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Minutes of
Round Table Discussion and ICGPSRO Future Plans
in Taipei, Taiwan on 11th of March 2016 at the:
3rd International Conference on GPS RO, March 9th to 11th 2016

Session Chairs: Guey-Shin Chang (NSPO, Taiwan) / Bill Kuo (UCAR, U.S.A.)

Panel Members and Topics:

- Climate: Sean Healy (ECMWF, England) / Andrea Steiner (University of Graz, Austria)
- Geodesy: Krzysztof Sosnica (Wroclaw University, Poland) / Cheinway Hwang (NCTU, Taiwan)
- Ionosphere: Mamoru Yamamoto (Kyoto University, Japan),Charles Lin (NCKU, Taiwan)
- Program/Operation: Anthony Mannucci (JPL, U.S.A.) / Axel von Engeln (EUMETSAT, Germany)

Minutes by: A. von Engeln / S. Healy

Summary

All panel members and the participants of the conference agreed to the following high priority issues for the near future:

- the need of full funding of the FORMOSAT-7/COSMIC-2 constellation, in particular the Polar component
- the need to prepare for the "diversification" in available RO data (different GNSS constellations, signals, processing, commercial data) and the need to develop standards for the processing and evaluation of this data
- the need to improve the use of GNSS data, for sampling not only the neutral but also the ionosphere. And, where possible, consider reflected signals in satellite design.

Topic Points

Neutral Atmosphere

B. Kuo introduced the benefits affecting the Neutral Atmosphere RO impact, pointing out the importance of RO data for NWP, Climate, and Typhoon/Hurricane detection and prediction. He emphasized the importance of the full FORMOSAT-7/COSMIC-2 (F7/C2) constellation (Equatorial and Polar component) and cautioned on an early adoption of commercial data use to replace the Polar component; with no data for a quality assessment available from any commercial provider, no clear and agreed data policy, this would put the continuity of high quality RO data availability at risk.

Discussion:

G.-S. Chang reiterated the commitment to keep the FORMOSAT-3/COSMIC (F3/C) open data policy for F7/C2 in place. B. Kuo asked NOAA and EUMETSAT participants for their current position on commercial data. J. Pica (NOAA, U.S.A.) responded that NOAA has established a commercial pilot program to assess data quality, timeliness, data policy. Although he emphasized that there is currently no viable source of commercial data. A. von Engeln (EUMETSAT, Germany) responded that EUMETSAT is aware of the development on the US side, but itself is not engaged or plans to setup an agreement with any commercial data provider. J. Haase (Scripps Institute of Oceanography, US) noted that in particular the data policy and open access to the data is needed for researchers. J. Pica responded that the pilot is looking at the near real time data provision and the aim is for sharing of data. J. LeMarshall (Bureau of Meteorology, Australia) expressed strong support for the full F7/C2 constellation, raising concerns on the so far unknown quality of commercial data. C. Ao (JPL, US) pointed out that in particular climate data needs high quality measurements and processing, thus a move to commercial data without a first clear and thorough quality assessments by the RO community (involving NWP, climate, space weather) could endanger these core benefits of the current data set. B. Schreiner mentioned the potential risk of commercial providers talking to politicians, where politicians don't know the characteristics of RO data and the needs of the RO community. Eric DeWeaver (NSF, US) cautioned that the potential move to CubeSat based measurements, including potential GNSS reflections, is technological demanding. G.-S. Chang mentioned that a Taiwan developed CubeSat based GNSS observation constellation would undergo a thorough assessments on limitations and possibilities. Depending on the outcome of this assessment, it could be the base for the follow on of F7/C2. S. Healy clarified that ECMWF does currently not see a great variation in the RO data quality, even though it is provided from different instruments and processing centres, thus the RO community is currently working nicely together to assure a high quality, consistent RO data stream. S Healy stressed the importance of a free and transparent dialogue between the data providers and users, in order to optimise the impact of the GPS-RO. John LeMarshall emphasised the large impact GPS-RO has had in the southern hemisphere.

