Sea Ice Climate Data Records

From an NSIDC perspective

Walt Meier

Contributions from:

Florence Fetterer, Ann Windnagel, Scott Stewart, Trey Stafford

National Snow and Ice Data Center
Advancing knowledge of Earth's frozen regions

CIRES

Affiliations

University of Colorado Boulder

Cooperative Institute for Research in Environmental Sciences

World Data System

Sponsors

National Aeronautics and Space Administration

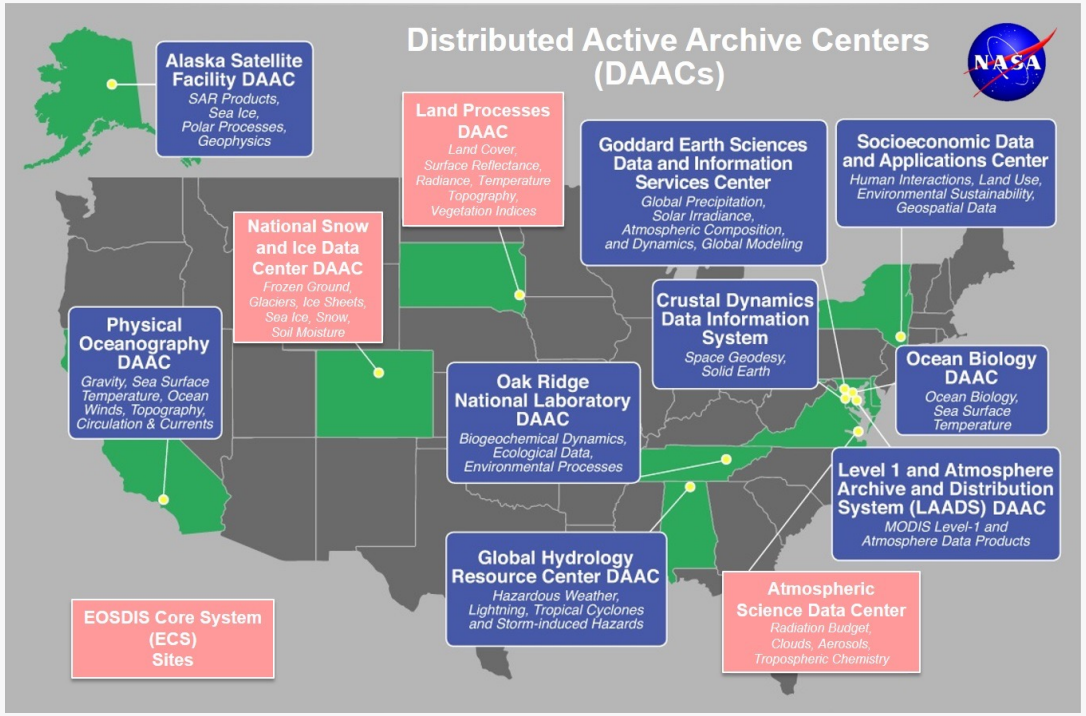
National Science Foundation

National Oceanic and Atmospheric Administration

NASA Snow and Ice DAAC at NSIDC

https://nsidc.org/data/data-programs/nsidc-daac

- DAAC = Distributed Active Archive Center
- NSIDC DAAC archives snow and ice, and other related geophysical parameters, from NASA satellite, airborne, and field missions
  - Passive microwave sea ice products
  - MODIS/VIIRS snow and ice products
  - ICESat, IceBridge, ICESat-2 (altimeters)
  - SMAP
- Amanda Leon, NSIDC DAAC Manager

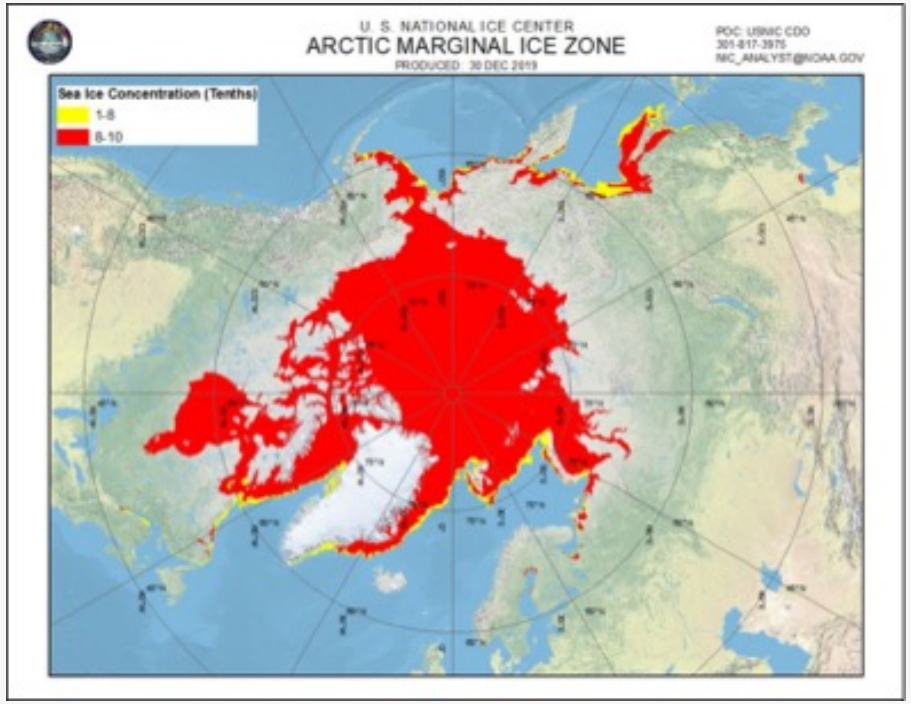


DAAC supported by NASA Earth Science Data Systems (ESDS) Program
Earth Science Data and Information System (ESDIS) Project

NOAA@NSIDC

https://nsidc.org/data/data-programs/noaa-nsidc

- NOAA archive center for snow and ice data
  - NOAA/NSIDC Sea Ice Concentration Climate Data Record
  - Sea Ice Index – monthly and daily images and extent values
  - Operational ice charts and climatologies
  - Data rescue efforts
  - SCICEX submarine data
  - Glacier photo collection
- Florence Fetterer, Program Manager
- Ann Windnagel, Project Manager

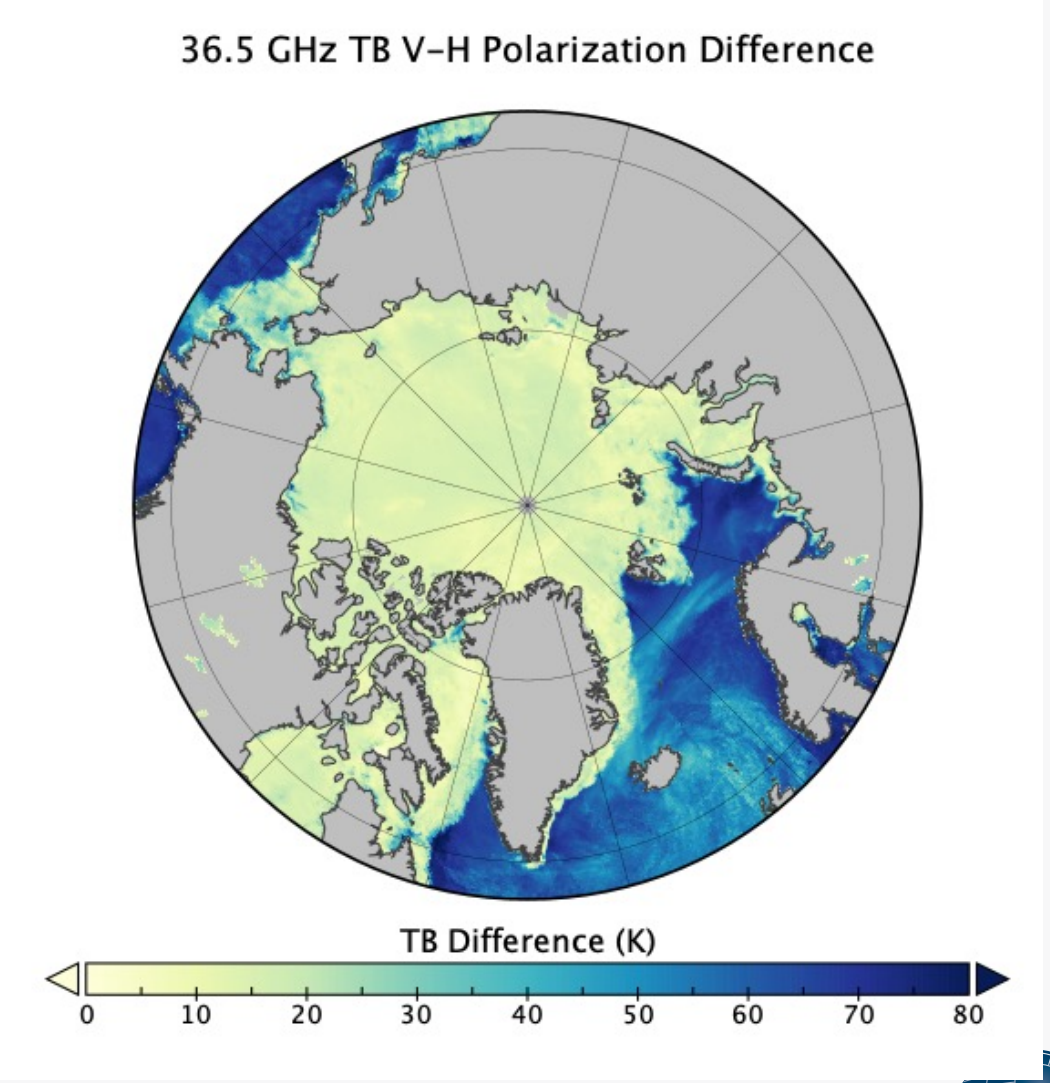


U.S. National Ice Center Marginal Ice Zone Chart

NOAA@NSIDC supported via cooperative agreement with NOAA NCEI,
and various funded projects (e.g., NOAA NESDIS STAR)

Sea ice concentration from passive microwave sensors

- Strengths
  - Complete daily coverage
  - All-sky capability
  - Continuous long-term record
  - Consistent sensor characteristics
- Limitations
  - Low spatial resolution
  - Surface ambiguities from heterogenous characteristics
    - Surface melt
    - Thin ice
    - Snow
  - Atmospheric emission (weather)
  - Land-spillover (mixed ocean-land)



21 March 2024

NASA AMSR2 AU_SI2, Meier et al., 2018, https://doi.org/10.5067/RA1MIJOYPK3P

Sea ice concentration from passive microwave sensors

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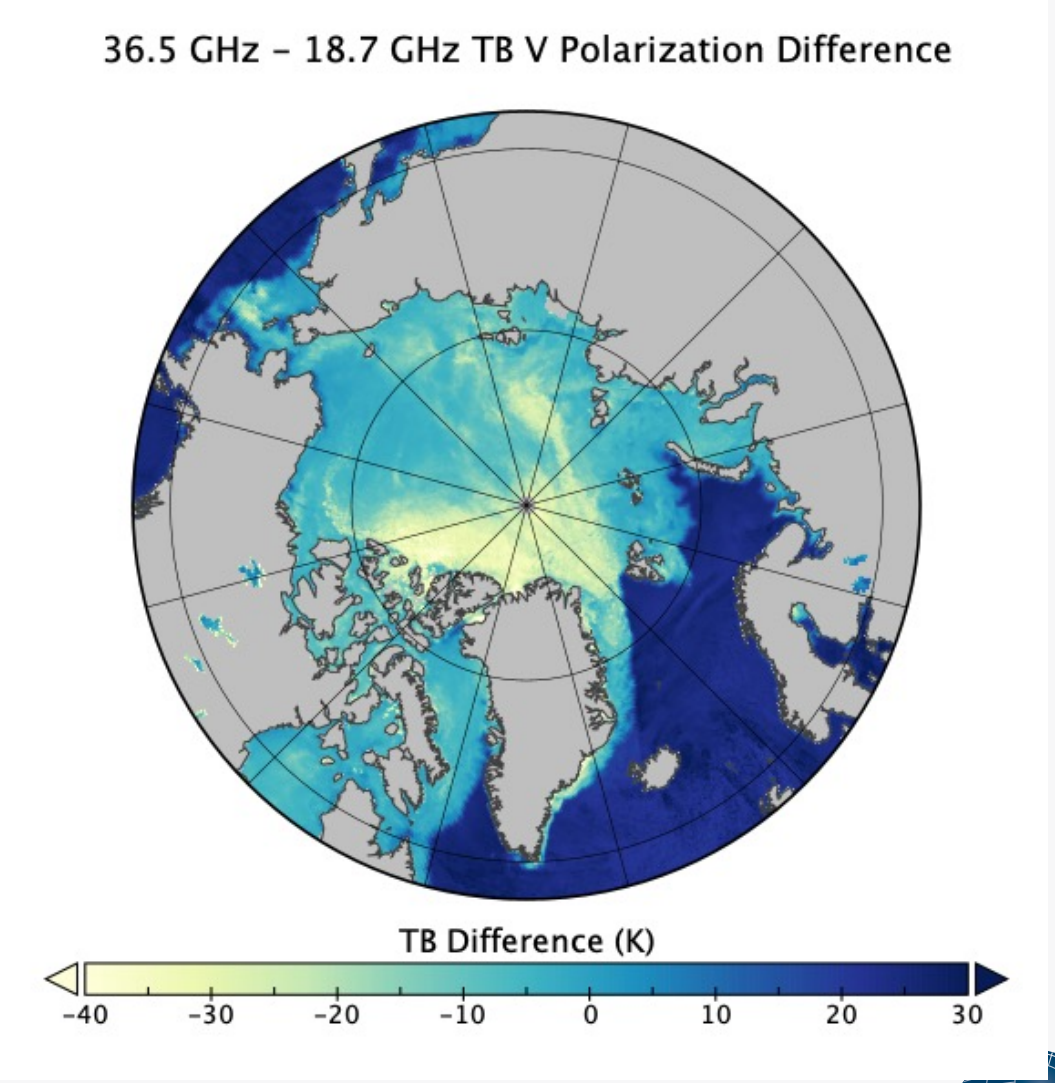

