All-sky observations: errors, biases, representativeness and gaussianity

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Thanks to: Bill Bell, Niels Bormann, Anne Fouillioux, Jan Haseler, Tony McNally

ECMWF

Assimilation of cloud and precipitation affected microwave radiances at ECMWF

- Microwave imagers, e.g. SSM/I, SSMIS, TMI, AMSR-E
  - Radiances are sensitive to humidity, cloud, precipitation, and the ocean surface
- 1D+4D-Var of cloud and precipitation-affected microwave imagers from June 2005
- All-sky assimilation of radiances directly into 4D-Var from March 2009
  - All-sky = clear, cloudy and precipitating conditions together (no cloud-clearing)
  - Cloud and precipitation are part of the 4D-Var minimisation
  - Increased weight of observations for summer 2010 (revised observation errors and quality control)
- All-sky 4D-Var microwave sounder (AMSU-A) radiances in testing

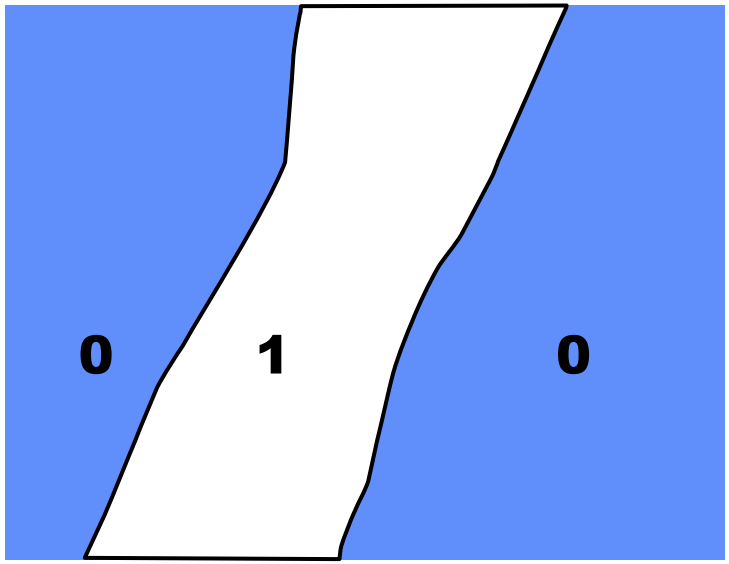
Introduction

- Adding cloud / precip observations to an operational system needs:
  - Neutral or improved medium-range forecast scores
  - Improved fits to other observations in analysis and first guess
  - (Fast computational speed)
- To achieve this:
  - Appropriate background and observation errors
  - Gaussian error statistics
  - Linearity of models (Philippe Lopez's talk)
  - Quality control
  - Representativeness of observations and model
  - Bias correction

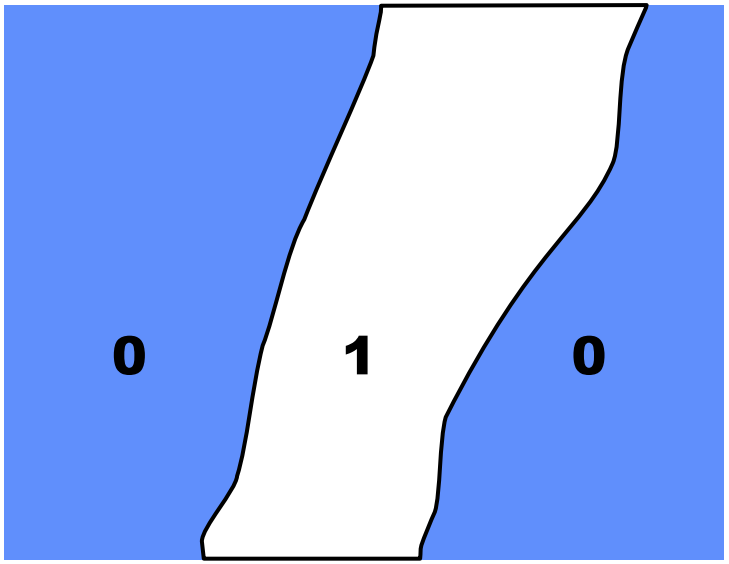
Observation errors and cloud sampling

Sampling

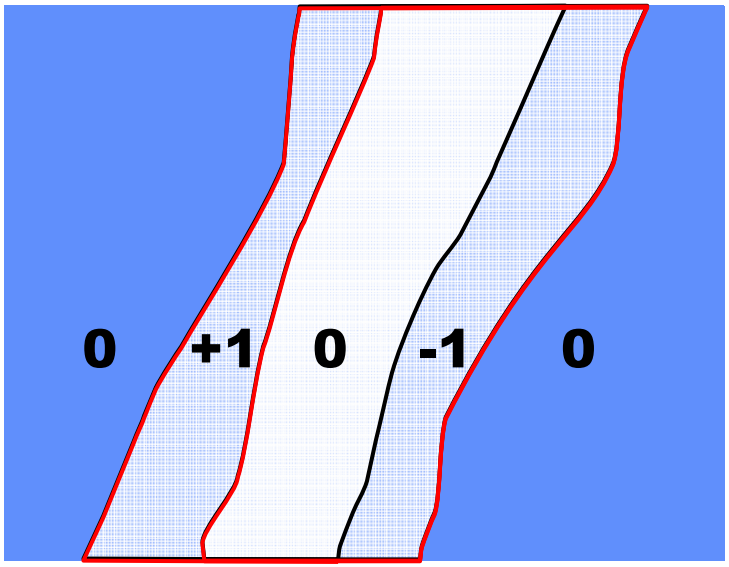
Observation (Obs)



First guess (FG)

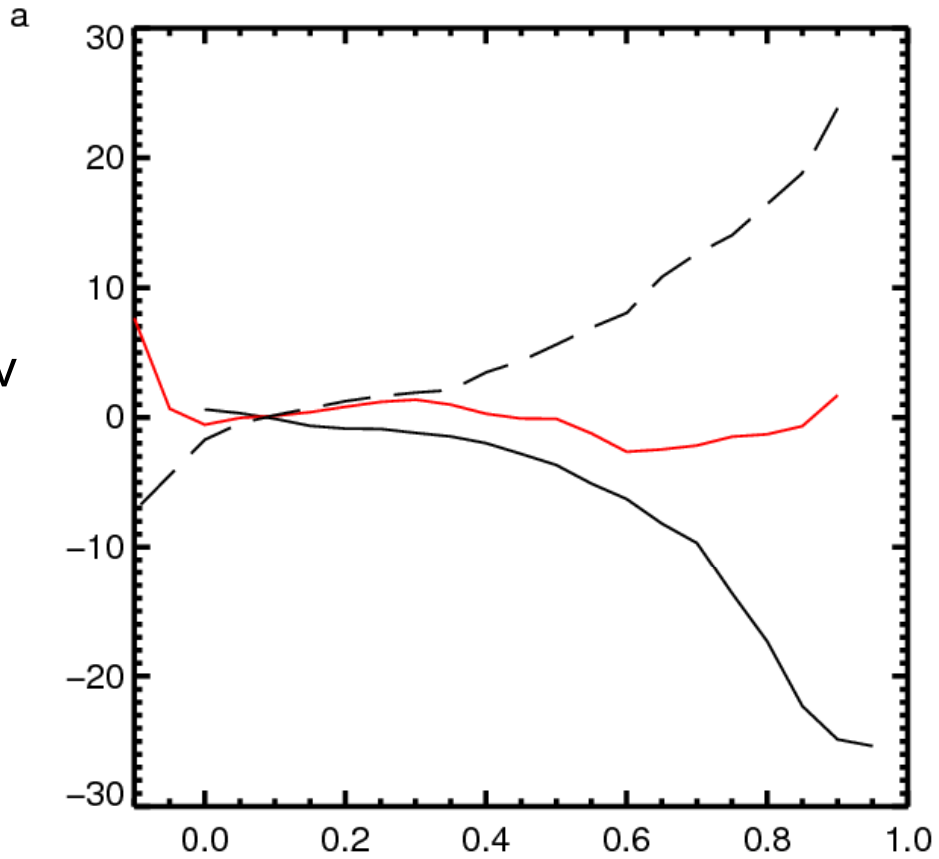


Obs - FG



All-sky SSM/I first guess departures

Mean channel 19v departures [K]



Cloud amount
derived from 37GHz radiances

as a function of observed cloud

as a function of mean of observed and forecast cloud

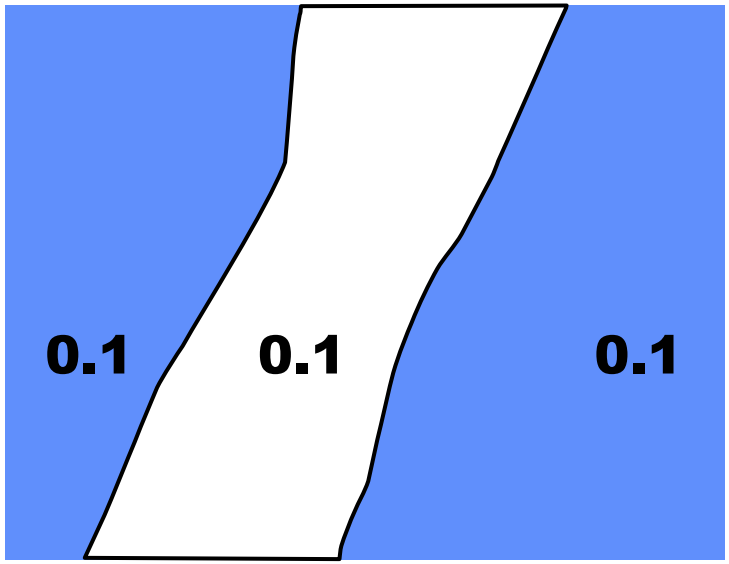
as a function of forecast cloud

Symmetry in all-sky assimilation

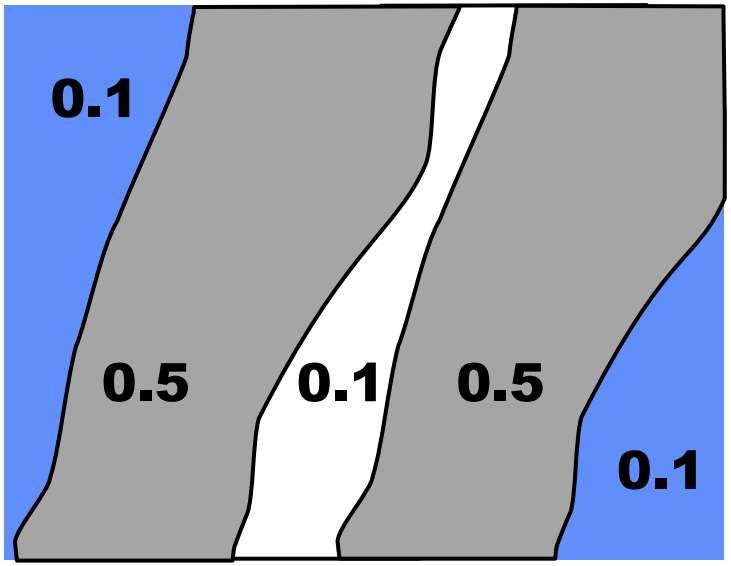
- Any property in a data assimilation system that varies as a function of cloud or rain may lead to “asymmetric” sampling errors
- Bias correction as a function of observed cloud
  - Never enough model cloud when cloud is observed
- Observation error as a function of observed cloud amount
  - Will “lock in” the sampling bias
- ‘Symmetric’ cloud / rain predictors:
  - Mean of observed and first guess cloud
  - Max of observed and first guess cloud
  - Constant error more appropriate for AMSU-A and rain radar

Error standard deviations – in an ideal world

Observation

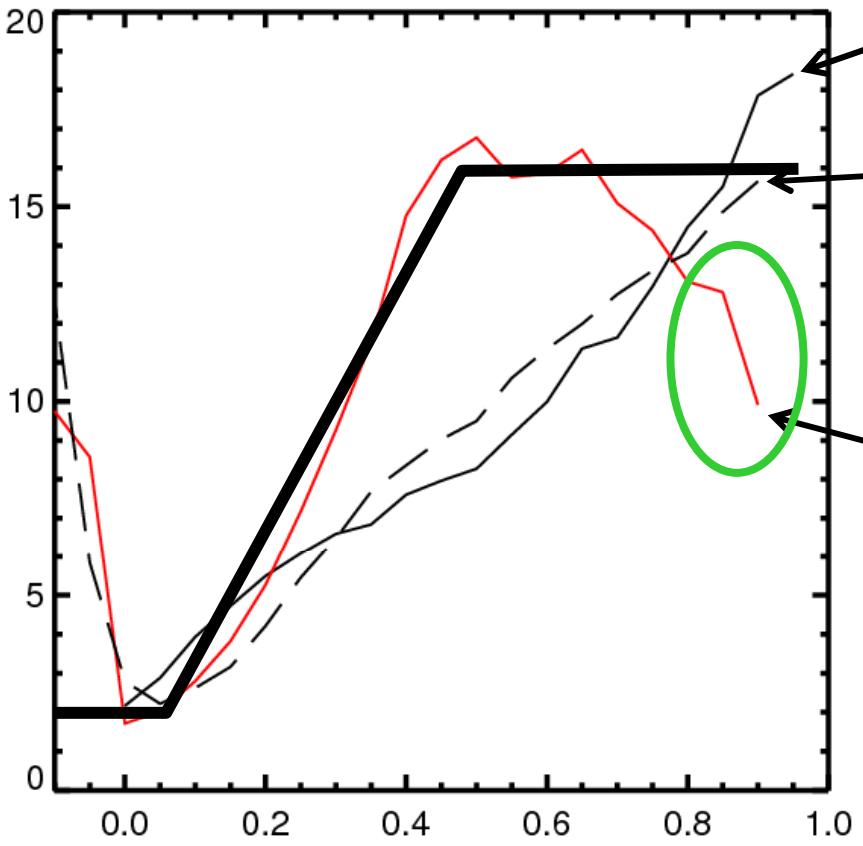


Background



All-sky SSM/I first guess departures

Std. dev. channel 19v departures [K]

