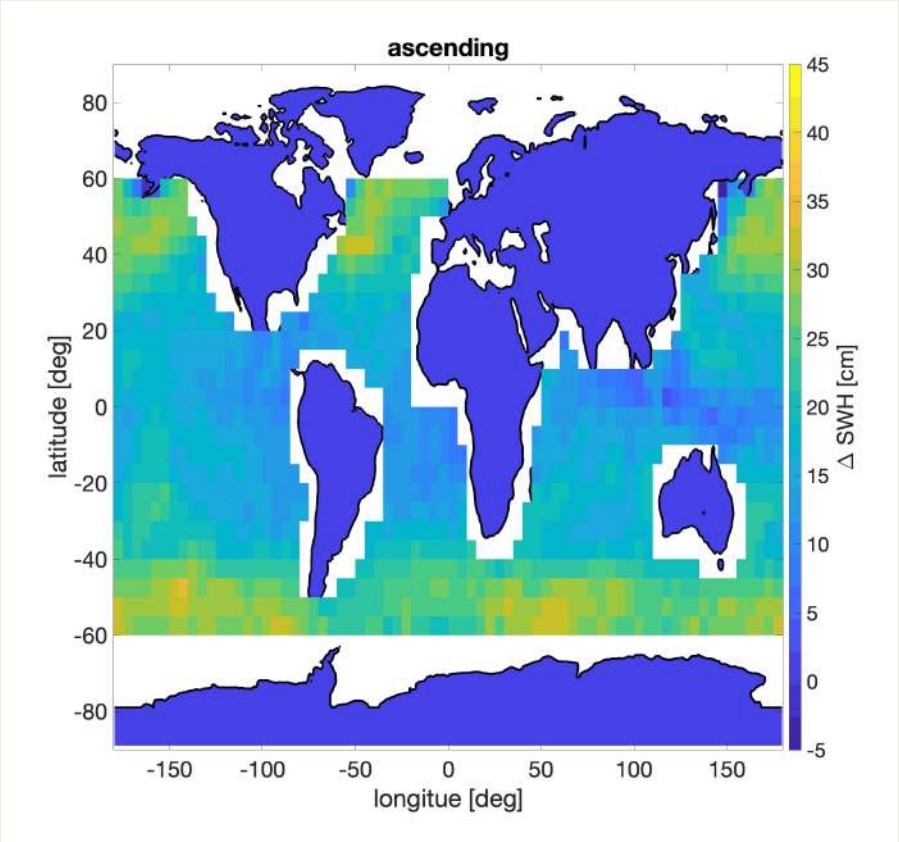
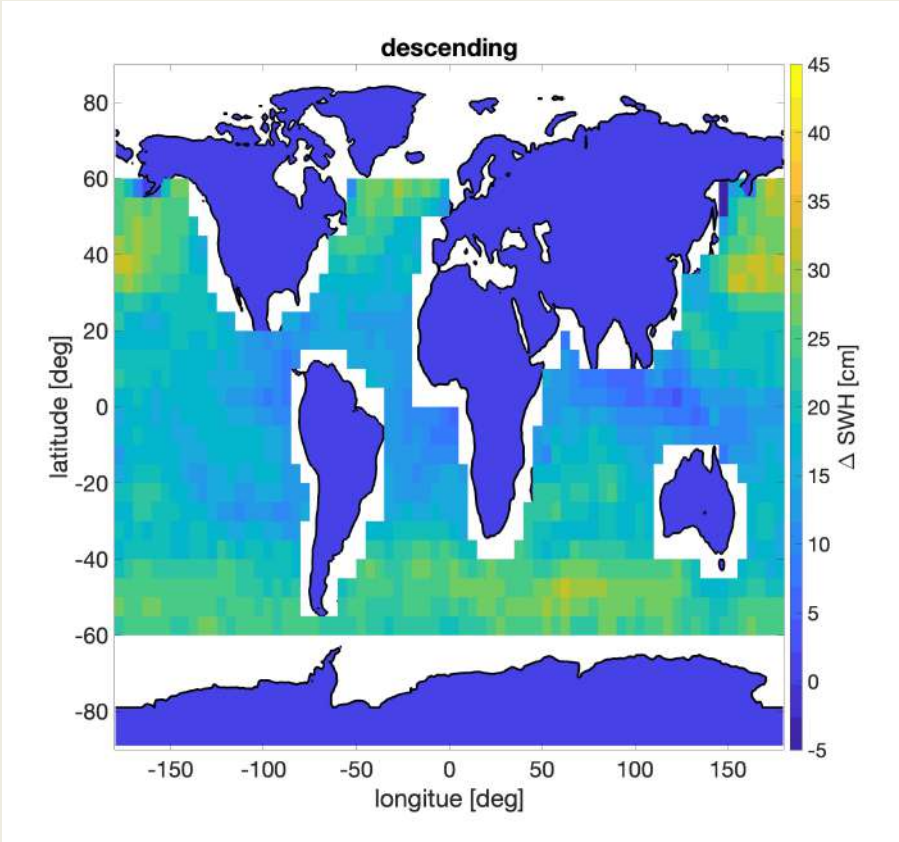
Vertical and Horizontal Wave Velocities and Their Impact on Sentinel-3 Measurements – An Overview

Christopher K. Buchhaupt, ESSIC/UMD/NOAA
Alejandro Egido, ESTEC
Walter H. F. Smith, NOAA
Doug Vandemark, UNH
Luciana Fenoglio, University of Bonn
Eric Leuliette, NOAA

7th Sentinel-3 Validation Team Meeting • 18-20 October 2022

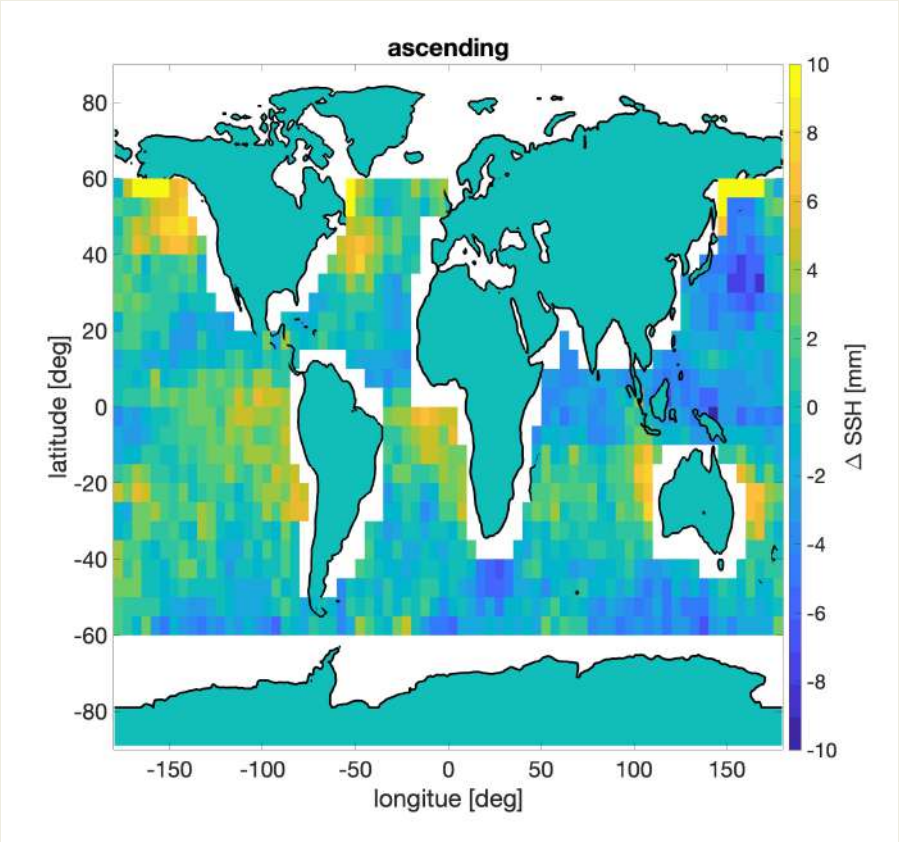
Motivation: SWH Inconsistencies





HR – LR SWH estimates. LR retracker is SINC2 STD. HR retracker is SINCS STD.
Left: Ascending tracks. Right: Descending tracks.

Motivation: SSH Inconsistencies



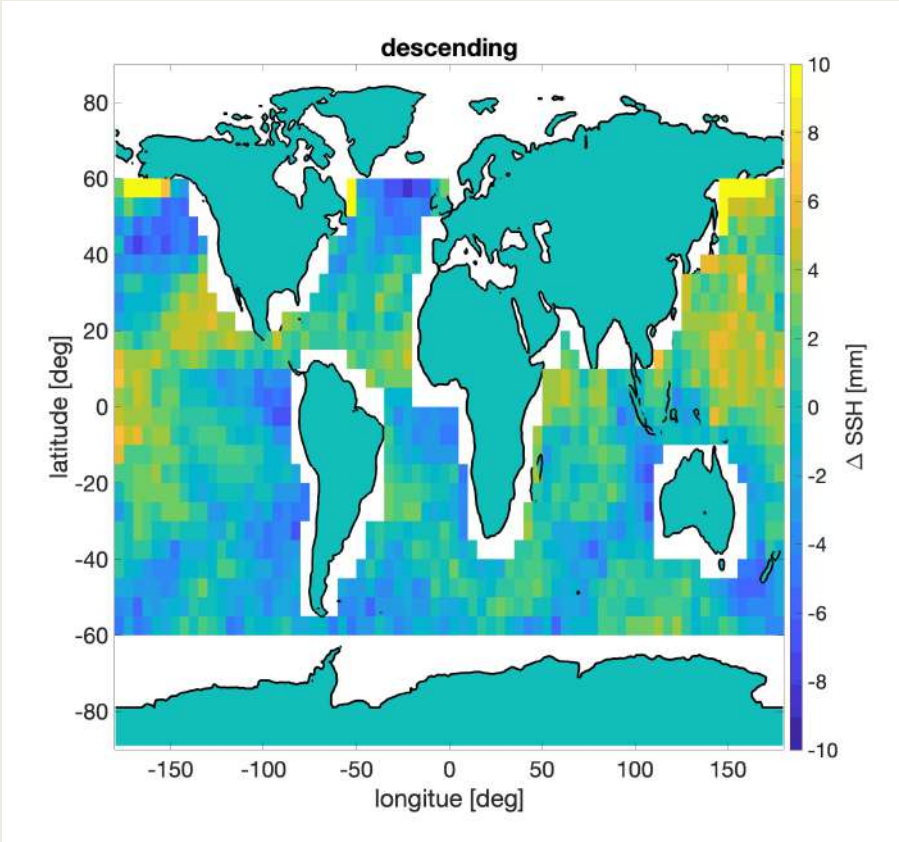


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Table of Content

Introduction

- LR signals sampled w.r.t. range (epoch) and pulse-to-pulse-time (slow-time)
  - Incoherent processing with integration time of pulse width
  - Signal stable w.r.t slow-time
  - Retracking only focuses on fitting power within range samples