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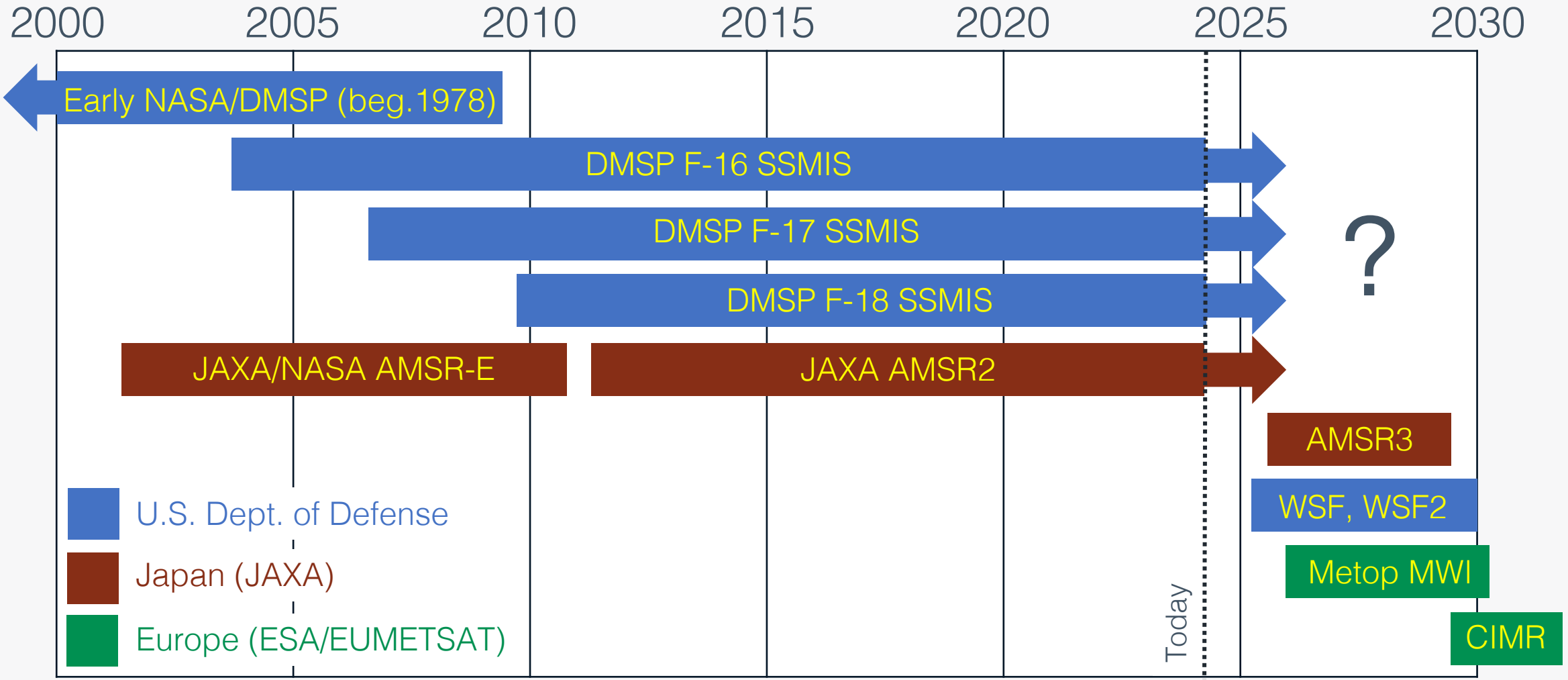
NASA AMSR2 AU_SI2, Meier et al., 2018, https://doi.org/10.5067/RA1MIJOYPK3P

PASSIVE MICROWAVE SENSORS FOR SEA ICE



DMSP = Defense Meteorological Satellite Program
SSMIS = Special Sensor Microwave Imager and Sounder
AMSR = Advanced Microwave Scanning Radiometer

WSF = Weather Satellite Follow-On
MWI = Microwave Imager
CIMR = Copernicus Imaging Microwave Radiometer

NSIDC

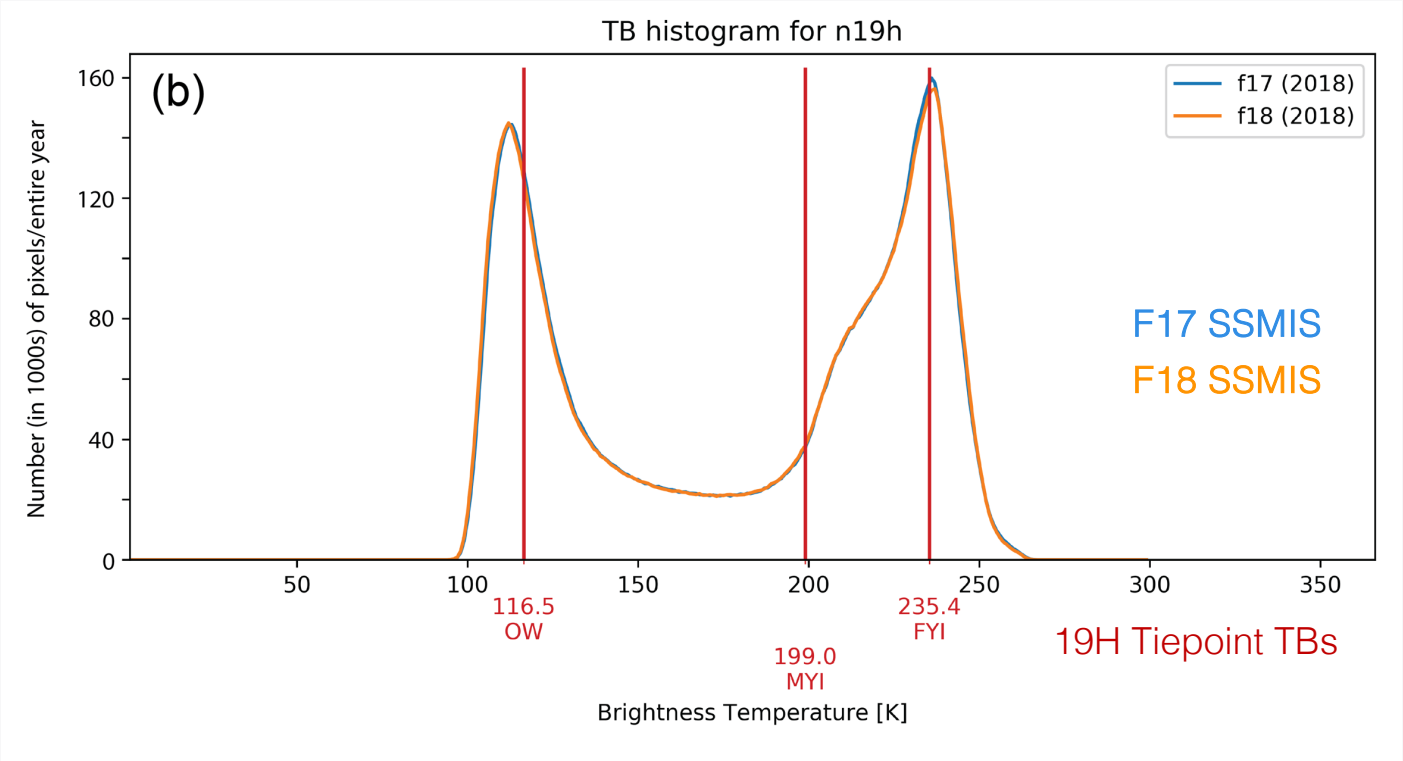
Development of passive microwave sea ice concentration climate records

- NASA Team (NT) algorithm (NASA Goddard)
  - SMMR, original development, 1978 – 1987
  - SSMI-SSMIS, inter-sensor calibration for consistency, 1987 – present
- NASA Bootstrap (BT) algorithm (NASA Goddard)
  - SMMR-SSMI-SSMIS, independent inter-sensor calibration, 1978 – present
- NOAA/NSIDC Climate Data Record (CDR)
  - SMMR-SSMI-SSMIS, combined NASA Team and Bootstrap algorithms
- OSI-SAF/CCI, 1978 – present
  - SMMR-SSMI-SSMIS, combined Bootstrap and Bristol algorithms
- AMSR-E and AMSR2 series from NASA, JAXA, OSI-SAF, 2002 – present

OSI-SAF = EUMETSAT Ocean and Sea Ice Satellite Application Facility
CCI = ESA Climate Change Initiative

INTERSENSOR CALIBRATION FOR SEA ICE

- Adjustment of algorithm coefficients (“tiepoints”) via TB regression
- If needed, adjustment of weather filter threshold to match extent
- Inter-calibration of TB values is not absolutely necessary



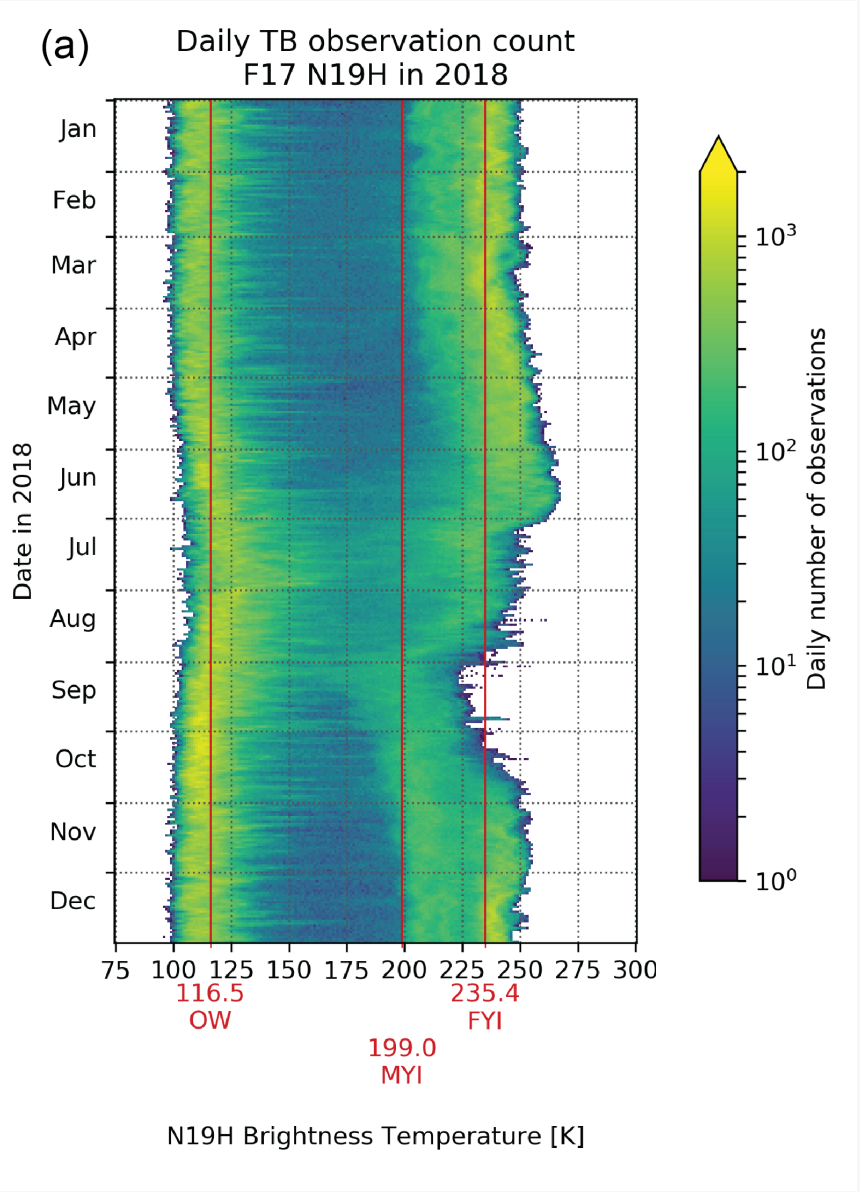
Tiepoints for 100% surface types:

- *Open water (OW)*
- *First-year ice (FYI)*
- *Multi-year ice (MYI)*

Meier et al., 2020,, https://doi.org/10.3390/rs12142197

INTERSENSOR CALIBRATION FOR SEA ICE

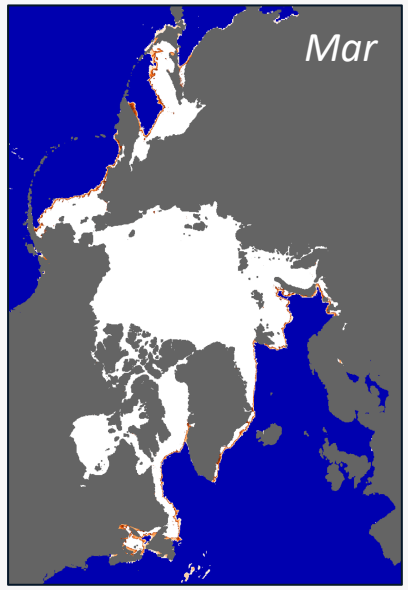
- Tiepoints effectively vary through the year due to differences in surface conditions, especially during melt and freeze-up
- Bootstrap and OSI-SAF use “dynamic tiepoints” that adjust daily

