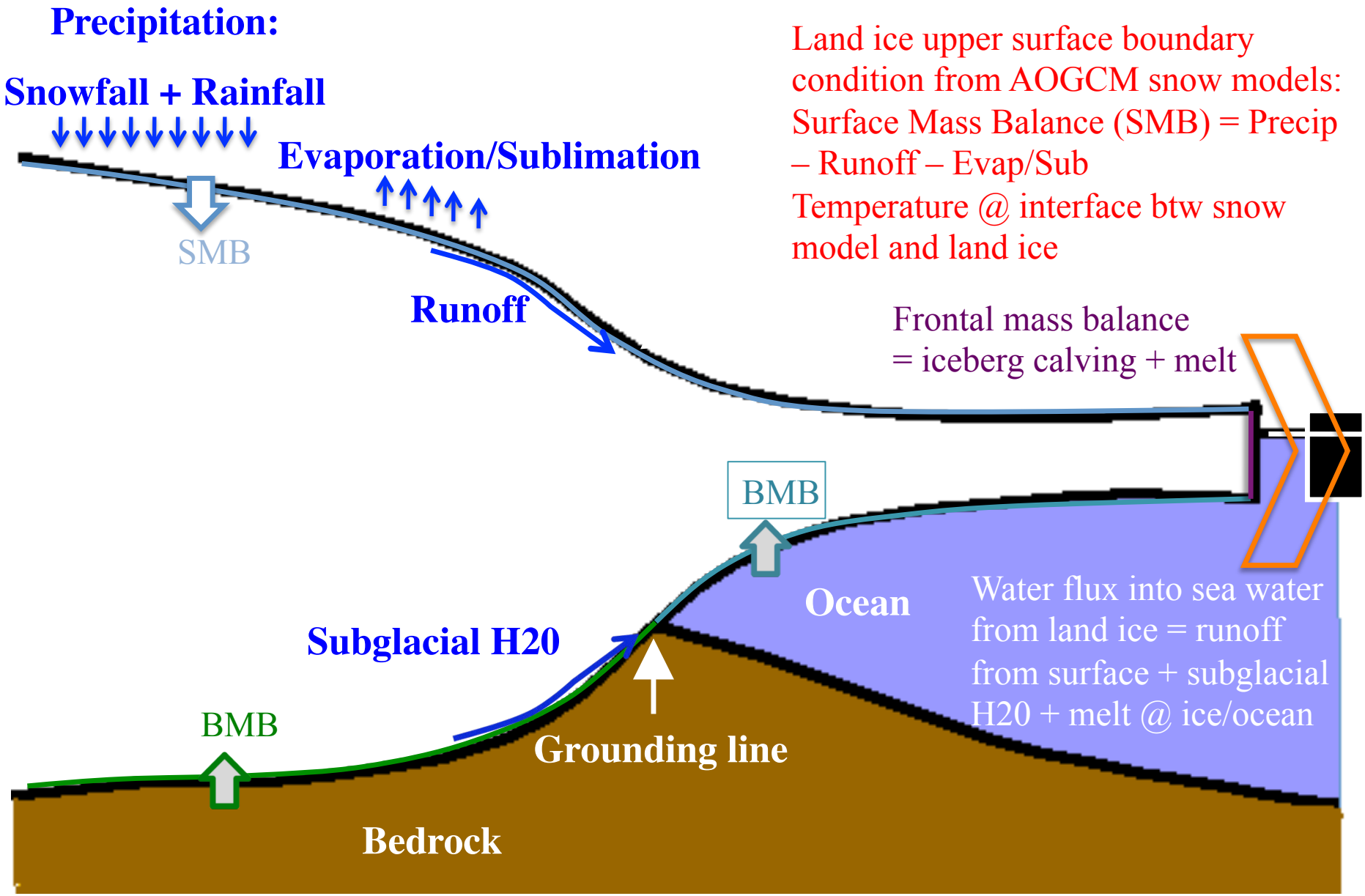
Drawing courtesy of C. Rodehacke

ISMIP Goals

- Initial emphasis is to bring ice sheet community efforts "in phase" with CMIP scenarios
  - In AR5, ice sheet projections were based on AR4 scenarios, while CMIP5 community used new RCP scenarios
- Ultimately, desire is to include fully coupled dynamic ice sheet models within AOGCMs for future CMIPs
  - Obtain future sea-level changes from a fully coupled system
  - Ability to investigate impacts/feedbacks from interactive ice sheets

