Atmospheric corrections for altimetry studies over inland water

M. Joana Fernandes[1,2], Clara Lázaro[1,2], Alexandra L. Nunes[2,4], Remko Scharroo[3]

[1] Universidade do Porto, Faculdade de Ciências, Porto, Portugal
[2] Centro Interdisciplinar de Investigação Marinha e Ambiental (CIIMAR), Porto, Portugal
[3] European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), Darmstadt, Germany
[4] Instituto Politécnico do Porto, ISEP, Porto, Portugal

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Scope and aim

- **Why?**

  Primarily aimed for ocean studies, satellite altimetry products often fail to provide valid corrections over IW regions

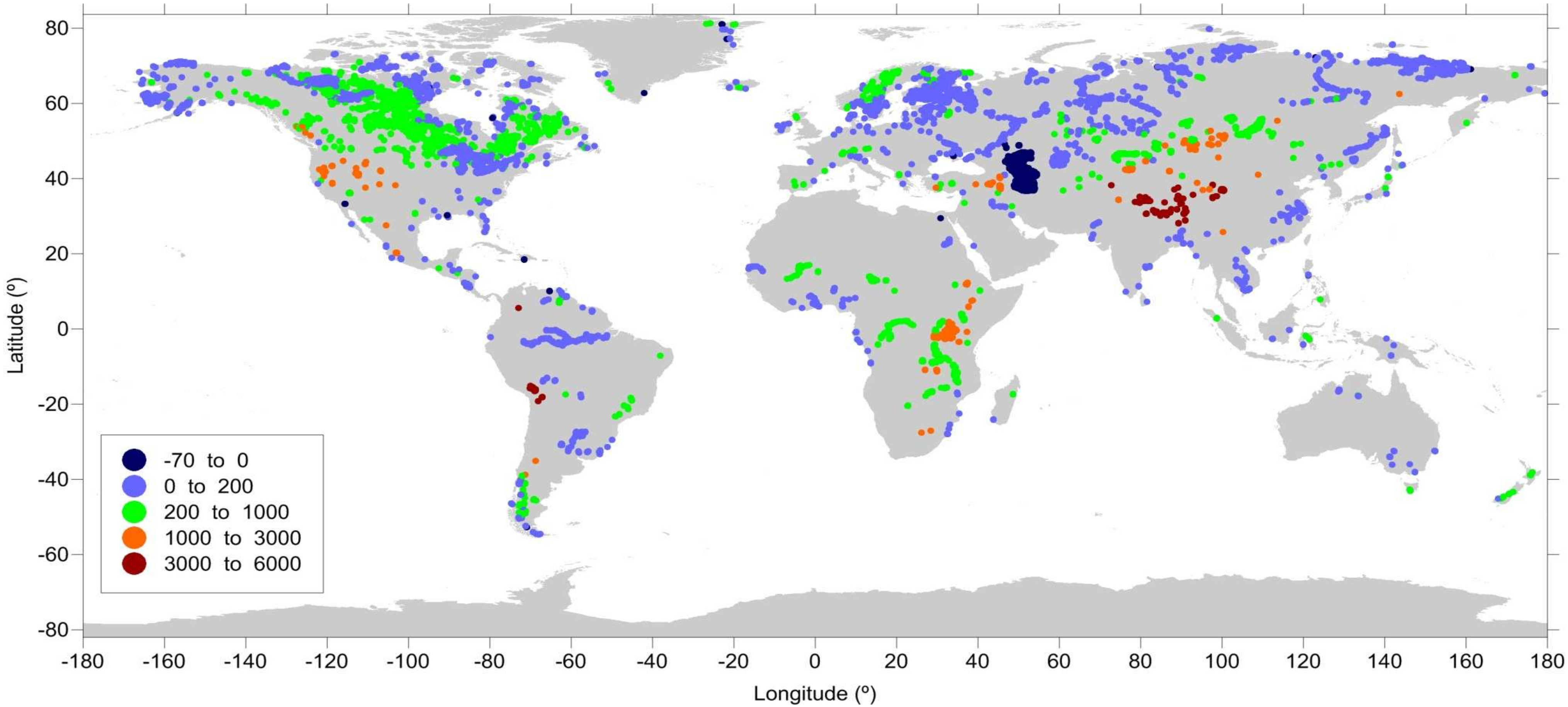
- **Aim:**

  To address the main issues associated with the atmospheric corrections that shall be applied to the satellite altimetry measurements over IW regions to achieve the required accuracy for most hydrological studies

- **How:**

  Investigate the various corrections present in the products of the most relevant altimetric missions, available in RADS

Altimeter measurements over inland waters - **Envisat**



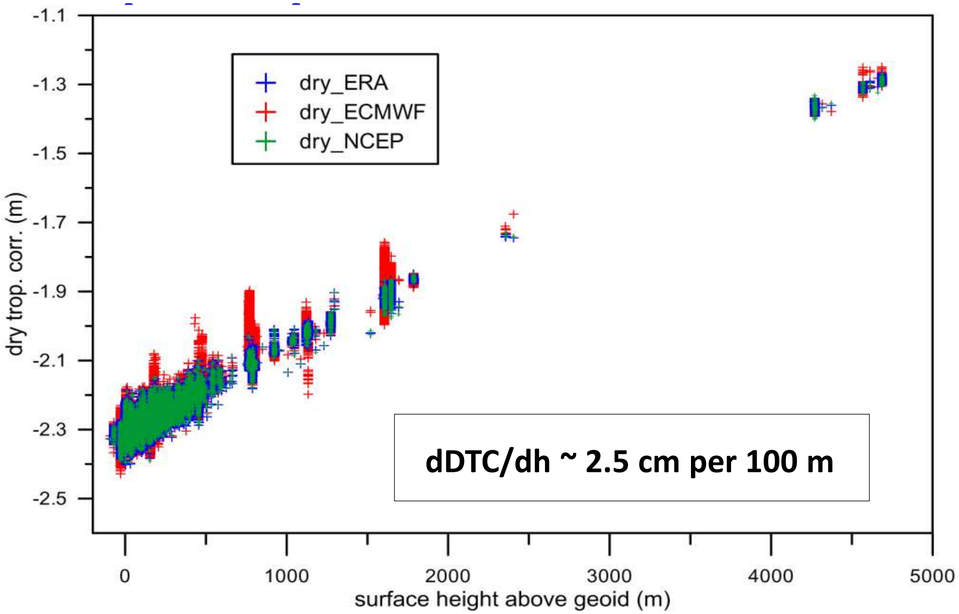
Location of inland water measurements for **Envisat**

