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Validation of the EUMETSAT OSI SAF 50 GHz sea ice emissivity product

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The Ocean and Sea Ice SAF near 50 GHz sea ice emissivity product

- Provides a first guess sea ice surface emissivity for NWP models assimilating AMSU and SSMIS data over sea ice
- Approach in between *atlas* and *dynamical retrieval*
- The emissivity estimate is a daily gridded product based on recent SSMIS (or SSM/I) passages
  - independent from sounding data to be assimilated
- Emissivity is relatively persistent on a day time scale over most of the ice cap – should be adequate for e.g. AMSU assimilation the following day

The Ocean and Sea Ice SAF near 50 GHz sea ice emissivity product: Method

- A sea ice thermal microwave emission algorithm for 50 GHz was developed under EUMETSAT's Ocean and Sea Ice Satellite Application Facility (OSI SAF) programme
- The method is based on correlations between the surface brightness temperature at 18 and 36 GHz with that at 50 GHz
- The model coefficients are estimated using simulated data from the combined thermodynamic and emission model

Emissivity formulation

Scan angle/pol. dependence: $\varepsilon(\theta) = \varepsilon_v(\theta)\cos^2(\theta_s) + \varepsilon_h(\theta)\sin^2(\theta_s)$

Horizontal and vertical part:

$$e_{50v}(\theta) = S\{1 - Rr_v(\theta)\} \qquad e_{50h}(\theta) = S\{1 - Rr_h(\theta)\}$$

with Fresnel reflection coefficients

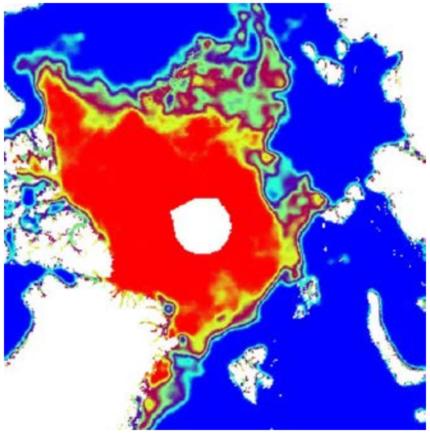
$$r_v(\theta) = \left| \frac{\varepsilon\cos\theta - \sqrt{\varepsilon - \sin^2\theta}}{\varepsilon\cos\theta + \sqrt{\varepsilon - \sin^2\theta}} \right|^2 \qquad r_h(\theta) = \left| \frac{\cos\theta - \sqrt{\varepsilon - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon - \sin^2\theta}} \right|^2$$

Empirical expressions for R and S were derived, where they depend on SSM/I or SSMIS GR1836 and PR36:

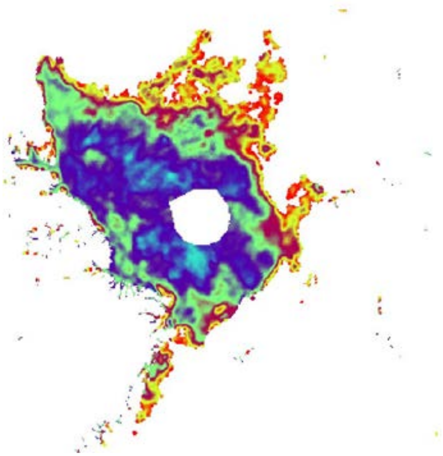
$$GR1836 = \frac{T_{v36} - T_{v18}}{T_{v36} + T_{v18}} \qquad PR36 = \frac{T_{v36} - T_{h36}}{T_{v36} + T_{h36}}$$

EUMETSAT OSISAF 50 GHz sea ice emissivity product

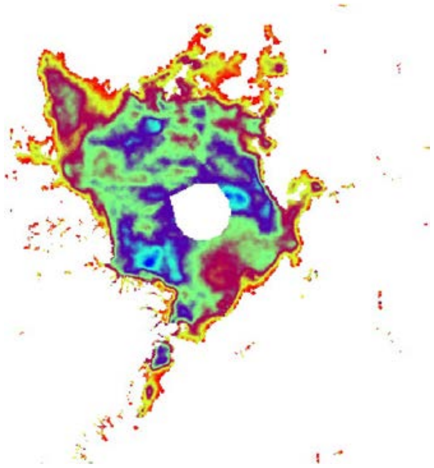
- Soon to be released:
- Daily gridded maps of the R and S parameters on 25 km grids (Arctic and Antarctic)