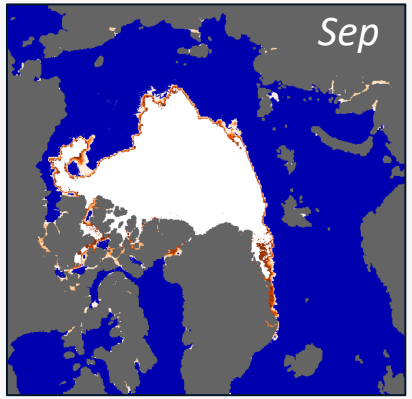


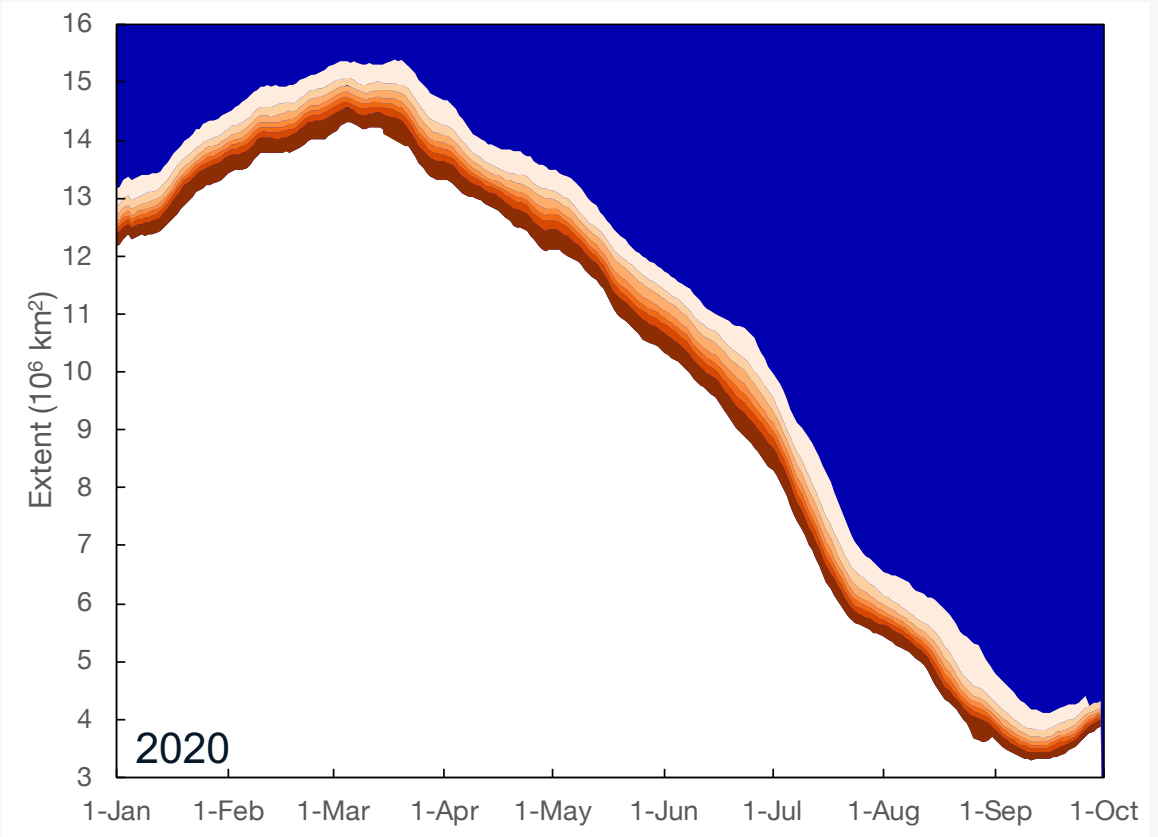
Meier et al., 2020,, https://doi.org/10.3390/rs12142197

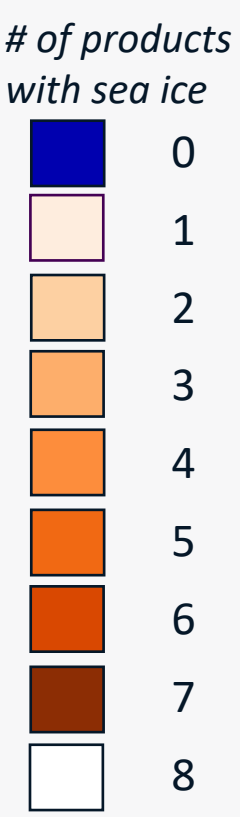
VARIATION IN PM SEA ICE EXTENT

Extent = sum of all grid cell areas with > 15% ice









AMSR2 Products: Bremen ASI, JAXA Bootstrap, NASA Team 2, OSI SAF
SSMIS Products: NOAA CDR, NSIDC NASA Team, OSI SAF
Other Products: MASIE (analyzed multi-sensor)

From Sea Ice Outlook 2020 Post-Season Report, https://www.arcus.org/sipn/sea-ice-outlook/2020/post-season

NSIDC

NASA Team and Bootstrap algorithm products

- Processed at NASA Goddard, delivered to NSIDC DAAC every ~3-6 months
- Sensor-specific adjustments to algorithm coefficients (”tiepoints”) for inter-sensor calibration → consistent time series
- Automated weather filters and land-spillover corrections
- Spatial and temporal interpolation to fill gaps
- Manual corrections to remove errors

Not documented!

- No grid cell error estimates or quality indicators
- Until recently, flat-binary with limited or no file-level metadata (now NetCDF)

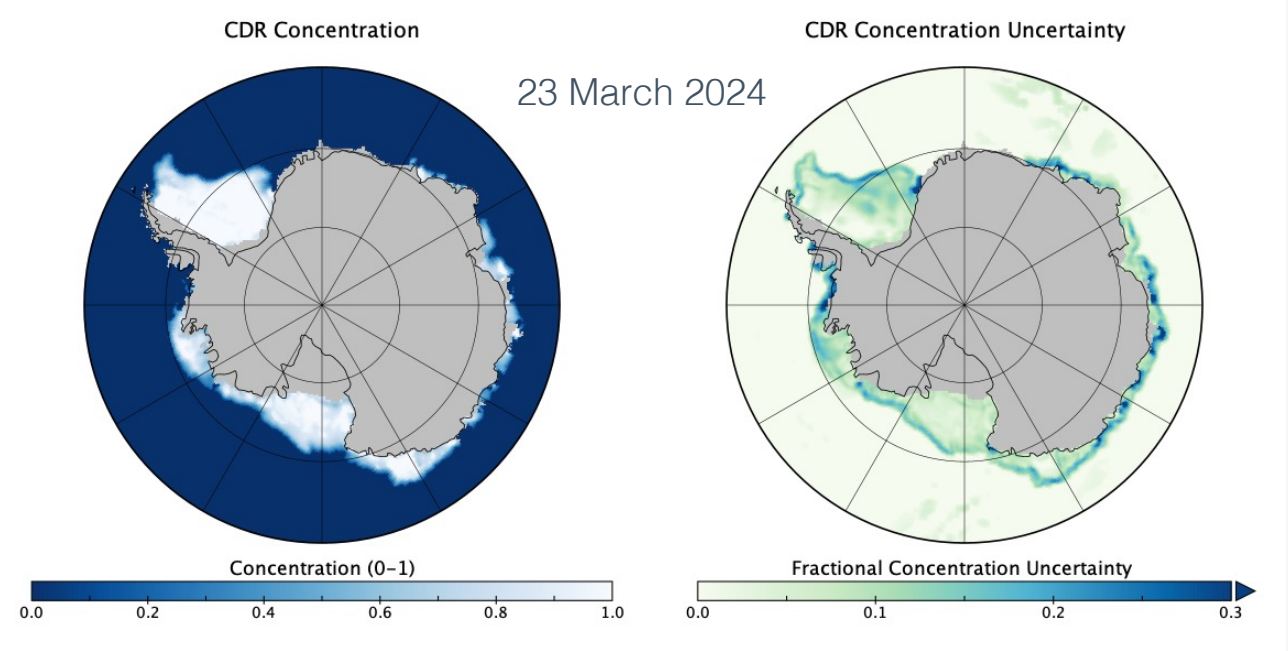
- NSIDC DAAC produces a NRT version of the NASA Goddard product, updated daily with 24-hour latency – no manual QC

NASA Team, DiGirolamo et al., 2022, https://doi.org/10.5067/MPYG15WAA4WX
Bootstrap, Comiso, 2023, https://doi.org/10.5067/X5LG68MH013O
NRT NASA Team, Meier et al., 2021, https://doi.org/10.5067/YTTHO2FJQ97K

NOAA/NSIDC SEA ICE CONCENTRATION CDR

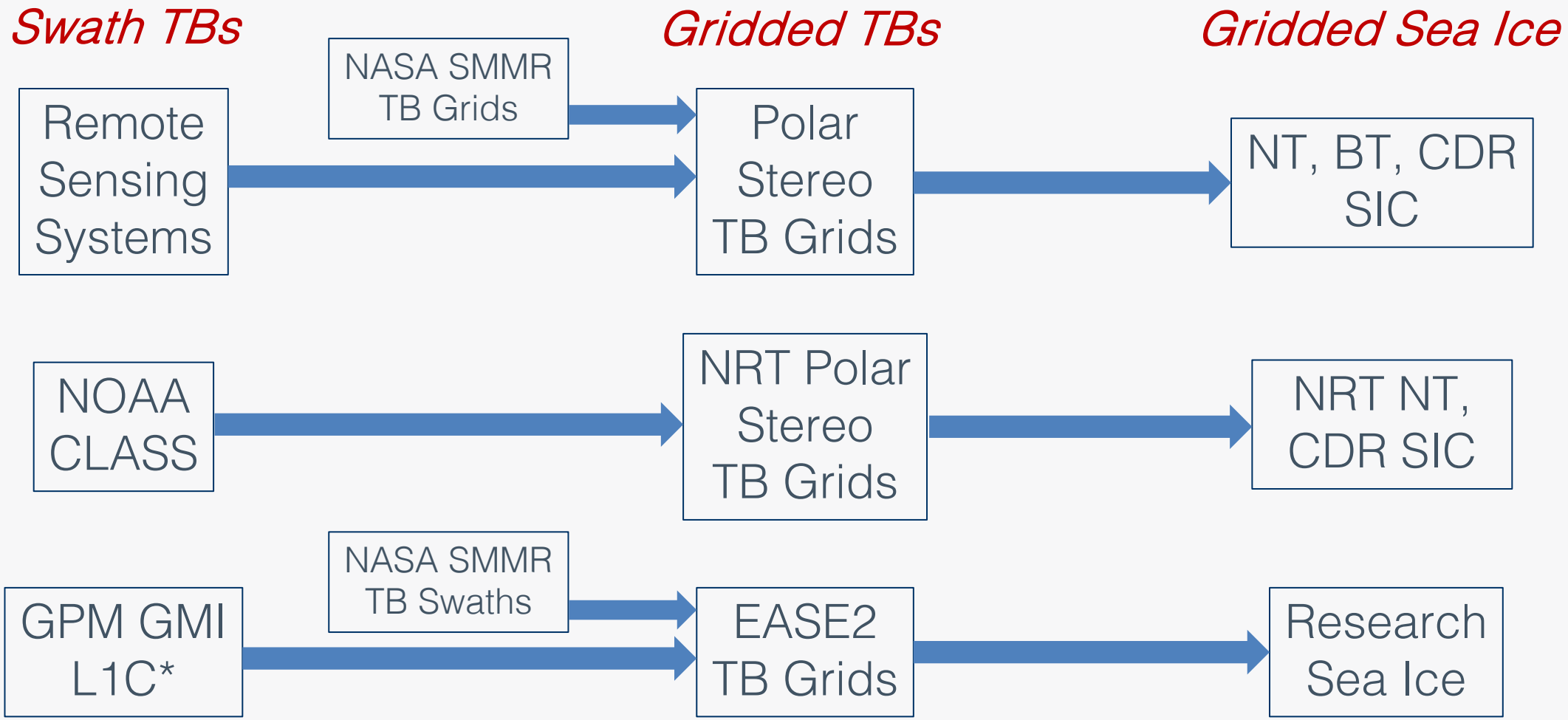
- Combined NASA Team and Bootstrap algorithm
- Processed at NSIDC
- Software publicly available

- All processing is automated, no manual QC
- Error estimates at every grid cell
- NetCDF4 with CF metadata
- NRT version provided



NOAA/NSIDC CDR Version 4, Meier et al., 2021, https://doi.org/10.7265/efmz-2t65
NRT CDR Version 2, Meier et al., 2021, https://doi.org/10.7265/tgam-yv28

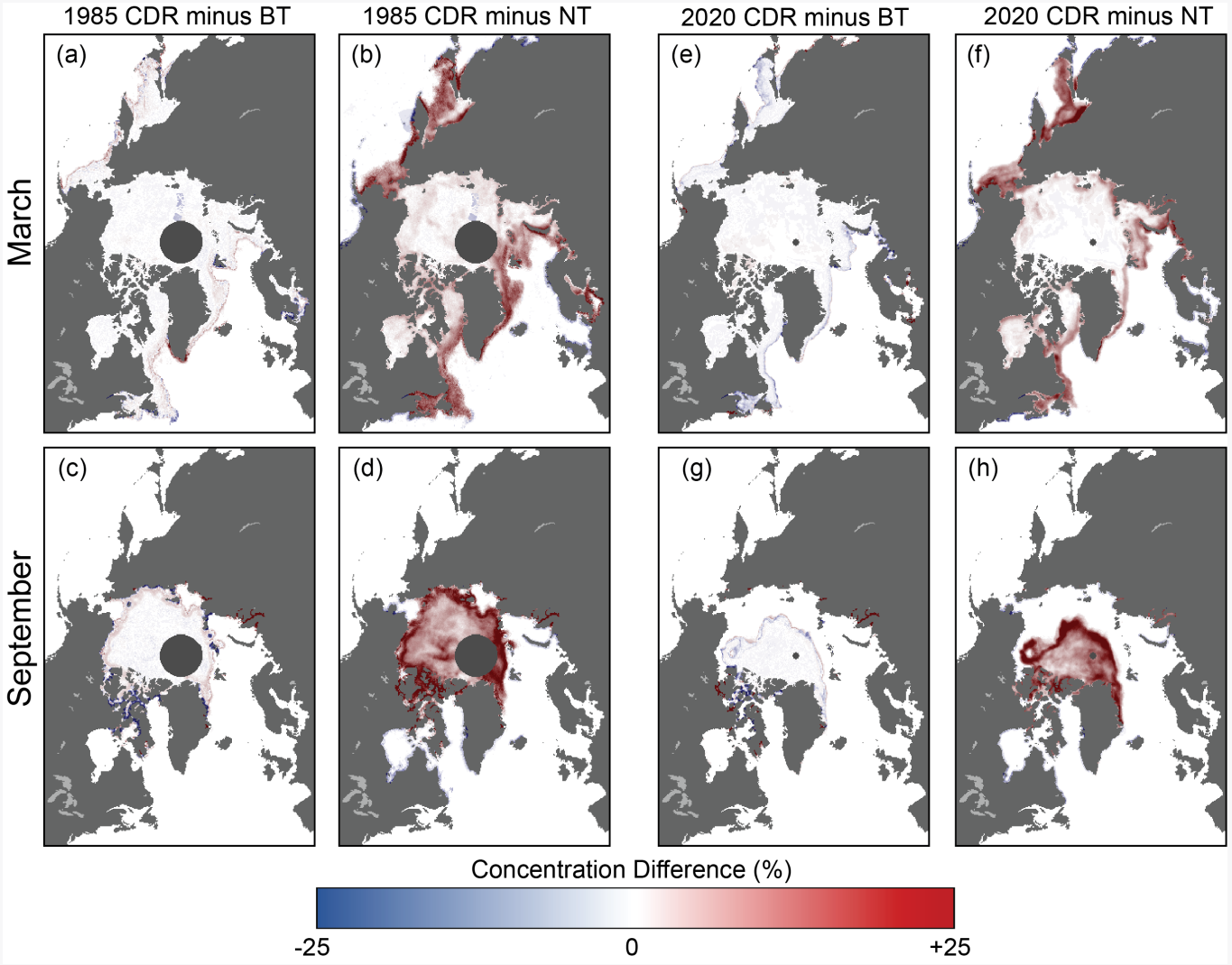
FCDR INPUT TO NSIDC SEA ICE



*Also known as CSU CDR TBs (Kummerow et al.)