Dry Tropospheric Correction (DTC)

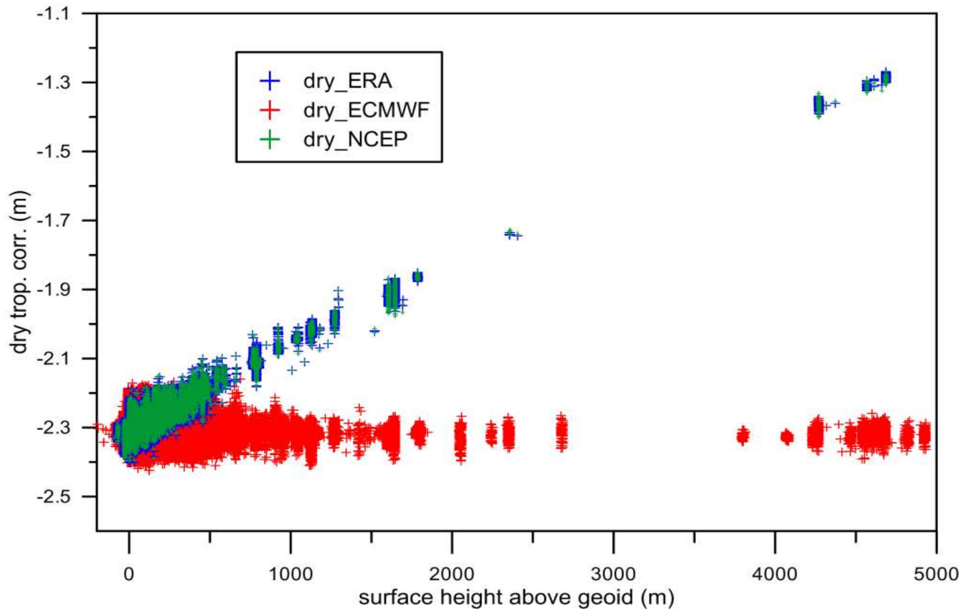
- DTC from 3 models were analysed:
  - **ERA Interim** and **NCEP**: computed in RADS from 0.75˚ and 2.5˚ grids respectively
  - **ECMWF**: from GDRs except for CryoSat-2 (computed in RADS from 16 km Gaussian grids)

