Overview of the near-real time wave products of the CFOSAT mission

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Overview

► The CFOSAT mission
► The SWIM instrument
► The NRT wave products
The CFOSAT mission

- CFOSAT: an innovative China/France mission for oceanography
- Joint measurements of oceanic wind and waves
  - **SWIM**: a wave scatterometer (new instrument)
  - **SCAT**: a wind scatterometer (fan beam concept)

This mission is a “world première”

- SWIM, new spaceborne instrument with technological innovations (rotating antenna, on-board digital processing)
- SCAT, new concept of wind scatterometer
- Access to 2D wave spectrum with high angular resolution and with global scale
- Joint measurements of winds and waves
The CFOSAT mission

► CFOSAT is:
  - a scientific mission for public services (Meteorology agencies, research centers, marine agencies, etc.)
  - a demonstration and pre-operational mission (for Météo France, EUMETSAT, CEPMMT, etc.)

► CFOSAT adds:
  - a new component to spatial oceanography systems
  - assimilation of CFOSAT data in meteorological models
  - possible integration of CFOSAT wave measures in GMES/MyOcean, GlobWave.
Key dates

2006
► Signature of the Memorandum Of Understanding CFOSAT

2007-2008
► Phase A CFOSAT
  Feasibility demonstration

2009-2010
► Phase B CFOSAT
  Preliminary design

2011-2014
► Phases C/D CFOSAT
  Detailed design
  Manufacturing of flight model and qualification models

2015
► Operational system in orbit
  Launch from China (end of 2014)
A China/France cooperation

**Principal Investigators**
- D. Hauser – CNRS/LATMOS
- Liu Jianqiang - NSOAS

**CFOSAT system – science & data**

- **Launch / campaign**
  - Platform
    - CNSA/DFH
  - SCAT
    - CNSA/CAS (CSSAR)
  - X-band TM
    - CNSA/CNES

- **Satellite**
  - SWIM
    - CNES
    - Contract: Thales Alenia Space

- **Satellite control**
  - Stations
    - CNSA
  - Control center
    - CNSA
  - Network
    - CNSA
  - Operations
    - CNSA

- **Operations / Mission**
  - X-band stations
    - CNSA/NSOAS
  - Chinese mission center
    - CHOFS
    - CNSA/NSOAS
  - Polar X-band stations
    - CNES
    - Contract: SSC
  - French mission center
    - FROGS
    - CNES/IFREMER
Scientific requirements

► Mission

- Minimum duration of 3 years
- Global coverage over the oceans (polar orbit)
- Data available in near-real time

► SWIM

Directional wave spectra from incidences 6° to 10°
- To be measured in the wavelength range 70m-500m
- With a 10% accuracy on wavelength, 15° accuracy on wave propagation direction
- With a 15% accuracy on spectral level around the peak of the spectrum

Significant wave height and wind speed from nadir
- 10% on SWH (or 50 cm whichever is better)
- rms <2 m/s on wind speed

Normalized radar cross-section form 0° to 10°
- Absolute accuracy of ±1 dB
- Relative accuracy between incidences ± 0.1 dB

► SCAT

Wind vector
- Wind speed range and precision: 2m/s or 10% (larger) @5~24m/s
- Wind direction precision: 20°

Backscattering coefficient precision: 0.5dB

Surface resolution
- 50km (standard product)
- 25km (experimental product)
Two scientific payloads

| SWIM: Surface Waves Investigation and Monitoring |
| SCAT: wind SCATterometer |

**SCAT**

Wind SCATterometer

Real aperture radar in Ku-band
- Fan beam concept
- Incidence angles (on ground): 20°-65°

- Antenna size: 1.2mx0.4m
- Alternate polarization: HH-VV
- Rotation speed: 3.2 rpm
- Power: 120 W
- Useful bandwidth: 0.5 MHz
Payloads

Two scientific payloads

**SWIM:** Surface Waves Investigation and Monitoring

**SCAT:** wind SCATterometer

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**SWIM**

Surface Waves Investigation and Monitoring

Real aperture radar in Ku-band

6 incidence angles: 0°, 2°, 4°, 6°, 8° et 10°

- Antenna diameter: 90 cm (~2° aperture)
- Polarization VV
- Rotation speed: 5.7 rpm

- Power: 120 W
- Useful bandwidth: 320MHz
- Pulse duration: 50 µs
- PRF: 2 - 7 kHz
Overview

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Two scientific payloads

**SWIM:** Surface Waves Investigation and Monitoring

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**SWIM**

**Surface Waves Investigation and Monitoring**

Real aperture radar in Ku-band

- 6 incidence angles: 0°, 2°, 4°, 6°, 8° et 10°

Antenna diameter: 90 cm (~2° aperture)

Polarization VV

Rotation speed: 5.7 rpm

Power: 120 W

Useful bandwidth: 320MHz

Pulse duration: 50 µs

PRF: 2 - 7 kHz
Modulation depends only on waves around 8° of incidence
- Use of incidence beams 6°, 8° and 10°
- Directional wave spectrum using 360° scans

Measurement of the backscattering coefficient $\sigma^0$ in all incidence angles (from nadir to 10°) with high resolution

Measurement of SWH from nadir echo

Radar cross-section from TRMM PR
SWIM concept

- **SWIM**
  - Ku-band
  - 6 beams with sequential illuminations
  - Bandwidth = 320 MHz
  - $P_e = 120$ W

