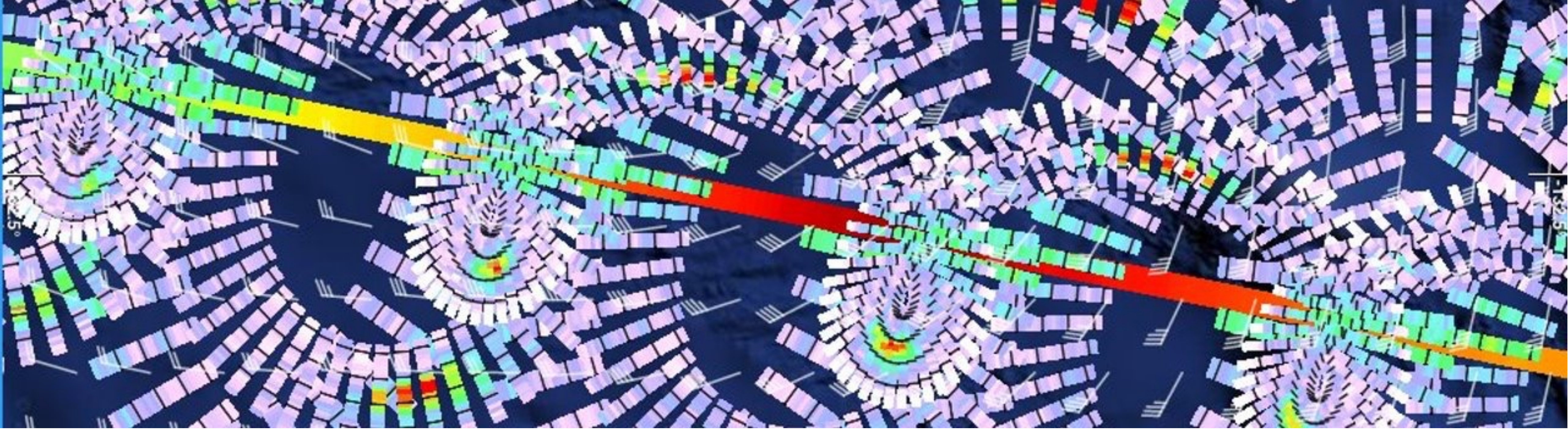


Towards a global Stokes drift product from SWIM/CFOSAT

Charles Peureux, Annabelle Ollivier, Hélène Etienne, Sandrine Mulet[1]
Cédric Tourain[2]
Lotfi Aouf[3]

CLS
COLLECTE LOCALISATION SATELLITES
1 : CLS, France

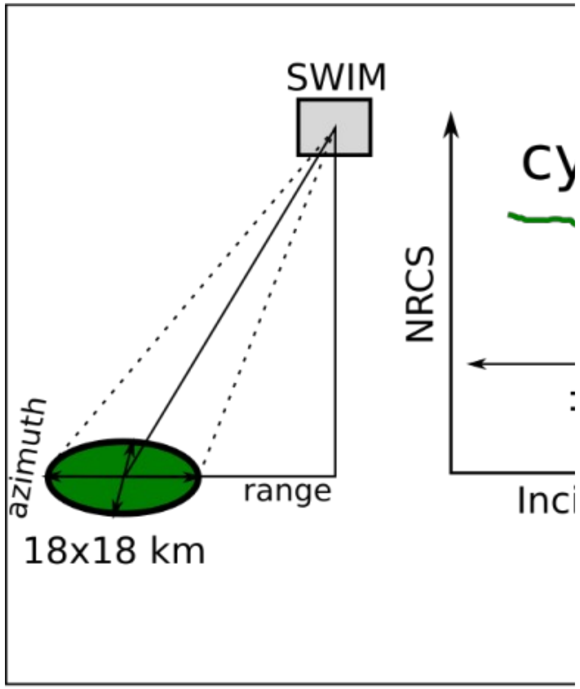
cnes
2 : CNES, France

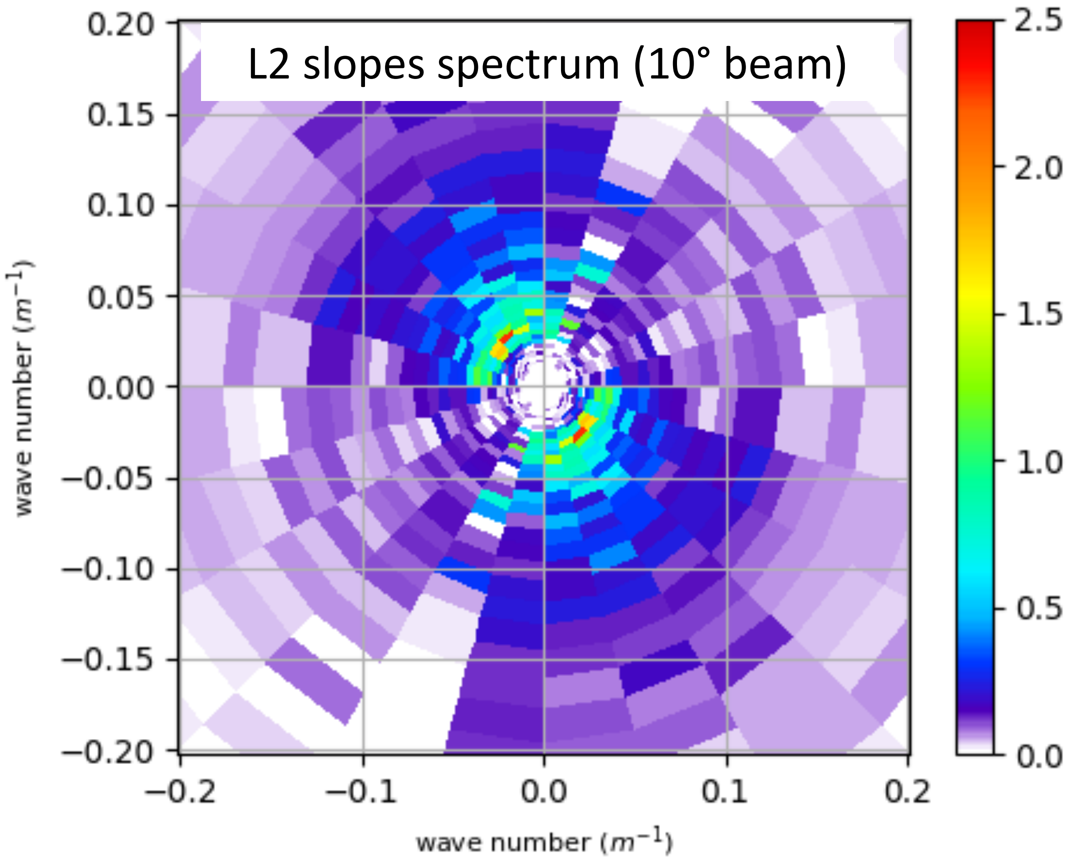
METEO FRANCE
3: Météo France

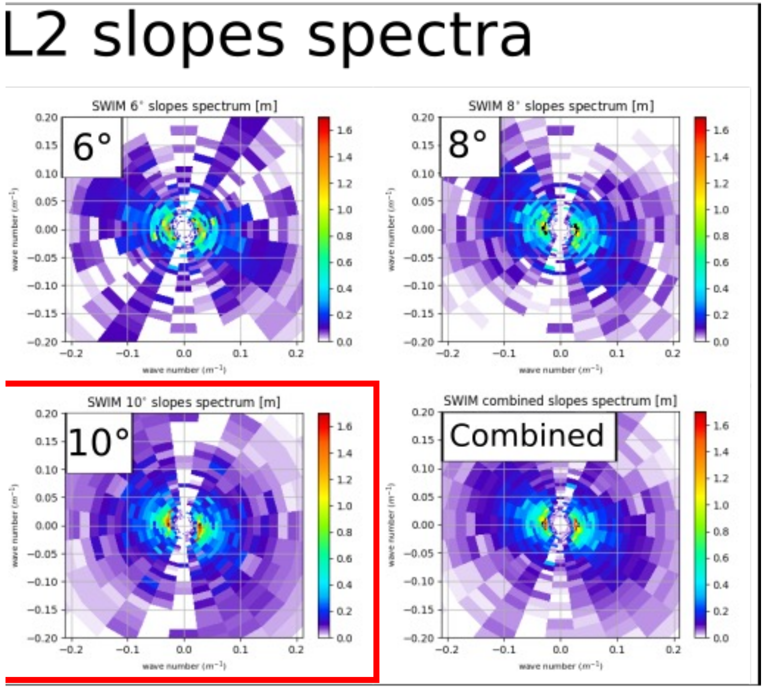
OSTST Meeting, Nov. 2 2022, Venice, Italy

Introduction - SWIM

NRCS modulations <-> ocean waves slopes

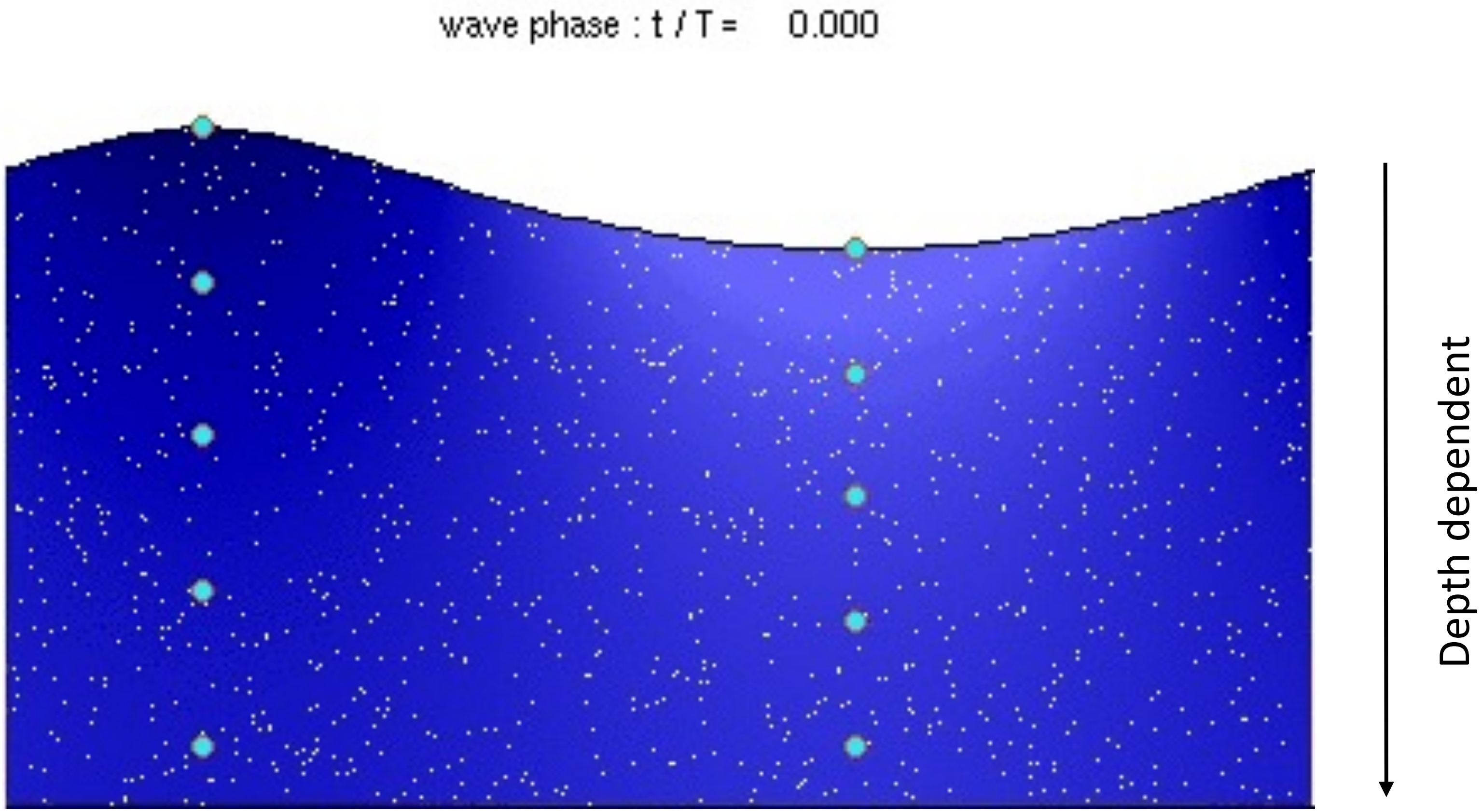






λ > 22 m

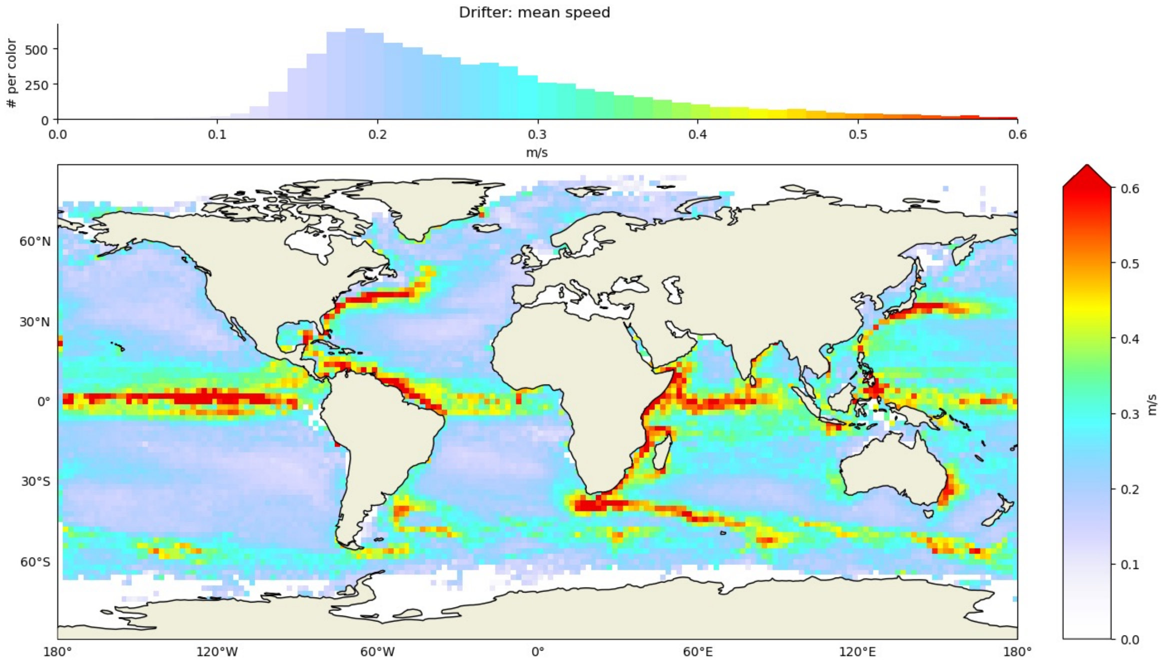
Introduction – Stokes drift



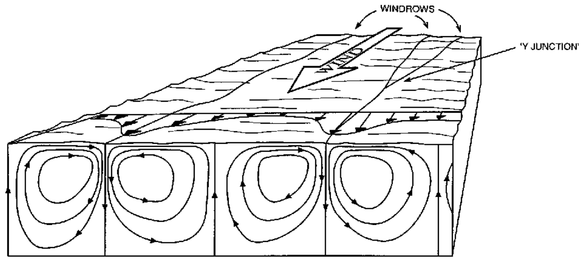
From wikipedia, Stokes drift

Introduction – Stokes drift

- Drift at the ocean surface (oil, plastics, larvae, plankton, etc …)



Mean drifters derived currents (courtesy of H. Etienne, CLS)



Lines of sargassum at a Langmuir cell border

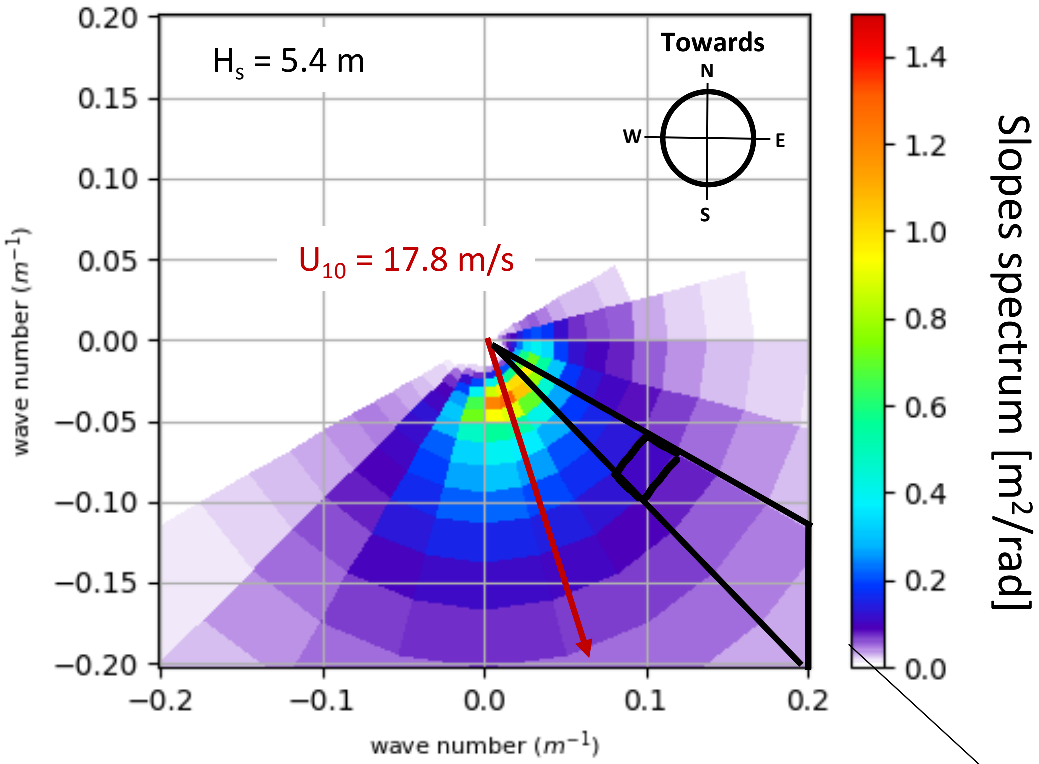
- Ocean surface circulation

The Stokes drift climate knowledge at the global scale only relies on models today

