Institute of Meteorology and Water Management
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Snow ECV
Requirements vs. Available Products

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Presentation outline:

- Snow as Climate Variable
- Requirements
- Available data sets
- Discussion and Conclusions

ECV – Snow Cover

- Snowfall and snow cover play key roles with respect to feedback mechanisms within the climate system (albedo, runoff, soil moisture, and vegetation)
- Important variables in monitoring climate change
- Key factor in runoff regimes in middle and high latitudes
- Snow depth and snow-cover duration affect the permafrost thermal state
- Melting of land ice and sea ice.

The **submission of in situ snow observations** from the WWW/GOS surface synoptic network has continued to **show some decline due to financial pressures** in many countries.

Furthermore, there is **no systematic global monitoring of the amount and quality of in situ snow-related reports** exchanged over the GTS.

As a result, the **creation of well- calibrated satellite products has been made more difficult.**

Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)

Domain	Essential Climate Variables	
Atmospheric (over land, sea and ice)	**Surface:**[8]	Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget.
	Upper-air:[9]	Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance).
	Composition:	Carbon dioxide, Methane, and other long-lived greenhouse gases[10], Ozone and Aerosol, supported by their precursors[11]
Oceanic	**Surface:**[12]	Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton.
	Sub-surface:	Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.
Terrestrial	River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture.	

„Given the highly-variable nature of the land surface, most terrestrial ECVs have a particularly strong **satellite component essential for global coverage**, whereas **in situ measurements provide key and detailed information at particular site**"

Satellite snow climatology - beginnings

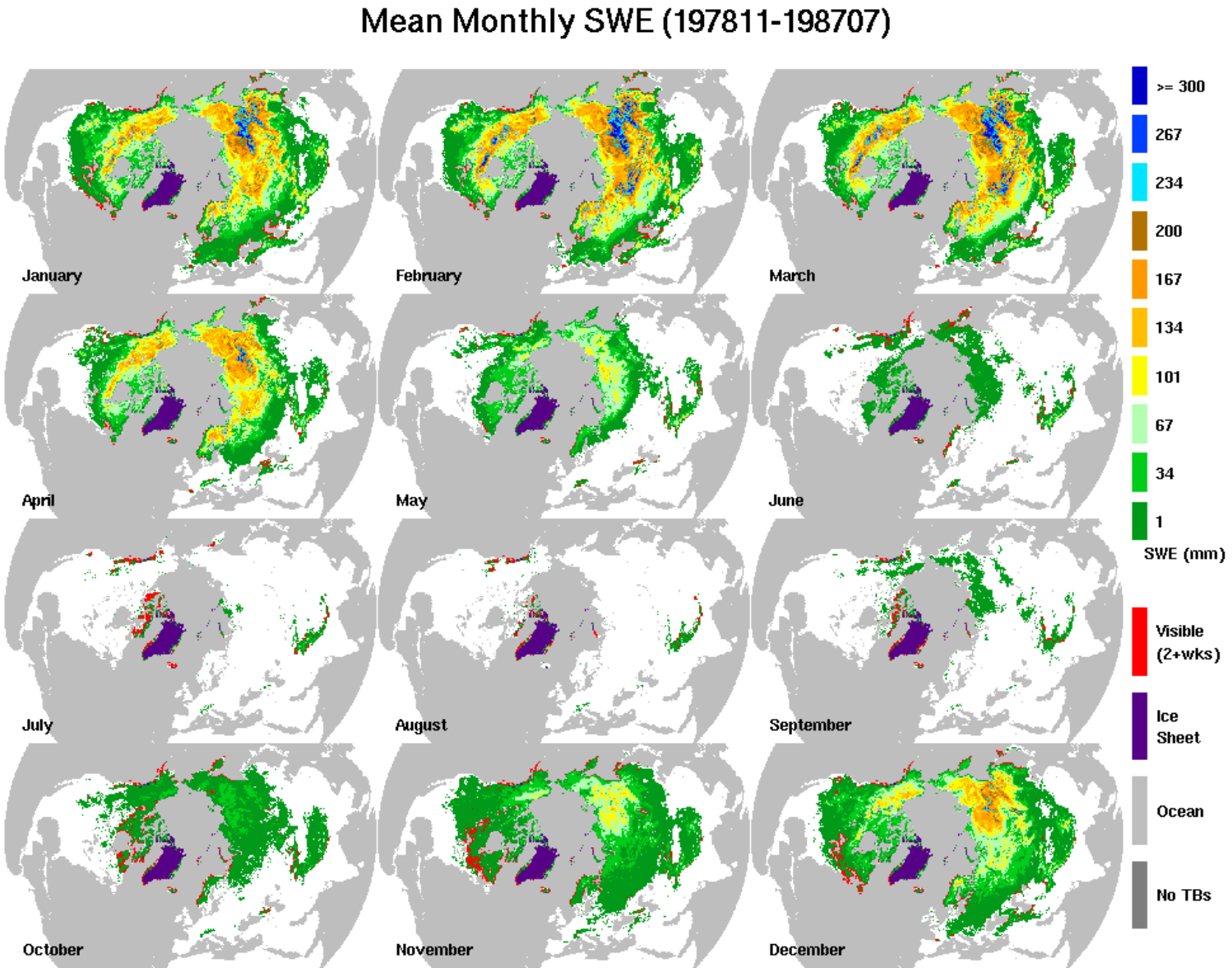
The National Environmental Satellite Data and Information Service (NESDIS) of NOAA began producing daily Northern Hemisphere snow extent maps in 1966, with weekly maps available from 1966 to 1999 and daily maps available in subsequent years.

Southern Hemisphere snow extent maps have been available since 1999 from the MODIS sensor. NSIDC provides a weekly global snow extent product, which combines optical (MODIS) and passive microwave (Special Sensor Microwave/Imager (SSM/I)) data for the period 2000 to the present.

Global snow water equivalent (SWE) products ha ve been available from the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) since 2002, but they remain to be validated

Nimbus-7, NOAA Polar Orbiting Environmental Satellites (POES), SMMR, SSM/I

https://nsidc.org/data/docs/daac/nsidc0271_ease_grid_swe_climatology/NL.197811-198707.BP_VIS40.NSIDC8.png



Requirements for snow observations (focusing on satellite observations)

OSCAR - Observing Systems Capability Analysis and Review Tool
https://www.wmo-sat.info/oscar/observingrequirements

Rolling Requirements Review (RRR) process overviewed by the **Inter-Programme Expert Team on Observing System Design and Evolution (IPET-OSDE)** of CBS.