Comparison of CDR, NT, and BT concentration

Northern Hemisphere

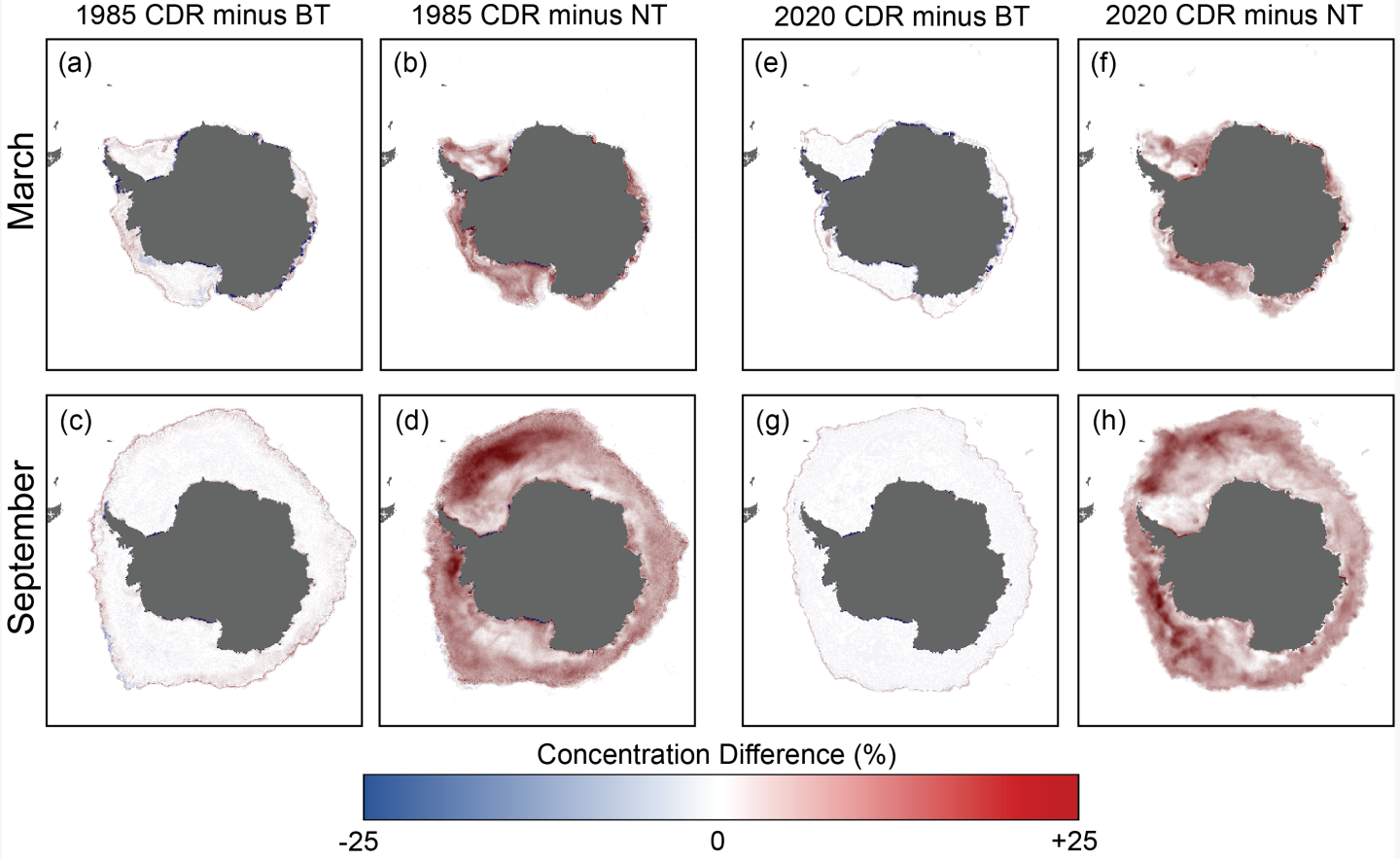


Bias in NT concentrations during melt is well-known

Meier et al., 2022, Remote Sensing, https://doi.org/10.3390/rs14030619

Comparison of CDR, NT, and BT concentration

Southern Hemisphere



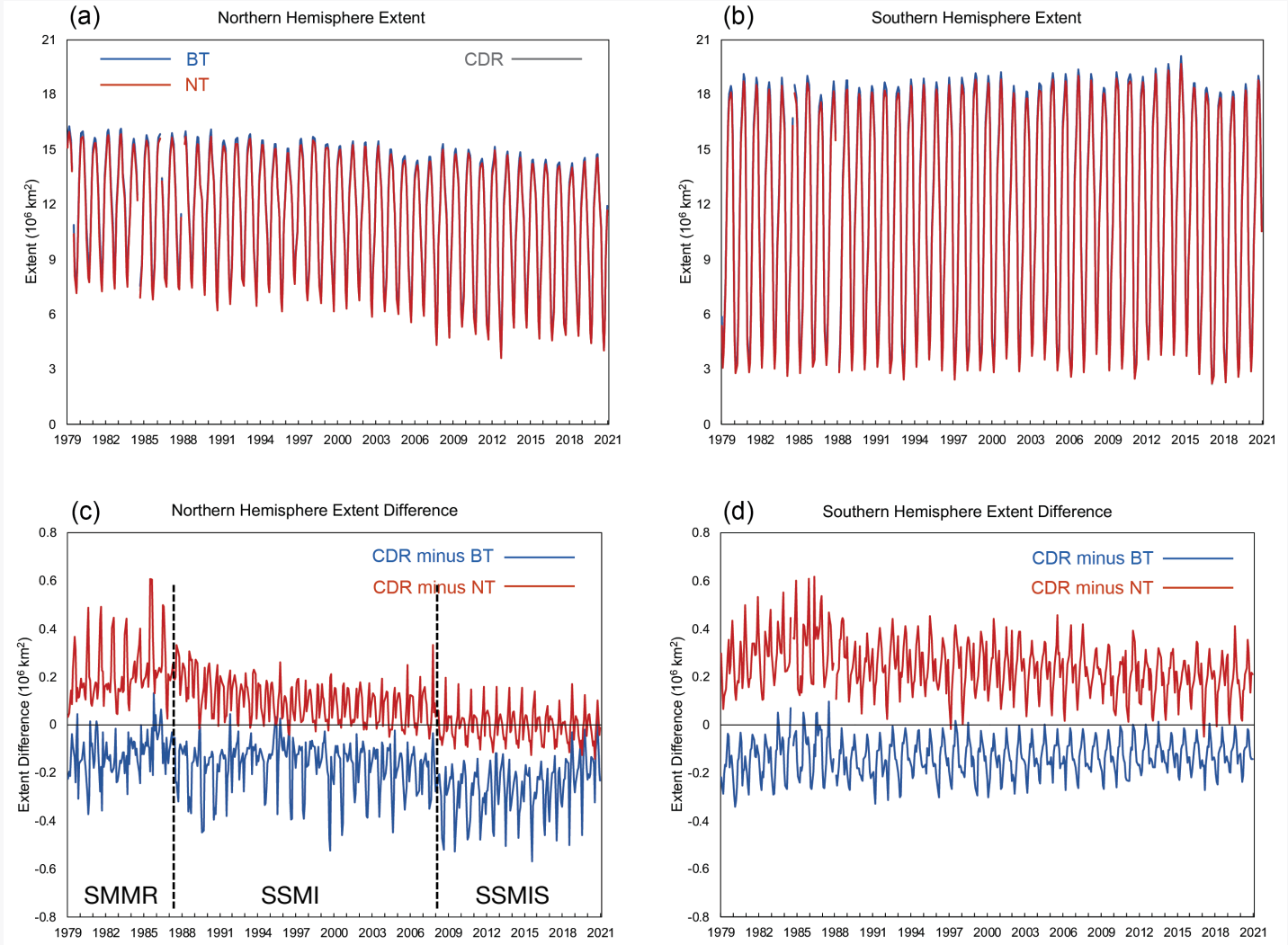
Bias in NT concentrations in Antarctic is also well-known.

Meier et al., 2022, Remote Sensing, https://doi.org/10.3390/rs14030619

Comparison of CDR, NT, and BT extent

Extent = sum of all grid cell areas with > 15% ice

North



South

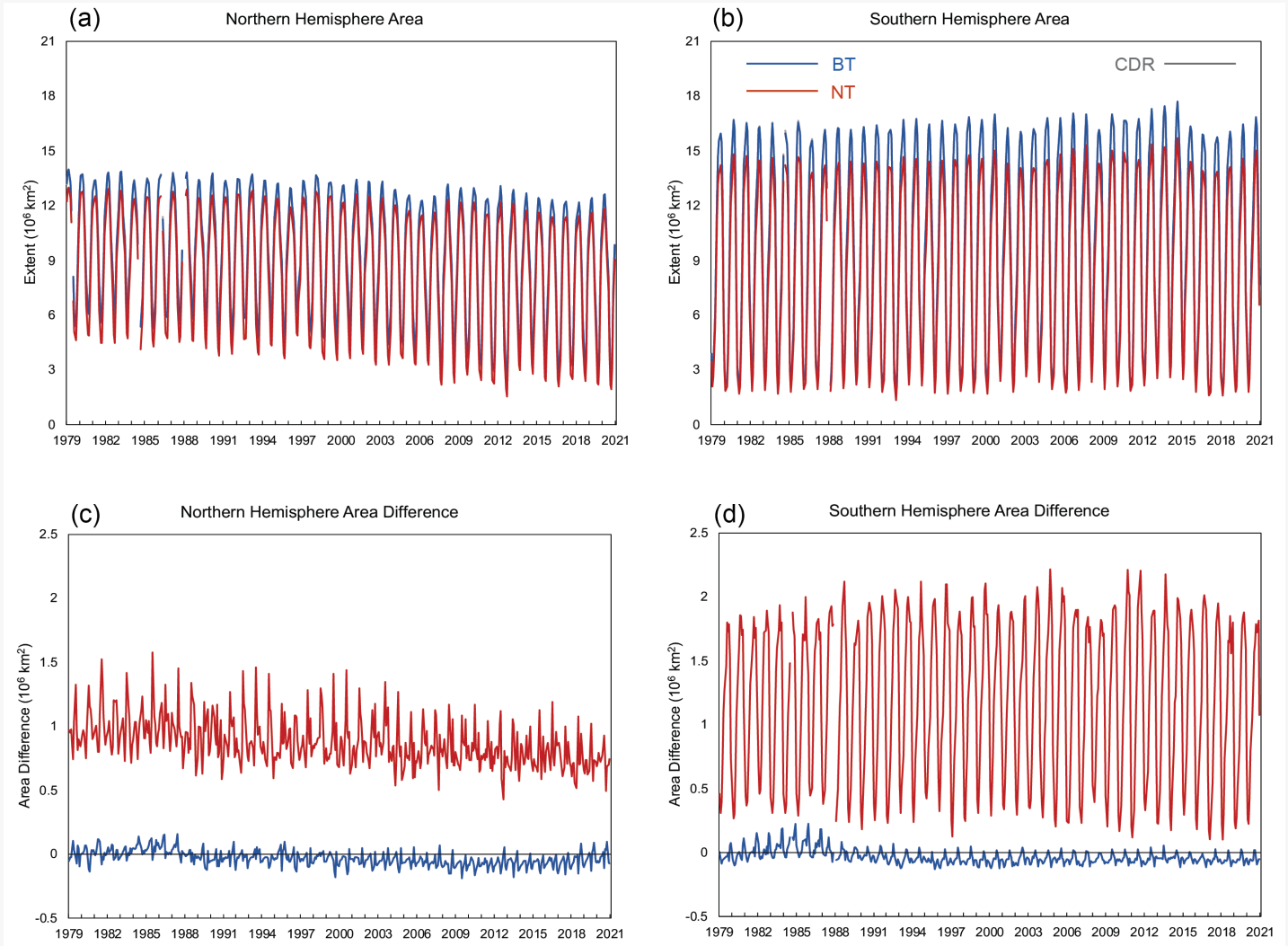
Difference in inter-sensor adjustments, particularly with NASA Team