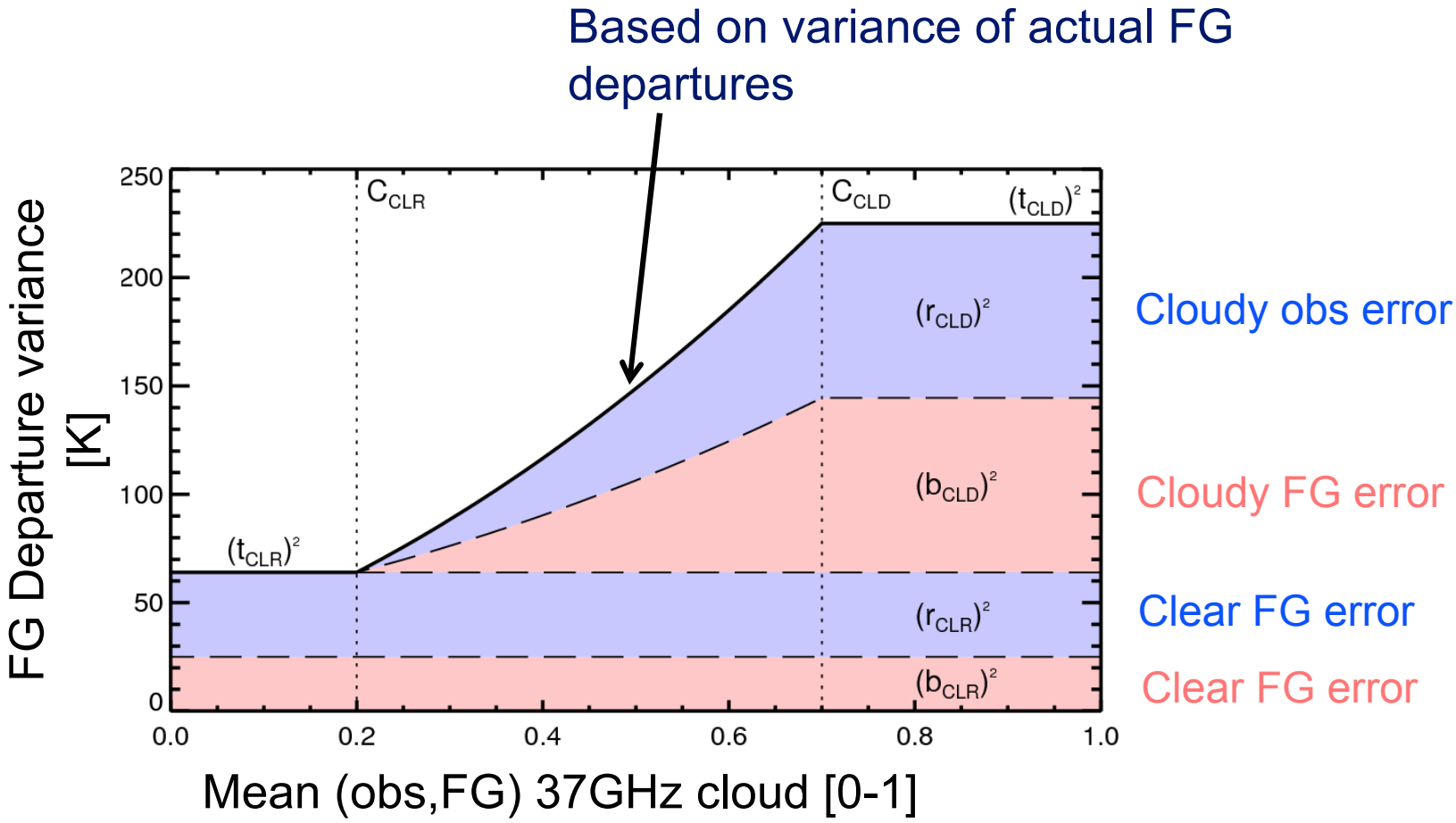


as a function of forecast cloud

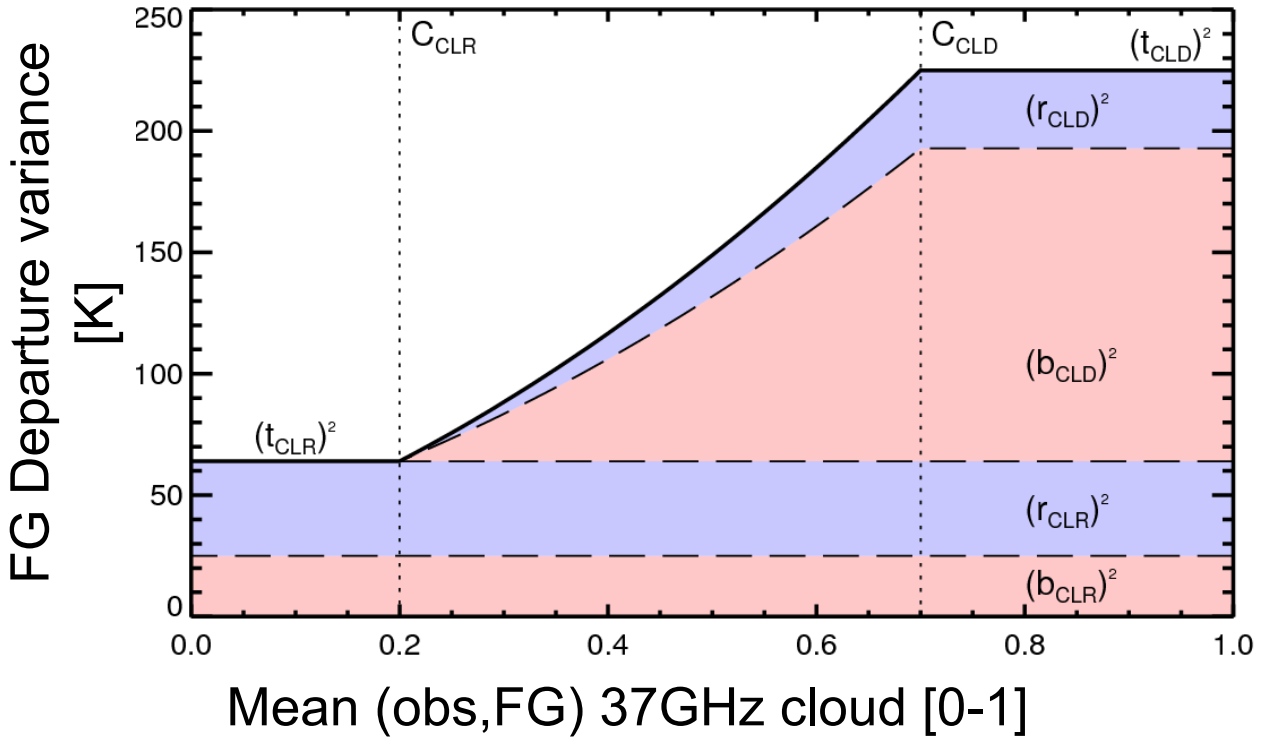
as a function of observed cloud

as a function of mean of observed and forecast cloud

Symmetric model for all-sky observation error



Symmetric model for all-sky observation error



Cloudy obs error

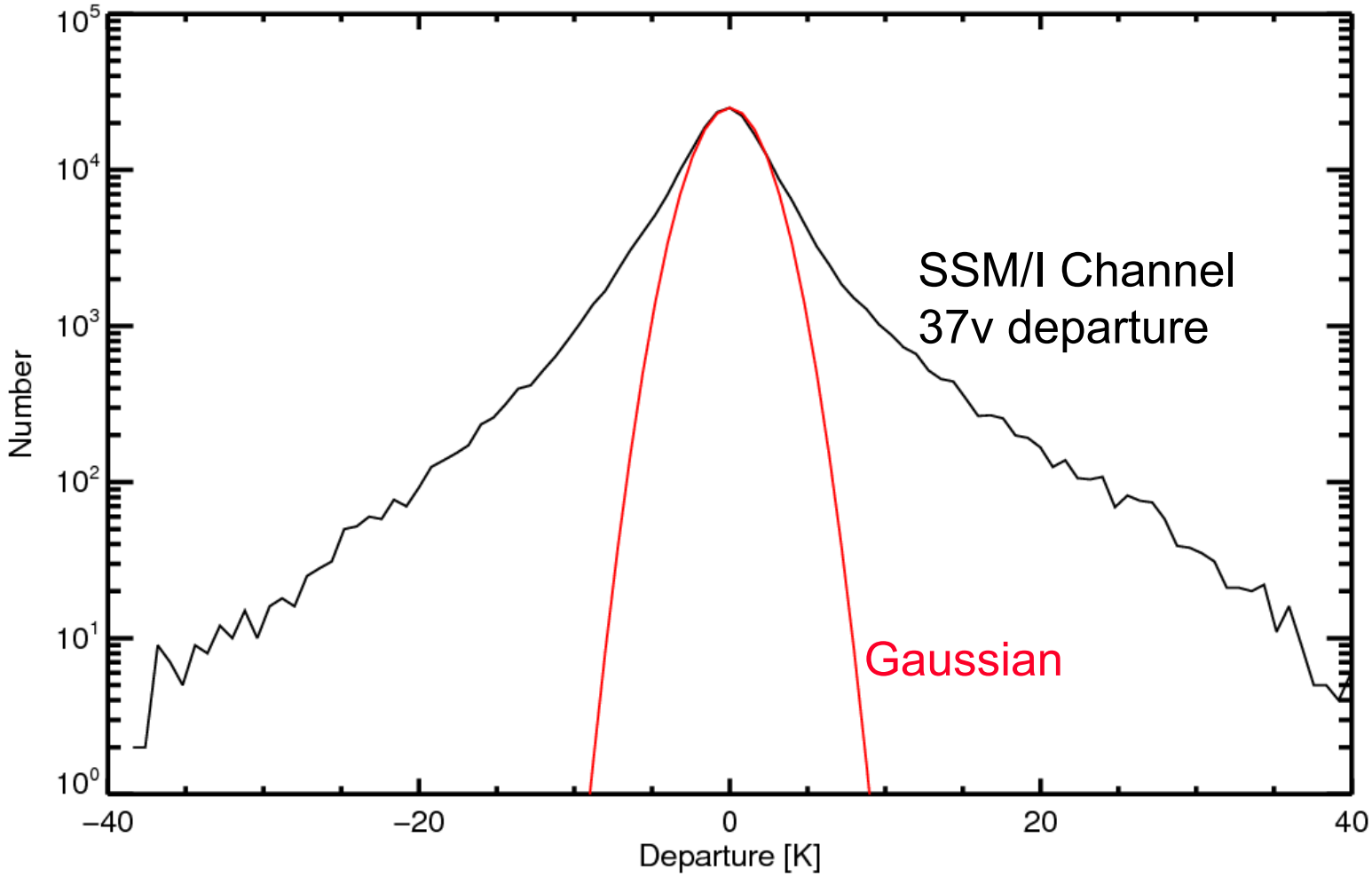
Cloudy FG error

Clear FG error

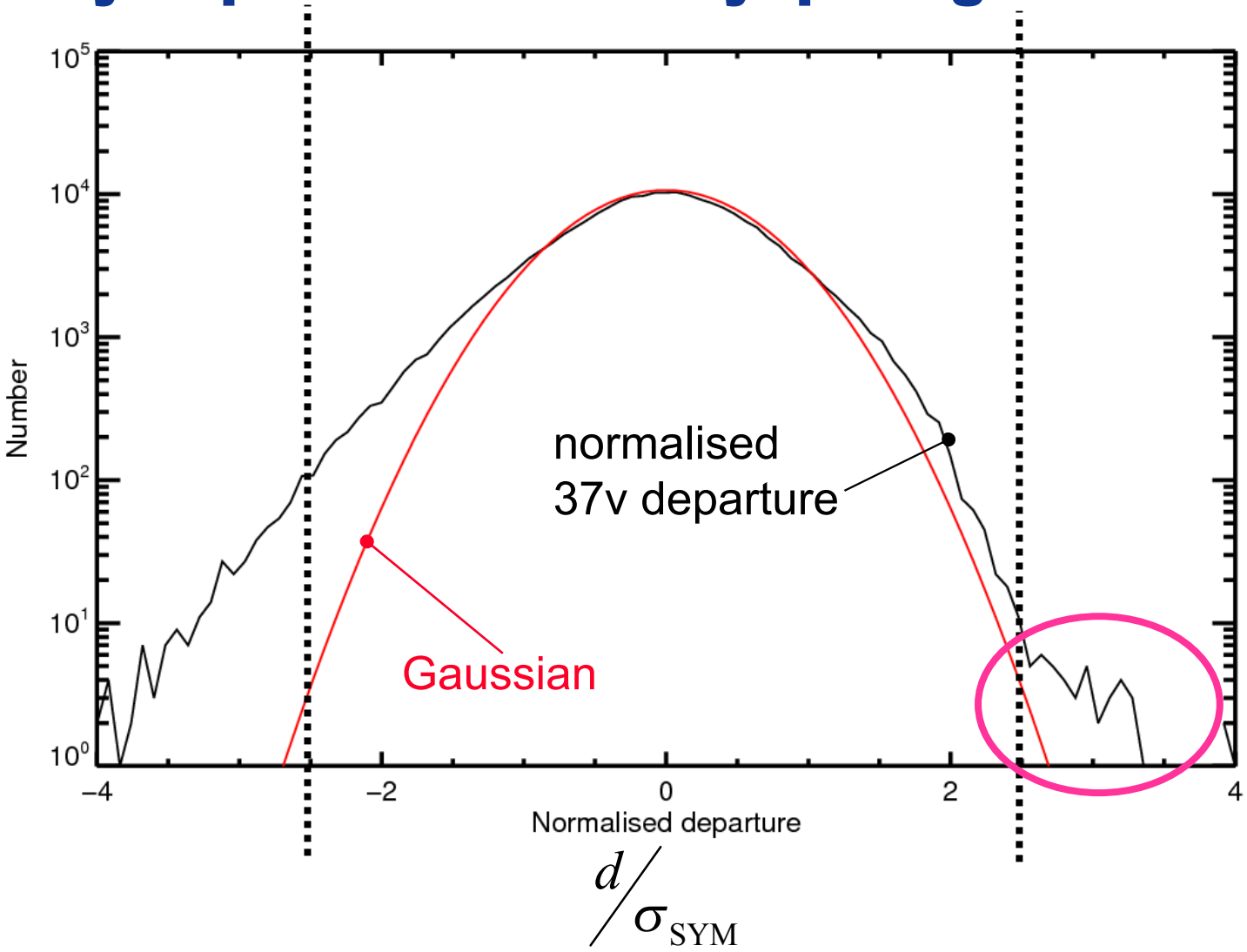
Clear FG error

Useful properties of “symmetric” errors

All-sky departures: not gaussian?

