Announcement of ROM SAF Visiting Scientist opportunity:

Statistical analysis of systematic errors in RO measurements

The ROM SAF is seeking a Visiting Scientist to perform the tasks described in the following. The duration is estimated to be three months to be carried out in the period from September/October to December 2013. The successful candidate should spend three weeks at the Danish Meteorological Institute (DMI) in the beginning of this activity and the remaining time at the home institute.

The payment for this Visiting Scientist Activity (VSA) will consist of half a salary compensation for ten weeks to be paid to the home institute. In addition, the ROM SAF will pay the trip and per diem for the three weeks stay at DMI.

If you are interested in this Visiting Scientist activity, please email a brief application and short CV to the ROM SAF Helpdesk (email: helpdesk@romsaf.org) before 24 July 2013.

Document Change Record

Version	Date	By	Description
1.0	5 July 2013	KBL	ROM SAF VS20 proposal (id: ROM_AS13_01); announcement text for the website;

ROM SAF

The Radio Occultation Meteorology Satellite Application Facility (ROM SAF) is a decentralised processing center under EUMETSAT which is responsible for operational processing of GRAS radio occultation data from the Metop satellites and radio occultation (RO) data from other missions. The ROM SAF delivers bending angle, refractivity, temperature, pressure, and humidity profiles in near-real time and offline for NWP and climate users. The offline profiles are further processed into climate products consisting of gridded monthly zonal means of bending angle, refractivity, temperature, humidity, and geopotential heights together with error descriptions.

The ROM SAF also maintains the Radio Occultation Processing Package (ROPP) which contains software modules that will aid users wishing to process, quality-control and assimilate radio occultation data from any radio occultation mission into NWP and other models.

The ROM SAF Leading Entity is the Danish Meteorological Institute (DMI), with Cooperating Entities: i) European Centre for Medium-Range Weather Forecasts (ECMWF) in Reading, United Kingdom, ii) Institut D'Estudis Espacials de Catalunya (IEEC) in Barcelona, Spain, and iii) Met Office in Exeter, United Kingdom. To get access to our products or to read more about the ROM SAF please go to: http://www.romsaf.org

Intellectual Property Rights

1 OBJECTIVES

Currently, inversions of bending angle (BA) profiles obtained from radio occultations (RO) suffer from negative bias in refractivity (N-bias) in the lowest troposphere. The biggest N-bias is observed in the tropics, where it reaches a value exceeding 2%. There have been a few studies where possible causes of the N-bias have been discussed:

1. S. Sokolovskiy, C. Rocken, W. Schreiner, D. Hunt, and J. Johnson, Postprocessing of L1 GPS radio occultation signals recorded in open-loop mode, Radio Science, Vol. 44, RS2002, doi:10.1029/2008RS003907, 2009.
2. S. Sokolovskiy, C. Rocken, W. Schreiner, and D. Hunt, On the uncertainty of radio occultation inversions in the lower troposphere, J. Geophys. Res., Vol. 115, D22111, doi:10.1029/2010JD014058, 2010.
3. M. E. Gorbunov, K. B. Lauritsen, S. S. Leroy, Application of Wigner distribution function for analysis of radio occultations, Radio Science, Vol. 45, RS6011, doi:10.1029/2010RS004388, 2010.
4. EUMETSAT Study on “Optimisation of Tracking Strategies for Radio Occultation”, Contract EUM/CO/10/460000812/CJA Order 4500005632, Reports by DMI, ECMWF, IAP, and RUAG Space AB, 2012.

Possible reasons of the N-bias that were discussed are these: 1) the non-linear nature of the inversion algorithms (CT/FSI) employed under multipath condition together with strong fluctuations due to the turbulence, 2) horizontal gradients mapping into the variations of the ray impact parameters, which breaks the applicability of the inversion methods, 3) stochastic wave guides redirecting rays with the strongest BA to lower heights, where they may be lost. There has also been a study of super-refraction:

5. F. Xie, D. L. Wu, C. O. Ao, E. R. Kursinski, A. J. Mannucci, and S. Syndergaard, Super-refraction effects on GPS radio occultation refractivity in marine boundary layers, Geophys. Res. Lett., Vol. 37, L11805, doi:10.1029/2010GL043299, 2010.

Super-refraction may be essential in some regions, but also a BA-bias, which is believed to be due to other mechanisms, is generally observed in RO data and the analyses that have been performed until now did not answer the question of the relative contribution of different mechanisms into the observed N-bias.

It is proposed to carry out a statistical study of the negative N-bias that should include: 1) a detailed statistical analysis of GRAS and COSMIC data inversions, and 2) realistic simulations of radio occultations and inversion of the simulated RO data. The statistical analysis should be based on a large array of RO events (a few hundred thousands). Detailed regionalized maps of the N-bias for different height levels should be produced. This will allow for identifying the correlation of N-bias with definite atmospheric conditions typical for different regions. Even though the main quantity to be studied is the N-bias, the bending angles should also be studied in selected regions.

