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Some Aspects On The Use Of Satellite Radiances In NWP Variational Analysis

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Intro

- Microwaves are the most used satellite data in the HIRLAM analysis

- AMSU-A (temperature sounder) over sea is used operationally in several HIRLAM countries.
  Positive impact up to +48h synoptic forecasts: temperature, geopotential.

How are microwaves used in HIRLAM today?

How can we use microwaves better?

Which problems do we have to face?

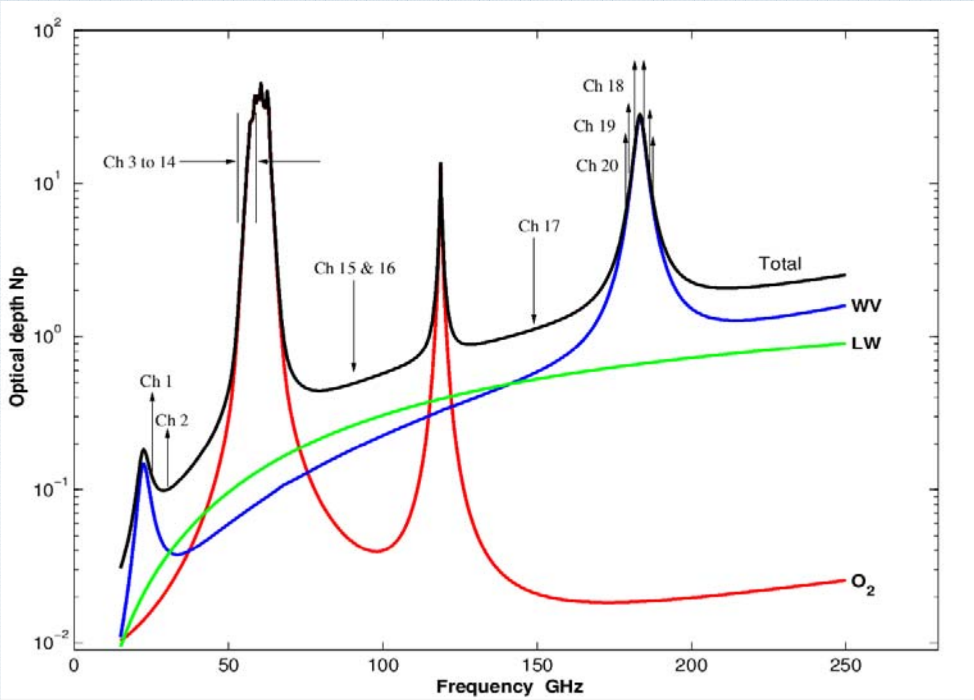
General Info On Microwaves

- Polar satellites (NOAA)

- Microwave spectrum: large 'window' regions

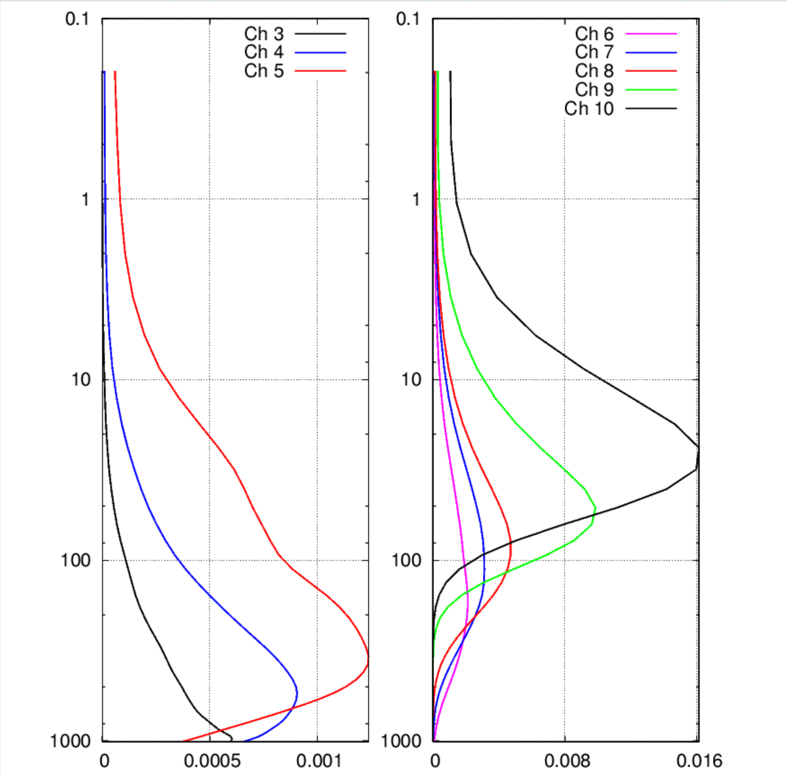
- Two strong absorption bands:
  57GHz (oxygen) AMSU-A
  and 183 GHz (water vapour) AMSU-B

