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Evaluation of remote-sensing snow observations for perspective of DA in NWP

/ after Maxime Quenon's Internship Report/

Ekaterina Kourzeneva,
Laura Rontu,
Terhikki Manninen
and Niilo Siljamo;
thanks for Elena Shevnina

8-9 March, Offenbach, DWD

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Scientific motivation:

A gap between new advanced remote-sensing observations of snow and simple methods of snow DA in NWP

Snow Extent (SE): a binary value (yes/no).

- No statistical interpolation (OI) methods.
- No understanding of observational error.
- Difficult to combine observations from different satellites.
- In DA, we just fully trust observations.

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Practical motivation and History

No remote-sensing snow observations are assimilated into HARMONIE: the situation should be improved.

Summer 2016, Maxime Quenon, the Intern from ENSG at FMI.

The main focus of his work:

To evaluate different remote-sensing snow products for the perpective of DA in NWP.

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Outlook

- Results from Maxime:
  Evaluation of different snow products:
  - data availability and quality
  - comparison with SYNOP data
  - comparison with model data

- Ideas:
  - observational error for binary data – what is it? how to calculate?
  - what can be a basis to develop the statistical interpolation methods for them

Towards improved objective analysis of snow, which combines data from different satellites

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Satellite snow products

SE:

categorical value

- MSG (METEOSAT)
  geostationary
  visual band -> cloudiness problem
  resolution ~ 3 km
  temporal resolution: raw ~ 15 min, final ~ 1 day
- METOP
  polar orbiting
  visual band -> cloudiness problem
  resolution ~ 1 km
  temporal resolution: raw ~ 12 hours, final ~ 1 day

Surface considered	No processing	Totally snow covered	Partially snow covered	No snow	Unclassified	Water
Value in the classification	0	1	2	3	4	5

MAXIME QUENON, 2016

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real value

- SYNOP
  in obs points
  at SYNOP times
  snow depth

real value

- Harmonie
  SWE
  snow fraction
  resolution ~ 2.5 km
  every 3 hours

Methods

- Averaging in time => data on daily basis
- Reprojecting from one grid to another using the nearest neighbor method
- Converting the binary data to the snow fraction when upcoming from the finer to coarser grid
- Converting SWE to the snow depth and back using the snow density climatology
- Converting SWE to the snow fraction and back using the ad hoc formula:

$$fraction = \frac{SWE}{SWE + 10}$$

- Converting the snow fraction to the binary SE using a threshold value of 0.5

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Methods

Visual comparison

- maps

Statistics

- contingency tables

	Analysis 2	
Analysis 1	Snow	No snow
Snow	*a*	*b*
No snow	*c*	*d*

- coefficients from the contingency tables and time series of them :

- histograms and double histograms of errors (differences)

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Snow data comparison

	SYNOP	MSG	METOP	Globsnow	Harmonie
SYNOP		✸	✸	✸	-
MSG			✸	-	✸
METOP				-	✸
Globsnow					✸
Harmonie					

