The impact and importance of GPS - RO in NWP

Presented by Dr. John Derber
National Centers for Environmental Prediction

ECMWF/ EUMETSAT ROM - SAF workshop on
Applications of GPS radio occultation measurements
16 to 18 June 2014

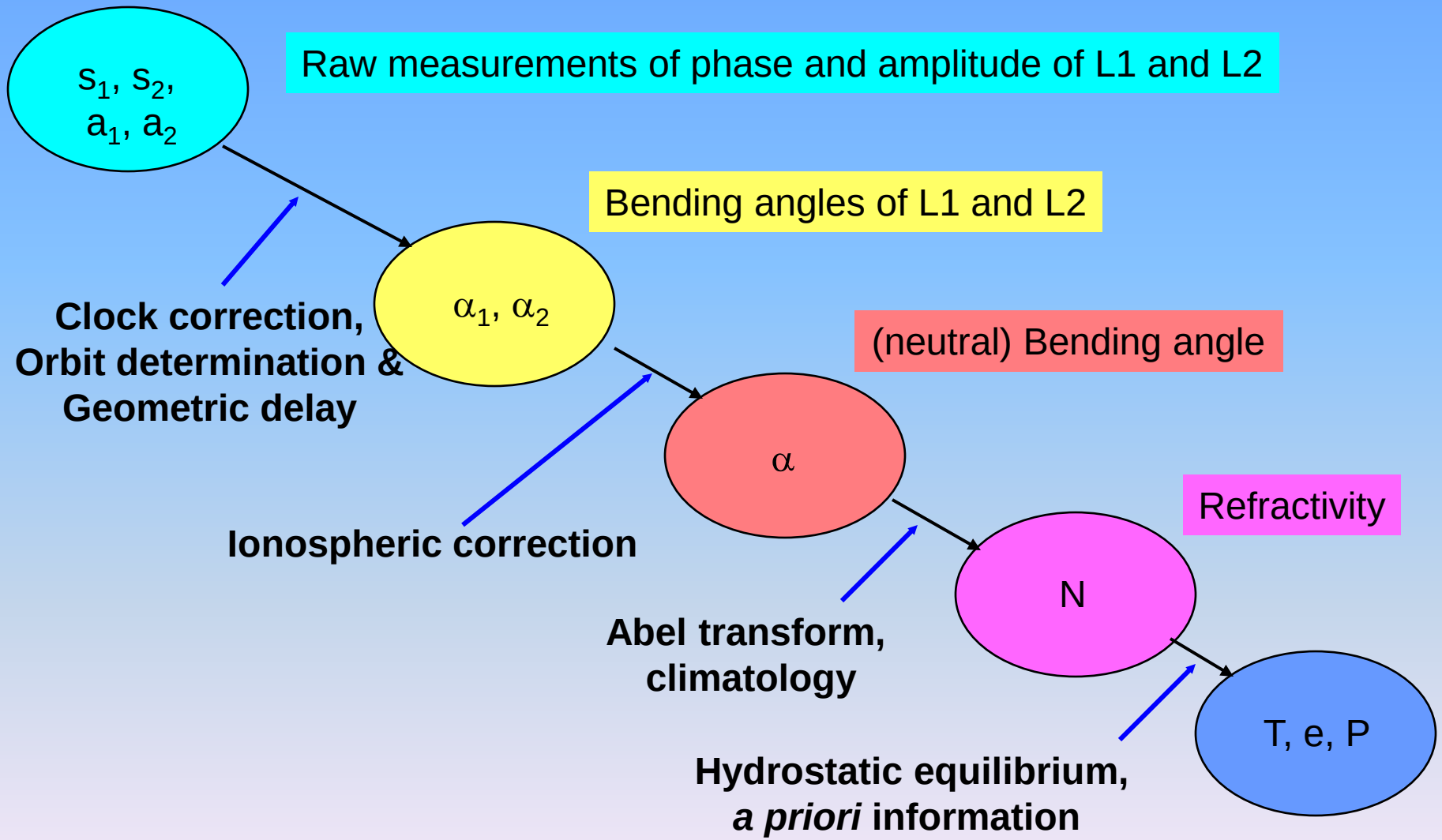
Outline

- GPS-RO data in atmospheric data assimilation
- Uses of GPS-RO data
  - Data and System monitoring
  - Reference observations
  - Density information in GPS-RO observations
- Impact of GPS-RO observations
  - Forecast sensitivity to observations
  - OSE experiments

GPS-RO data in atmospheric data assimilation

- Data must be used carefully. Improperly used or bad data can produce large negative impacts. Important to be aware of instrument characteristics before attempting to use data.
- Raw observations vs. pre-processed observations.
- No current component of observing system is used “perfectly” or “as well as possible”.
- Computational expense plays important role in design of system.

GPS radio occultation measurements & processing



GPS-RO data in atmospheric data assimilation

- Data must be used carefully. Improperly used or bad data can produce large negative impacts. Important to be aware of instrument characteristics before attempting to use data.
- Raw observations vs. pre-processed observations.
- No current component of observing system is used “perfectly” or “as well as possible”.
- Computational expense plays important role in design of system.

Atmospheric Analysis Problem

$$J = J_b + J_o + \ldots$$

$$J = (x-x_b)^T B_x^{-1}(x-x_b) + (K(x)-O)^T (E+F)^{-1}(K(x)-O) + \ldots$$

J = Fit to background + Fit to observations + other small terms

x = Analysis
x_b = Background
B_x = Background error covariance
K **= Forward model (nonlinear)**
O = Observations
E+F = R = Instrument error + Representativeness error

Important aspects of variational DA problem

- All data used at same time.
- Forward operator (K) – transforms control variables (x) into simulated observations.
  - Can include forecast model (4-D).
  - Generally more accurate implies more useful information extracted
  - Choice of forward model determines what observations to use (computational cost important)
  - If variables impacting forward model are not a part of x, then forward model error can be introduced.

