

Observation monitoring and data quality management in NWP

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Outline

- 1. Introduction**
2. Observation screening
3. Operational data monitoring
4. Other monitoring aspects
5. Concluding remarks

Used observations: conventional

- **SYNOP/SHIP/METAR**

- temperature, dew-point temperature, wind (land: 2m, ships: 25m)

- **BUOYS**

- ◆ **Moored buoys**

- ◆ **Drifters**

- temperature, pressure, wind

- **TEMP/TEMPSHIP/DROPSONDES**

- temperature, humidity, pressure, wind *profiles*

- **PROFILERS**

- wind *profiles*

- **Aircraft**

- ◆ **AIREPS**

- ◆ **AMDAR, ACRAS, etc**

- temperature, pressure, wind *profiles*

Used observations: satellites

- **Radiances**

- ◆ ATOVS: AMSU-A, AMSU-B/MHS, HIRS

- ◆ SSM/I, AMSR-E

- ◆ AIRS, IASI

- ◆ MVIRI, SEVIRI, GOES-, MTSAT-1R imagers 89.4%

- brightness temperature = level 1

- **GPSRO bending angles**

- ◆ COSMIC, GRAS

- bending angle = level 1

- **Atmospheric Motion Vectors (AMVs)**

- ◆ Meteosat 7/9, GOES-11/12, MTSAT-1R, MODIS-winds

- wind = level 2

- **Sea surface parameters**

- ◆ Scatterometer winds

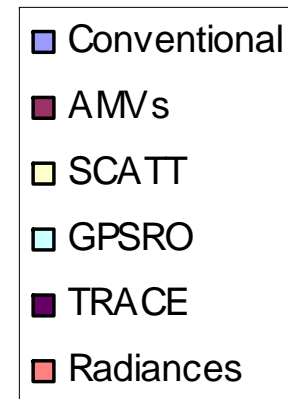
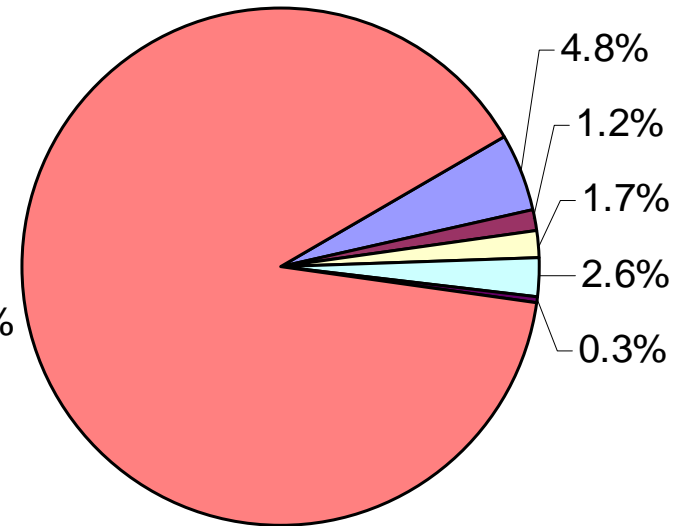
- ◆ Altimeter data

- wind speed and wave height = level 2

- **Ozone**

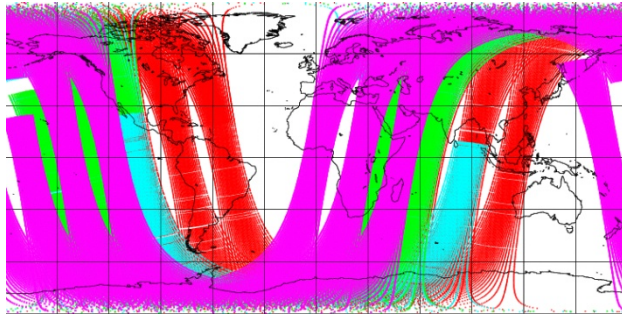
- ◆ SBUV, OMI

- total/partial column ozone = level 2

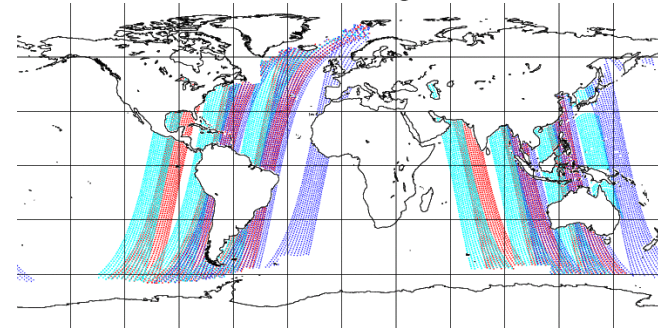


Example of satellite data coverage

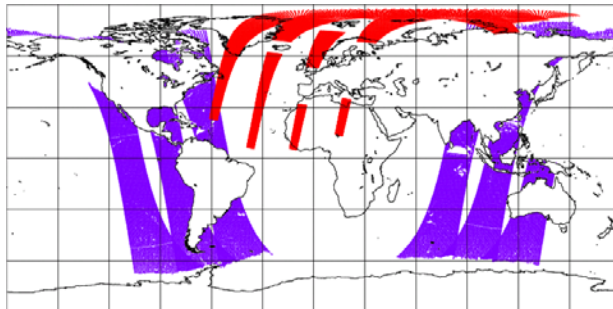
LEO Sounders



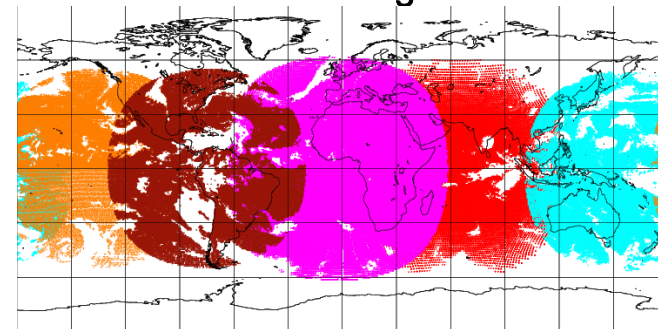
LEO Imagers



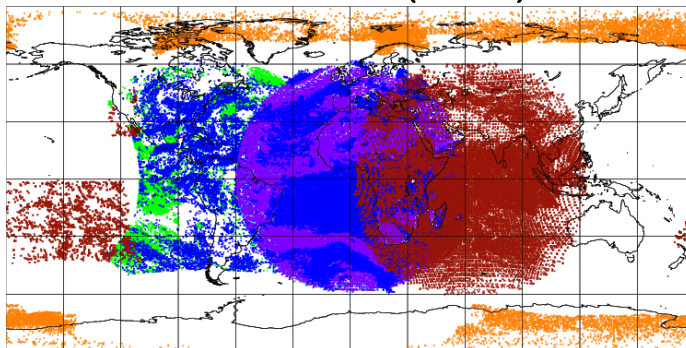
Scatterometers



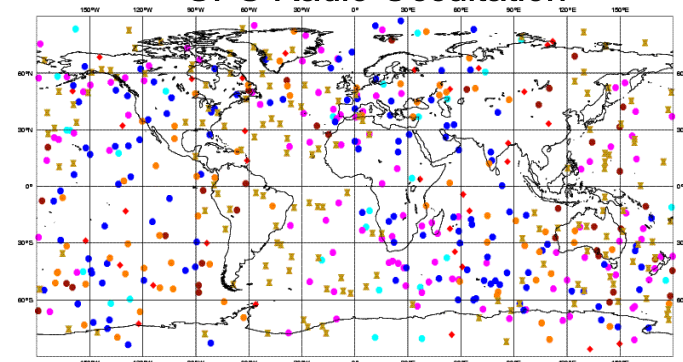
GEO imagers



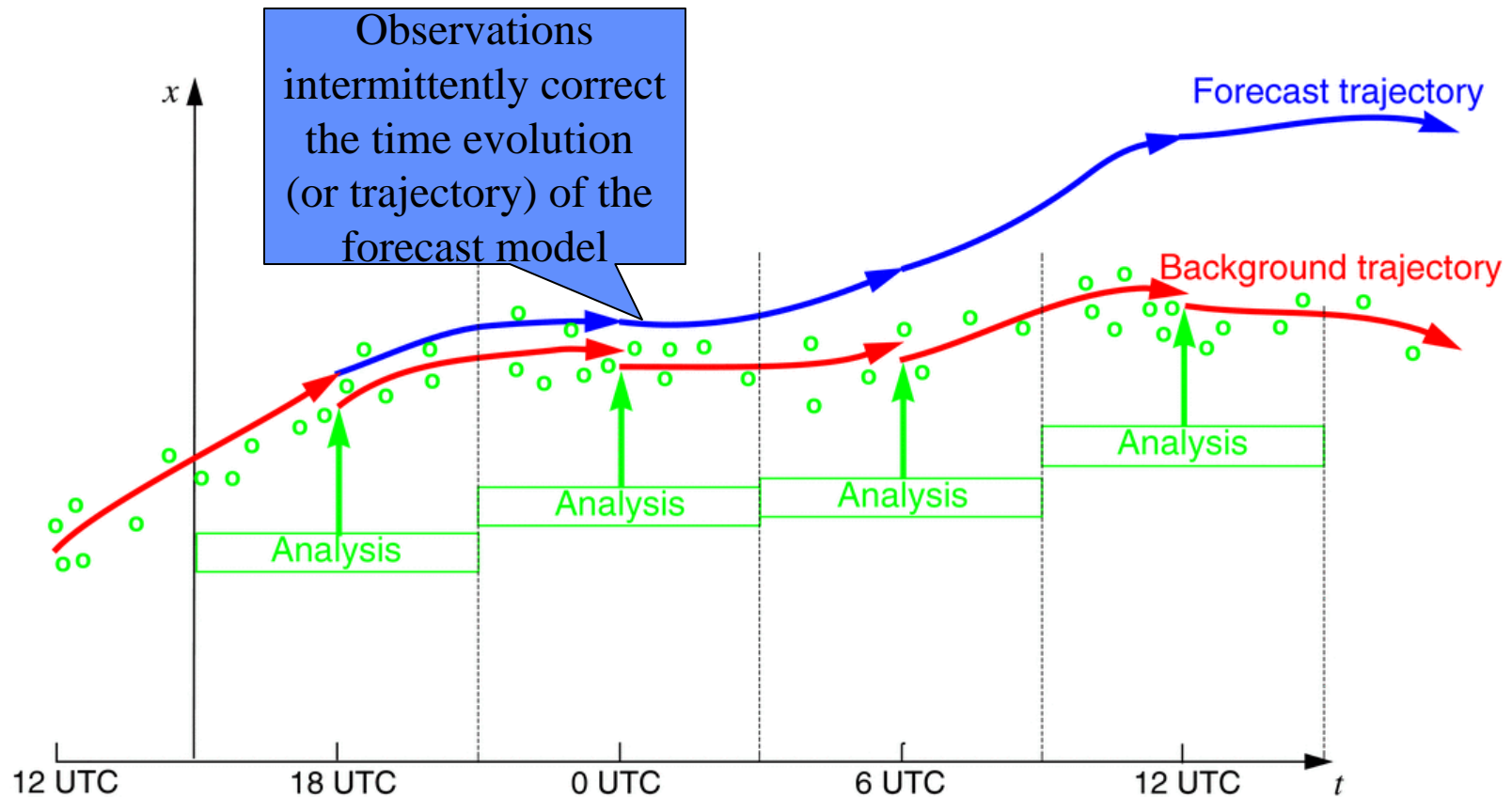
Satellite Winds (AMVs)



