# A new proposal for SSB modelling with three parameters exclusively derived from altimetric data

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# Outline

# Introduction

## Sea State Bias (SSB)

- Geophysical altimetric correction caused by the influence of local sea-state in the altimetric radar pulse
- SSB = Electromagnetic Bias + Skewness Bias + Tracker Bias
- Centimeter-scale measurement (≈30cm) remains as one of the largest source of uncertainty of the altimetric signal

## Motivation

- Development of a new global and multi-mission SSB model based on parameters solely derived from altimetric data
- Regional studies of SSB for different sea state regimes. Planned to implement in the forthcoming missions.

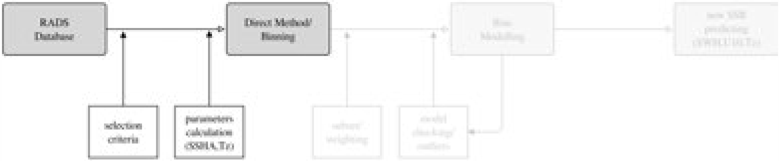
# Background information

- The usual estimates of SSB are obtained using empirical models derived from analysis of altimeter data
- Parametric, nonparametric and hybrid models
- 2D SSB: Significant Wave Height (SWH), Wind Speed (WS) [Gaspar et al., 2002; Scharroo and Lillibridge, 2005]
- 3$^{rd}$ predictor: Mean Wave Period (Tm) from WW3 [Tran et al., 2010]

# Background information

- Approaches to retrieve wave period information (Tz), 2 algorithms tested:
  - G03 (SWH, $\sigma^0_{Ku}$) [Gommenginger et al., 2003]
  - Q04 (SWH, $\sigma^0_{Ku}$, $\sigma^0_C$) [Quilfen et al., 2004]
- Direct Method [Vandemark et al., 2002]
  - SWH and WS binning of SSHA
  - Good and reliable SSB estimation
- Generalized Additive Models with Smoothing Splines
  - Flexibility, ease of implementation, computational requirements, extensibility and accuracy results
  - $y_i = \beta_0 + f_1(x_{i1}) + f_2(x_{i2}) + \ldots + f_p(x_{ip}) + \epsilon_i$

# Model design




1. Data extraction, limits and criteria
2. Ocean wave period estimation and analysis
3. SSHA ≈ SSB estimation with Direct Method
4. Model selection, checking and outliers removal
5. New SSB UPT predictions

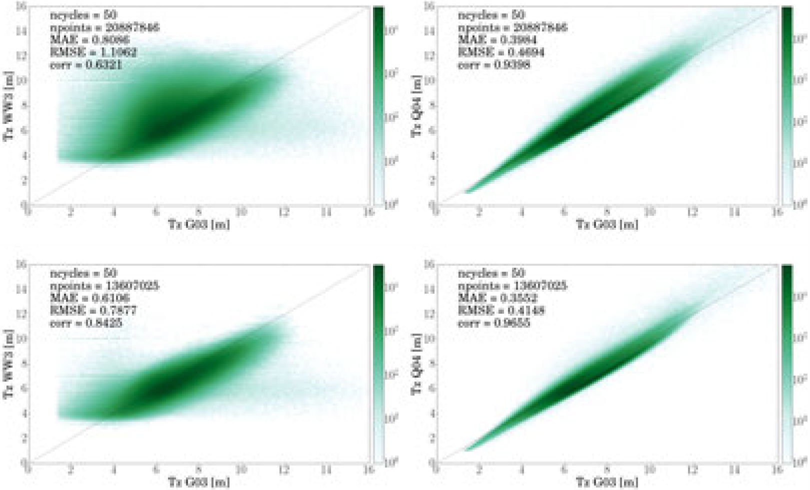
# Ocean wave period analysis

- Algorithms G03 and Q04 were selected due to their simplicity, ease of implementation and good agreement when compared with buoy measurements