Concentration



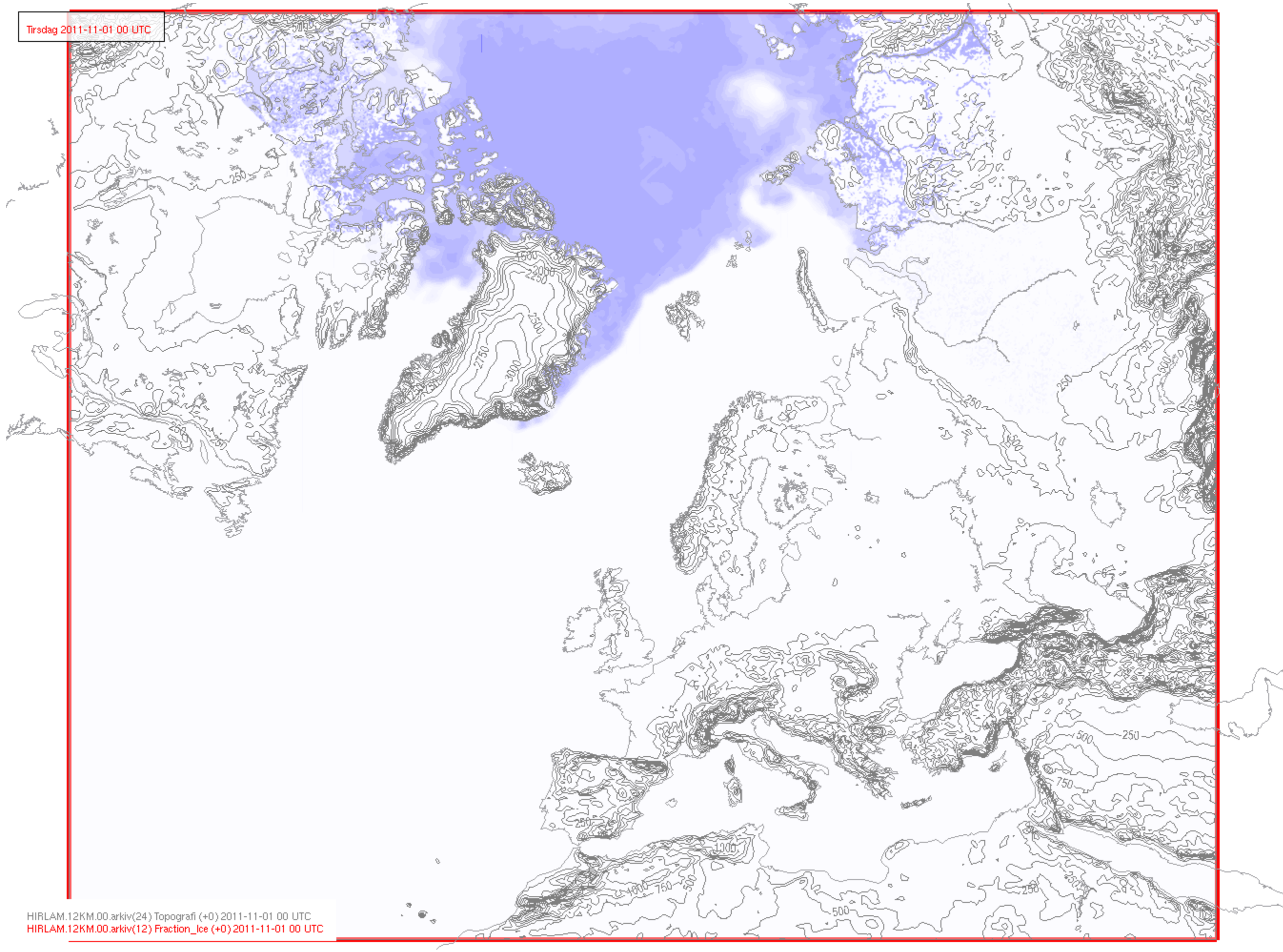
Emis: R



Emis: S

Validation of product

- **Study fit to AMSU-A observations using the emissivity model with RTTOV and HIRLAM surface temperatures and profiles**
- Norwegian operational HIRLAM 12 km regional model
- Period during Arctic sea-ice freeze-up 19 October to 30 November 2011
- Only points assumed to be nearly free of water (retrieved ice concentration ≥ 95%)



Checked fit with 3 different approaches to emissivity

1. The OSISAF product
2. Using multi-year sea ice concentration c_{MY} from OSISAF sea ice concentration algorithm with "tie-points" for first-year and multi-year emissivities

   $$e = c_{MY}\, e_{MY} + (1-c_{MY})\, e_{FY}$$

   (with e_{MY}=0.796 and e_{FY}=0.928)
3. Using "dynamical" emissivities calculated from the AMSU-A data themselves (ch 3):

   $$e = (T_{b\ obs} - T_{b\ sim}(e=0)) \ / \ (T_{b\ sim}(e=1) - T_{b\ sim}(e=0))$$