- HR signals sampled w.r.t. range (epoch) and relative velocity between scatterer and platform (azimuth)
  - Coherent processing with integration time of burst length
  - State-of-the-art focuses on fitting power in range samples
  - Sensitive to velocities occurring on the sea surface -> inconsistencies

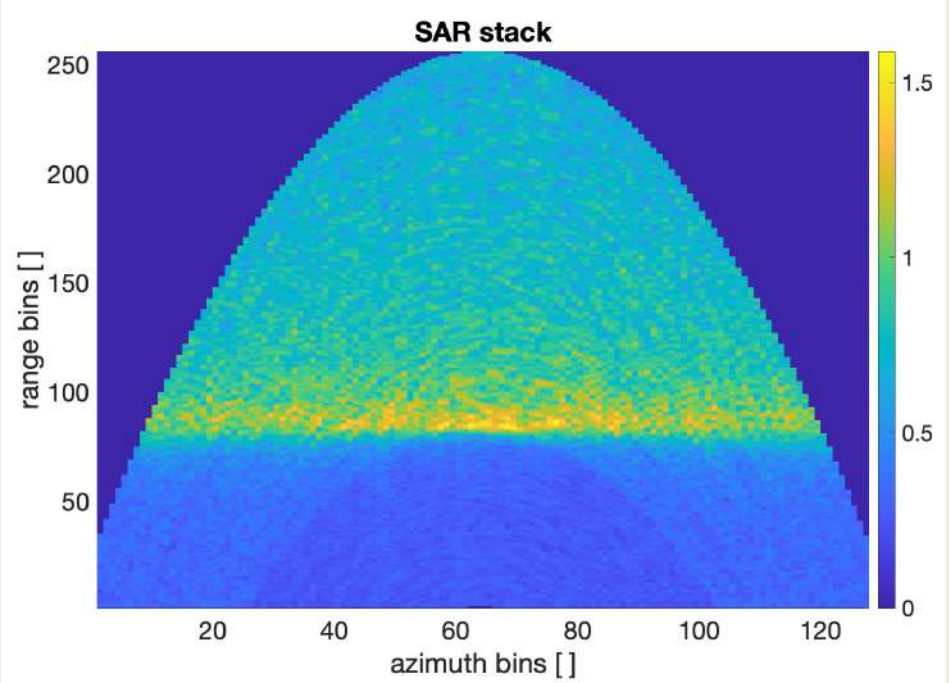
Introduction

- Vertical wave particle velocities (VWPV)
  - Random VWPV causes azimuth blurring effect
  - Mean VWPV at given incidence causes Doppler frequency scaling

- Horizontal velocities
  - Caused by currents, wind induced movement and swell
  - Random part neglectable
  - Acts like a Doppler frequency scaling

Introduction

- Idea: Use of Doppler information given in stack
- Estimated parameters
  - Wind speed
  - SSH
  - SWH = $4\sigma_z$
  - VWPV variation σ_v
  - Along-track surface velocity u_x
- Aim: Minimization of LR-HR inconsistencies



Note: Stack retracking requires handling of exponential distributed sample noise.
Here we transform it towards a symmetric Weibull distributed. This is further called ZSK.

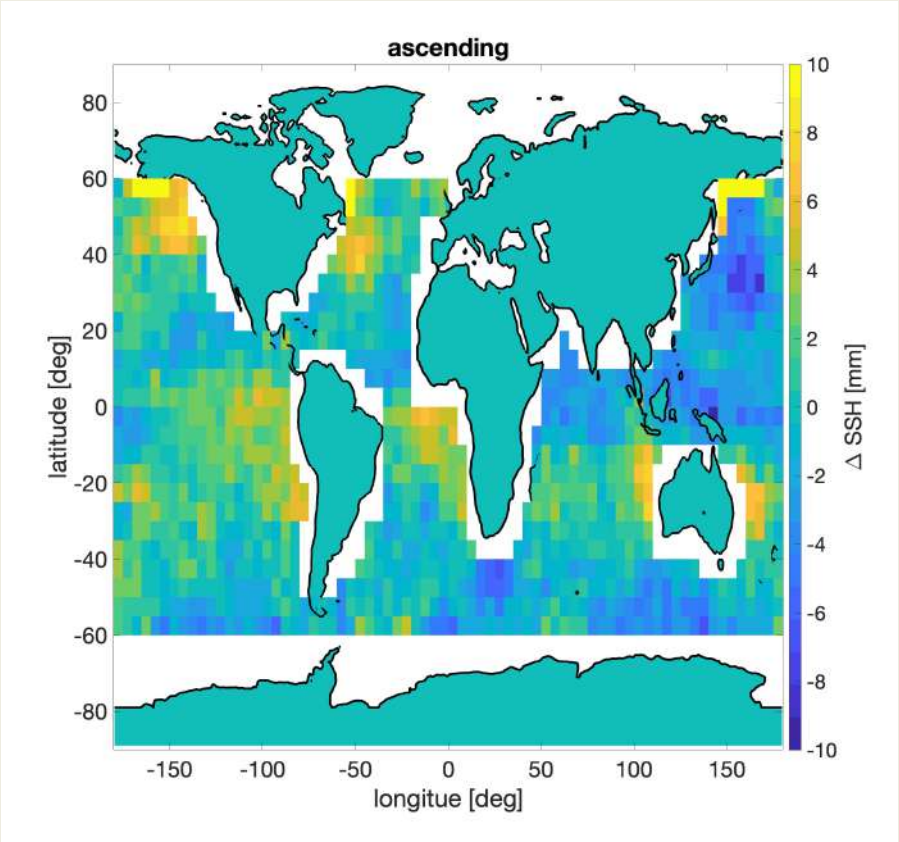
Sentinel-3A Cycle 81 Global Analyses

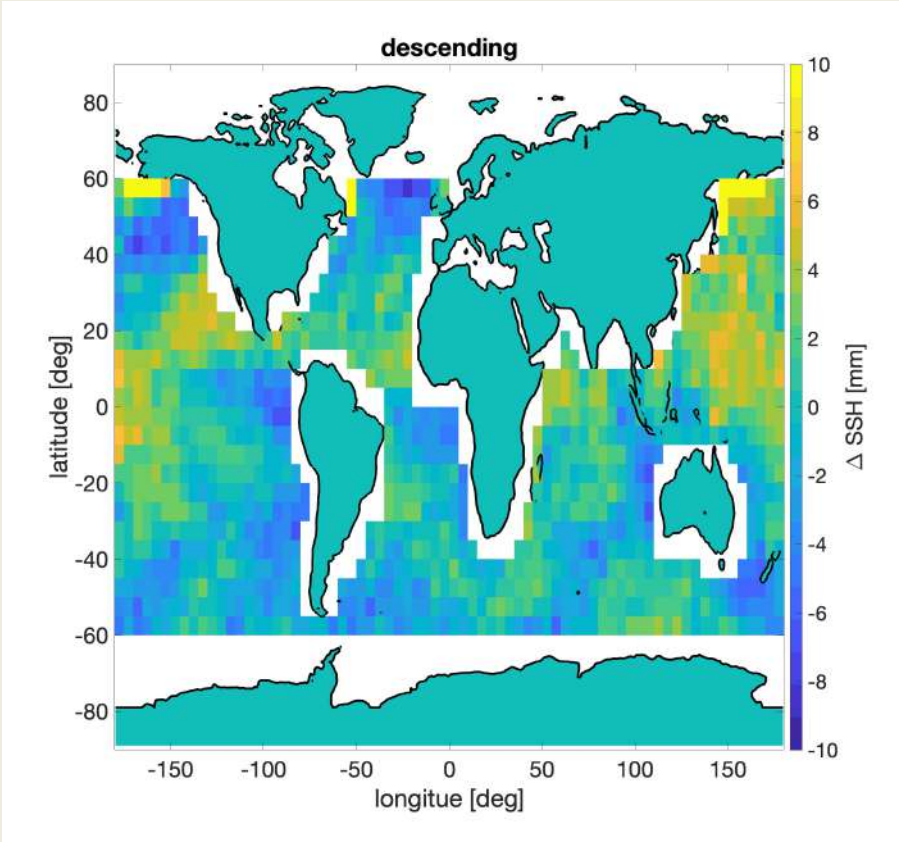
- Three different SAR (HR) retrackers used:
  - SINCS STD: Close to current state-of-the-art
  - SINCS-OV ZSK: VWPV stack retracker
  - SINCS-OV2 ZSK: VWPV plus u_x stack retracker

- Reduced SAR (LR) retrackers used:
  - SINC2 STD: Close to current state-of-the-art
  - SINC2 ZSK: Zero Skewness version of SINC2 STD

- SINCS STD is compared with SINC2 STD
- SINCS-OV ZSK and SINCS-OV2 ZSK with SINC2 ZSK

