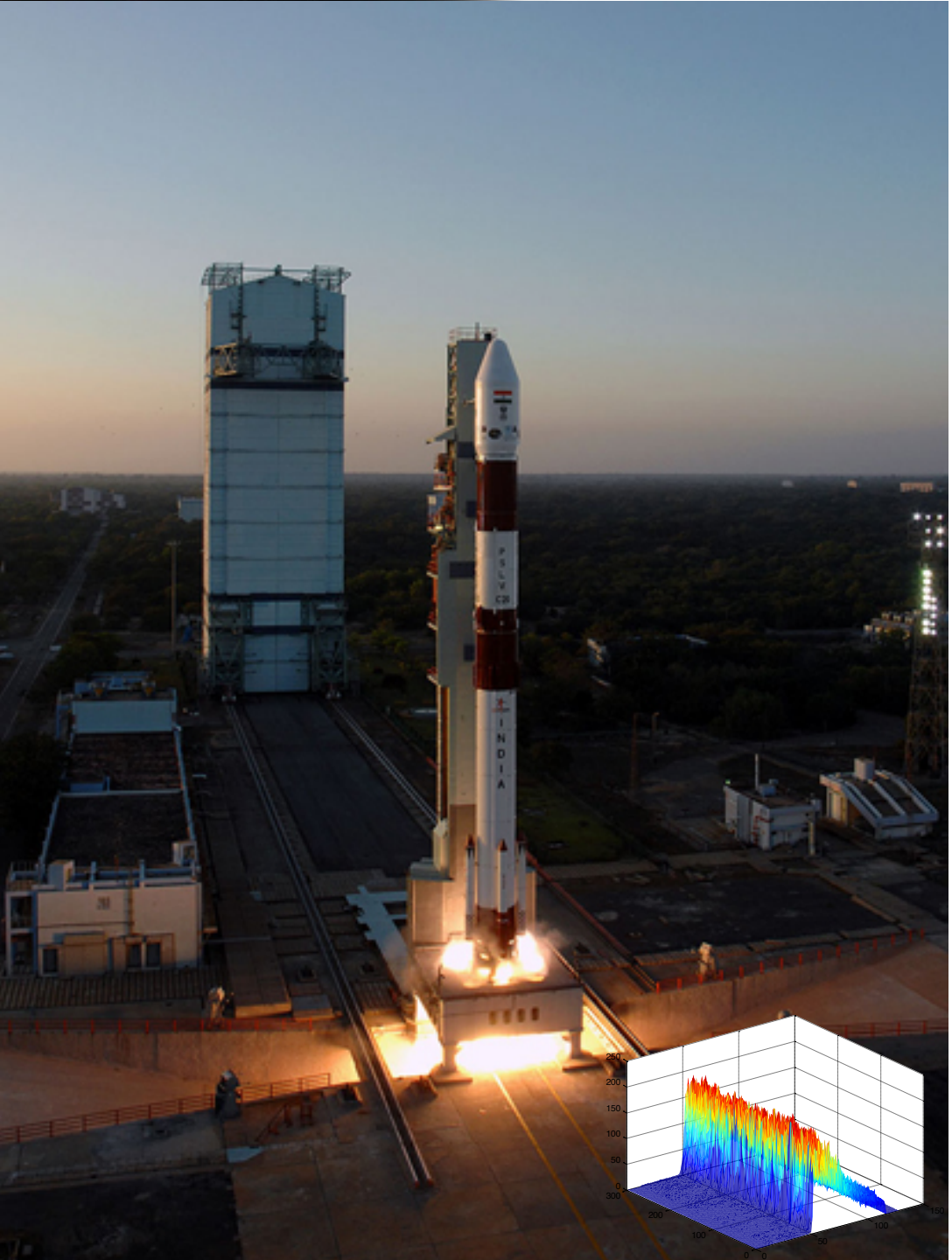
SARAL/AltiKa:
A Ka band altimetric mission

Jacques Verron, LGGE, Grenoble
Pierre Sengenes and the CNES and CLS project teams
and Contributions from SARAL/AltiKa PI's

aboratoire de Glaciologie et Géophysique de l'Environnement



- SARAL/AltiKa has been launched on 25 Feb. 2013 from SHAR on PSLV20
- First waveforms provided on Feb. 26
- GDR-T delivered to everyone early Sept. 2013

- **The SARAL/AltiKa mission**
  - History/Motivations
  - The mission
  - Science objectives/organisation
- **First Data**
  - Data availability/distribution
  - Data quality assessment
- **Insights at some preliminary applications**

The SARAL/AltiKa mission

History: Some milestones of SARAL

- **1998-2002:** Exploratory development
- **2003:** Phase B (instrument)
- **2005:** Phase 0 (satellite): completed on 2 types of microsatellites (CNES & SSTL) approved by CNES (instrument)
- **2005:** First discussions between CNES and ISRO: ALTIKA on-board OCEANSAT3
- **February 2007** : Signature of ALTIKA and ARGOS-3/SARAL MOU between CNES and ISRO
- **August – October 2009:** Delivery of Doris, ARGOS-3 package and ALTIKA FMs to THALES AS-F PIM AIT
- **End of 2009 :** formal agreement of EUMETSAT to take part to the SARAL mission
- **January 2010 – July 2011:** Integration and Qualification of Payload Integrated Module in France
- **July 2012:** PIM delivery to ISAC/ISRO in India (Bangalore)
- **August 2012 – February 2013**: Integration and Qualification of the SARAL S/C in ISRO facilities
- **February 25th, 2013 at 12:31 UTC** : Take-Off from SHAR

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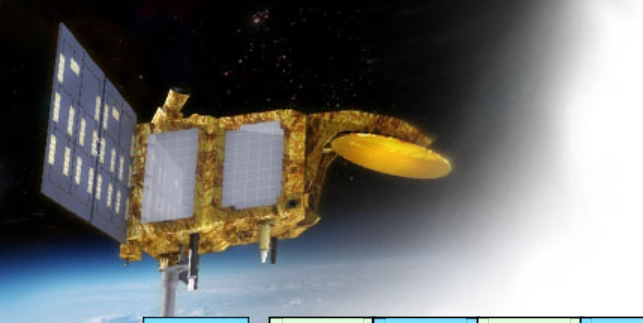
- **February 25th, 2013**

On Monday, Oct. 7, precise historical ENVISAT orbit reached !



OST Virtual Constellation Status

Launch Date	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Reference Missions - Higher Accuracy/Medium Inclination

12/01 **Jason-1** France/USA — Lost

Jason-3 Europe/USA

06/08 **Jason-2** Europe/USA

Jason-CS A/B Europe/USA

Complementary Missions - Medium Accuracy/Higher Inclination

03/02 **ENVISAT** Europe — Lost

Sentinel-3A Europe

Sentinel-3C/D Europe

Sentinel-3B Europe

02/13 **Saral** France/India

08/11 **HY-2A** China

HY-2B China

04/10 **CRYOSAT-2** Europe

GFO-2 USA

Broad-Coverage Mission

SWOT USA/France

COMPIRA Japan

Design Life | Extended Life | Approved | Proposed

Motivations

- **Necessity…**
  - Fill the gap after the 5 year ENVISAT mission and before JASON3 and Sentinel-3
  - Complement the JASON-2 mission
- **Continuity…**
  - Technological maturity
  - No experimentation in orbit required
- **Innovation….**
  - Number of technological improvements due to KA range
  - Account for the post-GODAE and IGOS requirements on instrument performances (in particular for the coastal ocean), continuity, multimission needs, …

The SARAL/AltiKa mission

- **SARAL (Satellite with ARgos and ALtiKa)**, two independent missions (AltiKa and ARGOS-3) on-board the ISRO SSB platform
  - First altimeter in Ka band
- **SARAL mission lifetime requirement**
  - ARGOS-3/SARAL lifetime requirement: 5 years, *objective : 7 years*
  - AltiKa/SARAL lifetime requirement: 3 years, *objective : 5 years*
- **SARAL/AltiKa satellite**
  - ISRO: SSB (Small Satellite Bus) platform, PSLV, command-control operations of the satellite.
  - CNES: PIM (Payload Integrated Module)
- **SARAL/AltiKa ground segment**
  - ISRO is responsible for providing near-realtime and delayed-time altimetry products to Indian users
  - CNES is responsible for OGDR and delayed products (GDR, IGDR, S-IGDR and S-GDR) to users outside India and to insure precise orbit control (DORIS and laser system data).
  - CNES is responsible for the coordination of AltiKa with the other altimetry missions (e.g. DUACS) and the long term CalVal.
  - EUMETSAT provides support to CNES for providing near-realtime products to users outside India

The SARAL/AltiKa mission

- **Orbit**
  - Sun-synchronous (6/18)
  - 800 km
  - 35 days
  - 98.55°
  - Same orbit/ground-track than ENVISAT (< Oct 2010)
- **AltiKa payload**
  - Single frequency Ka-band altimeter (35.75 GHz)
  - Dual-frequency radiometer (23.8 and 37 GHz)
  - DORIS receiver
  - Passive laser retroflector array
- **Single frequency Ka band altimeter with an enhanced bandwidth**
  - Reduced ionosphere effects (authorizes mono-frequency altimeter)
  - 480 MHz bandwidth : better vertical resolution
  - Ka-band and increased PRF (4 KHz) : improved spatial resolution and reduced 1Hz noise
  - Smaller footprint
  - Ka-band limitations : sensitivity to atmospheric water content

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Ka vs. Ku

- Improved vertical resolution
- Smaller footprints
- Improved along-track resolution
- Shorter decorrelation times for sea echoes
- Better discrimination in transition zones
- Lesser ionospheric errors
- *But sensitivity to small rains*

