Validation of CryoSat-2 SAR and SARin modes over rivers for the SEOM/SHAPE project

May 10 2016, Prague, Czech Republic

– Living Planet Symposium 2016 –

Nicolas Bercher, Pierre Fabry (ALONG-TRACK)
Américo Ambrózio (DEIMOS/ESRIN)
Marco Restano (SERCO/ESRIN)
Jérôme Benveniste (ESA-ESRIN)

Contact : nbercher@along-track.com

ALONG-TRACK
.com

Objectives

Objectives the SHAPE project

- This work is part of SEOM S3-4SCI SAR Altimetry - Inland Water project.
- Project name : SHAPE : Sentinel-3 Hydrologic Altimetry Processor prototypE
- While waiting for S3 data : use CroSat-2 L1B data
- Geodetic orbit + calibration exercise @ GS => need to migrate along the river path migration : records -> GS location
- SHAPE : to address several ROI : first one is Amazon, others : Danube, Brahmaputra

Objectives

Objectives

- Validate CryoSat-2 data products over rivers :
  - SHAPE project's products (from CryoSat-2 and/or Sentinel-3A)
  - CryoSat-2 official Baselines (in the mean time)
- Quantify the benefit of SAR/SARin over LRM

Questions

- How to validate Products from non-repeat orbit missions like CryoSat-2 ?
- Rely on river profiles estimation : how to address intercalibration issue to derive porofile from other altimetry missions ?

Time series processing at ALONG-TRACK

Fully automated processing (updated on-demand) :
Uses **Water Mask** + **Curvilinear Abscissa**

Time series processing at ALONG-TRACK

Fully automated processing (updated on-demand) :
Uses **Water Mask** + **Curvilinear Abscissa**

1. Automated Virtual Stations detection

- *A priori* knowledge of track/river crossings useless
- Virtual Stations are gathered from the altimetry data

Time series processing at ALONG-TRACK

Fully automated processing (updated on-demand) :
Uses **Water Mask** + **Curvilinear Abscissa**

1. Automated Virtual Stations detection

- *A priori* knowledge of track/river crossings useless
- Virtual Stations are gathered from the altimetry data

2. Time series processing

- Close to that of HYSOPE (new HydroWeb)
- Automated rejection of poorly populated time series or isolated measurements
(Necessary for SARAL data due to orbit instability)

Time series processing at ALONG-TRACK

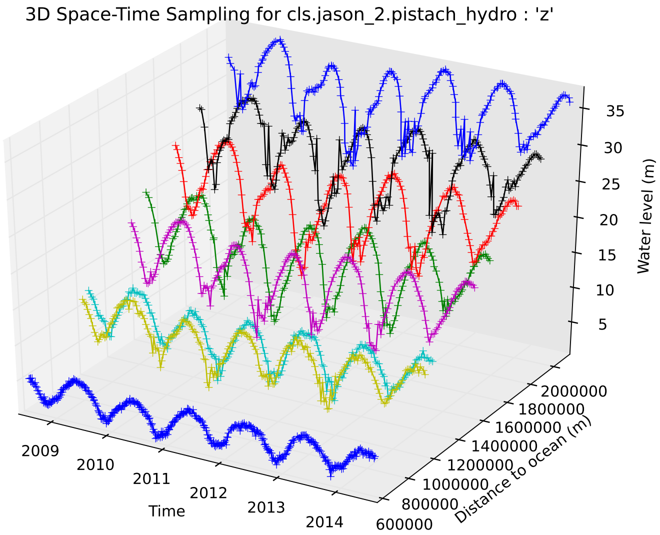
Fully automated processing (updated on-demand) :
Uses **Water Mask** + **Curvilinear Abscissa**

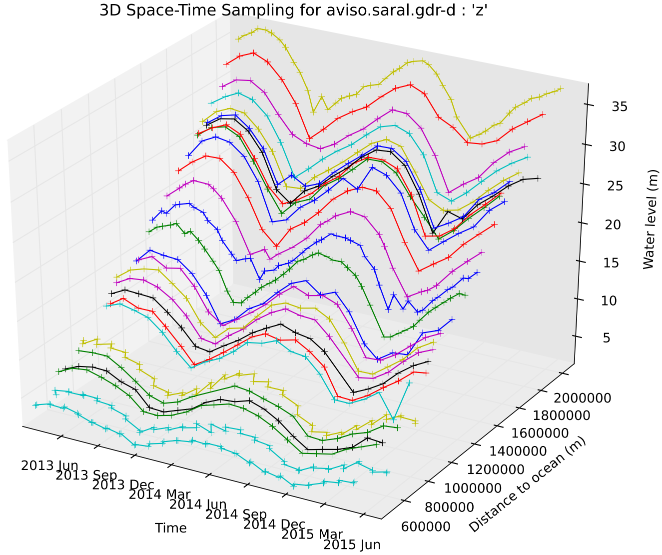
1. Automated Virtual Stations detection

- *A priori* knowledge of track/river crossings useless
- Virtual Stations are gathered from the altimetry data
- Would greatly benefit from regularly updated Water Masks

