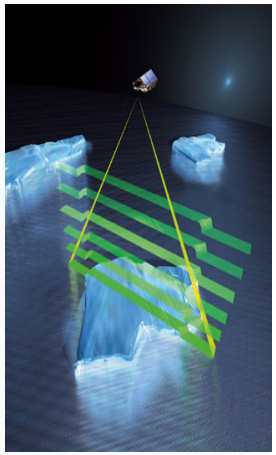


CryoSat-2 over Ocean

CP4O Team

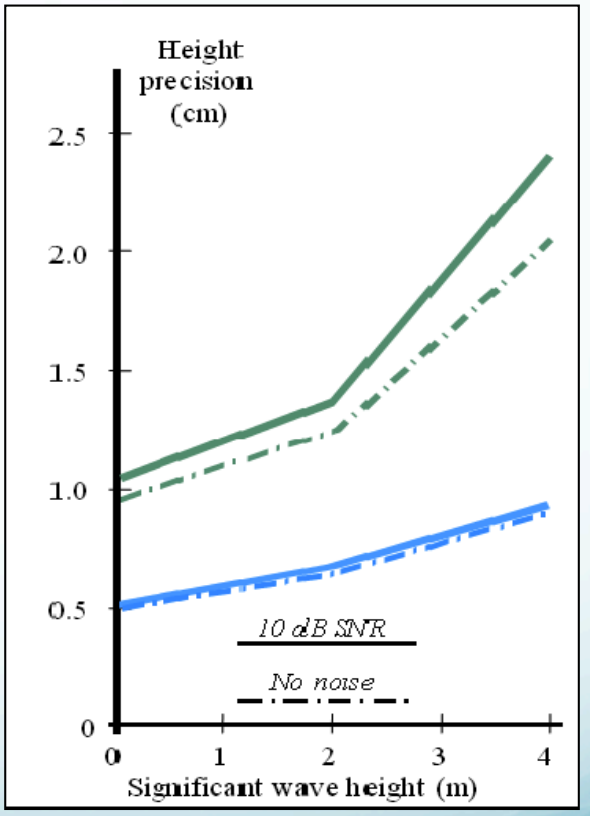
David Cotton, Marc Naeije, Maria-Paola Clarizia, Ole Andersen, Mathilde Cancet, Alejandro Egido, Joana Fernandes, Christine Gommenginger, Sylvie Labroue, Monica Roca, Jérôme Benveniste, Nicolas Picot, Salvatore Dinardo

d.cotton@satoc.eu

SAR Altimetry Expert Group Meeting, NOC, Southampton, 25-27 June 2013

SAR advantages

- More independent looks lead to improved retrieval precision
  - Two-fold improvement according to numerical studies by Jensen & Raney (1998)
- Finer spatial resolution along track
  - ~300 meters along-track
- Higher SNR
  - ~10 db more
- Better performance close to land
  - especially for track ~90° to coastline
- Less sensitivity to sea state



From: R.K. Raney 2005, 1st CryoSat User Workshop
(courtesy J.R. Jensen)

Challenges

- **Doppler Processing**
  - Waveform calibration, beam forming/stacking, range alignment/ compression, multi-looking
- **SAR Echo Model**
  - SAR echo is hybrid pulse limited and beam limited, new echo model needed
- **Continuity across modes and with previous missions**
  - Generating LRM like products from SAR mode data
- **How to process to resolve ocean features**
  - New processors
  - Improved corrections.

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SAMOSA Project

- Objectives -
  - Quantify range retrieval accuracy in pulse-limited and SAR mode as a function of significant wave height
    - Develop physically-based models for SAR altimeter ocean waveforms
    - Apply physically-based models to SAR ocean waveforms
      - Done for both simulated and real Cryosat SAR waveforms over ocean
  - Investigate method to reduce SAR mode data to pseudo-LRM (RDSAR)
  - Applications to ASIRAS (airborne SAR), analyses of SAR waveforms over inland water, coastal regions, ocean bottom topography,...

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SAMOSA3 model

- Simplification of SAMOSA2 but keeps its advanced features
  - fully-analytical, robust and computationally fast !