- Microwave instruments:
  - works day and night
  - almost unsensitive to clouds
  - precipitation and thin ice cirrus cause scattering
  - have course resolutions compared to IR instruments

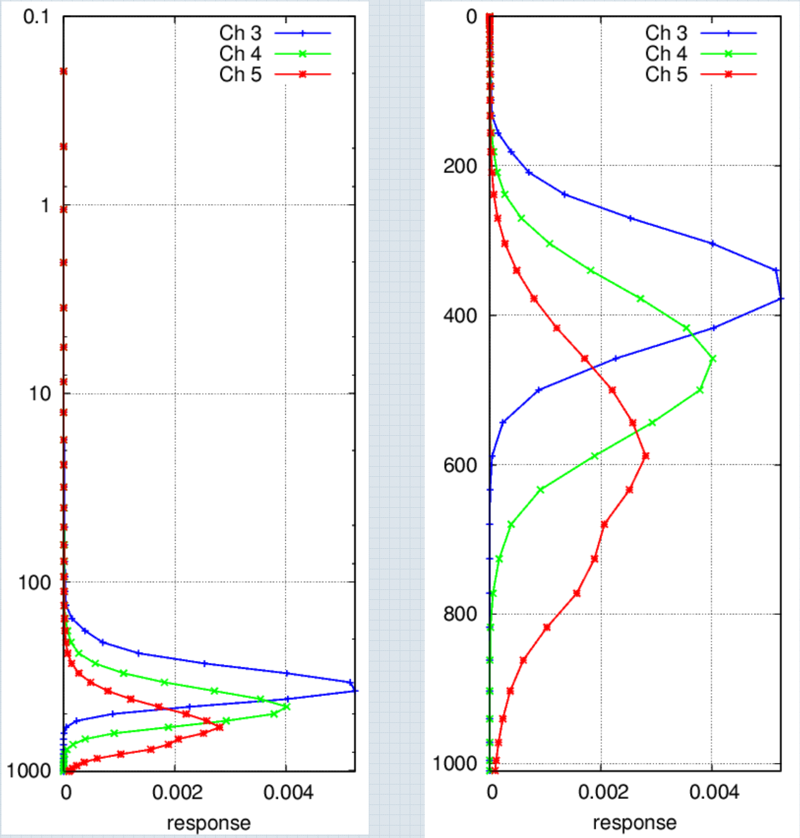


The Instruments AMSU-A and AMSU-B

Logscale on y



AMSU-A response functions
for some sounding channels: 3-10



AMSU-B response functions
For the sounding channels 3-5

Current Use Of Microwaves

Observation

Observation operator, RTTOV
A radiative transfer model

NWP profile at the
Observation location

$$(\mathbf{y}-\mathbf{Hx}_b)$$

The easiest setup:

- Only use observations not affected by scattering, or ground.
- Then, H only need to compute the radiative transfer though a clear atmosphere
- x_b will only be a profile of T and WV

Current Use Of Microwaves II

To do the easiest setup we need:

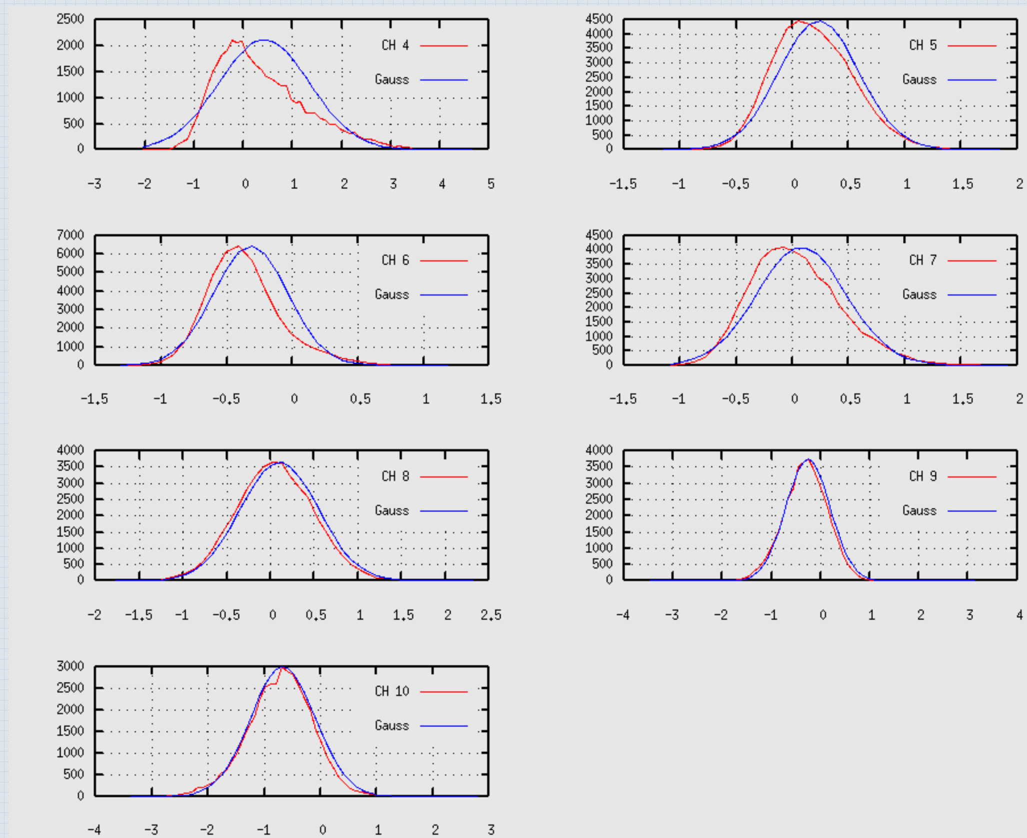
1. A way to remove (most) observations affected by scattering
   AMSU-A:
   CLW algorithm from NOAA/NESDIS
   TCLW estimated over ocean with background CH 1 and 2 + the obs scan angle
   Obs rejected if a threshold is exceeded, 0.12mm

   AMSU-B:
   CH 1 – CH 2 can be used as a crude precipitation index over sea

Only observations over sea!

Current Use Of Microwaves III

Distribution of ($y-Hx_b$) for AMSU-A, NOAA16 March 2005



We need to correct biases originating from y and H

Channel 4 is also influenced by the ground, T_{skin}

Y-axis: Number of observations
X-axis: ($y-Hx_b$) [K] 0.1 K slots
Sample from March 2005 SMHI operational suite NOAA16

Current Use Of Microwaves IV

Bias Correction

Simple linear regression model, Harris and Kelly scheme:

$$corr = p_0 + \sum_{j=1}^{N} c_j P_j$$

p_0: constant
c : coefficients
calculated from a reference data-set.
Problematic in regional models!
P : predictors

Predictors used for AMSU-A

1: Constant shift
2: Mean temperature between 1000-300hPa
3: Mean temperature between 200-50hPa
4: Surface temperature
5: Integrated water vapor content
6: Square of observation scan angle
7: The observation scan angle