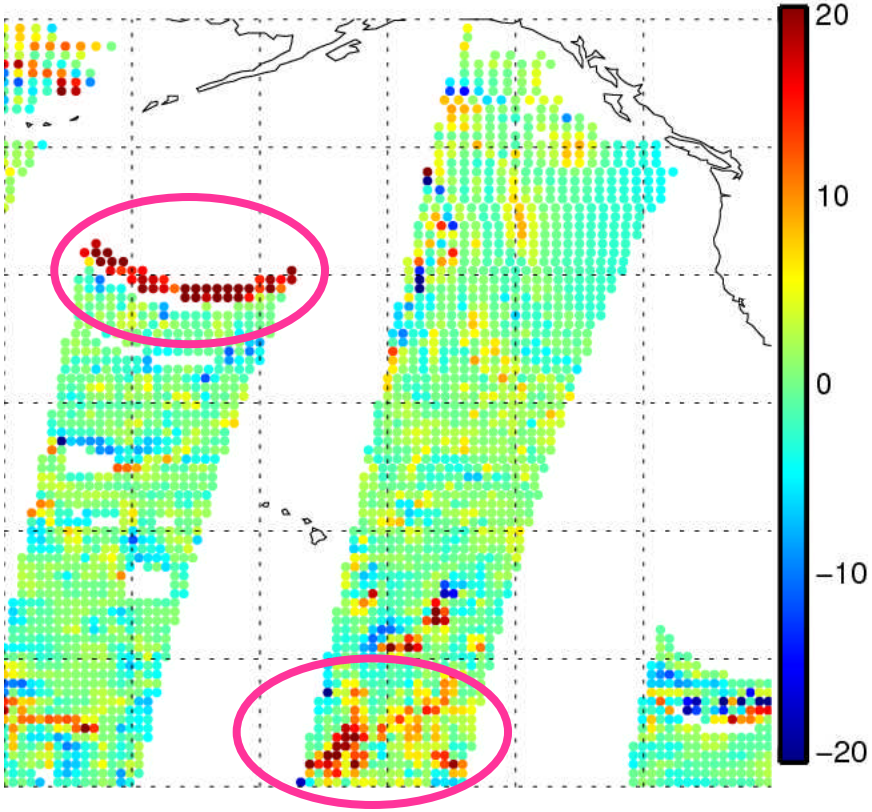


All-sky departures: actually quite gaussian



All-sky 4D-Var departures: QC

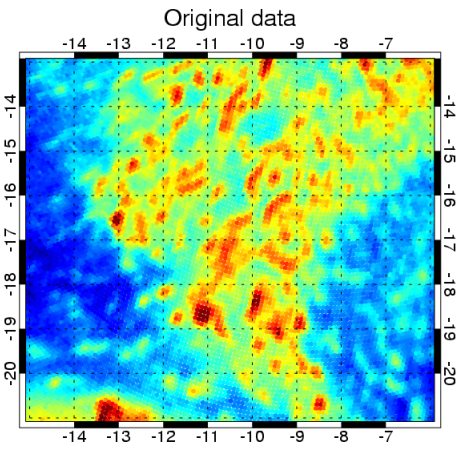
SSM/I 37v departure

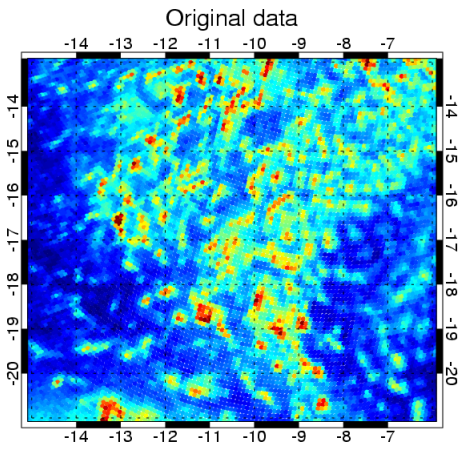


Representativity

19 GHz

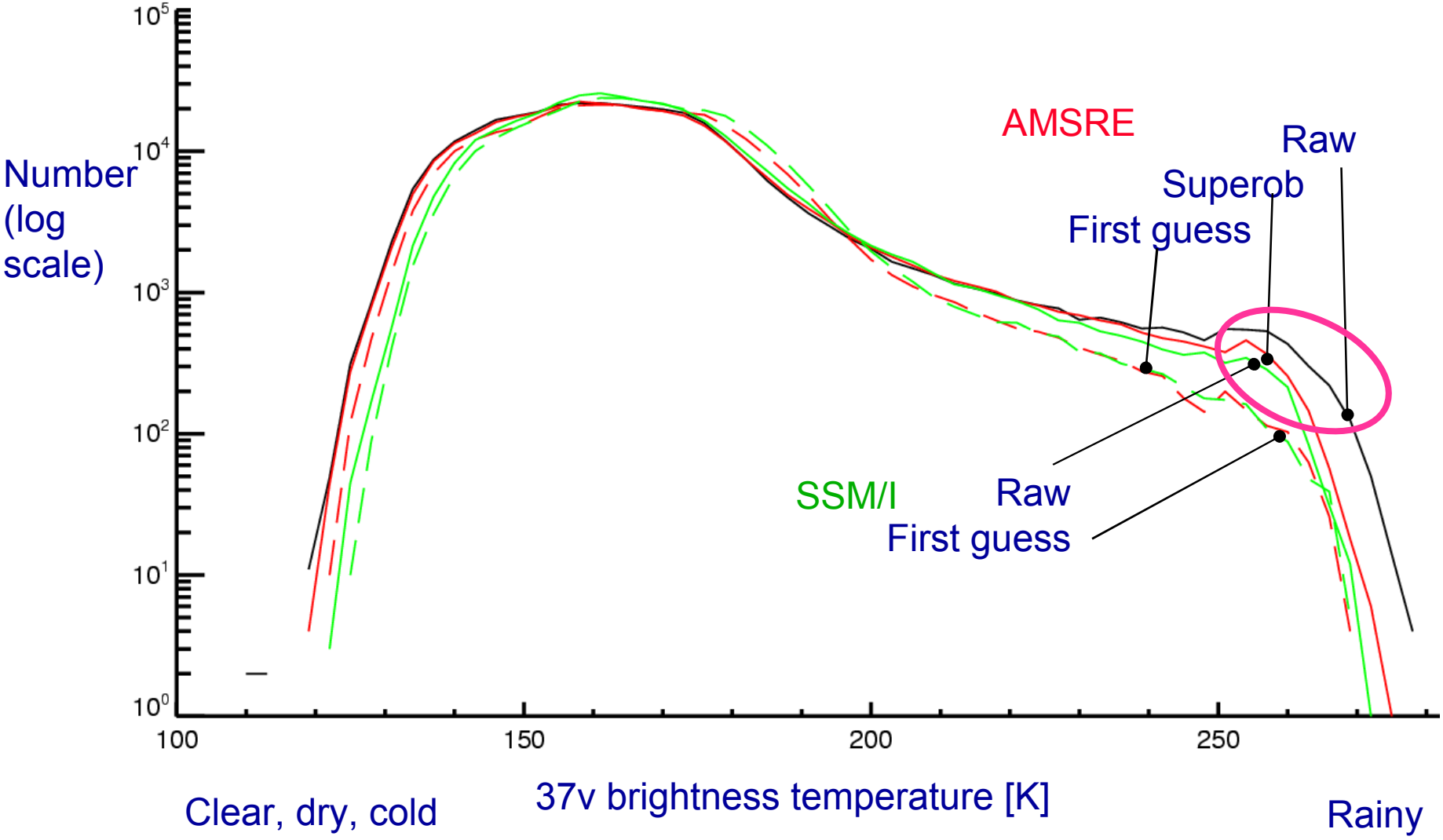
37 GHz





Raw AMSR-E data:
10km by 9km sampling

ECMWF


Number (log scale)
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10^4
10^3
10^2
10^1
10^0
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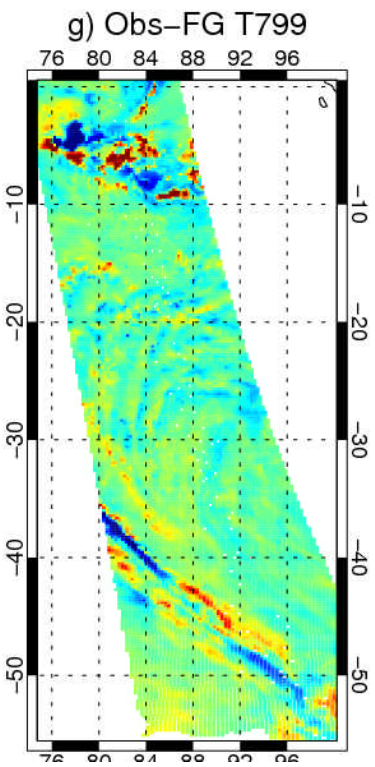
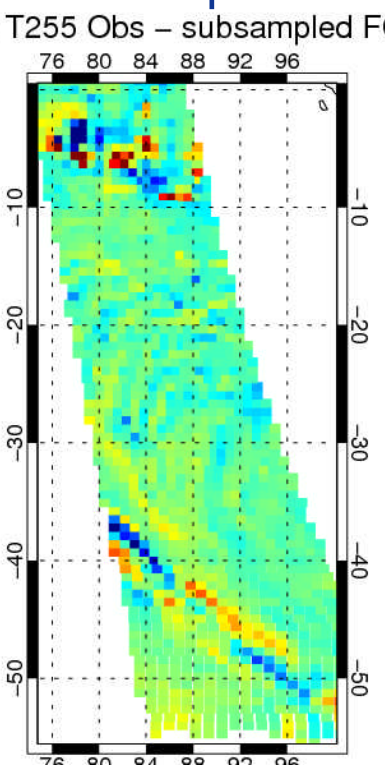
150
200
250
AMSRE
Raw
Superob
First guess
SSM/I
Raw
First guess
Clear, dry, cold
37v brightness temperature [K]
Rainy

Model representativity: saved by ‘effective resolution’ of cloud

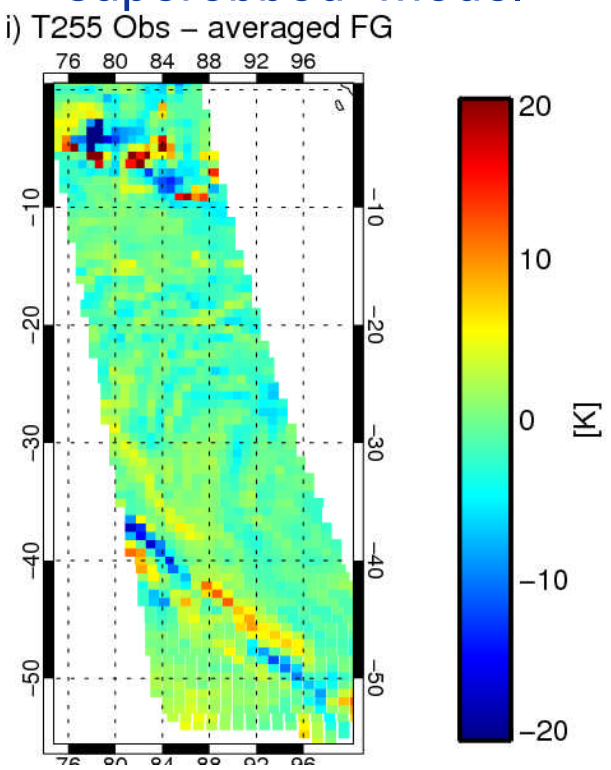
Hires obs – Hires model



Lores obs – subsampled model

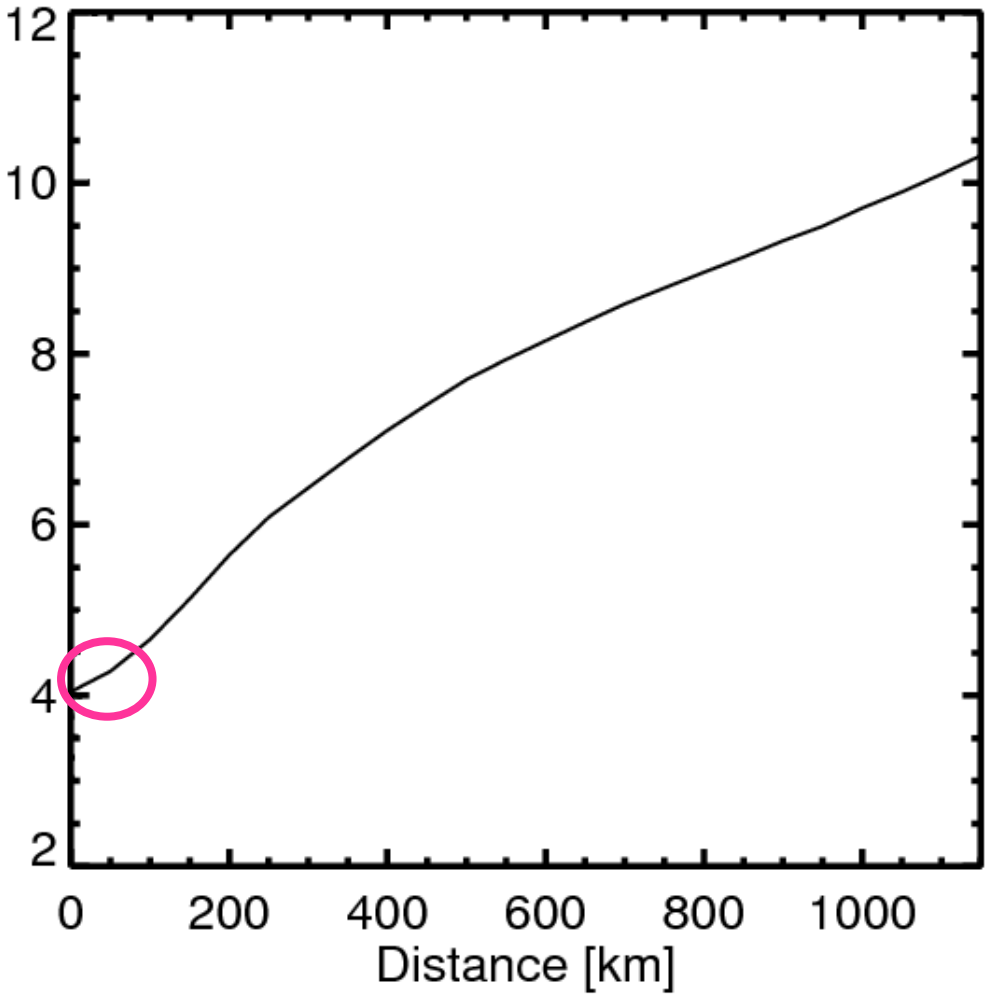


Lores obs – “superobbed” model



Error inflation with colocation distance model vs. observation

Std. dev. channel 19v departures [K]



Representativity - summary

- High-res PDFs (e.g. of precipitation or brightness temperature) are very different to lo-res PDFs
- Subsampling (or use of single observations) is wrong
- High-res observations → lo-res model

- Must spatially average ("superob") observations to appropriate model scale.

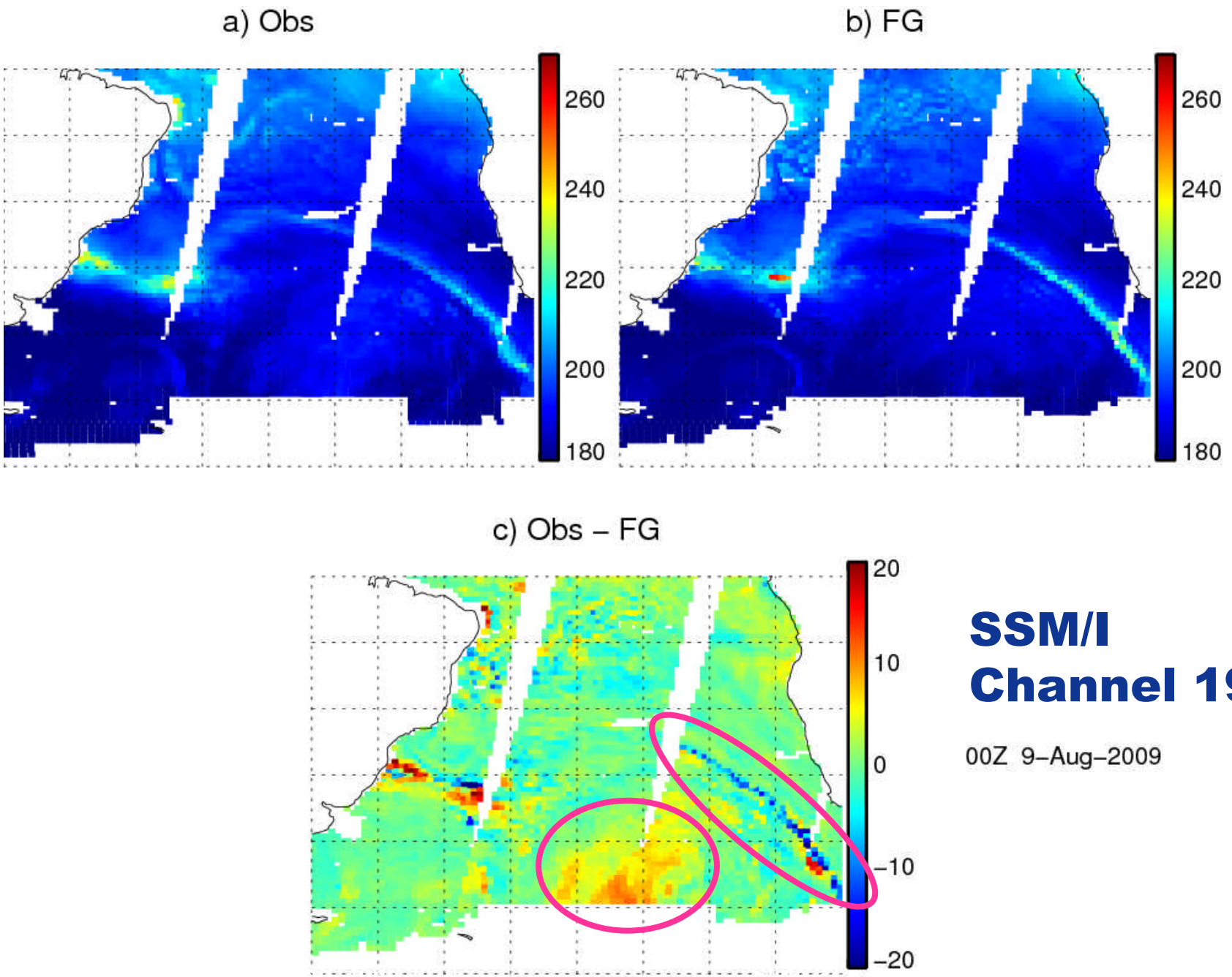
- High-res model → lo-res observation

- Must spatially average ("superob") model to appropriate observation scale
- But in practice, model cloud and FG error scales are much coarser than nominal resolution
    - So it's ~OK to subsample.
    - Model vs. observation colocation distance not too important (at least over 100-200km)

