Upgrading and harmonisation of ERS altimeter data: a problem solved?

Remko Scharroo, Marc Naeije, Ejo Schrama

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Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands Fax: +31 15 278 5322 http://www.deos.tudelft.nl/

Radar Altimeter Database System (RADS)

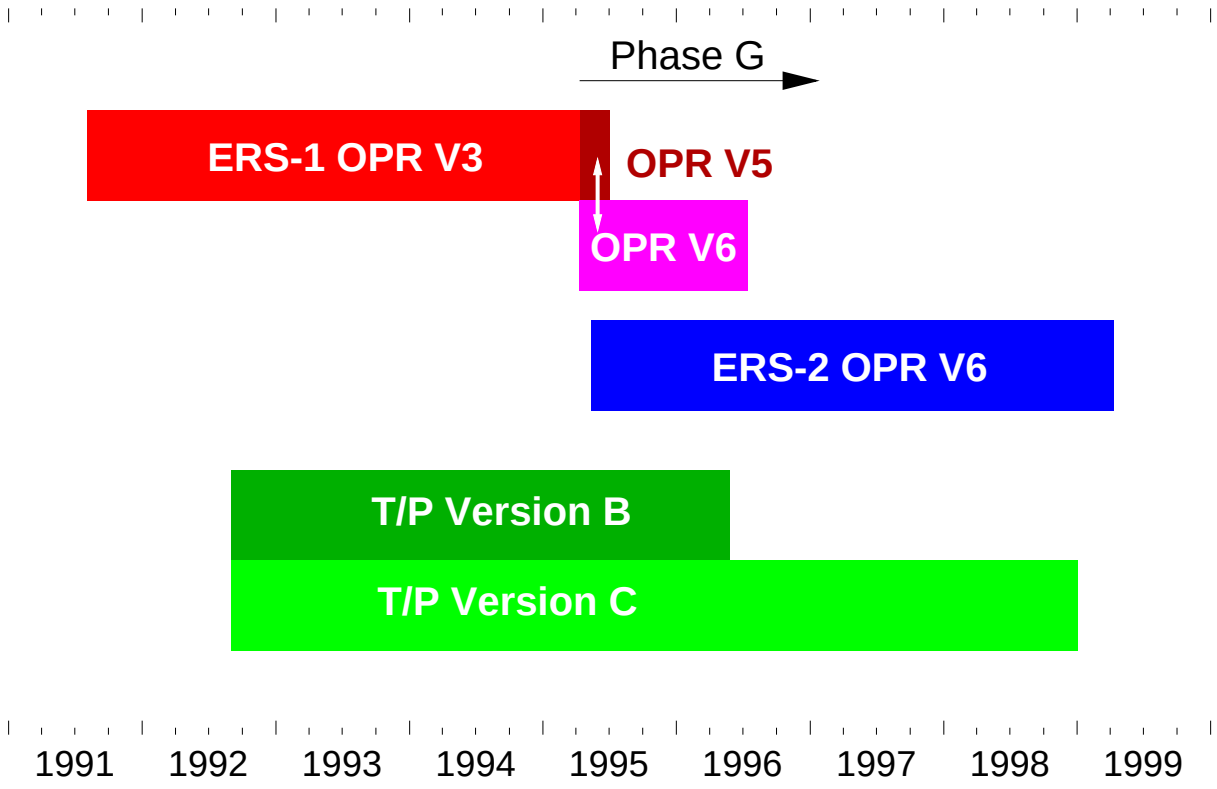
Aims

- Towards an upgraded and harmonised multi-mission altimeter data set
- Common format
- Common geophysical corrections
- Cross-calibrated measurements (range, SWH, σ_0, MWR)

Objectives

- Global and long-period (climate) variations
- Regional multi-satellite studies
- Easy access
- Incorporate in NEONET (Netherlands Earth Observation NETwork)