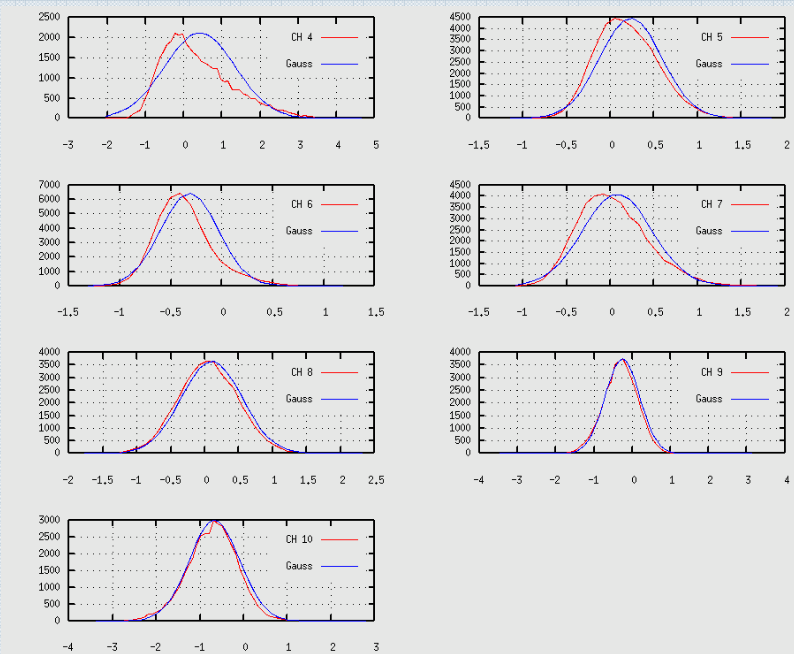
It may be important to study which predictors that are most important and remove the others

In tests with AMSU-B, at SMHI, the same scheme is used but predictors 4 and 5 are removed

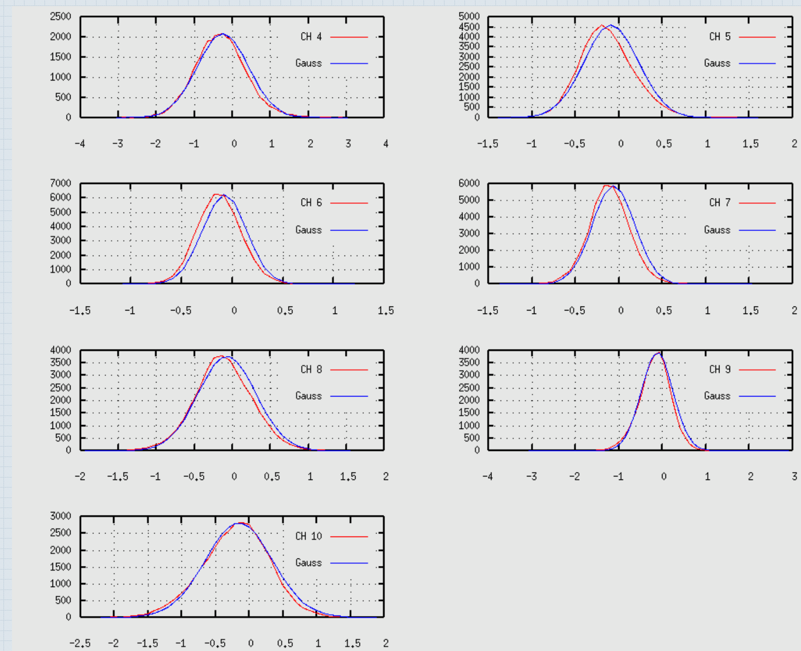
Current Use Of Microwaves V

Effect of bias correction

Raw data (again)



