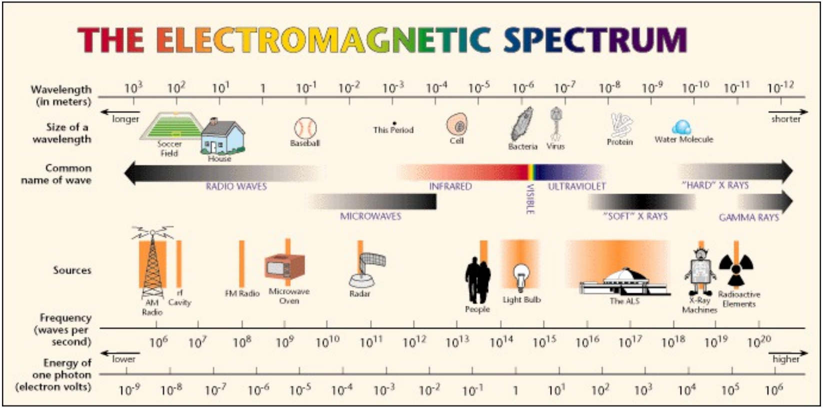
Improved use of microwave imager data in all-sky data assimilation at ECMWF

Katrin Lonitz,
Alan Geer and many other colleagues

ECMWF

EUMETSAT Fellow Day
9 March 2015

Microwave spectrum

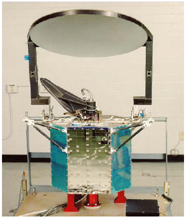


www.dianneemf.com/resources/EMF_Sources

Microwave instruments

Special Sensor Microwave Imager and Sounder **(SSMIS)**

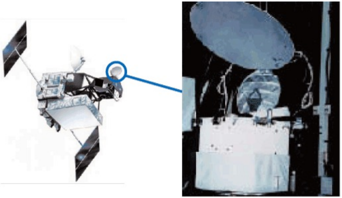
- dual polarized, conical scanning passive microwave radiometer
- 24 channels: 19 GHz - 183 GHz
- 37 GHz sensitive to clouds and light precip



nsidc.org/data/docs/daac/ssmis_instrument

Tropical Rainfall Measuring Mission's (TRMM) Microwave Imager **(TMI)**

- dual polarized, conical scanning passive microwave radiometer
- 5 channels: 10 GHz - 85.5 GHz
- 10GHz sensitive to precip



www.eorc.jaxa.jp/TRMM/about/purpose/concept_j.htm

Topics

Clouds over ocean in high latitudes - SSMIS

1 screening in cold-air outbreak regions

2 permittivity model and super-cooled liquid water

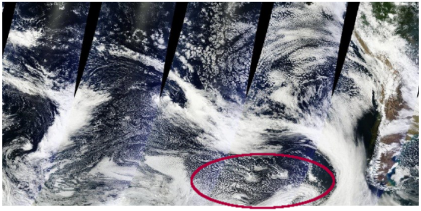
3 regions with low water vapour

Precipitation over ocean in the tropics - TMI

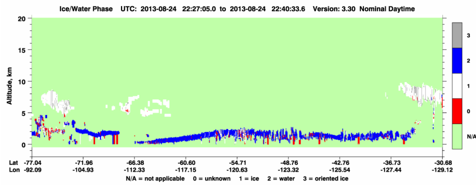
4 usage of low frequency channels

1 Cold-air outbreak (CAO) areas

- cold air is advected over relatively warm surface
- unstable conditions
- broken cloud fields with (super)-cooled liquid water
- occurrence: high latitudes



Composite MODIS image on 24 August 2013 at 08 Z. The whole area shown spans from 180°W to 60°W and from the equator to 60°S.

