



Observing Sea Level Rise in Venice: the Combined Perspective of Satellite Altimetry and In Situ Observations in the ESA CCI

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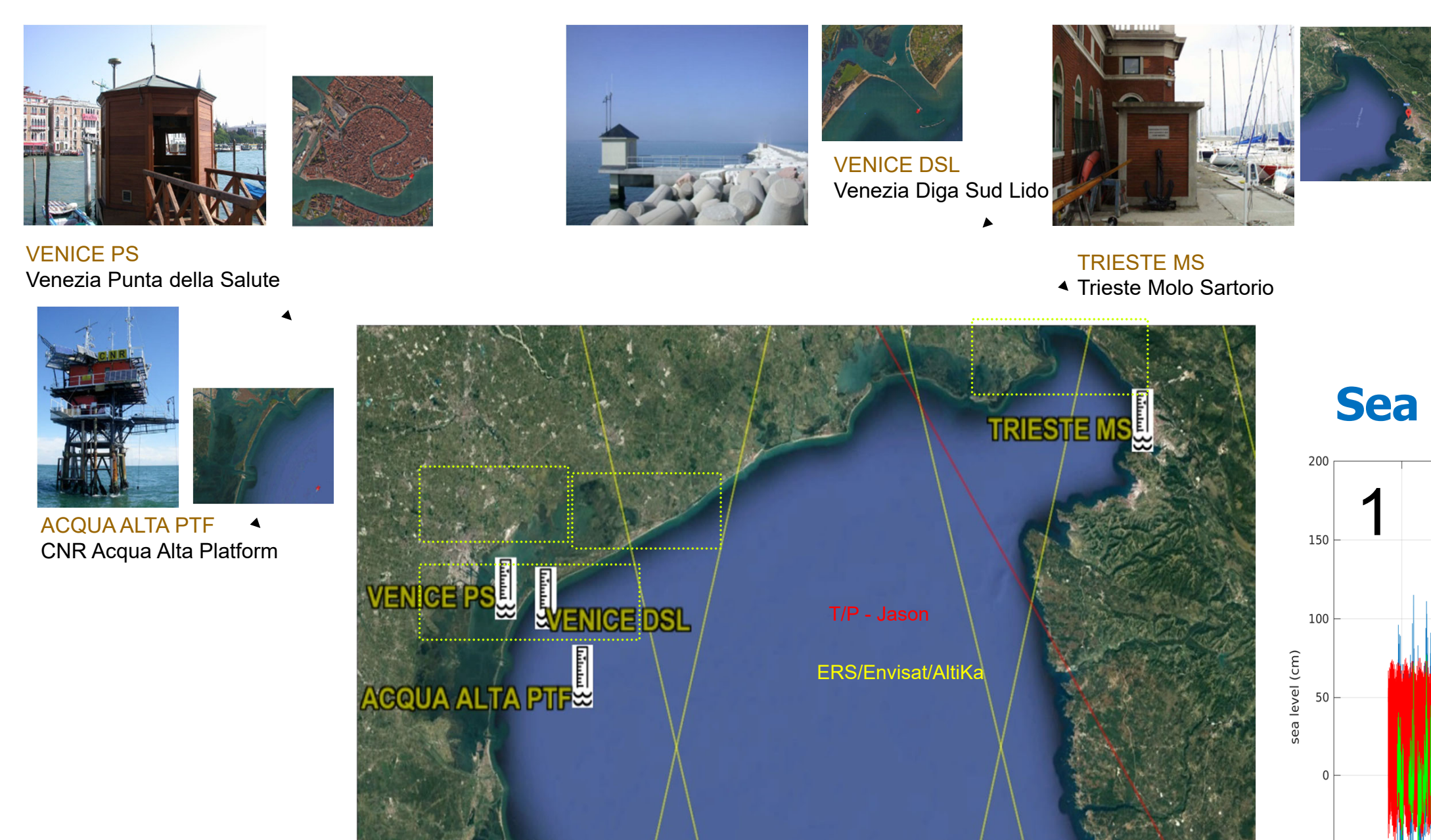
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Abstract