2. Time series processing

- Close to that of HYSOPE (new HydroWeb)
- Automated rejection of poorly populated time series or isolated measurements
  (Necessary for SARAL data due to orbit instability)


3D Space-Time Sampling for cls.jason_2.pistach_hydro : 'z'
Water level (m)
35
30
25
20
15
10
5
Time
2009
2010
2011
2012
2013
2014
Distance to ocean (m)
600000
800000
1000000
1200000
1400000
1600000
1800000
2000000


3D Space-Time Sampling for aviso.saral.gdr-d : 'z'
Water level (m)
35
30
25
20
15
10
5
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
Distance to ocean (m)
2013 Jun
2013 Sep
2013 Dec
2014 Mar
2014 Jun
2014 Sep
2014 Dec
2015 Mar
2015 Jun
Time

River Profile from repeat orbit missions (LRM)

River Profile

- Migration of CryoSat-2 data along river path requires River Profile (RP) to account for changing river slope
- In situ too sparse : not a sufficient to derive RP, also, we want to demonstrate the potential of altimetry alone

Data used

- River profile derived from multi-mission (LRM only !) (Jason-2/PISTACH + SARAL)
- Intercalibration required => common vertical reference

Intercalibration of repeat orbit missions (LRM)

- Intercalibration = common vertical reference
  (like an accurate river profile, static or seasonal)

Intercalibration of repeat orbit missions (LRM)

- Intercalibration = common vertical reference
  (like an accurate river profile, static or seasonal)
- But no such profiles database exist ot our knowledge

Intercalibration of repeat orbit missions (LRM)

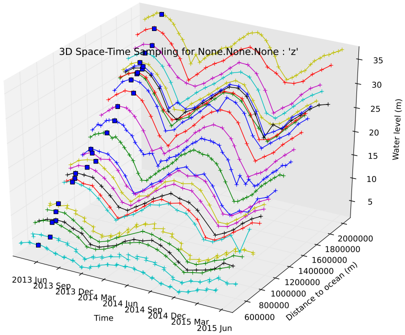
- Intercalibration = common vertical reference (like an accurate river profile, static or seasonal)
- But no such profiles database exist ot our knowledge

- We implemented a **simple approach** :
  Vertical reference = river profile from Jason-2/PISTACH **High Water Stage measurements**
  (Extensively validated : most accurate L2 product known to date [Bercher2012a])
- Calibration of SARAL w.r.t. Jason-2/PISTACH vertical reference
- Drawback : local systematic bias exist at Virtual Stations ($\neq$ retrackers, $\neq$ tuning, corrections, geoid models, etc.)

Calibration of SARAL into Jason-2/PISTACH

Calibration steps

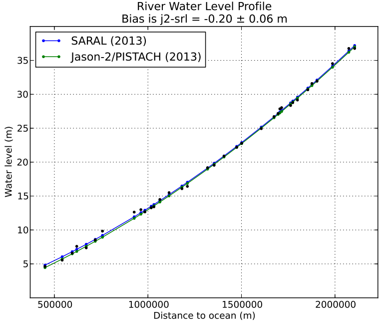
1. Automated detection of High Water Stage measurements



Calibration of SARAL into Jason-2/PISTACH

Calibration steps

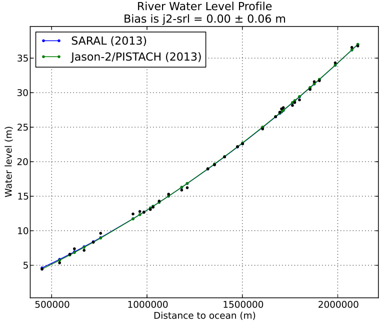
1. Automated detection of High Water Stage measurements
2. Profile interpolation using spline



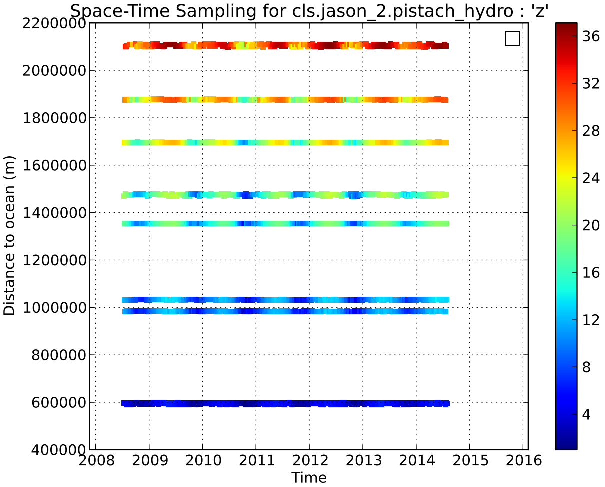
Calibration of SARAL into Jason-2/PISTACH