ISMIP Goals

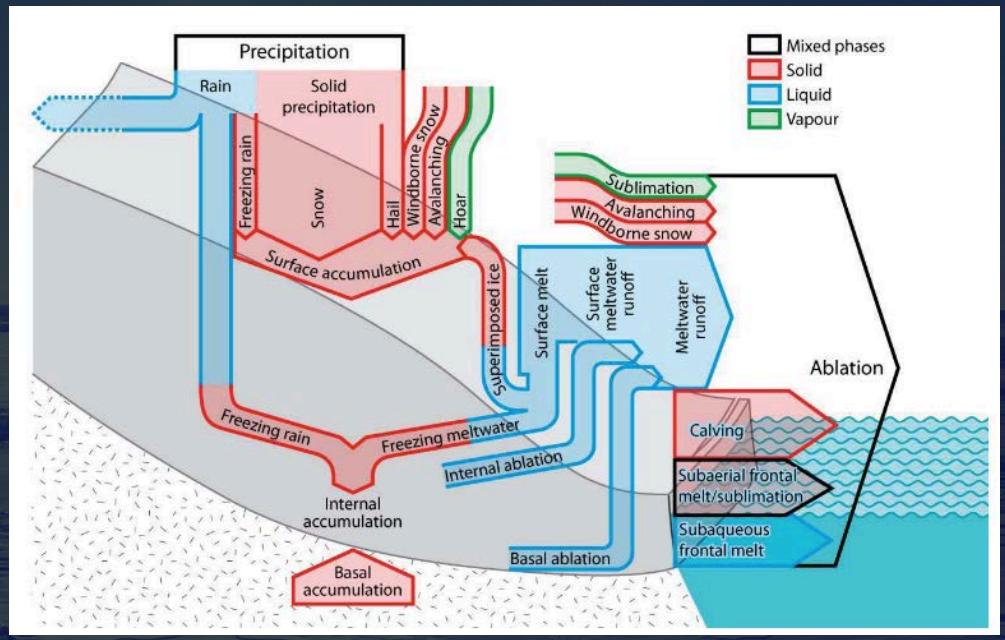
- *Primary goal:* to estimate past and future sea-level contributions from the Greenland and Antarctic ice sheets, along with associated uncertainty
- *Secondary goal:* to investigate feedbacks due to dynamic coupling between ice sheet and climate models, and impact of ice sheets on the Earth system
- Experimental design uses and augments the existing CMIP6 experiments to contribute to the CMIP6 science questions (1) *How does the Earth system respond to forcing?* and (3) *How can we assess future climate changes given climate variability, predictability and uncertainty in scenarios?*



Basal Mass Balance (BMB) and land ice basal temp computed differently depending on whether ice flows over bedrock or ocean

ISMIP6 Data Needs

- Precipitation (rain and snow)
- Surface melt, sublimation
- Ocean mass flux: surface runoff, basal melt, calving
- Temperatures: air, surface, snow, firn, basal



Marine Ice Sheet Ocean Model Intercomparison Project (MISOMIP)

- Community effort to improve models and understanding of ocean-ice sheet interactions
  - Led by D. Holland (NYU)
- Particular focus on West Antarctic Ice Sheet (WAIS)
  - Key target question: What is the response of WAIS to IPCC forcing scenarios?
- Several models of varying sophistication (idealized to realistic) being looked at
- 2nd meeting, May 16-18, 2016 in Abu Dhabi, UAE

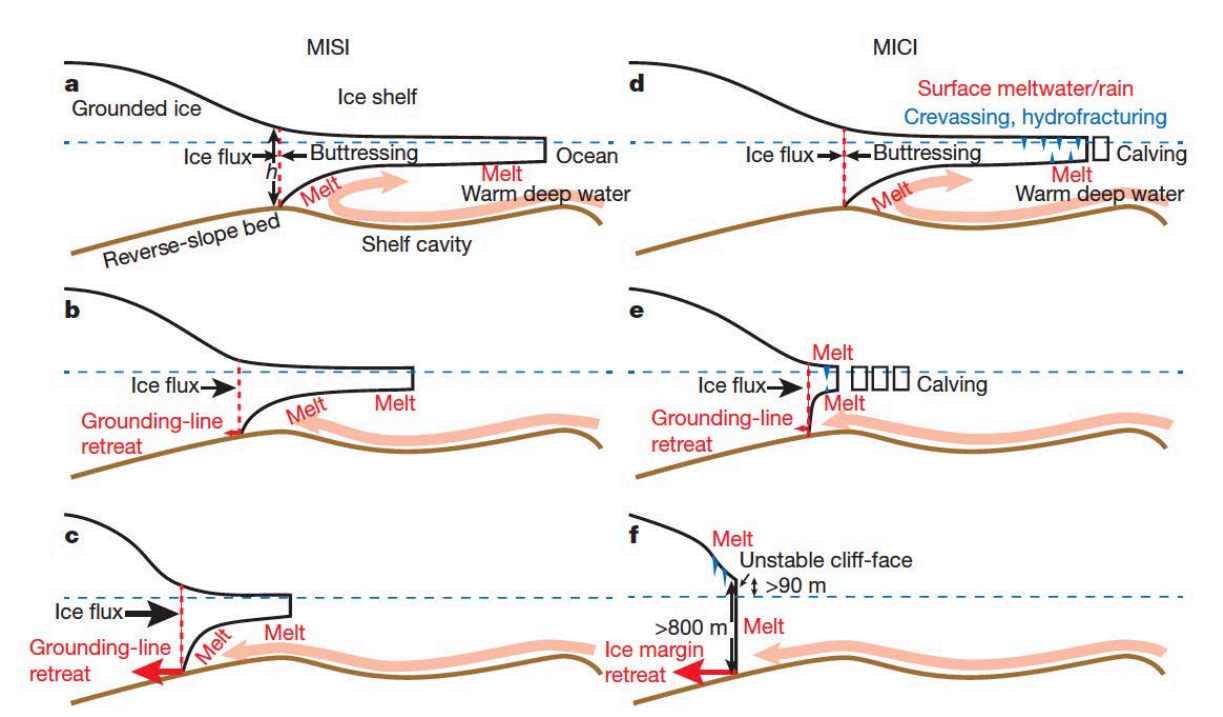
ARTICLE

Nature, 30 Mar

doi:10.1038/nature17145

Contribution of Antarctica to past and future sea-level rise

Robert M. DeConto[1] & David Pollard[2]



1 m SLR from WAIS by 2100?

WAIS Collapse?