Climate

A. Steiner started and pointed out that the high quality and long term stability of RO makes this an excellent data set to meet all the Fundamental Climate Data Record (FCDR) requirements. In particular the wealth of data from F3/C improved the capabilities of FCDR data set generation from RO. She mentioned the risk of a data gap after F3/C, in particular for higher latitude bands, if the Polar component of F7/C2 is not available. Global coverage is needed to generate FCDR data sets, she emphasized that the need for the F7/C2 polar component was also endorsed by IROWG in its latest meetings. S. Healy continued and pointed out that RO has made its impact on Numerical Weather Prediction (NWP), but in climate data sets are starting to be long enough to also have a significant impact. He also showed the impact of RO data in different re-analysis, leading to much better consistency between the ERA-Interim and JRA-55 re-analyses in the stratosphere.

Discussion:

E. DeWeaver started the discussion by stating that the temperature capabilities of RO are best known and suited for climate, however the water vapour detection in the lower troposphere relies on the use of model data, which might be introducing a bias into the RO based data. B. Ho (UCAR, US) pointed out that infrared sounders like AIRS and IASI can provide a wealth of information on water vapour and RO can be used to identify potential long term stability issues of these instrument types. He also pointed to the currently not much used possibility for climate assessments using bending angles. A. Steiner responded by pointing out that the ongoing ROTrends/SCOPE-CM RO-CLIM projects assess all possible climate data records from RO, including FCDRs and CDRs. J. LeMarshall re-iterated that temperature data sets are easy to be derived, but water vapour is more challenging. He asked whether the RO community is involved with the CLARREO mission. C. Ao mentioned that he is a member of the science team of CLARREO and that the interest in RO data is very high. E. DeWeaver ask to what extend the user needs have been assessed, e.g. some users might want to use more raw data (e.g. bending angles), while others want to use processed data like tropopause or planetary boundary layer height. S. Healy said that the ROM SAF is running regular user surveys, it is however often difficult to find users not directly involved in RO willing to invest the time to fill out these surveys. He also pointed to RO work that included RO operators into the CFMIP Observation Simulator Package (COSP), allowing to generate e.g. bending angles from climate model runs. Other activities to link RO data use with the climate community include work at JPL where RO is being converted to the obs4MIPS format, for comparison within the Coupled Model Intercomparison Project (CMIP). B. Schreiner (UCAR, US) mentioned their user surveys and discussions with the climate community showed that in particular the availability of "just" an atmospheric profile instead of a global climatology hampers the direct use/comparison to other climate data sets.

Geodesy

K. Sosnica introduced RO data/applications relevant for geodesy. Although it is not a primary RO mission objective, several interesting applications and products can be derived. The availability of laser reflectometers on COSMIC satellites allows to link the data to the terrestrial reference frame. And the use of up to 3 different GNSS sources makes the F7/C2 a very valuable data set for geodesy.

Discussion:

E. DeWeaver opened the discussion by asking how the coordination with the international laser ranging community is done. K. Sosnica replied that this is a "free" but also best effort service that requires coordination with the ground stations for scheduling the tracking of a satellite. Hence this could bring potential issues in the full use of the F7/C2 reflectometer. J. Weiss (UCAR, US) reported that they are in contact with several laser ranging stations for coordination, but only 4 are available to track the F7/C2 Equatorial component, and tracking priorities will become an issue. Station coverage is much better at higher latitudes, where the F7/C2 Polar component would be much better tracked. N. Yen (NSPO, Taiwan) suggested to invite people from the geodesy community also to other RO workshops.

Ionosphere

M. Yamamoto started with pointing out the impact of the ionosphere on communication satellites. Also, several LEO missions essentially fly within the ionosphere. RO data greatly improves the information available on the ionosphere and space weather. However the loss of the C/NOFS mission - which was considered a great success - affect the capabilities for low latitude monitoring, and the Equatorial F7/C2 component would be able to fill this observation gap. He also added that the neutral atmosphere can impact the ionosphere, hence the neutral atmosphere / ionosphere link provided by RO profiling is very beneficial in getting communities together. In addition, the radio beacons available on COSMIC satellites enables the detection of horizontal ionospheric features/variability. Charles Lin continued and mentioned the use or RO data in ionosphere / space weather forecast models. The increased coverage with the full F7/C2 constellation would be highly beneficial here; the Equatorial component will not be able to follow important movements of events to higher latitudes during ionospheric storms.