Important aspects of variational DA problem

- Instrument + Representativeness error determines weight given observation
  - Off diagonal terms allows correlated instrument or representativeness error
- Choice of which data to use is important.
  - Quality control
  - Thinning or superobing
  - Availability of data
- Background error determines weight given to short term forecast
  - Background error determines how information is distributed spatially and between variables
  - Analysis variable (x) definition enters into background error and forward model
  - Background can be as good or better than observations (in terms of variance), but will have different error structure

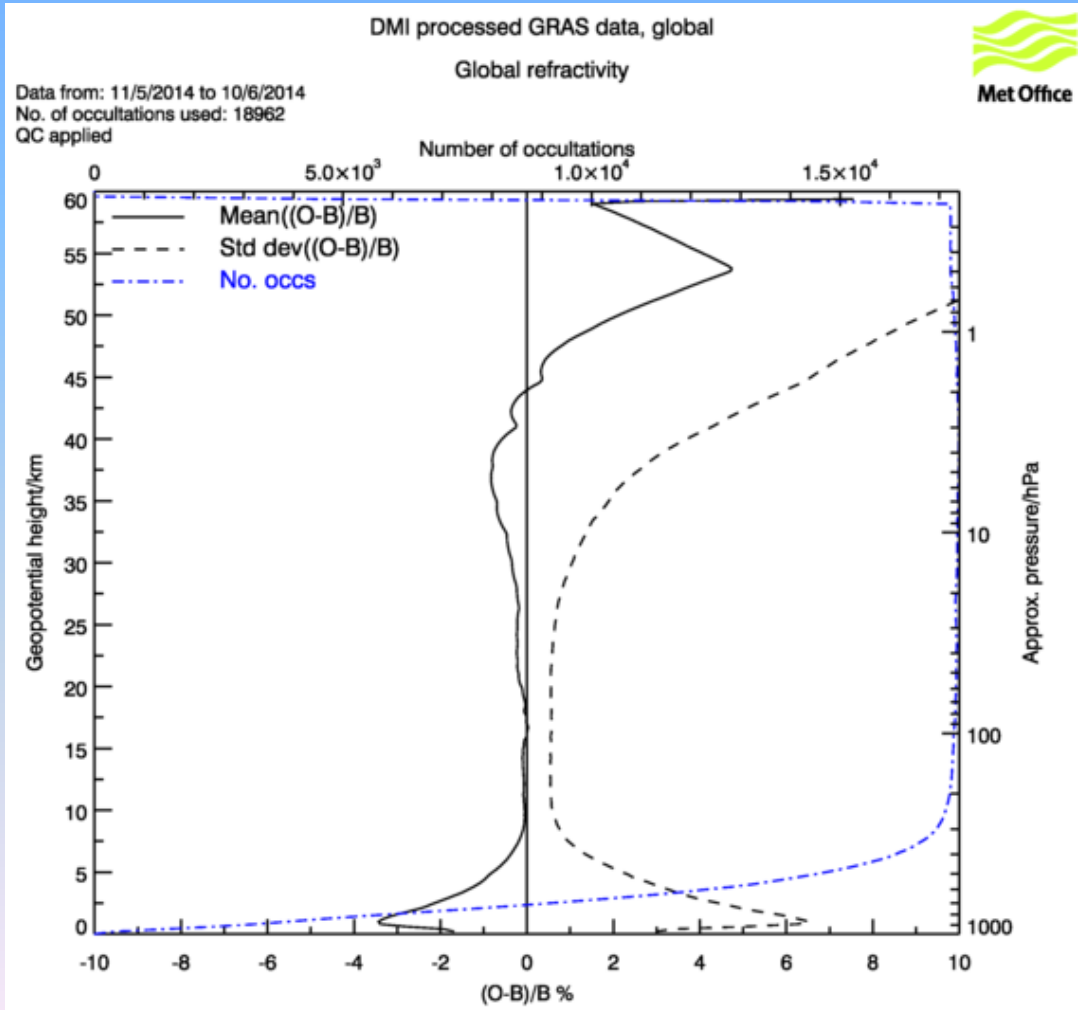
Outline

- GPS-RO data in atmospheric data assimilation
- Uses of GPS-RO data
  - Data and System monitoring
  - Reference observations
  - Density information in GPS-RO observations
- Impact of GPS-RO observations
  - Forecast sensitivity to observations
  - OSE experiments