- Sub-grid cloud/precip variability

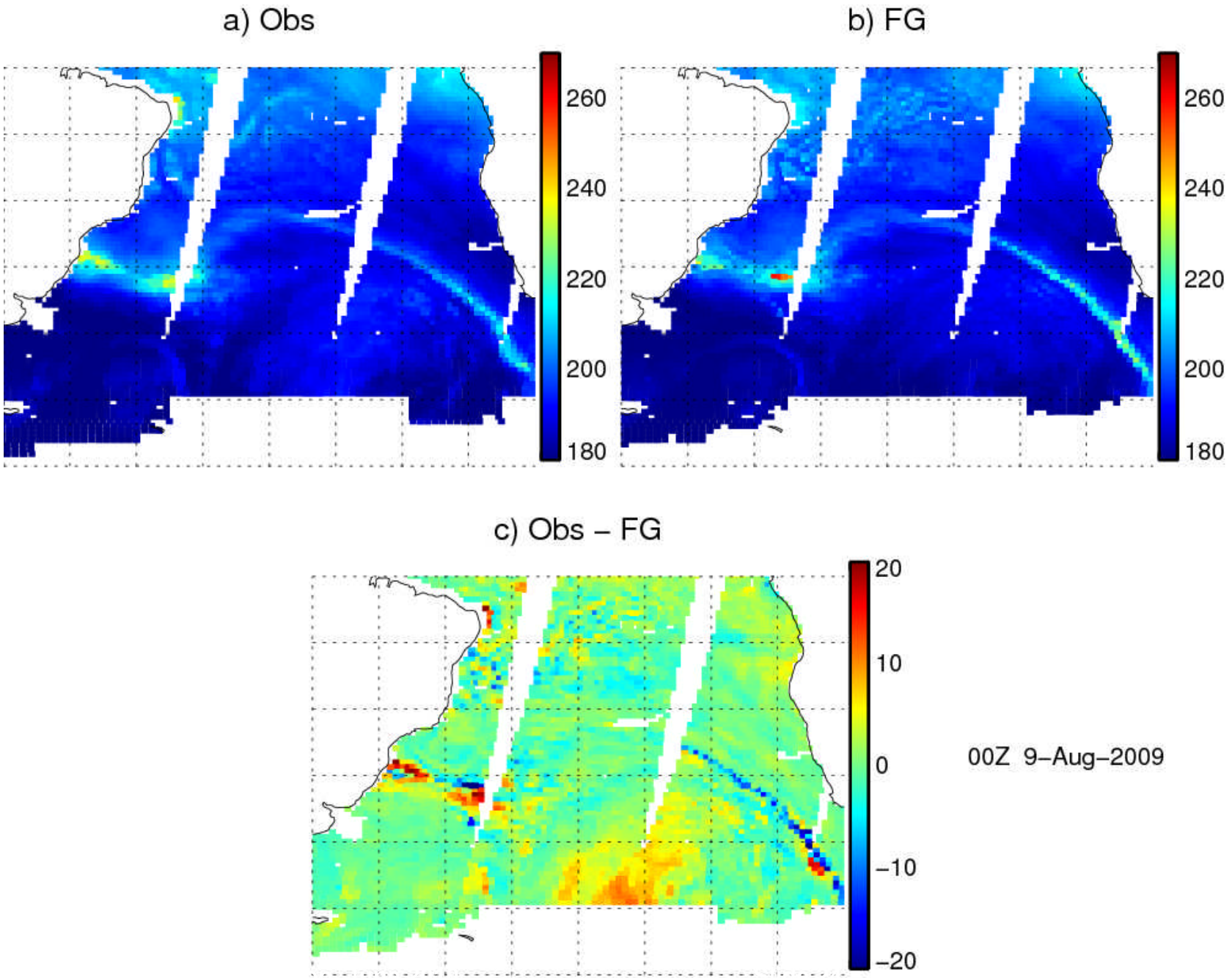
- Well-known issue for moist physics and observation operators

