Uncertainty estimates in the joint NSIDC and EUMETSAT sea ice re-processing of satellite microwave radiometer data

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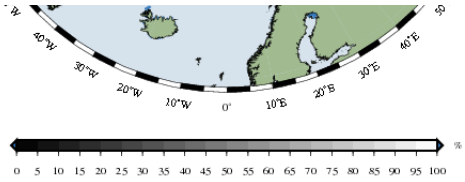
The re-processing project

- Initiated by EUMETSAT, the SSMI/I data (1987-2007) was purchased from RSS, extension planned.
- NSIDC extended the data record with SMMR data (1978-1987).
- Visiting scientists participated the processing chain setup and dataset collection.
- Evaluation of several ice concentration algorithms.
- New processing method: atmospheric correction, combination of ice concentration algorithms, dynamic tie-points, uncertainty estimates.
- The dataset is compared to National Ice Center ice charts.
- The dataset and documentation is available from:

http://osisaf.met.no/p/ice/ice_conc_reprocessed.html



The satellites have complete global coverage daily, we have several datasets, so why do we need another?

Sea ice concentration estimates have errors Different algorithms - different sensitivity

Issues:

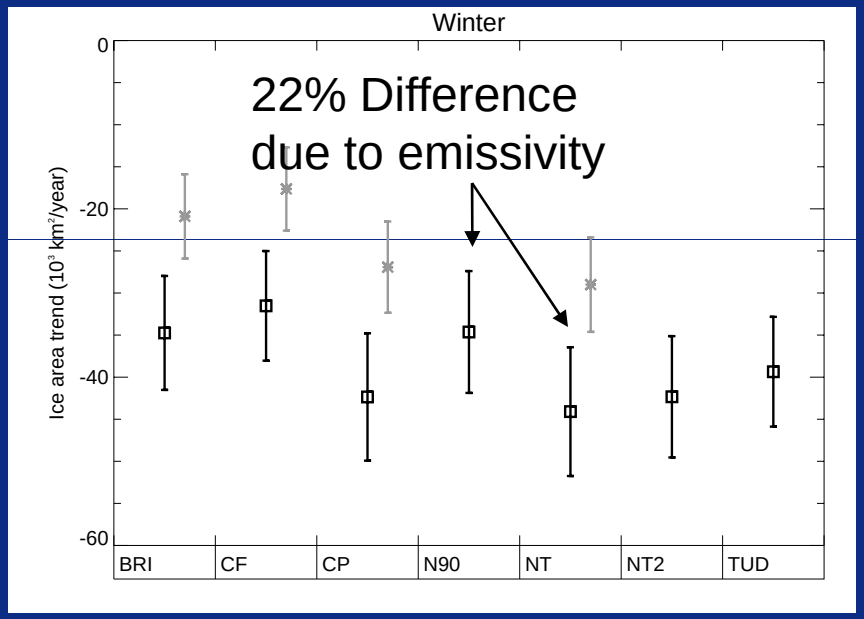
A. Sensitivity climate trend: The Arctic sea ice extent and area are changing together with the Arctic atmosphere and sea ice emissivity, this is affecting the trend:

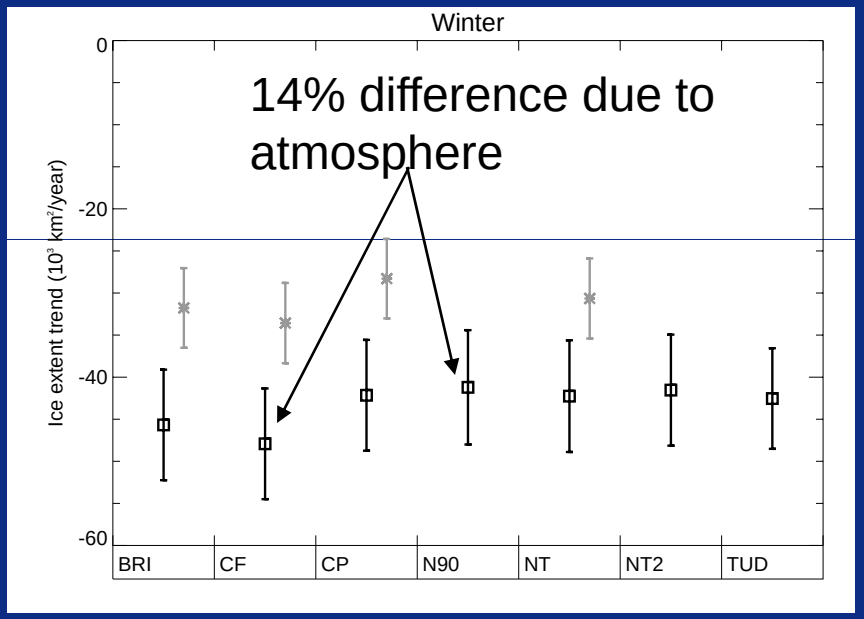
-Dynamic tie-points

B. Correlation to high resolution reference: SAR/ vis-IR/ ship obs/ RGPS: There is no correlation between the high concentration radiometer ice concentration and the reference variability, some algorithms are better than others but none are adequate (at near 100%):

-Uncertainty estimates

Different trends
The structural uncertainty

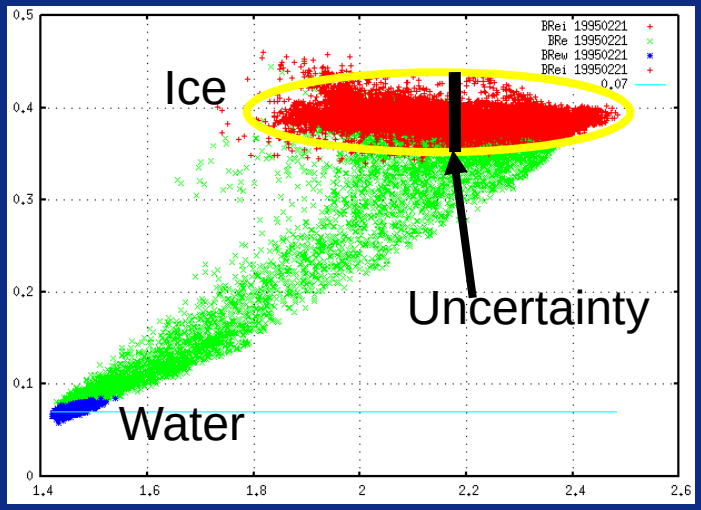


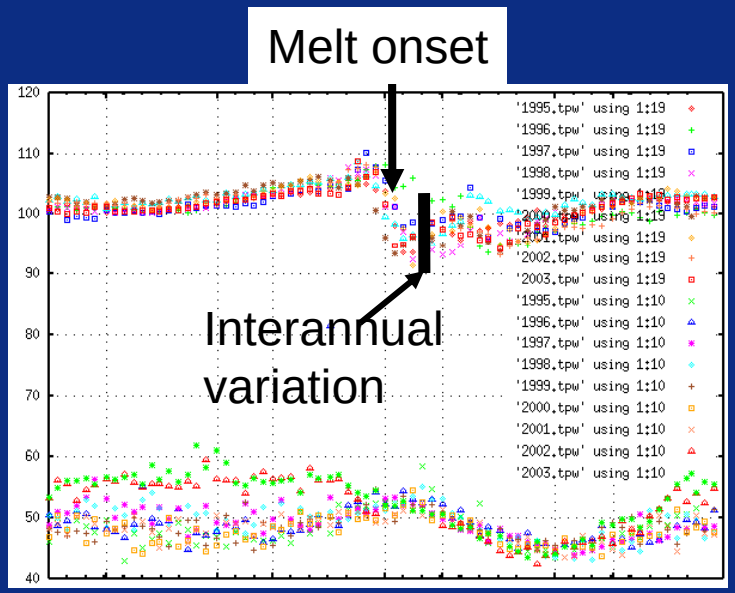


Observed trends in a) ice area and b) ice extent during winter (Oct. – Apr.) for the SSM/I dataset excluding the F8 satellite (1991-2004, black) and the entire dataset (1987-2004, grey). The 85GHz channels were not reliable on F8. Bars show ±1 STDEV.