Discussion:

B. Carter opened the discussion by mentioning discussions and proposals that focus on the use of RO data in space weather models. In particular the prospect of large numbers of observations from the full F7/C2 constellation will push the use of RO data in these models. J. LeMarshall raised the timeliness issue, where the space weather community would ideally like to have the data within a few minutes.

Program/Operational

T. Mannucci started with pointing out that instrumentation and use of GNSS is going to diversify. Commercial providers, potentially CubeSat developments, use of different GNSS constellations, signals and frequencies are going to impact programs. It was noted that the data from research missions is likely to reduce in the coming years. He also emphasized that all “neutral atmosphere RO” missions should be multi use, adding value to Earth Science. Thus make as much use as possible of GNSS observation capabilities: always include the ionosphere, consider GNSS-R. He also pointed out that the current concept of RO research instruments is going to receive less funding and thus relying on RO research satellites for global coverage is a risk. A. von Engeln continued by pointing out that the diversification will not only be on the instrument / GNSS use, but the actual observation characteristics will also depend on the GNSS signal use, the RO instrument observing the signal, the processing of these signals. So far the major impact has been seen in processing impacts, however processing centres put great efforts into finding / sorting out potential issues (e.g. ROTrends, SCOPE-CM RO-CLIM projects). These current best-effort projects will need to be continued, improved, and better funded. There is also likely a need to “harmonize” the processing for NWP use, e.g. smoothing, wave optics processing, and provide better error statistics estimates for NWP assimilation. He also pointed out that improved coordination between ionospheric and atmospheric data use should be pursued. There are currently missing standards for the use of ionosphere data over the GTS. In addition, real time RO data is a possible new development in the near future, and processing centres, modellers should prepare to make full use of it.

Discussion:

B. Kuo started by emphasizing the need for a processing “gold standard” in order to prepare for the diversification, and to set up a backbone (or core) processing system against which other RO data is evaluated. The ROSA developments showed the risks of not having such a standard (ROSA data is still not available in NRT, 3 ROSA instruments have been providing hardly any useful data). J. Wickert (GFZ, Germany) reiterated that diversification will require better standards. G.-S. Chang stated that commercial GNSS-RO providers will be invited to future ICGPSRO meetings. T. Mannucci closed by mentioning the upcoming CGMS meeting, where the RO community should point to the risk in RO coverage and work on to ensure that the Polar part of F7/C2 is fully funded.

Note: Copies (partly modified) of the given presentations are available in the Appendix.

APPENDIX (Slide Presentations where available)

Session 9

Round Table Discussions

03-11-2016

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NARLabs

Round Table Panelists

- Chairs & Neutral Atmosphere
  Guey-Shin Chang / Bill Kuo
- Climate
  Andrea Steiner / Sean Healy
- Geodesy
  Krzysztof Sosnica / Cheinway Hwang
- Ionosphere (no presentation)
  Mamoru Yamamoto / Charles Lin
- Program and Operations
  Axel von Engeln / Tony Mannucci

NARLabs

Neutral Atmosphere

- F3/C1 has demonstrated great values for NWP and tropical cyclone prediction. The lower tropospheric measurements are critical for weather prediction.
- The open loop tracking in F3/C1 has been critical to provide good RO measurements in the lower tropical troposphere.
- Polar constellation of F7/C2 is very important to global NWP, and for enhancing observations over the tropics. No commercial data provider has provided (or demonstrated) data of equivalent quality to F3/C1 (not to mention F7/C2). It is essential to complete F7/C2 with both tropical and polar constellation.
- F7/C2 will be launched in a year. Need to continue improvement in algorithm development and processing, after launch, to ensure best RO data quality to support weather applications.