Meier et al., 2022, Remote Sensing, https://doi.org/10.3390/rs14030619

Comparison of CDR, NT, and BT area

Area = sum of all grid cell areas with > 15% ice, with each cell weighted by its concentration

North

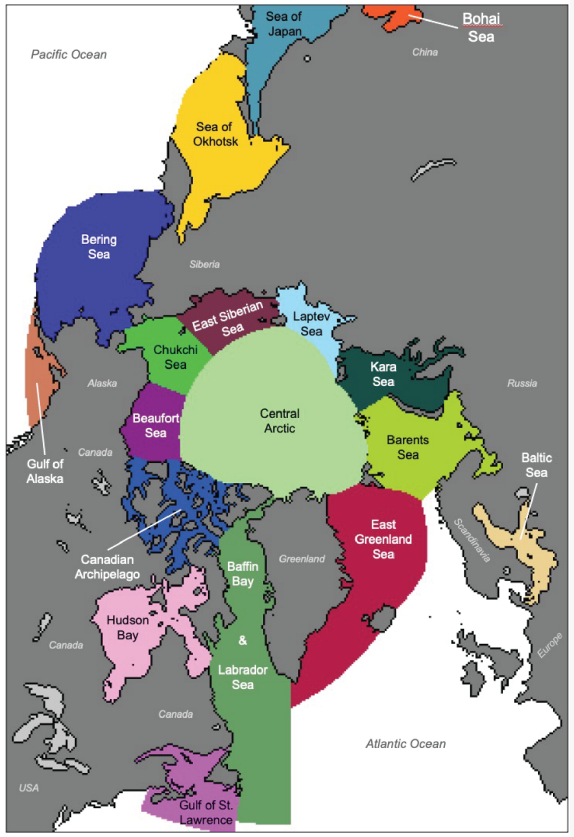


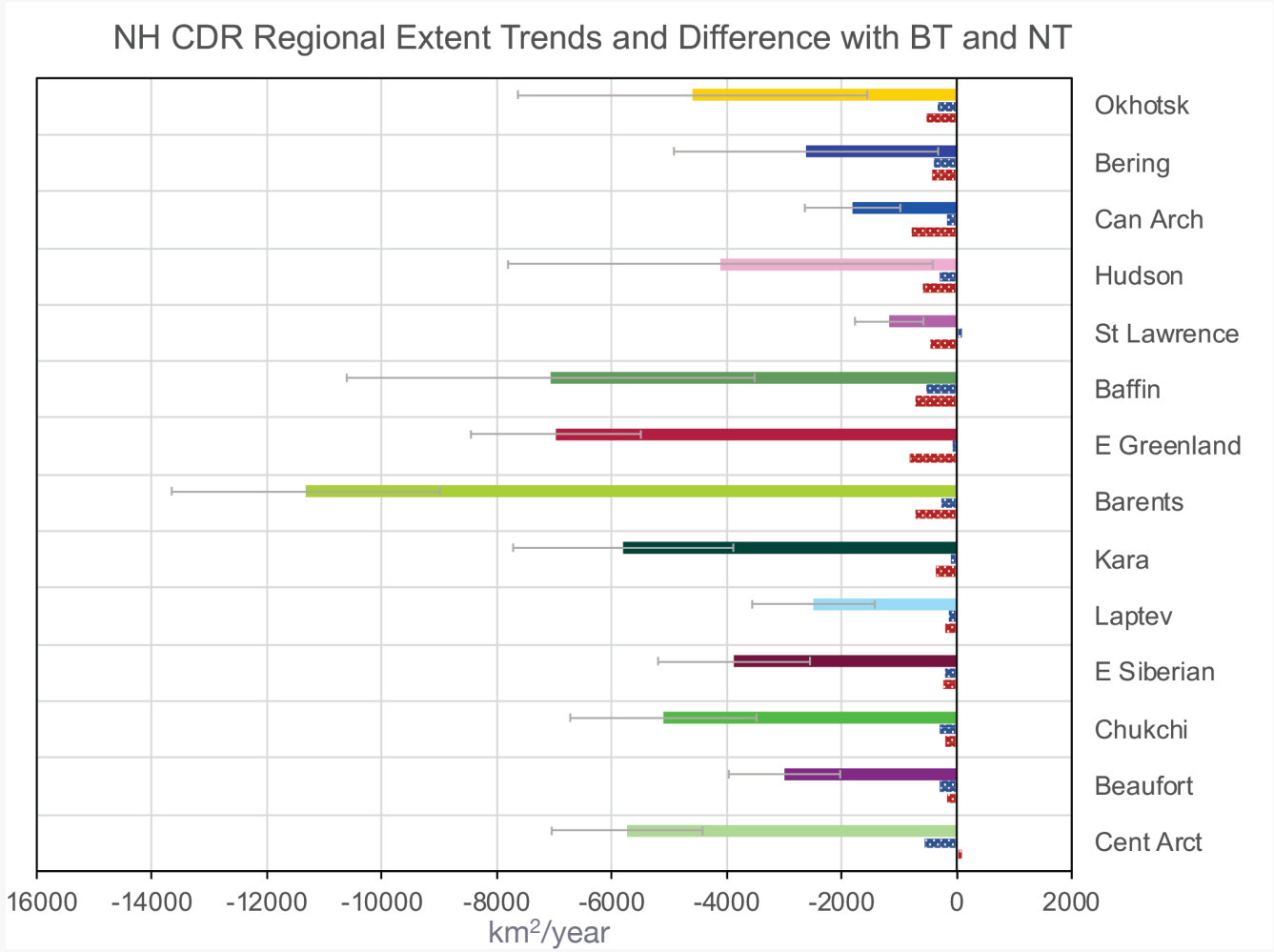
South

Inter-sensor calibration has less effect on area.

Meier et al., 2022, Remote Sensing, https://doi.org/10.3390/rs14030619

REGIONAL TRENDS: NORTH, 1979 – 2020

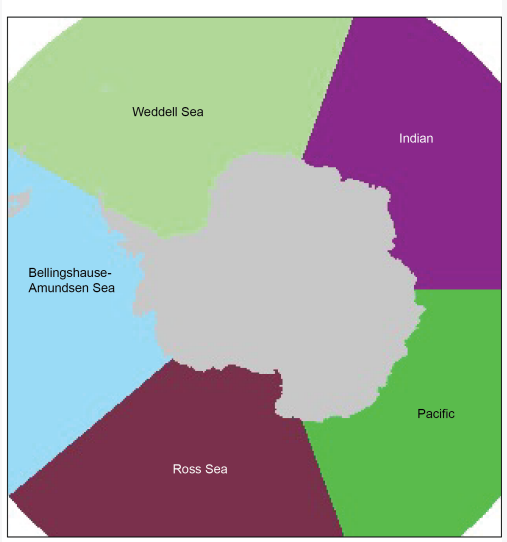


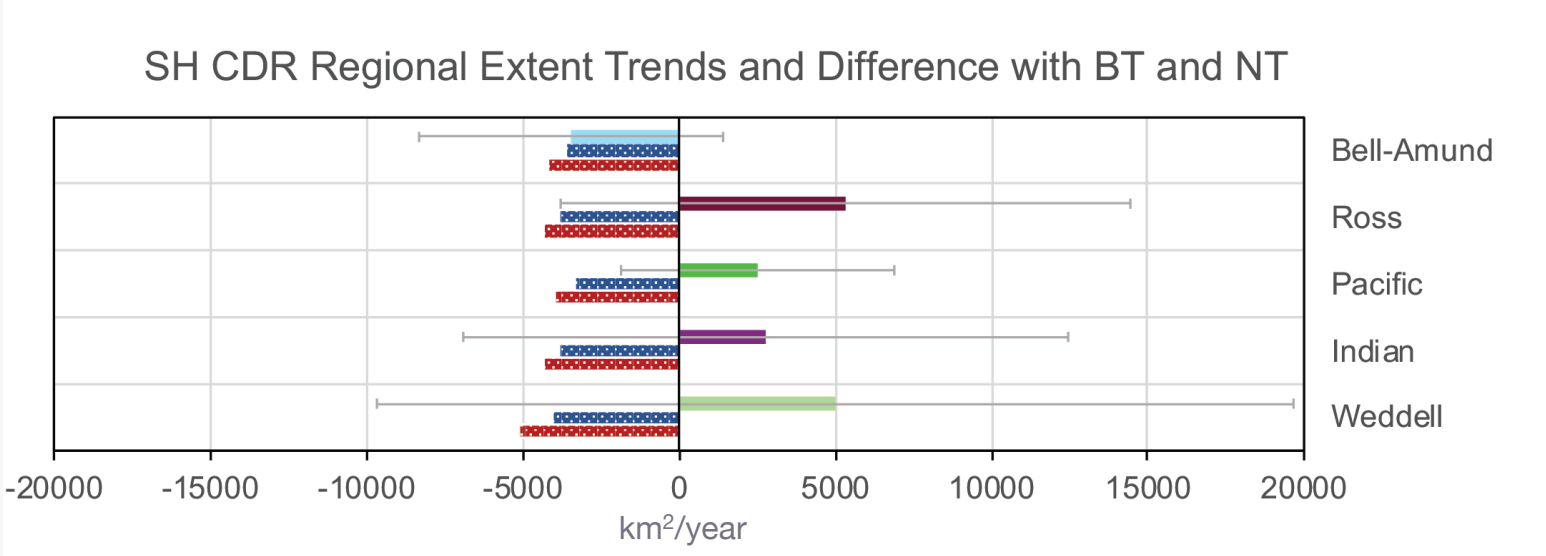


- Trends negative and statistically significant in all regions
- Trend differences generally small relative to trends

Meier et al., 2022, Remote Sensing, https://doi.org/10.3390/rs14030619

Regional trends: South, 1979 – 2020





- Trends positive in most regions
- Negative trend in Bellingshausen-Amundsen Sea region
- Trends are not statistically significant
- Trend differences at a similar scale as trend values

Meier et al., 2022, Remote Sensing, https://doi.org/10.3390/rs14030619

NSIDC Sea Ice Index: Value-added climate indicators aka "easy data"