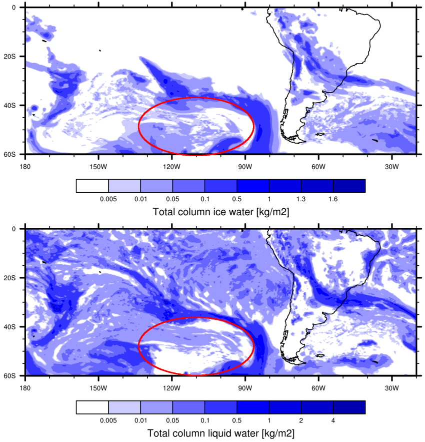


www.calipso.larc.nasa.gov/products/lidar/browse_images/show_dat
30&browse_date=2013-08-24

Model fields in areas of CAO

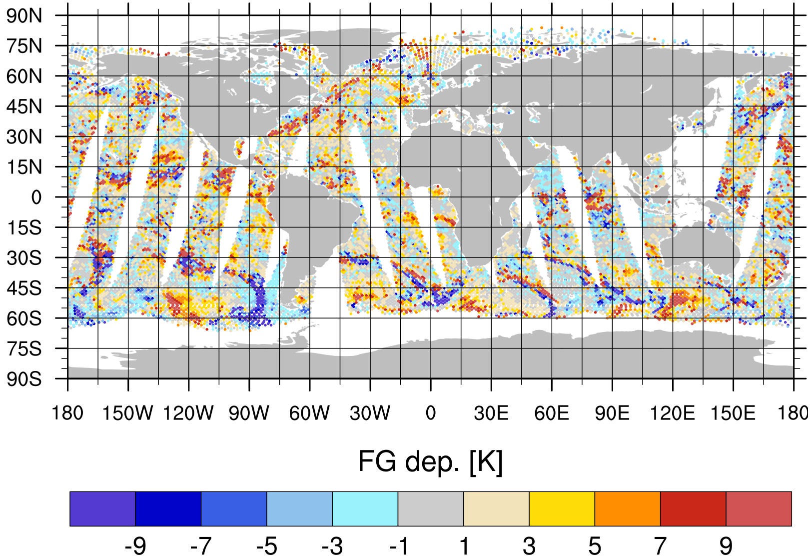
- around 0.1 kg m^{-2} total column ice water
- hardly any liquid water clouds
- observed brightness temperatures > modeled brightness temperatures (positive FG departures)

= sytematic bias in these CAO regions

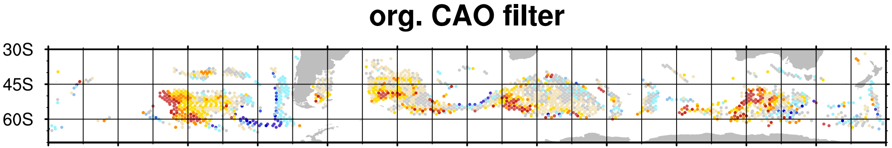


Model fields from cycle 40r2 on 24 August 2013 at 12Z. Top panel: modeled total column ice water [kg m^{-2}]. Bottom panel: modeled total column liquid water [kg m^{-2}].

FG departures



Old Screening



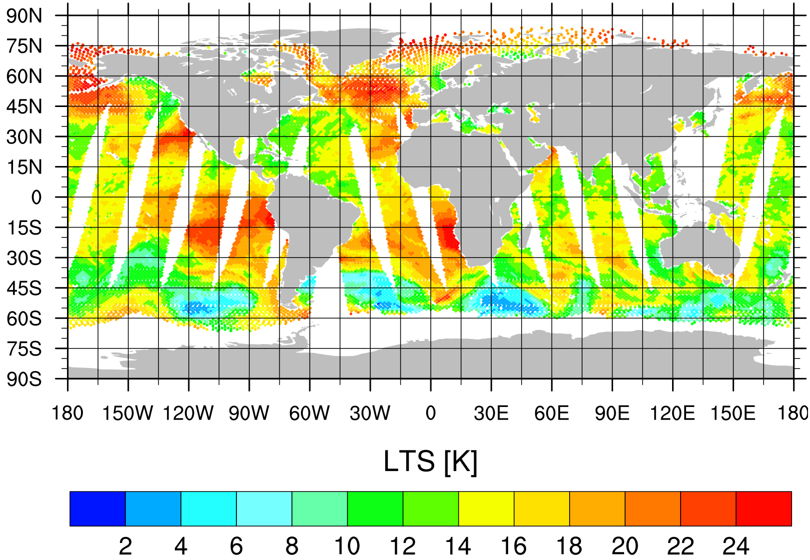
Predictors:

$$\frac{\text{CWP}}{\text{CWP+IWP}} < 0.5$$

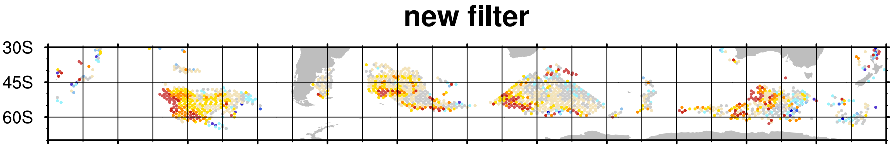
$$\text{TotalWater} > 0.01 \text{kg m}^{-2}$$

$$\text{TCWV} < 15 \text{ kg m}^{-2}$$

Lower tropospheric stability (LTS)



New Screening

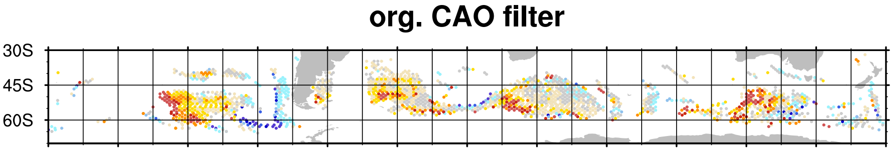


Predictors:

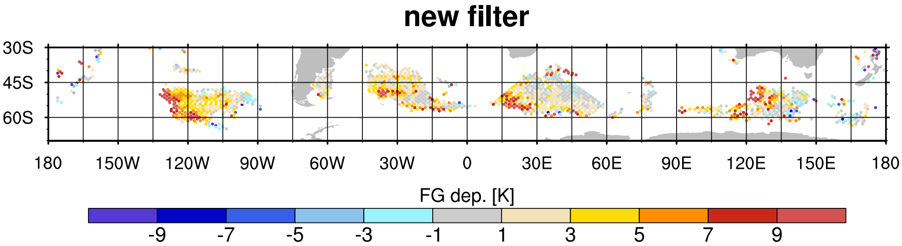
$$\frac{\mathrm{CWP}}{\mathrm{CWP}+\mathrm{IWP}} < 0.5$$

$$\mathrm{LTS} < 12\mathrm{K} \text{ with } \mathrm{LTS} = \Theta_{700\,\mathrm{hPa}} - \Theta_{\mathrm{sfc}}$$

Screening

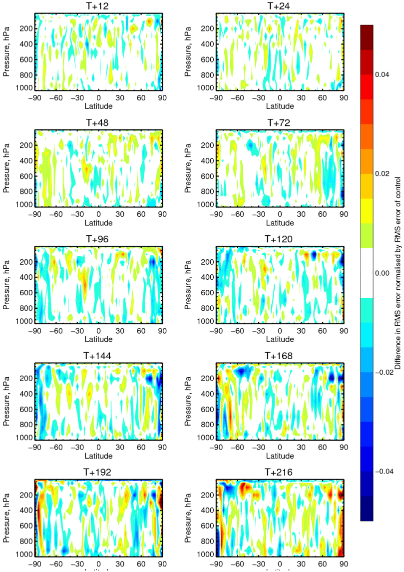


$$\frac{\mathrm{CWP}}{\mathrm{CWP+IWP}} < 0.5 + \mathrm{TotalWater} > 0.01\mathrm{kg\,m^{-2}} + \mathrm{TCWV} < 15\,\mathrm{kg\,m^{-2}}$$