GPS Radio Occultation



The Data Assimilation Process



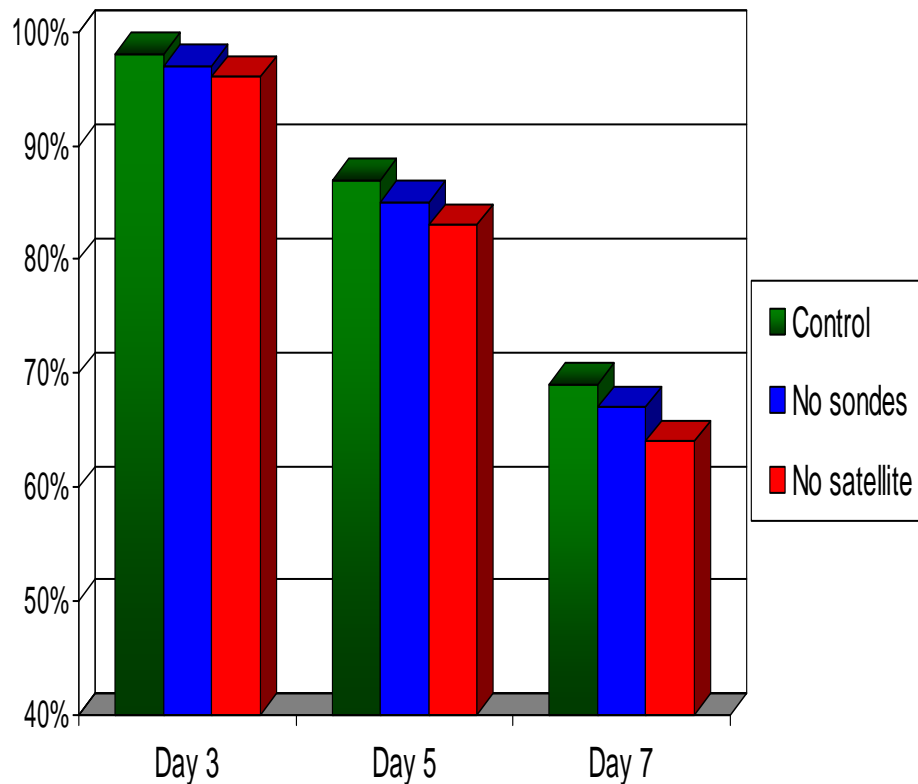
Adjustments depend on differences between observations and short-term forecast (“FG or background departures”)

Use of satellite data

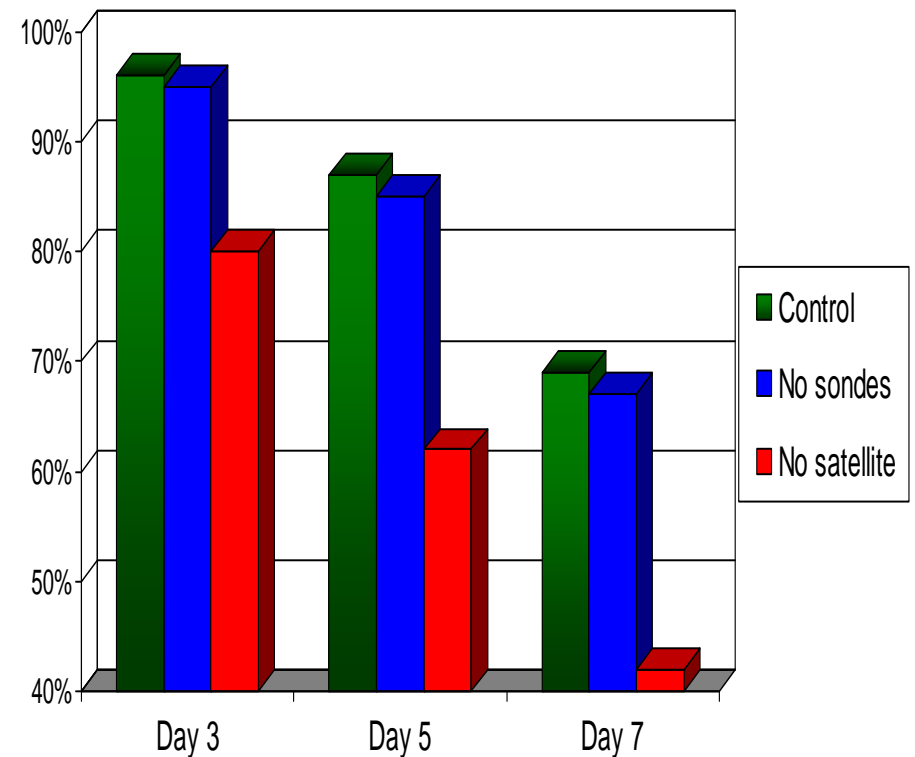
- **Aim to use “raw” observations (preference for level 1 data).**
 - ◆ **E.g., use radiances for passive IR or MW data**
 - Errors and biases simpler
 - Less dependent on processing changes
 - Early use and access to the data
- **Radiance biases are estimated as part of the analysis process**
 - ◆ **Bias models accounting for air-mass biases, scan-biases**
 - ◆ **Continuously updated**
 - ◆ **Requires anchoring observations**
 - ◆ **“Variational bias correction”**

Forecast impact of observations

Anomaly correlation of 500hPa height for northern hemisphere



Anomaly correlation of 500hPa height for southern hemisphere



Outline

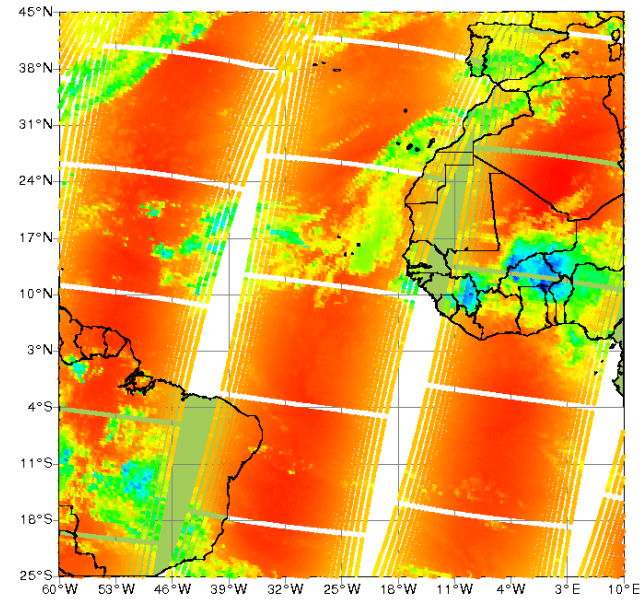
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Stages of observation screening

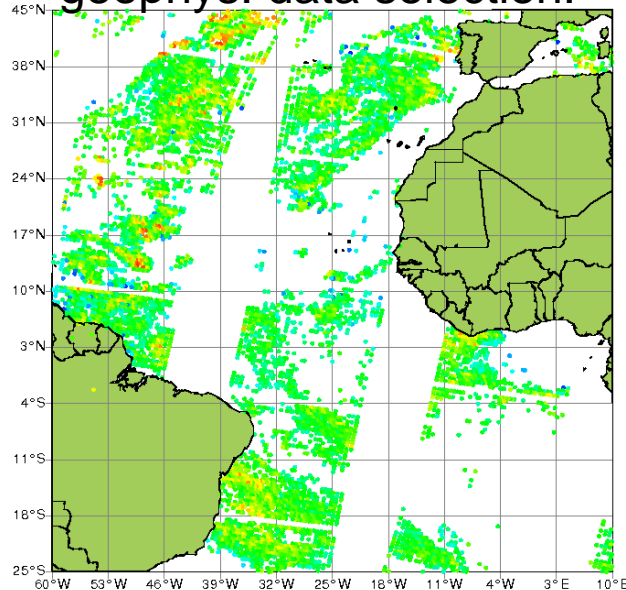
- **Blacklisting**
 - ◆ **Removal of “clearly bad” data, e.g.:**
 - Degraded instruments/channels
 - Radiosonde stations with past problems
 - Data flagged by providers as “bad”
- **Geophysical data selection:**
 - ◆ **Removal of “difficult” data, e.g.:**
 - Cloudy radiances
 - Surface-sensitive IR radiances
- **Quality control against background:**
 - ◆ **Removal of outliers**
- **Thinning (for satellite data):**
 - ◆ **Preference for “better” data**
- **Assign error to observation (mostly fixed and prescribed).**

Example: HIRS ch. 6

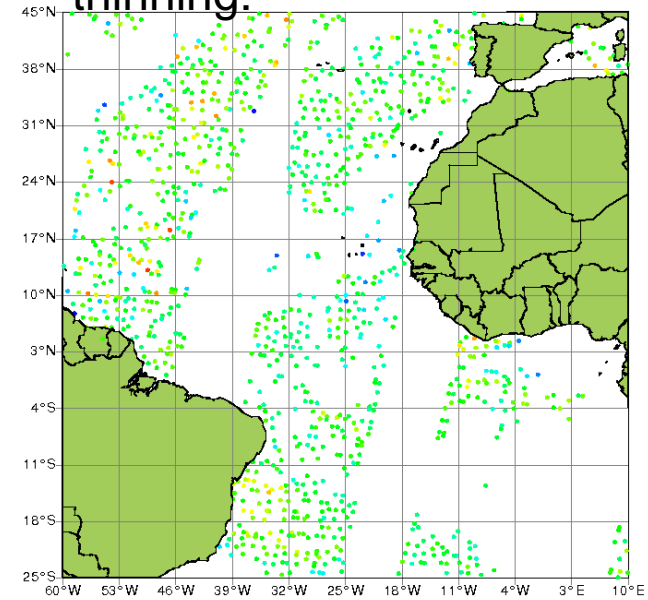
All data:



After blacklisting and
geophys. data selection:



After background QC and
thinning:



Observation
minus
background [K]



“Quality” information from data providers

- **Information provided very diverse, depending on observation, e.g.:**
 - ◆ **Good/bad flags**
 - ◆ **“Quality indicators” for cloud drift winds (0-100%)**
 - But characteristics not unified for different providers
 - ◆ **Expected retrieval errors for trace-gas retrievals**
 - But errors often underestimated
 - ◆ **Information on observation conditions, e.g.,**
 - Information on cloudiness for IR radiances
 - Rain contamination for scatterometer data
 - Solar elevation for UV/VIS-based ozone retrievals
- **Additional information from providers is helpful and used in the data selection where useful.**
- **For selected observations, additional information could be used to adjust assigned errors, but mostly this is not done.**

Outline

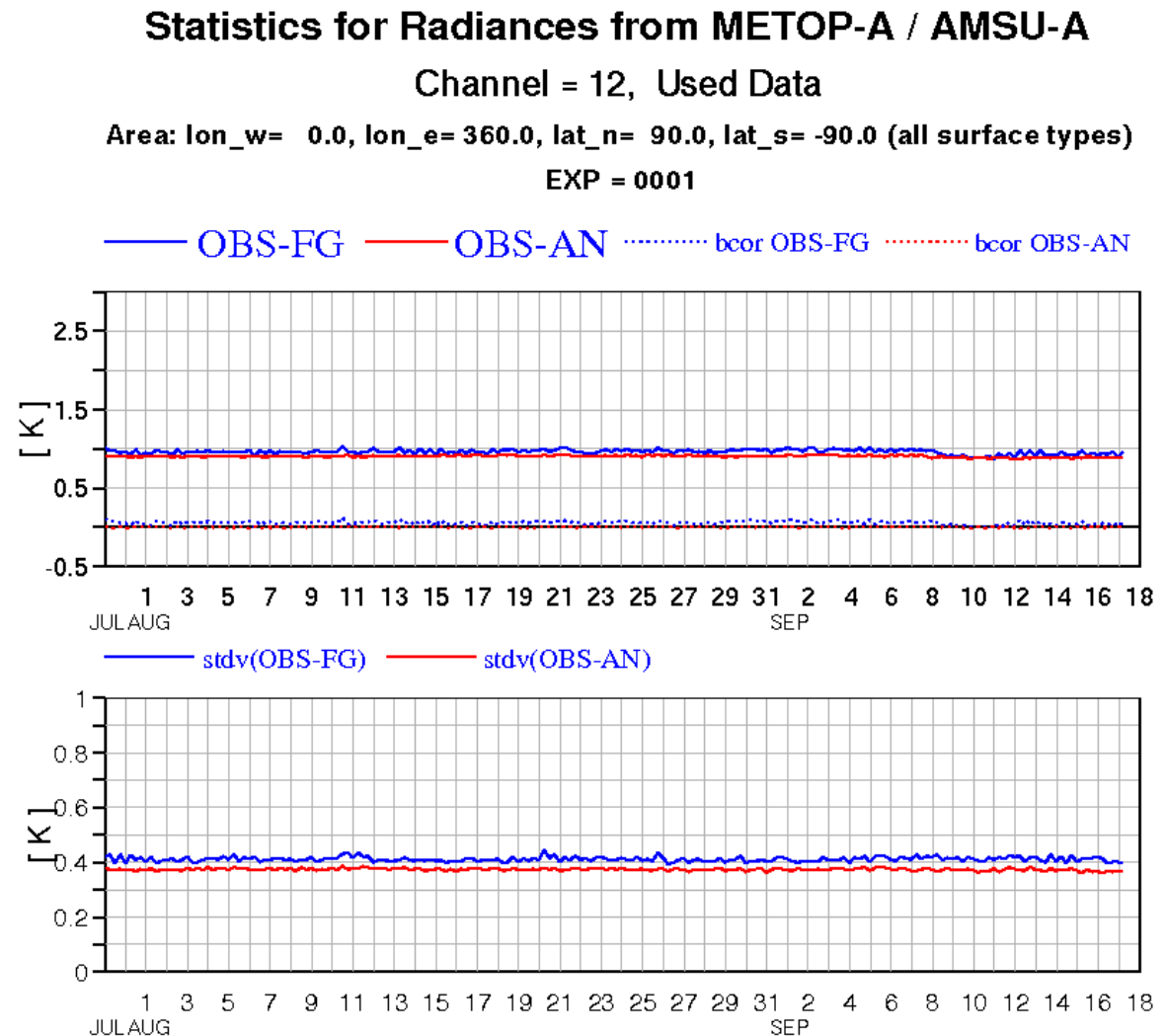
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Importance of operational data monitoring

- **Main goal: Ensure availability and quality of used observations.**
 - ◆ Any significant degradation in quality or availability of observations may affect the quality of the forecast.
- **Crucial to report any **change**, in order to trigger corrective action if needed (e.g., blacklisting).**
- **Monitoring consists of generating statistics over large data samples, for variables relevant to data assimilation:**
 - ◆ Background and analysis departures
 - ◆ Bias corrections
 - ◆ Data counts
 - ◆ For different data selections/areas/displays
- **Monitoring outputs are also important to define and re-evaluate data usage (adjustment of data assimilation choices).**

Monitoring of departure statistics

- **Statistics usually stable in time.**
- **Statistics can be compiled for different data selections (e.g., “all”, “clear”, “used”), over different regions/surfaces, etc.**



Monitoring of departure statistics

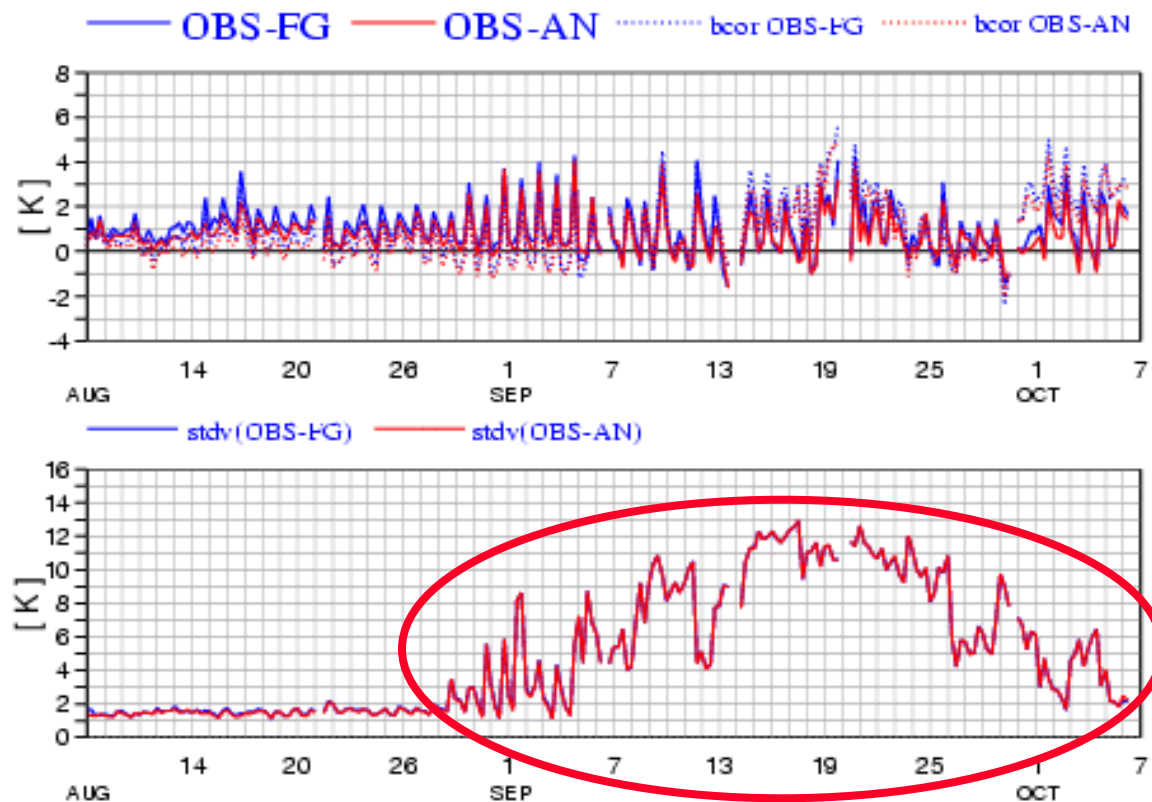
- Problems with data are usually very apparent.