Biases between model and cloud / precipitation affected observations



SSM/I Channel 19v

00Z 9–Aug–2009


a) Obs
b) FG
c) Obs – FG
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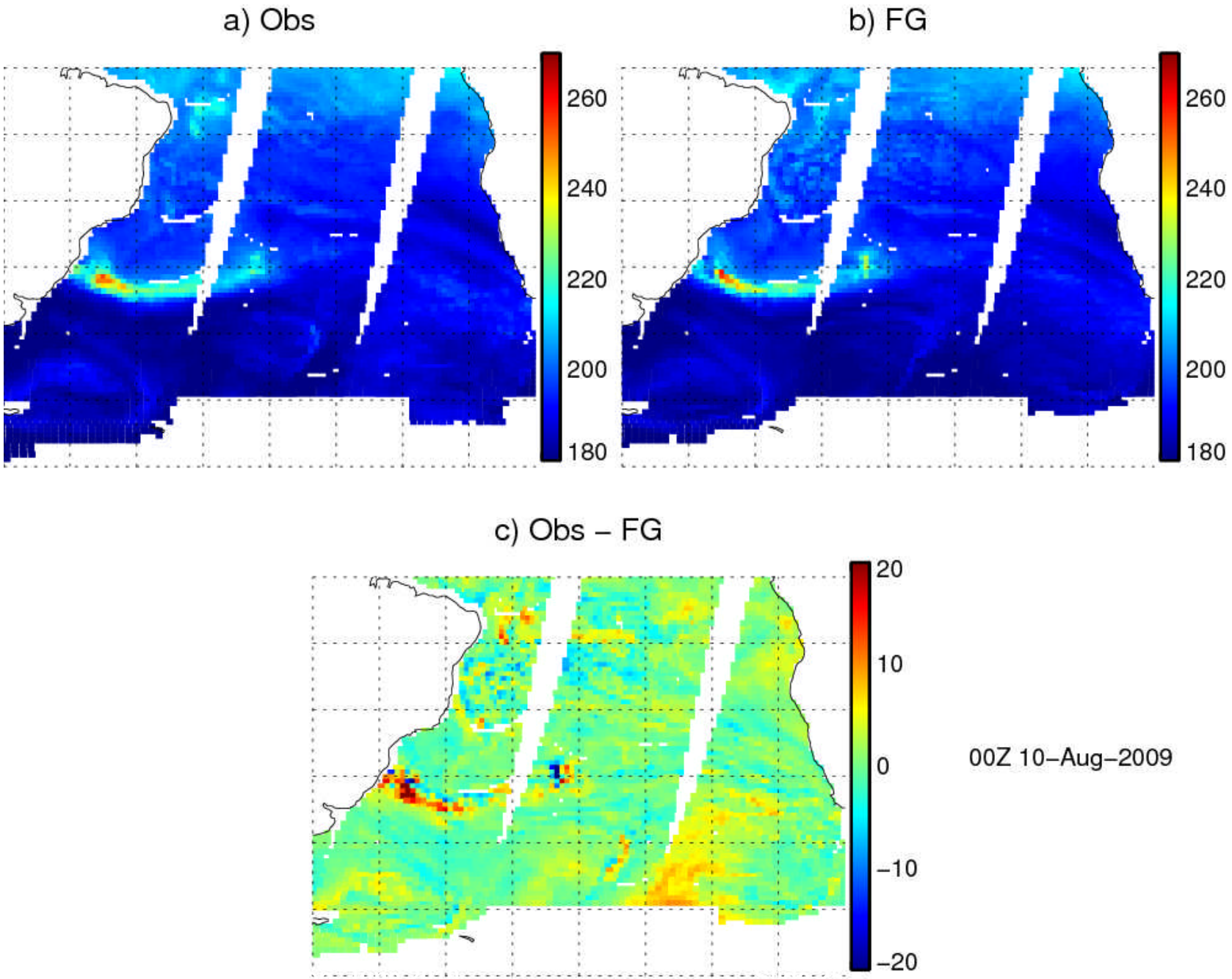
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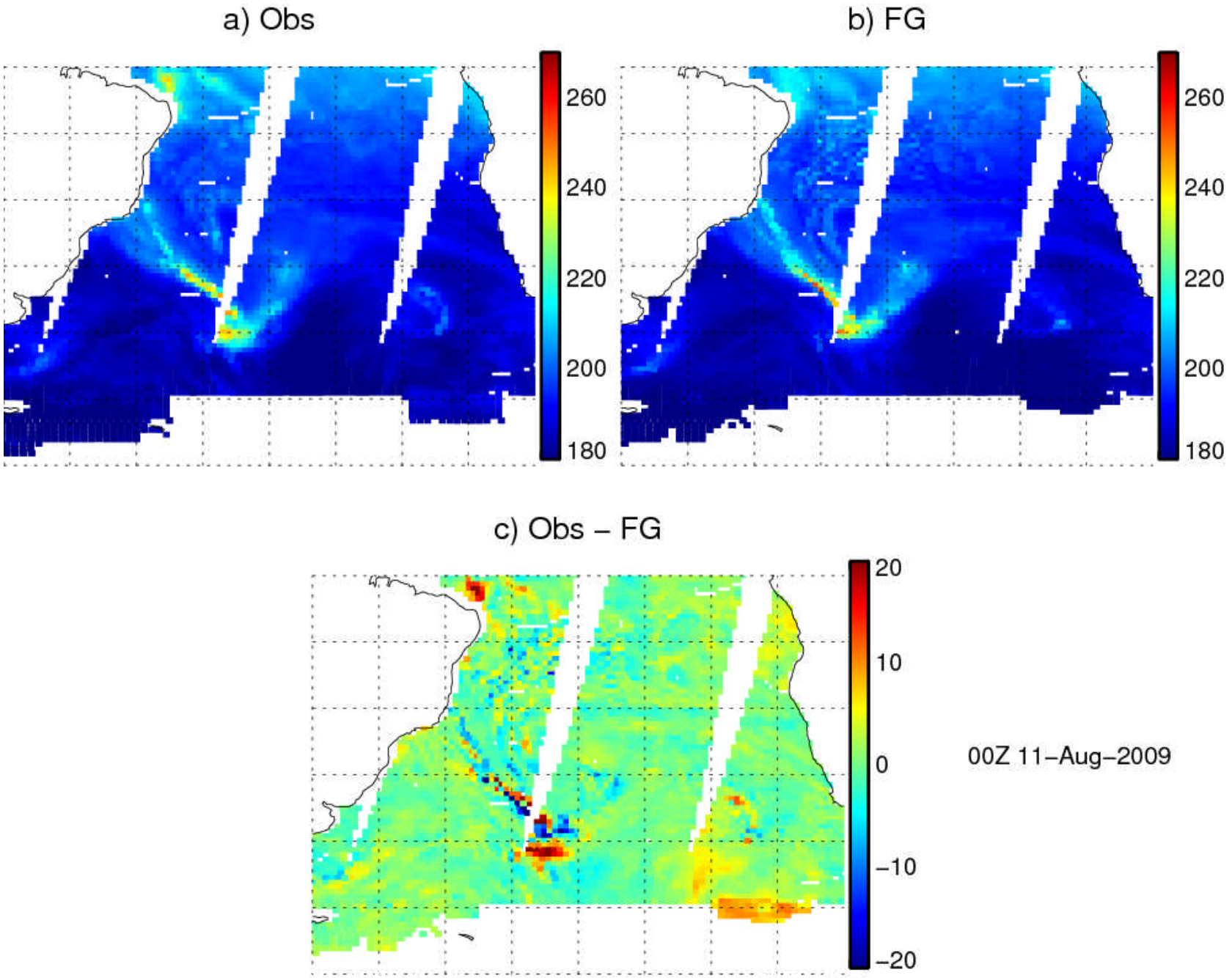
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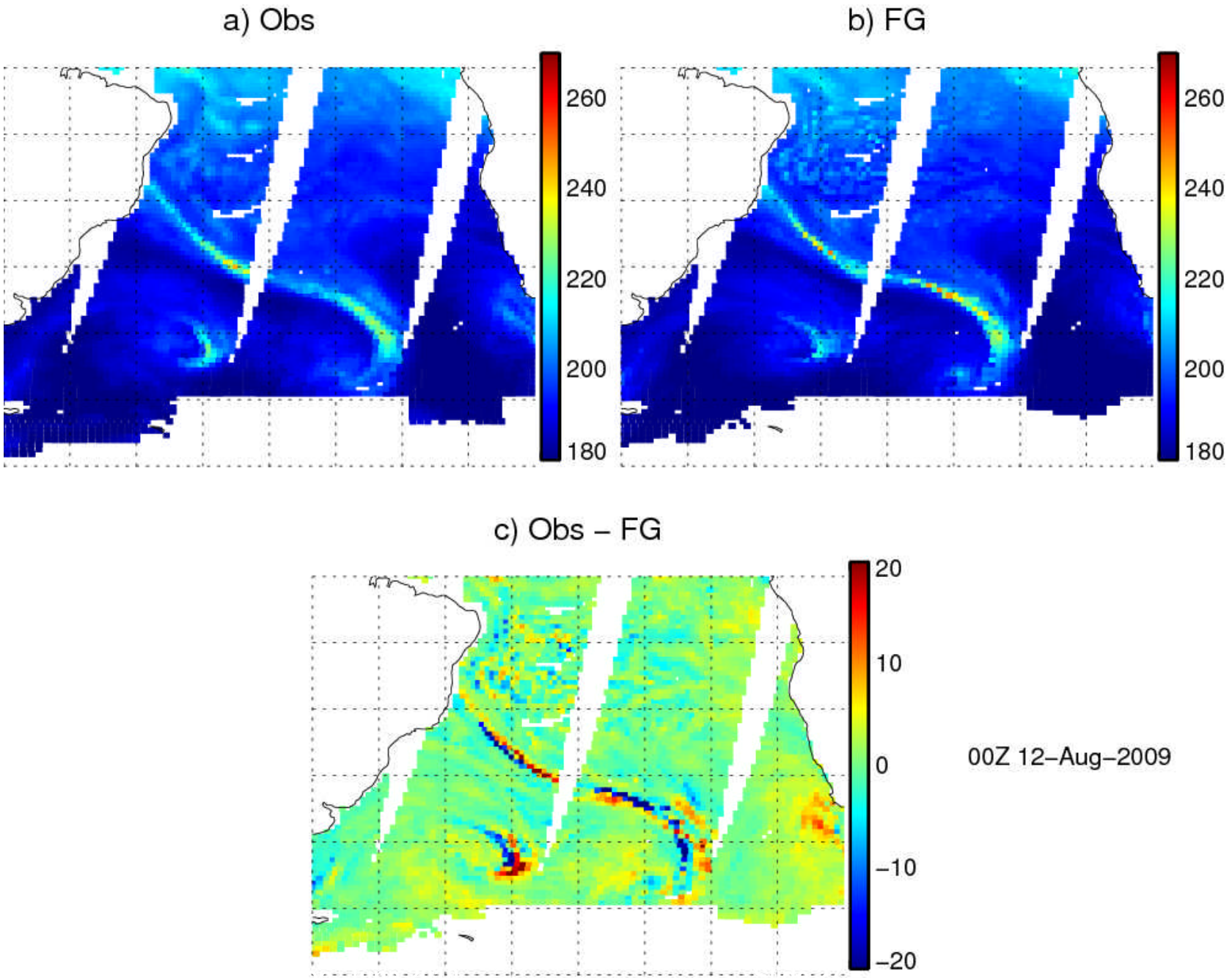
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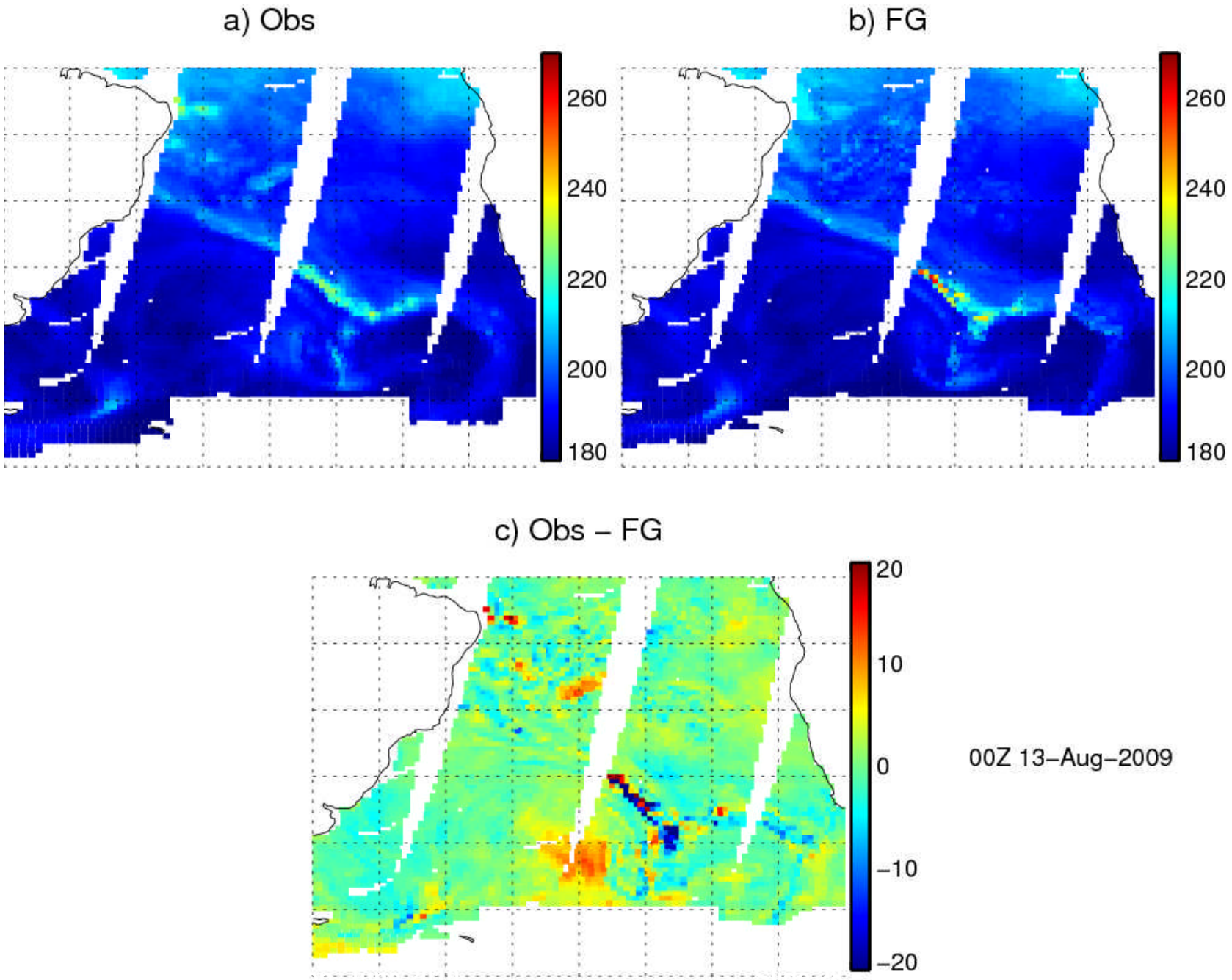
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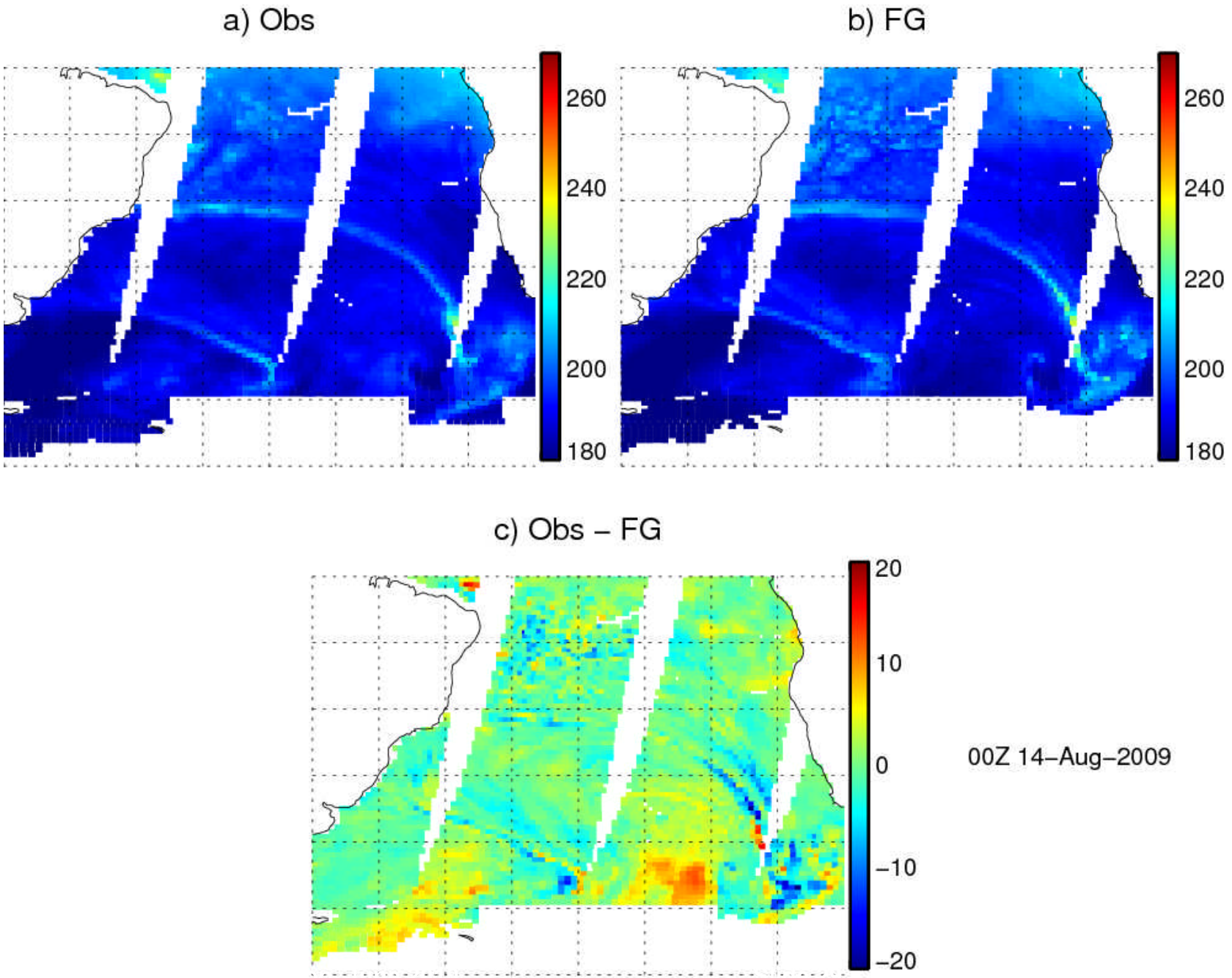
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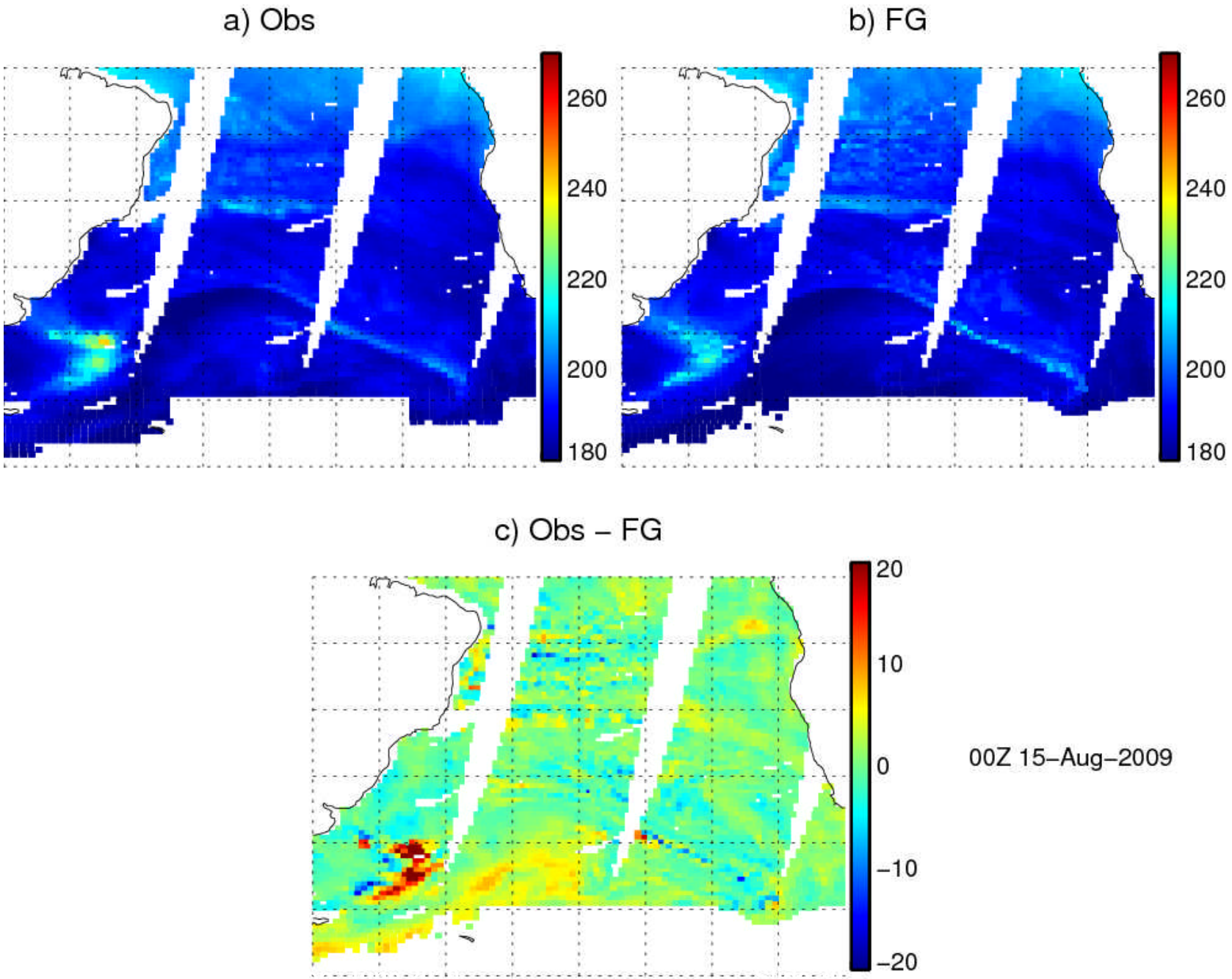