Dynamic tie-points

- **Tie points are derived with error bars:**
  - **Prerequisite to estimating uncertainty in ice concentrations**
- **Tie points are determined dynamically:**
  - **Offers a consistent way to reconcile intersensor differences**
  - **Takes into account interannual and seasonal signature variations**





Estimation of uncertainties – sources of ice concentration uncertainty

- Foot-print smearing when the foot-print is different than the grid resolution
- Foot-print mismatch when Tb's at different frequencies are used.
- Geolocation error when the satellite is not exactly oriented
- Sensor noise may be different at different channels and may therefore affect algorithms differently
- Atmospheric noise when the water in the atmosphere is affecting the measurements
- Emissivity noise is both the variable water surface and ice emissivity

$$e_{total}^2 = e_{smear}^2 + e_{geol}^2 + e_{tiep}^2$$

SSM/I scanning geometry and resolution

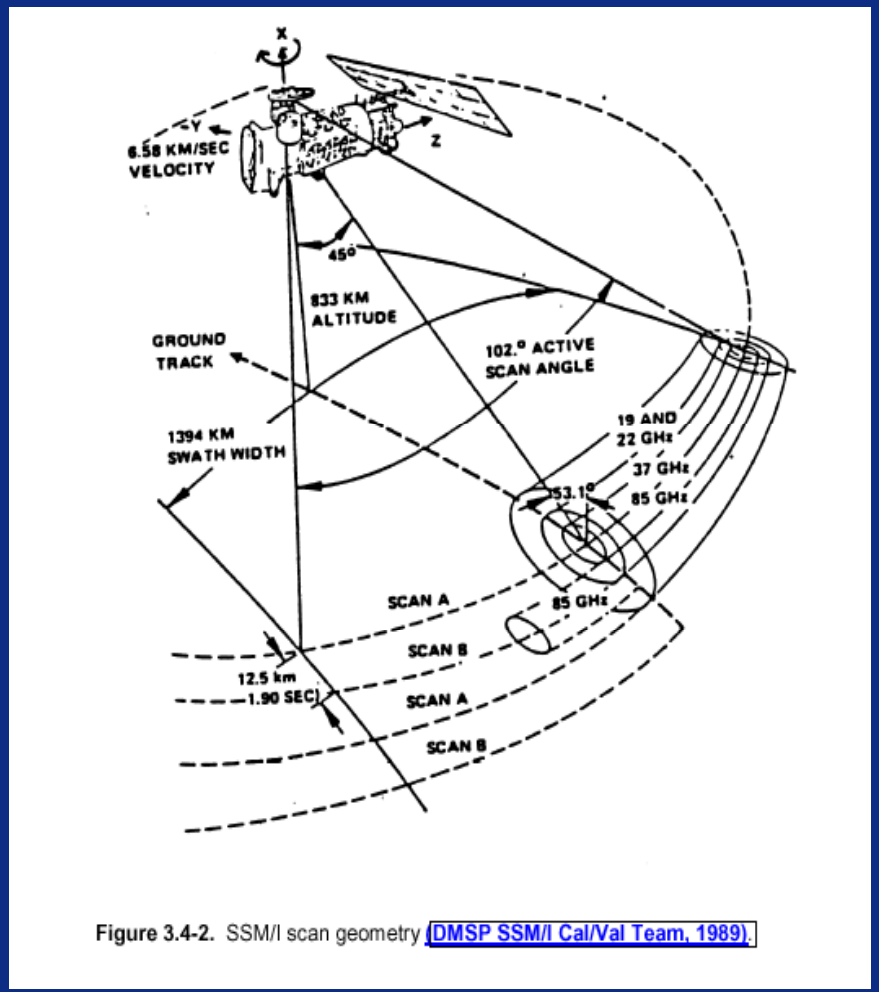


Figure 3.4-2. SSM/I scan geometry (DMSP SSM/I Cal/Val Team, 1989).

Instantaneous field of view

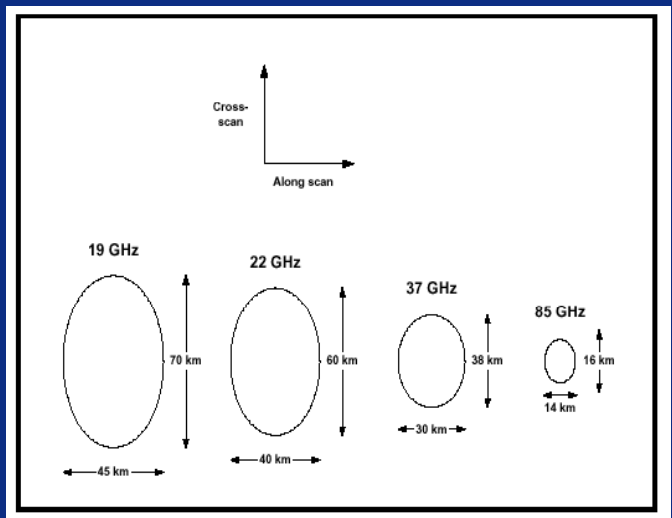


Figure 3.5-2. SSM/I footprint sizes (not to scale).

Integrated field of view

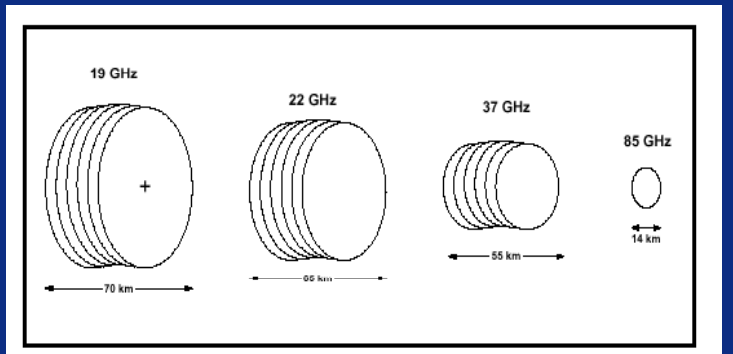


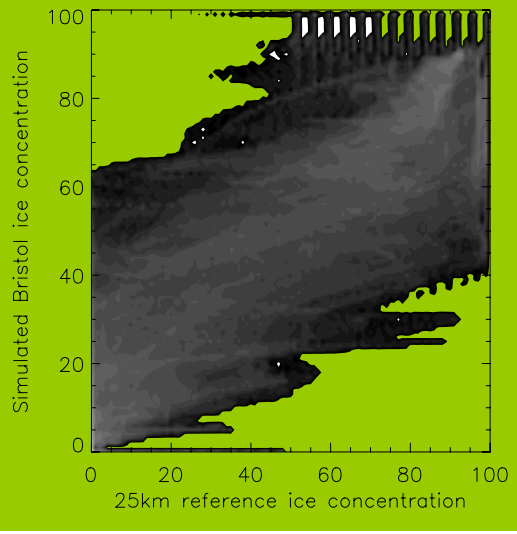
Figure 3.5-3. SSM/I sample sizes (not necessarily to scale). This illustrates the effect of integration as the channel footprints sweep over an area during the integration period of about 8 milliseconds.