Statistics for Radiances from Aqua / AIRS

Channel = 2104, All Data

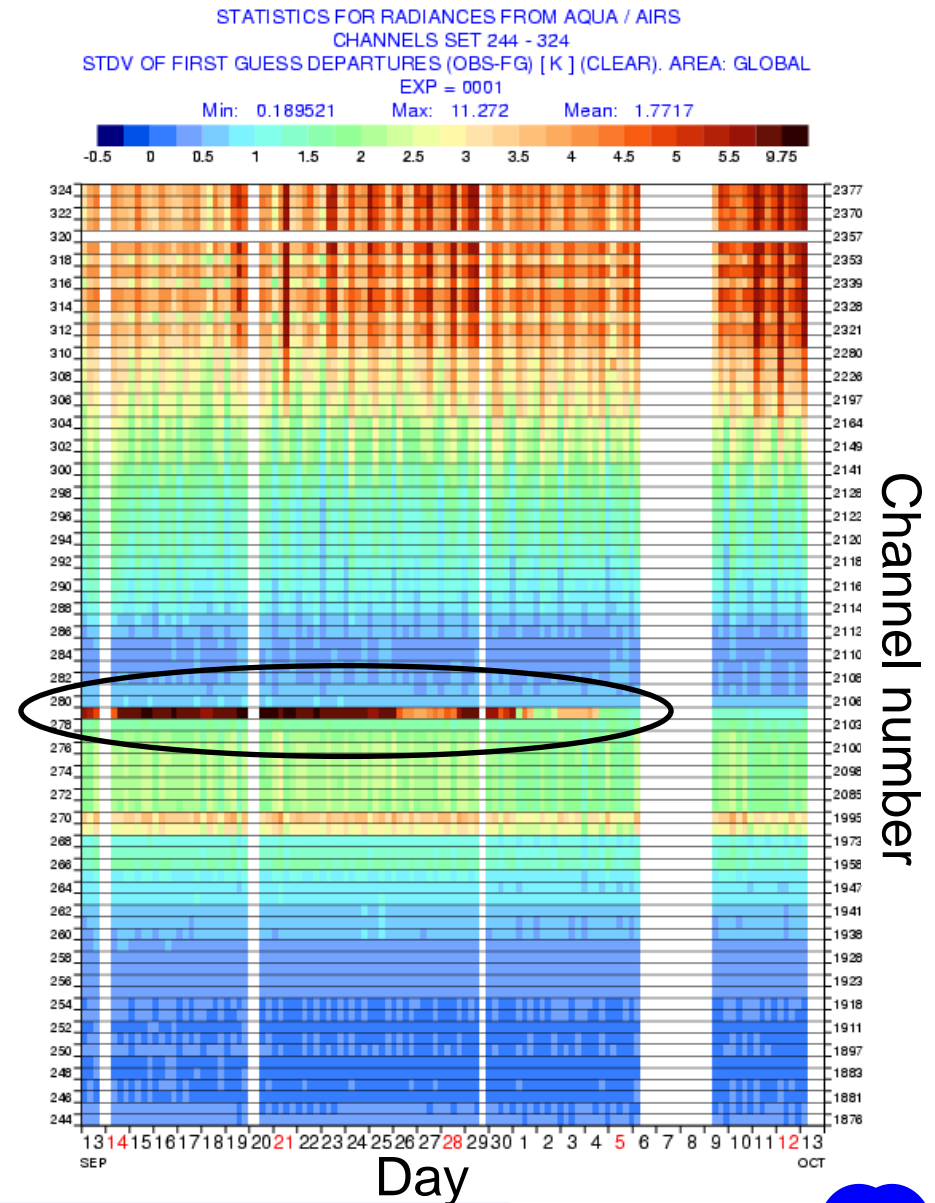
Area: lon_w= 0.0, lon_e= 360.0, lat_n= -70.0, lat_s= -90.0 (over sea)

EXP = 0001



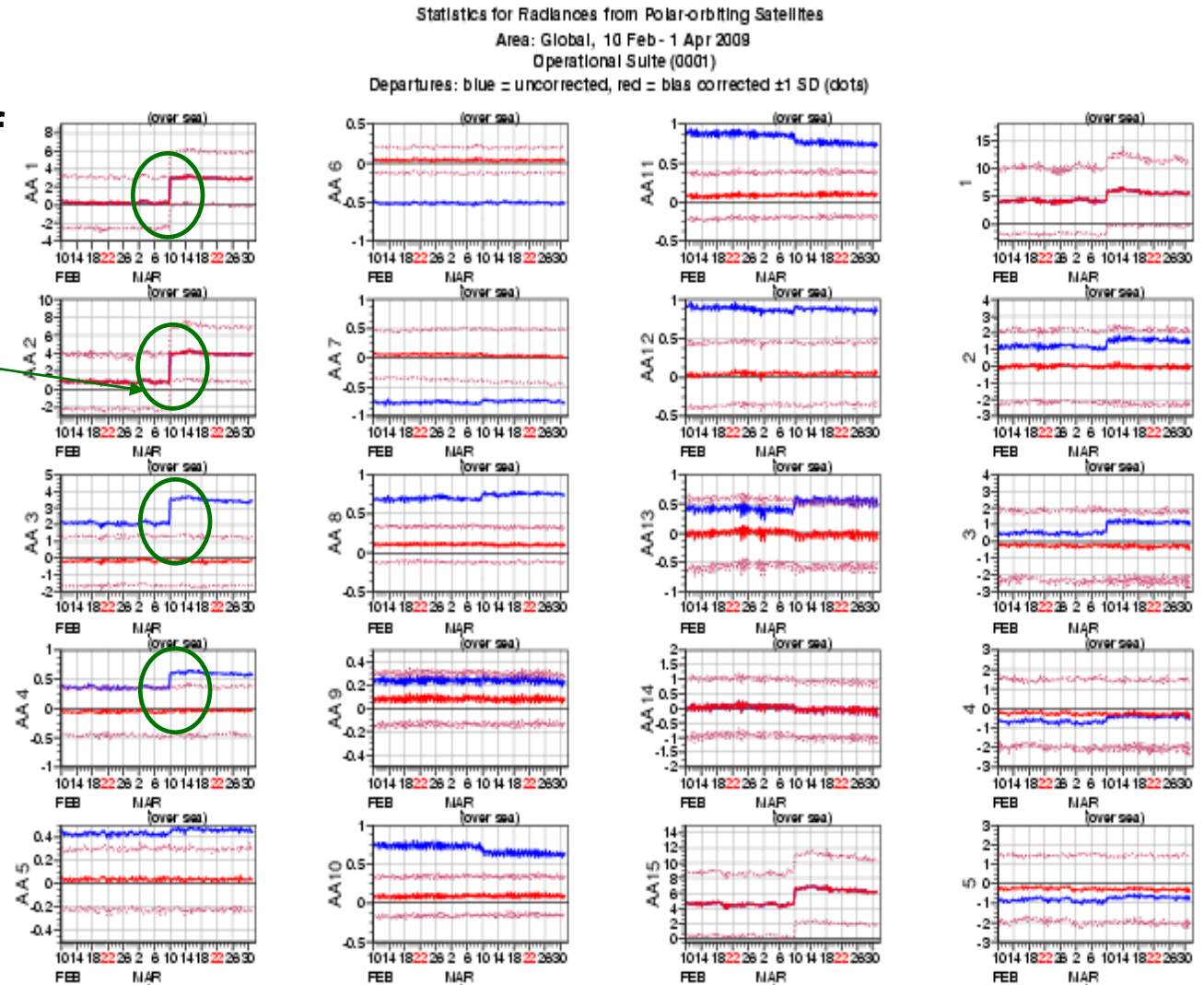
Data monitoring

- If anomaly occurs, check consistency with other data.
- Here, increase in noise for just one channel of AIRS.
- Further monitoring plots can be consulted to investigate the problem.



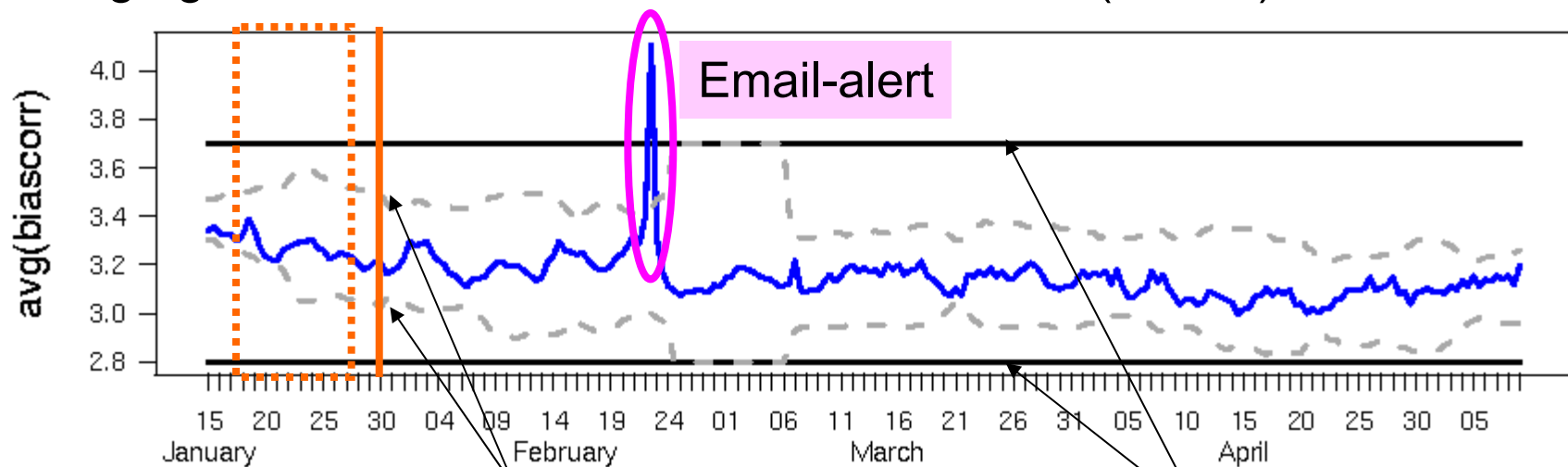
Monitoring of departure statistics

- Statistics also show upgrades of the assimilation system, e.g., new radiative transfer model.



