Satellite Altimetry – and recent advances towards the coast

Thanks to: Paolo Cipollini, Christine Gommenginger, Francisco Mir Calafat, Marcello Passaro, Helen Snaith

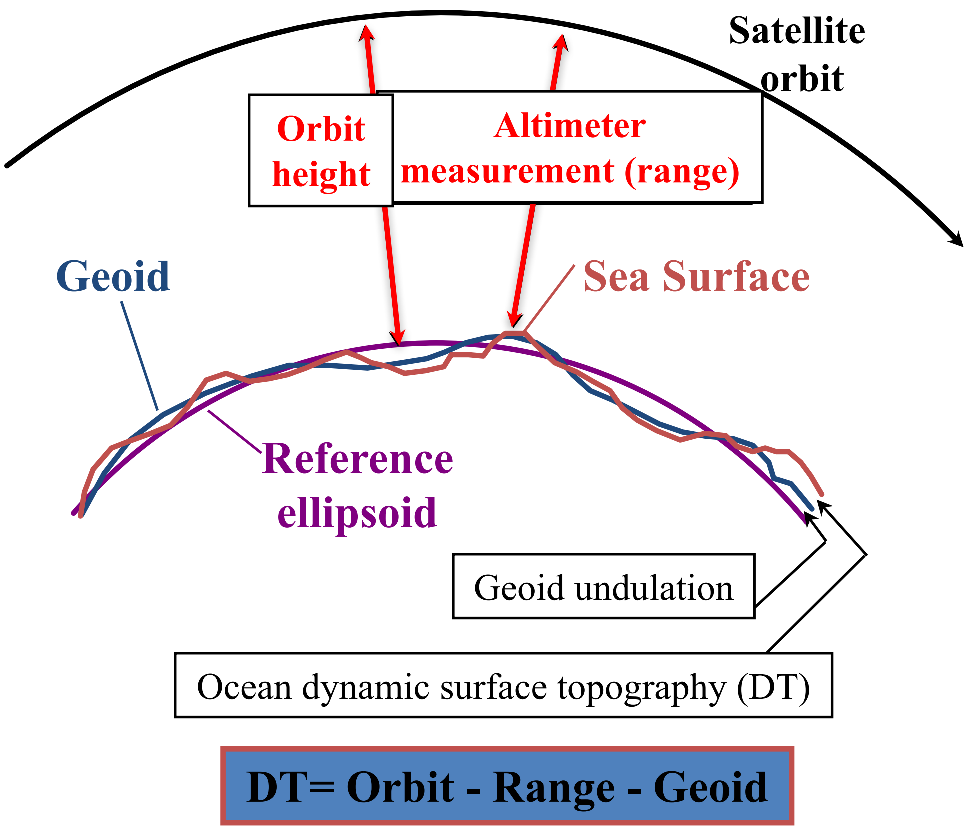
National Oceanography Centre

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

SATOC
SATELLITE OCEANOGRAPHIC CONSULTANTS

Basic Principles of Altimetry

- The altimeter is a radar at vertical incidence
- The signal returning to the satellite is from quasi-specular reflection
- Measure distance between satellite and sea (**range**)
- Determine position of satellite (precise **orbit**)
- Hence determine **height** of sea surface (absolute if **geoid** is known, otherwise relative)
- also measures **waves** and **wind**



“Retracking” of the radar waveforms

= fitting the radar echoes (waveforms) with a waveform model,
→ we estimate the three fundamental parameters