Winter 2015-2016

Daily statistics, sampling in space

Europe, Scandinavia, Finland

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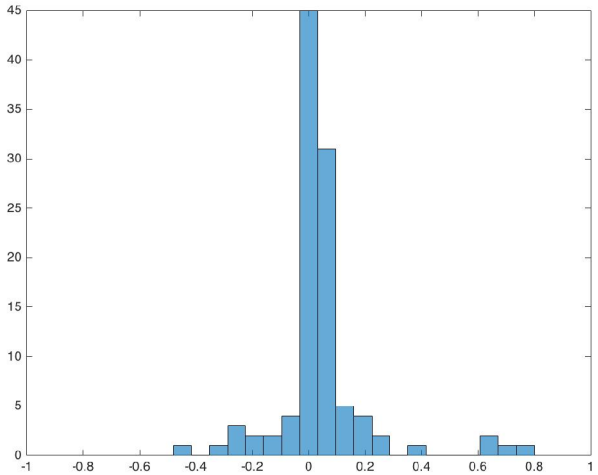
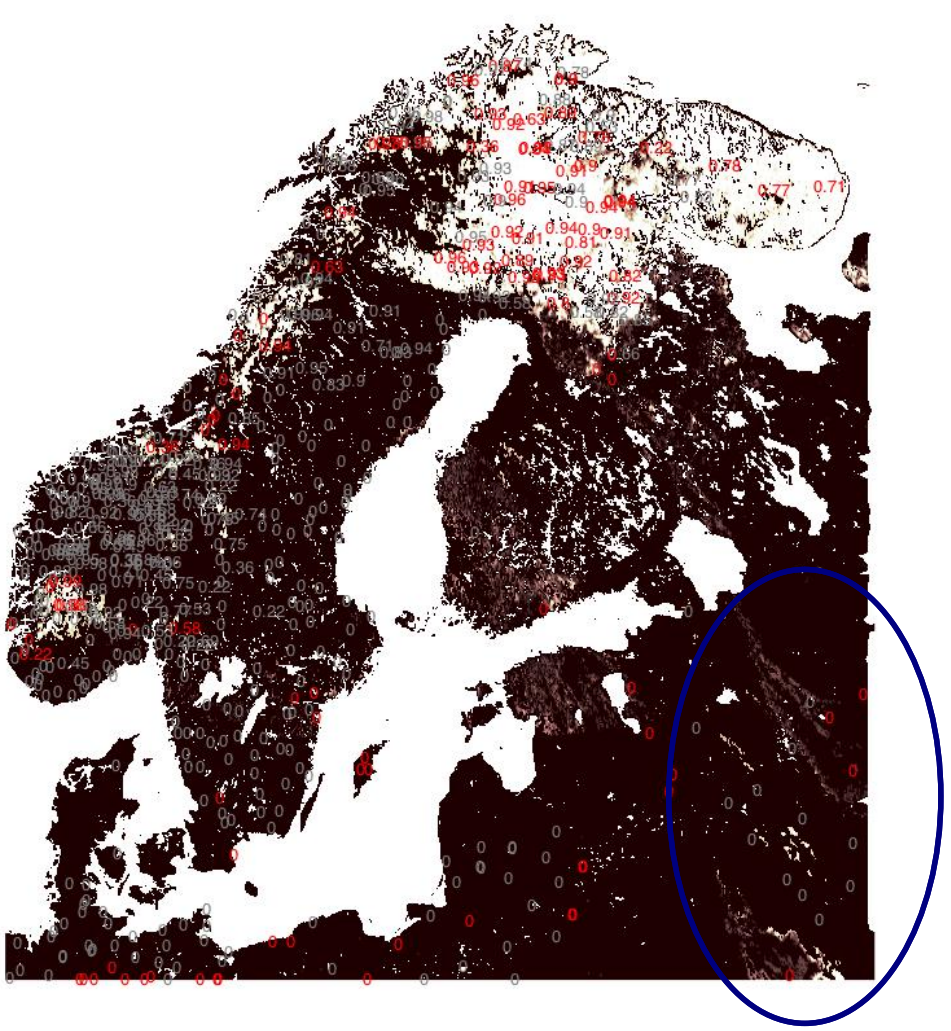
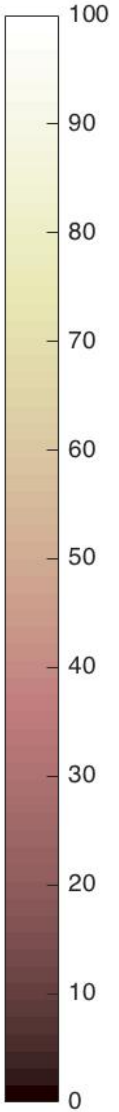
METOP vs SYNOP



Diff=METOP-SYNOP

✓ "False" snow in METOP





29.04.2016

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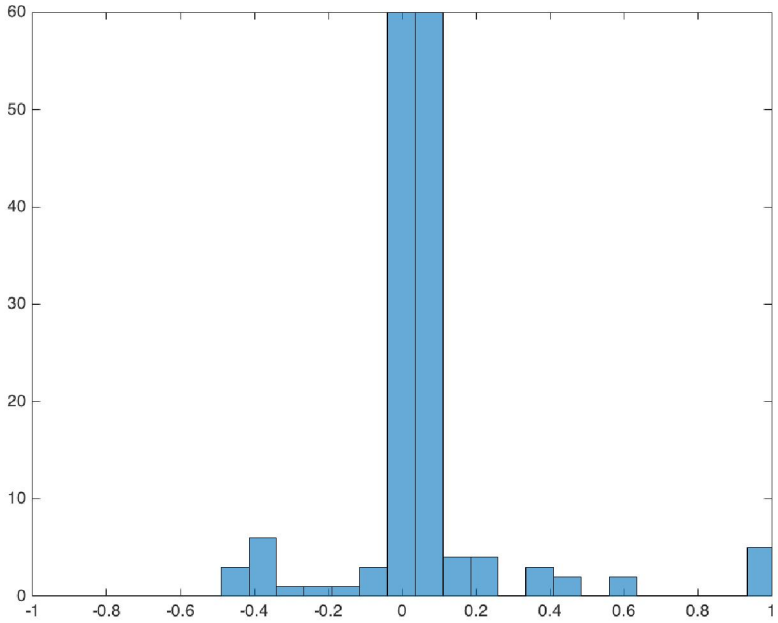
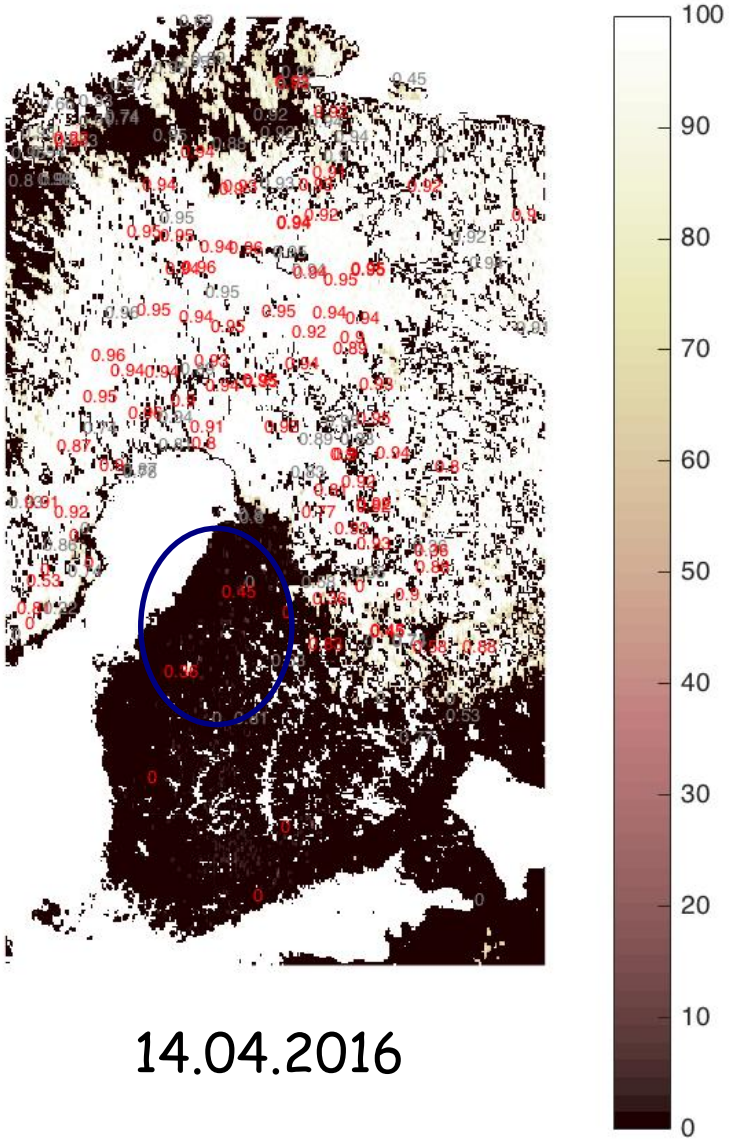
METOP vs SYNOP