Science

- **Scientific Objectives:**
  - Ocean mesoscale variability
  - Coastal ocean altimetry
  - Data assimilation and operational oceanography
  - Continental waters, Ice sheet monitoring, Sea level change, Sea state, Low rain characterization, …
- **Mission scientific group (France)**
  - Active since 2002
- **International call of opportunites (2010)**
  - Total of 64 teams selected
    - 23 proposals from India
    - 16 proposals from France
    - 27 proposals from other internationals: USA (11), Europe (10), Australia (3), Taiwan (1), Japan (1), Brazil (1)
  - Good coverage of the topics: CALVAL global & *in situ*, parameter analysis & reprocessing, coastal/regional altimetry & ocean dynamics, operational/model/ assimilation, continental waters, ice, mean sea level, bathymetry, etc…

First Data

Data processing

- First OGDR processed by CNES on February, 26th early morning – just a few hours after launch
- First IGDR processed by CNES on March, 6th
- Automatic processing of OGDR at EUMETSAT and ISRO started on March, 19th.
- Automatic processing of IGDR at CNES started on March, 19th
- Start of the GDR processing on July, 12th after the integration of Patch V1
- GDR_T open to all users, early September

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9th

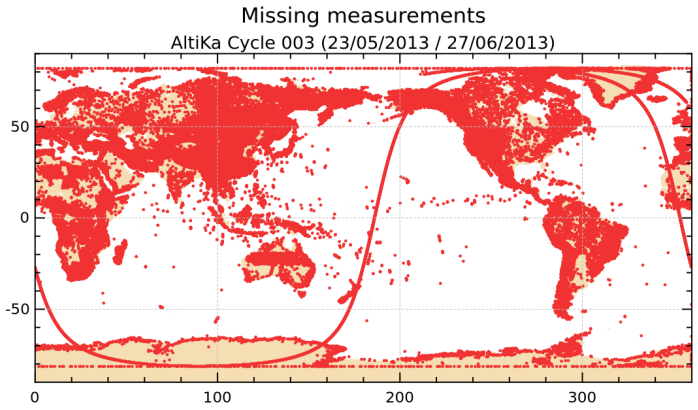
on

Data Latency

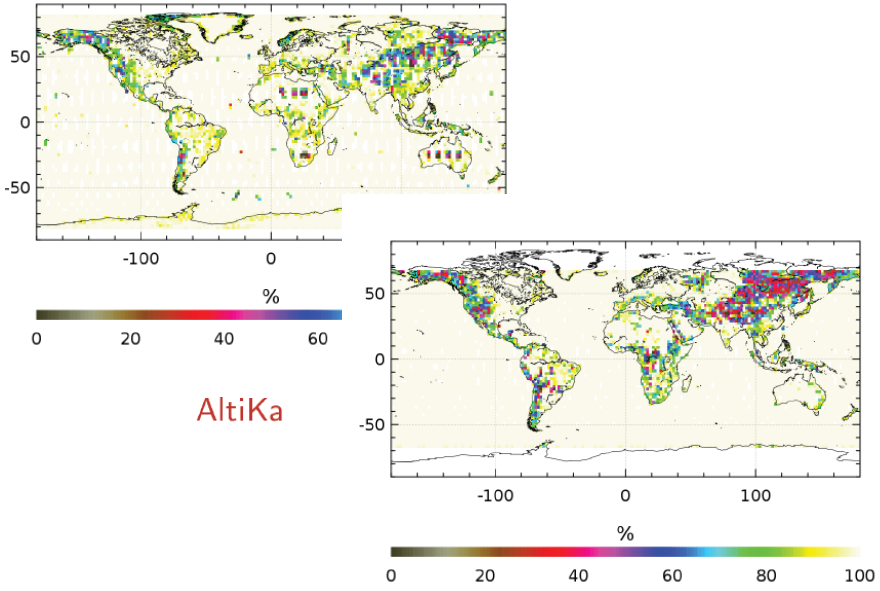
- Very quick availability of the data
- Operational products (OGDR, IGDR) generated and distributed in a timely manner with a comfortable margin

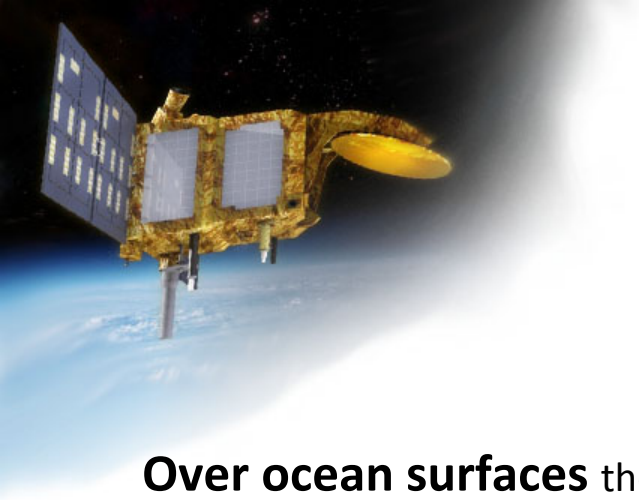
Data coverage

Over ocean surfaces the number of missing data is about 0.6 %, slightly above the JASON-2 (in routine JASON-2 is about 0.02%). Likely due to rain, but less impact than expected



Over land surfaces the SARAL data return exceeds the one of JASON-2 (3% of missing data for SARAL over all surfaces, 4.1% for JASON-2). Likely due to the smaller footprint.





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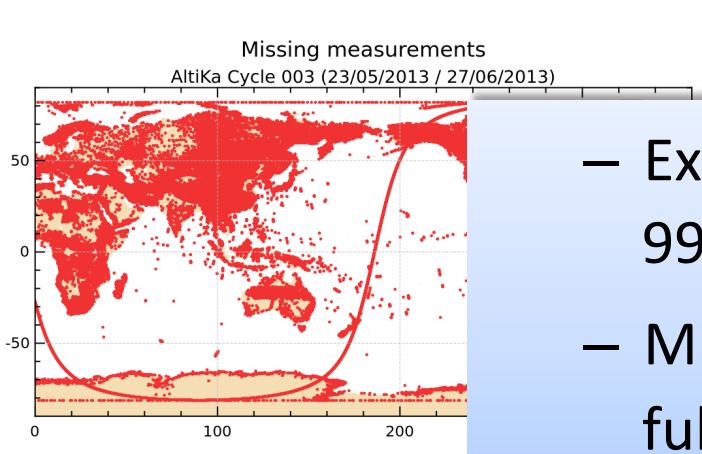
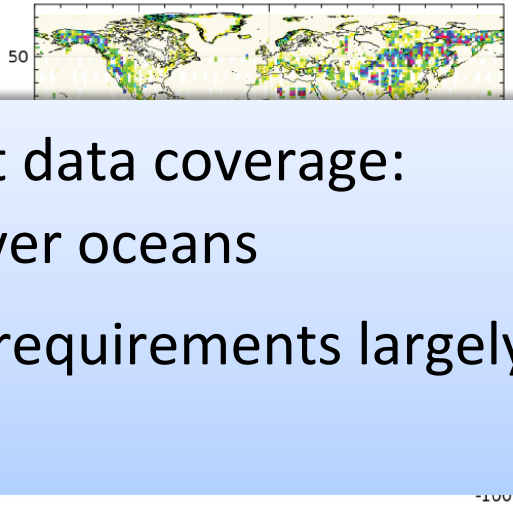




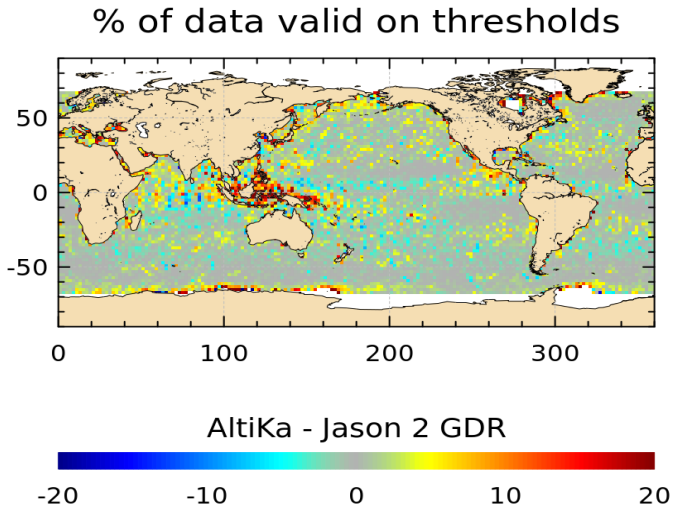
- Excellent data coverage: 99.4% over oceans
- Mission requirements largely fulfilled

Data editing

More valid data than Jason-2 in the Western Pacific

(good behavior even in rain cell areas)

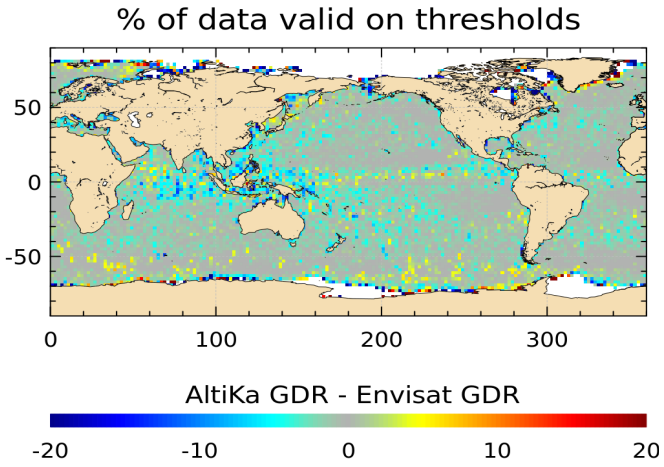
Comparison to Jason-2
(over the same period)



Less valid data than Envisat

(in rain cell areas)

Comparison to Envisat
(three years earlier)