Stokes drift estimation from SWIM

Kenyon 1969

MODEL (WAM)



3.7 cm/s

Stokes component =

$$\int k \times dk \; d\varphi \times S(k,\varphi) \times \text{Phase velocity} \times e^{2kz}$$

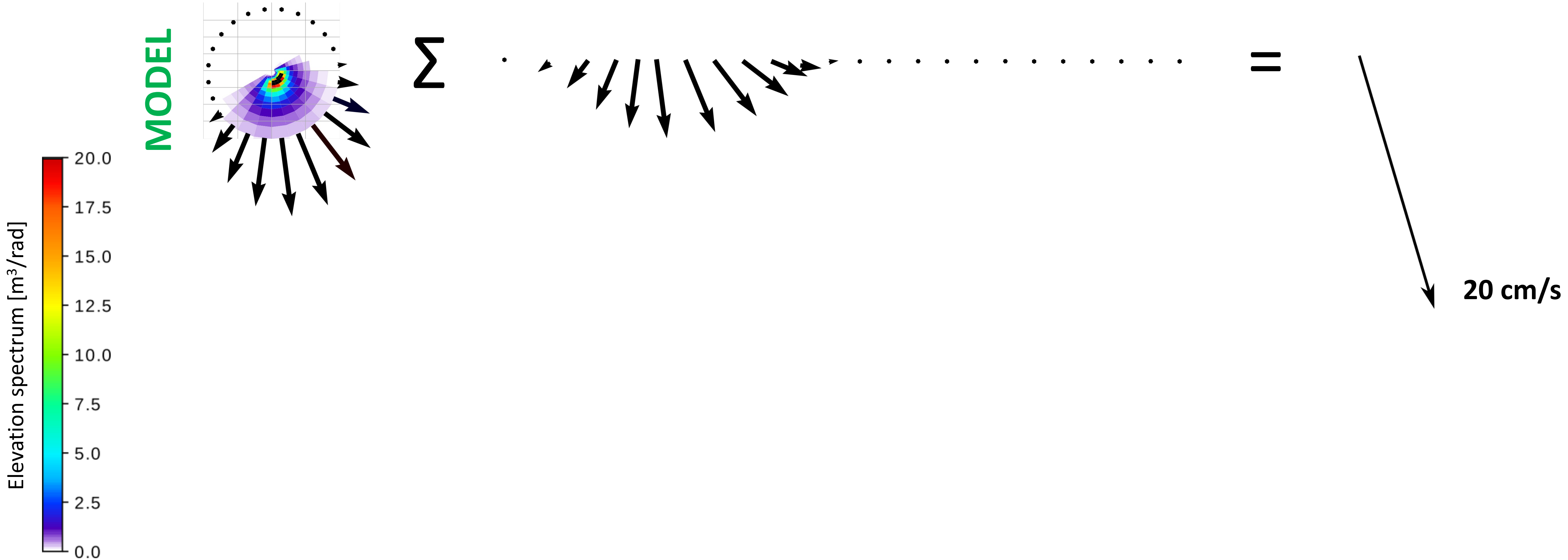
Phase velocity $= \sqrt{\frac{g}{k}}$

z = depth

Stokes drift estimation from SWIM

Scale : **1 cm/s**

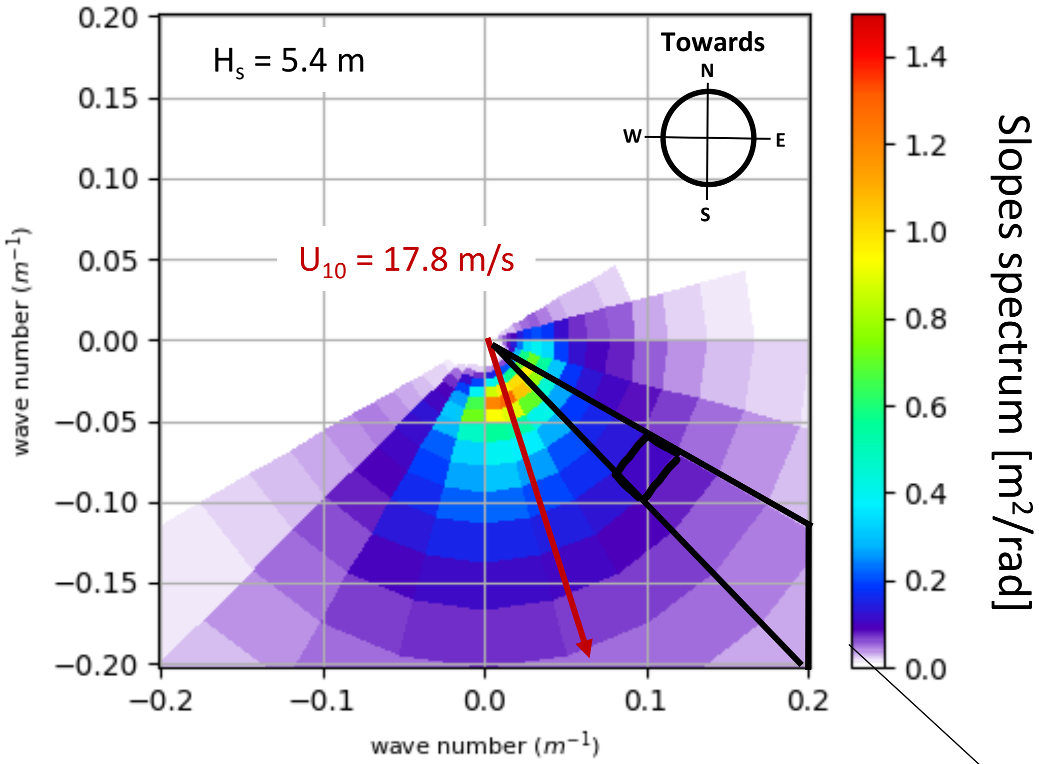
SPECTRUM **COMPONENTS** **STOKES DRIFT**



Stokes drift estimation from SWIM

Kenyon 1969

SWIM RAW (10°)



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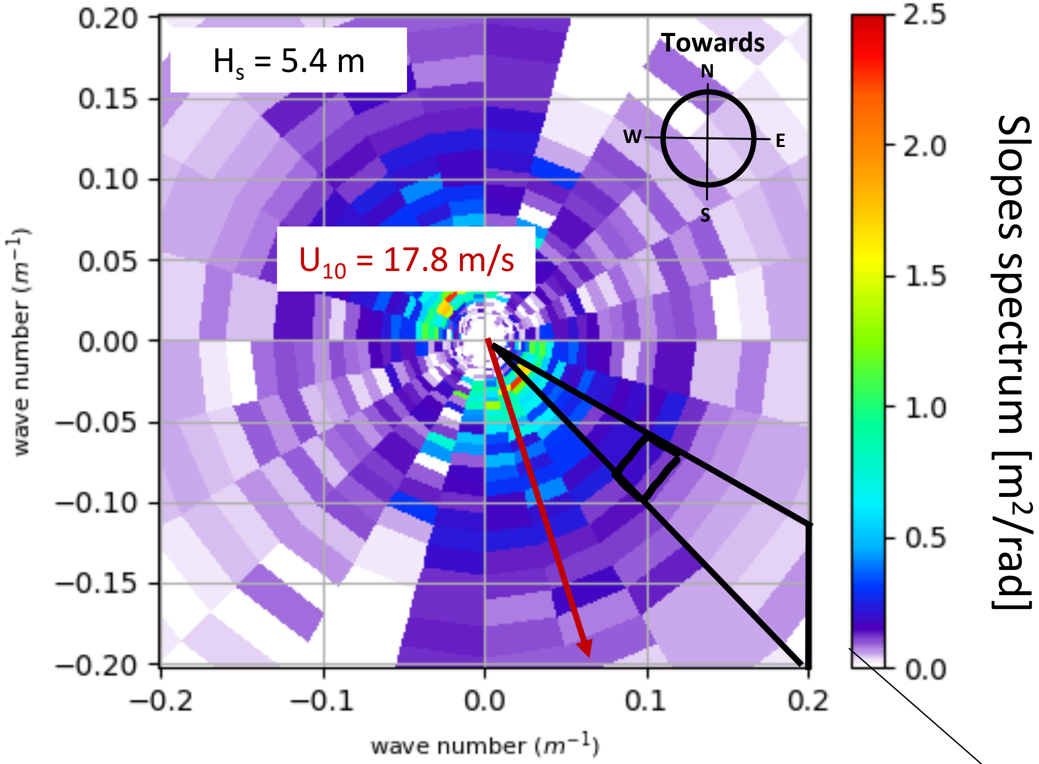
Stokes drift estimation from SWIM

Kenyon 1969

SWIM RAW (10°)



Stokes component =

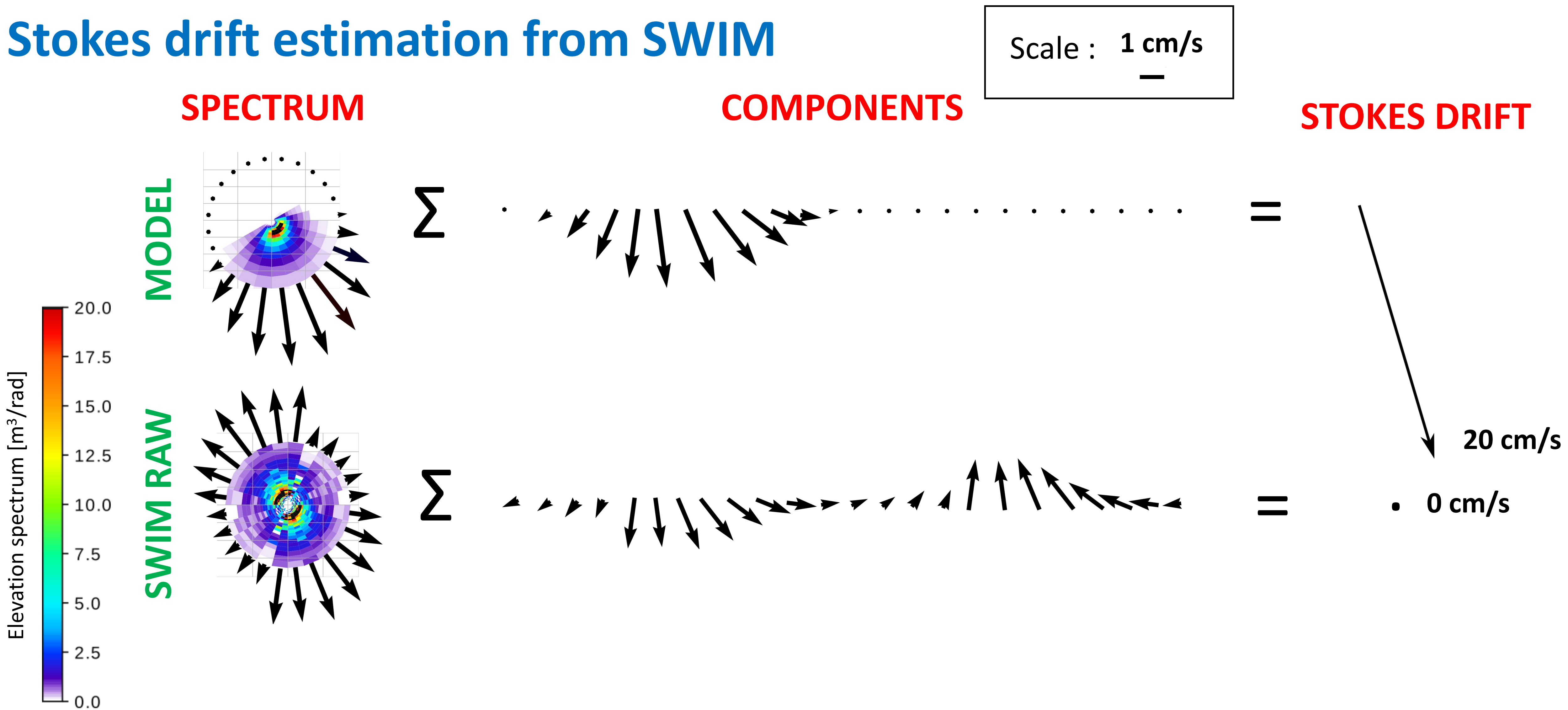
$$\int k \times dk\, d\varphi \times S(k,\varphi) \times \text{Phase velocity} \times e^{2kz}$$

Phase velocity $= \sqrt{\frac{g}{k}}$

z = depth

2.3 cm/s

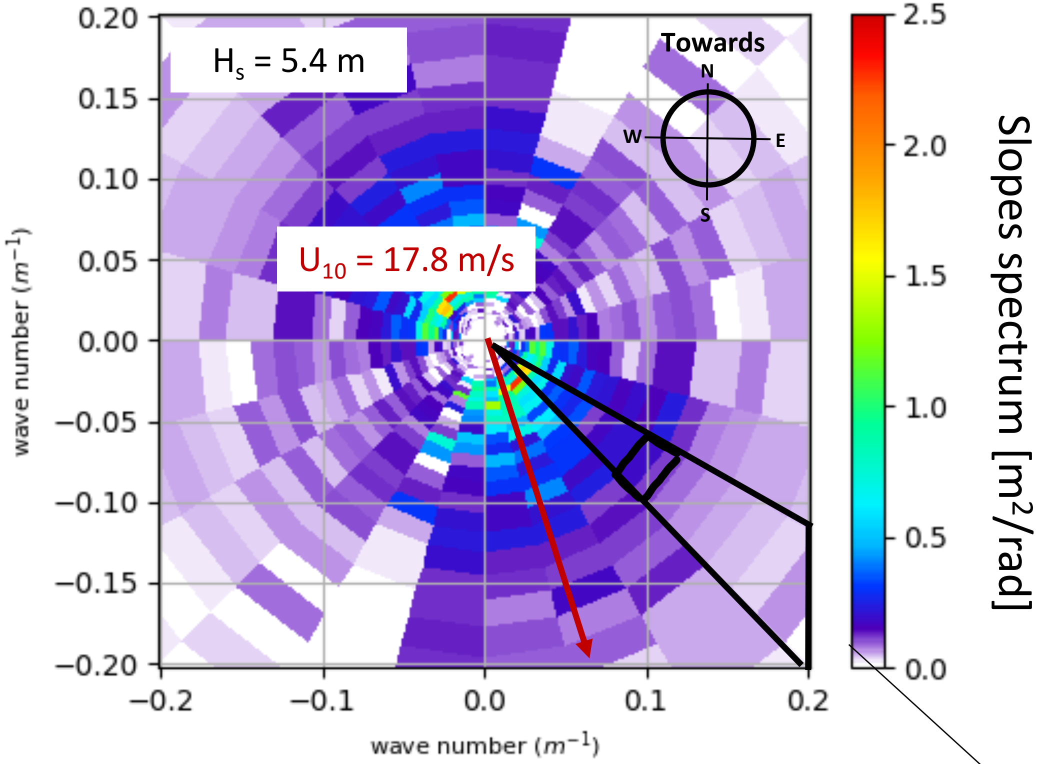
Stokes drift estimation from SWIM



Stokes drift estimation from SWIM

Kenyon 1969

SWIM RAW (10°)



Stokes component =

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Phase velocity $= \sqrt{\frac{g}{k}}$

