Satellite snow extent for NWP

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Lugnaquilla, Wicklow, Ireland the 10th November 2019

Advanced Very High Resolution Radiometer AVHRR instrument

Onboard of several geostationary and polar orbiting satellites since early 1980'ies: NOAA satellites, MetOp

Measurement of reflectivities/radiances in optical wavelengths (visible and near-IR solar radiation), also some thermal channels

Available data resolution increased from early 5 km (global GAC) to present-day 1 km (local LAC) scale

Snow extent is derived in several applications intended for climate and NWP usage:
MetNo CRYOCLIM, EUMETSAT H-SAF, ESA CCI

Global snow extent products derived from AVHRR radiances

CRYOCLIM Met Norway

Intended for climate applications

Algorithm:
0) No cloud masking
1) Detection of snow and cloud probabilities
2) Equal-Area Scalable Earth (EASE) grid

EUMETSAT HSAF

Intended for NWP application

Algorithm:
0) No cloud masking
1) Detection of snow
2) Interpolation to lat/lon grid

Operational since 2017
MetOp, 1 km resolution

ESA CCI

Snow extent test product in development of multichannel snow products

Algorithm:
1) Cloud masking
2) Detection of snow
3) Interpolation to lat/lon grid

AVHRR Fundamental Climate Data Record

Based on data from the Advanced Very High Resolution Radiometer (AVHRR) onboard the U.S. National Oceanic and Atmospheric Administration (NOAA) polar-orbiting satellites. The AVHRR Polar Pathfinder (APP) is a fundamental climate data record that provides AVHRR channel reflectances in satellite projection pixels

Global snow extent products derived by

CRYOCLIM Met Norway

1982 – 2015+
resolution ~ 5km

Since 2015 additional data beyond the project

EUMETSAT HSAF

~~1982 – 2016~~
~~resolution ~ 5km~~

Federative Activity funding cancelled 20.1.2020

ESA CCI

1982 – 2019
resolution ~ 5km

Climate Change Initiative
http://cci.esa.int
http://snow-cci.enveo.at

HSAF, MetNo, CCI snow extent compared for spring 2016 by Kouki and Siljamo, FMI: statistics, examples, preliminary conclusions. Note: 2016 is not official CRYOCLIM!

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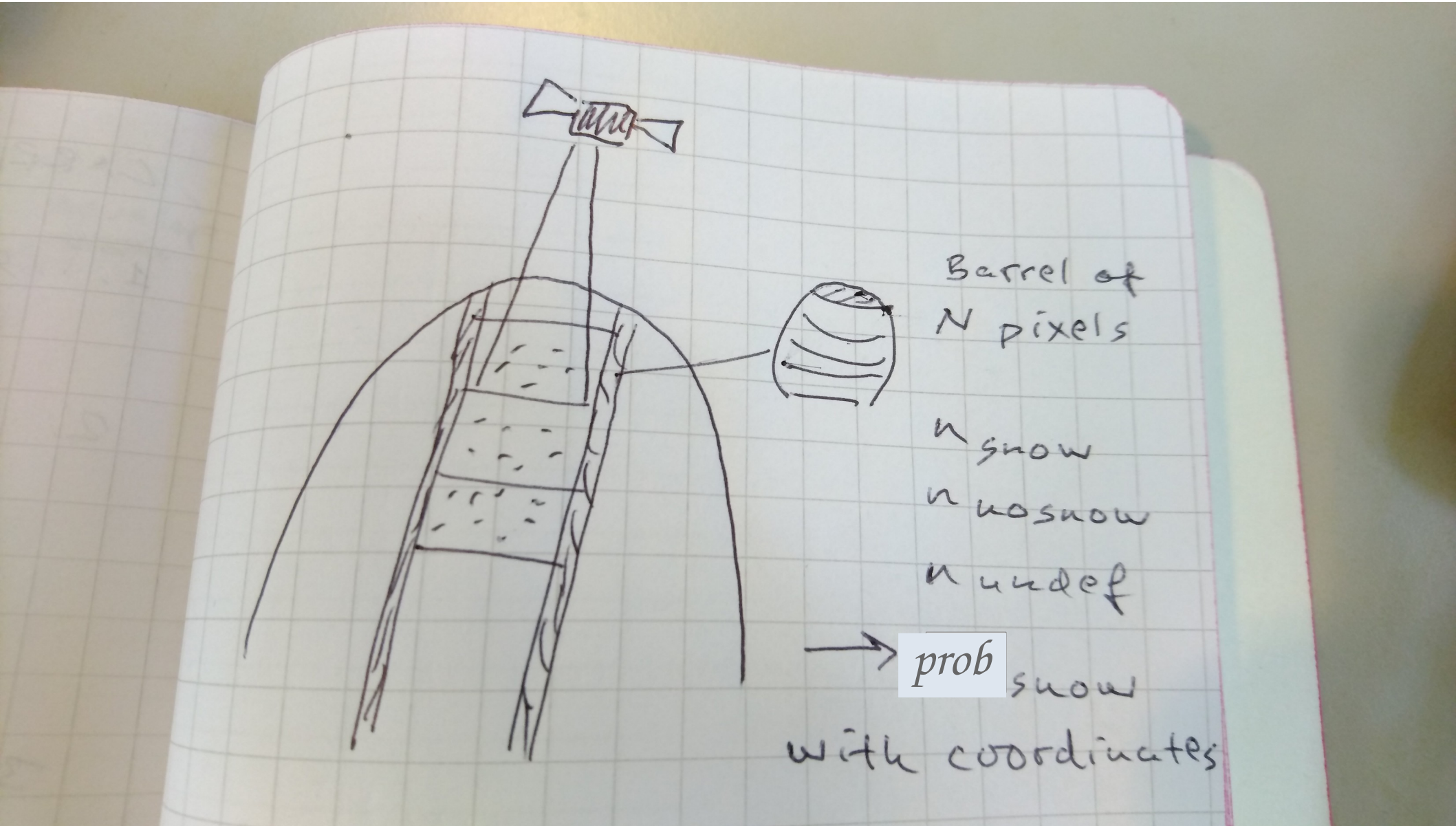
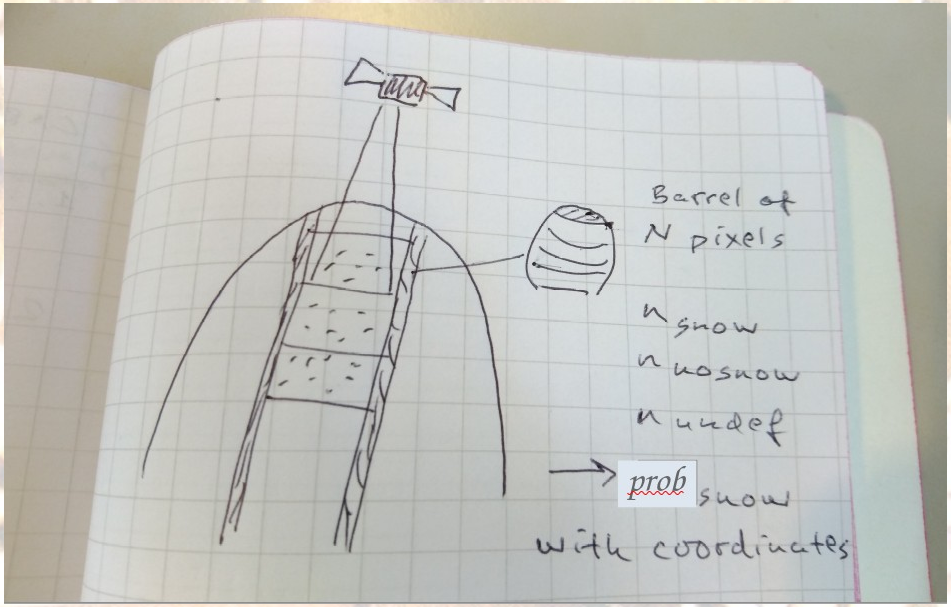
Collection of barrels along the satellite flight track



