Global coastal altimetry data enable an improved look at coastal dynamics and sea level

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presented by **Christine Gommenginger[1]**

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Satellite Altimetry: a mature technique

- provides **sea level**, wind, **significant wave height**
- workhorse of operational forecasting systems – extensively used in FOAM/NEMO, ECMWF, Mercator,…
  - synergy with SST, ARGO
- 23 years (and counting) of good quality data from 9 missions, continuity of service secured for next decade
- use for climate studies (long-term **sea level rise**): ESA Climate Change Initiative
- precise (i.e. repeatable) and accurate (i.e. small biases)
- even more impetus from technological advances:
  - **SAR altimetry from CryoSat-2 (2010–), Sentinel-3 A(forthcoming)/B/C/D, Sentinel-6 (2018)**
  - **Ka-band altimetry from AltiKa (2013–)**

Satellite Altimetry Instruments/Missions

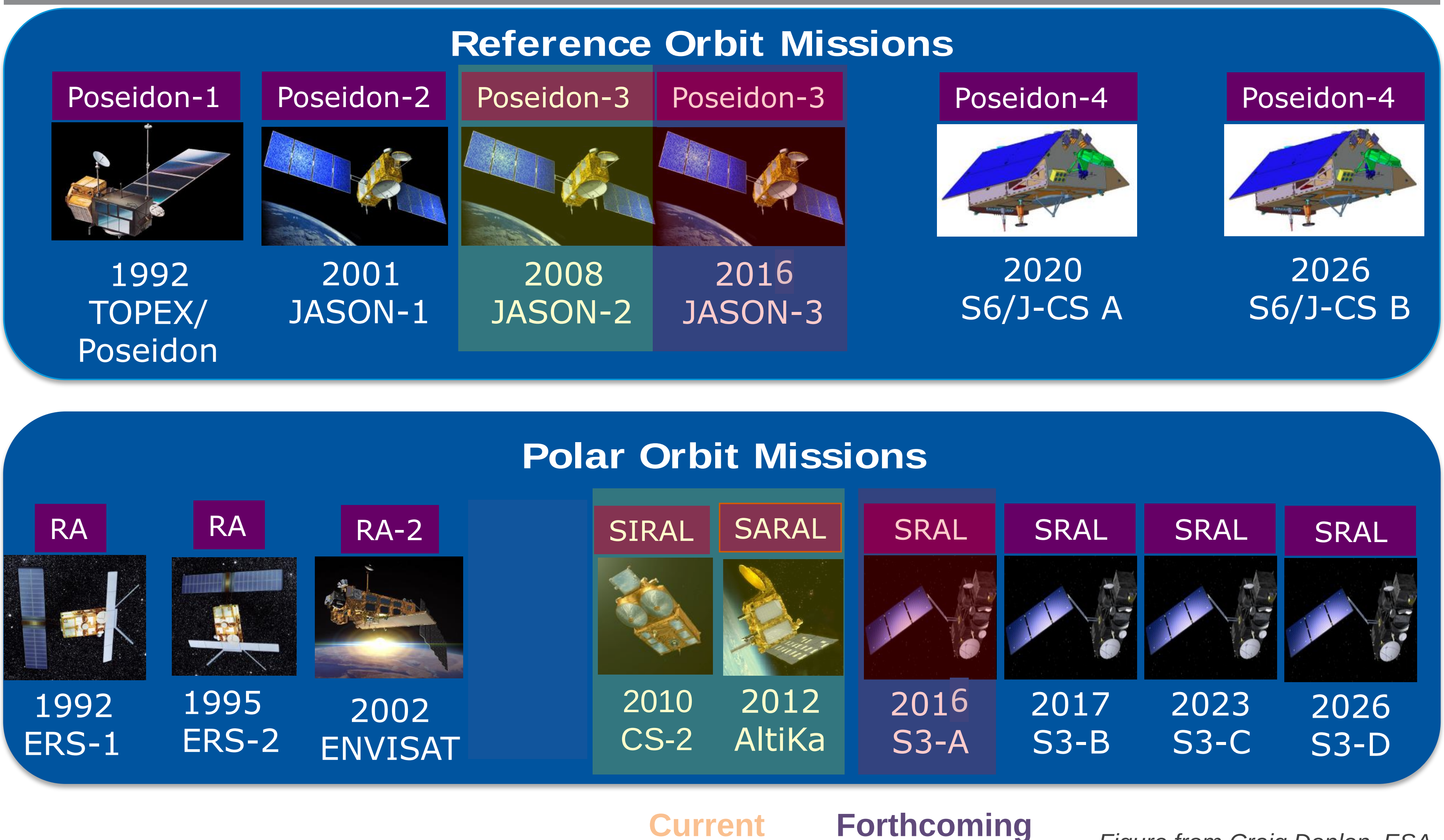
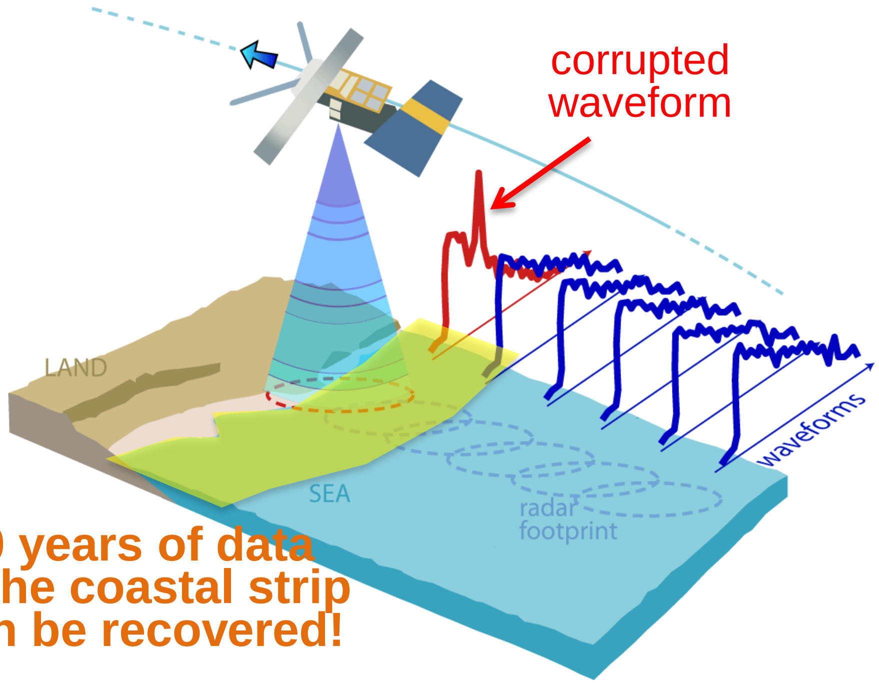


Figure from Craig Donlon, ESA

The new frontier - coastal altimetry



20 years of data in the coastal strip can be recovered!