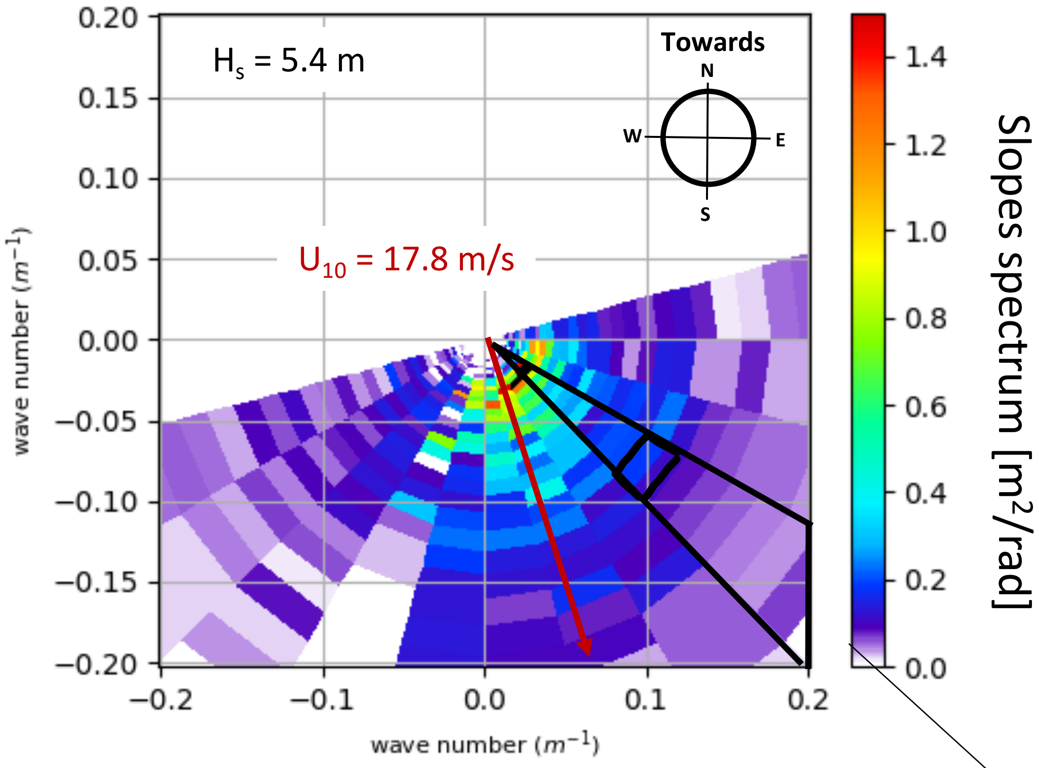
z = depth

2.3 cm/s

Stokes drift estimation from SWIM

Kenyon 1969

SWIM (10°)



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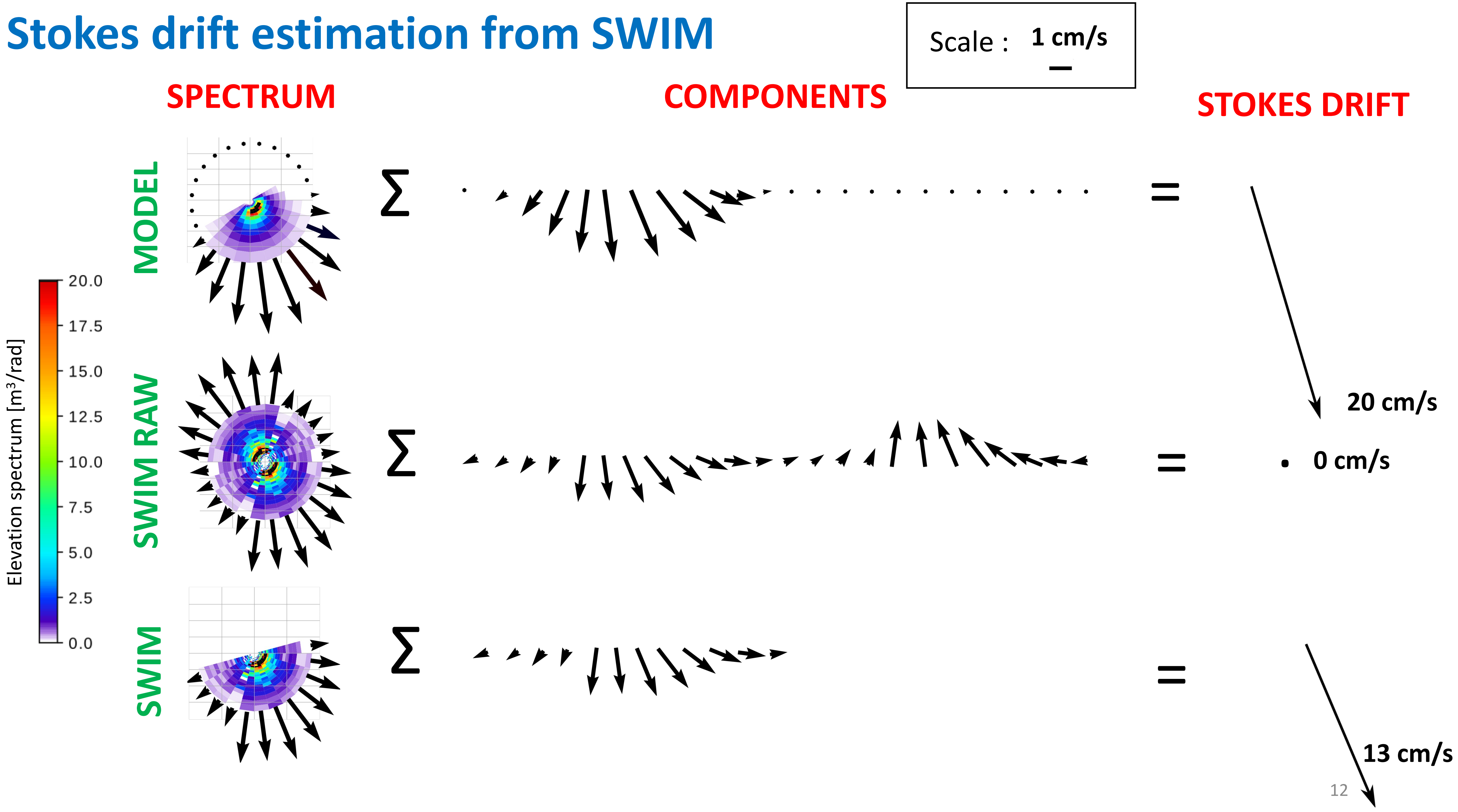
Stokes drift estimation from SWIM



SWIM Stokes drift estimation from SWIM

Known limitations :

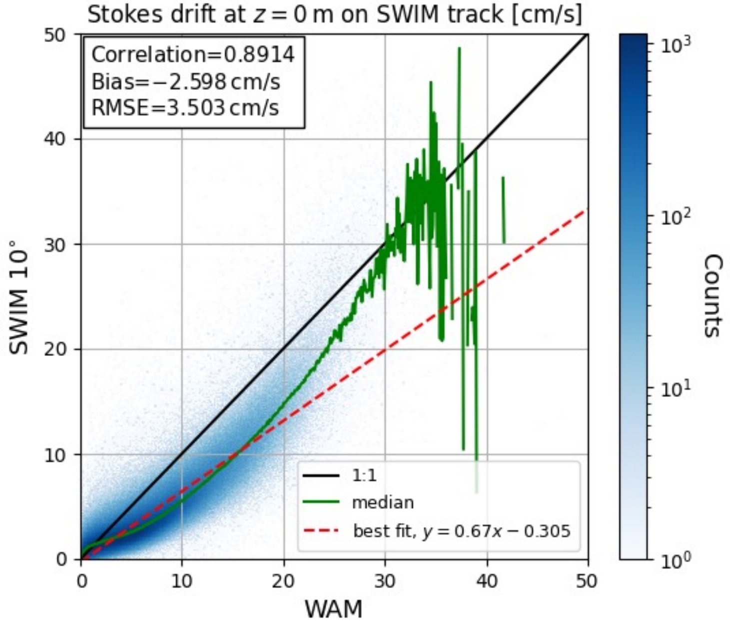
- Ambiguity
- Truncation

Test performed using :

- WAM and SWIM (focus on 10°) **colocated** on year 2021
- Wind direction from ECMWF forecast (in SWIM L2)

Performances - overview

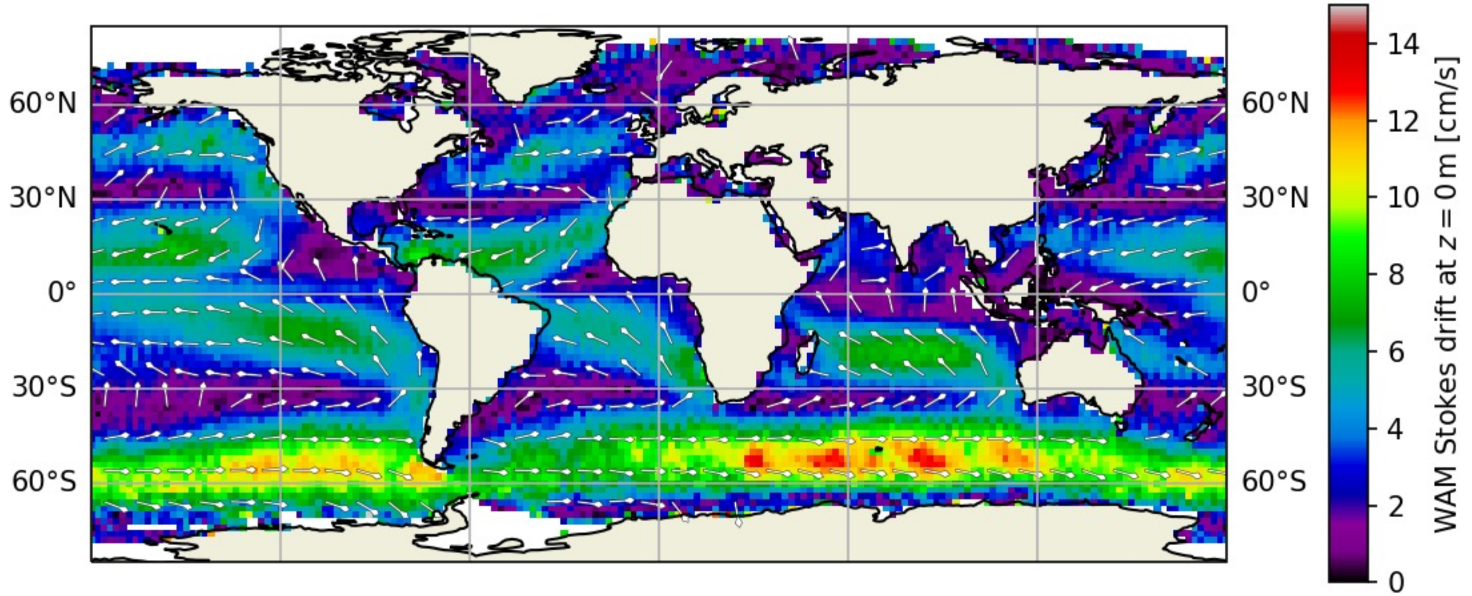
depth = 0 m



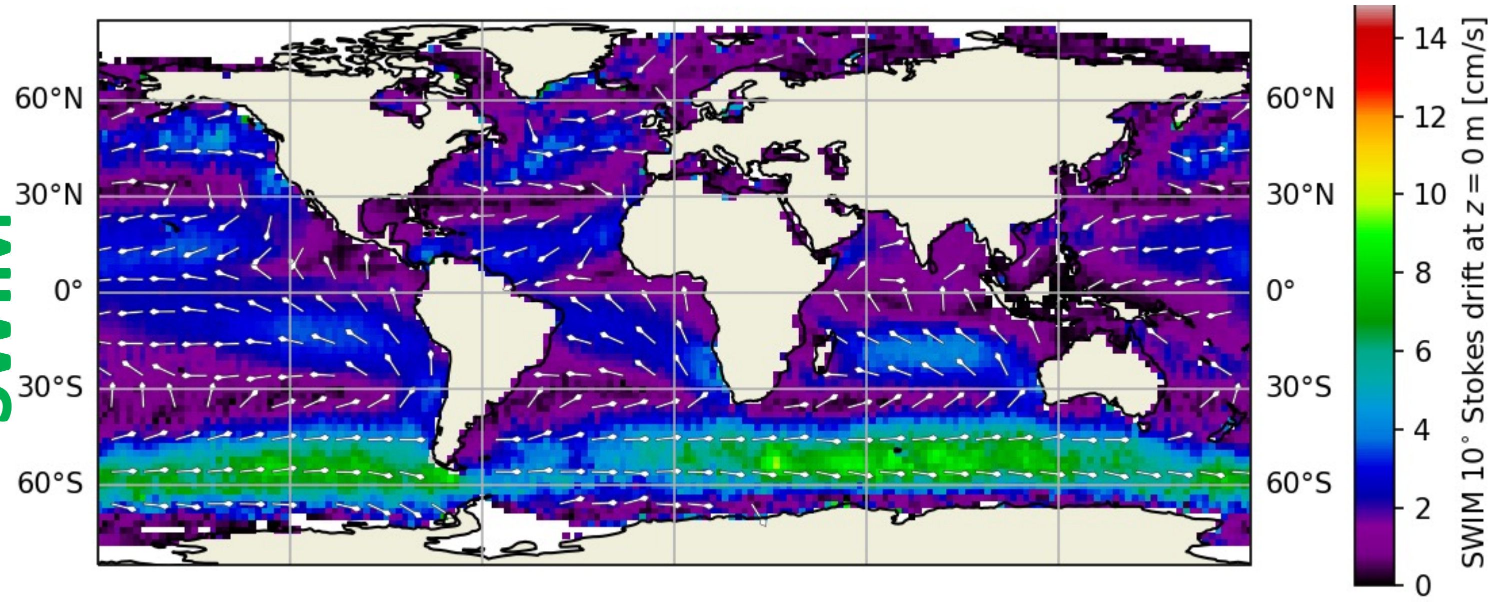
Negative bias caused by short waves truncation