Use of barrels

Barrels of raw data are collected during the satellite overpasses: hence, there is no need for

- interpolation of the satellite data to a lat-lon grid
- screening/thinning of satellite data in NWP analysis



Observation-based $prob_{snow}$ → $snow\ depth_{pseudo}$ observation for optimal interpolation

How to apply the pseudo-observations in the analysis: quality control, use of $prob_{snow}$, obs error std ...

- further developments needed

Step 1: thinning

HSAF obs in pixels → HSAF obs in lat-lon points

Step 2: creating pseudo-obs

no snow in H SAF
snow in NWP
→ 0 snow in pseudo-obs

snow in H SAF
no snow in NWP
→ 5-10 cm snow in pseudo-obs

Step 3: optimal (statistical) interpolation

SYNOP obs
pseudo obs from H SAF
NWP background field
→ gridded snow analysis, initial conditions for the next NWP forecast

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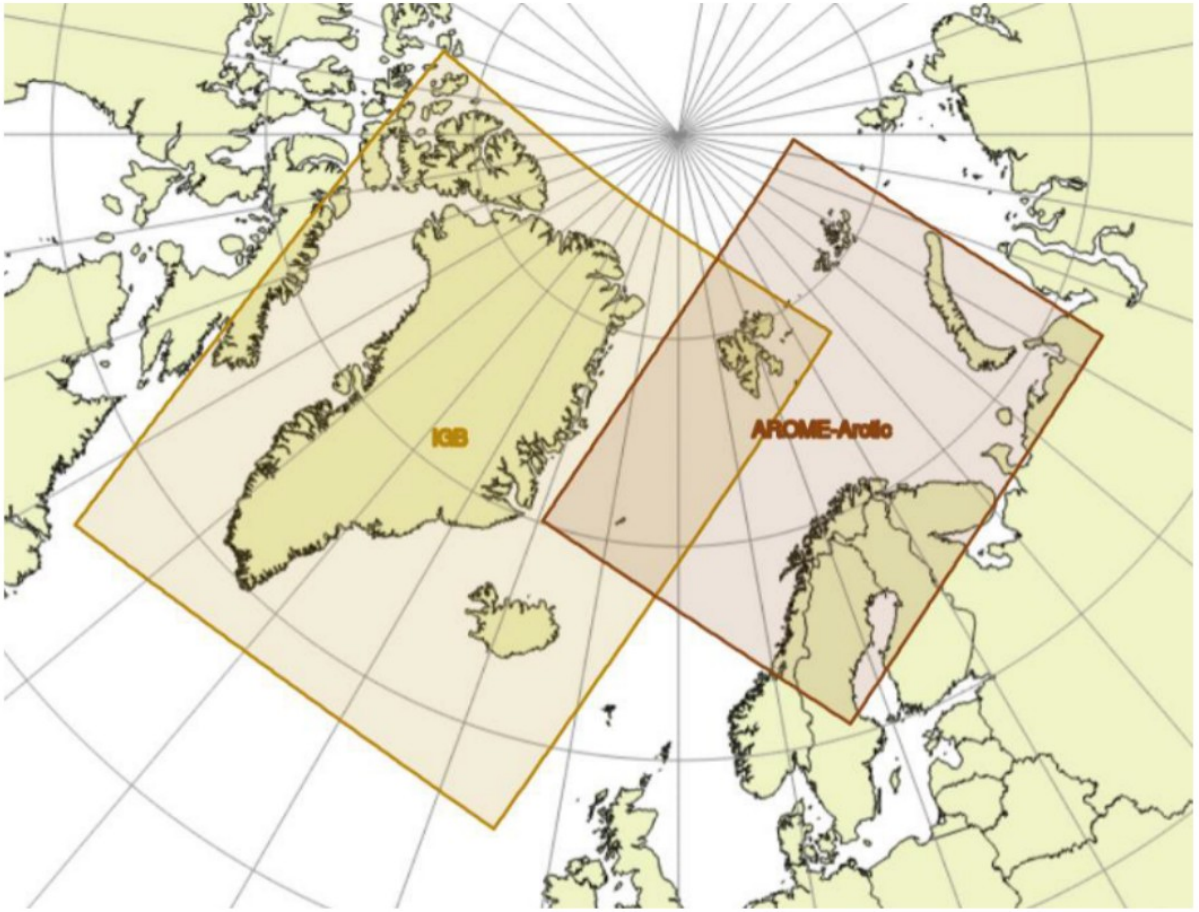


Experimenting by trial and error, oops ...