- Mean Wave Period $T_z = \sqrt{m_0/m_2}$ using the wave spectral moments of WAVEWATCH 3 obtained from RADS

- Swell Ratio (SR): $(Swell\_Height/SWH_{WW3}) < 0.9$

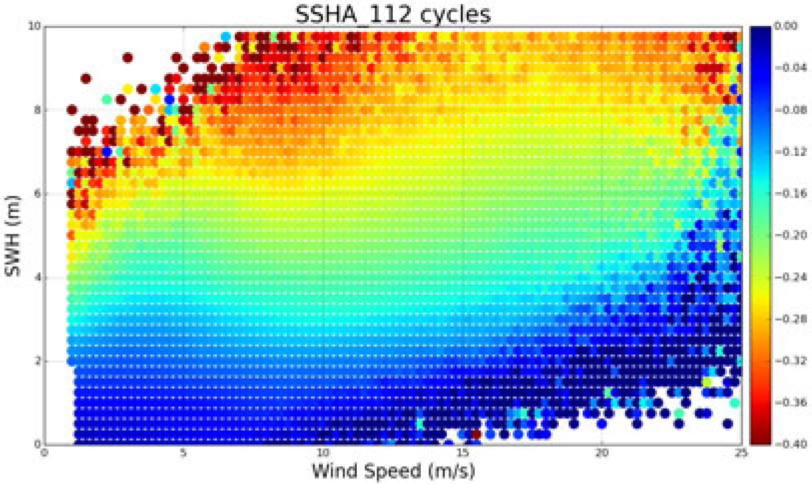
# Ocean wave period analysis: SR $<$ 0.9



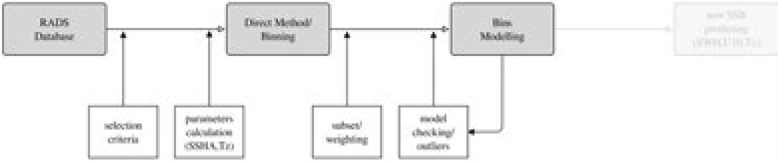
# SSHA estimation with Direct Method

- SSH uncorrected for SSB binned against WS and SWH
- $SSHA(WS, SWH)_{bin} = \langle (SSH - MSS) \rangle_{bin}$
- 2 MSS used: DTU10 and DTU13
- Bins width of 0.25 m/s in WS and 0.25 m in SWH
- Large noise in the extremes of the SSHA domain for high SWH and WS values decreasing with the number of cycles involved in the binning estimation