Mean Stokes drift vector over 2021 (2x2°) on SWIM track

MODEL

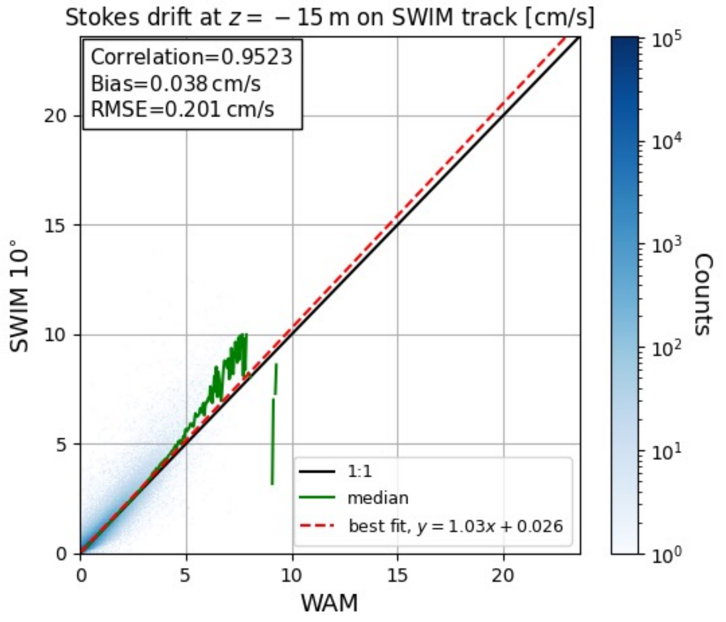


SWIM



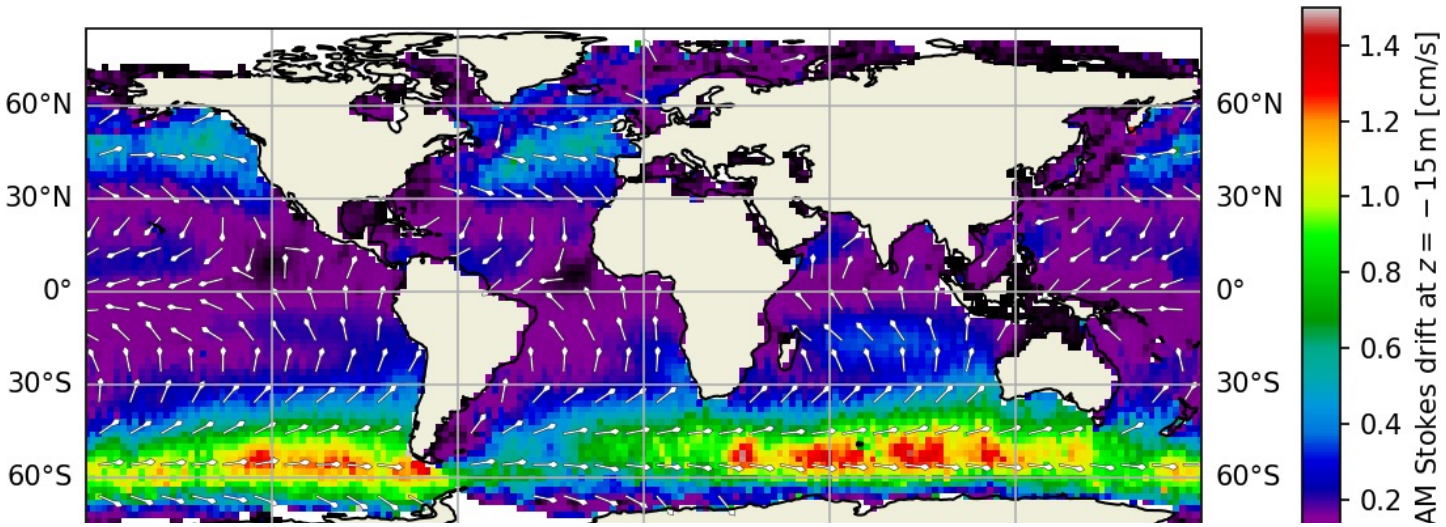
Performances - overview

depth = -15 m



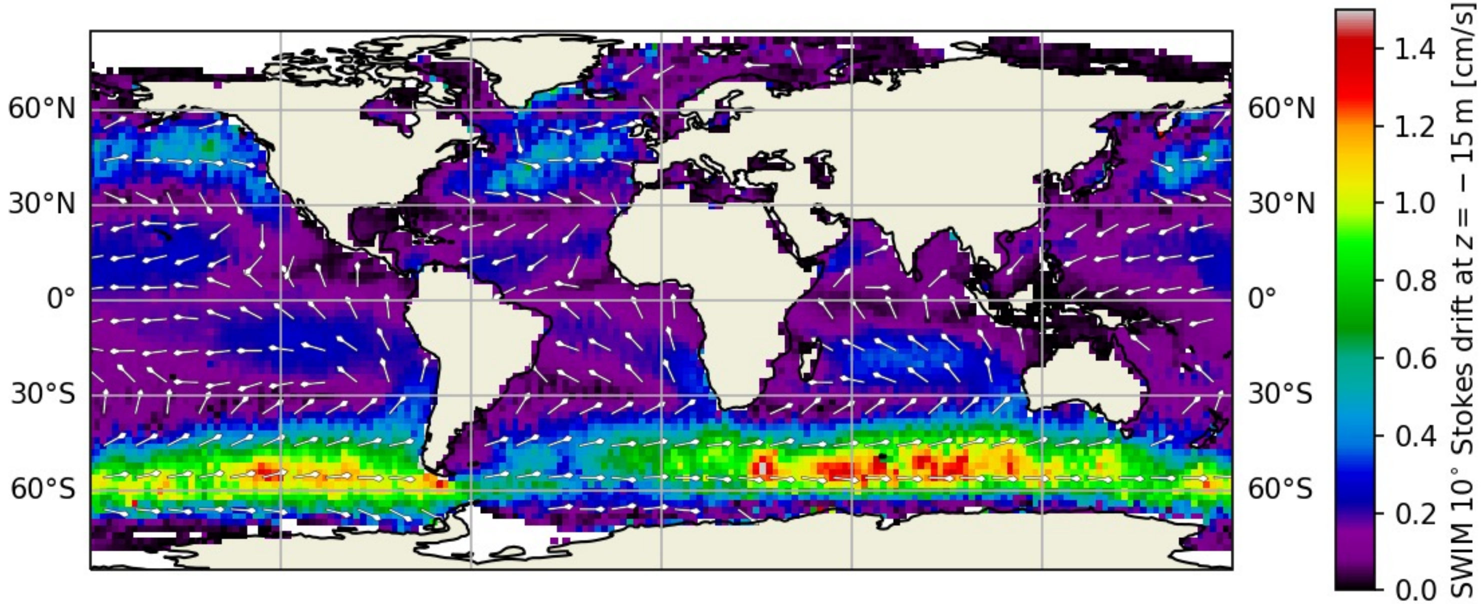
Mean Stokes drift vector over 2021 (2x2°) on SWIM track

MODEL

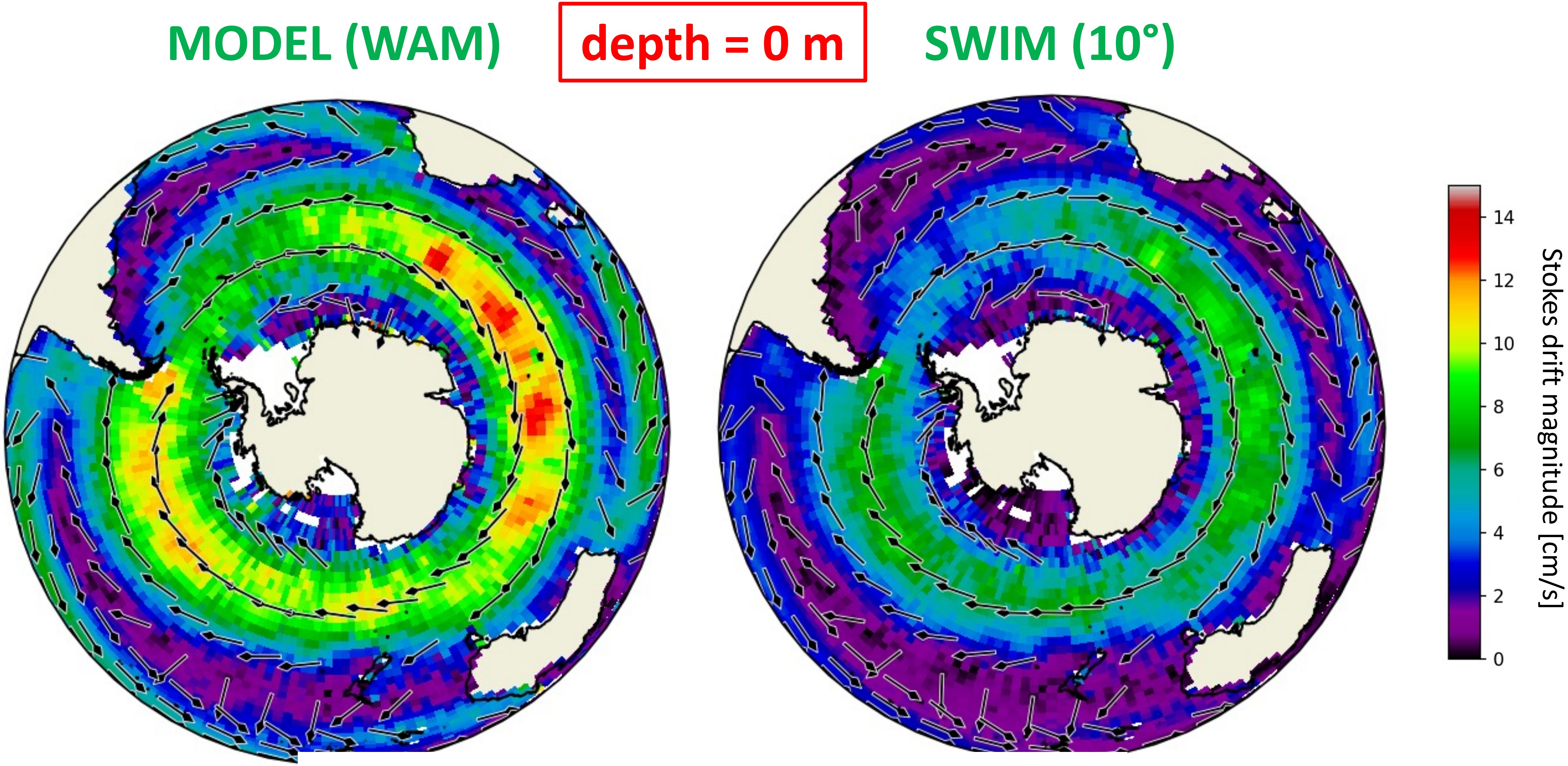


Mean over 2021

SWIM



Performances – Southern Ocean

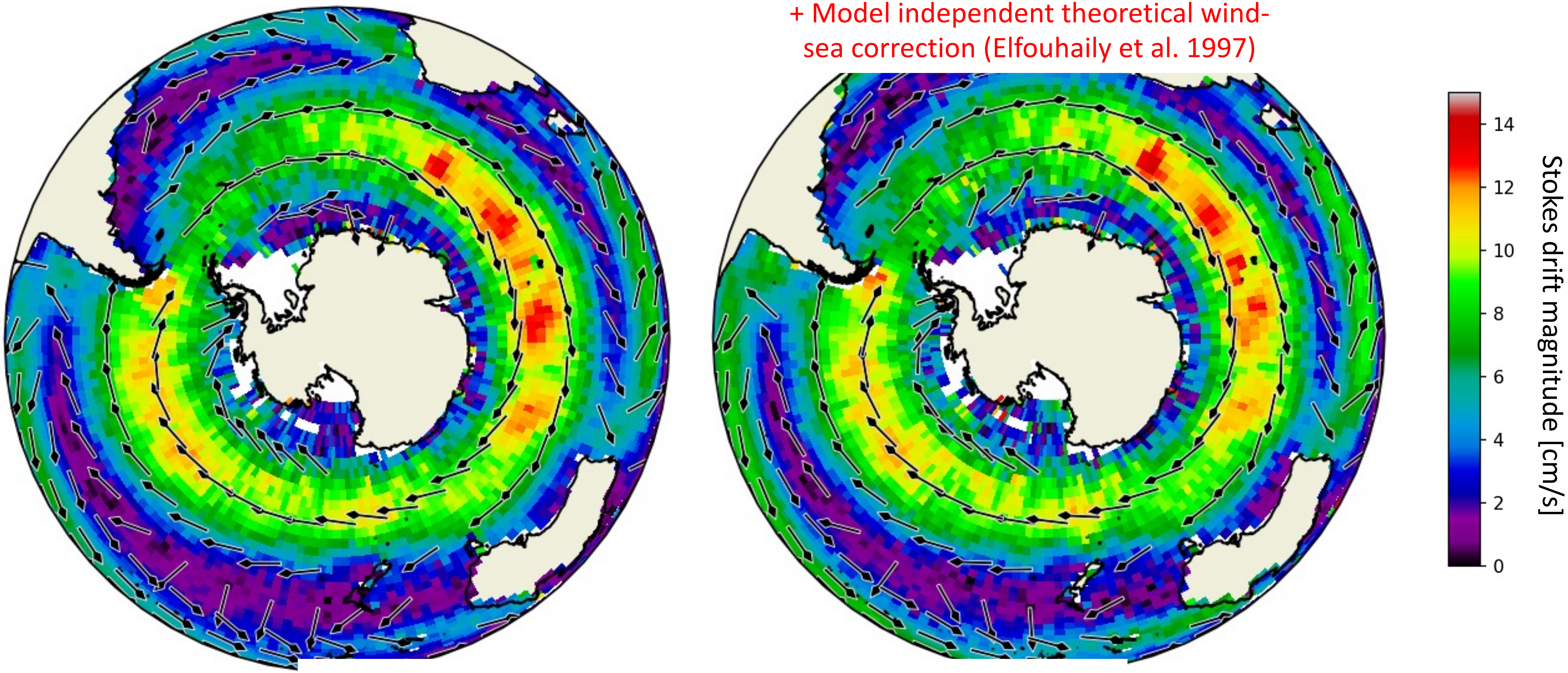


Mean Stokes drift vector over 2021 (2x2°) on SWIM track

Performances

MODEL (WAM) | **depth = 0 m** | **SWIM (10°)**

+ Model independent theoretical wind-sea correction (Elfouhaily et al. 1997)



Mean Stokes drift vector over 2021 (2x2°) on SWIM track

Conclusions

- **Prototype algorithm and validation presented**

- **Encouraging results**
  - Z = 0 m : truncation biases (~20 to 40%), coherent with waves spectrum knowledge
  - Z = -15 m : very low bias (<<1%) → Stokes transport

-> *Demo products available on demand*

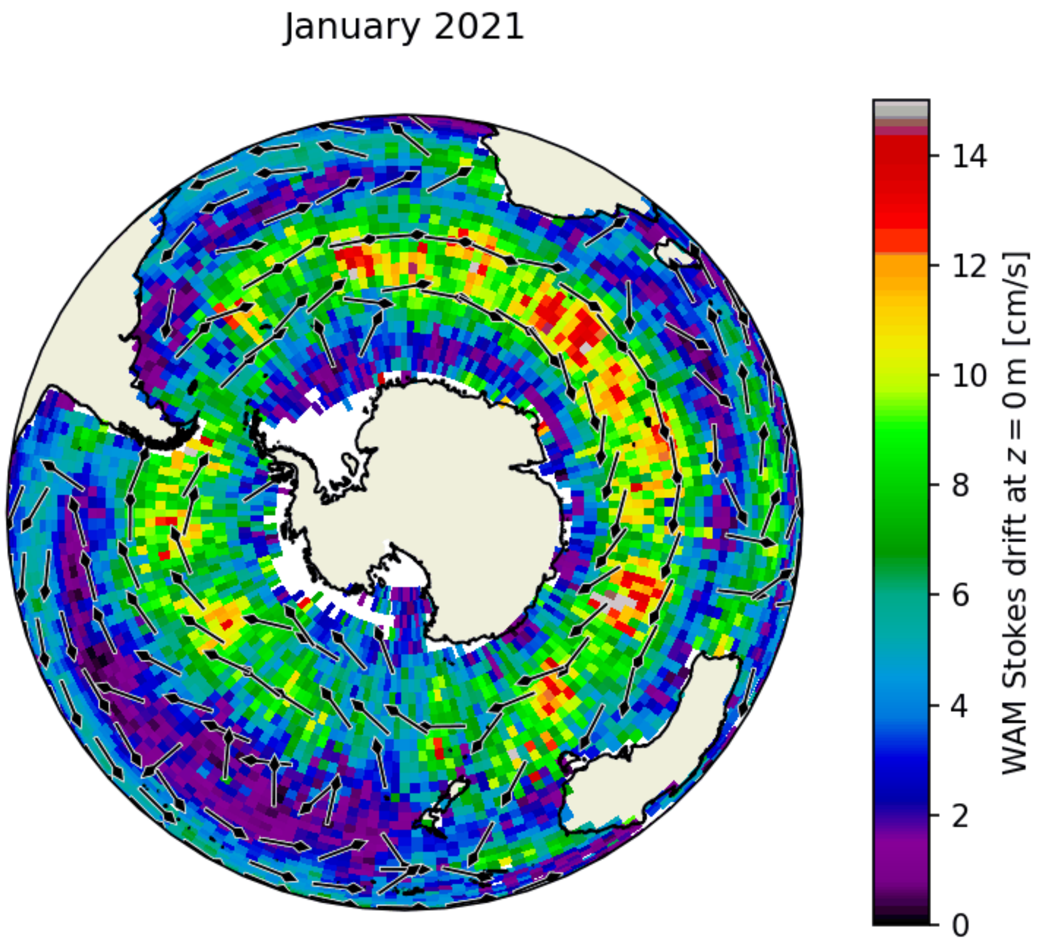
- **Way forward**
  - Algorithm to correct for truncation and ambiguity
  - Young seas/multiple wave systems

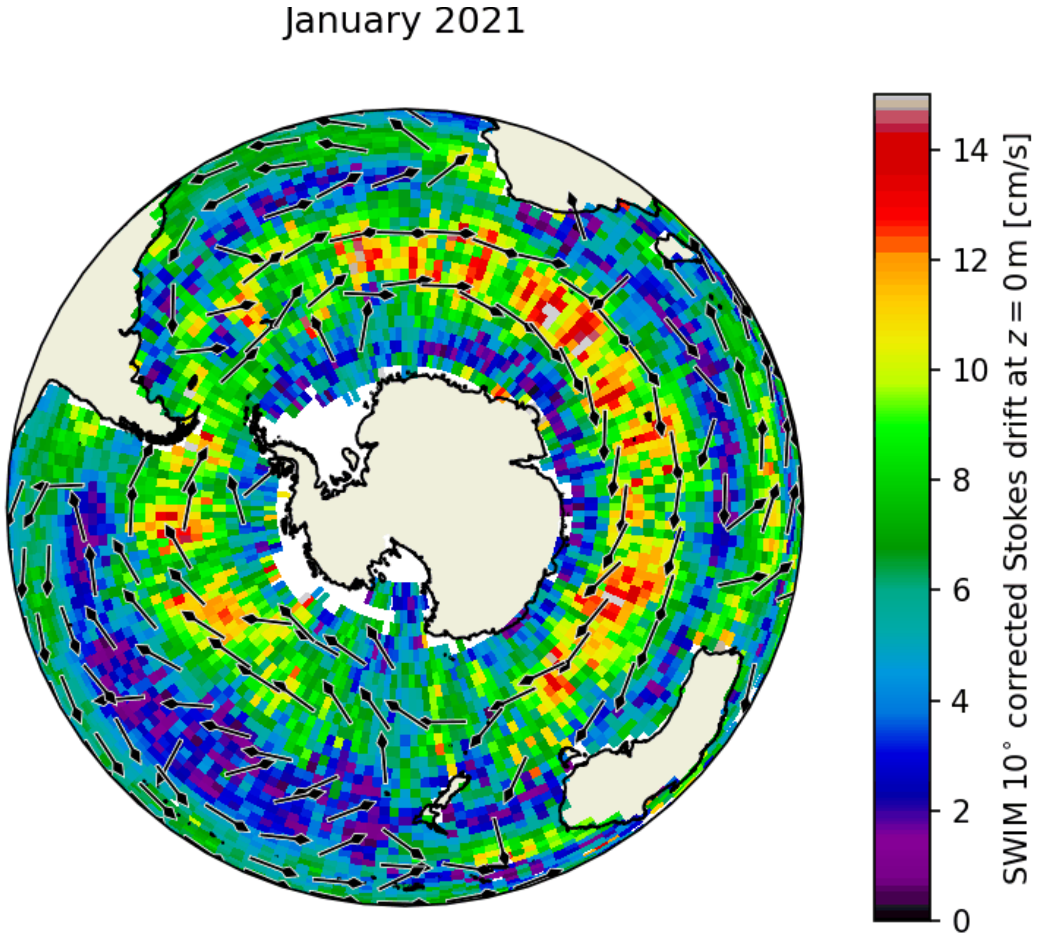
- **Longer term perspectives**
  - Beams combination to improve performances
  - Using synergy with SCAT wind for full independence from any model
  - SWIM added value to be further characterized (~100 km variability)

