Status of *other* altimetry missions

J. Lambin, CNES
with the help of many!
Altimetry constellation need

- One « high accuracy » reference mission
  - TOPEX, Jason series => to be continued by Jason-CS?

- One at least (ideally 3 for operational applications) complementing altimetry missions (GFO, ENVISAT...)

- Up to now, each mission considered, then decided and implemented independantly
  - Error budget specified for one mission
  - Most users use data from several satellites intercalibrated through multi-mission products
  - OSTST has a key role in decisions that concern one satellite but impacts the whole altimetric system
    - Jason-1-Jason-2 formation flying phase
    - GFO extended mission up to end of 2008
    - Sentinel 3A -3B phasing?
What is a reference altimetry mission?

- TOPEX, Jason series
  => to be continued by Jason-CS?

- Payload required:
  - Dual-frequency altimeter => range + ionospheric delay + SWH + σ0
  - Microwave radiometer => tropospheric delay
  - Precise orbit determination suite (GPS, DORIS, laser) => altitude

- Orbit choice
  - Time/space sampling trade-off
  - Minimizing tide aliasing: non-sun-synchronous, mid-inclination
  - Suitable for POD

- Data latency (orbit quality dependent):
  - Near-Real Time (< 3 hr) availability of the L2 products: OGDR
  - Slow Time Critical (STC) (1 to 2 days) delivery of higher quality products for assimilation in models (e.g. SSH, SST): IGDR
  - Delayed time (~GDR), final product
Error budget of altimeter missions

- Orbit error
- Alt. Instr. error
- Ionosphere
- Troposphere
- EM Bias

Centimeters

Geos 3
SEASAT
GEOSAT
ERSI
T/P (before launch)
T/P (after launch)
Jason-1 (before launch)

Ocean signal
The error budget required is slightly less constrained
- less demanding POD => intercalibration with ref. mission
- mesoscale oriented => longer cycles, better spatial coverage
- Sun-synchronous is OK

Payload similar: altimeter – radiometer – POD

Same data latency and content

Future generation / alternatives
- Swath altimetry: SWOT
- Constellations (Iridium-NEXT?)
Ocean Surface Topography Constellation Roadmap

Medium accuracy SSH from high-inclination sun-synchronous orbit
- HY-2A China
- Saral/AltiKa India/France
- HY-2B, -2C, -2D

Swath altimetry from high-inclination orbit (several orbit options)
- CRYOSAT-2 ESA
- Sentinel-3A Europe
- Sentinel-3B, -3C, -3D
- SWOT USA/Europe
- Orbit to be assessed

High accuracy SSH from mid-inclination orbit
- Jason-1 Fr./USA
- Jason-2 Europe/USA
- Jason-3 Europe/USA
- Jason-CS/Jason-4 Europe/USA

In orbit  Approved  Planned/Pending approval  Needed
Upcoming altimetry missions

■ Currently in under development
  ◦ Cryosat2: ESA, launch planned for Nov 2009
  ◦ HY2 A: CNSA (China), launch planned for Sept 2010
  ◦ AltiKa/SARAL: CNES/ISRO, launch planned for Dec 2010
  ◦ Sentinel 3A & 3B: ESA, launch planned for end 2012

■ Currently planned, not completely approved yet
  ◦ Jason-3: EUMETSAT/NOAA, launch target mid 2013
  ◦ GFO-2: NOAA, launch target 2013
  ◦ SWOT: NASA/CNES, launch target > 2016

■ Longer-term plans
  ◦ HY2 B: CNSA
  ◦ Sentinel 3C: ESA
  ◦ Jason-CS series: EUMETSAT/NOAA, launch target 2017
ESA, November 2009

Ice dedicated mission:
- Objective: to determine fluctuations in the mass of the Earth’s major land and marine ice fields

Lifetime 3 years + 6 month commissioning

Orbit => “geodetic type”
- Altitude: 717 km, Inclination 92°
- non sun-synchronous
- Repeat cycle: 369 days (30 d sub-cycle)

Spacecraft and Payload recurrent from lost CryoSat

Instruments
- SIRAL (SAR/Interferometric Radar Altimeter):
  - Low-Resolution / SAR / SARIn modes
  - KU-band (single frequency, no radiometer)
- POD: DORIS and laser

Ocean data: acquisition in LRM mode; integration to DUACS still under way
- CNSA (Chinese National Space Agency) + CNES contribution

- Launch planned Sept 2010

- Payload:
  - Dual-frequency altimeter Ku/C
  - Nadir 3-frequency radiometer
  - 5-frequency scanning radiometer
  - Wind/wave scanning scatterometer
  - DORIS/GPS/LRA