# SSHA estimation with Direct Method



# Model design

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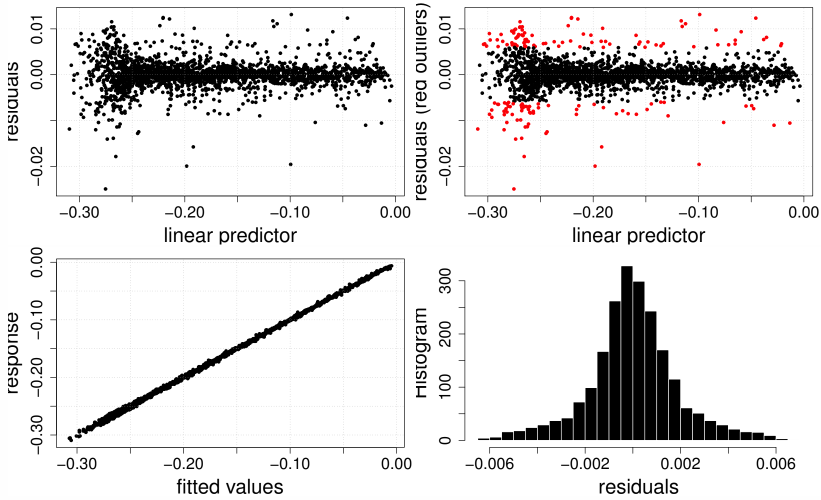
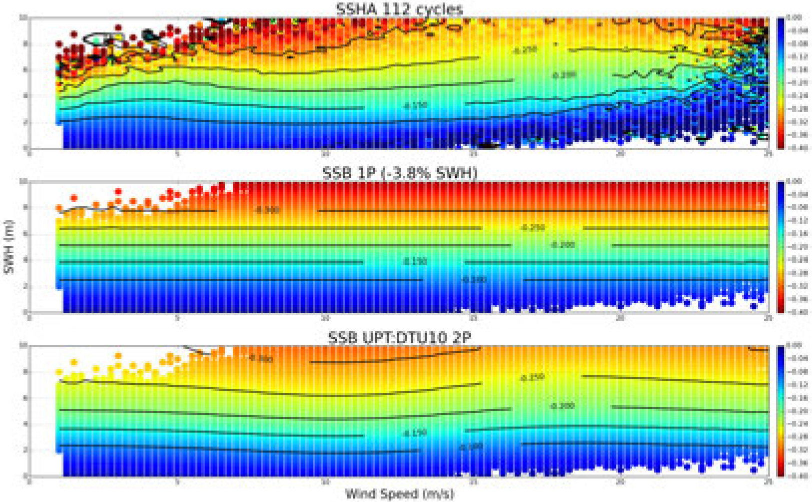
# SSB modeling with smoothing splines and GAMs

- Training dataset estimated for the first 3 years of Jason-1 (112 cycles)
- Careful selection criteria for bins validation and weighting
- Outliers removal based on residual analysis
- 2 approaches considered:
  - $SSB_i = \beta_0 + f_1(SWH_i) + f_2(U10_i)$
  - $SSB_i = \beta_0 + f_1(SWH_i) + f_2(U10_i) + f_3\left(SWH_i, \sigma^0_{Ku}\right)$

# SSB modeling with smoothing splines and GAMs



# SSB modeled: Training dataset (cycle 001-112)



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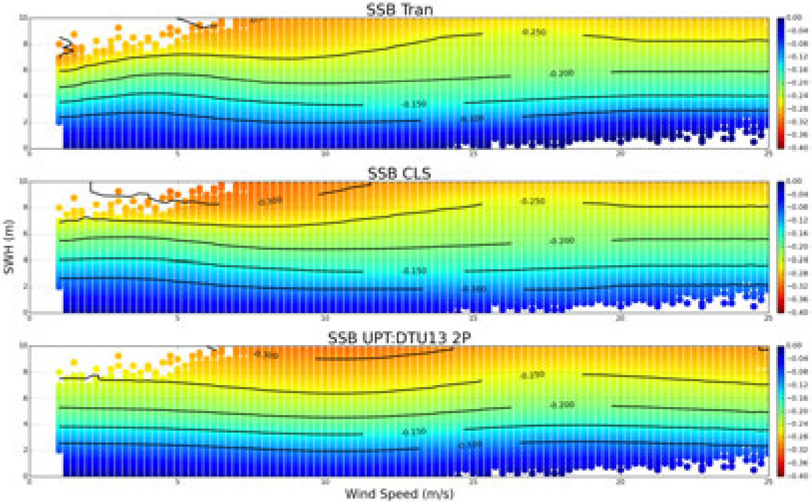
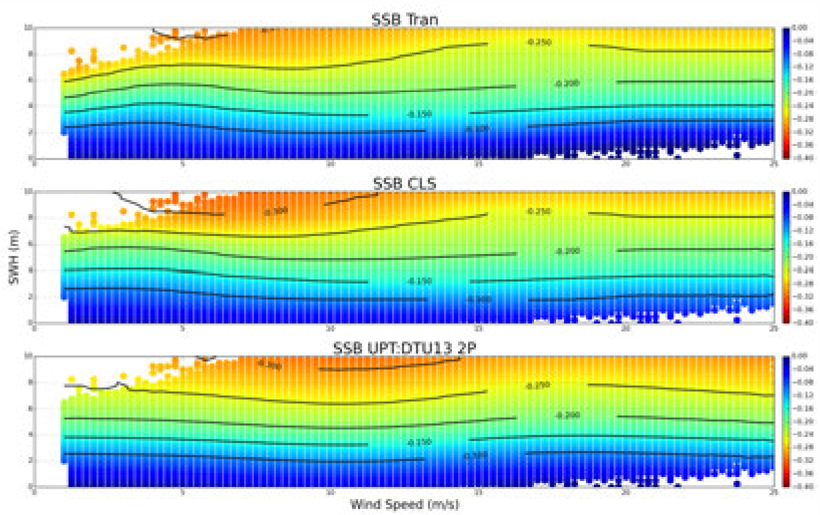