DTC - Inconsistency

Inconsistency in the handling of the height dependence



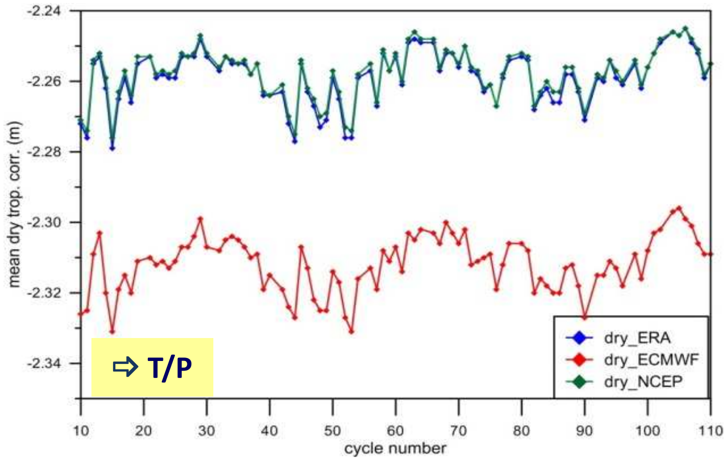
J1, J2, Envisat, CryoSat-2, SARAL

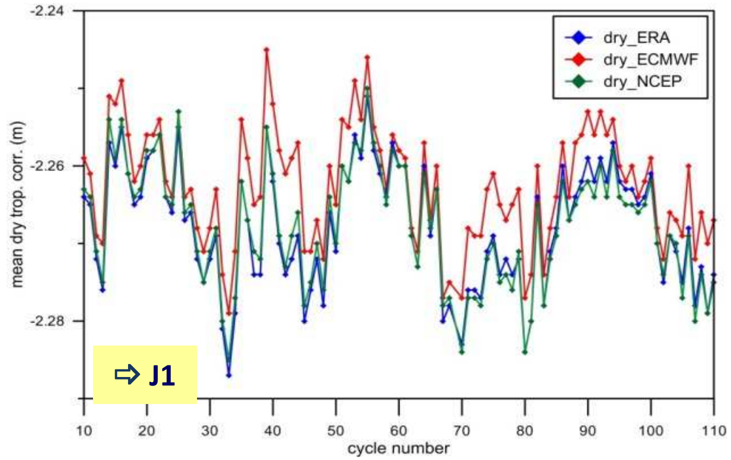


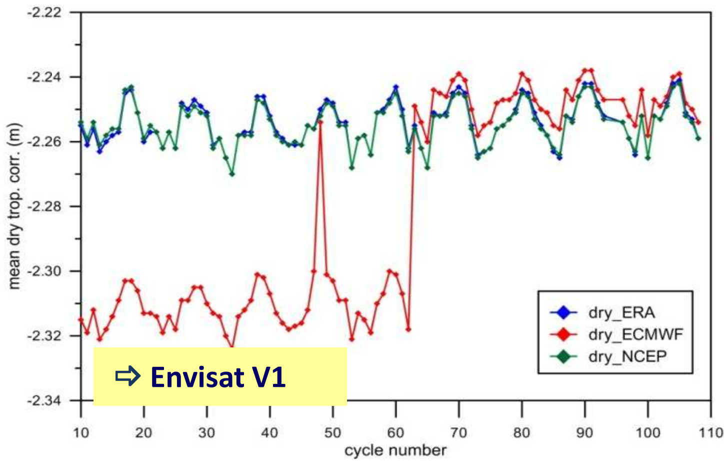
T/P, ERS

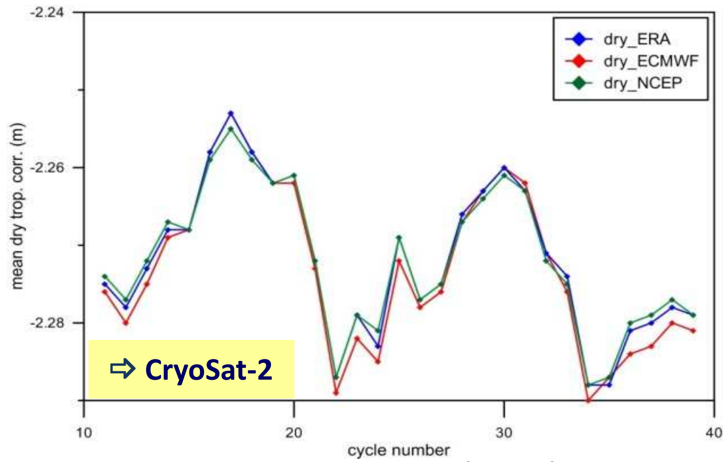
DTC from three models: **ECMWF operational**, **ERA interim** and **NCEP** (m) versus surface height above geoid (m) for various satellites.

DTC - Large biases (when DTC is provided at sea level)









Mean cycle values of the DTC from **ECMWF operational**, **ERA interim** and **NCEP** (in m) versus cycle number, for various altimetric missions

DTC - "V-shape" Interpolation errors

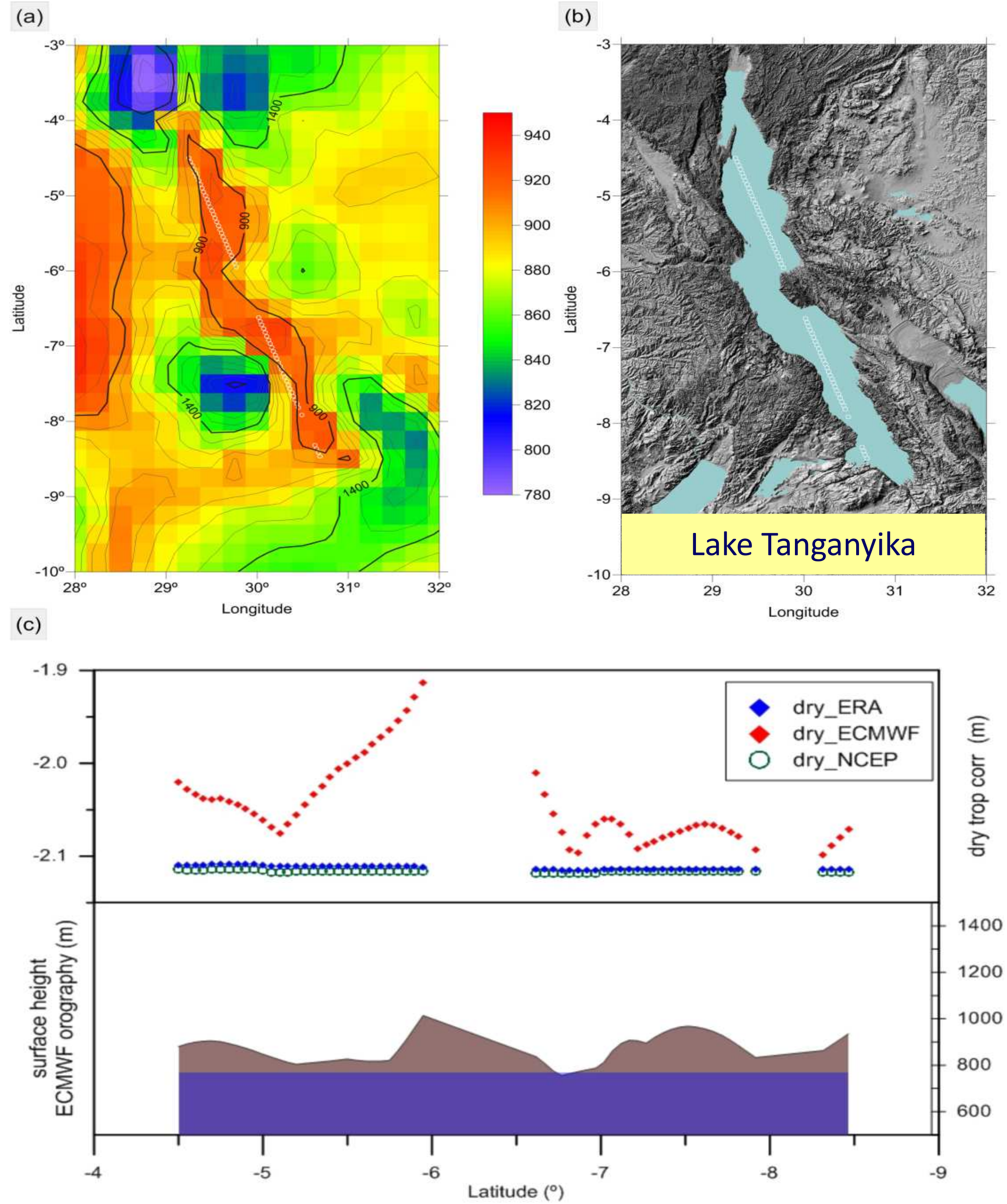
(when DTC is computed from surface pressure grids)

