Techniques for modelling land, snow and sea ice emission and scattering in support of data assimilation

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METEO FRANCE
Toujours un temps d'avance

Outline

On the need for a good knowledge of emissivity

Variability of emissivity

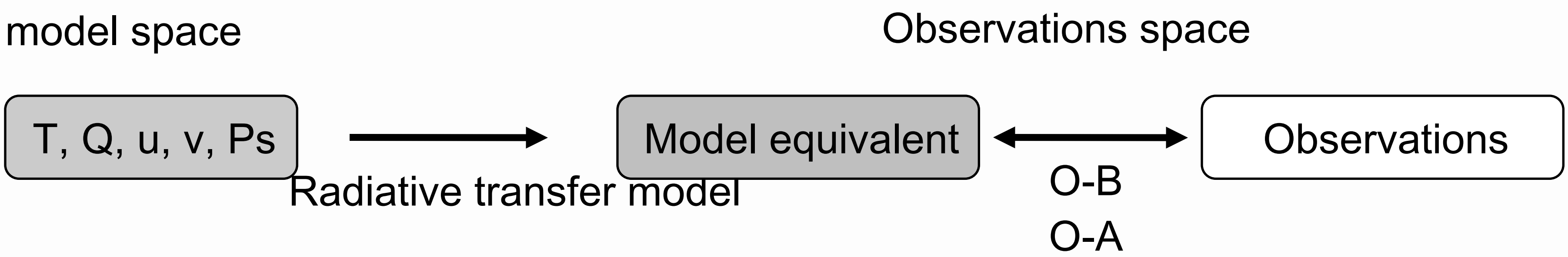
Emissivity modelling for data assimilation over land, snow, sea-ice

Some assimilation results

Conclusions

On the need for a good knowledge of emissivity

Satellites observations: Tbs (no direct measurements of T, Q)

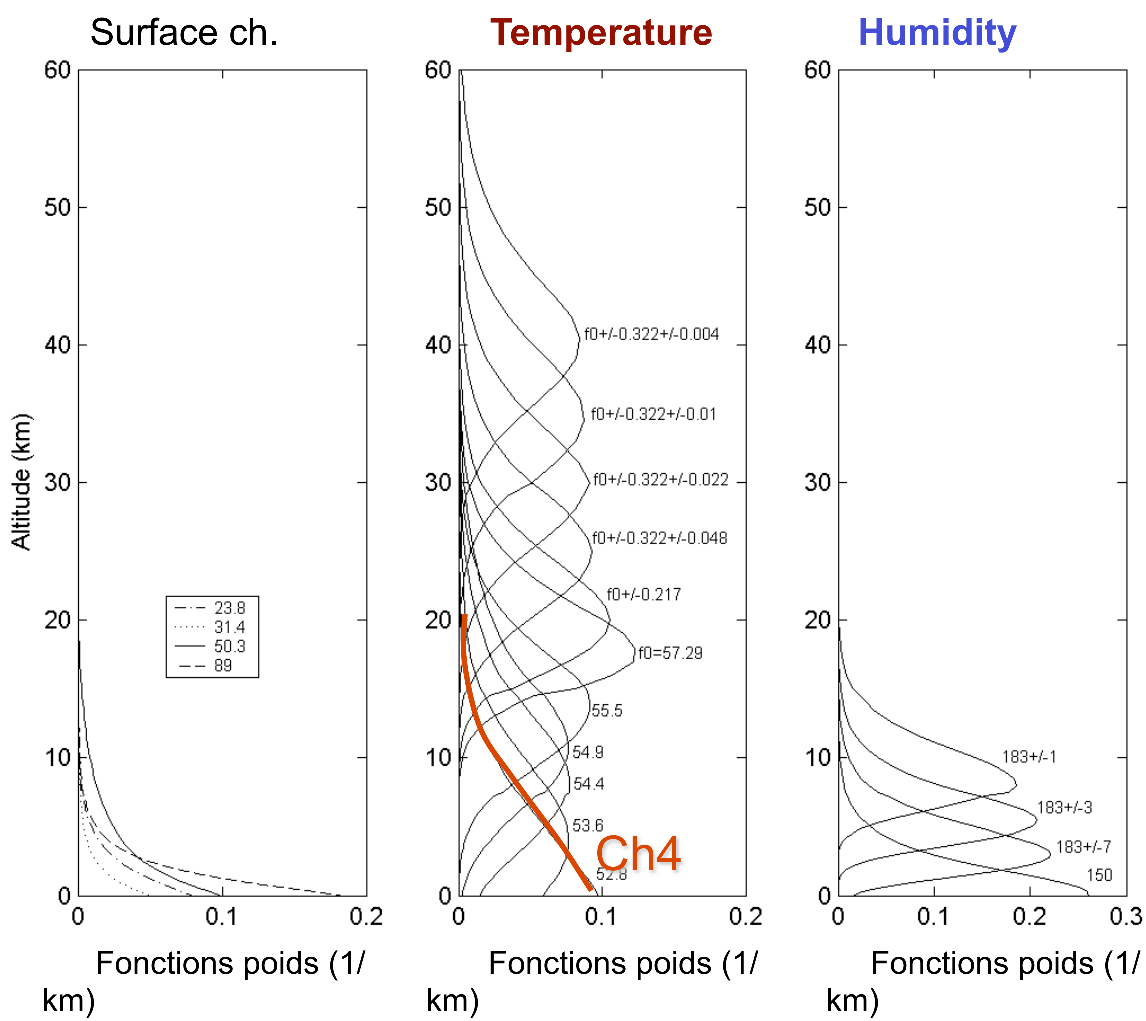


- Simulations of radiative transfert model: atmospheric fields but also surface conditions

- Data quality contrôle: to reject cloudy/rainy data (AMSU-A Ch4: 52.3 GHz, AMSU-B Ch2: 150 GHz, SSMI/S Ch2: 52.3V and Ch8: 150 H)

- Other conditions : bias correction (Dee [2004], Auligné et al. [2007]), good specification of observation and model errors, ….

On the need for a good knowledge of emissivity



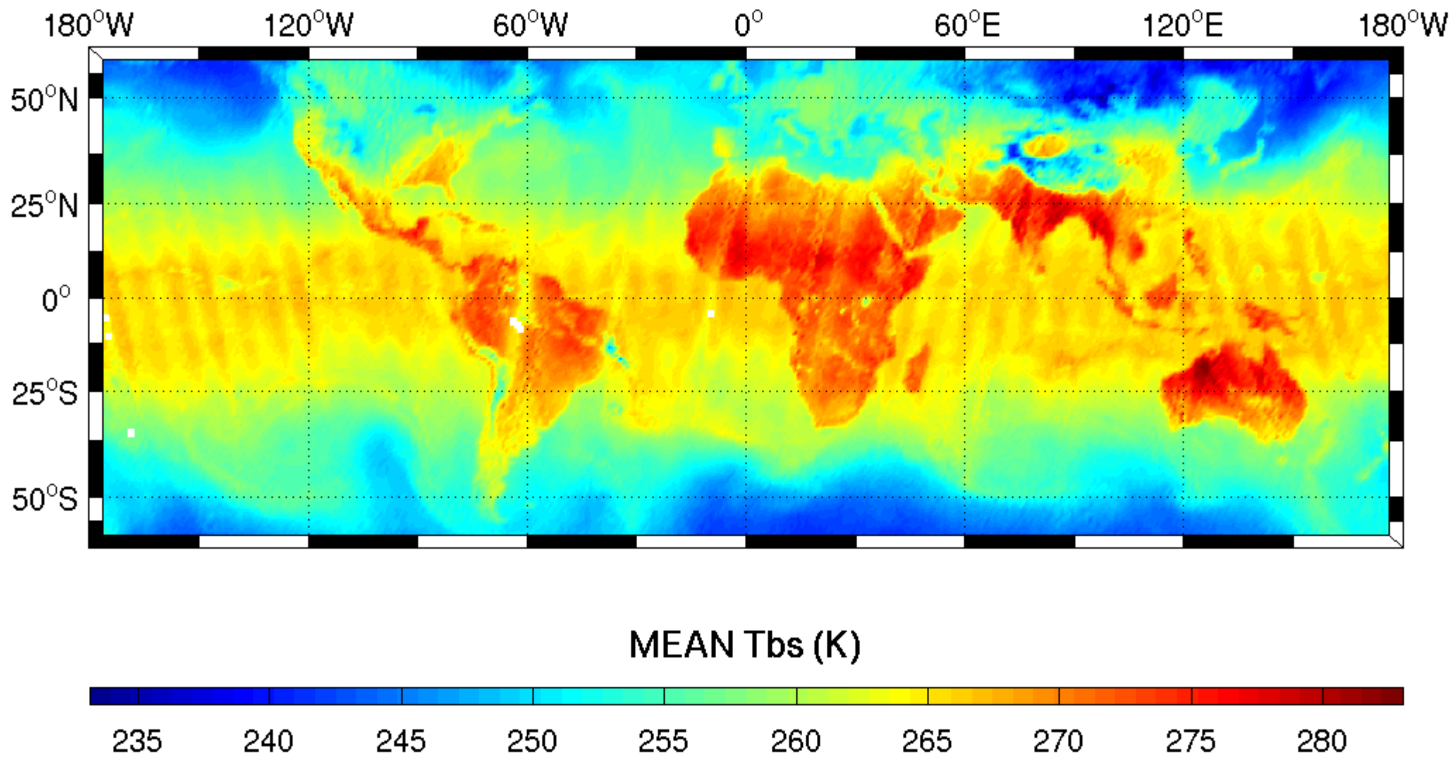
AMSU-A/-B Weighting functions (standard atmosphere)

Effect of the surface

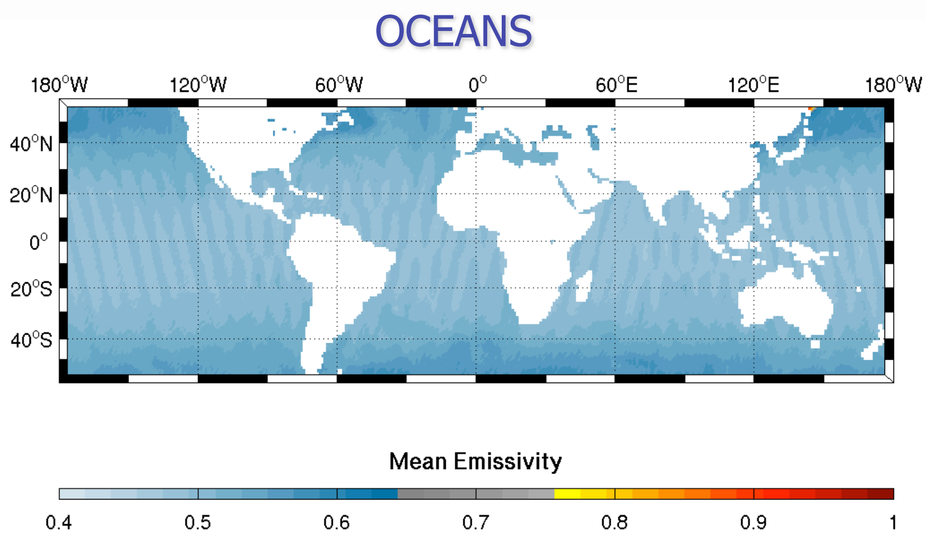
On the need for a good knowledge of emissivity

To assimilate surface sensitive channels: separate the surface effect from the atmospheric signal

AMSU-A, ch4: 52.8 GHz, 08/04/2010



On the need for a good knowledge of emissivity

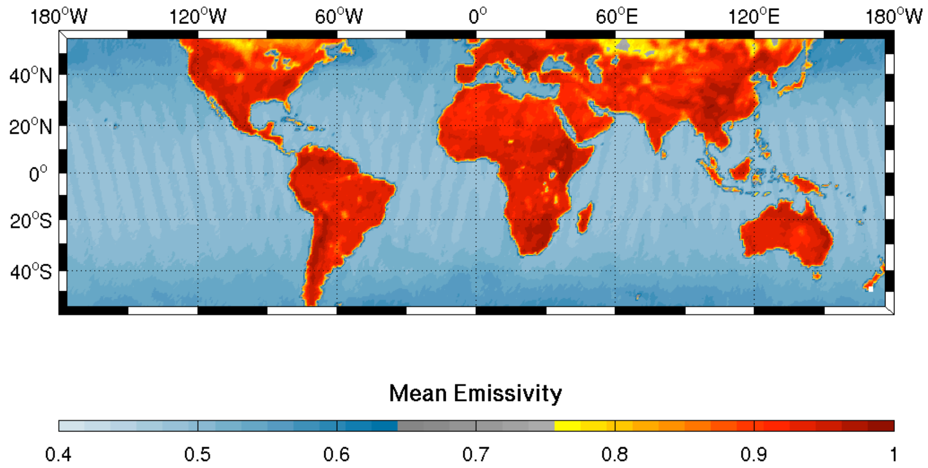


Emissivity ~ 0.5: the surface contribution to the measured signal < land surfaces

Assimilation: emissivity model Fastem (English, Hewison [1998], Deblonde, English [2000], Liu et al. [2010]) meets NWP requirements

On the need for a good knowledge of emissivity

OCEANS LAND



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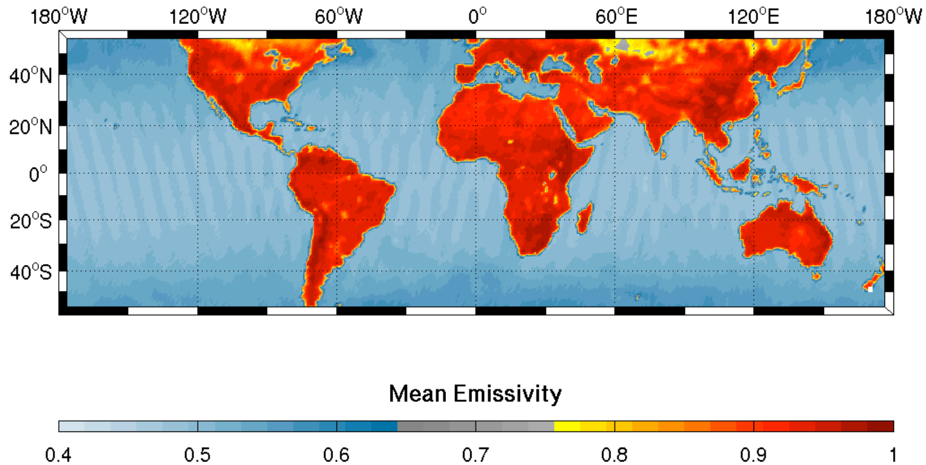
Emissivity ~ 1: Higher contribution of the surface, complexe variations in space/time, surface conditions, type, …

Assimilation: Difficult

On the need for a good knowledge of emissivity

OCEANS LAND



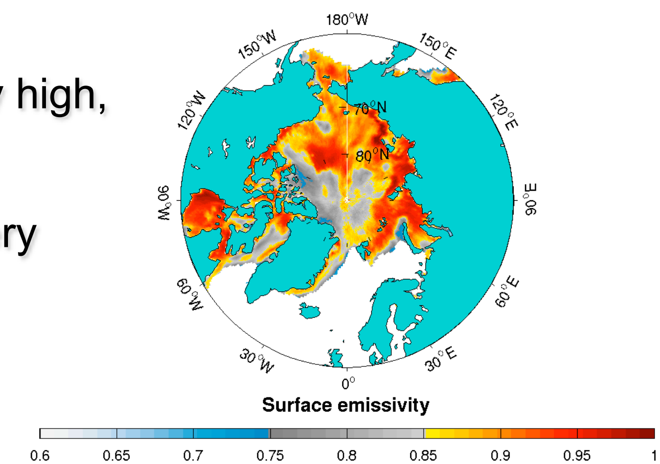
Emissivity ~ 0.5: the surface contribution to the measured signal < land surfaces

Assimilation: emissivity model Fastem (English, Hewison [1998], Deblonde, English [2000], Liu et al. [2010]) meets NWP requirements

SEA ICE

Emissivity : very high, highly variable

Assimilation: Very difficile



Emissivity ~ 1: Higher contribution of the surface, complexe variations in space/time, surface conditions, type, …

Assimilation: Difficult

On the need for a good knowledge of emissivity

- **In-situ measurements:**
  Different surface types (bare soils to forests)
  Calvet et al. (1995), Matzler (1994, 1990), Wigneron et al. (1997) among others

- **Airborne measurements:**
  Different surface types (forests, snow)
  Hewison and English (1999), Hewison 2001, …

- **Satellite estimations:**
  Regional to global scales, many frequencies, many sensors
  Choudhury (1993), Felde and Pickle (1995), Jones and Vonder Haar (1997), Karbou et al. (2005), Morland et al. (2000, 2001), Prigent et al. (1997, 1998), among others

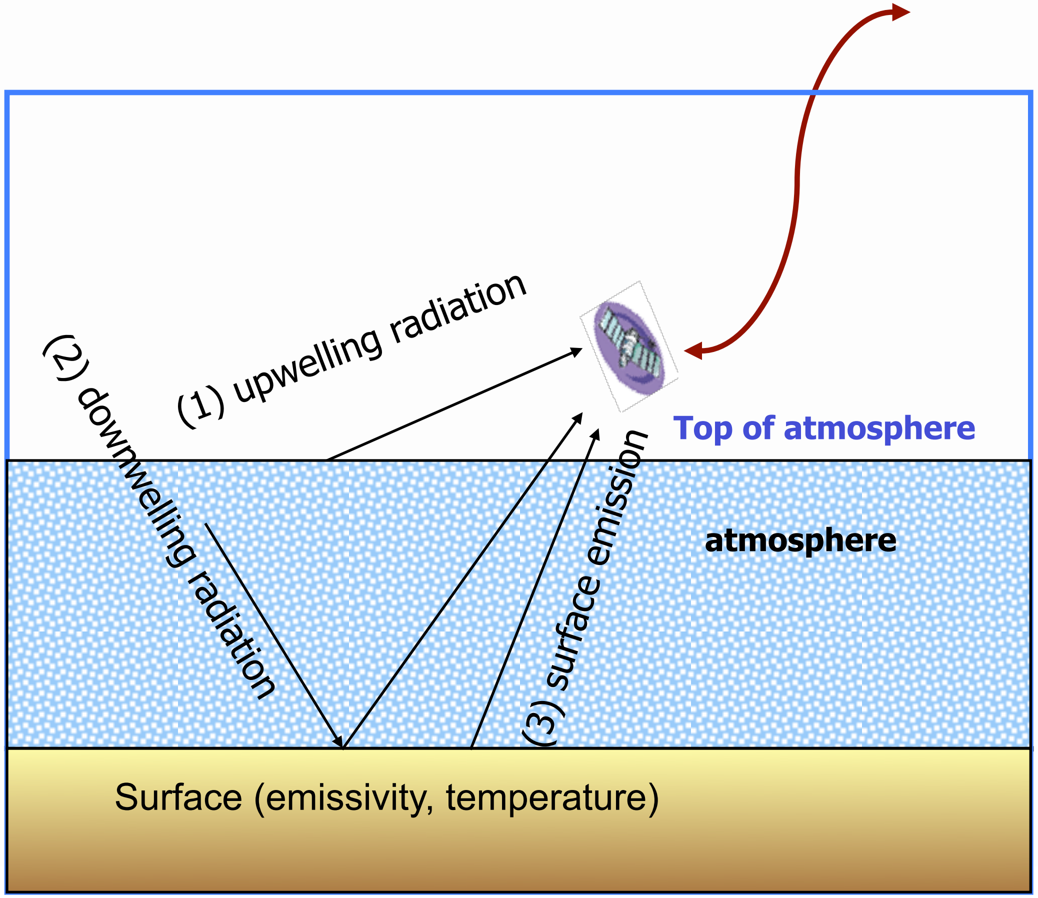
- **Modelling approaches:**
  Limitations:
  - Complexity of interactions between radiation and the large variability of the medium
  - For atmospheric retrievals, need of accurate input parameters (vegetation characteristics, soil moisture, roughness) at a global scale.