Smearing error simulator

- Truth is 1km cloud-free modis where the intensity or “albedo” is scaled with ice concentration.
- Each modis ice concentration pixel is assigned a brightness temperature (using tie-points)
- Elliptical Gauss-shaped antenna pattern is used to compute ‘measured’ brightness temperatures at 19, 37 and 85GHz
- The measured brightness temperatures are used in the CF, NASA, Bristol, TUD and 85GHz polarisation algorithms.
- The ice concentration is compared with truth at different resolutions.

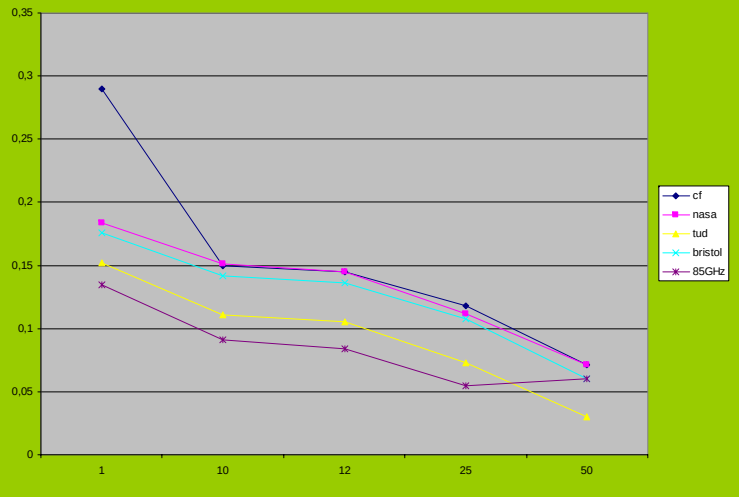
Microwave radiometers

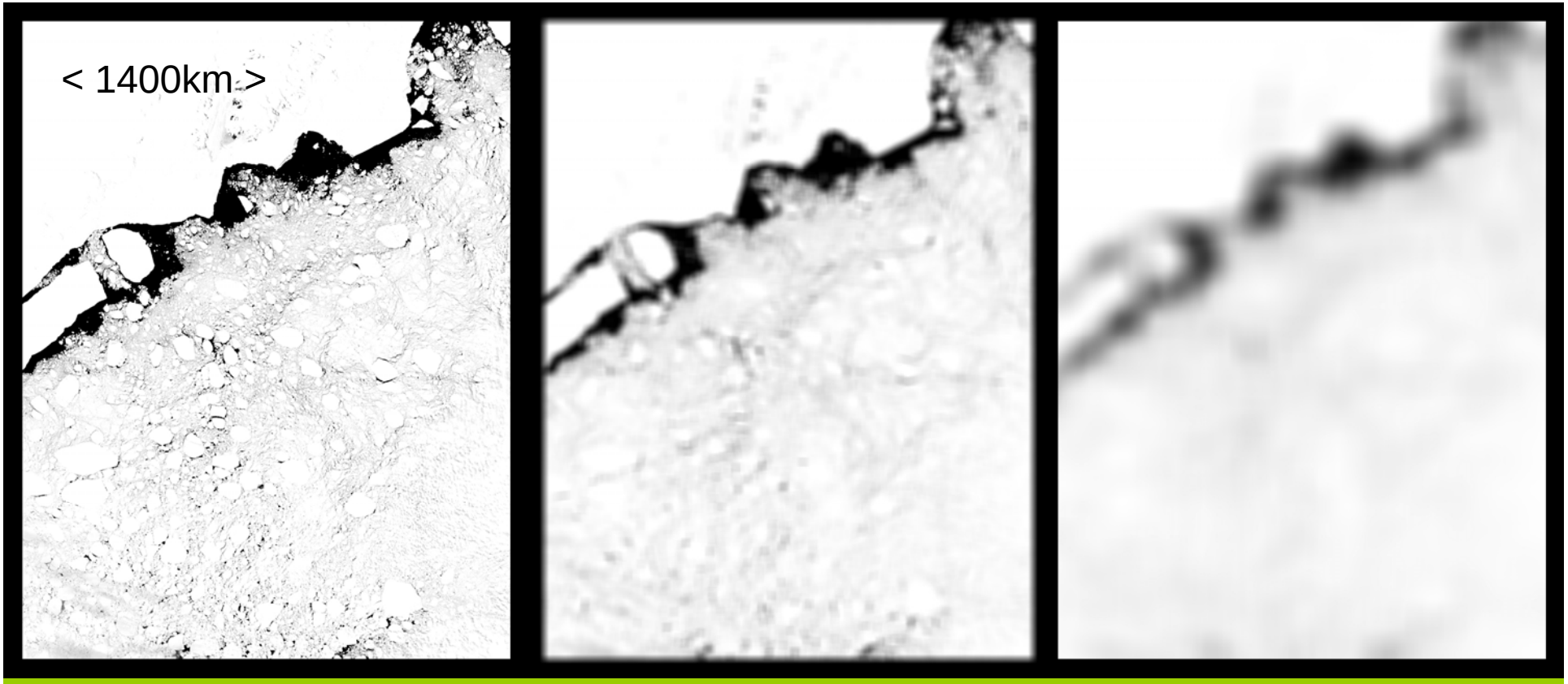
Instrument	Frequency scan x track	Frequency scan x track	Frequency scan x track	Frequency scan x track	Frequency scan x track	Frequency scan x track	Incidence angle
SMMR 1978-1987	6.6 V, H 148 x 95	10.7 V, H 90 x 60	18.0 V, H 45 x 30	21.0 V, H 40 x 25	37.0 V, H 20 x 15		51
SSM/I 1987-			19.3 V, H 45 x 70	22.2 V 40 x 50	37 V, H 30 x 37	85.5 V, H 13 x 15	53
AMSR 2001-	6.9 V, H 43 x 75	10.7 V, H 27 x 48	18.7 V, H 16 x 27	23.8 V, H 18 x 31	36.5 V, H 8 x 14	89.0 V, H 4 x 6	55