Sentinel-3A Cycle 81 SSH HR-LR Differences





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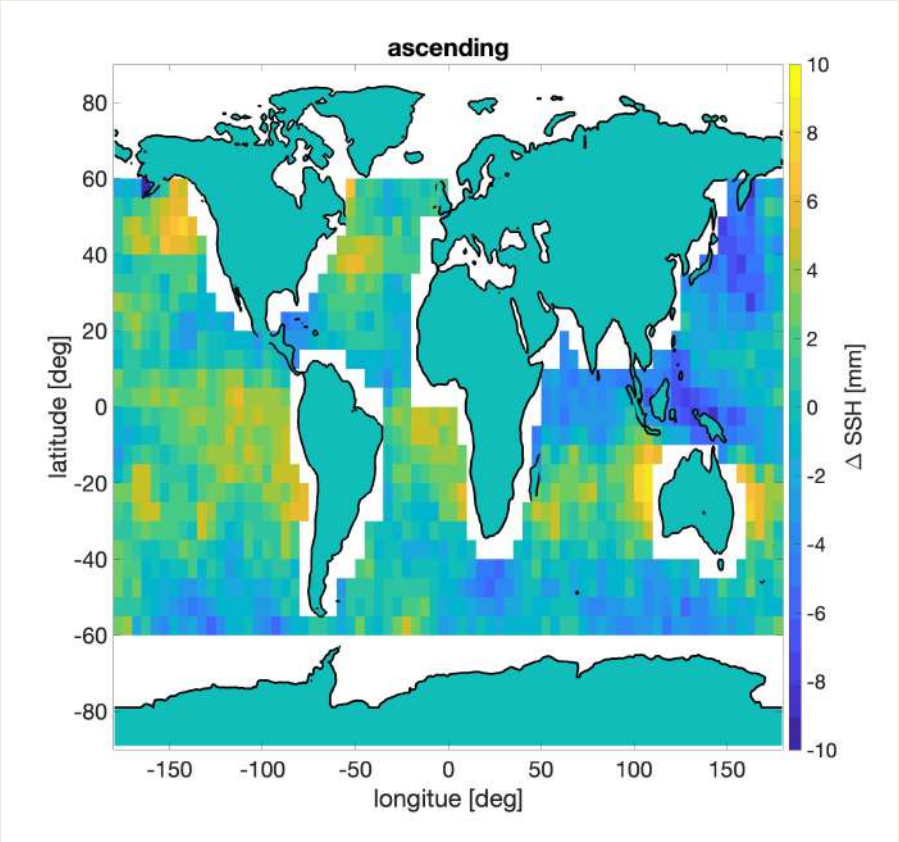

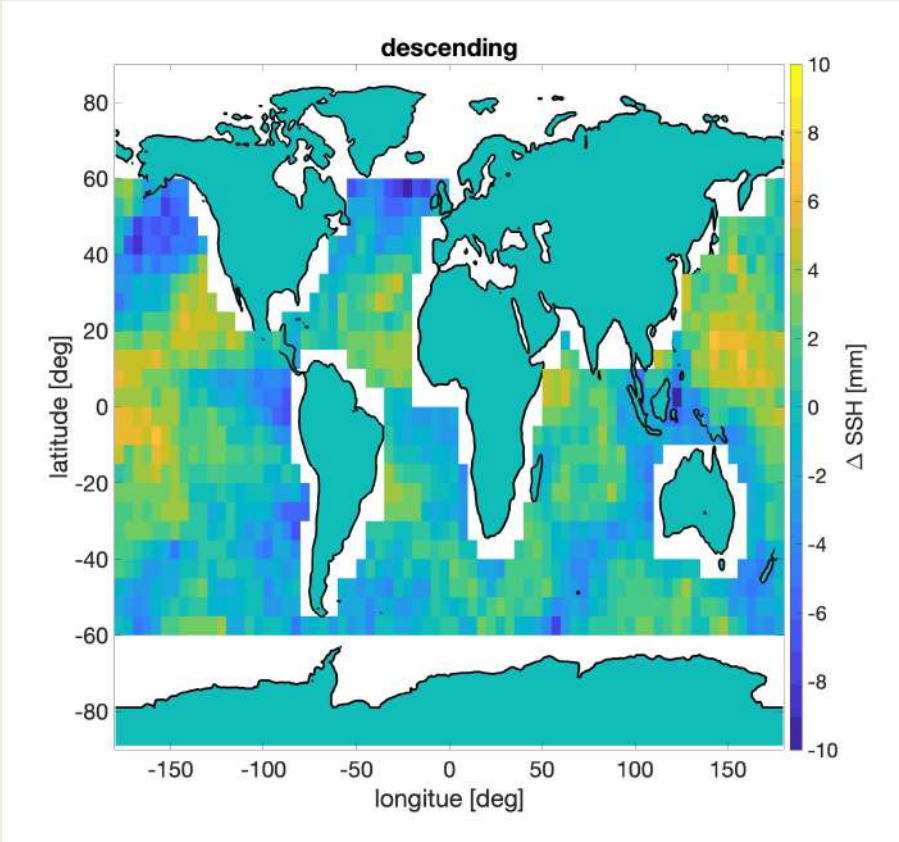

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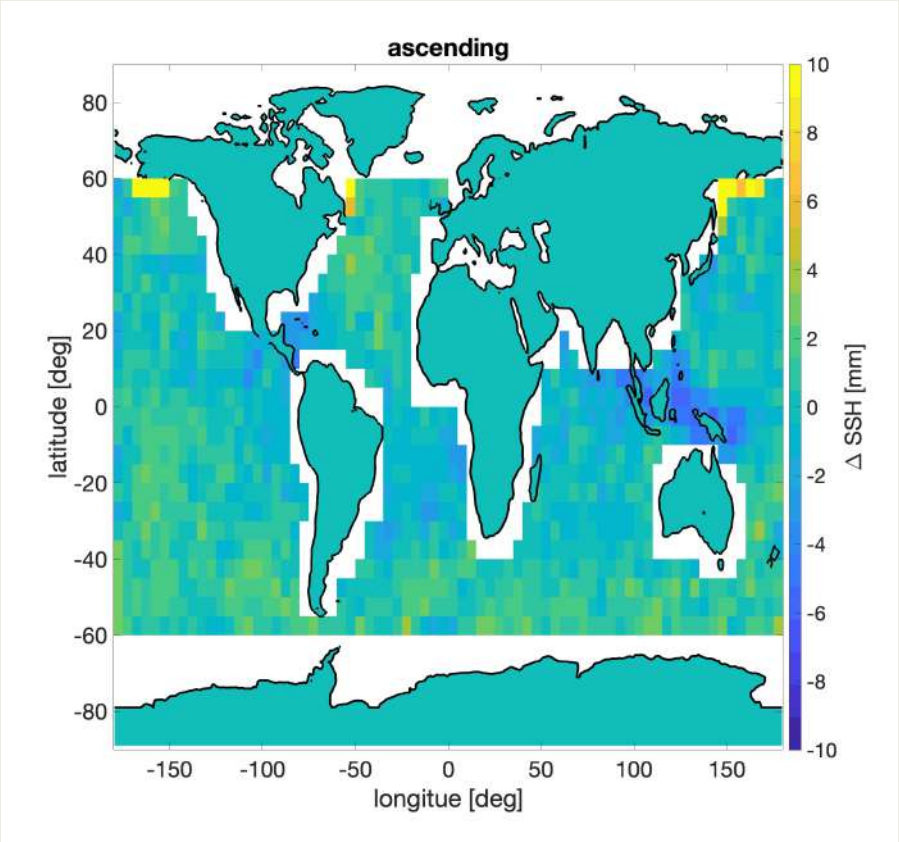