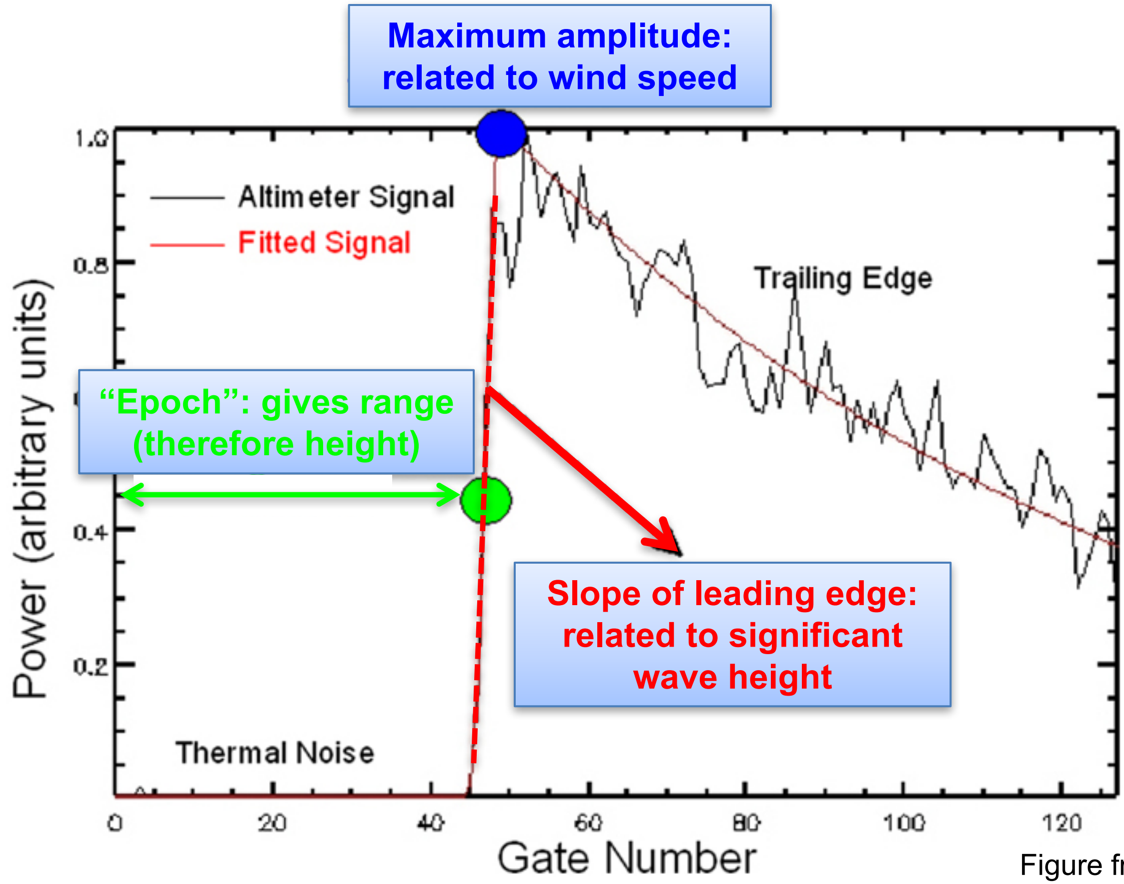
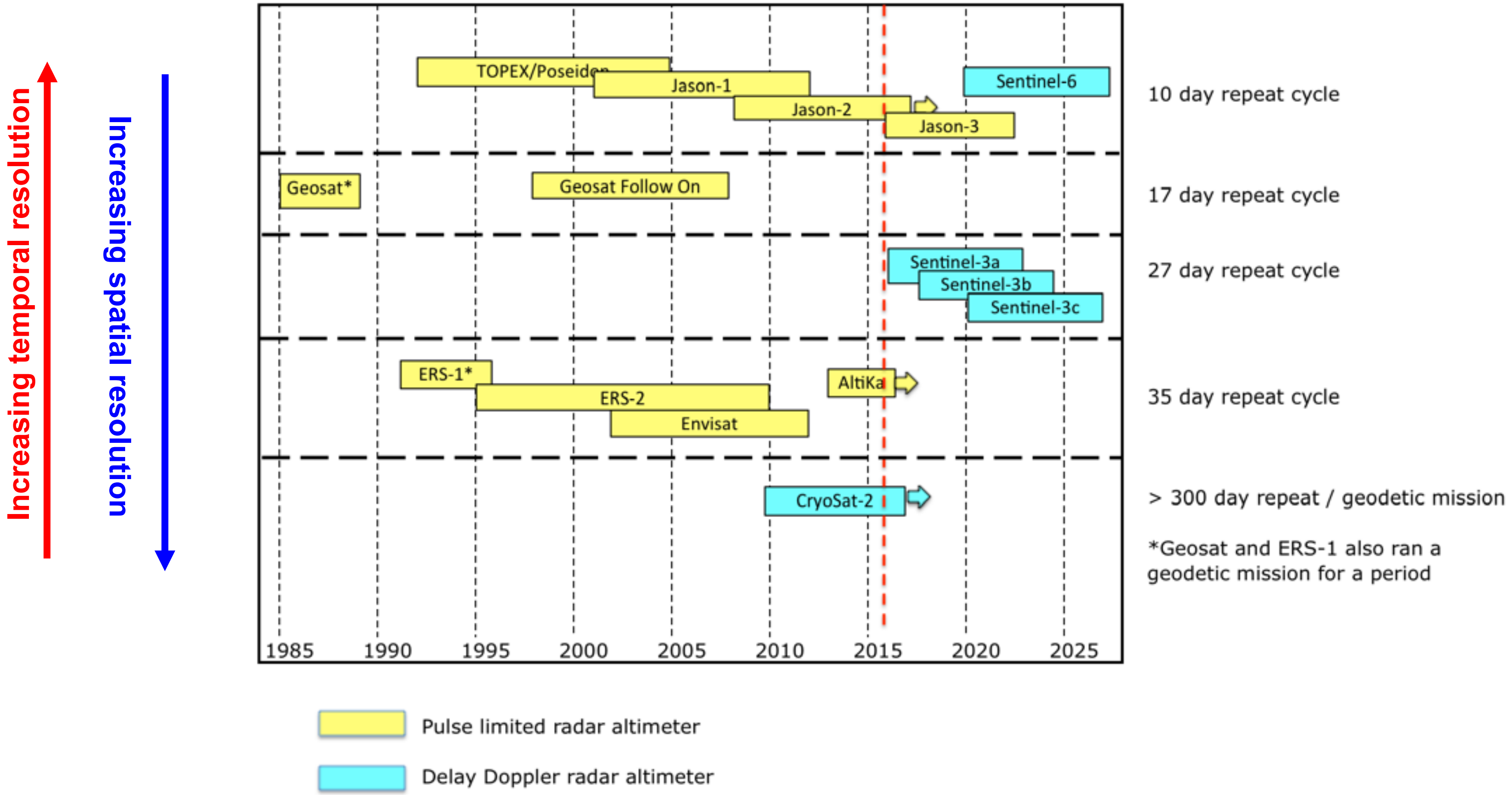


Figure from J Gomez-Enri et al. (2009)