Performances

MODEL (WAM) **depth = 0 m** **SWIM (10°)**

+ Model independent theoretical wind-sea correction (Elfouhaily et al. 1997)





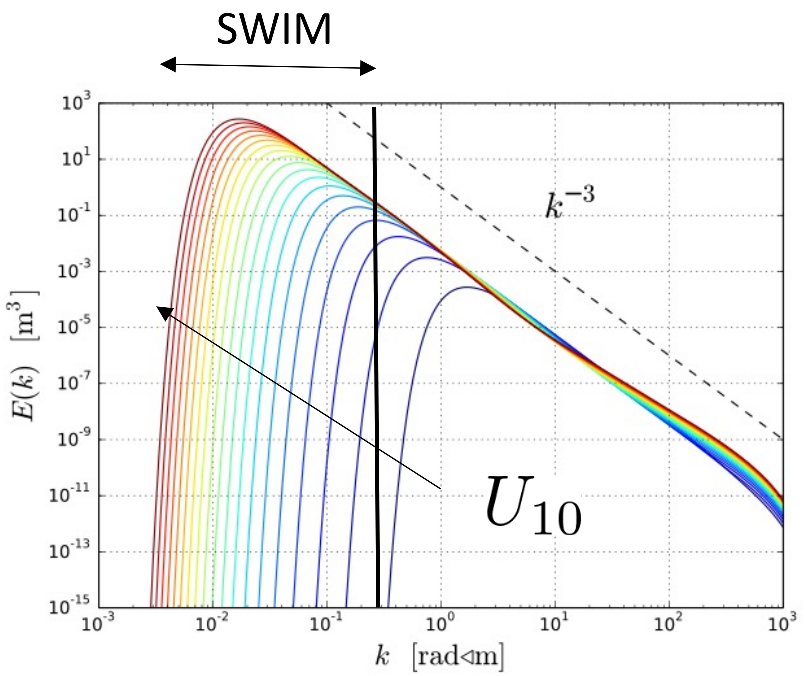
Mean Stokes drift vector over 2021 (2x2°) on SWIM track

Additional

Stokes theoretical correction

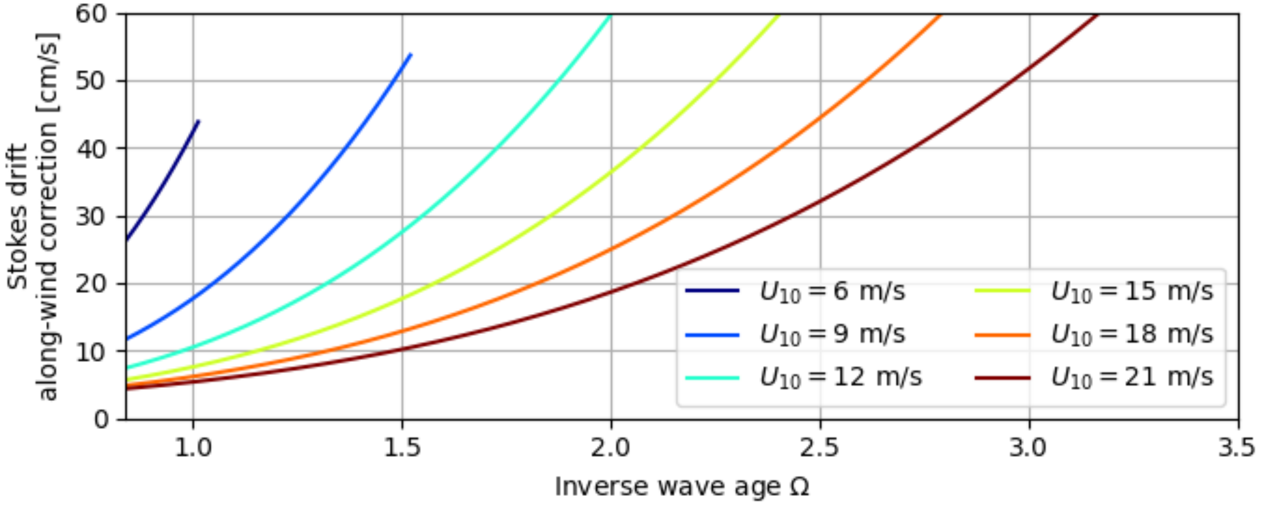
Elfouhaily et al. 1997

Adding in the wind direction the Stokes drift expected from an Elfouhaily spectrum for waves 0 < λ < 22m



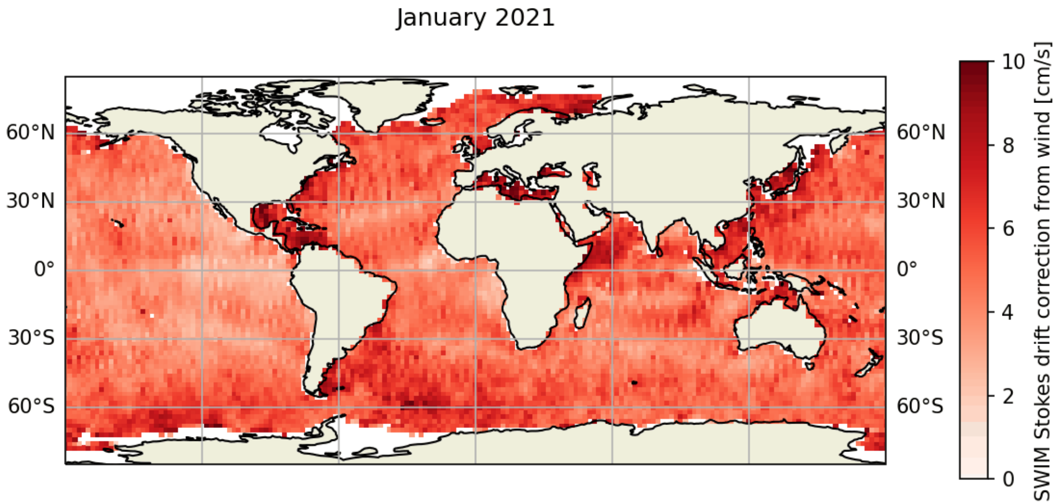
$$\Delta U_S(z=0) \simeq U_{S0}\sqrt{\Omega}\left[1+\left(\frac{U_{10}}{\Omega U_0}\right)^{-2.5}\right]$$

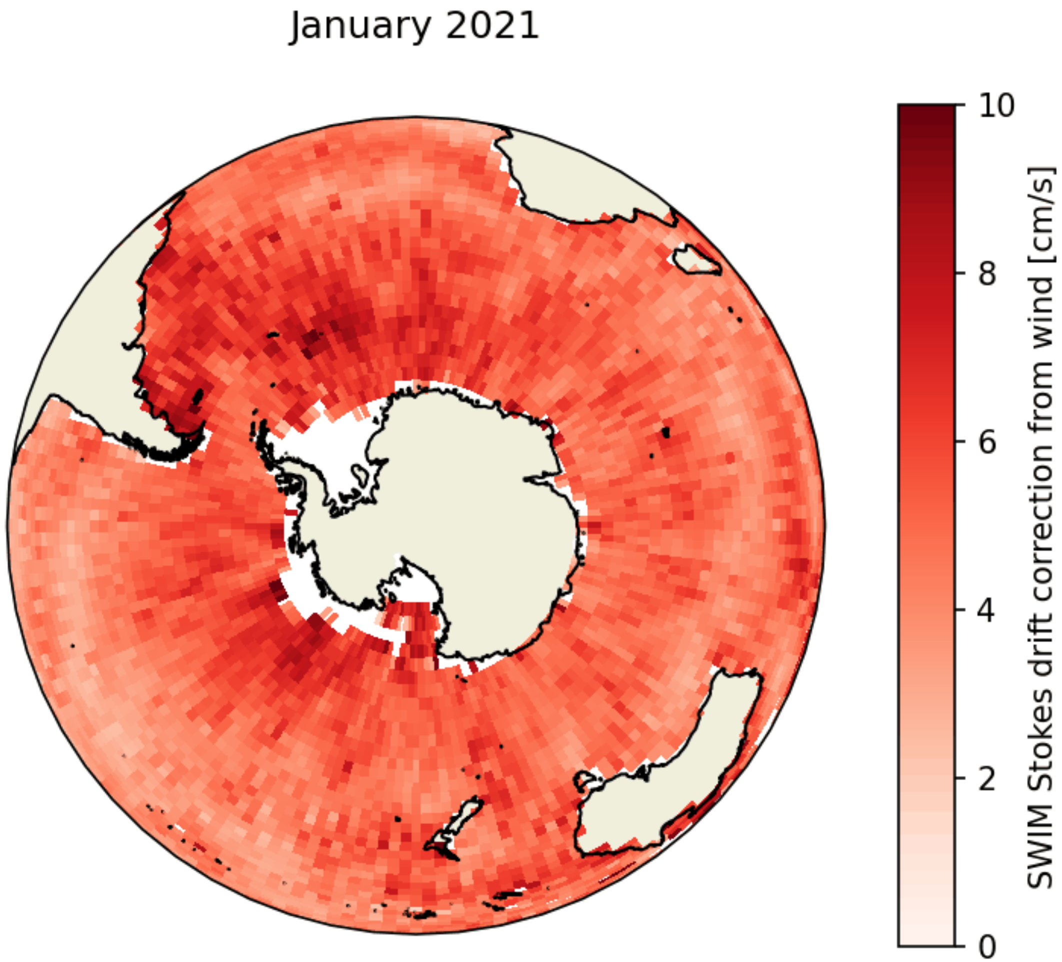
$$U_{S0} = 3.7\,\mathrm{cm/s} \qquad U_0 = 15.3\,\mathrm{m/s} \qquad \Omega \simeq \frac{U_{10}}{c_p}$$



Stokes theoretical correction

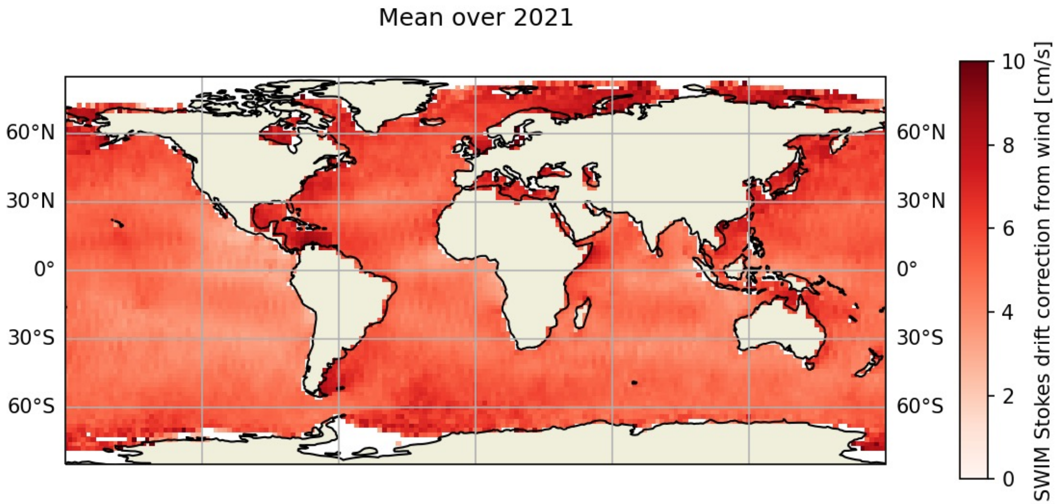
U_{10} from ECMWF forecast
Peak from SWIM 10°

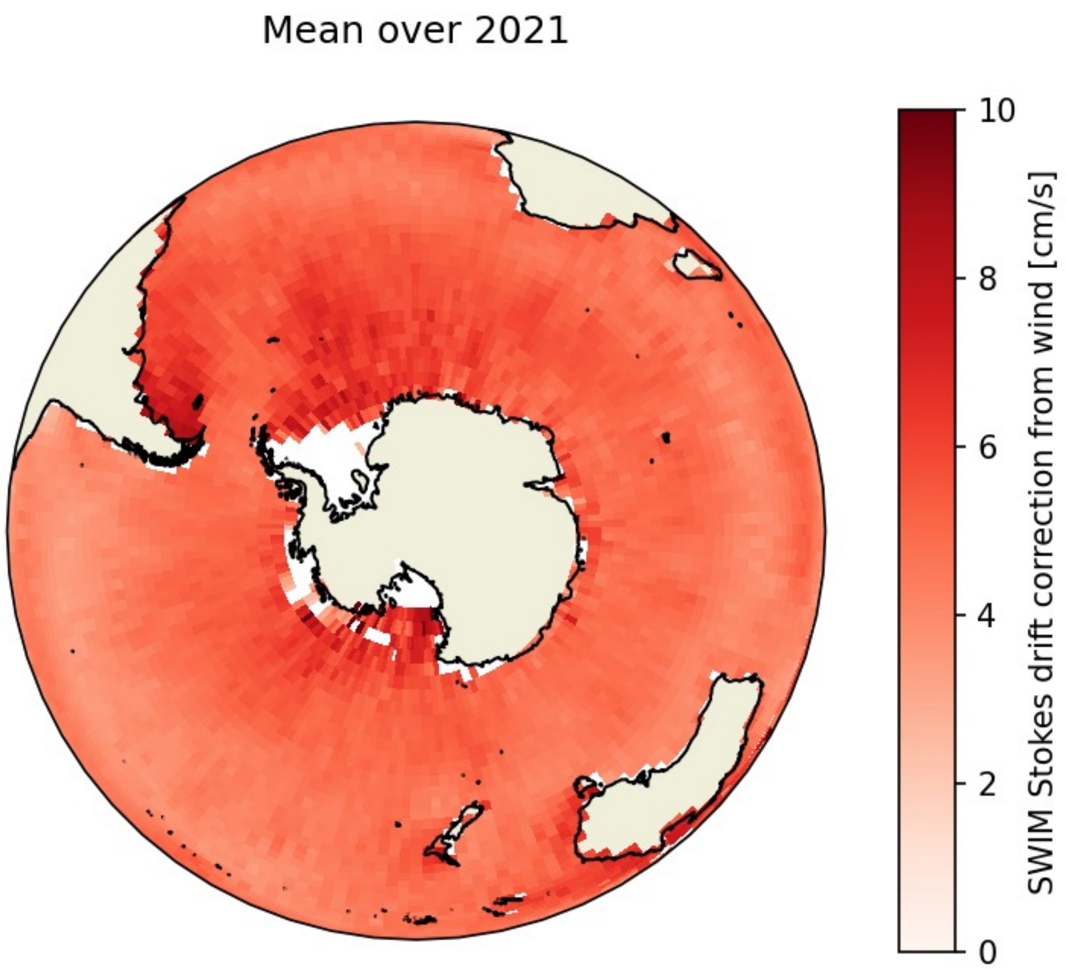




Stokes theoretical correction

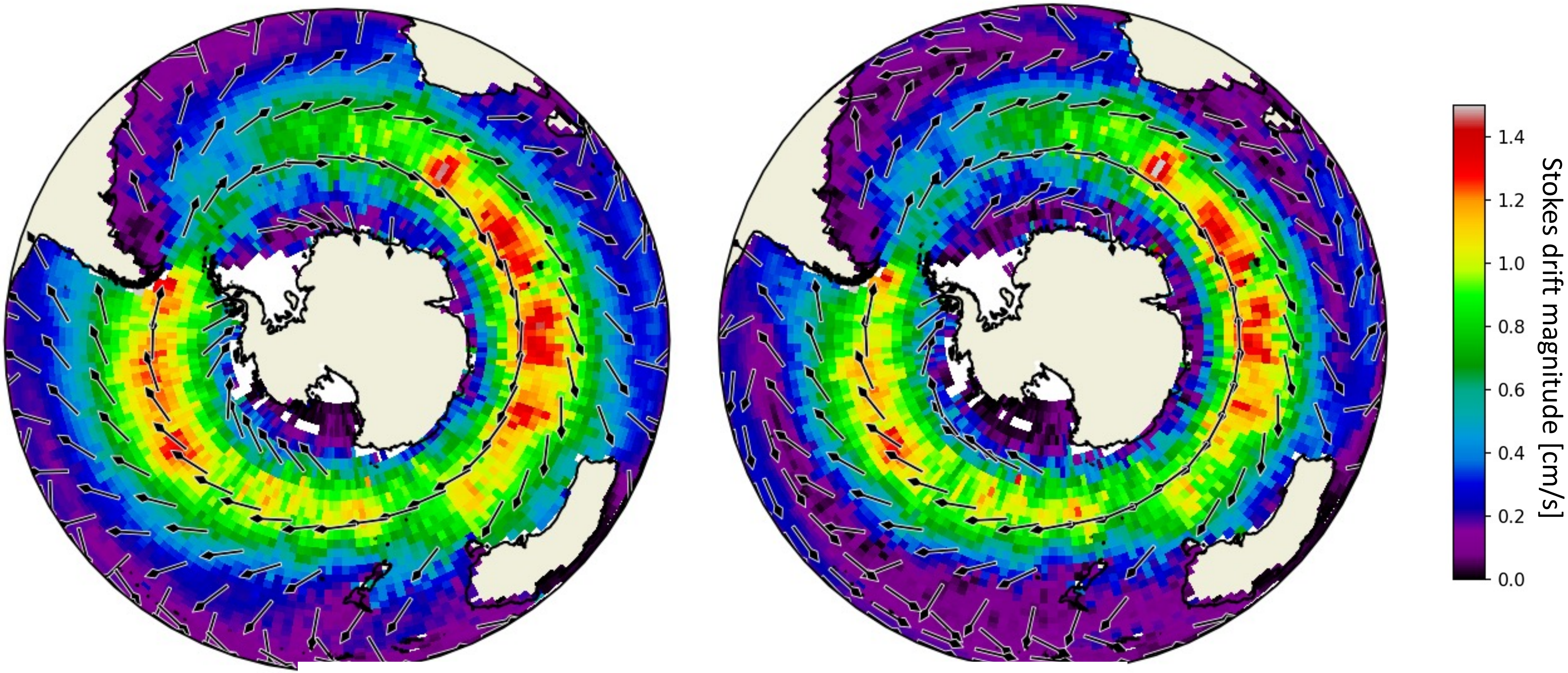
U_{10} from ECMWF forecast
Peak from SWIM 10°