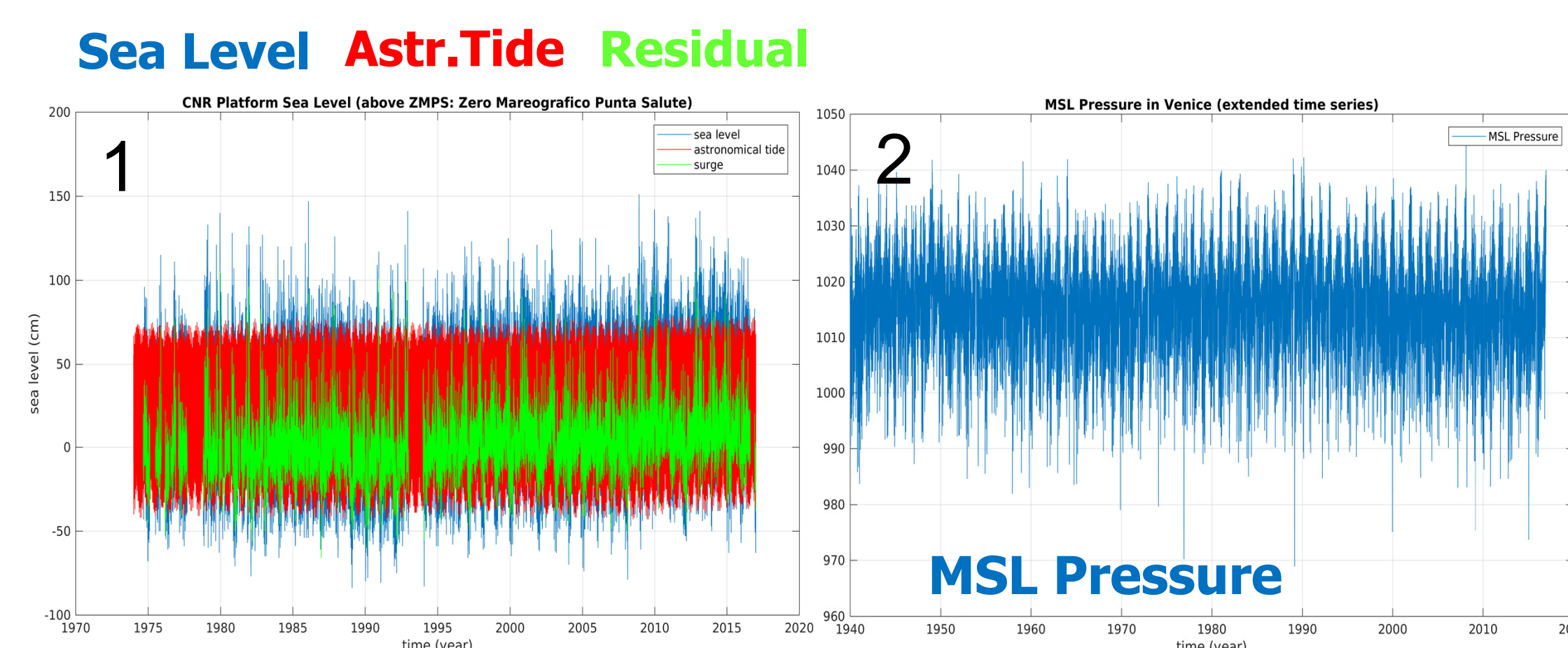
Sea level is the major threat to Venice and tracking its variability is crucial to safeguard the city. Even if the MOSE barrier was designed to defend effectively against storm surges, the long term implications of gradually rising sea levels has not been sufficiently investigated. Since 1990's, a series of radar altimetry missions accumulated a satellite-based record of sea level that is now long enough to estimate trends. The European Space Agency (ESA) Climate Change Initiative (CCI) project on "Sea Level" has reprocessed these altimeter data over 1993-2015 to provide homogenous sea level for all altimetry missions. The ESA Sea Level CCI products are generated using open ocean altimetry data, and include along track sea level anomalies (SLA) at 1 Hz (around 7 km) and monthly gridded time series of multi-mission merged SLA at a spatial resolution of 0.25° (around 25km) from which some oceanic indicators (e.g., trends) are derived. Sea level measurements from tide gauges around Venice and Trieste are used as references of sea level trends at the coast. Comparisons with the closest CCI grid points will permit to estimate the importance of vertical land movements and identify local processes that might impact on the local sea level rise. In this poster, we assess the quality of the current Sea Level CCI products in the Adriatic Sea, and in particular around the city of Venice. The aim is to determine how much the actual Sea Level CCI products can be considered reliable in this site. During the CCI+ phase (2018-2019) the objective is to extend the satellite-based sea level climate record to the coastal zone with quality comparable to the open ocean. Coastal altimetry has demonstrated that if standard products are reprocessed with dedicated algorithms reliable data can be obtained up to few kms from the coasts. Therefore, additional along-track data sets (e.g., CTOH, COSTA, etc.) with consistent coastal processing for all missions and derived products dedicated to coastal regimes will be used to evaluate their current capabilities and perspectives for usage in long term sea level research studies. We aim at determining how close to the coast the actual Sea Level CCI products can be considered reliable. the relative sea level rise budget.

