National Snow and Ice Data Center
Supporting Cryospheric Research Since 1976

Creation and Preservation of a Sea Ice Climate Data Record

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NOAA SDS Meeting
1 October 2009

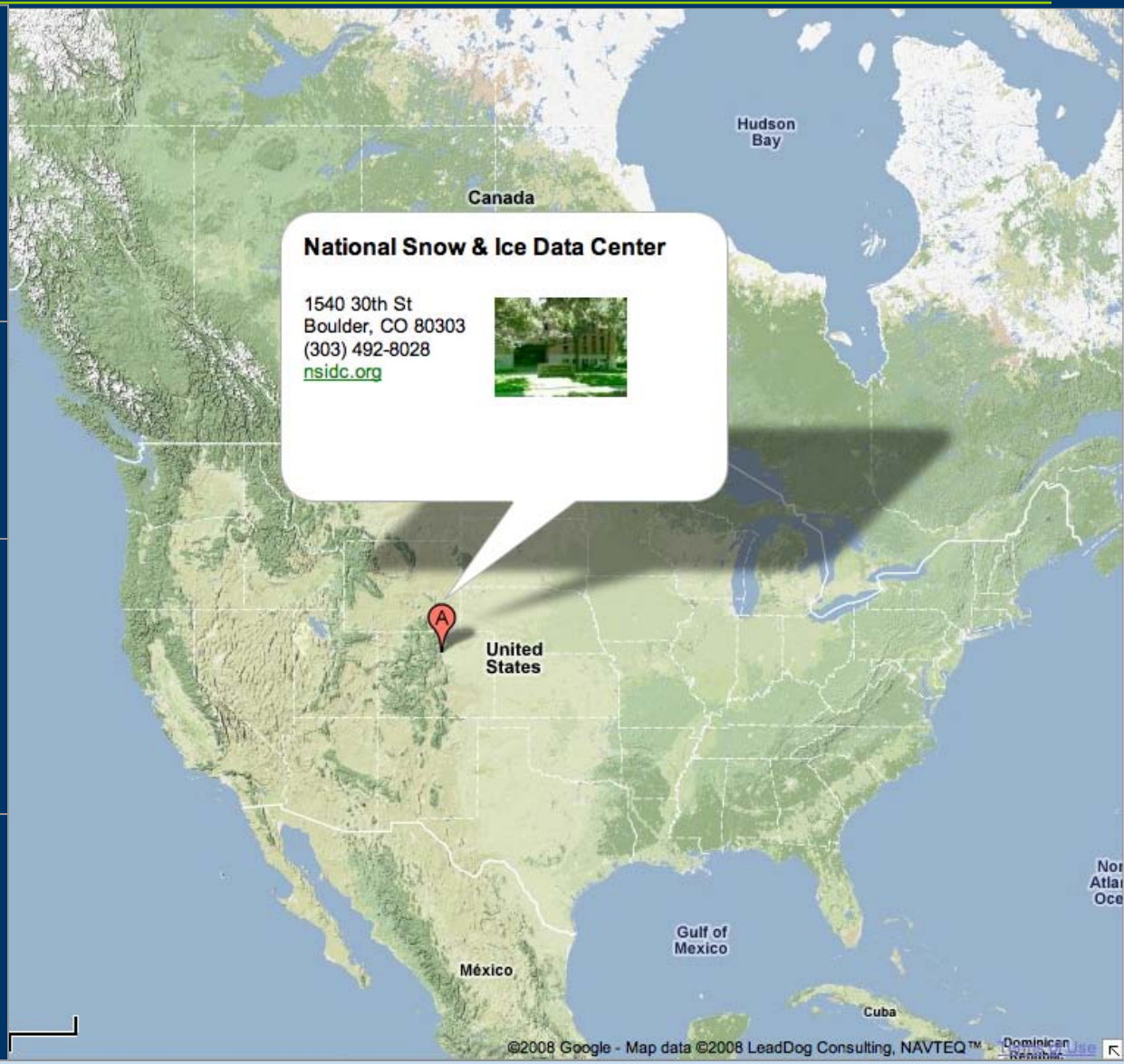
Affiliations and sponsorship

Cooperative Institute for Research in Environmental Sciences

University of Colorado at Boulder

World Data Center for Glaciology (since 1976)

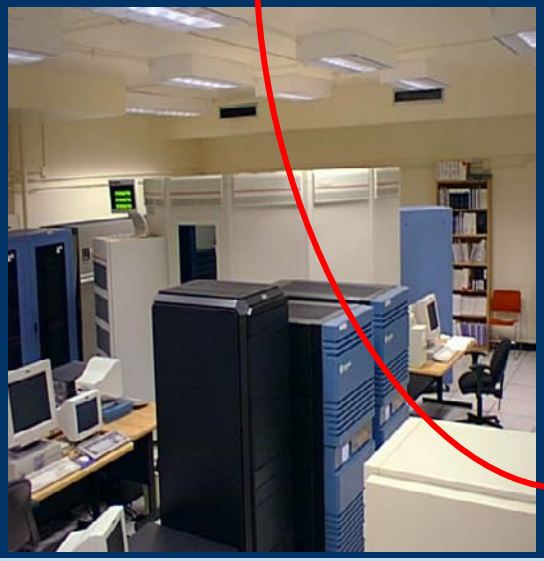
Main sponsors:



NSIDC Distributed Active Archive Center

Data from NASA's past and current Earth Observing System (EOS) satellites and other satellite and field measurement programs.

Passive microwave	Visible/Infrared	Satellite Altimetry
AMSR-E (Aqua) AMSR (ADEOS II) SMMR (Nimbus 7) SSM/I, SSMIS (DMSP)	MODIS (Terra/Aqua) snow and ice products AVHRR polar data (NOAA series)	ICESat/GLAS altimetry and atmospheric lidar data Digital Elevation Models (DEMs)



Ingest	Archive	Distribution
~30 TB/year	~29 TB/year	12.9 TB/year
1,910,000 products per year	1,800,000 granules per year	600,000 products per year 11.5 TB by network 1.4 TB by media

Source for current NSIDC sea ice climate record

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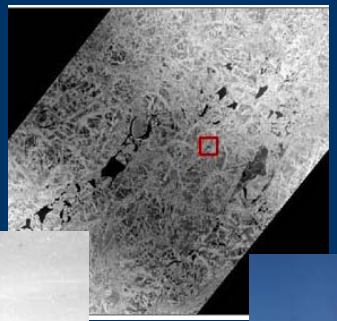
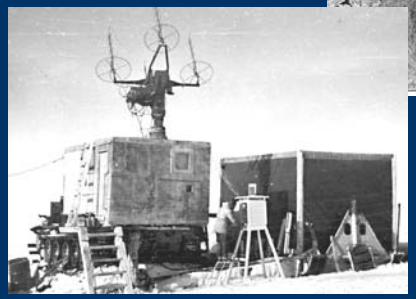
Emphasis on

- in situ data sets,
- data rescue
- products from the operational community,
- outreach products: Google Earth data sets, Sea Ice Index

Florence Fetterer, NOAA Liaison





Products in cooperation with operational communities:

- Sea Ice Charts of the Russian Arctic in Gridded Format, 1933-2006 ***[Arctic and Antarctic Research Institute, St. Petersburg]***
- National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format ***[Navy/NOAA/Coast Guard National Ice Center]***
- Operational Sea Ice Index Planned ***[National Ice Center]***
- Arctic Sea Ice Melt Pond Statistics and Maps, 1999, 2000, and 2001 ***[USGS/Reconnaissance imagery]***
- Surface Heat Balance of the Arctic (SHEBA) Reconnaissance Imagery ***[USGS, Civil Applications Committee - first public release of literal IDPs for arctic research]***
- Submarine Upward Looking Sonar Ice Draft Profile Data and Statistics ***[US and British Navies]***
- Joint US-Russian Env. Working Group Arctic Atlases on CD-ROM ***[Medea Project and others]***
- Snow Data Assimilation System (SNODAS) ***[National Weather Service]***
- IMS Daily Northern Hemisphere Snow and Ice Analysis at 4 km and 24 km Resolution ***[NOAA and NIC]***

