Importance of GPS-RO in NWP and climate reanalyses at the European Centre for Medium-range Weather Forecasts

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ECMWF
Plan

- Introduction to ECMWF
- GPSRO at ECMWF
ECMWF
An independent intergovernmental organisation established in 1975 with 18 Member States and 16 Co-operating States.
The ECMWF operational forecast system
(since 26 January 2010)

- **Data assimilation system**: twice per day, 16km
  (outer loop T1279, inner loop T159/255/255)

- **High resolution deterministic forecast**: twice per day
  16 km (T1279), 91-level, to 10 days ahead

- **Ensemble forecast (EPS)**: twice daily, 51 members,
  32/63 km (T639/319), 62-level, to 15 days ahead

- **Ocean waves**: twice daily
  - Global: 10 days ahead at 25 km
  - Ensemble: 15 days ahead at 50 km

- **Monthly forecast**: once a week
  51-members, 50/80 km 62 levels

- **Seasonal forecast**: once a month
  41-members, 125 km 62 levels, to 7 months ahead
Continuous progress in NWP scores
anomaly correlation for 500hPa height NH reaches 60%
Comparison with other centres:
ANC, year 2010, Northern Hemisphere

Accuracy (%) vs Forecast day

- ECMWF
- CMC, Canada
- JMA, Japan
- Met Office, UK
- NCEP, USA

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Comparison of EPS scores from TIGGE
whole year 2010

Northern Hemisphere Extratropics – 850 hPa temperature

Continuous ranked probability skill score

Forecast day

CMC
NCEP
MetOffice
ECMWF
Comparison of TC forecasts from HKO, 2008-2009, western North Pacific
Evolution of ECMWF scores comparison northern and southern hemispheres

Anomaly correlation of ECMWF 500 hPa height forecasts

Northern hemisphere
Southern hemisphere

Year

81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11

%

Day 3
Day 5
Day 7
Day 10

Courtesy of ECMWF. Adapted and extended from Simmons & Hollingsworth (2002)
Satellite data used by ECMWF

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Value of GPS-RO in the Global Observing System

- ECMWF now assimilates over ~20 million observations per day, but we use less than 10% of the available satellite radiances.

- It is surprising that a relatively small number of the GPS-RO observations can have a large impact. We believe this arises because:
  - GPS-RO has superior vertical resolution than satellite sounders.
  - GPS-RO can be assimilated without bias correction.

- GPS-RO complements the satellite radiance information.
GPS-RO at ECMWF

- 2003: EUMETSAT Fellowship to introduce a GPS-RO assimilation capability in the IFS.
- ECMWF joined the EUMETSAT GRAS Satellite Application Facility (GRAS SAF) in March 2007.
Impact of GPS-RO on ECMWF operational biases against radiosonde measurements
Impact on the southern hemisphere geopotential height RMS scores

- a) 1000 hPa
- b) 500 hPa
- c) 200 hPa
- d) 100 hPa

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Bending angle statistics for rising and setting occultations

Ability to detect high-resolution vertical structures

BLACK = setting
GREY = rising

SH, FORMOSAT-3 COSMIC
The forecast sensitivity (Cardinali, 2009, QJRMS, 135, 239-250) denotes the sensitivity of a forecast error metric (dry energy norm at 24 hour range) to the observations. The forecast sensitivity is determined by the sensitivity of the forecast error to the initial state, the innovation vector, and the Kalman gain.
GPS-RO impact on bias correction of radiances

- Satellite radiances are bias corrected to the NWP model using a variational bias correction (VarBC) approach.
- VarBC requires some measurements to be assimilated without bias correction, to prevent a drift in the biases applied to the measurements. These are called “anchor measurements”.
- **GPS-RO is an anchor measurement.** We have demonstrated how it anchors radiance bias corrections.
- The effect is most clear for the AMSU-A measurements in the stratosphere (e.g., AMSU-A, Ch.9).
Recent experiment removing GPSRO from ERA-Interim (Dec. 08, Jan-Feb 09)

Impact on bias correction. E.g., globally averaged MetOP-A, AMSU-A channel 9 bias correction.

![Graphs showing bias correction with and without GPSRO assimilation]

**GPSRO assimilated**

**No GPSRO**

Bias correction applied to radiance

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Reanalysis applications
Consistency of GPS-RO bending angles

ERA-Interim daily Obs minus Background statistics GPSRO B.A. (percent) N.Hem. (20N-90N)
Is GPS-RO impact saturated?
Challenges: Humidity information
(e.g., Tropics, 850 hPa)

The improvement with FM-3/COSMIC is significant at the 95% level but it is still considerably poorer than the “full system”.
Challenge/opportunity
Limited impact on water vapour

Is this a fundamental limitation imposed by the actual information content of the measurements, or does it reflect:

- the current level of GPS-RO observation numbers.
- current limitations of the data processing techniques and/or usage in operational NWP?

NWP usage: currently using 1D observation operators and probably quite conservative observation errors.

- implement more accurate 2D observation operators.
- more realistic observation error estimates.
FORMOSAT-3/COSMIC data numbers

Processed data for cosmicrt

Occultations per day

Date


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Courtesy of Nick Yen (NSPO)  Up to 2011/2/28
Current GPS-RO observation numbers

- COSMIC numbers are in decline, and a strategy to bridge the gap between COSMIC and COSMIC-2 must be supported.


- EUMETSAT hope to process ROSA measurements from Oceansat-2 and Mega-Tropiques in NRT.

- GFZ (TerraSAR-X) and UCAR (SAC-C, C/NOFS) should be commended for making data from research missions available in NRT.
Summary

- GPS-RO is an important addition to global observing system.
  - Positive impact on forecast scores
  - Detection of high-resolution vertical structures

- GPS-RO impact is not saturated.

- Important applications in reanalysis and climate monitoring (anchoring impact)

- Challenges remain: e.g, deriving water vapour information.

- Clear requirement for FORMOSAT-7/COSMIC-2.
Thank you for your attention