In the **coastal zone** altimetry encounters specific problems:

- corruption of the radar waveforms
- inaccurate corrections for some effects, for instance water vapour ('wet tropospheric') and tides

Traditionally, data in this zone are flagged as bad and left unused

In recent years a vibrant community of researchers has started to believe that **most of those coastal data can be recovered and is holding annual Coastal Altimetry Workshops (10th edition in Oct 2016)**

http://www.coastalt.eu/community

Also important for **SAR & Ka-band altimetry, having good coastal performance - and for coastal wave field**

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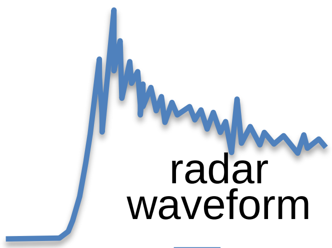
In this talk we'll see:

- Some **technical improvements** that make coastal altimetry possible
- Examples of **validation** of coastal altimetry data
  - i.e. how good are they? How close to the coast can we get?
- Two very different **applications:**
  - monitoring of storm surges
  - coastal sea level rise

ALES: an improved retracker for coastal altimetry

RETRACKING:

Fitting a model to the radar echoes (waveforms) to retrieve geophysical parameters (**range** → sea level, **significant wave height**, backscatter → wind)

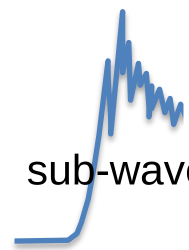


Adaptive Leading-Edge Subwaveform (ALES) retracker developed at NOC
(Passaro et al., Rem. Sens. Env., 2014)

Pass 1: identification of leading edge and initial estimate of SWH

$h_{s(1)}$

ALES algorithm for width of sub-waveform window
(from Monte Carlo Simulations)

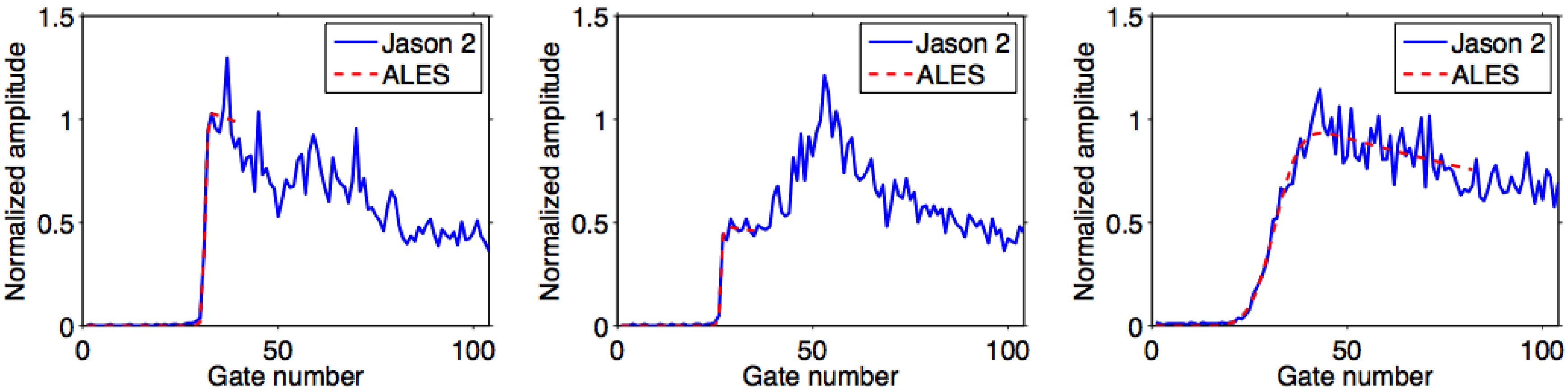


Pass-2: subwaveform retracking
(Brown Model)

estimated parameters
range, h_s, σ_0

In practice ALES **uses only a portion of the waveform**, discarding the ‘tail’, which is less important for the estimate of the parameters and is often corrupted in the coastal zone

Examples of Jason-2 retracking by ALES



Open ocean
SWH = 0.75 m

Coastal ocean
SWH = 1.65 m

Open ocean
SWH = 9.5 m

- Validated for SSH for Envisat, J-1, J-2, AltiKa
- Validated for SWH for Envisat, J-1/2 (Passaro et al., 2015)
- J-2 data **available now from PODAAC**, Envisat, J-1 coming