Accounting for emitting surface temperature

- HIRLAM surface temperatures used
- Emitting layer extends below surface, higher efficient emitting temperature (can be predicted using the surface temperature)

- Bias correction procedure applied on brightness temperatures with HIRLAM surface temperature as one of the predictors partly removes the “O minus B” misfit due to wrong emitting temperature in the comparison

TABLE I
PENETRATION DEPTHS IN CENTIMETERS FOR DIFFERENT SURFACE TYPES AT −10 °C INTERPOLATED FROM [22]

ν [GHz]	Dry snow	Multi-Year ice	First-year ice
23.8	143.35	7.76	1.52
31.4	129.91	7.32	1.45
50.3	96.47	6.23	1.28
89.0	28	4	0.94
150	13	2	0.75

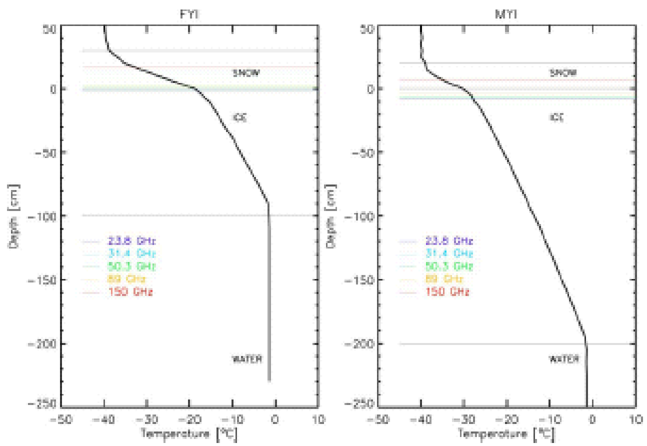


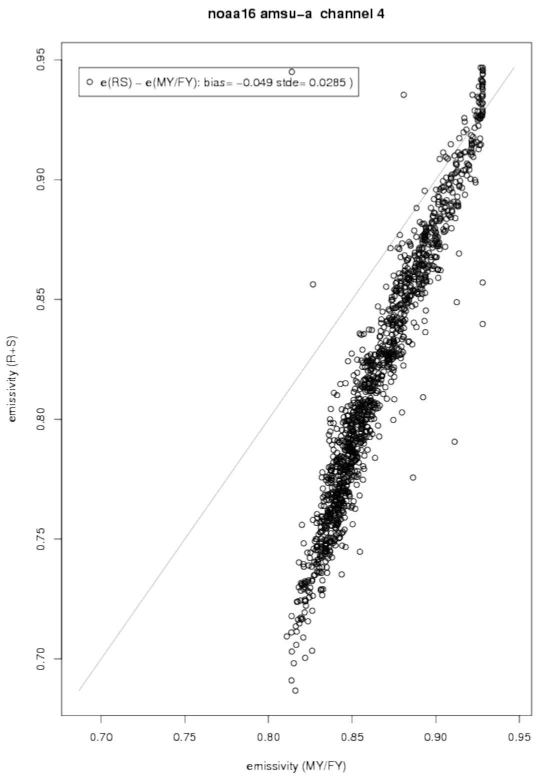
Fig. 1. Examples of temperature profiles of snow and ice and penetration depths assumed for different frequencies for (left) the FYI and (right) the MYI.