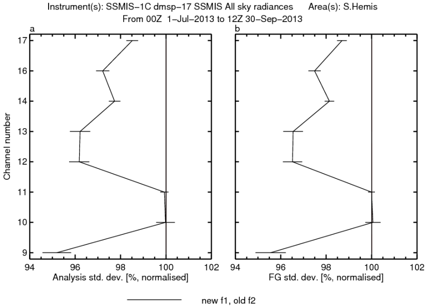


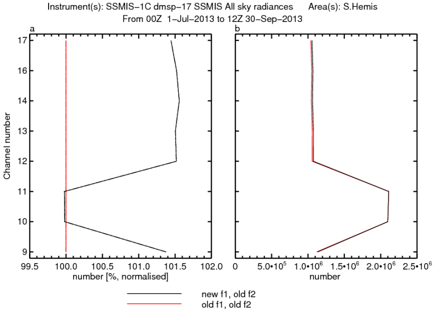
$$\frac{\mathrm{CWP}}{\mathrm{CWP+IWP}} < 0.5 + \mathrm{LTS} < 12\mathrm{K}\ \text{with}\ \mathrm{LTS} = \Theta_{700\,\mathrm{hPa}} - \Theta_{\mathrm{sfc}}$$

Normalised difference in RMSE error: relative humidity



Std. dev. in FG/AN dep. and number of SSMIS data





Summary

1 CAO screening

- New filter uses stability information to identify CAO areas.
- Neutral impact on forecast scores.
- 1.5% more SSMIS data in winter hemisphere.

2 Permittivity

Absolute permittivity ϵ:
is the measure of the resistance that is encountered when forming an electric field in a medium.

$$\epsilon = \epsilon_r \epsilon_0$$

ϵ_r ... relative permittivity (dielectric constant)
ϵ_0 ... vacuum permittivity

2 Permittivity

Absolute permittivity ϵ:
is the measure of the resistance that is encountered when forming an electric field in a medium.

$$\epsilon = \epsilon_r \epsilon_0$$

ϵ_r ... relative permittivity (dielectric constant)
ϵ_0 ... vacuum permittivity

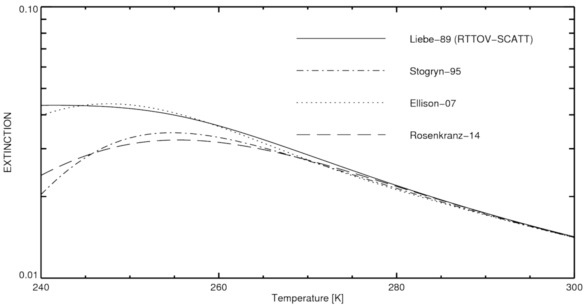
Absorption (and hence extinction) of clouds depends on volume fraction of cloud liquid water, speed of light and **relative permittivity of liquid water**.

Relative permittivity of water depends on **frequency** and **temperature**.

Permittivity - Supercooled liquid water

- supercooled liquid water = water below 0°C
- liquid water absorption below 0°C not well known due to missing laboratory experiments

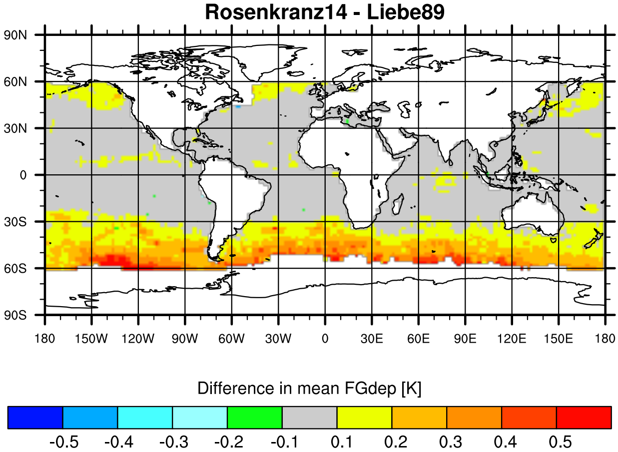
⇒ absorption models differ quite a lot, especially for frequencies between 10 - 1000 GHz