Automated warnings

- Necessary due to volume of observations.
- Selected statistics are checked against an expected range.
- E.g., global mean bias correction for GOES-12 (in blue):



Soft limits (mean \pm 5 stdev being checked, calculated from past statistics over a period of 20 days, ending 2 days earlier)

Hard limits (fixed)

Email alert:

```
GOES-12 GOESIMG 2 clear radiances : out of range:  
  avg (fg_depar)=1.34775547847879,  expected range: -0.38 0.47  
  avg (biascorr)=4.10498646958382,  expected range: 3.0 3.4
```

Automated warnings: example

Automated warning system indicates increase in the noise for NOAA-16 AMSU-A data:

Checking 0001 DCDA 2009012700

=====

atovs

=====

NOAA-16 AMSU-A 9 clear radiances : out of range:

(2 times in last 10 days for at least one item)

http://intra.ecmwf.int/users/str/sat_check/atovs_207_3_9_210.png

Considerably: stdev(fg_depar)=0.32668, expected range: 0.17(H) 0.29

NOAA-16 AMSU-A 10 clear radiances : out of range:

(11 times in last 10 days for at least one item)

http://intra.ecmwf.int/users/str/sat_check/atovs_207_3_10_210.png

Slightly: avg(fg_depar)=0.019286, expected range: 0.021 0.107

Severely: stdev(fg_depar)=0.427388, expected range: 0.19(H) 0.28(H)

NOAA-16 AMSU-A 12 clear radiances : out of range:

(5 times in last 10 days for at least one item)

http://intra.ecmwf.int/users/str/sat_check/atovs_207_3_12_210.png

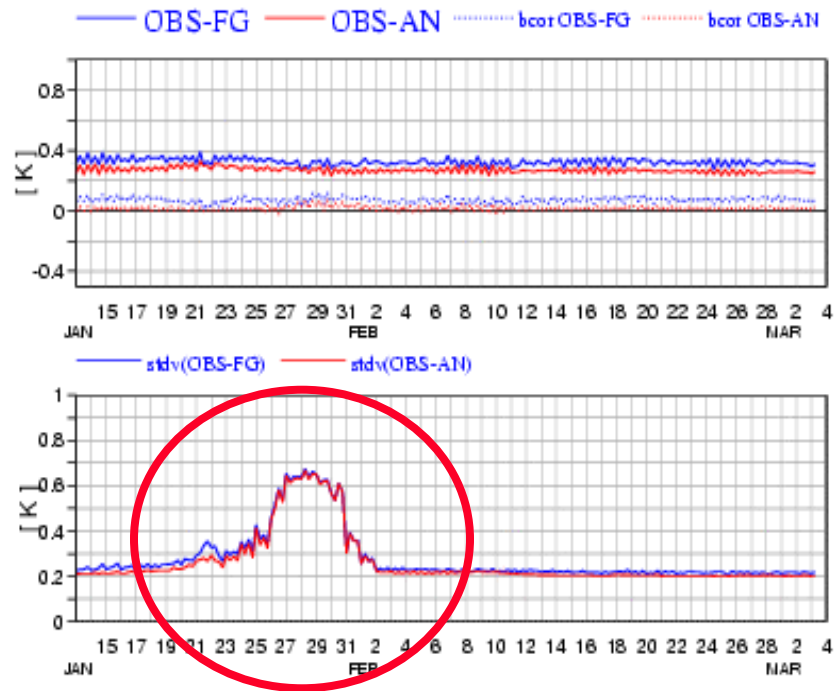
Severely: stdev(fg_depar)=0.584939, expected range: 0.32(H) 0.48(H)

Automated warnings: example

Statistics for Radiances from NOAA-16 / AMSU-A

Channel = 10, Selected data: clear

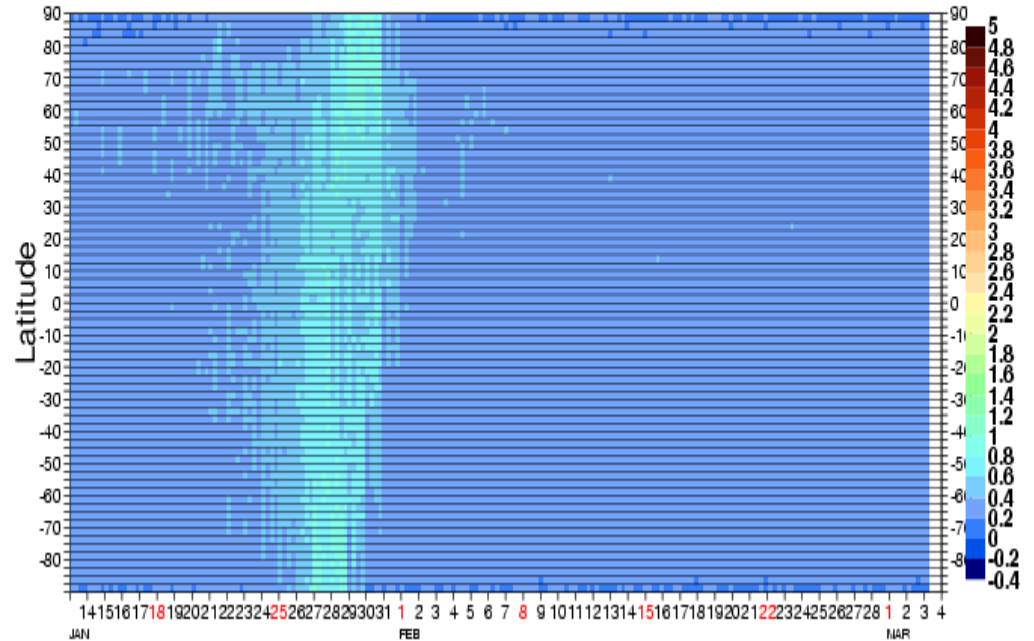
Area: lon_w= 0.0, lon_e= 360.0, lat_n= 90.0, lat_s= -90.0 (all surface types)
EXP = 0001



STATISTICS FOR RADIANCES FROM NOAA-16 / AMSU-A
STDV OF FIRST GUESS DEPARTURES (OBS-FG) [K] (CLEAR)

CHANNEL = 10

EXP = 0001, DATA PERIOD = 2009011300 - 2009030400
Min: 0.136874 Max: 1.0036 Mean: 0.362573

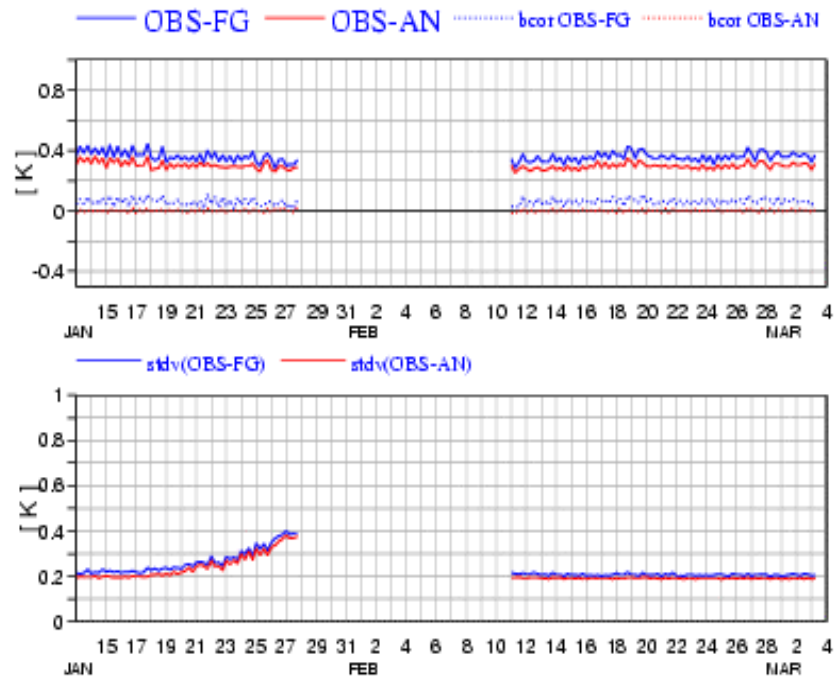


Automated warnings: example

Statistics for Radiances from NOAA-16 / AMSU-A

Channel = 10, **Used Data**

Area: lon_w= 0.0, lon_e= 360.0, lat_n= 90.0, lat_s= -90.0 (all surface types)
EXP = 0001