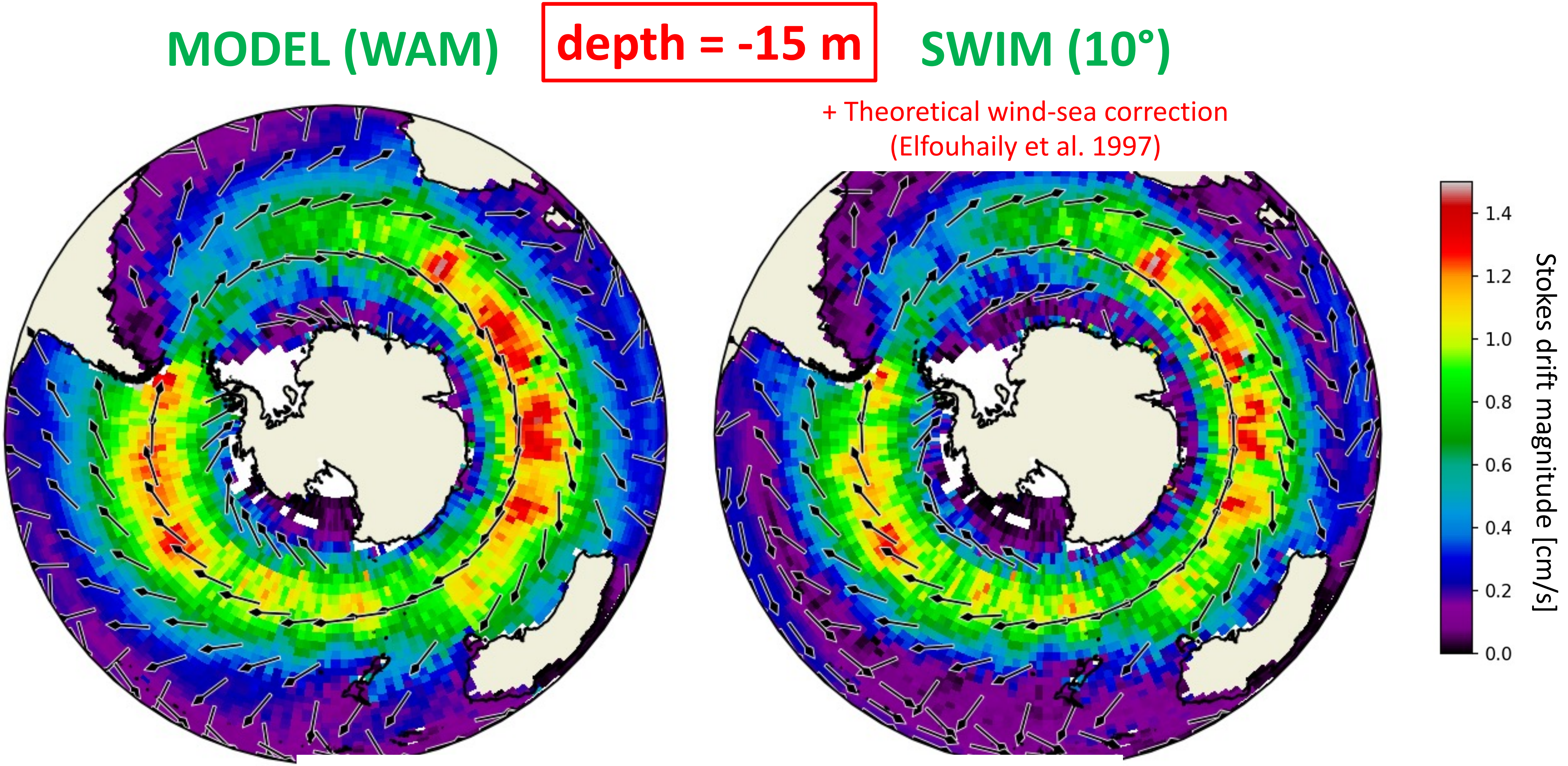
Performances

MODEL (WAM) **depth = -15 m** SWIM (10°)



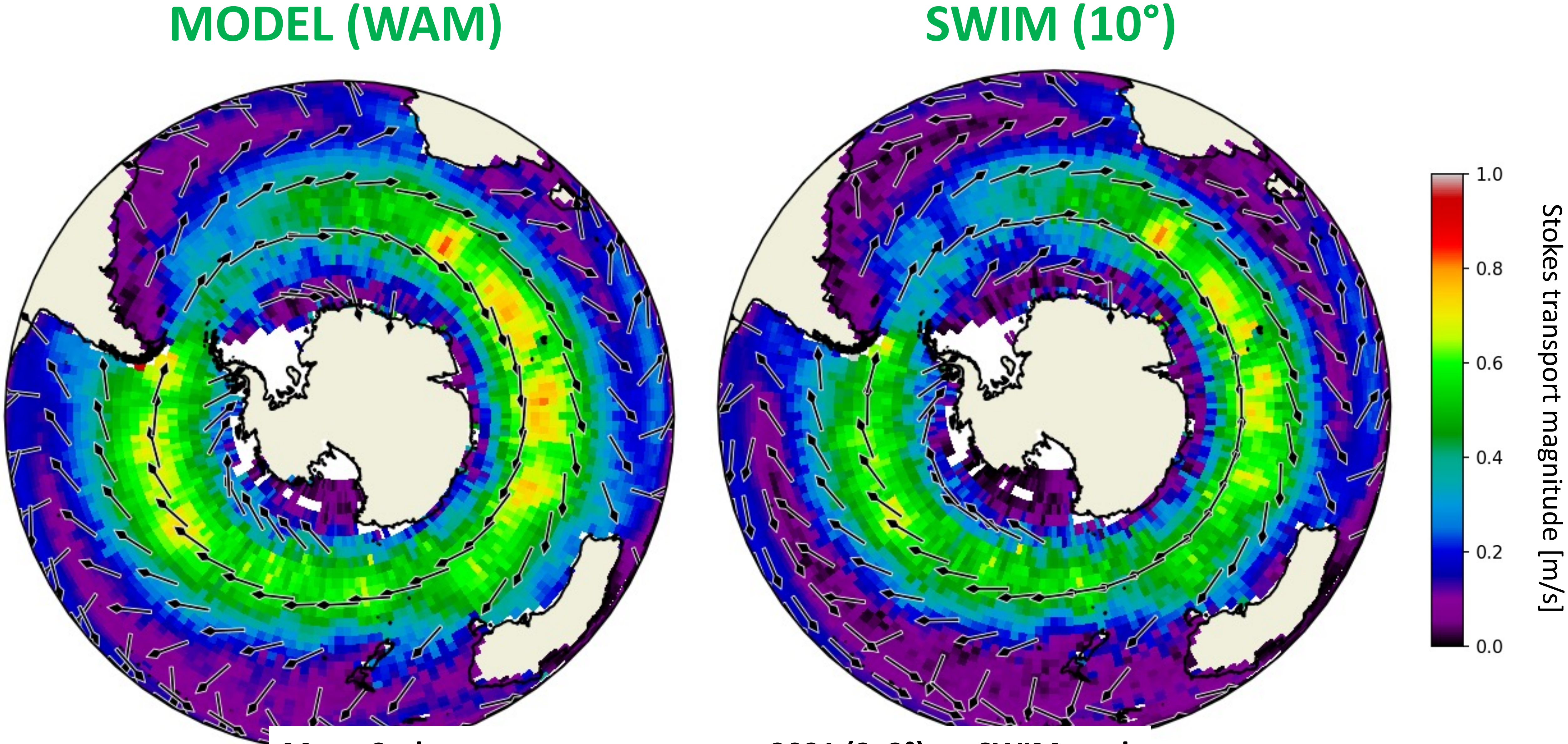
Mean Stokes drift vector over 2021 (2x2°) on SWIM track

Performances



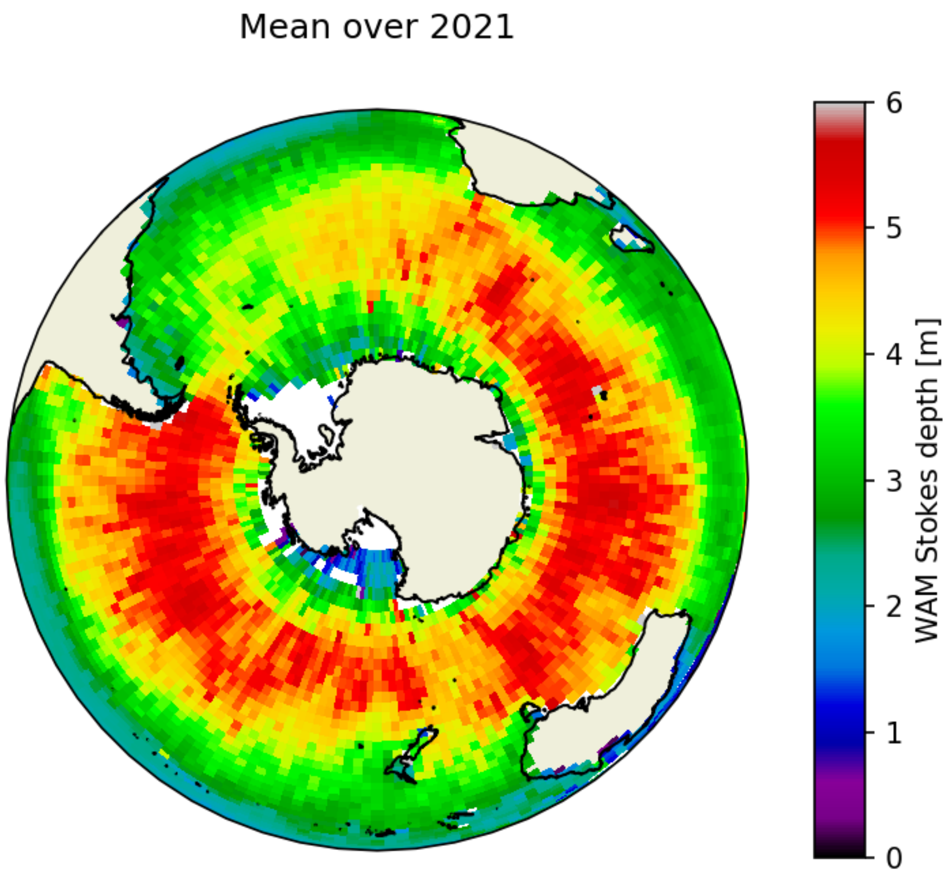
Mean Stokes drift vector over 2021 (2x2°) on SWIM track