Illustration of DTC errors for J1 pass 222 over lake Tanganyika.

a) Pass location over ECMWF orography (contour interval of 100 m) and surface pressure (colour map, in hPa) of the closest in time ECMWF Op. model grid;

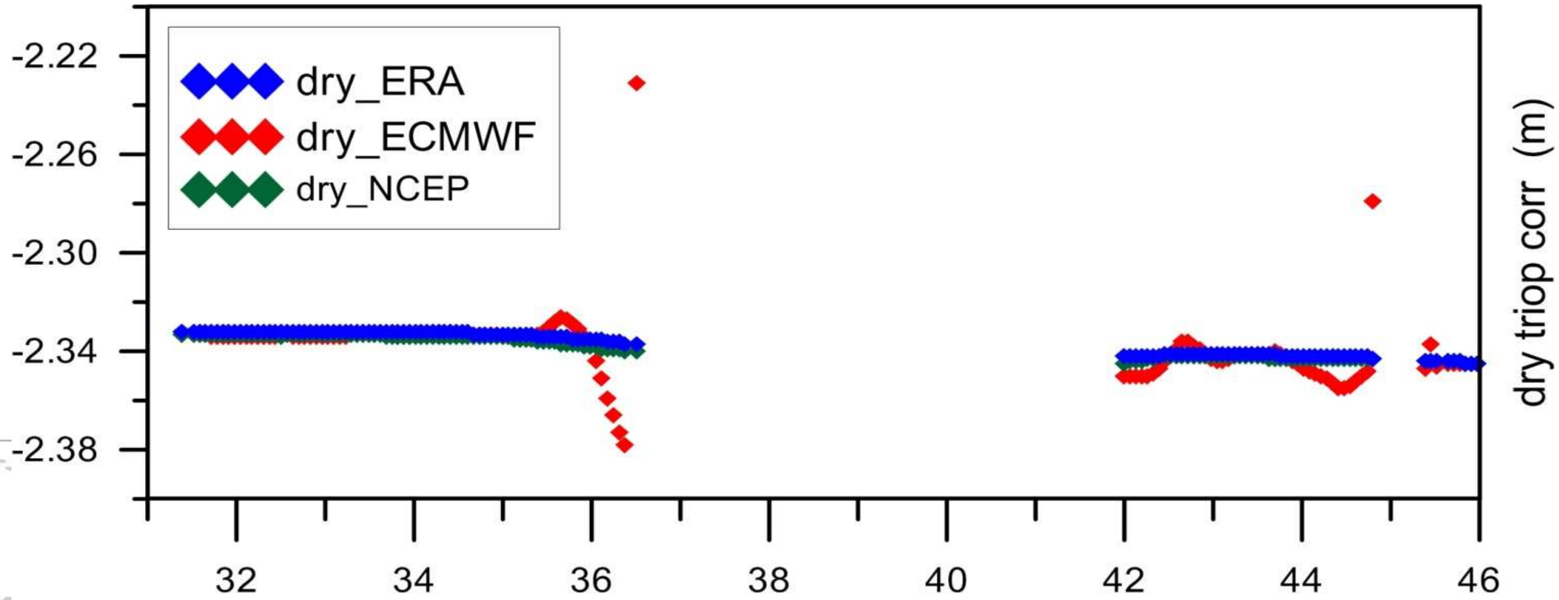
b) Pass location over a DEM;

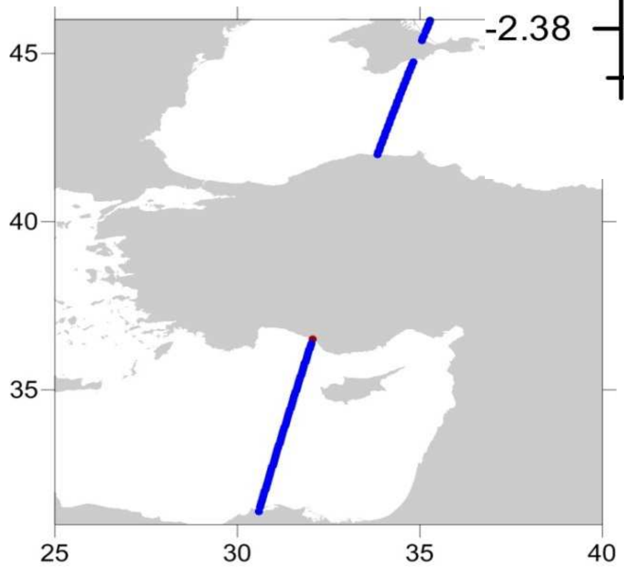
c) Top panel: DTC (m) for pass 222, cycle 62; bottom panel: surface height from ECMWF orography (in brown, m) and lake level height above EGM2008 geoid (as measured by J1, in blue, m).



DTC - Coastal Regions

Interpolation errors – coastal regions





DTC from **ECMWF Op.**, **ERA** and **NCEP** (m) for Envisat Cycle 12 pass 128 over the Mediterranean Sea and the Black Sea.