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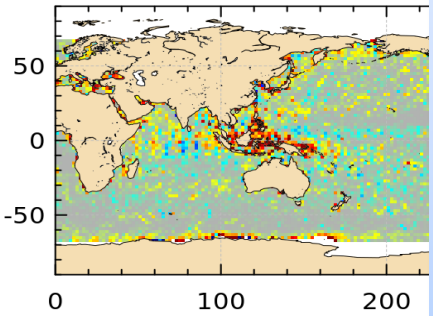


AltiKa - Jason 2

Ka vs. Rain

- Less impact of rain than expected: 2.6 % data edited over the 4 first cycles
- The initial figure (based on conservative hypothesis and system margins) was 5-10% of data

AltiKa performances: noise levels

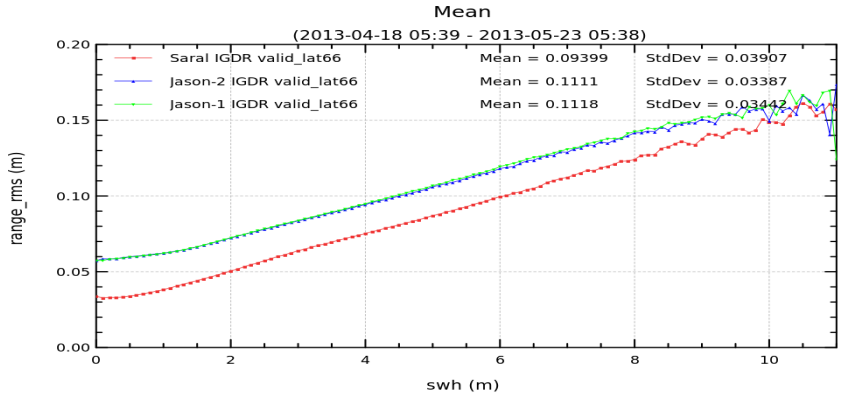
Altimeter parameter	Specifications	Measured on ground	In flight data
1 Hz range	1.5 cm	0.9 cm	0.9 cm
1Hz SWH	6.3 cm	5.7 cm	5 cm
1 Hz Sigma0	0.2 dB*	N/A	0.012 dB

For 1s average, 2 m SWH, 7.8 dB Sigma0
* Includes the noise and the non-calibrated drift error

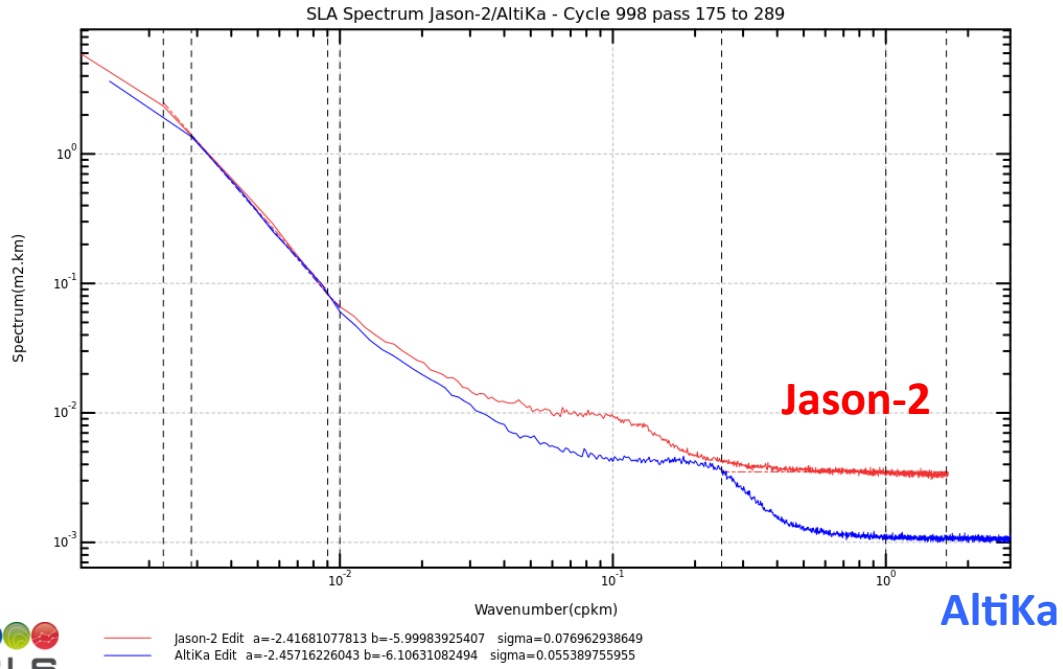
AltiKa vs Jason-1/2:

- Saral: 5.1 cm → 0.8 cms at 1Hz
- JA2/JA1: 7.2 cm → 1.6 cms at 1Hz

(At SWH=2m, range_rms (40Hz for Saral, 20 Hz for JA2/JA1)



SLA Spectrum analysis



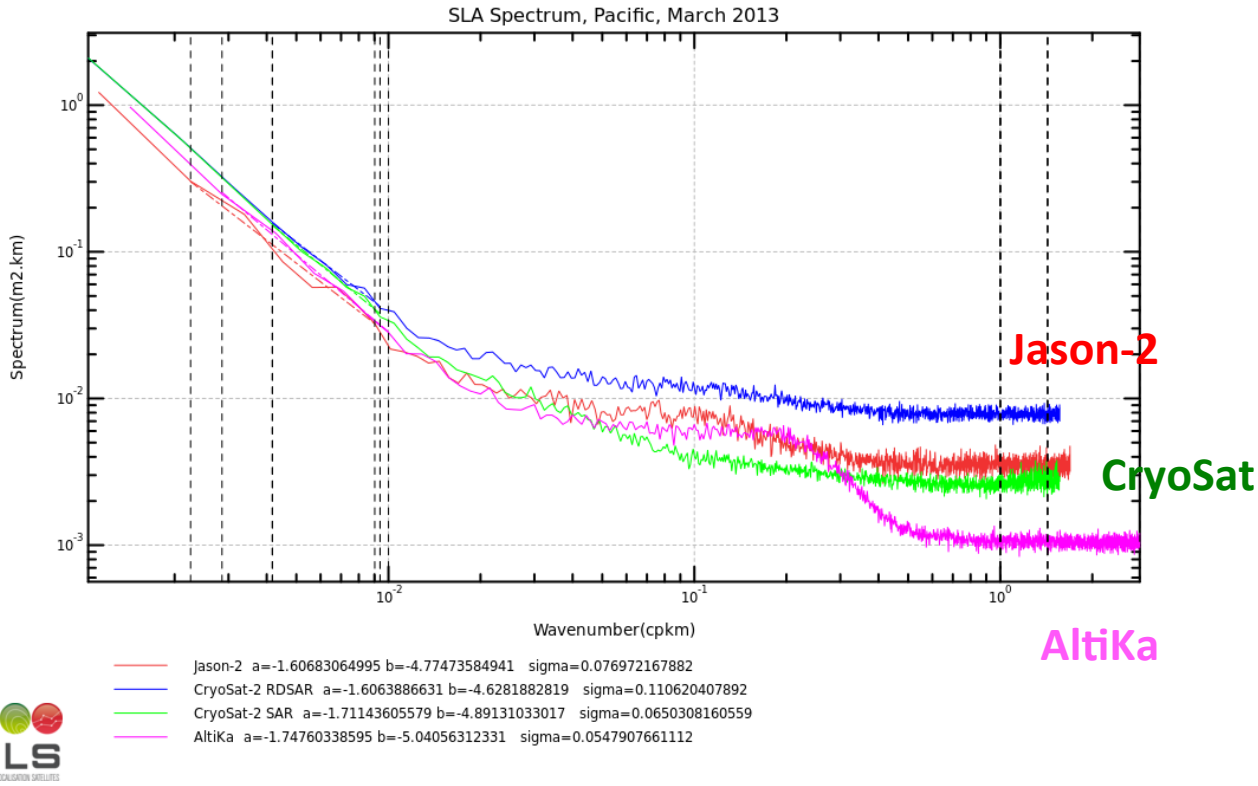
HR Noise:
7.2 cm @ 20Hz
5.1 cm @ 40Hz

The SLA spectrum is similar to Jason-2:

- 40Hz AltiKa SLA noise < 20Hz Jason-2
- SLA noise spectral hump is still present on AltiKa but shifted to shorter scales (smaller footprint)

SLA Spectrum analysis

Can be compared to CryoSat SAR (processed by CNES over the Pacific zone)

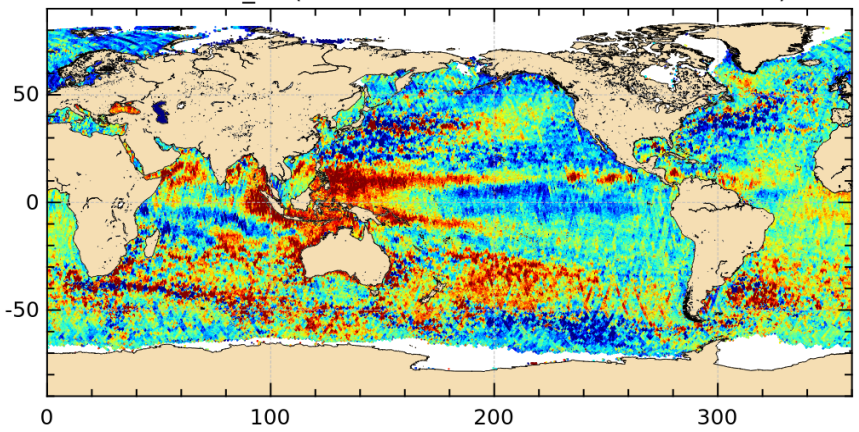


Sea Level Anomalies

Maps of SLA are very similar for Saral and Jason-2, with Rms values as low as Jason-2 mission