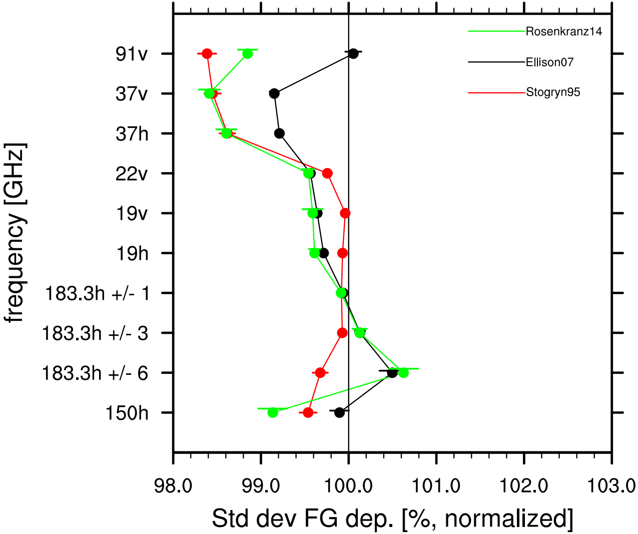
Mean FG dep. - SSMIS 37vGHz

different permittivity models

- Liebe (1989)
- Stogryn (1995)
- Ellison (2007)
- Rosenkranz (2014)
  new MW measurements [e.g. Cadeddu and Turner (2011), Kneiffel et al. (2014)]



normalised std. dev. FG dep. - SSMIS



Summary

2 Permittivity model

- Permittivity models disagree for supercooled liquid water
- Small impact on mean FG dep. small variations in the spread of FG dep.

3 Regions with low water vapour

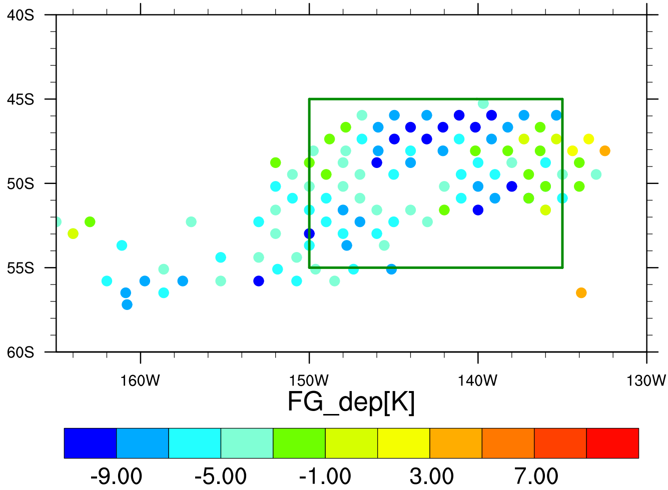
Motivation

- Degraded temperature scores in SH winter were caused by negative temperature increments of 5 - 10 K in cycle 37r3 (2011)
- Analysis increments occurred over ocean in regions with low water vapour and low wind speed [RD Memo by Geer (2011)].
- Increments come from all-sky assimialtion of MWI when departures are negative (model has too much liquid water).

Methodology

1. Select region over ocean with large negative FG departures under conditions with low water vapour in SH.
2. Assimilate these MWI observations only (only SSMIS-F17, no sounding channels, no land).
3. Investigate how temperature and TCWV field change at the beginning of the assimiation window.

