

SAR Altimetry in the Gulf of Bengal

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Content



- Motivation
- Region & altimetry + auxiliary data
- CryoSat-2 data processing
- Scientific Results:
 - Sea level SAR & PLRM, LRM vs models & in-situ
 - Seasonal, inter-annual variability, trends
- Outlook

SAR altimetry

Motivation

German Bight (SAR GPOD/PLRM SINC2)

□ SAR/DDA Observation: SSH, SWH, U10

Open ocean 1Hz (Fenoglio et al., AdSR 2015)

- Precision SAR : 0.9 cm, 6.6 cm, 6 cm/s (SWH@2m)
- Precision PLRM : factor 2 SSH, 1.4 SWH, 0.7 U10
- Accuracy 1Hz SAR : 7 cm, 14 cm, 1.3 m/s
- PLRM/SAR : No bias, STDD 3 cm, 20 cm, 0.27 m/s (SSH,SWH,U10)

Coastal zone 1Hz/20 Hz SSH

- Precision/accuracy SAR
- Precision/accuracy PLRM
- 0-10 Km SAR vrs PLRM
- 0-10 Km alti-model

- : as in open ocean
- : worse by a factor 2 vrs SAR
- : no bias, 26 cm, 0.80 (bias, STDD, slope)

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: STDD worse by factor 2 in PLRM

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| Conclusion and Outlook

Motivation

German Bight (SAR GPOD/PLRM SINC2)

Coastal Zone





Motivation |

I Results

Study area and Data

From Project Team:

C-2 SAR from ESRIN GPOD service (from FBR, Baseline B& C) C-2 PLRM from TU Darmstadt (from FBR, Baseline C) Wet Correction from UPorto (**GPD+**)

From Third-Party

Tide Gauges from University of Hawaii (hourly) Numerical Ocean Circulation Model from IWM (Institute of Water Modelling), year 2014 ECMWF wave and wind data (mars system) Ocean Tide Correction from **OSU TPXO8-ATLAS**

(http://volkov.oce.orst.edu/tides/tpxo8 atlas.html)

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MSS DTU13 and GEOID EGM 2008 Water/Land Mask from MODIS (250 m) Bathymetry from OSU TPXO8-ATLAS

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http://belmont-sealevel.org

| Conclusion and Outlook

SAR Processing FBR-> L1b

Method:





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SAR Processing L1b -> L2

- Echo not/weakly contaminated/not specular \rightarrow SAMOSA 2 (Ray et al. 2014)
- Echo contaminated (high misfit) → SAM+ (SAMOSA 2 with Mean Square Surface Slope (mss) as free parameter & SWH set to zero)
 - SAM+ mitigates contamination: First-Guess epoch is position of the correlation peak between 20 consecutive wf
- Look Up Table (LUT) in open ocean, constant α_p (0.55) in coastal zone







PLRM Processing

FBR -> L1b : Incoherent average of echoes (20 Hz data 64 individual echoes x 4)

- L1b -> L2 :
 - TALES : Sub-waveform ALES (Passaro et al., 2015) adapted for Cryosat-2 PLRM using SINC2 instead of BMLE3
 - STAR : Sub-waveform detection by conditional random field (tomorrow talk Uebbing- Instrument Processing)



SAR altimetry



Selection Criteria for Open Sea and Coastal Zone

□ 1Hz/20Hz:

- -15 m<SLA<15 m, -1.5m <SWH<15m
- Bathymetry > 2 m
- Distance to land >150 m
- No inland water data
- SLA referred to MSL
- □ 3 sigma criteria for STD of SLA for SAR & PLRM separately
 - Dabs(SLA namedian(SLA)) < 3 sigma(SLA)
 - For open ocean and coastal zero separately
 - For 1 Hz and 20 Hz data



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Selection of corrections : ocean tide

DIFF between TPX and CS-2 FBR otide correction



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Selection of corrections : wet trop



DIFF between GPD+ and CS-2 FBR wet correction



GPD+ - ECMWF variance reduction for 20Hz SAR data: 4.58 cm^2



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Study Area & Data

| Conclusion and Outlook

| PLRM & SAR Processing

I Results

SSHp

SLAp = all corrections, TXP ocean & GPD+ MSS DTU13

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SAR SSH – GEOID MAP





comparable contamination in SAR and PLRM

SSHp – EIGEN - bias



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Open Ocean 1 Hz - SAR vrs TALES

1 Hz

Scatterplots

20 Hz

SAR altimetry workshop



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Study Area & Data Coastal Zone 20 Hz - SAR SLAp vrs TALES SLAp EUMETSAT igg Scatterplots TECHNISCHE UNIVERSITAT DARMSTADT Scatter Coastal Zone PLRM SLAp vs. SAR SLAp % 100 Coastal Zone PLRM SLAp vs.SAR SLAp 1.5 100 90 90 80 80 70 70 0.5 CS2_SARP_SLA_1Hz [m] 60 60 50 50 Regression Slope: 0.993 40 Regression Slope: 0.968 40 -0.5 30 STDD: 0.178m STDD: 0.607m 30 Bias: 0.006m Bias: -0.030m 20 NP: 72312 20 NP: 2383 NP retained(%): 97.025 % NP retained(%): 3.197 % of 74529 10 of 74529 10 -1.5 -0.5 0 0.5 1.5 1.5 -1 1.5 -0.5 0 0.5 -1 CS2_PLRM_SLAp_20Hz [m] CS2_PLRM_SLAp_1Hz [m]