Requirements are expressed for geophysical variables in terms of 6 criteria: **uncertainty**, **horizontal resolution, vertical resolution, observing cycle, timeliness,** and **stability** (where appropriate).

For each of these criteria the table indicates 3 values determined by experts:

- The **"threshold"** is the minimum requirement to be met to ensure that data are useful
- The **"goal"** is an ideal requirement above which further improvements are not necessary
- The **"breakthrough"** is an intermediate level between "threshold" and "goal" which, if achieved, would result in a significant improvement for the targeted application. The breakthrough level may be considered as an optimum, from a cost-benefit point of view, when planning or designing observing systems.

WMO OSCAR – List of requirements for snow cover parameters - uncertainy

ID	Variable	Application Area	Layer(s)	Uncertainty Goal		Uncertainty Breakthrough		Uncertainty Threshold	
12	Snow cover	CLIC	Land	10	%	13	%	20	%
47	Snow cover	Agricultural Meteorology	Land	2	%	4	%	10	%
108	Snow cover	Climate-AOPC	Land	10	%	13	%	20	%
220	Snow cover	GEWEX	Land	10	%	20	%	50	%
299	Snow cover	Global NWP	Land	10	%	20	%	50	%
375	Snow cover	High Res NWP	Land	5	%	15	%	20	%
404	Snow cover	Hydrology	Land	5	%	8	%	20	%
446	Snow cover	Nowcasting / VSRF	Land	10	%	13	%	20	%
677	Snow cover	Climate-TOPC	Land	5	%	7	%	10	%
486	Snow depth	Ocean Applications	Sea	0,005	cm	0,02	cm	0,05	cm
699	Snow depth	Nowcasting / VSRF	Land	0,1	cm	0,5	cm	2	cm
405	Snow status (wet/dry)	Hydrology	Land	5	HR, FAR	0	HR, FAR	2	HR, FAR
13	Snow water equivalent	CLIC	Land	5	mm	8	mm	20	mm
48	Snow water equivalent	Agricultural Meteorology	Land	5	mm	23,2	mm	500	mm
109	Snow water equivalent	Climate-AOPC	Land	5	mm	6,5	mm	10	mm
221	Snow water equivalent	GEWEX	Land	5	mm	10	mm	20	mm
300	Snow water equivalent	Global NWP	Land	2	mm	10	mm	20	mm
376	Snow water equivalent	High Res NWP	Land	5	mm	8	mm	20	mm
406	Snow water equivalent	Hydrology	Land	5	mm	8	mm	20	mm
758	Snow water equivalent	SSLP		5	mm	10	mm	20	mm

Snow extent: **Goal: 5-10%, Threshold: 10-20%**

Snow depth: **not treated as climate variable**

Snow Water Equivalent: **Goal: 5mm, Threshold: 10-20mm**

WMO OSCAR – List of requirements for snow cover parameters – Horizontal resolution

ID	Variable	Application Area	Hor.Res. Goal	Hor.Res. Breakthrough	Hor.Res. Threshold
12	Snow cover	CLIC	1 km	2.9 km	25 km
47	Snow cover	Agricultural Meteorology	1 km	2.2 km	10 km
108	Snow cover	Climate-AOPC	100 km	200 km	500 km
220	Snow cover	GEWEX	15 km	50 km	250 km
299	Snow cover	Global NWP	5 km	15 km	100 km
375	Snow cover	High Res NWP	1 km	5 km	20 km
404	Snow cover	Hydrology	0.1 km	1 km	100 km
446	Snow cover	Nowcasting / VSRF	5 km	10 km	50 km
677	Snow cover	Climate-TOPC	0.1 km	0.45 km	10 km
486	Snow depth	Ocean Applications	5 km	10 km	15 km
699	Snow depth	Nowcasting / VSRF	5 km	10 km	15 km
405	Snow status (wet/dry)	Hydrology	0.1 km	0.464 km	10 km
13	Snow water equivalent	CLIC	10 km	13.6 km	25 km
48	Snow water equivalent	Agricultural Meteorology	30 km	2.2 km	10 km
109	Snow water equivalent	Climate-AOPC	100 km	200 km	500 km
221	Snow water equivalent	GEWEX	15 km	50 km	250 km
300	Snow water equivalent	Global NWP	5 km	15 km	100 km
376	Snow water equivalent	High Res NWP	0.5 km	2 km	20 km
406	Snow water equivalent	Hydrology	0.1 km	0.464 km	10 km
758	Snow water equivalent	SSLP	50 km	100 km	500 km

Snow extent: **Goal: 0.1-100km,** **Threshold: 10-500km** ⟸ MW instruments

Snow Water Equivalent: **Goal: 15-100km,** **Threshold: 250-500km**

WMO OSCAR – List of requirements for snow cover parameters – Observing cycle, Timeliness