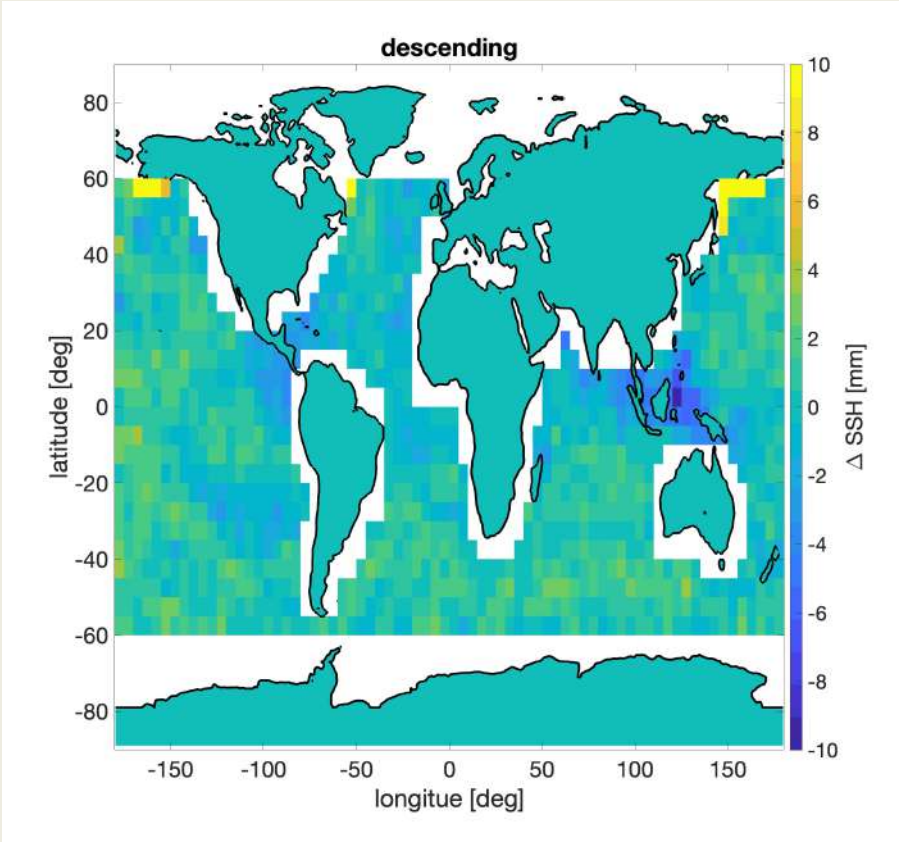

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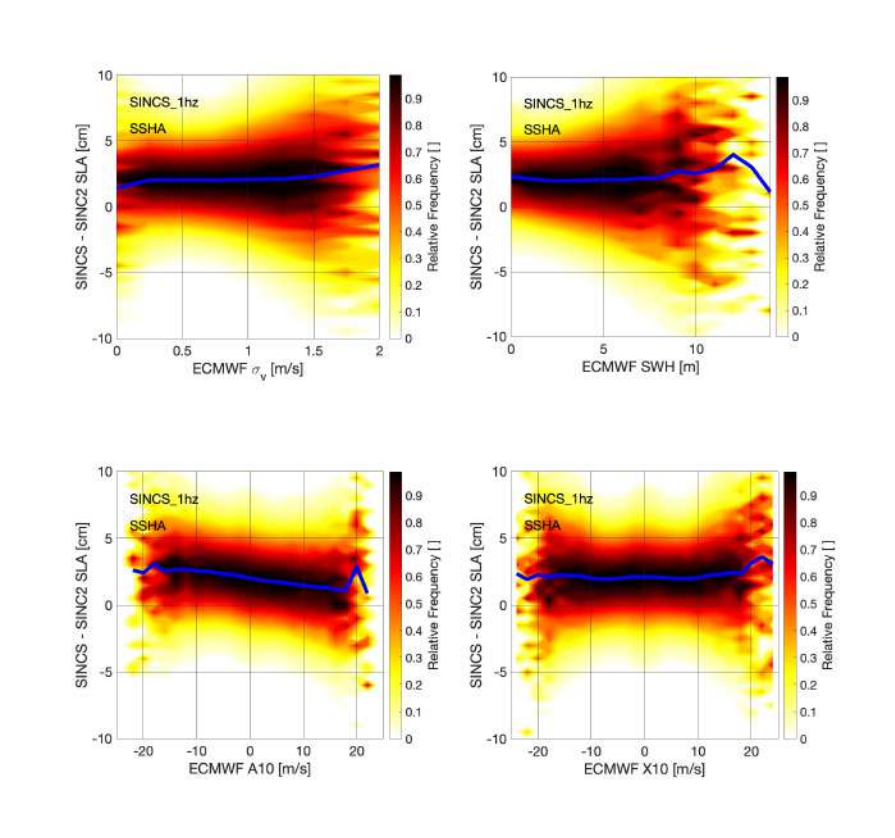

1-Hz LR-HR SLA differences w.r.t ECMWF parameters.
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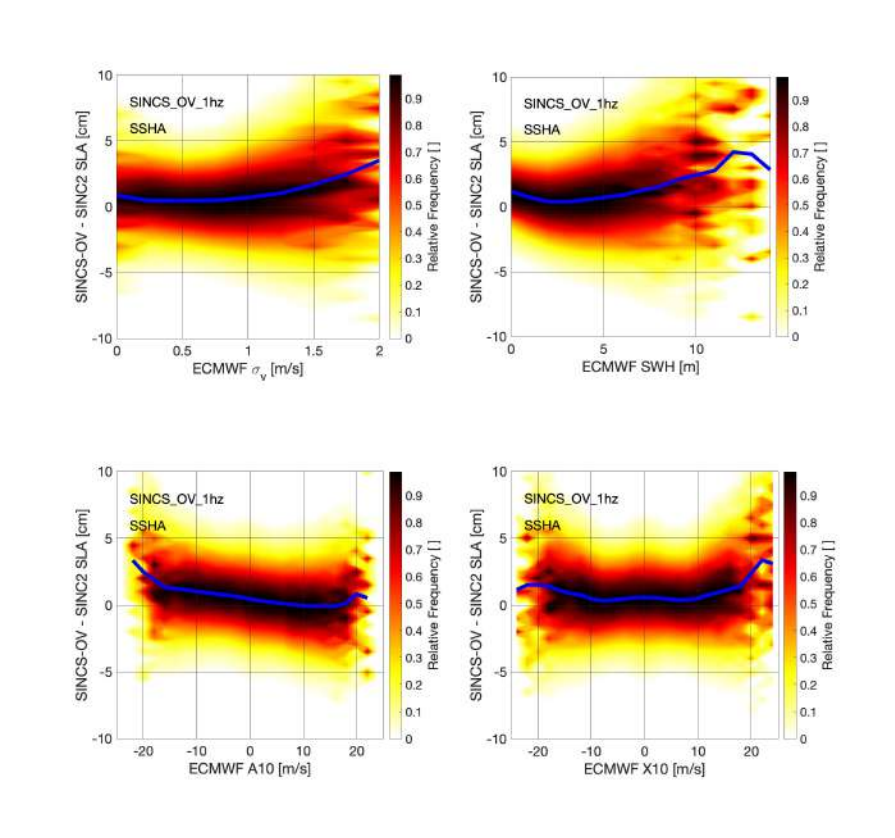

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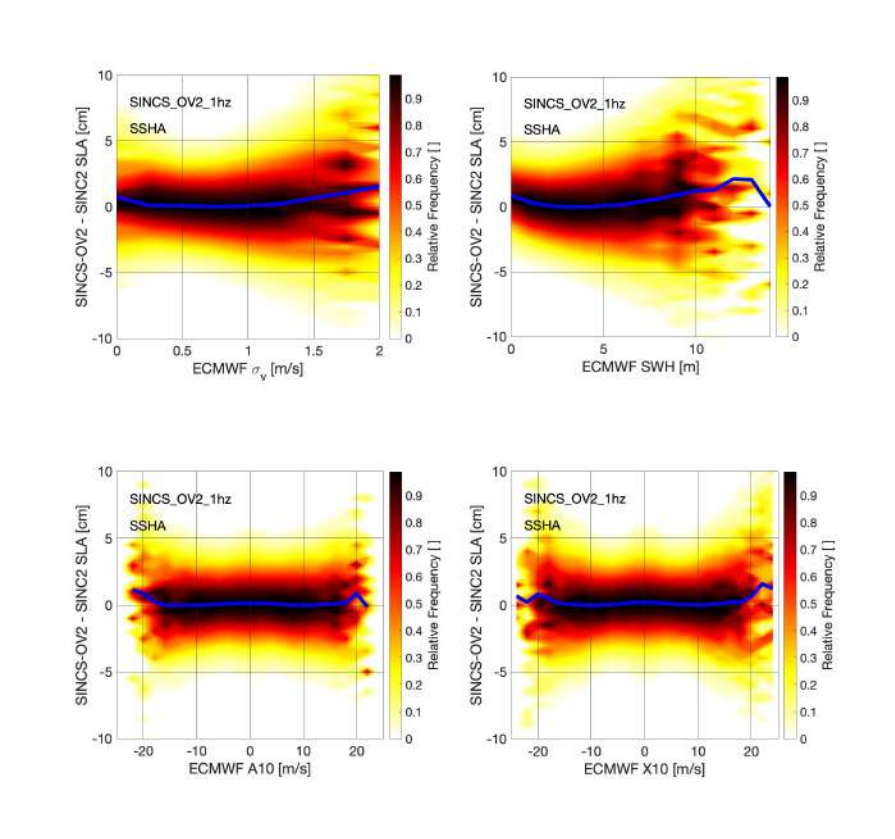

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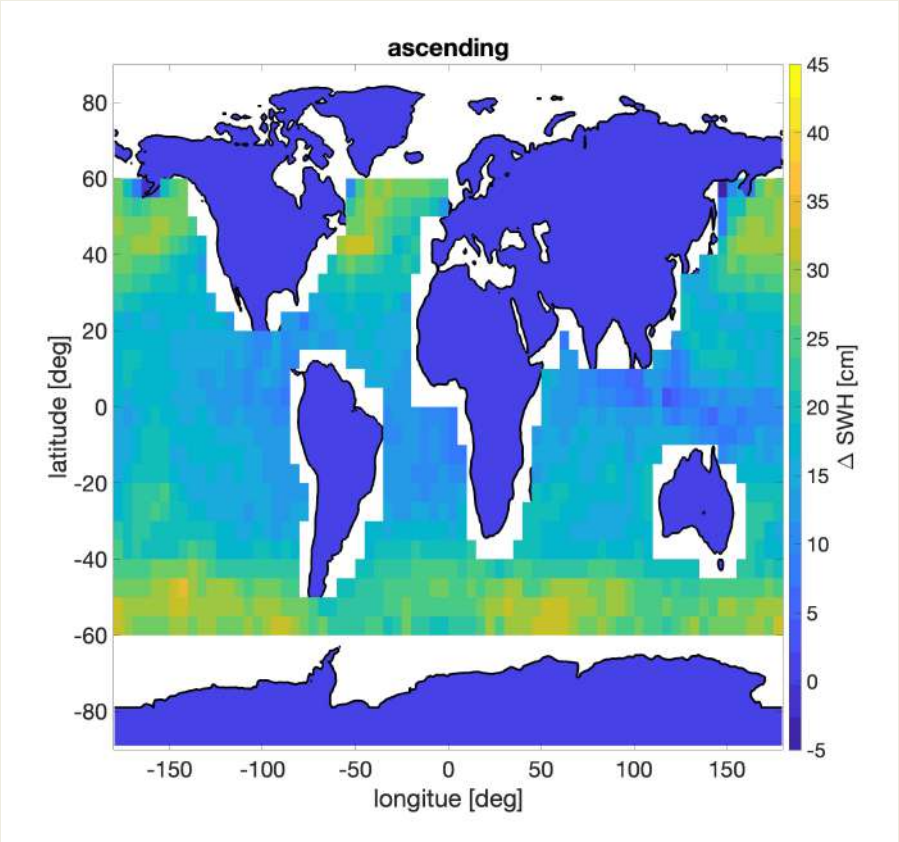

