GMASI Operational Processing and Historic Reprocessing: Status, Updates, Plans

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Outline

- GMASI System Overview
- Operational System Upgrade
- Historical Reprocessing Status
- Further Plans

Motivation for Automated Snow/Ice Mapping

Improve/facilitate operational snow/ice characterization

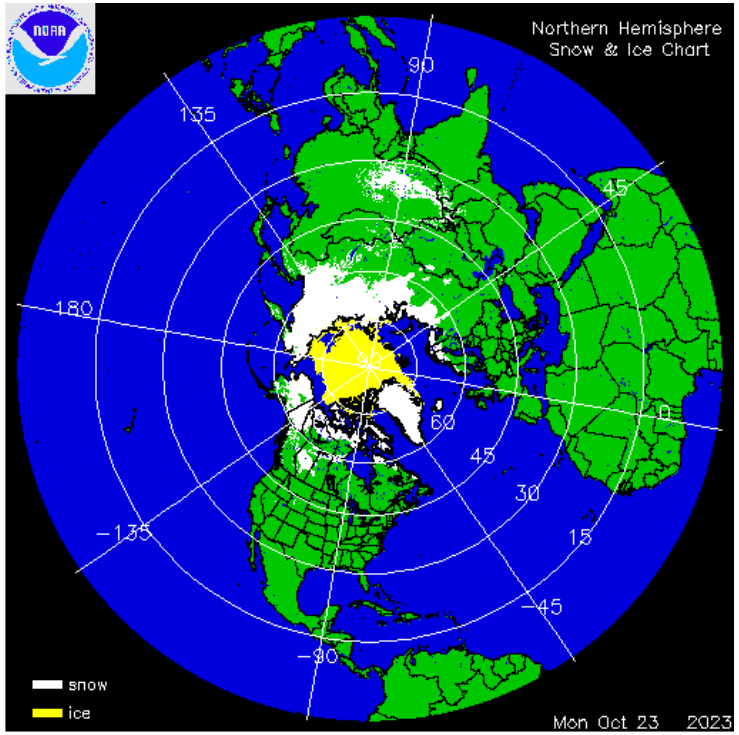
- NWP, hydrology, remote sensing, traffic, etc.

Establish reliable historical records and trends

- Climatology, climate modelling, reanalysis
- Current NOAA snow climatology is at 180km , weekly

Benefits vs Interactive Approach:

- Smaller operational costs
- Extended area coverage (+ Southern Hemisphere)
- Consistent over time
- Allows reprocessing



IMS (Interactive Multisensor Snow and Ice Mapping System)

- Primary NOAA operational snow product since 1972

GMASI-Autosnow Snow/Ice Mapping System

Approach: Fully automated data processing and retrievals

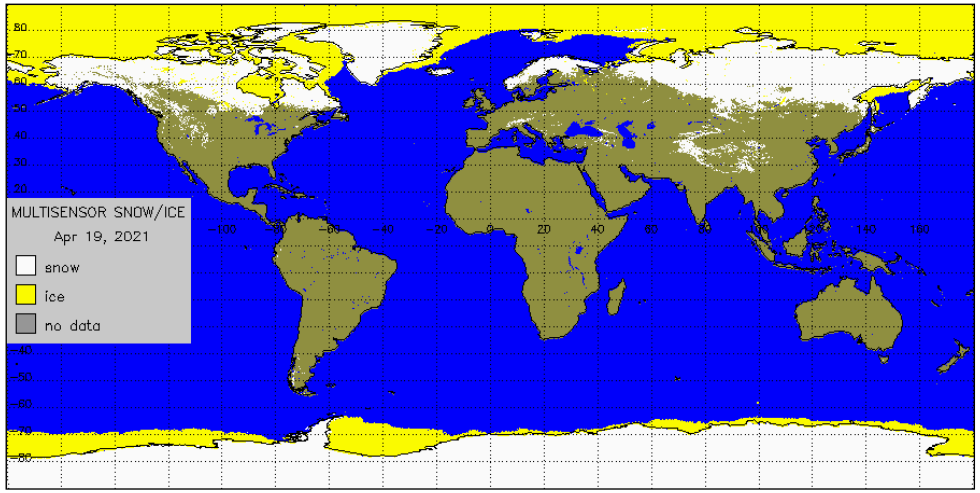
Technique: Synergy of optical (AVHRR) and microwave (SSMIS) observations

Output: Maps of snow and ice, 4km (2km) resolution, daily, global, spatially continuous

Snow/Ice characterization: Binary (yes/no)

Operational product: Since 2006, updated in 2011, upgraded in 2023

Reprocessed product: Full continuous daily record since 1988 (intermittent in 1987)