Satellite Altimetry: a mature technique

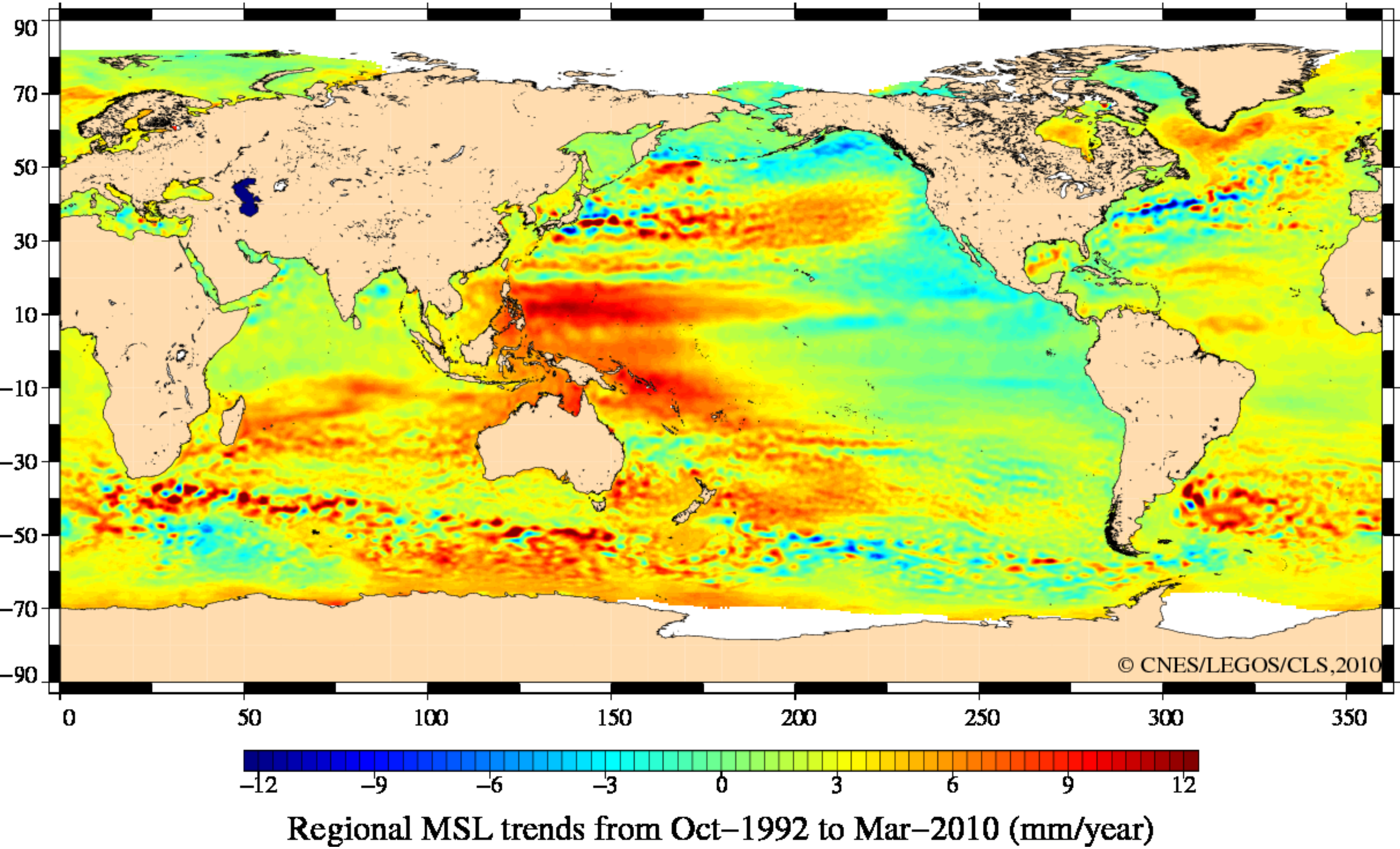
- workhorse of operational forecasting systems – extensively used
  - (but there are still research issues to be resolved for the assimilation)
- 25 years of good quality data
- use for climate studies (long-term **sea level rise**): ESA Climate Change Initiative
- precise (i.e. repeatable) and accurate (i.e. small biases)
- new impetus from recent technological advances:
  - **SAR altimetry from CryoSat-2 (2010–), Sentinel-3 A/B/C/D (2016-), Sentinel-6 (2018)**
  - **Ka-band altimetry from AltiKa (2013–)**