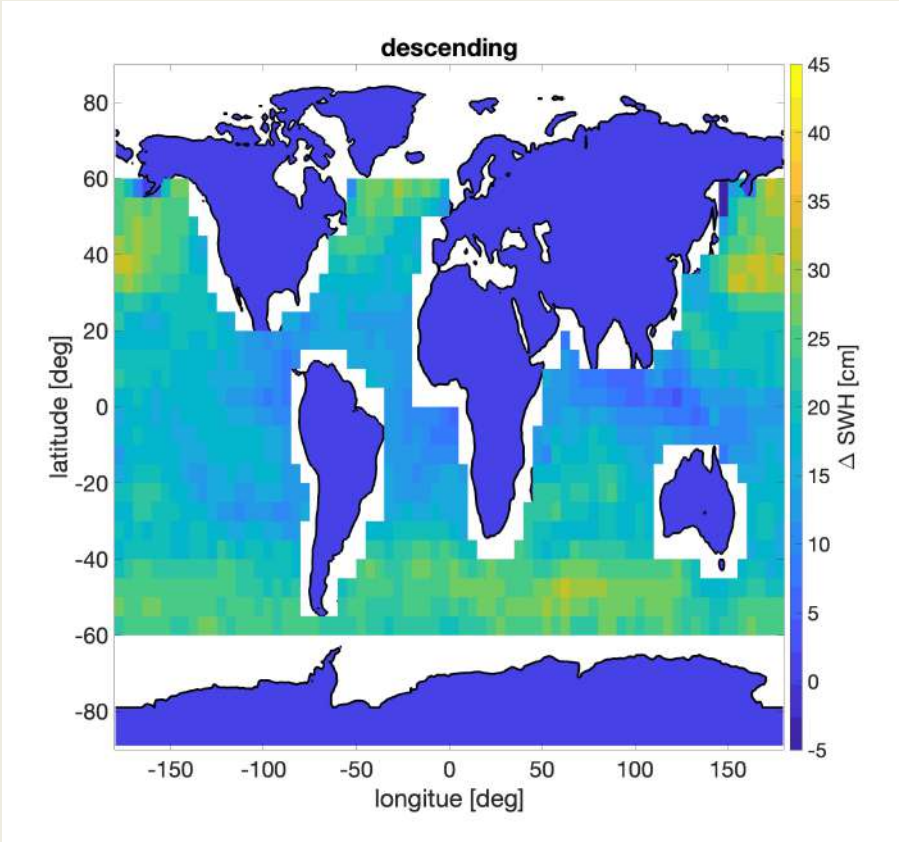

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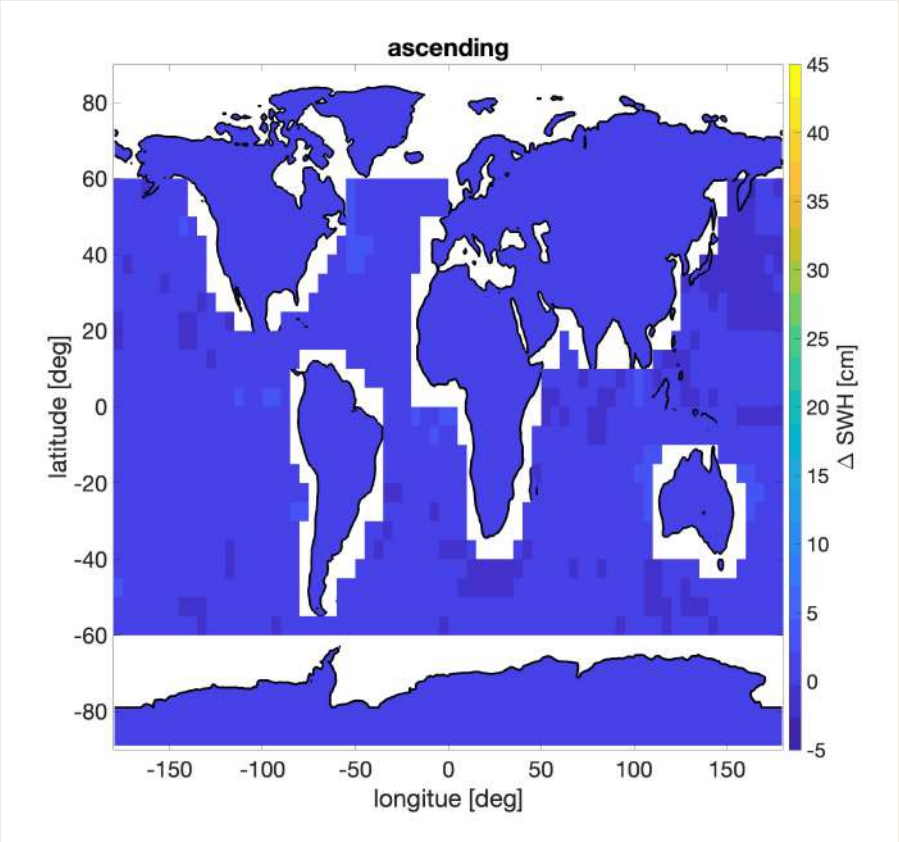

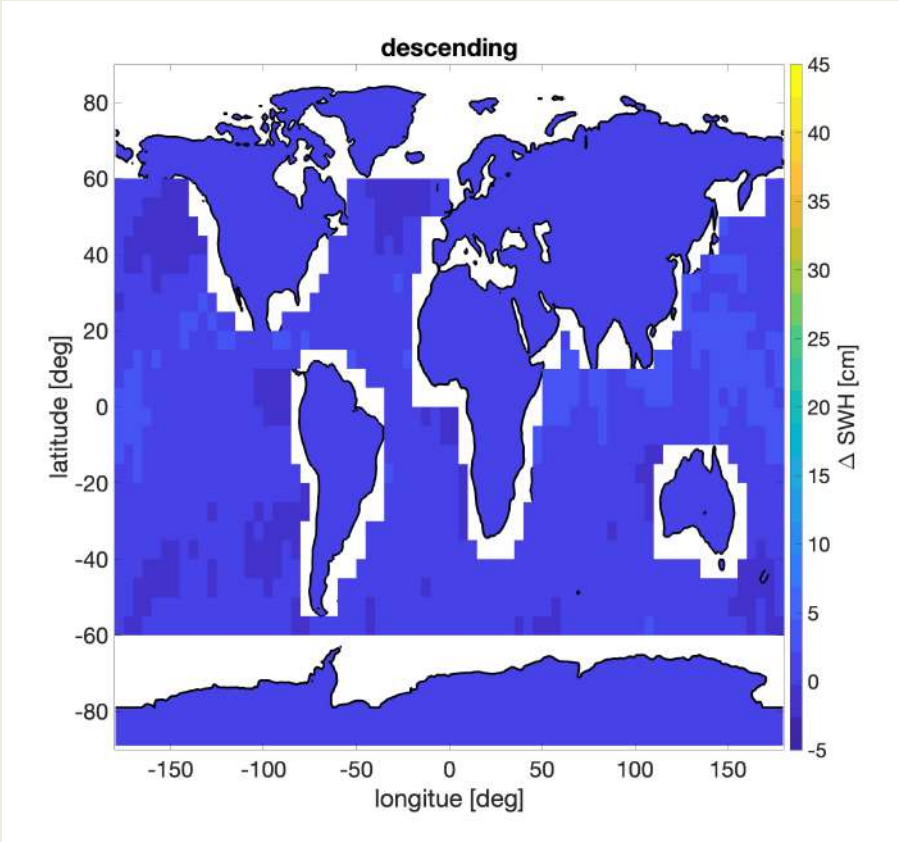

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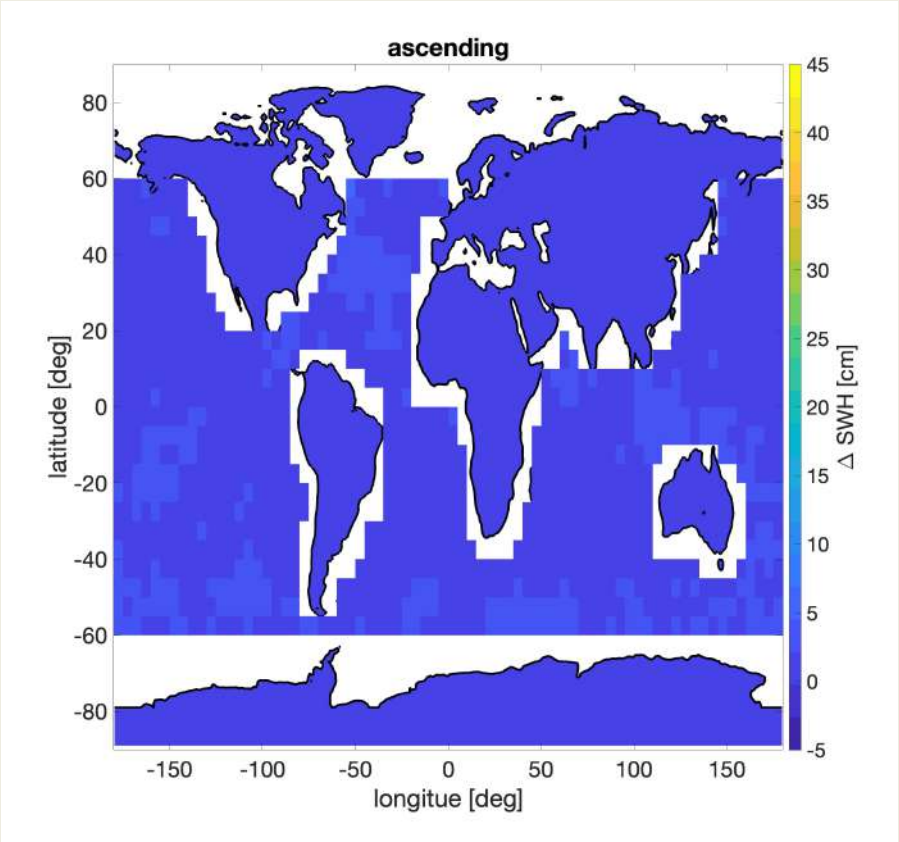