GMASI Daily Snow/Ice Map

GMASI: Algorithm Details

Decision-tree threshold-based image classification

Repeated daily microwave observations used

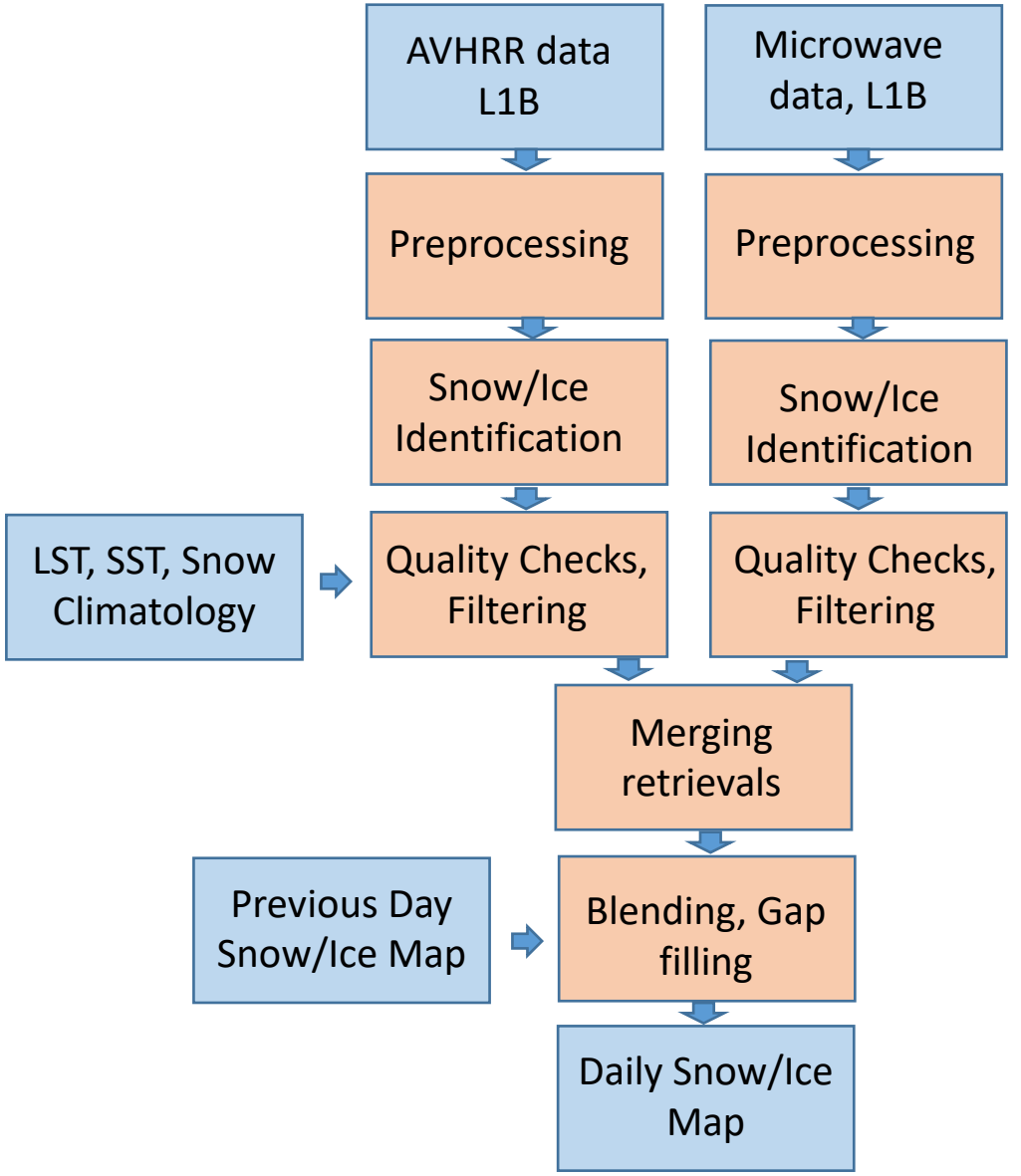
Climatology-based consistency checks/filters

No other “dynamic” input except satellite data

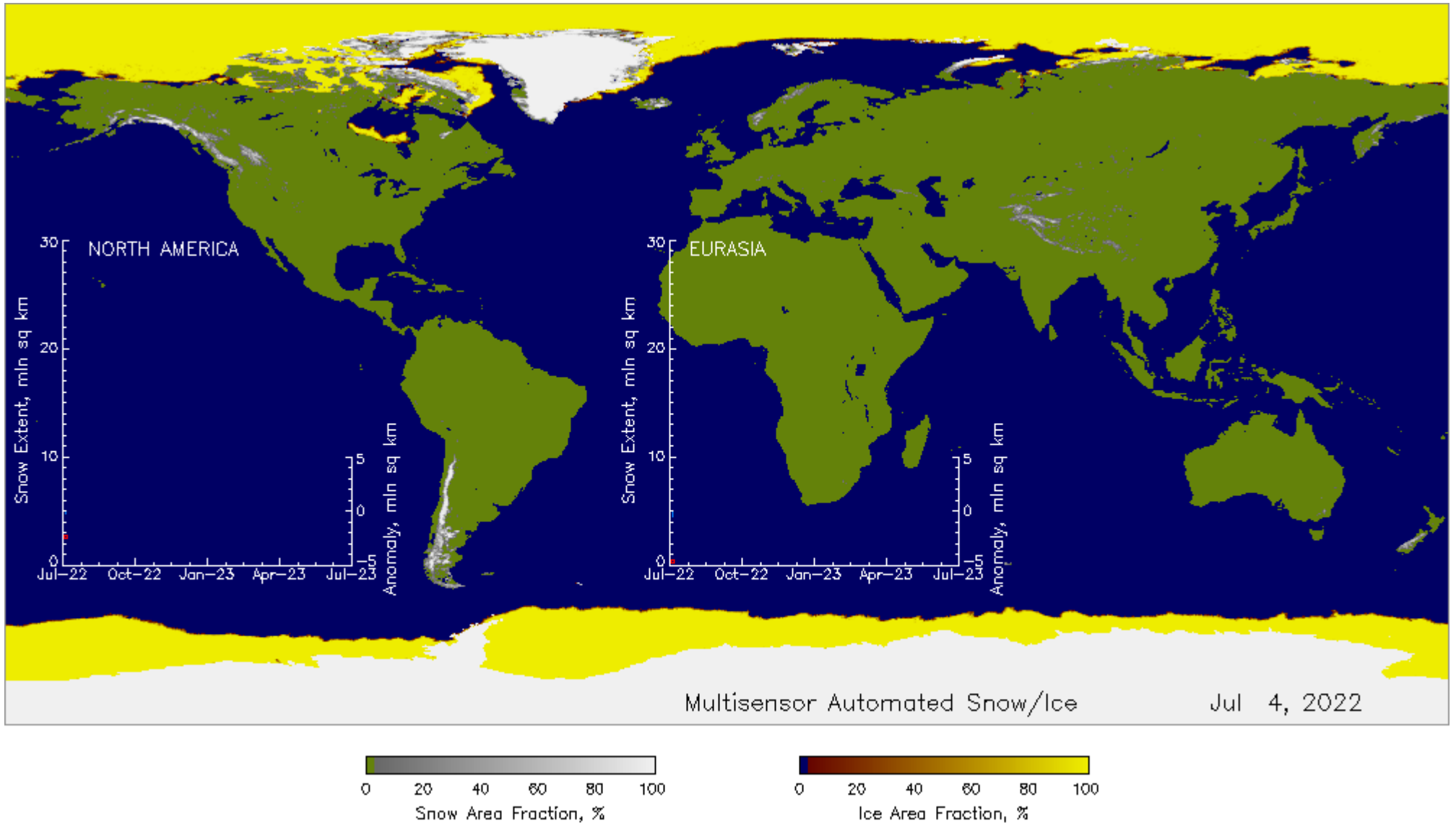
Recurrent gap-filling

Exclusions

- Low elevation low-latitude regions are assumed always snow-free
- Antarctica is assumed always snow-covered



GMASI: Daily Snow/Ice Maps



Season 2022-2023

New GMASI Operational Product: Now at 2 km Resolution

Product Features

- Daily
- 0.02^0 (~ 2km) resolution, lat-lon (geographical) grid
- NetCDF5 & grib (no binary any more)
- One global snow/ice map, no separate NH and SH maps any more
- Number of days since last update