DTC - Summary

Summary of present DTC from ECMWF:

- T/P, ERS – given at sea level
- J1, J2, Envisat – from surface pressure grids
- CryoSat-2, SARAL – no major issues (from SLP, further reduced to surface height)

DTC computation for IW:

1) Compute correction at sea level from SLP grids (modified Saastamoinen model, Davis et al. 1985)
2) Interpolate to altimeter ground track point
3) Reduce to surface height using appropriate formulae (dP/dh=f(h,T))

Wet Tropospheric Correction (WTC)

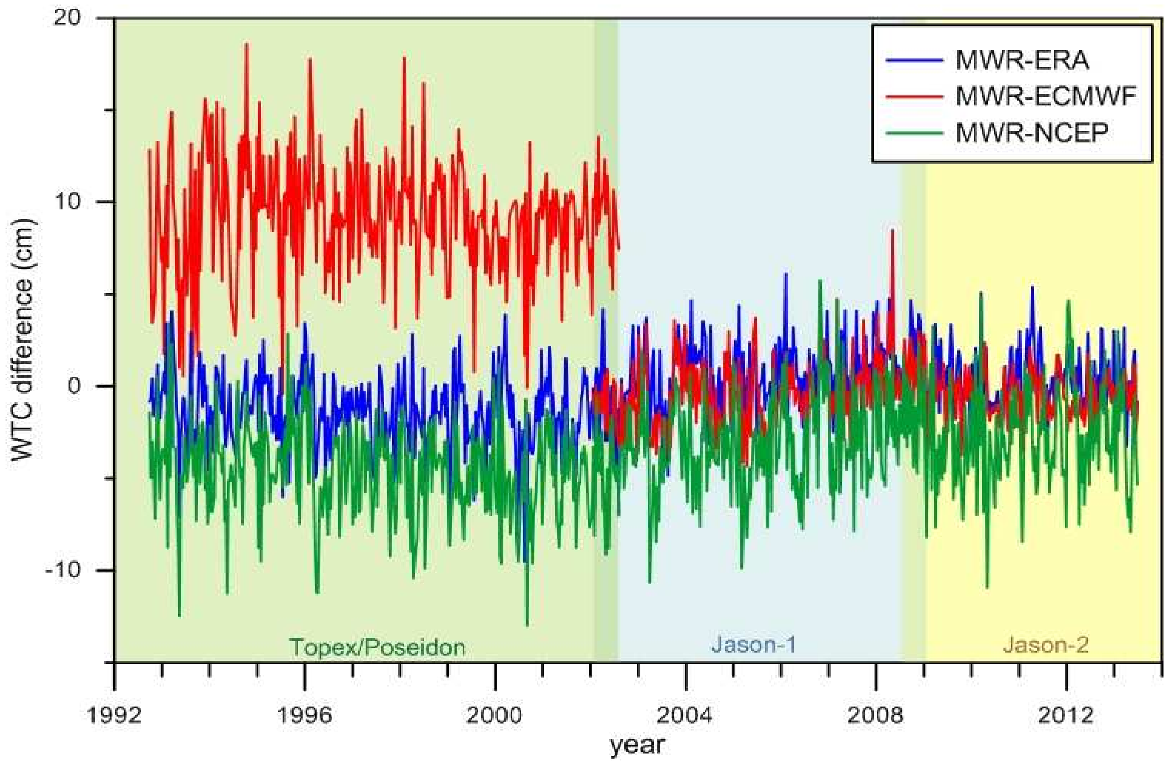
- WTC from on-board microwave radiometers (**MWR**)
- WTC from 3 models:
  - **ERA Interim** and **NCEP**: computed in RADS from 0.75˚ and 2.5˚ grids respectively
  - **ECMWF**: from GDRs except for CryoSat-2 (computed in RADS from 16 km Gaussian grids)

WTC - Inconsistency

Inconsistency of model-based WTC

WTC from ECMWF operational:

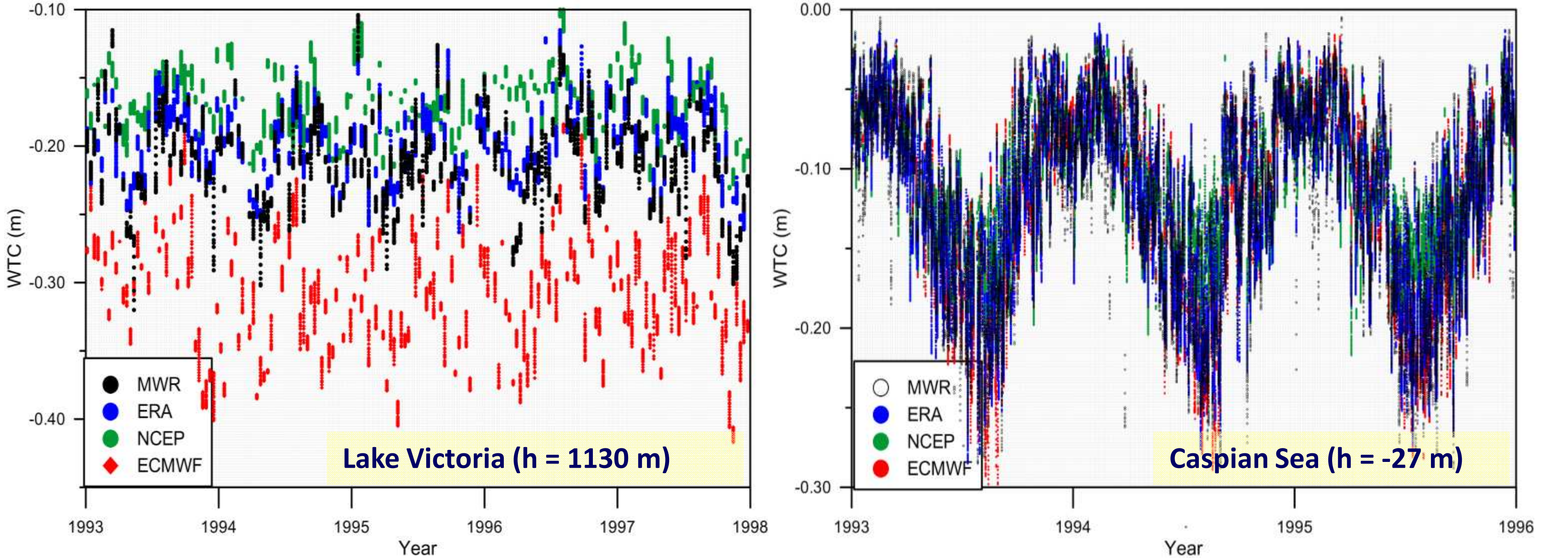
- **T/P – at sea level**
- **All other missions - at surface height**