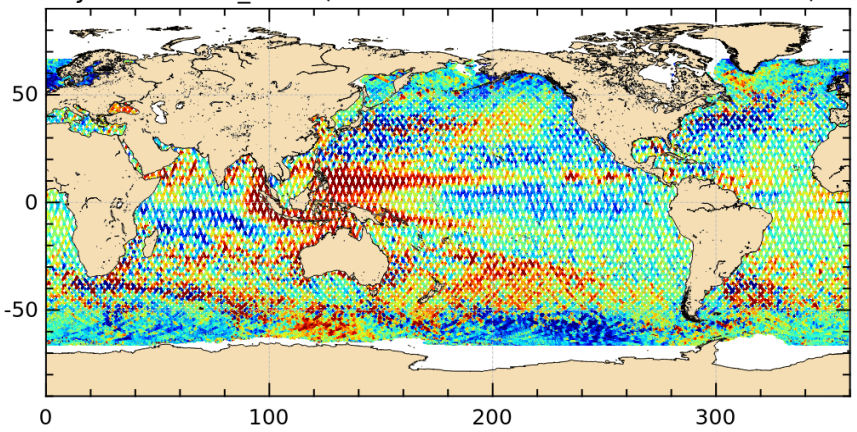
AltiKa Ka-band SLA

Saral valid_all (2013-04-18 05:39 - 2013-05-23 05:38)



Jason-2 Ku-band SLA

Jason-2 valid_lat66 (2013-04-18 05:39 - 2013-05-23 05:38)



SLA Mean cm	AltiKa	Jason-2	AltiKa -Jason-2
	-2.8	3.2	-6.5

- AltiKa 6.5 cm below Jason-2 (SSB, ? …)

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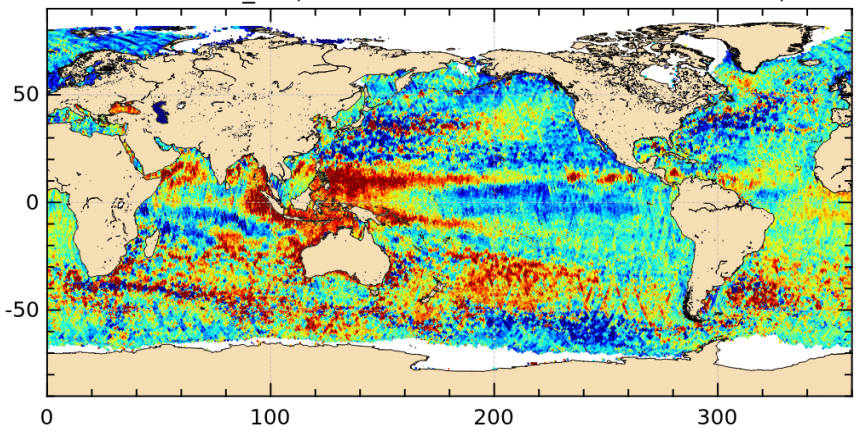

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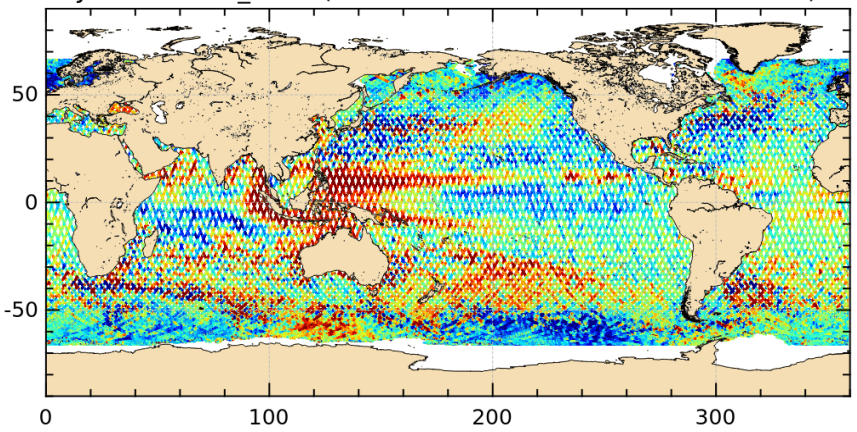
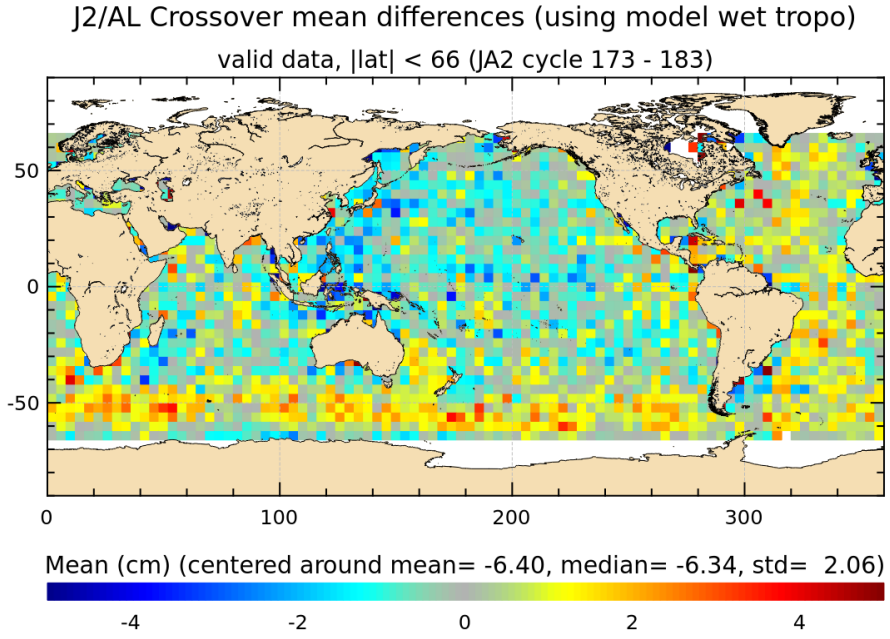


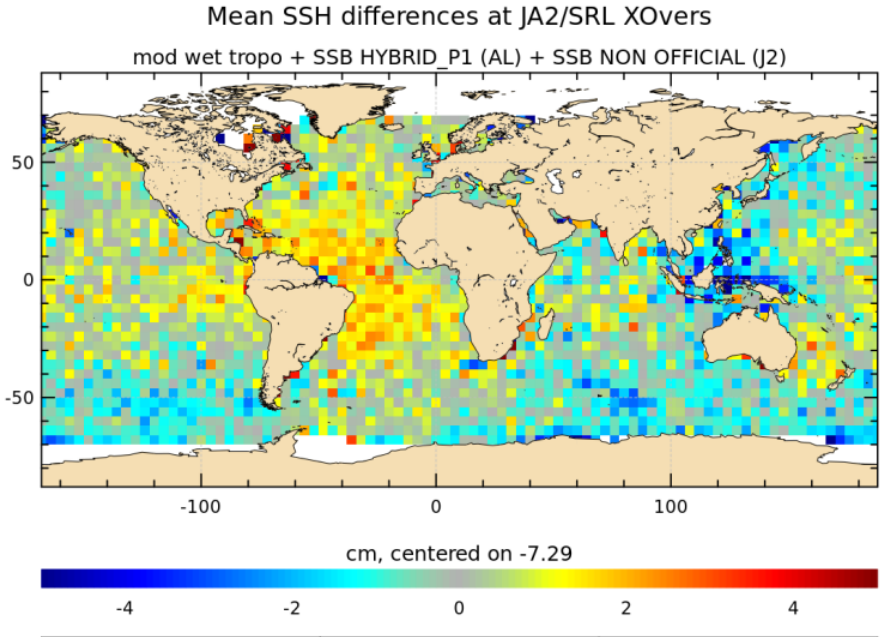
SLA StDev cm	AltiKa	Jason-2
	10.96	10.85

- AltiKa comparable to Jason-2

Performances analysis : Crossover

- Multi-mission crossover:
  - The mean at Jason-2/SARAL crossovers is already very low
  - Will be improved in the coming months by the improvement of the orbit estimation accuracy, SSB, radiometer wet tropospheric correction, …