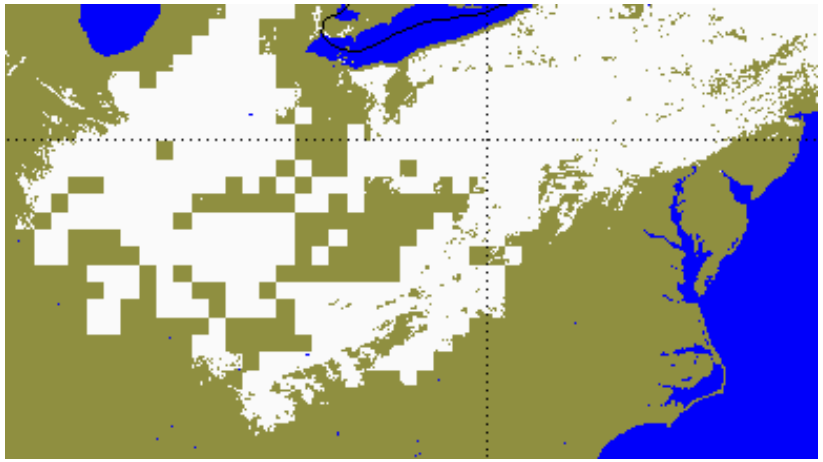
- Land/water mask is the same as in the older 4km product
- Operational since April 2023
- New and old systems were run parallel for 6 months (April-September 2023)

Algorithm Modifications/Changes in 2 km System

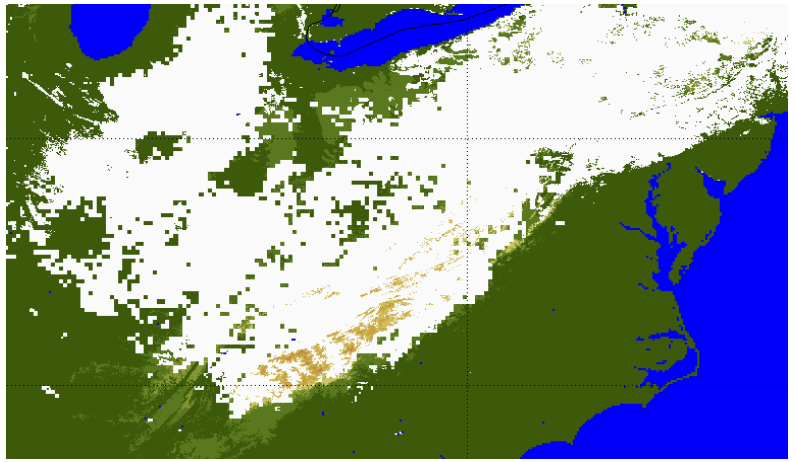
- AMSR2 and GMI are used instead of SSMIS F16, -17 and -18
- Enhanced spatial resolution of microwave retrievals using repeated views
- Improved orthorectification of AVHRR
- Additional/improved static datasets used (SST climatology, high-res elevation)
- Minor retrieval algorithm improvements, software optimization

Effect of Algorithm Changes

- Better delineation of snow/ice boundaries
- Less obvious “blocky structures” due to improved resolution of microwave retrievals
- Better reproduction of alpine snow covers



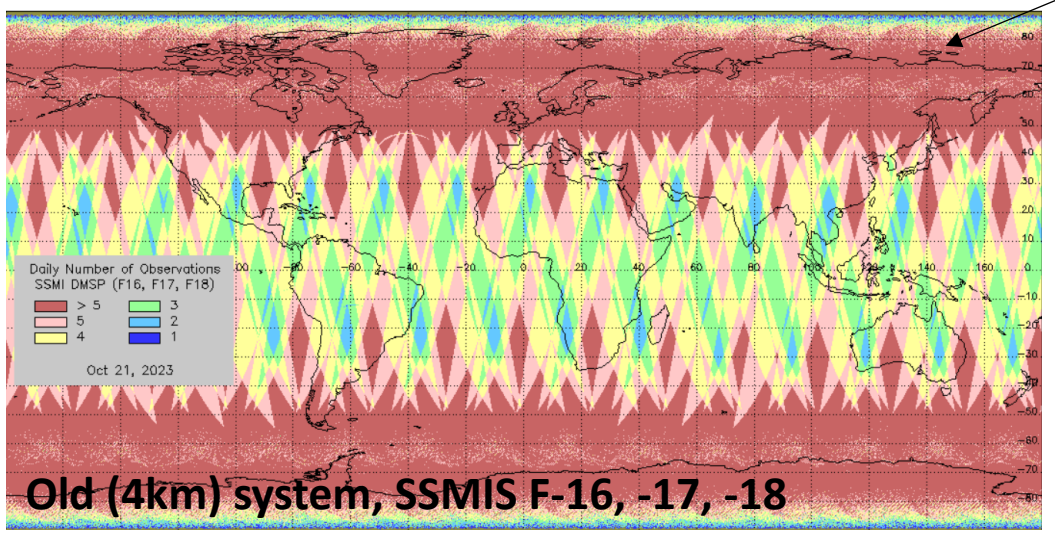
Old (4km) GMASI
operational product



New (2km) GMASI
operational product

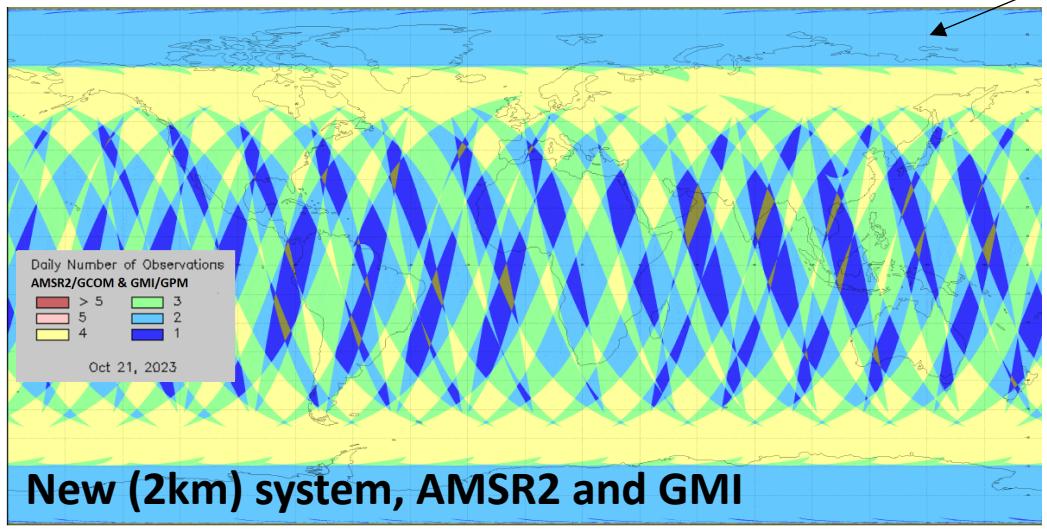
Passive Microwave: Fewer Daily Observations