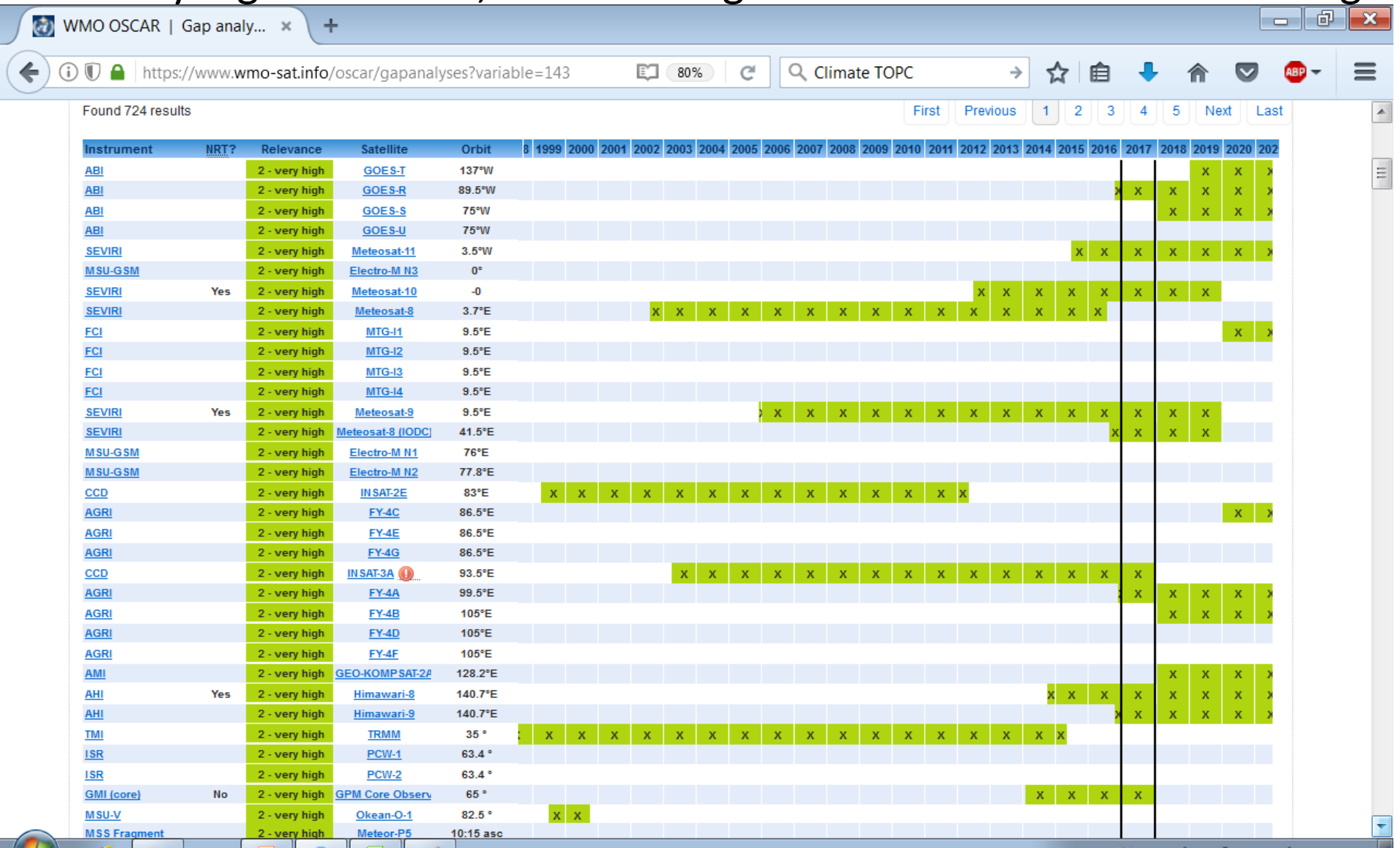
ID	Variable	Application Area	Observing Cycle Goal	Observing Cycle Breakthrough	Observing Cycle Threshold	Timeliness Goal	Timeliness Breakthrough	Timeliness Threshold
12	Snow cover	CLIC	24 h	41 h	5 d	7 d	7 d	30 d
47	Snow cover	Agricultural Meteo	5 d	6 d	7 d	24 h	24 h	6 d
108	Snow cover	Climate-AOPC	24 h	2 d	7 d	6 h	6 h	24 h
220	Snow cover	GEWEX	24 h	2 d	7 d	30 d	30 d	90 d
299	Snow cover	Global NWP	3 h	24 h	5 d	3 h	3 h	5 d
375	Snow cover	High Res NWP	60 min	3 h	12 h	60 min	60 min	12 h
404	Snow cover	Hydrology	24 h	46 h	7 d	24 h	24 h	6 d
446	Snow cover	Nowcasting / VSRF	60 min	6 h	24 h	60 min	60 min	6 h
677	Snow cover	Climate-TOPC	24 h	3 d	30 d	30 h	30 h	15 d
486	Snow depth	Ocean Application	24 h	24 h	24 h	3 d	3 d	7 d
699	Snow depth	Nowcasting / VSRF	10 min	60 min	24 h	10 min	10 min	24 h
405	Snow status (wet/dry)	Hydrology	30 min	4 h	12 d	60 min	60 min	6 d
13	Snow water equivalent	CLIC	24 h	41 h	5 d	7 d	7 d	30 d
48	Snow water equivalent	Agricultural Meteo	7 d	11 d	30 d	24 h	24 h	7 d
109	Snow water equivalent	Climate-AOPC	24 h	2 d	7 d	6 h	6 h	24 h
221	Snow water equivalent	GEWEX	12 h	24 h	7 d	30 d	30 d	90 d
300	Snow water equivalent	Global NWP	3 h	24 h	5 d	3 h	3 h	5 d
376	Snow water equivalent	High Res NWP	60 min	3 h	6 h	60 min	60 min	24 h
406	Snow water equivalent	Hydrology	24 h	46 h	7 d	24 h	24 h	6 d
758	Snow water equivalent	SSLP	24 h	2 d	7 d	24 h	24 h	7 d

Observing cycle: **Snow extent:** **Goal 24h,** **Threshold: 5-30 days**
SWE: **Goal: 12-24h,** **Threshold: 5-7 days**

What we need **vs.** **what we have**

OSCAR - Gap analysis for snow extent - *https://www.wmo-sat.info/oscar/gapanalyses*

Listed: 724 satellite instruments, since early 60-ties, among them: 68 with very high relevance, 220 with high relevance for snow monitoring.



Instrument	NRT?	Relevance	Satellite	Orbit
ABI		2 - very high	GOES-T	137°W
ABI		2 - very high	GOES-R	89.5°W
ABI		2 - very high	GOES-S	75°W
ABI		2 - very high	GOES-U	75°W
SEVIRI		2 - very high	Meteosat-11	3.5°W
MSU-GSM		2 - very high	Electro-M N3	0°
SEVIRI	Yes	2 - very high	Meteosat-10	-0
SEVIRI		2 - very high	Meteosat-8	3.7°E
FCI		2 - very high	MTG-I1	9.5°E
FCI		2 - very high	MTG-I2	9.5°E
FCI		2 - very high	MTG-I3	9.5°E
FCI		2 - very high	MTG-I4	9.5°E
SEVIRI	Yes	2 - very high	Meteosat-9	9.5°E
SEVIRI		2 - very high	Meteosat-8 (IODC)	41.5°E
MSU-GSM		2 - very high	Electro-M N1	76°E
MSU-GSM		2 - very high	Electro-M N2	77.8°E
CCD		2 - very high	INSAT-2E	83°E
AGRI		2 - very high	FY-4C	86.5°E
AGRI		2 - very high	FY-4E	86.5°E
AGRI		2 - very high	FY-4G	86.5°E
CCD		2 - very high	INSAT-3A	93.5°E
AGRI		2 - very high	FY-4A	99.5°E
AGRI		2 - very high	FY-4B	105°E
AGRI		2 - very high	FY-4D	105°E
AGRI		2 - very high	FY-4F	105°E
AMI		2 - very high	GEO-KOMPSAT-2A	128.2°E
AHI	Yes	2 - very high	Himawari-8	140.7°E
AHI		2 - very high	Himawari-9	140.7°E
TMI		2 - very high	TRMM	35 °
ISR		2 - very high	PCW-1	63.4 °
ISR		2 - very high	PCW-2	63.4 °
GMI (core)	No	2 - very high	GPM Core Observ	65 °
MSU-V		2 - very high	Okean-O-1	82.5 °
MSS Fragment		2 - very high	Meteor-P5	10:15 asc

http://globalcryospherewatch.org/reference/snow_inventory.php

Selected databases:

Database - Snow extent	Coverage	Period	Resolution	Frequency
GlobSnow Snow Extent	NH	1995-	0.01 deg	daily
NOAA AMSR2 Snow Products	Global	2014-	25 km	daily
JAXA AMSR2 Snow Products	Global	2012-	10km 25km	daily
US National Ice Center Operational Global Snow Products (IMS)	NH/Global	1997- 2004-	24km 4 km 1km	daily
Global 4KM Multisensor Automated Snow/Ice Map Product (GMASI)	Global	2006-	4 km	daily
CryoClim Multi-Sensor Snow Cover Product	NH	1982-	5 km	daily
Japanese Global Snow Cover Extent for Climate Dataset (GHRM5C)	Global	1979- 2013	0.05 deg	daily
MODIS Snow Products Collection 6	Global	2000-	500m	daily
NOAA-CDR	NH	1966-	190.5 km	weekly monthly

+ many PanEuropean and North American databases

What does it mean daily product ?
Availabilty of file, or real information about snow extent ?

http://globalcryospherewatch.org/reference/snow_inventory.php

Selected databases:

Database - Snow Water Equivalent	Coverage	Period	Resolution	Frequency
Globsnow SWE	NH	1979-	25 km	daily
NASA Standard AMSR-E	NH	2002-2011	25 km	daily
NOAA AMSR2 Snow Products	Global	2014-	25 km	daily
JAXA AMSR2 Snow Products	Global	2012-	10km 25km	daily
GRACE - Area-averaged estimates of terrestrial water storage anomalies (snow + ice + soil + ground water)	Global	2002-	1x1 deg	monthly

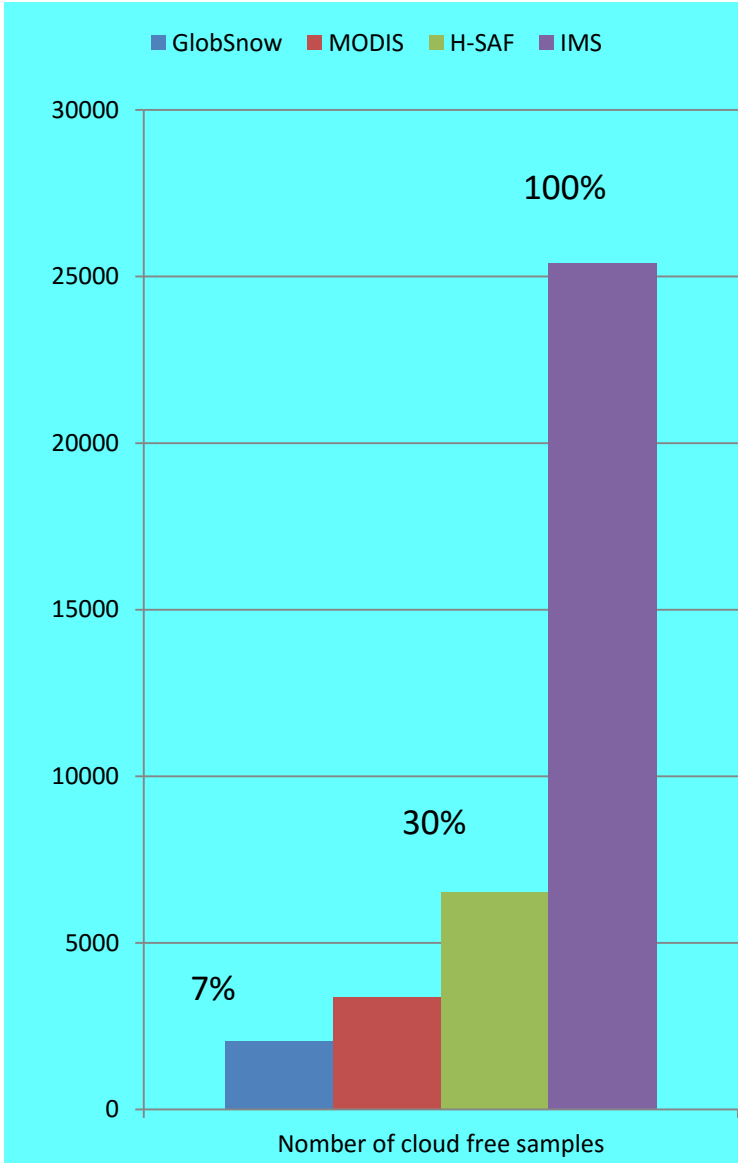
Main limitations:

Visible sensors – mainly affected Observing Cycle:
- Cloudiness,
- Sun elevation,