Mean cycle differences between the MWR-derived WTC and the corresponding values from three NWM (**ERA Interim**, **ECMWF-Op.** and **NCEP**), over **Lake Victoria (h = 1130 m)**, for **T/P phase A, J1 phase A and J2**. Only measurements over inland water with valid MWR correction were considered. ECMWF Op. values are from the GDRs of each mission.

WTC – Height reduction errors

Heights of e.g. 100 m and 500 m induce WTC errors of 5% and 28% respectively (1 cm and 5.6 cm for a WTC of 20 cm).



WTC for all **T/P** measurements over **Lake Victoria** (left, h = 1130 m) and the **Caspian Sea** (right, h=-27 m) for a set of T/P cycles, approximately 5 years (left) and 2 years (right). The x-axis is along-track point number, considering only measurements over inland water with valid MWR correction.

WTC - summary

WTC computation for IW:

- MWR-based corrections – usable in large lakes; not appropriate for small lakes, river channels, etc.
- GNSS-derived WTC – suitable for small regions possessing permanent GNSS stations (small lakes, reservoirs, etc.)
- WTC from models – most suitable in most regions
- Best model: ERA Interim; overall accuracy (1σ) of 1 to 3 cm, depending on region; like all models, ERA may have local biases of 1-2 cm
- ECMWF Operational model not provided in a consistent way:
  - For T/P is given at sea level – large errors, height reduction cannot be performed with enough accuracy
  - For all other missions it is correctly provided at the surface height

Ionospheric Correction (IC)

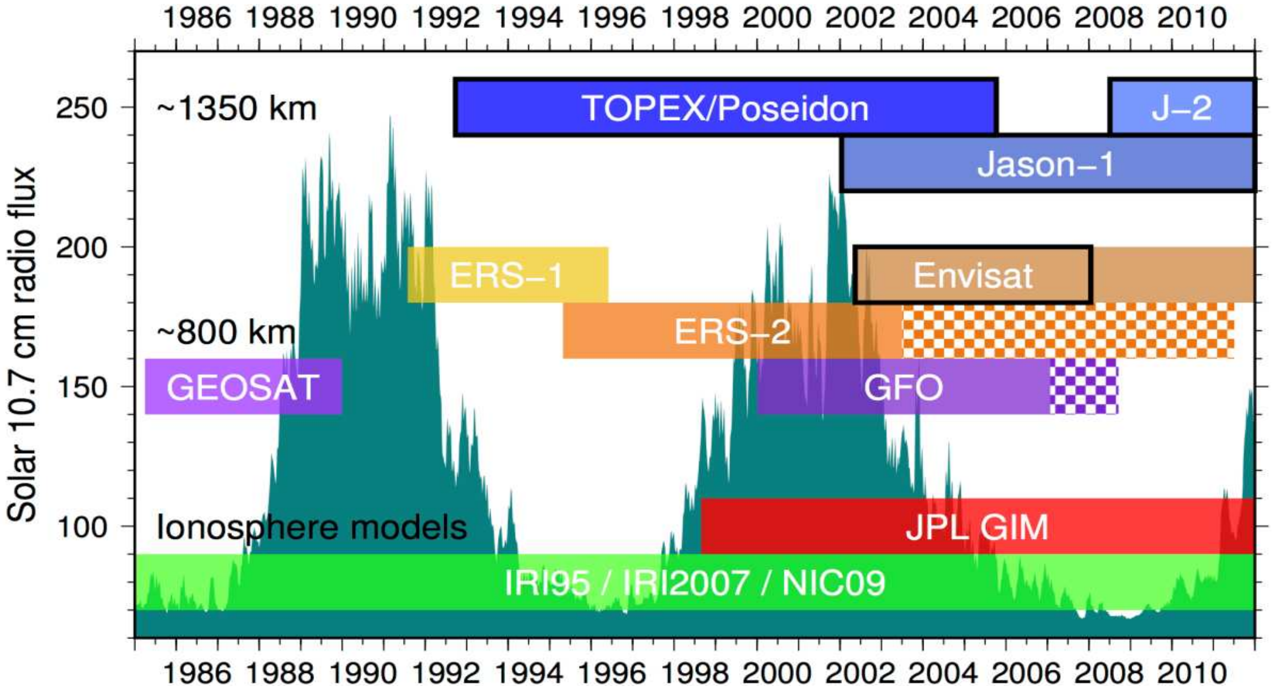
- **No surface height dependence**
- **Dual-frequency IC** : errors due to different terrain effects in the Ku, C and S bands and the difficulty in performing an efficient smoothing, make it unsuitable for use in most IW regions.