- cold start instead of warm start
- missing barrels
- missing CARRA conv.obs
- poor knowledge of oulan-bator-odb-CANARI

Comparable experiments: carbar5 and carpro, operational PRO

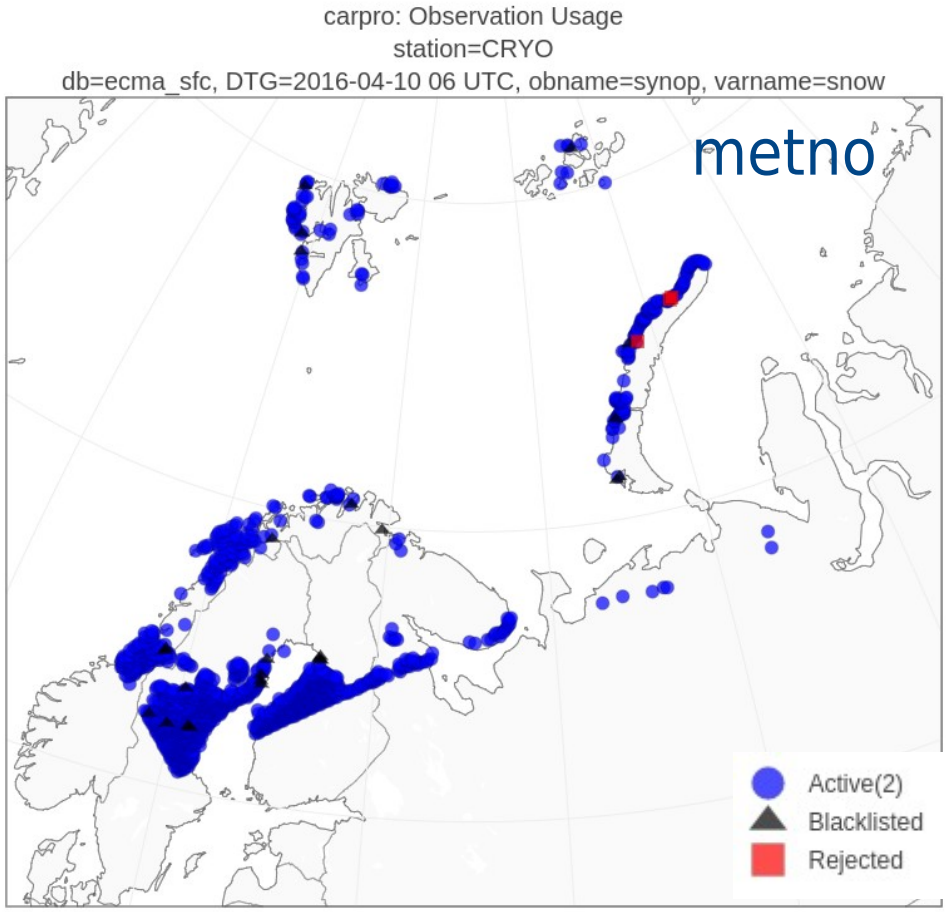
Table 1: CARRA barrel experiments

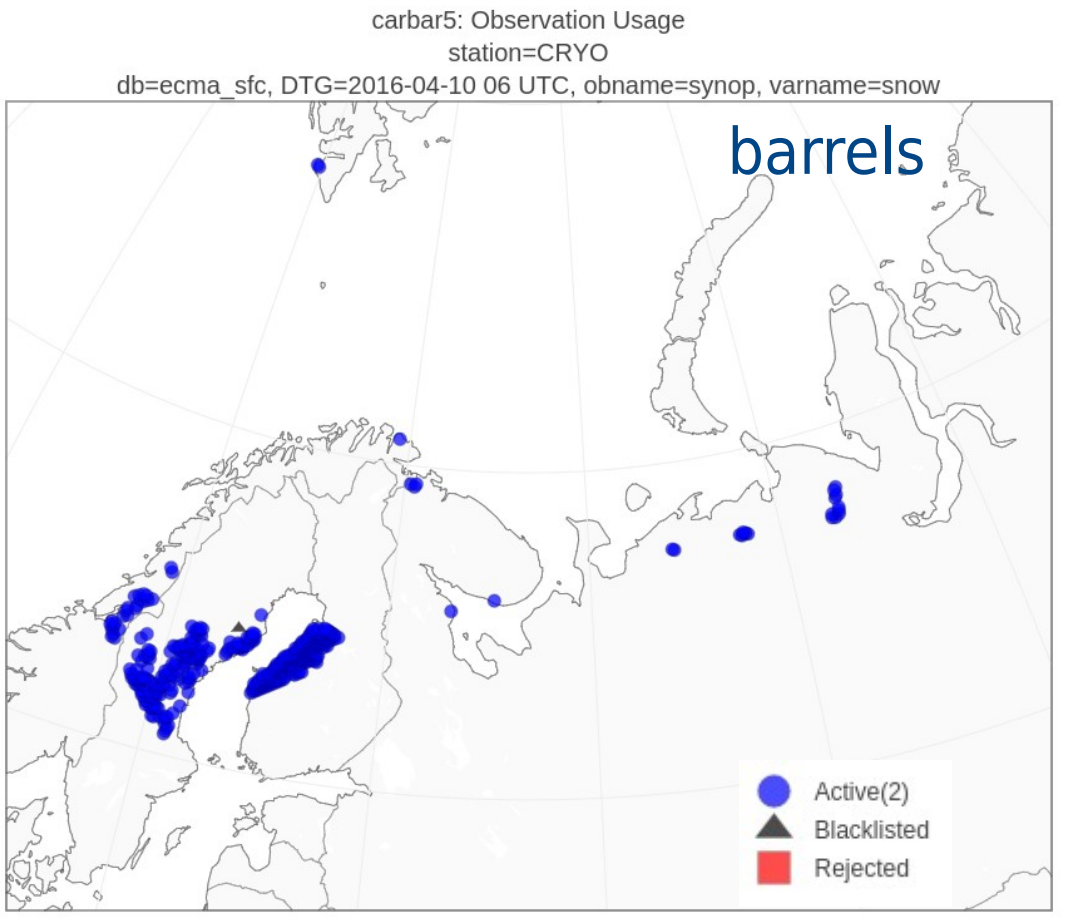
Experiment	CANARI version	Satellite snow	Initial start	Note
carbar5	barrels	HSAF barrel 10km	warm	a few misplaced barrels LISTE_NOIRE_DIAP reference
carpro	reference	CRYO 5-10km	warm	all obs
PRO	production	CRYO 5-10km	-	files from archive
carref	reference	CRYO 5-10km	cold	
carnos	reference	none	cold	
carbar	reference	HSAF barrel 20km	cold	
carbar1	reference	HSAF barrel 10km	cold	first trial, some missing barrels
carbar2	updated	HSAF barrel 10km	cold	first code update trial
carbar4	reference	HSAF barrel 10km upd	warm	barrels + no extra obs LISTE_NOIRE_DIAP modified