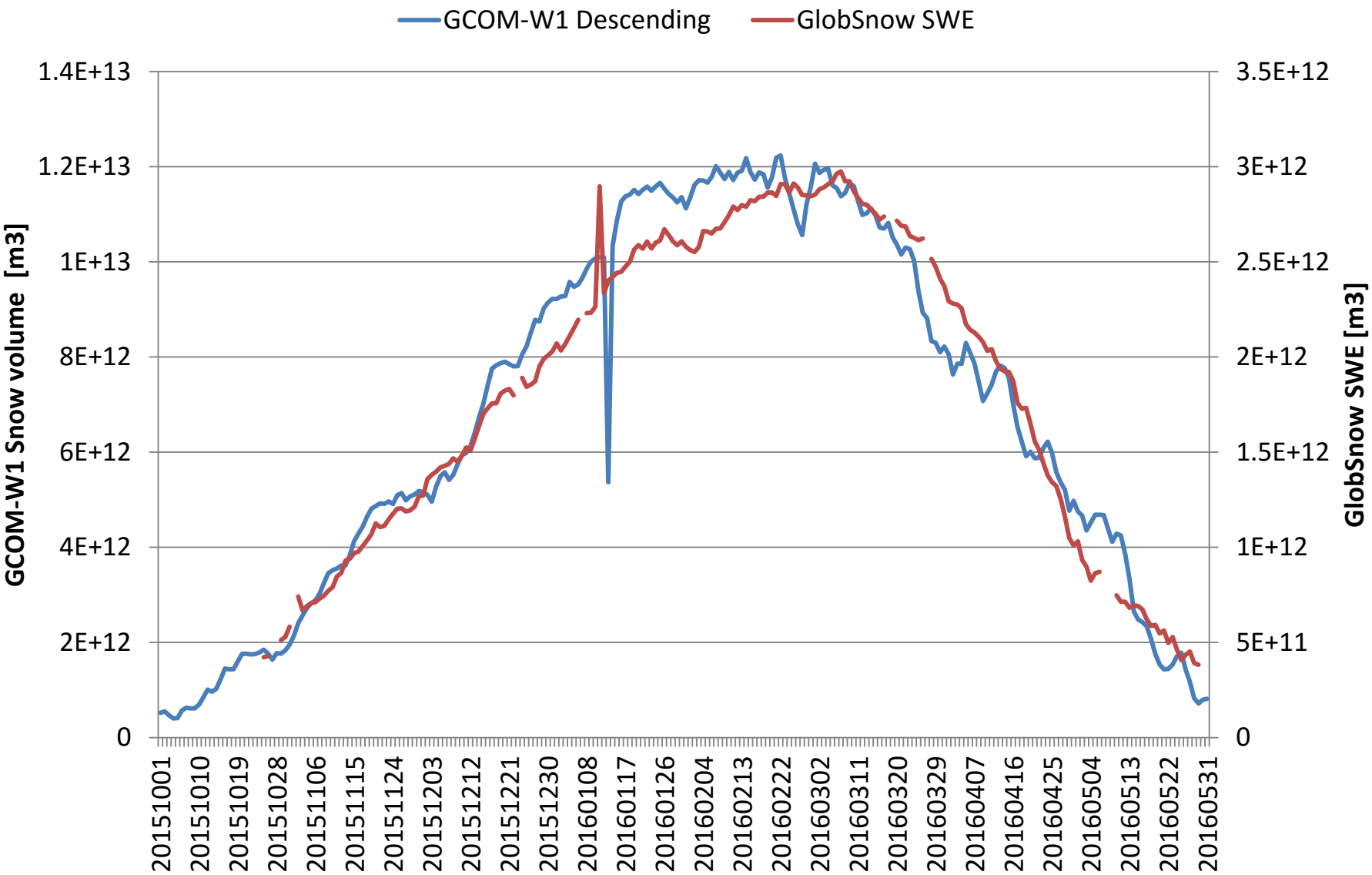
Microwave passive sensors – mailnly affected uncerainy, horizontal resolution could be better:
- Shallow snow cover,
-Uncertainty,
- Horizontal resolution,
- Snow melting.

Microwave active sensors:
-Uncertainty,
- Snow melting

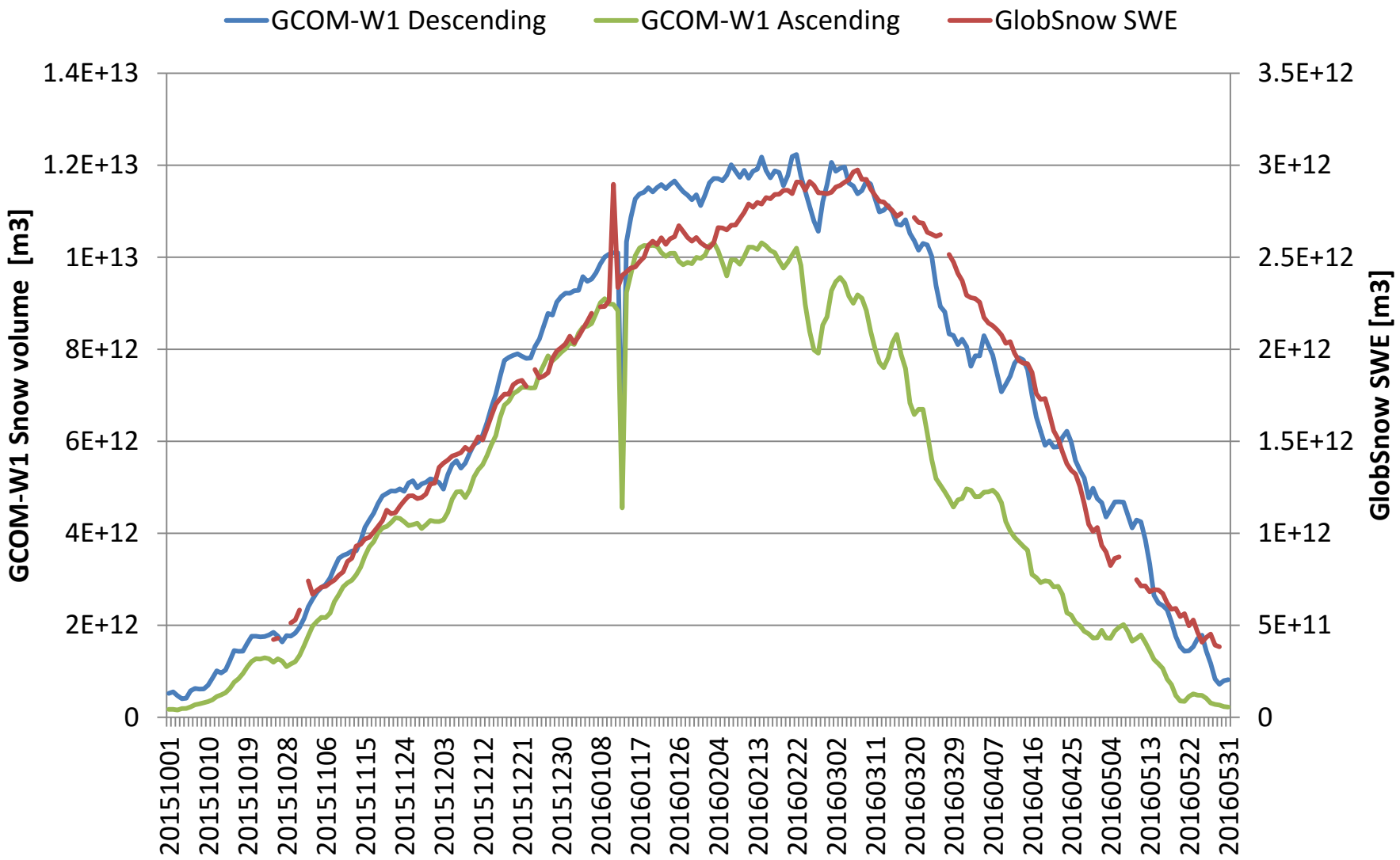
Area of Poland,
two winters Oct-May.