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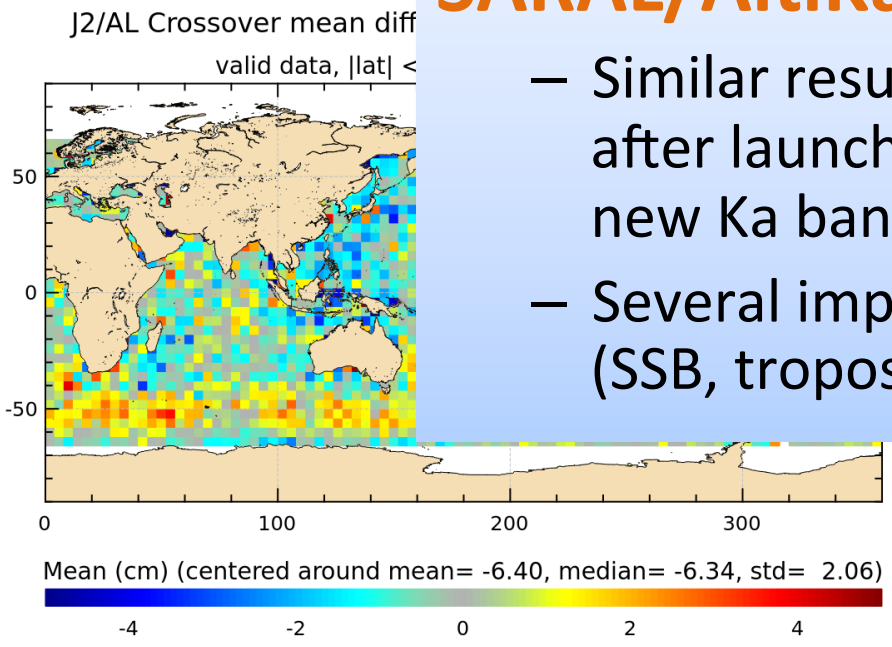
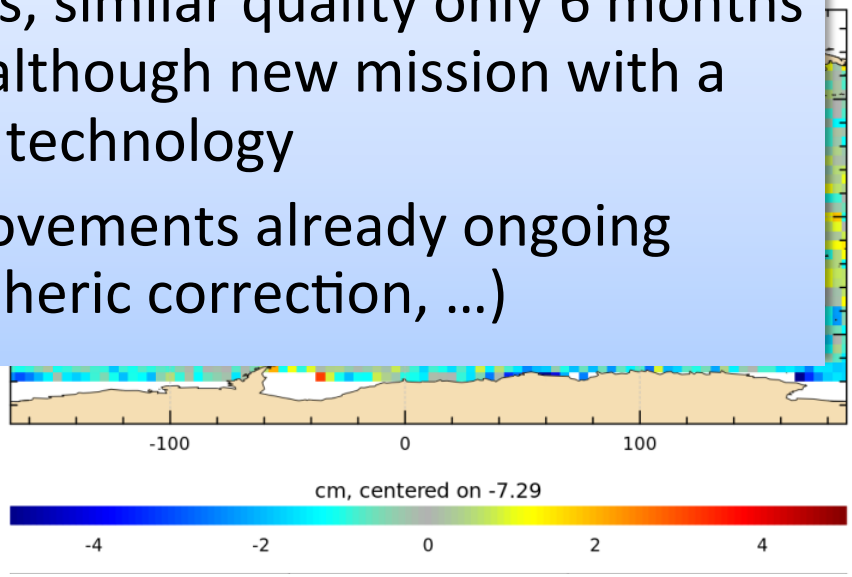
SARAL/AltiKa vs. JASON-2

- Similar results, similar quality only 6 months after launch although new mission with a new Ka band technology
- Several improvements already ongoing (SSB, tropospheric correction, …)

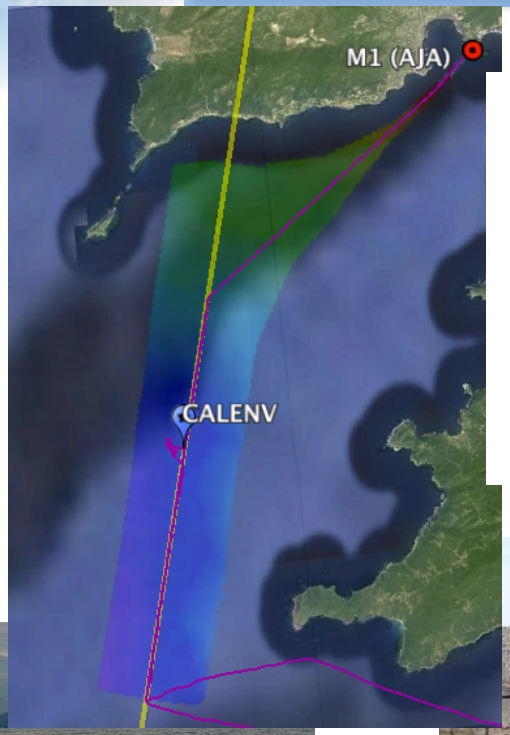


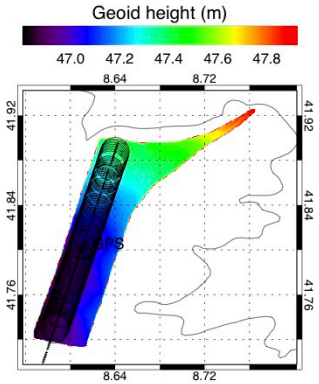


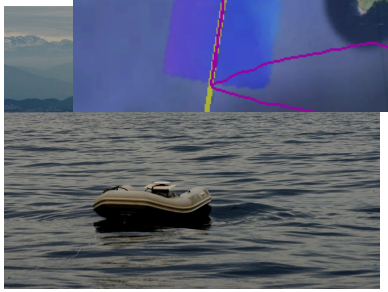
Insights on some preliminary applications

Absolute Altimeter Calibration in Corsica

P. Bonnefond, FOAM team, Géoazur, Sophia-Antipolis







Independent instruments :
- From tide gauge (coastal)
- From GPS measurement (offshore)

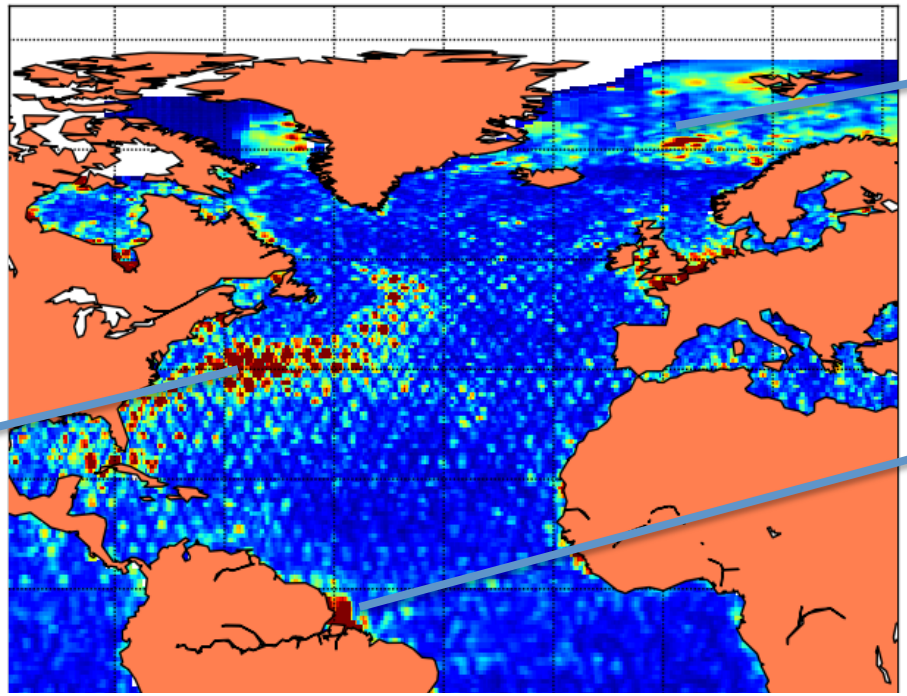
- **Refined Geoid near the coast:**
  - No land contamination seen in the waveforms, Good 40Hz data up to 3 km from coast
  - Global standard deviation very low (28 mm) compared to JASON-2 (50-60 mm)
- **Absolute SSH bias derived from GPS:**
  - -67 mm (JASON-2: 0 mm)
  - ⇒ Comparable to relative bias from global Calval analysis:
    SARAL – JASON-2 = -65mm
- **Stability of the absolute SSH bias:**
  - 14 mm (JASON-2: 35 mm)

Altika in DUACS

Y. Faugere, A Delepoulle, F.Briol, I Pujol and DUACS Team, N Picot, E Bronner

- SARAL/Altika has been integrated in Duacs on July 1st with an unexpected handover with JASON-1
- Duacs quality control confirms good performances of Altika
- Allows to maintain good quality products despite the loss of Jason-1

Standard deviation of [J2/C2/Al – J2/C2 maps] on July (cm)



More variability over 66°

High energy in the Gulf Stream (Impact > 20cm))

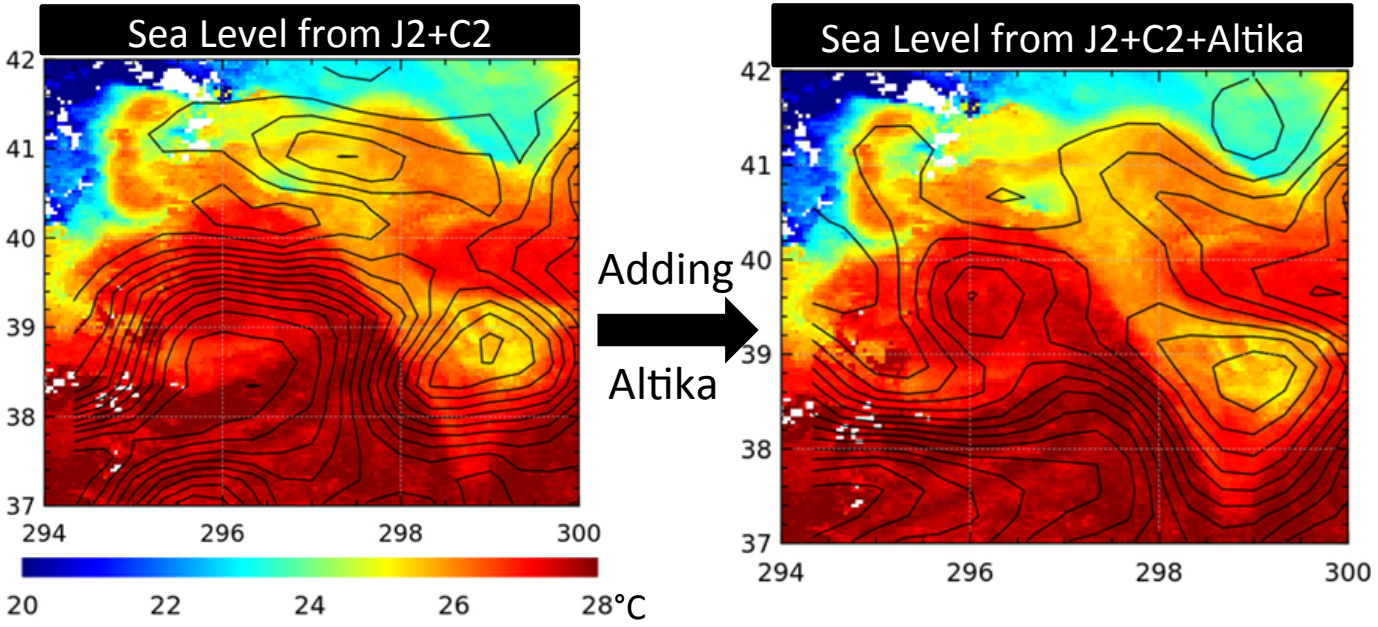
Coastal structures (or error) captured with new sampling