Example of observation usage: satellite snow only

Reference CARRA_NE setup warm start
All observations included in experiments

2016040106





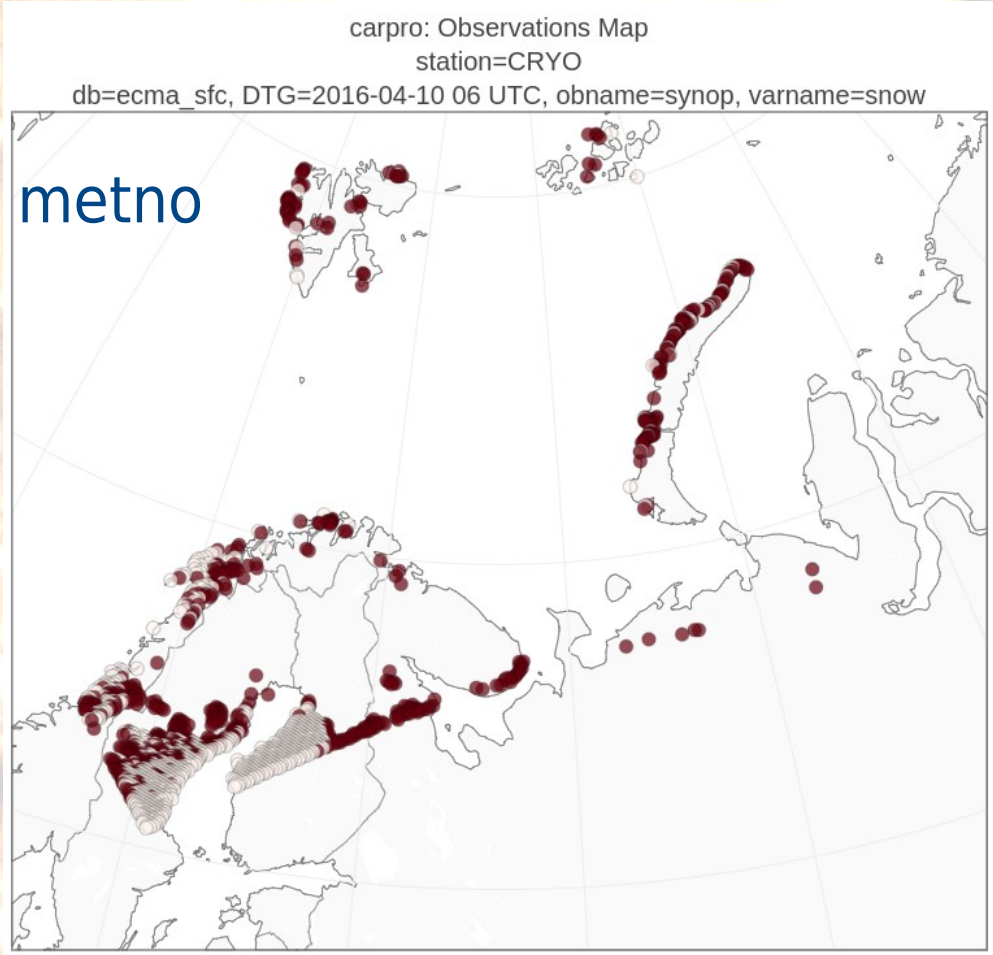
Cryo = 5-10km MetNo CRYO
observations filtered over several days

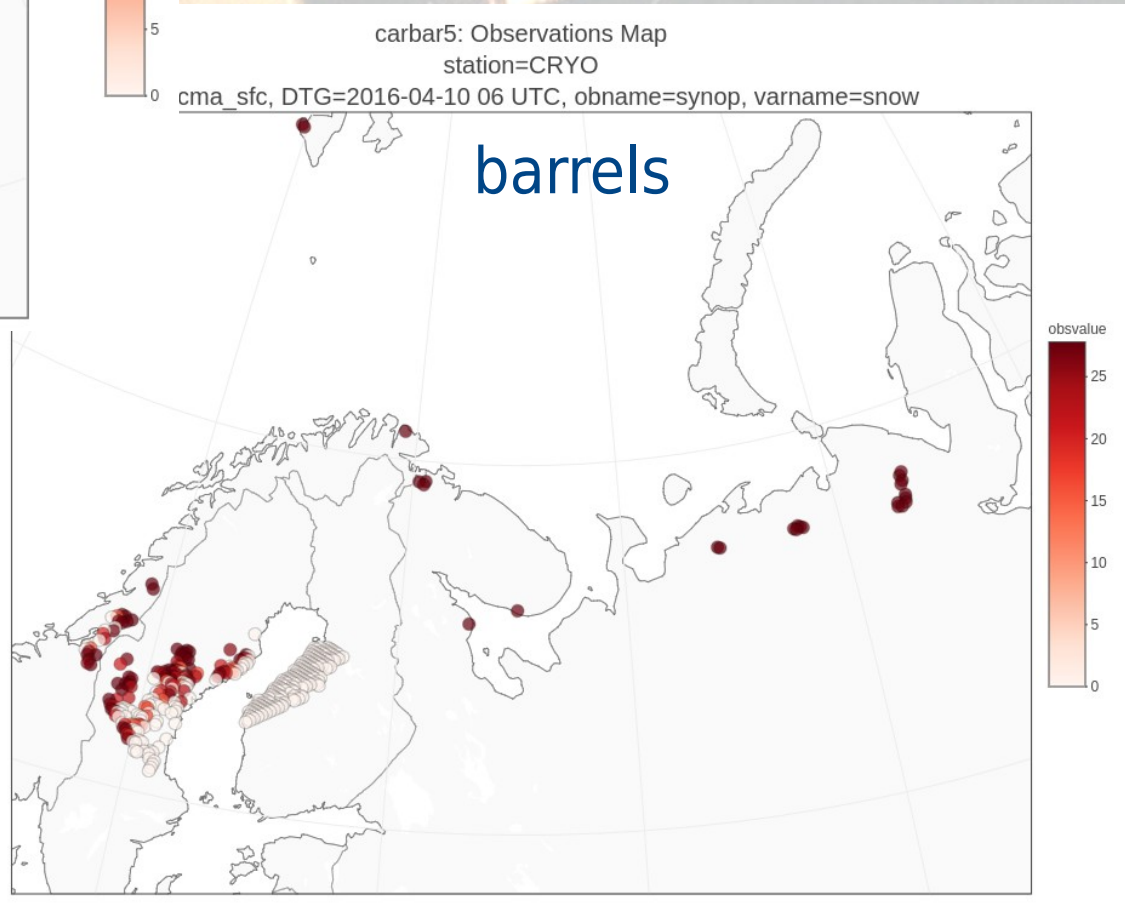
Barrels = H-SAF track → 10 x 10 km
observations from this day only