Calibration steps

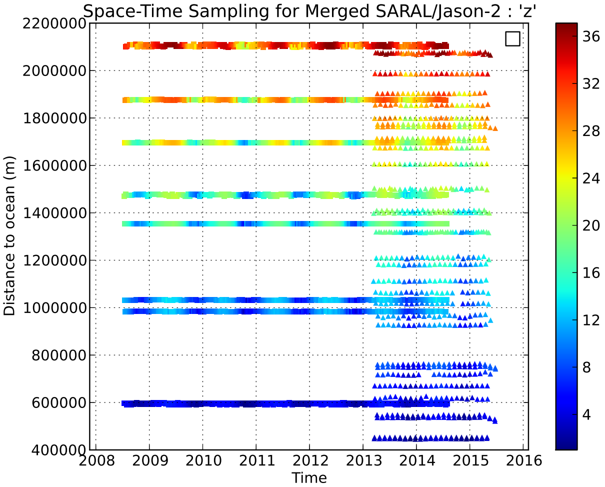
1. Automated detection of High Water Stage measurements
2. Profile interpolation using spline
3. Shift SARAL measurements vertically (bias=0.20 m)



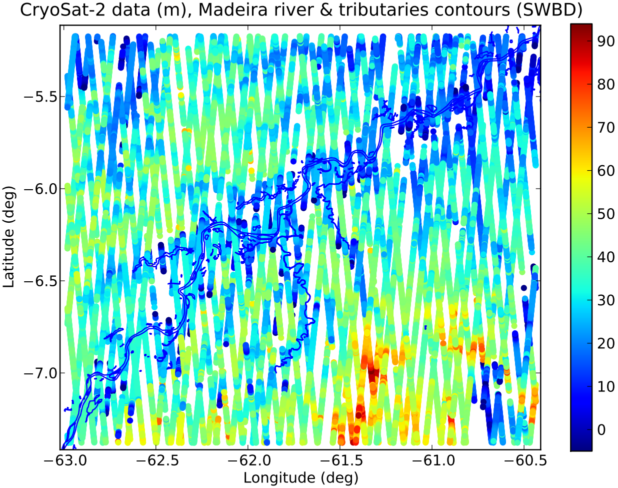
Intercalibration overview



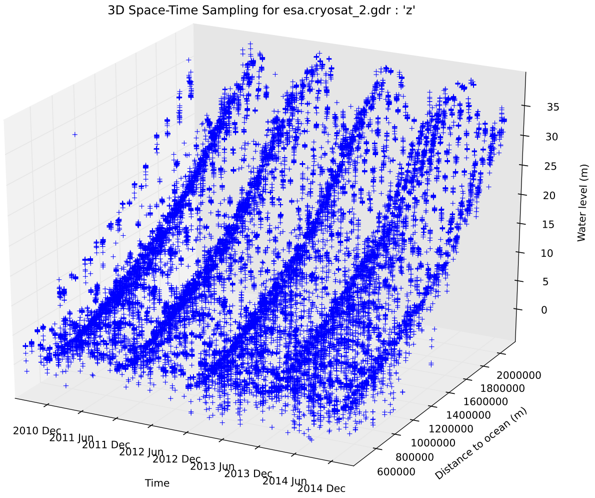
Intercalibration overview



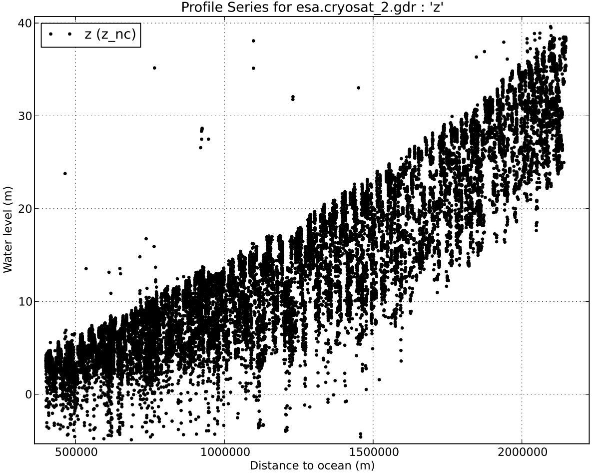
Map of CryoSat-2 measurements



CryoSat-2 measurements extracted within the Water Mask



Profile view of CryoSat-2 within the Water Mask



Migration CryoSat-2 meas. along the river path

We developed a technique to migrate measurements along the river path to derive "Pseudo Time Series" (PTS)
→ Usual filters/editing can be applied to each PTS.