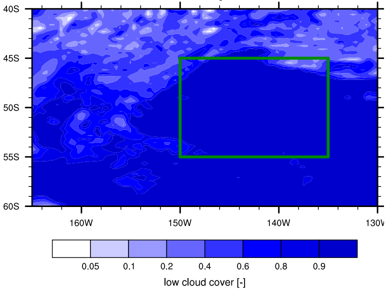
Region of interest

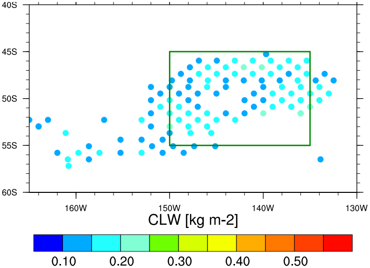


$$\mathrm{TCWV} < 8\,\mathrm{kg\,m^{-2}} + \mathrm{CWP} > 0.1\,\mathrm{kg\,m^{-2}} + \mathrm{wind} < 10\,\mathrm{m\,s^{-1}}$$

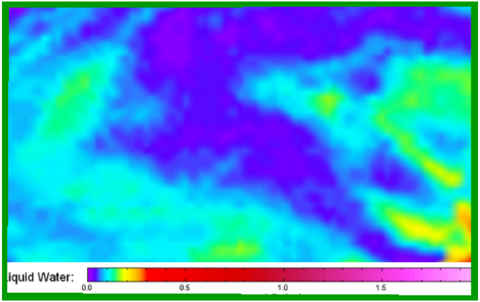
Model - Observations

modeled liquid water

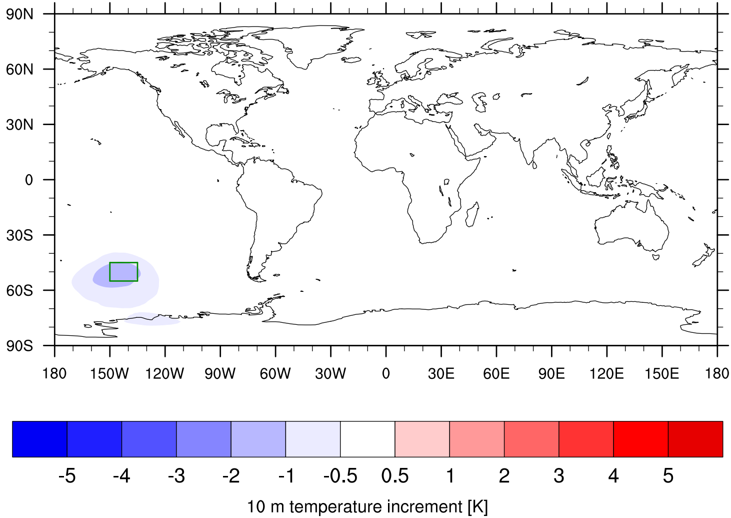




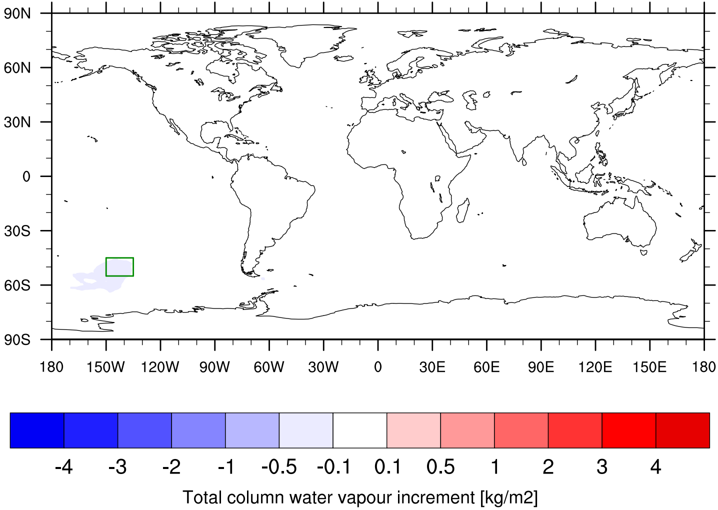
observed liquid water



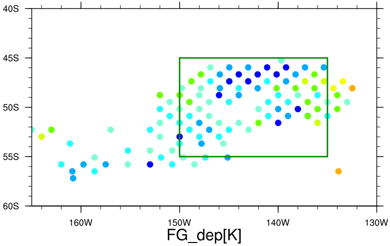
Temperature increment

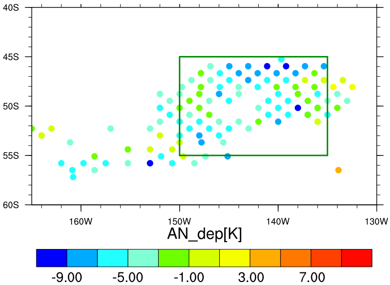


Humidity increment



Departures


40S
45S
50S
55S
60S
160W
150W
140W
130W
FG_dep[K]


40S
45S
50S
55S
60S
160W
150W
140W
130W
AN_dep[K]
-9.00
-5.00
-1.00
3.00
7.00

Summary

3 Regions with low water vapour