5-6 observations per day with SSMIS sensors (4km system)



Old (4km) system, SSMIS F-16, -17, -18

2 observations per day with AMSR2 (2km system)



New (2km) system, AMSR2 and GMI

Repeated observations are used for snow/ice identification

Only two AMSR2 observations are available daily above ~ 68N

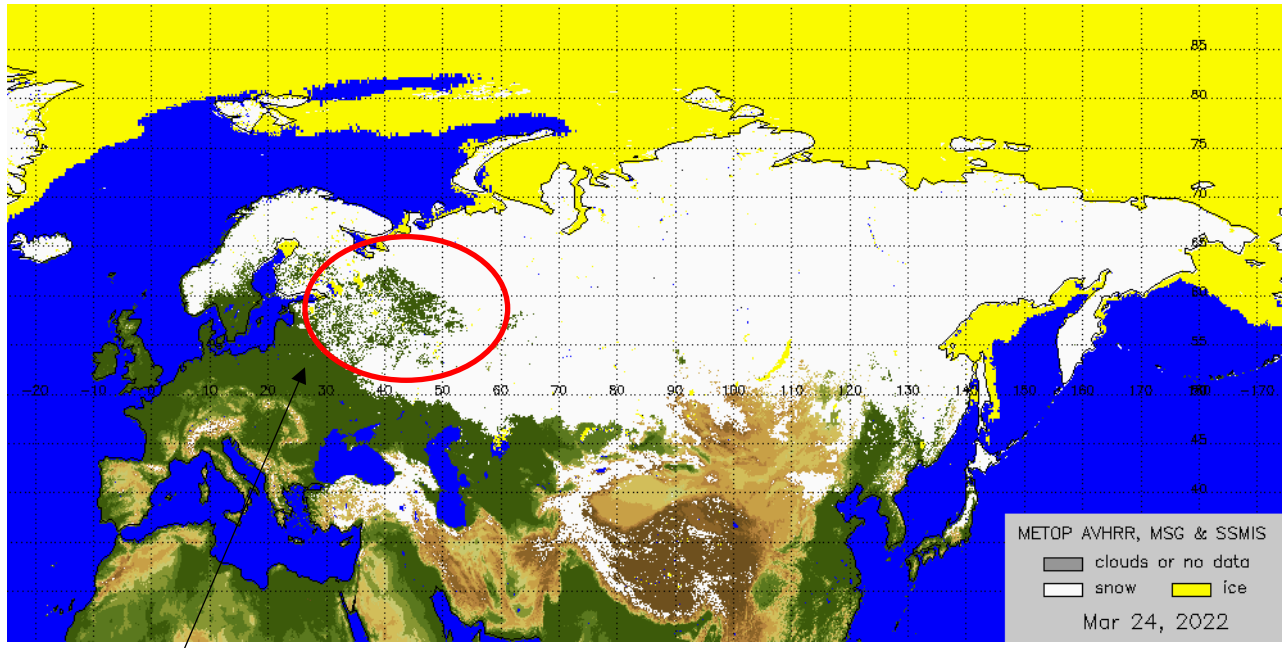
Potential effect: Less timely reproduction of snow/ice changes at high latitudes with the new system

Challenging Situations

Situations when both snow/ice remote sensing techniques (optical & microwave) may be inefficient

- Ice onset on small waterbodies
- Spring snow melt in dense forests
- Snowmelt during persistent cloudiness
- Prolonged snowstorm

This may cause inaccuracies in the maps or delayed reproduction of changes



Melting snow misses

New vs Old GMASI Operational Product: Quantitative Comparison

	Yearly Mean*	Daily Range
Snow cover distribution mismatch (%)	3.05	1.8 … 5.3
Ice cover distribution mismatch (%)	1.50	1.0 … 2.7
Snow extent difference (%)	-0.3	-2.6 … 2.4
Ice extent difference (%)	-1.1	-2.7 … 0.1

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*October 2022-October 2023, Northern Hemisphere

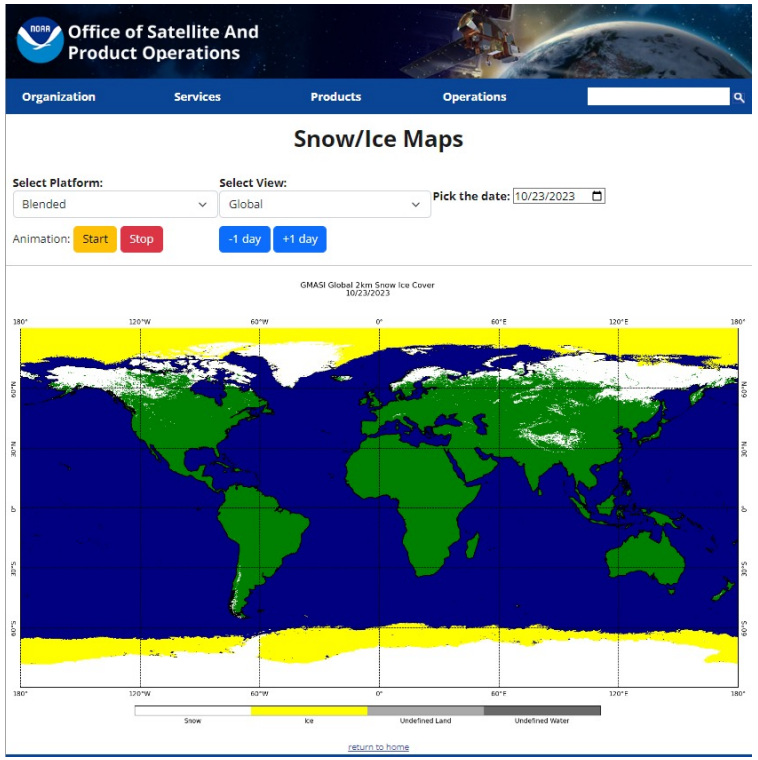
Note: Marginal decrease in the extent of mapped snow and ice cover in the new 2km product

GMASI 2km Operational Data Access

Direct download from NESDIS STAR
https://www.star.nesdis.noaa.gov/pub/smcd/emb/snow/gmasi_enterprise_2km_operational/