ftp://podaac.jpl.nasa.gov/allData/coastal_alt/L2/ALES/

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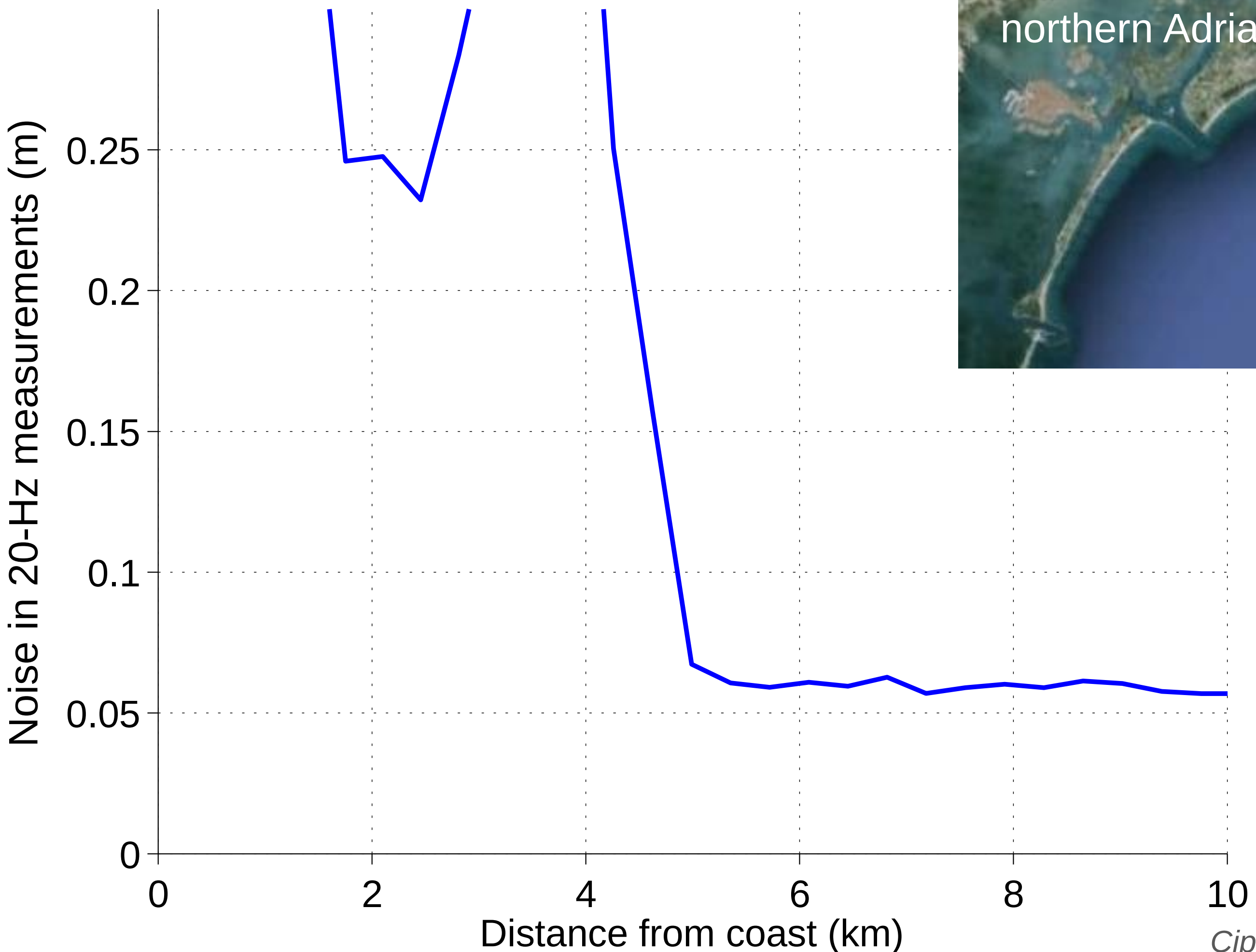
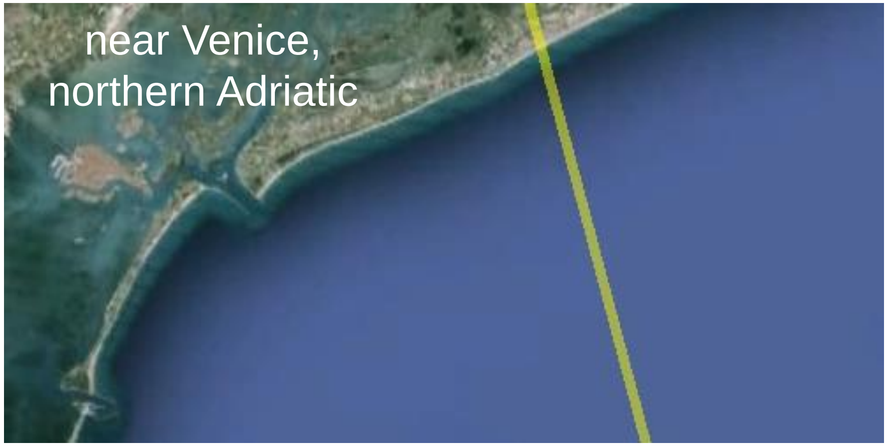
Example of improvements with ALES

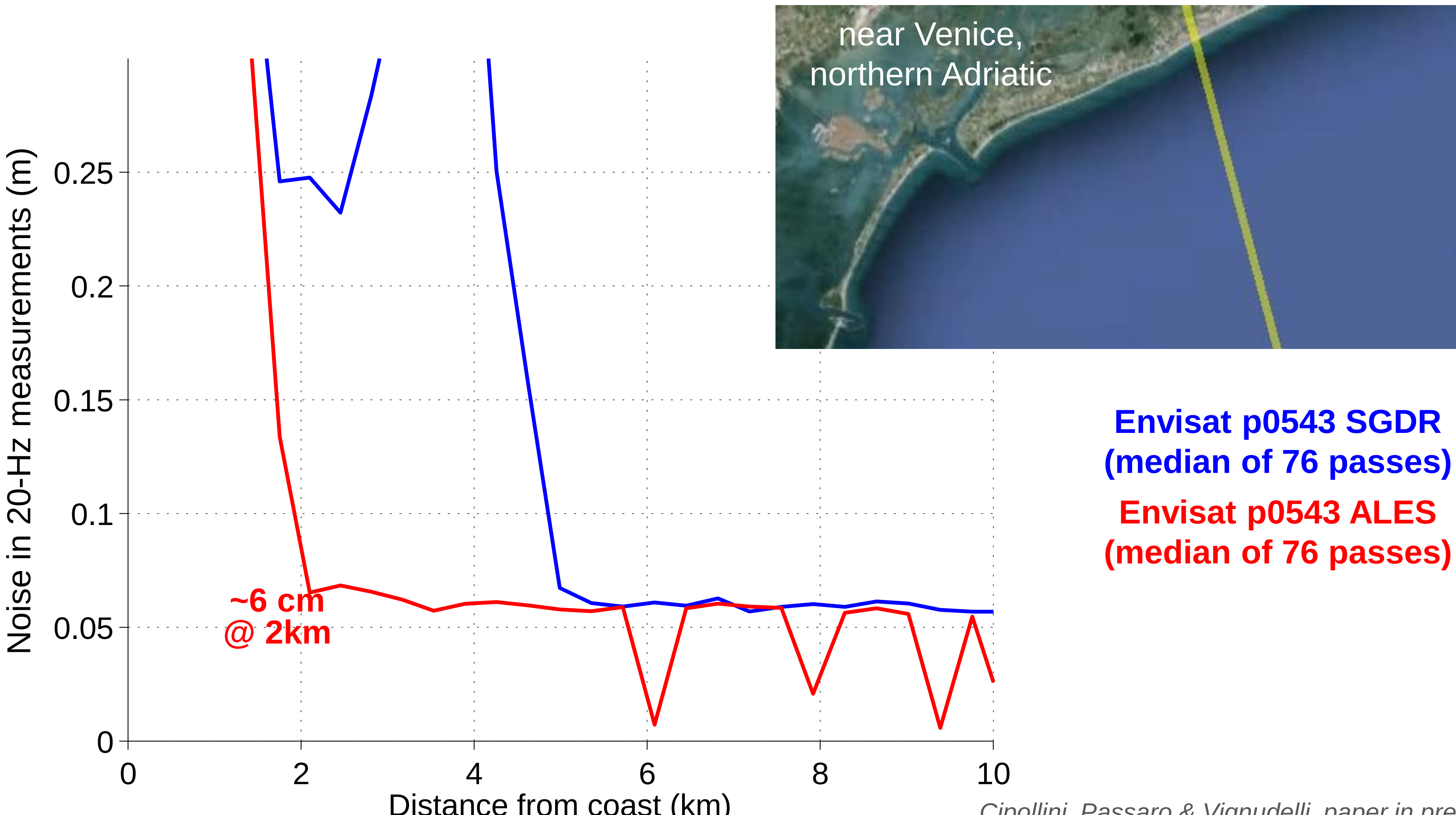




Envisat p0543 SGDR (median of 76 passes)

Cipollini, Passaro & Vignudelli, paper in prep.