Comparison of amount of snow in NH for last winter 2015/2016:
-Snow volume calculated from GCOM-W1 SND product (Descending passes)
- Water volume calculated from Globsnow SWE

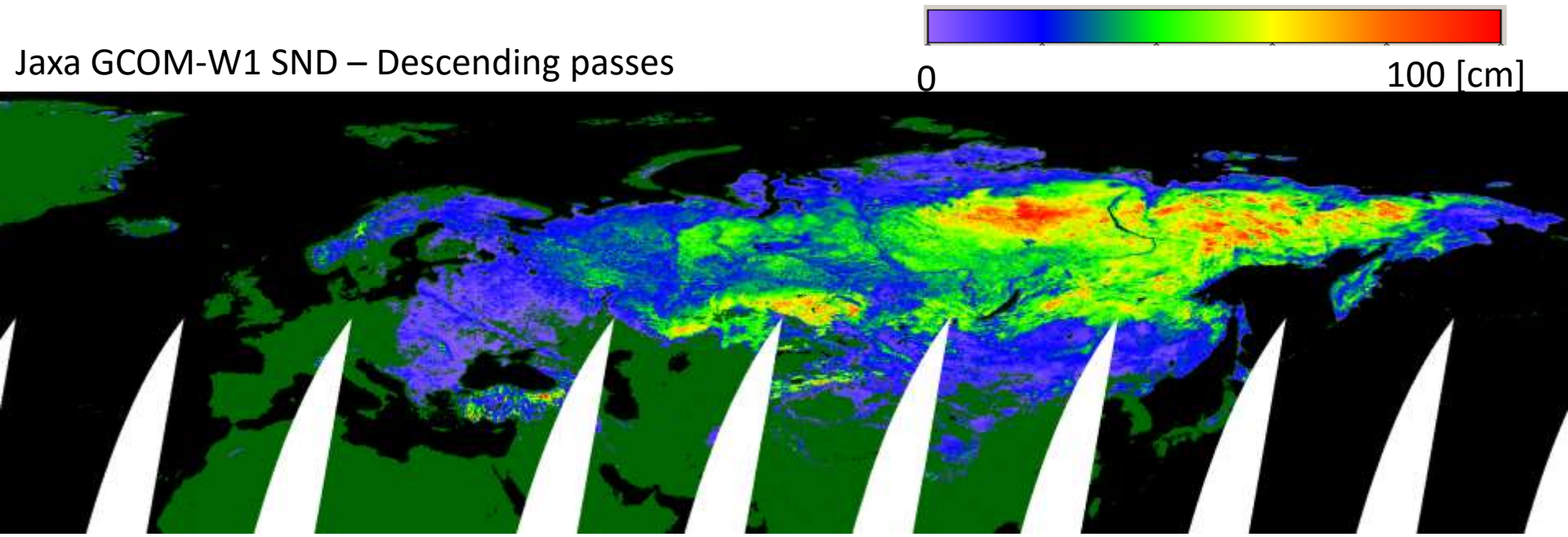


Comparison of amount of snow in NH for last winter 2015/2016:
-Snow volume calculated from GCOM-W1 SND product (Ascending and Descending passes)
- Water volume calculated from Globsnow SWE