Order from NOAA CLASS
https://www.avl.class.noaa.gov/saa/products/search?sub_id=0&datatype_family=SNOW_ICE

Imagery:
https://www.ospo.noaa.gov/Products/land/autosnow/



ATBD:
Should become available online shortly

New daily product becomes available at 0200-0300 UTC

GMASI: Historical Reprocessing

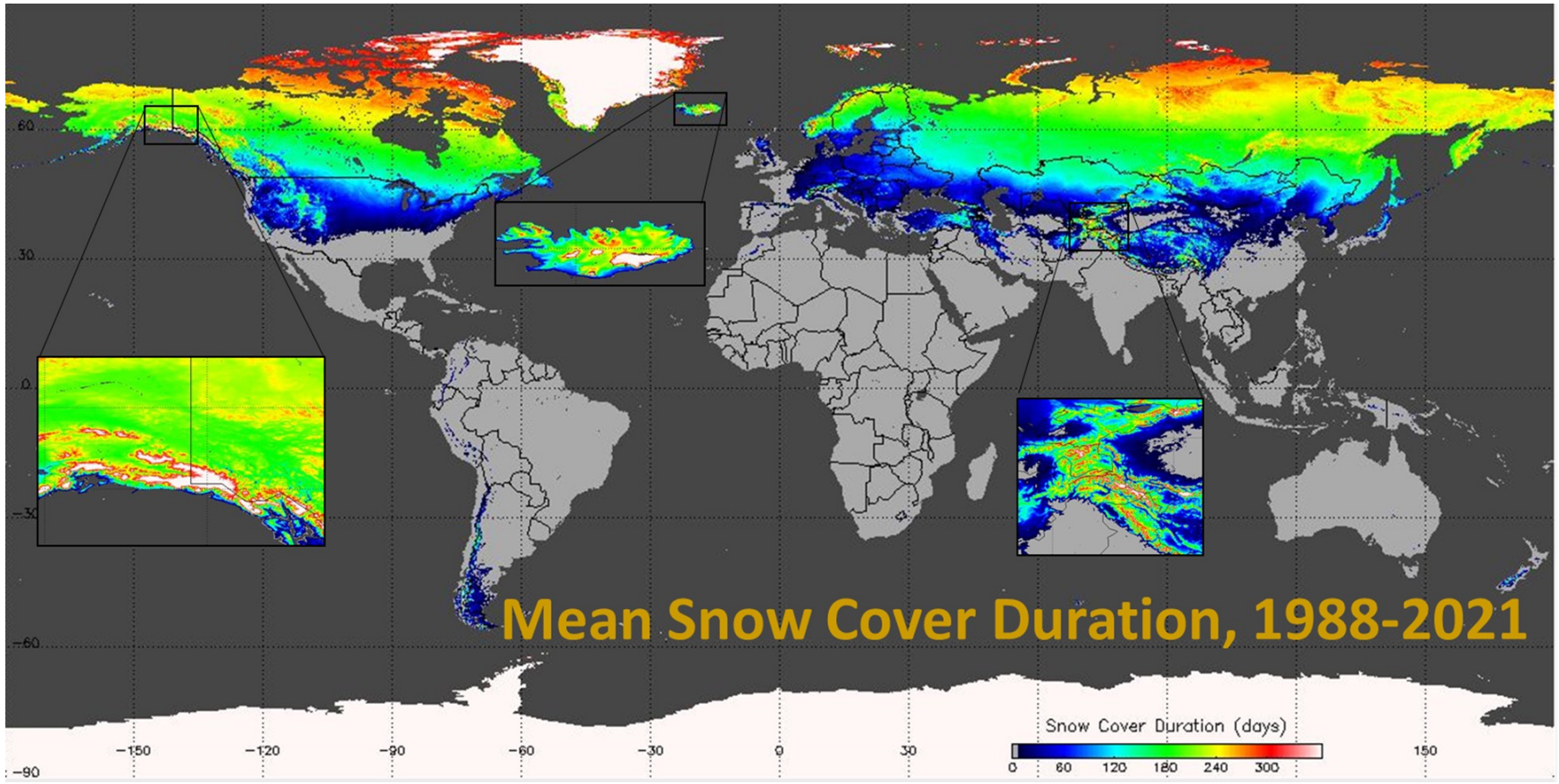
- Daily maps at 4km since mid-1987, continuous coverage 1988-current
- Format: Flat binary data files, compressed
- Sensor used: AVHRR (NOAA, METOP) and SSMI/SSMIS
- Algorithm is the same as the algorithm used in the operations
- Dataset is routinely updated, although updates are not operational.

Year	AVHRR Platform	Number of SSMI(S)	SSMI/SSMIS Platform									
			F-08	F-10	F-11	F-13	F-14	F-15	F-16	F-17	F-18	F-19
1987	NOAA-09	1										
1988		1										
1989	NOAA-11	1										
1990		1										
1991		2										
1992		2										
1993		2										
1994 (I-VIII)		2										
1994 (IX-XII)	NOAA-12	2										
1995	NOAA-14	3										
1996		3										
1997		4										
1998		3										
1999		3										
2000		3										
2001	NOAA-16	3										
2002		3										
2003	NOAA-17	3										
2004		3										