Example of improvements with ALES



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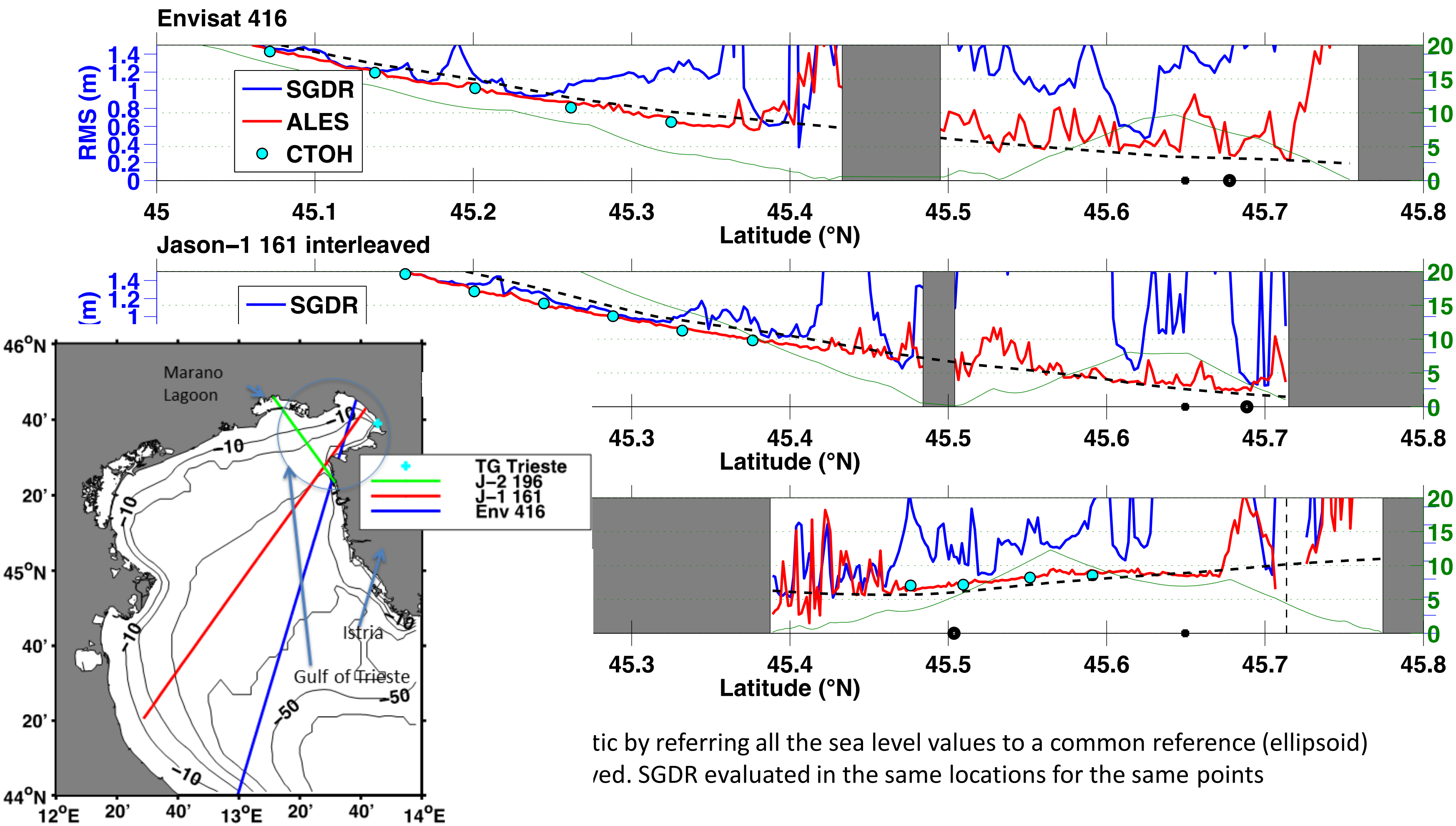
Validation at Trieste Tide Gauge

RMS difference between time series of (absolute!) Sea Level
between Altimetry and Tide Gauge



tic by referring all the sea level values to a common reference (ellipsoid)
ved. SGDR evaluated in the same locations for the same points

More validation, other improvements

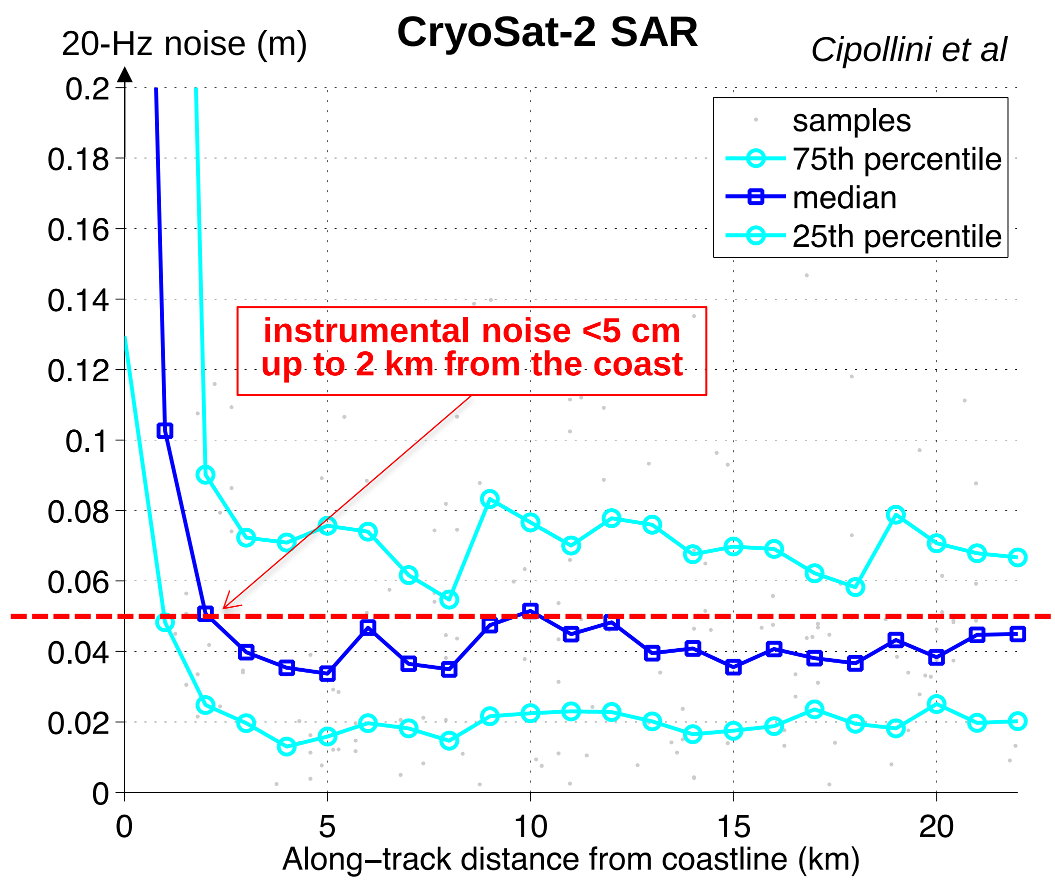
- Further validation of the ALES product:
  - South Africa for SSH (Passaro et al 2014)
  - German Bight for significant wave height (Passaro et al TGRS 2015)
  - Danish Straits for Seasonal Signals in SSH (Passaro et al JGR 2015)