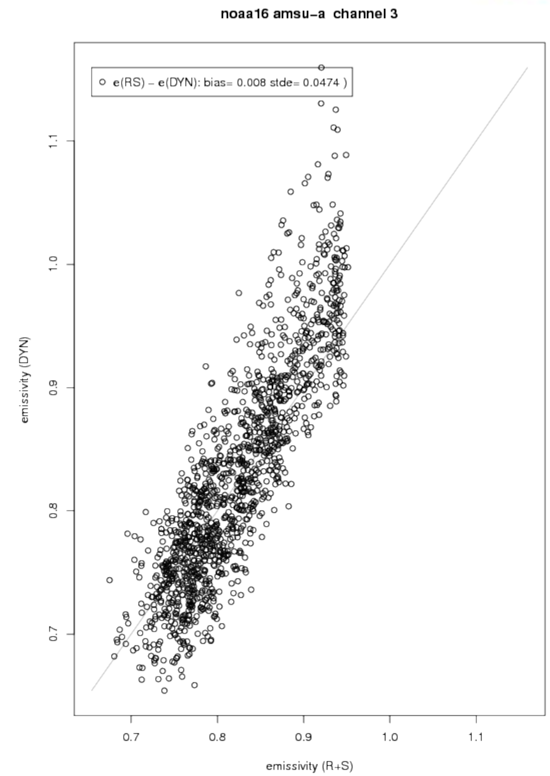
Physical basis described by Mathew et al, 2008 (above)

Leads to empirical expression:

$T_{emitting} = aT_{2m} + b$

Comparison of OSISAF emissivities with other methods
Left: vs “tie-point” method, Right: vs “dynamical”

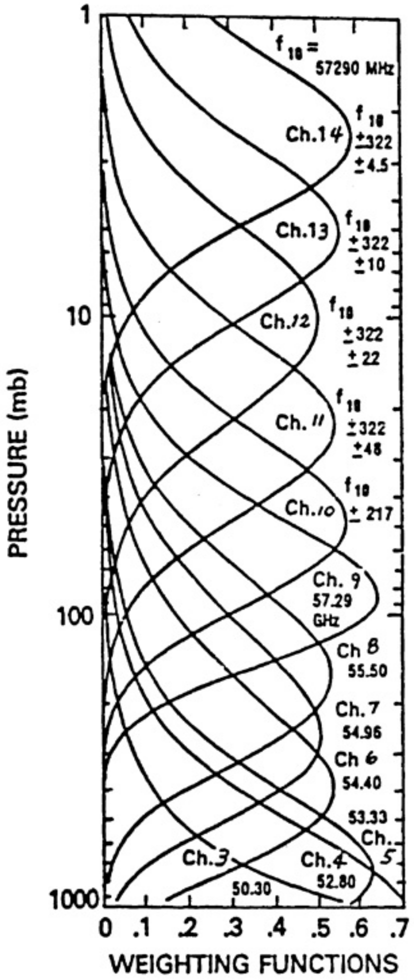




- Strong correlation with “tie point” method (underlying GR1836 dependence)
- Larger dynamic range in OSISAF product (handles incidence angle variations)
- Actual values with OSISAF method fits better with emissivity information given in literature (“tie-point” method could have been adjusted to be closer to one-to-one line)