%



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| Conclusion and Outlook

Coastal Zone 20 Hz : altimetry vrs IWM

TALES





l Results

| Conclusion and Outlook



Coastal Zone 20 Hz : Standard Deviation of Differences

SLAp with all points common to SAR and PLRM/TALES

	Area	SAR STDD	TALES STDD	Npoints
SAR – PLRM	Open Ocean 1Hz		0.048	9702
SAR – PLRM	Open Ocean 20Hz		0.118	325715
SAR - PLRM	Coastal 20Hz		0.607	72312
with – IWM	Coastal 20Hz	0.693 (- 0.523)*	0.817, (- 0.546)*	11557

higher for SAR

Agreement with IWM: * : Bias

SAR altimetry

l Results

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Coastal Zone 20 Hz : Standard Deviation of Differences

10% less point in STAR compare IWM

	Area	SAR	TALES STDD	STAR STDD	Number of Points	Number			
SAR – PLRM	Open Ocean 1Hz		0.048	0.052	9689	9702			
SAR – PLRM	Open Ocean 20Hz		0.126	0.108	358275	325715			
SAR - PLRM	Coastal 20Hz		0.509	0.385	63922	72312			
with – IWM	Coastal 20Hz	0.624 (- 0.523)	0.709 <i>,</i> (- 0.546)	0.470 (-0.564)	10160	11557			
Agreement with SAR: higher in STAR than in TALES									

Agreement with IWM:

higher in STAR, then SAR, worse in TALES

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COASTAL ZONE : SAR vrs Models





| Conclusion and Outlook

SLA vs. Distance to coast after 3-sigma criterium





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Altimetry and tide gauges



Possible effect of Data quality and sampling



Motivation | Study Area & Data

ata | PLRM & SAR Processing

I Results

| Conclusion and Outlook

Seasonal, interannual and long-trend variability





SSHp - EIGEN

D2c > = 10 Km

150 m < D2c < 10 km

Larger amplitude near coast Same patterns Motivation |

Study Area & Data | PLRM & SAR Processing I Results

| Conclusion and Outlook

Seasonal, interannual and long-trend variability



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D2c > = 10 Km

150 m < D2c < 10 km

Larger amplitude near coast Same patterns Event in August 2014 in open zone and no coast 26





Motivation |

Study Area & Data | PLRM & SAR Processing I Results

| Conclusion and Outlook

Seasonal, interannual and long-trend variability



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D2c > = 10 Km

150 m < D2c < 10 km

Larger amplitude near coast Same patterns Event in August 2014 in open zone and no coast 27





Study Area & Data | PLRM & SAR Processing Motivation |

I Results

| Conclusion and Outlook

Seasonal, interannual and long-trend of SWH



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SWH

150 m < D2c < 10 km

Bias wrt model& PLRM in SAR



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a | PLRM & SAR Processing

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Seasonal, interannual and long-trend of SWH



Date

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STD(SWH)

D2c > = 10 Km

150 m < D2c < 10 km

Lower for model, SAR and PLRM



Motivation | Study Area & Data | PLRM & SAR Processing | Results

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Seasonal, interannual and long-trend of wind speed



STD(U10)

D2c > = 10 Km

150 m < D2c < 10 km

Larger amplitude near coast Same patterns Event in August 2014 in open zone and no coast



01 2015

07 2015

01 2016

07 2016

07 2014

Date

01 2014

01 2012

07 2012

01 2013

07 2013

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Conclusions

- Open ocean: consistency PLRM & SAR ocean SSH (3 y)
 - No relative bias, SSH STDD 4-5 cm (was 3 cm in GB)
 - No relative bias, SWH **STDD 18 cm** (was 20 cm in GB)
- Coastal zone SSH/SLA: PLRM & SAR (3 y, 1 y model)
 - 150m-10 Km SAR/PLRM SSH : STDD 60 cm/40 cm
 - GPD+ (4-5 cm2 reduction), TPXmodel relevant (20 cm)
 - Better agreement SAR with model near coast (STDD)
- Coastal zone SWH: bias in SAR wrt PLRM&Model
 - 150m-10 Km SAR/PLRM SWH: STDD 110 cm
- Accuracy (in-situ validation):
 - 1Hz 10-20 : STD=40 cm (higher as in GB)
- Climatic Signal :
 - Monthly sea level better agreement of SAR with model, STDD smaller, geographical patterns reproduced

SAR Processing L1b -> L2

SAM+ Retracker to mitigate land contamination: First-Guess epoch (retracker initialization) is the position of the correlation peak between 20 consecutive waveforms



I Results | Conclusion and Outlook







STD_SLA(Dist)_finemodel(tpxtide).jpg La Rocheile – France – 31 Oct. 2016