- Some other recent developments in coastal altimetry:
  - **improved wet tropospheric correction** from GNSS path delay measurements and spaceborne Microwave Radiometers (GPD+ correction by J. Fernandes et al, Univ. Porto)
  - improvements in tidal models (FES2014, GOT4.8)
  - improvements in reference surfaces (CNES-CLS13 mean dyn topo, DTU15 mean sea surface)

SAR altimetry in the coastal zone

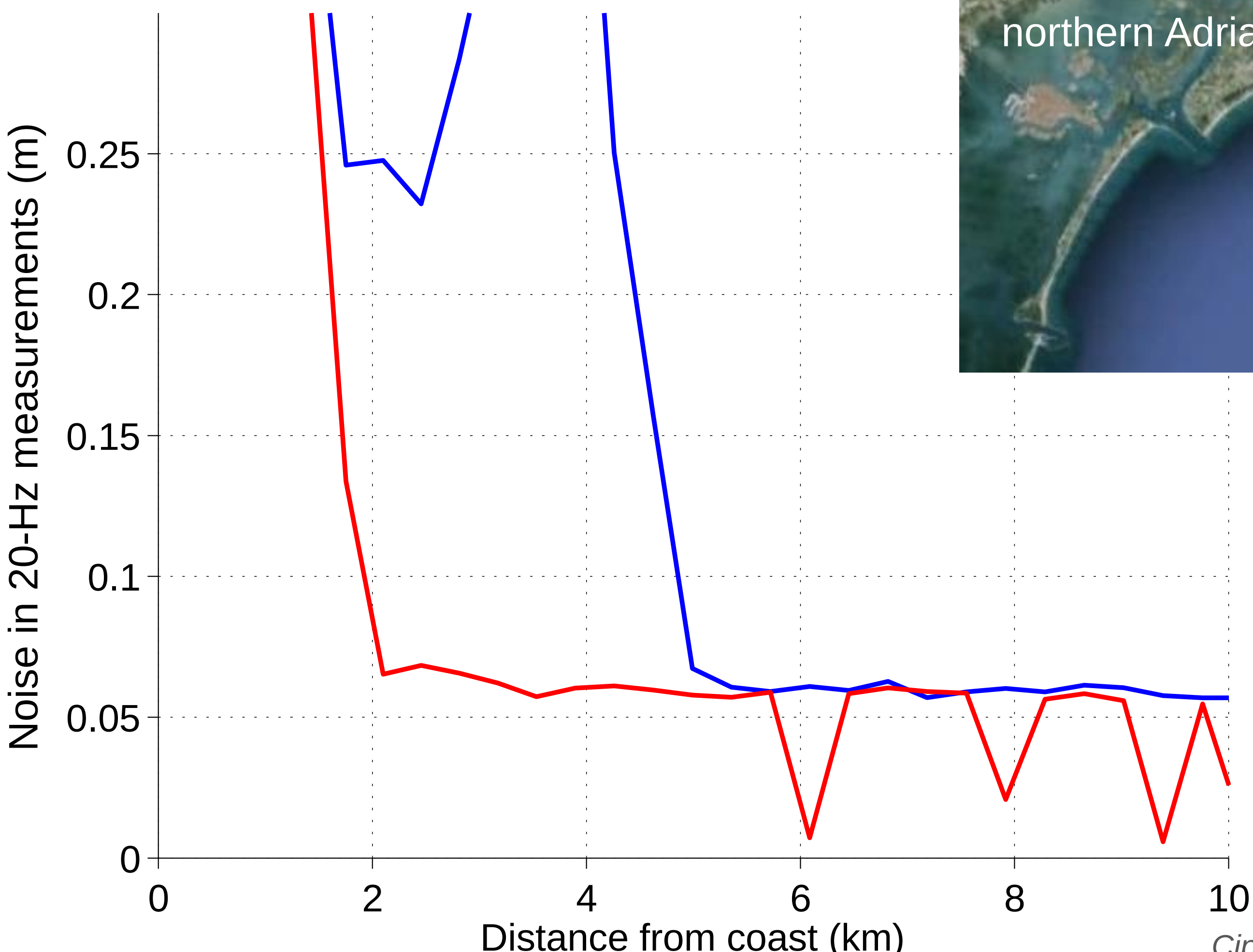
SAR altimetry is maturing

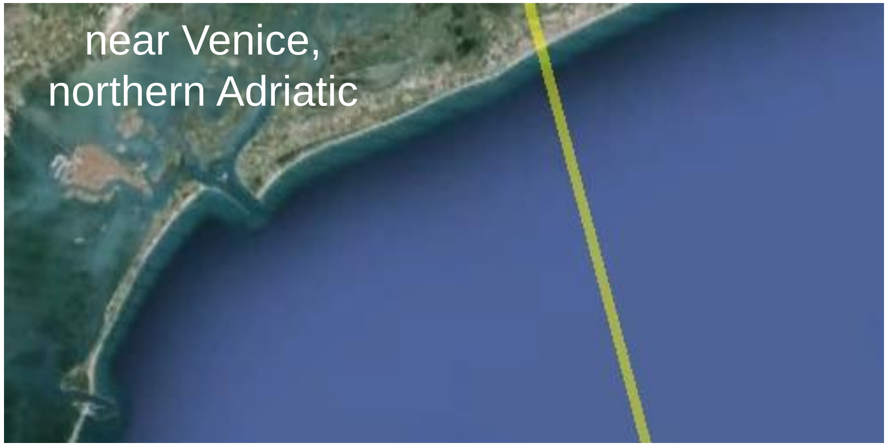
- particularly valuable in coastal zone (higher resolution, higher SNR, reduced impact of land/bright targets) **as clearly demonstrated by CryoSat-2**
- Will be **global (with all coasts) with Sentinel-3**



