Sea Ice Remote Sensing using AMSR 89 GHz data

Georg Heygster, Gunnar Spreen, Lars Kaleschke

Institute of Environmental Physics, University of Bremen

Joint AMSR Science Team Meeting 2005,
Honolulu, Sep 13-15

Overview

1. Why Remote Sensing of sea ice?
2. Outline of algorithm
3. Tie point selection
4. Error estimation
5. Handling sensor imperfections
6. Operational applications
7. Conclusions and outlook

1. Motivation

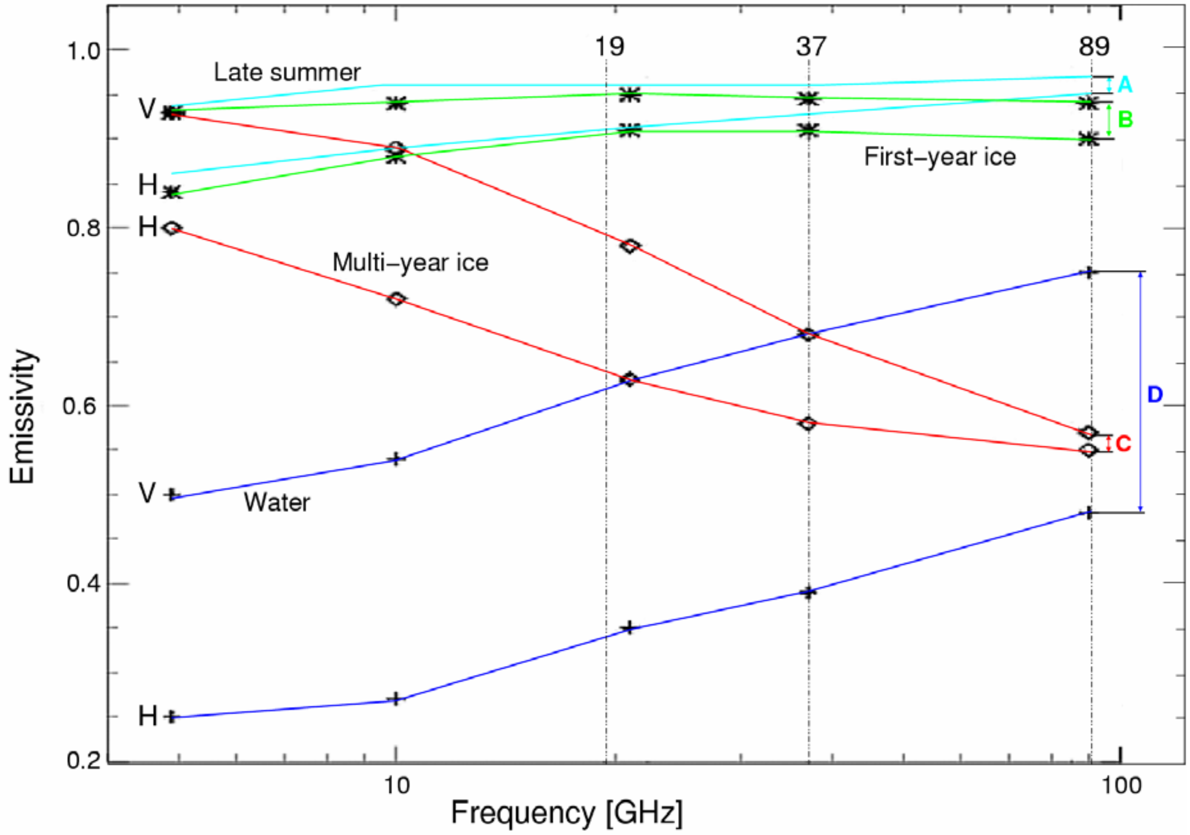
High resolution sea ice information needed in NRT at

- high ice concentrations for NWP: heat transfer $\sim (1-C)$
- Low ice concentrations for navigation

2. ASI (ARTIST Sea Ice) algorithm

- Svendsen et al. (1987): Use polarization differences near 90 GHz:

- High for OW
- Low for all ice types



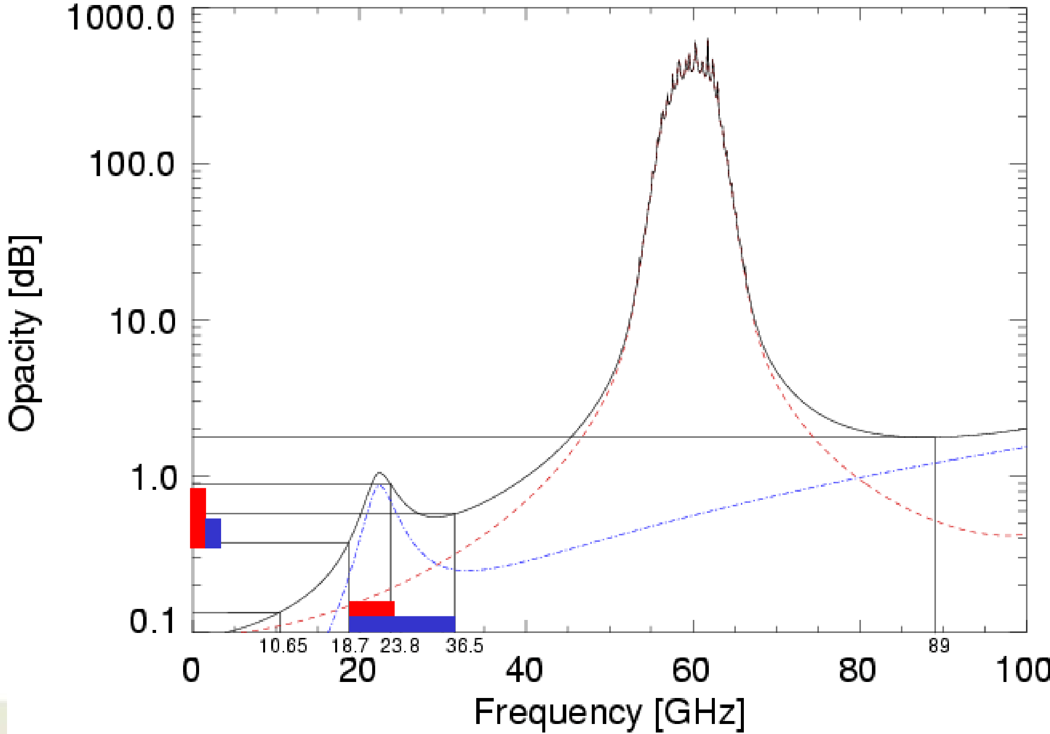
ASI algorithm (2)

Hybrid algorithm:

- Modified 89 GHz Svendsen et al. (1987) algorithm for ice covered regions → *higher resolution*
- Lower frequencies for ice-free ocean → *less atmospheric effects*
- 3 weather filters:

IF $GR(36,19) > 0.045$
OR $GR(23,19) > 0.04$
OR $C_{BOOTSTRAP} > 0.05$

THEN $C_{ASI} = 0$



Svendsen et al. 1997
Kaleschke et al. 2001

Modified Svendsen Algorithm

- Polarization difference near surface...

$$P_s = CP_I + (1-C)P_W$$
$$= C(P_I - P_W) + P_W$$

C ice concentration

P_I polarization difference of ice

P_W polarization difference of water

- ...and at TOA:

$$T_{B,V} - T_{B,H} = [e^{-\tau}(1.1e^{-\tau} - 0.11)]\ P_S = a\ P_S$$

(Svendsen 1987)

$$P = a\ [C(P_I - P_W) + P_W]$$

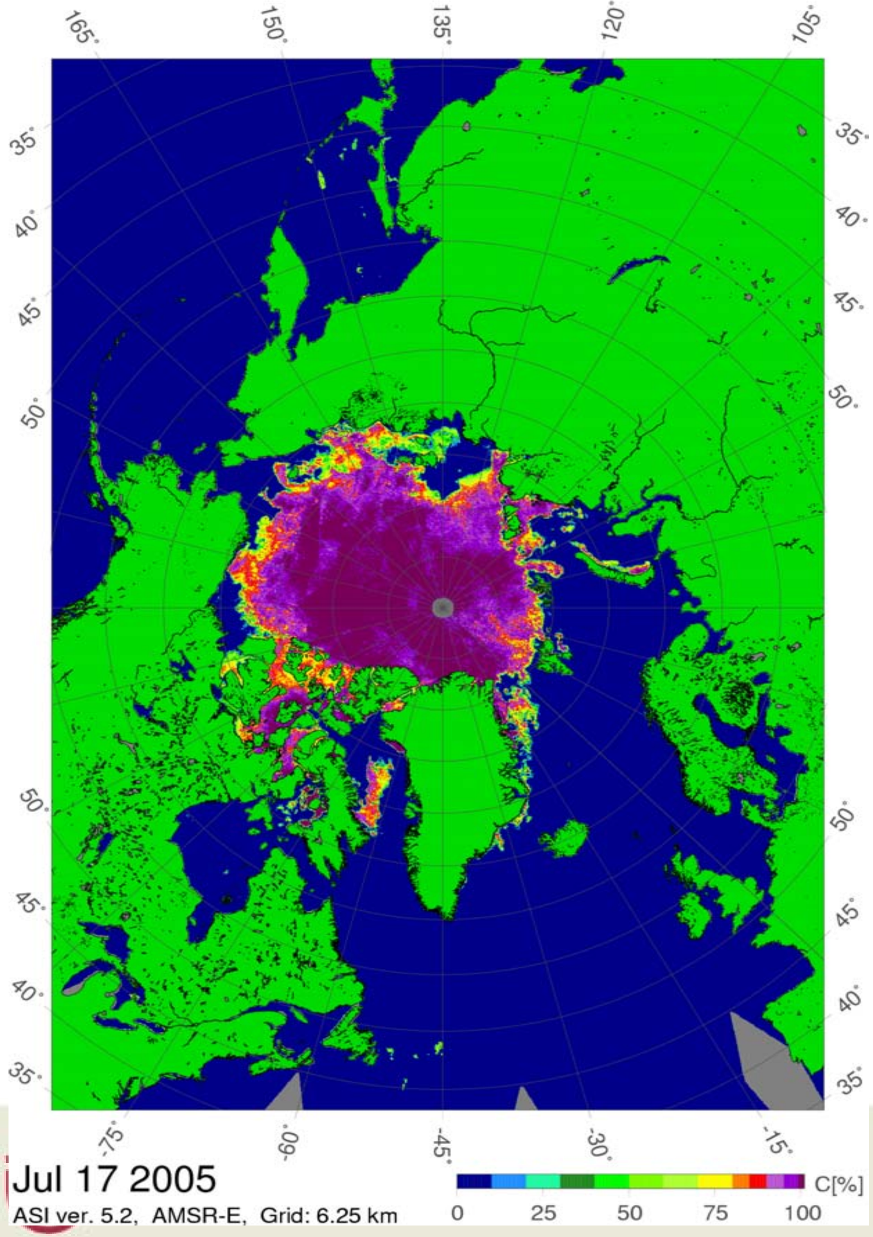
- a atmospheric Influence, varies with C, approach

$$C = d_3 P^3 + d_2 P^2 + d_1 P + d_0$$

- Determine d_i from known P for C=0 and 1 (tie points P_0, P_1), dC/dP (C =0 and 1) and ratio $P_W/(P_I - P_W) = -1.14$