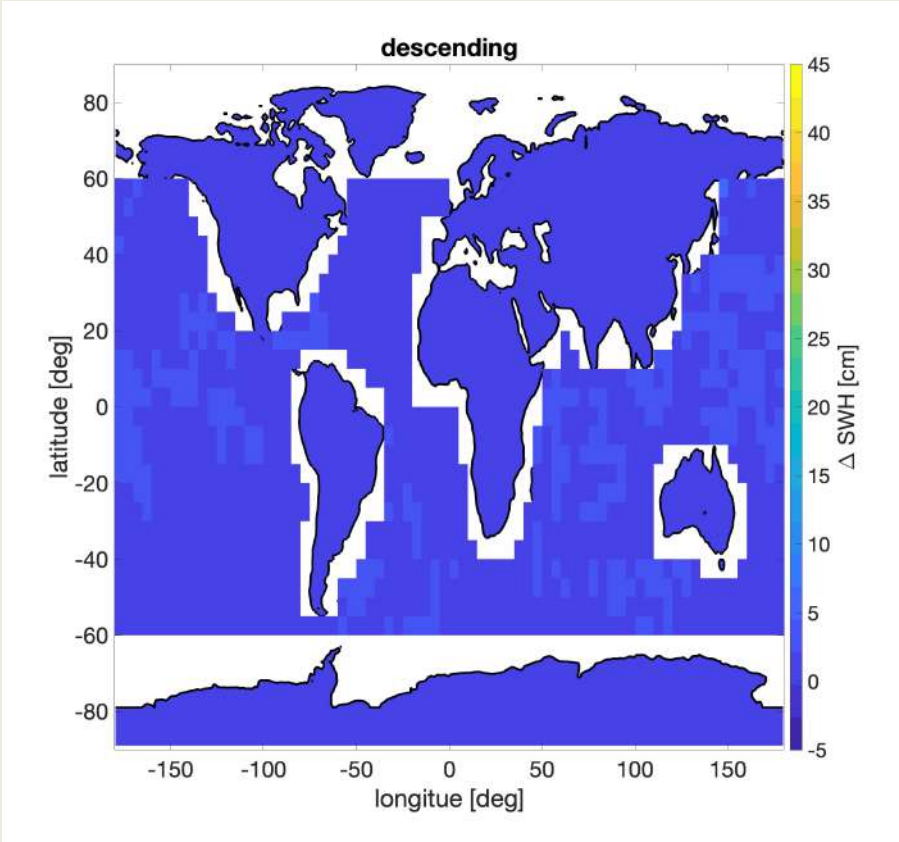

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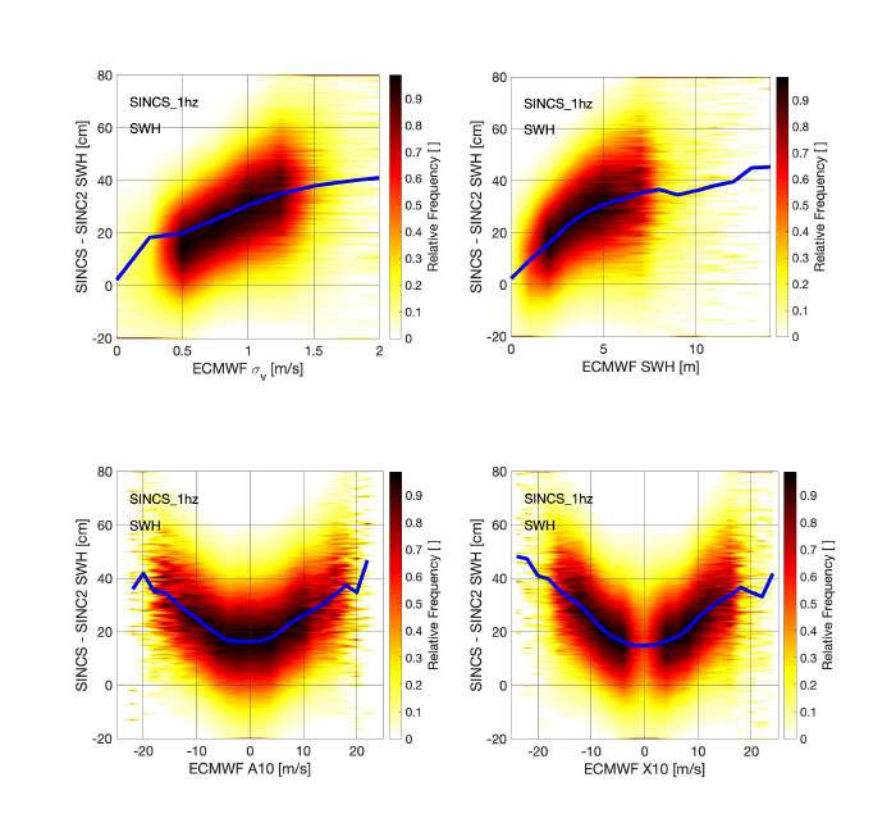

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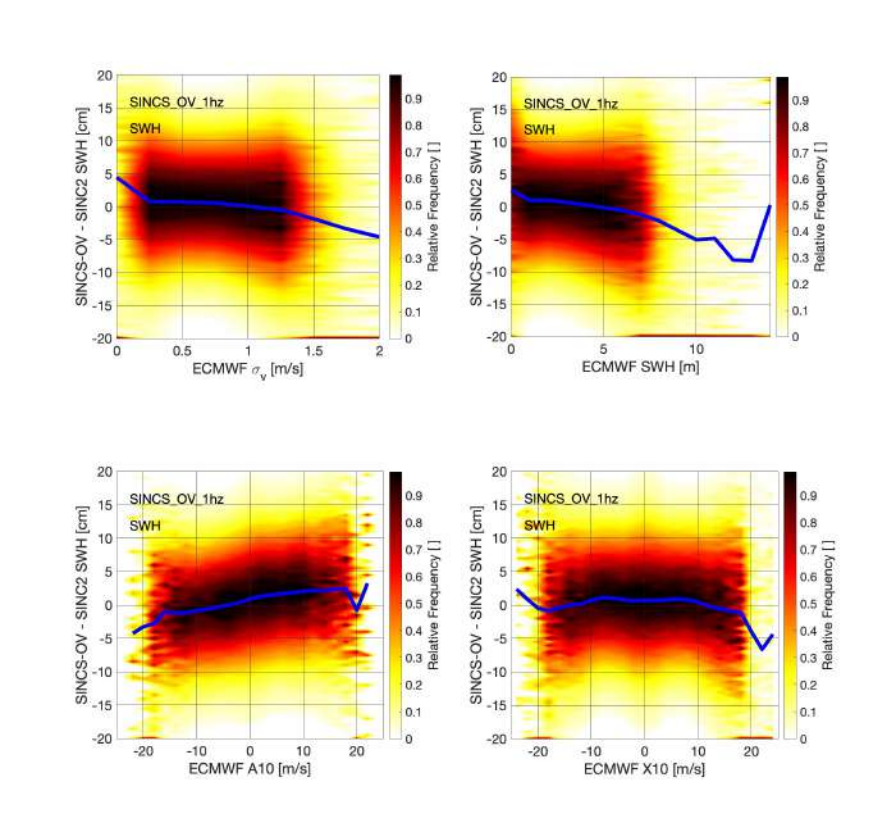

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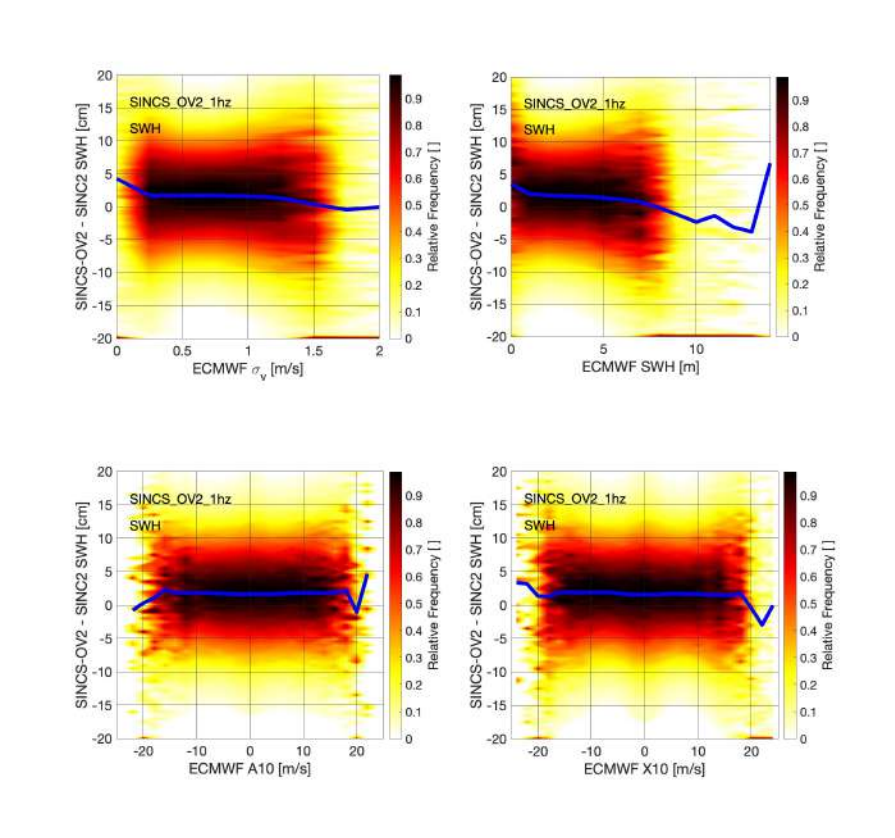