Climate (1)
Some Discussion Points

- Climate applications likely to increase as GNSS-RO time-series lengthens.
- More use of GNSS-RO in the broader community. We need to continue to invite these scientists to GNSS-RO meetings (this conference/IROWG).
- Calibration of radiance datasets (Ho)
- Evaluation of CMIP5 models using GPS-RO (Kishore)
- Gravity wave studies (Alexander). GNSS-RO is providing additional information, relative to other limb sounders
- Radiosonde bias corrections estimated with GNSS-RO
- Reanalysis applications. (An anchor measurement)

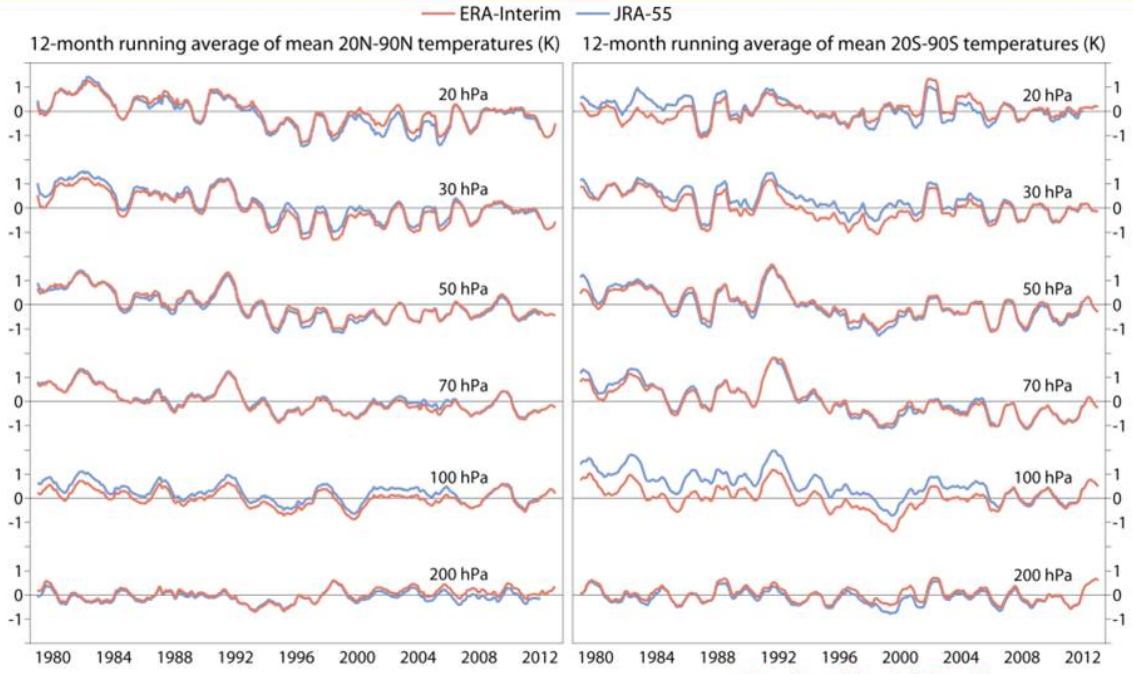
Climate (2)
Use of GNSS-RO in Reanalysis

- Better consistency between re-analyses since the introduction of COSMIC

Climate (3)

NARLabs

GPSRO and Extratropical-Mean Temperatures from ERA-Interim and JRA-55



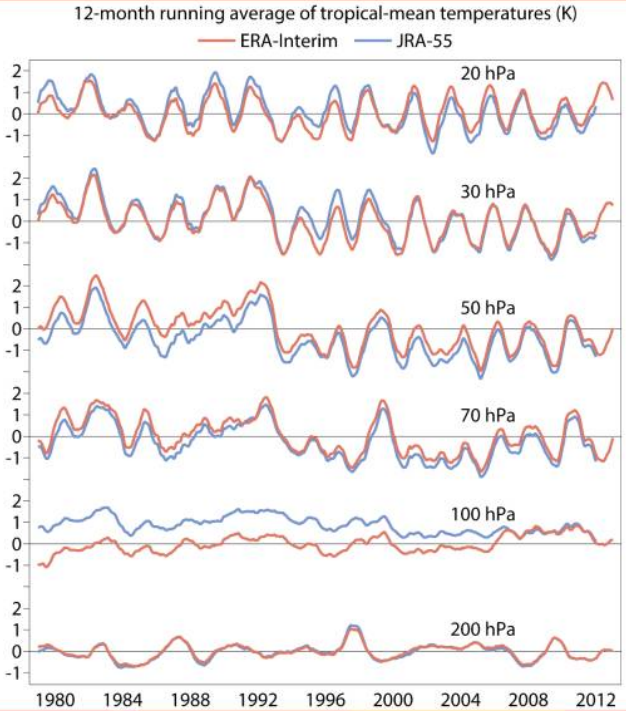
Values are relative to ERA-Interim means for 1981-2010