Migration CryoSat-2 meas. along the river path

We developed a technique to migrate measurements along the river path to derive "Pseudo Time Series" (PTS)
$\rightarrow$ Usual filters/editing can be applied to each PTS.

Steps

- Derive a (simple) profile $p(x)$ from the Multi-Mission Product (SARAL + Jason-2 in our example)

Migration CryoSat-2 meas. along the river path

We developed a technique to migrate measurements along the river path to derive "Pseudo Time Series" (PTS)
$\rightarrow$ Usual filters/editing can be applied to each PTS.

Steps

- Derive a (simple) profile $p(x)$ from the Multi-Mission Product (SARAL + Jason-2 in our example)
- On a given point x_0 along the river path (x) :

Migration CryoSat-2 meas. along the river path

We developed a technique to migrate measurements along the river path to derive "Pseudo Time Series" (PTS)
$\rightarrow$ Usual filters/editing can be applied to each PTS.

Steps

- Derive a (simple) profile $p(x)$ from the Multi-Mission Product (SARAL + Jason-2 in our example)
- On a given point x_0 along the river path (x) :
  - Select CryoSat-2 meas. $Z(x)$, within range $x \in [x_0 - dx; x_0 + dx]$, dx being a user parameter

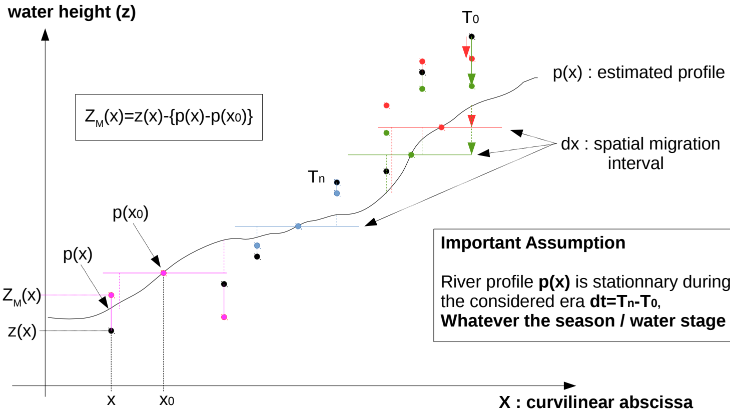
Migration CryoSat-2 meas. along the river path

We developed a technique to migrate measurements along the river path to derive "Pseudo Time Series" (PTS)
$\rightarrow$ Usual filters/editing can be applied to each PTS.

Steps

- Derive a (simple) profile $p(x)$ from the Multi-Mission Product (SARAL + Jason-2 in our example)
- On a given point x_0 along the river path (x) :
  - Select CryoSat-2 meas. $Z(x)$, within range $x \in [x_0 - dx; x_0 + dx]$, dx being a user parameter
  - For each meas., perform local migration $Z \rightarrow Z_M$: $Z_M(x) = Z(x) - (p(x) - p(x_0))$

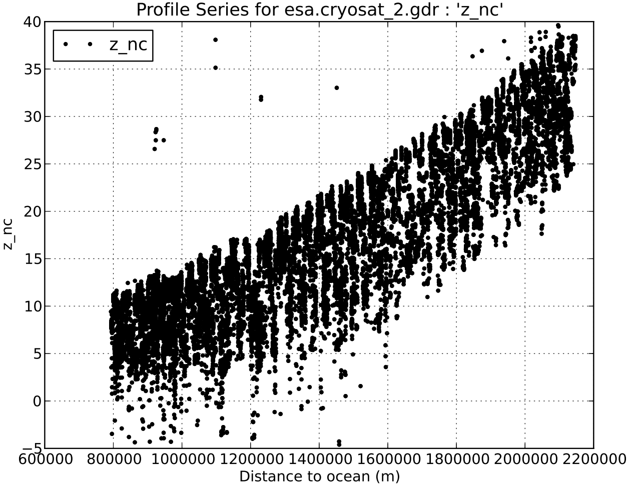
Spatial migration of spatio-temporal water heights from Level-2 geodesic orbit altimetry