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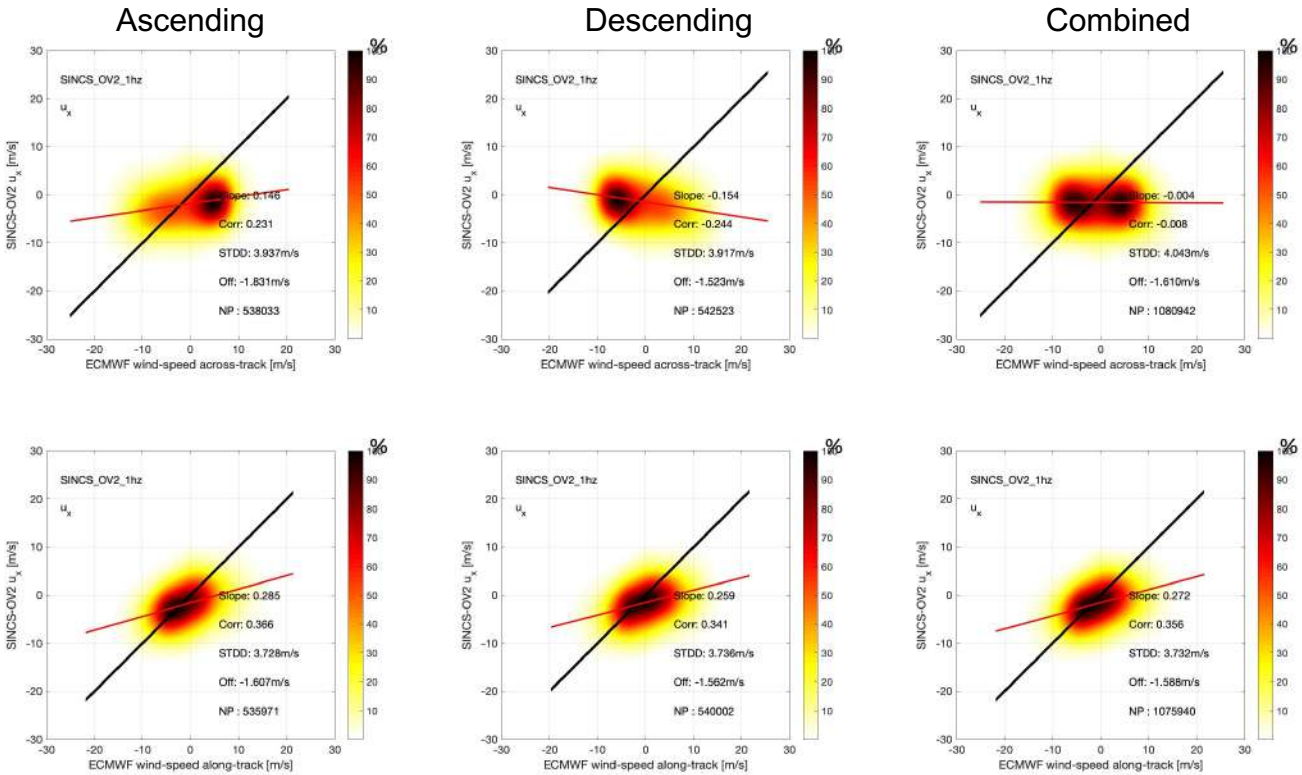
u_x w.r.t Wind Speed – Sentinel-3A



Scatterplot between 1-Hz SINCS-OV2 ZSK estimated along-track surface velocities and ECMWF wind speed values.

Conclusion

- 2D SAR retracking can retrieve two additional wind-wave parameters, the VWPV standard deviation σ_v and the along-track surface velocity u_x.
- Reduces the inconsistencies w.r.t. reduced SAR (LR).
  - About $\pm$1cm SSH depending on along-track surface velocity.
  - About 0cm to 40cm SWH depending on VWPV variation.
- Relationship between u_x and along-track windspeed
- How about swell and currents?
- Overall work still in progress, but $\sigma_v + u_x$ probably needs to be considered in the future e.g. with 2D retracking.

Simulation of Sentinel-3A Data

- Performing 10,000 Monte-Carlo-Runs for each SWH and wind direction θ_w combination:
  - $H_s = \{\, 0\text{m}, 1\text{m}, 2\text{m}, 4\text{m}, 8\text{m}, 12\text{m} \,\}$
  - $\theta_w = \{\, 0°,\ 22.5°,\ 45°,\ 67.5°,\ 90°,\ 112.5°,\ 145°,\ 167.5°,\ 180° \,\}$
  - $\sigma_v = \sqrt{0.01365\ g\ H_s}$ (Eq. based on elevation skewness of 0.1)
  - $U_{10} = 2.1375\ \sqrt{g\ H_s}$ (Eq. base on Pierson-Moskowitz spectrum)
  - $u_x = \frac{U_{10}}{2}$ (Eq. based on conservative estimate)
  - $g = 9.81\ {}^{m}/_{s^2}$ is the gravity acceleration.
- Retracking done with Levenberg-Marquardt Algorithm and
  - SINCS-OV ZSK (LSAR 2D: σ_v)
  - SINCS-OV2 ZSK (LSAR 2D: $\sigma_v + u_x$)

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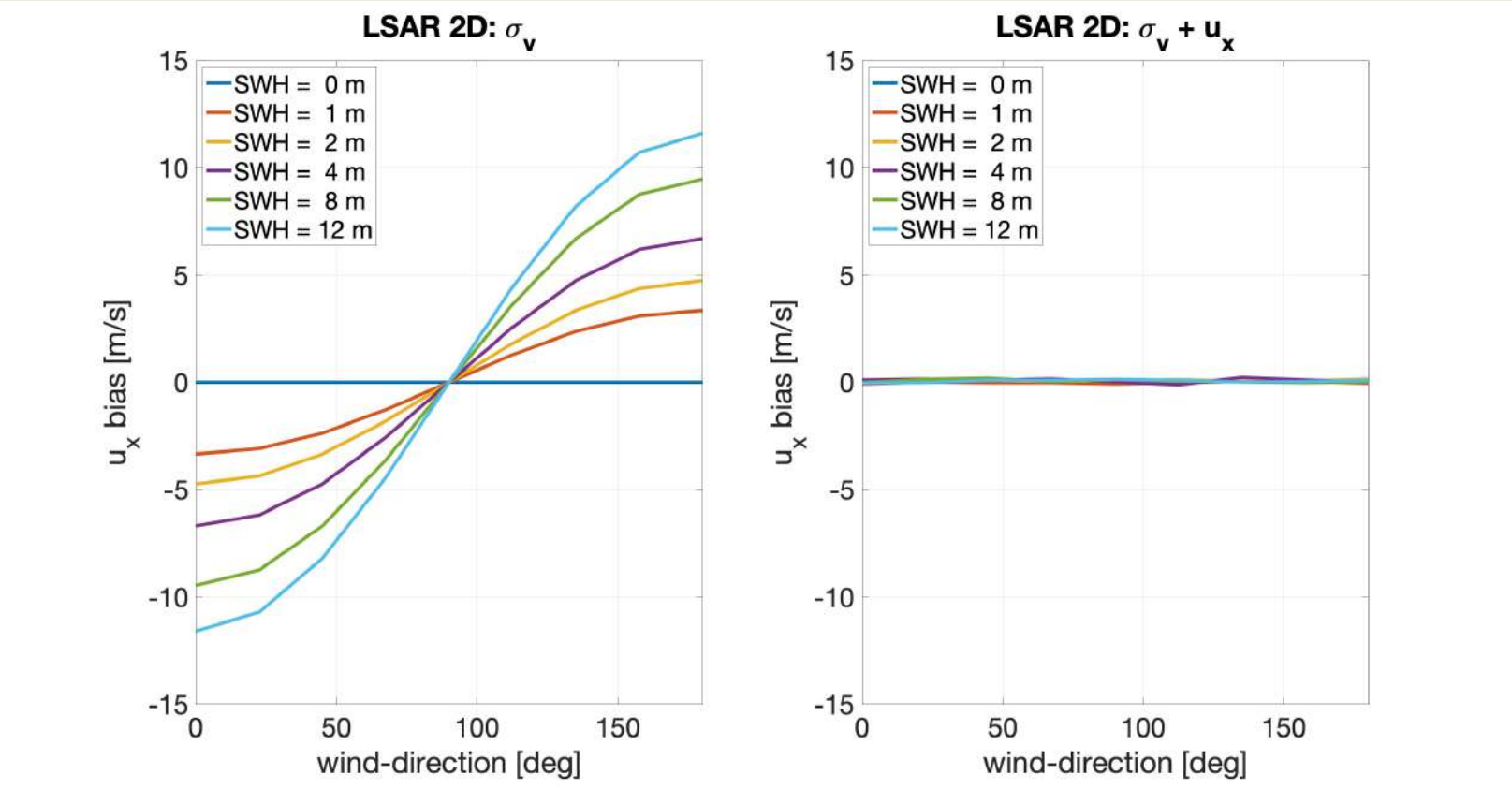

Estimated minus modelled u_x values in meter per second as function of SWH and wind-direction w.r.t. altimeter track.
Left: SINCS-OV ZSK which does not estimate u_x. Right: SINCS-OV2 ZSK which does estimate u_x.