- Brightness temperatures are adjusted through reductions in temperature instead of TCWV.
- Further investigation necessary.

4 Low frequency channels

Current use of precipitation influenced MW obs:

All-sky microwave humidity radiances

- 183 GHz channels on SSMIS and MHS
- since 2012 [Geer et al. 2014, ECMWF Newsletter 140]

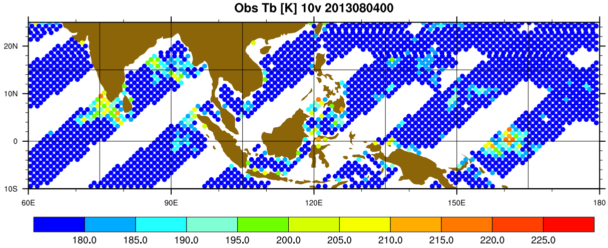
All-sky microwave imager radiances

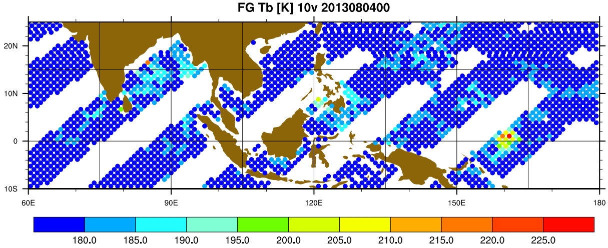
- 19 – 90 GHz channels from SSMIS and TMI
- since 2009 [Bauer et al. 2010, QJRMS]

Possible future use of precipitation influenced MW obs:

- 10 GHz channels on (TMI) GMI

Location of tropical precipitation



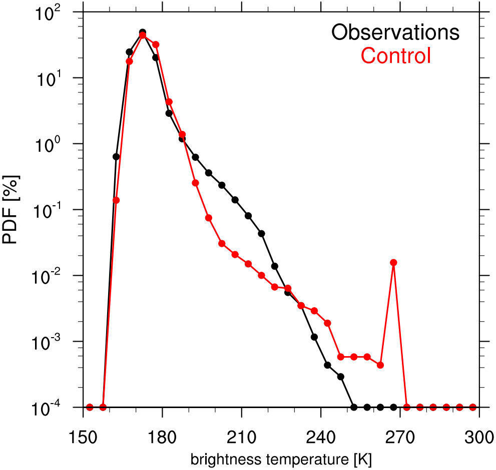


model resolution:
40 km x 40 km (T511)