Area of Investigation, in situ data and relevant altimetry ground tracks



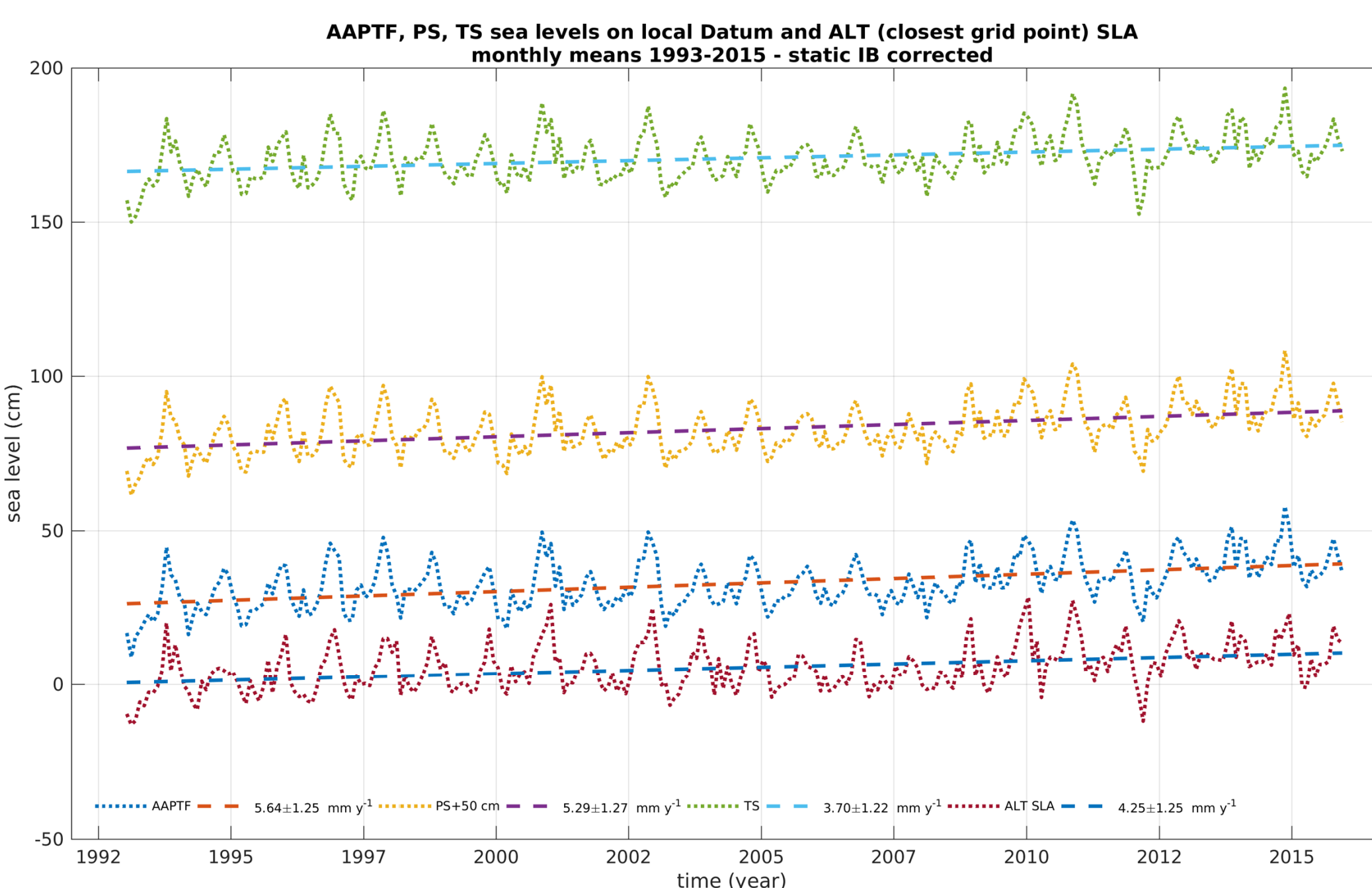
The City of Venice is today **on average 30 cm lower than early 1900s**. The IPCC 5th report (2013) predicts an increase in sea level **between 18 and 59 cm** during the next 100 years, and sea level observations highlight that **rising is not geographically uniform**.

It is thus of particular interest to have accurate sea-level observations in this area in order to better assess the climate-related contribution. In plot (1) is reported the **hourly sea level (blue line)** at the CNR Platform Acqua Alta above the local historical reference (ZMPS). The **astronomical tide contribution (red line)** and the **residual difference (green line)** after subtracting from the sea level are also reported. Other climatological variables are to be considered: for example the **MSL atmospheric pressure** (plot 2) and the wind (stress). The atmospheric loading is well observed by TG measurements. Climate-related changes of meteorological and marine variables are an important input **to define future scenarios** not only of **MOSE infrastructure**, designed to protect Venice from storm surges, but also of the coastal settlements of the northern Adriatic Sea.