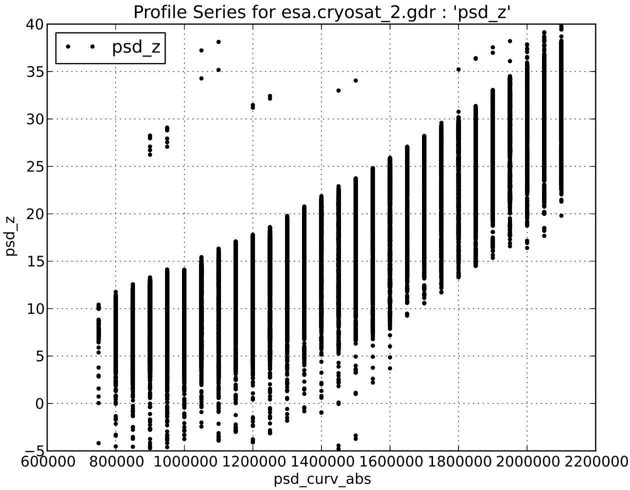
Important Assumption

River profile **p(x)** is stationnary during the considered era **$dt=T_n-T_0$**,
Whatever the season / water stage

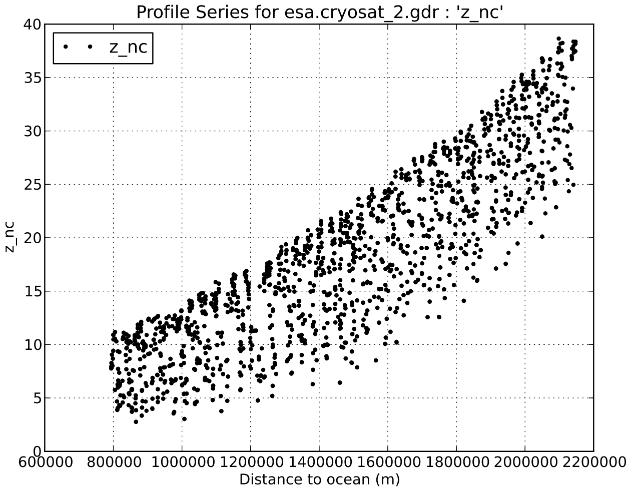
Profile view : filtered in time, before migration



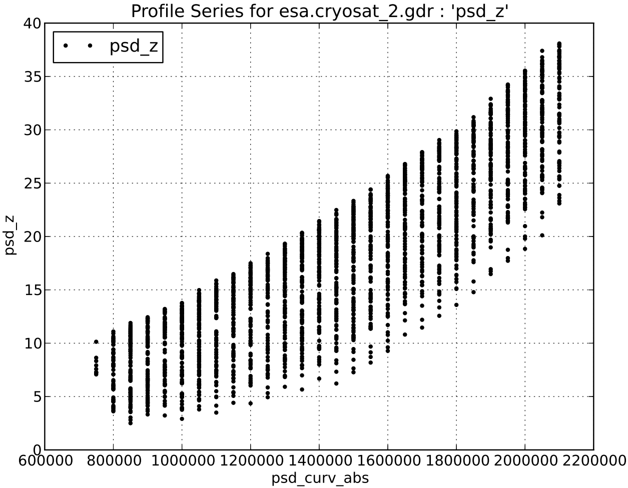
Profile view : filtered in time, after migration



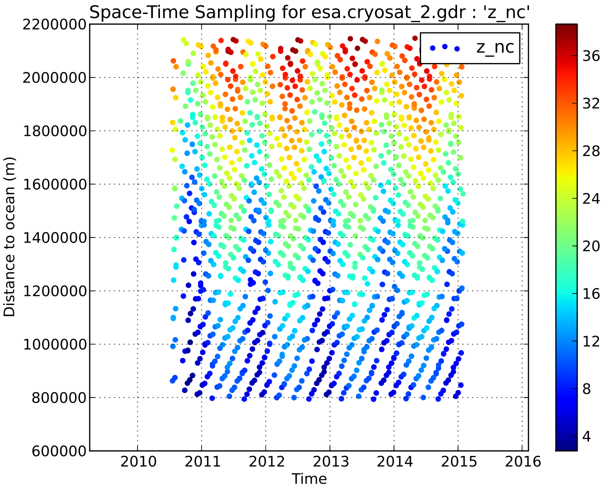
Profile view : filtered in time, before migration