Managed by NOAA@NSIDC

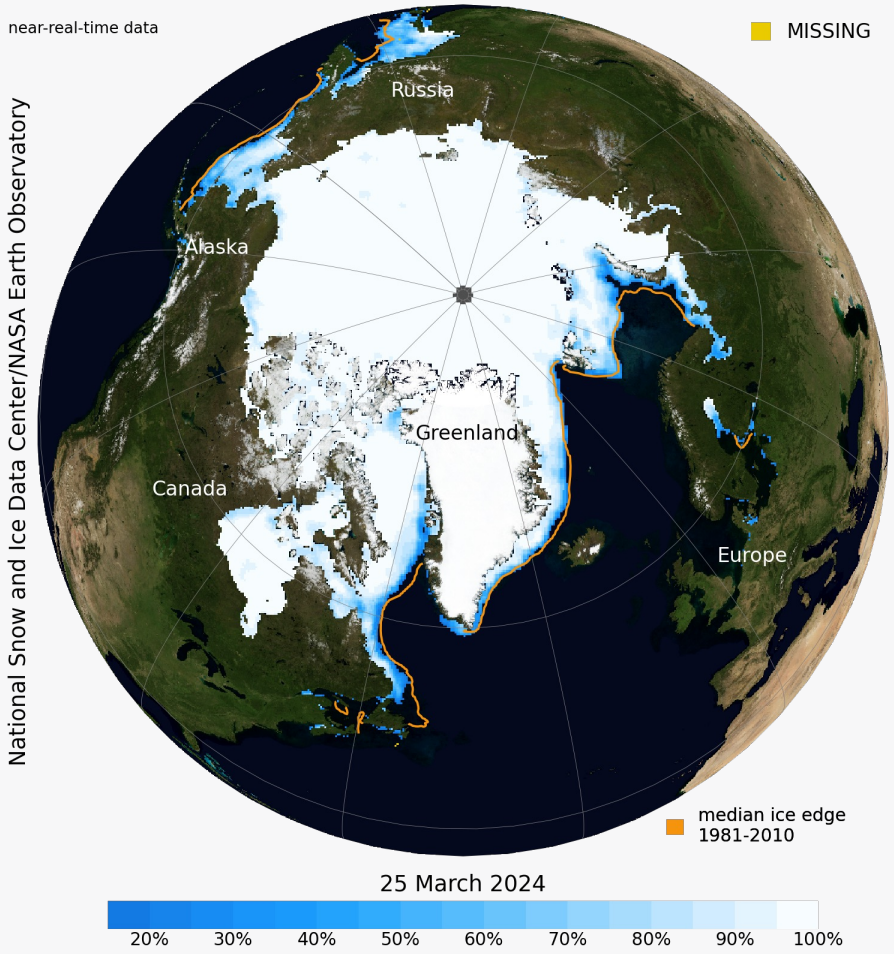
Sea Ice Extent and Sea Ice Area

- Spreadsheet data values
- Regional and hemispheric values
- Timeseries graphs

Images

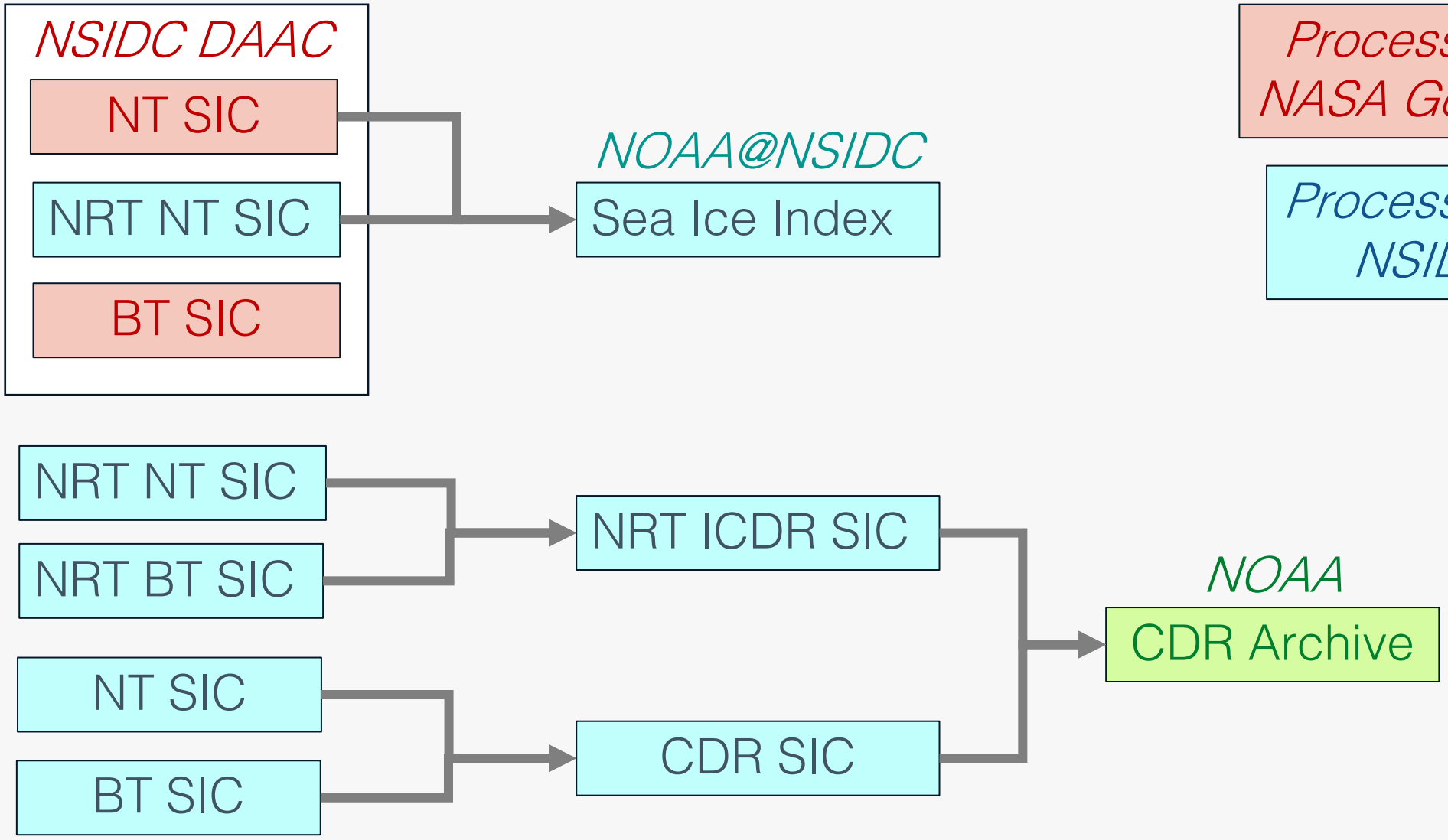
- Extent
- Extent Trend
- Concentration
- Concentration Anomaly
- Concentration Trend

