European Geophysical Society
XXIV General Assembly
Den Haag, 19-23 April 1999

Session G7 - Poster G005

http://www.deos.tudelft.nl/altim/rads/

A Recipe for Upgrading ERS Altimeter Data

Remko Scharroo, Ejo Schrama, and Marc Naeije

Delft University of Technology, Delft Institute for Earth-Oriented Space Research

Kluyverweg 1, 2629 HS Delft, The Netherlands; e-mail: remko@deos.tudelft.nl

Abstract

ERS-1 and ERS-2 altimeter data from the ESA Ocean Product (OPR) have been upgraded and merged into the DEOS Radar Altimeter Database System (RADS, together with TOPEX/POSEIDON (T/P) data. A long list of adjustments to the measurements and geophysical corrections finally compiles an accurate and harmonised ERS data set, that meets the standards required for research in geodesy, oceanography and climate change.

The recipe that can be followed by each user of ERS-1 and -2 OPR altimeter data is provided in this poster and some new data analyses demonstrate the quality of the RADS ERS-1/2 data set.

OPR Version 3, Version 6, and Version 5

From the radar return pulse the altimeter determines, in principle, three characteristics: the travel time of the pulse, the slope of the leading edge of the power profile (the waveform) and the total power. This is done by an algorithm called tracker; in case this is done on-ground, we talk about *retracker*. Straightforward conversion to the main measurements of *range*, *Significant Wave Height*, and *wind speed* follows.

ERS-1 data is released in two versions of OPR data: *Version 3 (V3)* for Phases A through F and *Version 6 (V6)* for Phase G. ERS-2 data was only released in OPR V6. The differences between the versions are:

Format: V3 conforms to CEOS format, V6 to CCSD format

Retracker: V6 is based on a more accurate retracker, which means that all measurements of range, SWH and wind speed are incompatible with V3

Propagation corrections: Data from the Microwave Radiometer (MWR) on V6 are processed with new calibration values in the algorithms to convert brightness temperatures to wet tropospheric delay. A new sea state bias model was introduced.

Orbit: V6 finally has a bit more accurate orbit

Geophysical corrections: V6 features newer models for ocean tides, loading tides, and mean sea surface, currently out-of-date

Without significant adjustments, V3 and V6 data can not be merged together or with T/P data for accurate geodetic or oceanographic study. This poster shows how to harmonise V3 with V6 and how to upgrade them both.

For the intercomparison of V3 and V6 we have used ERS-1 cycles 145–148 processed with *Versions 5 (V5) and 6* of the OPR processing. V5 is identical to V3, except that the product format corresponds with V6. In the following V5 can be read as V3.

References

[1] J. Stum et al., An inter-calibration study of TOPEX/POSEIDON, ERS-1 and ERS-2 Altimetric Missions, Final Report of IFREMER Contract No 97/2.426 086/C, CLS Ramonville, April 1998

[2] P. Gaspar and F. Ogor, Estimation and analysis of the sea state bias of the new ERS-1 and ERS-2 altimeter data (OPR version 6), Report of task 2, IFREMER contract 96/2.246 002/C, CLS Ramonville, Dec 1996

[3] M-H. Calvez et al., Validation of ERS-2 OPR Cycle XXX, CLS.OC.NT/96.011

[4] L. Eymard and S. A. Boukabara, MWR2 anomaly: Proposal for correction, CETP Report, Nov 1996.

[5] L. Eymard and S. A. Boukabara, Calibration-Validation of the ERS-2 microwave radiometer, Final Report, ESA Contract 11031/94/NL/CN.

Significant Wave Height (SWH)

Since V6 uses a retracker different from V3, the registration of wave height will be different. Figure 1 shows the scatter plot of SWH from V5 and V6. Clearly V5 underestimates all wave heights, but particularly low wave heights which are often set to zero. The difference between V5 and V6 wave heights is shown in Figure 2. The line fit obtained by DEOS is determined through least-squares adjustment of four parameters (two slopes and the location of the breaking point) and better represents the difference at higher wave heights than the line fit by [1]: This fit leads to the correction algorithm (SWH in meters):

SWH(V5)<1.256:	SWH(V6) = 0.900 SWH(V5) + 0.247
else:	SWH(V6) = 1.003 SWH(V5) + 0.117

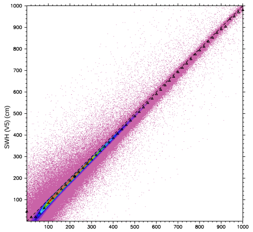

Figure 1. Comparison of wave heights from OPR Version 5 and 6.