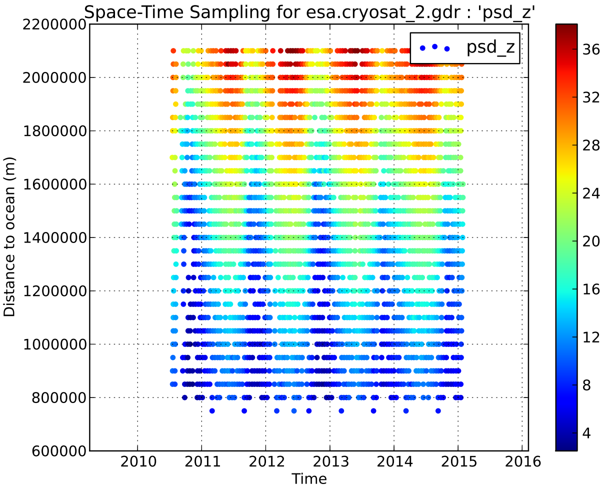
Profile view : filtered in time, after migration



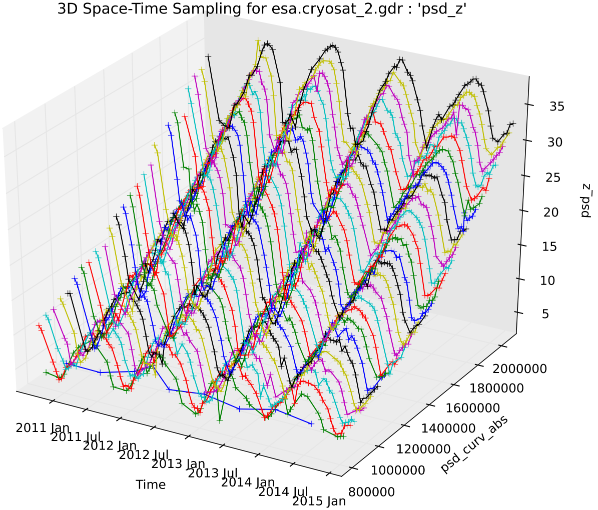
Space & time sampling : filtered in time, before migration



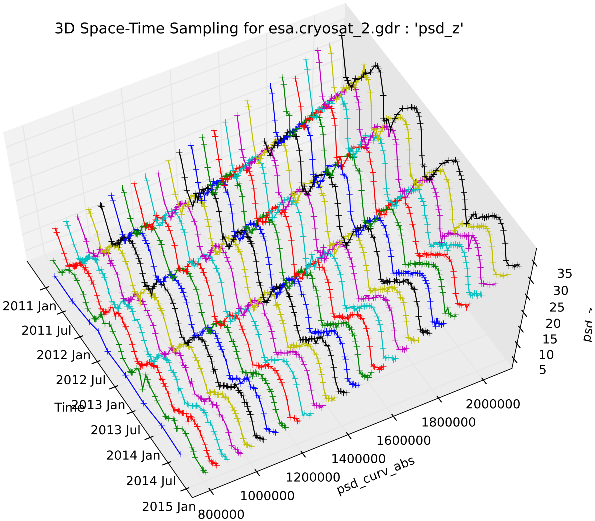
Space & time sampling : filtered in time, after migration



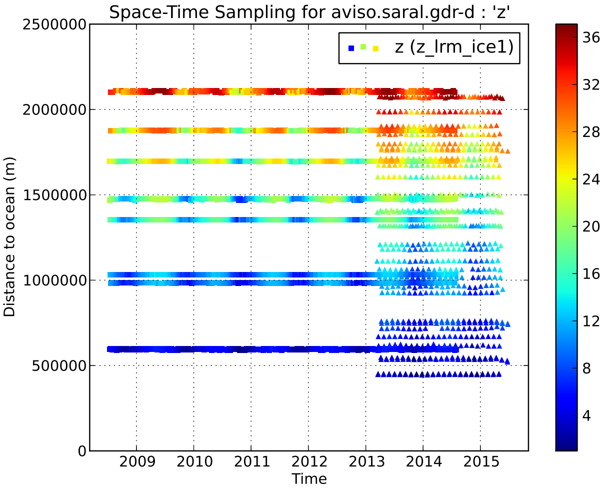
Space & time 3D, filtered in time, after migration



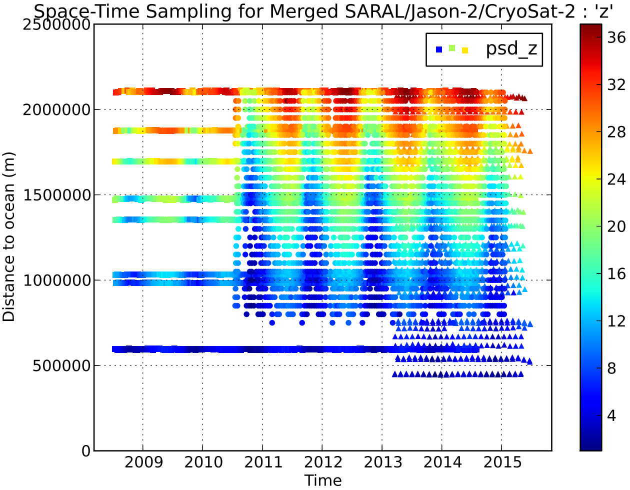
Space & time 3D, filtered in time, after migration