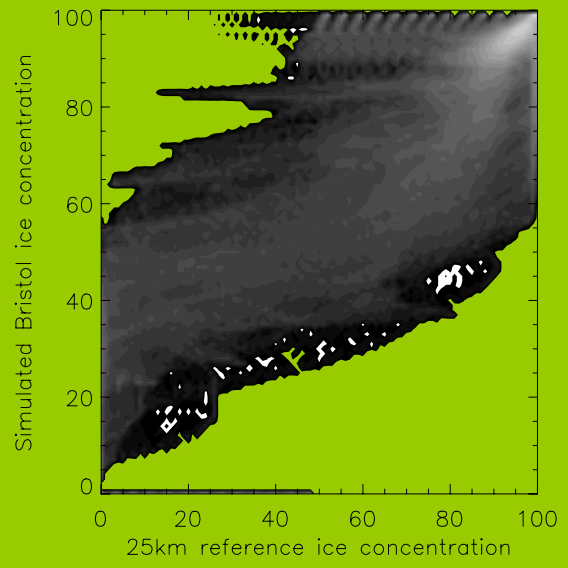


1km - 25km - Bristol

Total concentration 22%

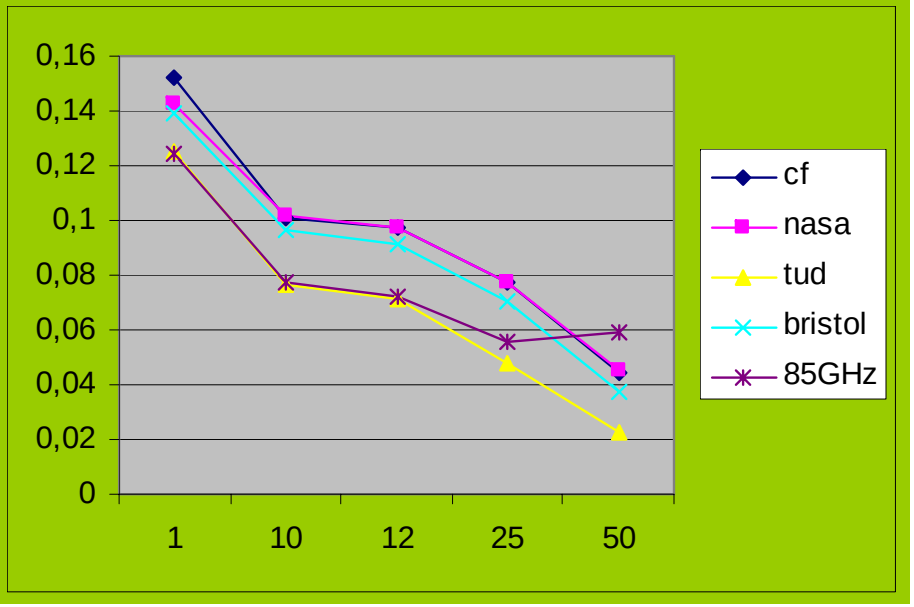


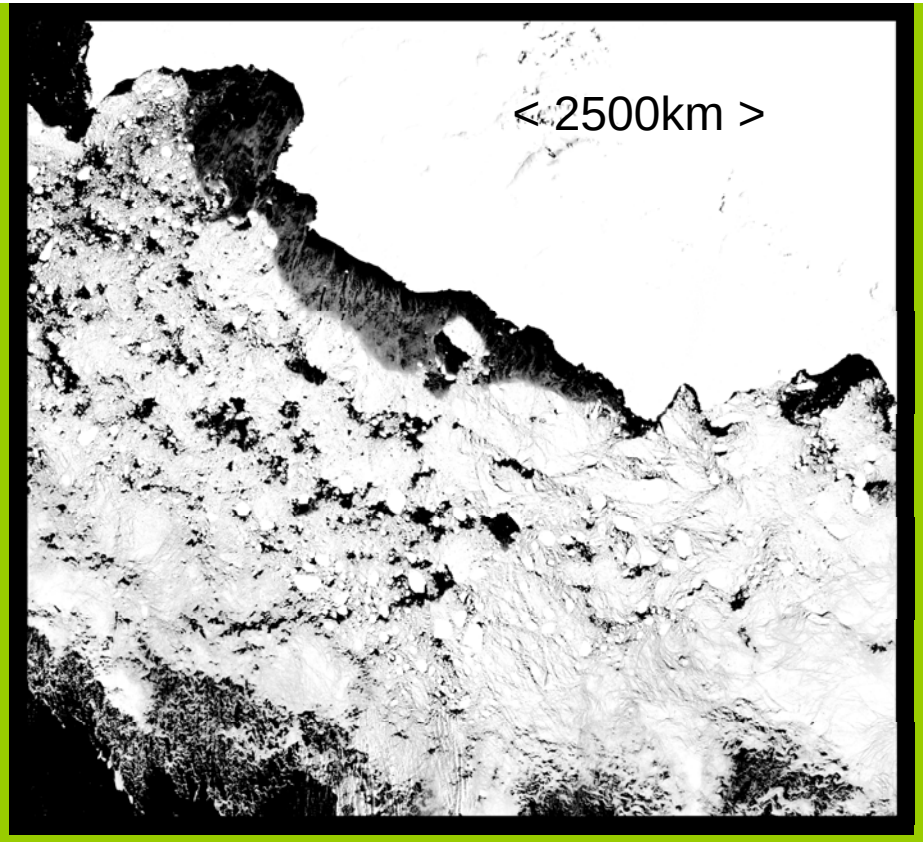


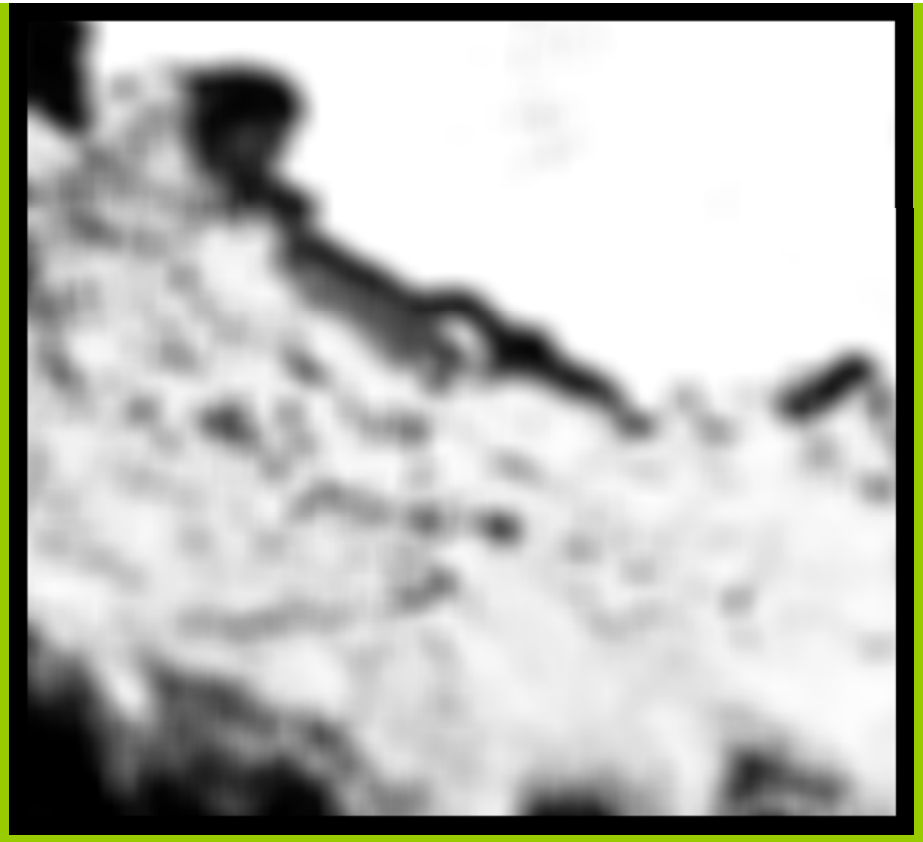


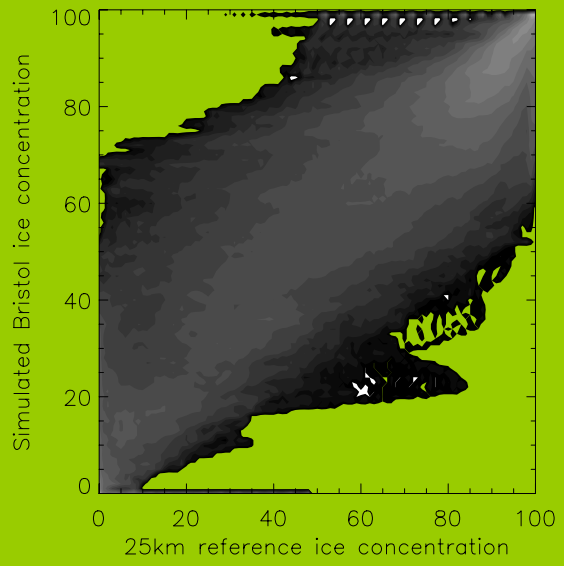
1km - 25km - 50km

total concentration 91%



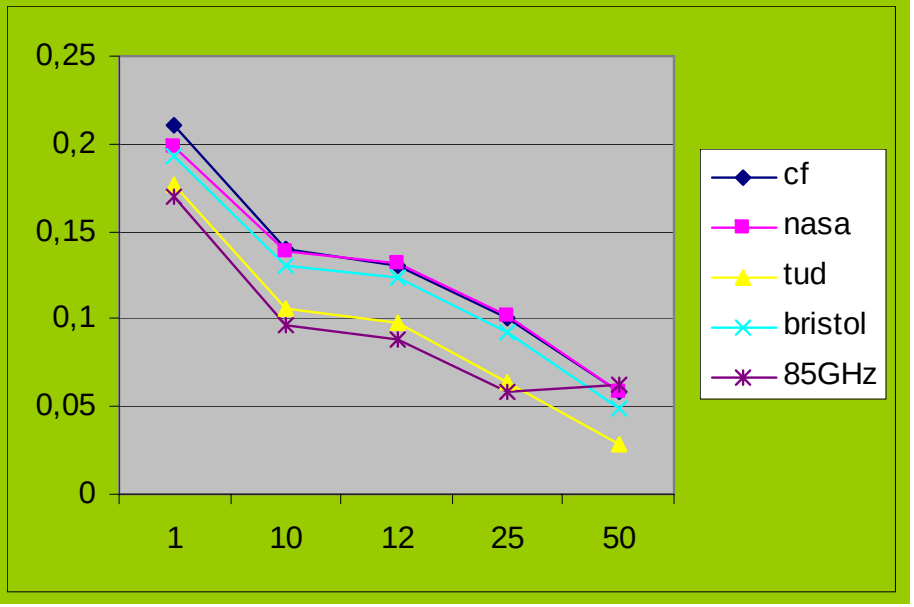