Energy and Environment

Scientists nearly double sea level rise projections for 2100, because of Antarctica

A | 2680 | Save for Later | Reading List

By Brady Dennis and Chris Mooney March 30

Follow @brady_dennis | Follow @chrismooney

Washington Post, 30 Mar

SCIENCE

Climate Model Predicts West Antarctic Ice Sheet Could Melt Rapidly

By JUSTIN GILLIS MARCH 30, 2016

A view from a NASA airplane of large icebergs that have broken from the calving side of Thwaites Glacier in Antarctica in November 2014. A disaster scenario of West Antarctic ice sheet disintegration could occur much sooner than previously thought, new research suggests. Jim Yungel/NASA

NY Times, 30 Mar

Many uncertainties remain

Sea floor depth, west Greenland

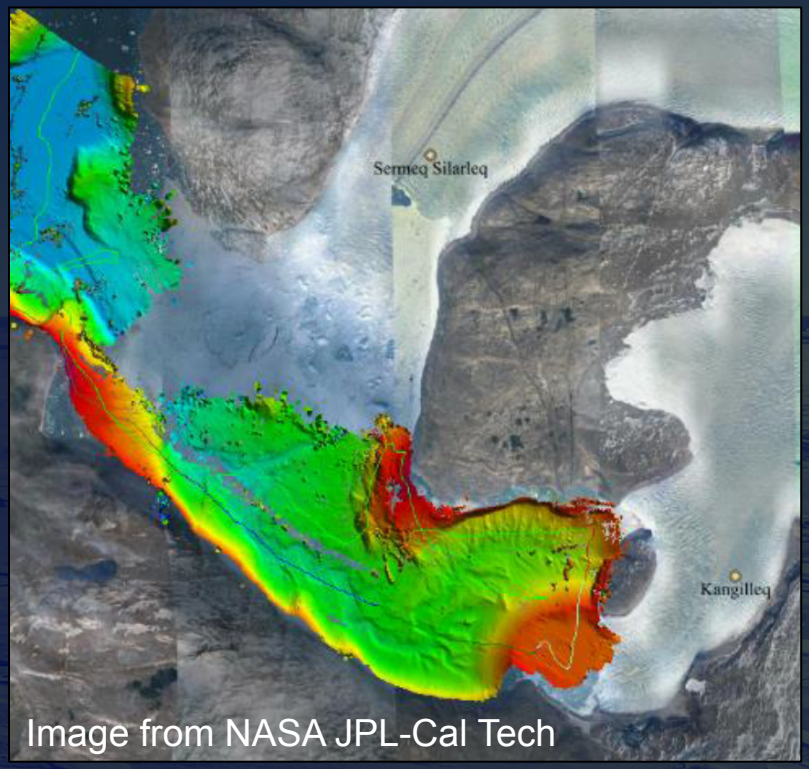


Image from NASA JPL-Cal Tech

- Bathymetry
- Ocean temperature and salinity profiles at ice front and under ice
- NASA Oceans Melting Greenland (OMG) project collecting data from coastal glaciers
  - Ship and aircraft obs

Sea Ice MIP (SIMIP)

- *SIMIP goal:* Understand the simulated sea-ice evolution and its biases in the CMIP6 experiments on the process level
- *SIMIP approach:* SIMIP is a *diagnostic MIP*
  - No model experiments
  - Request for clearly defined variables that will allow an in-depth analysis of the three budgets that govern sea-ice evolution and its role in the Earth's climate system.
- *WCRP Grand Challenge:* SIMIP directly contributes to the goals of the WCRP GC "Cryosphere in a Changing Climate"
- *CMIP6 science questions:* addresses first two CMIP6 science questions (climate response to forcing and sources and consequences of model biases), by analyzing the sea ice evolution and investigating the sources of model biases

SIMIP Key Questions

- *Key gap:* Causes of large spread in sea ice extent in CMIP5 simulations are not clear, and CMIP5 model output does not allow an in-depth analysis of these biases as budgets can not be closed and high frequency output of important variables is lacking.
- New output will address the following science questions:
  - What causes biases in the simulation of the sea-ice state?
  - How much do simulations of the Earth's climate benefit from improvements in the sea-ice model component?
  - What's the internal variability of the Earth's sea-ice cover?
  - How sensitive is the sea-ice cover to changes in the external forcing?