Satellite Altimeter Missions

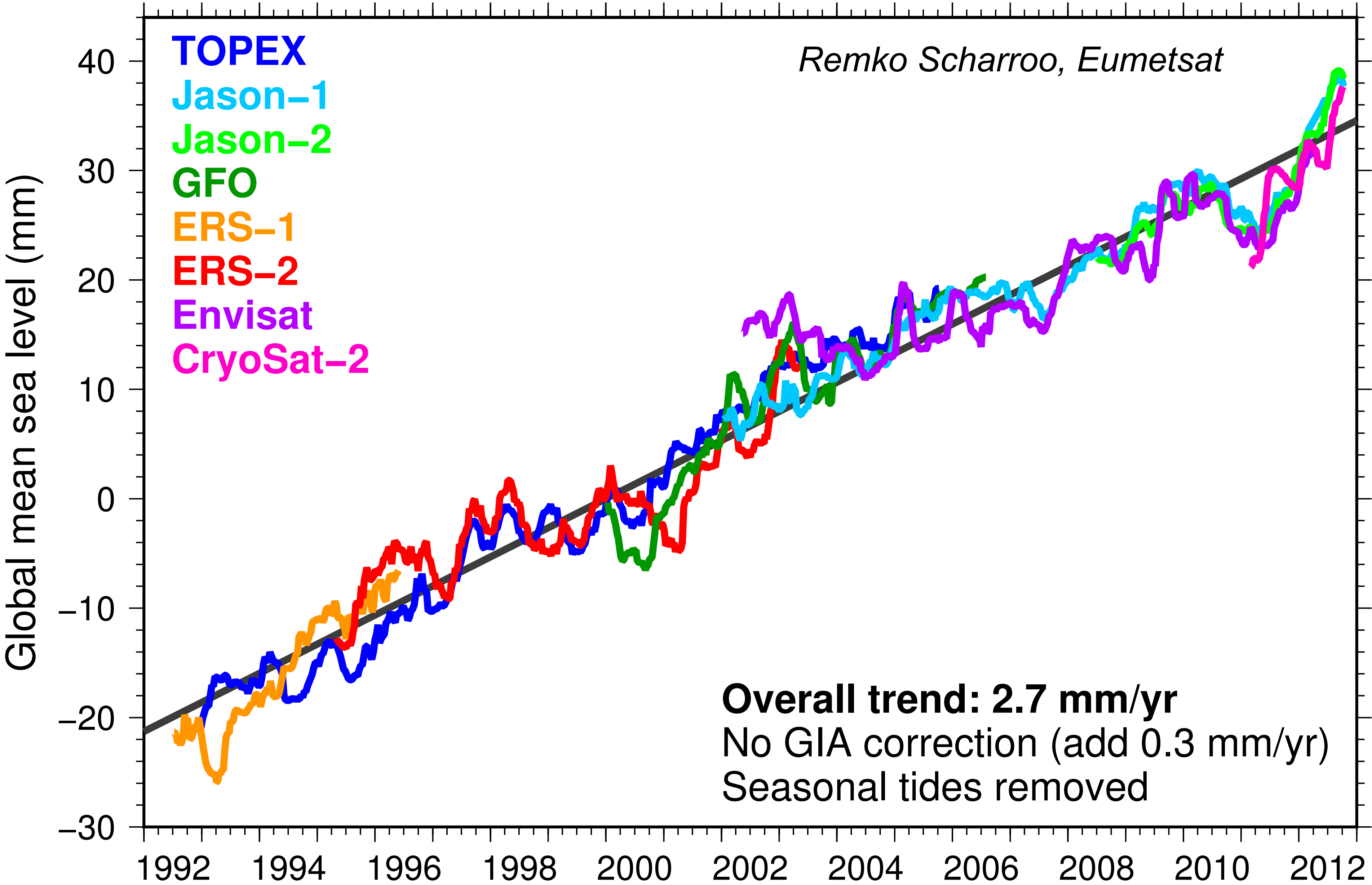


SEA LEVEL TRENDS - map

→ Sea Level component on dedicated ESA programme, the "Climate Change Initiative"