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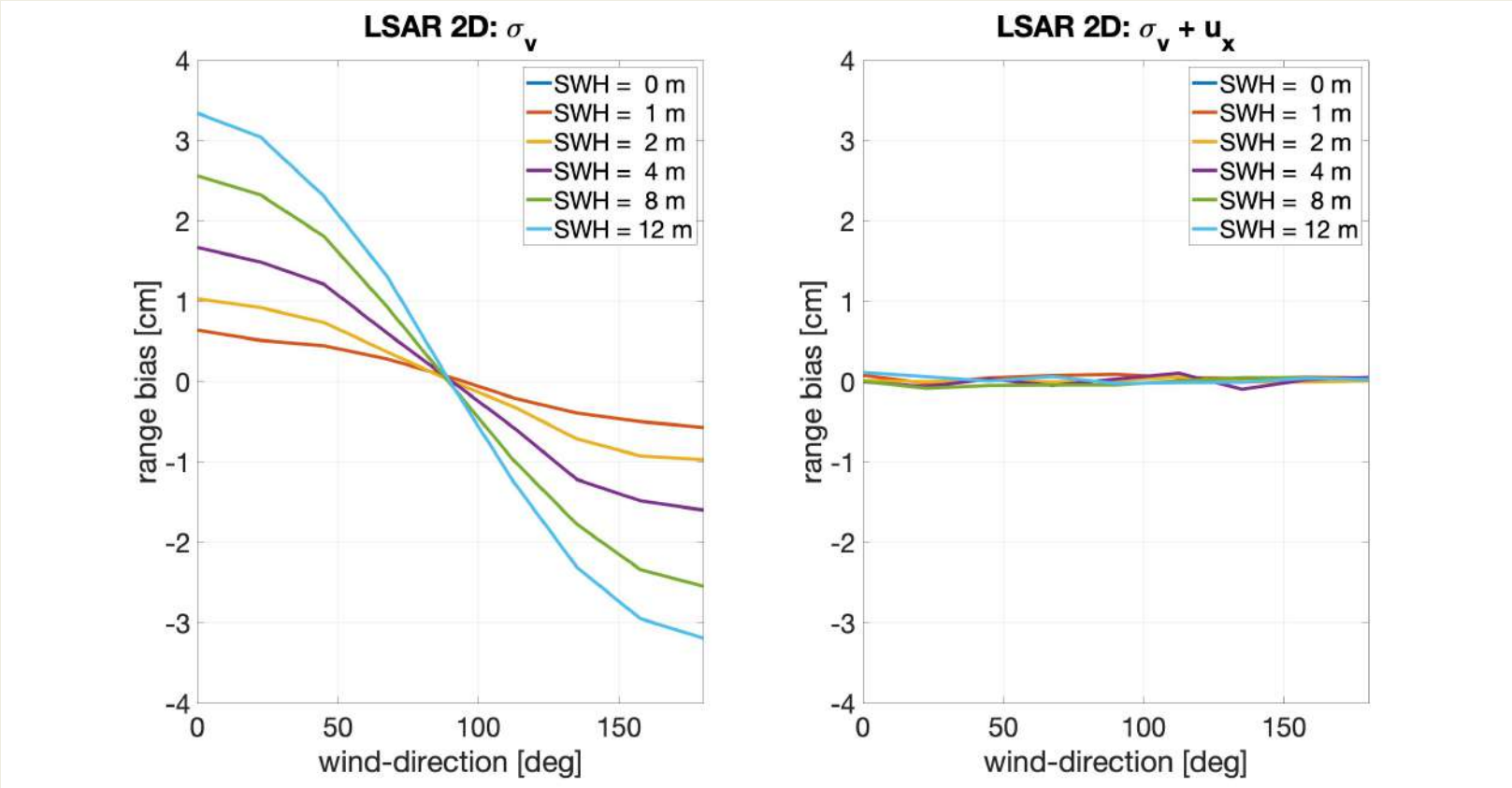

Estimated minus modelled range values in meter as function of SWH and wind-direction w.r.t. altimeter track.
Left: SINCS-OV ZSK which does not estimate u_x. Right: SINCS-OV2 ZSK which does estimate u_x.

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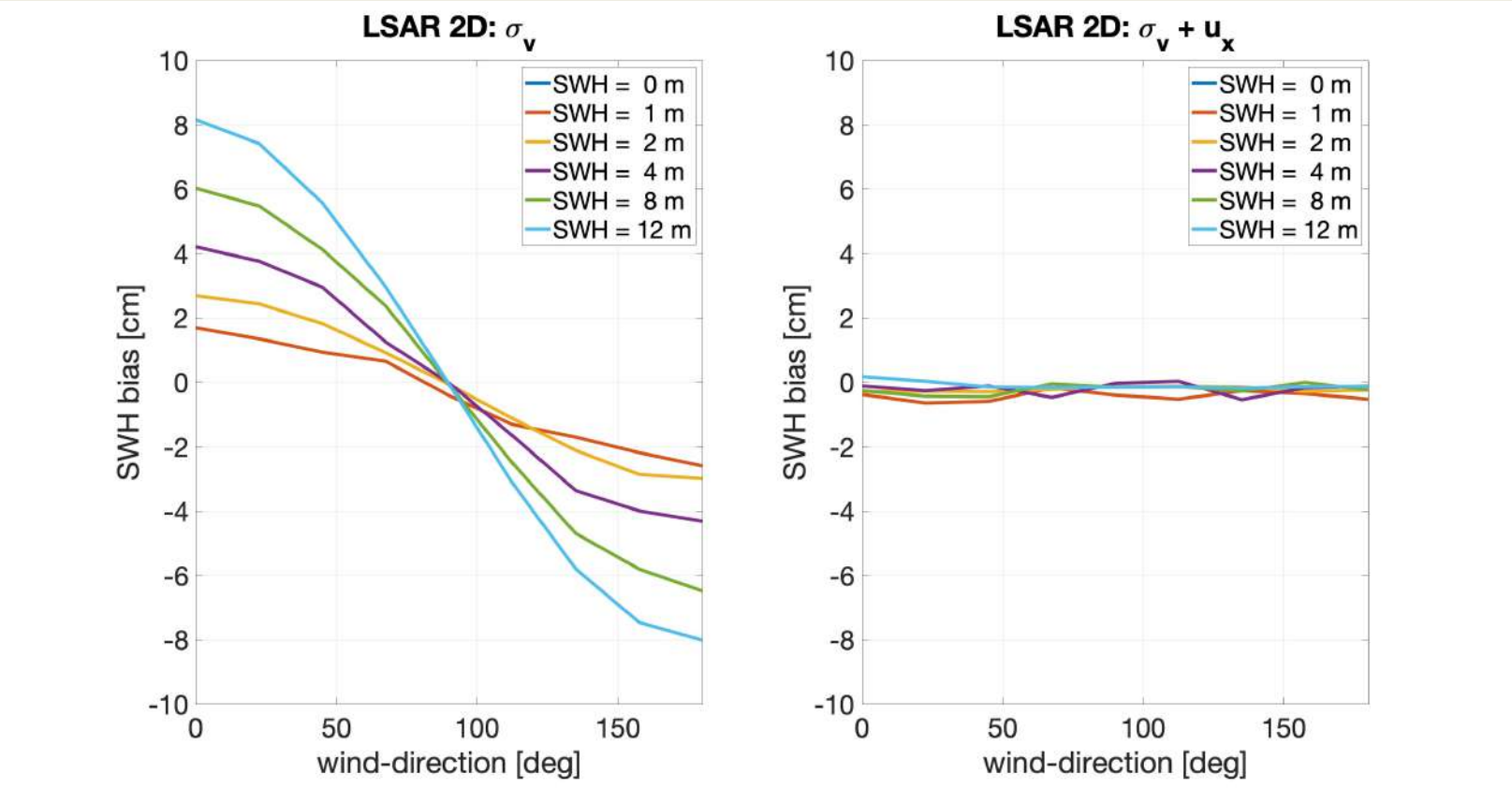

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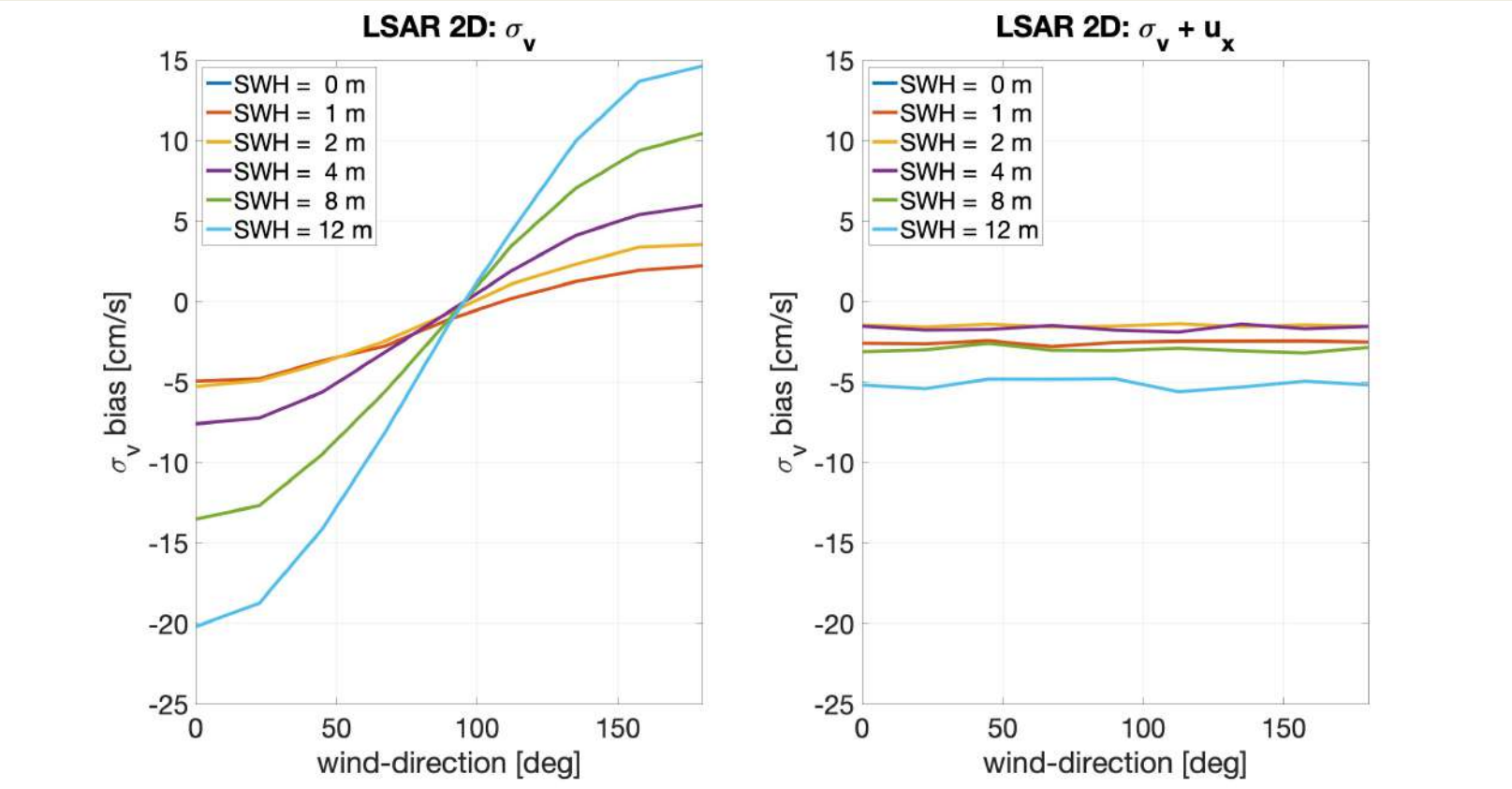

Estimated minus modelled σ_v values in meter per second as function of SWH and wind-direction w.r.t. altimeter track.
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