Sea Ice Concentration Uncertainties

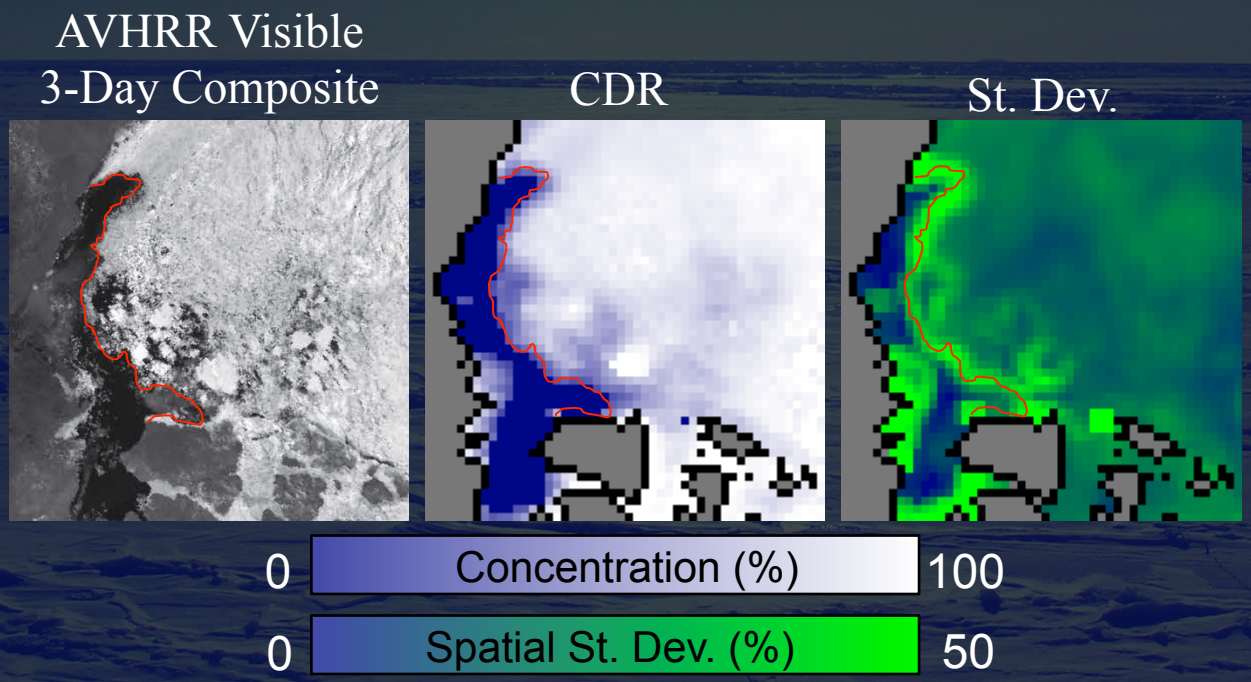
- Sea ice concentration (from passive microwave sensors) is one of longest and most complete satellite climate records
- Uncertainty estimates are critical for optimal use of sea ice concentration fields for model validation, initialization, assimilation
- While numerous validation studies have been done to generally characterize concentration error, until recently grid cell level uncertainty estimates did not exist

Concentration Uncertainties: Three Approaches in Existing Datasets

- Concentration/algorithm variability: NOAA/NSIDC CDR
- Sensor footprint and coefficient characteristics: EUMETSAT OSI-SAF and ESA CCI
- Algorithm iteration: NASA Team 2 algorithm (L. Brucker, NASA Goddard)

NOAA/NSIDC CDR

- Neighborhood spatial variability (st. dev.) from two algorithms
- More variability in high error regions (melt, thin ice, near ice edge)



Meier et al., Polar Research, 2014

EUMETSAT OSI-SAF

- "Smearing" error due to mismatch of sensor footprints and grid resolution
- Algorithm error – tiepoint variability for pure surface types

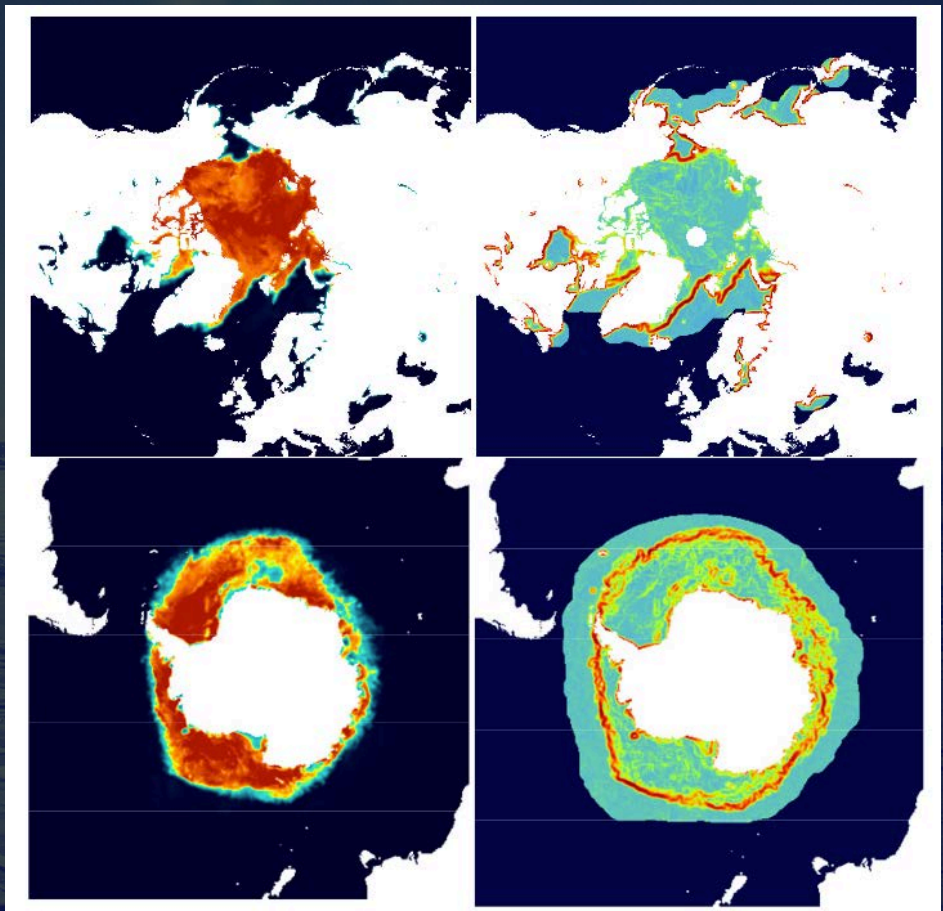
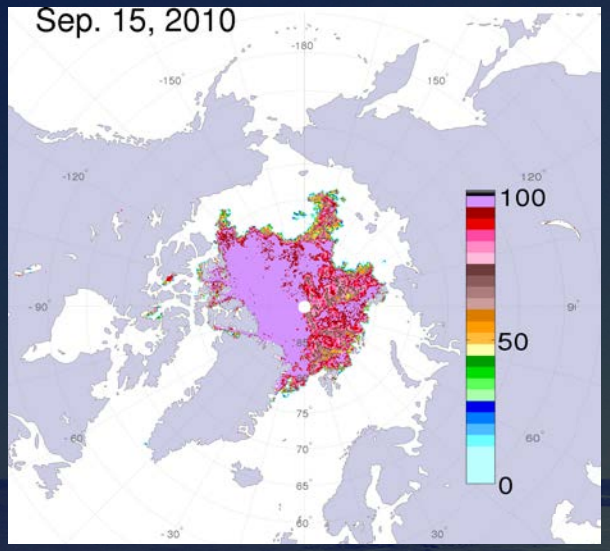