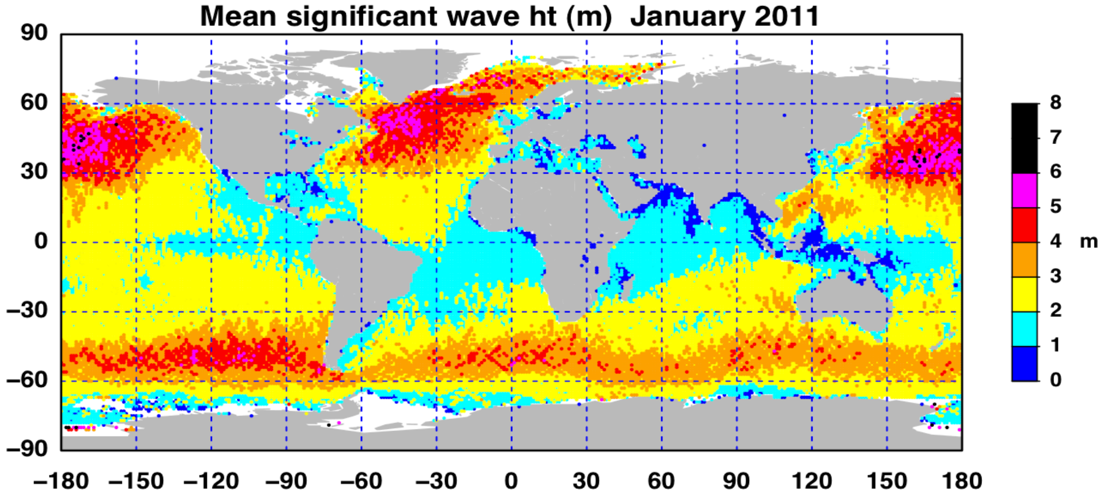


SEA LEVEL RISE - global

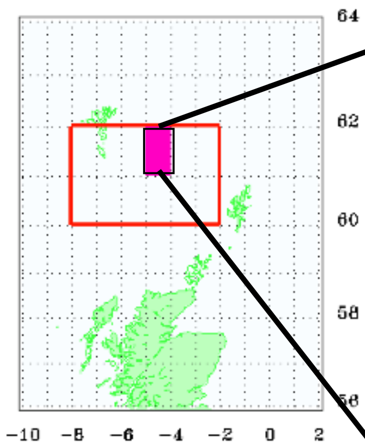


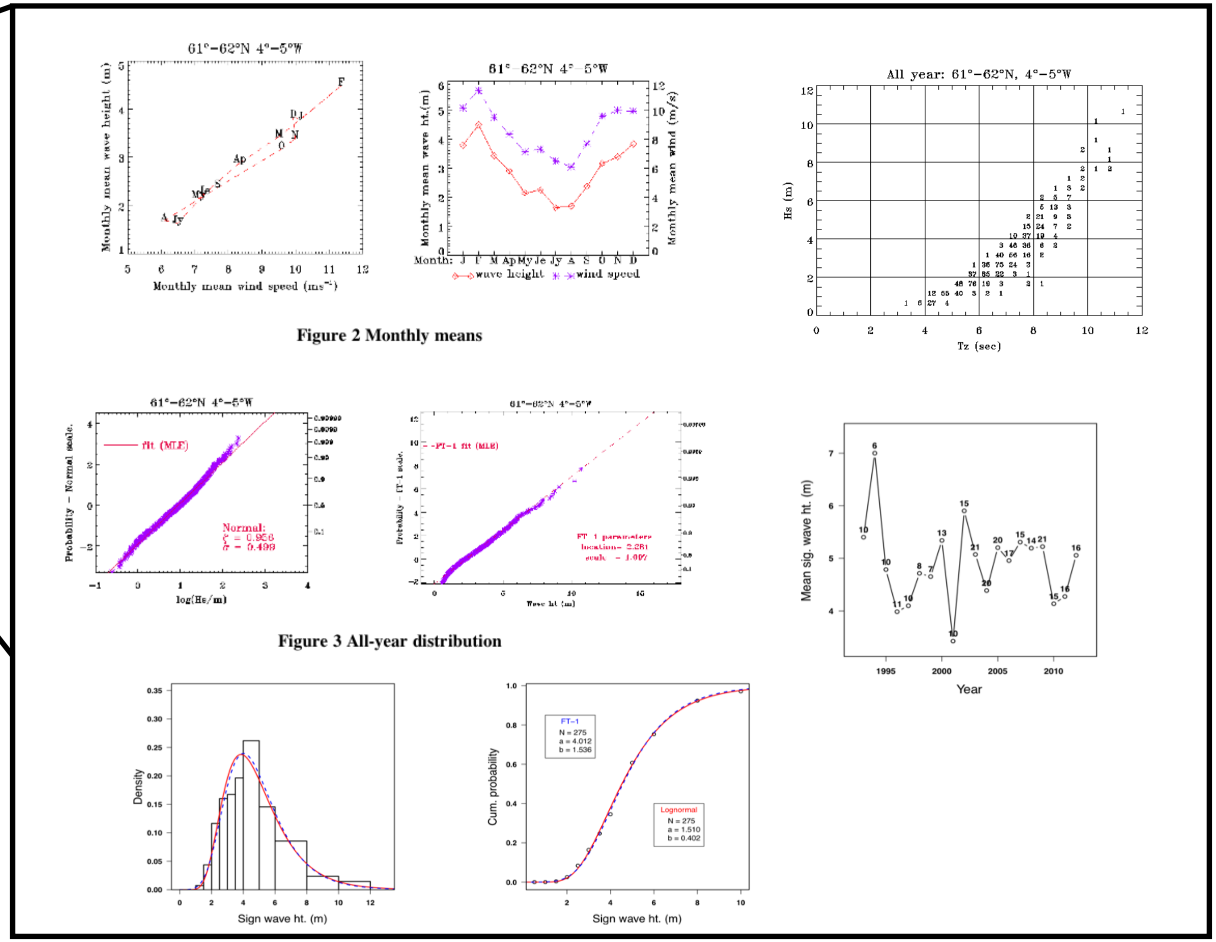
Wave Climatologies / Statistics

- Satellite provide true global coverage under all conditions
- Sufficient sampling to support monthly climatologies and statistical analyses
- For research (global and regional interannual variability & long term trends)
- For design and planning: extreme values, probabilities



Wave Climate Statistics Examples

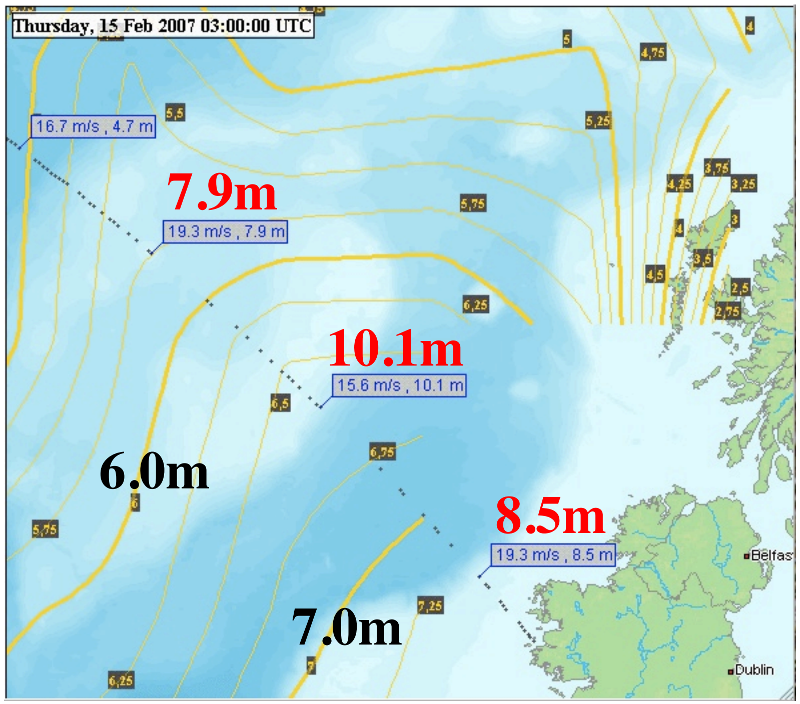




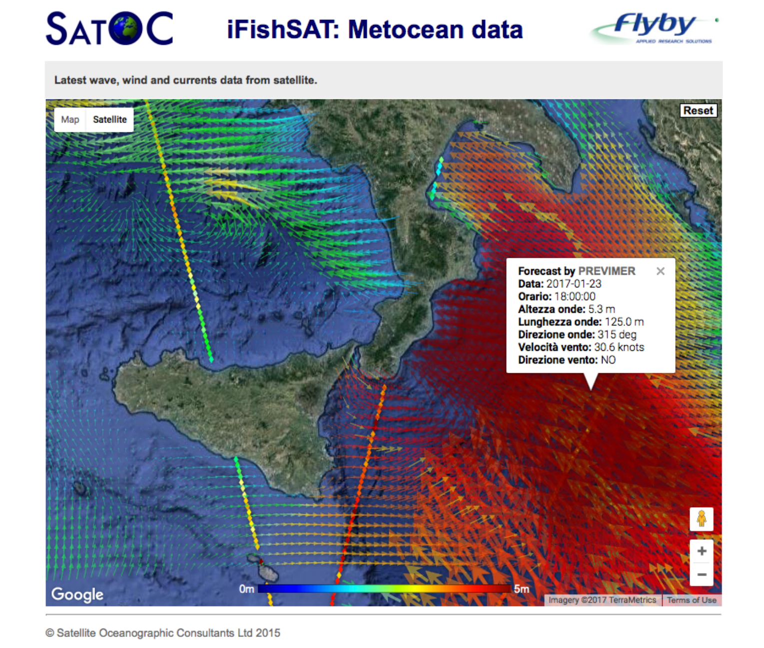
- Probabilities / return periods for extreme waves.
- Seasonal / inter-annual variability.
- Joint wave height / wave period, and wave height wind speed distributions / analyses.
- Needed for design: How high do I need to build my platform?
- For Operational Planning: What is the chance of experiencing sig wave height > 2m in October where I want to work?