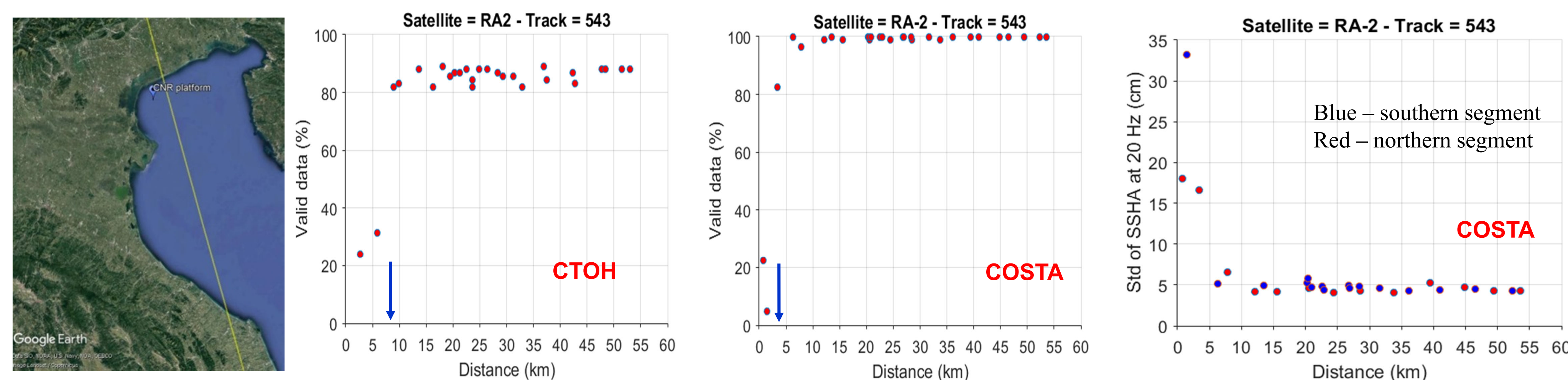
Sea level rise in the Northern Adriatic during altimetry era

Sea Level Anomaly (SLA) observations from satellite are now long enough to permit a comparison with **in situ sea level (SL)** measured with standard tide gauges (TGs). In the northern Adriatic Sea the **Venezia CNR Platform "Acqua Alta"** (AAPTF), **Venezia Punta Salute** (PS), and **Trieste Molo Sartorio** (TS) are among the longest SL timeseries. Hourly SL are filtered with the Doodson X0 filter to create the monthly Means (following PMSL guidelines). Measured trends are overlapped. The **ESA CCI project on "Sea Level"** has reprocessed these altimeter data over 1993-2015 to provide homogeneous SLA for all altimetry missions (Legeais et al. 2018). The **v2.0 dataset** was released in December 2016, with details provided at <http://www.esa-sealevel-cci.org/products>. A comparison has been performed using the nearest CCI grid point to the location of AAPTF.



Preliminary results show **SL trends in the Northern Adriatic Sea much higher than GMSL** (Global Mean Sea Level), with **marked differences between Venice and Trieste**. ISPRA, the Italian Institute for Environmental Protection and Research computed **Vertical Land Motion (VLM) at Punta Salute** during 2010-2015 VLM finding values around -1.33 mm/yr and -1.45 mm/yr, with a mean of **-1.4 mm/yr** (Baldin and Crosato, 2017). If those last rates can be assumed representative of the altimetry era 1993-2015, we achieve the closure of the budget
AAPTF trend: $5.65 - 1.4 = 4.25$ mm/yr
PS trend: $5.29 - 1.4 = 3.89$ mm/yr
ALT trend: 4.25 mm/yr
However, in order to confirm the closure, an independent estimate of the VLM has to be done during 1993-2015

Case-study of Envisat track 453



The percentage of valid data lowers when approaching the coast, as expected. COSTA is able to capture **more valid data in open sea**. COSTA looks better than CTOH very close to the coastline (**benefits of re-tracking**). COSTA provides std of SSHA at 20 Hz. Averaging all cycles, the **noise increases in close proximity to the coast**, as expected. **Noise keeps below 5 cm until 5 km from the coast**.

Acknowledgments

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Reference

Vignudelli S., De Biasio F., Scozzari A., Zecchetto S., Papa A.: Sea level trends and variability in the Adriatic Sea and around Venice, in Proceedings of International Association of Geodesy Symposia - International Review Workshop On Satellite Altimetry Cal/Val Activities and Applications", 23-26 April 2018, Crete, Greece (accepted), 2018.

Evolution during the CCI+ phase (2018) – Jason-2 196