5.7 rpm

$H \approx 519$ km

Incidences: $0^\circ$-$2^\circ$-$4^\circ$-$6^\circ$-$8^\circ$-$10^\circ$

Antenna aperture: $\sim 2^\circ \times 2^\circ$

$18 \times 18$ km

519 km

88 km

$N_{imp}$ pulses per cycle
SWIM concept

**SWIM**

**Ku-band**
6 beams with sequential illuminations
Bandwidth = 320 MHz
$P_e = 120$ W

Macro-cycle: ~210 ms

Nadir:
PRF = 2124 Hz
Nimp = 110
Tcycle = 51 ms
Same concepts of range tracking as conventional altimetry
Overview

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► The NRT wave products
Système

Waves & Wind Mission Center
Brest
Differed time product (L2S, L3, L4)

Instruments Mission Center
Toulouse
NRT Products (L1&2)

Control center and S-band network
Xi’an

Utilisateurs
Overview of SWIM products

Level 0: raw data (backscattered power versus range) @ 0, 2, 4, 6, 8, 10°

Nadir products (0°)
- NRT CWWIC (CNES)
  - L2a
    - Hs, Wind speed + ice and land parameters (TBD)
  - L1b
    - Modulation spectrum

Wave products (6°, 8°, 10°)
- NRT CWWIC (CNES)
  - L2a/L2b/L2c
    - Directional wave spectra + parameters of wave partitions
- Differed time IWWOC (IFREMER)
  - L2S
    - Alternative signal analysis + extrapolated wave properties along propagation path

σ° products (0°, 2°, 4°, 6°, 8°, 10°)
- NRT CWWIC (CNES)
  - L1a
    - Calibrated and geocoded waveforms
  - L2a
    - σ0 mean profiles versus incidence and azimuth
Overview of SWIM products

Level 0: raw data (backscattered power versus range) @ 0, 2, 4, 6, 8, 10°

Nadir products (0°)

NRT
CWWIC (CNES)

L2a
Hs, Wind speed
+ ice and land parameters (TBD)
Nadir products (2/2)

**Level 1b:**
Calibrated nadir waveform

**Level 2a:**
- SWH (Significant Wave Height)
- WS (Wind speed)
- SIGMA0 (at nadir)
Wave products (1/3)

Level 0: raw data (backscattered power versus range) @ 0, 2, 4, 6, 8, 10°

Wave products (6°, 8°, 10°)

NRT
CWWIC (CNES)

L1b
Modulation spectrum

L2b/L2c
Directional wave spectra + parameters of wave partitions
Wave products (2/3)

**Level 1a: calibrated wave form**

- Mean trend suppression
- Ground projection

**Level 1b: modulation spectrum**

- Speckle correction + averaging in k
- Repeated for all azimuths
- 2D Modulation spectrum (for each incidence angle)

**Modulation spectrum** $P_m(k)$

**Spectral density**

**Wavenumber** $k$
WAVE PRODUCTS (3/3)

Level 1b: modulation spectrum

Level 2a: wave spectra (for each incidence angle)

Level 2b: 2D wave spectra at scale of 70x90 km² (merging 6°, 8°, 10° spectra)

Level 2c: partitioning and geophysical parameters

2D Modulation spectrum (for each incidence angle)
Level 0: raw data (backscattered power versus range) @ 0, 2, 4, 6, 8, 10°

\[ \sigma^0 \text{ products (1/2)} \]

\[ \sigma^0 \text{ products (0°, 2°, 4°, 6°, 8°, 10°)} \]

NRT CWWIC (CNES)

L1a
Calibrated and geocoded waveforms

L2a
\(\sigma^0\) mean profiles versus incidence and azimuth
σ₀ products (2/2)

Level 0: non calibrated wave form, per cycle

Level 1a: Calibrated wave form, geocoded

Level 2a: Normalized radar cross-section profiles
From 0° to 11° (per azimuth view angle) at a scale of 70 x 90 km and associated radiometric accuracy

- σ₀ estimate from radar equation
- Geometry
- Ground projection

Repeated for all azimuths and combining incidence
## Available data

<table>
<thead>
<tr>
<th>File name</th>
<th>Content</th>
<th>Availability rate (TBC)</th>
<th>Size per day</th>
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</thead>
<tbody>
<tr>
<td>SWI_L1A___</td>
<td>Level 1a data: calibrated waveform in radar geometry with geo-location</td>
<td>15 files per day</td>
<td>22.6 Go</td>
</tr>
<tr>
<td>SWI_L1ALG___</td>
<td>Level 1a data in speckle mode</td>
<td>1 file per day</td>
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<tr>
<td>SWI_L1B___</td>
<td>Level 1b data: modulation spectrum from the 6°, 8° and 10° beams</td>
<td>15 files per day</td>
<td>43.4 Go</td>
</tr>
<tr>
<td>SWI_L2______</td>
<td>Level 2 data: wave spectra per incidence beam, combined wave spectra per 70x90 km² cells, partitions of sea states and associated geophysical parameters, nadir SWH and WS, backscattering profiles.</td>
<td>15 files per jour</td>
<td>3.4 Go</td>
</tr>
<tr>
<td>SWI_NRT______</td>
<td>NRT file for meteorological services: wave spectra, nadir SWH and WS, backscattering profiles.</td>
<td>15 files per jour</td>
<td>8.1 Go</td>
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Available on web site (AVISO ?) registration required

Available on meteorological network (TBC)
CFOSAT China France Oceanography Satellite:
China/France cooperation on oceanography
Two scientific payloads: SCAT (wind) and SWIM (wave)

CFOSAT products:
Vectorial wave product
Co-located wind vectors

Planning:
Operational mission in 2015