Near Real Time Applications

- Real time altimeter data routinely assimilated into operational wave models, also used to add value in some specialist forecasts
- Target for Jason and Sentinel-3: 75% of Fast Delivery data should be available within 3 hours (and 95% within 5 hours)



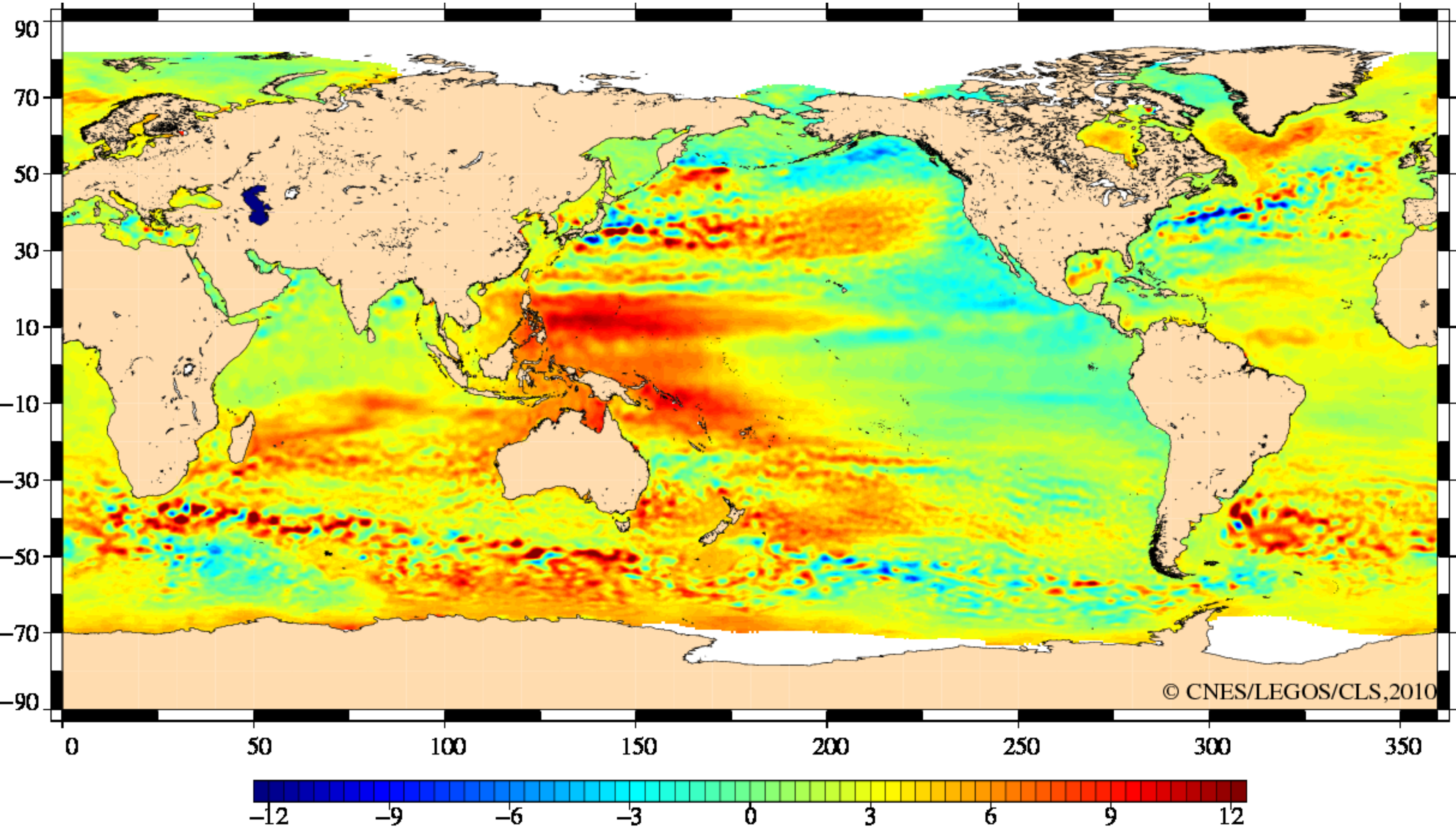
Jeppessen “Ocean View”: **Satellite altimeter data** and **wave model forecast**



iFishSAT – ESA project satellite wind/wave data and ocean wind/wave models

SEA LEVEL TRENDS - map

→ Sea Level component on dedicated ESA programme, the “Climate Change Initiative”



Regional MSL trends from Oct−1992 to Mar−2010 (mm/year)