Produced by Adrian Simmons

Climate (4)

NARLabs

Tropical-Mean Temperature Time Series from ERA-Interim and JRA-55



Assimilation of GSPRO data brings ERA-Interim and JRA-55 together in the extratropical stratosphere, but not in the tropical stratosphere

Values are relative to ERA-Interim mean for 1981-2010

Climate (5)

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Datasets for GCM (NWP + Climate) Developers

- ROM SAF work with the Hadley Centre, introducing the bending angle and refractivity forward models into the COSP simulator
- Compare Hadley centre model output with the monthly mean bending angle/refract clims.

Climate (6)

NARLabs

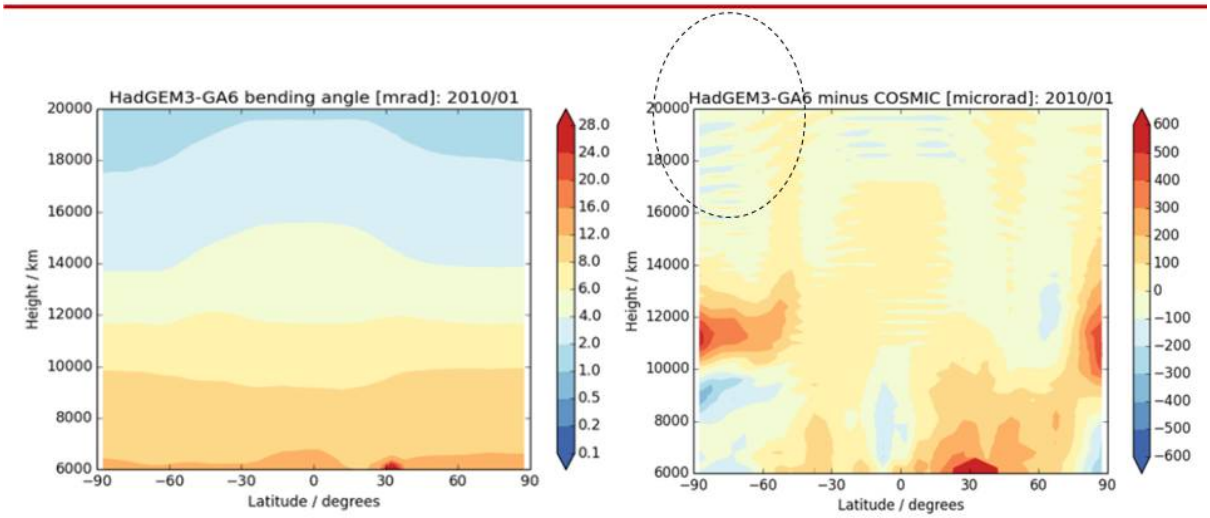
COSP Simulator

- The bending angle and refractivity operators are now Hadley centre version of the COSP simulator: Compare model output with the ROM SAF GNSS-RO climatologies.
- Work in progress, but important for us to maintain these contacts if we want the Hadley centre to routinely use these products.

Climate (7)

NARLabs

One month of comparisons against COSMIC.



Provided by Alejandro Bodas-Salcedo, Hadley Centre.

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Geodesy

- Grace and FORMOSAT-3/COSMIC RO Data
- RO Data for FS-7/C-2 Equatorial Constellation
- RO Data for FS-7/C-2 Polar Constellation

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Programs

- Anticipate diversification of RO instruments, GNSS source, data provider with impact on NWP and climate/trends. Includes commercial data and policy, cube sats, faster breadboard to in-orbit turn over, ...
- Future GNSS constellations should be multi-use: new concept of "value" in Earth science (GNSS RO, GNSS-R, ionosphere)
- Current research RO data going to decrease in future

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Operations

- Improved observation errors in NWP/climate
- Improved/Agreed processing for NWP/climate?
- Better coordination between ionospheric and atmospheric data – ease of use for atmospheric users (gridded iono data, irregularity maps, etc.)
- Provision of ionospheric data over weather networks (e.g. GTS) – standards needed
- Better integration of ionospheric data into weather processing (if needed)
- Real time RO data is technically feasible