- rejected and blacklisted satellite snow observations?
- border zone along the southern (land) boundary?

Example of observed values: satellite snow only

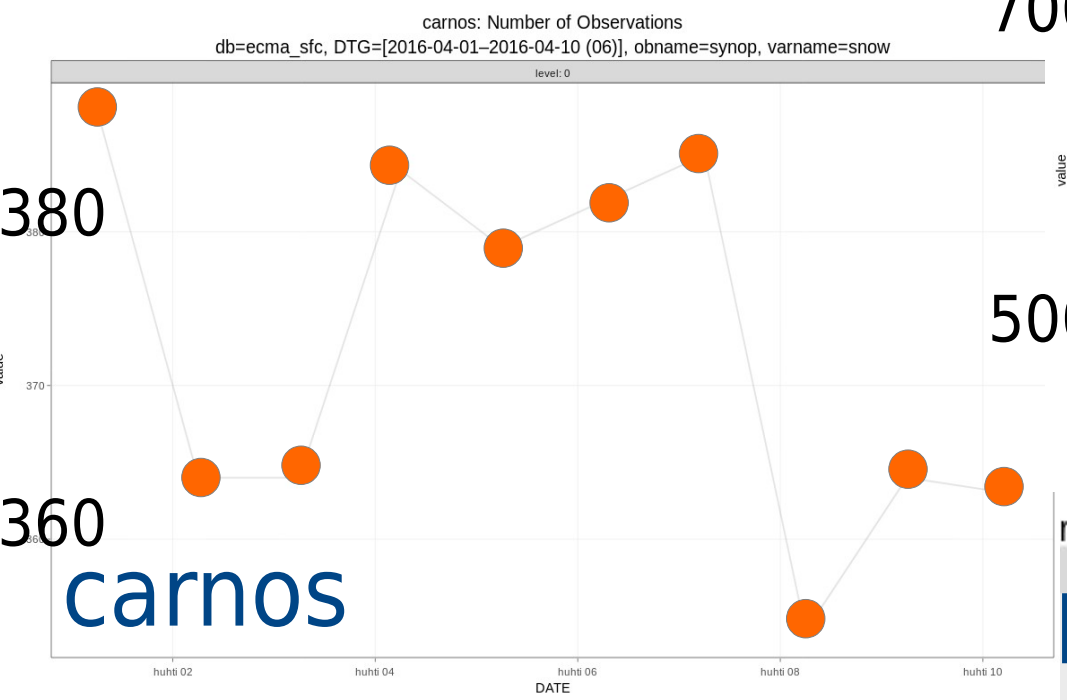
2016040106



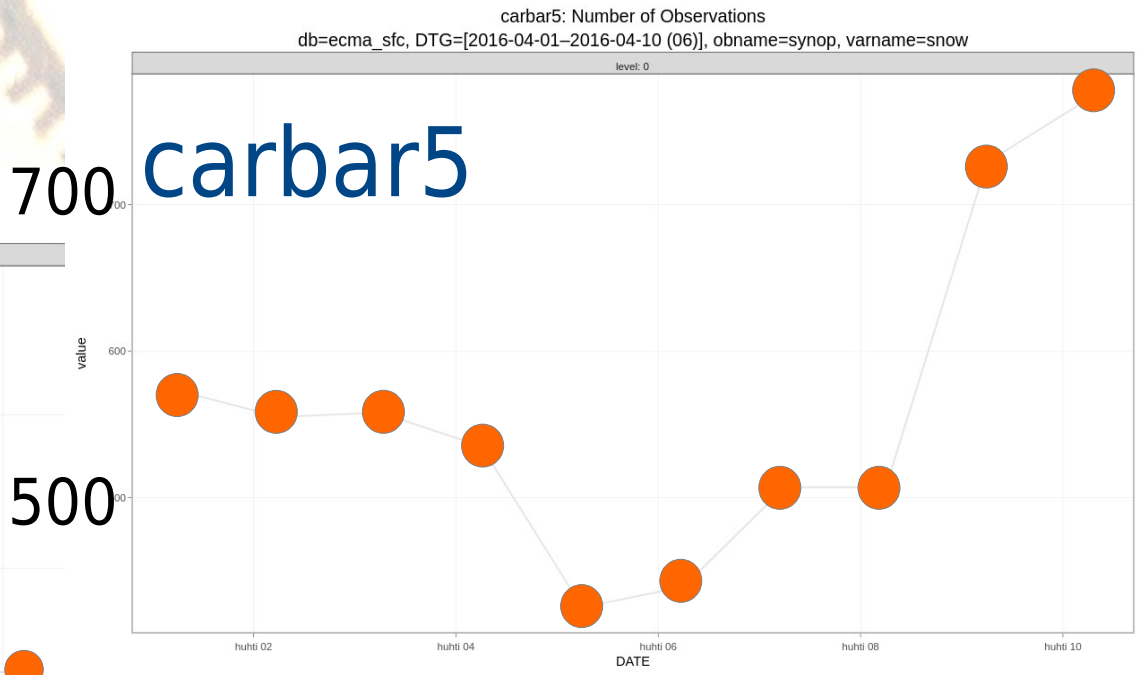


- metno both cleans and adds snow at Norwegian, Svalbard, Novaya Zemlja coast
- barrels miss data over coastlines – overall less observations/activity
- barrels now suggest prob * (10 cm) v.s. metno 10 cm of snow depth where addition is needed