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Sea Ice Index

Access to imagery and summary data from sea ice climate record, i.e., a Climate Information Record (CIR)

Project Overview

- Project Goals: Work toward upgrading sea ice concentration products to CDR level by:
  - Improving metadata
  - Developing data quality estimates
  - Improving intersensor calibration where possible
- Source Data: Passive microwave data
  - Nimbus-7 SMMR, DMSP SSM/I and SSMIS, NASA AMSR-E
  - Future sensors: GCOM-W AMSR2, NPOESS MIS
- ECVs:
  - Gridded sea ice concentration
  - Total sea ice extent and area
  - Ultimately, also sea ice drift and sea ice age
- User community:
  - Cryosphere, climate modeling, ocean, atmosphere, biology
  - Fisheries, native communities, shipping, natural resources
  - Policymakers, national defense (e.g., U.S. DoD NORTHCOM)
  - Educators, students, media, blogosphere, general public

Source Data – brightness temperatures (Tb)

	SMMR	SSM/I	SSMIS	AMSR-E	AMSR2	MIS
Years of operation	1978-1987	1987-2009	2002-	2002-	2011/2012	2016
Freq. (GHz)	6.9, 19, 22, 37	19, 22, 37, 85	19, 22, 37, 91, +	6.9, 19, 22, 37, 89	6.9, 19, 22, 37, 89	
IFOV 37 GHz (km)	~40	~40	~40	~15	~15	
Gridded Res. (km)	25	12.5/25	12.5/25	6.25/12.5	6.25/12.5	
Selected Algs.	NT BT	NT BT	NT BT	NT2 ABT Bremen	??	??

+ = higher frequency sounding channels, potential for atmospheric characterization
6.9 GHz can provide ice surface temperature for better sea ice
85-91 GHz provides higher spatial resolution and better ice surface and atm. characterization

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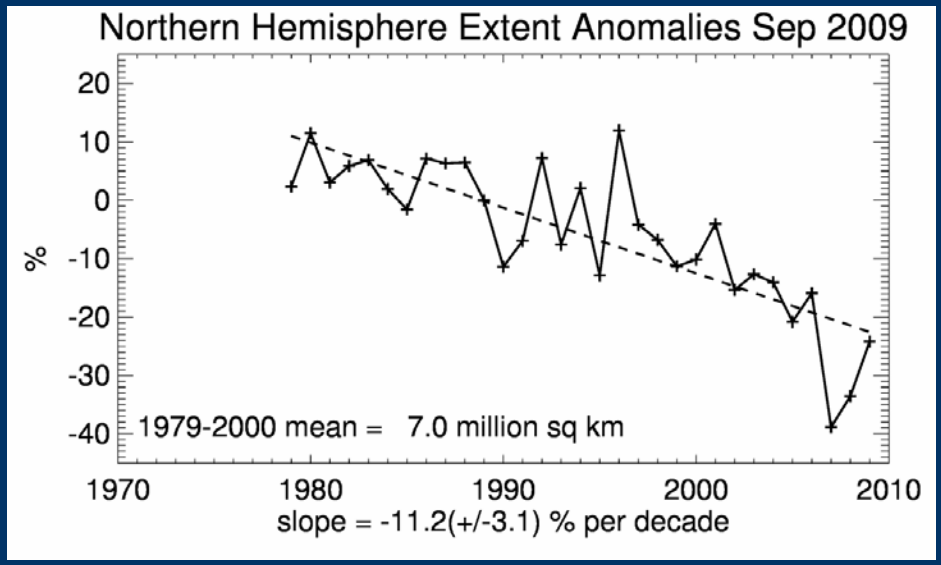
Are sea ice concentration fields CDRs?

- Yes
  - Long-term (now over 30 years)
  - Consistent (intersensor calibration)



- No
  - Data quality known in general, but not in detail (e.g., at the granule or grid-cell level)
  - Sensor overlap periods limited (a few weeks or months)
  - Potential for improvement in calibration
  - Several different products – no “authoritative” concentration field
  - Very limited metadata

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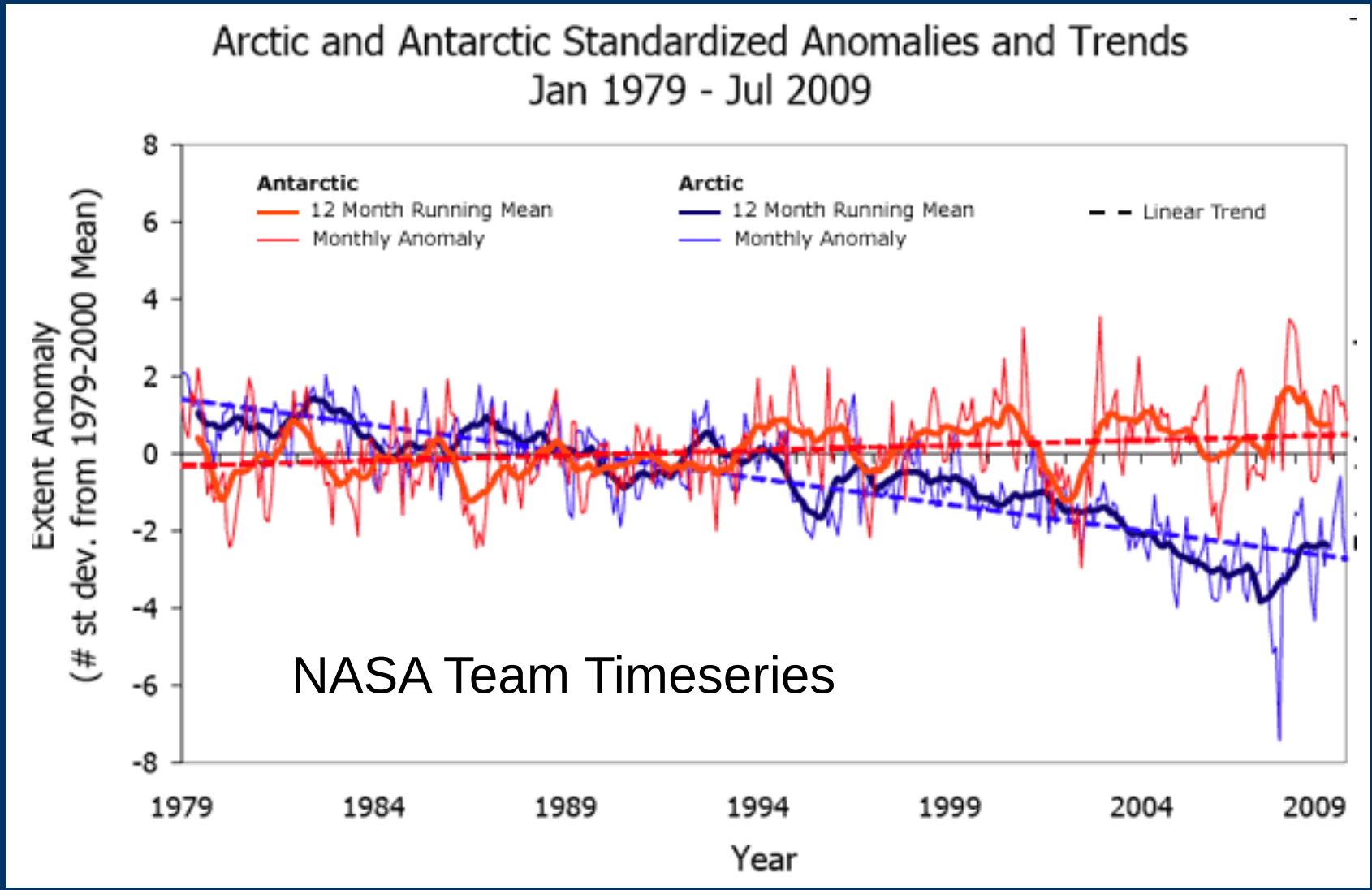
Approach – current standard processing