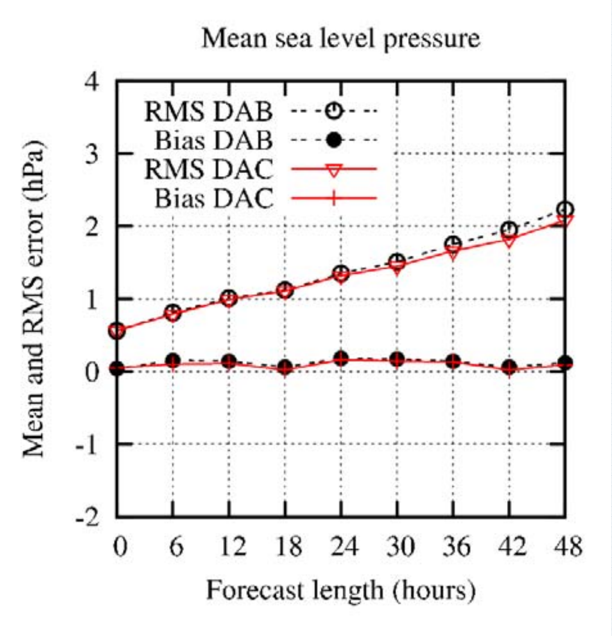
Bias corrected



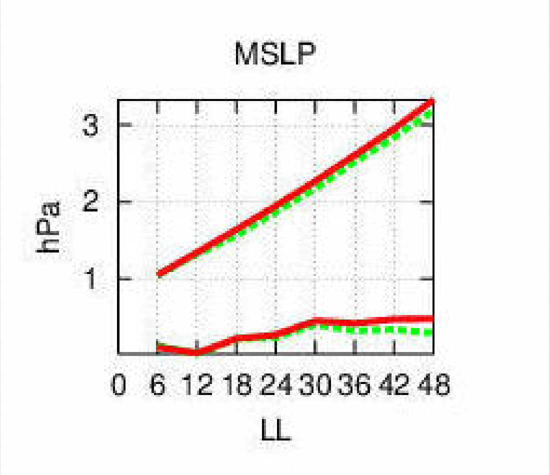
Y-axis: Number of observations
X-axis: $(y\text{-}Hx_b)$ [K] 0.1 K slots
Sample from March 2005 SMHI operational suite
NOAA16

Current Use Of Microwaves VI

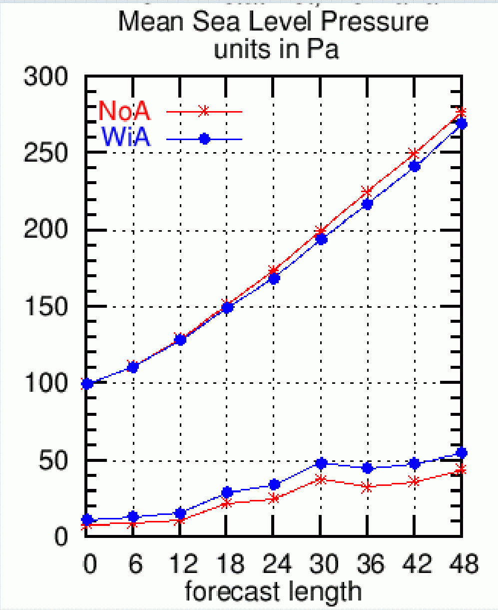
Impact of AMSU-A



From FMI, Finland
Oct 2005
Kalle Eerola



From SMHI, Sweden
Dec 2003



From DMI, Denmark
Nov 2003
Bjarne Amstrup

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Better Use Of Microwaves

AMSU-A Over Sea

Channel 4 is not used because it senses the ground

Early assimilation experiments showed a negative impact if CH 4 was used

Over sea, it is the surface skin temperature T_{skin} that is the problem

If we have a first guess to T_{skin} that is sufficiently good, it is possible to have T_{skin} as a free parameter during the minimization

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Better Use Of Microwaves II

T_{skin} As Free Parameter

Method:

- Assign a σ_b for T_{skin}
- Extend the control vector, χ, with one element for each AMSU observation, i.e. only in observation space
- Use the RTTOV gradient with respect to T_{skin}

This allows T_{skin} to vary during the minimization, which makes the cost-function smaller.

Implemented in test-code, but not fully tested yet, in HIRLAM.

$$\nabla J = \chi + U^{-T} \overline{H}^T R^{-1} \left(y - Hx_b + \overline{H} \delta x \right)$$

$$\delta x = U^{-1} \chi$$

$$\chi_{Tskin} = \frac{\delta T_{skin}}{\sigma_b}$$

$$\delta x = \begin{pmatrix} \delta u \\ \delta v \\ \delta T \\ \delta q \\ \delta \ln P_s \\ \delta T_{skin} \end{pmatrix}$$