  Grody (1998), Karbou (2005), Isaacs et al. (1989), Weng et al. (2001), …

Variability of emissivity

Emissivity estimation using the radiative transfer equation

Under several assumptions



$$Tb = \overbrace{\varepsilon . Ts \tau}^{(3)} + \overbrace{(1-\varepsilon)\tau . T(\downarrow)}^{(2)} + \overbrace{T(\uparrow)}^{(1)}$$

Ill posed problem : uncertainties about the surface and the atmosphere

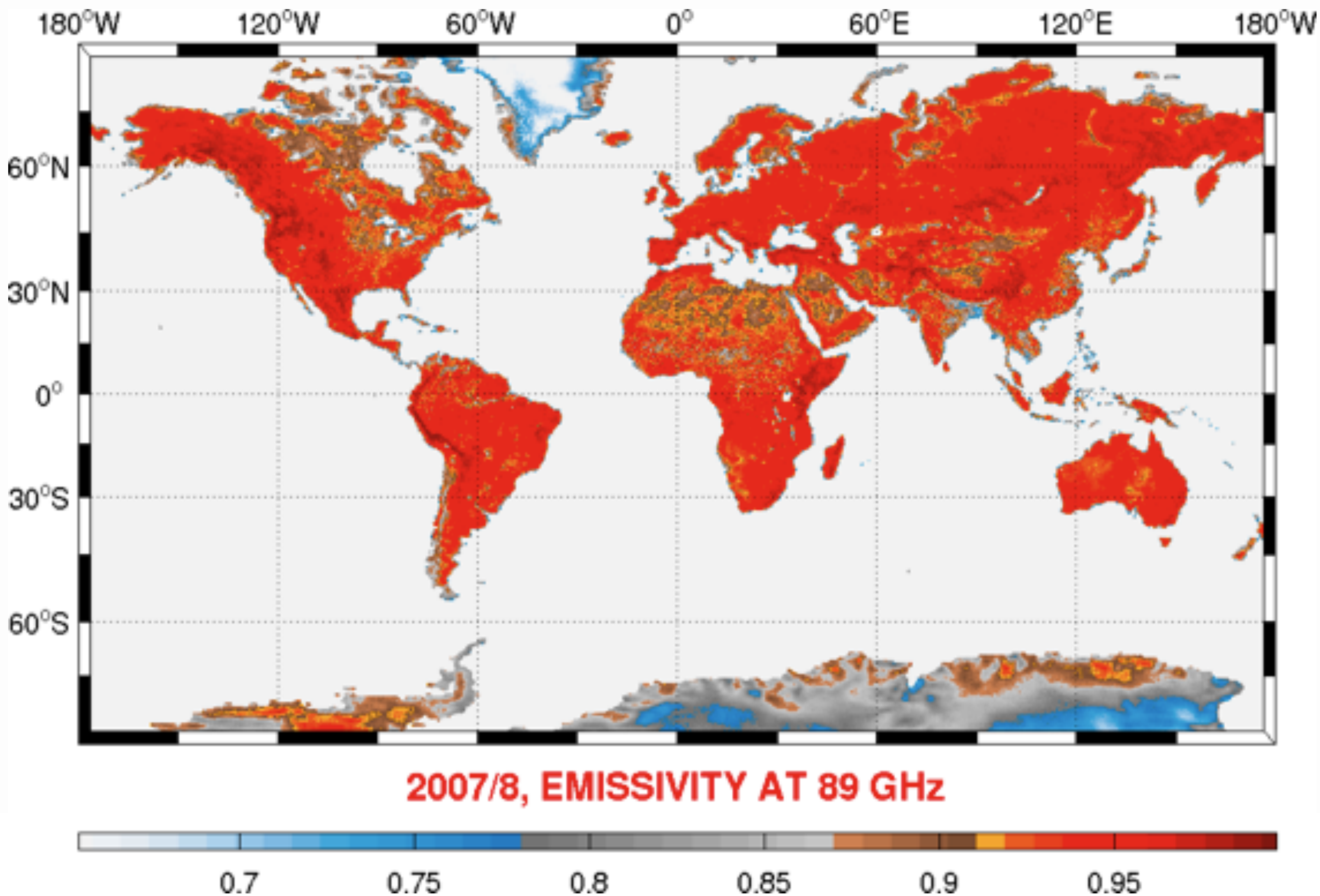
==> radiative transfer model (RTTOV) +
T/Q profiles (short range forecasts, analyses, reanalyses) +
Ts (IR retrievals /short-range forecasts, analyses)

Emissivity estimation:

$$\varepsilon = \frac{Tb - T(\uparrow) - T(\downarrow) \times \tau}{\tau \times (Ts - T(\downarrow))}$$

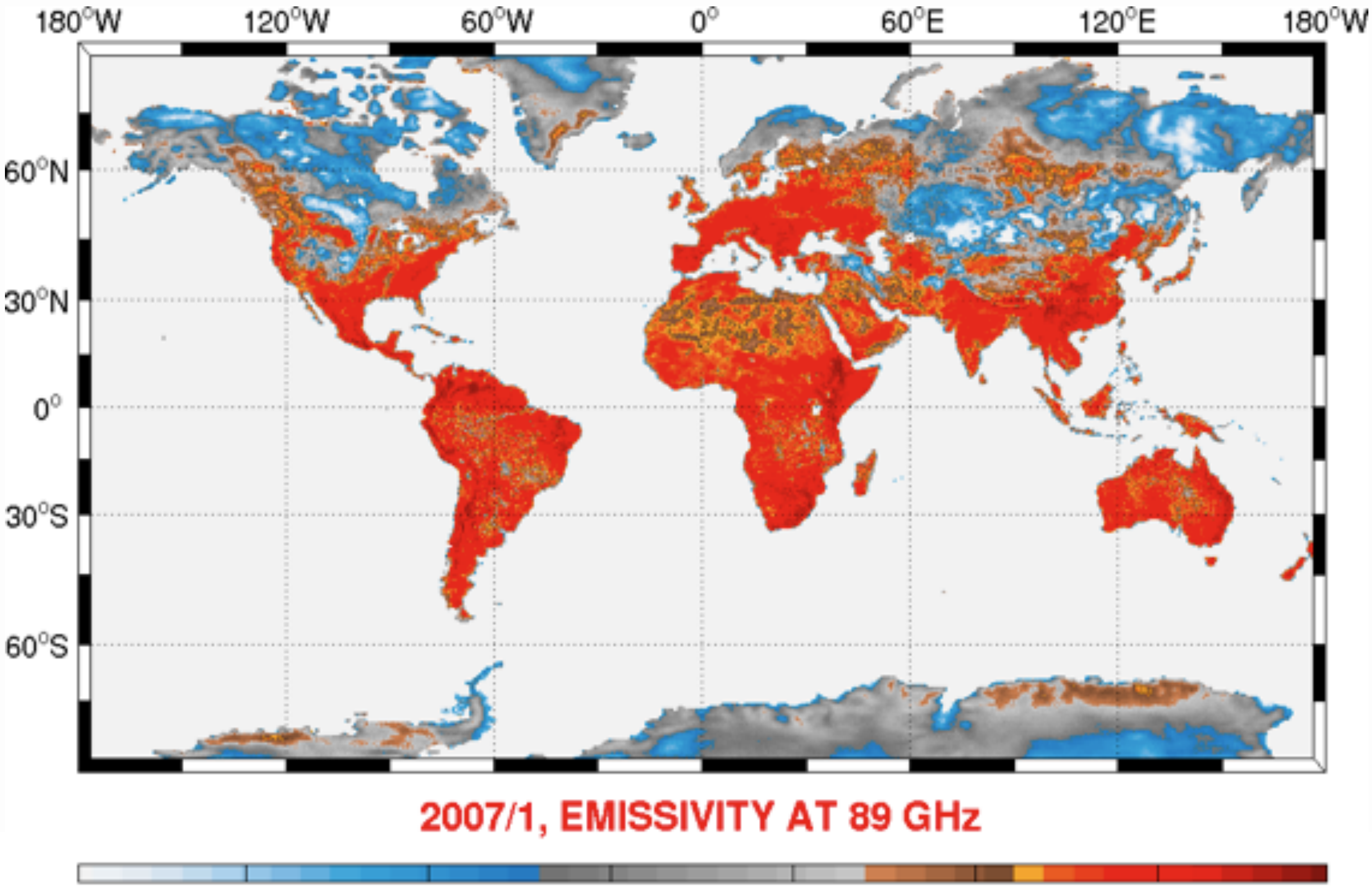
Variability of emissivity

AMSU-A 89 GHz, August



Variability of emissivity

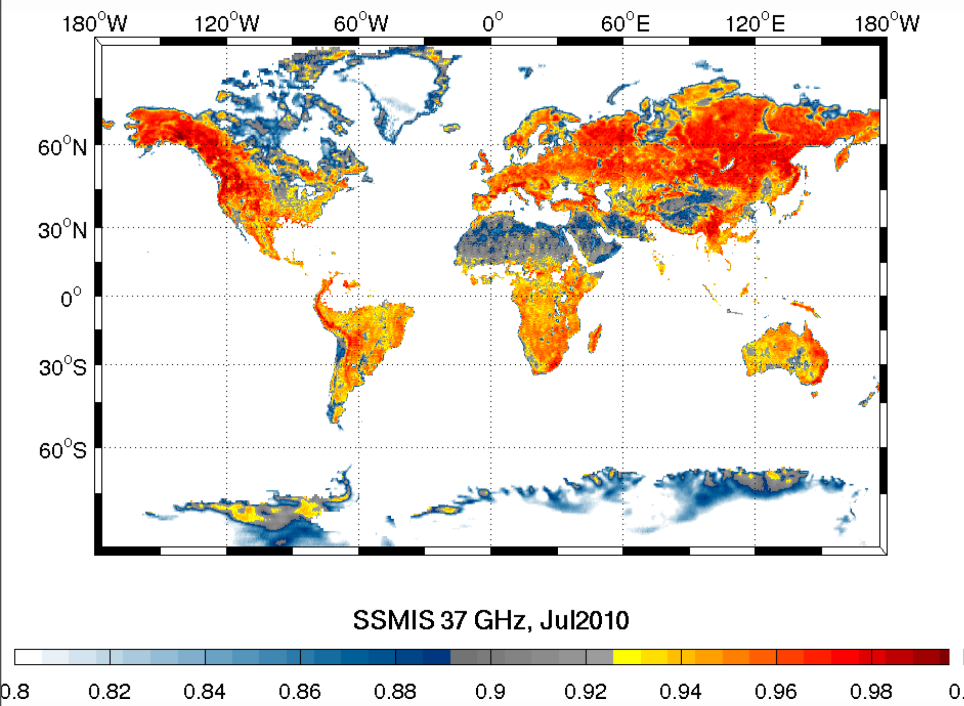
AMSU-A 89 GHz, January



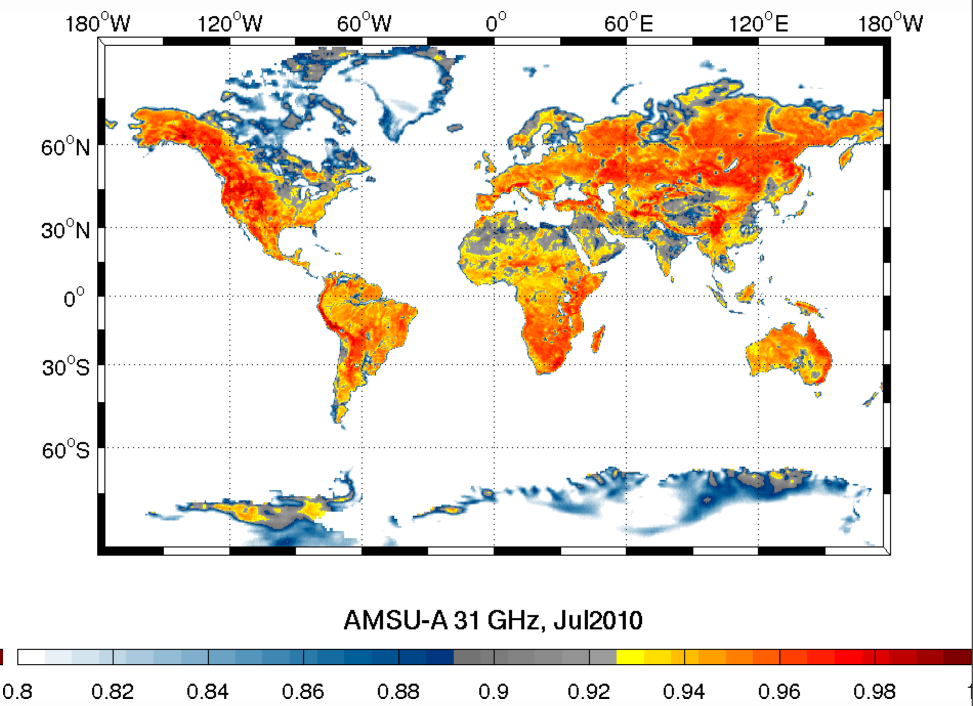
Variability of emissivity

July 2010

SSMI/S, 37 GHz (V+H)/2



AMSU-A, 31 GHz

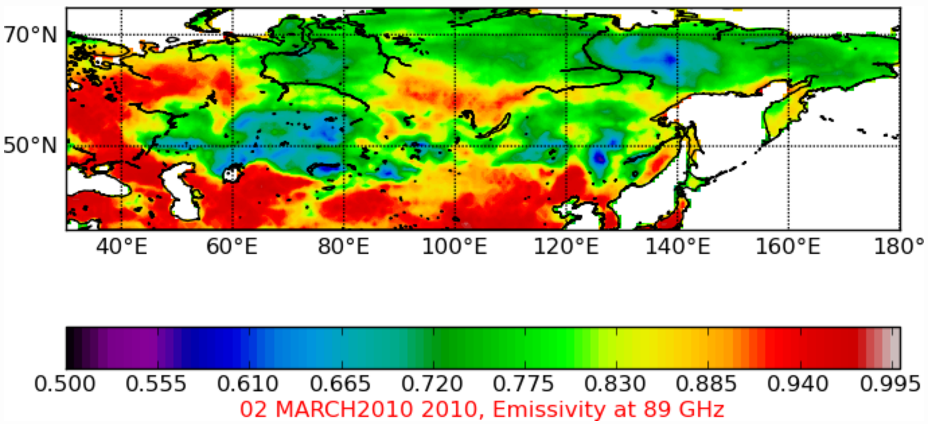


Variability of emissivity

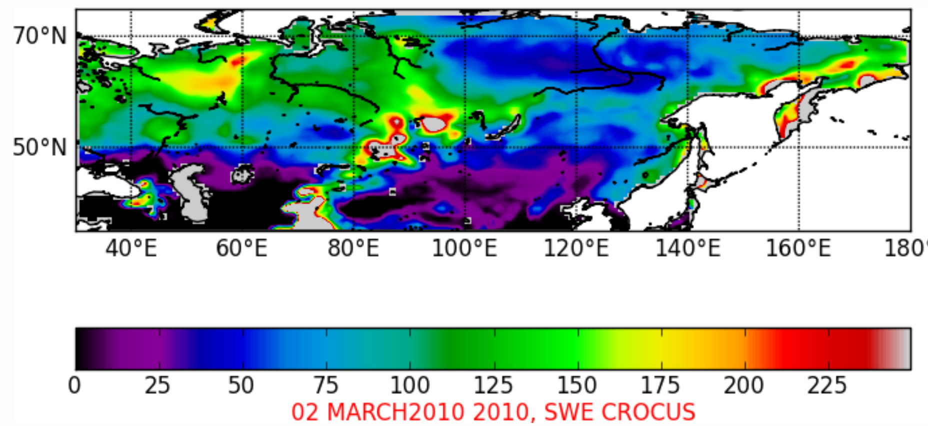
SURFEX/ISBA-Crocus snow model: meteorological forcing from era-interim (Brun et al. 2013); in-situ snow depth data (or SWE) are available for evaluation of the snow model simulations: Crocus did not make use of these data

SWE Products from NSIDC (observations AMSR-E ~ 36 GHz), **SWE products from Globsnow** (synop data + observations SSMI, AMSR-E ~ 18.7 & 36 GHz)

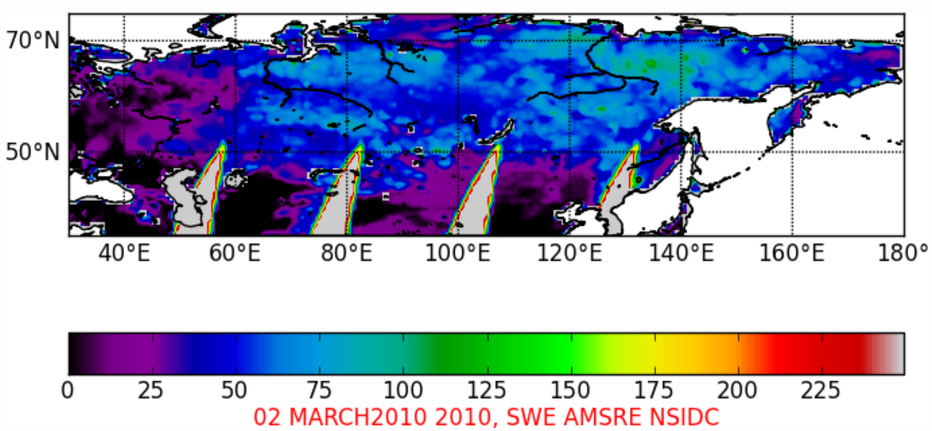
ε(89 GHz)