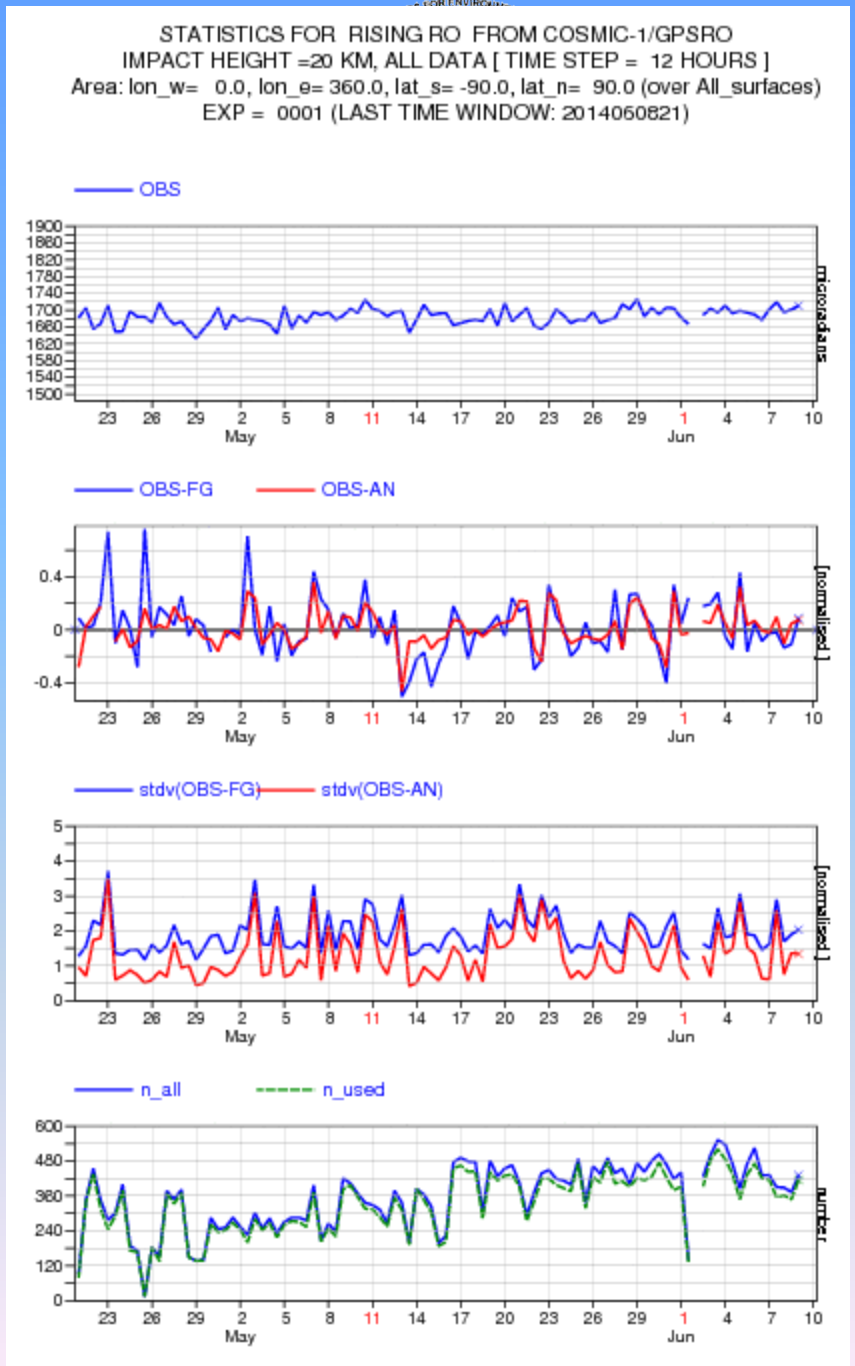
Data and System Monitoring

- Operational centres use the short term model forecasts compared to the observations to monitor the observations and the forecast system.
- Often the NWP centres see problems with instruments prior to notification by provider (Met Office especially).
- The data monitoring can also show problems with assimilation and forecast systems.
- Needs to be ongoing/real time.