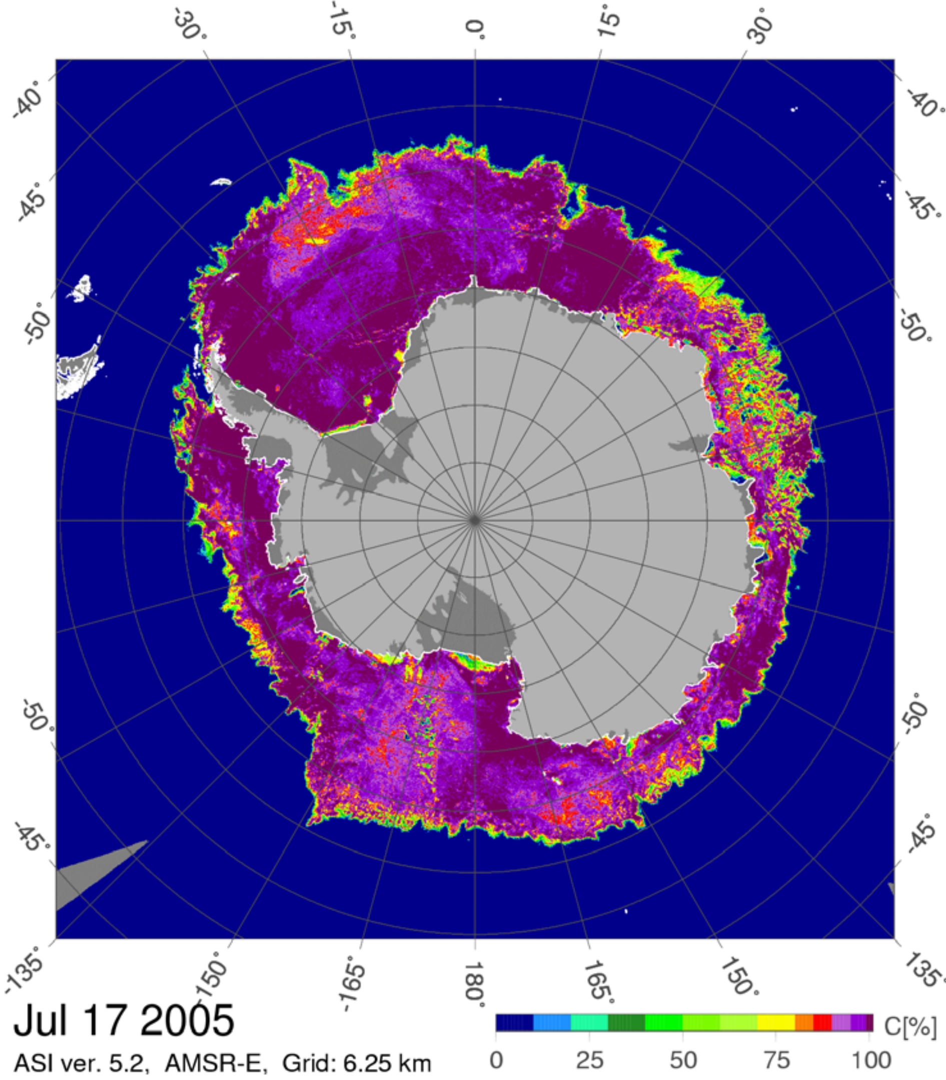
P

Results – Hemispheres (www.iup.physik.uni-bremen.de)



Jul 17 2005

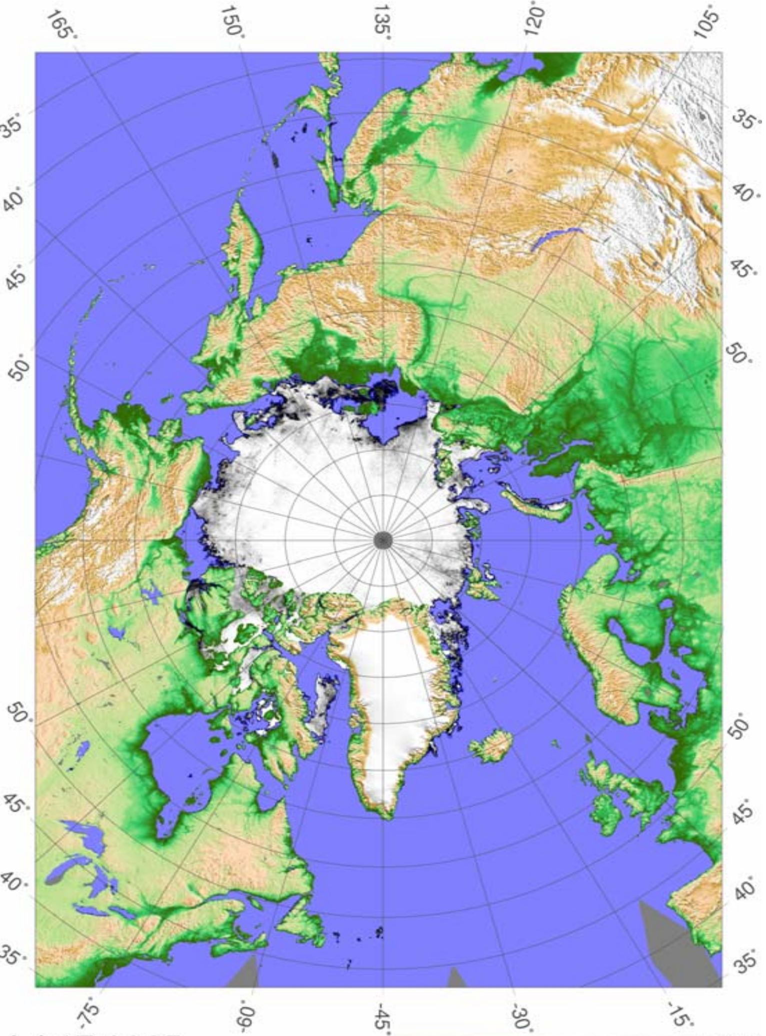
ASI ver. 5.2, AMSR-E, Grid: 6.25 km



Jul 17 2005

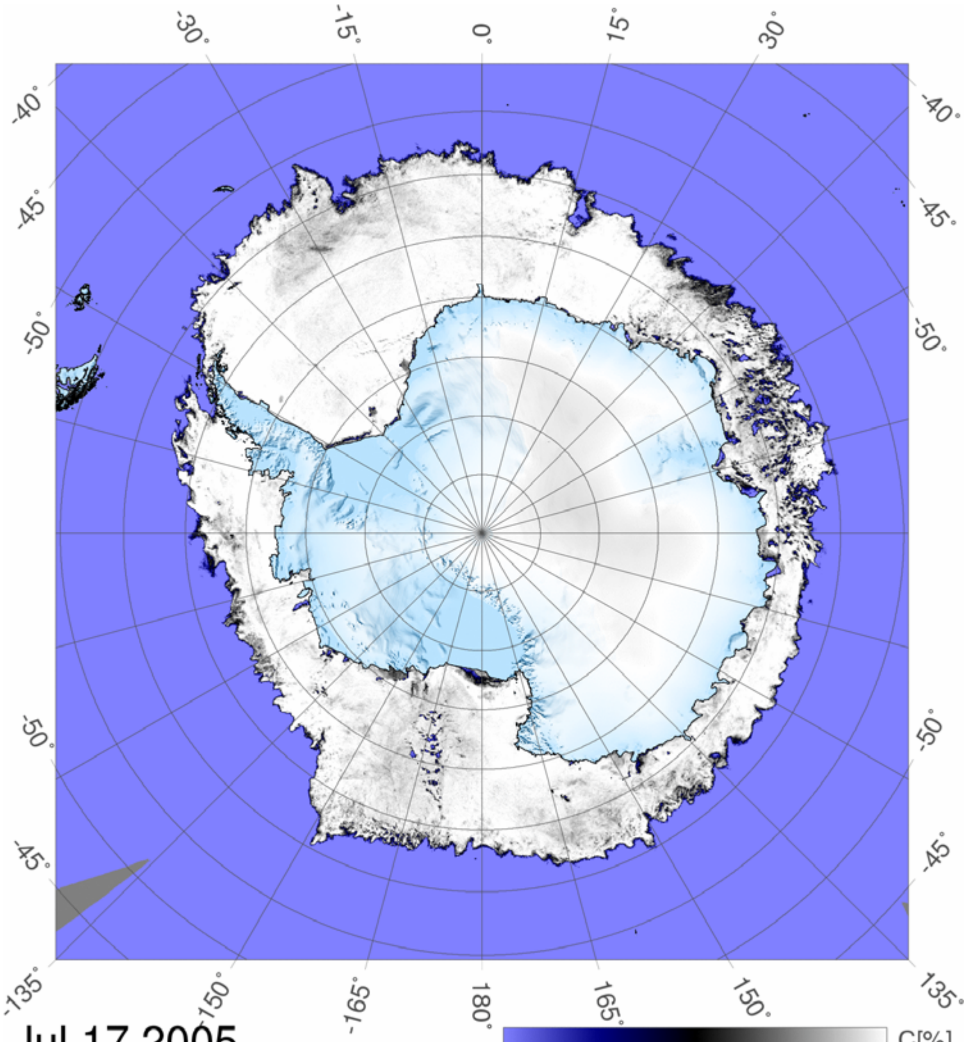
ASI ver. 5.2, AMSR-E, Grid: 6.25 km

Results – Hemispheres (www.iup.physik.uni-bremen.de)