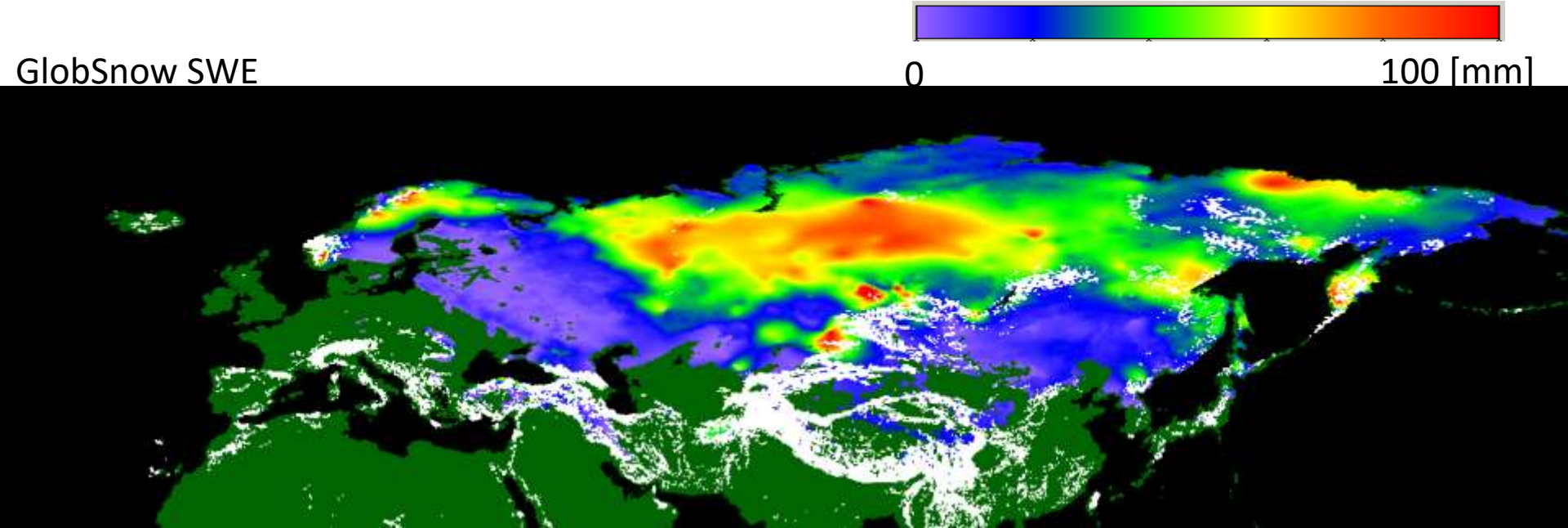


Comparison of JAXA GCOM-W1 Snow depth and GlobSnow SWE – 1.01.2016

Jaxa GCOM-W1 SND – Descending passes



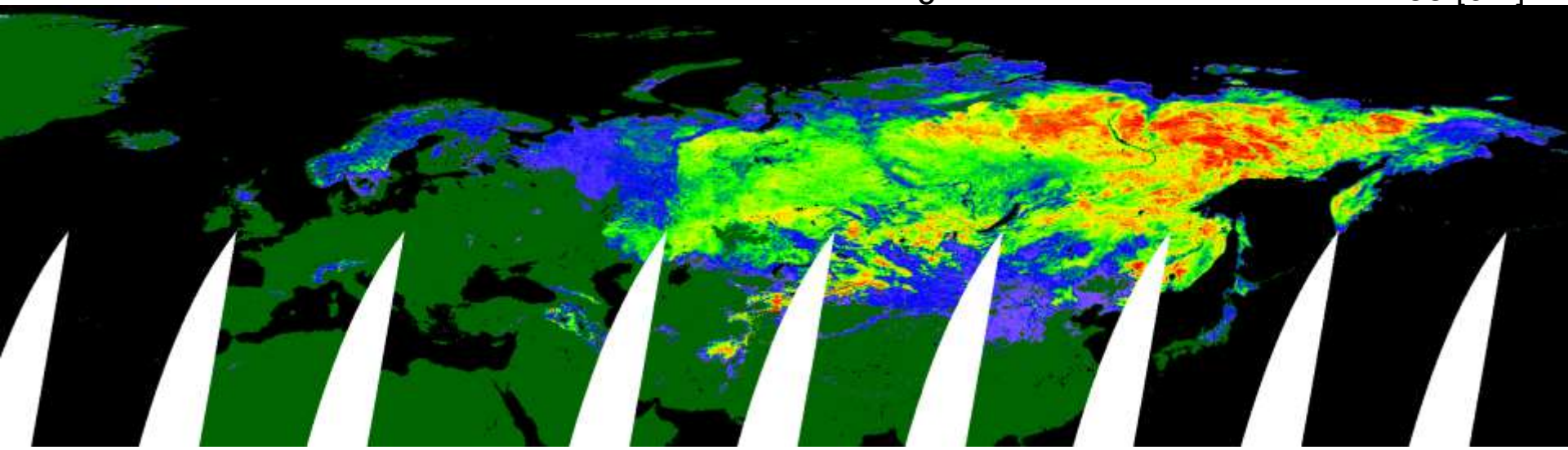
GlobSnow SWE



Comparison of JAXA GCOM-W1 Snow depth and GlobSnow SWE – 15.02.2016

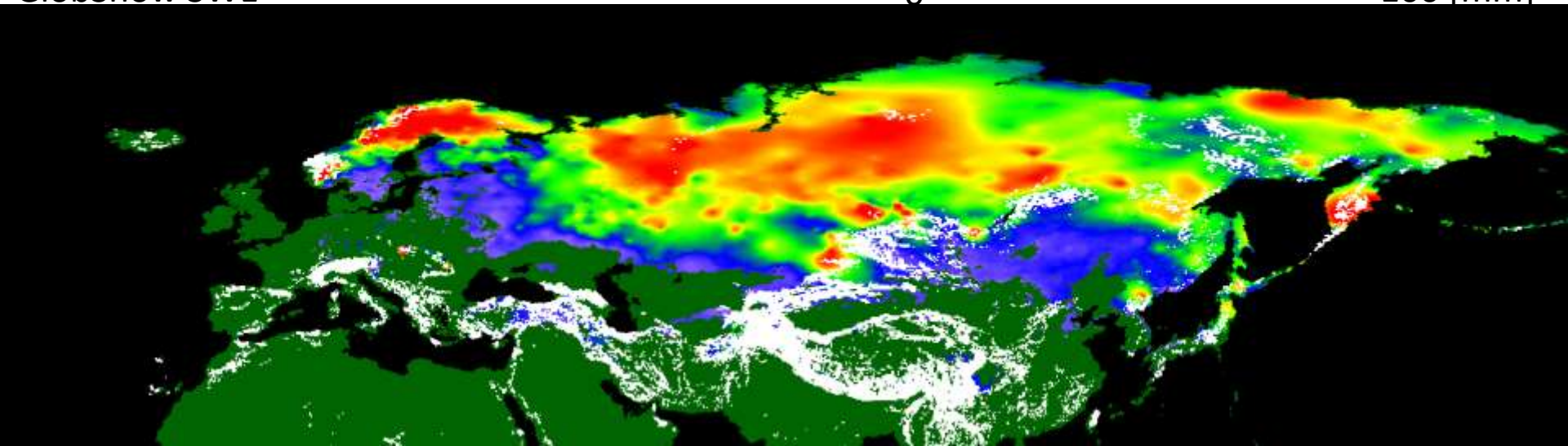
Jaxa GCOM-W1 SND – Descending passes

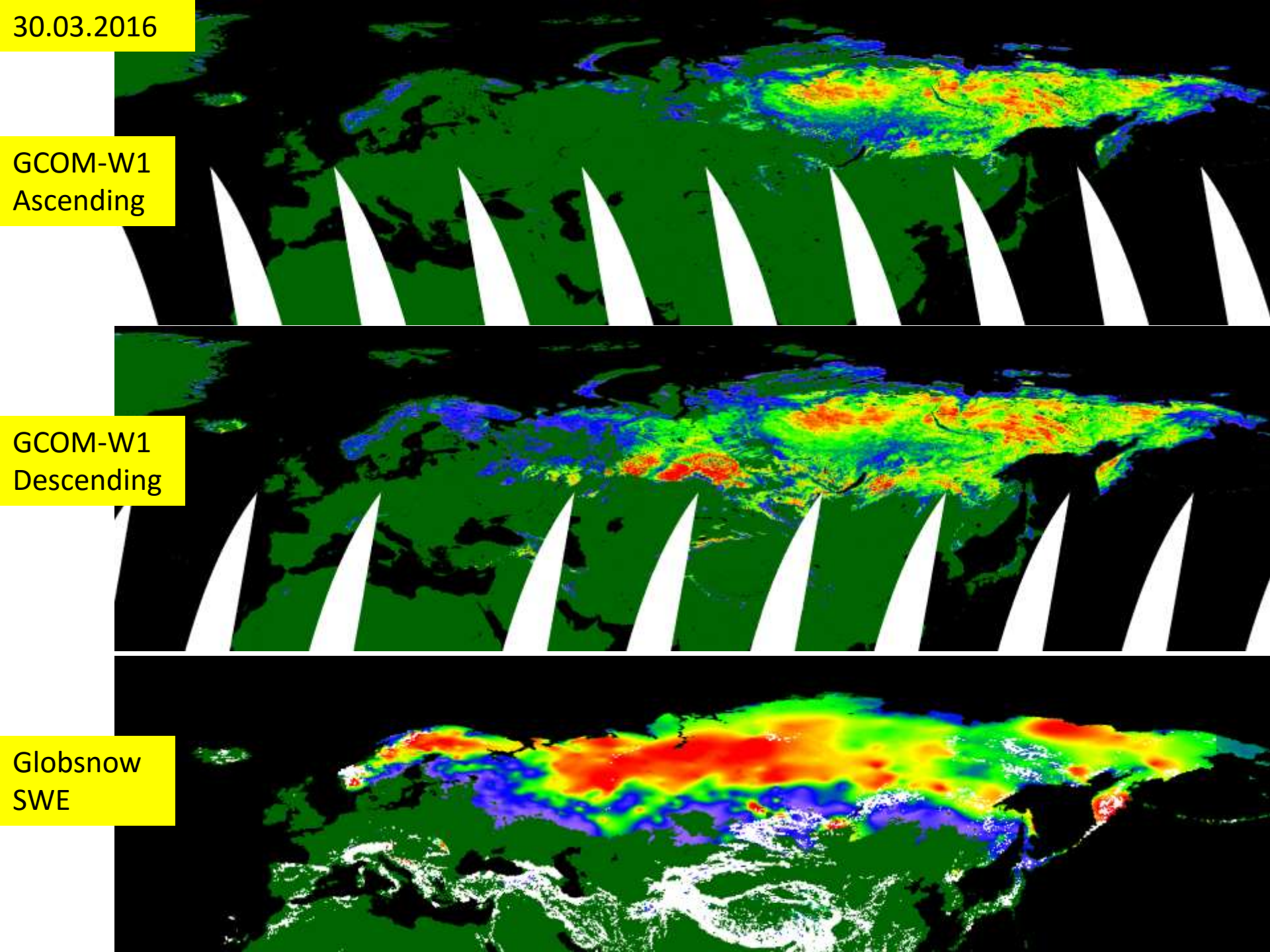
0 100 [cm]