Better Use Of Microwaves III

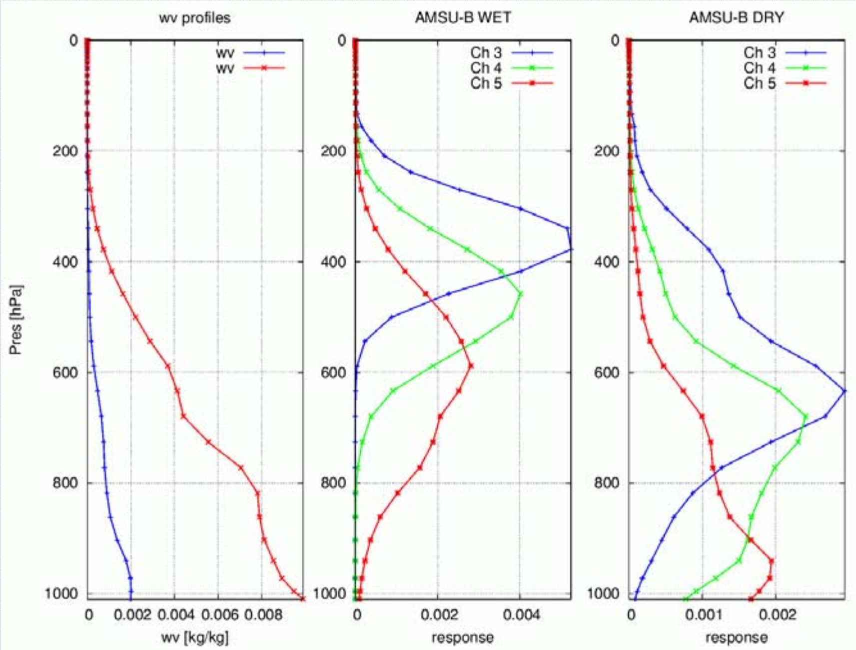
High Peaking AMSU channels over land and ice

Done at most NWP centres:
AMSU-A CH 6-10 do not sense the surface

They could be used over all surfaces

AMSU-B channel 3 could be used over land

Untested in HIRLAM
Inner and outer loops might help for AMSU-B



AMSU-B response functions for two cases

Better Use Of Microwaves III

Low Peaking AMSU channels over land (ice?)

Land sensing observation

Radiative transfer model will need estimates of T_{skin} and ε_{surf}

$$(\mathbf{y}-\mathbf{H}\mathbf{x}_b)$$

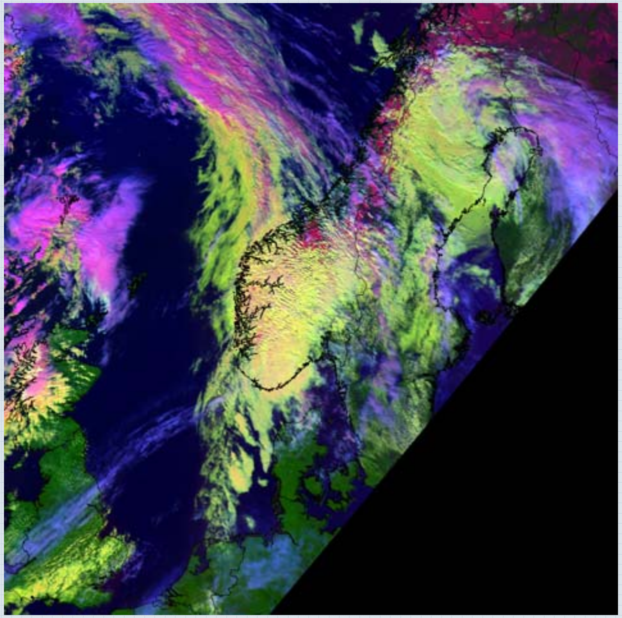
Most centres are trying different ways to produce emissivity atlases for the globe

Few experiments were it is actually assimilated with positive impact (as far as I know)

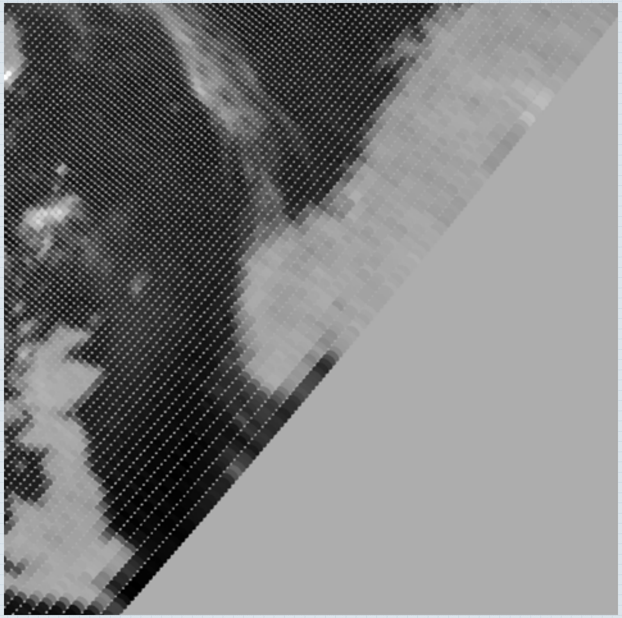
Area for the future!