Data from “Brighton Box” (South UK) processed by GPOD @ ESRIN within ESA CP4O Poject

Adding SAR to Venice example





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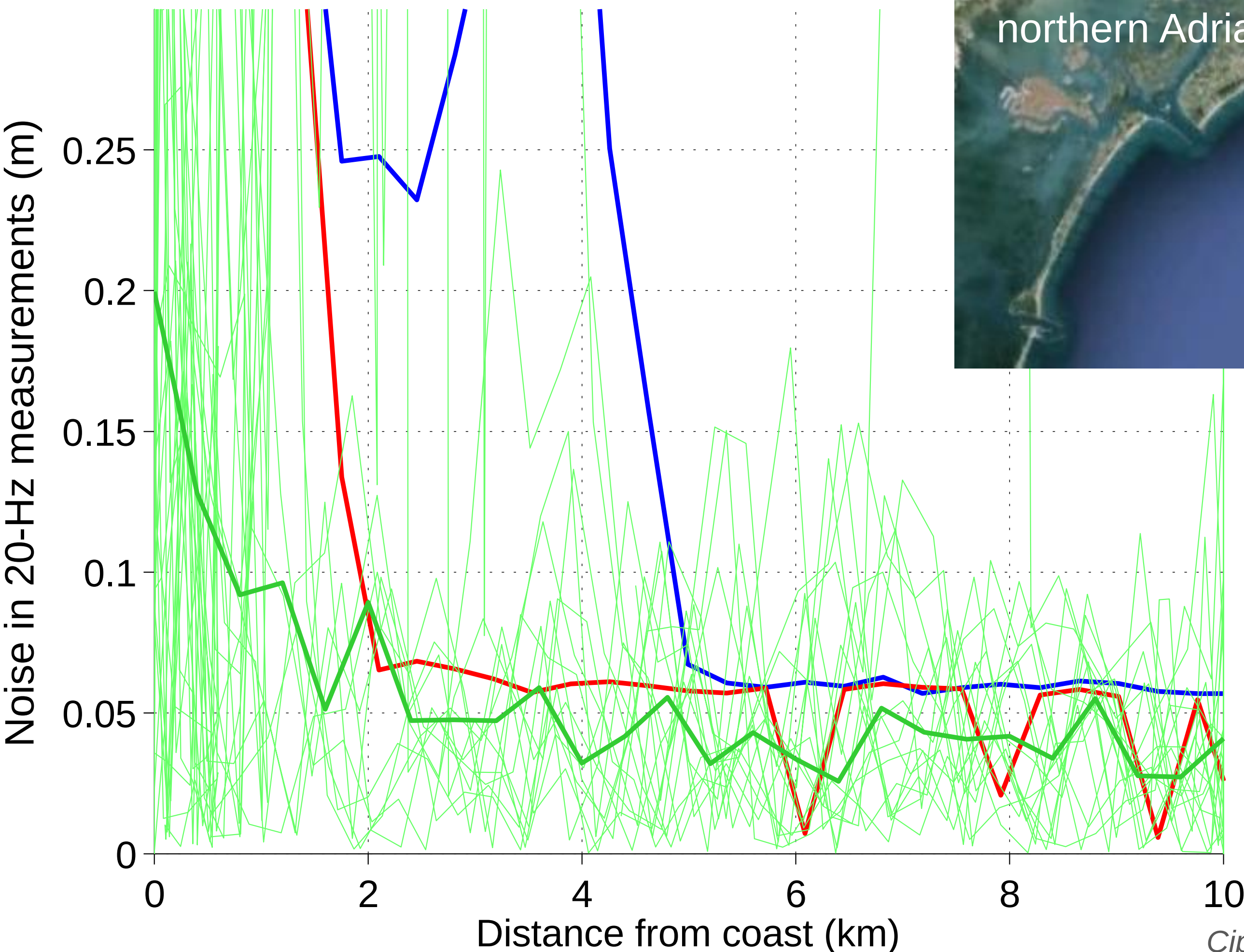


Envisat p0543 SGDR (median of 76 passes)

Envisat p0543 ALES (median of 76 passes)

CryoSat–2 SAMOSA (single passes)