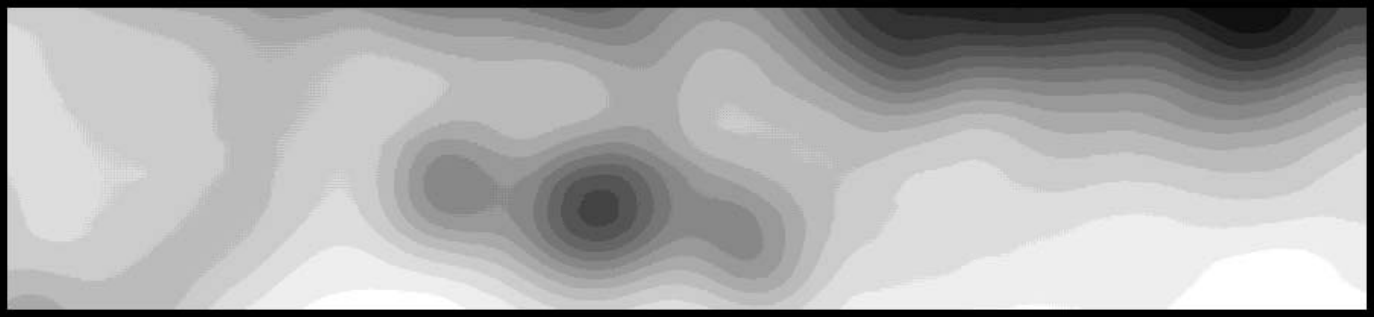


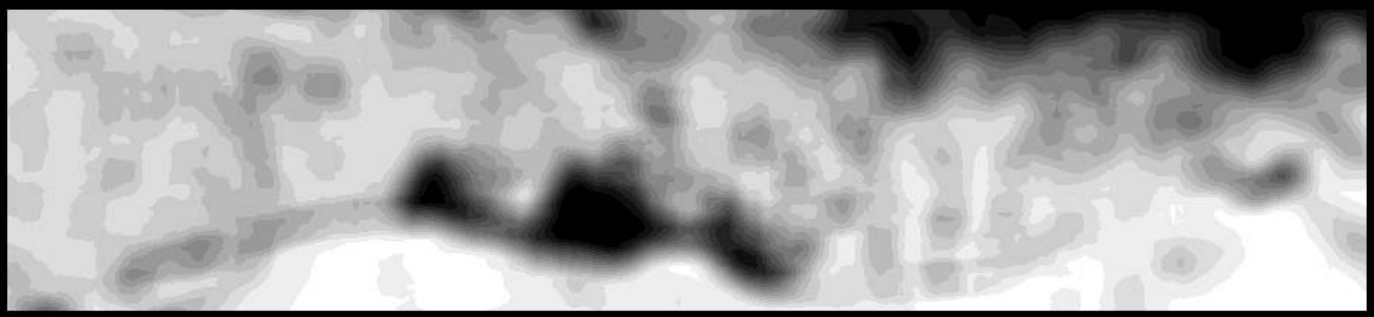


1km - Bristol

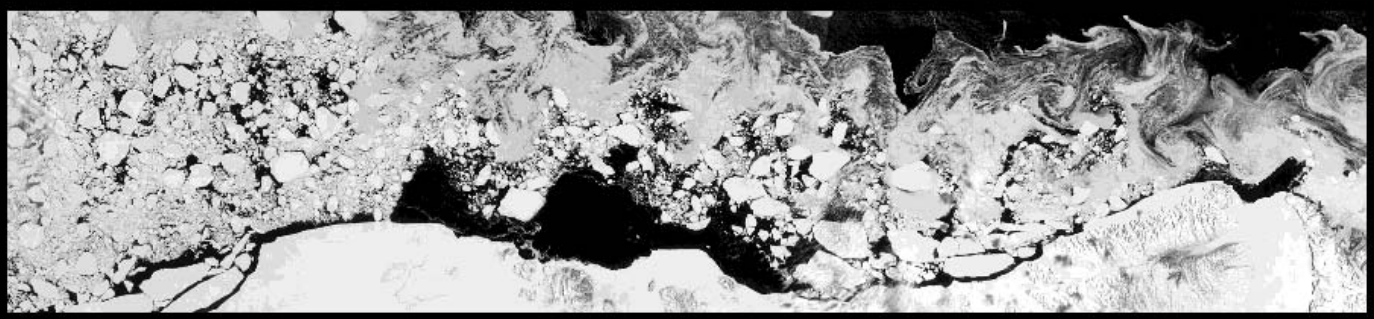
Total concentration 79%



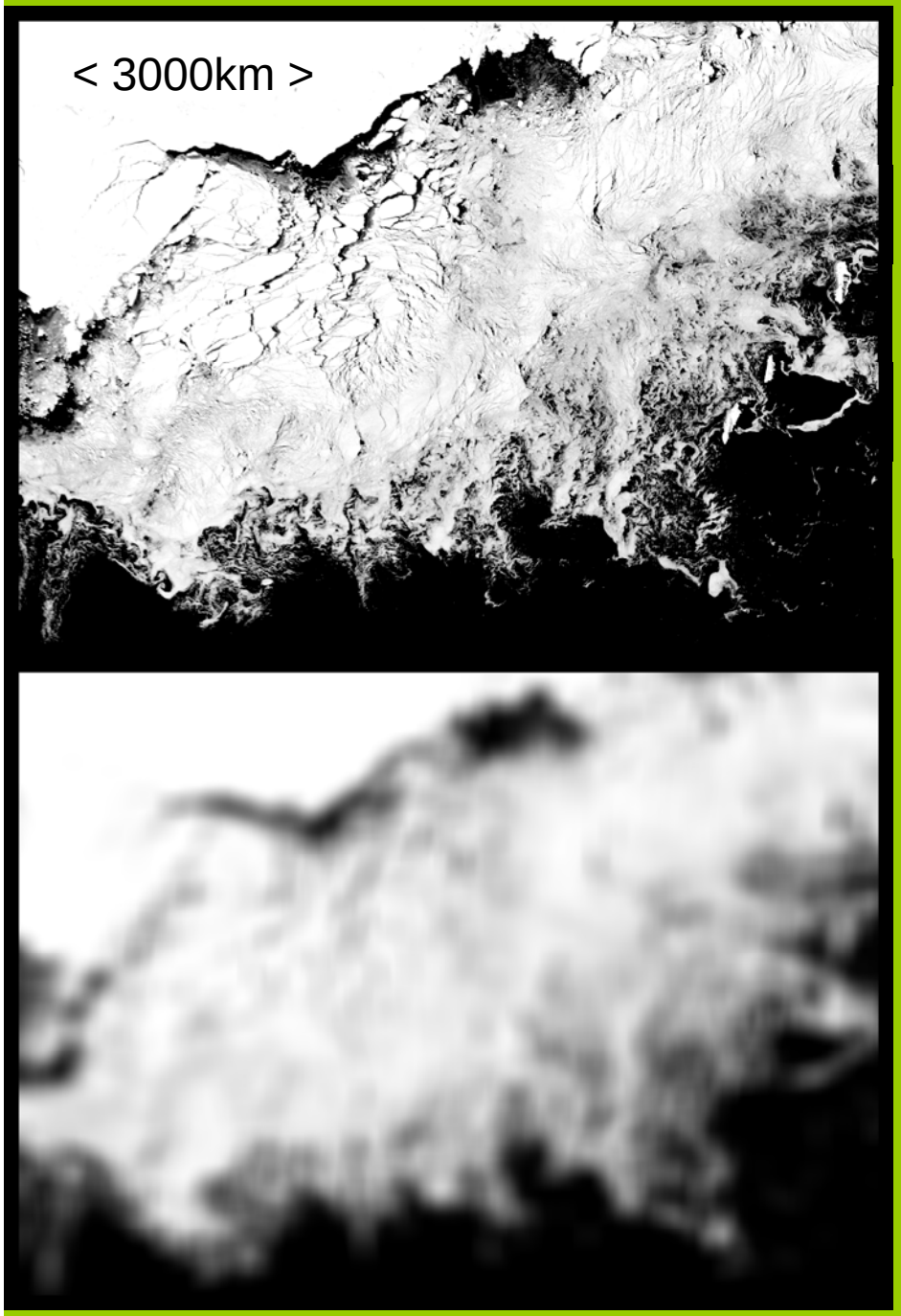


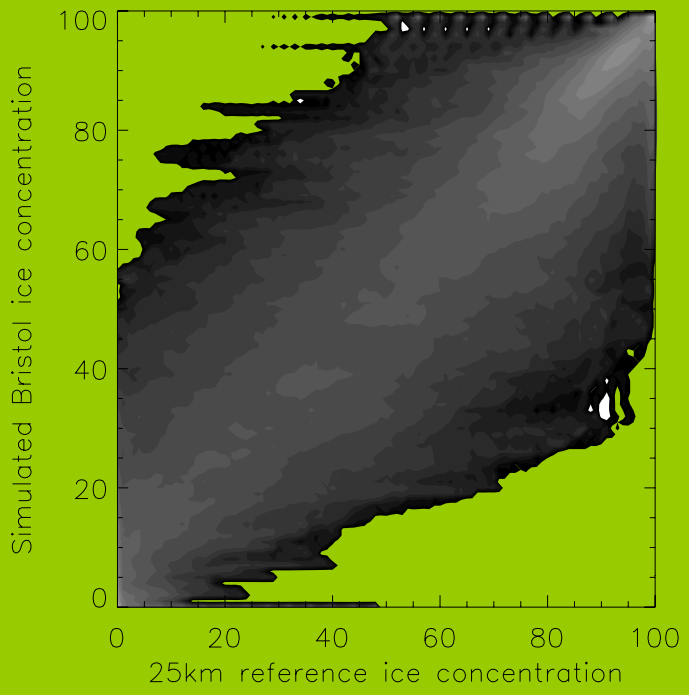


< 800km >



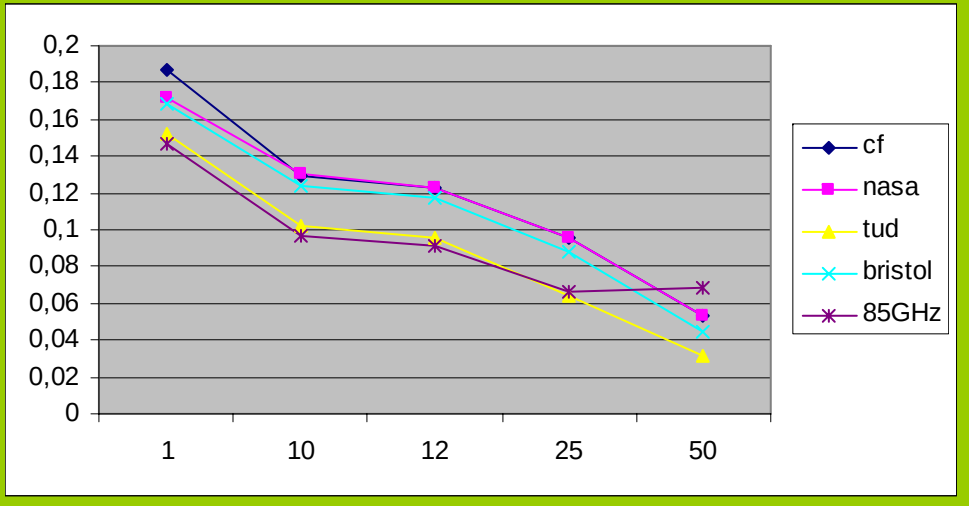
1km – 10km – 25km – Bristol SMMR





1km - Bristol