- Orbit (sun-synchronous 6-18, 99.35°):
  - First 2 years with a 14-day cycle
  - Then one year with geodetic orbit (168-day cycle, 5-day approx. subcycle)

- Products availability?
  - Through DUACS multi-mission products (not confirmed yet)
SARAL/AltiKa

- **CNES/ISRO** end-2010
- **AltiKa/SARAL** main objectives:
  - Ocean mesoscale variability studies with an improvement of vertical and spatial resolution
  - Data assimilation in a global ocean model
  - Potential new applications on ice, land, coastal areas

- **Altimetric gap filler** between ENVISAT & SENTINEL3
  - Lifetime 3 years
  - Same orbit, same ground track as ENVISAT

- **Payload:**
  - **AltiKa:** Ka-band altimeter (higher accuracy)
  - Dual-frequency radiometer (sharing the same antenna)
  - POD based on DORIS/LASER

- **Data policy:** ~ the same as JASON missions
  - First India/France scientific workshop held on 22-24 April in Ahmedabad
  - International Research Announcement planned in 2009
AltiKa performance

- Better performance near the coastline
  - Reduced footprint (altimeter and radiometer)
  - Tracking modes (~ Jason-2)
- Higher precision in open ocean
  - Ka-band => reduced altimeter range noise
- Drawback: sensitivity to rain & cloud attenuation

<table>
<thead>
<tr>
<th>1 Hz RMS, SWH=2m</th>
<th>OGDR 3 Hours</th>
<th>IGDR 1.5 days</th>
<th>GDR 30 days</th>
<th>GOALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altimeter noise</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>Ionosphere</td>
<td>0.6</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>EM Bias (% H1/3)</td>
<td>1.2%</td>
<td>1.2%</td>
<td>1.2%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Dry troposphere</td>
<td>1.5</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Wet Troposphere</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1</td>
</tr>
<tr>
<td>Altimeter range RSS</td>
<td>4.5</td>
<td>3.5</td>
<td>3.5</td>
<td>2</td>
</tr>
<tr>
<td>RMS Orbit (radial)</td>
<td>Req : 30 Goal : 10</td>
<td>Req : 4 Goal : 2.5</td>
<td>Req : 3 Goal : 1.5</td>
<td></td>
</tr>
<tr>
<td>Total RSS sea surface height</td>
<td>Req : 5.3</td>
<td>Req : 4.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Error budget specification
ESA, (GMES program)

Mission Profile:
- 7-year lifetime (consumables for 12 years)
- SSO orbit (10h desc), 27-day repeat, 98.65°, alt 814.5 km

Satellite Payload:
- Ocean and Land Colour Instrument (OLCI)
- Sea and Land Surface temperature (SLST)
- Sentinel-3 Ku/C Radar Altimeter (SRAL)
- Dual Frequency MicroWave Radiometer (MWR):
  - POD: GPS/DORIS/Laser

Launch
- end-2012 for 3A,
- 30 months later for 3B
- Phasing 3A and 3B not optimal for altimetry
SRAL and MWR Overview

- Dual frequency Ku/C band Radar Altimeter
- End-to-end range accuracy: 3 cm (ocean)
- Observed surfaces
  - Open ocean, coastal ocean
  - Ice sheets (interiors and margins)
  - Sea ice
  - In-land water (rivers & lakes)
- High horizontal resolution (SAR mode)
- Open-loop tracking over rough surfaces

- Noise Injection Radiometer, with cold sky calibration
  - 2 channels: 23.8 & 36.5 GHz,
  - Footprints: 20 km, co-located with SRAL
- Wet tropo correction accuracy: 1.4 cm typ.
• **Data from the Sentinel Missions will be provided, in principle**
  - For any category use (i.e. not only ‘GMES data use’)
  - Free of charge (unless there are technical, legal and financial constraints)
  - To European users while for users in other countries bilateral agreements or data exchange agreements could be negotiated