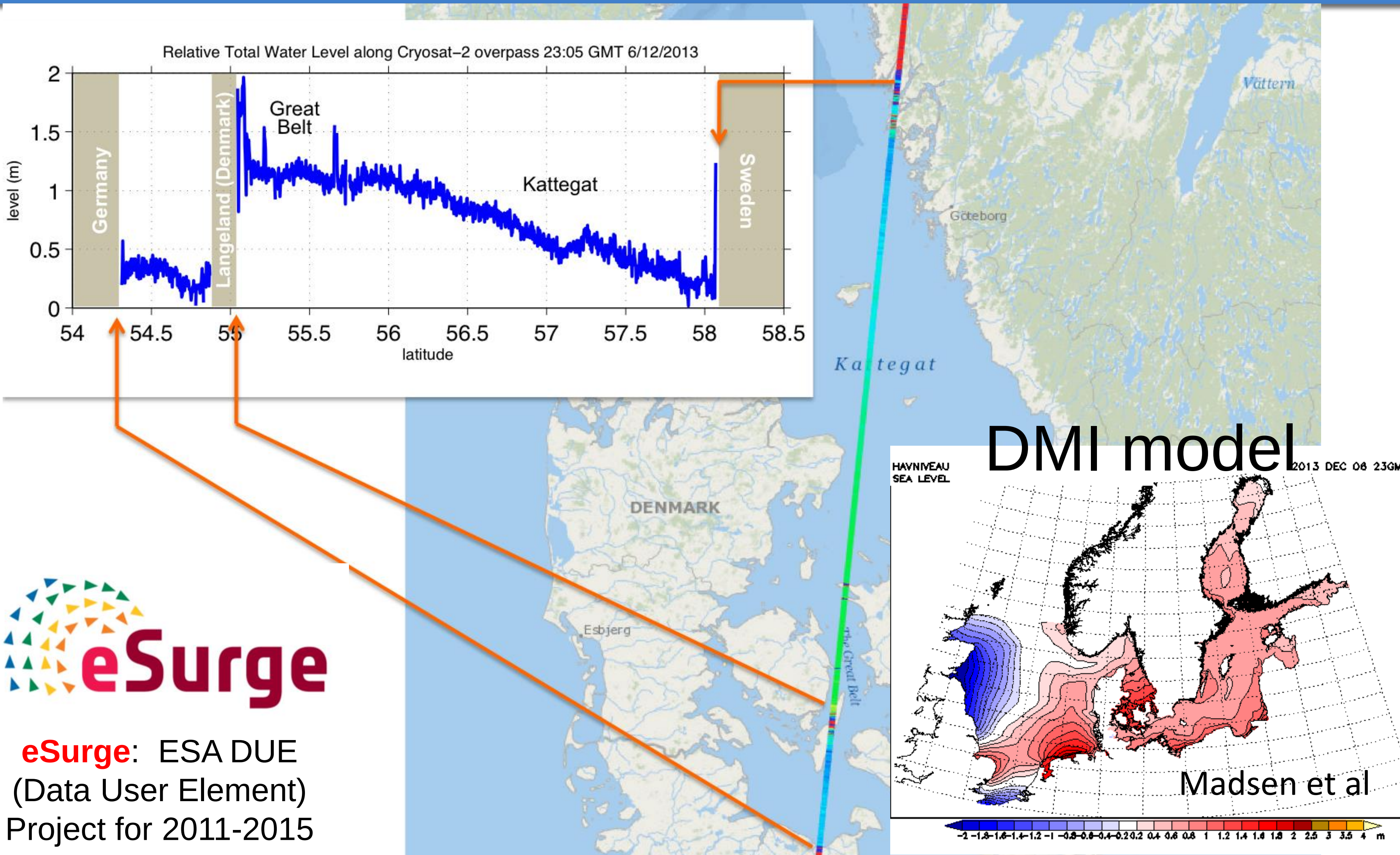
CryoSat–2 SAMOSA (median of 11 passes)

Cipollini, Passaro & Vignudelli, paper in prep.

Application example 1 : storm surges

Surge due to Hurricane Katrina,
29 August 2005

C2 SAR observations of Xaver storm surge - Dec2013



Friday 6 Dec 23:05 – data were available in NRT

eSurge

eSurge: ESA DUE (Data User Element) Project for 2011-2015

www.storm-surge.info

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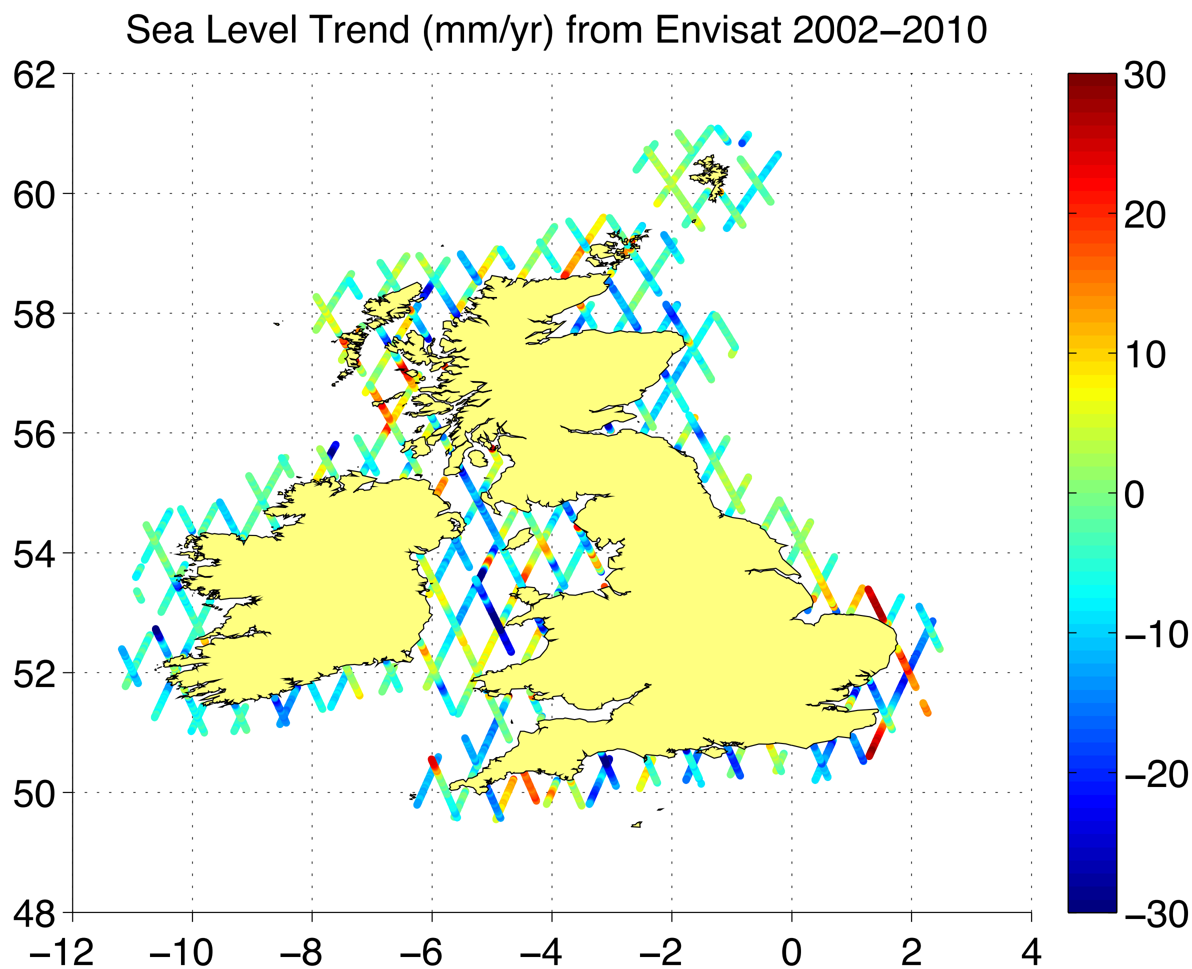
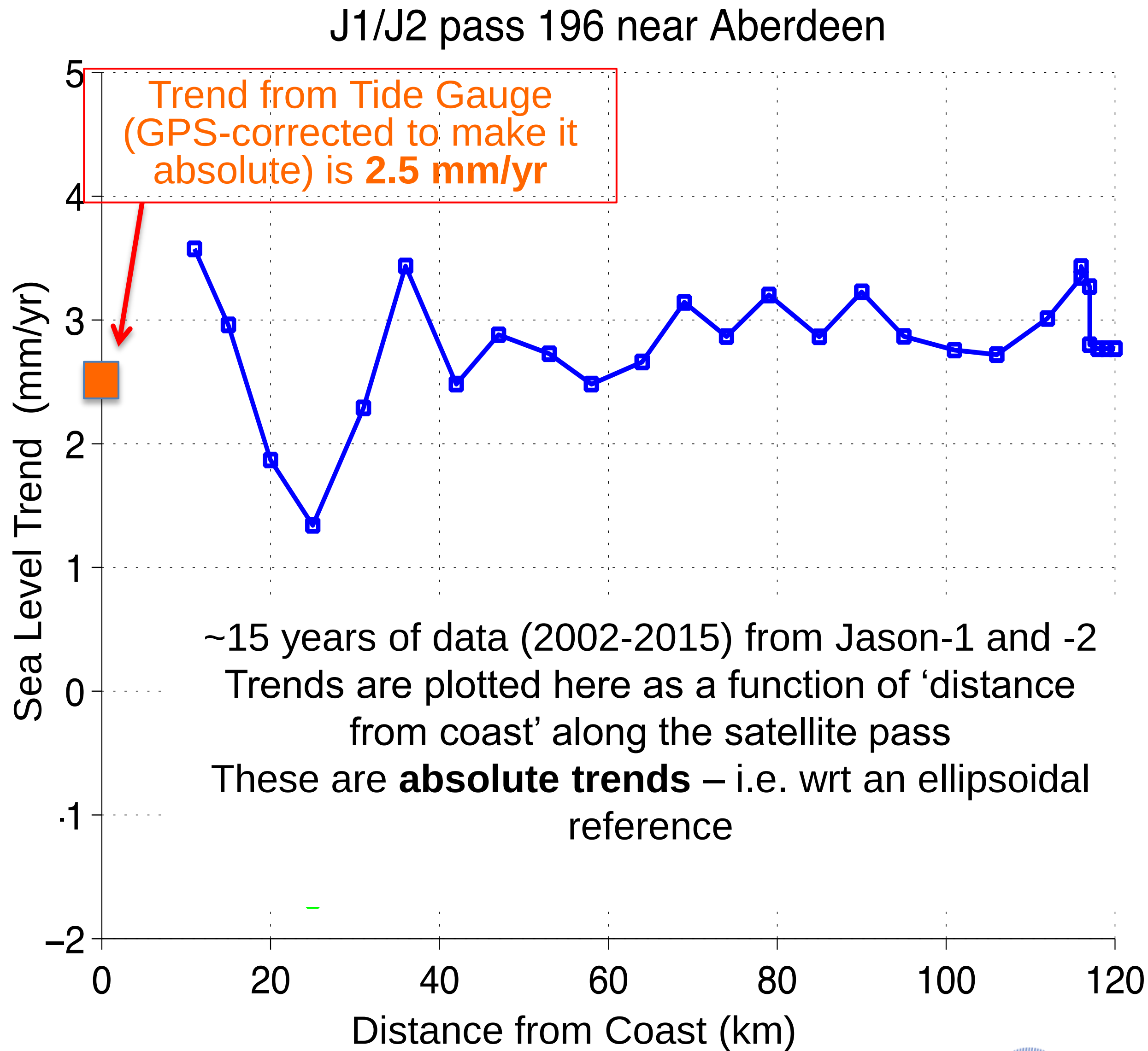
Application example 2 : coastal sea level