	SAMOSA1	SAMOSA2	SAMOSA3
Non-linear wave statistics	N	Y	N
Asymmetric antenna	N	Y	Y
Earth ellipticity effects	N	Y	Y
Across-track mispointing	N	Y	Y
Correct response to mispointing	N	Y	Y
Fully analytical	Y	N	Y
Computationally efficient	Y	N	Y

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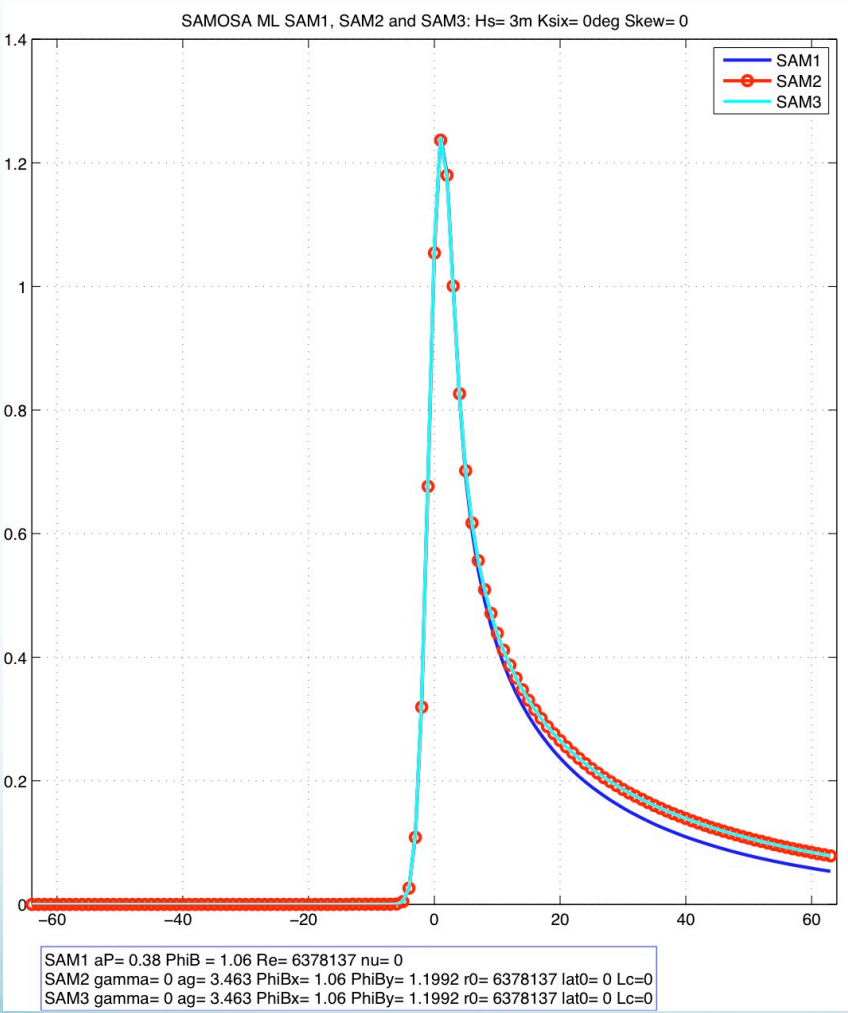
Comparing SAM1, SAM2 and SAM3



- With ASYMMETRIC antenna beam and Earth ellipticity effects included:
  - SAM3 and SAM2 are equivalent

Simplifying SAM2 has negligible effect

  - Marked difference between SAM2/SAM3 and SAM1 in trailing edge
    - symmetric antenna in SAM1

