

#### A review of topical issues in SAR Altimetry

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National Oceanography Centre Natural environment research council





#### Rationale

- This workshop is a tangible proof of the capabilities of / impact of /efforts put into research on SAR altimetry over water surfaces
  - but not only some issues are common to other surfaces
- The excellent performance of CryoSat-2 has fuelled many recent studies

#### **Cryosat-2 the first SAR altimeter in orbit**

#### **ESA-funded studies:**

SAMOSA (2007–2011) – Waveform models, S-3 DPM CP4O (2012–2016) – science from LRM & SAR over open ocean/coasts SCOOP (2015–) – SAR mode exploitation over open ocean/coasts → includes a review of the state of the art in SAR-altimetry

## Inputs

- Starting point: SAR expert group meeting, NOC June 2013 (Gommenginger et al)
- OSTST & CAW 2013/14/15
- CP4O findings and final 'scientific roadmap'
- SAR mode literature



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EUMETSAT CALL-FOR-OFFER 205721

JASON-CS SAR MODE ERROR BUDGET STUDY REVIEW OF STATE OF KNOWLEDGE FOR SAR ALTIMETRY OVER OCEAN

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#### Two previous milestones

- 2013 review:
  - SAR Alt working well over ocean: low SSH/SWH; transitions
    SAR/LRM smooth; no 'bump' in spectra; better coastal data
  - Many waveform & retracking models: empirical, numerical, semi/analytical and fully-analytical (incl SAMOSA3 for S-3 DPM)
  - Strong "Interleaved mode" recommendation for Jason-CS
  - many remaining issues: sensitivity to mispointing; lack of SSB, effects of swell
  - discussion on some technical aspects was just starting at that time: windowing in azimuth, zero-padding, 'peeling' of the stack prior to multi-looking, etc
- CP40 scientific roadmap
  - Looked into SAR Processing Issues:
    - Properly sampling peaky waveforms; benefits of padding
    - Optimising Doppler processing / selection / weighting;
    - Purpose / optimisation of windowing
    - SAMOSA model implementation (PTR, Thermal noise)

SAR altimetry

#### Key Issues and Remaining Challenges





#### Stack issue 1: weighting

- in particular: how to weight outer doppler bins
- for optimal speckle rejection, the amplitude of those beams that are attenuated because of the viewing geometry must be weighted-up
  - CLS working on this in SCOOP
- the concept of a "weighting-up" of the outer doppler beams is also present in the AC/DC approach, see later



# Stack issue 2: exploiting the distribution of power in the stack

- use for mispointing (Moreau et al OSTST2014)
- use for pitch estimation (Scagliola et al GRSL 2015)
- mispointing also can be derived from stack in the AC/DC approach



# Stack issue 3: individual Doppler retracking

- proposed by Moreau et al at OSTST2015
- retrack each look in the stack separately, and then average their estimates
  - this way every look gives the same contribution to the noise reduction
- does not require Doppler beam weighting nor antenna pattern compensation
- being investigated in SCOOP

#### Computation on finer ground step

- Dinardo et al CAW2013, OSTST2015
  - 84Hz natural choice (burst repetition frequency)
  - datation time and geo-location information are provided at each burst center in the FBR products, so no interpolation required



Dinardo et al., OSTST2015

SAR altimetry

workshop



L1

# Full SAR focusing

- suggested by Raney (2014) at CAW-8, developed by Egido and Smith, first presented at OSTST2015, published in TGARS 2016
- resolution 0.5 m, noise close to theoretical limit of 0.5 cm @1Hz
- can potentially yield data with the maximum achievable signal-to-noise ratio
- two talks today: theory and applications

#### AC/DC

- Amplitude compensation/Dilation compensation
- Ray et al
  - OSTST2014
  - GRSL, 2015
  - potential noise reduction, by up to x2.5 for SSH and x4.0 for SWH, and a simplified re-tracking
  - see poster by Makhoul et al



workshop

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12

#### L1→L2 Improvements in SAMOSA models

- Reference for SAMOSA2 and SAMOSA3 formulations is Ray et al., 2015.
- comprehensive details on further improvements have been presented by several authors for instance Roca et al CAW/OSTST2013, Martin-Puig et al OSTST2014, Dinardo et al., IGARSS2015
  - DPM for Sentinel-3 in its latest version (2.5.0; Gommenginger et al, 2015;) is now adapted to any kind of SAR mode processing → planned for implementation in IPF in early 2017



#### **Coastal-specific retracking**



#### Improvement in Wet Tropo

• GPD+ (Univ. of Porto)

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- from Alt MWR, ~800 GNSS stations, 19 imaging MWR;
- calibrated wrt to SSM/I and SSM/IS;
- available globally for 9 missions (ERS 1/2, Envisat, GFO, T/P, J1, J2, CS2, SARAL)
- significant improvement in coastal and polar regions, significant impact on regional sea level trends.

Temporal evolution of weighted sea level anomaly (SLA) variance differences along-track (blue) and at crossovers (green) between GPD+ and ECMWF Op model over the period of CS2 sub-cycles 04 to 78 (RADS convention). "N. Xovers" represents the number of crossovers per sub-cycle. "Obs (%)" represents the percentage of points with available observations for the GPD+ WTC estimation.



#### ...and a remaining challenge

- SSB for SAR and effects of swell
  - does SAR altimetry require a specific SSB solution?
  - does swell induce a bias, and does it depend on direction?
- Results from an EUMETSAT study see talk later this morning

## Conclusions & Roadmap

- We are seeing enormous technical progress at all levels of processing
- Roadmap-1: include ameliorations at stack level, like weighting, ACDC...
- Roadmap–2: further explore fully-focused SAR, especially for coastal and inland water applications
- Sentinel-3 is about to enable many global applications (surges, sea ice, inland waters, assimilation into wave models)