Trends around British Isles

Sea Level SpaceWatch pilot Project funded by UK Space Agency



Trends near Aberdeen Tide Gauge



~15 years of data (2002-2015) from Jason-1 and -2
Trends are plotted here as a function of 'distance from coast' along the satellite pass
These are **absolute trends** – i.e. wrt an ellipsoidal reference

Conclusions

- Coastal Altimetry has improved dramatically by virtue of both improvements in processing and corrections
- Further impetus is coming from the excellent SAR altimetry data, as demonstrated by CryoSat
- we can often get to 1-2 km from coast with no or very little degradation in perfomance
- validated data are now available (for instance from the ALES processor)
- application range from extremes (surges) to climate (sea level trends)

Stefano Vignudelli · Andrey Kostianoy · Paolo Cipollini
Jérôme Benveniste (Eds.)
Coastal Altimetry

Radar altimetry over the oceans represents a success story for satellite-based Earth Observation. However there is an important marine domain where altimetry has remained underexploited until recently: the coastal zone. Data in that region have been usually discarded due to problems with the altimeter radar echoes and to the lack of those corrections needed for an accurate estimation of sea level. Several scientists around the world have set out to fill this gap in knowledge and *push altimetry closer to the coast* by means of new/better corrections and dedicated reprocessing of the data. The importance of the new topic of Coastal Altimetry has now been recognised by the major space agencies like ESA and CNES. The last few years have seen the coalescence of a lively Coastal Altimetry Community, holding regular international workshops. This book summarises the promising advances in the topic, with the twofold aim to form a handy reference for the latest technical improvements and to present a number of case studies illustrating the value of altimetry data for coastal studies. The 20 chapters represent the work of a great number of research groups around the world, making the book an authoritative account of the state of the art in this novel topic.

Stefano Vignudelli is a researcher at the Consiglio Nazionale delle Ricerche in Pisa, Italy. His areas of expertise include satellite remote sensing of the marine environment, particularly the development of radar altimetry in the coastal zone through new methods for data processing, validation studies and oceanographic applications.

Andrey G. Kostianoy is a Chief Scientist at the P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, in Moscow, Russia. He is a specialist in physical oceanography. His research has focused on satellite monitoring, oceanography of coastal zones, regional climate change and environmental problems of the Black, Caspian and Aral seas.

Paolo Cipollini is a Senior Research Fellow at the National Oceanography Centre, Southampton, U.K. He is a specialist in satellite oceanography with focus on observations of planetary waves, satellite data processing and coastal altimetry. He is the manager of the ESA initiative for Coastal Altimetry research and development (COASTALT).

Jérôme Benveniste is a Senior Advisor at the European Space Agency, Esrin, Italy. He is a specialist in physical oceanography and applications of radar altimetry, developing new altimetry products, algorithms and validation. He has recently launched the ESA initiative for Coastal Altimetry research and development.

ISBN 978-3-642-12795-3

9 783642 127953

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