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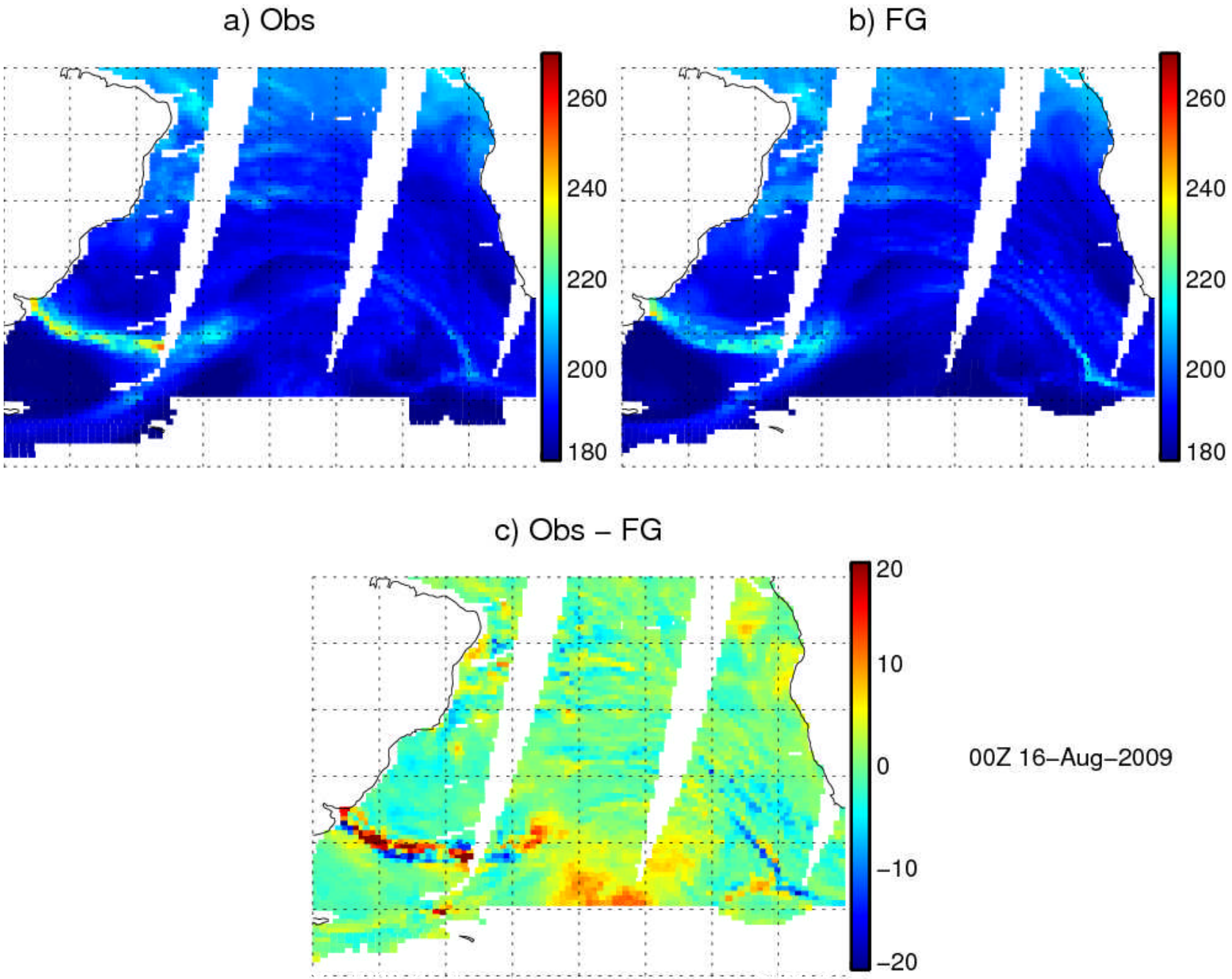
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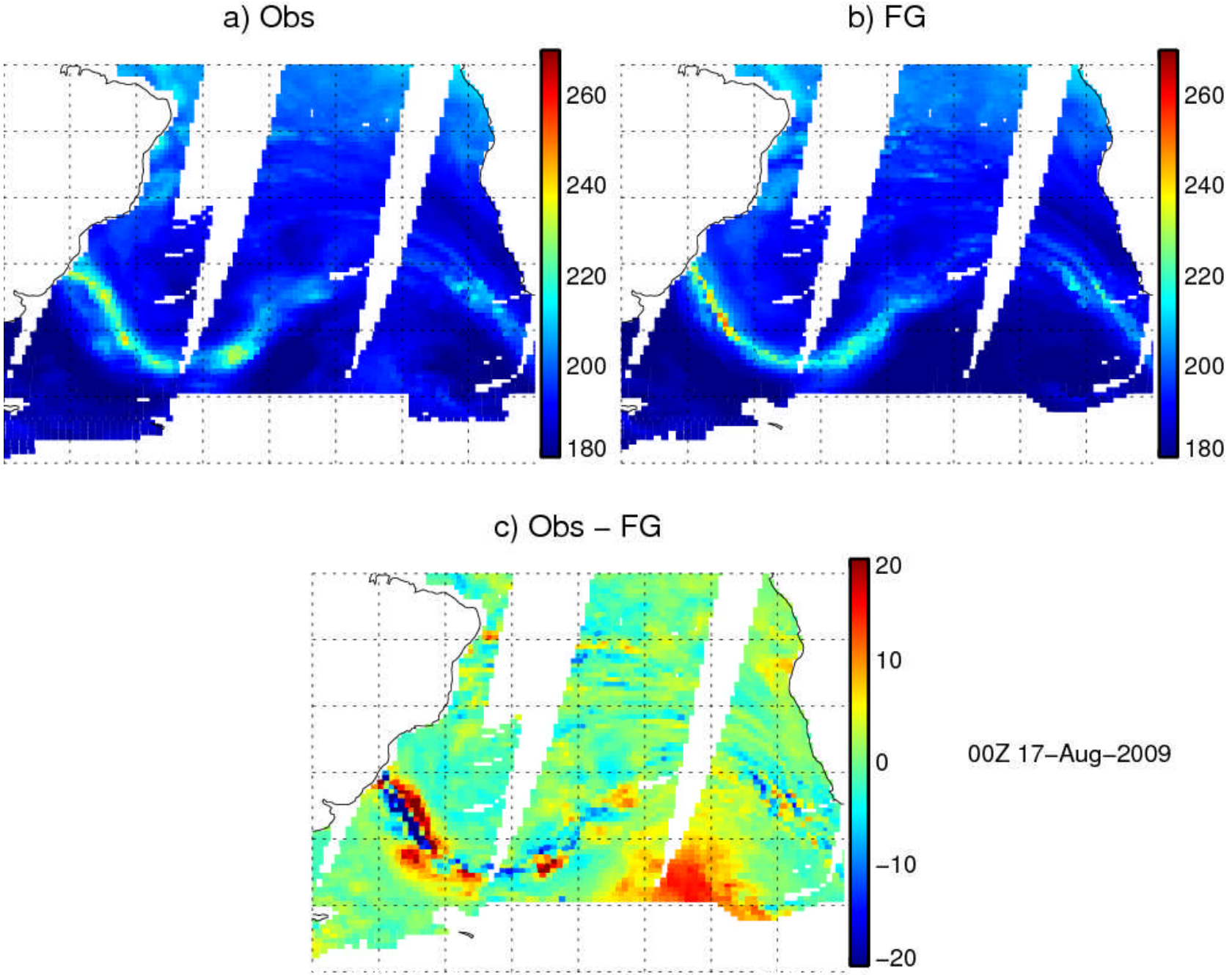
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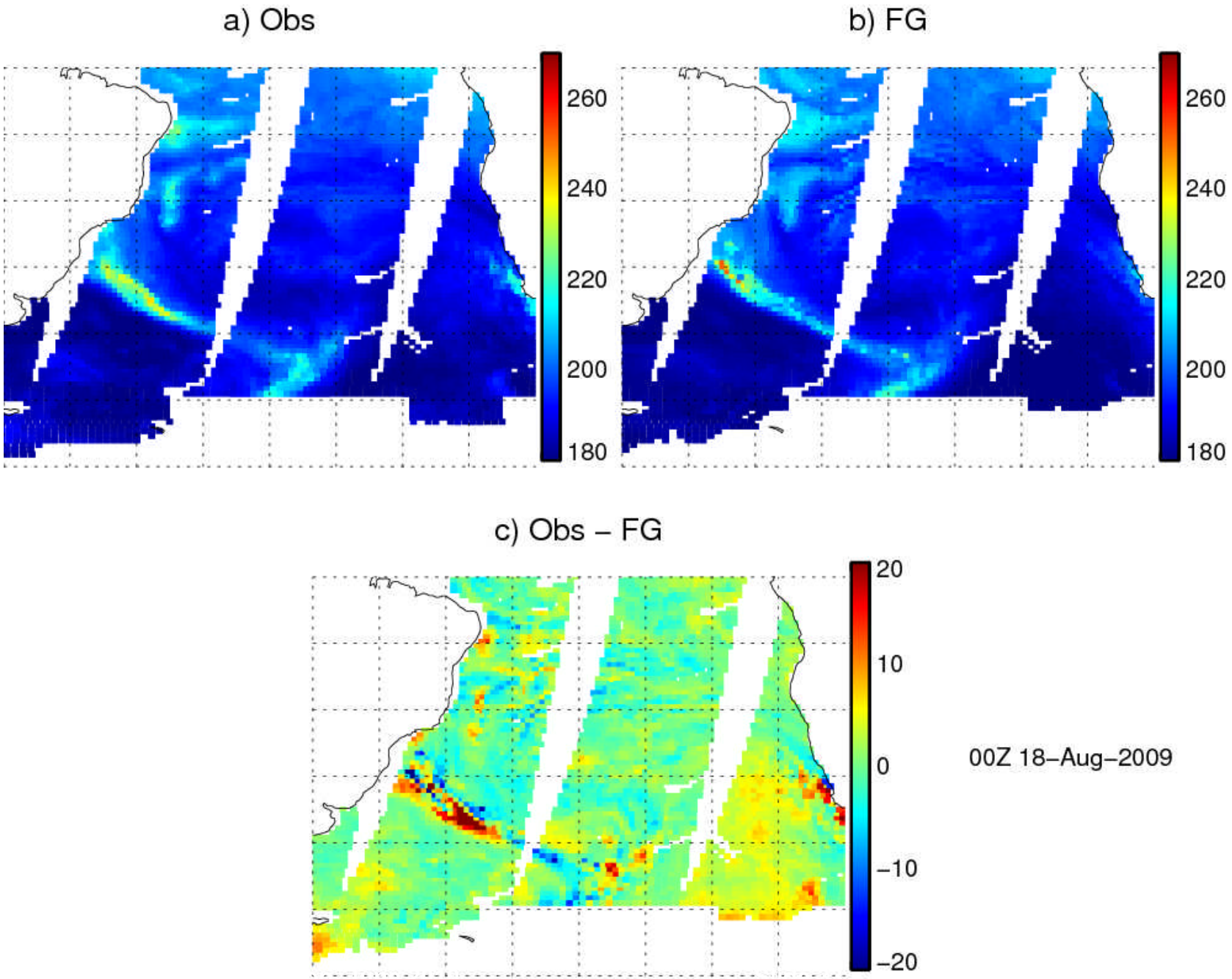
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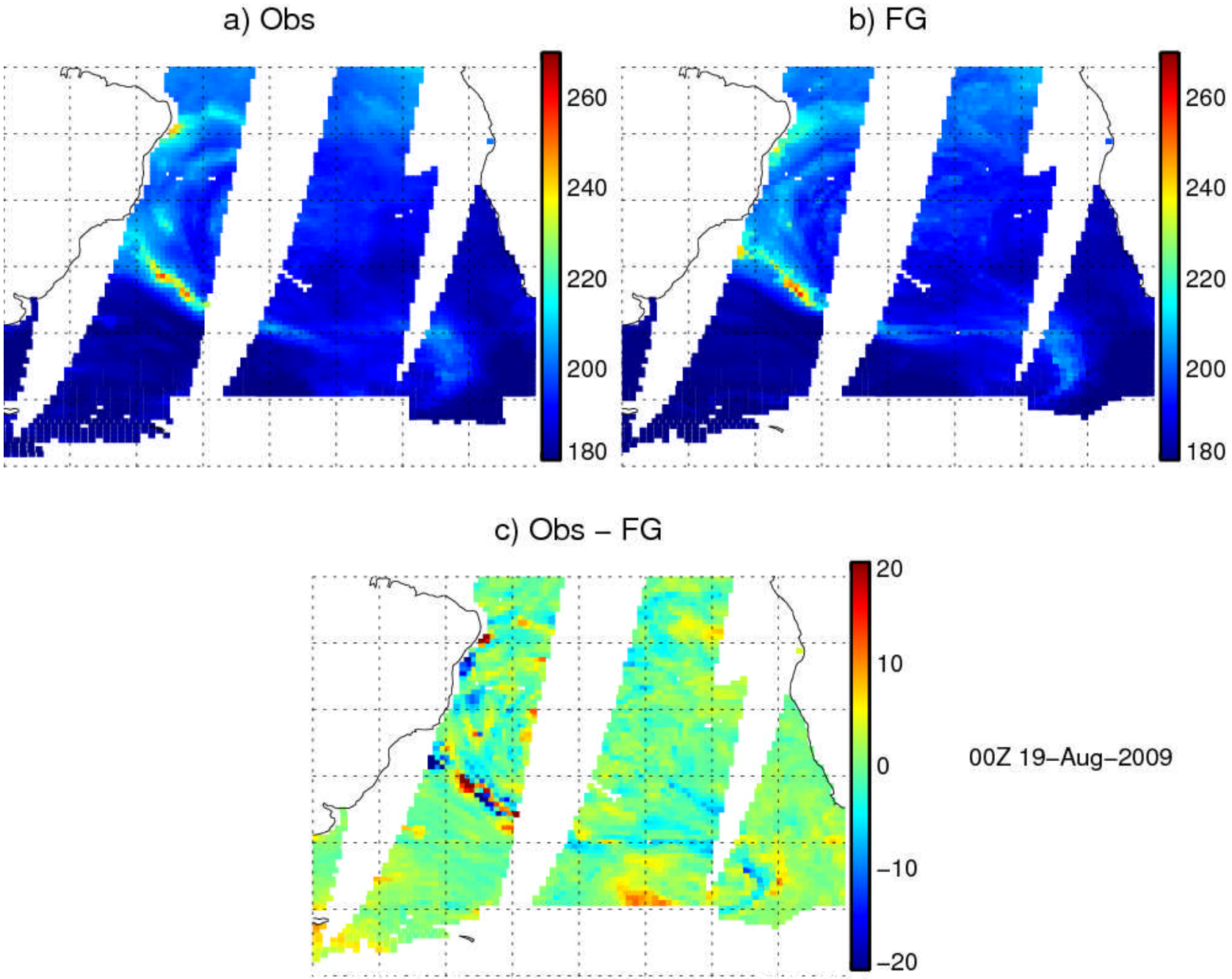
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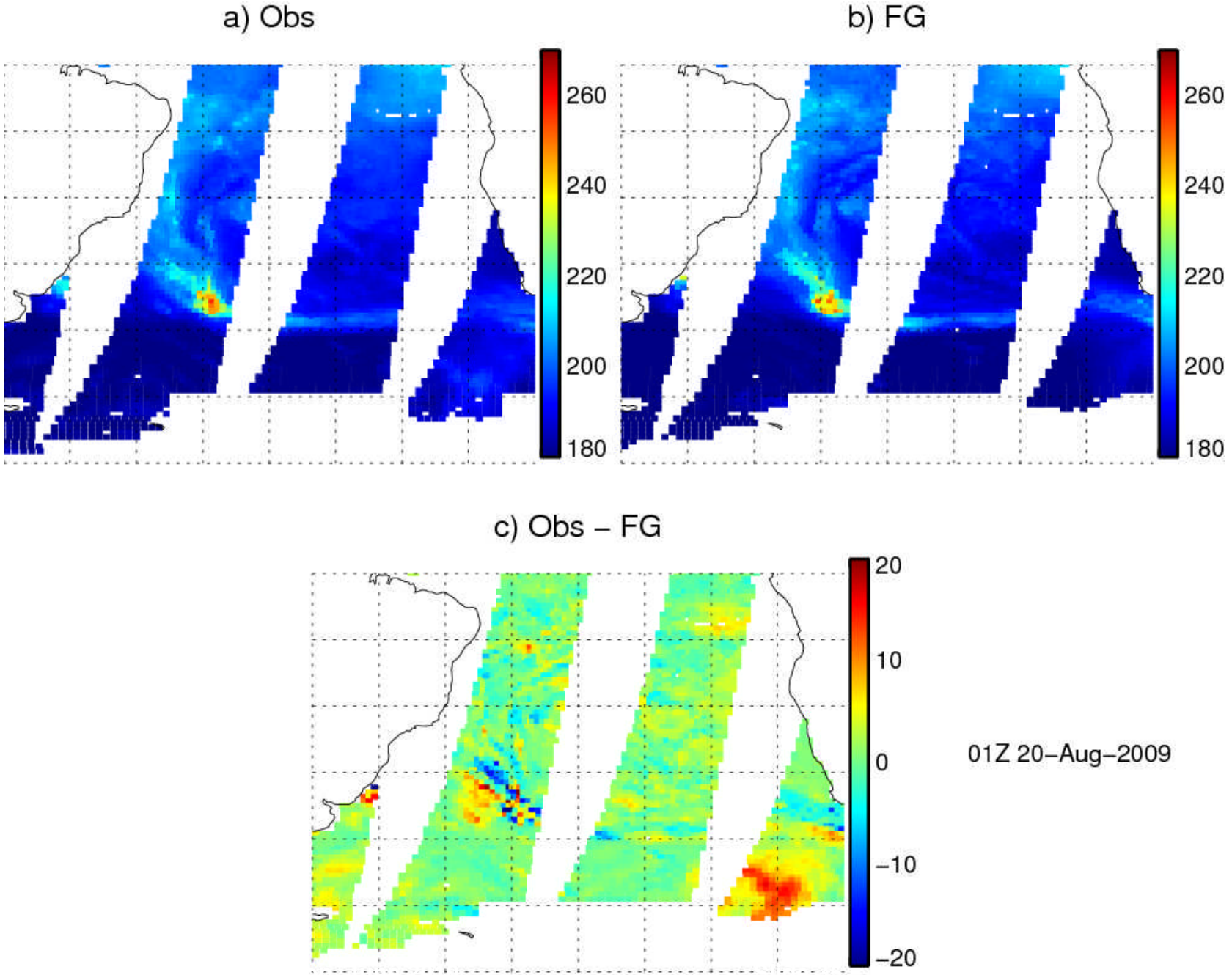
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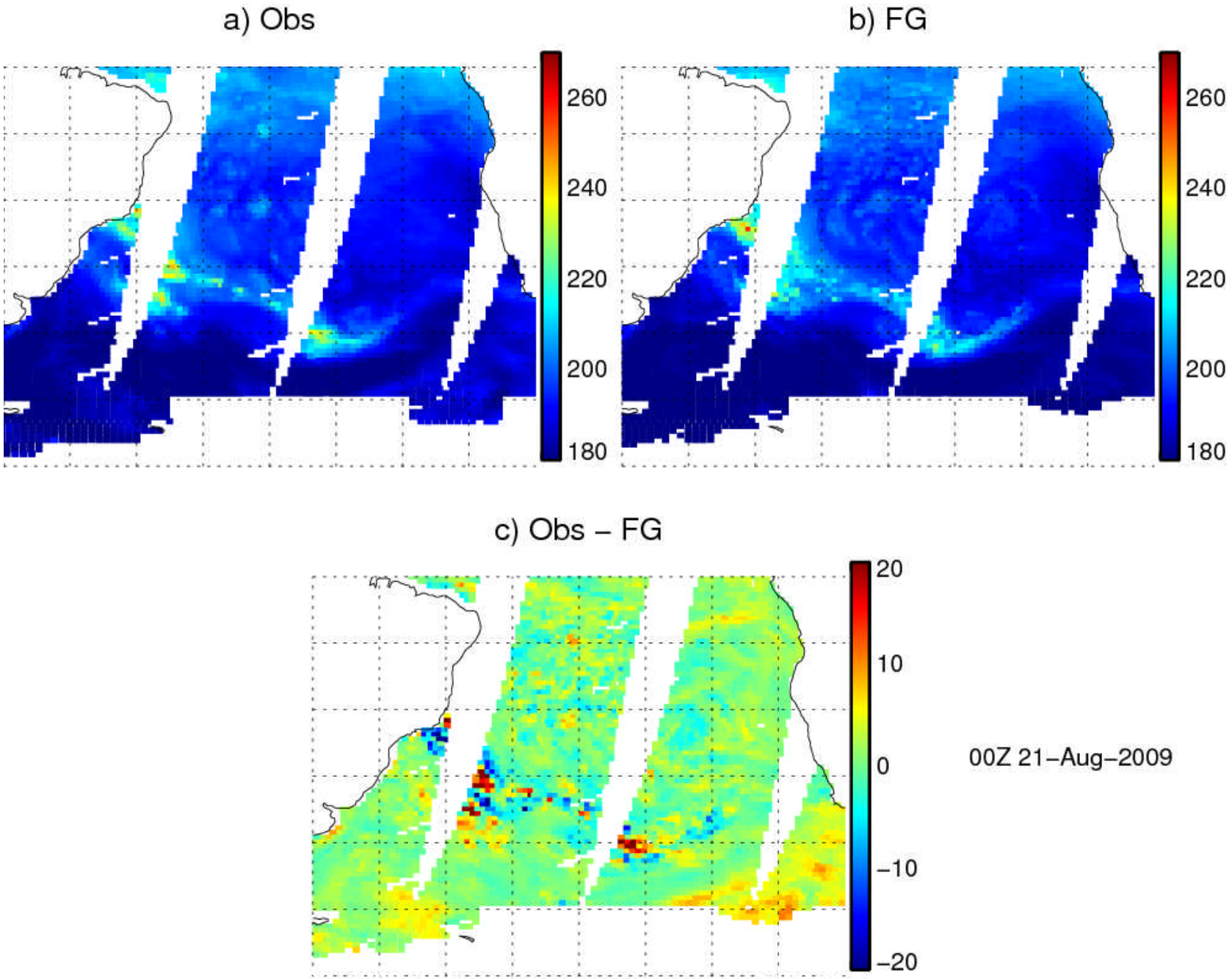
a) Obs
b) FG
c) Obs – FG
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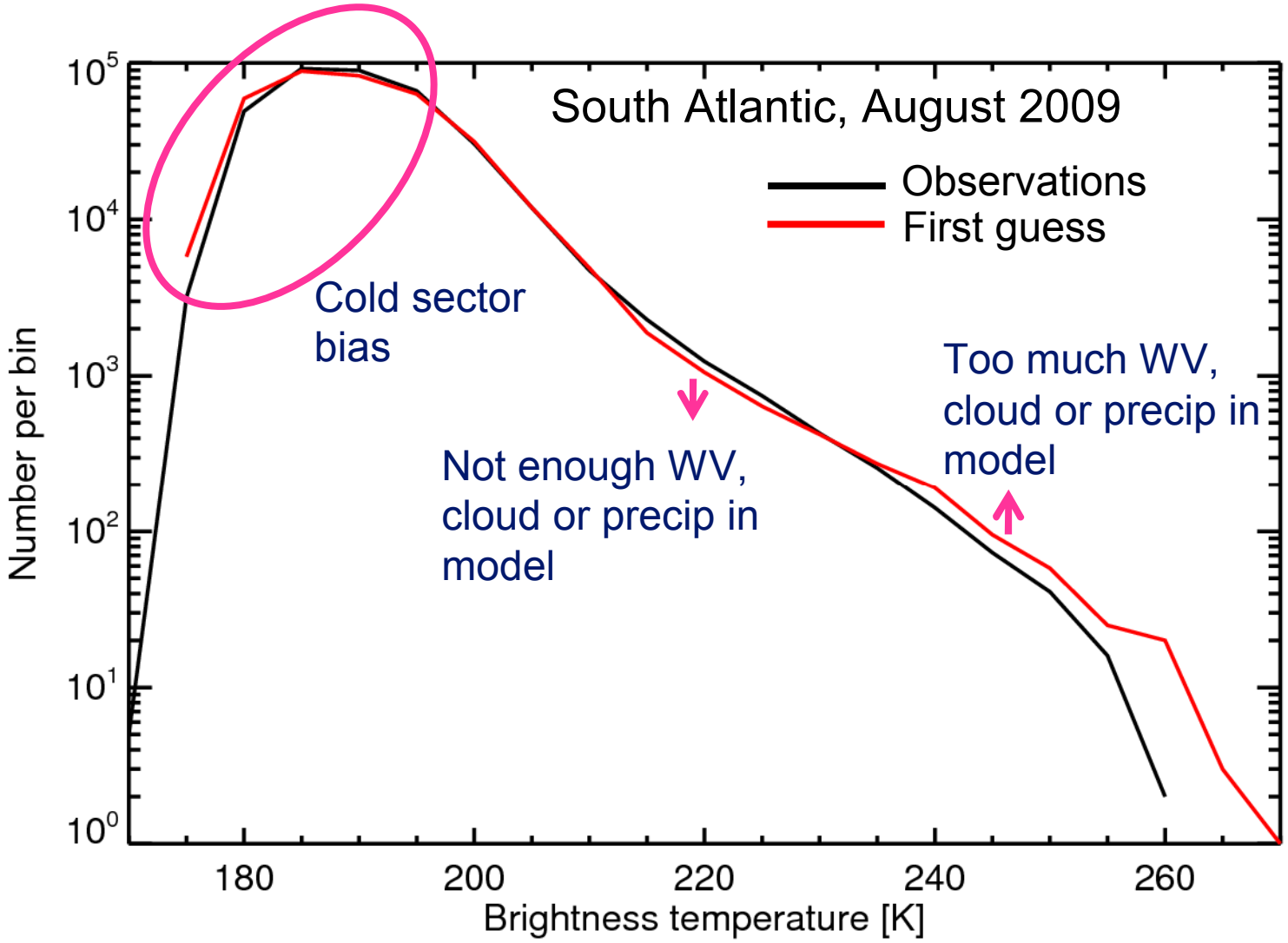
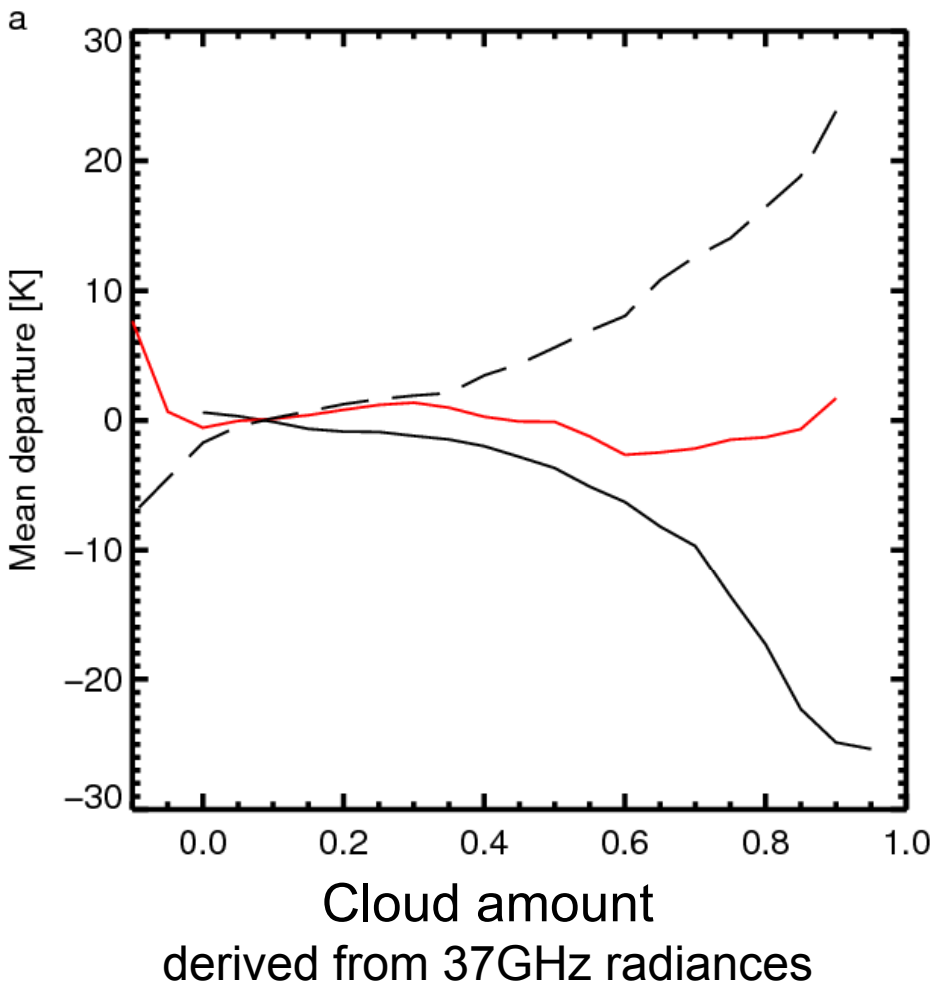
00Z 21–Aug–2009