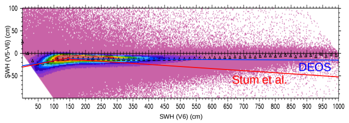

Figure 2. Difference between V5 and V6 SWH as a function of SWH

Wave height comparison between ERS and TOPEX (Figure 3) shows that the TOPEX altimeter is suffering from a serious drift, which, through the Sea State Bias (SSB) will affect the range stability!

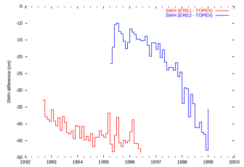

Figure 3. Comparison between ERS and TOPEX wave heights at crossovers.

Range and Sea State Bias (SSB)

The change of retracker directly influences the range measurement, but it will also be affected indirectly through the sea state bias, part of which is tracker-related and depends on SWH. Figure 4 investigates this dependency, by plotting the difference between V5 and V6 ranges against wave height. There appears none, from which we conclude that SSB is the same for V6 and V5' (after correction SWH correction), with SWH in m and wind speed U in m/s [2]:

ERS-1 (V5'+V6):	SSB = SWH (–0.047 –0.0035 U +0.000160 U^2)
ERS-2:	SSB = SWH (–0.048 –0.0026 U +0.000126 U^2)

In Figure 5 we show that the range difference V5-V6 depends mainly on SWH difference V5'-V6. This is largely undone when correcting for sea state bias. A constant of 24 mm remains due to retracker change and an error in V3 processing.

ERS-1 (V5): RANGE(V6) = RANGE(V5) – 0.024 m

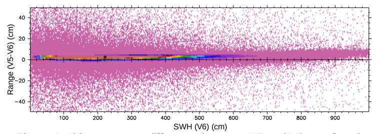

Figure 4. Altimeter range difference between V5 and V6 as a function of wave height.

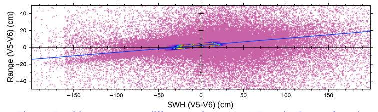

Figure 5. Altimeter range difference between V5 and V6 as a function of the wave height difference between V5 and V6.

Time Tagging

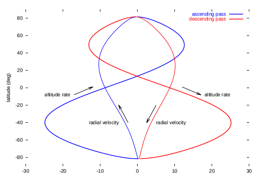

Figure 7. Radial and vertical velocity.

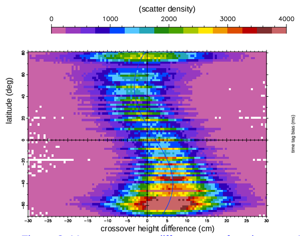

Figure 8. Mean crossover difference as function of latitude.

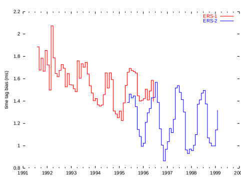

Figure 9. ERS time tag bias estimated from crossover height differences.

Because the satellite altitude may change as much as 25 m/s (Figure 7) accurate time tagging (better than 1 ms) is required. The error in the time tagging can be determined from crossovers height differences, especially around the mid-latitudes where the effect is the largest. The line in Figure 8 represents a time tag bias of 1.5 ms for ERS-1. For ERS-2 it is 1.3 ms; the difference is explained by an error in the OPR processing [1]. Before interpolating your DEOS orbits, correct the time tag:

ERS-1 (V5 and V6):	TIME' = TIME + 1.5 ms
ERS-2:	TIME' = TIME + 1.3 ms

The temporal evolution of the estimated time tag bias (with a clear annual cycle) shown in Figure 9 is not yet understood.

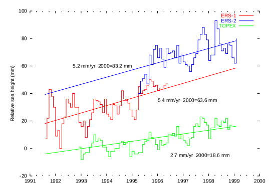

Figure 10. Monthly mean sea height difference with OSU MSS95 mean sea surface model.

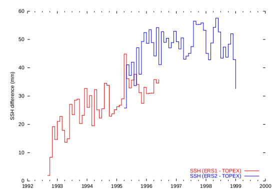

Figure 11. Monthly mean crossover height differences between ERS and TOPEX.

Geophysical Corrections and Orbits

Ocean tide models currently favoured are FES95.2.1 and a slightly more accurate CSR 3.0, now surpassed by CSR 4.0.

Pole tide is not included on ERS OPR data. A subroutine and a table with pole positions are required.

Mean sea surface model OSU MSS95 is significantly better than the one on OPR V3.

Geoid models have improved since OSU91A and JGM-3. Use EGM96 instead.

Orbits featuring on V3 and V6 have a radial accuracy of approximately 14 and 10 cm, while current state of the art is 5 cm. DEOS provides accurate orbits for the entire ERS-1 and ERS-2 missions, computed with an improved JGM-3-derived gravity model (DGM-E04).

Reference ellipsoids differ between ERS and TOPEX products. The above geoid and mean sea surface models are referenced to the TOPEX ellipsoid (GRS80-70cm). Add 70 cm to the DEOS orbital altitudes and you are in line with TOPEX.