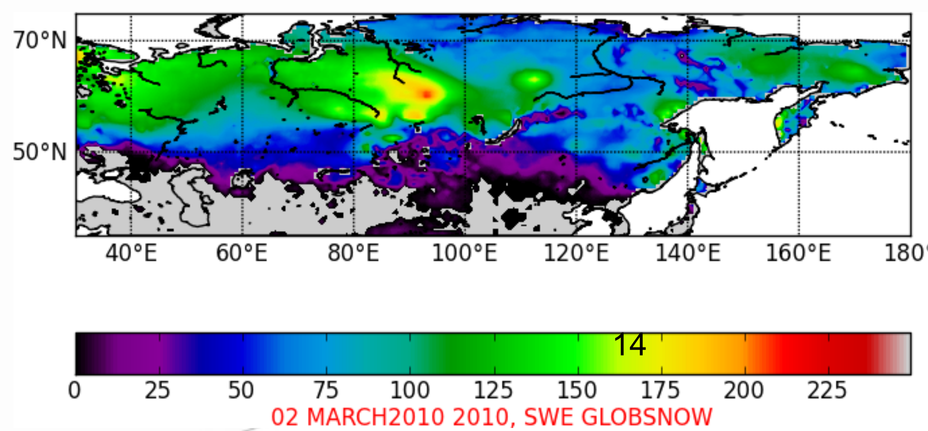
Crocus



NSIDC



Globsnow



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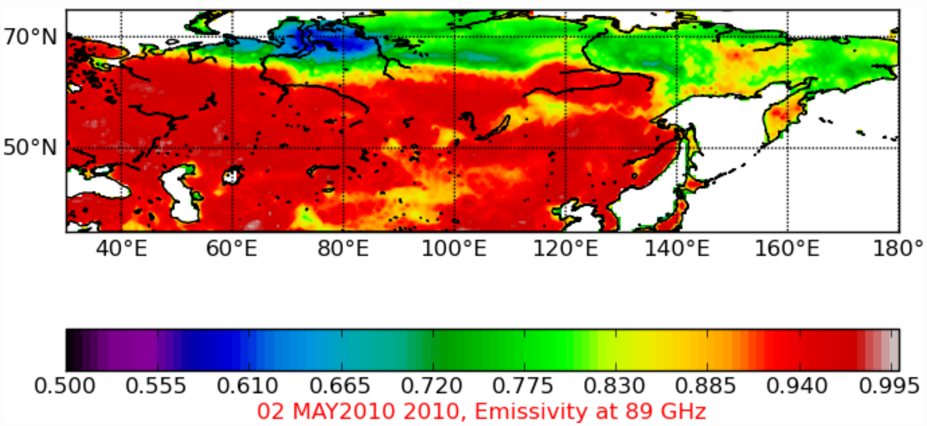
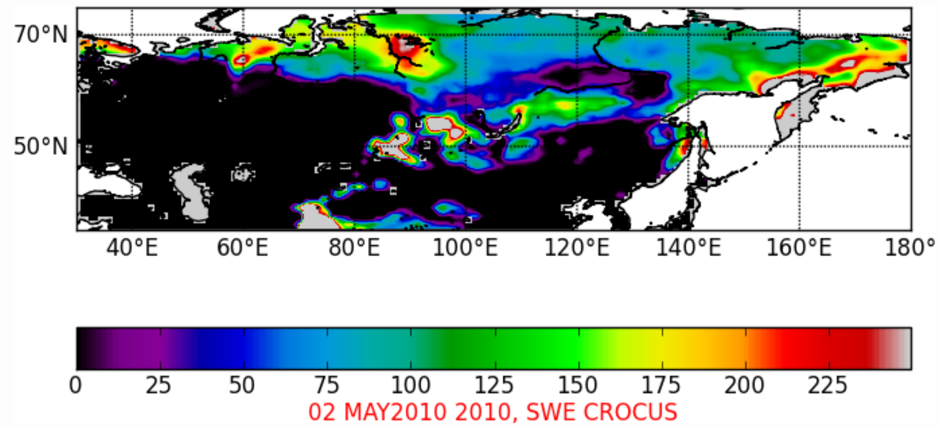
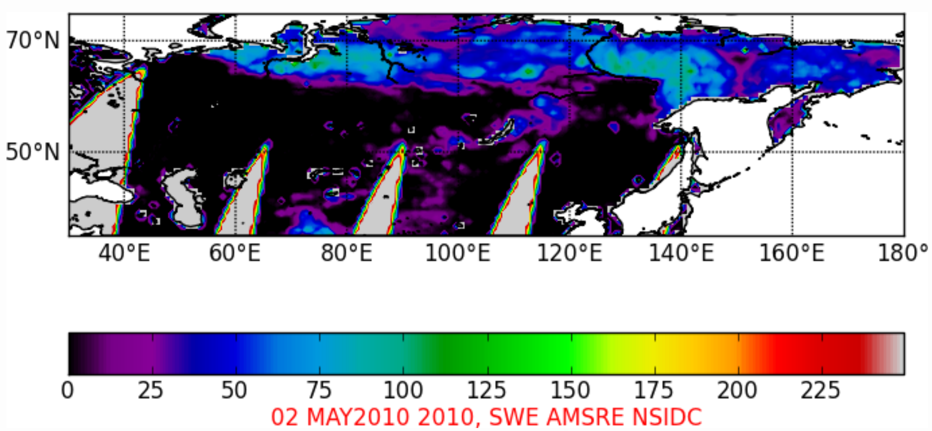


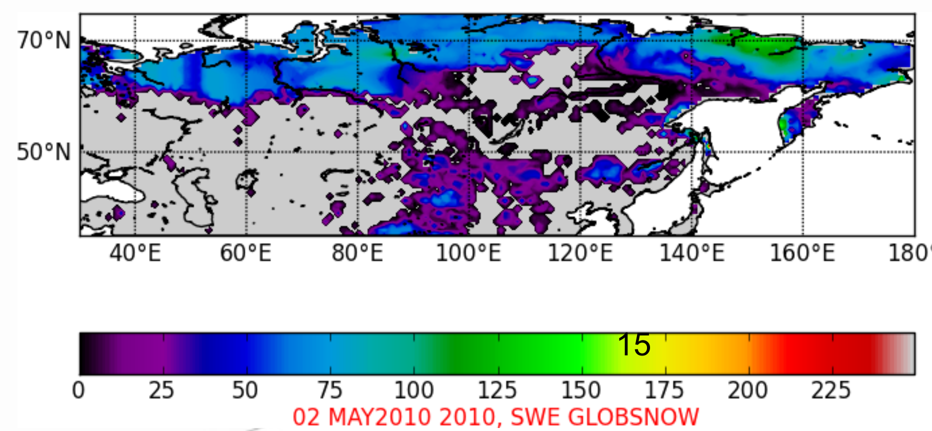
Crocus



NSIDC



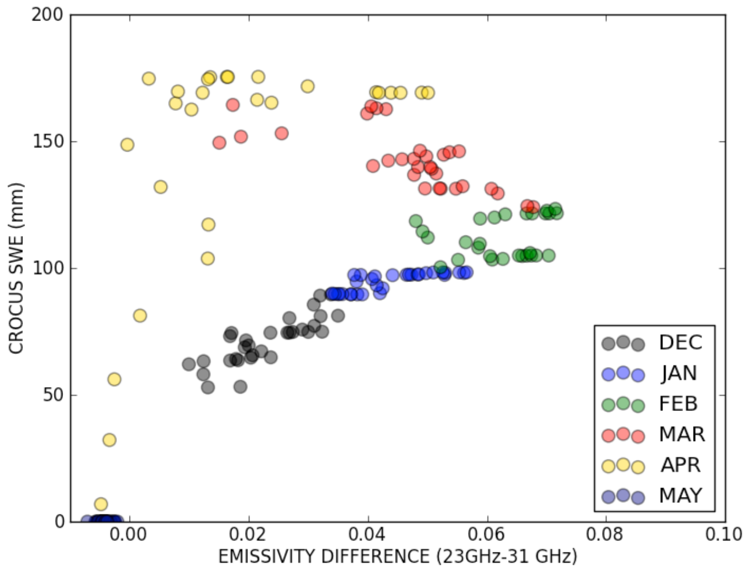
Globsnow



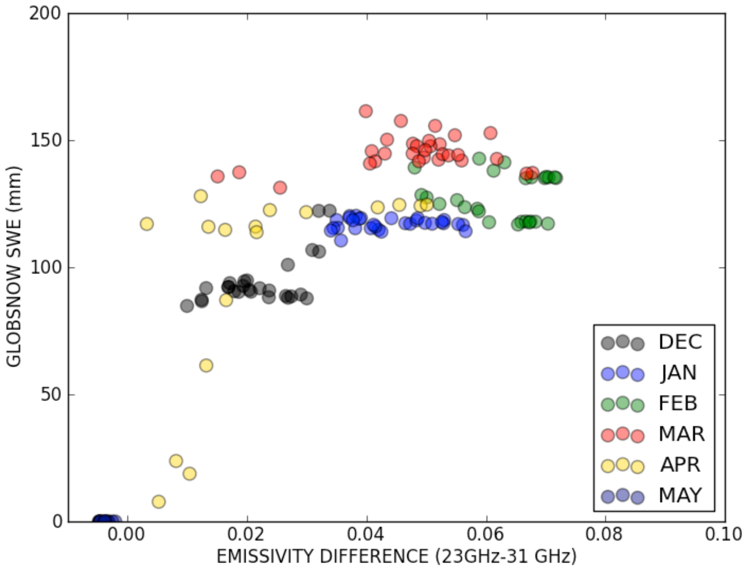
Variability of emissivity

Comparison near a synoptic station

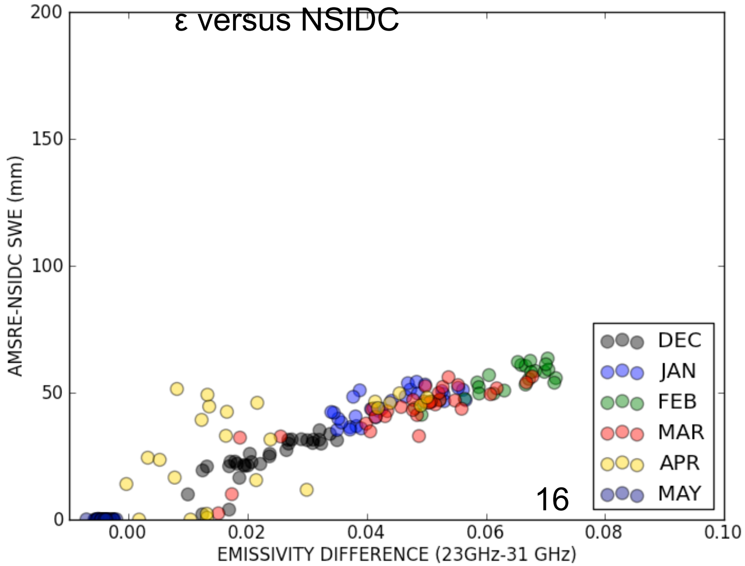
ε versus Crocus



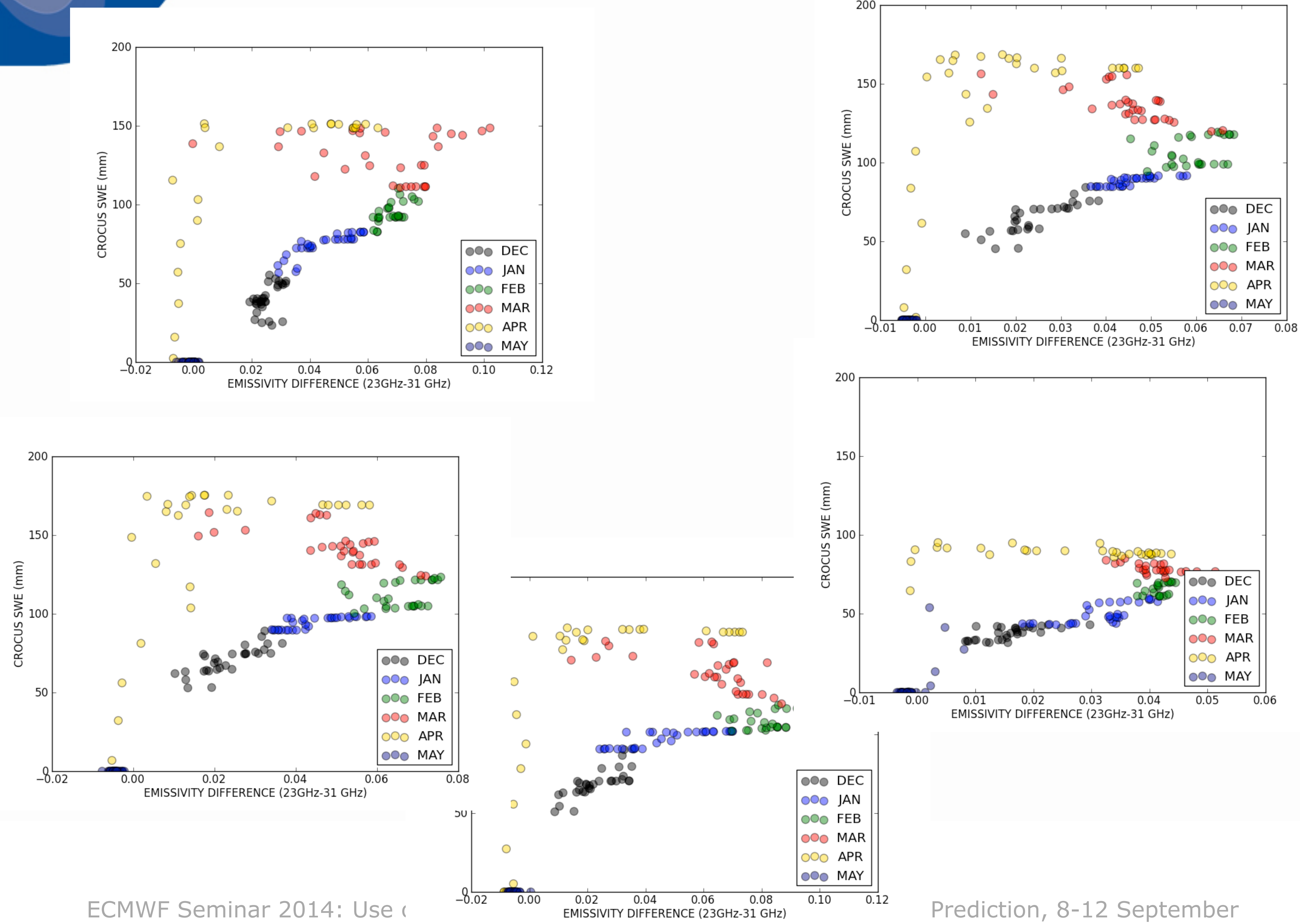
ε versus Globsnow



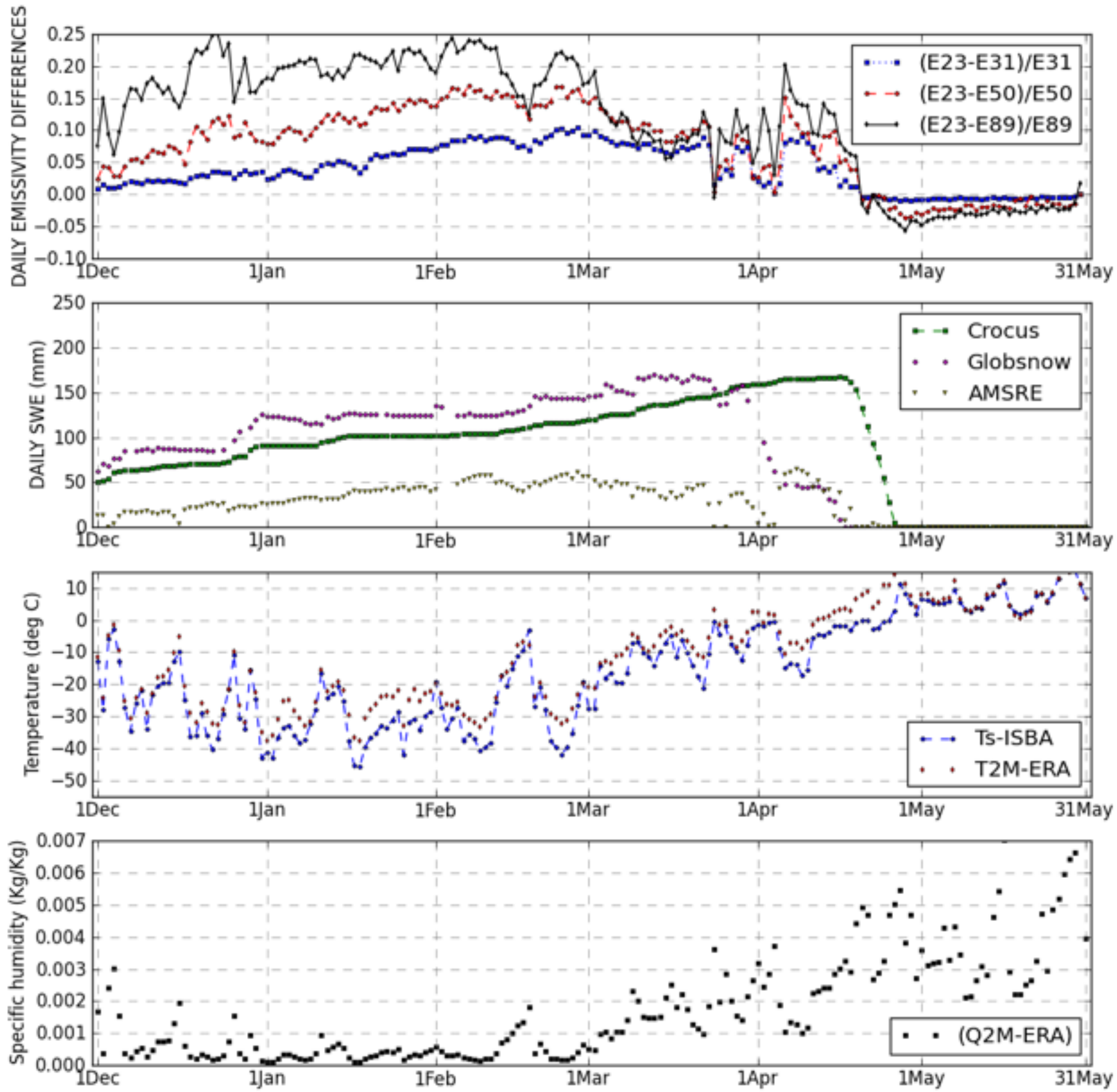
ε versus NSIDC



Variability of emissivity



Variability of emissivity

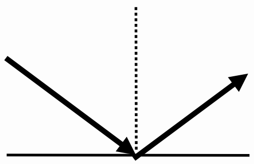


Variability of emissivity

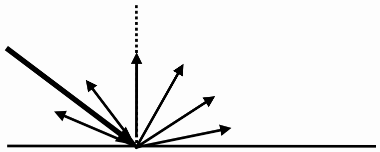
Effect of the specular assumption over Antarctica following Matzler (2005) study