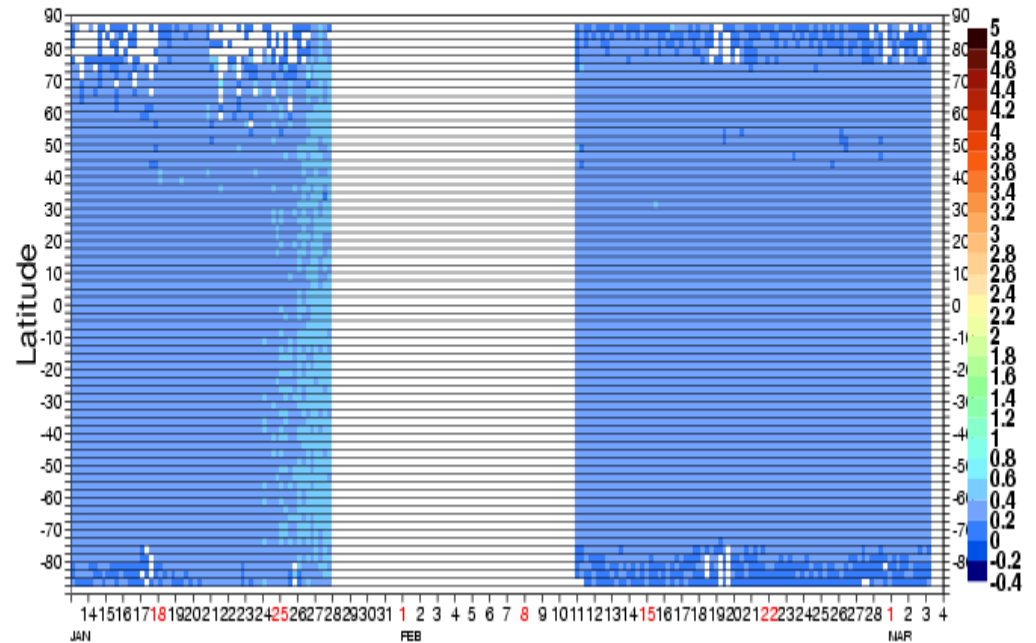


STATISTICS FOR RADIANCES FROM NOAA-16 / AMSU-A
STDV OF FIRST GUESS DEPARTURES (OBS-FG) [K] **(USED)**

CHANNEL = 10

EXP = 0001, DATA PERIOD = 2009011300 - 2009030400

Min: 0 Max: 0.657172 Mean: 0.286458



Data temporarily blacklisted

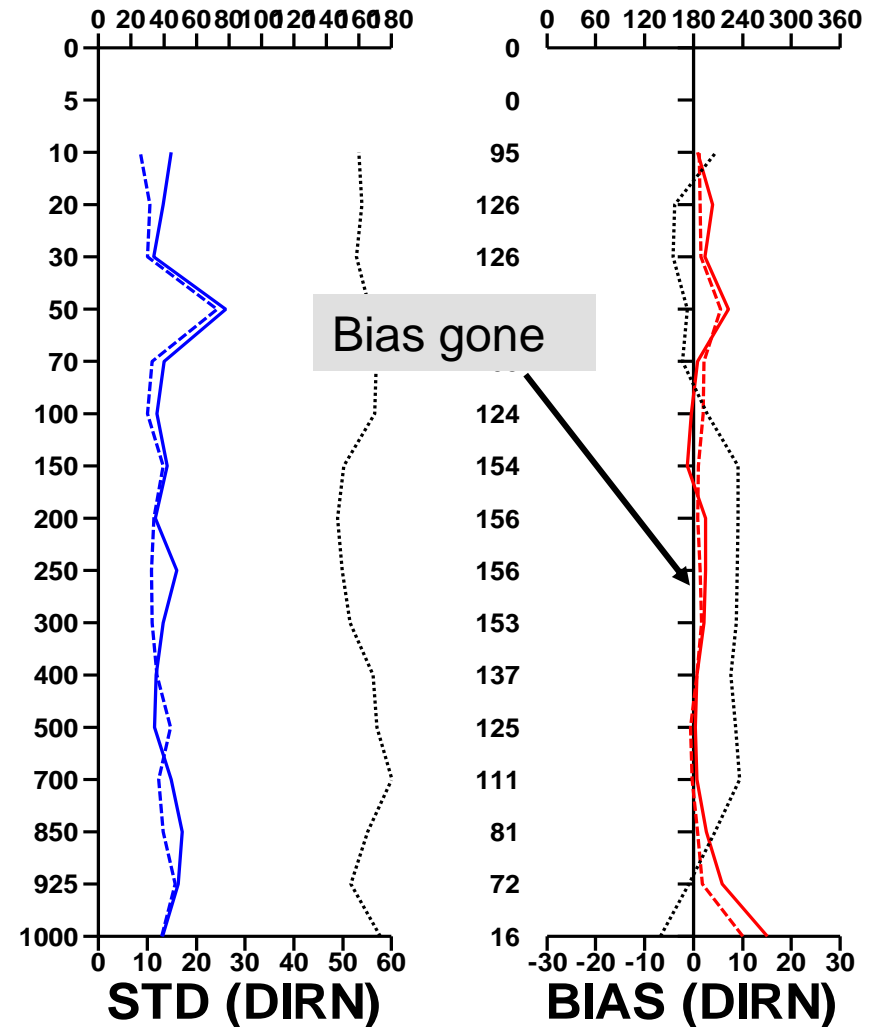
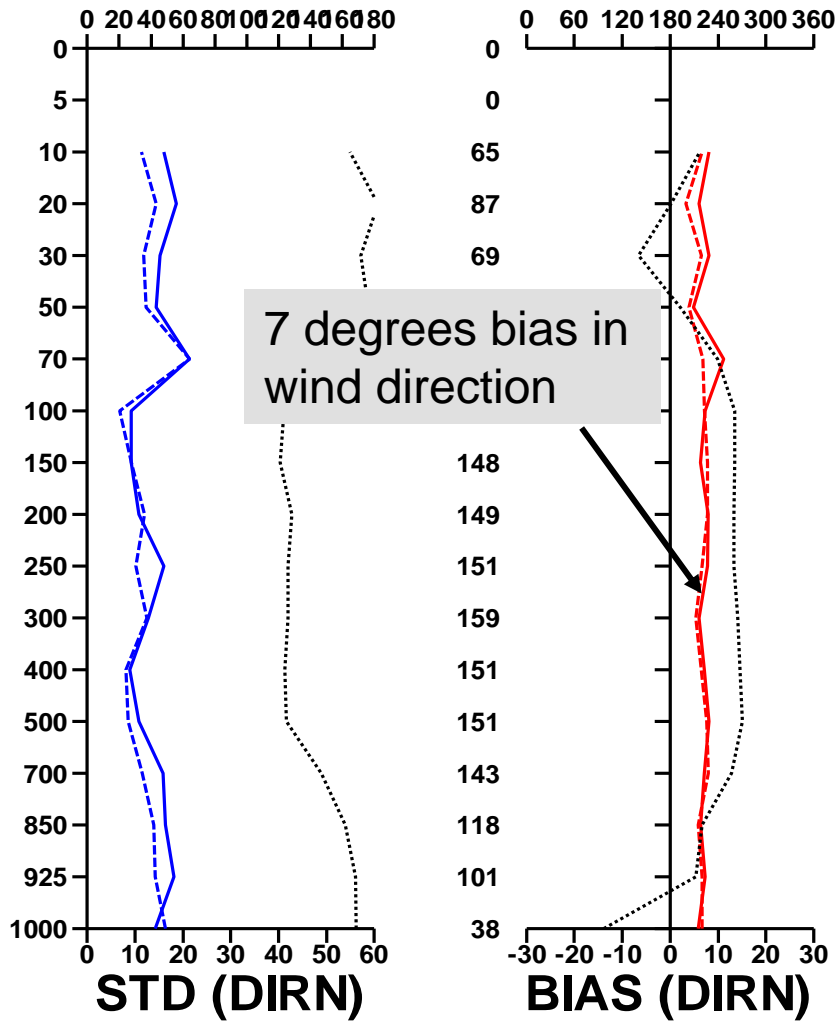
Radiosondes monitoring

- **ECMWF is the Lead Centre for Radiosondes Monitoring.**
 - ◆ **Monthly Global Reports.**
 - ◆ **Twice a year the Consolidated Report for Suspect Stations**
 - ◆ **Once a year the list of the best stations to be used as a reference for the assessment of NWP performance**
- **Main Monitoring Centres exchange information regularly.**
- **The results are fed back to WMO.**
- **Sometimes data providers take action when problems are reported, but often then don't.**

Corrective action by data providers

Jan-Jun 2001

Jul - Dec 2001



Communication between centres/agencies

- **Email notifications from (satellite) agencies:**
 - ◆ Advance warnings for upcoming changes, manoeuvres, etc.
 - ◆ Warnings when problems have been detected.

- **Exchange of information between NWP centres:**
 - ◆ Monitoring statistics available on the internet.
 - ◆ Automated alerts available on the internet.
 - ◆ Intercomparison of monitoring statistics on the internet: e.g.,
 - ➔ NWP SAF winds monitoring, monitoring of EARS/RARS data
 - ◆ Community alerts if a problem has been detected.

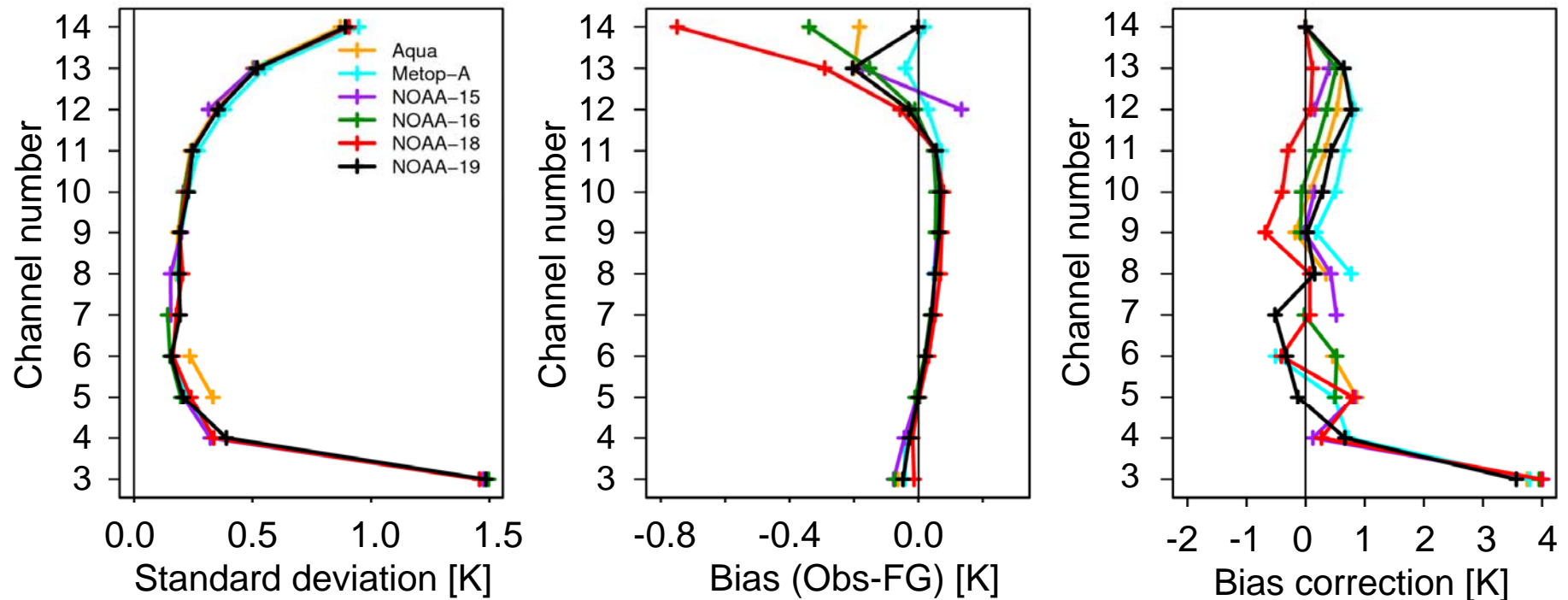
- **Exchange of information/coordination in international working groups and meetings:**
 - ◆ E.g., ITSC, IWWG, IPWG, North America/Europe Data exchange meetings.