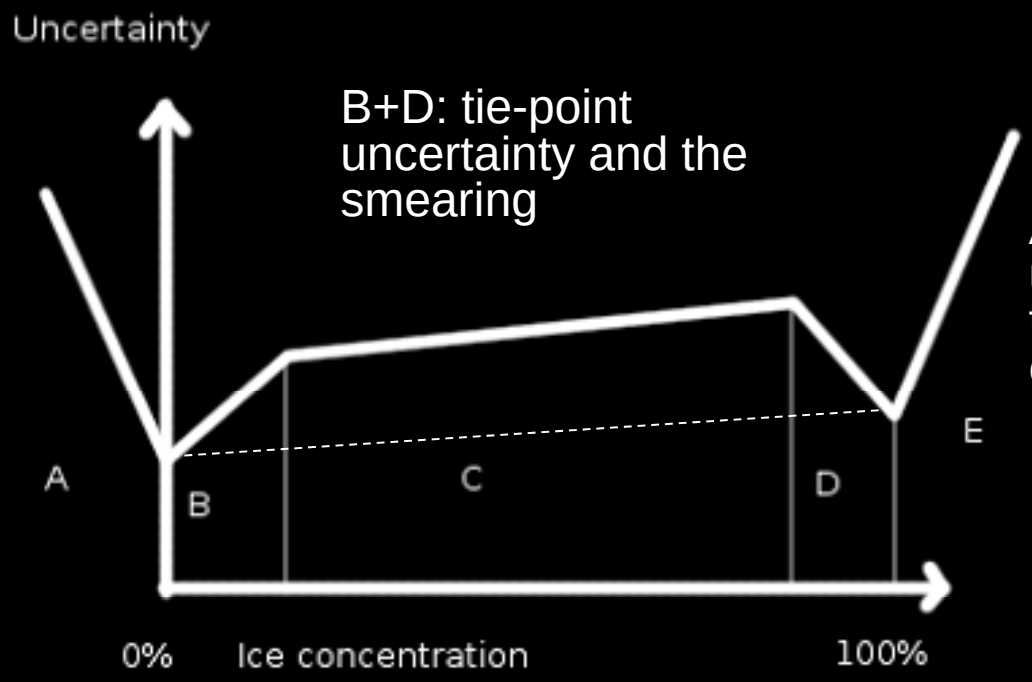
Total concentration 65%



Gridding error - smear

SMMR SSMI AMSR	1km	10km	25km	50km	Geo Std(r)=5.1
CF	23 23 21	15 15 13	11 11 8	6 6 3	0.35 0.3 0.5
NASA	24 24 23	15 15 13	11 11 8	6 6 3	0.35 0.3 0.5
TUD	- 21 20	- 10 9	- 6 5	- 3 3	- 0.5 0.7
Bristol	23 24 22	13 14 11	9 10 6	4 5 2	0.4 0.3 0.5
C85	- 17 15	- 10 9	- 10 10	- 12 11	- 0.8 1.2