Currently uses the NASA Team product

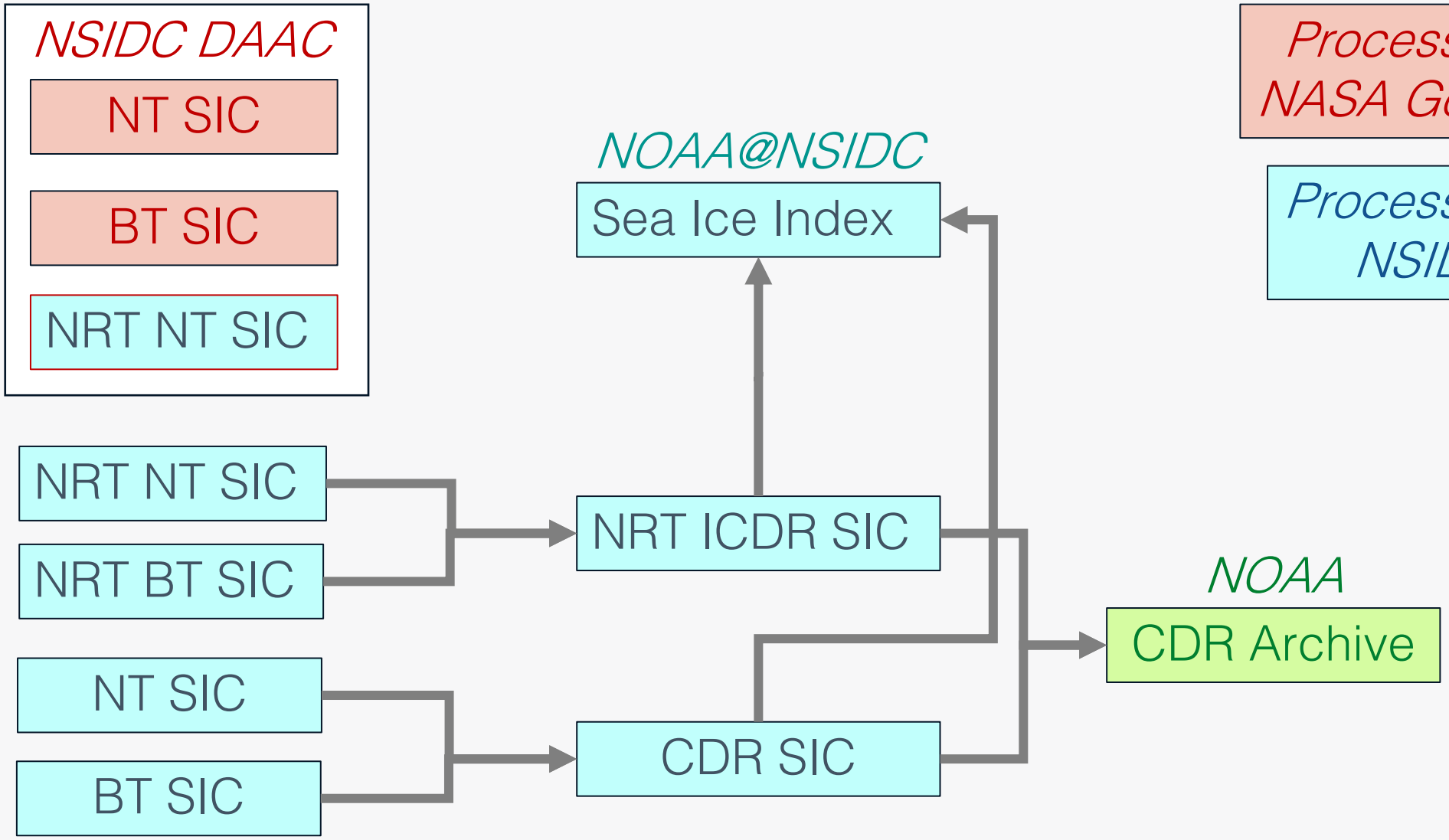


Sea Ice Index: Fetterer, et al., 2017, https://doi.org/10.7265/N5K072F8

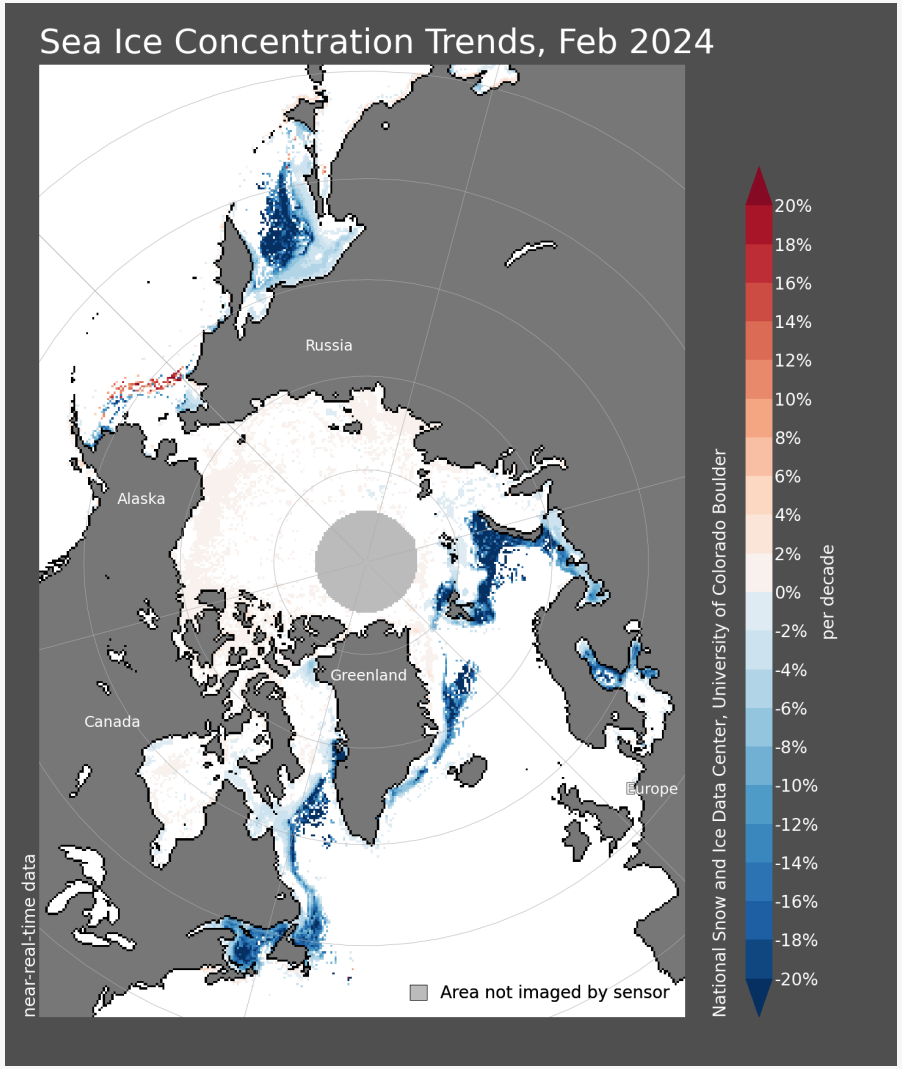
Sea Ice Index processing flow - current

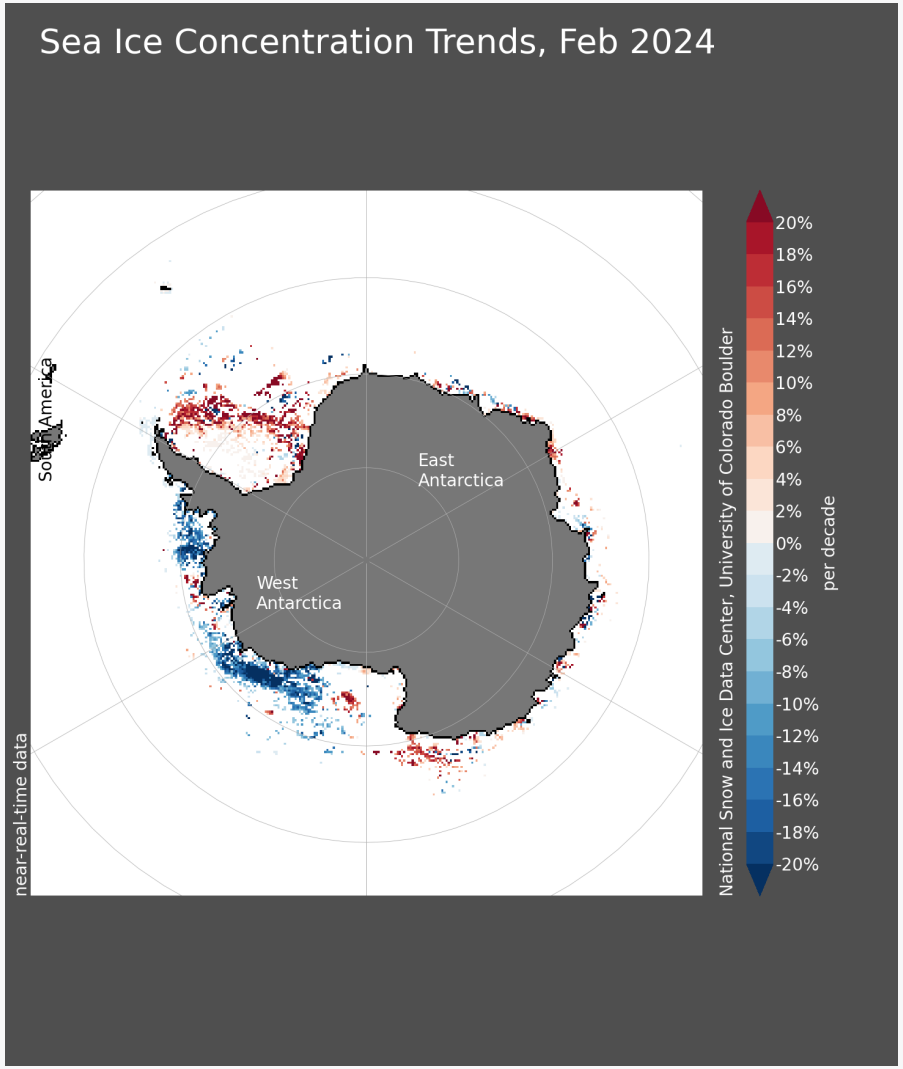


Sea Ice Index processing flow - future

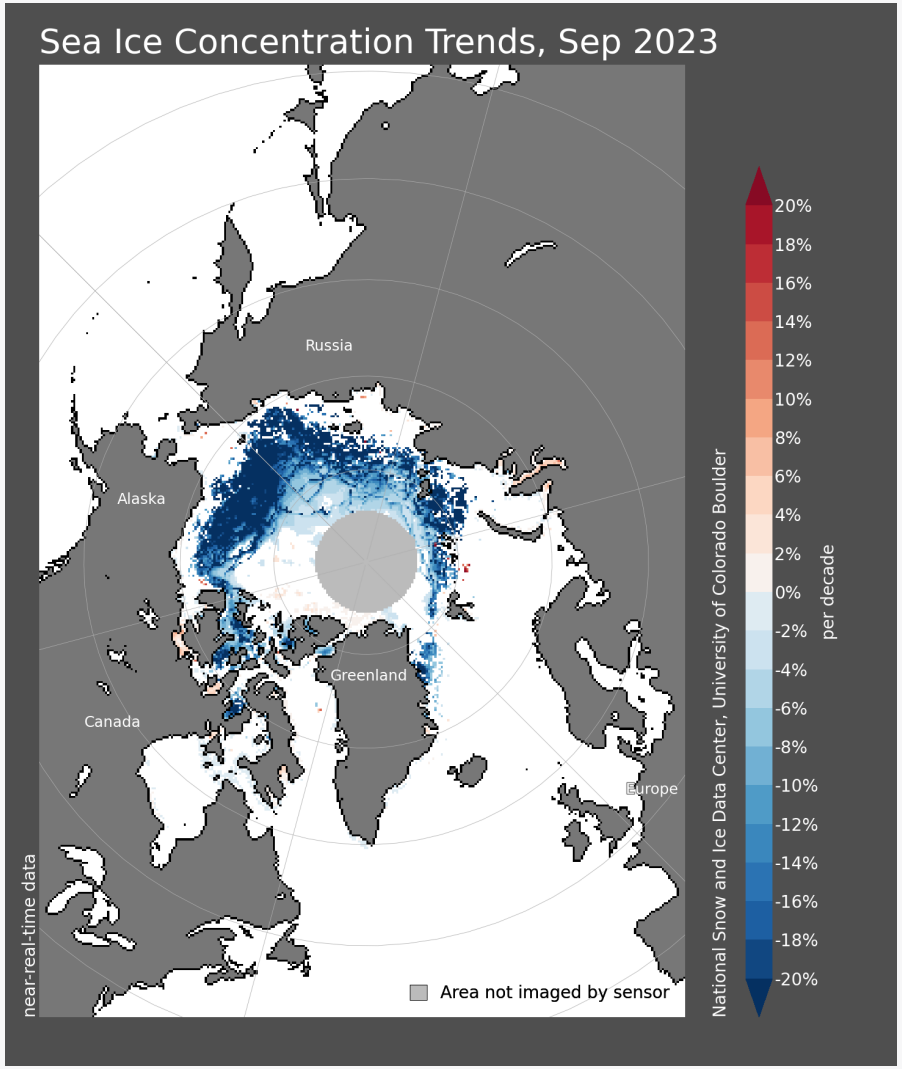


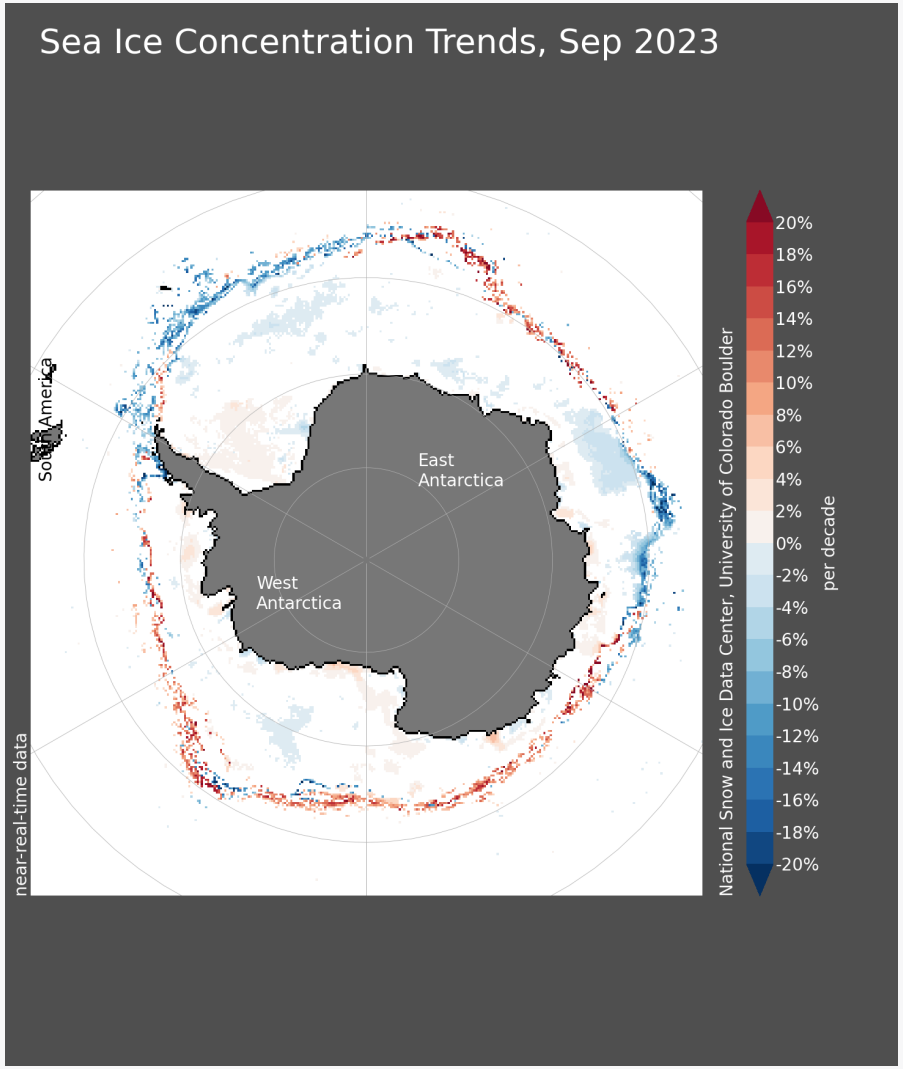
SII CONCENTRATION TRENDS - FEBRUARY



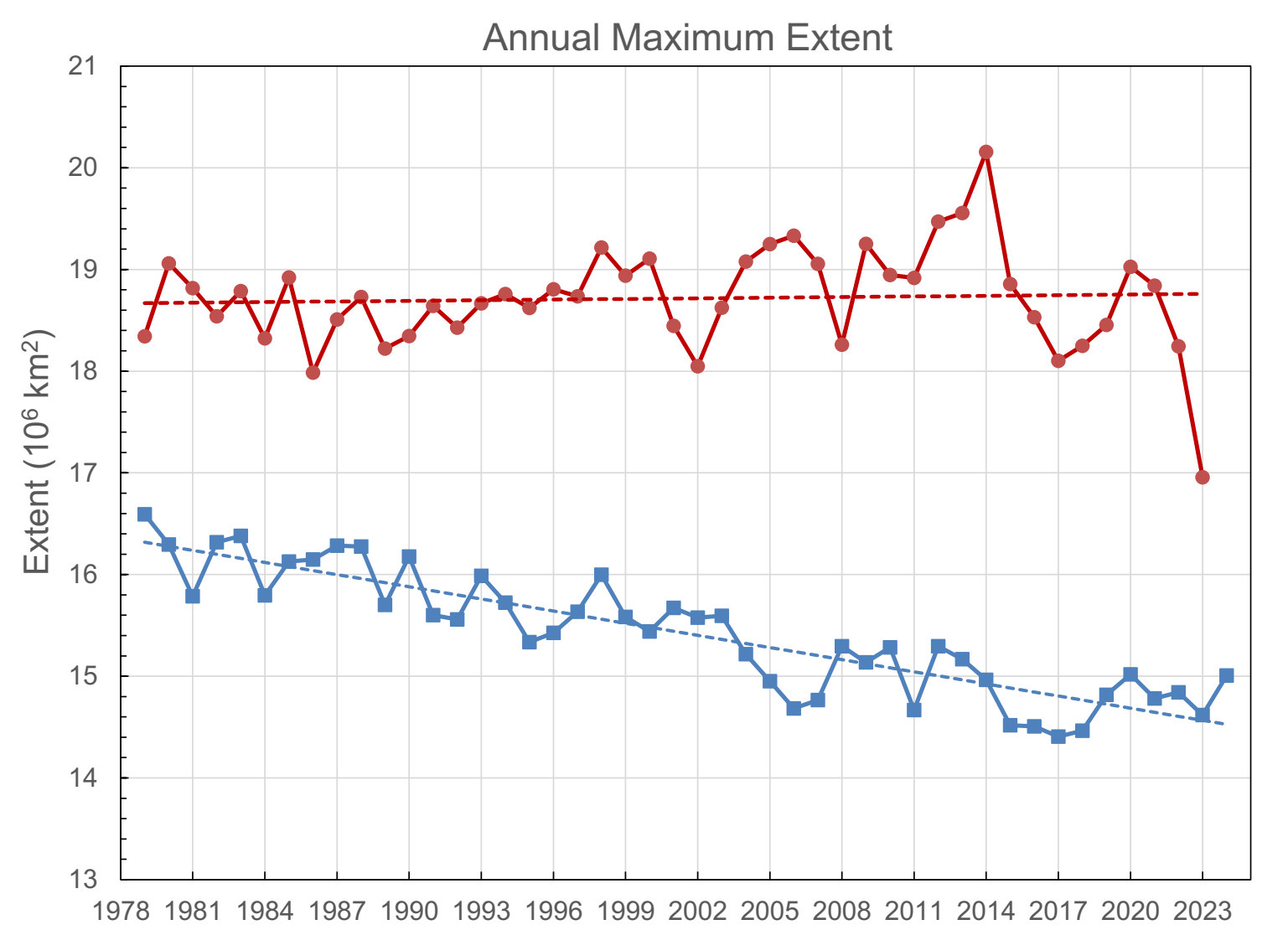


SII CONCENTRATION TRENDS - SEPTEMBER





Annual maximum sea ice extent trends from SII

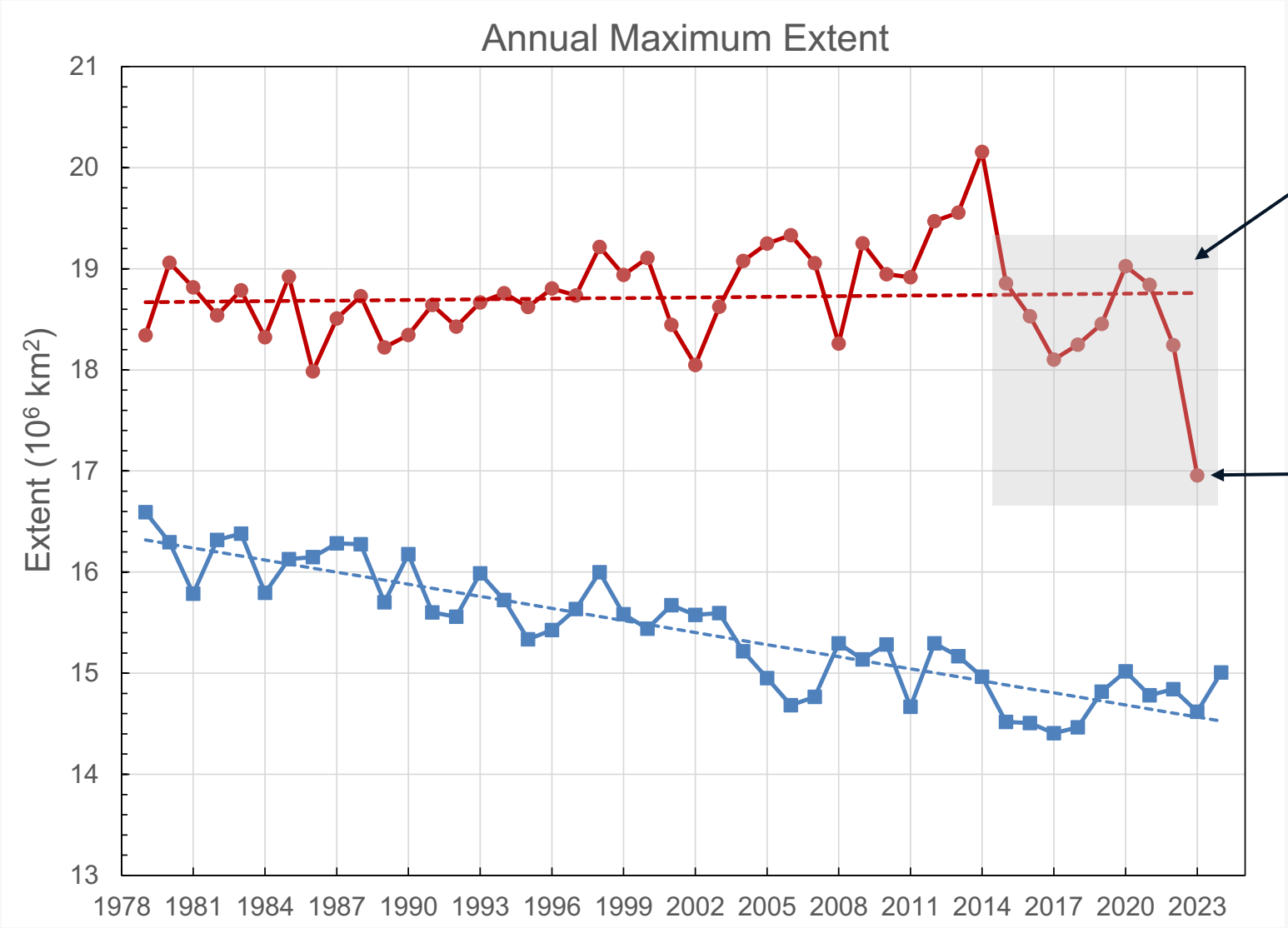


Southern Hemisphere
Trend = +2,100±11,900 km^2/yr

Northern Hemisphere
Trend = -39,800 ± 6,100 km^2/yr

NSIDC

Annual maximum sea ice extent trends from SII



Regime shift?