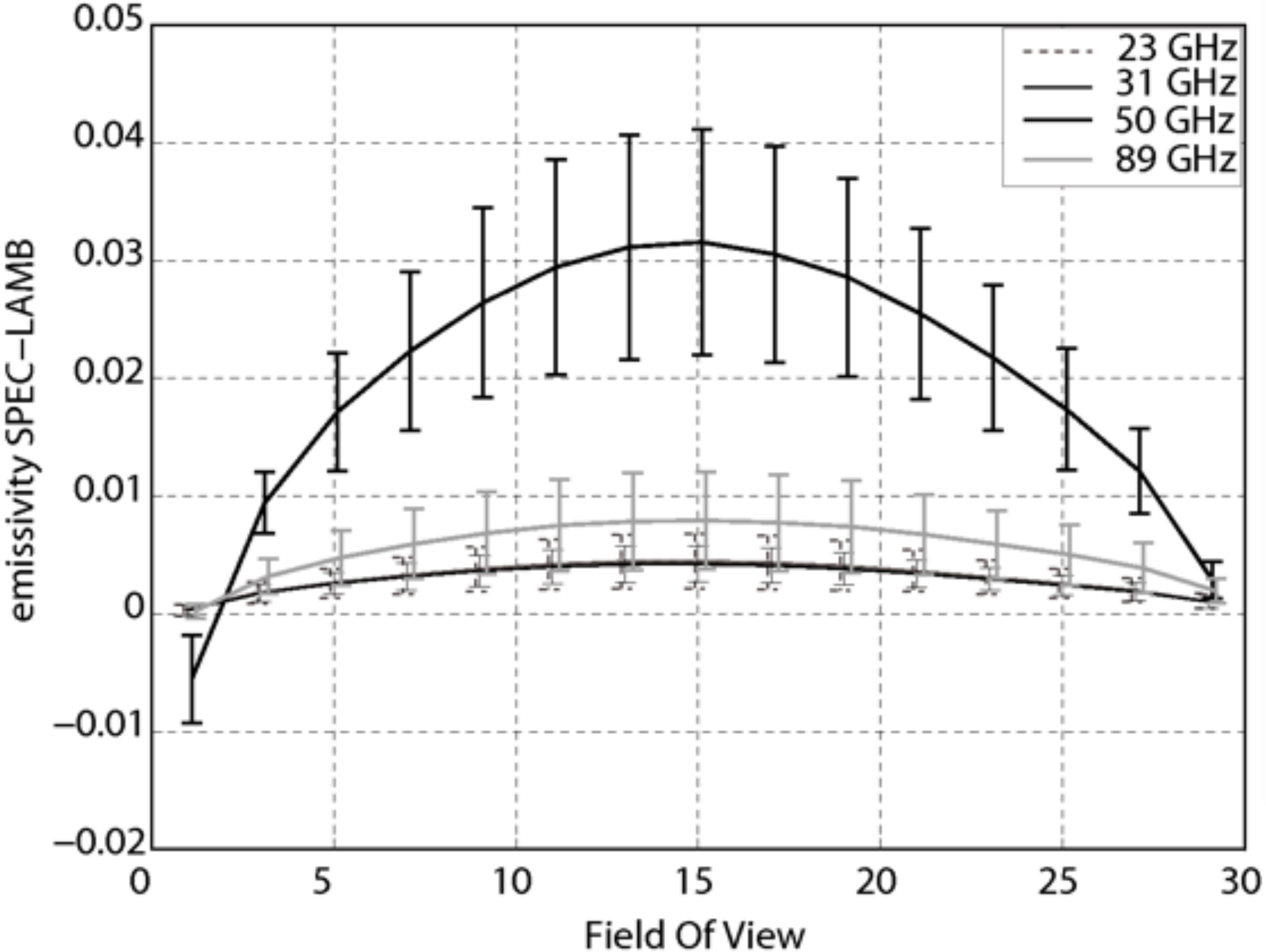
from Guedj et al. 2010

specular



lambertian

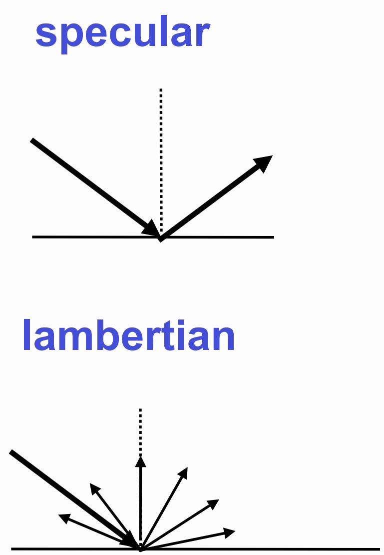


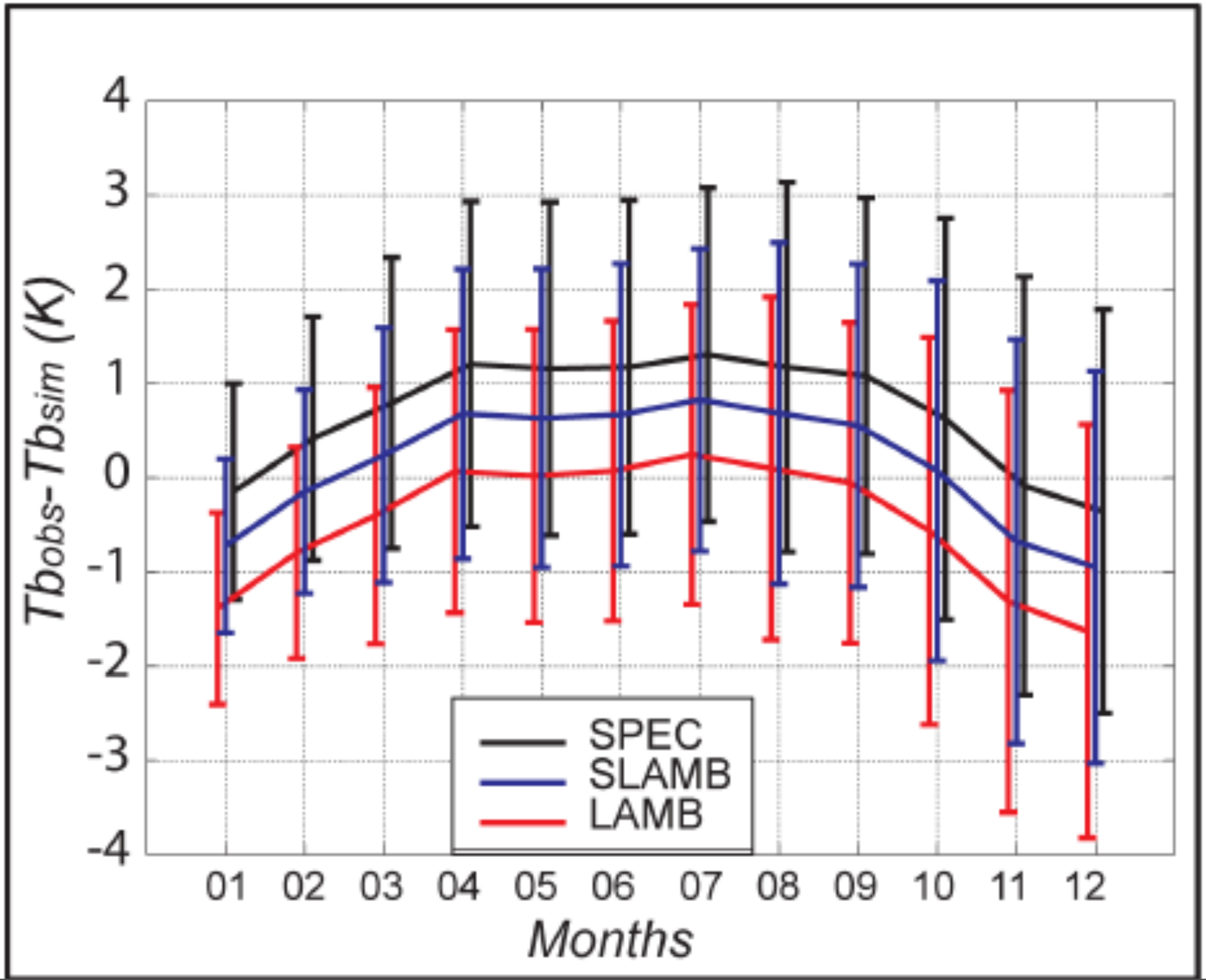


Variability of emissivity

Effect of the specular assumption over Antarctica following Matzler (2005) study

AMSU-A ch5, from Guedj et al. 2010

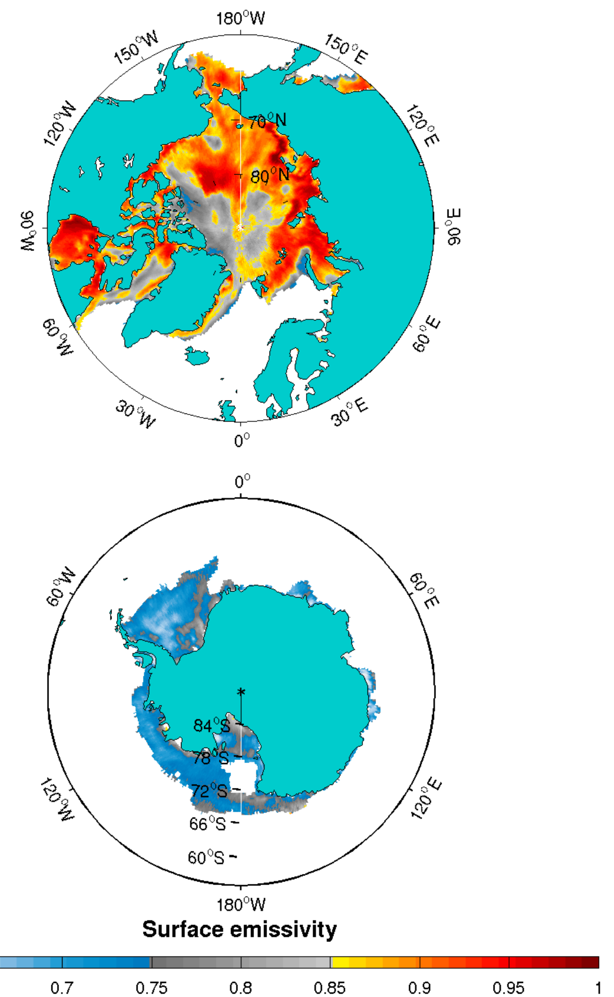




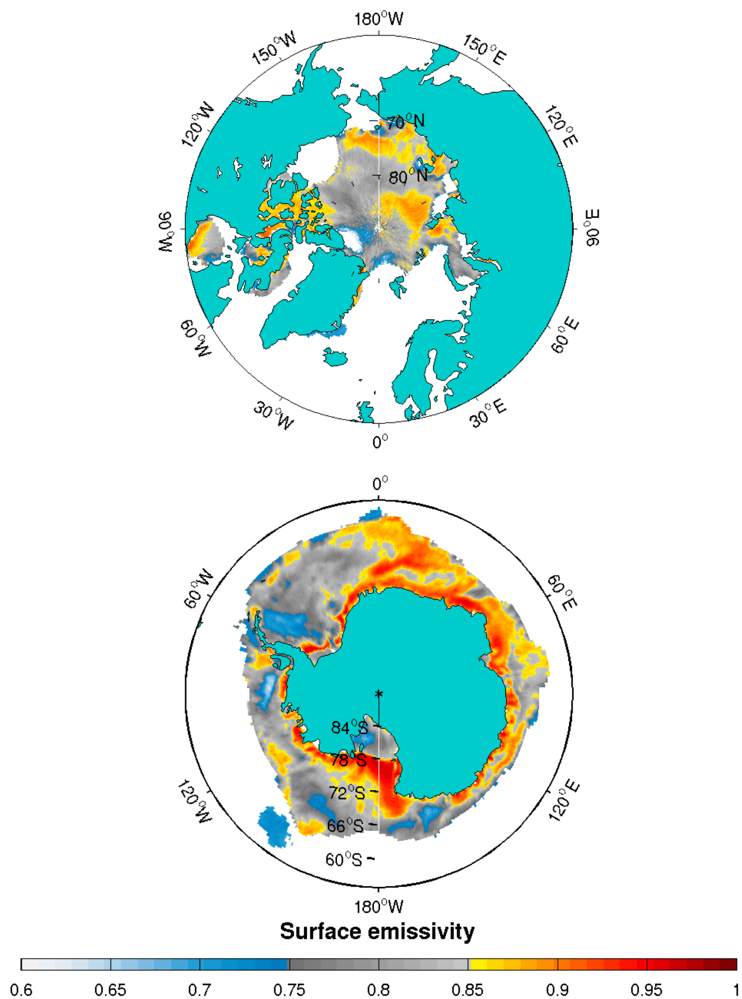
Variability of emissivity

Very high variability of sea ice emissivity

January 2009



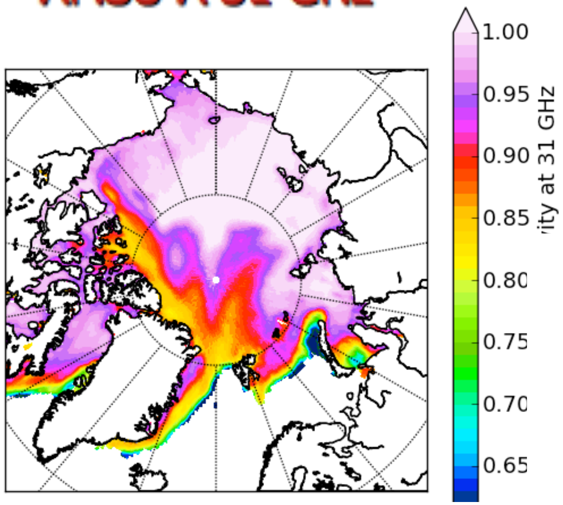
July 2009



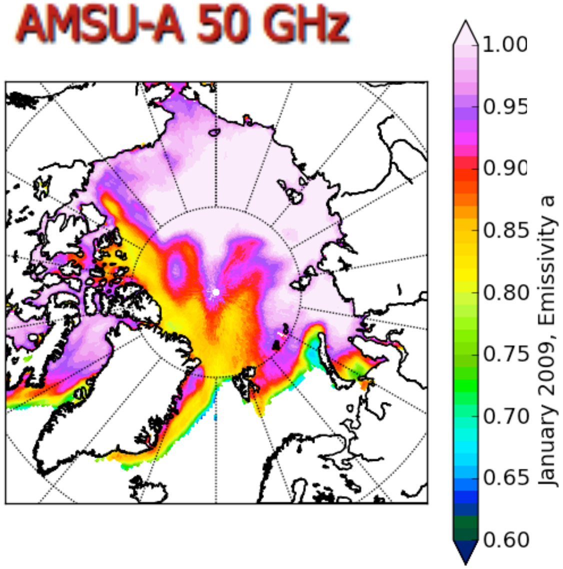
Variability of emissivity

Emissivity varies with sea ice types

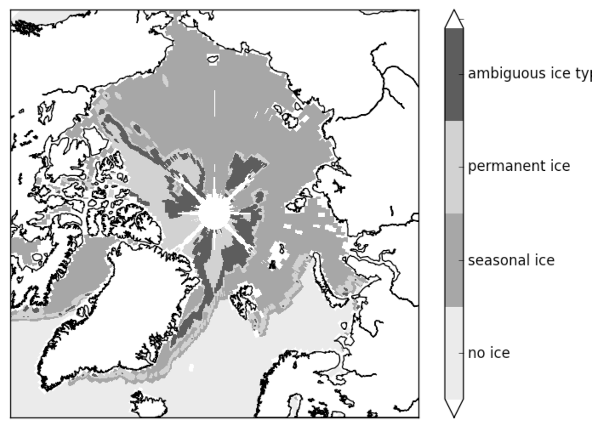
AMSU-A 31 GHz



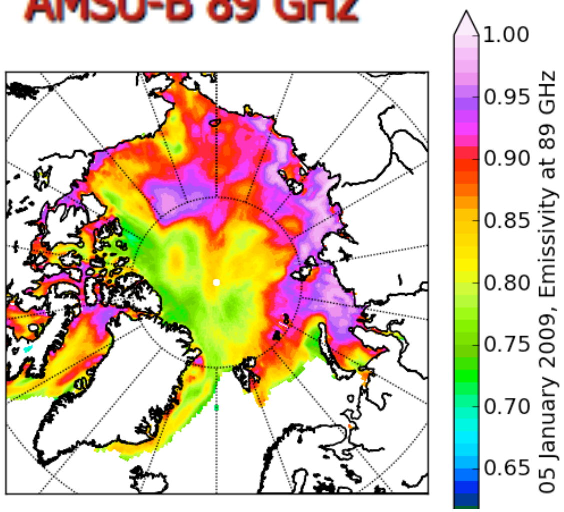
AMSU-A 50 GHz



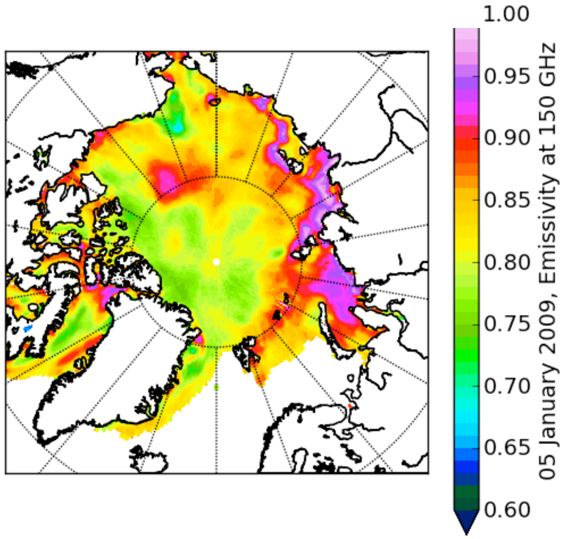
Ice types from OSISAF



AMSU-B 89 GHz

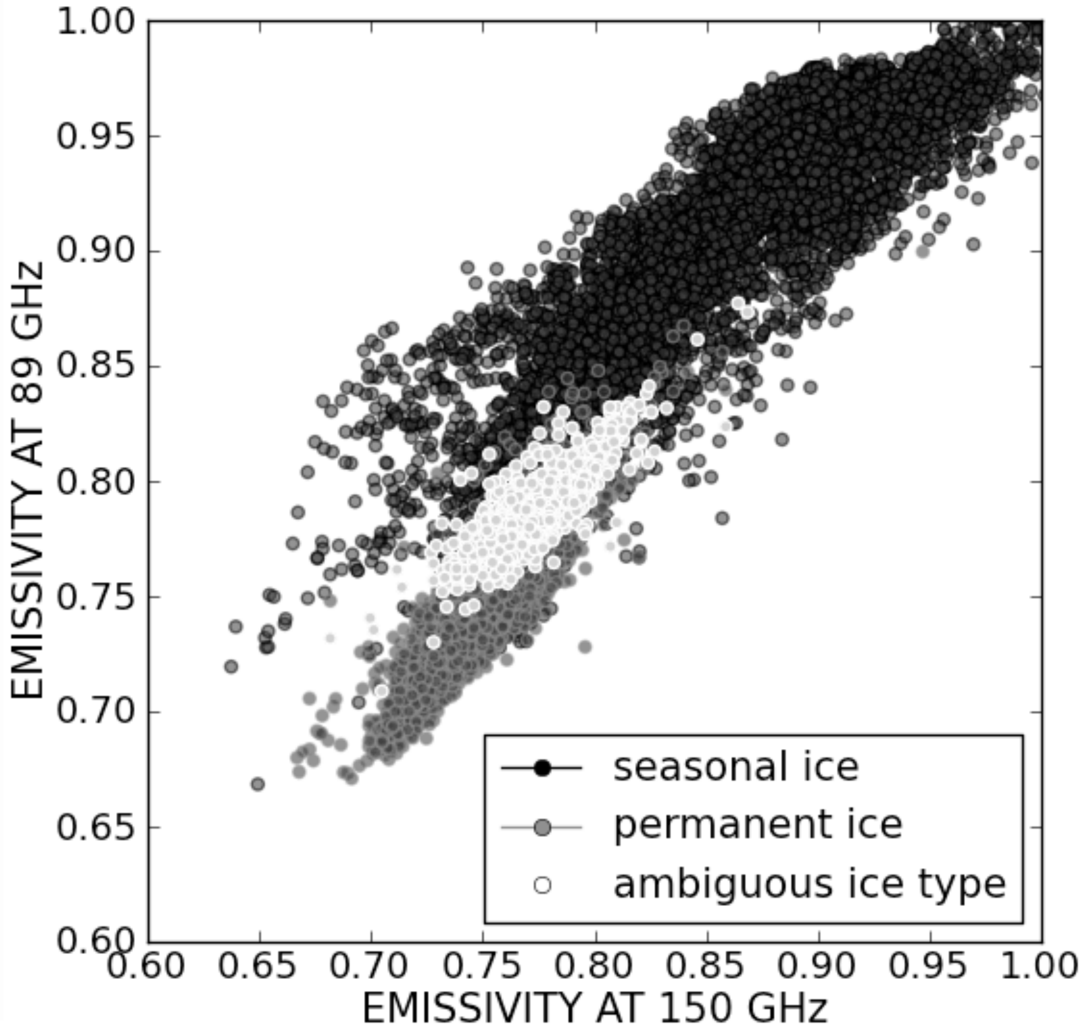


AMSU-B 150 GHz



Variability of emissivity

Emissivity varies with sea ice types



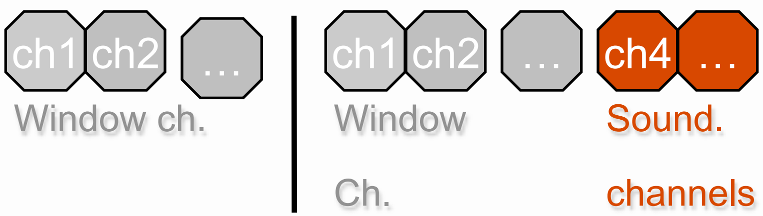
Some assimilation results

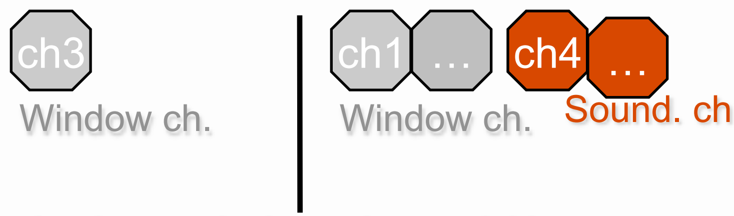
How to use emissivity retrievals in data assimilation ?