Various Altimeter Data Products



Various Altimeter Data Products

	OPR V3/5	OPR V6	T/P Verson C	RADS
Format	CEOS/CCSDS	CCSDS	CCSDS	RAW
Retracking	V3	V6	none	**
Bias	not applied	E2: applied	applied	applied
Drift	add SPTR&USO	add SPTR&USO	add internal cal	corrected
SWH	cutoff	no cutoff	drift?	recalibrated
Dry/Wet tropo	ECMWF *	ECMWF *	ECMWF	ECMWF (corrected)
Wet radio	MWR	MWR (recal.) *	TMR	** (recalibrated)
Ionosphere	Bent	Bent	DualFreq/DORIS	** (smoothed)
SSB	Barrick&Lipa	-5.5% *	BM4	BM3/BM4
Orbits	GFZ PGM035	GFZ PGM055	JGM-3	JGM3 (and DGM-E04)
Ellipsoid	WGS84	WGS84	TOPEX	TOPEX
Earth tides	CTE	CTE	CTE	CTE
Ocean tides	Enh. Schwiderski	FES95.2	FES95.2 & CSR3.0	FES95.2 & CSR3.0
Pole tide	none	none	available	available
Geoid	GRIM4-C2	JGM3/OSU91A	JGM3/OSU91A	EGM96
MSS	GFZ MSS93A	GFZ MSS95A & OSU MSS95	OSU MSS95	OSU MSS95

* correction recommended ** whatever/best available

Versions

Version 3: ERS-1 Phase A-F

Version 6: ERS-1 Phase G and ERS-2

Version 5: Identical to Version 3, except format and orbits. 4.5 Cycles of ERS-1 Phase G

$\Rightarrow$ compare with Version 6

Differences

Format: CEOS (V3), CCSDS (V5, V6)

Retracker: Changed in V6: impact on range, SWH, windspeed

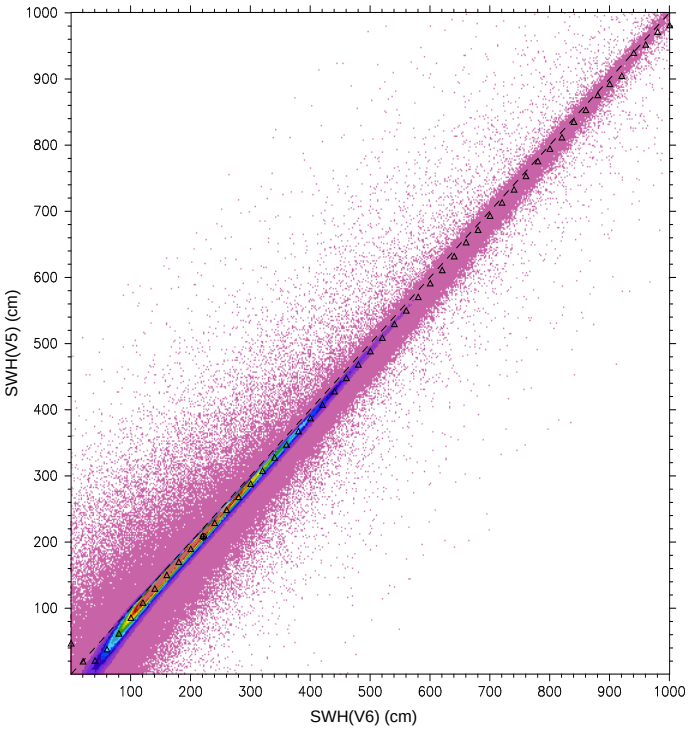
Propagation corrections: MWR recalibrated, new sea state bias

Orbit: New orbit on V6

Geophysical corrections: Many updated (some now out-of-date)