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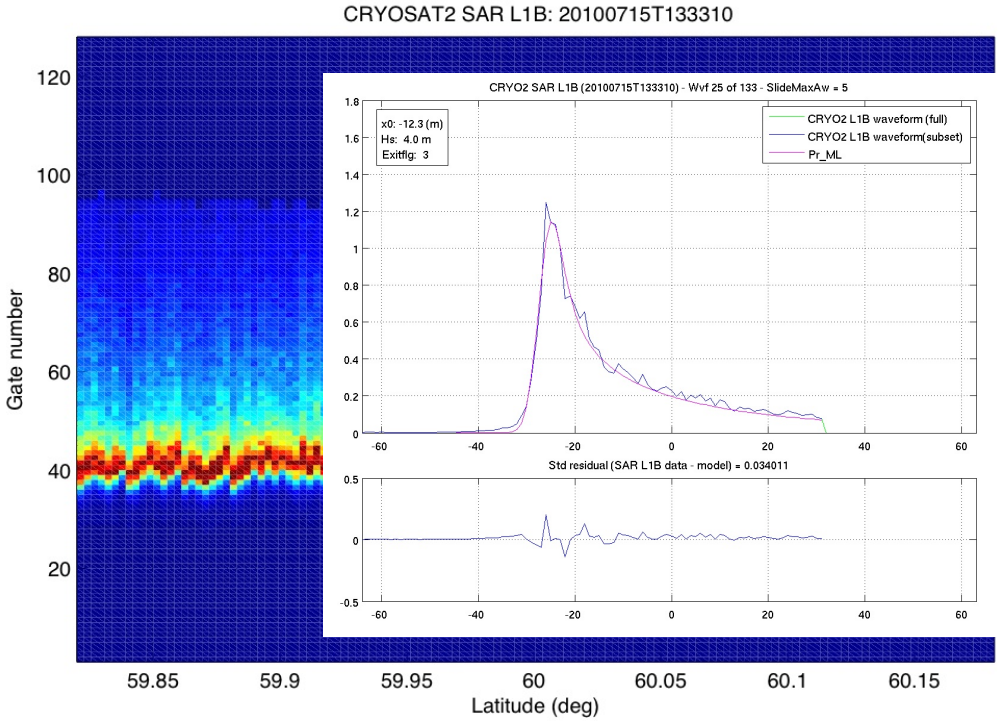
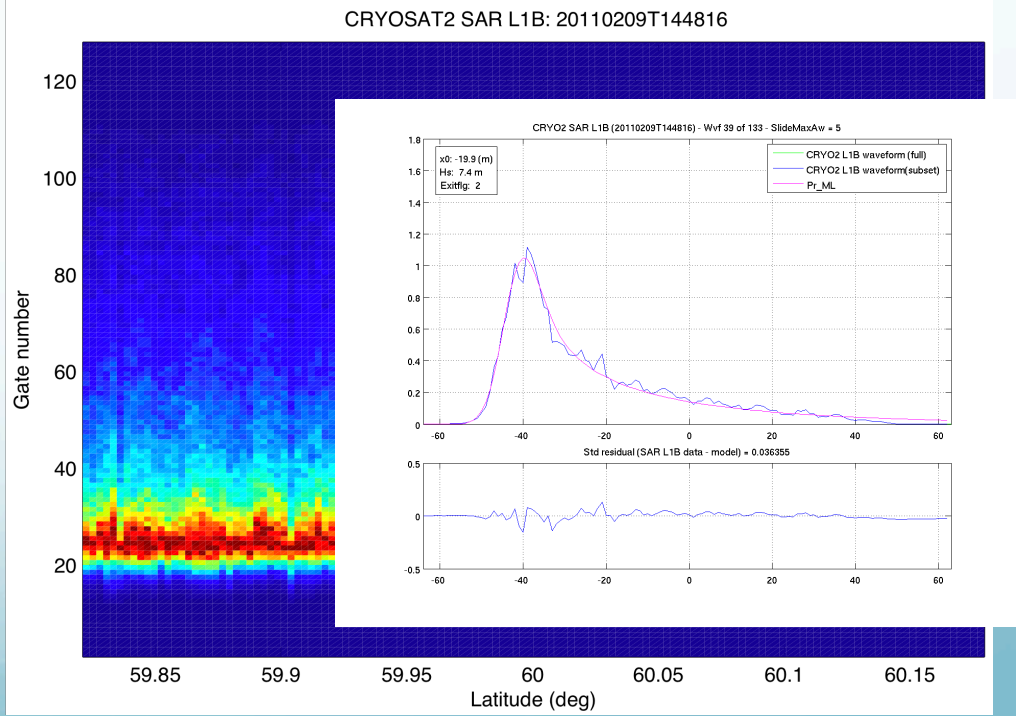
Cryosat-2 SAR in Norwegian Sea





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National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Norwegian Sea: SSH noise
(July 2010-June 2012)