Figure 2-2: Maps of Sea Ice Concentration (left) and total uncertainty (right) from the SICCI SSM/I dataset, valid for 1995-11-15

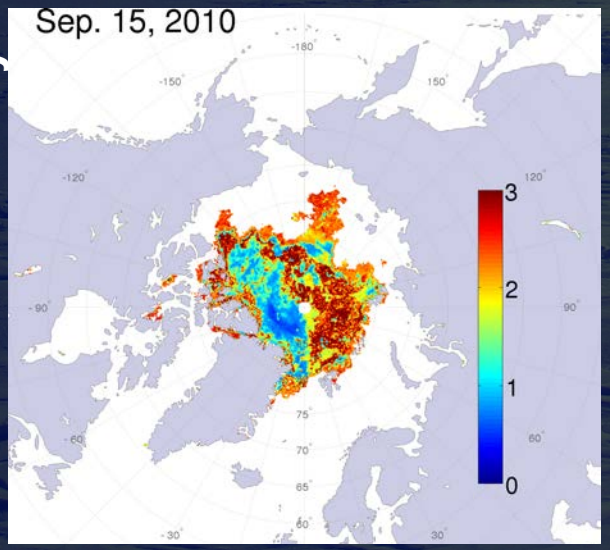
Tonboe et al., The Cryosphere Discussions, 2016

NASA Team 2

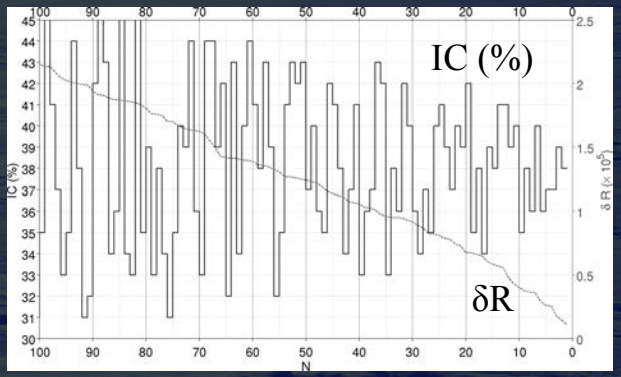
Ice concentration



Relative uncertainty



- Iterative algorithm – converges to a solution consistent with radiative transfer model
- Uncertainty based on concentration variation as iteration converges
- Not yet operational



Iteration →

Brucker et al., IEEE TGRS, 2014

Concentration uncertainties

- All three methods are relative uncertainties
- Need to be calibrated to obtain absolute uncertainties
- Biases in concentration are a significant part of uncertainty in some conditions (e.g., melt)
- What should ice concentration indicate?

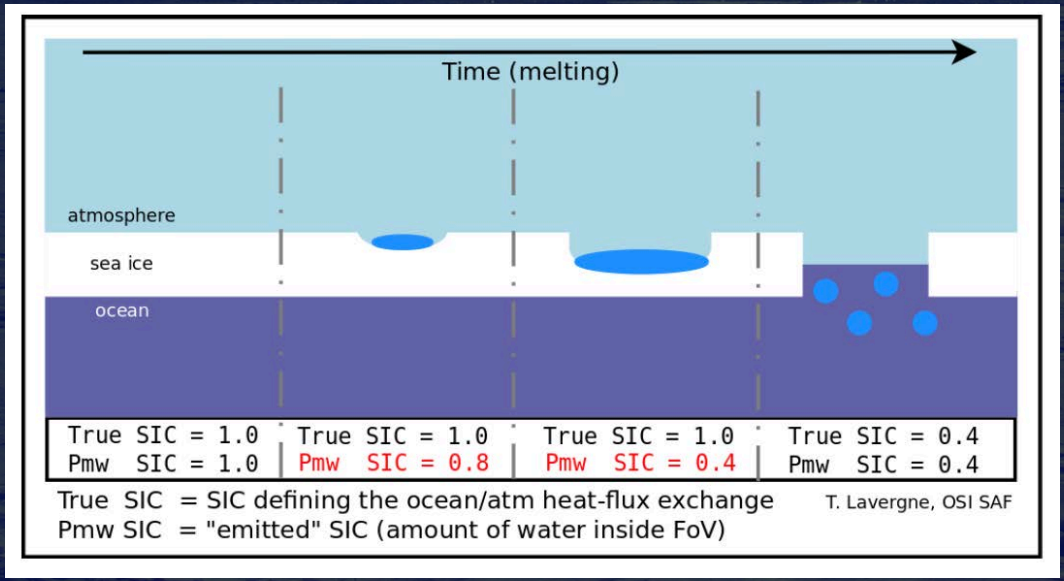
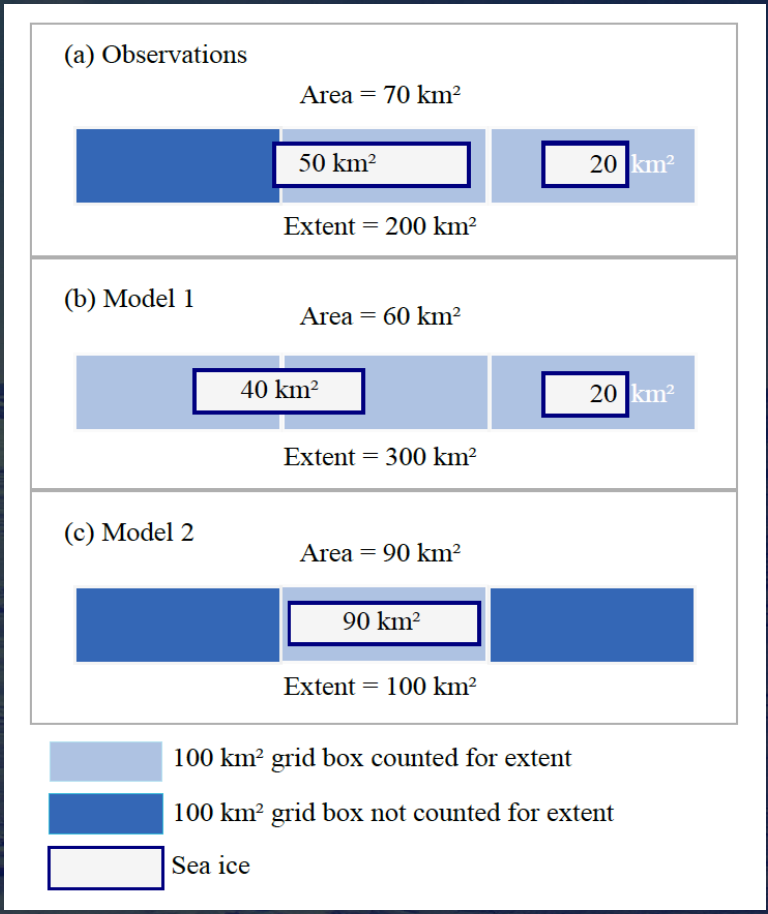