Diff=METOP-SYNOP

✓ "Not detected" snow in METOP



14.04.2016

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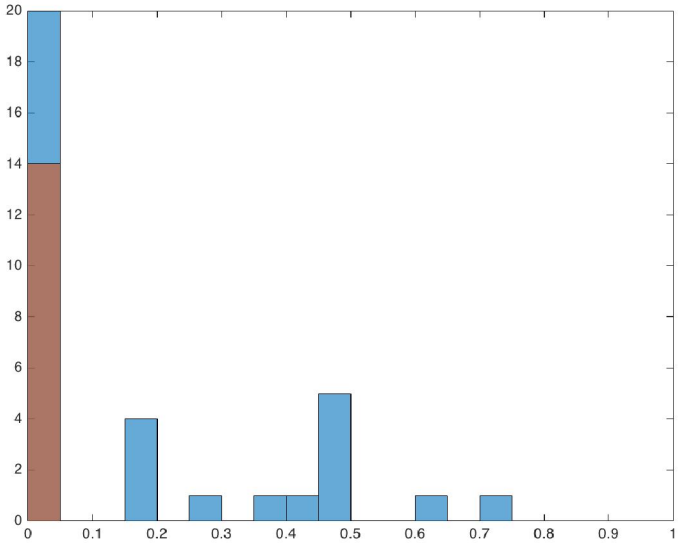
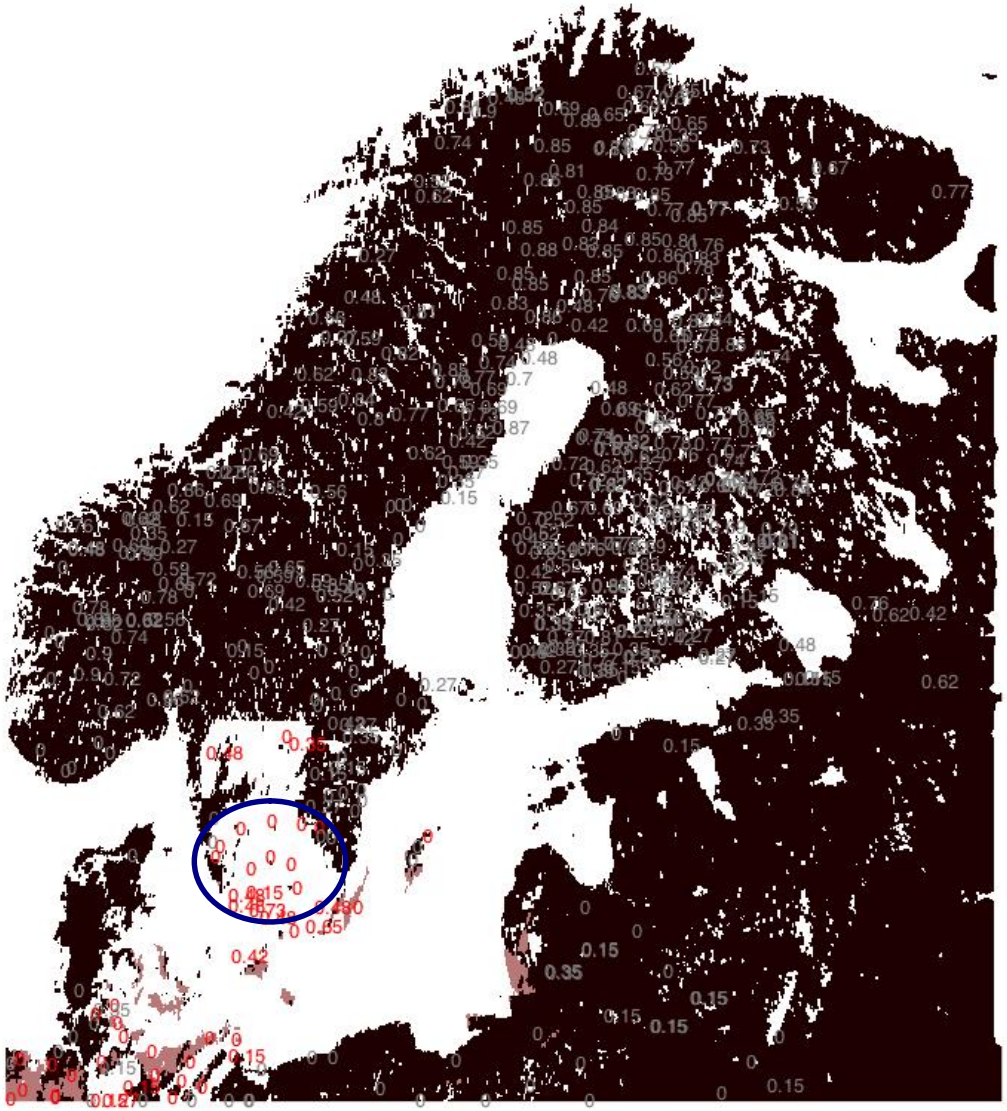
MSG vs SYNOP