possible ways for use: « climatology » or « dynamical update of emissivity »

Emissivity climatologies from window channels (one month, two weeks …)

Estimate the emissivity using one window channel for every atmos. And surface situation





- Take into account the emissivity change with obs. angle (AMSU)
- Uncertainties if the surface conditions change (rain, snow, …)
- Very useful to estimate the Ts

- choose the best window channel (the most sensitive to the surface or the closest channel, in frequency, to sounding channels ?)
- With this method, we account for the angular dependence of the emissivity and for any change in the surface condition

At ECMWF, a kalman filter was developped to dynamically update atlases (Krzeminski et al. 2008)

Some assimilation results

Effect of a dynamical update of emissivity (without adding more channels)

- Interfaced with RTTOV (Eyre 1991; Saunders et al. 1999; Matricardi et al. 2004)

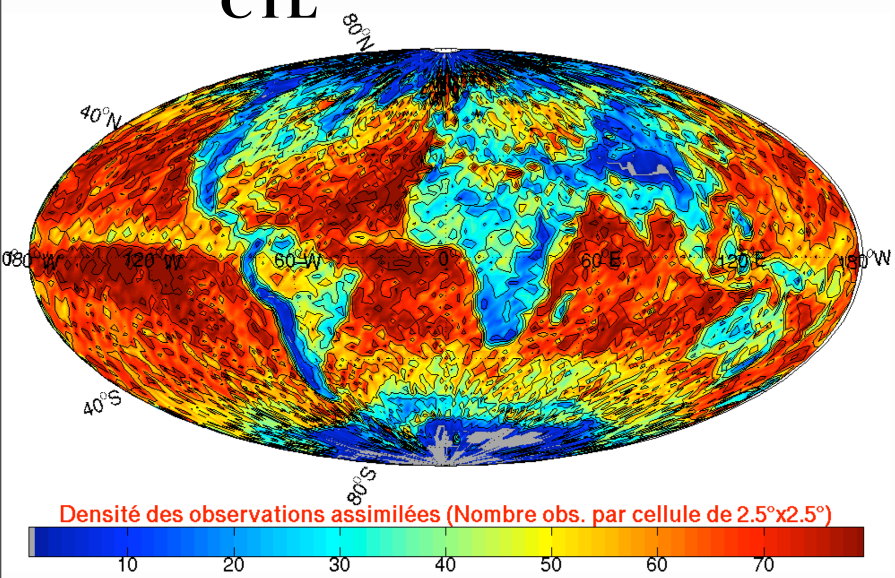
- Land emissivity is computed from selected surface channels (AMSU-A ch3 (50 GHz) and from AMSU-B ch1 (89 GHz))

Some assimilation results

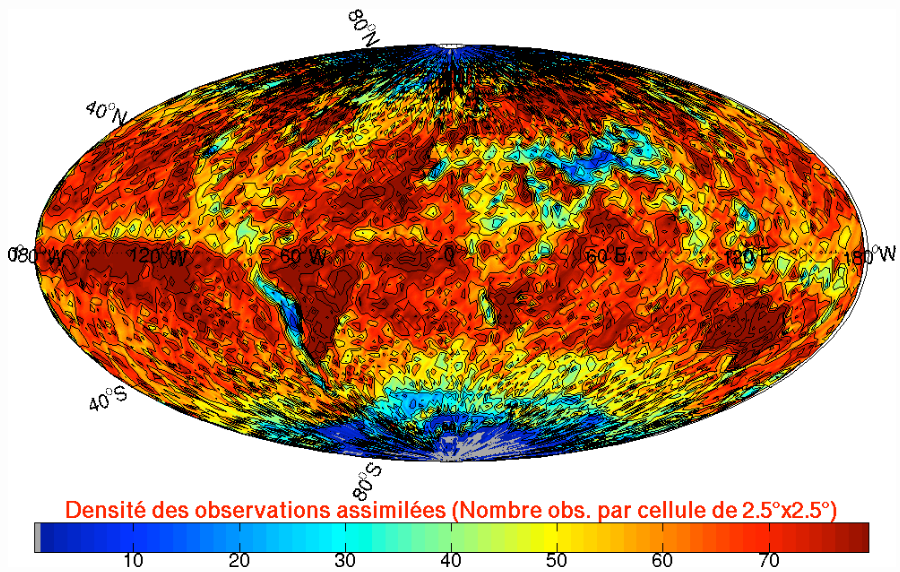
Effect of a dynamical update of emissivity (without adding more channels)

AMSU-A Ch7 obs. Density (sensitive to Temperature 10 km) during august 2006

CTL



EXP

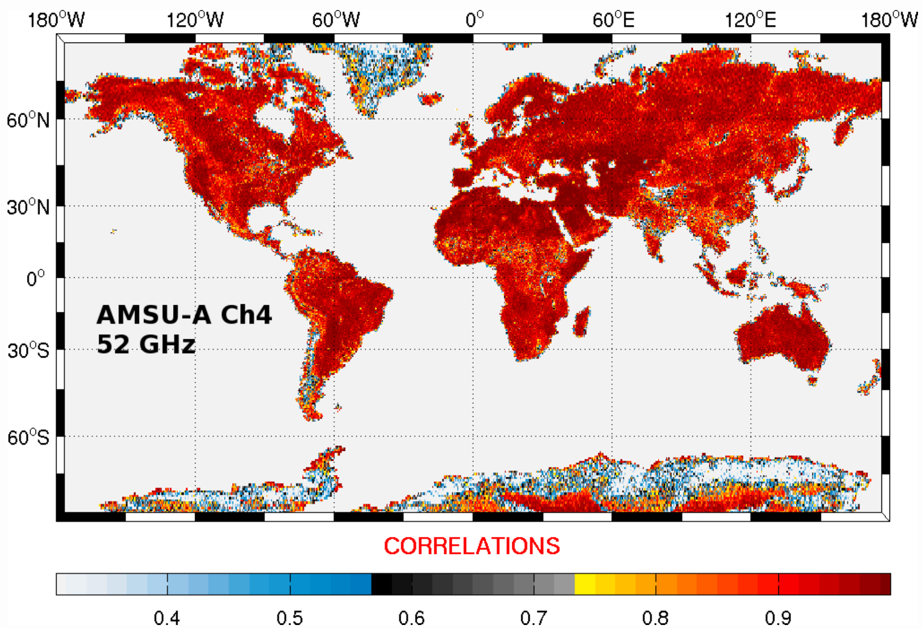


Some assimilation results

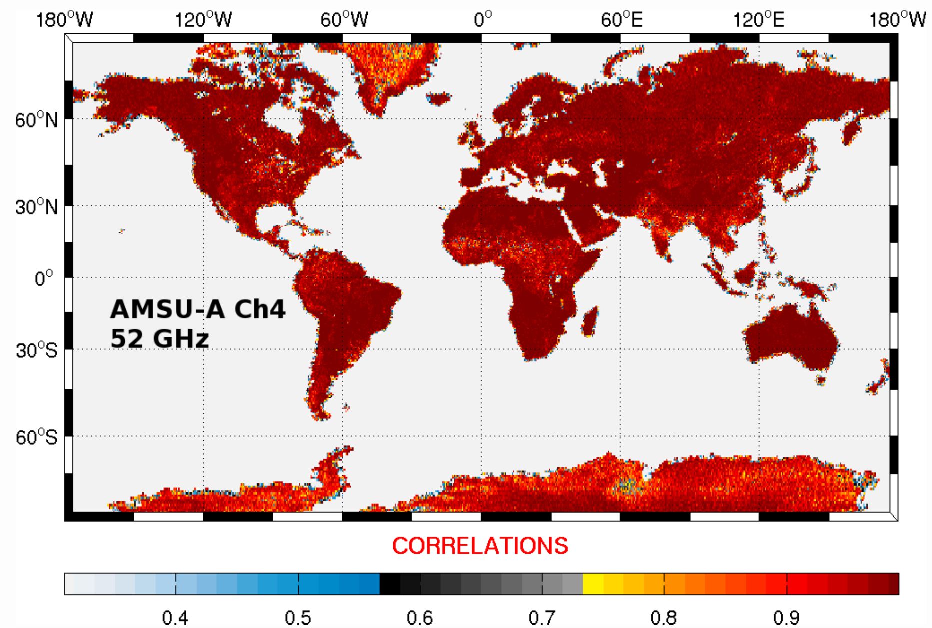
Effect of a dynamical update of emissivity (without adding more channels)

Correlations between Obs and RTTOV Sim., AMSU-A ch4, August 2006

CTL

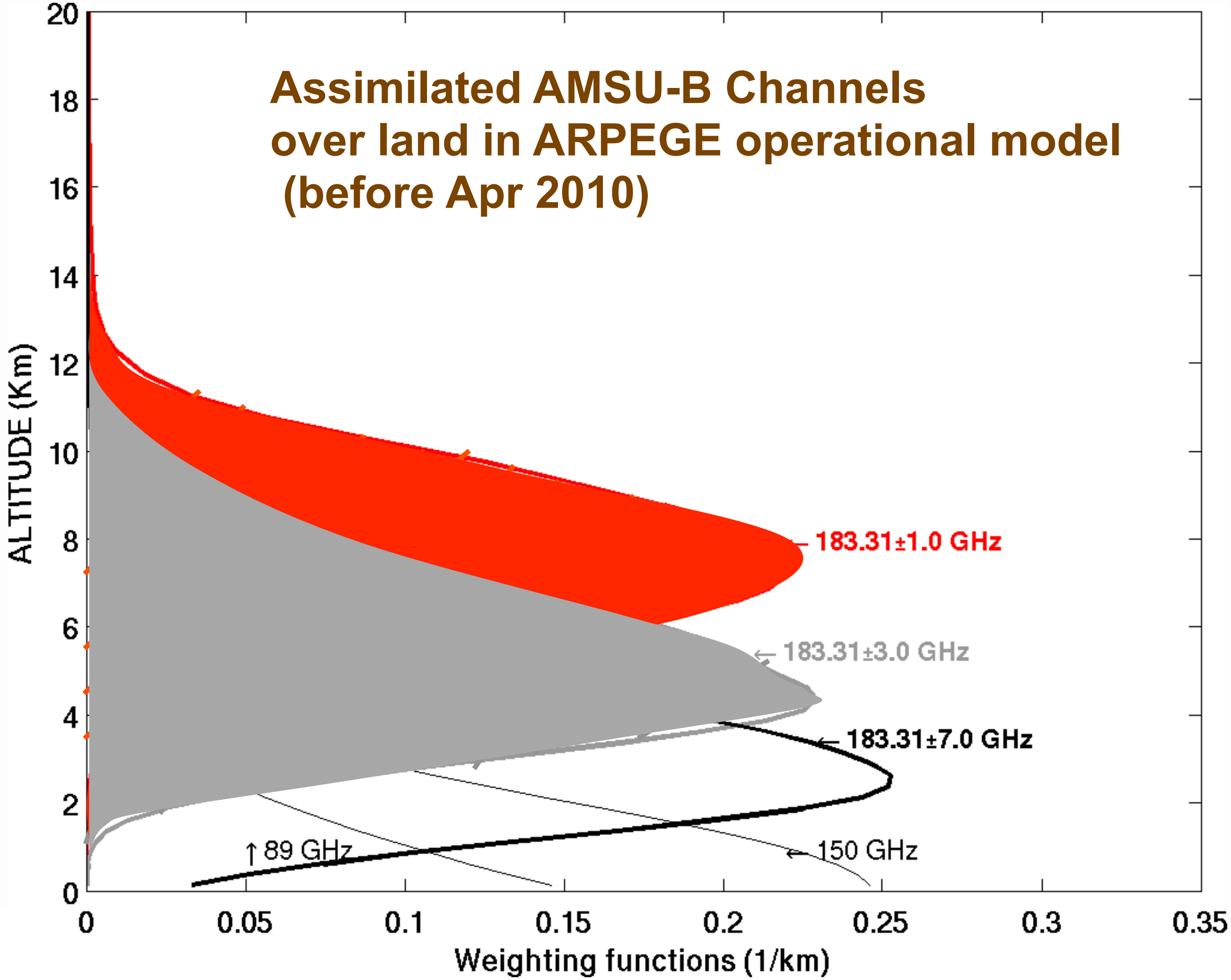


CTL + dynamical emis.



Some assimilation results

Effect of a dynamical update of emissivity with the assimilation of surface sensitive channels



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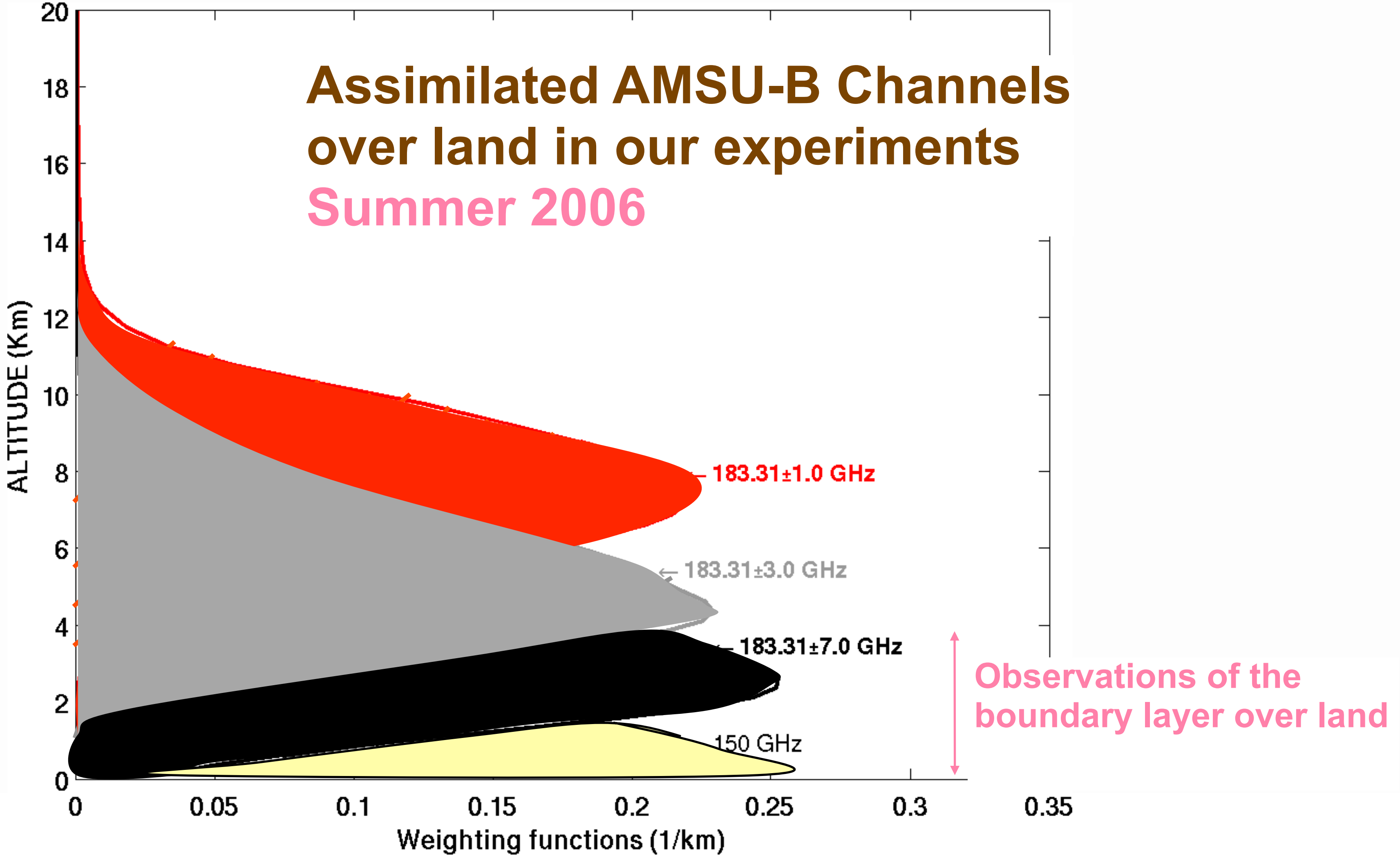


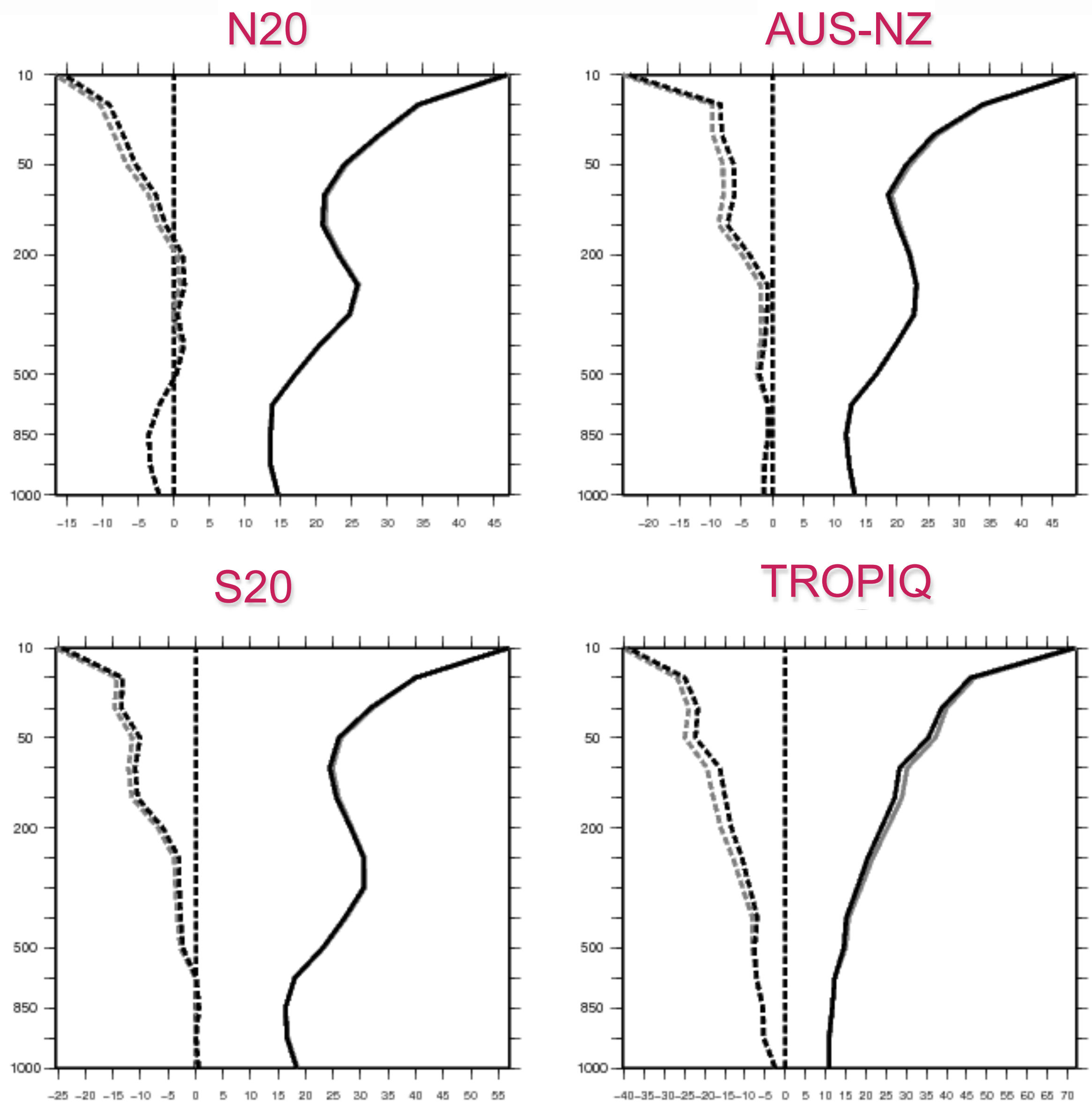
Some assimilation results

Effect of a dynamical update of emissivity with the assimilation of surface sensitive channels