Jason-2 + SARAL



Jason-2 + SARAL + CryoSat-2 Migrated

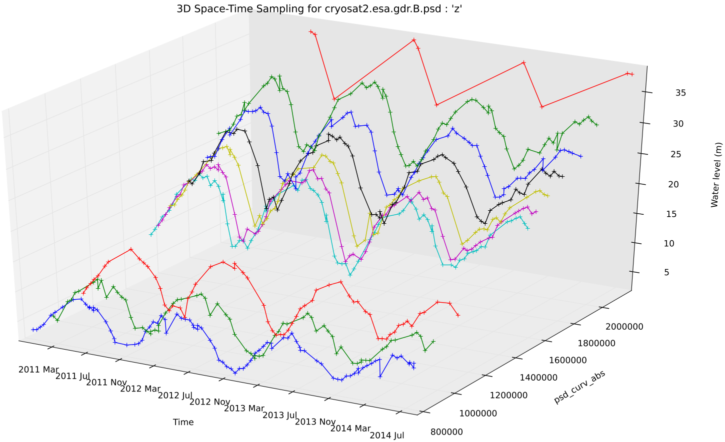


Validation of CryoSat-2 L2 Baseline B : Method

1. Validation over the Amazon river against in situ data (Using in situ data from ANA, Brazil)
2. Migration of CryoSat-2 data at Gauging Station (GS) locations
3. Space-time collocalisation-codating of time series
4. Error computation for each time series

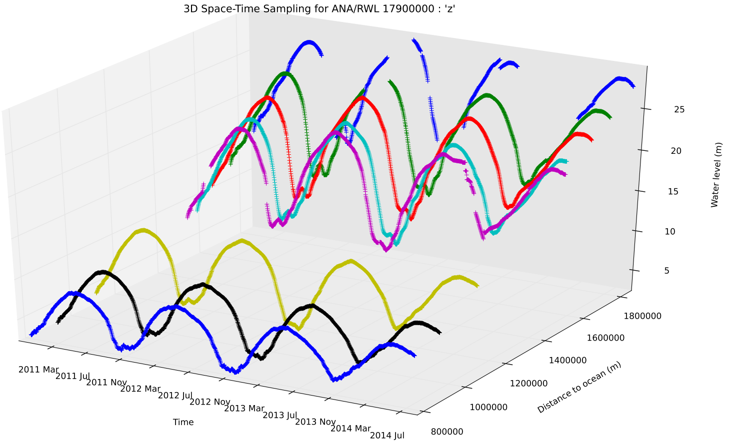
Migration of CryoSat-2 data at GS locations

CryoSat-2 Baseline B time series



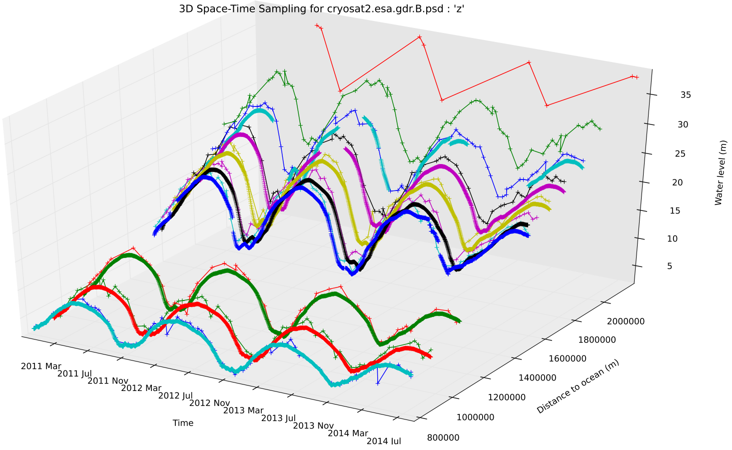
Migration of CryoSat-2 data at GS locations

Collocated-codated in situ time series



Migration of CryoSat-2 data at GS locations

CryoSat-2 & in situ time series



Validation Results

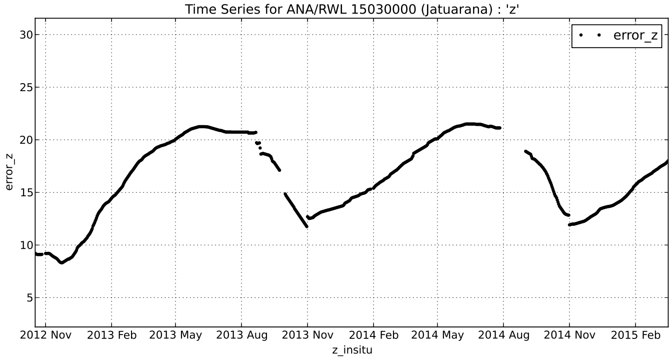
CryoSat-2 Baseline B validation results

Error RMS (m)