✓ "False" snow in MSG



23.11.2015

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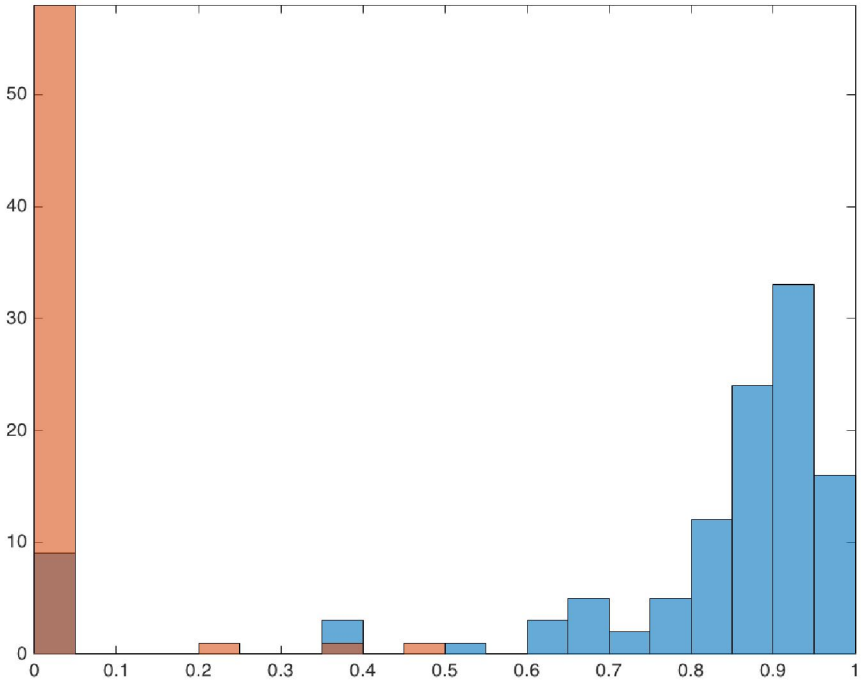
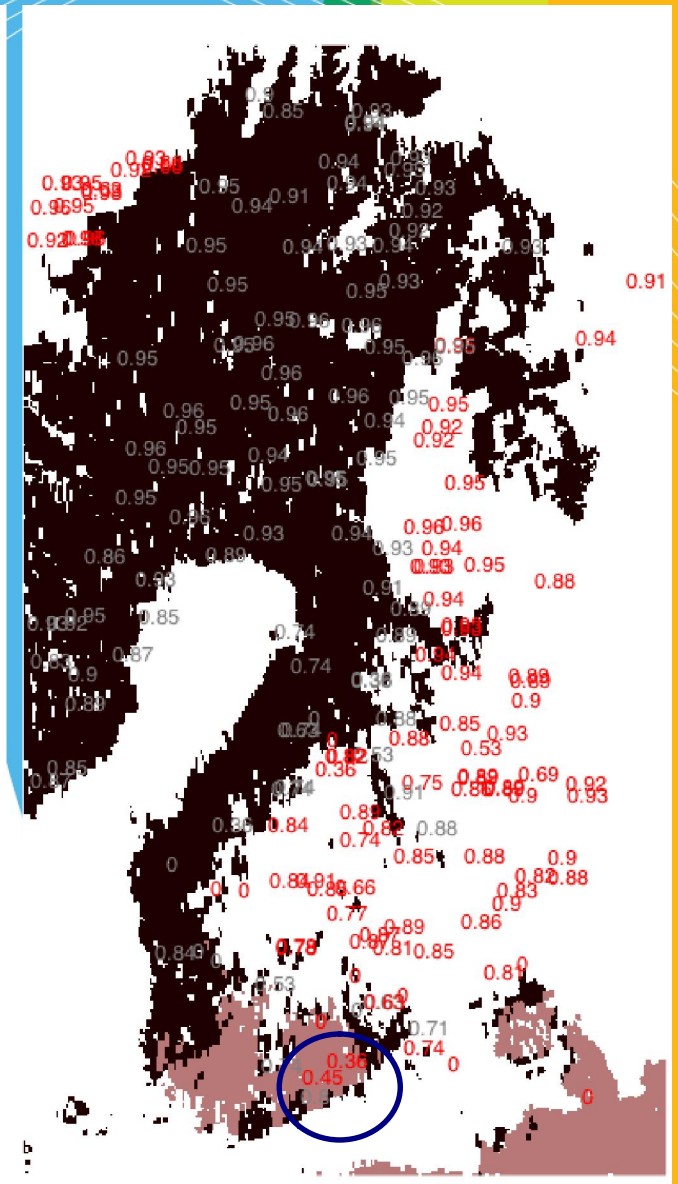
MSG vs SYNOP