Comparison V5 and V6

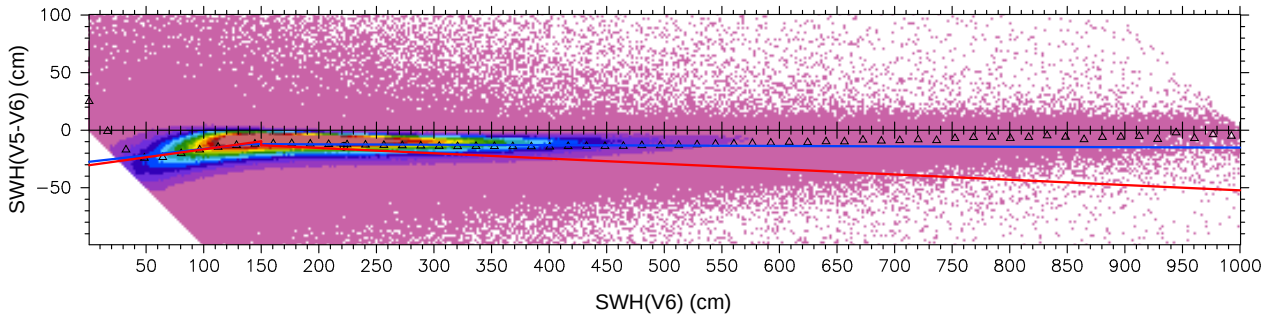
- V5 clearly underestimates wave-height, especially at low wave height
- Many values set to zero (in fact *negative*)



Looking for harmonisation

- Difference of SWH (V5-V6) as function of SWH (V6) makes difference more evident.
- Mean difference approx. 14.0 cm, but dependends on SWH
- Least squares fit of a broken line (4 parameters) through the scatterogram:

if SWH(V6)<c then SWH(V5-V6) = a (SWH(V6) - c) + d
else SWH(V5-V6) = b (SWH(V6) - c) + d



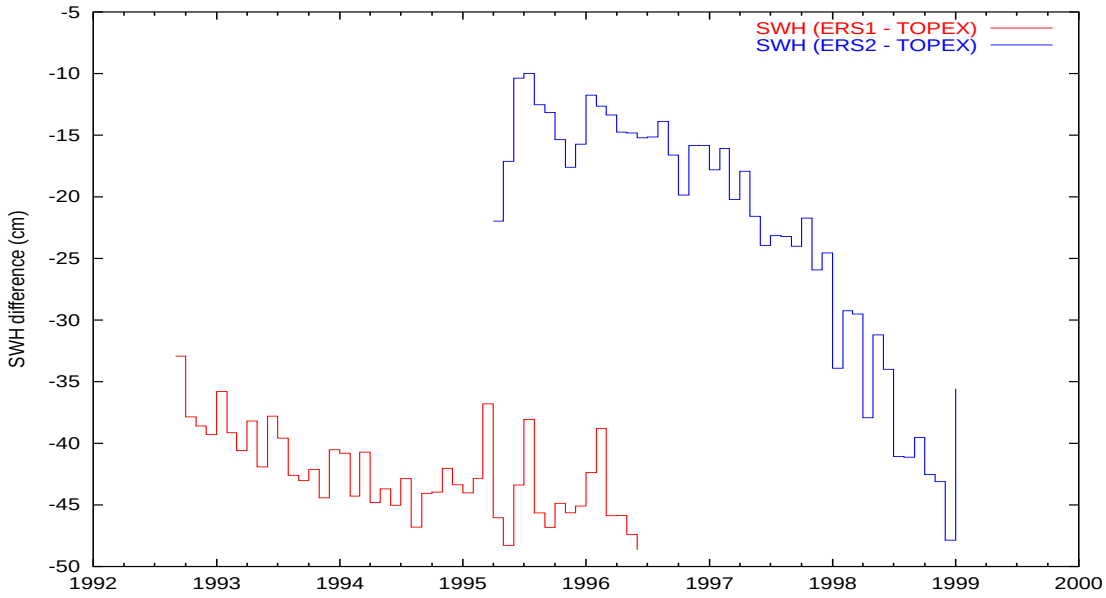
- Leads to:

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

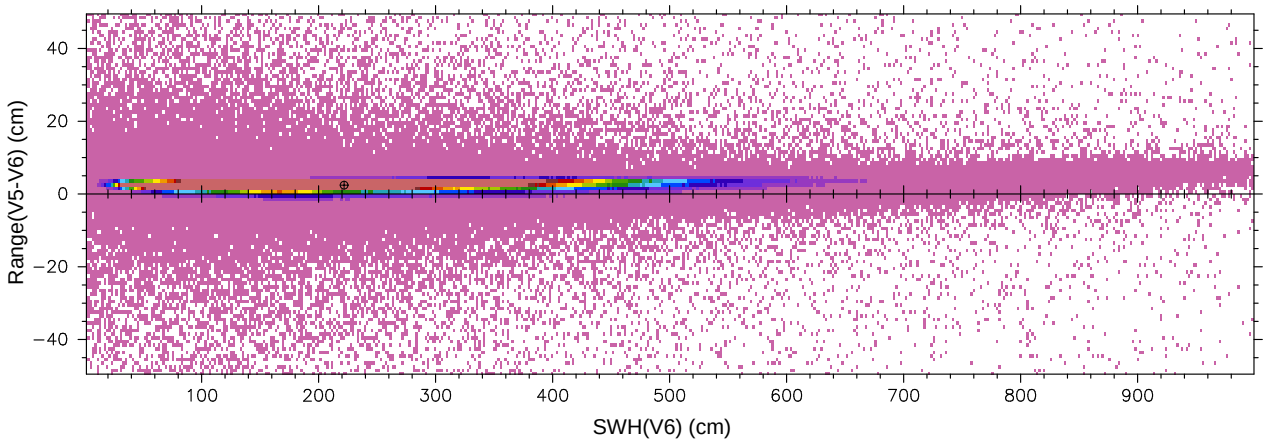
Significant Wave Height (SWH)

ERS-TOPEX comparison (crossovers)

- TOPEX wave heights seem to drift significantly!
- This will also affect the range stability



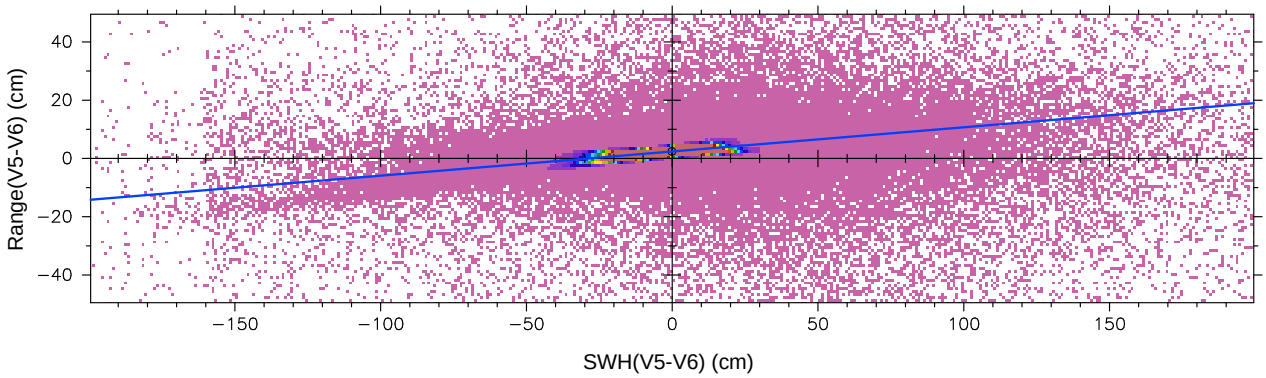
Δrange as function of SWH



- Different SWH means different SSB, part of which is tracker related
- No apparent dependence on SWH ⇒ Same SSB for V5 and V6
- Gaspar and Ogor [1996] BM3 algorithm:

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)

Δrange as function of ΔSWH



- Clear (linear) dependancy of Δrange on ΔSWH (≈8%)
- Largely undone when correcting for SSB
- Remains 24 mm range bias due to error in V3 processing

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

Geophysical Corrections

Ocean tide and loading: Currently favourable models are FES95.2 and CSR 3.0, now surpassed by CSR 4.0

Pole tide: Simple routine and table of pole positions

Mean sea surface: OSU MSS95 much more accurate than GFZ MSS95A

Geoid: EGM96 more accurate than OSU91A/JGM3

Orbits: D-PAF orbits on OPR are accurate to 14 (V3) and 10 cm (V6). DUT/DEOS orbits to 5 cm.

Reference ellipsoid: EGM96 and MSS95 are wrt TOPEX ellipsoid. Add 70 cm to Delft orbit to convert from GRS80.

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/

Radiometer Wet Tropospheric Corrections

Loss of gain in ERS-2 MWR

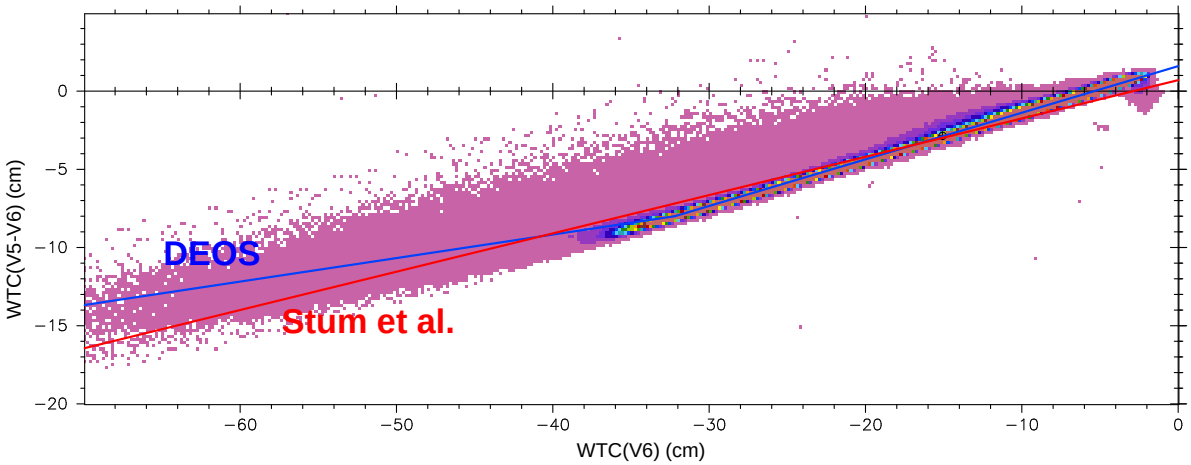
- Loss of gain in the 23.8 GHz channel of the ERS-2 MWR
- Recalibration of Brightness Temperature needed
- Use *Eymard and Boukabara* [1997]: it gives slightly better crossover statistics than [1996] recommended in OPR reports:

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

Comparison V5 and V6

- Different parameters in TB→WTC algorithm
- Brightness temperatures not in V3 product
- Empirical correction (4 parameter fit, again):