AMSU-B Over Ice: SMHI Test

NOAA17 3/5-2006 11:52UTC



AVHRR RGB image Ch 1,3,4



AMSU-B Ch1-Ch2

The simple index not useful over other surfaces than sea

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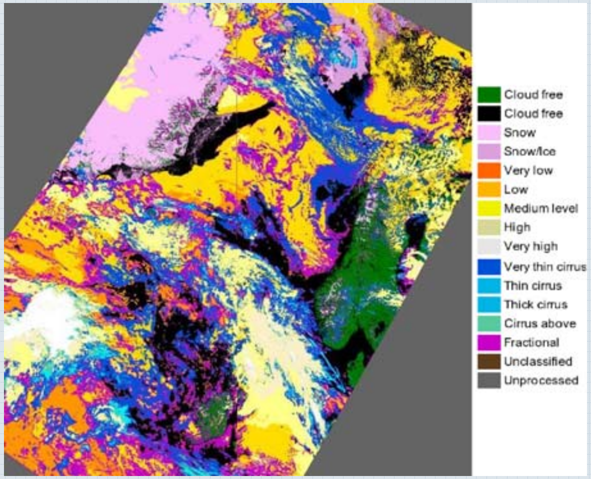
AMSU-B Over Ice: SMHI Test

- We have worked with the OSI-SAF cloud mask, AVHRR.

- Strategy:

  1: Over sea
  Compare observations flagged by the SI with cloud types from the OSI-SAF cloud mask

  2: Over ice
  Use the results from 1 to do cloud screening over ice



In this work we have studied obs – first guess departures

AMSU-B Over Ice: SMHI Test

- Bias correction predictors:
  1: Constant shift
  2: Mean temperature between 1000-300hPa
  3: Mean temperature between 200-50hPa
  4: Square of observation scan angle
  5: The observation scan angle

- T_{skin} : HIRLAM surface temperature
- ε_{surf} : 0.75
  From a work at University of Bremen*

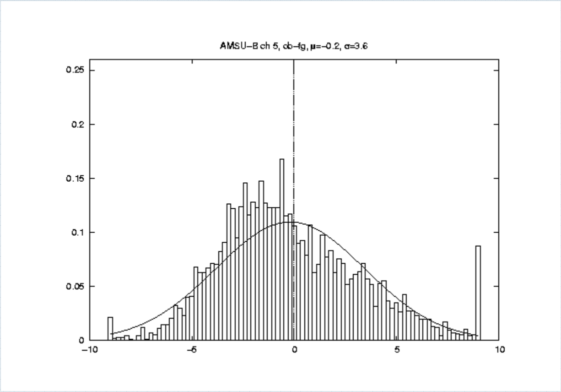
- RTTOV-7

*Selbach .N: Determination of total vater vapor and surface emissivity of sea ice at 89GHz, 157GHz and 183 GHz in the arctic winter.

Dissertation im Fachbereich Physik/Elektrotechnik der Universitet Bremen, 2003

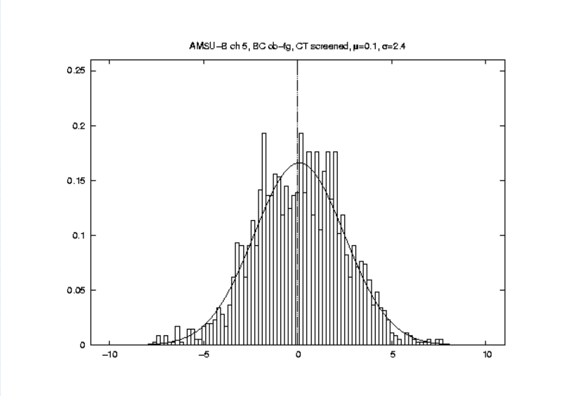
AMSU-B Over Ice: SMHI Test

Channel 5 NOAA16
Period: March, June 2004 and January 2005



No cloud screening
No bias correction

Distribution of obs minus first guess departures: $(y-Hx_b)$



The OSI-SAF cloud mask and bias correction applied

The distribution is skewed. → And is more symmetric now.

THE END