# SSB modeled: Outside dataset (cycle 150-250)



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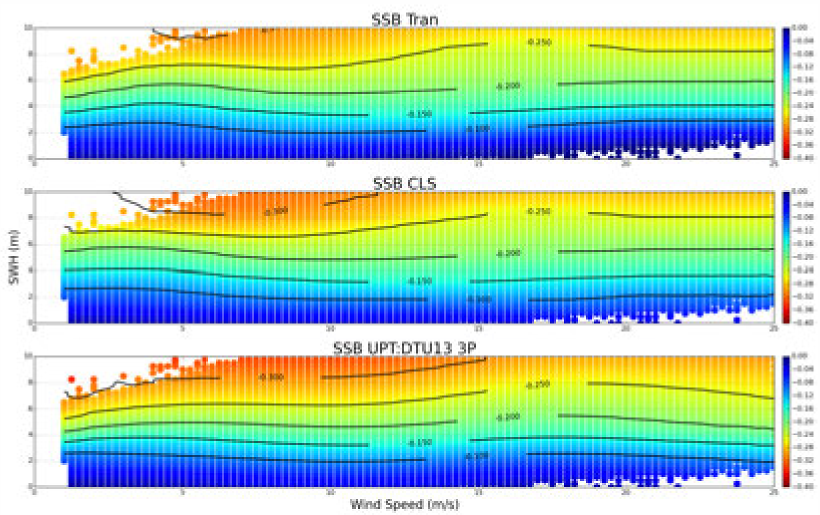

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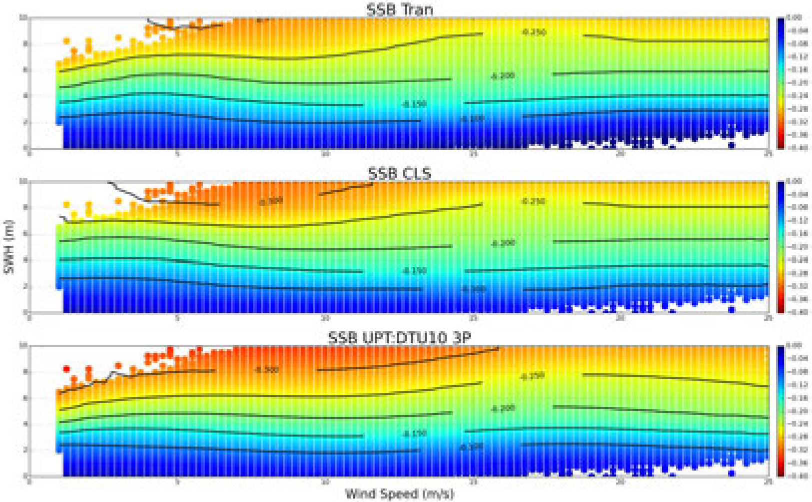
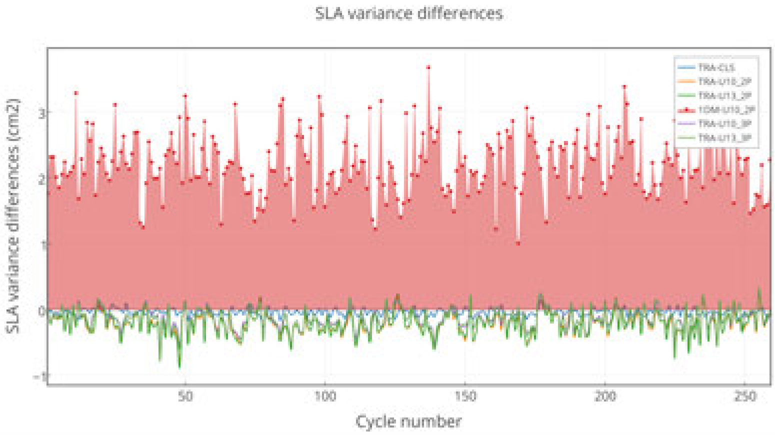