Jul 17 2005

ASI ver. 5.2, AMSR-E, Grid: 6.25 km



Jul 17 2005

ASI ver. 5.2, AMSR-E, Grid: 6.25 km

3. Selection of tie points P_0, P_1

3 possibilities:

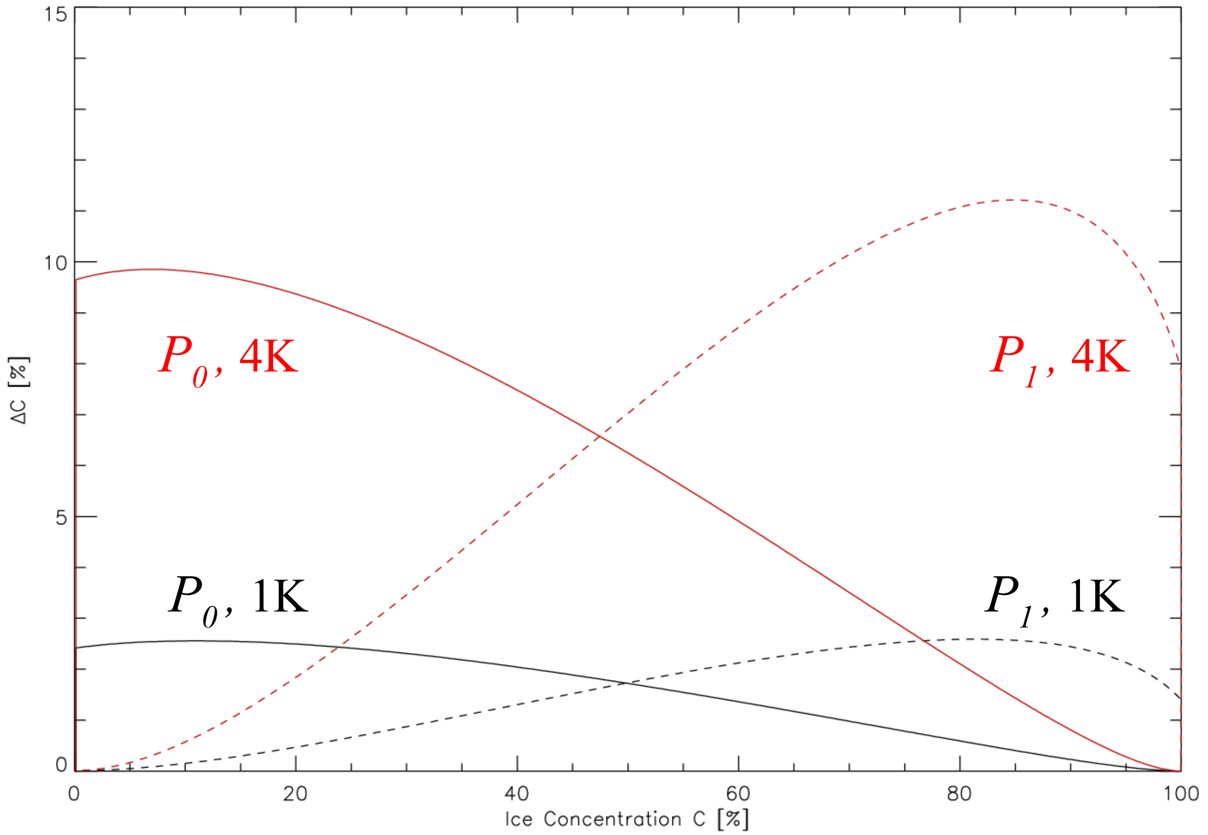
1. Use maximum and minimum P values of swath data as varying P_0 and P_1
   - *Svendsen approach, not successful due to variability of maxima and minima.*
2. Fixed tie-points from statistical comparison with reference measurement.
   - *ASI approach for operational use:* $P_0 = 47$ K, $P_1 = 11.7$ K
3. Adapt tie-points to adjust to reference sea ice concentrations (Bootstrap or NASA-TEAM).
   - *ASI approach for regional studies*.

Arctic

Antarctic

4. Error Estimation

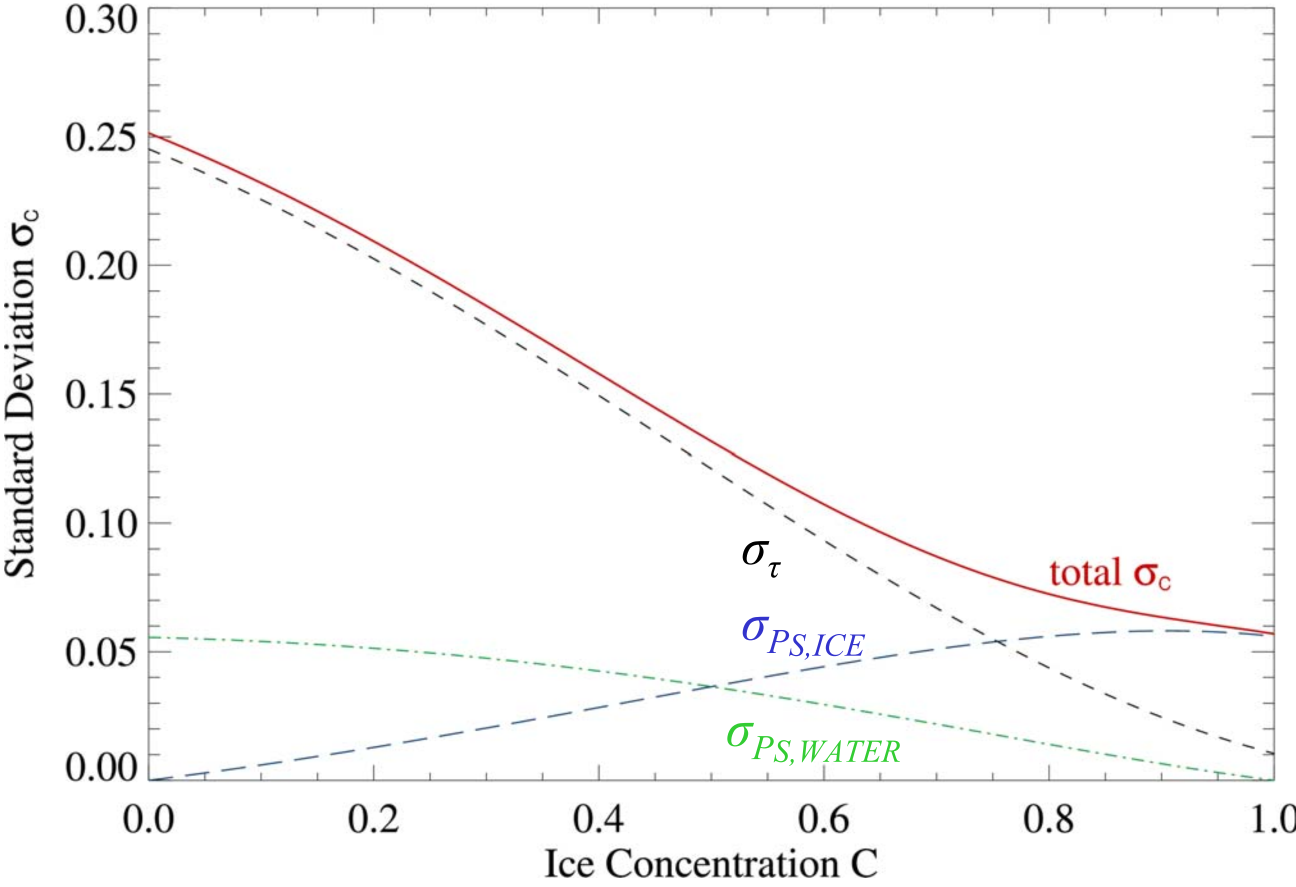
- $C = C(P, P_0, P_1)$
- sensitivity of C against changes of P_0, P_1 by ±0.5 and ±4 K:



Error Estimation (2)

- Standard deviations calculated for in-situ measurements of opacity τ and polarization differences P_S:

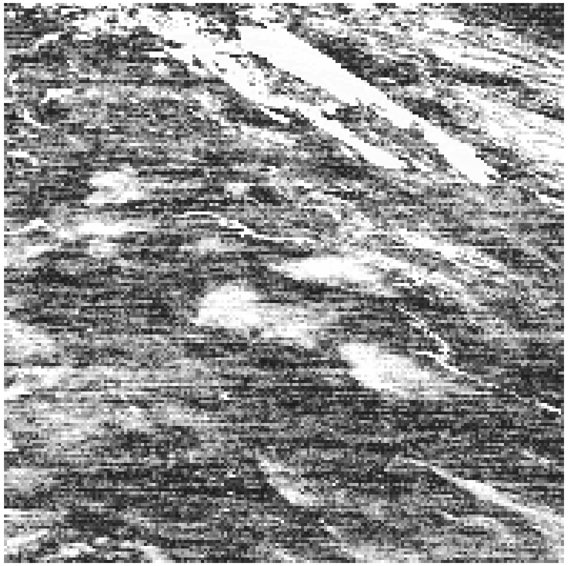
Error budget:



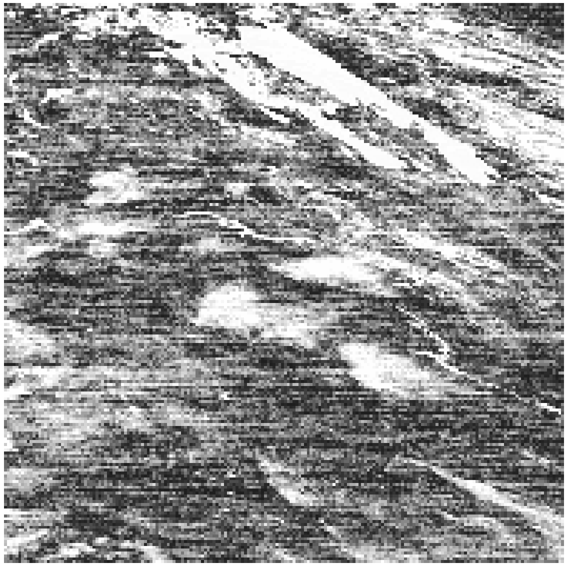
5. Handling sensor imperfections

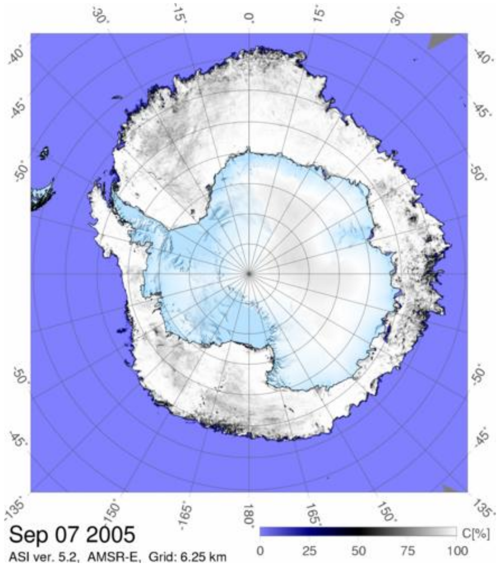
1. **AMSR-E 89 GHz A-scan failure** (Nov. 2004)
    - Little influence due to multiple overpasses at high latitudes

2. **Low frequency sensor noise**
    - 89 GHz B scan
    - $\sigma_{\Delta y} \approx \sigma_{\Delta x} + 0.3\ \mathrm{K}$ typ.
    - other channels?
    - Source?
    - Experience?

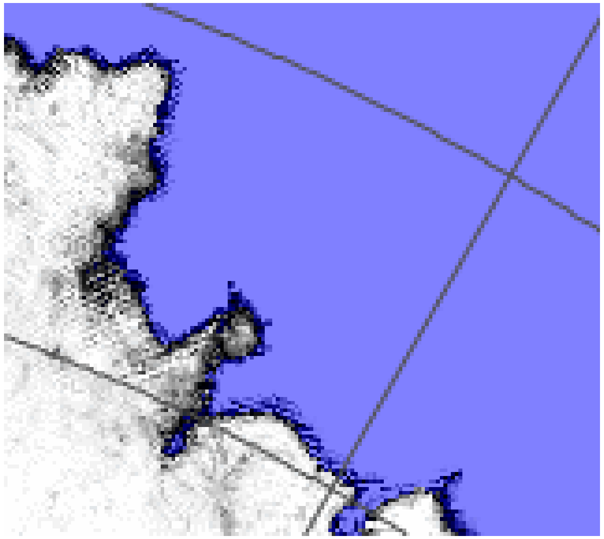


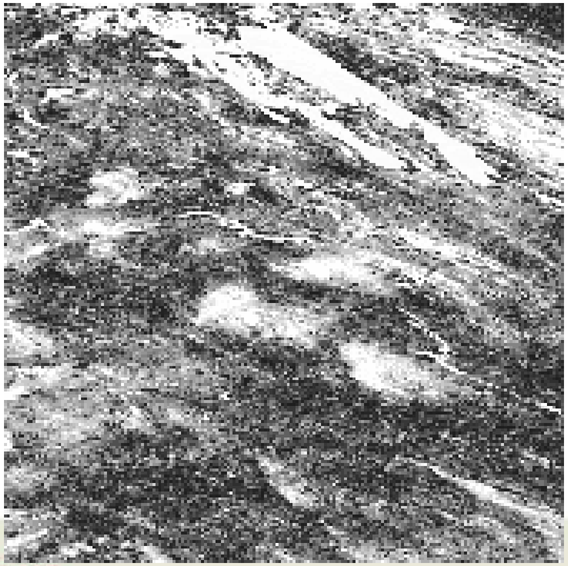
Low frequency sensor noise





Sep 07 2005
ASI ver. 5.2, AMSR-E, Grid: 6.25 km

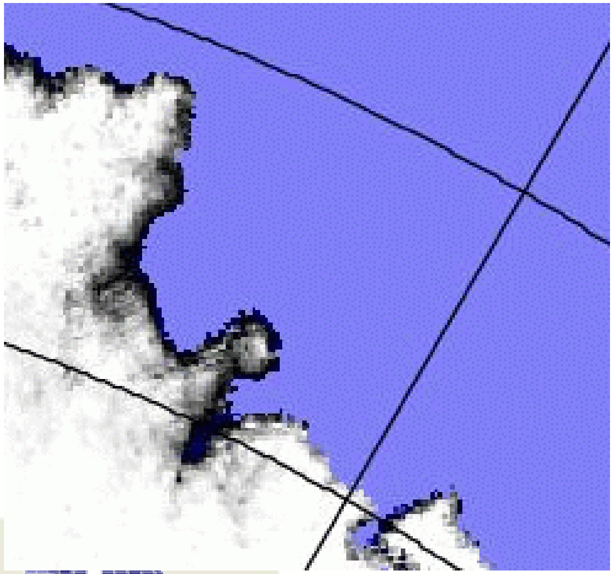




Procedure:

Adaptive local moment matching

(L. Kaleschke)



6. Operational Aspects

Daily regional maps (3km)

Arctic:

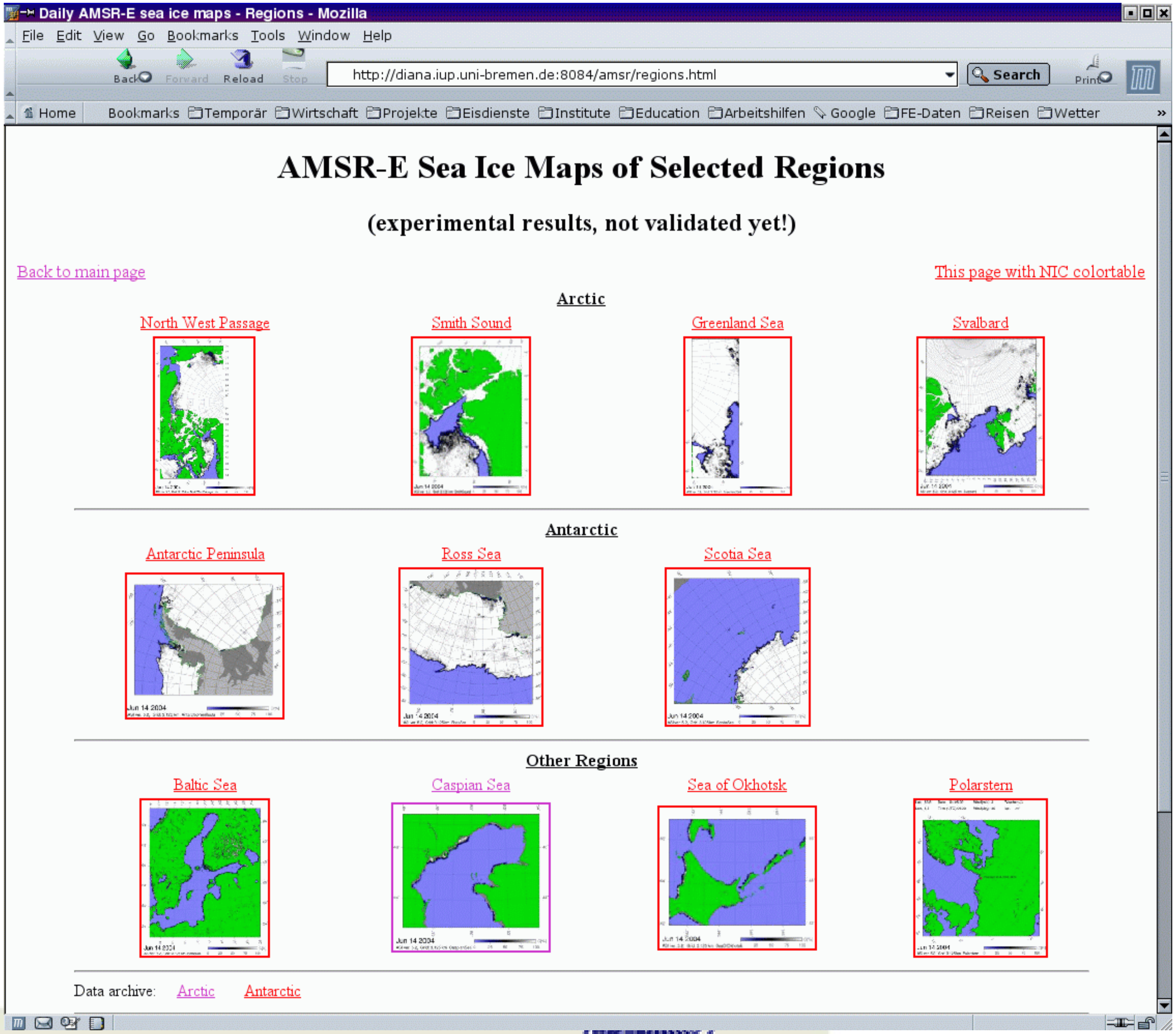
- North West passage
- Smith Sound
- Greenland Sea
- Svalbard

Antarctic:

- Peninsula
- Ross Sea
- Scotia Sea

Other:

- Baltic Sea
- Caspian Sea
- Sea of Okhotskh
- Polarstern



http://diana.iup.uni-bremen.de:8084/amsr/regions.html

AMSR-E Sea Ice Maps of Selected Regions

(experimental results, not validated yet!)