- NRT Tbs → "Near-real-time sea ice" (NASA Team)
  - Previously F13, F15 SSM/I from NASA Marshall
  - June 2009: F17 SSMIS from CLASS
  - Sea ice processed at NSIDC
- Processed Tbs → "Preliminary sea ice" (NASA Team)
  - Tbs from Remote Sensing Systems (RSS)
  - Sea ice processed at NSIDC
- Processed Tbs → NASA Goddard –> "Final sea ice" (NASA Team and Bootstrap)
  - Tbs from RSS
  - Sea ice processed at NASA Goddard, archived at NSIDC
- Sea ice processing almost completely consistent
- Only "Final" sea ice stored in permanent archive
- Currently funded through NASA DAAC

Approach – improvements toward a sea ice CDR

- Metadata
  - Implement current standards and retain flexibility to meet evolving future standards
  - Granule level information
- Data quality estimates
  - Multiple concentration estimates
  - Ancillary fields
  - Provide grid cell level data quality
- Intersensor calibration at product level
  - Use newer sensors
  - Make calibration more quantitative
  - Use longer overlap where possible
  - Integrate SMMR-SSM/I-SSMIS with AMSR-E

Results


Arctic and Antarctic Standardized Anomalies and Trends
Jan 1979 - Jul 2009
Antarctic
12 Month Running Mean
Monthly Anomaly
Arctic
12 Month Running Mean
Monthly Anomaly
Linear Trend
Extent Anomaly
(# st dev. from 1979-2000 Mean)
8
6
4
2
0
-2
-4
-6
-8
1979
1984
1989
1994
1999
2004
2009
Year
NASA Team Timeseries

Data set metadata status

- Upgrades to a web service that provides data set level metadata compatible with a variety of standards have been completed
- ISO – 19115 (1/2) outputs have been reviewed by internal staff
- Sample ISO – 19115 metadata have been sent to Ted Habermann (NOAA NGDC) for review
- Public release of the web service to occur soon

File level metadata status

- Initial tests have demonstrated that the combination of METS/PREMIS/ISO 19115 works well
  - ISO 19115 to capture scientific aspects of the data including lineage, geospatial and temporal coverage, etc.
  - PREMIS to capture ownership, media migration and other archive management related aspects of the OAIS preservation information
  - METS to provide a wrapper and link between all related components (e.g., the data file, its metadata file, the data set level metadata record, etc.)
- The METS/PREMIS/ISO combination is compatible with digital library standards such as OAI-PMH metadata harvesting

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Sea ice concentration status

Archived at NSIDC

- SMMR-SSM/I
  - NASA Team (NTA)
  - Bootstrap (SBA)
- AMSR-E
  - NASA Team 2 (NT2)
  - AMSR Bootstrap (ABA)

Other algorithms

- ASI (AMSR) – Univ. of Bremen
- Bristol (BRI)
- Norsex (NOR) – Norwegian Polar Institute
- Cal/Val (CAL), aka AES-York

Different algorithms are sensitive in different ways to surface features (melt, open water, snow, etc.). Variation across algorithm products can provide an estimate of uncertainty.

Estimate uncertainty from variability across algorithms

1. NTA – NSIDC SSM/I standard product
2. NT2 – AMSR-E standard product
3. ABA – derived from AMSR-E standard product
4. ASI – produced at Univ. Bremen from AMSR-E

Run in-house from SSM/I:

5. SBA
6. BRI
7. NOR
8. CAL

Common (expanded) land mask and weather filters

All gridded to 25 km polar stereographic grid

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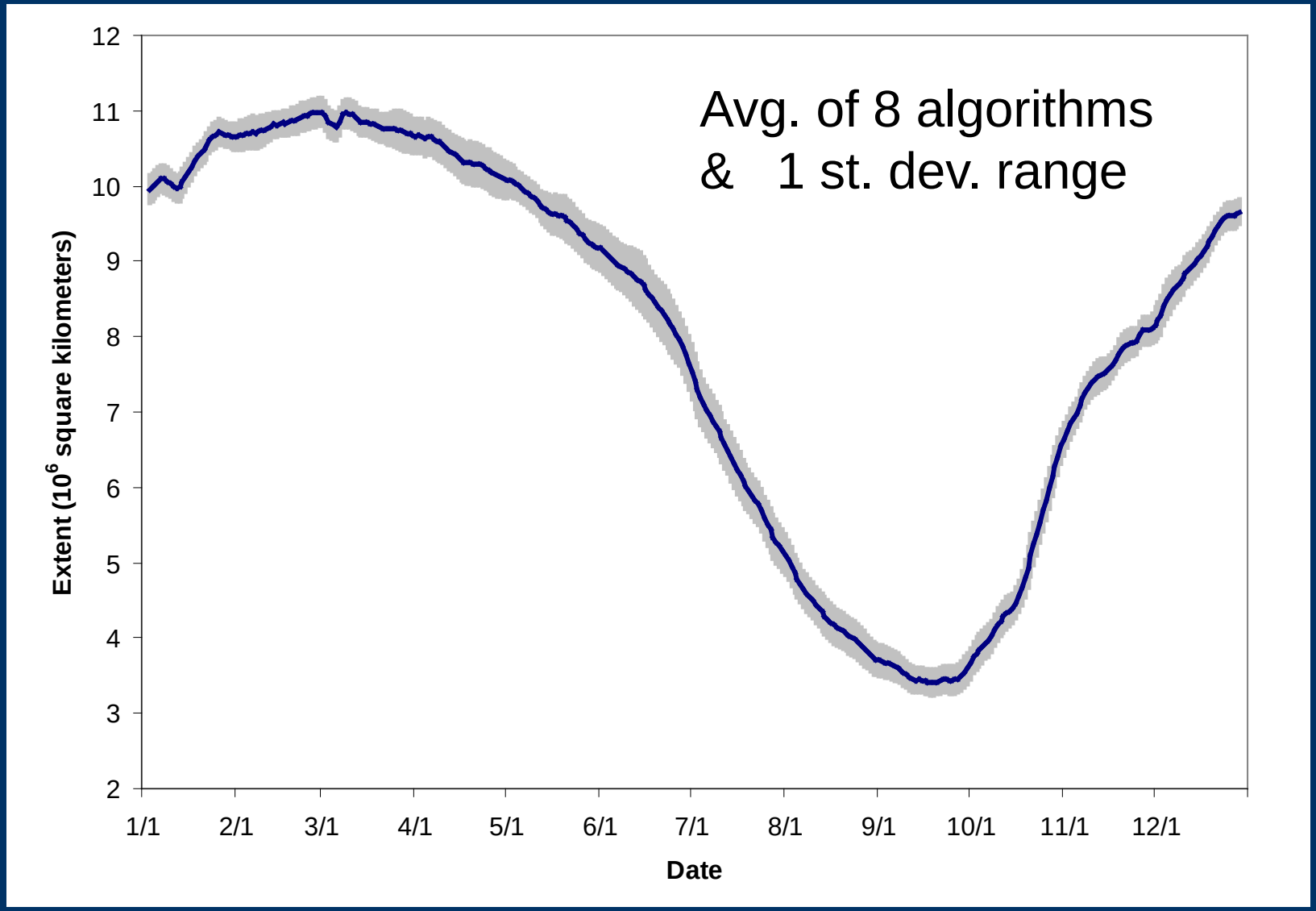
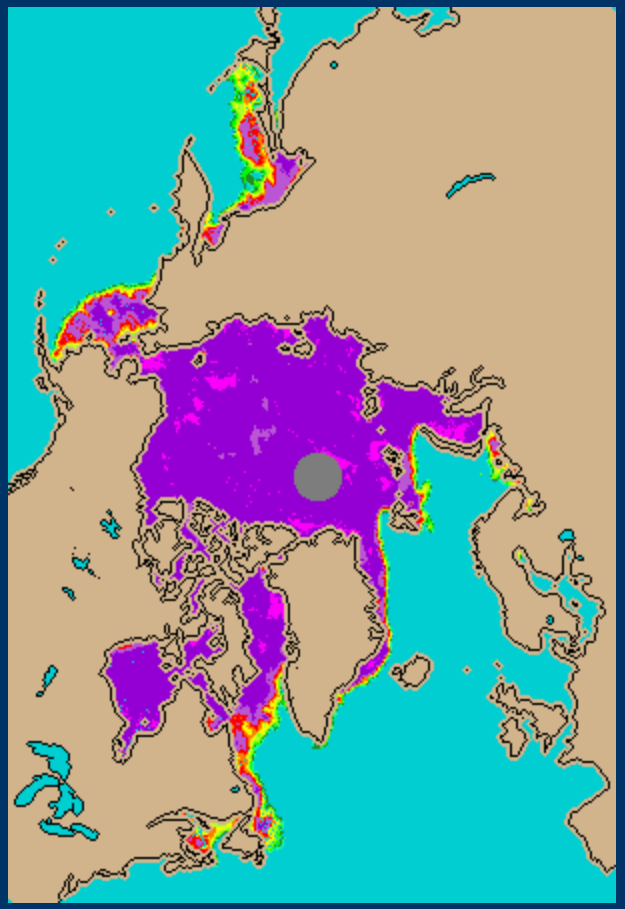
2007 total sea ice extent