PDF of brightness temperature: Channel 19v

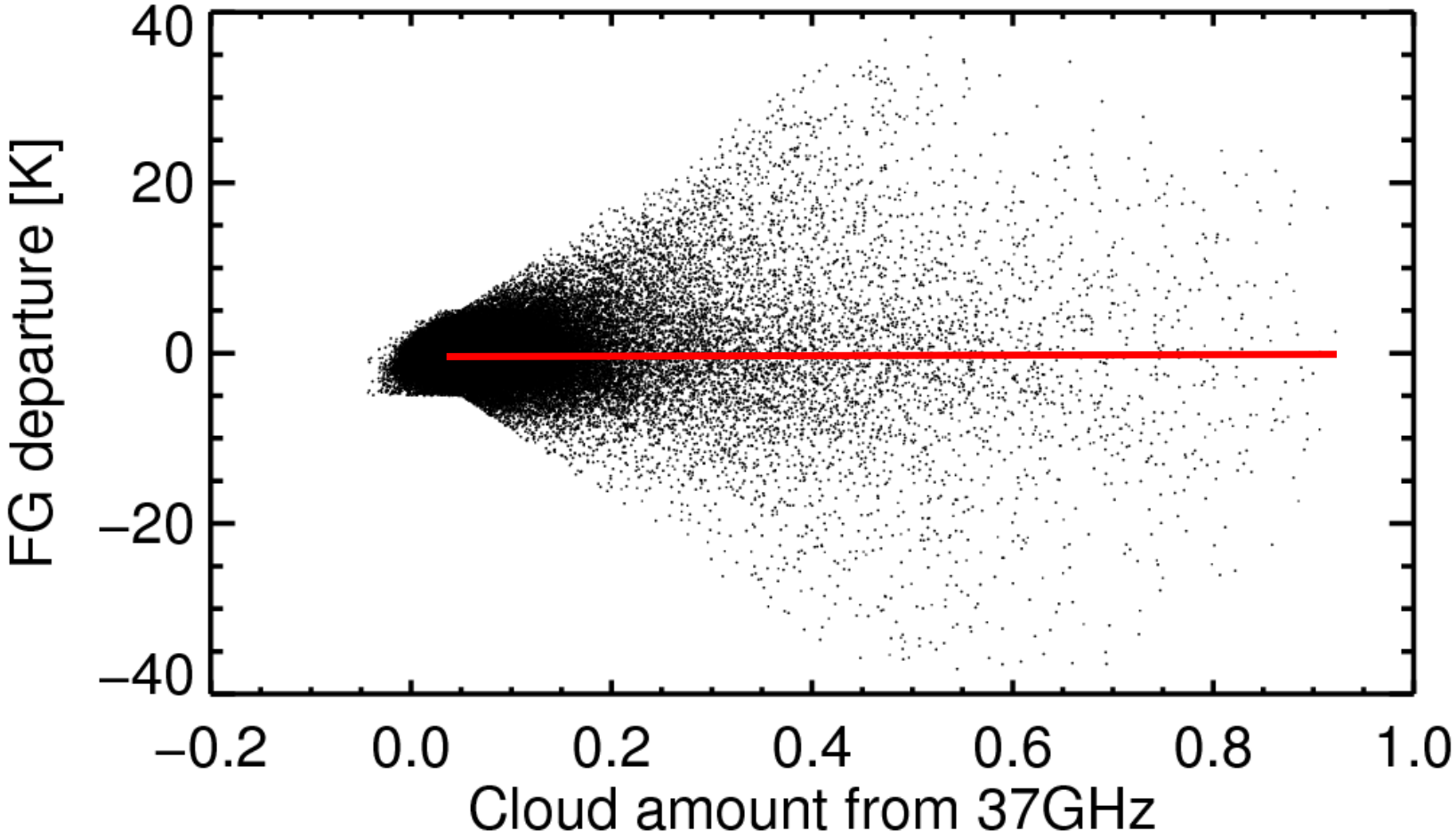


Bias correction as a function of cloud



as a function of mean of observed and forecast cloud

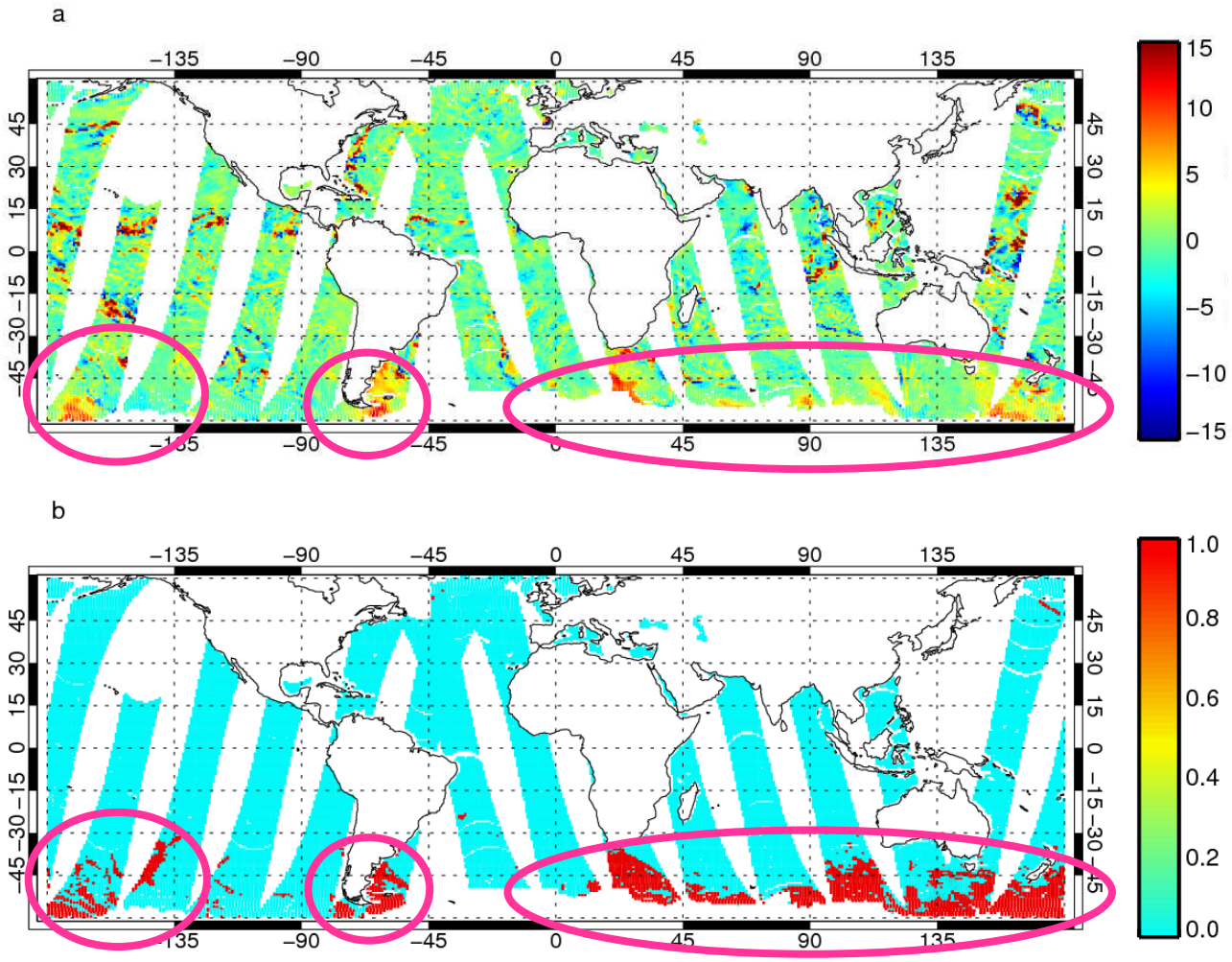
Difficulties with adaptive bias correction



Difficulties with adaptive bias correction

- Signal to noise:
  - biases of ~2K against standard deviations of 15K
- Biases can be determined by a few observations at the extreme cloudy end
  - Vulnerable to interactions with quality control
- “Mean cloud” predictor is not well targeted
  - But no success with more precise approaches either e.g., tropics vs. midlatitude separation

Screening criteria for bad biases



FG departures [K]

Cold sector bias indicator [0-1]