Back to main page

This page with NIC colortable

Arctic

North West Passage | Smith Sound | Greenland Sea | Svalbard

Antarctic

Antarctic Peninsula | Ross Sea | Scotia Sea

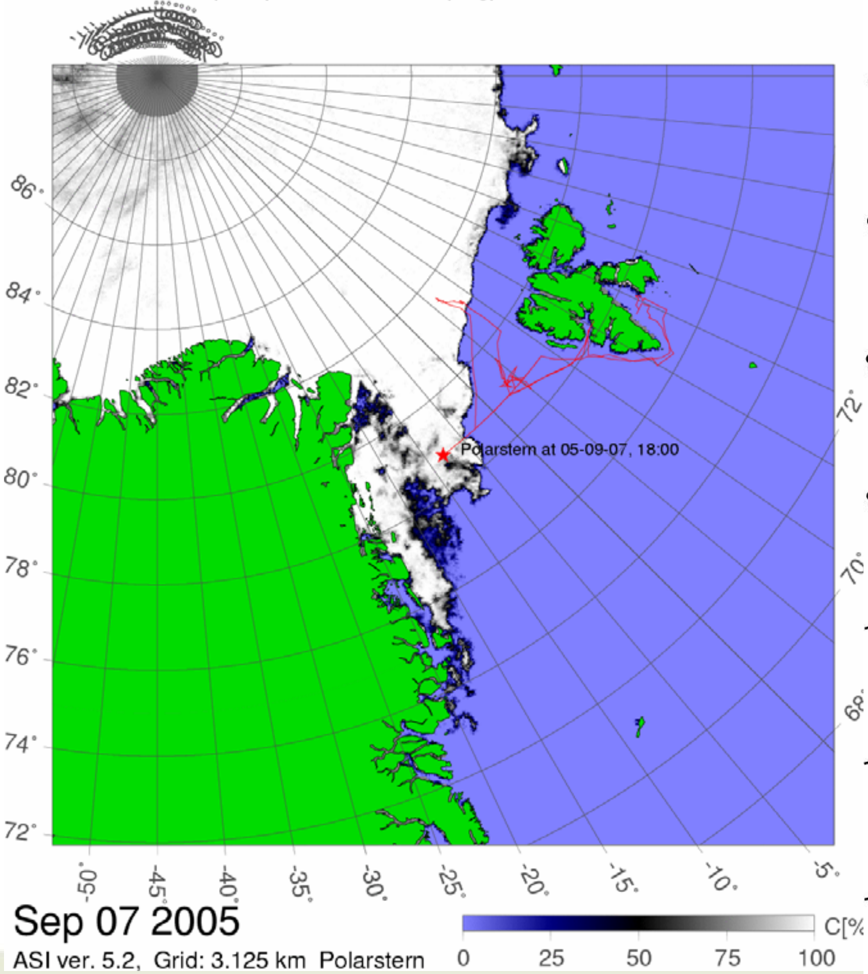
Other Regions

Baltic Sea | Caspian Sea | Sea of Okhotsk | Polarstern

Data archive: Arctic Antarctic

Service for R/V Polarstern

Lat: 78.8 Date: 05-09-07 Wind(m/s): 3 Weather: 1422
Lon: -8.0 Time (UTC):18:00 Wind(deg): 60 Ice: 48095



Sep 07 2005

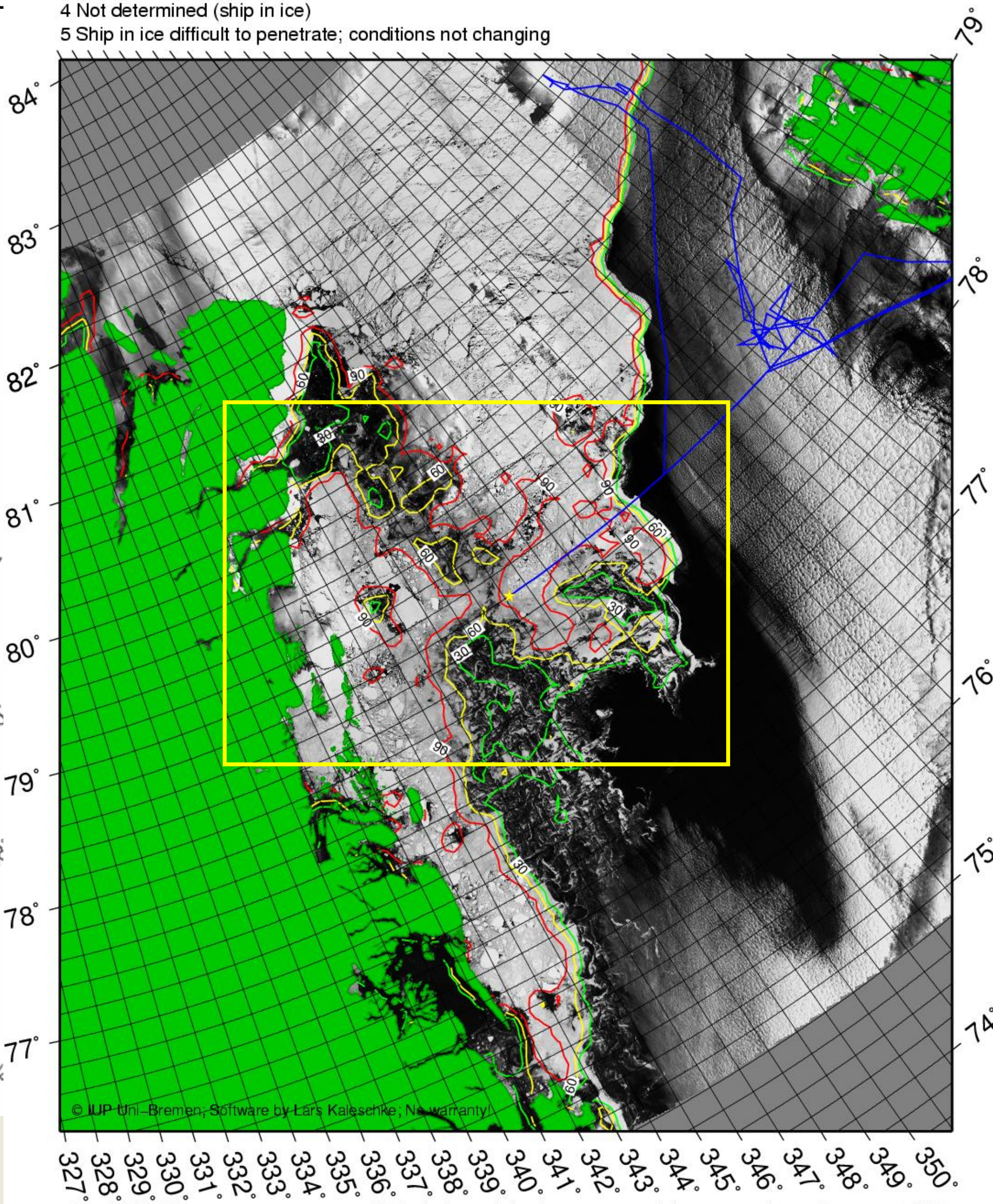
ASI ver. 5.2, Grid: 3.125 km Polarstern

Universität Bremen

Follow Polarstern

Latest ice observation (red star):05–09–08 06:00 UTC (not always at latest position, see bottom line)

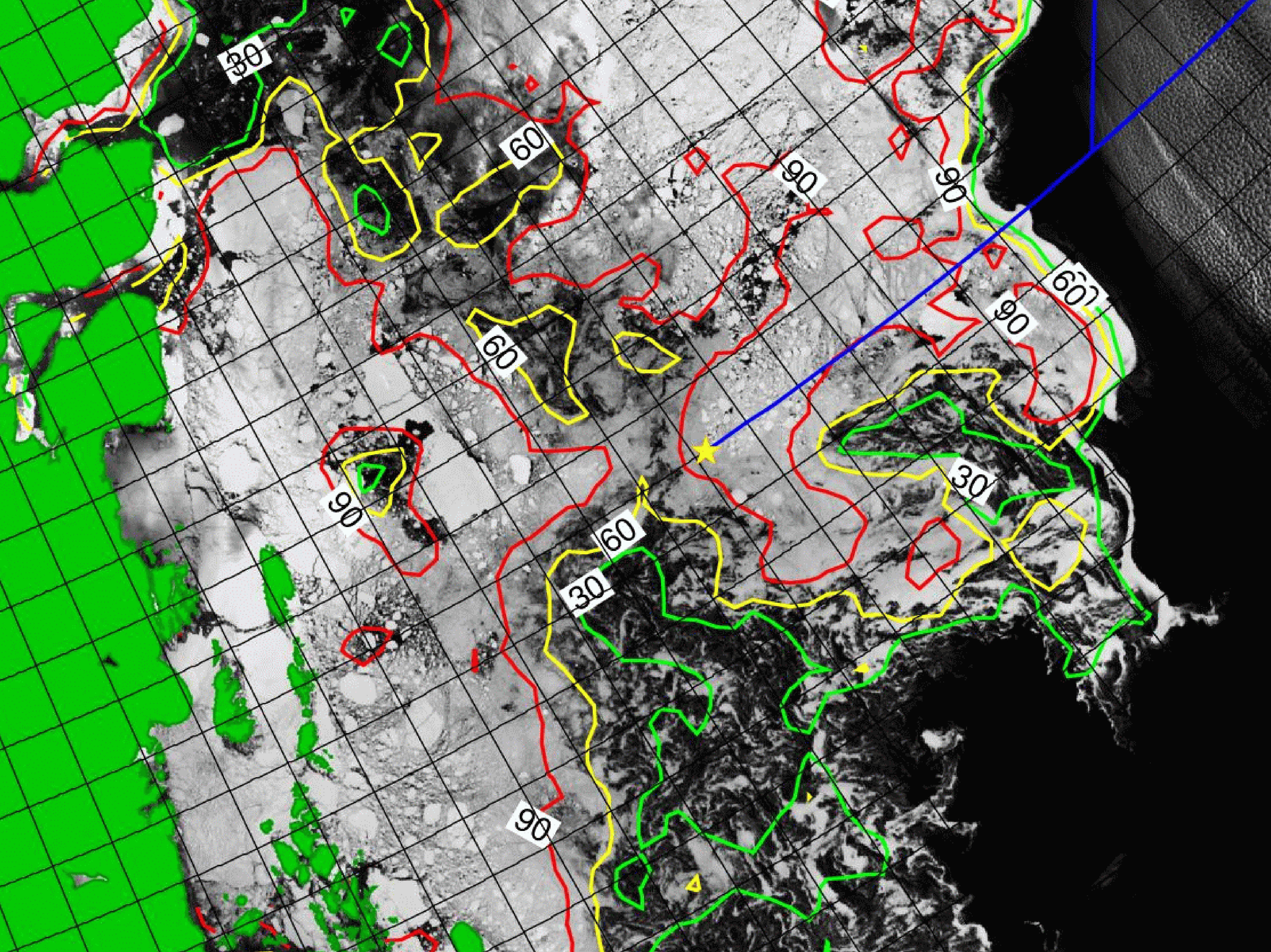
1 Close pack ice 6/8 to < 7/8 concentration
2 All medium and thick first–year ice
3 No ice of land origin
4 Not determined (ship in ice)
5 Ship in ice difficult to penetrate; conditions not changing