✓ "Not detected" snow in MSG

04.04.2016

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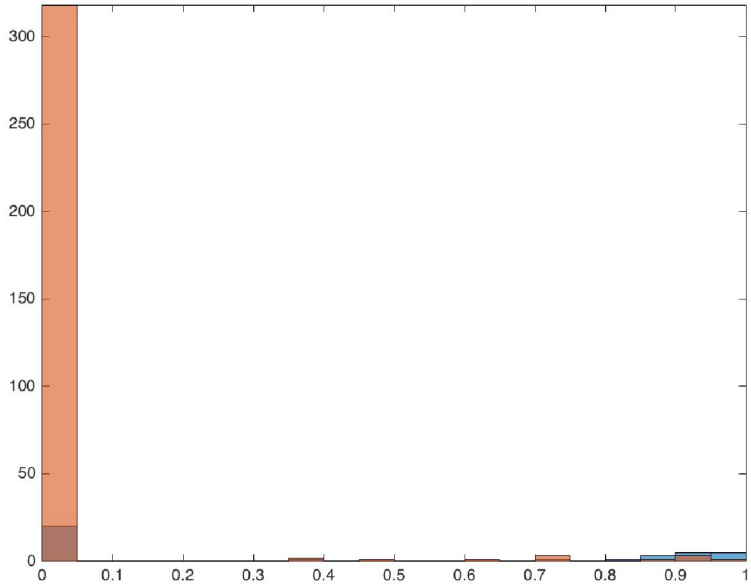
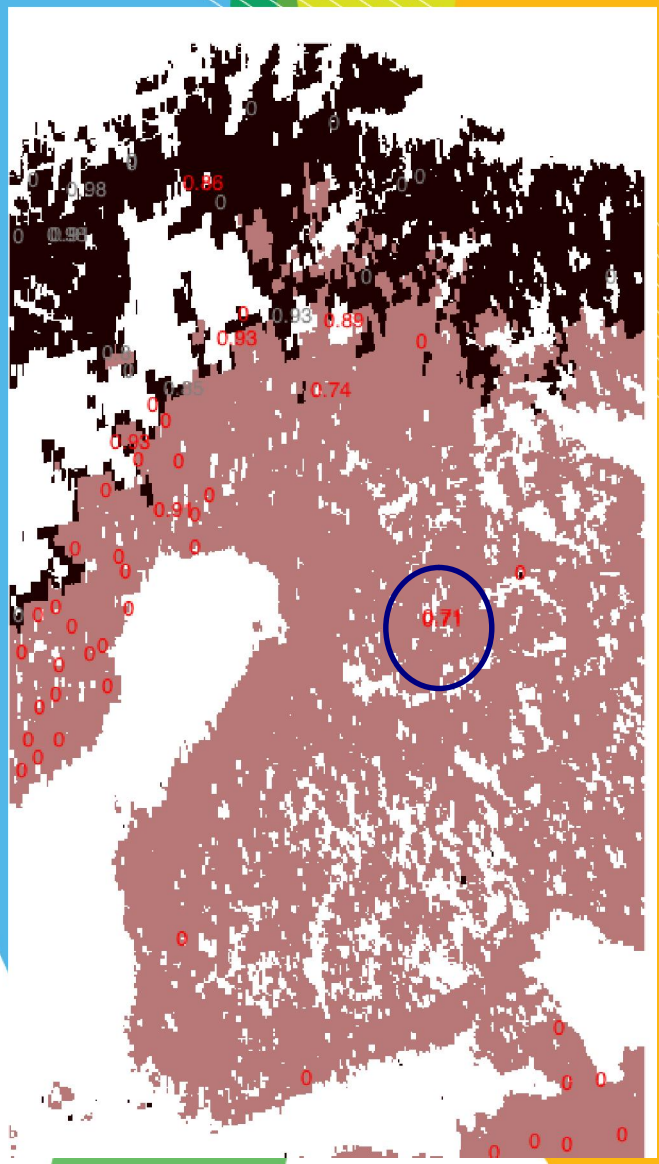
MSG vs SYNOP





✓ Are SYNOPs always truth?