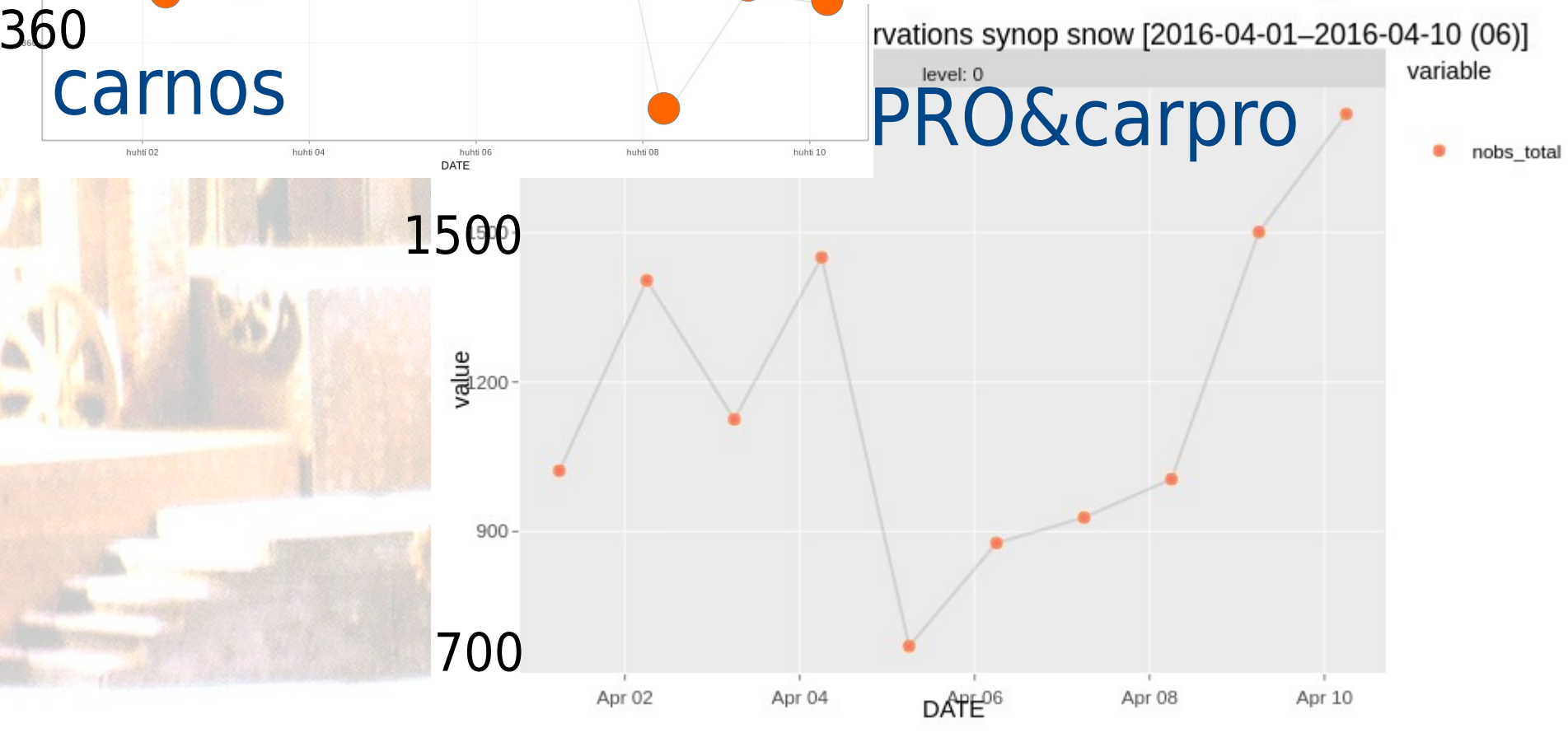
Snow observations used 20160401-20160410