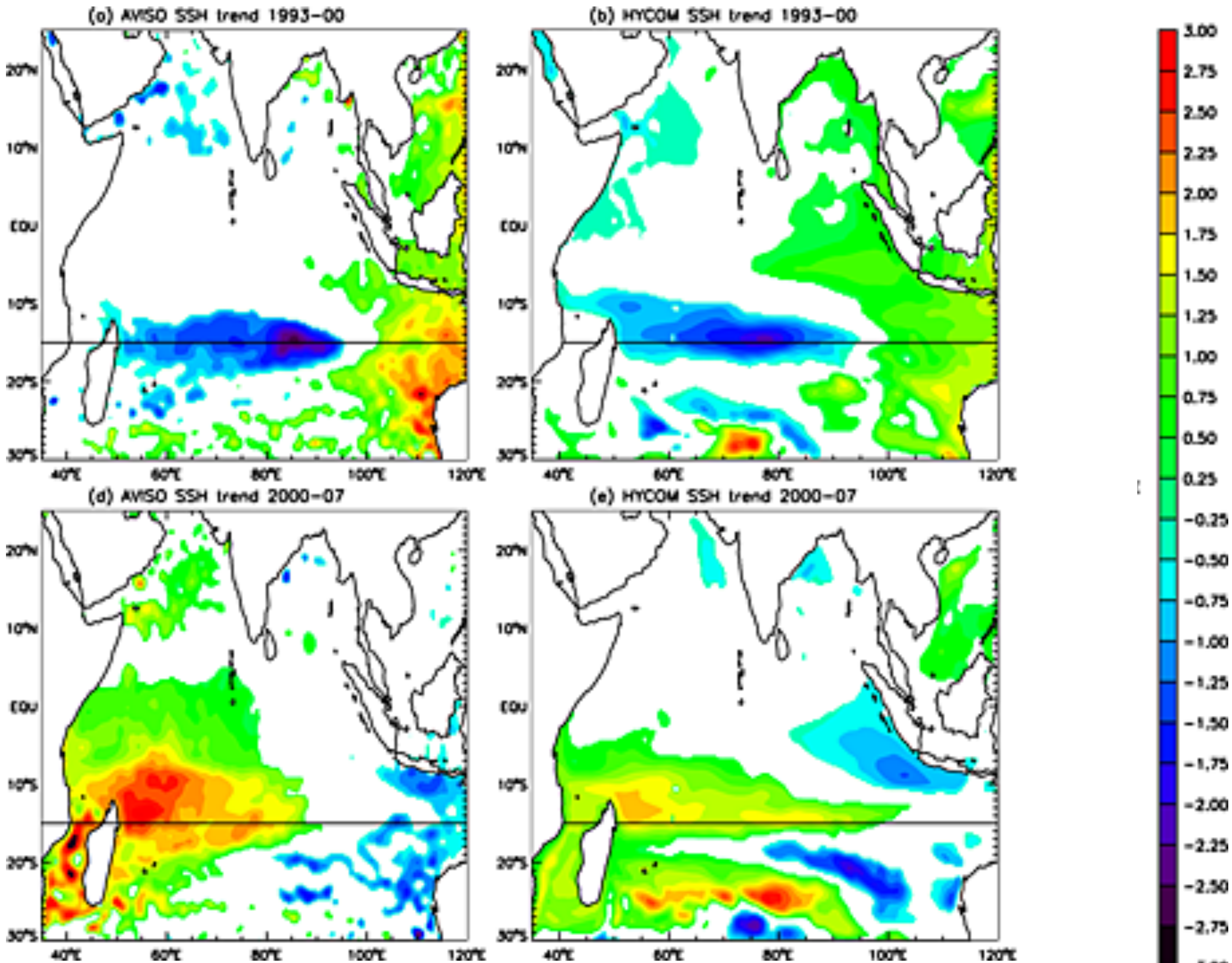
Regional Variability in SSH

SSH Trend

Satellite Altimeter | **Ocean Model (HYCOM)**

1993-2000

2000-2007

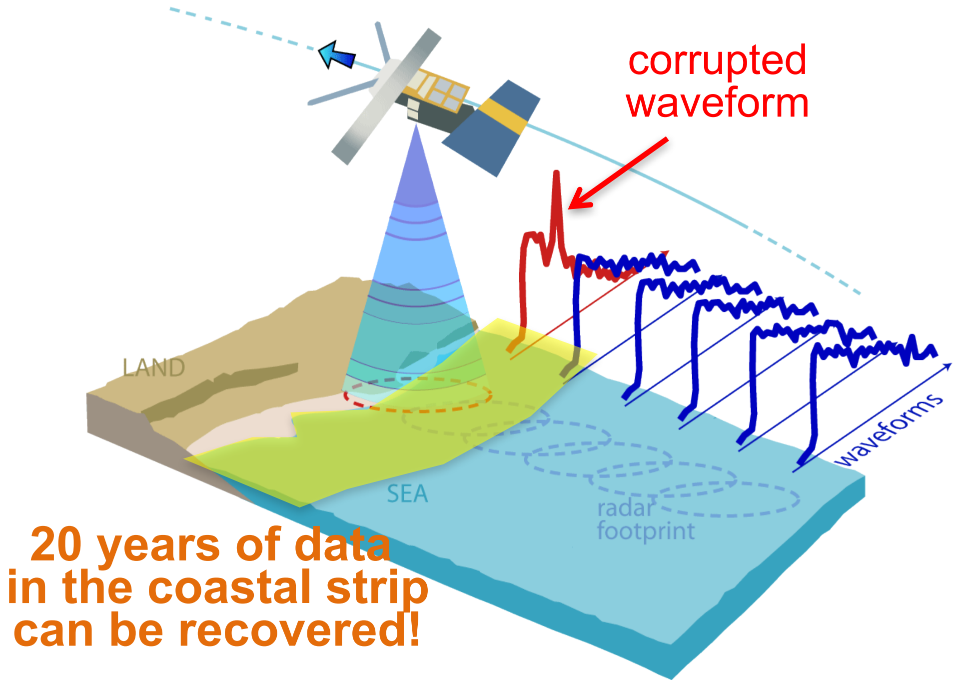


Journal of Geophysical Research: Oceans

Volume 118, Issue 1, pages 381-398, 31 JAN 2013 DOI: 10.1029/2012JC008317

http://onlinelibrary.wiley.com/doi/10.1029/2012JC008317/full#jgrc20035-fig-0005

The new frontier - coastal altimetry



Traditionally, data in the **coastal zone** are flagged as bad and left unused

(coastal zone: as a rule of thumb 0-50 km from coastline, but in practice, **any place where standard altimetry gets into trouble** as waveforms are non-Brown and/or corrections become inaccurate)

In recent years a vibrant community of researchers has started to believe that most of those coastal data can be recovered