Realistic simulations of RO events should be based on atmospheric reanalyses from ECMWF and selected radio sondes. Such data provide a very good approximation of atmospheric conditions, although these can be biased themselves. The reanalyses should be complemented with a turbulence model, isotropic and anisotropic. Reproducibility or irreproducibility of the N-bias in the processing of the artificial data will allow for the localization of the possible cause of the N-bias in the real inversions. The objectives of the current study can be summarised as follows:

O1. Perform a detailed statistical analysis of COSMIC RO data for one to two years and GRAS data for two years and compare the retrieved refractivity with corresponding ECMWF reanalyses and selected radio sondes; include analysis of bending angles for selected regions;

O2. Perform realistic simulations of RO observations using a wave optics propagator; realistic simulations should be performed for different atmospheric conditions ("categories") for 4 days from different seasons and should calculate idealised bending angles and refractivities.

2 TASKS AND METHODS

The statistical analysis should be based on the subdivision of the whole globe into relatively small latitude-longitude cells in order to arrive at an accuracy of the bias estimate of about 0.08% for the whole year and 0.16% for a season. This accuracy is high enough to regionalize the N-bias. Another option is the investigation of the N-bias structure as a function of latitude and local time, which is a combination of UTC and longitude.

The computation of such a detailed statistics will require a large computational time. In order to optimize it, one should mostly investigate the statistics of the refractivity retrieval. On the other hand, the investigation of superrefraction requires the statistics of bending angles. The computation of reference bending angles for ECMWF fields should be based on the forward modeling which may significantly increase the computational time. One should attempt to identify regions where superrefraction plays a significant role in forming the N-bias. In such regions, one should investigate the statistics of bending angles.

Understanding of the nature of the N-bias requires realistic wave optics simulations of RO events in horizontally non-uniform turbulent atmosphere with super-refraction layers, and inversion and statistical analysis of the artificial RO events. By setting simulation parameters, one should investigate the possibility of the reproduction of the N-bias. This will tell whether turbulent fluctuations of the signal are one of the causes of the N-bias and estimate its eventual contribution.

The tasks necessary for the implementation of the project are the following:

T1. Setting up the automated processing of large array of RO data from the GRAS and COSMIC missions and comparison to ECMWF reanalysis fields and selected radio sondes;

T2. Statistical analysis of inversions of COSMIC data for one to two years and GRAS data for two years with a detailed regionalization for different lat-lon bands, seasons and, eventually, daytime;

T3. Wave optics simulation package to be used for the simulation of small scale isotropic and anisotropic turbulence;

T4. Simulation of RO data for 4 days from different atmospheric categories from different seasons using a model including regular horizontally non-uniform atmosphere and atmospheric turbulence;

T5. Inversions and statistical analysis of artificial RO data.

3 DELIVERABLES

The VS activity has the following list of deliverables:

D1. Data base of regionalized statistical comparisons of GRAS and COSMIC data with ECMWF reanalyses and selected radio sondes;

D2. Scientific report (and possibly a journal publication);

The data and software deliverables generated in the framework of this VS activity will be owned by EUMETSAT. The candidate will sign a Letter of Agreement where a related statement is included.

4 VSA MILESTONES AND SCHEDULE

Milestones:

M1: KO and signature of Letter of Agreement; First Payment;

M2: Delivery of the deliverables D1, D2; Final Payment;

Time schedule:

	2013				**2014**			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Milestones			M1	M2				
WP 1								
WP2								

5 VSA CANDIDATE

The qualifications of the candidate should include good knowledge of raw RO data, advanced wave optics retrieval methods, turbulence, and wave optics simulations methods.

ANNEX VSA TENTATIVE WORKPLAN

WP 1	***Processing and simulations of RO data***		
Task description	T1. Setting up the automated processing of large array of RO data from the GRAS and COSMIC missions and comparison to ECMWF reanalysis fields and selected radio sondes; T2. Statistical analysis of inversions of COSMIC data for one to two years and GRAS data for two years with a detailed regionalization for different lat-lon bands, seasons and, eventually, daytime; T3. Wave optics simulation package to be used for the simulation of small scale isotropic and anisotropic turbulence; T4. Simulation of RO data for 4 days from different atmospheric categories from different seasons using a model including regular horizontally non-uniform atmosphere and atmospheric turbulence;		
Input	COSMIC and GRAS data; ECMWF fields; Radio sondes; WOP code;	Output	Simulated RO data;
Start of WP	September/October 2013	End of WP	November 2013

WP 2	***Statistical analysis of RO data***		
Task description	T5. Inversions and statistical analysis of artificial RO data		
Input	Simulated RO data (WP 1)	Output	D1. Database; D2. Scientific Report;
Start of WP	November 2013	End of WP	December 2013