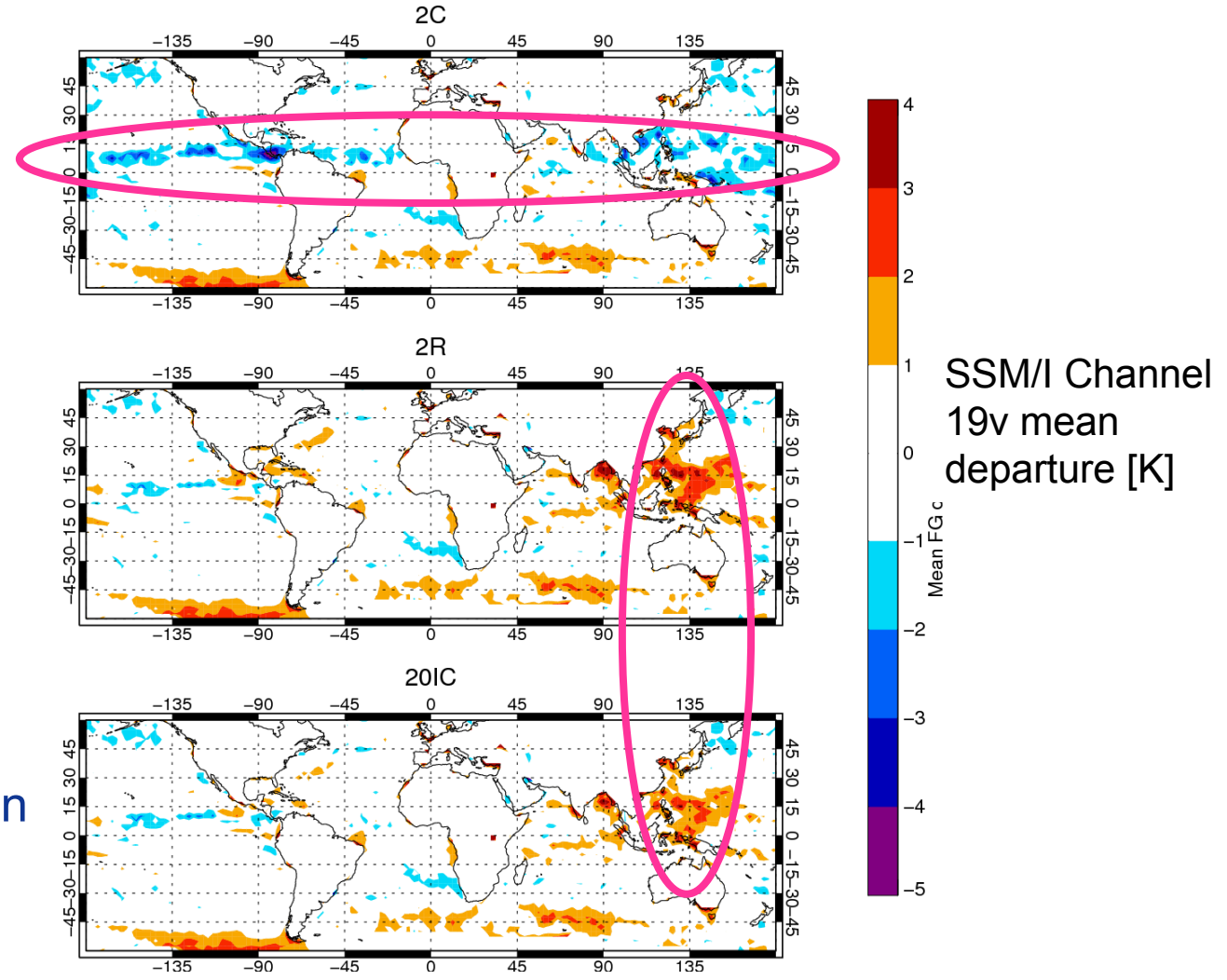
ECMWF

Biases fixed: cloud overlap in the RTTOV-SCATT radiative transfer model

Original overlap

Revised overlap

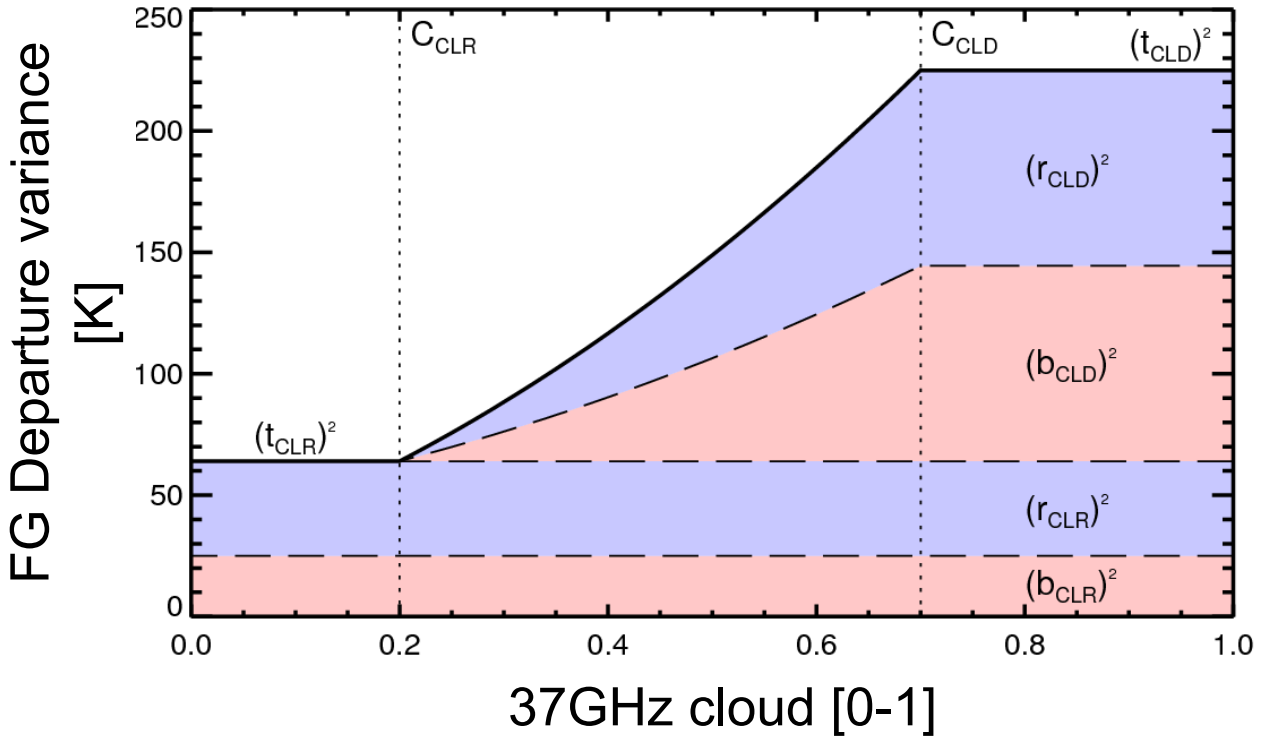
20 independent column reference



ECMWF

Error tuning experiments

Symmetric model for all-sky observation error



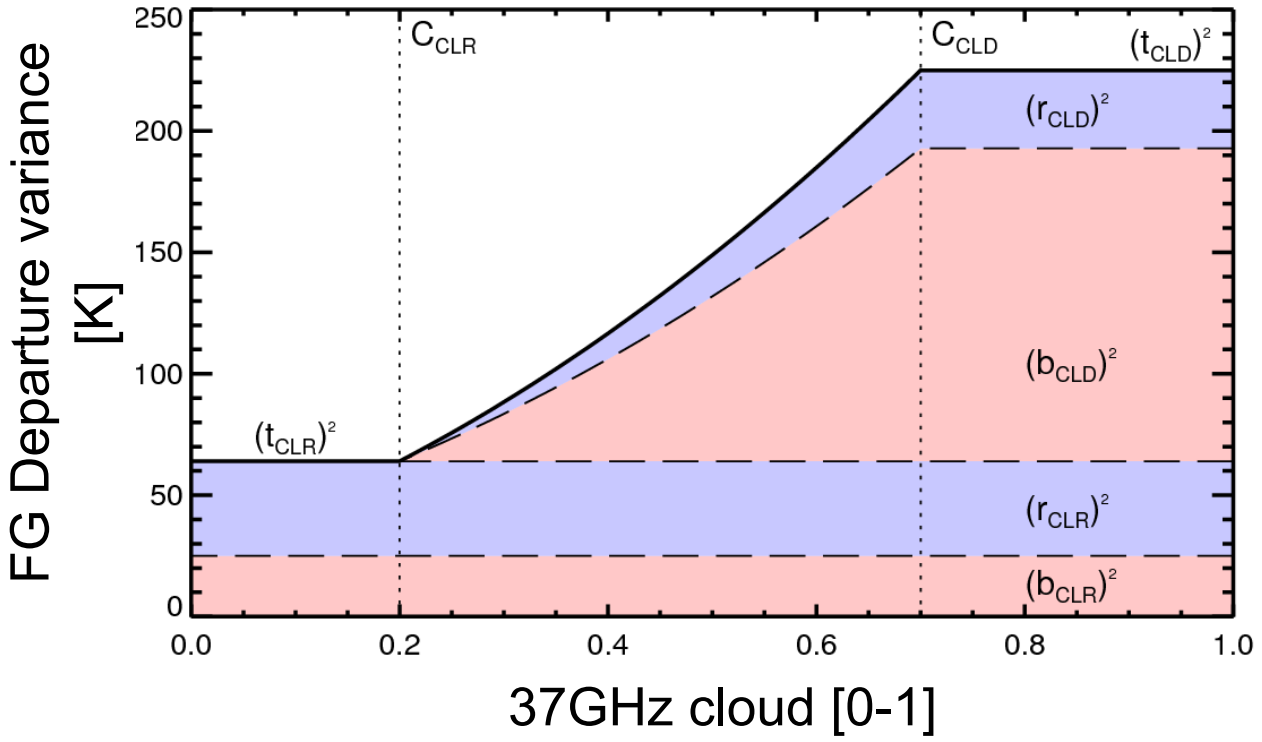
Cloudy obs error

Cloudy FG error

Clear FG error

Clear FG error

Symmetric model for all-sky observation error



Cloudy obs error

Cloudy FG error

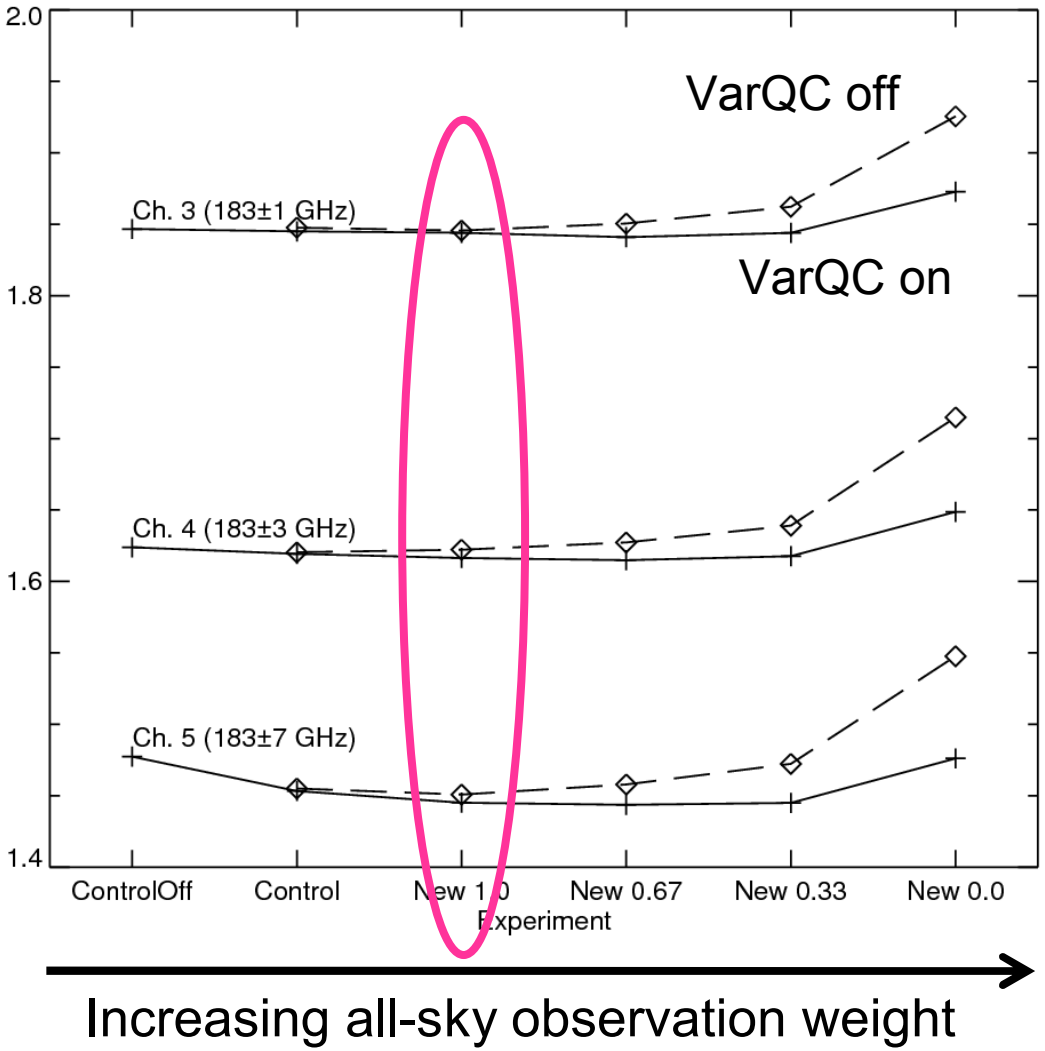
Clear FG error

Clear FG error

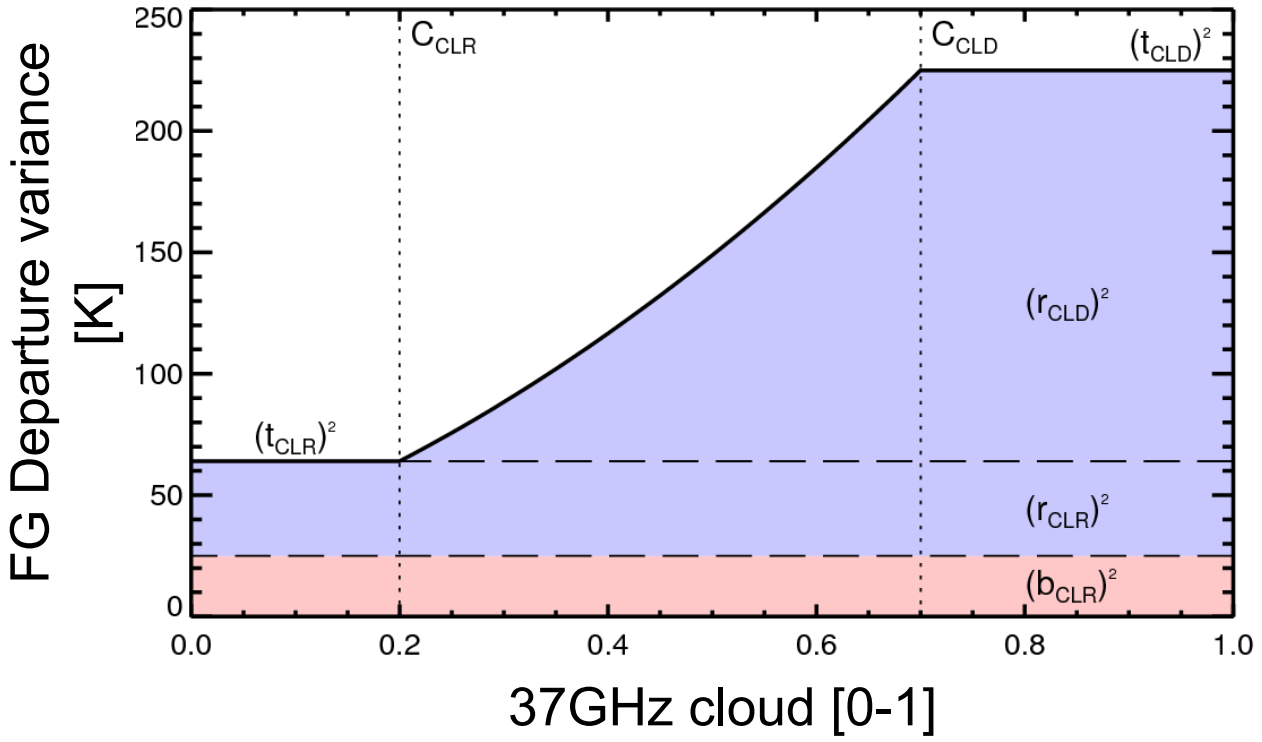
ECMWF

All-sky observation error tuning

AMSU-B
FG departure
std. dev. [K]



All-sky observation error in practice



Cloudy obs error

Clear FG error

Clear FG error

ECMWF

All-sky observation error after tuning experiments

- Channel 19v in cloudy areas:
  - FG departure standard deviation: 15 K
  - Observation error: 14.96 K
- In practice, ALL cloudy error is assigned as observation error. Why?
  - ECMWF system does not correctly represent background error covariances in cloudy areas?
  - Error correlations not considered – see Niels Bormann's talk.
  - **Forecast model bias**

Status

- Observation errors – *Stopgap solution*
  - Need to be symmetric (i.e. not causing sampling biases)
  - Symmetric approach for all-sky assimilation
  - Observation error being used to account for forecast model error!
- Quality control - *OK*
  - Threshold checks using symmetric model for FG departures
  - VarQC
- Gaussianity and linearity – *OK for now*
- Representativity – *Saved by very broad scales of model cloud*
- Model biases – *The real problem*
  - E.g. fronts, cold sectors
  - Correlated errors

Recommendations

- Background errors
  - Need to represent broad areas of uncertainty around fronts and clouds
  - Ensemble methods should help
- Bias correction
  - Predictors must be symmetric
  - Refine current methods (e.g. better VarBC predictors)
  - New methods to represent cloud and precipitation biases?
- Model biases
  - Screen out observations that disagree with the model
  - Improve the models
  - Weak constraint 4D-Var
  - Parameter estimation