Figure from ESA CCI Product User Guide, Version 2

Sea ice extent versus area

- Extent less affected by biases (simple ice/no-ice)
- But extent can be ambiguous
- Use of sea ice data to compare to models is not straightforward
- Agreement between models and observations varies depending on model and dataset (Notz et al., 2014)



15% concentration threshold for extent

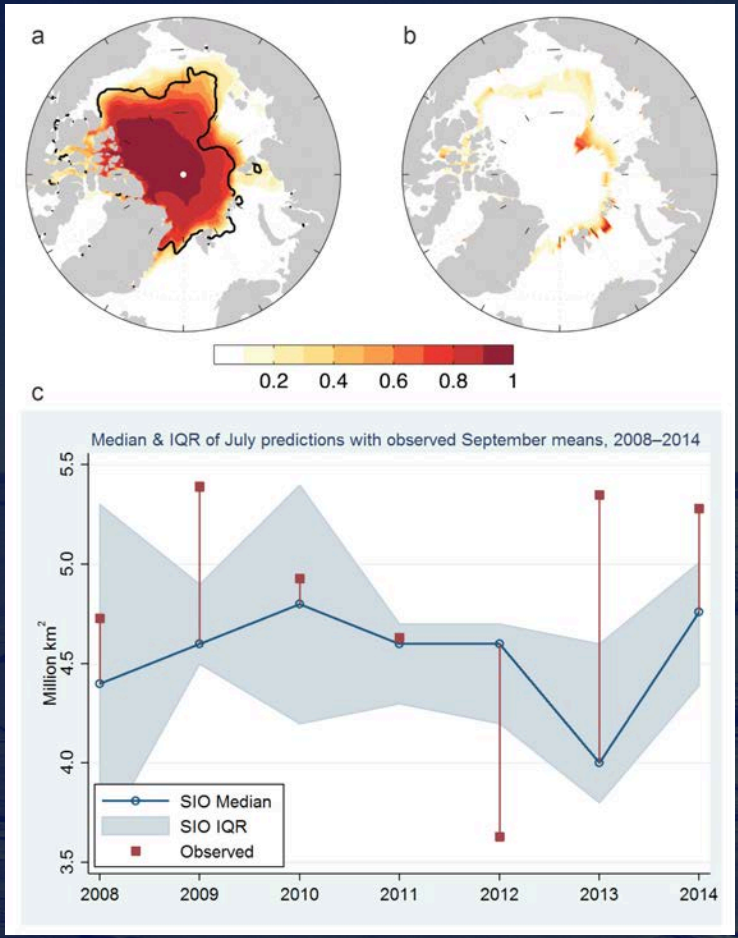
Notz et al., The Cryosphere, 2014

Future of Passive Microwave Sea Ice

Satellite	Launch Year	Operational?
DMSP F15	1999	Yes – some degraded performance
DMSP F16	2003	Yes – early calibration issues
DMSP F17	2006	Yes
DMSP F18	2009	Yes
DMSP F19	2014	No – failed Feb2016
DMSP F20	Cancelled!	
JAXA AMSR-E	2002	No – failed Oct 2011
JAXA AMSR2	2012	Yes
JAXA AMSR3&4	Cancelled!	
JAXA AMSR Follow-on?	????	
EUMETSAT Metop SG-B	End 2022?	