Jason-1	JPL GIM	dual-freq.	smoothed dual-freq.
N-W Atlantic	88.5	89.2	85.5
Great Lakes	64.2	64.0	64.3
Envisat	JPL GIM	dual-freq.	smoothed dual-freq.
N-W Atlantic	129.5	129.7	129.3
Great Lakes	62.9	63.1	62.7

Standard deviations (in mm) of the crossover height differences for Jason-1 and Envisat during the years 2003-2004, using JPL GIM, non-smoothed dual-frequency range measurements, and smoothed dual-frequency range measurements for the correction of the ionospheric refraction. The N-W Atlantic Ocean region (52°- 40° W, 41°- 49° N) is shown for comparison.

IC - summary

- From 1998 onwards, whenever dual-frequency measurements cannot be used, the **JPL GIM model**, properly interpolated and scaled (as recommended by Scharroo and Smith 2010), shall be used.
- Prior to 1998, the climatological model **NIC09** can be used, with increased errors for periods of high solar activity.

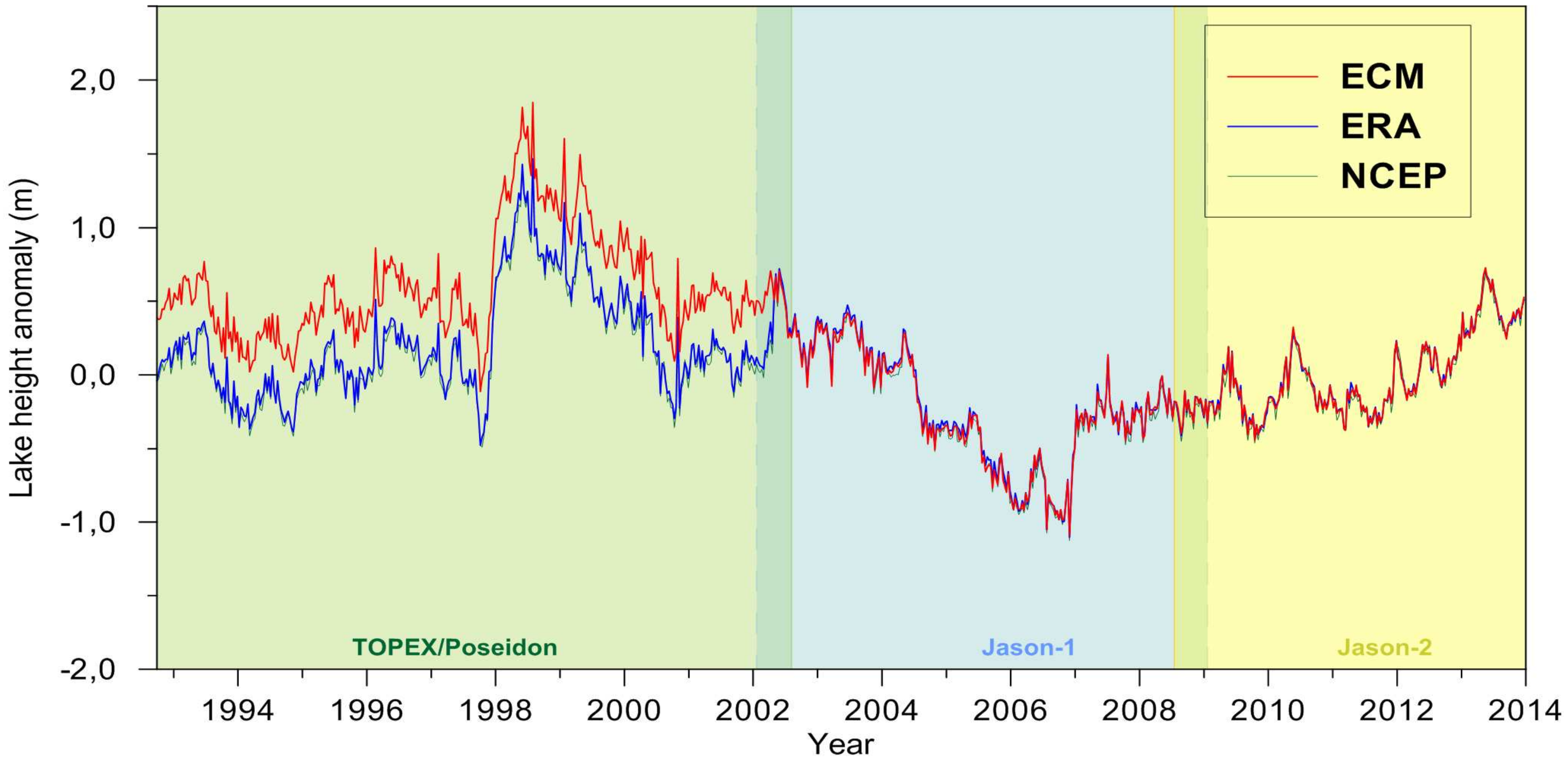


Variation of solar 10.7 cm radio flux during the last two solar cycles. The time span of the altimetric missions is shown. Outlined rectangles of T/P, J1, J2 and Envisat indicate the availability of dual-frequency measurements. The checkered patterns indicate limited data coverage. TEC models are shown at the bottom.