Scores geopotential height / Radiosondes, 48h, 1 month

CTL --- BIAS
__ RMSE

EXP --- BIAS
__RMSE



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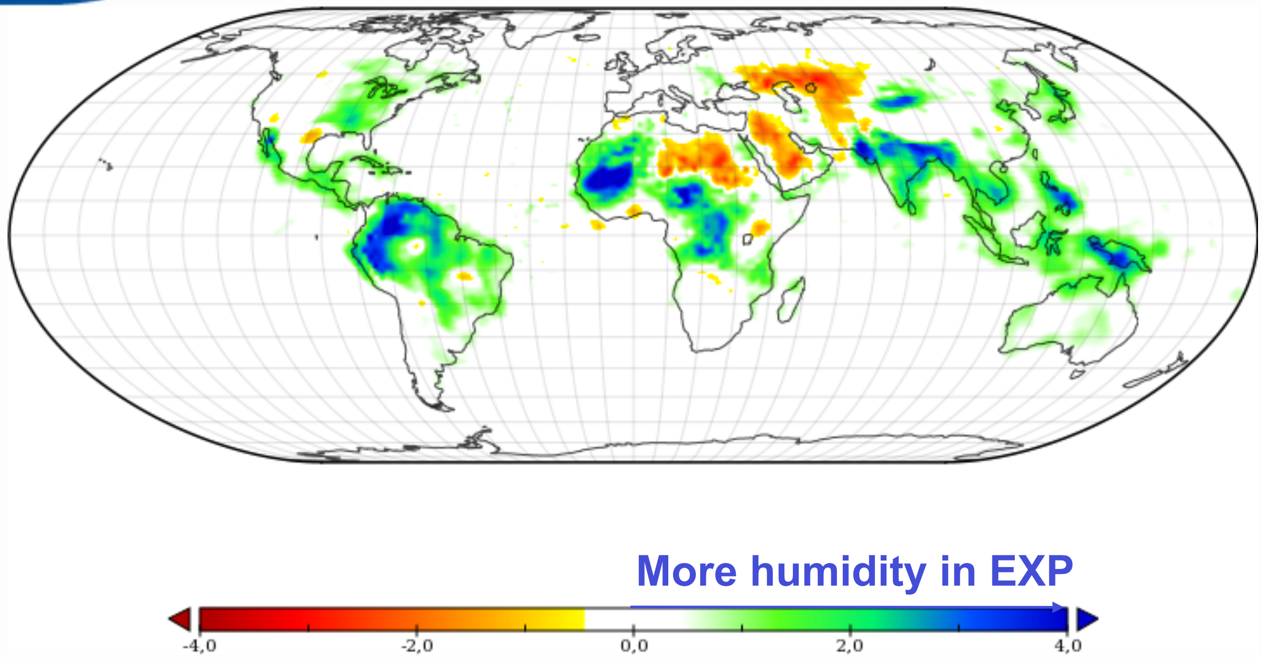
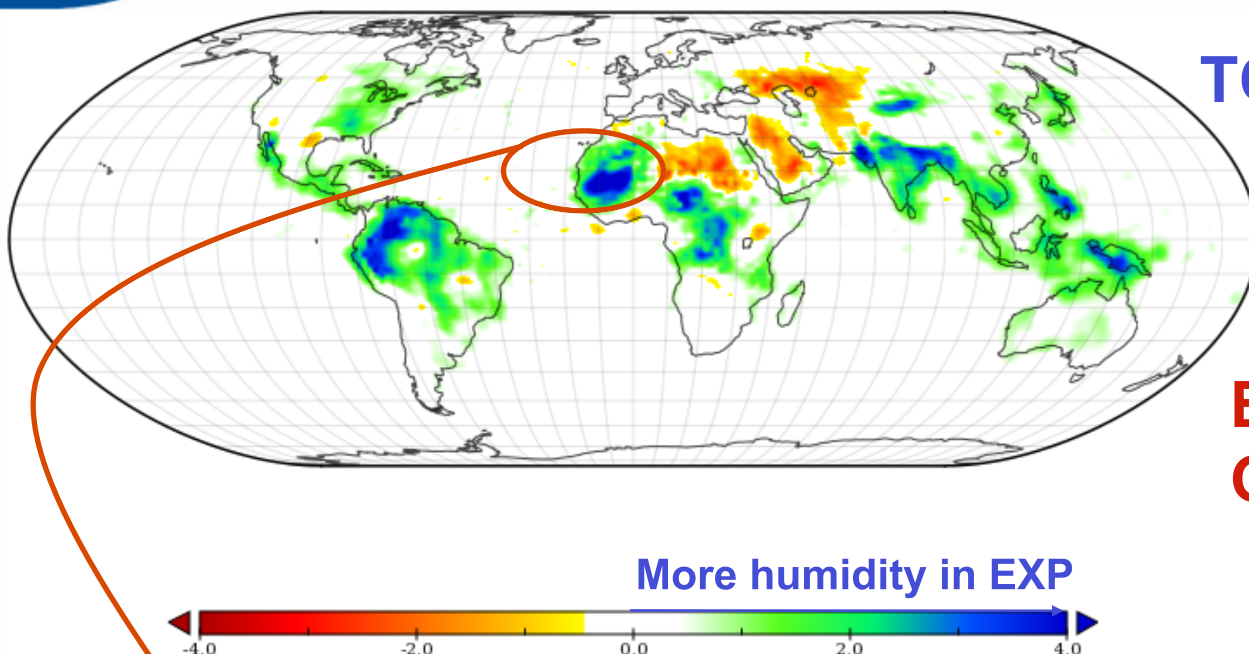


TCWV (EXP-CTL)

Similar humidity features with the assimilation of MERIS over land (Bauer 2009)

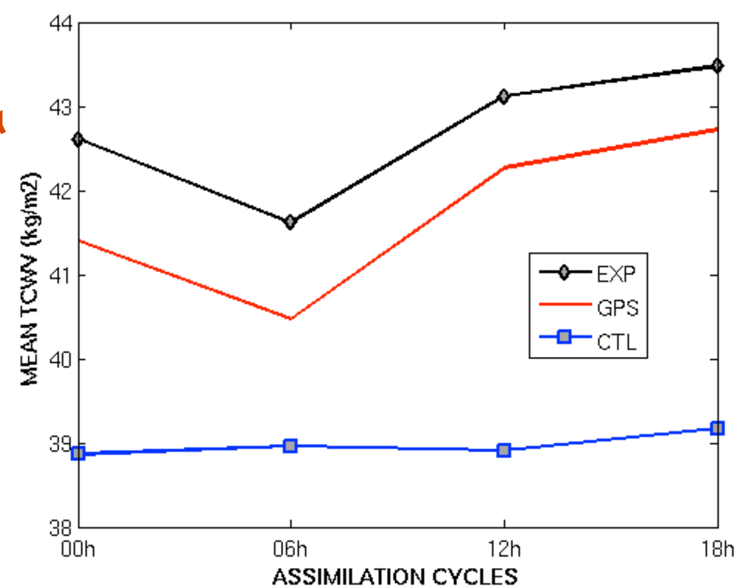
Some assimilation results

Effect of a dynamical update of emissivity with the assimilation of surface sensitive channels



TCWV (EXP-CTL)

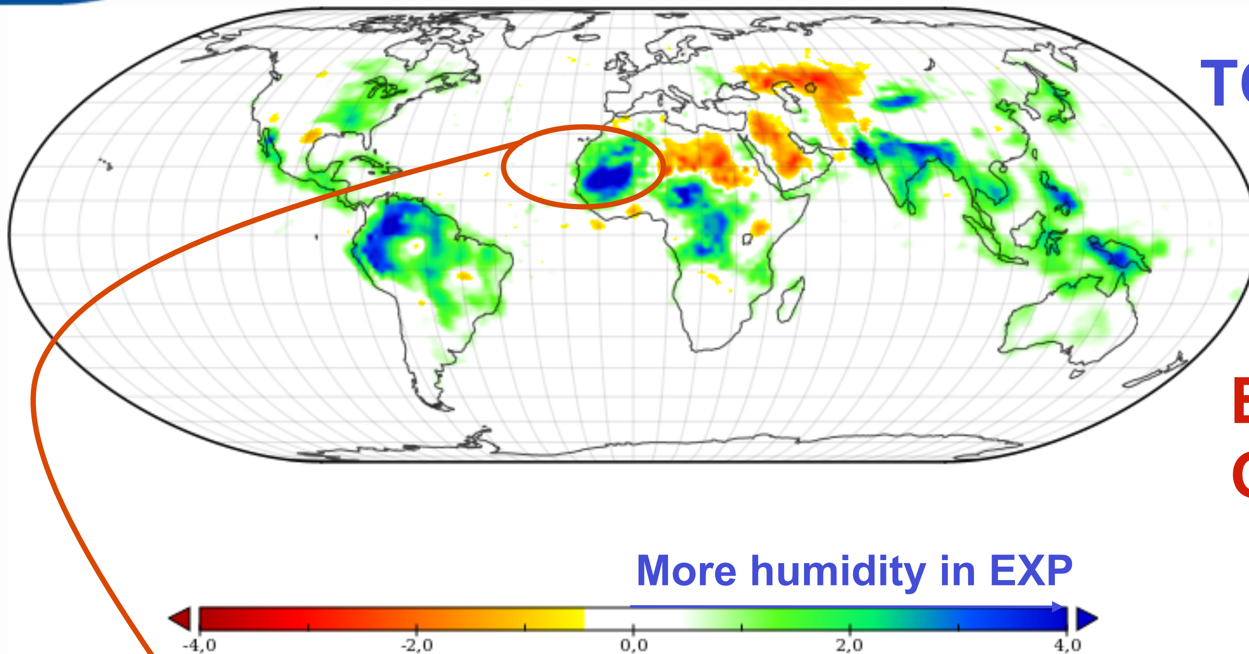
Evaluation against GPS measurements



TCWV diurnal cycle, Timbuktu (MALI)

Some assimilation results

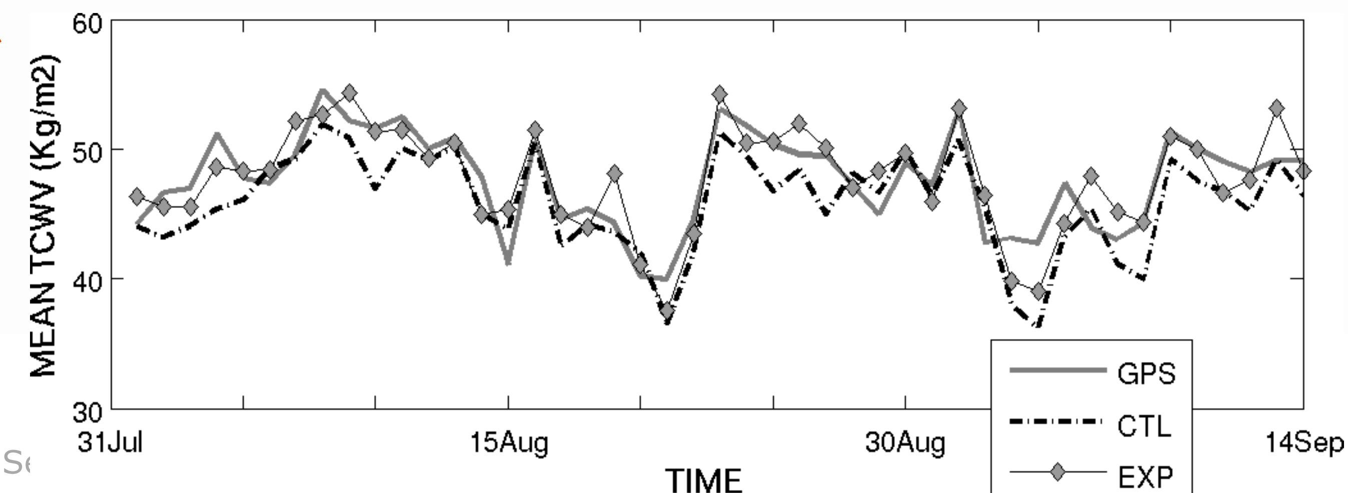
Effect of a dynamical update of emissivity with the assimilation of surface sensitive channels



TCWV (EXP-CTL)

Evaluation against GPS measurements

TCWV daily time series, Ouagadougou



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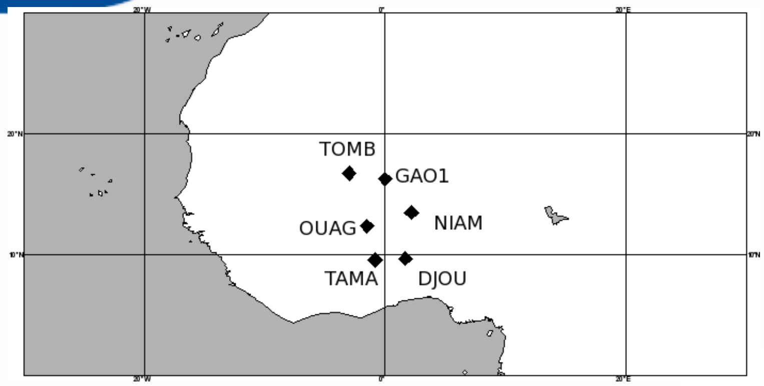
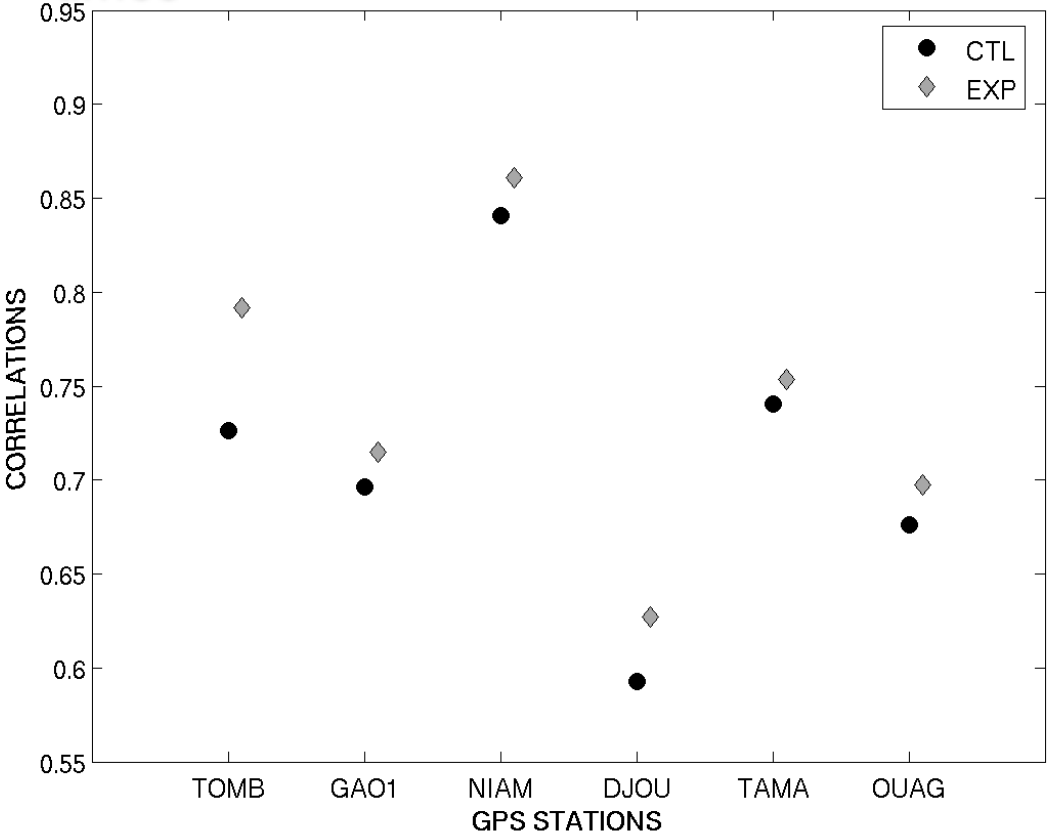