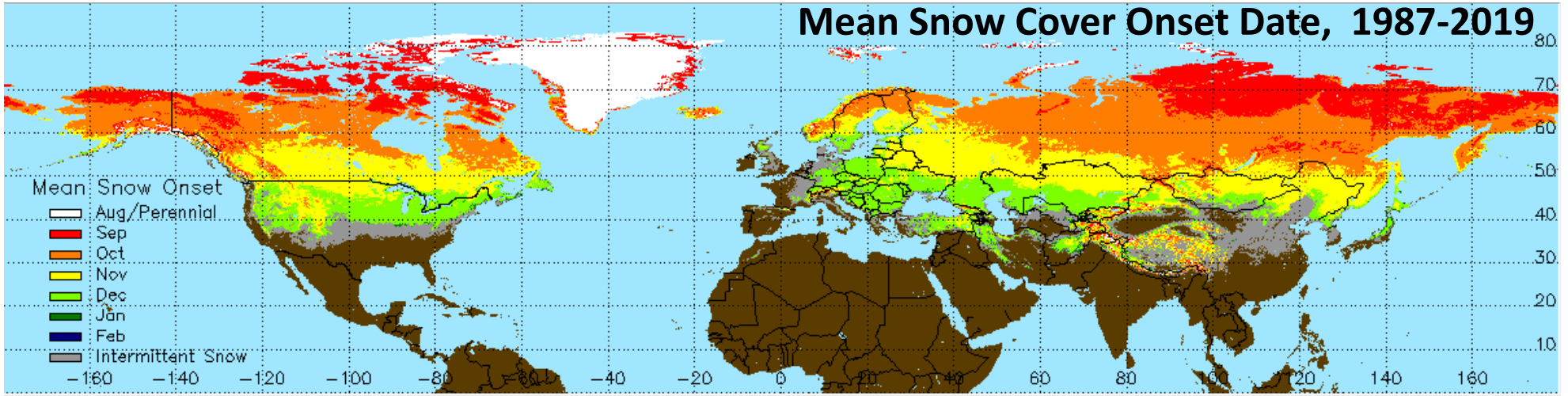
Year	AVHRR Platform	Number of SSMI(S)	SSMI/SSMIS Platform									
			F-08	F-10	F-11	F-13	F-14	F-15	F-16	F-17	F-18	F-19
2005	NOAA-17	3										
2006		4										
2007	METOP-A	4										
2008		4										
2009		4										
2010		3										
2011		4										
2012		4										
2013	METOP-B	4										
2014		4										
2015		5										
2016		5										
2017		4										
2018		4										
2019		4										
2020		4										
2021		4										
2022		3										
2023		3										

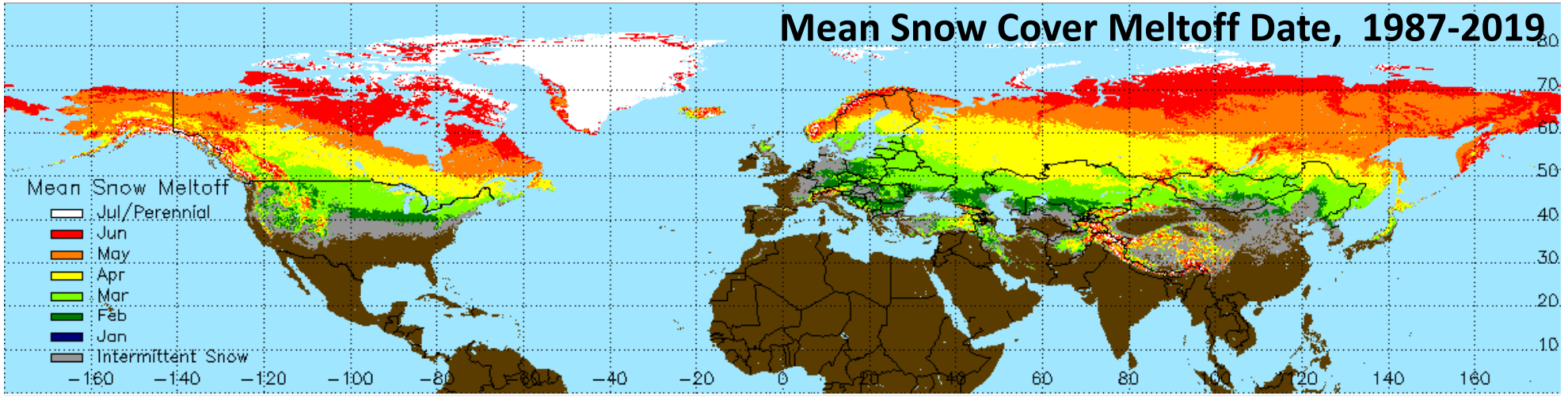
Sensors used in GMASI historical reprocessing