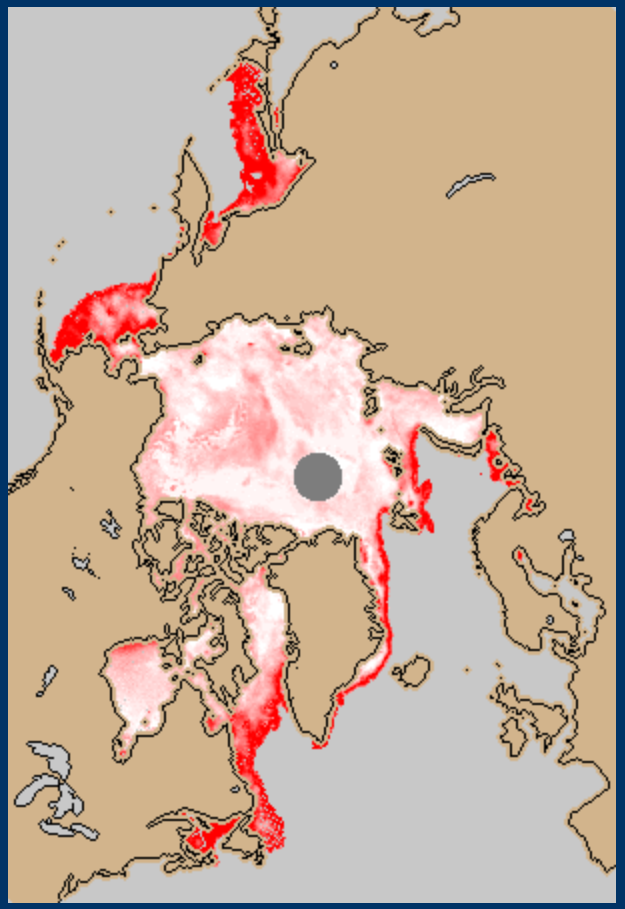
March – September 2008 Sea Ice

Avg. Concentration



0 20 40 60 80 90 100 %

Conc. Range



0 25 %

Max – Min concentration

Quality Field

4 8

algorithms >15%

likely melt

Combined from all 8 algorithms

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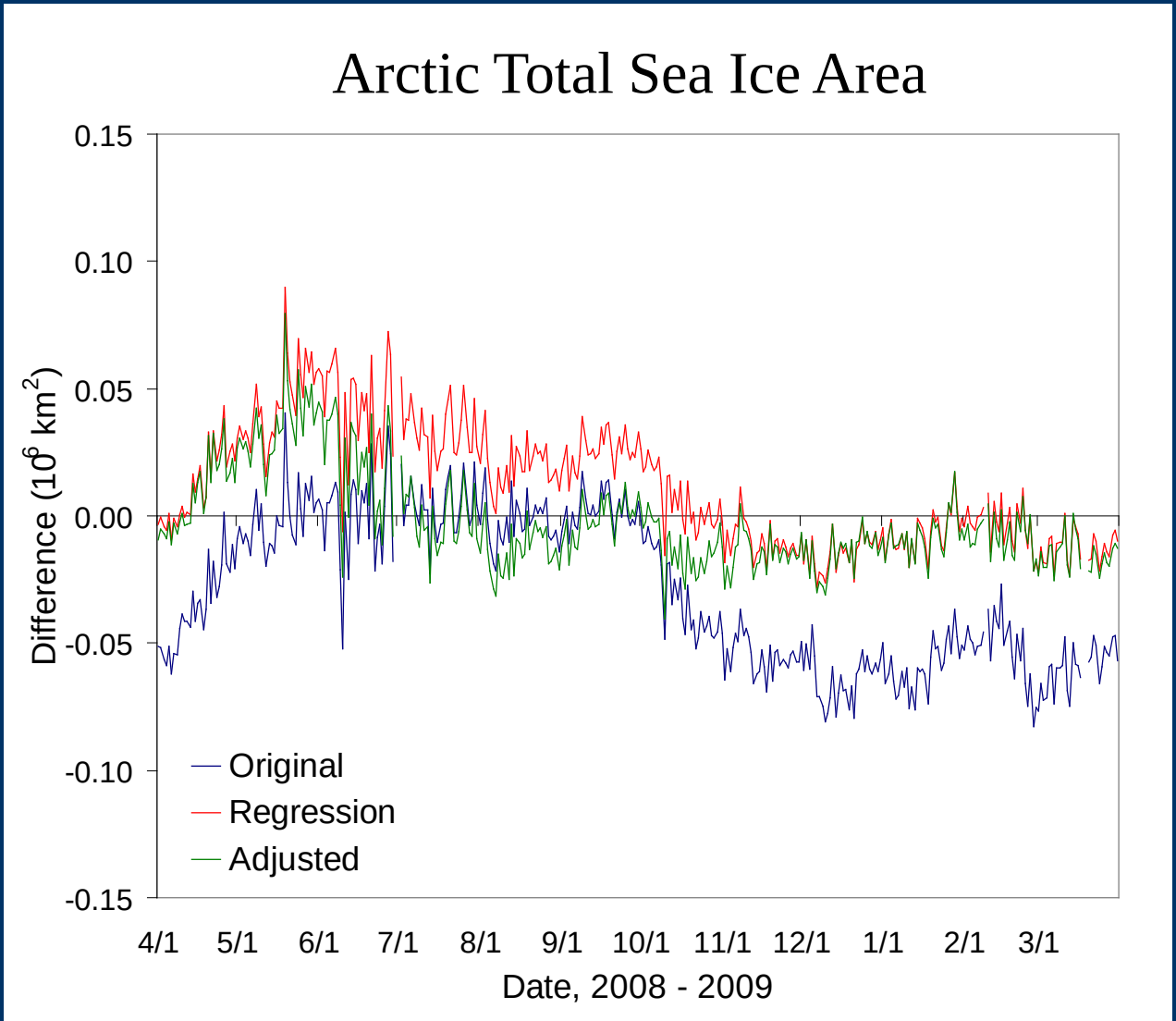
Intersensor calibration