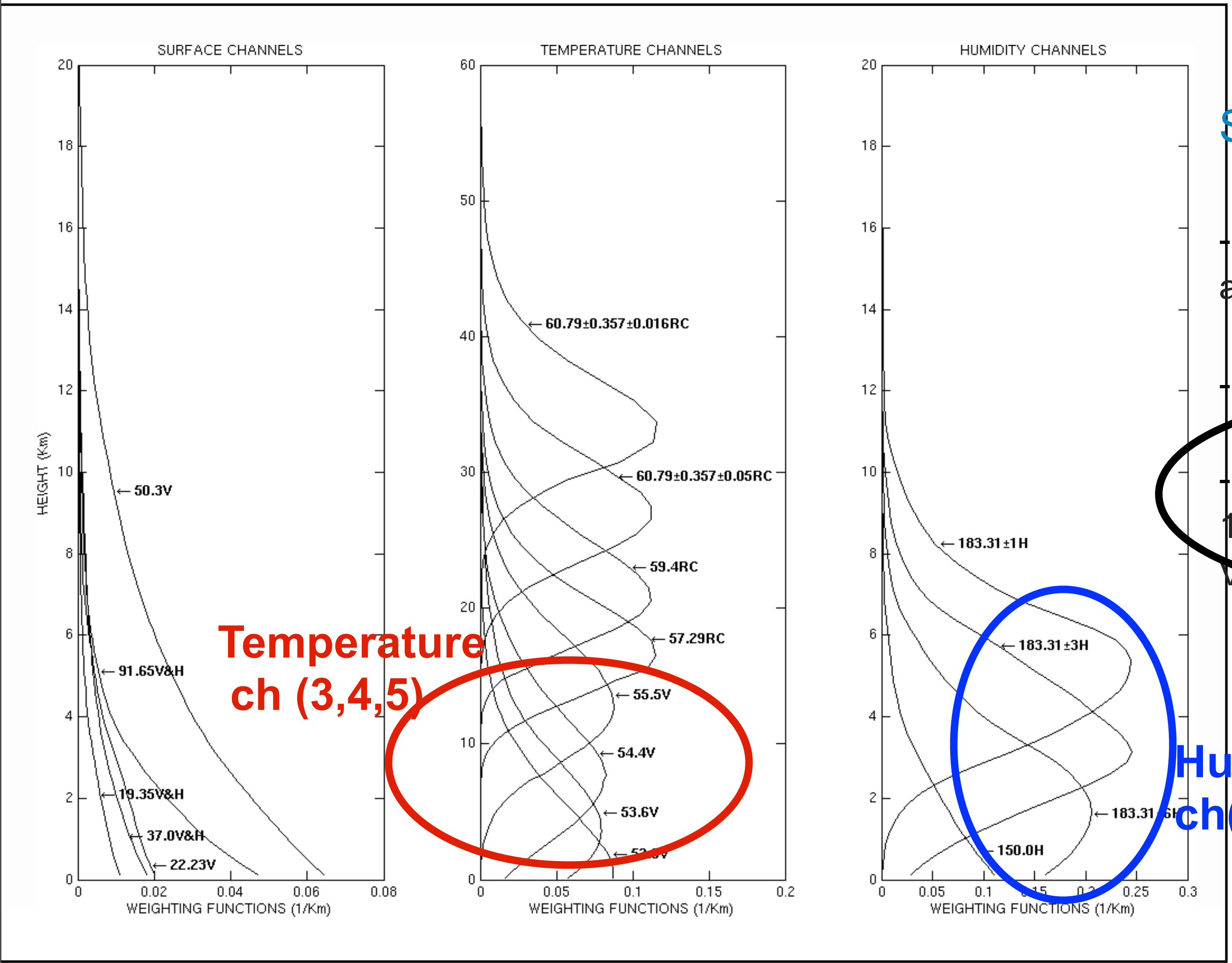
Correlations with GPS, 45 days, synoptic times



Some assimilation results

Effect of a dynamical update of emissivity with the assimilation of surface sensitive channels

Feasability studies to assimilate some SSMI/S sounding channels



SSMI/S:

- conical scanning: fixed observation angle (53°)
- Polarisation: V and/or H
- Window channels: 19.35 V&H, 22.23 V, 37 V&H, 50.3 V, 91.65 V&H GHz

Over sea

Some assimilation results

Effect of a dynamical update of emissivity with the assimilation of surface sensitive channels

Emissivity (~183 GHz) = Emissivity at 91H GHz (ch18)
Emissivity (~54-60 GHz) = Emissivity at 50V GHz (ch1)

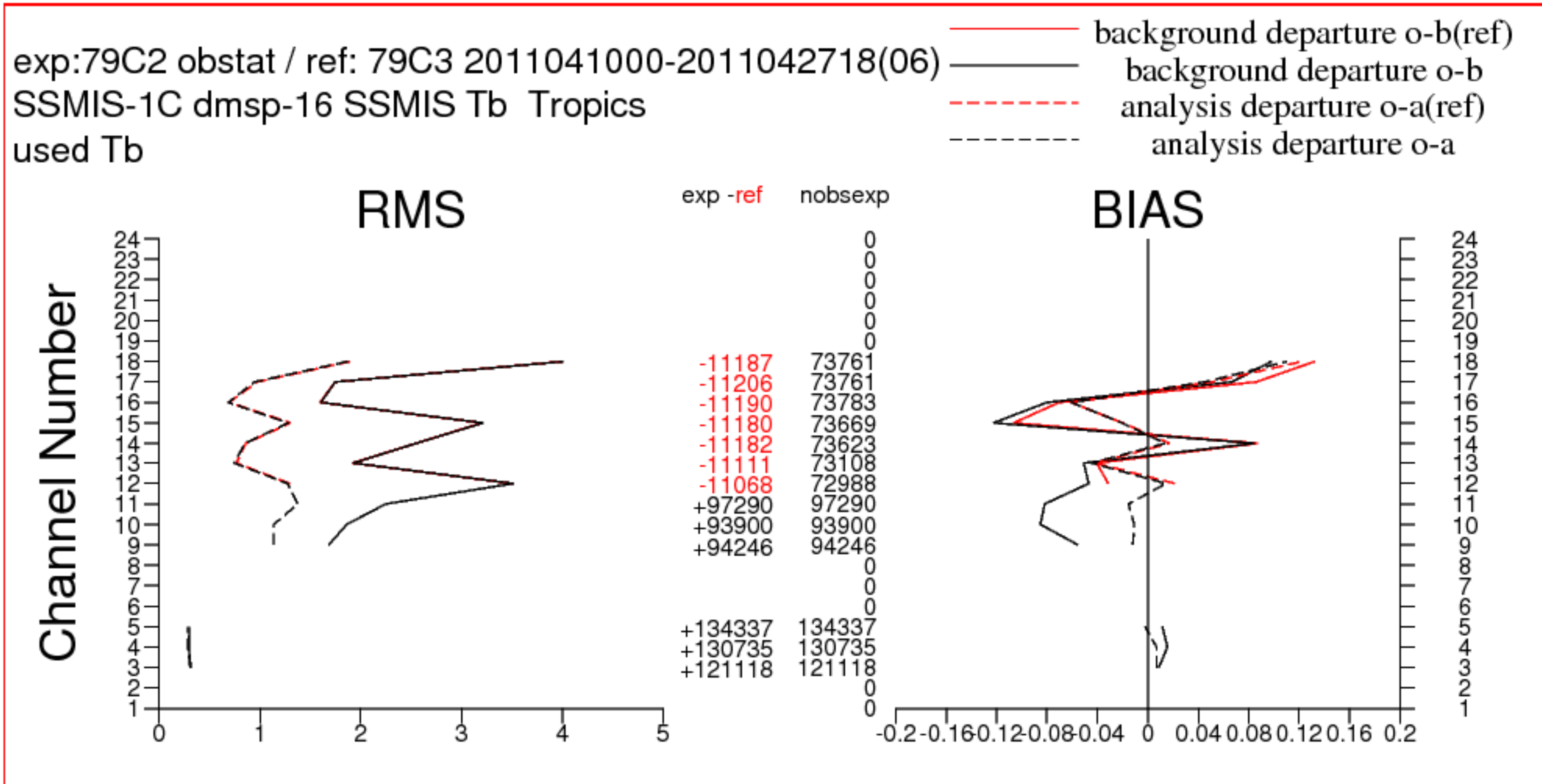
Data impact studies for evaluation:

- **Period: 01/04/2011 to 29/05/2011**
- **CTL: the current operational system**
- **EXP: CTL + assimilation of SSMIS channels 3-5 & 9-11 over sea and land**
- **Data from DMSP-16 and -17**
- **Quality control: SSMIS ch2 (52V, 0.7K) and SSMIS ch8 (150H, 2.7K)**
- **Obs error: 0.5K & 2K**

Some assimilation results

Effect of a dynamical update of emissivity with the assimilation of surface sensitive channels

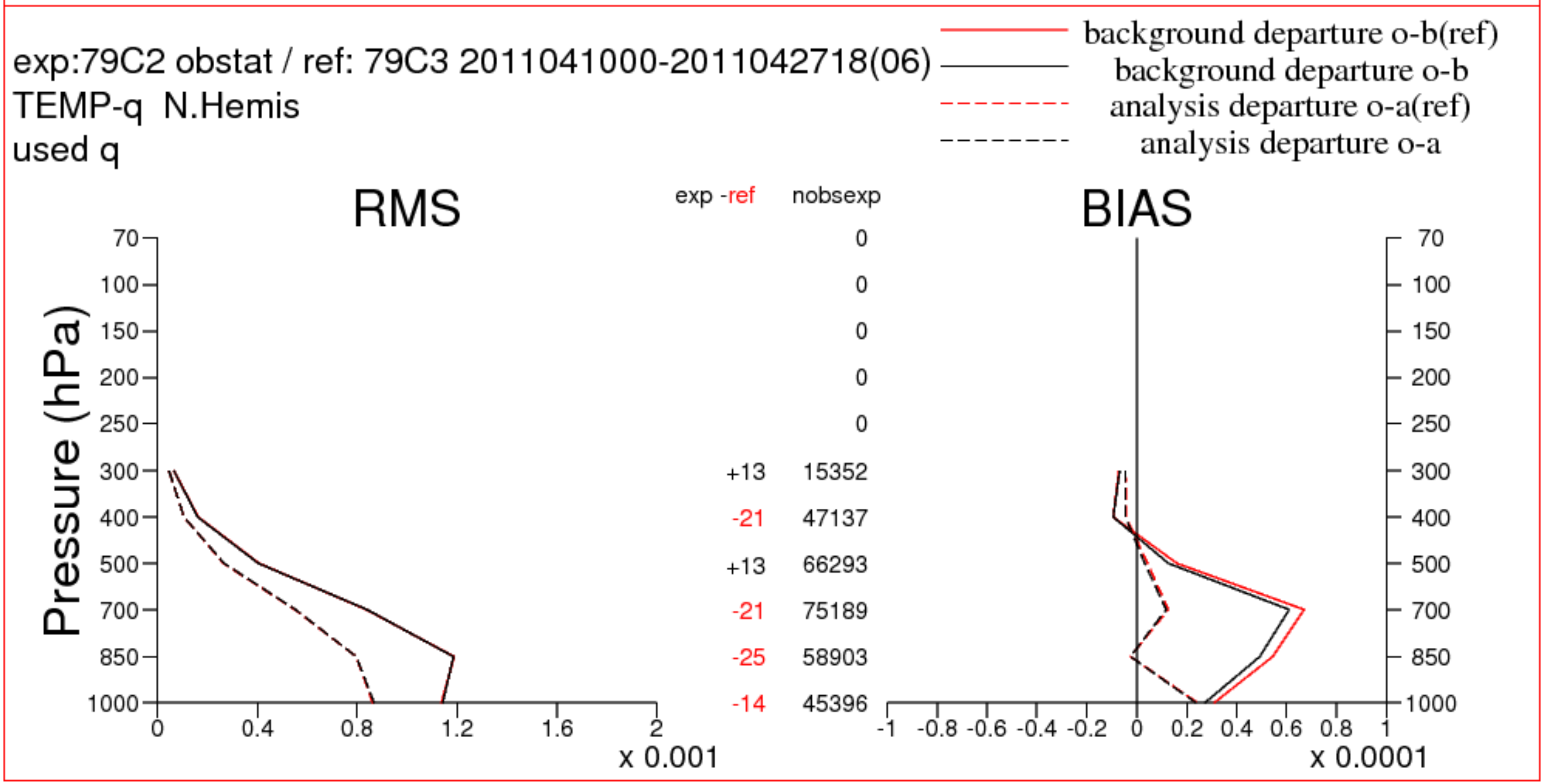
Fit to observations: SSMI/S



Some assimilation results

Effect of a dynamical update of emissivity with the assimilation of surface sensitive channels

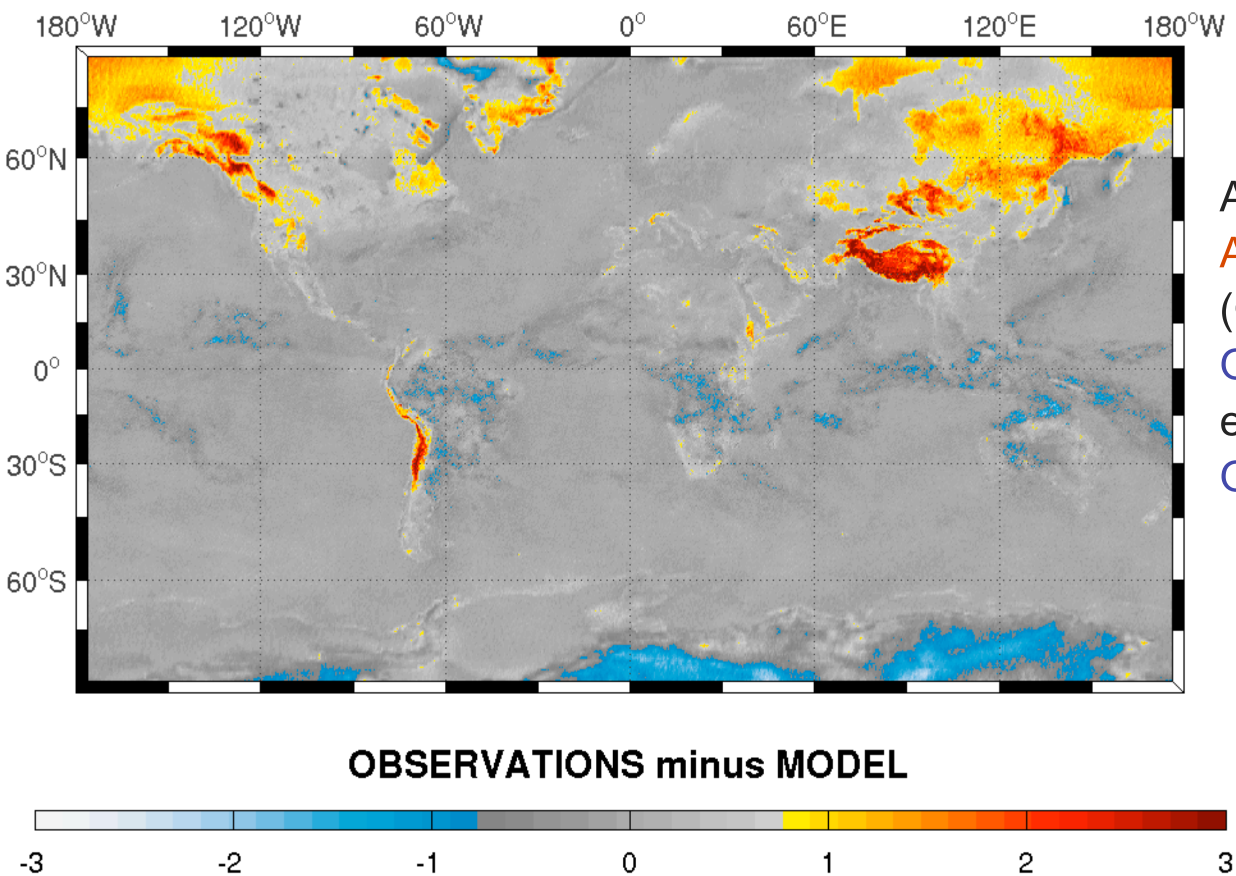
Fit to observations: Radiosondes



Some assimilation results

assimilation over sea ice

For AMSU-A: use the 50 GHz emissivity for temperature sounding (52-60 Ghz) over sea ice

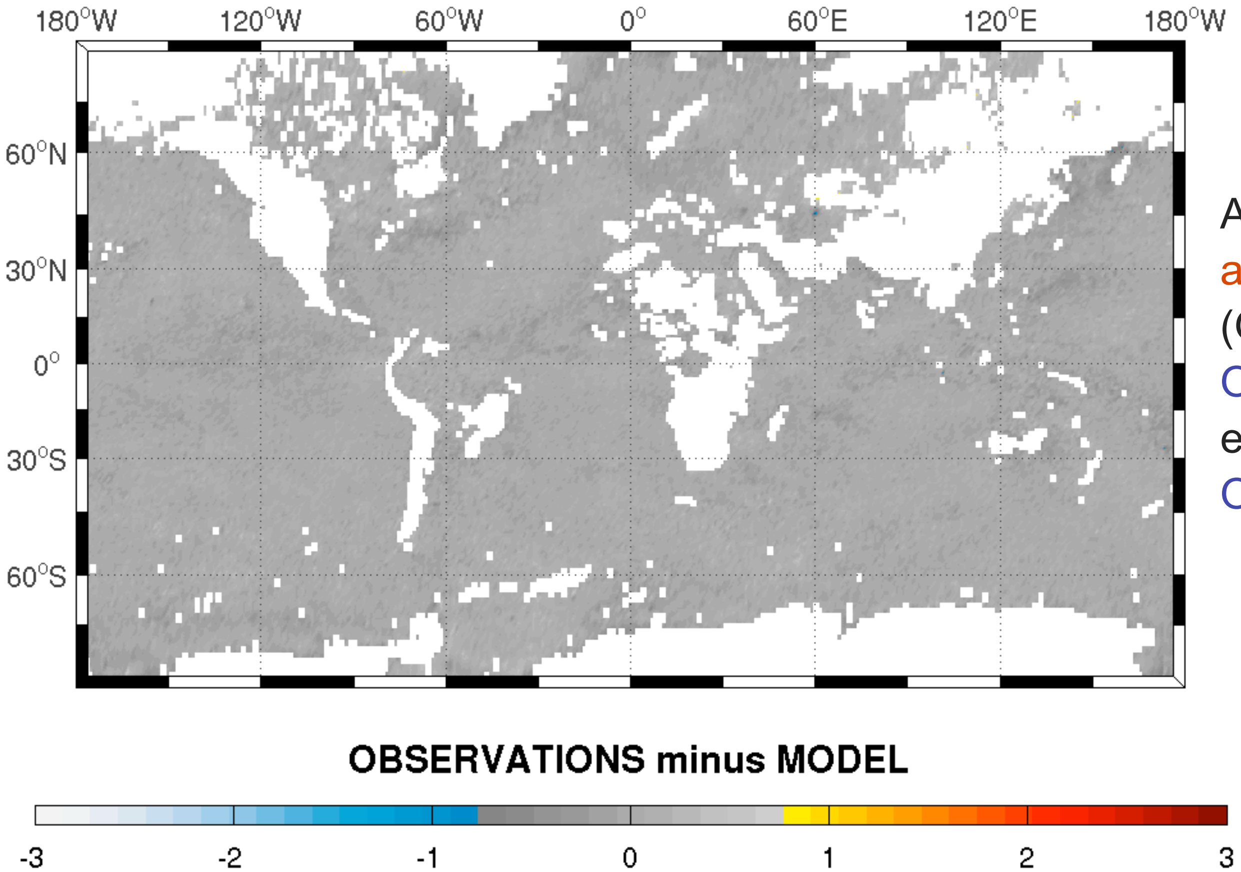


AMSU-A channel 5 (53 GHz)
All observations
(One week of data)
Over land & sea-ice: retrieved emissivity at 50 GHz
Over sea: FASTEM model

Some assimilation results

assimilation over sea ice

For AMSU-A: use the 50 GHz emissivity for temperature sounding (52-60 GHz) over sea ice;