NorwSea Mean stdeviation of 20Hz SSH over 6 seconds

Jason-2 L2 LRM
Cryosat-2 L1B SAR (Baseline A)
Cryosat-2 L1B SAR (Baseline B)

J2 LRM
C2 SAR

Mean std @20Hz SSH (m)

0.25
0.2
0.15
0.1
0.05
0

0
2
4
6
8
10
12
(m)

Cryosat-2 SAR (Hs < 2m)
SSH std 20Hz: 4.952 cm
1Hz: 1.107 cm

Jason-2 LRM (Hs < 2m)
SSH std 20Hz: 6.928 cm
1Hz: 1.549 cm

SA

2013

Summary & Conclusions

- Physically-based models of multi-looked SAR waveforms over the ocean have been developed in the SAMOSA project and used to retrack Cryosat-2 L1B SAR waveforms over the ocean
  - Excellent fit between theoretical SAMOSA models and Cryosat-2 SAR data over a wide range of conditions
- The latest SAMOSA3 model offers a fully-analytical, robust and computationally efficient formulation, able to capture essential aspects of SAR ocean altimeter waveforms
  - E.g. asymmetric antenna beam and across-track mispointing
- SAMOSA3 recommended for the Detailed Processing Model for Sentinel-3 STM SAR ocean operational retracking

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CryoSat Plus for Oceans (CP4O)

Two Year project supported by the ESA Support to Science Element programme and CNES

Objectives:

- Build a sound scientific basis for new applications of CryoSat-2 data over the *open ocean*, *polar ocean*, *coastal seas* and for *sea-floor mapping*.
- Generate and evaluate new methods and products that will enable the full exploitation of the capabilities of the CryoSat-2 SIRAL altimeter, and extend their application beyond the initial mission objectives.
- Ensure that the scientific return of the CryoSat-2 mission is maximised. Preparation for Sentinel-3, Jason C-S

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CP4O Sub-Themes – Science Objectives

Open Ocean

- **Low Rate Mode**: Accuracy /continuity with previous and concurrent missions
- **SAR Mode:** RDSAR processing, New SAR re-tracking schemes

Coastal Ocean

- **SAR Mode:** Fine scale coastal features / minimise land contamination
- **SARIN Mode:** Discriminate/mitigate contamination from off-nadir land targets

Polar Ocean

- **LRM, SAR and RDSAR**:
- Processing schemes applicable to sea-ice affected regions
- Improvements to mean sea surface, mean dynamic topography, polar ocean circulation, polar tide models

Sea Floor

- **SAR Mode:** Ability to map uncharted sea-mounts / features

Geophysical Corrections

- Ionosphere, wet troposphere, regional tide models

State of the Art

- **Known issues with ESA Cryosat-2 products (Baseline A and B).**
  - Need to resolve mispointing, time tag, tracking point issues
  - Effect of truncation of waveform trailing edge in Baseline B
    - Does it change sensitivity of retrieved SSH to mispointing?
    - impact on coastal applications (mitigate land signals) ?
  - Some addressed in new FD Marine Product, and to be addressed in "Baseline C" – expected early 2014.

- **Other Issues**
  - Is there an effect of long waves, wave direction on SAR SSH and SWH ?
  - Spreading of the SAR leading edge (in baseline B) impacts C2 SAR retrieval accuracy
  - Sea State Bias model for SAR waveform re-tracking

CP4O Data Sets Coverage

		Initial Development and Validation	Large scale assessment
1	**LRM** for **Open Ocean**	Global (RADS & CLS)	
2	**RDSAR** for **Open Ocean**	NE Atlantic / Pacific	Global?
3	**SAR** for **Open Ocean**	NE Atlantic / Pacific	Global?
4	**SAR** for **Coastal Ocean**	South Coast UK	Gulf of Cadiz, North-West Mediterranean & German Bight
5	**SARIn** for **Coastal Ocean**	Cuba, Chilean Coast	N/A
6	**SAR** for **Polar Ocean**	Arctic (initially Baffin Bay)	
7	**SAR** for **Sea Floor** Mapping	North Pacific	
8	Improved **wet trop correction**	Global, full C2 mission	
9	Improved **iono correction**	Mediterannean Sea, European continental shelf	
10	Improved **regional tides**	North East Atlantic (coastal)	
11	**Other** improved **corrections**	Global (RADS)	