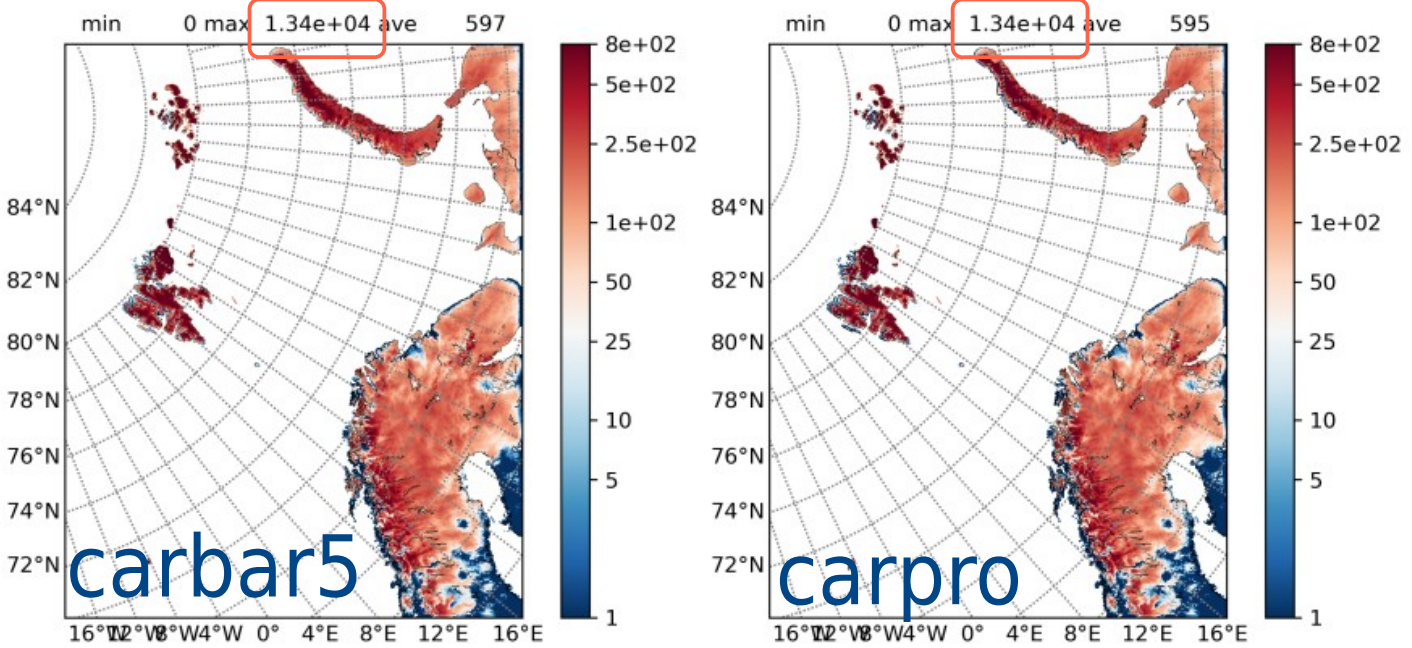
carnos

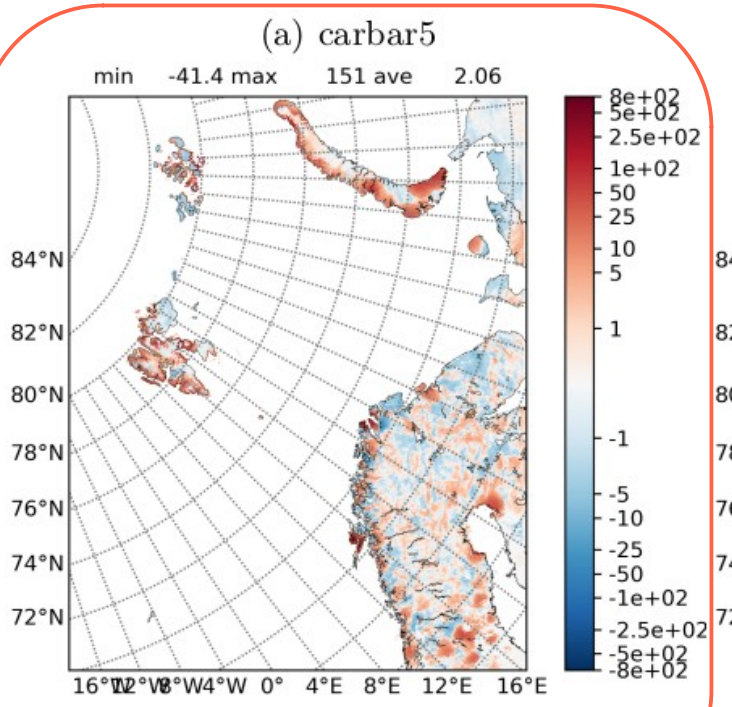


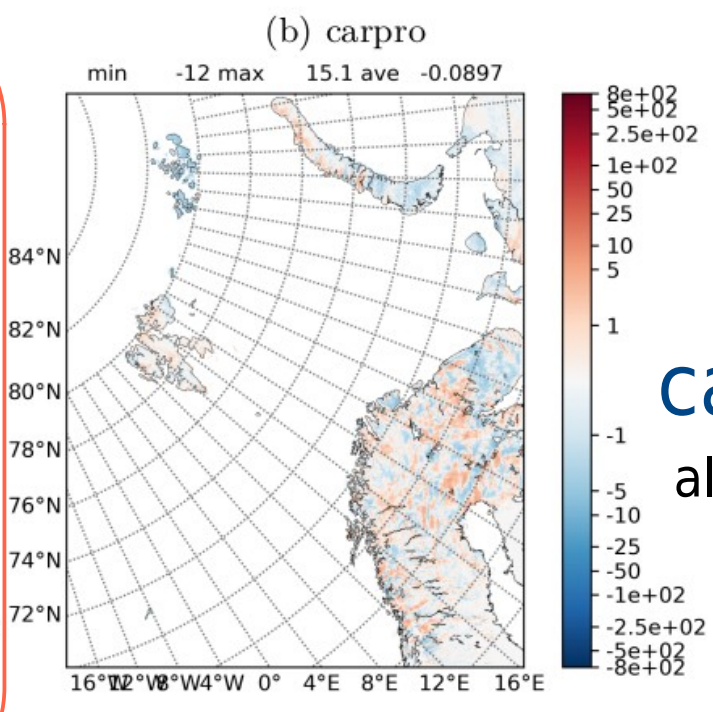
carbar5



PRO&carpro







(c) carbar5 - carpro : barrels v.s. reference (d) PRO - carpro: production v.s. reference