0 5 cm

Altika in DUACS

Y. Faugere, A Delepoulle, F.Briol, I Pujol and DUACS Team, N Picot, E Bronner

Comparison between DUACS Absolute Dynamic Topography (contours) to SST (color) on the Gulf Of Mexico on July 26

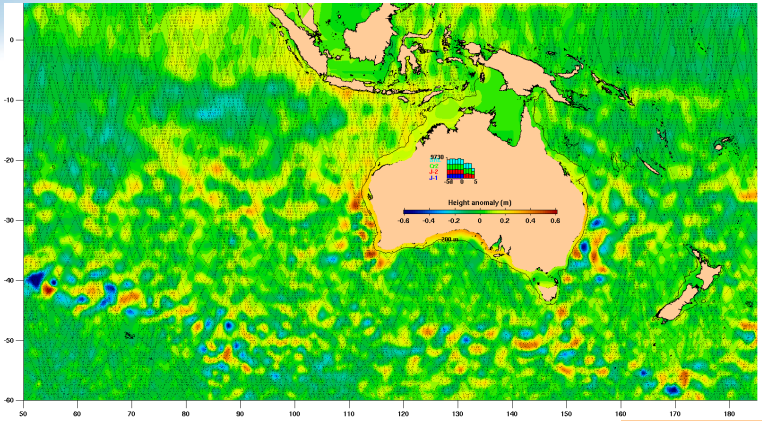


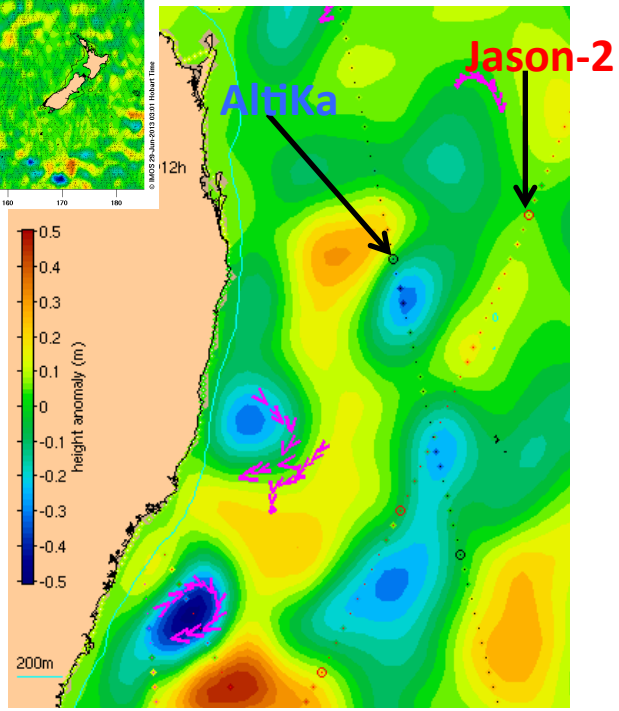
- The mesoscale is better resolved with Altika (3 satellites) with a **better positioning of the eddies**.
- First results highlights the potential interest of Altika to **even improve the resolution** of Duacs products

Use of AltiKa NRT sea level anomaly in the Australian multi-mission analysis

D. Griffin, M. Cahill, CSIRO Marine and Atmospheric Research

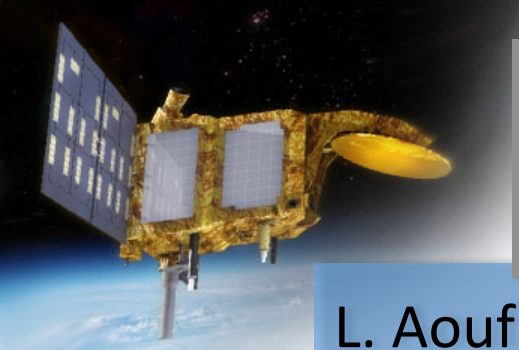
End of Jason-1 era, start of AltiKa era





- Real-time oceanography needs 3-4 good altimeters
- Loss of Jason-1 left only Jason-2 and Cryosat-2. Fortunately, the SARAL project team had just announced that AltiKa data would be released
- Australia did not hesitate to include the data in our real-time systems
- Our routine data-editing procedures did not need modification. Rain-induced errors are rarer than anticipated

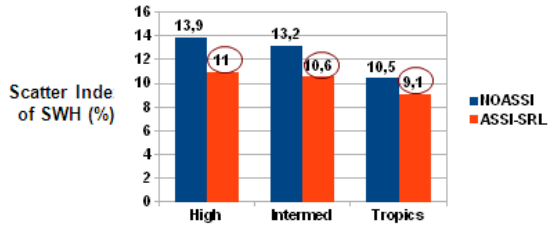
- The quality of SARAL data, and speed of delivery post-launch, exceeds expectations
- SARAL was the first altimeter to discover a major cyclonic eddy off eastern Australia, and tracked its progress towards the Australian coast
- Cryosat-2's sampling pattern provided dense sampling of the eddy – but for a few days only



Assimilation of SARAL/AltiKa SWH into a NWP operational system

L. Aouf, J. M. Lefèvre, Météo-France, Toulouse

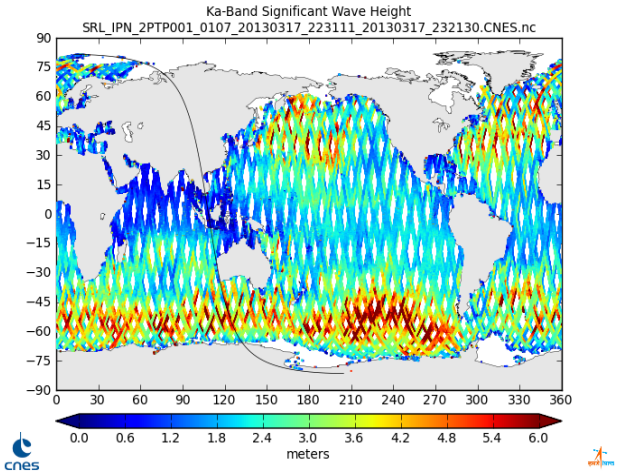
Assimilation of SARAL/Altika in MFWAM in different ocean basins



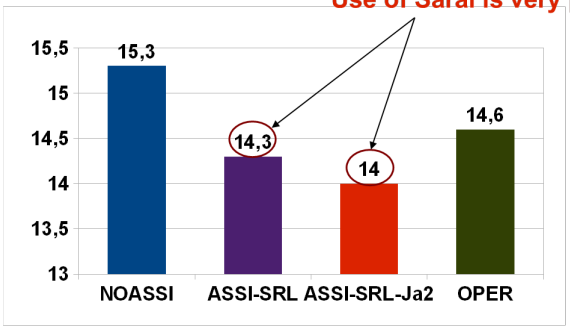
Collected data :	290257	311068	191552

High Lat |φ|> 50°
Intermediate lat 20°<|φ|<50°
Tropics |φ|<20°

Validation with Jason 1 & 2 METEO FRANCE Toujours un temps d'avance



Use of Saral is very promising !

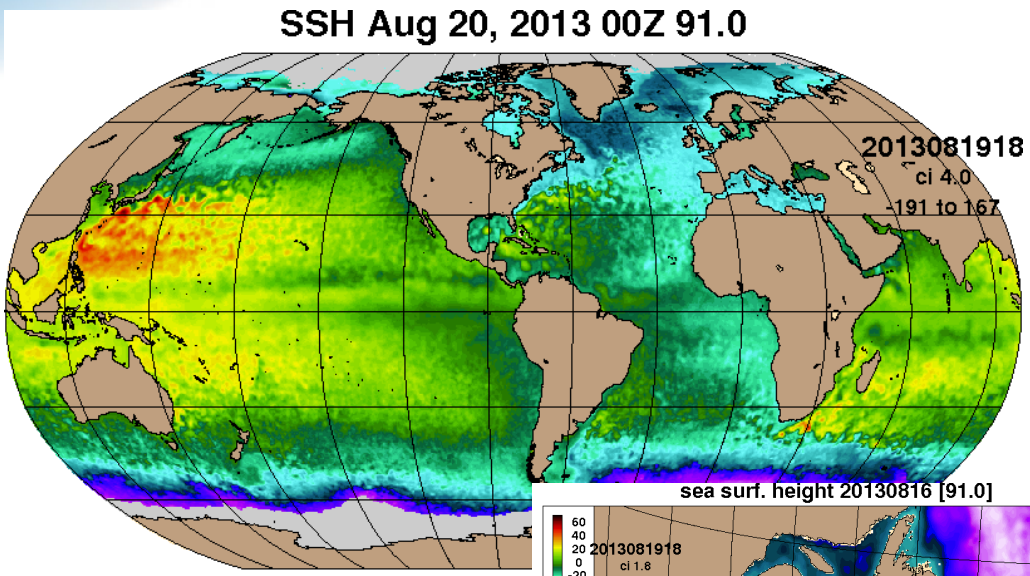


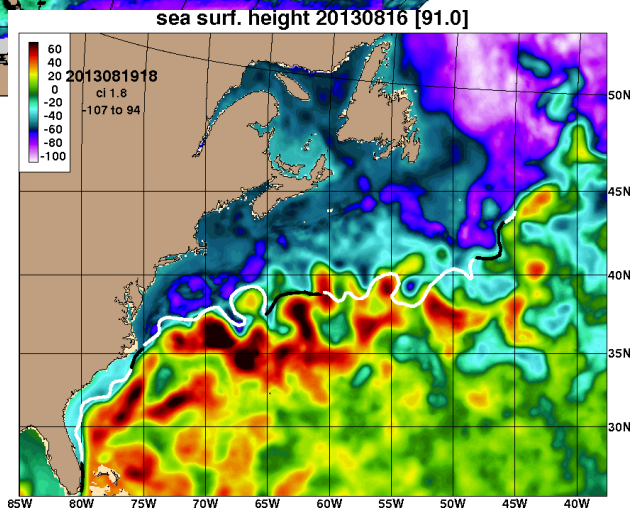
NOASSI : without assimilation
ASSI-SRL : assimilation of SARAL/Altika
ASSI-SRL-JA2 : assimilation of SARAL and Jason-2
OPER : Operational MFWAM with assimilation of Jason-1 & 2

- Positive impact on the wave analysis and forecast : ready to be used operationnaly in MFWAM
- Use of Saral with Jason-2 showed promising results (SWH errors are greatly reduced SI < 9% in the tropics)
- Work is in progress for the use of Saral/Altika in regional model MFWAM-Réunion (0.25°): watch on next cyclonic season!