09.05.2016

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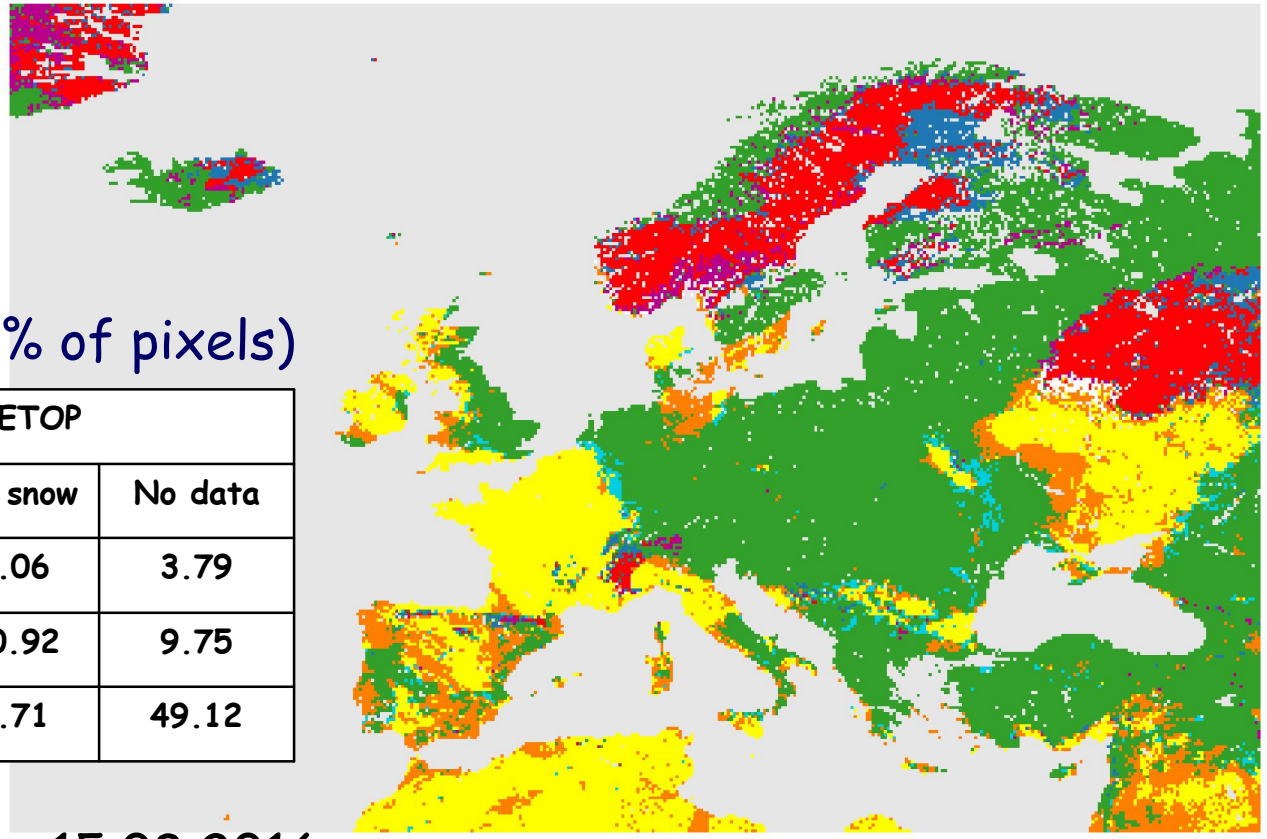
METOP vs MSG

		METOP		
		Snow	No snow	No data
MSG	Snow	Red	Orange	Blue
	No snow	White	Yellow	Brown
	No data	Pink	Cyan	Green



15.03.2016

Contingency table (% of pixels)

		METOP		
		Snow	No snow	No data
MSG	Snow	11.6	0.06	3.79
	No snow	0.37	20.92	9.75
	No data	2.70	1.71	49.12