- For sea ice, intercalibration at brightness temperature is not sufficient for consistency
  - High variability in sea ice signal (e.g., melt, ice edge)
  - Need to calibrate at product level (concentration, area, extent)
- Focus so far has been on intercalibration of current sensors
  - F13 failing, F15 sensor issues, F17 data availability
  - Principles developed can be applied to reprocessing
  - Use linear regression of Tbs and tiepoint adjustment (using iterative cost function approach) to minimize total area and extent over full year and seasonally
  - Full-year intercalibration to account for seasonal variability in both hemispheres – never done before for sea ice in near-real-time

Intersensor calibration



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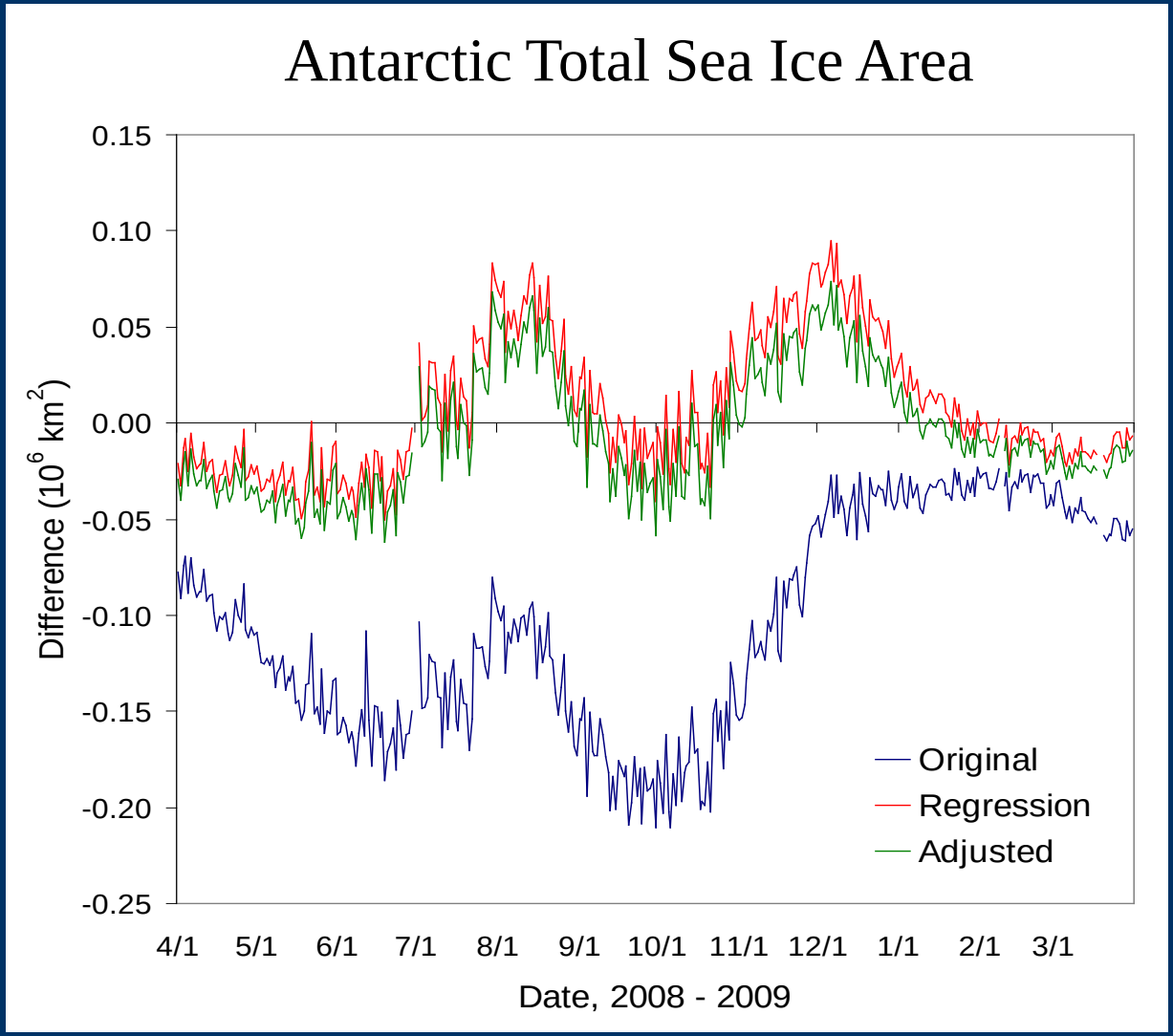
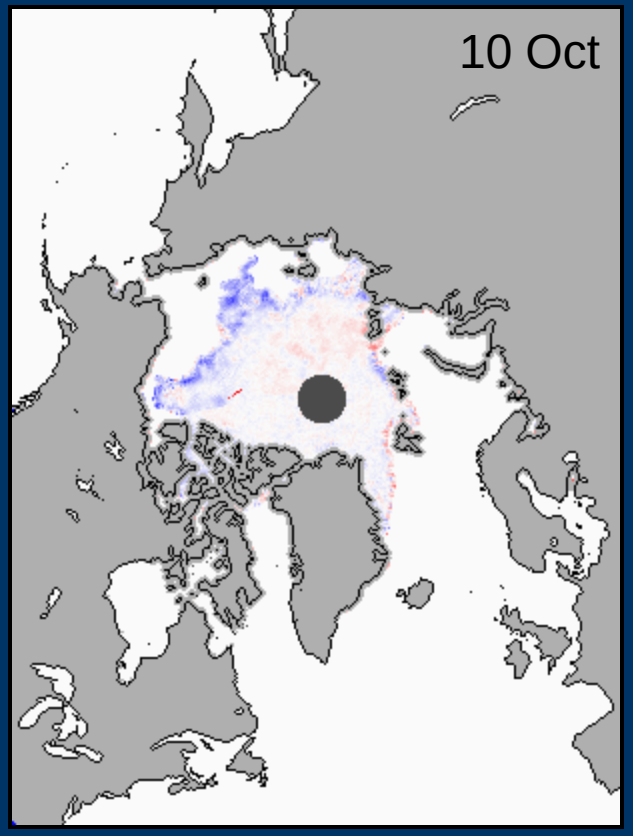
Intersensor calibration