Monitoring the SARAL/AltiKa Performance in the Global Ocean Forecast System

J. Richman and G. Jacobs, Oceanography Division, Naval Research Laboratory



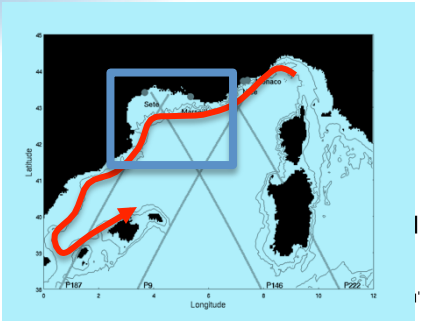


1/12.5 Operational Global Ocean Forecast System using Global HYbrid Ocean Coordinate Model (HYCOM) assimilating SSH, SST and in situ T,S profiles. AltiKa has been added to this system.

- AltiKa is providing valuable information to the realtime global and regional forecast models
- AltiKa is performing as good as Jason-2
- The addition of a second altimeter has a significant impact on the forecast skill of the model.
- The short latency of AltiKa allows us to shorten our hindcast cycle
- Realtime monitoring shows stable statistics for noise

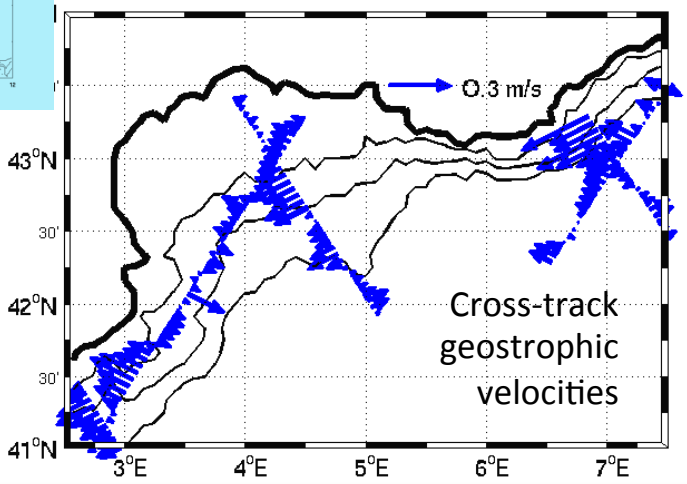
Variability of the Northern Current (NW Mediterranean Sea) observed by SARAL/AltiKa

F. Birol, F. Niño, C. Delebecque, S. Fleury, R. Morrow, CTOH/ LEGOS, Toulouse



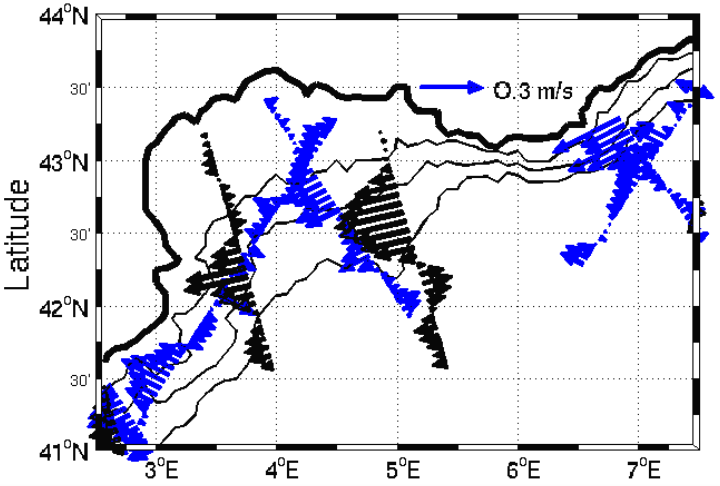
Jason-2 only

Time: 23082 - 23092



Jason-2 and **AltiKa**

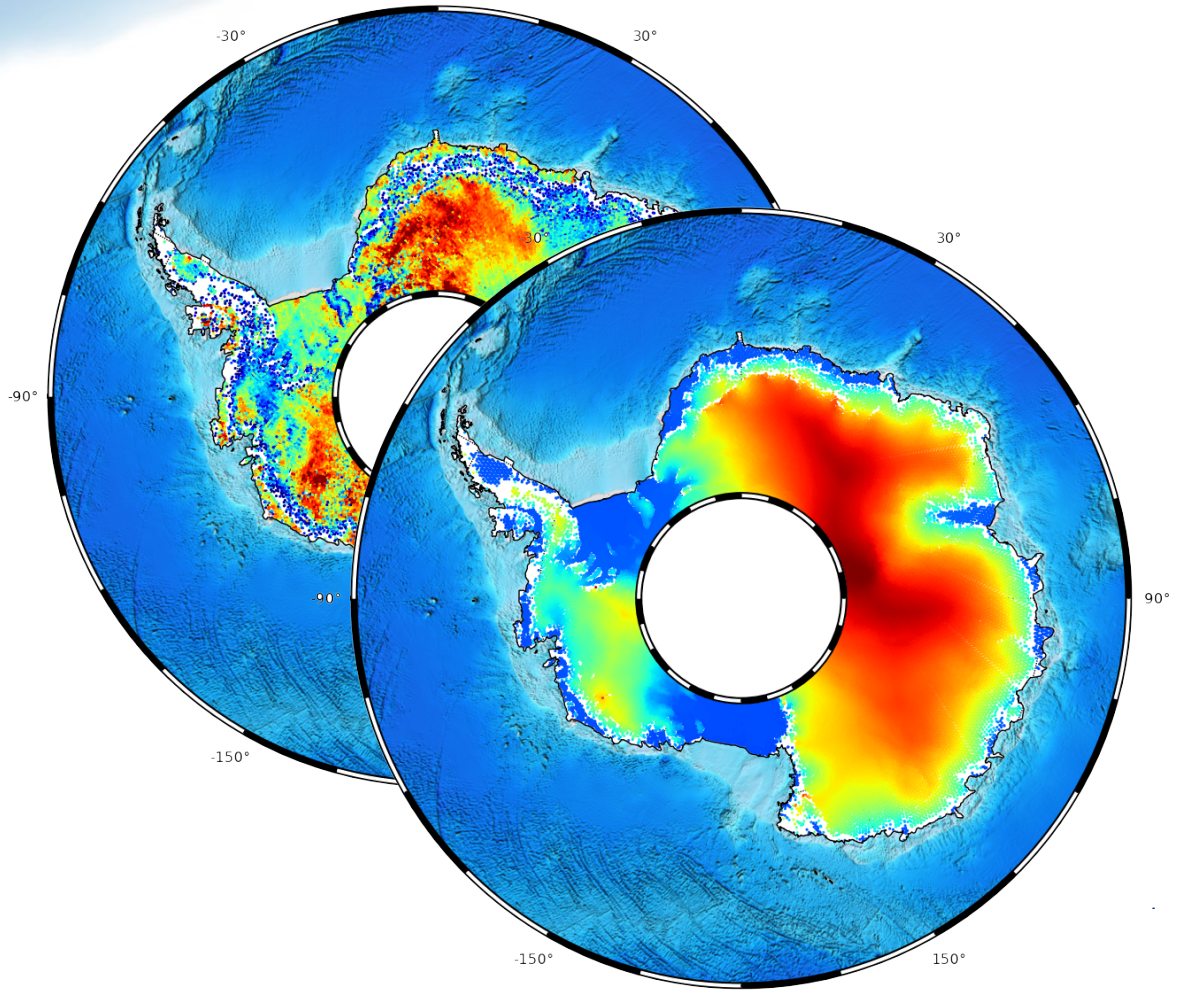
23082 - 23092



- Very good complementarity between Jason-2/AltiKa data
- AltiKa significantly improves the observation of the coastal dynamics
- Along-track spatial resolution at least as good as Jason-2 one (even slightly better because better signal-to-noise ratio)
- Good performance near the coast

Altika over the Antarctica Ice Sheet and first steps to understand Ka measurements on Ice