Uncertainty model

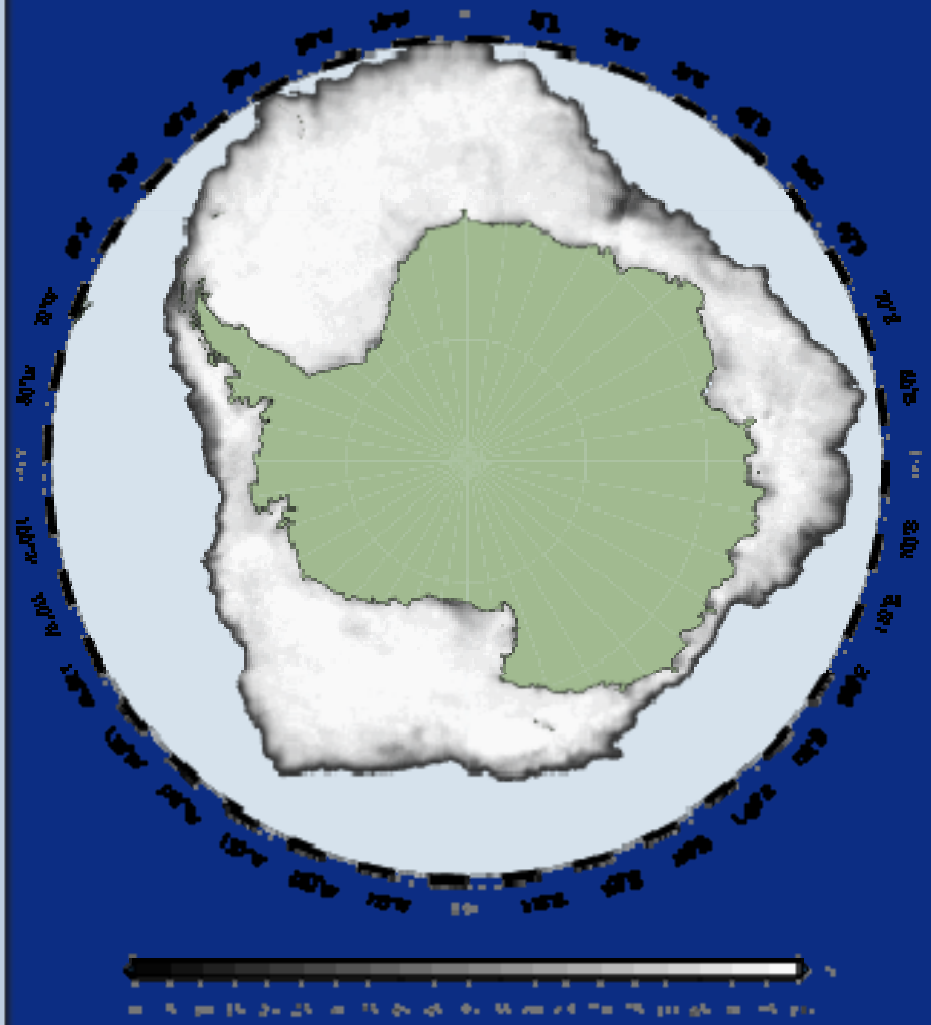


B+D: tie-point uncertainty and the smearing

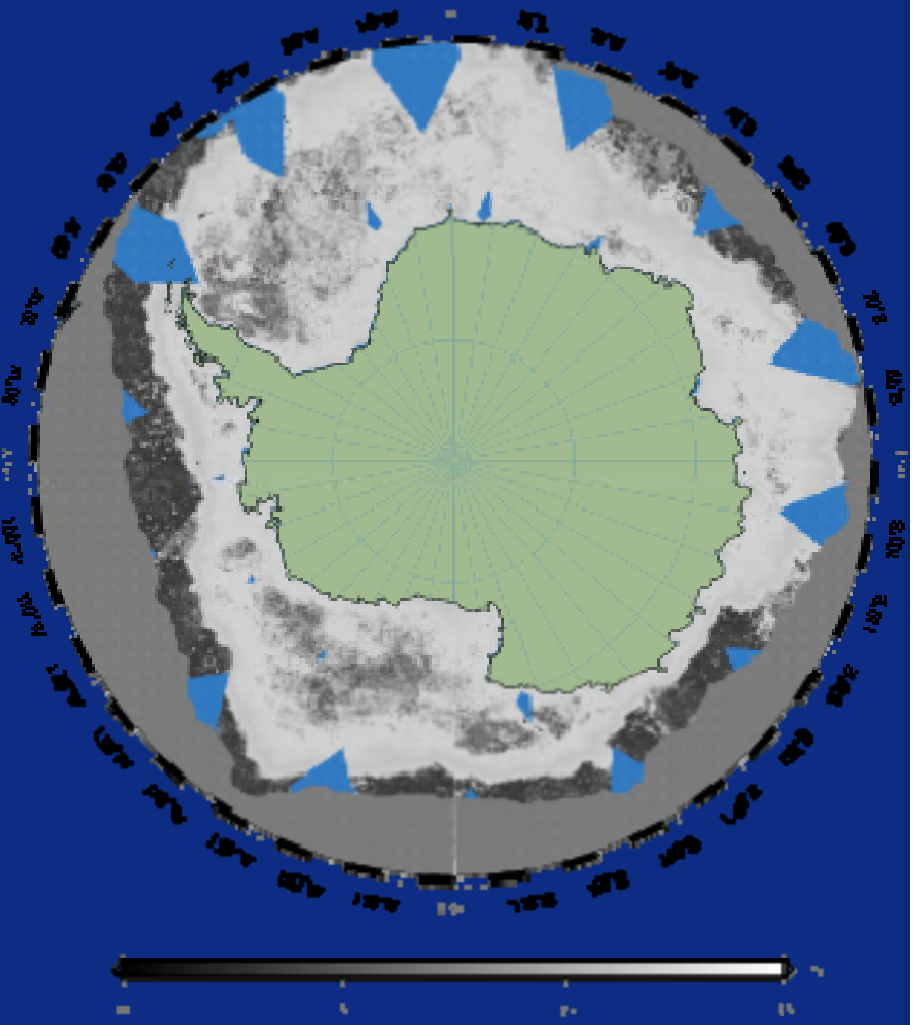
A+E: tie-point uncertainty and the over/under estimation

C: Smearing offset by tie-point uncertainty

Ice concentration 19810730



Ice concentration uncertainty 19810730



The total error

- The smearing includes both foot-print smear and foot-print mismatch, these cannot be separated.
- The tie-point error includes sensor noise, emissivity noise and residual atmospheric noise
- The geolocation error seems small in our trials
- the total error is about 10% at 25km (Bristol/ SMMR)
- the total error is about 14% at 10km (Bristol/ SMMR)
- the total error is about 10% at 10km (TUD/ AMSR)