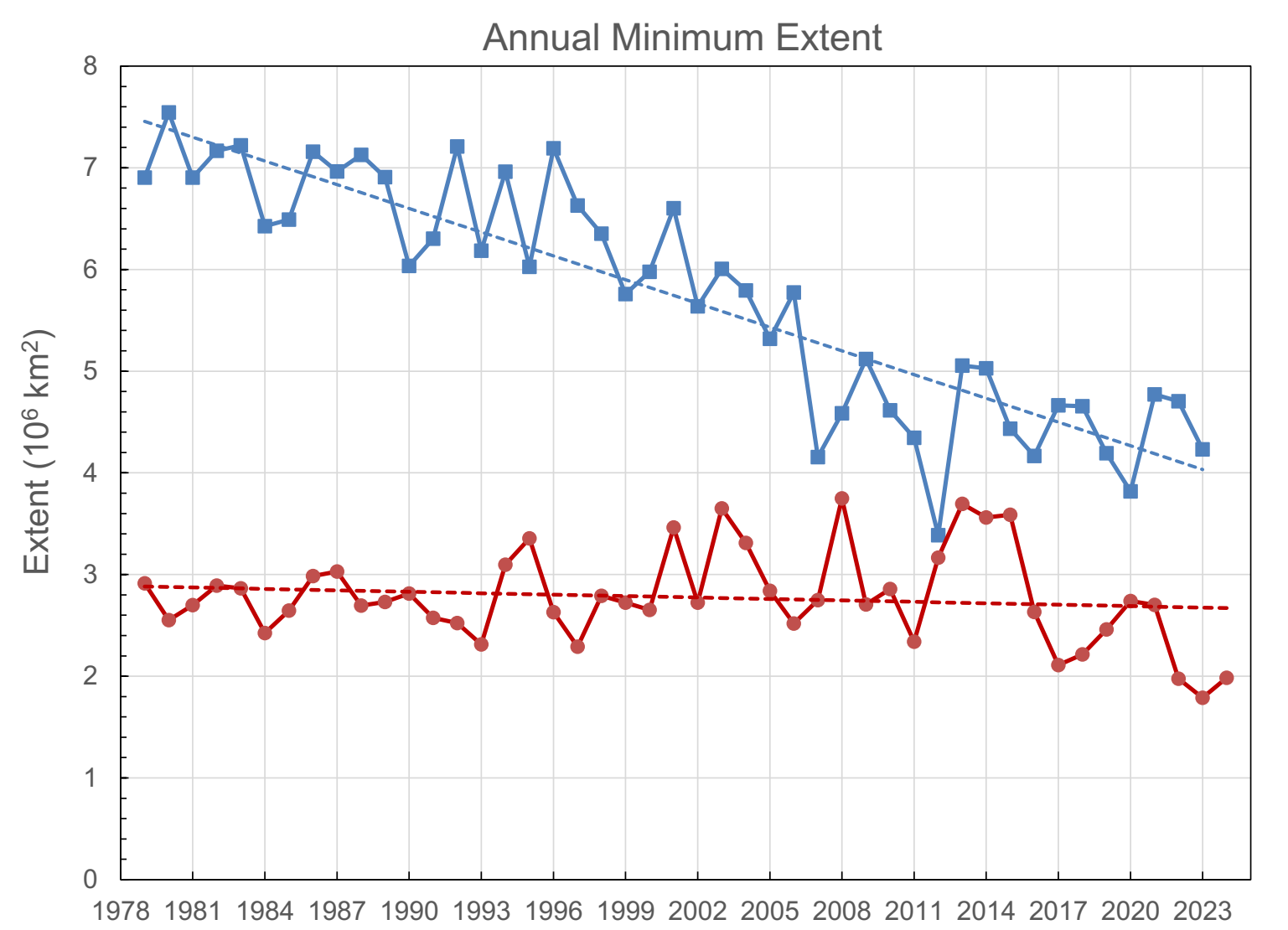
Southern Hemisphere
Trend = +2,100±11,900 km^2/yr

Extreme record low in 2023

Northern Hemisphere
Trend = -39,800 ± 6,100 km^2/yr

NSIDC

Annual minimum sea ice extent trends from SII

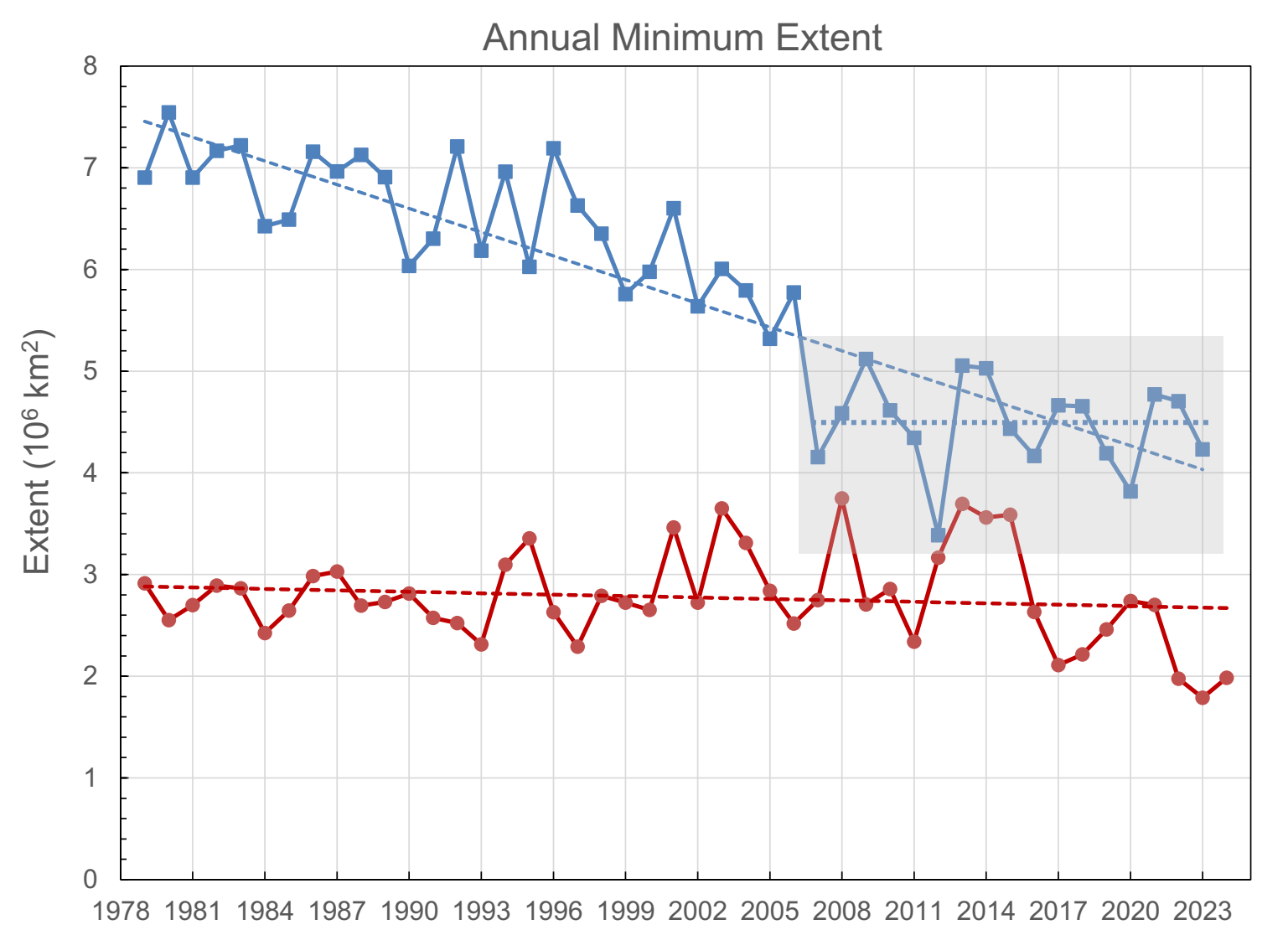


Northern Hemisphere
Trend = -77,800 ± 11,900 km^2/yr

Southern Hemisphere
Trend = -4,700±10,200 km^2/yr

NSIDC

Annual minimum sea ice extent trends from SII



No. Hemisphere, 2007-2023
Trend = -800 ± 46,100 km^2/yr

Southern Hemisphere
2022-2024 are three lowest years

Other sea ice climate records at NSIDC

- Melt onset

  Bliss et al., 2022, https://doi.org/10.5067/TRGWQ0ONTQG5

- Motion

  Tschudi et al., 2019, https://doi.org/10.5067/INAWUWO7QH7B

- Age

  Tschudi et al., 2019, https://doi.org/10.5067/UTAV7490FEPB

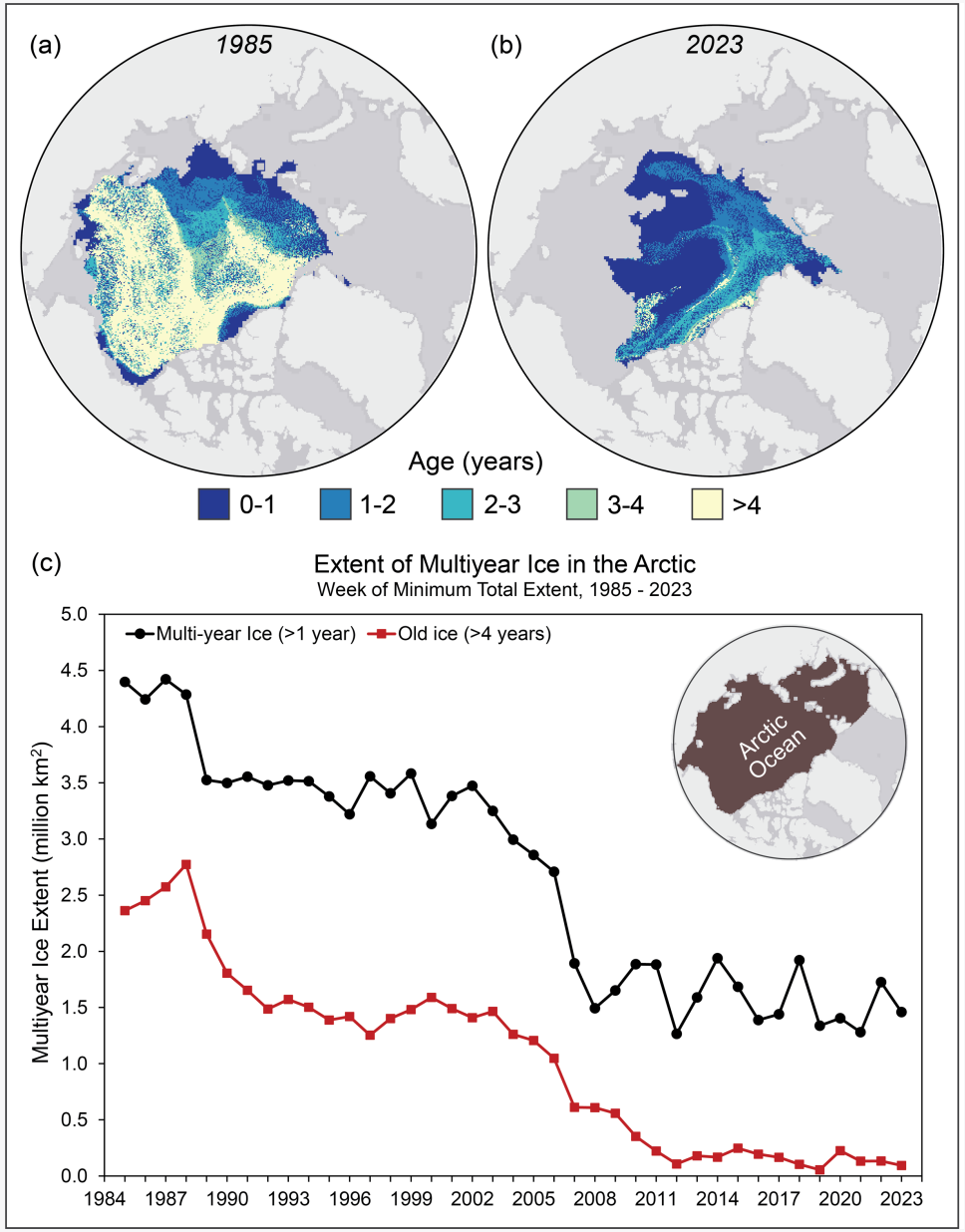
- Freeboard/Thickness

  ICESat/IceBridge/ICESat-2, CryoSat-2

  Kwok et al., 2023, https://doi.org/10.5067/ATLAS/ATL10.006

  Petty et al., 2023, https://doi.org/10.5067/ZCSU8Y5U1BQW

  → Not yet mature enough or of sufficient length for a CDR



Future work, Currently in progress

- Add AMSR2 to NOAA/NSIDC CDR for future resiliency (CDR V5)
  - Initially, a parallel concentration parameter to the primary SSMIS SIC CDR
  - AMSR2 inter-calibrated with SSMIS with adjustments to match ice edge
  - AMSR2 (or AMSR3) will be ready to ”take over” CDR time series from SSMIS
- Transition Sea Ice Index use CDR
  - Full provenance and transparency for Sea Ice Index
  - Initially, CDR source will be internal for QC and comparison with NT source
- Improvements to NASA (NT and BT) algorithms (with NASA Goddard)
- Consider changing to CSU/L1C for source TBs for all SIC products
- Prepare for future sensors (JAXA AMSR3, WFS MWI-M1, EPS-SG-B1 MWI)

Thank You!

- The NASA Team and Bootstrap algorithm products are supported by the NASA Snow and Ice DAAC and the NASA Earth Science Data Information Systems Project (ESDIS).
- The NOAA/NSIDC Sea Ice CDR is supported by NOAA NCEI and the NOAA Climate Data Record program.
- The Sea Ice Index and NOAA@NSIDC are supported by the NOAA cooperative agreement NA22OAR4320151, for the Cooperative Institute for Earth System Research and Data Science (CIESRDS).