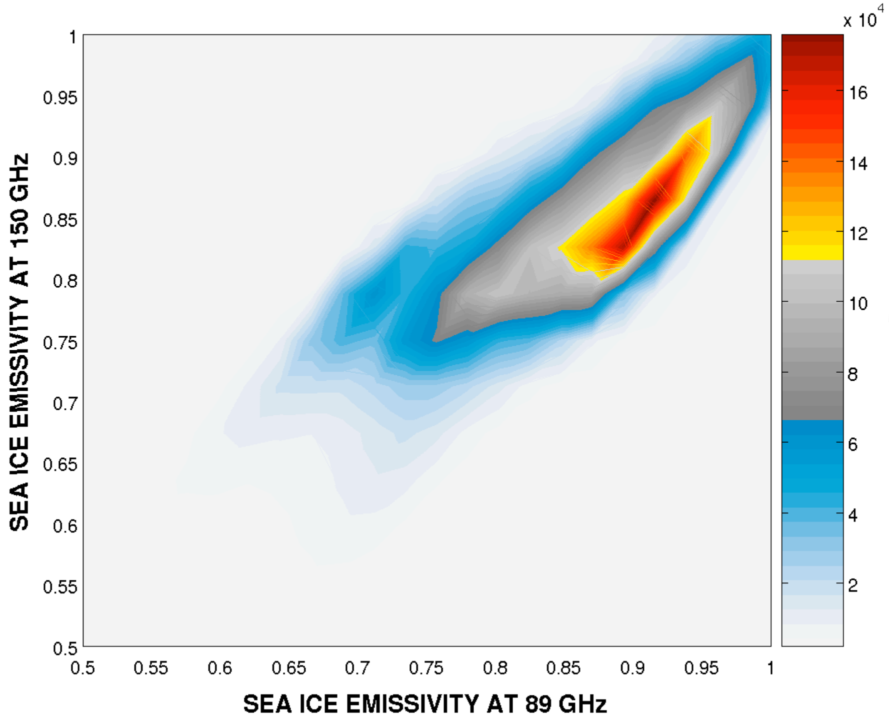


AMSU-A channel 5 (53 GHz)
assimilated observations
(One week of data)
Over land & sea-ice: retrieved emissivity at 50 GHz
Over sea: FASTEM model

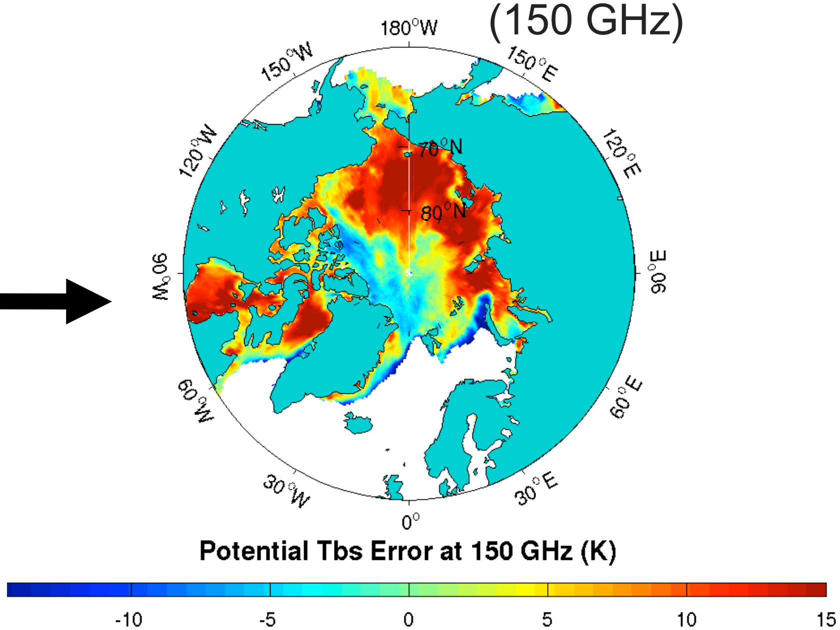
Some assimilation results
assimilation over sea ice

For AMSU-B in particular, can we still use the 89 GHz emissivities for sounding channels without any frequency dependence parameterization ?

January 2009



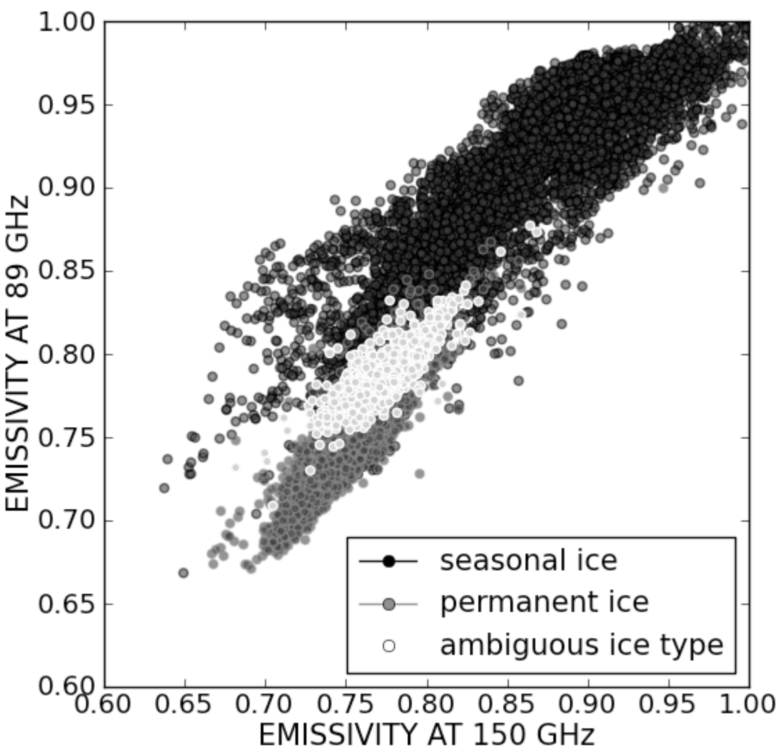
AMSU-B channel 2 (150 GHz)

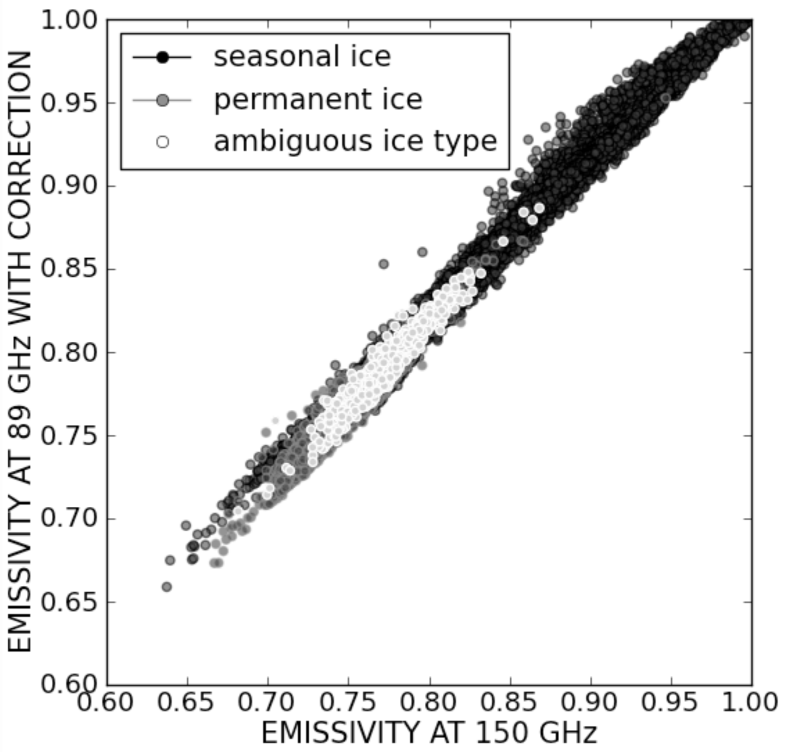


Some assimilation results

assimilation over sea ice

For AMSU-B in particular, can we still use the 89 GHz emissivities for sounding channels without any frequency dependence parameterization ?





Emissivity (~183 GHz) = Emissivity at 89 GHz + f (Tb 89, Tb150, Ts)

Some assimilation results

assimilation over sea ice

For AMSU-B in particular, can we still use the 89 GHz emissivities for sounding channels without any frequency dependence parameterization ?

Use of frequency parameterization for sea ice: to describe the emissivity change from 89 GHz to 183.31 GHz

Emissivity (~183 GHz) = Emissivity at 89 GHz + f (Tb 89, Tb150, Ts)
Emissivity (~54-60 GHz) = Emissivity at 50 GHz

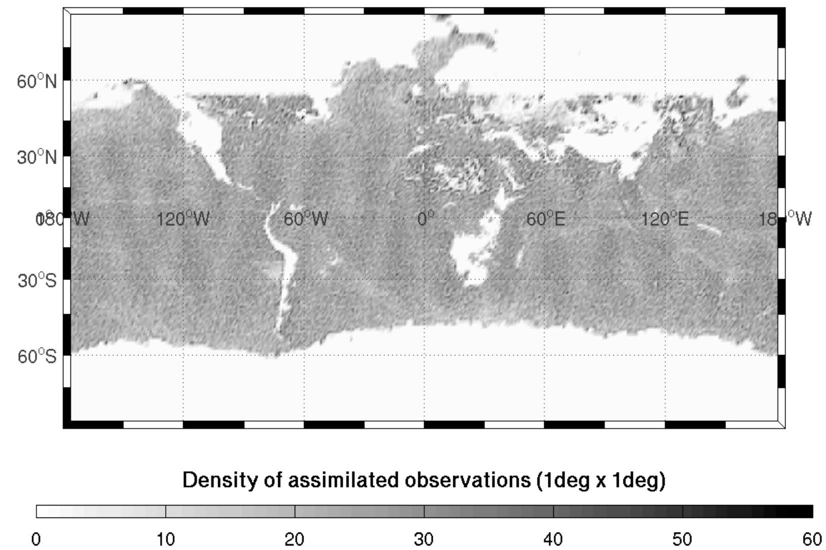
Data impact studies for evaluation:

- Period: 15/12/2009 to 04/02/2010
- CTL: the current operational system
- EXP: CTL + emissivity model over sea ice + assimilation of AMSU-A/-B over sea ice

Some assimilation results
assimilation over sea ice

Usage of AMSU-B channel 5 (183.31 ± 7.0 GHz) in ARPEGE

CTL

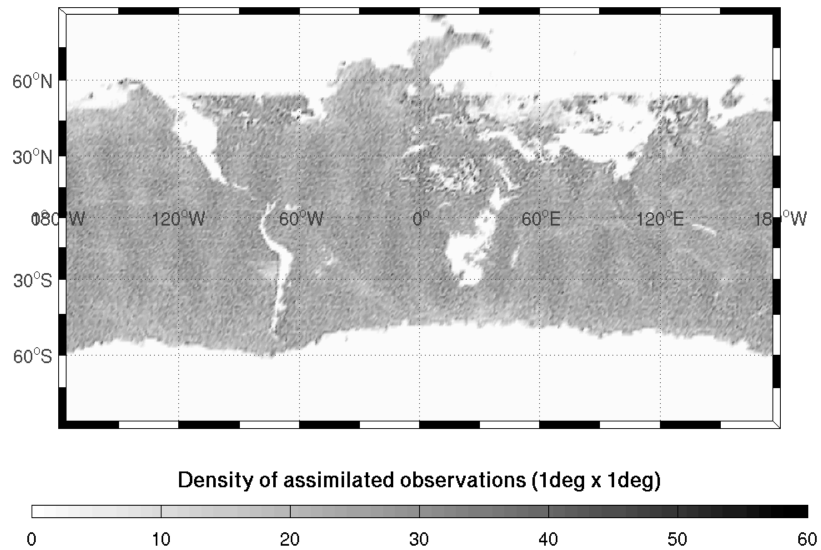


Some assimilation results

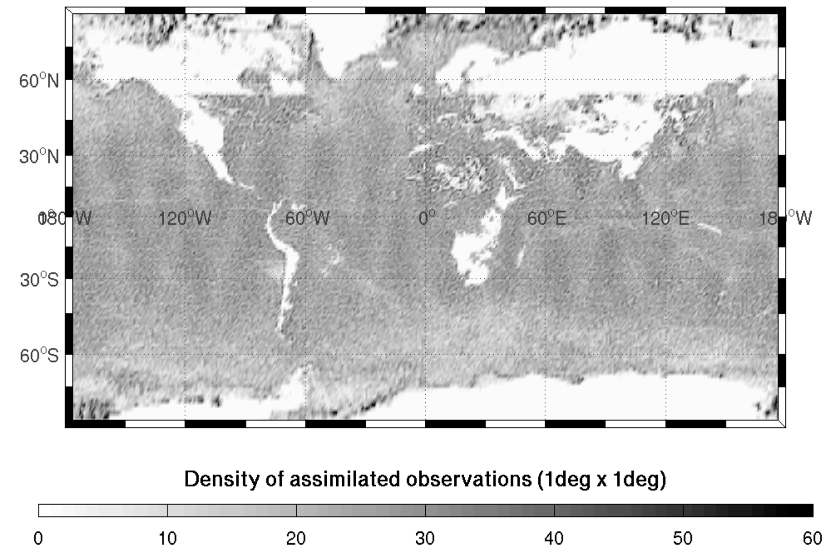
assimilation over sea ice

Usage of AMSU-B channel 5 (183.31 ± 7.0 GHz) in ARPEGE

CTL



EXP

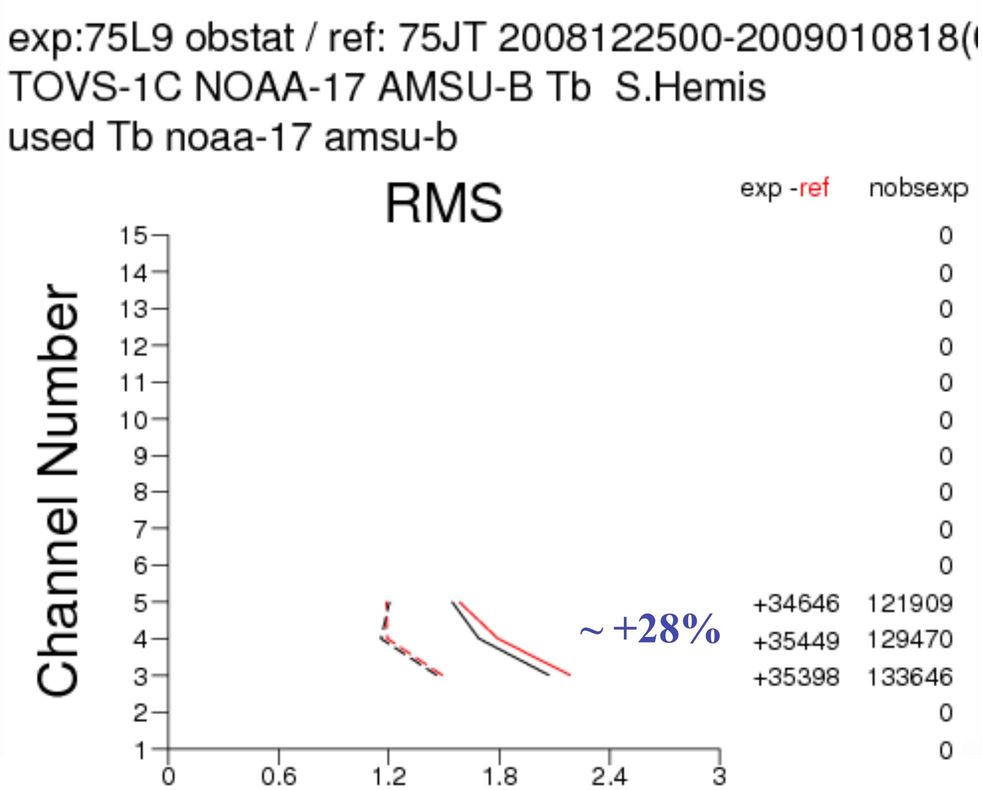


Some assimilation results

assimilation over sea ice

Fit to observations: improvement or neutral effect

RMS errors of AMSU-B departures from Analyses and First-guess (NOAA-17), S. Hemis



CTL --- Analyses
__ First-Guess

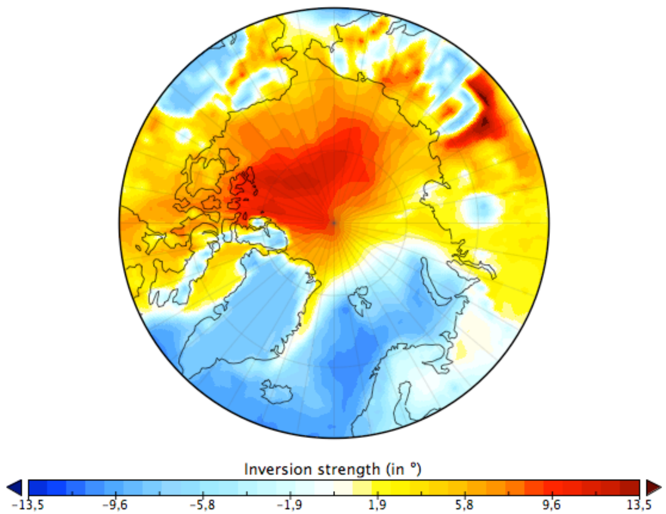
EXP --- Analyses
__First-Guess

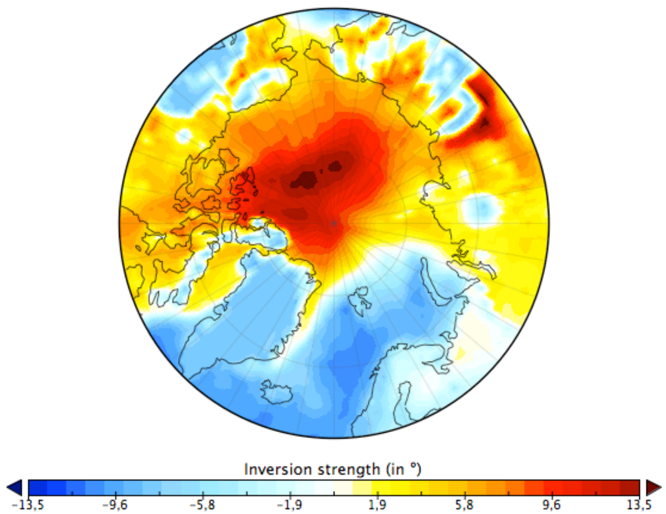
Some assimilation results

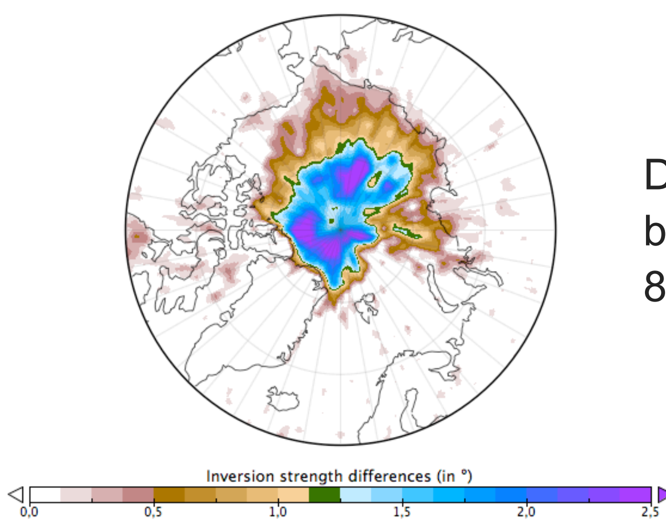
assimilation over sea ice

Control + AMSU over sea ice

Control







Difference in inversion strength brought by a larger warming at 850hPa than at 1000 hPa

Conclusions

- Emissivity retrieval from surface channels is a convenient way to improve the assimilation of data over land
- Method developed for AMSU-A/-B MHS instruments but can be used for SSMI, SSMIS, AMSRE, ATMS, SAPHIR
- Method gives good results over land, sea-ice and improves RTTOV simulations over snow

- Improve the bias correction over land (new predictors ?), Gérard et al. 2010
- Improve the representation of the skin temperature
- Snow, sea ice issues: a specularity parameter ?
- Surface modelling an issue for IR
- Need for in increased coupling between land and atmospheric data assimilations

Thank you for your attention