Applications: Snow Cover Duration

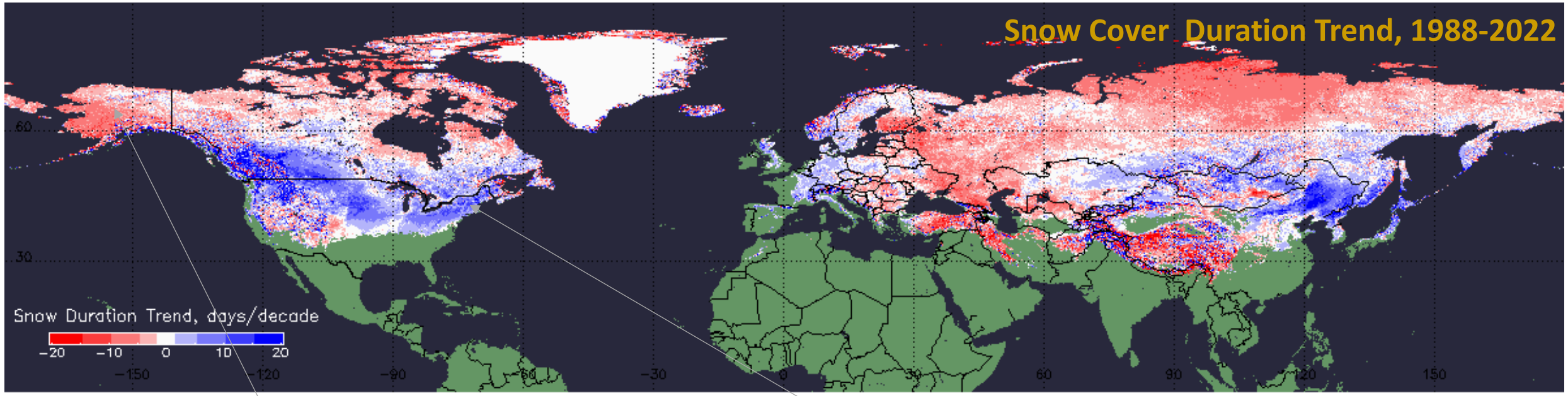


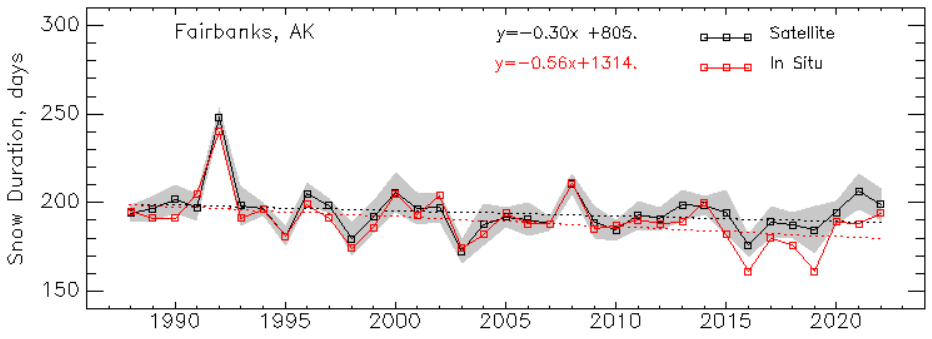
Applications: Snow Onset and Melt-Off

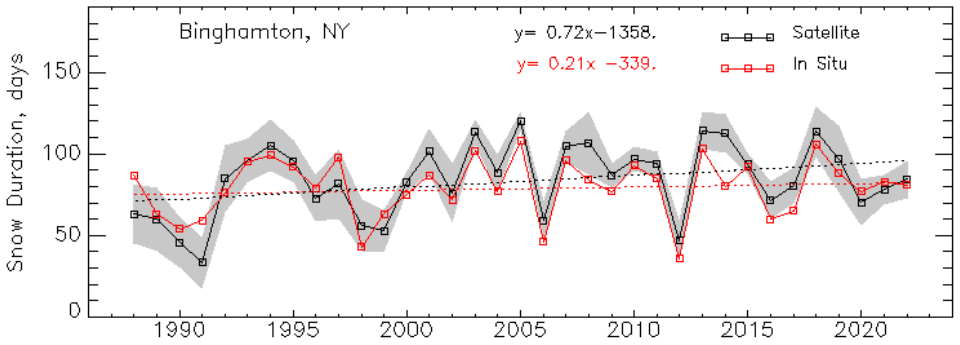




Applications: Snow Duration Trend

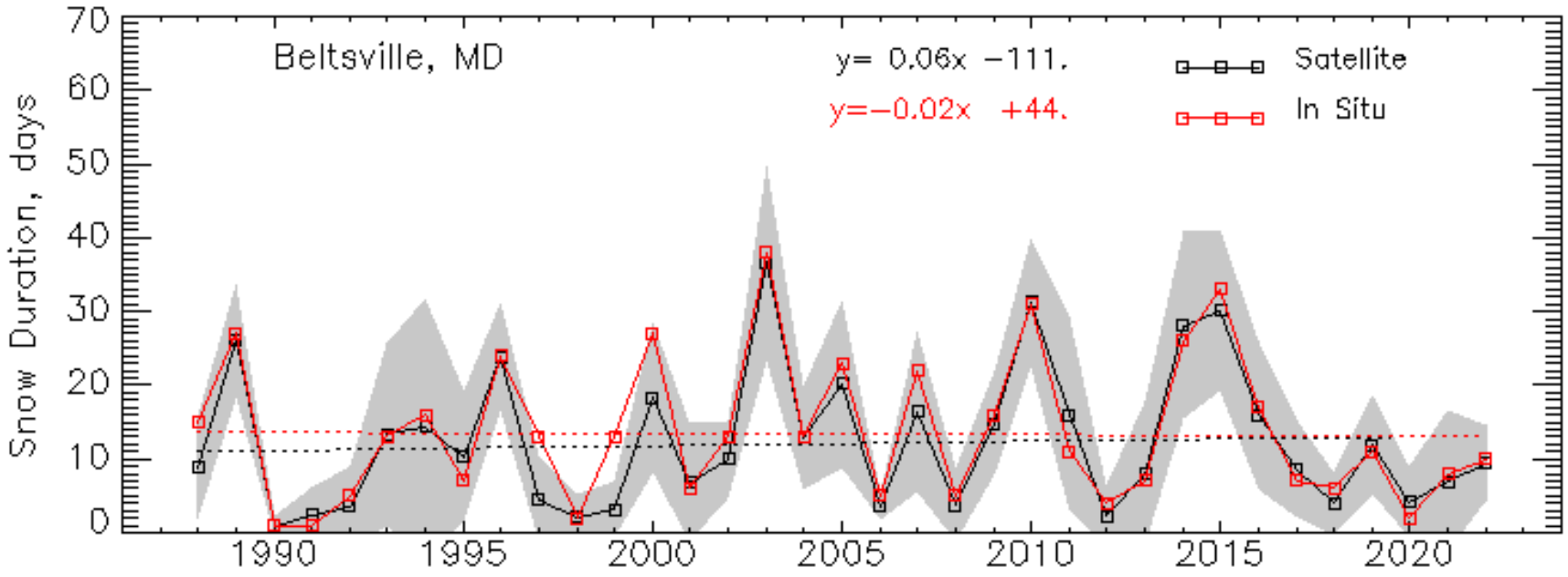






Satellite vs In Situ Snow Duration

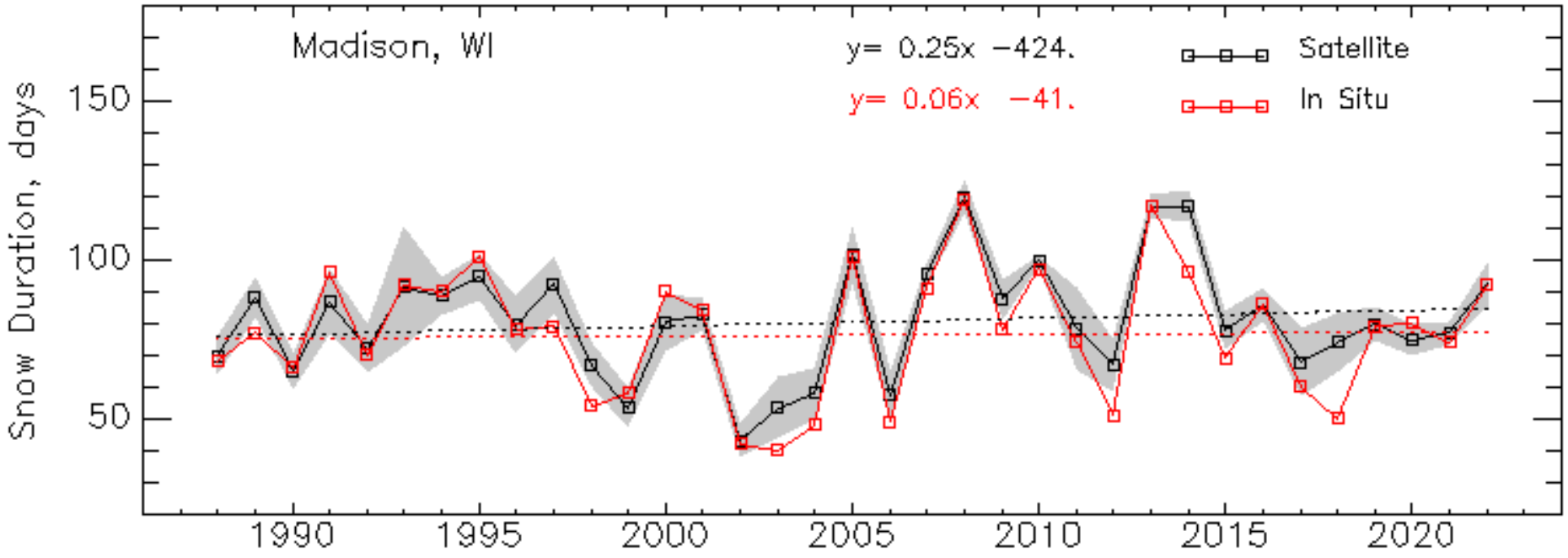
Snow Cover Duration at Beltsville, MD 1988-2022