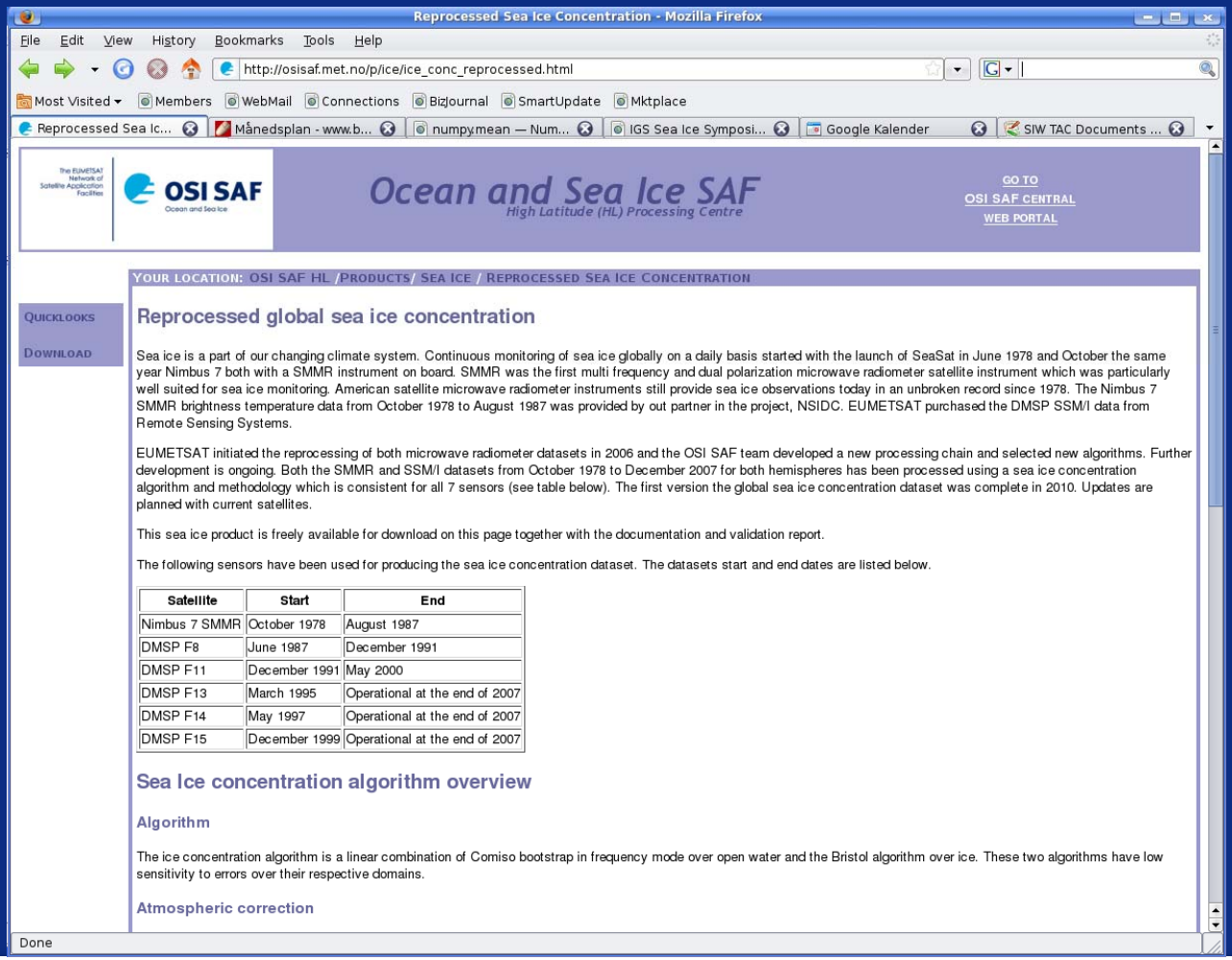
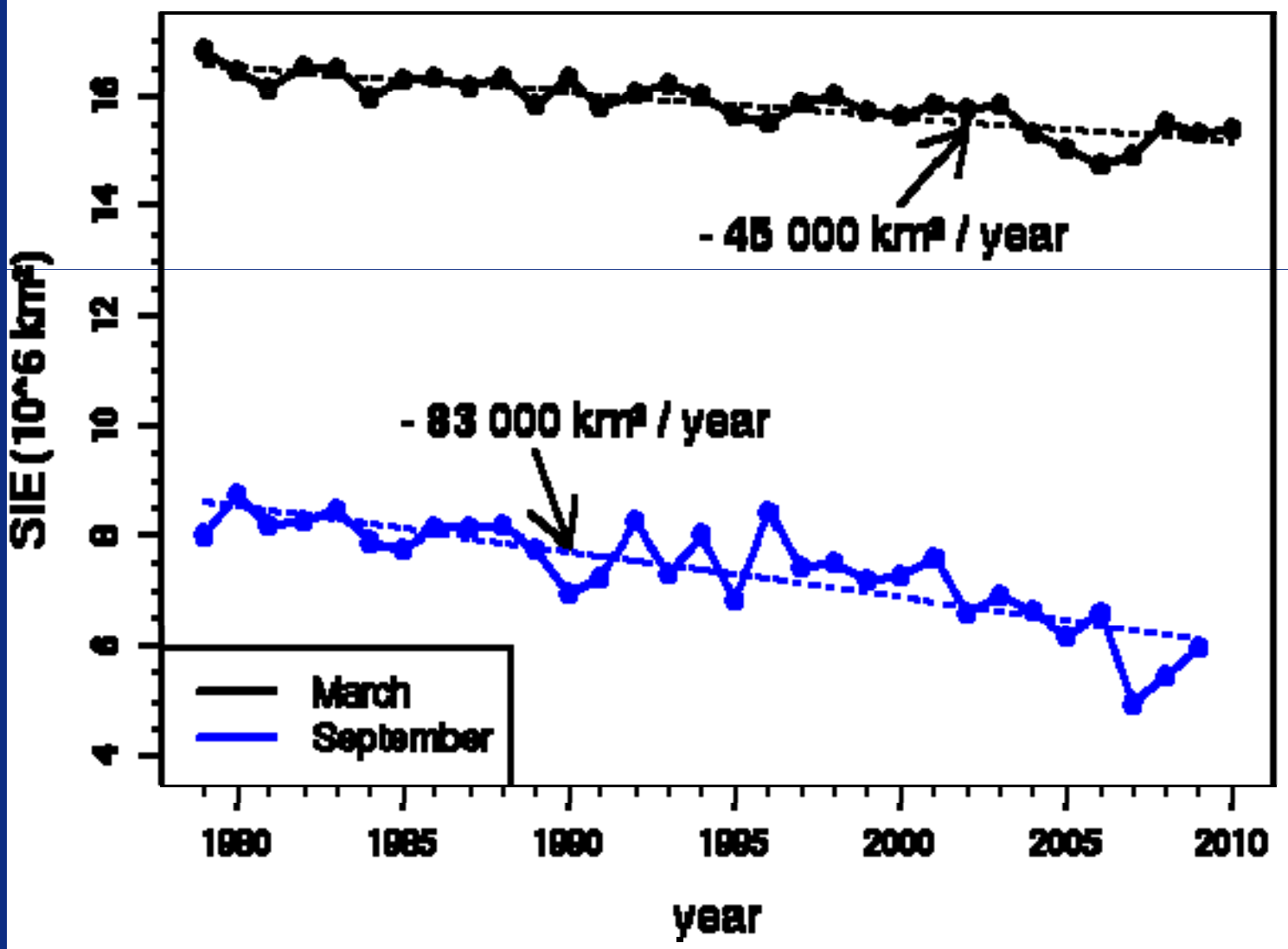
Future

- Periodic updates
- Model correction of near coastal pixels
  - Visiting scientist UH 2010
- Geo-location correction
  - An issue especially for SMMR
- Updates of the uncertainty model
  - Split into components… discussions with the Hadley centre
  - Include structural uncertainties
- Temporal and spatial correlations
- Uncertainties on the extent and area estimates

Get the NetCDF dataset in EASE or PS grid:

http://osisaf.met.no/p/ice/ice_conc_reprocessed.html

including documentation, validation report, quick-looks and uncertainty estimates.



Arctic Sea Ice Extent (SIE)