AMSR2 is currently the only PM sensor operating within its nominal mission lifetime

Sea Ice Prediction Network



(Top) multimodel ensemble for Sep 2014 ice edge and observed extent (black line); [Bottom] median and interquartile range of July predictions compared with observed mean September extent, 2008-2014

- U.S. supported project (NSF, ONR, DOE, NASA): http://www.arcus.org/sipn
- Focus on seasonal sea ice prediction
  - Sea Ice Outlook: http://www.arcus.org/sipn/seaiceoutlook
  - Framework for model intercomparison and evaluation
  - Provide resource for observations to initialize and validate models: http://nsidc.org/data/sipn/
  - Design metrics to assess model performance
- Collaboration with other prediction efforts
  - WCRP Polar Climate Predictability Initiative
  - WMO Polar Prediction Project
  - Year of Polar Prediction (YOPP)

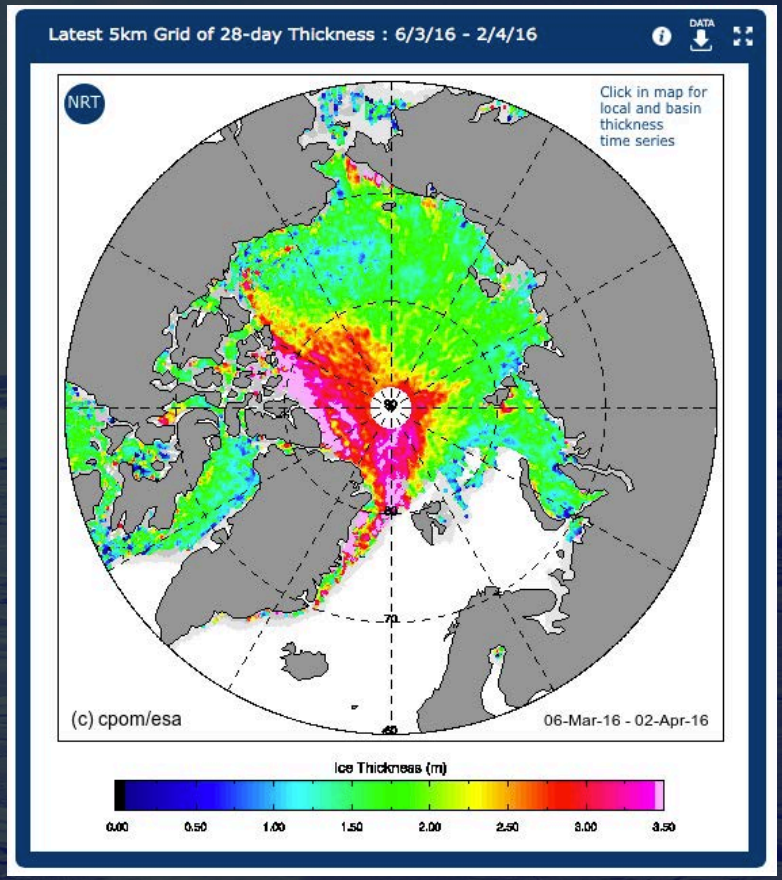
Figure from Stroeve et al., Eos, 2015

Feedback to SIPN

- Uncertainty estimates needed
- Timely data needed for model initialization
  - Especially sea ice thickness
- Congruence between observation and model parameter (e.g., mean thickness vs. thickness distribution)
- Many modelers want swath data, not gridded data that has traditionally been produced
- Higher resolution, especially for operational models (IMS/MASIE)