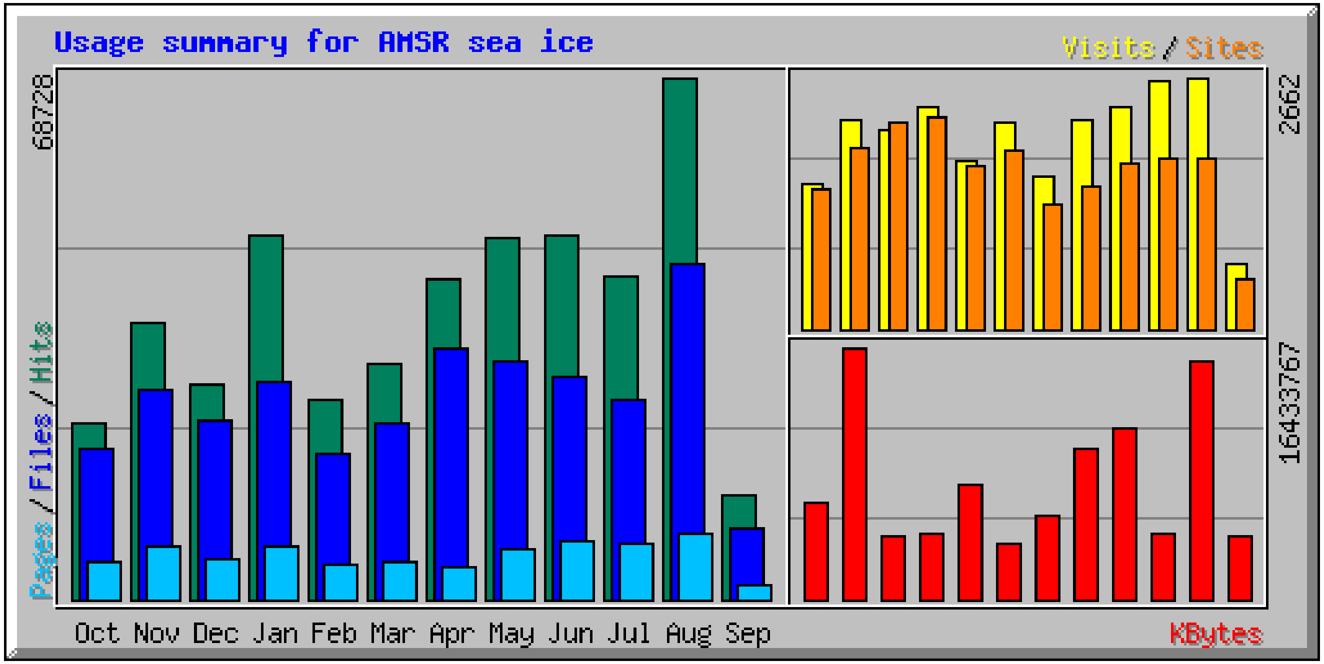
Aqua MODIS λ=670 nm; 2005–09–06 0845 UTC; adaptive scaled radiance; 250m resolution; processed: 2005 Sep 08 12:20 UTC

Sea ice concentration isolines 30%, 60%, 90% from AMSR–E 20050906

Polarstern (yellow star) lat: 78.8 lon:–10.8 wind 6 m/s T=–5.5 C 05–09–08 06:00 UTC


30
60
90
90
60
90
60
90
30
60
30
90

Web page – Usage statistics



Typical month April 2005:

Per day: 1400 hits, 1100 files, 145 pages

Total: 5.5 GB, 1300 sites

7. Conclusions and Outlook

- Sea ice remote sensing near 90 GHz possible
- Daily data available NRTat www.iup.physik.uni-bremen.de
- Good coincidence with MODIS and Polarstern observations

- Continued under
  - ESA/EU GMES project Polar View
  - EU IP DAMOCLES, Developing Arctic Modelling and Observing Capabilites for Long-term Environment Studies

Acknowledgements

This work was supported by

- German Research Foundation DFG under grants He 1746/10-1,2,3
- EU under project IOMASA (Integrated Observing and Modeling to the Arctic Surface and Atmosphere) EVK3-CT-2002-00067
- ESA/EU GMES initiative ICEMON (ESA ESRIN contract 17060/03/I-IW

Backup: RTE for horizontally homogeneous atmosphere

$$T_B = \varepsilon T_s e^{-\tau} + T_{atm}(1-e^{-\tau}) + (1-\varepsilon)T_{atm}(1-e^{-\tau})e^{-\tau} + (1-\varepsilon)T_{sp}e^{-2\tau}$$

surf atm reflected cosmic

τ atm. opacity

ε surf. emissivity

2 fields of progress

- Using 85/89 GHz data for sea ice concentration
- AMSR(-E)

SSM/I			**AMSR(-E)**		
Frequency [GHz]	Resolution [km x km]	Radiometric resolution[K]	Frequency [GHz]	Resolution [km x km]	Radiometric Resolution[K]
			6.925	70 x 70	0.3
			10.65	50 x 50	0.5
19.35	69 x 43	0.4	18.7	25 x 15	0.5
22.235	60 x 40	0.7	23.8	30 x 18	0.5
37	37 x 29	0.4	36.5	14 x 18	0.5
85.5	15 x 13	0.8	89	6 x 4	1.0
Incidence angle: 53.1°			Incidence angle: 55°		
Swath width: 2400 km			Swath width: 1600 km		

Bootstrap algorithm

- Basic Bootstrap Algorithm (BBA, Comiso et al. 2003)
- Preliminary tie points
- 19 and 37 GHz: Lower
  - atmosph influence and
  - horizontal resolution (25 km)

- Condition: C(Bootstrap) < 5% ➔ C(ASI) = 0

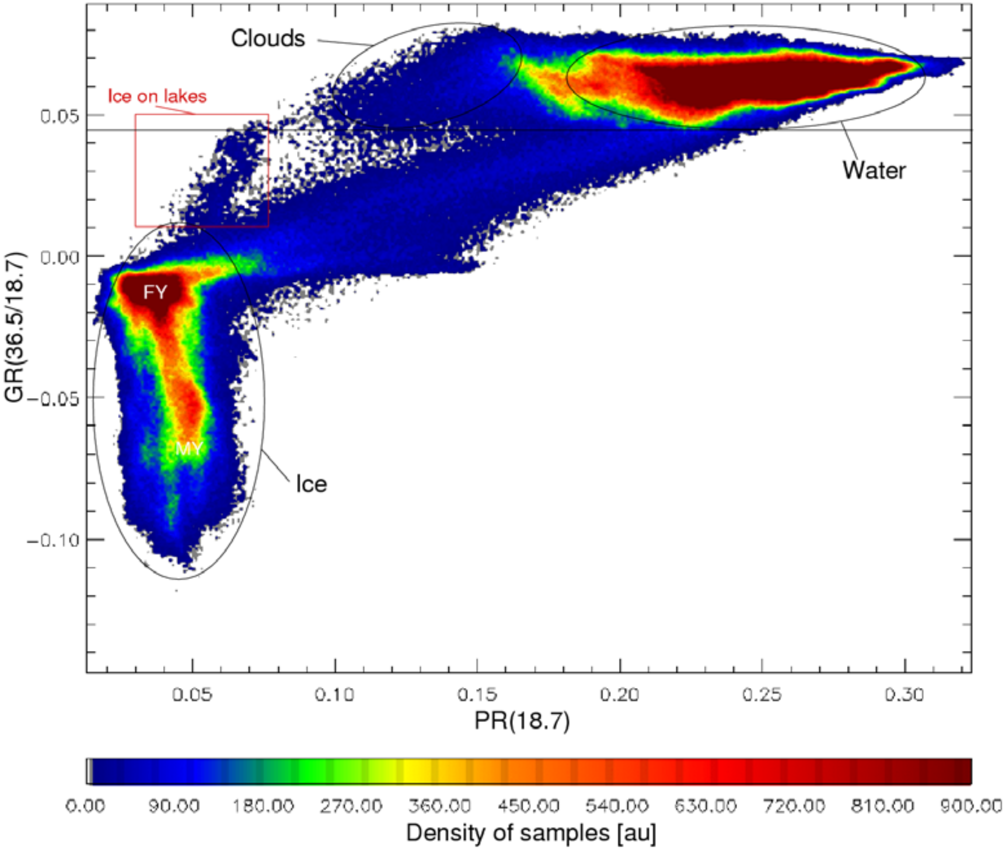
First Weather Filter: Gradient Ratio (37,19)

$$GR(37,19) = \frac{T_B(37V) - T_B(19V)}{T_B(37V) + T_B(19V)}$$

- Gloersen and Cavalieri (1986) for SMMR
- Illustrated in PR-GR plane
- Most sensitive to CLW and wind
- Cuts off C ~ 15 %

- Condition:

  GR(37,19) > 0.045
  ➔ C(ASI) = 0

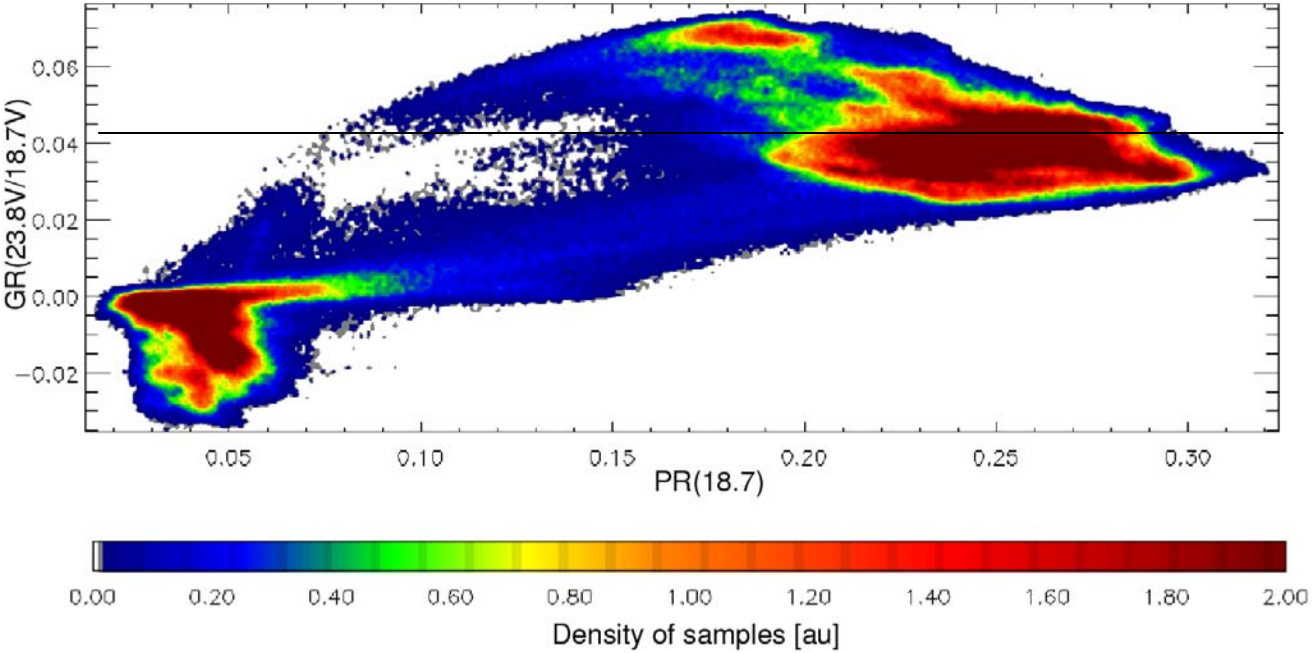


Universität Bremen

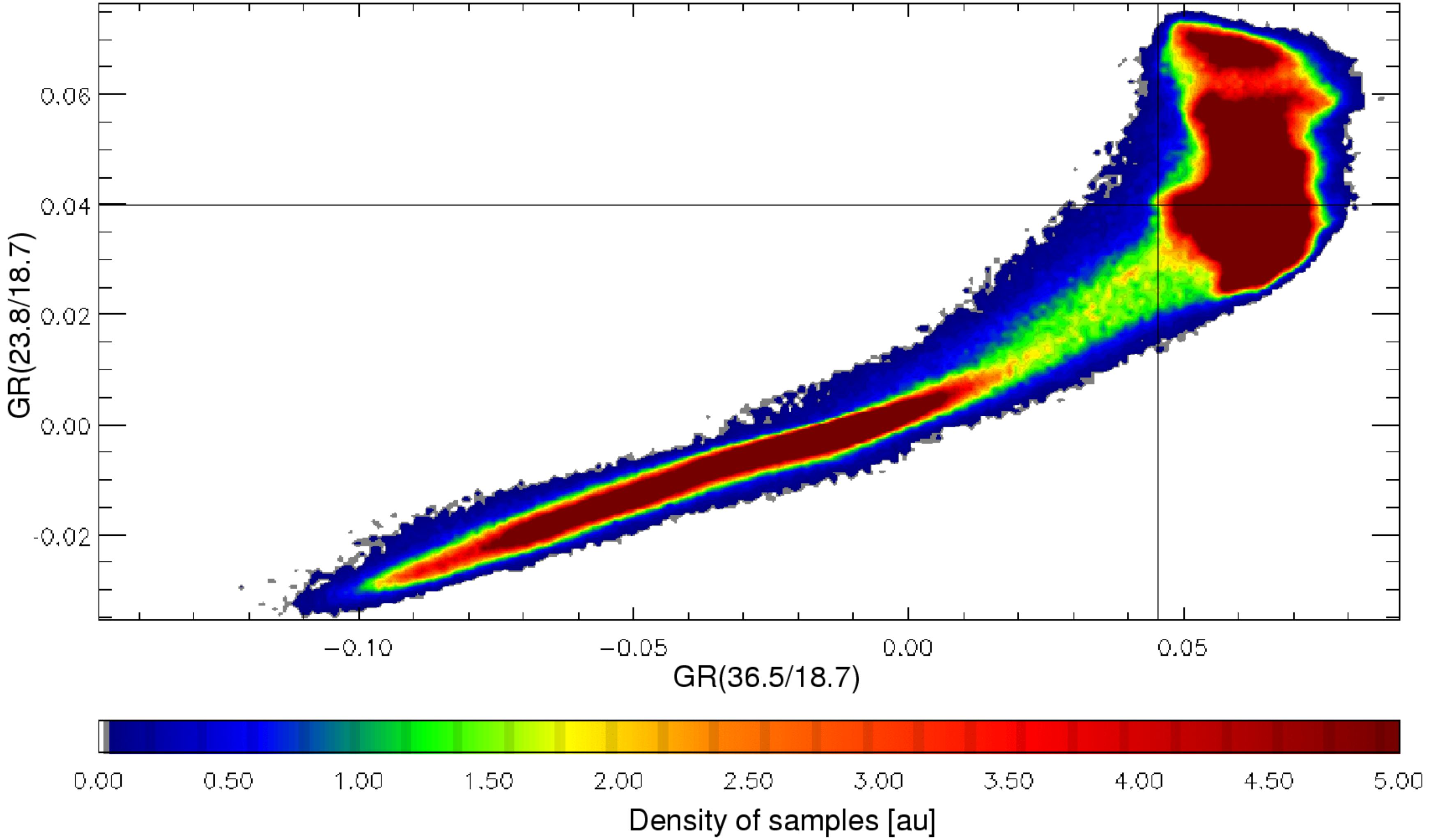
Second Weather Filter: GR(24,19)

- Test for high water vapor values
- Relative Tb change from 19 to 24 GHz

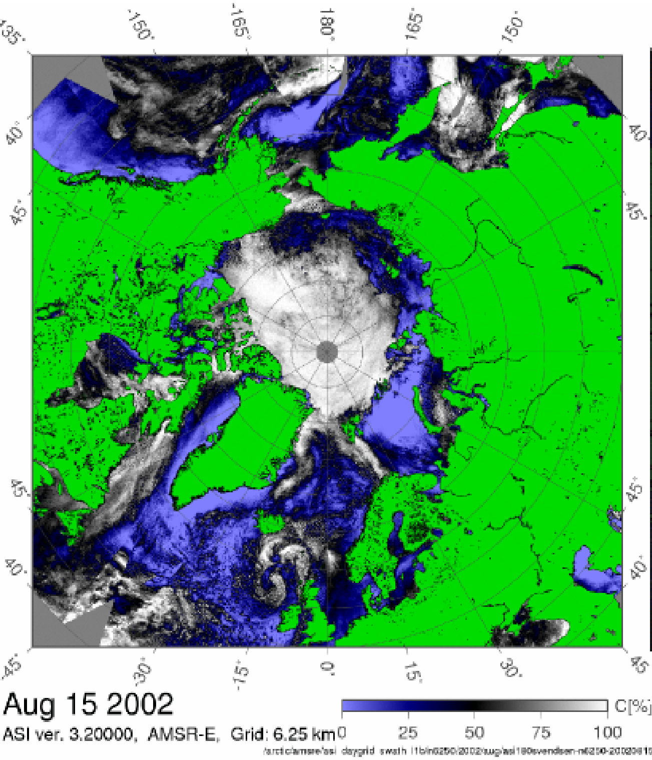
- Condition:
  GR(24,19) > 0.04
  ➔ C(ASI) = 0