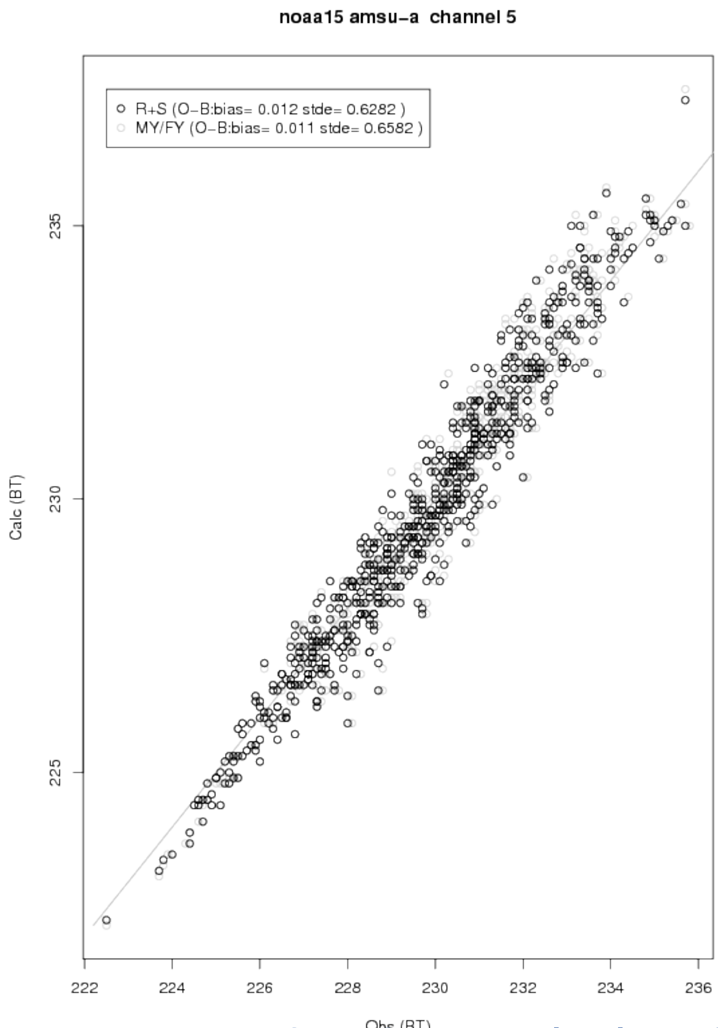
- Larger scatter vs “dynamical” method
- Best-fit-line close to one-to-one