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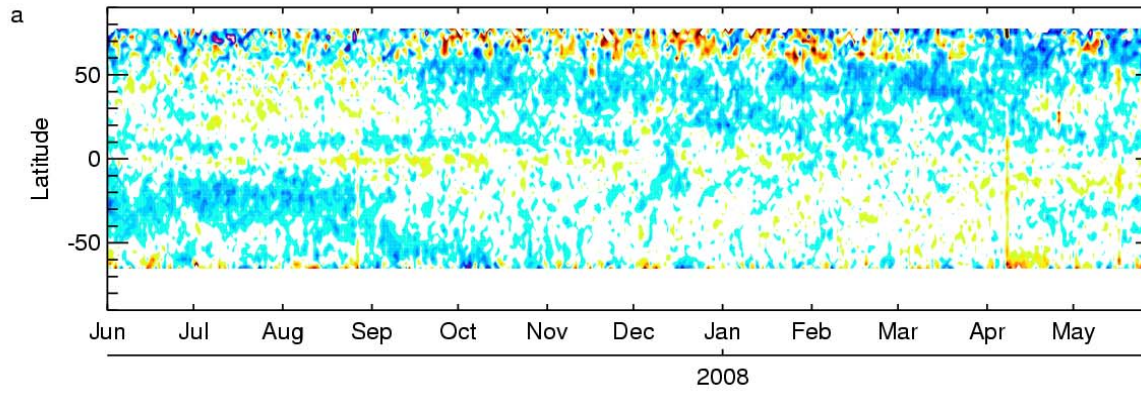
Check-out of new data

- New data is monitored and evaluated in forecast impact trials first.
- Comparison with expectations/other instruments.
- Contribution to cal/val activities.
- Example: FG-departure statistics for NOAA-19 AMSU-A:

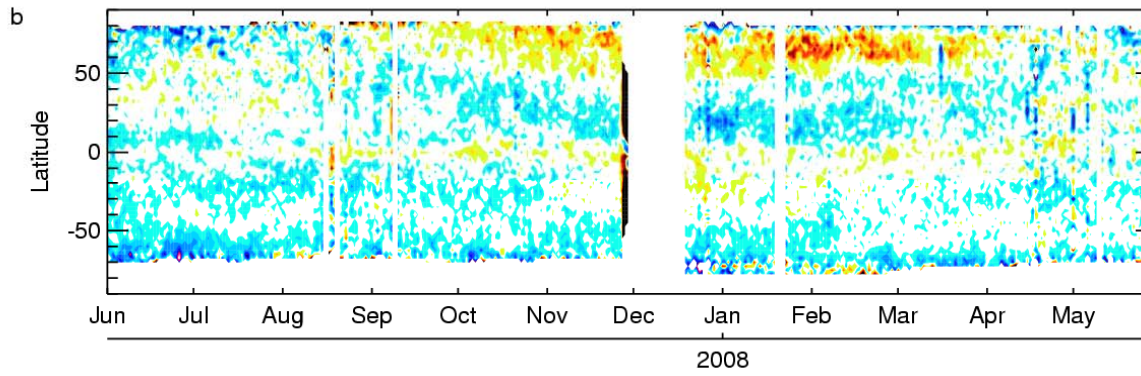


Example: Biases in TMI data

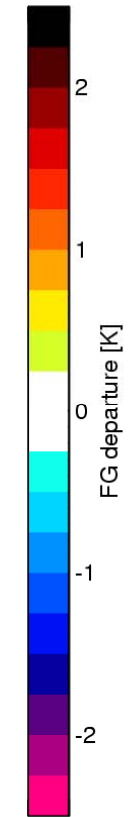
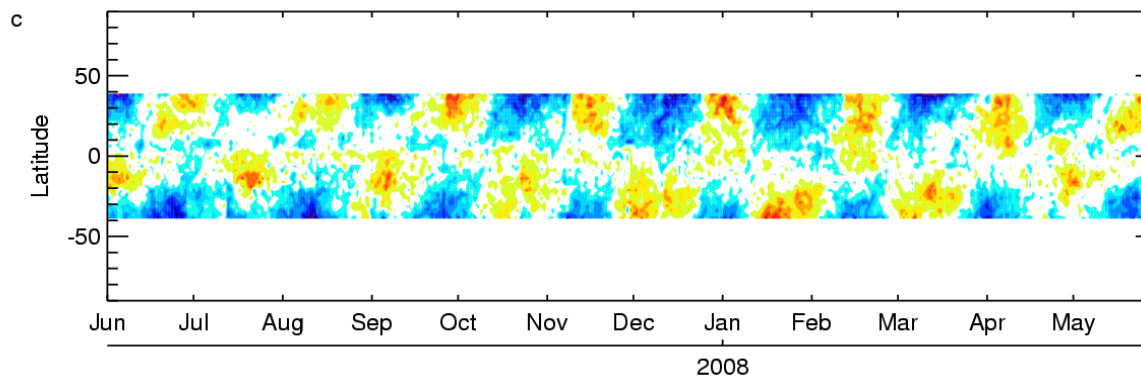
SSM/I



AMSR-E



TMI



First guess departure [K]

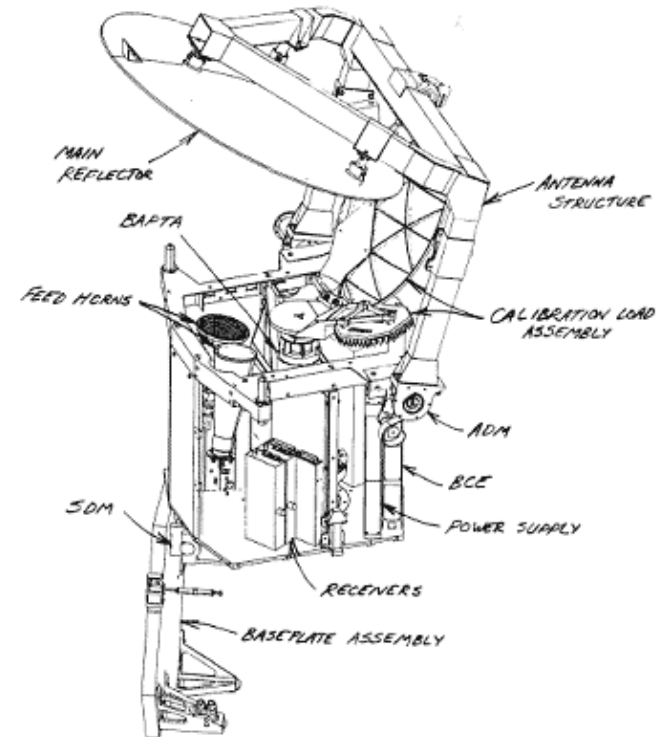
Emissive reflector biases

- All conical-scanning microwave imagers (TMI, SSMI, SSMIS, AMSR-E ...) incorporate a spinning reflector
- If the reflector is emissive:

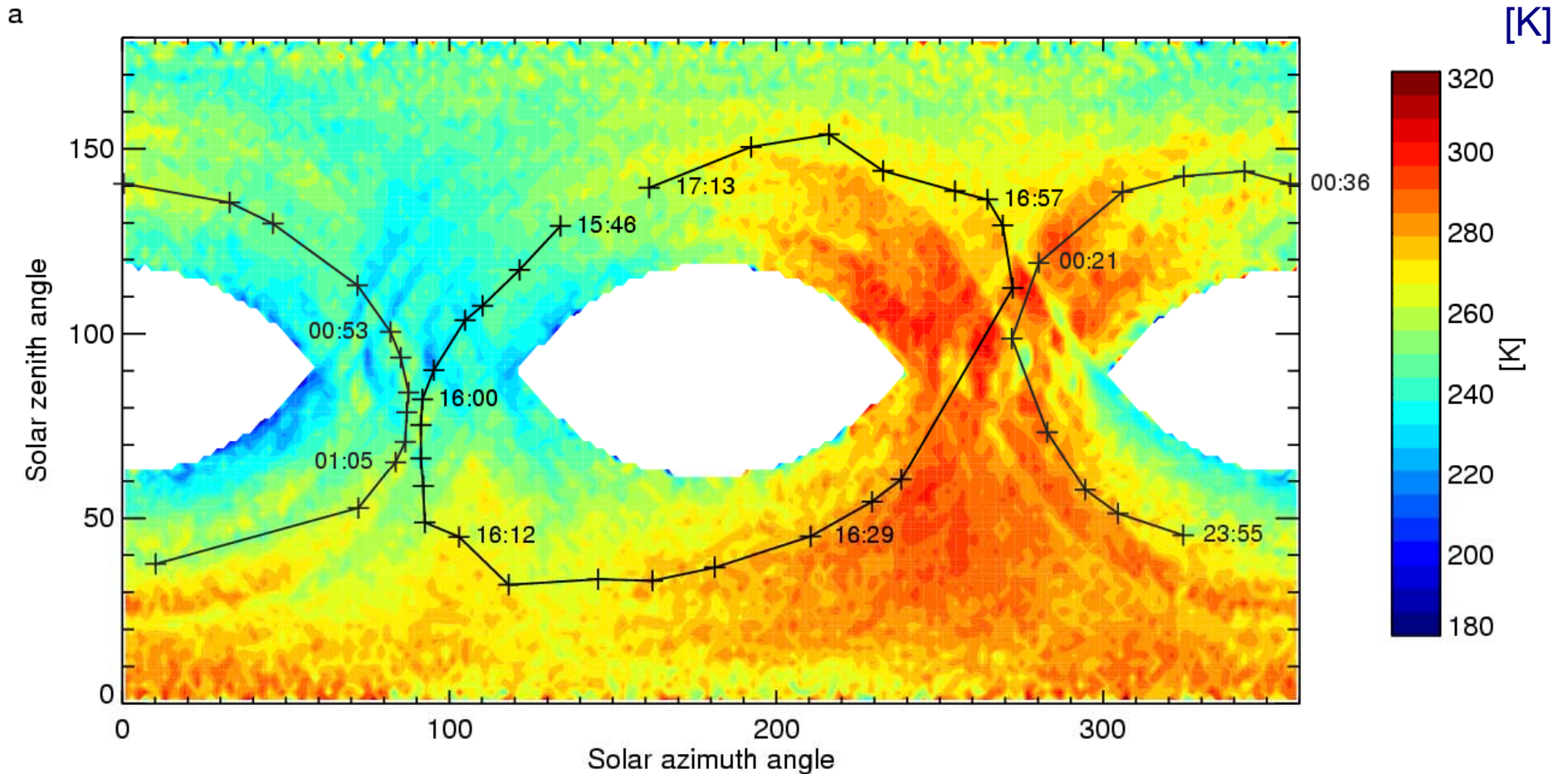
$$T_{MEASURED} = (1 - \varepsilon)T_{TRUE} + \varepsilon T_{REFLECTOR}$$

Reflector emissivity

- Unfortunately a common situation:
 - ◆ SSMIS – Bill Bell, 2008, IEEE
 - ◆ TMI – Frank Wentz, 2001, IEEE