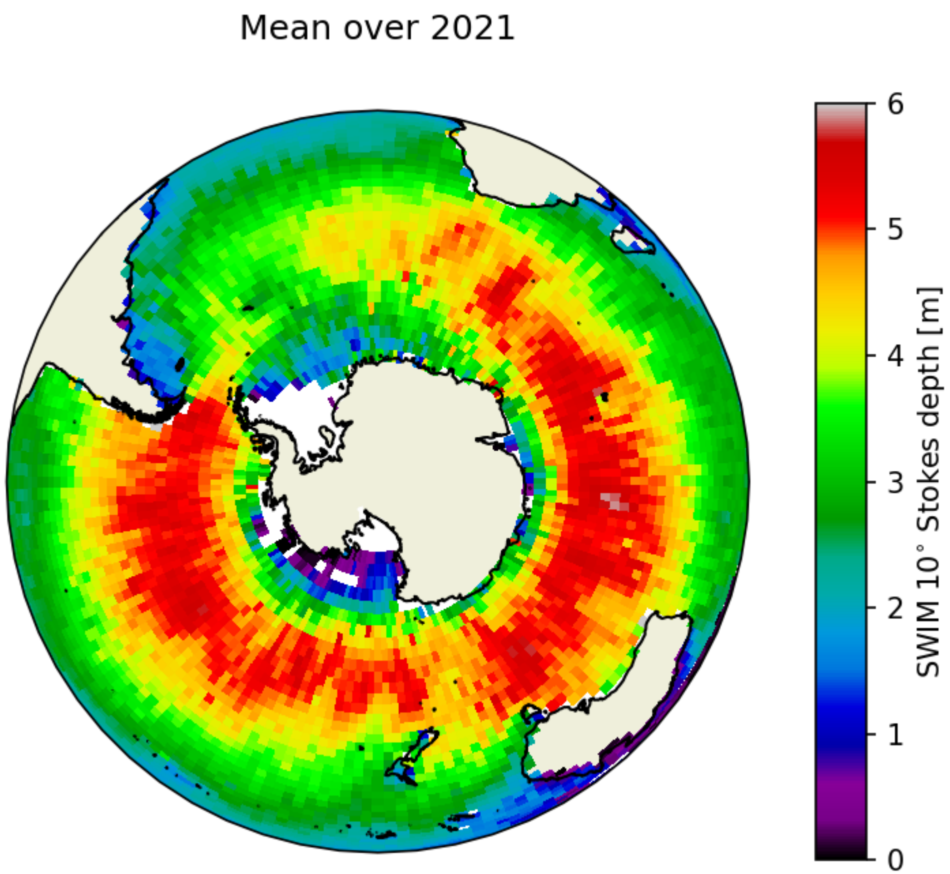
Performances



Mean Stokes transport vector over 2021 (2x2°) on SWIM track

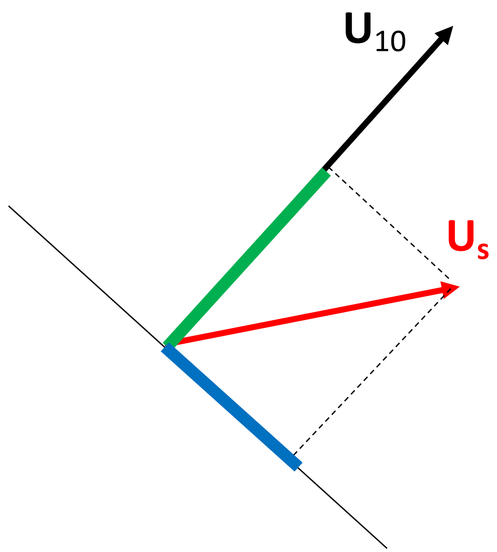
Performances





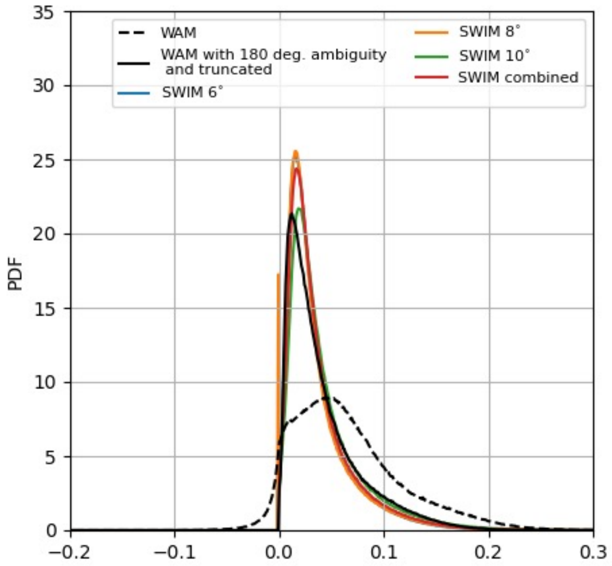
Performances - disambiguation

Hypothesis : Stokes drift direction ~ wind direction

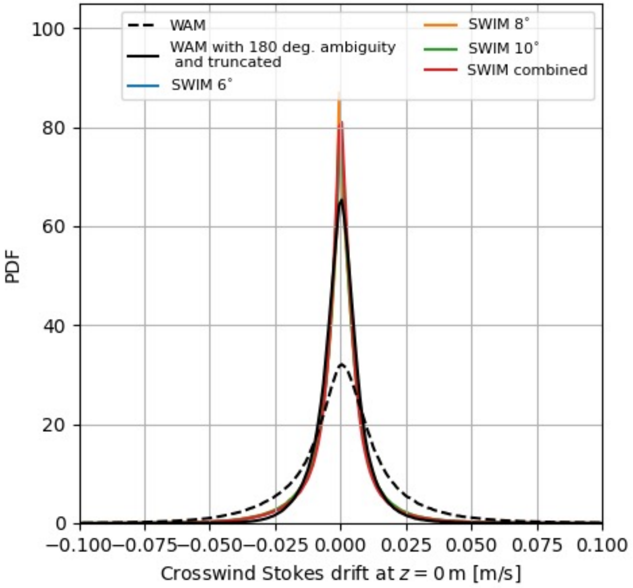


z = 0 m

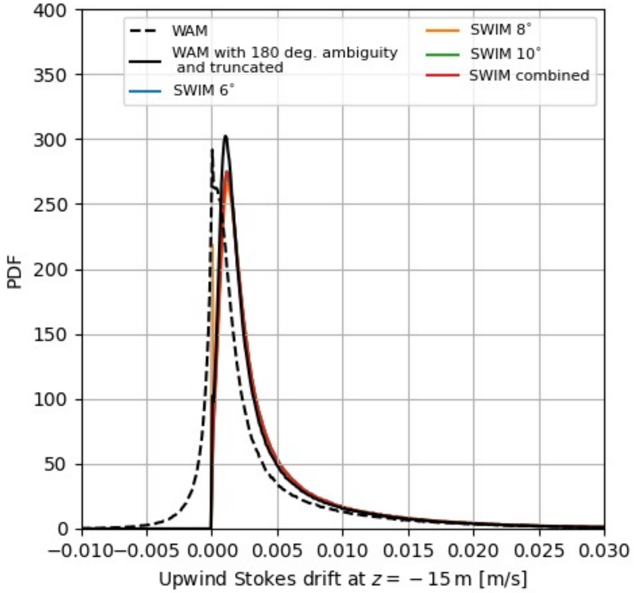
Along-wind Stokes drift

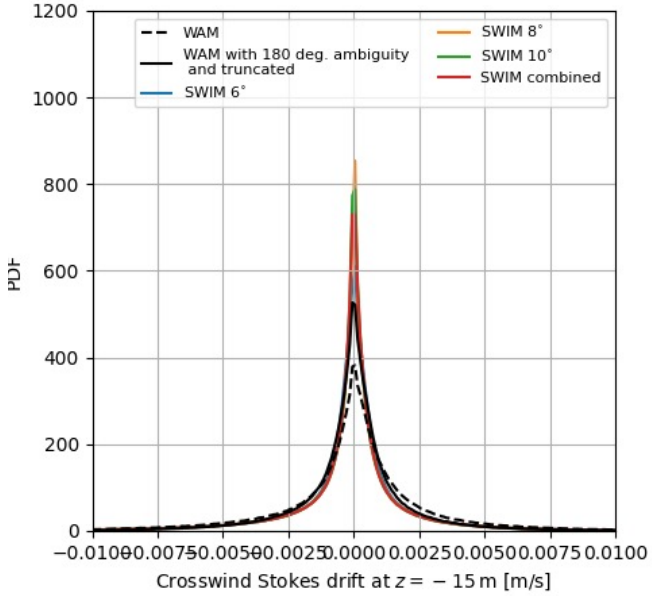


Crosswind Stokes drift



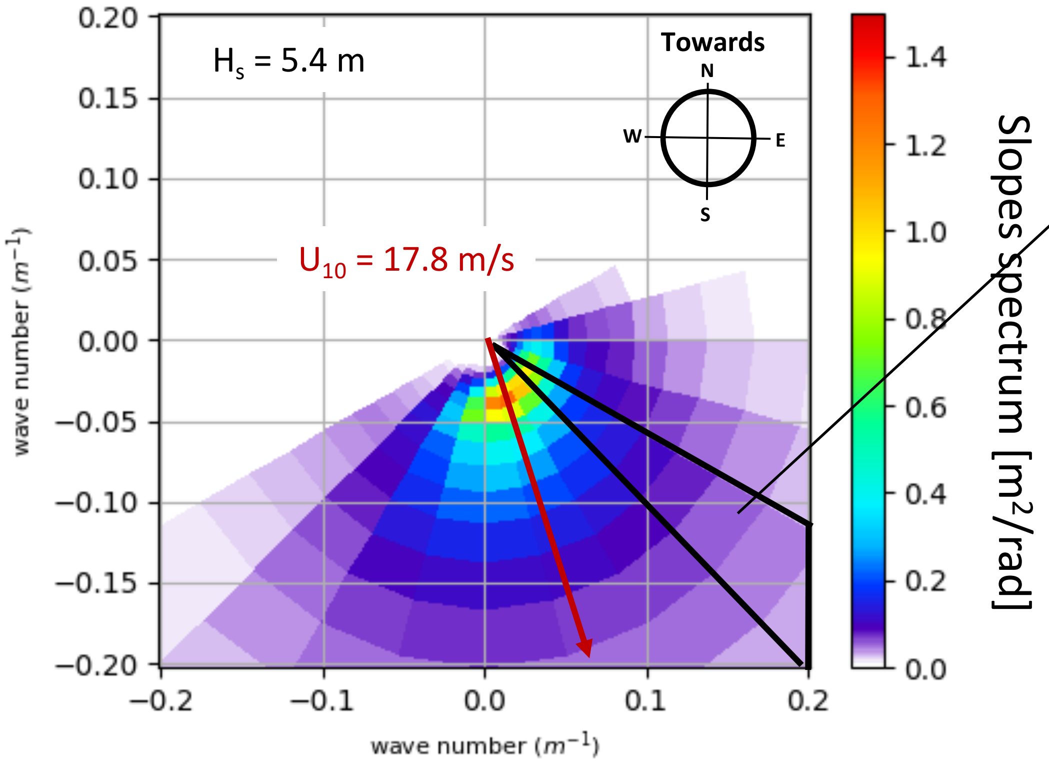
z = -15 m



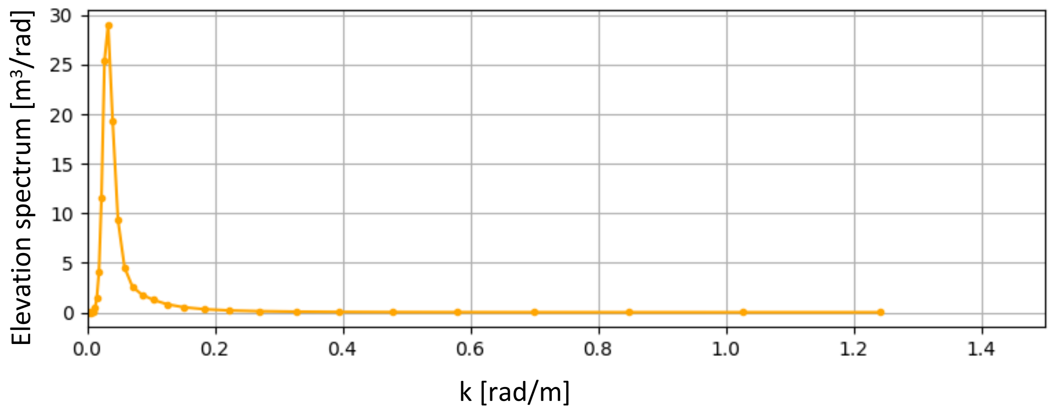


Stokes drift estimation from SWIM

MODEL (WAM)

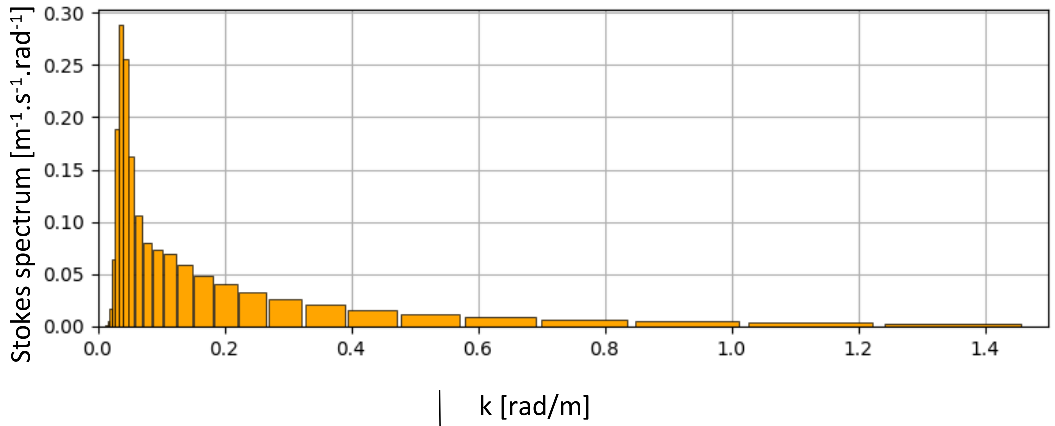


Kenyon 1969



Kenyon 1969

$$\times 2\sqrt{g}k^{1.5}$$

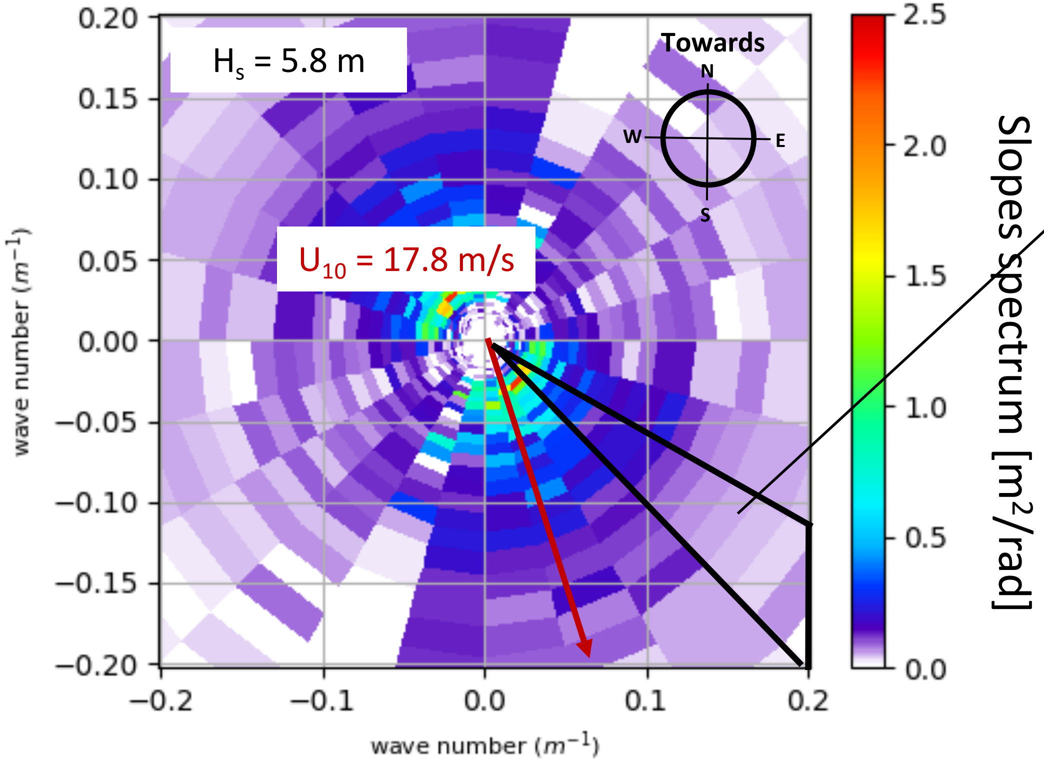


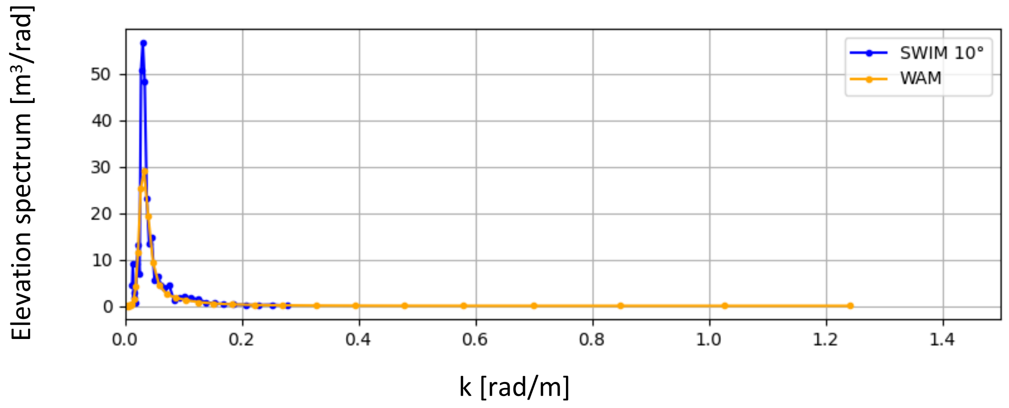
$$\int \dots dk$$

3.7 cm/s

Introduction - Stokes drift estimation

SWIM RAW (10° beam)





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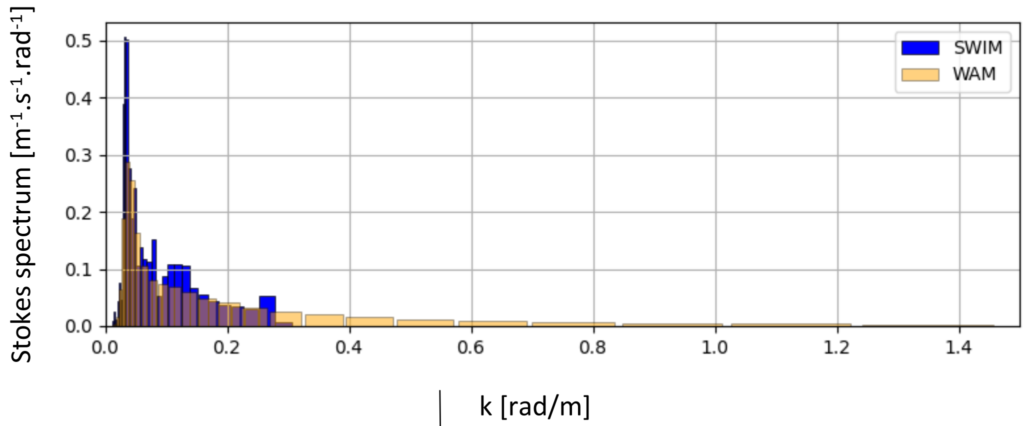
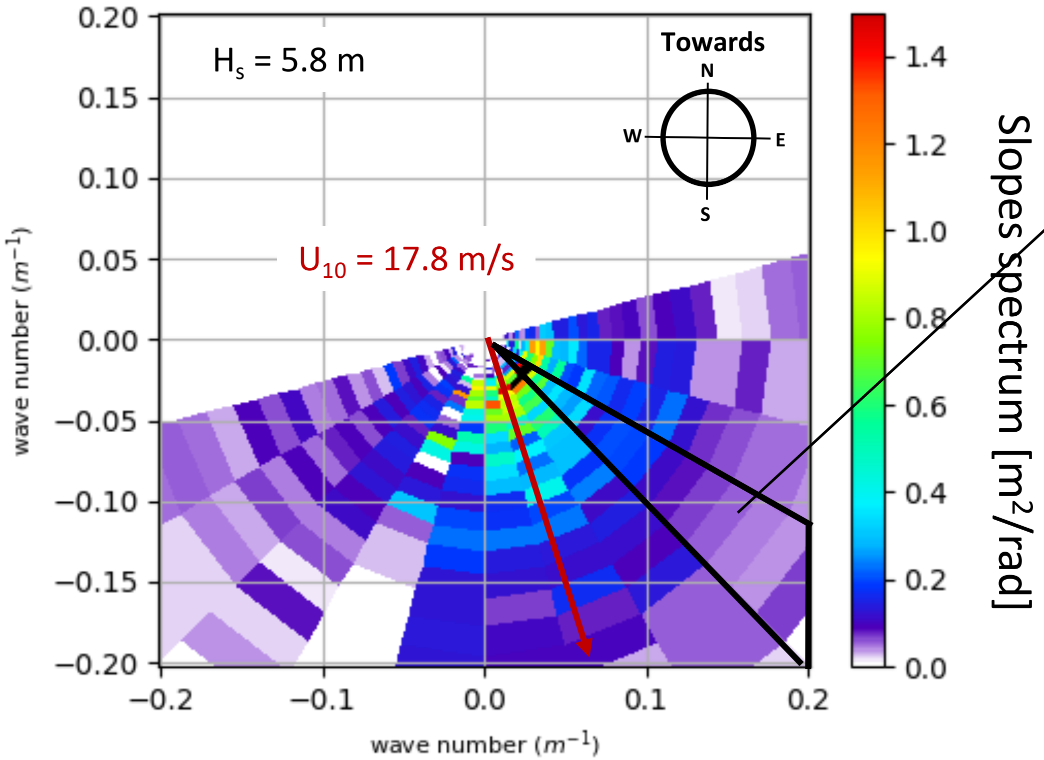


