Validation of refractivity profiles derived from METOP and TerraSAR-X open-loop data

Florian Zus, Georg Beyerle, Stefan Heise, Torsten Schmidt and Jens Wickert
(zusflo@gfz-potsdam.de)
Outline

Open Loop (OL) tracking, as an alternative to Closed Loop (CL) tracking, is used on the FORMOSAT-3/COSMIC mission and proves to increase the data yield and quality of RO retrievals in the Lower Troposphere (LT). Receivers onboard of METOP(*) and TerraSAR-X are capable of CL/OL tracking; it is anticipated that retrievals show similar characteristics.

In this talk:

(1) Some details of GFZs in-house experimental processing software package (POCS-X) are provided.

(2) Results from a TerraSAR-X profile-to-profile comparison are shown (POCS-X minus UCAR).

(3) RO retrievals are compared with ECMWF model equivalents.

* EUMETSAT data available through an ESA funded study; contract 21995/08/NL/EL.
(1) POCS-X

The inversion software POCS-X (developed by G. Beyerle @ GFZ) is used to derive bending angle (BA) & refractivity (N) profiles.

Level 1:

- The phase & amplitude of the entire signal is assembled from CL/OL data.
- The residual phase extraction requires NavBits (Navigation data Bits). External NavBits, collected by GFZ's ground station network, are used (Beyerle et al., 2009, GPS Solutions).

Level 2:

- The FSI (Full Spectrum Inversion) is used to obtain BAs. FSI retrieved BAs are replaced by Doppler retrieved BAs for ray-heights > 12 km.
- BA-profiles are inverted to N-profiles using Abel Transform.
Filter options

FSI:

- Filtering: no
- Signal truncation in the time-domain: no
- Signal truncation in the impact parameter-domain: yes; the valid impact-range is estimated using the FSI amplitude drop-off.

Doppler:

- Savitzky-Golay smoothing filter applied to excess phase rate; polynomial degree $p=3$, window width $w=71$.
- Statistical Optimization of BAs for ray-heights $> 40$ km; MSIS climatology deals as the background.
Quality Control (QC)

**Early stage QC** examines data gaps, L1/L2 excess phase path ratios, etc...

**Final stage QC** compares the RO profiles to the ECMWF profiles. If the fractional N-deviation exceeds $\pm 10\%$ at any altitude between 5 km and 30 km the entire profile is rejected (no final stage QC below 5 km).

QC example for METOP RO events:
Total number of RO events (black), number of profiles after early stage QC (blue) and number of profiles after final stage QC (red) versus day of year (Period: Y2007, DOY: 273-300).
METOP and TerraSAR-X processing features

Level 1:

**METOP**
- Internal NavBits (contained in EUMETSAT netcdf file) are used if external NavBits are not available (NavBit coverage Y2007 ~ 75%)
- CL data @ 50 Hz, OL data @ 1 kHz
- zero differencing
- etc...

**TerraSAR-X**
- External NavBits are used only (NavBit coverage Y2009 ~ 95%)
- CL data @ 50 Hz, OL data @ 50 Hz
- single differencing

Level 2: TerraSAR-X processing is identical to METOP processing.
(2) TerraSAR-X (POCS-X - UCAR)

Fractional BA/N-deviation versus ray height/altitude. The thick/thin line indicates the mean/one-sigma standard deviation.


The agreement is very good, a possible explanation for the mean deviation at altitudes < 5 km is the following ...
The RO signal is truncated in the time-domain following the ad hoc procedure proposed by Sokolovskiy et al. 2009, Radio Science (also see Sokolovskiy et al. 2010, JGR).

Fractional BA/N-deviation versus ray height/altitude.

Return to POCS-X ...
Fractional N-deviation & number of data points versus altitude.
LT: Northern Hemisphere POCS-X - UCAR

Fractional N-deviation & number of data points versus altitude.
Fractional N-deviation & number of data points versus altitude.

LT: Southern Hemisphere POCS-X - UCAR
Fractional N-deviation & number of data points versus altitude.
Fractional N-deviation & number of data points versus altitude.

* The RO signal is truncated in the time-domain.
Fractional N-deviation & number of data points versus altitude.


A possible explanation for the mean deviation at altitudes > 15 km is the following...
Fractional N-deviation & number of data points versus altitude.


* Savitzky Golay filter: polynomial degree $p=2$, window width $w=41$.

Return to POCS-X ...
Fractional N-deviation & number of data points versus altitude.

Mean deviation (left), standard deviation (middle) & number of data points (right) versus altitude. NH (blue), SH (red) & TR (black).

Fractional N-deviation & number of data points versus altitude.

Fractional N-deviation & number of data points versus altitude.


* Savitzky Golay filter: polynomial degree p=2, window width w=41.

Return to POCS-X ...
LT: TerraSAR-X - ECMWF

Fractional N-deviation & number of data points versus altitude.

LT: TerraSAR-X - ECMWF

Mean deviation (left), standard deviation (middle) & number of data points (right) versus altitude. NH (blue), SH (red) & TR (black).

Summary

- GFZ's experimental software POCS-X works as intended; TerraSAR-X profile-to-profile comparison (POCS-X minus UCAR) shows very good agreement.

- RO retrievals derived from METOP & TerraSAR-X OL data show good quality. The main features are very similar to COSMIC:
  - The tropospheric penetration depth obtained from OL data shows a vast improvement compared to the tropospheric penetration depth typically obtained from CL data; the 50% altitude is reduced by about 2 km.
  - Biases (negative & positive) in the LT mainly stem from the tropical LT.

- RO retrievals derived from TerraSAR-X OL data are available in NRT (output of GFZ's operational software POCS). Monitoring is performed @ e.g. http://www.grassaf.org/.