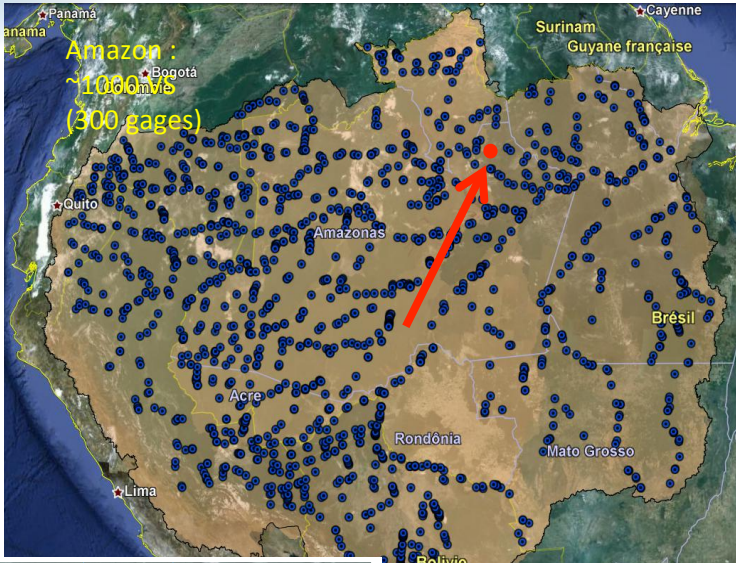
F. Rémy, D. Blumstein, A. Michel, T. Flament , LEGOS, Toulouse

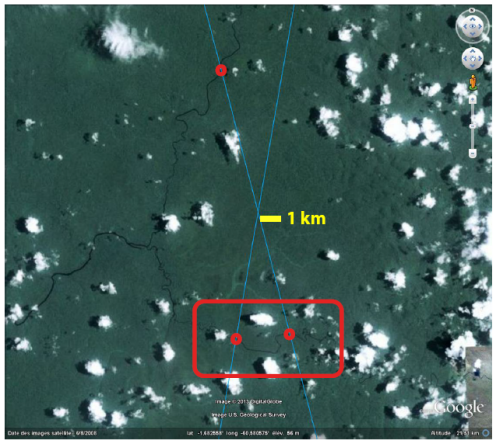


- Altika very good on snow surface and ice (even some new results)
- Large backscatter sensitivity in space over ice and snow, due to interaction between small wavelength and surface ice grain, snow metamorphism, surface roughness, wetness, thin snow layer on ice… (need a dedicated electromagnetical model)
- The smaller penetration leads to a greater sensitivity to surface and subsurface echoes and thus leads to larger temporal fluctuations (need to explore this for climate survey)

SARAL/AltiKa altimetry over rivers

S. Calmant, LEGOS, J. Santos da Silva, UEA, D. Medeiros Moreira, CPRM, D. Blumstein, LEGOS, F. Seyler, Espace

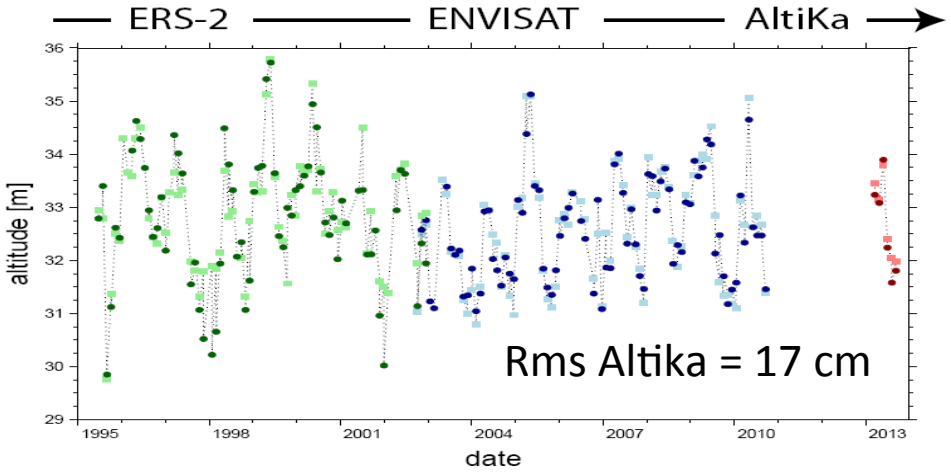




Rio Pardo

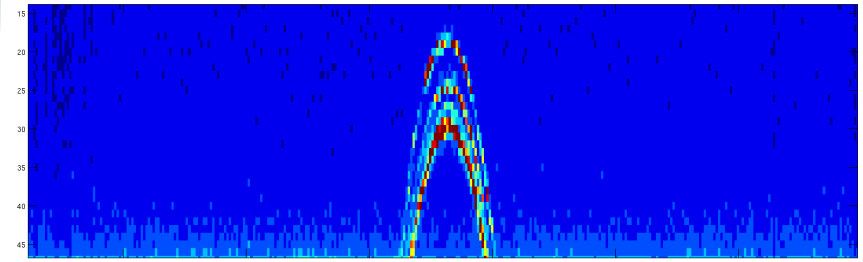
Rms Error:
17 cm SARAL
25 cm ENVISAT
40 cm ERS2

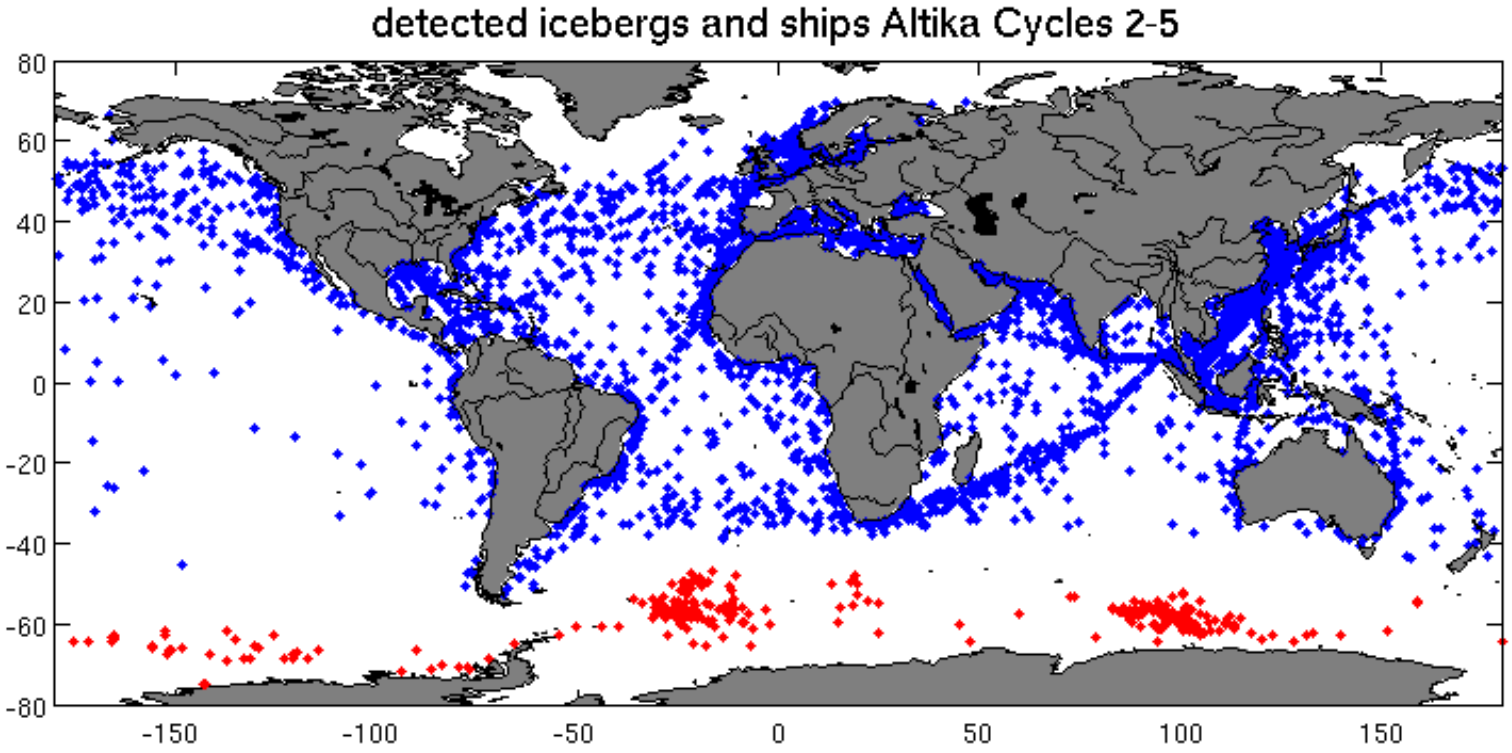
- AltiKa performs better than ENVISAT over rivers
- All the ENVISAT series can be extended
- Altika could become a new reference if
  - Stable groundtrack
  - Long duration (AltiKa-2 !)
- Major new feature : NRT



Icebergs and ships tracking with SARAL/AltiKa

J. Tournadre, LOS, IFREMER, Brest





Conclusions

- **System**
  - Excellent cooperation ISRO-CNES
  - All components of the SARAL/AltiKa system are working properly
  - Excellent stability of instruments so far
- **Data**
  - **Availability**
    - Easy !
    - Very high availability of data despite the feared effects of rain
    - Fast GDR distribution
  - **Quality**
    - All products data quality are inline with mission requirements
    - Similar to JASON-2 and sometimes better
  - **On going actions (CNES PEACHI):**
    - To further improve processing algorithms, including computation of SSB table, ice retracking algorithm, …
    - Some algorithms are still to be tuned: neural network used for radiometer data ground processing, Sea State Bias computation, altimeter wind speed and ICE2 retracking

in sankrit सरल saral means easy

- **First look from science PI's**
  - Some enthousiasm for these new/good data …
  - Easy to fit in operational systems
  - Improved (mesoscale) resolution in the open ocean: new opportunities
  - Improved access to the coastal ocean
  - Beyond the improved resolution, also new openings for ice sheet and continental waters
- **AltiKa and future directions**
  - Ka band innovations may bring some opportunities to understand Ku better
  - A step towards improved resolution … and preparation for SWOT
  - The new frontiers of altimetry are going to be open even more widely: coastal oceanography, cryosphere, hydrology, …


Thank you !