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Fast Delivery (&lt;3hr)</th>
<th>Climate Goal (offline)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSH</td>
<td>-</td>
<td>10 cm**</td>
<td>3.5 cm</td>
</tr>
<tr>
<td>Significant Wave Height</td>
<td>0.5 - 20 m</td>
<td>4% (= 8 cm @ 2 m)</td>
<td>1% (= 2 cm @ 2 m)</td>
</tr>
<tr>
<td>O° Windspeed</td>
<td>-10 dB — +50 dB</td>
<td>±1.0 dB rms, 0.017 dB/s stability** 2.0 m/s</td>
<td>±0.5 dB rms, 0.017 dB/s stability** 1.5 m/s</td>
</tr>
<tr>
<td>Along track sampling</td>
<td>-</td>
<td>&lt;10 km (open ocean) 1 km (open ocean)</td>
<td>&lt;300 m (over sea ice) &lt;300 m (over sea ice)</td>
</tr>
<tr>
<td>Coverage</td>
<td>-</td>
<td>3-10 days</td>
<td>(to be optimised with other Alt missions)</td>
</tr>
<tr>
<td>Revisit time</td>
<td>-</td>
<td>2-3 days</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surface type</th>
<th>Measurement mode</th>
<th>Tracking mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open ocean</td>
<td>LRM</td>
<td>Closed loop</td>
</tr>
<tr>
<td>Coastal zones</td>
<td>SAR</td>
<td>Open loop / Closed loop</td>
</tr>
<tr>
<td>Sea ice</td>
<td>SAR</td>
<td>Closed loop</td>
</tr>
<tr>
<td>Ice sheet interiors</td>
<td>LRM</td>
<td>Closed loop</td>
</tr>
<tr>
<td>Ice sheet margins</td>
<td>SAR</td>
<td>Open loop</td>
</tr>
<tr>
<td>Inland water</td>
<td>SAR</td>
<td>Open loop</td>
</tr>
<tr>
<td>Other</td>
<td>Depends on S/C resources</td>
<td>Depends on S/C resources</td>
</tr>
</tbody>
</table>
NOAA/EUMETSAT cooperation with CNES & NASA contributions

- Launch: mid-2013
- Mission design: OSTM/Jason-2 like
- Data => same as OSTM/Jason-2
- Pending approval (in December 2009)

... and Jason-CS?

« Continuity of Service »

- Target launch date: 2017
  - 1 year overlap with Jason-3
- new platform
- different orbit?
NASA/CNES, launch possible in ~2016

Mission combining research needs associated to hydrology and oceanography:
- mapping of water level for rivers, lakes, and oceans (including coasts)

Payload:
- Wide-swath interferometric, Ka-band altimeter
- Nadir altimeter
- Radiometer
- GPS/DORIS/Laser

Orbit: 22-day repeat cycle, 78° inclination, alt. 970 km

CAL/VAL phase orbit: 3-day repeat cycle
**SWOT will completely change the way we use altimetry:**

- Time/space sampling requirements => how do we fill the holes?
- High resolution data within the swath => integration into large scale picture (data or model)?
From now to next years

Current status

Several new missions will be launched soon, but:
- Cryosat-2 => ocean data not secured yet, and quality will not match traditional missions (no C or S band, no radiometer)
- HY-2 => data availability is not secured yet

Things get better with SARAL, Sentinel-3

Then, two main uncertainties:
- Jason-3
- Sentinel 3B phasing
Current altimetry missions

■ **Jason1**: in extended mission, fully operational
  - Moved to interleaved orbit with Jason-2 in Jan/Feb 09, after 6-month « formation flying phase »
  - Vulnerable to equipments failure risk

■ **Jason-2**: launched in June 2008,
  - OGDR distributed operationally since Dec 2008,
  - IGDR distributed operationally since Jan 2009
  - GDR will be released after OSTST (July 2009)
  - DUACS products already available
  - Very good product quality

■ **ENVISAT**
  - Excellent synergy with Jason1 (T/P and ERS complementarity further improved)
  - S-band missing: degraded quality by lack of ionospheric delay correction
  - Will be put on a drifting orbit in 2010
Three altimeters in operations?

- Probability model to get:
  - 3 fully operational missions (100% of the time)
  - On different ground tracks (Jason-1 / Jason-2, AltiKa / ENVISAT)

- CalVal phase = redundant sampling (failure prob cancelled by Ja-2)
- Interleaved phase = probabilities stack
- At nominal quality level (e.g.: mapping OSSE says CryoSat = 50%)

- Typical figures:
  - Nominal satellite lifespan = 75% chance to have the ground track covered
  - Probabilistic death at 2.2 * nominal lifespan
  - Risk of failure at launch (or early life anomalies) not taken into account

- Note: “3rd party” missions (China in particular) not taken into account
Concluding remarks

- There is a rich panel of missions under development or planning => let us hope they will all succeed!

- Getting homogeneous information on error budget and/or specifications proved to be challenging
  - From one mission to another, but also from one error source to another
  - Maybe some effort should be put in promoting some standard metrics?

- Space agencies (NASA, CNES) tend to put as priority innovative missions
  - Transition to operational agencies of already mature concepts
  - Promising in a long term perspective, but
  - Potential issues in the continuity of the long-term record

- Multiple missions decided/developed by multiple agencies/countries
  - Coordination not guaranteed, higher programatics risk
  - Data availability on a case-by-case basis; whereas combined multi-mission product are the most effective
  - Efforts from CEOS (through NOAA and EUMETSAT) to improve altimetry mission coordination: « OST Constellation Mission Requiremnt Document » in preparation