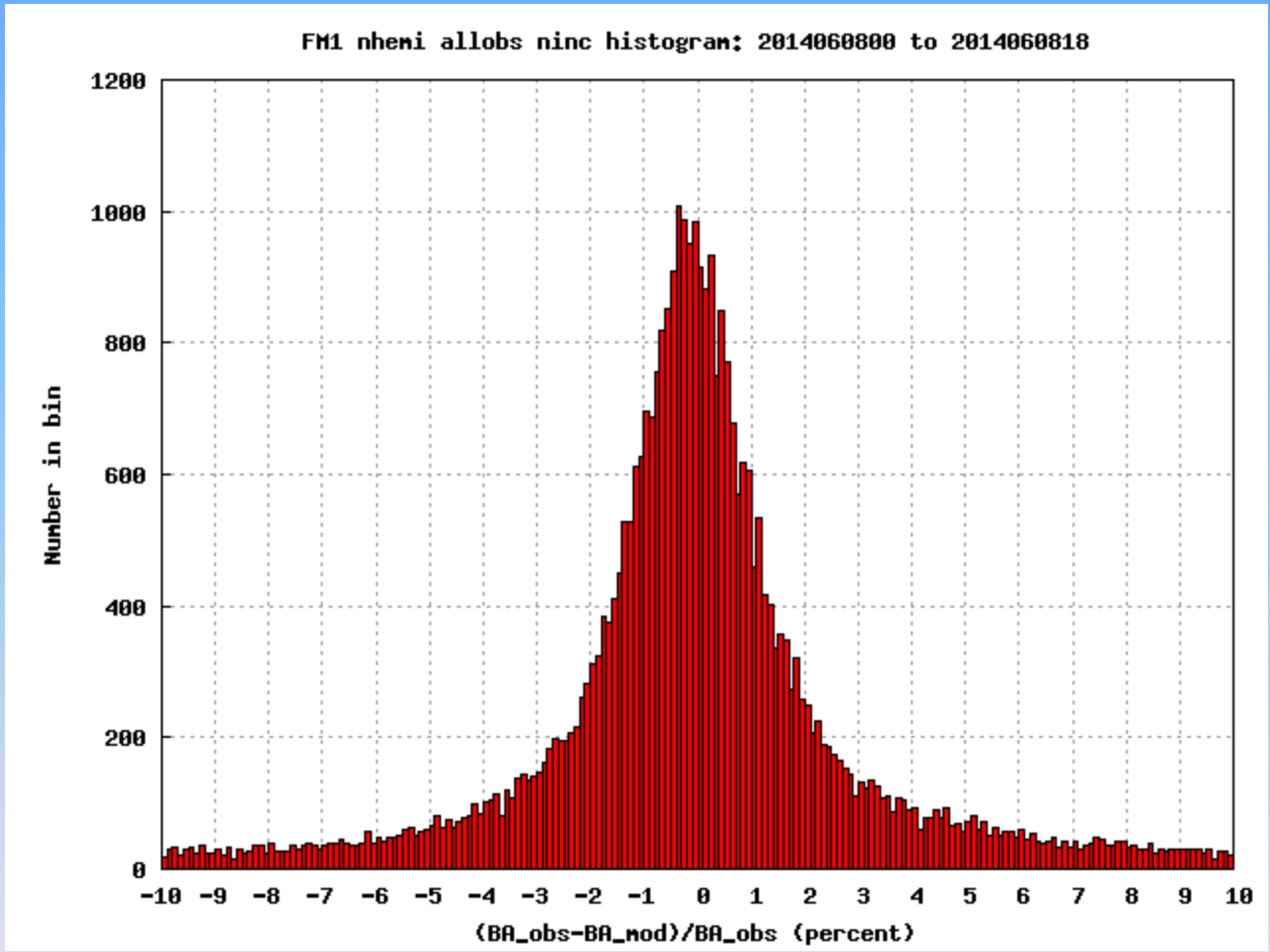
Data and system monitoring



ECMWF


STATISTICS FOR RISING RO FROM COSMIC-1/GPSRO
IMPACT HEIGHT =20 KM, ALL DATA [TIME STEP = 12 HOURS]
Area: lon_w= 0.0, lon_e= 360.0, lat_s= -90.0, lat_n= 90.0 (over All_surfaces)
EXP = 0001 (LAST TIME WINDOW: 2014060821)
OBS
OBS-FG
OBS-AN
stdv(OBS-FG)
stdv(OBS-AN)
n_all
n_used
May
Jun

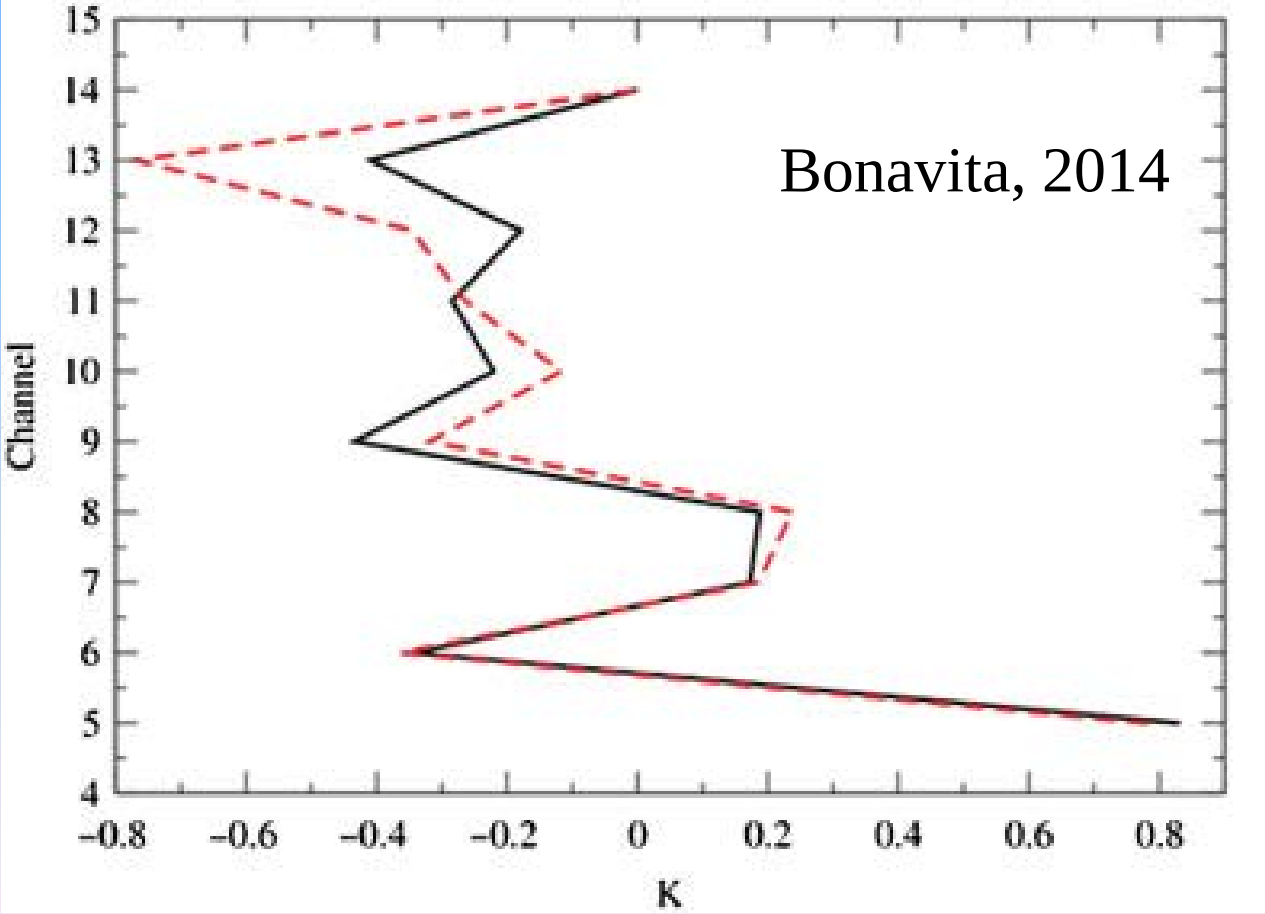
NCEP


FM1 nhemi allobs ninc histogram: 2014060800 to 2014060818
Number in bin
1200
1000
800
600
400
200
0
-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10
(BA_obs-BA_mod)/BA_obs (percent)