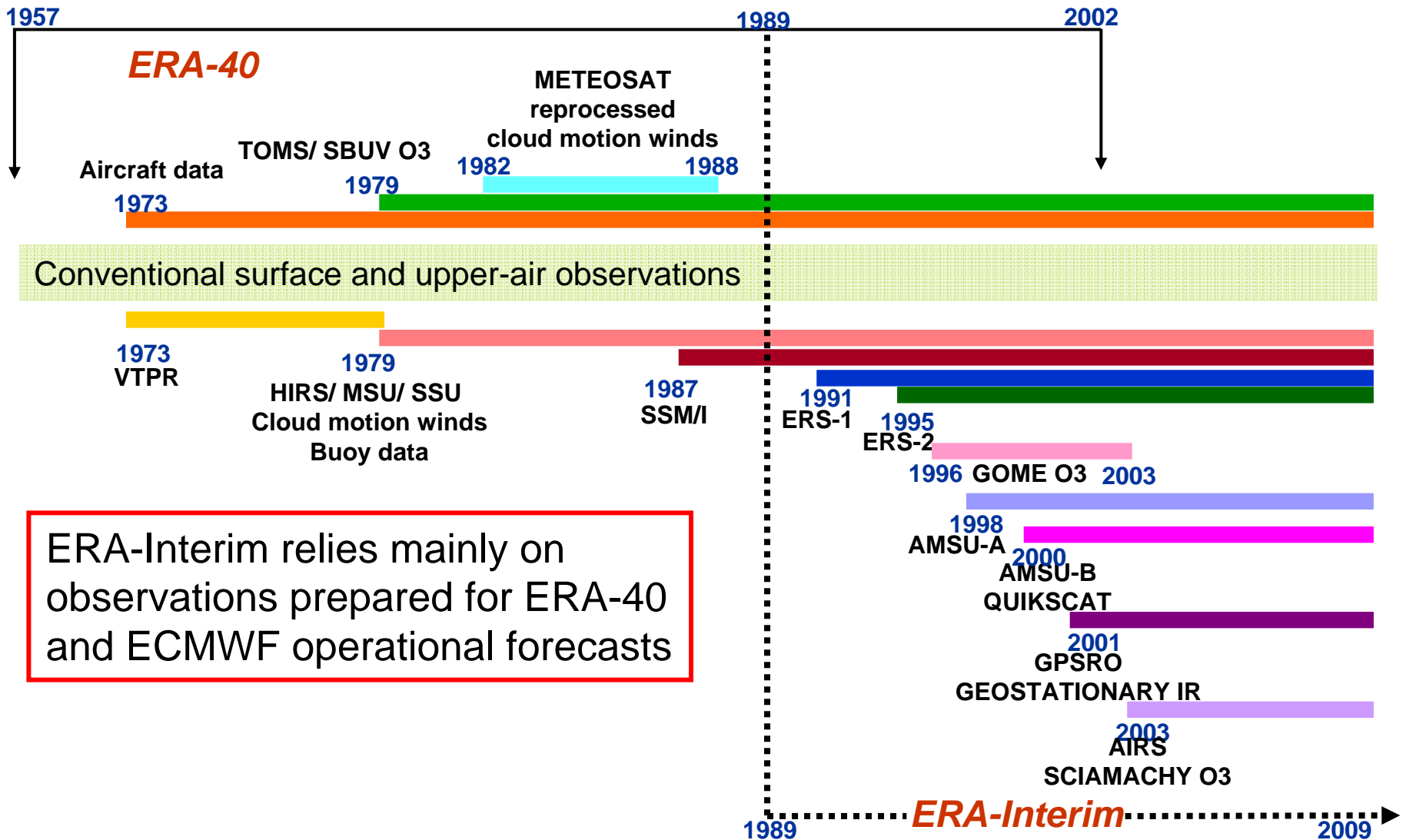
TMI reflector temperature estimated from first guess departure biases



Reflector temperature is not measured on-board for TMI.

Reanalyses

- Use a fixed modern data assimilation system to analyse past observations
- E.g., ERA-40, ERA-Interim

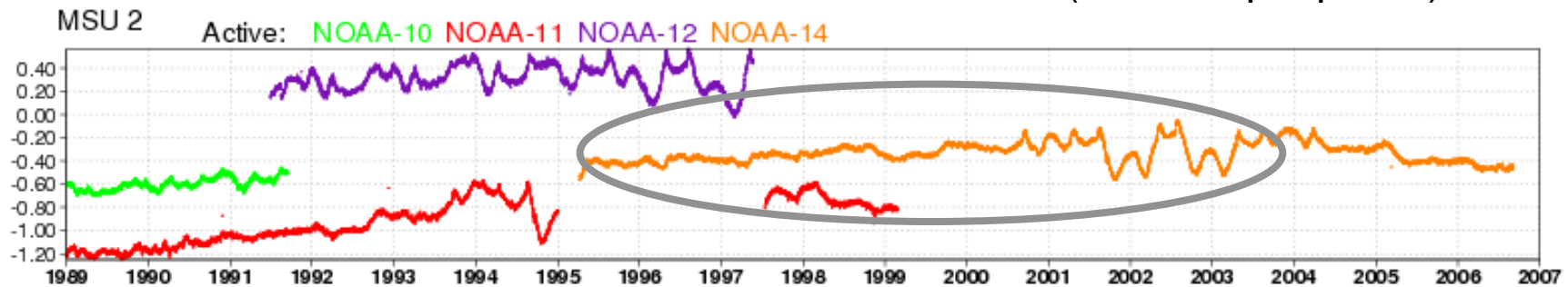


ERA-Interim relies mainly on observations prepared for ERA-40 and ECMWF operational forecasts

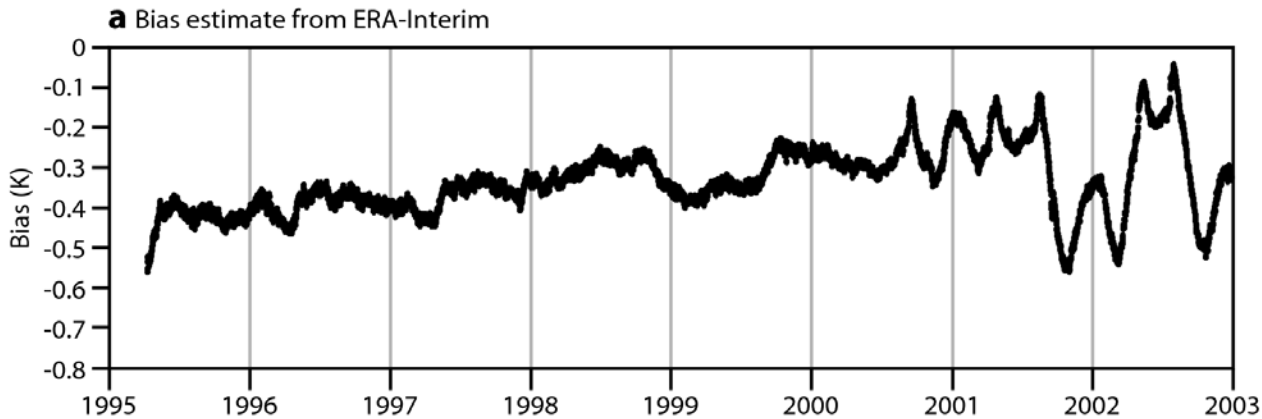
Reanalysis can be used to remove biases from observations

Variational bias correction of satellite radiances in ERA-Interim
Dee and Uppala 2009 (QJRMS, in press)

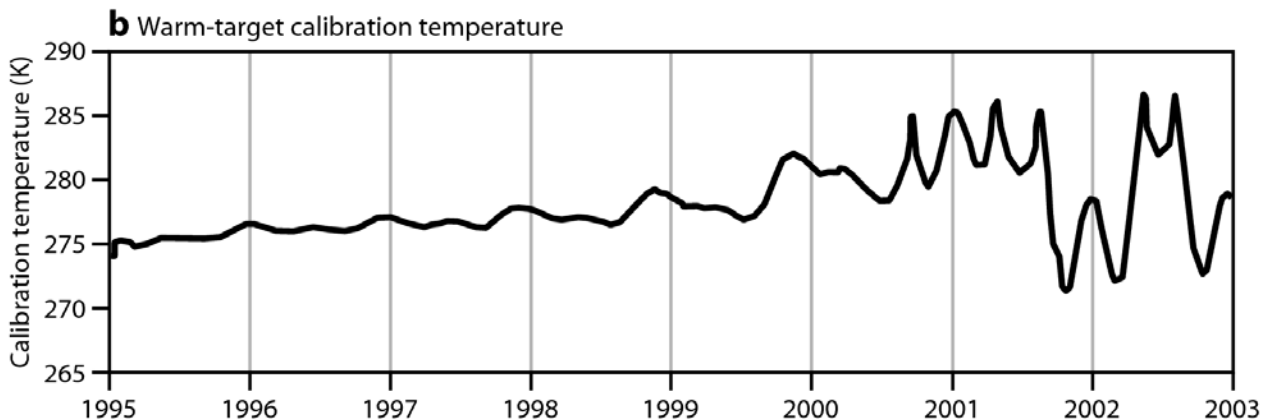
Global mean bias corrections for MSU channel 2 (lower troposphere)



MSU ch2 instrument bias due to warm-target fluctuations



Variational bias estimates for NOAA-14 from **ERA-Interim**



Actual **warm-target temperatures** on board NOAA-14 (Grody *et al.* 2004)

MSU instrument errors are identified based on all information available to the reanalysis

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Concluding remarks

- **Monitoring of observation quality in NWP is essential and continuous.**
 - ◆ Crucial to ensure quality of forecast (or reanalysis)
 - ◆ Mostly based on background departures
 - ◆ Automatic alert procedures to trigger further investigation
 - ◆ Always something new to find
- **Quality information provided with data can be useful.**
 - ◆ Accuracy estimates, flags
 - ◆ Information on observing conditions (instrument parameters, atmospheric conditions)
 - ◆ Used for data selection/quality control, assignment of observation errors
- **Modern data assimilation systems provide a framework for overall assessment of consistency and quality of observations.**
 - ◆ Estimation of (relative) biases
 - ◆ Detection of “poor” data

Examples of quality information (1)

- **“Quality indicator” for AMVs:**

- ◆ For each AMV, characterises the consistency of derived winds
- ◆ Available from all AMV producers
- ◆ Used for data selection, thinning, and observation error assignment in NWP

- ◆ **Advantages:**

- Automates quality control
- Allows flexible data selection for users
- Forecast-independent QI available

- ◆ **Limitations:**

- Does not characterise all errors
- Different characteristics for different wind producers despite similar implementation
- Indirect measure of accuracy, not necessarily an indicator of quality in all situations
- Need for “calibration” if used to indicate observation errors

Examples of quality information (2)

- **Retrieval error for trace gas profiles:**
 - ◆ **Based on estimates from physical retrieval algorithms**
 - ◆ **Available with some data**

 - ◆ **Advantages:**
 - ➔ Useful information for data quality assessment
 - ➔ Can be used as basis for observation error/data selection

 - ◆ **Limitations:**
 - ➔ Error budgets often incomplete or unclear
 - ◆ **Random error only? Radiative transfer error?**
 - ◆ **Cloud contamination?**