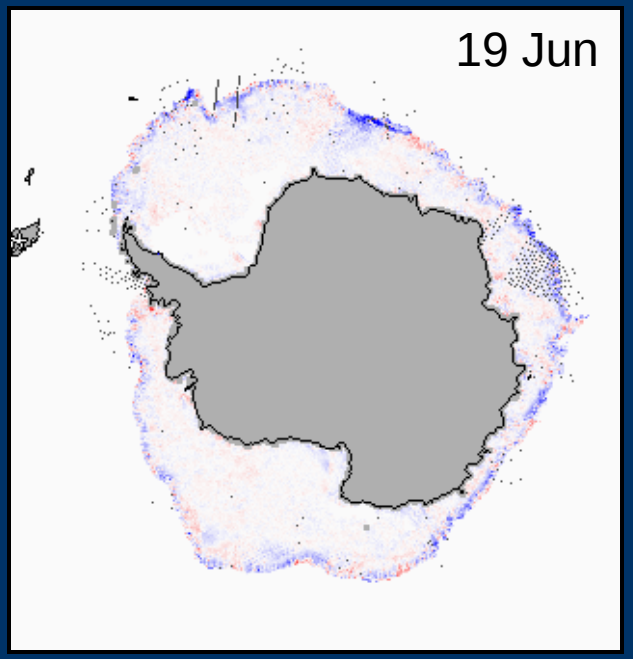


Intersensor calibration

Largest Arctic F17-F13 Difference



Largest Antarctic F17-F13 Difference



% Concentration

-25 0 +25

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Product maturity

Maturity	Sensor Use	Algorithm stability	Metadata & QA	Documentation	Validation	Public Release	Science & Applications
1	Research Mission	Significant changes likely	Incomplete	Draft ATBD	Minimal	Limited data availability to develop familiarity	Little or none
2	Research Mission	Some changes expected	Research grade (extensive)	ATBD Version 1+	Uncertainty estimated for select locations/times	Data available but of unknown accuracy; caveats required for use.	Limited or ongoing
3	Research Missions	Minimal changes expected	Research grade (extensive); Meets international standards	Public ATBD; Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.
4	Operational Mission	Minimal changes expected	Stable, Allows provenance tracking and reproducibility; Meets international standards	Public ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.
5	All relevant research and operational missions; unified and coherent record demonstrated across different sensors	Stable and reproducible	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Public ATBD, Operational Algorithm Description (OAD) and Validation Plan; Peer-reviewed algorithm, product and validation articles	Consistent uncertainties estimated over most environmental conditions by multiple investigators	Multi-mission record is publicly available with associated uncertainty estimate	Used in various published applications and assessments by different investigators
6	All relevant research and operational missions; unified and coherent record over complete series; record is considered scientifically irrefutable following extensive scrutiny	Stable and reproducible; homogeneous and published error budget	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Product, algorithm, validation, processing and metadata described in peer-reviewed literature	Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation	Multi-mission record is publicly available from Long-Term archive	Used in various published applications and assessments by different investigators

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Plans for final year

Metadata plans - File level metadata

- METS/PREMIS/ISO metadata will be developed for existing data files
- Additional quality information will be integrated into metadata, such as:
  - An indication of missing data and regions of missing data
  - Melt indicator
  - Pixels near the ice edge
  - Pixels where comparison to other sea ice algorithms indicates concentration differences

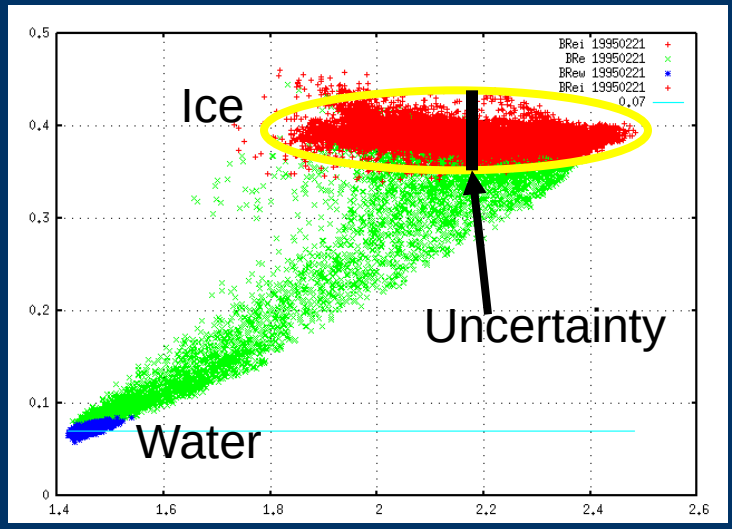
Data quality field plans

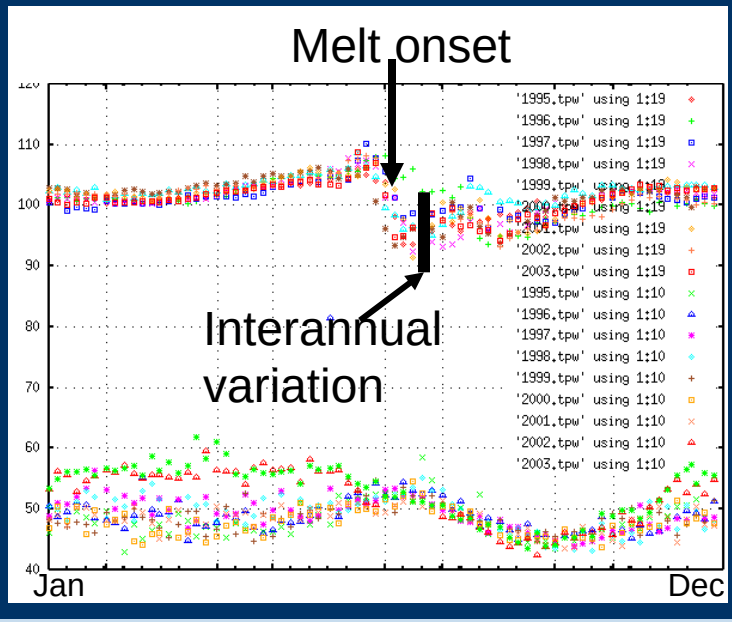
- Assess algorithms in more detail
  - Not all algorithms created equal
  - Biases in certain conditions
- Investigate use of other ancillary fields (e.g., surface air temps, dynamic SSTs instead of SST climatology)
- Apply lessons learned from collaboration with ESA EUMETSAT

ESA EUMETSAT OSISAF sea ice product

Collaboration between NSIDC the ESA Satellite Application Facility, Ocean and Sea Ice (OSISAF)

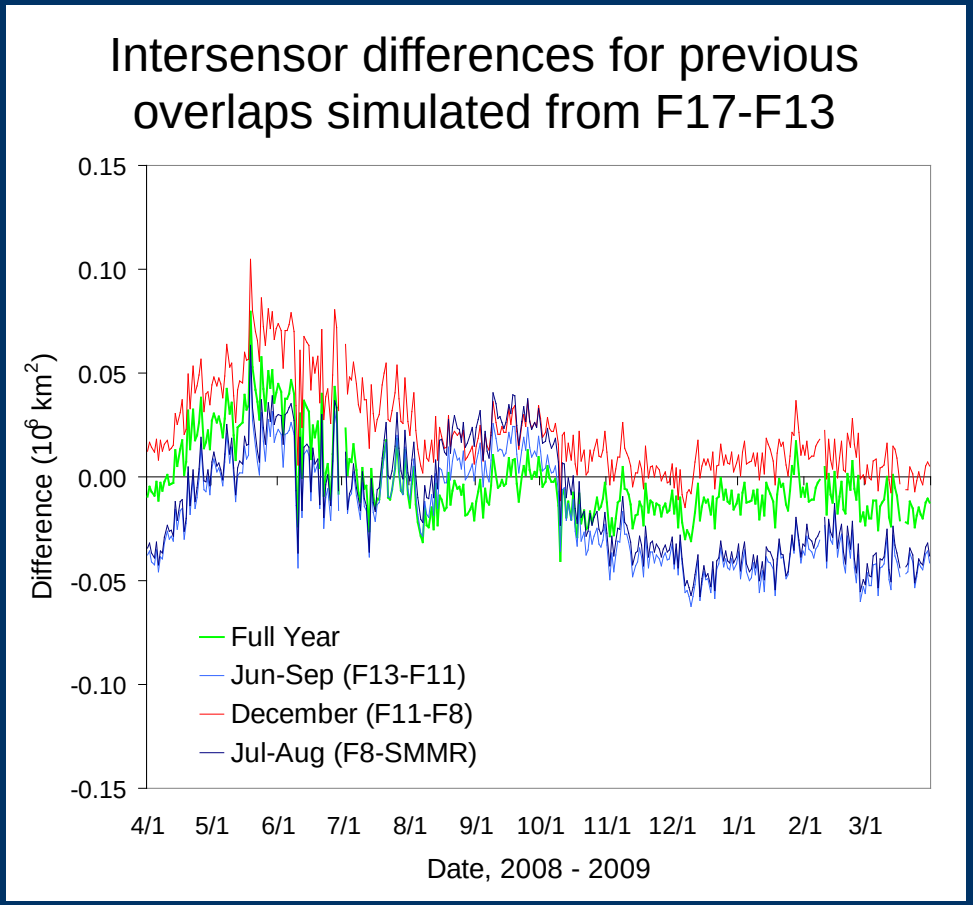
- Joint workshop in Feb 2007
- NSIDC SMMR T_B Processing (contract with EUMETSAT)
- OSISAF SSM/I T_B and Sea Ice Processing
  - Combined Bristol, Bootstrap, and high-freq. algorithm
  - Atmospheric correction from ECMWF
  - Dynamic tiepoint calculation with uncertainties based on variability of sea ice surface
- Continuing informal (i.e., unfunded) collaboration