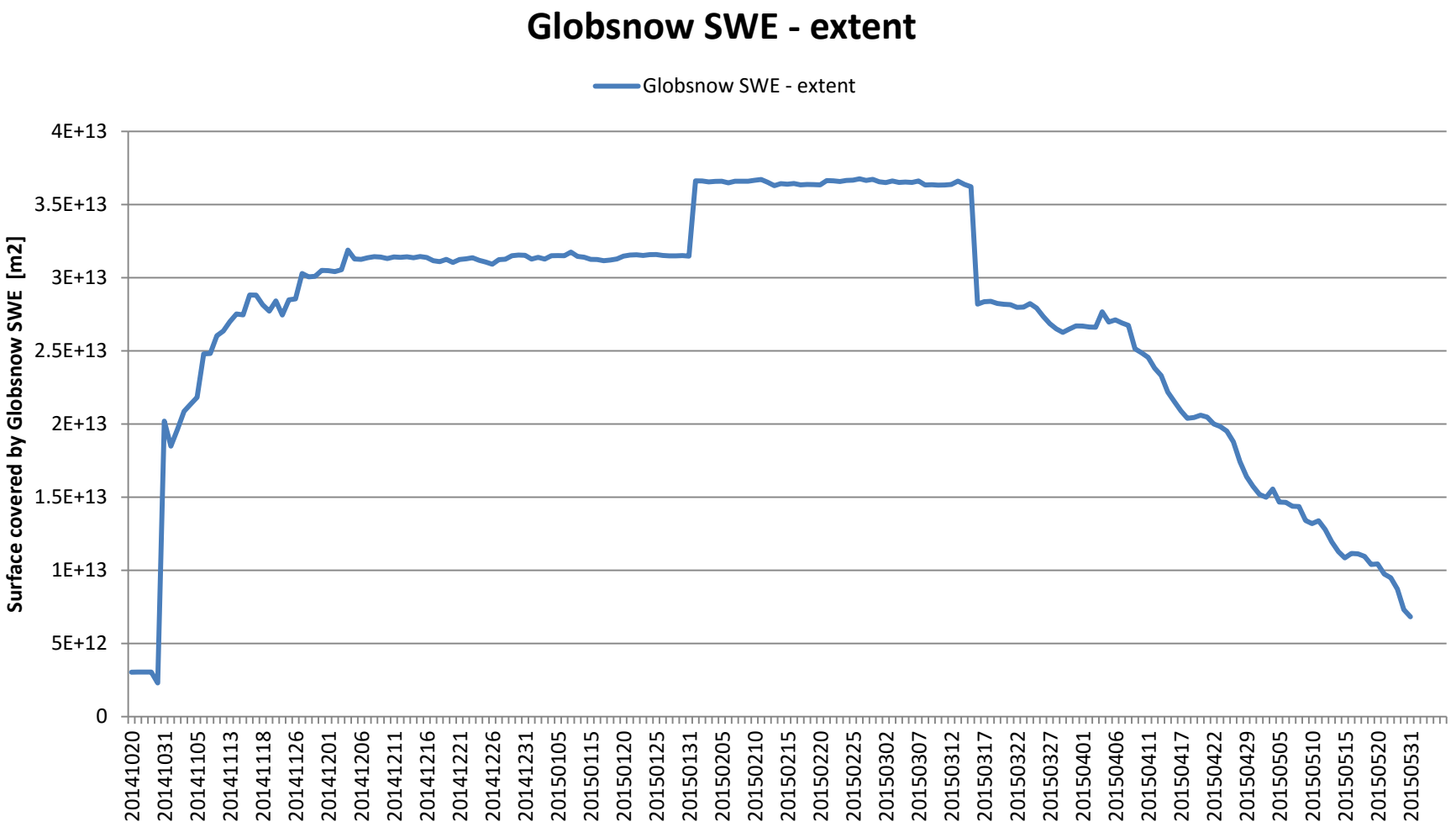
GlobSnow SWE

0 100 [mm]




30.03.2016
GCOM-W1
Ascending
GCOM-W1
Descending
Globsnow
SWE

NH Snow Extent calculated fron Globsnow SWE for winter 2014/2015



Conclusions:

1. We have time series of satellite observations covering ~50 years (visible sensors) and ~40 years (MW sensors) – climate data set.

2. Could we provide: stable and close to real observations, time series of physical parameters – snow extent, snow depth, SWE ?

3. Most problems of Vis/NIR observations is real observing cycle, limited by cloudiness and Sun elevation.

4. In case of MW observations, we still do not have products satysfying climatological requirements !!!

5. What about SAR ? I will be happy to hear better news.

Thank you
for your attention

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