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.
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,...
**SAMOSA3 model**

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

<table>
<thead>
<tr>
<th>Feature</th>
<th>SAMOSA1</th>
<th>SAMOSA2</th>
<th>SAMOSA3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-linear wave statistics</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Asymmetric antenna</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Earth ellipticity effects</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Across-track mispointing</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Correct response to mispointing</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Fully analytical</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Computationally efficient</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
</tbody>
</table>
Comparing SAM1, SAM2 and SAM3

- With **ASYMMETRIC** antenna beam and Earth ellipticity effects included:
  - SAM3 and SAM2 are equivalent
  - Marked difference between SAM2/SAM3 and SAM1 in trailing edge

Simplifying SAM2 has negligible effect

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

SAR Altimetry Expert Group Meeting, NOC, Southampton, 25-27 June 2013
Cryosat-2 SAR in Norwegian Sea
Norwegian Sea: SSH noise
(July 2010-June 2012)

SSH std 20Hz: 4.952 cm
1Hz: 1.107 cm

SSH std 20Hz: 6.928 cm
1Hz: 1.549 cm
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
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
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
## CP40 Data Sets Coverage

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