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

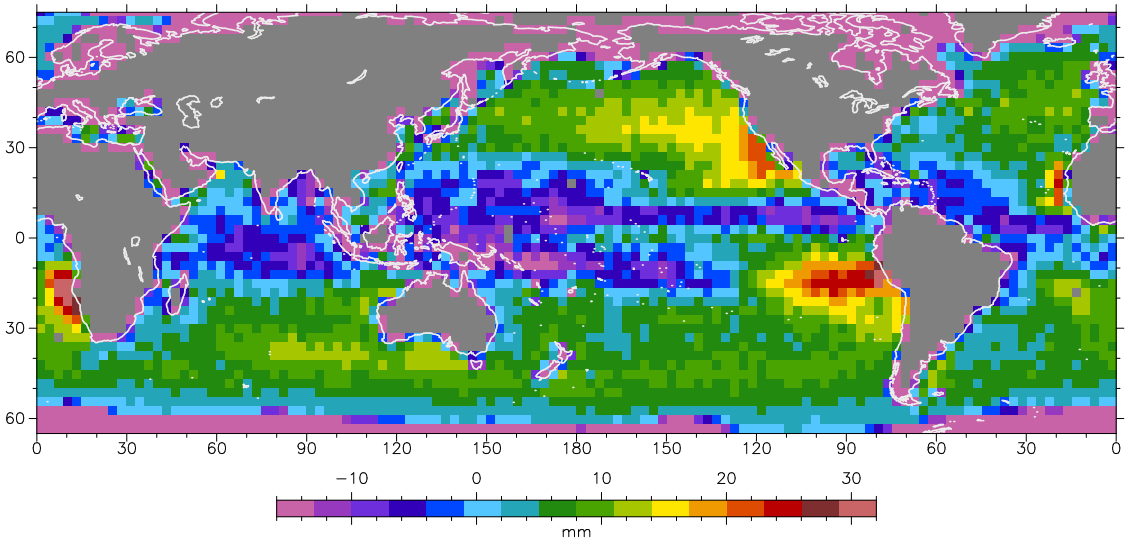


Comparison ERS-2 Radiometer and Model Wet Tropo

- Error in retrieval WTC from ECMWF grids until 1 Dec 1997:

  All ERS-1 and -2 data before 1 Dec 1997: MWTC' = 0.850 MWTC - 0.006

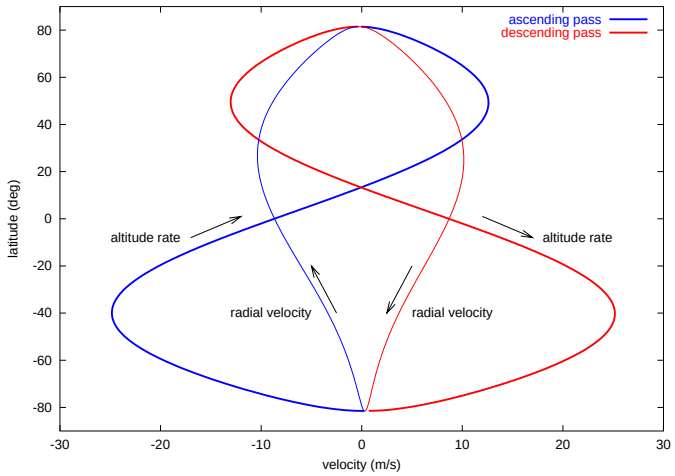
- Mean 1995-1998

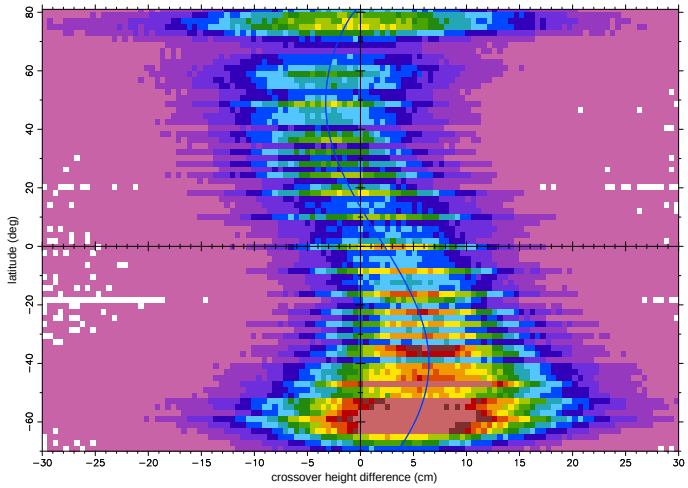


Time Tagging

- Vertical velocity of the satellite is 25 m/s maximum
  ⇒ Time tagging should be precise to better than 1 msec
- Visible in crossovers
- Estimate time tag bias by least squares, reducing crossover rms:

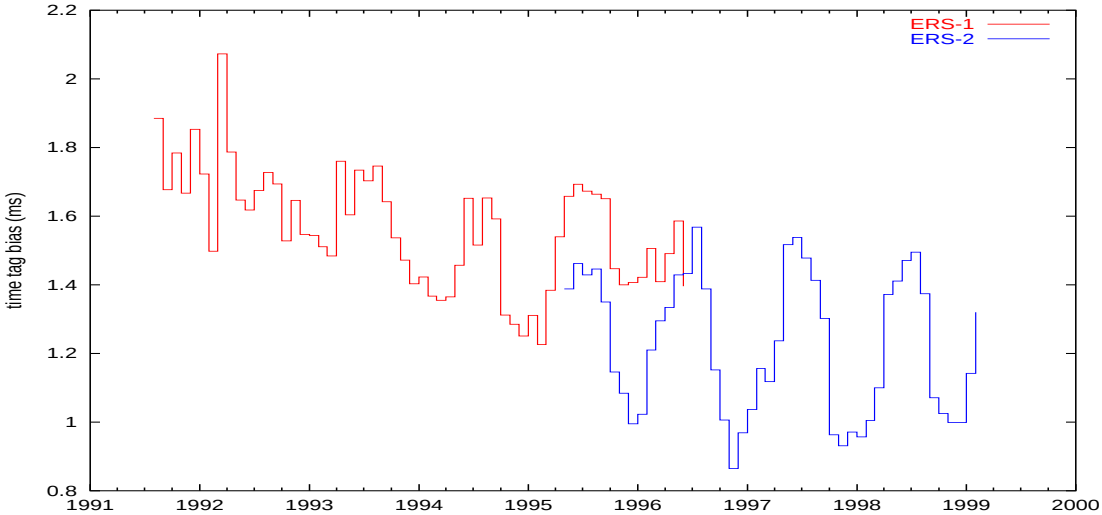
ERS-1 (V5 and V6): TIME' = TIME + 1.5 ms
ERS-2: TIME' = TIME + 1.3 ms





Time Tagging (Evolution in time)

- Annual cycle and trend (?) not yet understood
- Aliasing of geophysical night/day signal in time tag bias?
- 0.3 ms (the wrong way) due to processing error in ERS-2



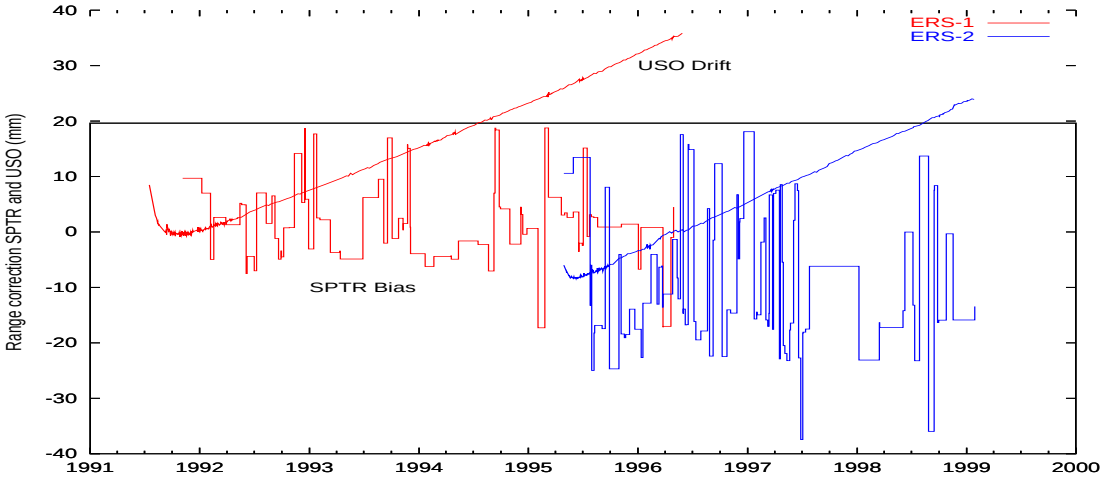
ERS-1 (V5 and V6): TIME' = TIME + 1.5 ms
ERS-2: TIME' = TIME + 1.3 ms