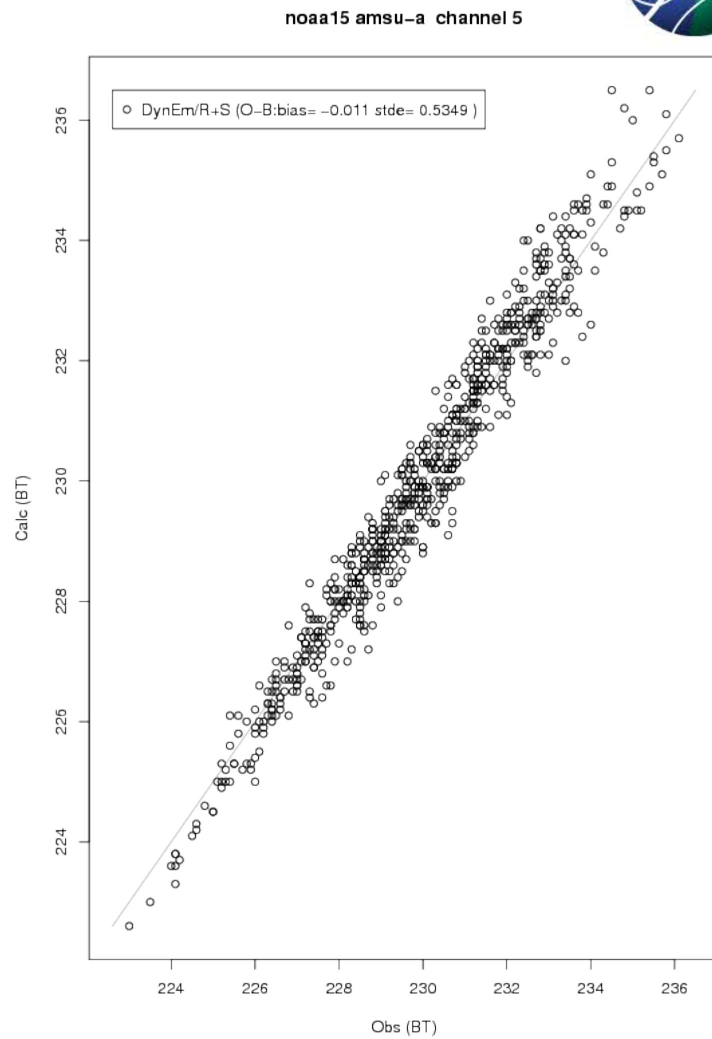
Validation



- We will show fit to AMSU-A observations using the emissivity model with RTTOV and HIRLAM surface temperatures and profiles
- Results for channels 3-7 to be presented
- Data from NOAA-15 and NOAA-16

Example ch 5 – comparison of fit with OSISAF and dynamical method





- Left: Obs vs calculated Tb's for OSISAF (black dots) and "tie point" (gray dots)
- Right: Obs vs calculated Tb's for dynamical method

Statistics for fit to AMSU-A ch 3-7 with “tie point” and OSISAF method

	NOAA-15 FY/MY	NOAA-15 OSISAF	NOAA-16 FY/MY	NOAA-16 OSISAF
Channel 3	5.5844	**3.9544**	5.4543	**3.975**
Channel 4	1.7597	**1.5371**	-	**-**
Channel 5	0.6582	**0.6282**	0.6542	**0.6251**
Channel 6	0.2365	**0.2357**	0.2155	**0.2132**
Channel 7	0.1956	**0.1958**	0.2699	**0.2699**

- Standard deviations of departures in Kelvin between the simulated AMSU-A observations with the two emissivity models and (bias corrected) observations
- Generally better fit with the OSISAF method

Statistics for fit to AMSU-A ch 3-7 with dynamical and OSISAF method

	NOAA-15 Dyn (ch3)	NOAA-15 OSISAF	NOAA-16 Dyn (ch3)	NOAA-16 OSISAF
Channel 3	0	**3.9544**	0	**3.975**
Channel 4	0.8592	**1.5371**	-	**-**
Channel 5	0.5349	**0.6282**	0.5559	**0.6251**
Channel 6	0.2317	**0.2357**	0.2153	**0.2132**
Channel 7	0.2007	**0.1958**	0.2677	**0.2699**