Reference observations

- GPS-RO observations are high quality, reliable, and not very instrument dependent
- Other data (e.g., Satellite radiances, radiosondes) often require bias correction due to errors in instrument characterization and forward modelling.
- Since there is not much other reliable data available high in the atmosphere, the GPS-RO data can serve as reference observations (see prior presentation by J. Eyre)

Reference observations



Density information in GPS-RO observations

- Distribution to temperature and moisture determined by background error covariances and forward model
- Impact discussed below

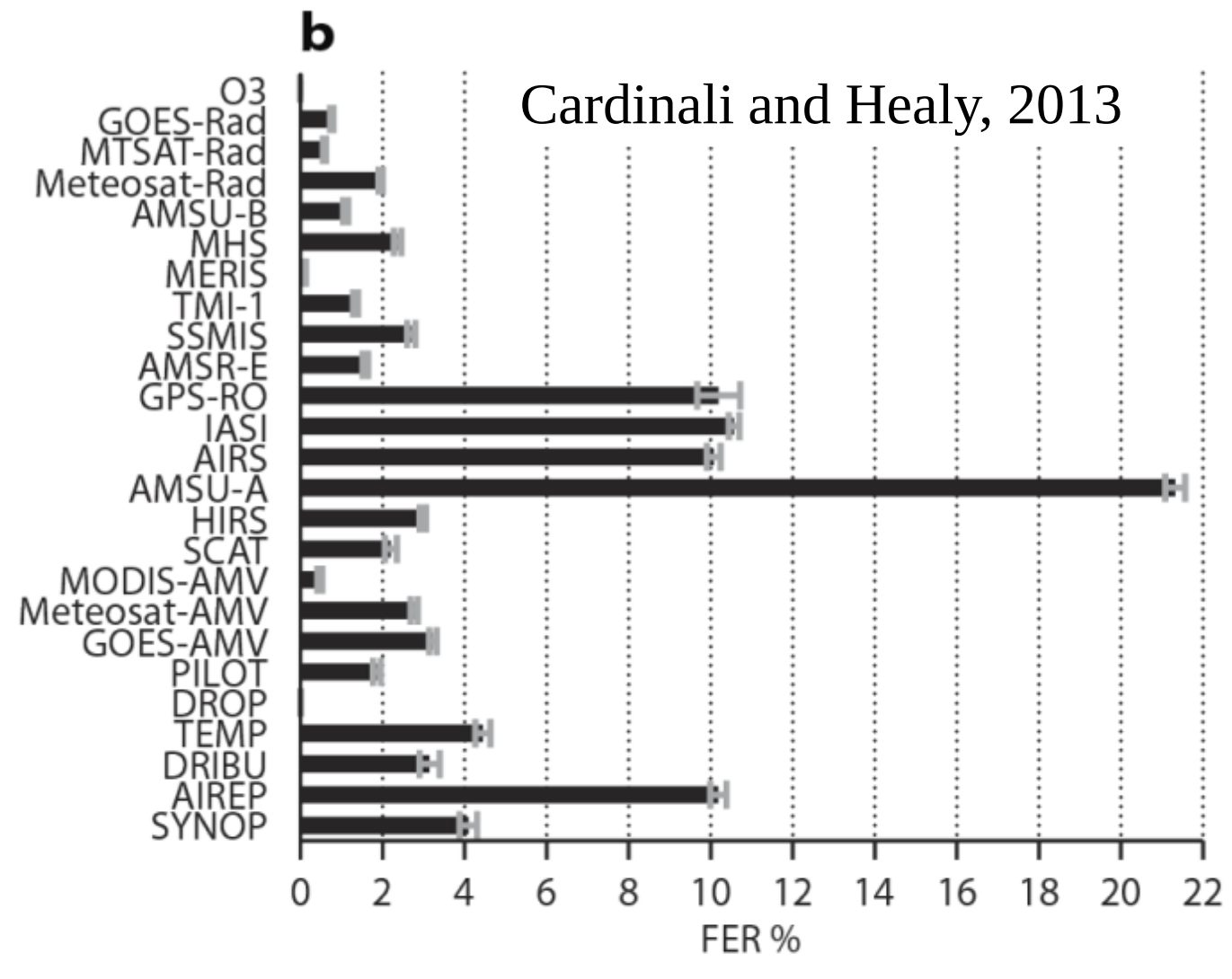
Outline

- GPS-RO data in atmospheric data assimilation
- Uses of GPS-RO data
  - Data and System monitoring
  - Reference observations
  - Density information in GPS-RO observations
- Impact of GPS-RO observations
  - Forecast sensitivity to observations
  - OSE experiments