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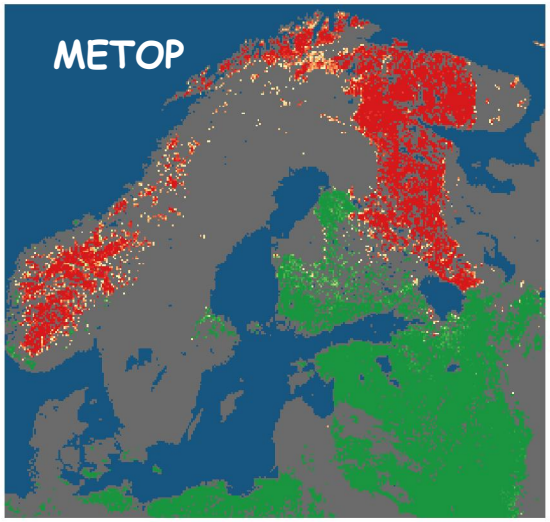
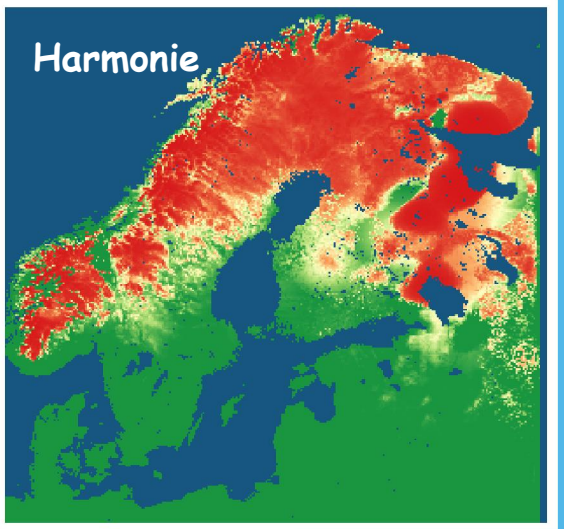
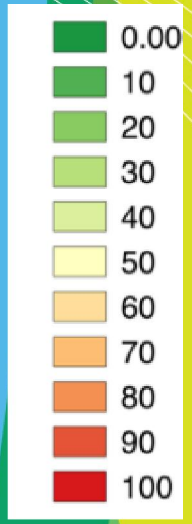
METOP vs Harmonie