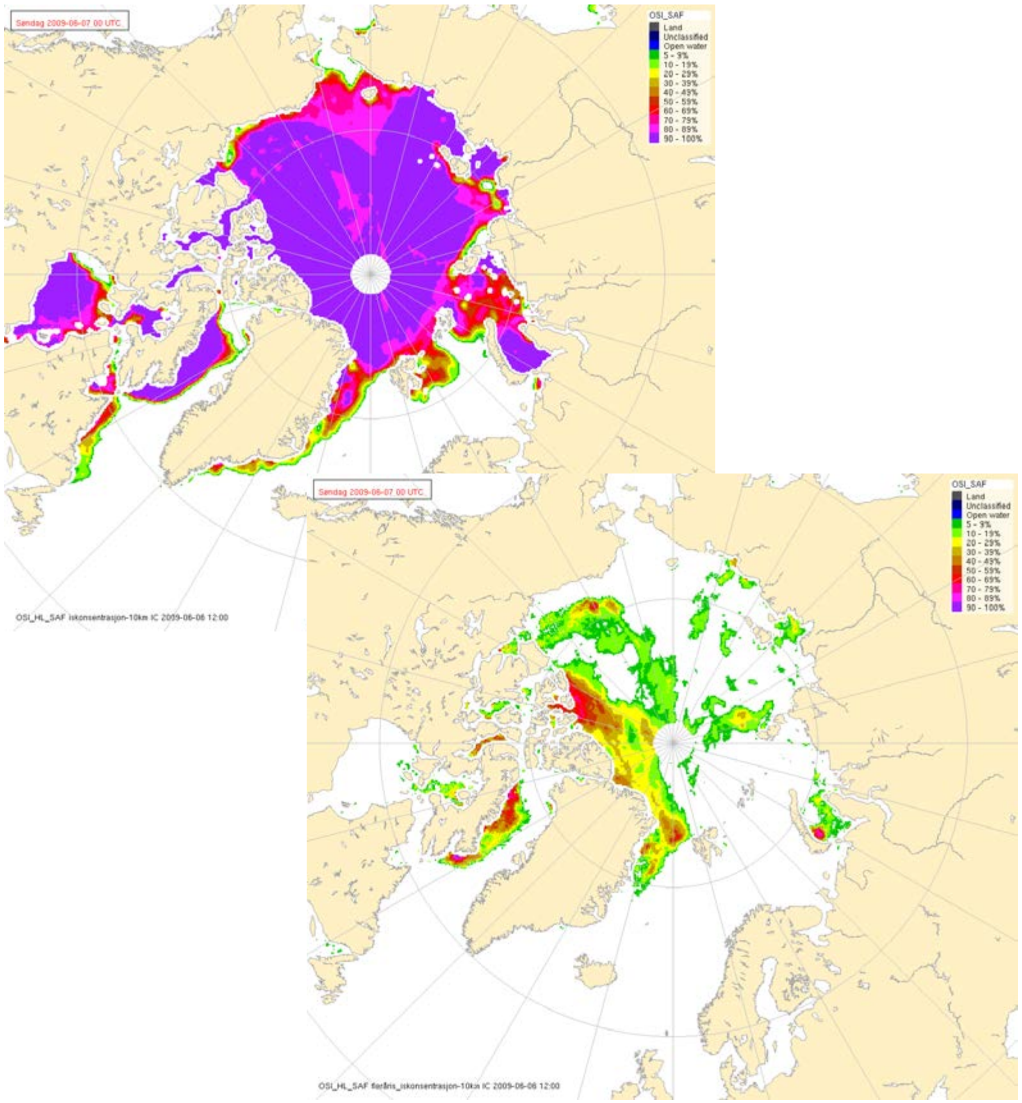
- Standard deviations of departures in Kelvin between the simulated AMSU-A observations with the two emissivity models and bias corrected observations
- Fit of ch 3 with dynamical method is perfect by definition
- Fit of OSISAF method is comparable for channels 6 and 7
- Dynamical method attributes all misfit of AMSU-A ch 3 to emissivity – risk of removing some lower-tropospheric atmospheric signal

Summary

- The evaluation of the novel OSISAF 50GHz sea ice emissivity product during the Arctic sea ice freeze-up period shows promising results
- The OSISAF emissivity estimate is indendent of the sounding observations to be assimilated (unlike the dynamical method, which has a risk of removing some atmospheric signal)
- Surface contribution to signal also needs emitting temperature
- The new product may be useful for microwave sounding assimilation over sea ice

Thank you!

A first approach to emissivity



- If we can handle areas with near 100% ice coverage, we still cover a large area (disregards marginal ice zone)
- Use OSISAF concentration chart to find near-100% ice covered area
- In this area multi-year sea ice from OSISAF was used as predictor for sounding ch emissivity

Emissivities (earlier work)

Use OSI SAF FY and MY ice concentrations with typical values (Toudal) of AMSU emissivities for these surfaces:

$$\varepsilon = c_W \varepsilon_W + c_F \varepsilon_F + c_M \varepsilon_M,$$

$$c_W + c_F + c_M = 1.$$

AMSU-A channel	First year ice	Multi year ice
1	0.971	0.874
2	0.970	0.829
3	0.928	0.796
4	0.928	0.796
5	0.928	0.796
6	0.928	0.796
7	0.928	0.796
8	0.928	0.796
9	0.928	0.796
10	0.928	0.796
11	0.928	0.796
12	0.928	0.796
13	0.928	0.796
14	0.928	0.796
15	0.913	0.744

- Could be further improved by adding yearly variations, incidence angle dependence, …