- PSD-Amazon-0793km : 0.6 m ($\mu = 0.1\ m \pm \sigma = 0.6\ m$)
- PSD-Amazon-0909km : 1.0 m ($\mu = 0.7\ m \pm \sigma = 0.7\ m$)
- PSD-Amazon-1084km : 0.8 m ($\mu = 0.7\ m \pm \sigma = 0.5\ m$)
- PSD-Amazon-1512km : 2.5 m ($\mu = 1.4\ m \pm \sigma = 2.0\ m$)
- PSD-Amazon-1558km : 1.7 m ($\mu = 1.6\ m \pm \sigma = 0.7\ m$)
- PSD-Amazon-1633km : 2.3 m ($\mu = 2.1\ m \pm \sigma = 1.0\ m$)
- PSD-Amazon-1723km : 3.1 m ($\mu = 3.0\ m \pm \sigma = 0.9\ m$)
- PSD-Amazon-1838km : 4.0 m ($\mu = 3.9\ m \pm \sigma = 0.8\ m$)
- PSD-Amazon-1957km : 4.5 m ($\mu = 4.3\ m \pm \sigma = 1.2\ m$)

Validation Analysis : error in in situ data

Large Errors can occur in in situ datasets, e.g., at Jatuarana (ANA station 15030000)



Conclusion

We developed a framework to perform CryoSat-2 validation over rivers :

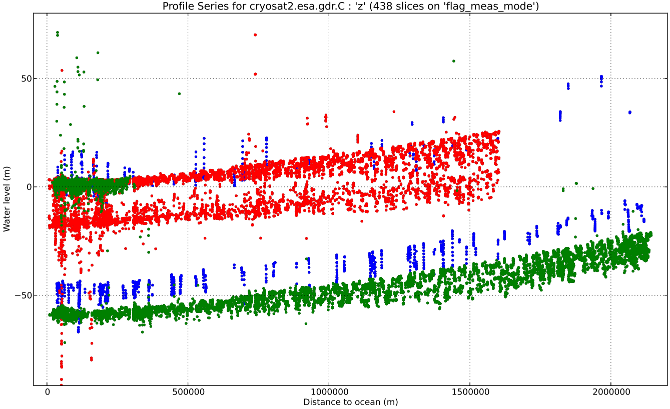
- **Migration of space-time spread data** along river path (i.e., from geodesic orbit)
  - Production of time series from repeat orbit missions (Jason-2/PISTACH, SARAL)
  - **Intercalibration** of repeat orbit missions
  - Estimation of simple river profiles (from LRM only !)
  - Filtering and editing of meas. from geodesic orbit missions
- Validation of CryoSat-2 ESA/L2/B against in situ data
  - Migration at **GS locations**
  - Collocalisation-Codating CryoSat-2 and in situ
  - Error computation **against in situ data** missions

Perspectives

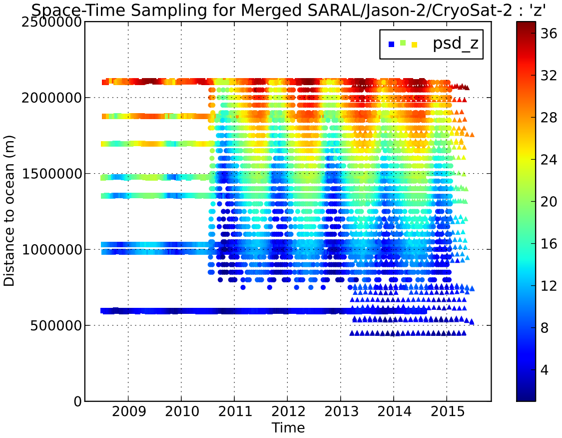
- Improve the river profiles estimation techniques
- Improve the use of the river profiles in the Migration
- Refine everything we can : each module can be improved in order to produce better products !
- Include in situ data
- And many more things. . . this is only the beginning !

About CryoSat-2 Baseline C

But... Baseline C/L2 to have troubles. . .



– Thank you ! –


Space-Time Sampling for Merged SARAL/Jason-2/CryoSat-2 : 'z'
psd_z
Distance to ocean (m)
Time
2500000
2000000
1500000
1000000
500000
0
2009
2010
2011
2012
2013
2014
2015
36
32
28
24
20
16
12
8
4