Impact of tropospheric corrections on water level time series

Time series for Lake Victoria (h = 1130 m), pass 120

- **TP series has a bias of 39 cm**

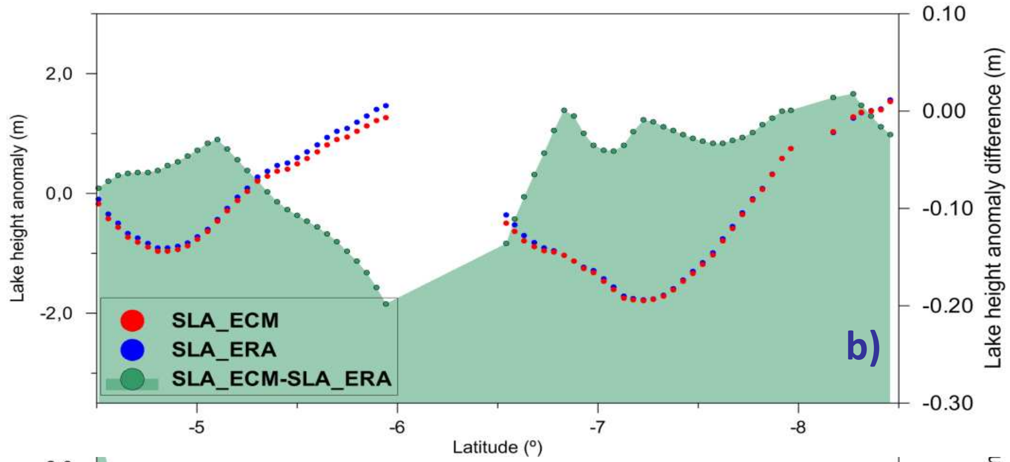


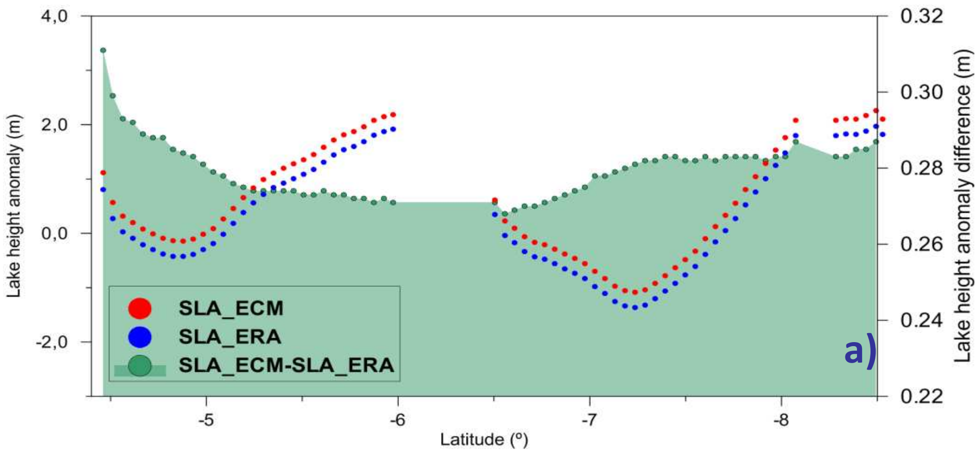
Median water level anomalies (m) for Lake Victoria, Africa, derived using tropospheric (dry + wet) corrections from three models, for each cycle of T/P phase A, Jason 1 phase A and Jason 2. Water level heights are referred to EGM2008 geoid. A mean lake height of 1135 m has been removed.

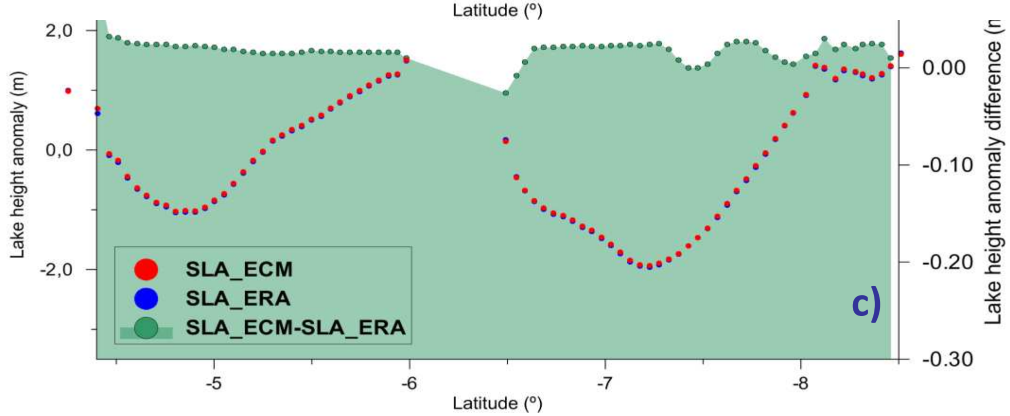
Impact of tropospheric corrections on mean lake profiles

T/P and J1 pass 222 over Lake Tanganyika (h=769 m)

(a) T/P cycles
(b) J1 cycles 1-149
(c) J1 after cycle 150







Water level anomalies (m) along T/P and J1 Pass 222 over Lake Tanganyika, derived using tropospheric (dry and wet) corrections from two models. Water level heights are referred to the EGM2008 geoid. A mean lake height of 769 m has been removed. Results for NCEP are not shown, since they are very similar to those from ERA Interim.

Summary of main issues

- **DTC**: from SLP, reduced to surface height using appropriate height reduction formulae (accounting for T dependence) and DEM
- **WTC**: from MWR over central parts of large lakes; from a model (e.g. ERA Interim) over small lakes and rivers; from GNSS when available
- **IC**: smoothed dual frequency (large lakes), JPL GIM (after 1998) or NIC09 (before 1998)

Ref: Fernandes MJ, Lázaro C, Nunes AL, Scharroo R (2014): Atmospheric Corrections for Altimetry Studies over Inland Water. *Remote Sensing* 6 (6): 4952-4997, doi:10.3390/rs6064952