GMASI: Range of snow cover duration within 50 km of Beltsville, MD

Satellite vs In Situ Snow Duration

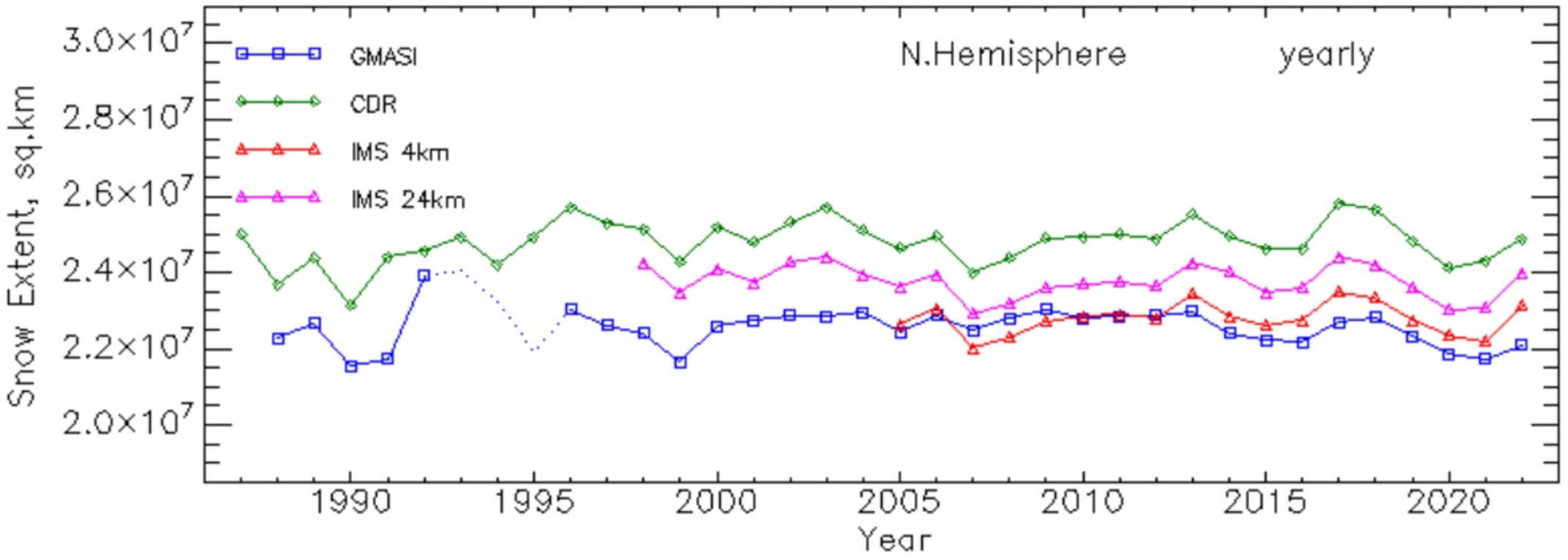
Snow Cover Duration at Madison, WI 1988-2022



GMASI: Range of snow cover duration within 50 km of Madison, WI

Snow Area Extent

Yearly Mean Snow Extent



The extent of mapped snow decreases with the increase of the spatial resolution of the product

Snow Extent Trends

Snow extent change, linear trends (% per year) 1988-2022

GMASI vs NOAA CDR dataset

	Northern Hemisphere		Eurasia		North America	
	GMASI	CDR[1]	GMASI	CDR	GMASI	CDR
Jan	0.04	0.11	0.01	0.13	0.09	0.08
Feb	0.05	0.11	-0.03	0.09	0.17	0.15
Mar	-0.04	0.03	-0.16	-0.01	0.15	0.09
Apr	-0.01	0.00	-0.17	-0.09	0.21	0.12
May	-0.12	-0.36*	-0.28*	-0.53*	0.04	-0.20
Jun	-0.33	-1.50*	-0.78*	-2.74*	-0.10	-0.84*
Jul	-0.26*	-1.13*	-0.63*	-5.29*	-0.19*	-0.36*
Aug	-0.24*	-0.28	-1.09*	-4.03*	-0.15*	0.13
Sep	-0.54*	0.27	-1.08	0.06	-0.21*	0.35
Oct	-0.13	0.85	-0.11	1.17	-0.16	0.46
Nov	0.05	0.31	0.03	0.37	0.09	0.32
Dec	0.06	0.05	0.02	0.01	0.12	0.11
Annual	-0.02	0.06	-0.08	0.05	0.06	0.08

[1] CDR: NOAA Climate Data Record (CDR) at 180 km spatial resolution

* Statistically significant trend ($p < 0.05$)

Reprocessed Data Access

Landing directory:
https://www.star.nesdis.noaa.gov/pub/smcd/emb/snow/gmasi_reprocessing

/dailymaps : Binary snow cover maps and browse imagery
/snowduration: Snow duration yearly maps, multiyear trend maps and associated imagery
/snowextent: Continental-scale snow daily snow extent data and charts, 1988-2022
/readme: Readme file explaining the content of folders

Summary

New 2km system and dataset

- Operational generation started in April 2023
- Dataset may be extended back to 2007 to cover 17 years

Old 4 km system and dataset

- Daily generation of 4 km resolution snow maps continues
- Currently covers the time period of about 36 years (1988-2023)
- Snow/Ice cover climatology and phenology parameters can be established

All daily products and climatology data files are available for download and testing

Plans

Upgrades to Operational System:

Add METOP-SG, AMSR3 (2024-2025), MWI (2026 ?)

Upgrade to 1 km resolution (2025 -?)

Historical Reprocessing:

Continue updating the current 4 km dataset

Extend 2 km products back to 2007 (beginning of METOP era)

Extend 4 km products back to 1980 (older AVHRR ? SMMR ?)

Add Snow Depth and Snow Water Equivalent (SWE) retrievals

- Synergy of in situ data analysis and microwave retrievals

Thank You !