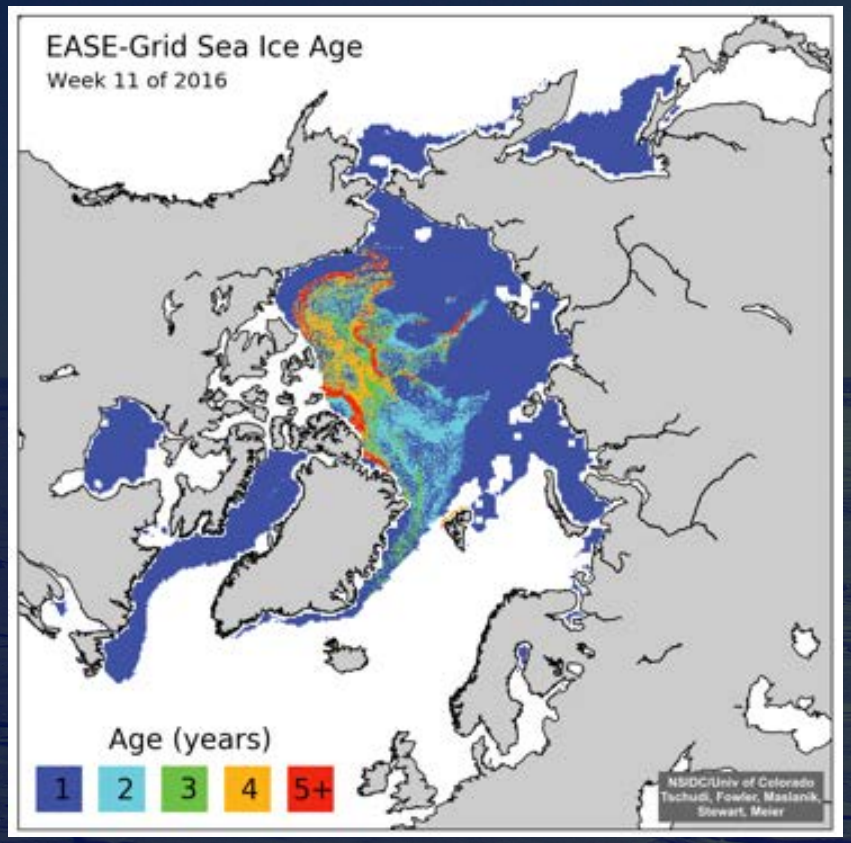
Sea Ice Thickness

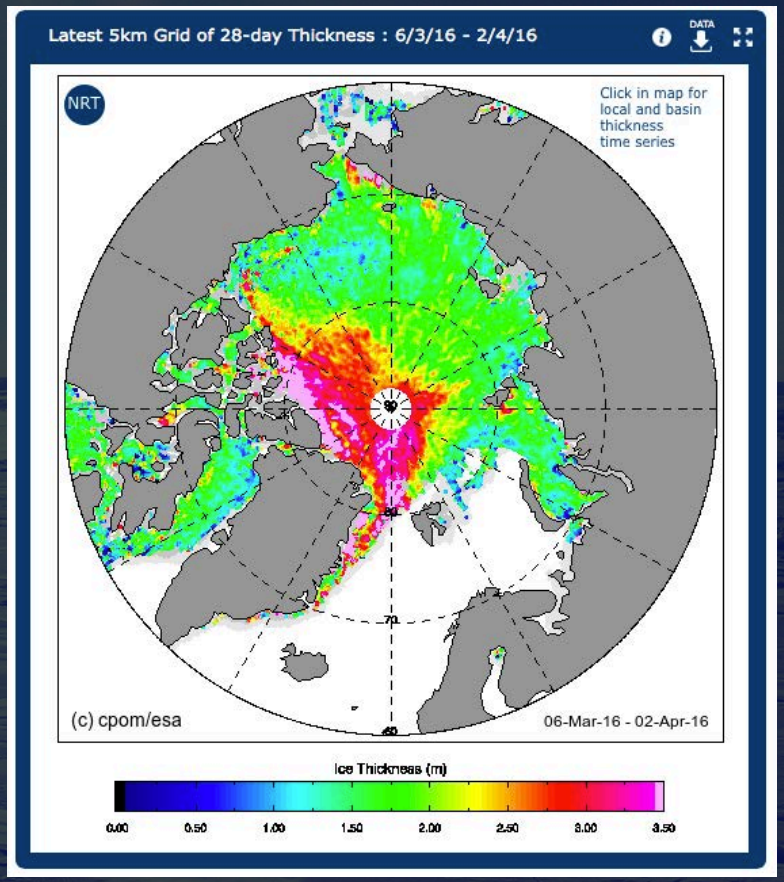
- CryoSat-2
  - Uncertainties not included
  - 28-day composite for complete coverage
  - Raw swath data not available
  - Potential biases due to density assumptions, snow depth (Zygmuntowska et al., 2014)
- IceBridge
  - Limited spatial coverage and time period
  - 6-8 week lag (ok for seasonal outlooks?)



UCL CPOM, http://www.cpom.ucl.ac.uk/csopr/seaice.html

Ice Thickness

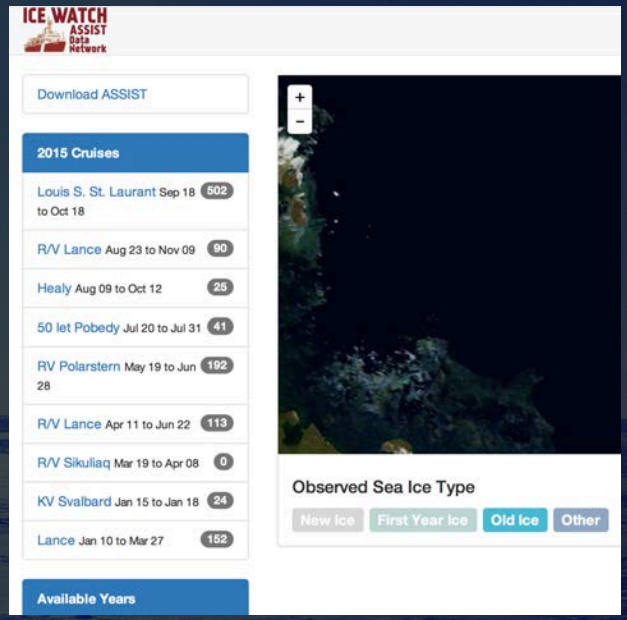




Ice Age from M. Tschudi et al., NSIDC, http://nsidc.org/data/nsidc-0611

CliC Sea Ice Working Group

- ASPeCt ship obs
  - Adapted from Antarctic protocols: added features unique to Arctic
- ASSIST/IceWatch
  - Software to record ship observations of ice per ASPeCt protocols
  - Data entered and saved in a consistent format
  - Needs permanent archive location (currently at UAF, http://icewatch.gina.alaska.edu)
- Sea ice/cryospheric flagship observations in the Arctic
  - Goal is to help standardize and integrate sea ice observations at existing sites (Barrow, Tiksi, Ny Alesund, CHARS, Cape Baranov, etc.)
  - Potential coordination with Global Cryosphere Watch (CryoNet)



CliC Emerging Activity

Sea Ice Biogeochemistry Forum

- Follow on from Biogeochemical Exchange Processes at Sea Ice Interfaces (BEPSII)
- Joint SOLAS-CliC forum
- Focus on collaboration among relevant projects/ groups and avoiding redundancies
- Connect to stakeholders (Arctic communities, biodiversity conservation programs)

Other CliC Activities

- Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC)
  - Now 2019-2020, AWI Polarstern icebreaker
- Arctic Freshwater Synthesis – completed, six manuscripts accepted/published in JGR
- ESM-SnowMIP – improve snow in Earth System Models; also several activities related to snow observations
- Polar Coordinated Regional Downscaling Experiment (Polar CORDEX) – RCM comparisons
- Permafrost Carbon Network
- Linkages between Arctic Climate Change and Mid-Latitude Weather

Photo by Terry Haran, NSIDC