Intersensor calibration plans

- Longer overlap periods would improve intersensor calibration (right)
- Include AMSR-E for intersensor calibration
  - Initial studies completed
  - Use most recent, highest quality sensor instead of oldest



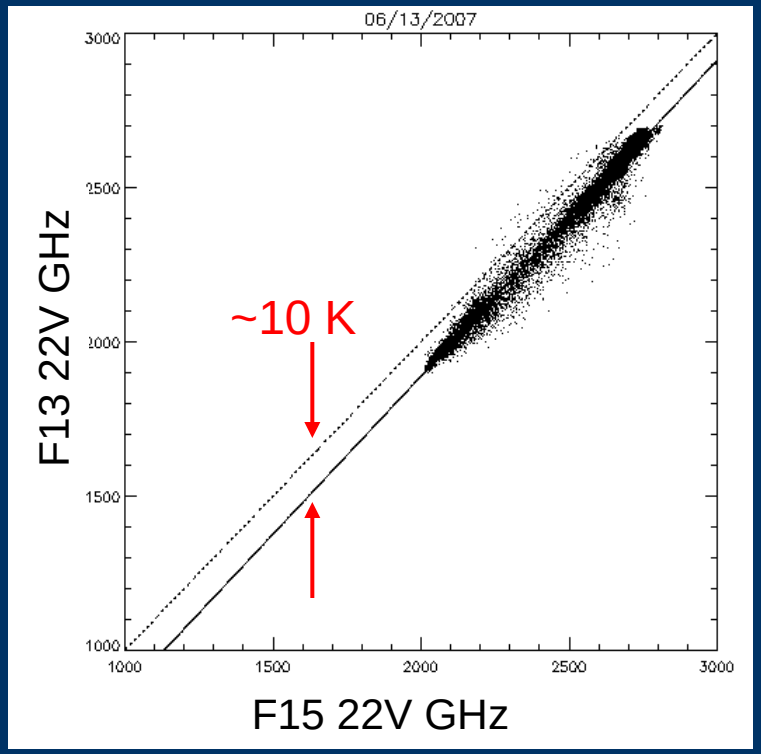
Issues for sea ice concentration products

- Final Tbs from Remote Sensing System
  - Versioning has changed (calibration, geolocation, etc.)
  - Reprocess entire timeseries from consistent version and maximum overlap
  - Reprocessed Tbs, SDS FCDRs?
- How to integrate capabilities of newer sensors while keeping consistency
  - AMSR-E, higher spatial resolution, new channels
  - MIS, GCOM-W, etc.
  - Parallel timeseries?: (1) consistent long-term climate record, (2) best available product at time
  - Merged product as single sea ice estimate, with input algorithms provided if desired

Issues for near-real-time data

- Operational requirements vs. CDR requirements
  - F15 radcal beacon, interference with 22 GHz
- New sensor, SSMIS
  - 37H GHz channel bias during summer 2009
  - Apparently undiscovered for 4 months
  - Reprocessing status unclear
- New data source for NSIDC – was NASA Marshall, now NOAA CLASS
  - Limited documentation and user services
  - Lack of familiarity with products
- NRT will not be CDRs, but:
  - there is increasing demand for timely and reliable near-CDR quality products
  - NRT issues ultimately feed into CDR issues

Issues with NRT passive microwave data



The primary source for long-term sea ice fields is U.S. Defense Department operational satellites

- Limited satellite information
- Limited overlap periods
- Changes made without warning and without consultation with climate community (e.g., F15 beacon)
- Errors can occur without notice – may not be immediately noticeable
- Focus is on operational uses, not climate products