Figure 11: Snow water equivalent, unit kg/m^2, date: 2016041006+0003h

carpro-PRO

almost identical

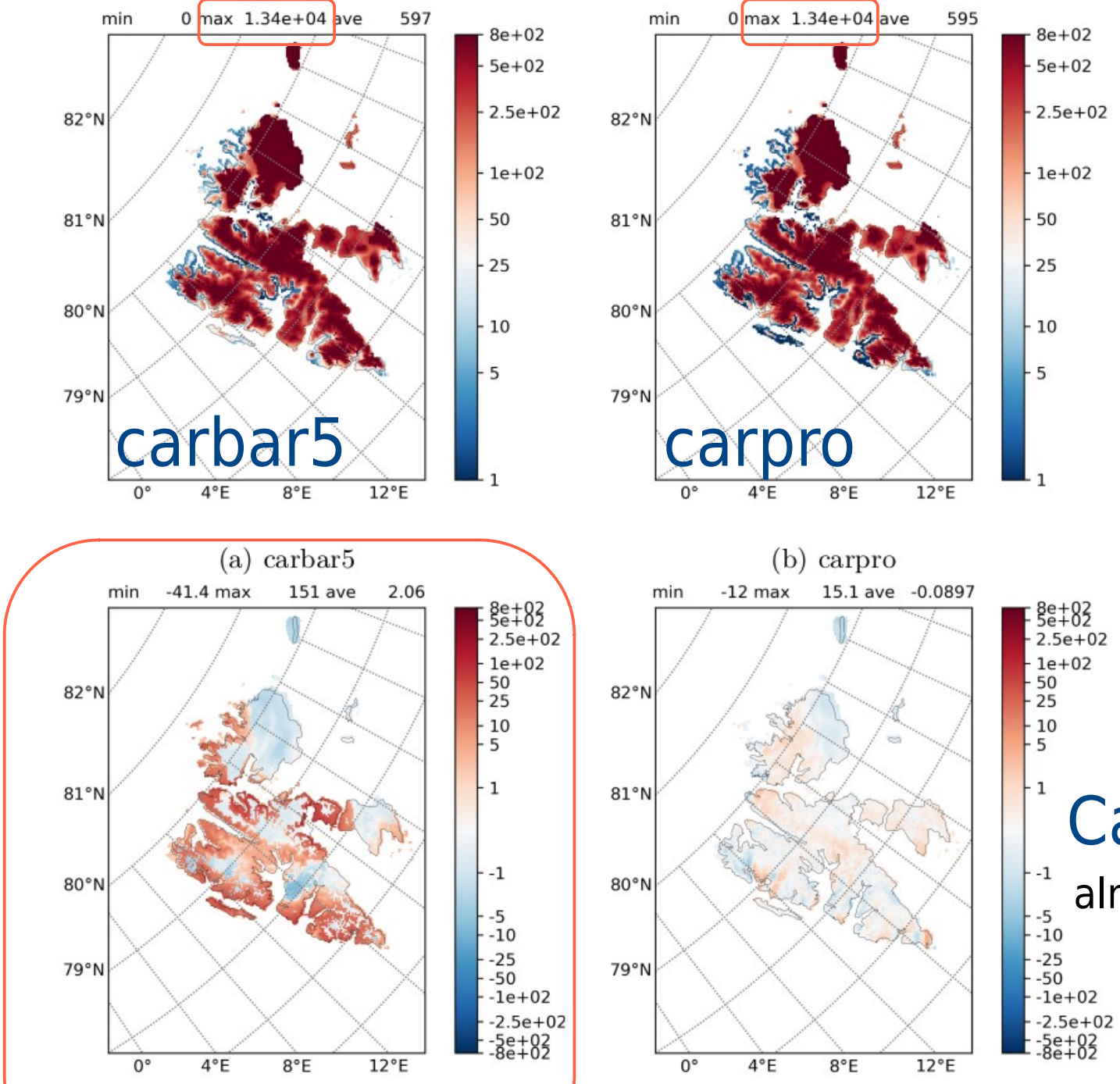


Figure 11: Snow water equivalent, unit kg/m^2, date: 2016041006+0003h

Carpro-PRO

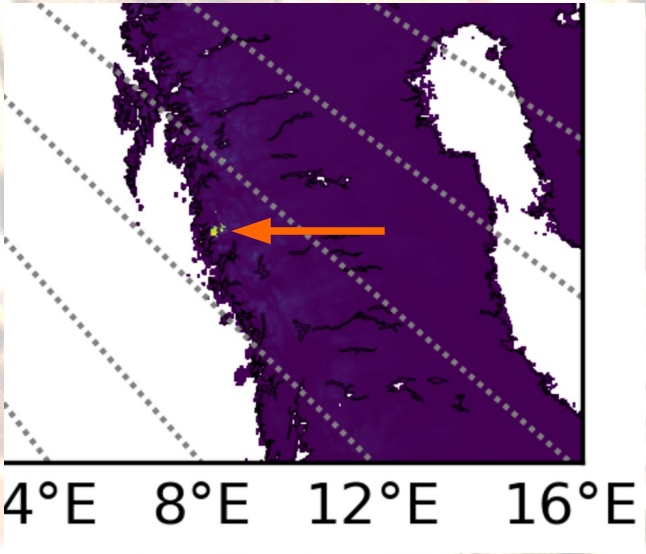
almost identical

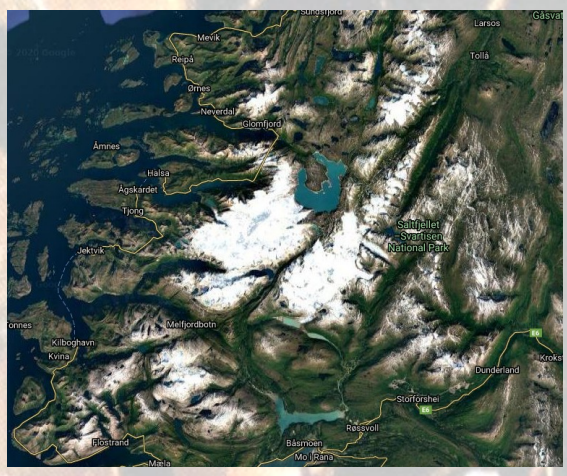
Questions about snow analysis

- Blacklisted observations in obsmonitor:
  anflag=8 – not related to LISTE_NOIRE_DIAP?
- Who is blacklisting (or simply not using) satellite snow observations?

→ problem of quality control and/or obsmon behaviour

- Large values of forecast SWE in production and warm start experiments?





Saltfjället glacier at coast

→ Coast problem and glacier problem

Coast problem

Snow observations from stations and satellite can be good
but they may not fit the model grid in points
where the first guess is not well defined

How to define snow depth/SWE at station location
when there is too much water surface in the surrounding gridbox?
(question of observation operator)

In addition, there are at least three different
descriptions of the land-water fraction:

Fine resolution from ECOCLIMAP – known to SURFEX (SWE first guess)
Coarser resolution from m-climate files – known to CANARI (analysis)
Coarser resolution form ECMWF physiography – used in cold starts only

Blacklisting of stations/satellite data becomes grid-dependent!

Glacier problems

In HARMONIE, there are no real glaciers
neither in the forecast model nor in the surface data assimilation

Analysis treats glacier as any snow where
SWE is known from the first guess and observation
Does the analysis try to distribute glaciers to the surrounding grid points and, in the quality control, to the nearby station locations?

Does the forecast model treat the permanent snow differently from the seasonal snow? Does the glacier snow grow, melt etc. thus influencing the first guess for analysis?

The permanent snow definitions differ:
- Permanent snow from ECOCLIMAP is well known to SURFEX from PGD files, artificial snow depth possibly assigned there
- There are no glaciers in the m-climate files known to CANARI
- In cold start, ECMWF permanent and seasonal snow together enter HARMONIE forecast

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Satellite snow extent data is useful but
data from different sources differ

Snow barrels seem to be a good approach for the future
especially when based on high-resolution radiances

To be able to benefit from such data, improvement of
our surface data assimilation is necessary

Improvements could be started from solution of the
coast and glacier problems already detected

Obsmonitor is an excellent tool but needs
development and better understanding


THANK YOU
for
YOUR ATTENTION!
Lugnaquilla, Wicklow, Ireland the 10th November 2019