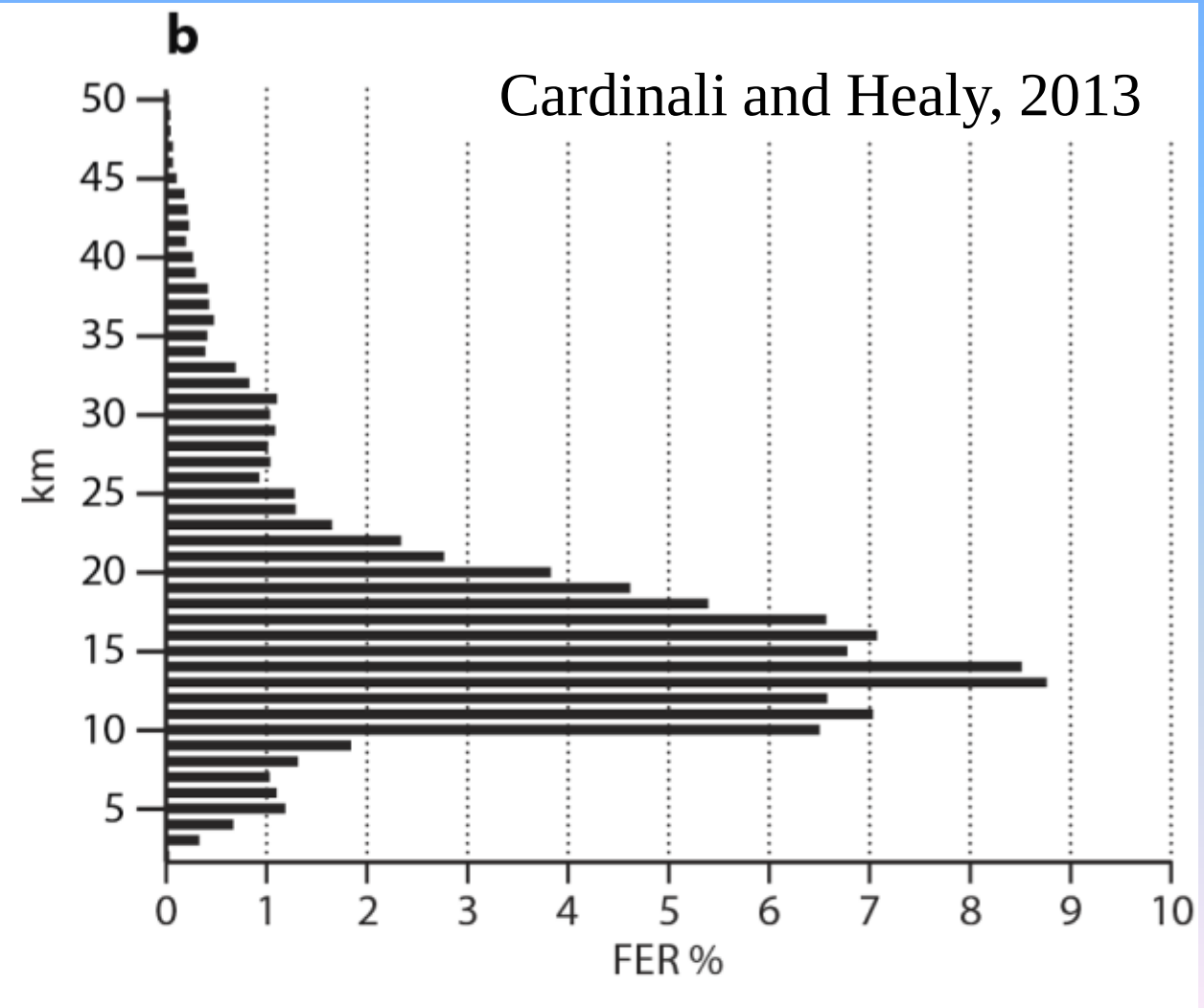
Impact of GPS-RO observations

- Includes both density information and reference observation signal (not monitoring)
- Analysis/forecast diagnostics (e.g. DFS, FER)
  - Impact of redundancies in observing system
- Observing System Experiments
  - All impacts dependent on assimilation system
  - Similar results from most operational systems