4 August 2013

Sensitivity studies on intensity of tropical precipitation

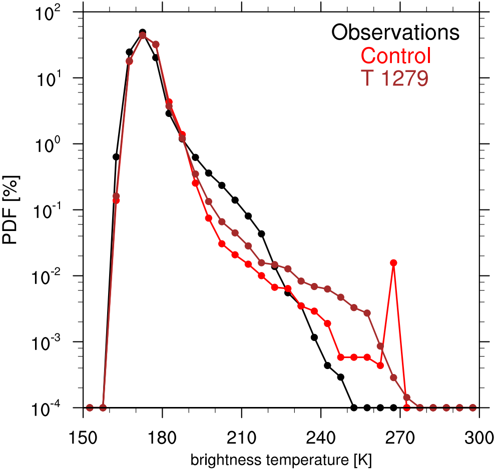
model resolution: 40 km x 40 km (T511)
data between 30S and 30N, August 2013



- What is the impact of model resolution?
- What is the influence of modifications in the observation operator?
- How crucial is superobbing and data filtering?

Impact of model resolution

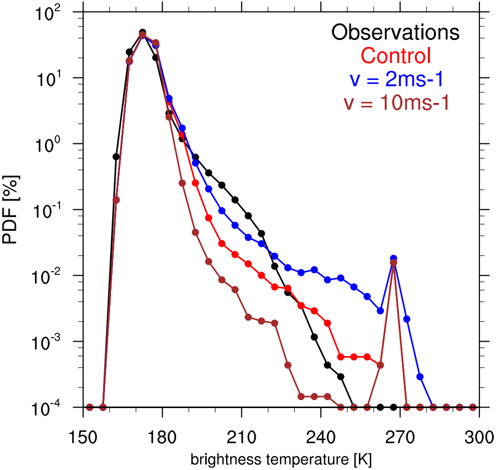
model resolution: 40 km x 40 km (T511) and 16 km x 16 km (T1279)
data between 30S and 30N, August 2013



- What is the impact of model resolution?
  - ⇒ Number of high brightness temperatures increases.
- spatial resolution in 10 GHz: 72 km x 43 km

Impact modification to fall speed parameterization

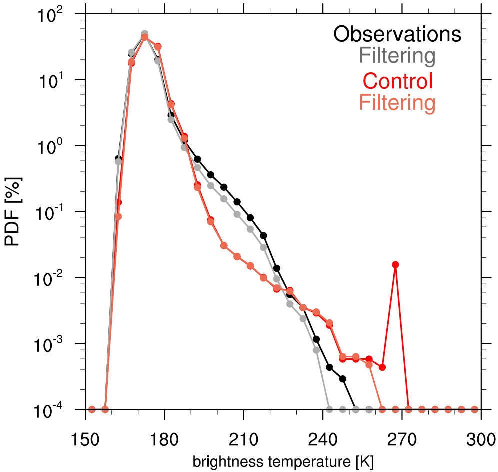
model resolution: 40 km x 40 km (T511)
data between 30S and 30N, August 2013



- What is the influence of modifications in the observation operator?
  - ⇒ Assuming lower fall velocities of drops increases number of high brightness temperatures.

Data filtering

model resolution: 40 km x 40 km (T511)
data between 30S and 30N, 1 - 4 August 2013



- How crucial is filtering?
  - ⇒ Careful data filtering of land-contaminated observations is important!

Summary

4 Usage of low frequency channels

- Filtering of land-contaminated observations is most crucial.
- Need for better land-sea mask.

Summary

1 CAO screening

- New filter uses stability information to identify CAO areas.
- Neutral impact on forecast scores
- 1.5% more SSMIS data in winter hemisphere.

2 Permittivity model

- Permittivity models disagree for supercooled liquid water
- Small impact on mean FG dep. small variations in the spread of FG dep.

3 Regions with low water vapour

- Brightness temperatures are adjusted through reductions in temperature instead of TCWV.
- Further investigation necessary.

4 Usage of low frequency channels

- Filtering of land-contaminated observations is most crucial.
- Need for better land-sea mask.