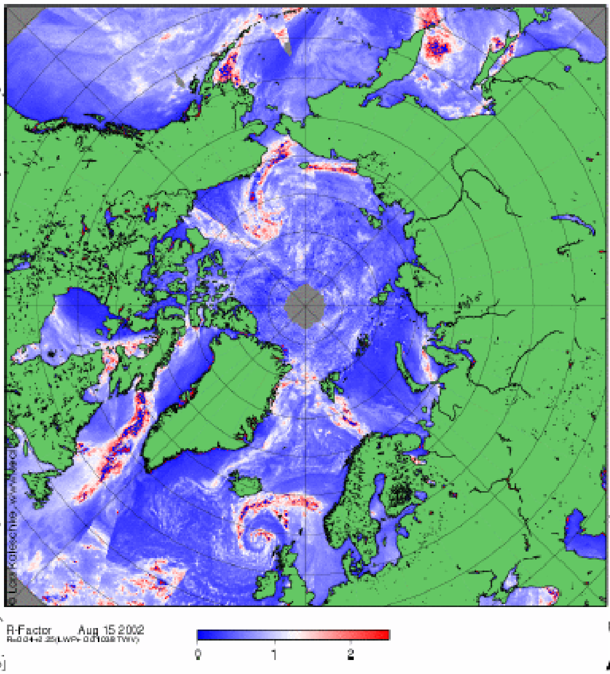
2 Weather Filters: Comparison



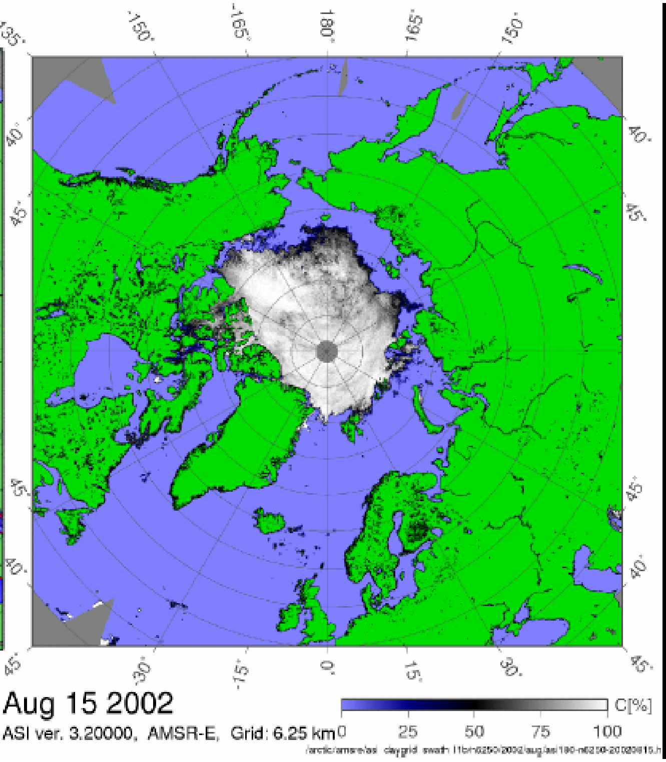
Effeciency of Weather Filters



Modified 89 GHz Svendsen

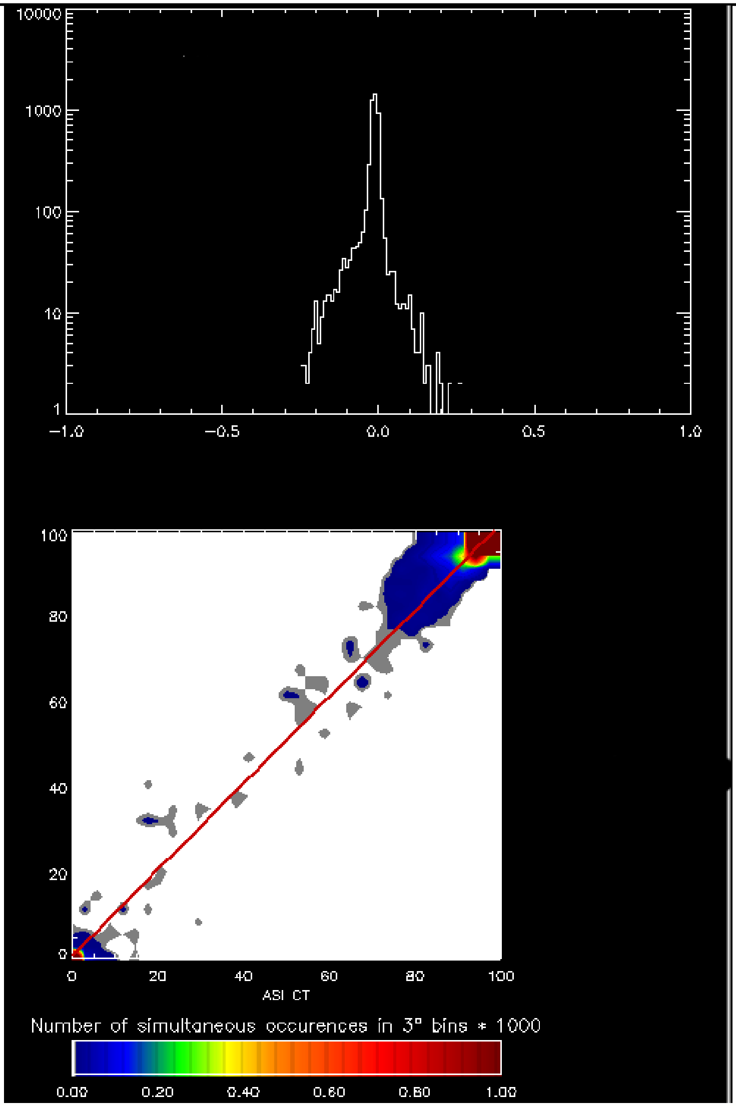


cloud signature



ASI

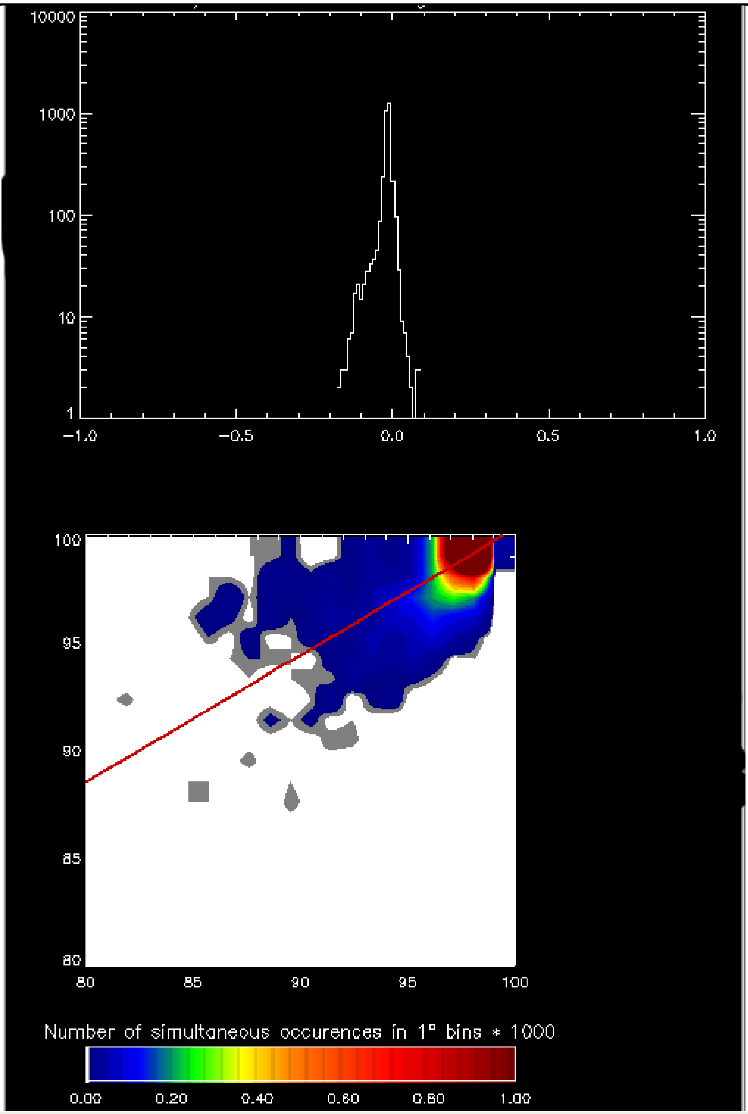
Cross Validation: Bootstrap BBA (1)



ASI – BOOTSTRAP (Baffin Bay),
ASI smoothed to 19 GHz,
0% < C < 100 %:

mean = -1 +- 4 %
cc = 0.99
y = 1.0 x + 0.7

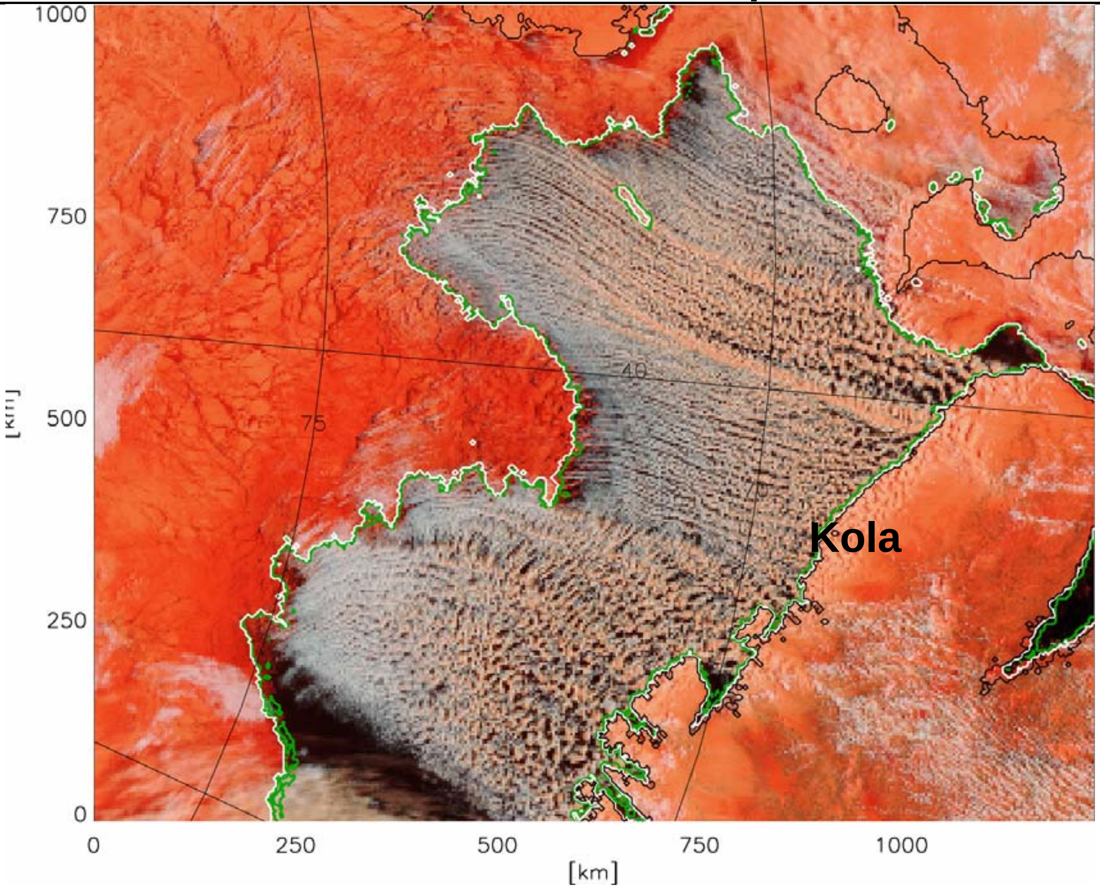
Cross Validation: Bootstrap BBA (2)



ASI – BOOTSTRAP (Baffin Bay),
ASI smoothed to 19 GHz,
80% < C < 100 %:

mean = -1 +- 2 %
cc = 0.75
y = 0.6 x + 41.3

Comparison - MODIS



black – Land contour

green – ASI 15 %

White – IED Ice Edge Detection Alg. (Hunewinkel et al. 1998)