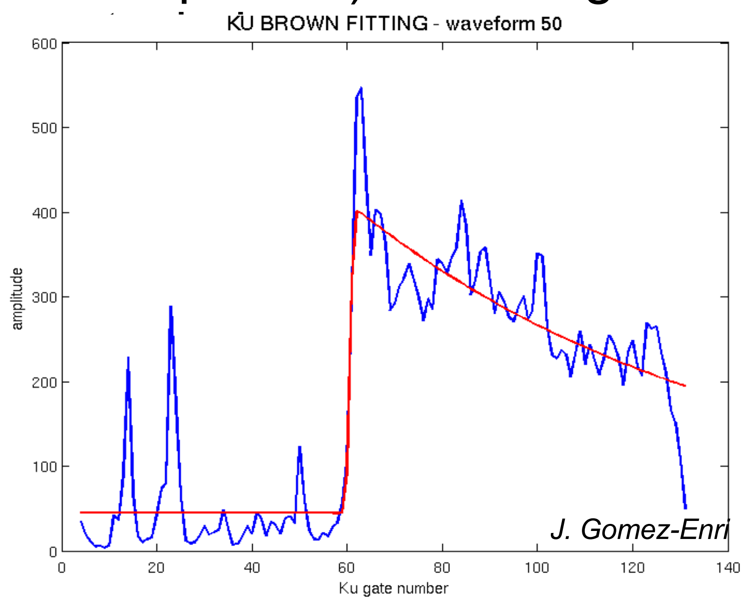
http://www.coastalt.eu/community

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

How we recover more data

0-10 km

A. Specialized **retracking**
   - Use better waveform models, accounting for change of shape in coastal environment
   - Use specialized (2-D or sequential) retracking



0-50 km

B. Improved **Corrections**
   - Most crucial is the correction of path delay due to **water vapour** (“wet tropospheric” correction)
   - Some applications require correction of **tidal** and **high-frequency** signals, which are also difficult to model in the coastal zone

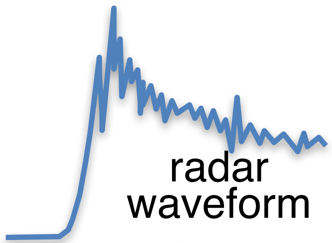
COASTALT

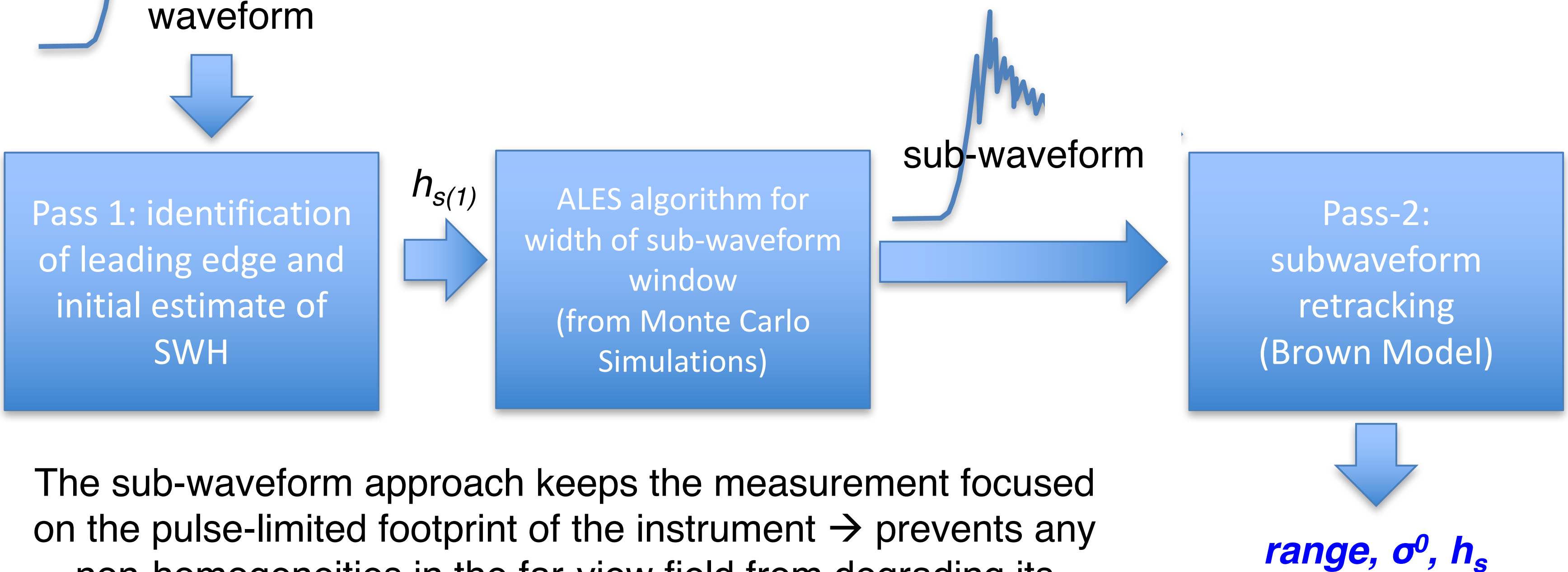
www.coastalt.eu

esa

NOC's ALES retracker

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





The sub-waveform approach keeps the measurement focused on the pulse-limited footprint of the instrument → prevents any non-homogeneities in the far-view field from degrading its accuracy.

→ very good for **coastal zone and fine scales**

Summary and conclusions

- Altimetry is a mature technique of proven value over the open ocean, and whose future is secured by a string of missions
- Recent improvements in processing technniques and corrections have opened up a number of applications in the coastal zone
- Support to R&D by Space Agencies has been instrumental for this advance, and remains crucial for the future
- Application to coastal monitoring

Application for C-RISe

To support applications in understanding and management of coastal risk

- Coastal Sea Level and wind/wave data (2000-2016)
  - Along track from NOC Coastal Altimeter processor
  - Validate against in-situ (Tide Gauge) data
  - Regional and inter-annual variability
- Gridded wind and wave climatologies (1985-2016)
  - ESA Globwave database (1° x 1°)
  - Statistical analyses
- Near Real Time wind and wave data
  - Along track – altimeter and scatterometer
  - + met-ocean model?