# Summary Statistics for 260 cycles (Jason-1 Phase-A)

| SSB model | mean | std | min | max |
|---|---|---|---|---|
| SSB 1P | -0.0996 | 0.0504 | -0.380 | 0.000 |
| SSB CLS | -0.1115 | 0.0474 | -0.321 | -0.004 |
| SSB Tran | -0.1069 | 0.0467 | -0.309 | 0.037 |
| SSB UPT:DTU10 | -0.1148 | 0.0497 | -0.356 | -0.019 |
| SSB UPT:DTU13 | -0.1087 | 0.0510 | -0.348 | -0.012 |

# SLA variance analysis by cycle



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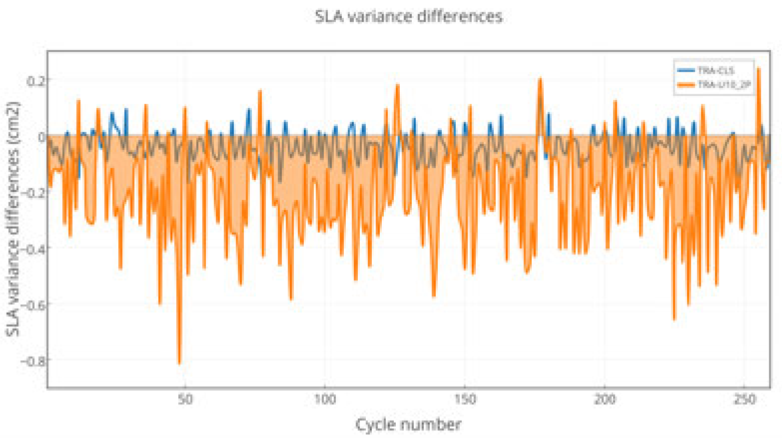

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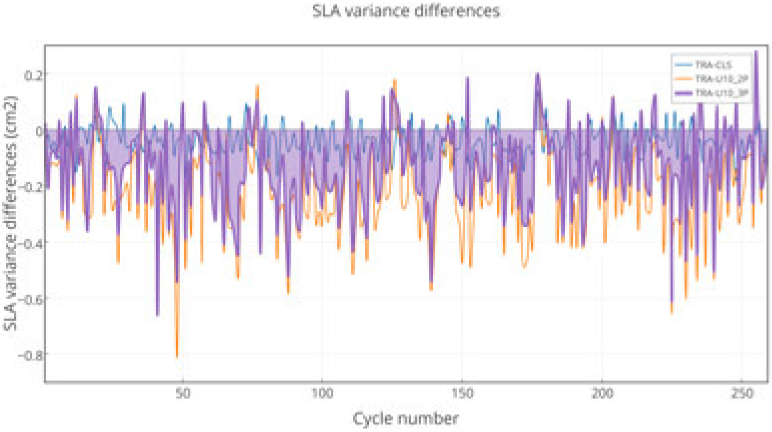