Altimeter Biases and Drifts

Calibration value: -40.92 cm for ERS-2. Also for ERS-1?

SPTR correction: an attempt to model the effect on electronics when the instrument has been switched off, cooled down, and switched on again

USO correction: correction due to frequency change of on-board oscillator



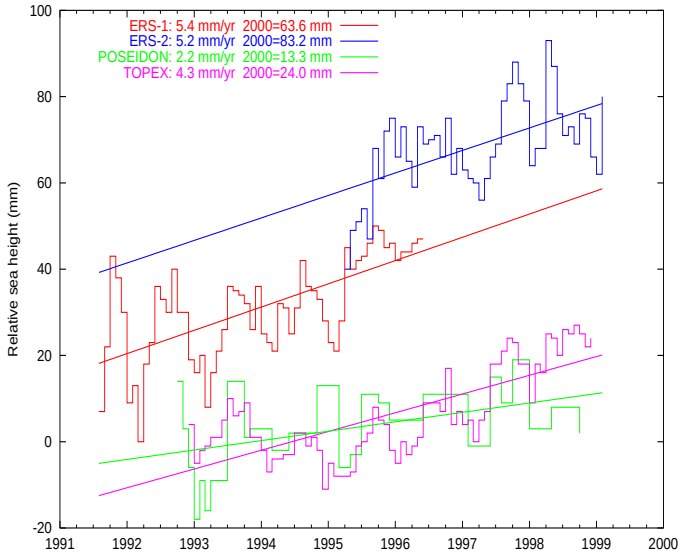
ERS-1: RANGE = RANGE + SPTR_bias + OSU_drift + 0.4092

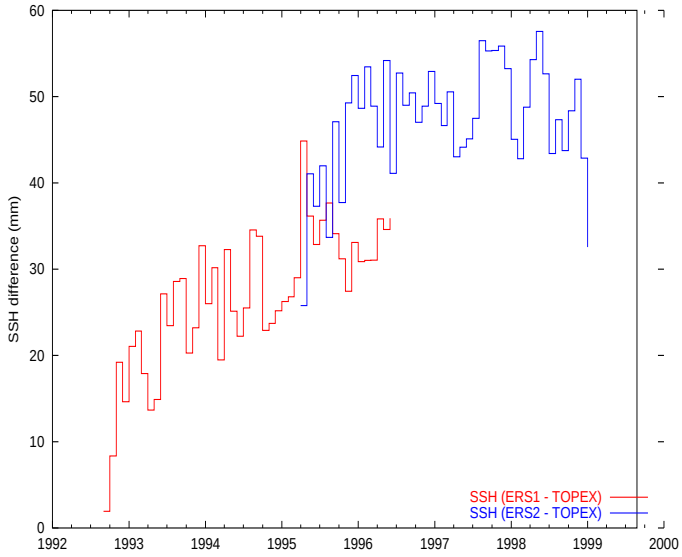
ERS-2: RANGE = RANGE + SPTR_bias + OSU_drift

Sea Level Trends

Left: Monthly mean height differences with the OSU MSS95 mean sea surface model (actually mean of pass-by-pass 1-cpr fits)

Right: ERS-1/TOPEX and ERS-2/TOPEX crossover height differences





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/