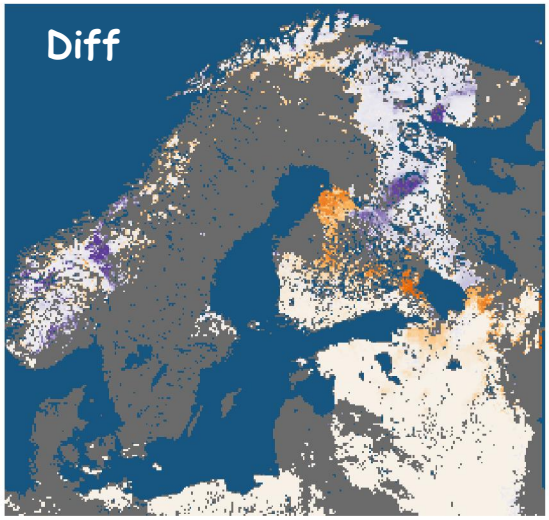
Snow fractions

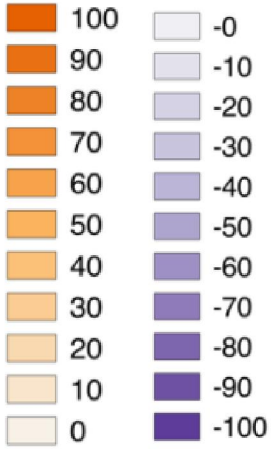
16.03.2016

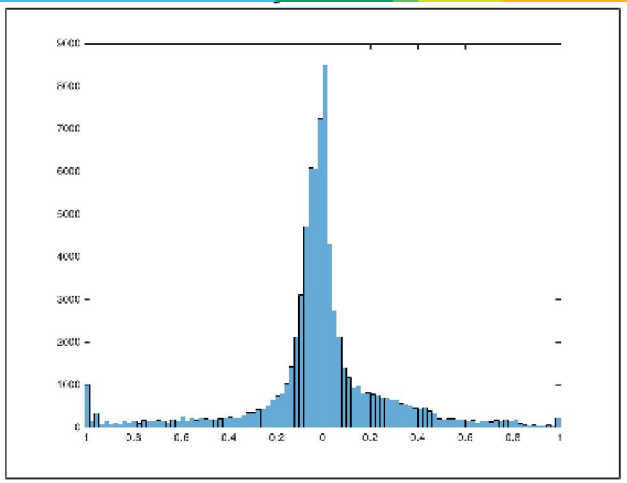












Diff=Harmonie-METOP

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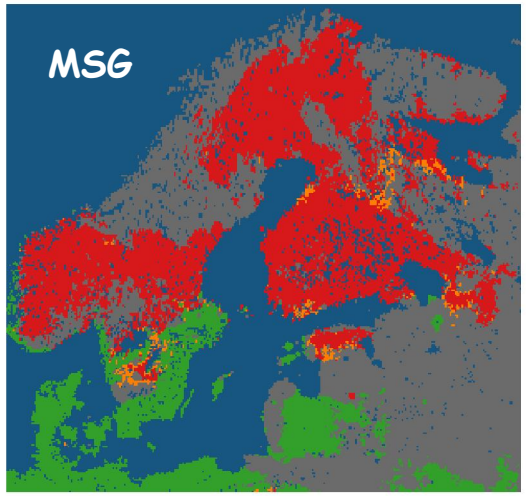
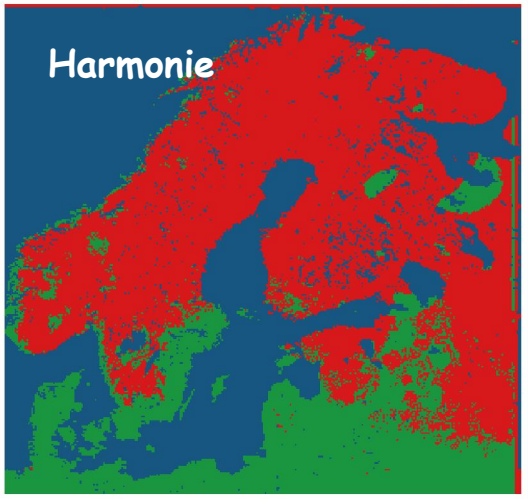
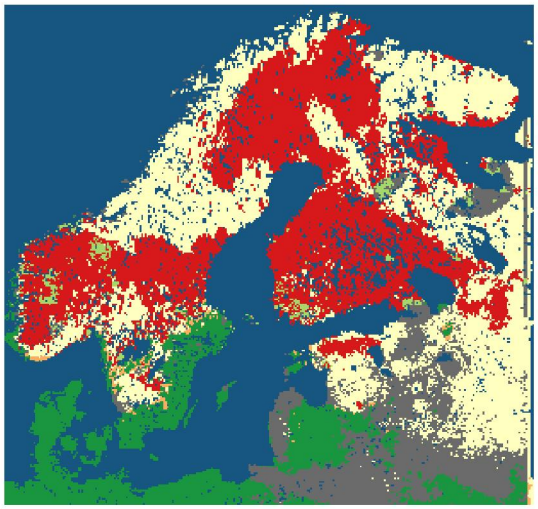
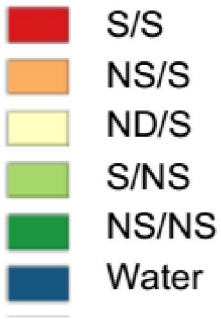
MSG vs Harmonie







16.03.2016



Contingency table (% of pixels)

		Harmonie	
		Snow	No snow
MSG	Snow	64,76	1.47
	No snow	3.10	30.33

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Conclusions from comparisons

- Overall agreement between all sources of data is good. But we look into details … All data sources contain errors.
- SYNOP data: representativeness errors, coding errors.
- Both METOP and MSG data overestimate SE due to cloud contamination.
- Both METOP and MSG may have errors of "not detected snow"
- METOP may give the "added value" to MSG products

- Errors for all types of observations, as well as model errors, should be considered in NWP snow analysis
- How to improve the analysis system?

Ideas: basis for OI

- Use Contingency tables to develop OI for SE
- Make sampling in time
- Calculate SE climatology:

$$f \swarrow \begin{Bmatrix} 0 \\ 1 \end{Bmatrix} \quad \begin{Bmatrix} N_1 \\ N_2 \end{Bmatrix} \qquad N_1 + N_2 = M$$

$$\bar{f} = \frac{1}{M}\left(0 \cdot N_1 + 1 \cdot N_2\right) \qquad \bar{f} = \frac{N_2}{M} \qquad \bar{f} = p$$

- Consider the deviation:

$$f' = \left(f - \bar{f}\right) \swarrow \begin{Bmatrix} -p \\ 1-p \end{Bmatrix}$$

Ideas: basis for OI

- **Consider the value:**

$$\left(f'(r_1) - f'(r_2)\right)^2$$

		$f'(r_1)$	
		$-p(r_1)$	$1-p(r_1)$
$f'(r_2)$	$-p(r_2)$	n_{11}	n_{12}
	$1-p(r_2)$	n_{21}	n_{22}

- **Define a structure function:**

$$b(r_1, r_2) = \frac{1}{M}[(p(r_1) - p(r_2))^2 (n_{11} + n_{22}) +$$
$$(p(r_2) - p(r_1) + 1)^2 n_{12} +$$
$$(p(r_2) - p(r_1) - 1)^2 n_{21}]$$

Ideas: basis for OI and obs error

- Define an autocorrelation function:

$$m(r_1, r_2) = \frac{1}{M}[p(r_1)\,p(r_2)\,n_{11} - (1 - p(r_1))\,p(r_2)\,n_{12} - p(r_1)\,(1 - p(r_2))\,n_{21} + (1 - p(r_1))\,p(r_2)\,n_{22}]$$

- Define an obs. error:

$$\tilde{f} = f + \delta$$

$$\overline{\delta} \approx 0 \qquad \overline{\delta^2} = \frac{d_{12} + d_{21}}{M}$$

δ		f	
		0	**1**
$\tilde{f}$	**0**	**0** d_{11}	**-1** d_{12}
	1	**1** d_{21}	**0** d_{22}

… etc.

- Following Gandin, 1965, calculate an obs. error and develop OI

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Thank you for your attention.

Questions?