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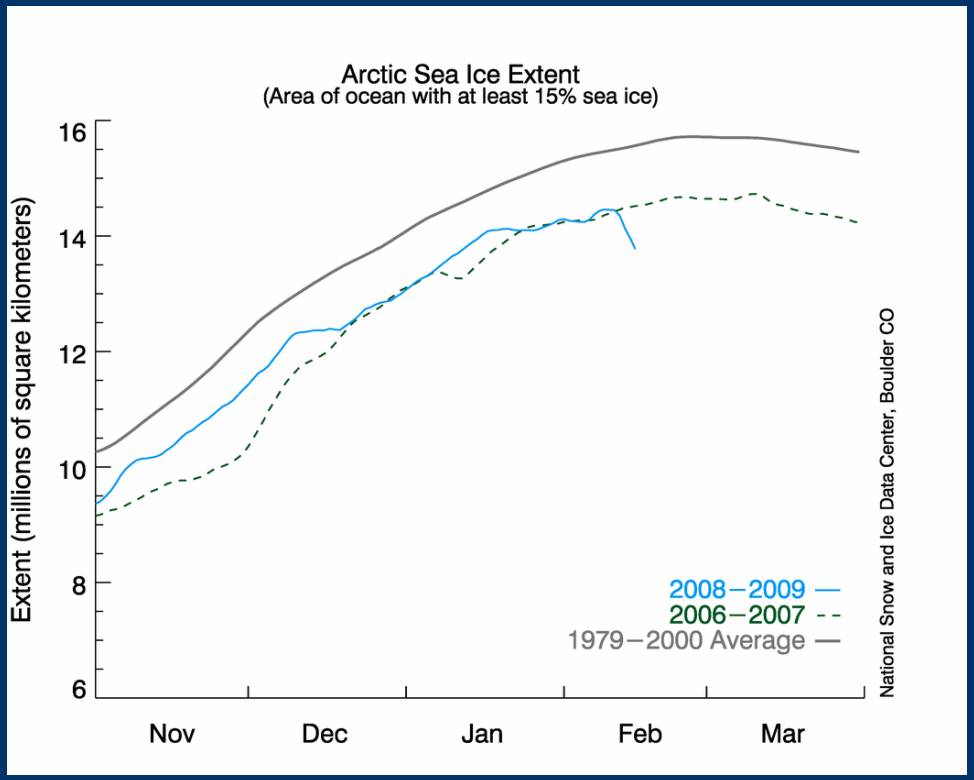
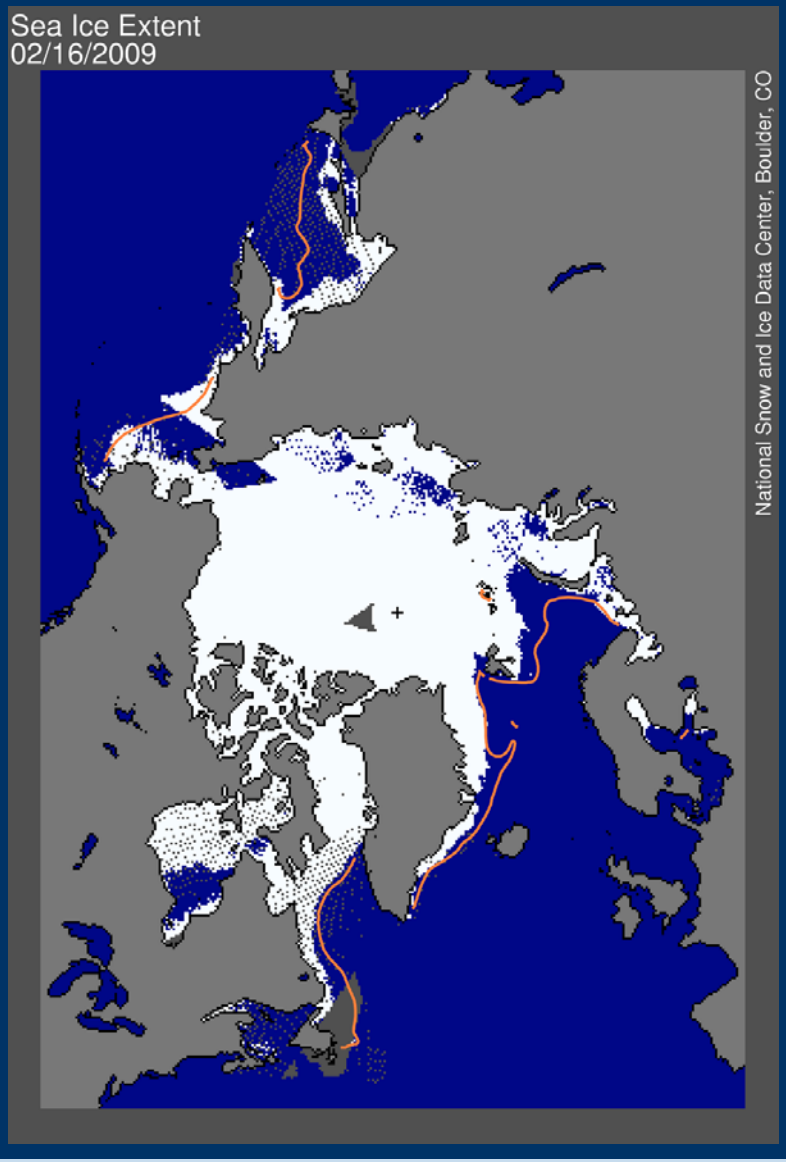
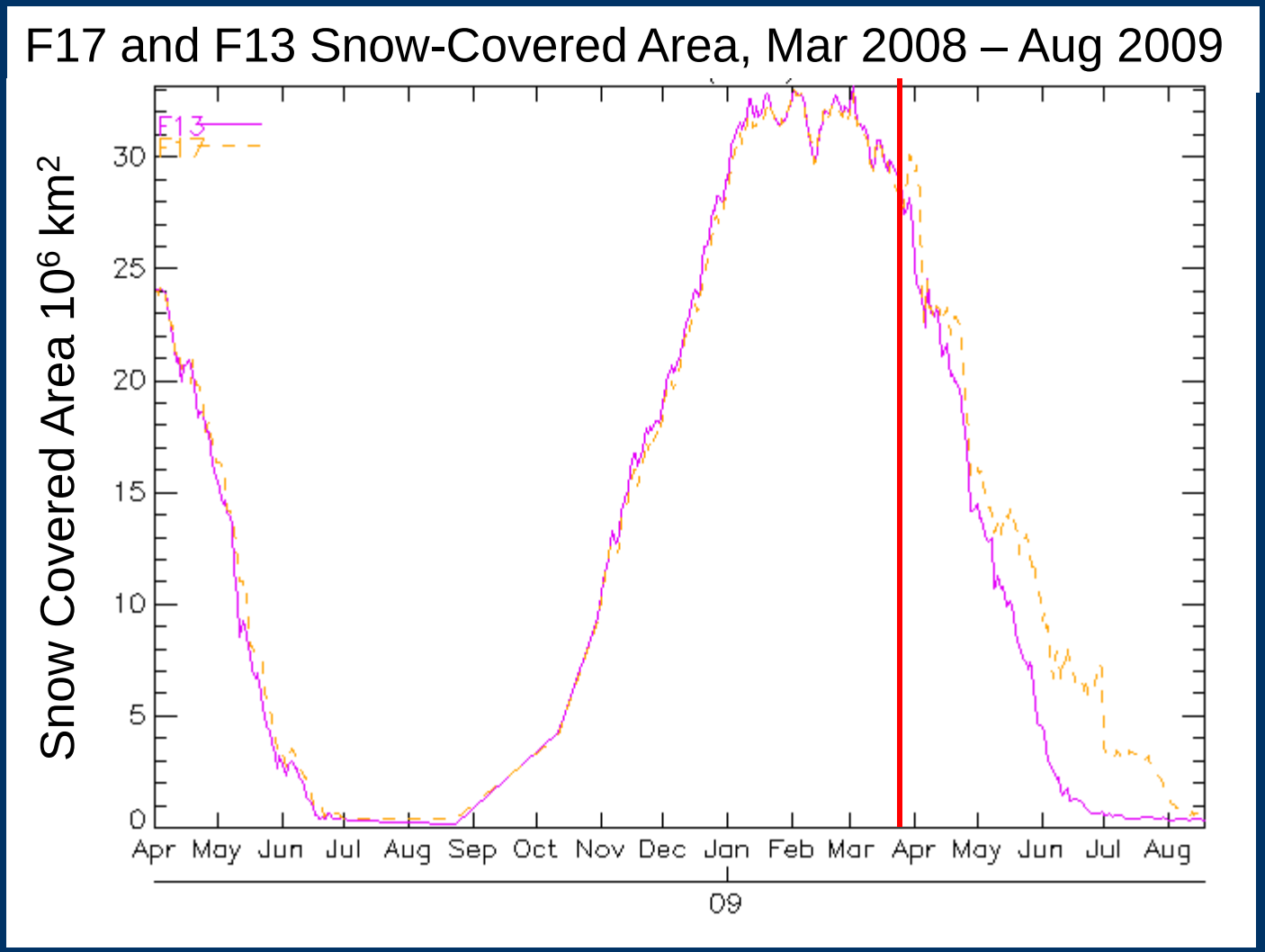
F15 Radcal Beacon and 22 GHz





Caused by sun-sensor angle.
Unnoticed bias for ~2 weeks before “crash”.

F17 37H, snow covered area – summer 2009



Caused by 3-4 K bias in F17 37H.

Uncorrected for over 4 months.

Correction ~1 week after NSIDC inquiry.

Schedule for remaining year

- Add metadata to NSIDC sea ice products
- Run NASA Team 2 on SSM/I
  - Intercompare with AMSR-E NASA Team 2
  - Further intercalibration AMSR-SSM/I
- When it becomes available, examine EUMETSAT product for possible collaboration and adaptation of some methods for data quality estimates
- Look for opportunity to do full reprocessing (using reprocessed Tb FCDRs?)
- Integrate with cryosphere CDR product development team (J. Key, Univ. Wisc., PI)
  - First product team meeting, 28 October in Boulder
- Collaborate on algorithm development for JAXA GCOM-W AMSR2 (science team meeting, Jan 2010)

Resources

- Key personnel
  - W. Meier, PI (research, data management)
  - R. Duerr (metadata), F. Fetterer (research, NOAA liaison), J. Stroeve (research)
  - Programmer, operations support; student
- Equipment
  - SAN archive, Linux servers at NSIDC, DAAC-funded
  - May need more infrastructure for future full reprocessing (esp. for Tbs)
- Key collaborating projects or personnel
  - NASA Goddard (J. Comiso, D. Cavalieri), ESA EUMETSAT, snow CDR (D. Robinson), cryospheric CDR science team (J. Key), JAXA
- NOAA points-of-contact or collaborators, as applicable
  - F. Fetterer (NSIDC), T. Haberman (NGDC), C. Fox (NGDC), J. Key (SSEC), J. Intrieri (NOAA)
- Target NOAA Data Center
  - Possibilities: NSIDC, NCDC, NGDC?