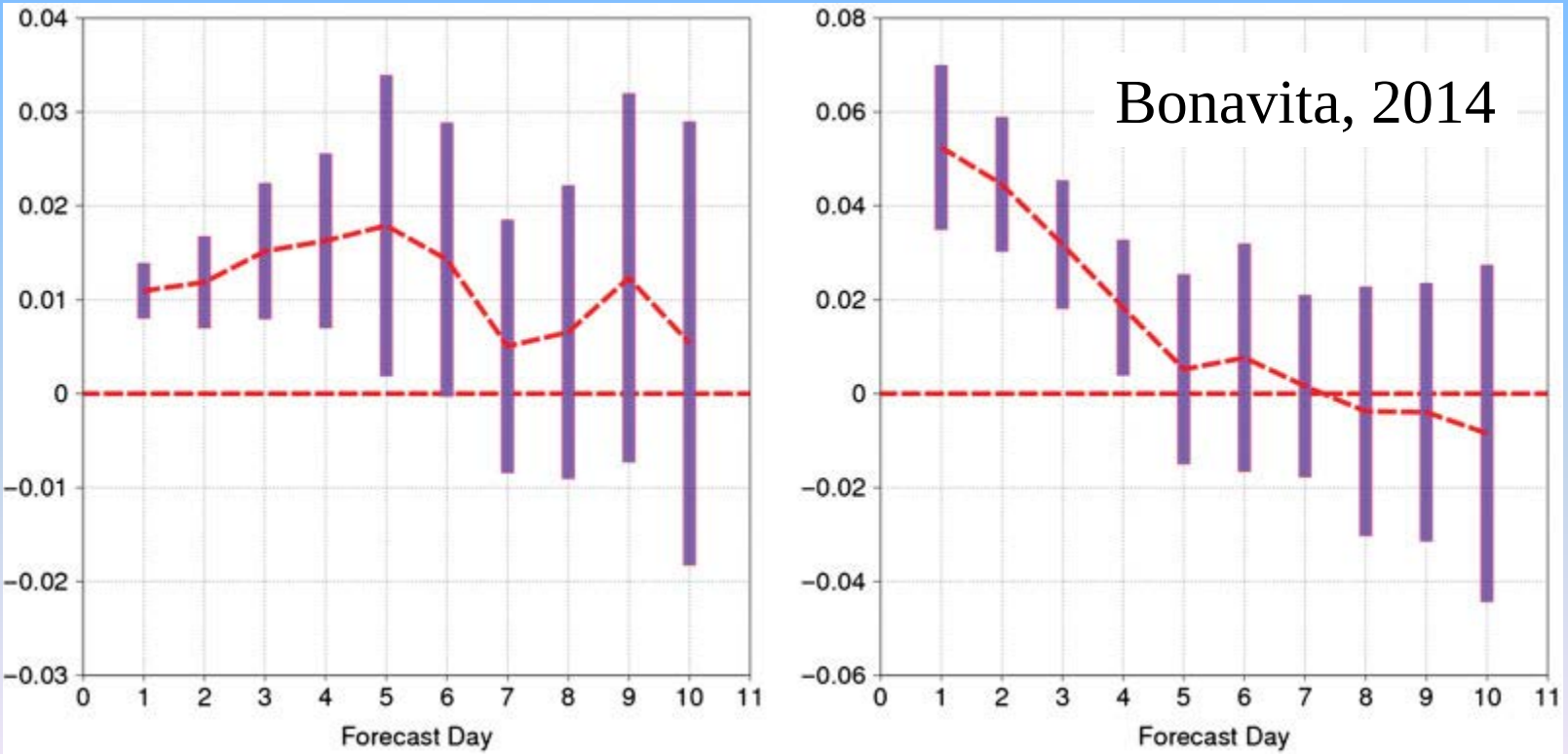
Forecast Error Reduction



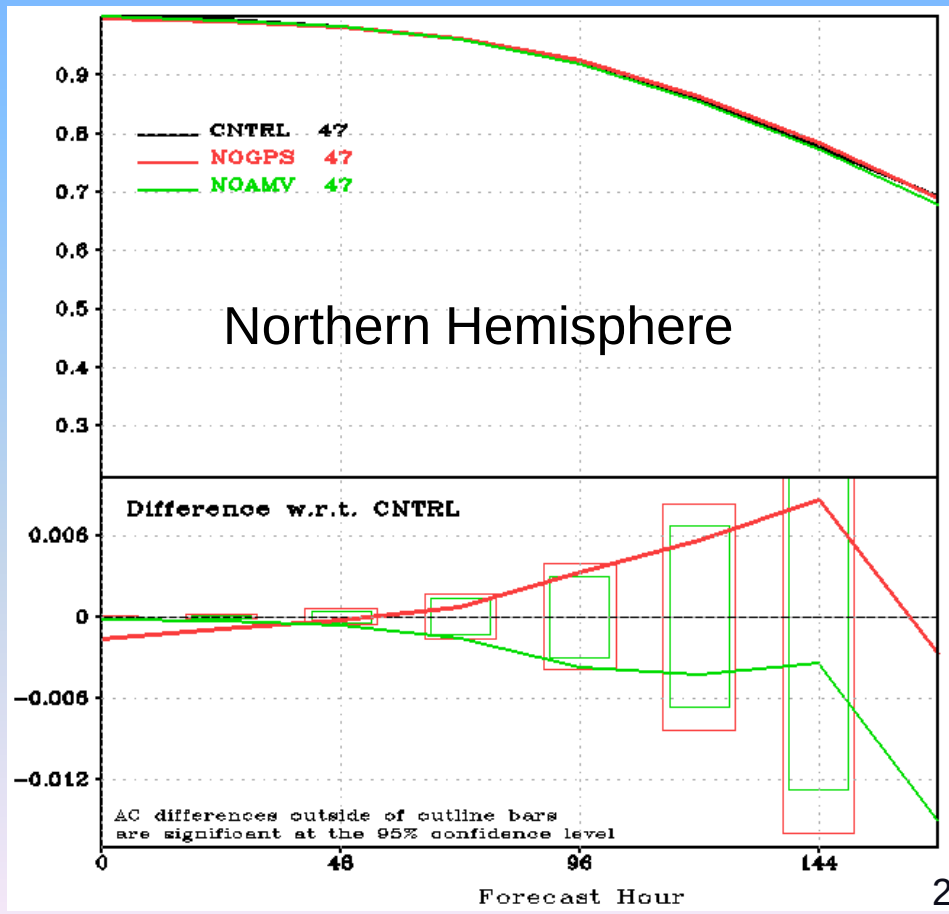
Forecast Error Reduction

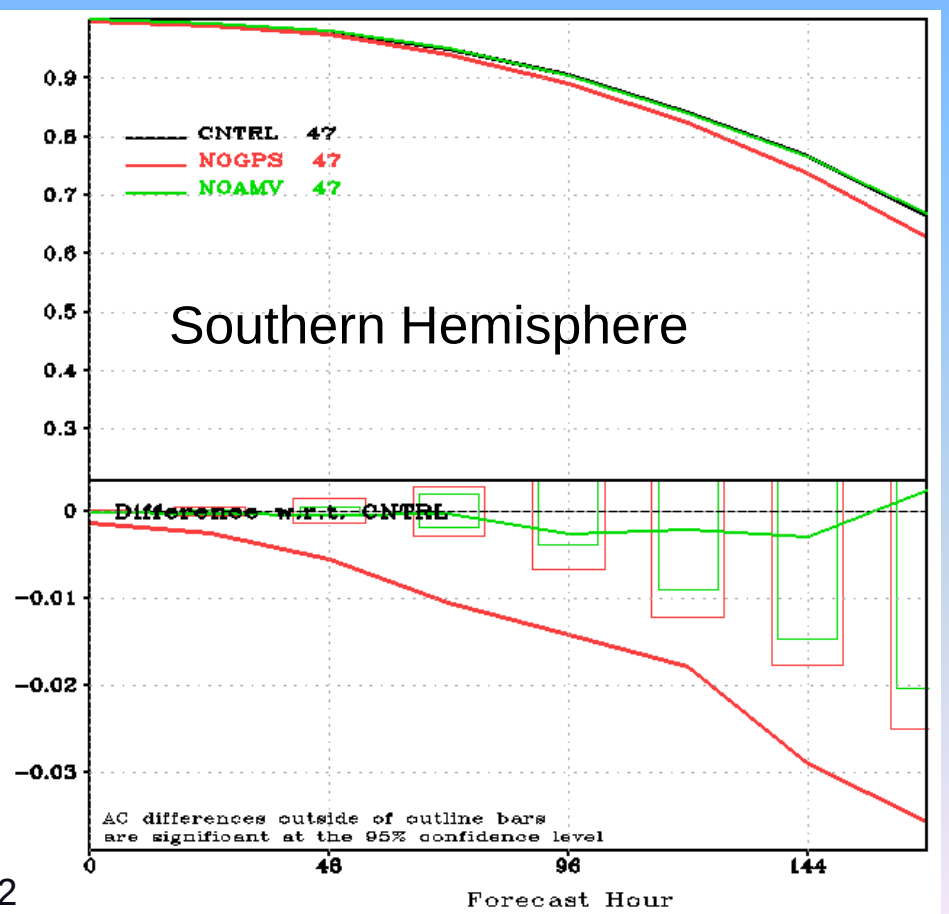


OSE – anomaly correlation

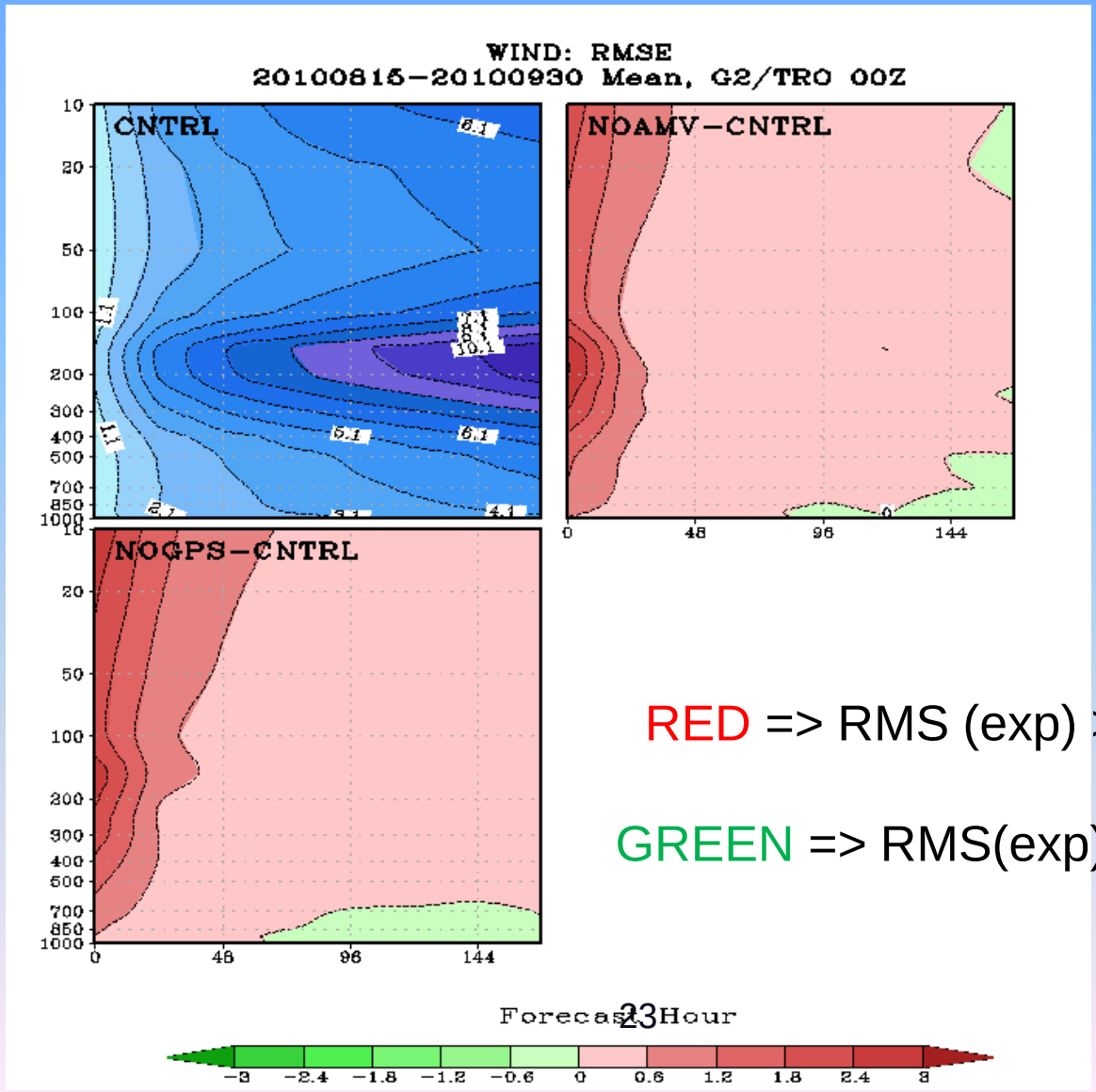


500 hPa Anomaly Correlations
15 Aug – 30 Sep 2010
Jung and Riishojgaard





No GPS-RO / No AMV
15 Aug -30 Sep 2010
Jung and Riishojgaard



RED => RMS (exp) > RMS(control)

GREEN => RMS(exp) < RMS(control)

Final Comments

- GPS-RO observations do have a positive impact on NWP, but not overwhelming
- The data is important for it's direct impact on model skill, as a reference data set for bias correction and for monitoring purposes
- Largest impact is in upper troposphere and lower stratosphere
- Through improved data assimilation techniques more information can be extracted from the observations