What to get	and where?
Ocean tides	ftp://ftp.csr.utexas.edu/pub/tide/
Pole tide	http://www.deos.tudelft.nl/altim/rads/
Sea surface	ftp://helmert.eng.ohio-state.edu/pub/osumss95/
Geoid	http://cddisa.gsfc.nasa.gov/926/egm96/egm96.html
Orbits	http://www.deos.tudelft.nl/ers/precorbs/

Altimeter Biases and Drifts

Although at can not be assessed now, we assume that altimeters of ERS-1 and -2 have the same range bias of 40.92 cm, as was measured on ERS-2 in laboratory environment. This is close to the *Venice Calibration* value of 41.5 cm.

Both ERS-1 and ERS-2 altimeters suffer from rather unfortunate jumps in the range bias when the instruments have been temporarily switched off. A correction for this effect (known as *SPTR bias correction*) could be determined from on-board calibration data. Although the correction takes away most of the effect, improvements of this correction are in progress.

Furthermore, the frequency of the oscillators (USO) in the altimeters slowly change with age which leads to a drift in the retrieved altimeter range, unless it is accounted for. One should apply both SPTR and USO corrections from the tables at ftp://ftp.estec.esa.nl/pub/RA

ERS-1: RANGE = RANGE + SPTR_bias + OSU_drift + 0.4092
ERS-2: RANGE = RANGE + SPTR_bias + OSU_drift

Sea Level Trends

After all data have been harmonised (including T/P) sea level trends are computed in two ways

Figure 10 Monthly mean height differences with the OSU MSS96 mean sea surface model (actually of pass-by-pass 1-cpr fits)

Figure 11 ERS-1/TOPEX and ERS-2/TOPEX crossover height differences

Although the sea level trends from ERS-1 and -2 are somewhat higher than TOPEX, adding the Wallops bias correction result all in a sea level change of approximately 5 mm/year.

Radiometer Wet Tropospheric Corrections

The 23.8 GHz channel of the ERS-2 radiometer suffered a major loss of power on 26 June 1996 at 16:00. The retrieval of the wet tropospheric delay correction from brightness temperature values had to be recalibrated. Algorithms are given in [3] and [4], but we choose [5] because it provides a slightly lower crossover rms. First correct the ERS-2 brightness temperature TB23 (K) after 26 June 1996, then recompute the radiometer wet tropospheric correction (WTC, negative in metres):

$$TB23' = 0.93\,TB23 + 19.18$$
$$WTC = -1.65435 + 0.54668 \log_{10}(280-TB23') -0.22558 \log_{10}(280-TB36) + 0.00137\,(U-7)$$

The parameters in the above algorithm are different from V3, but here no brightness temperatures are available. Our correction algorithm comes from the comparison of V5 and V6 wet tropospheric delays (Figure 6) and differs from the one in [1], but does better justice at low and high numbers:

WTC(V5)<–0.402:	WTC(V6) = 0.869 WTC(V5) + 0.027
else:	WTC(V6) = 0.770 WTC(V5) – 0.012

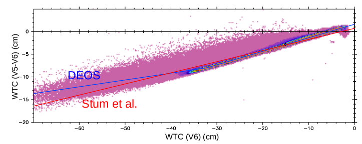

Figure 6. Comparison between radiometer wet tropospheric delay in OPR Versions 5 and 6 as a function of the delay itself.

Model Wet Tropospheric Correction

An error was discovered in the computation of the model wet tropospheric delay. It impacts on all ERS-1 data (V3 and V6) and ERS-2 data until 1 December 1997 [3]. (MWTC negative in meters).

All data before 1 Dec 1997: MWTC' = 0.850 MWTC - 0.006

Comparison between model and radiometer wet tropospheric corrections of ERS-2 (1995-1998) Figure 12 shows still large discrepencies, which are not yet explained.

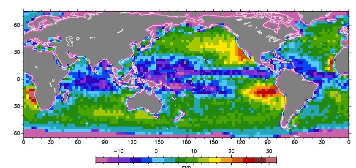

Figure 12. Mean difference between wet tropospheric delay corrections determined by ERS-2 radiometer and ECMWF model. The model is generally more wet (except Tropics).

To Do ...

Still, numerous smaller and bigger items have not been completely resolved:

- Different drift between TOPEX and ERS: Is it due to TOPEX? Or due to radiometer differences?
- ERS-1 and -2 sea surface heights differ by approximately 2 cm: This could be a bias difference or still caused by SPTR.
- SPTR correction tables are still being upgraded, this should remove part of the variations in the ERS bias.
- What is the impact of the apparent SWH drift in TOPEX on its range and sea level trends?
- Keep in touch at http://www.deos.tudelft.nl/altim/rads/