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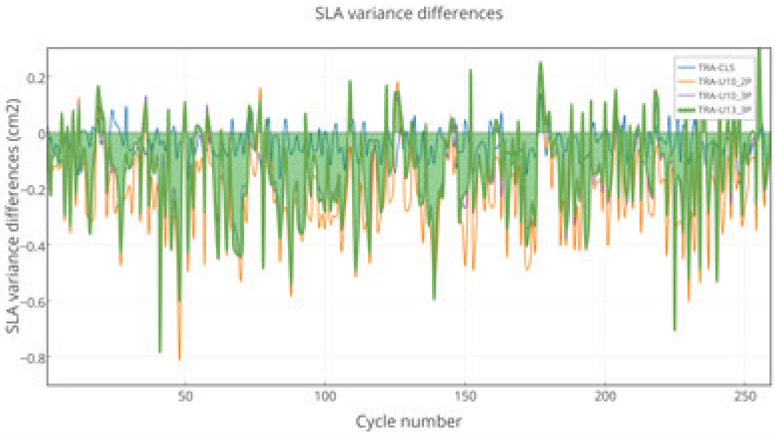
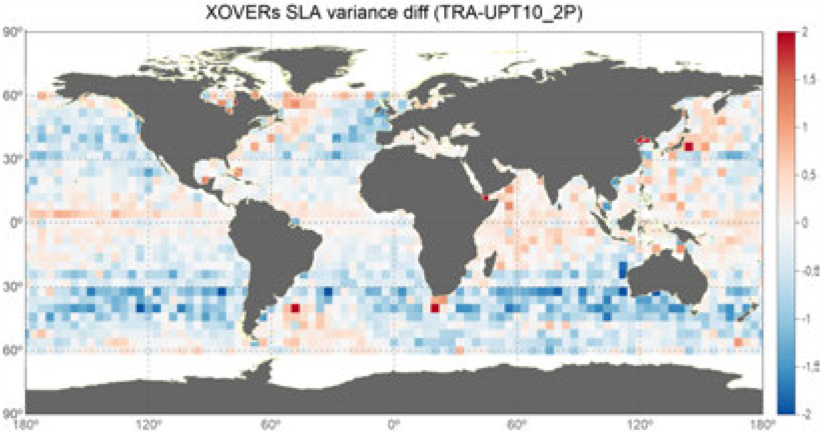


# Spatial analysis of SLA variance



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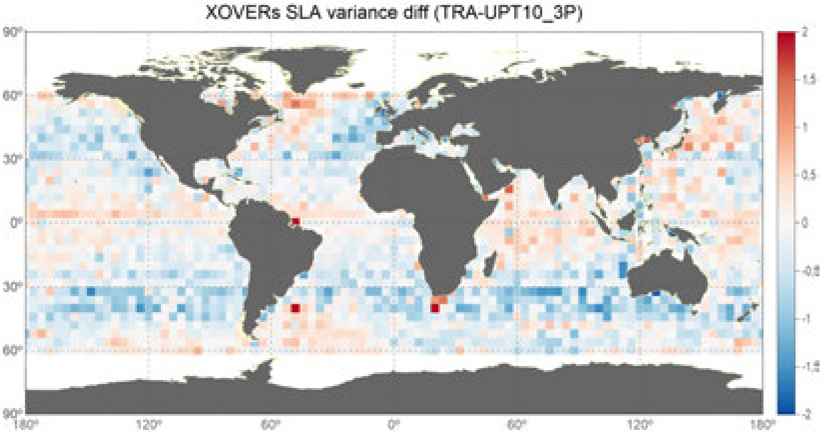

# Conclusions and future work

- This is a study in progress
- Reliable model easy to handle and control, flexible enough to be adapted in other missions
- Other Tz derived methods should be tested in the future
- Model design can be improved with additional predictors, fine tunning and calibration methods
- Push to the limit with smaller training datasets
- Regional studies for different sea state regimes and altimeter ocean observations from other sensors