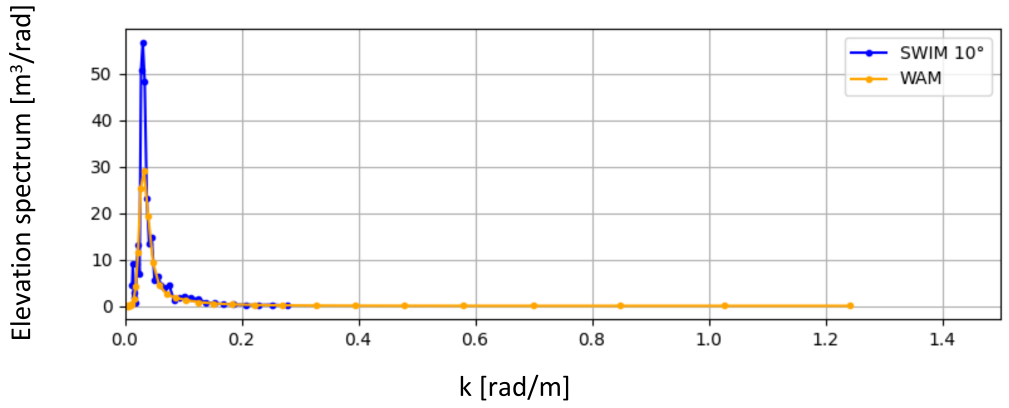
$$\int \dots dk$$

2.9 cm/s

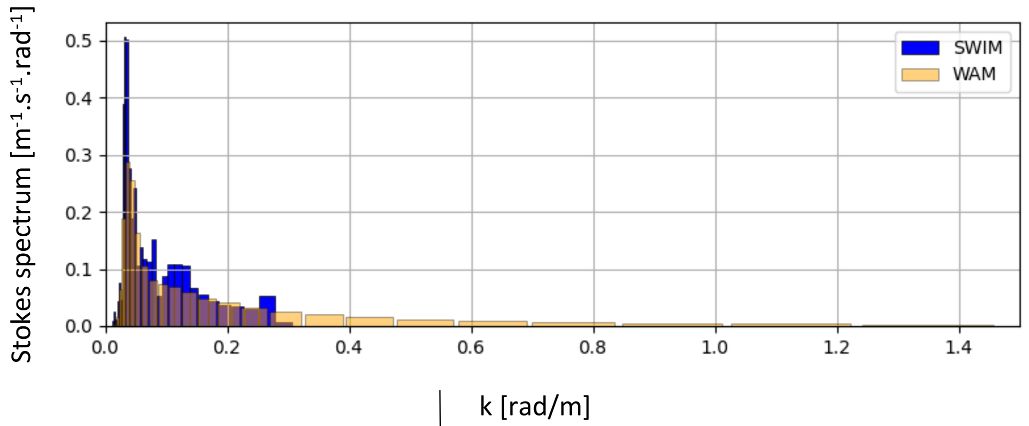
Introduction - Stokes drift estimation

SWIM (10°)





$$\times 2\sqrt{g}k^{1.5}$$

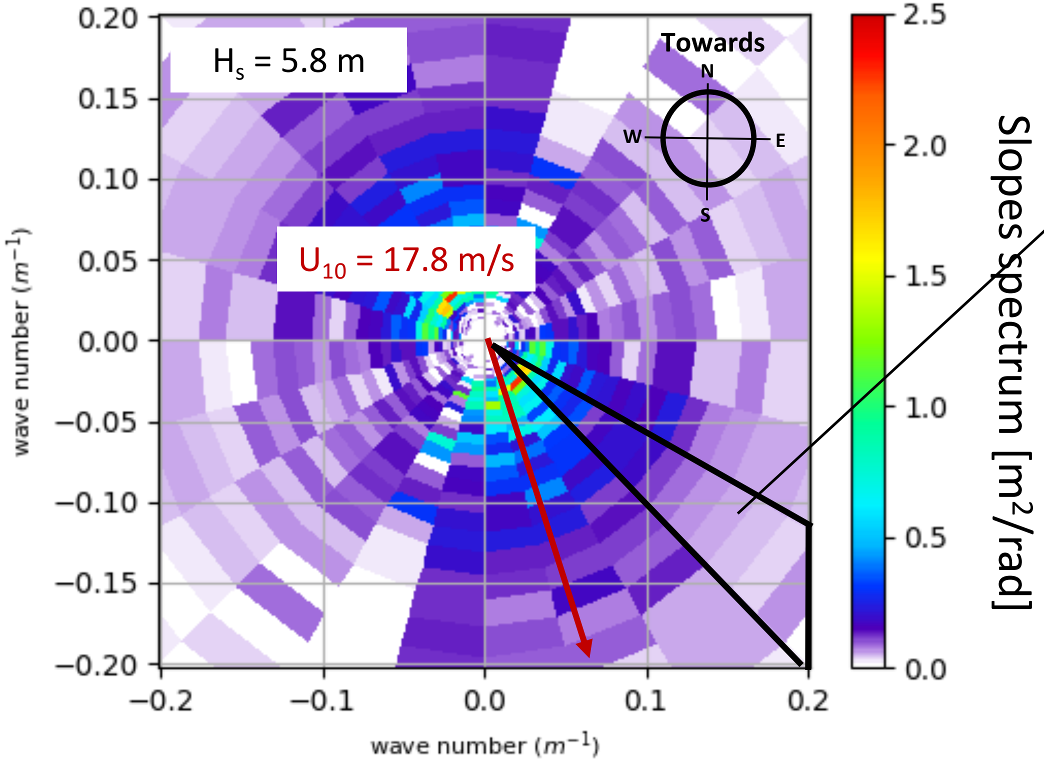


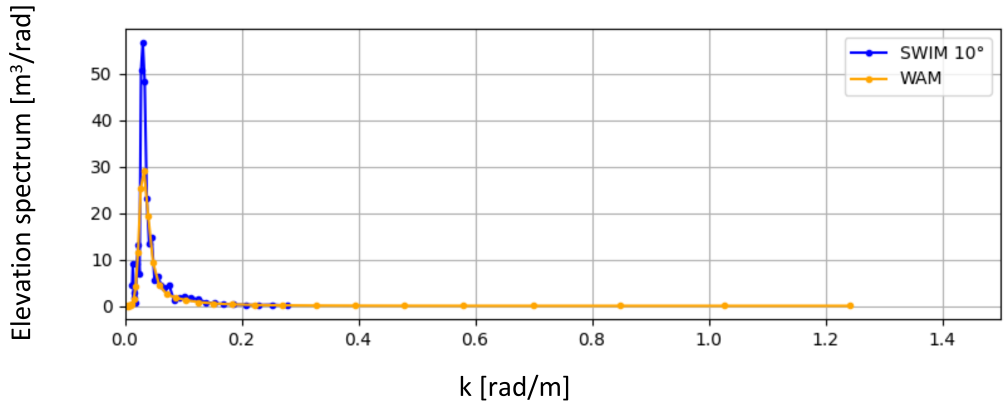
$$\int \ldots dk$$

2.9 cm/s

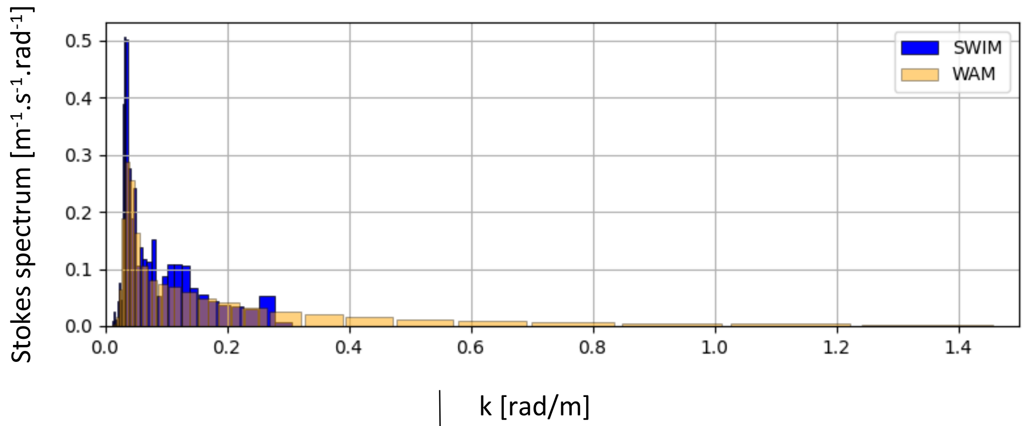
Introduction - Stokes drift estimation

SWIM RAW (10° beam)





$$\times 2\sqrt{g}k^{1.5}$$

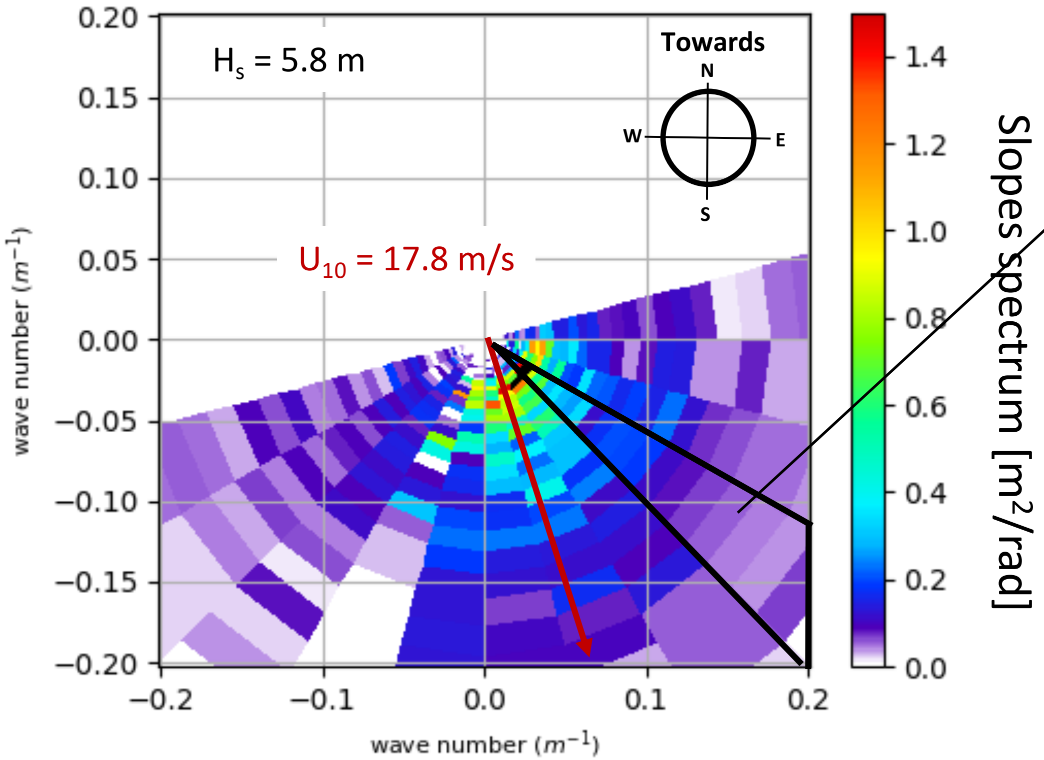


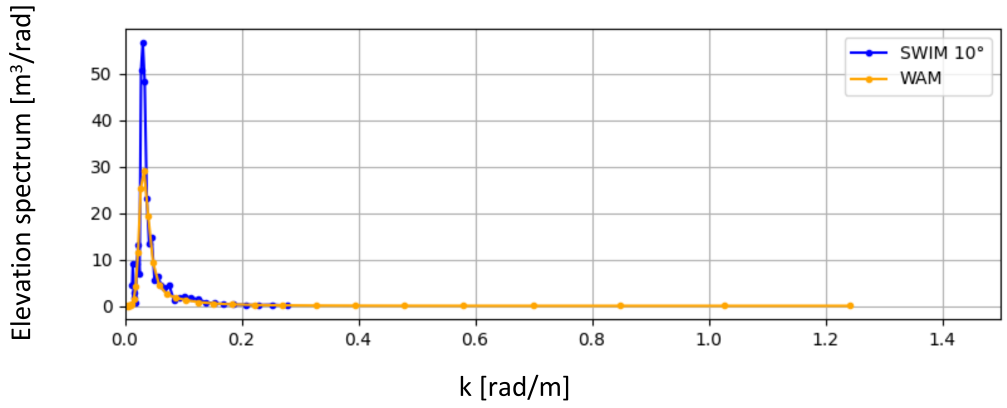
$$\int \ldots dk$$

2.9 cm/s

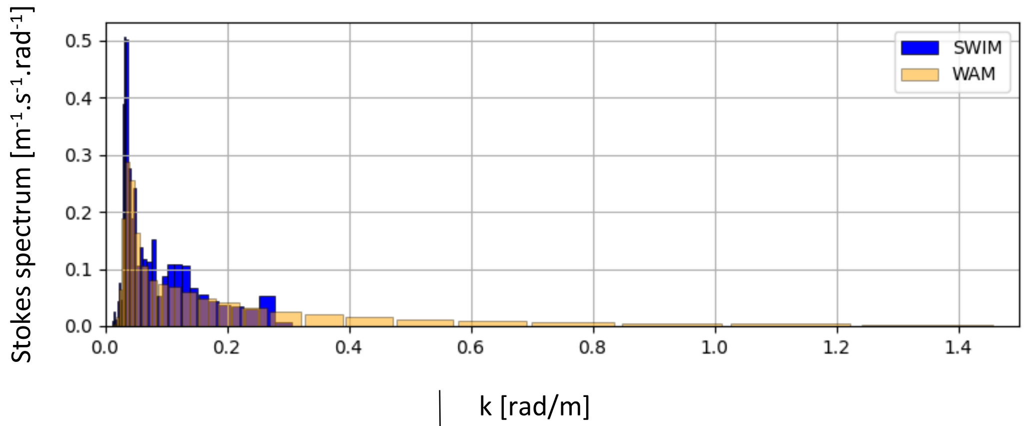
Introduction - Stokes drift estimation

SWIM (10°)





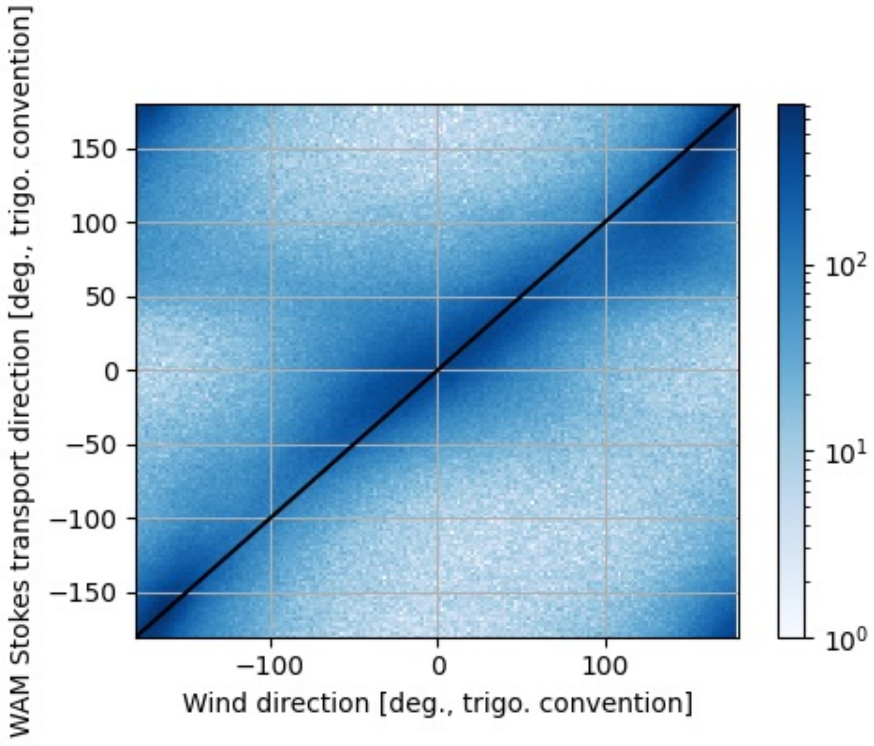
$$\times 2\sqrt{g}k^{1.5}$$



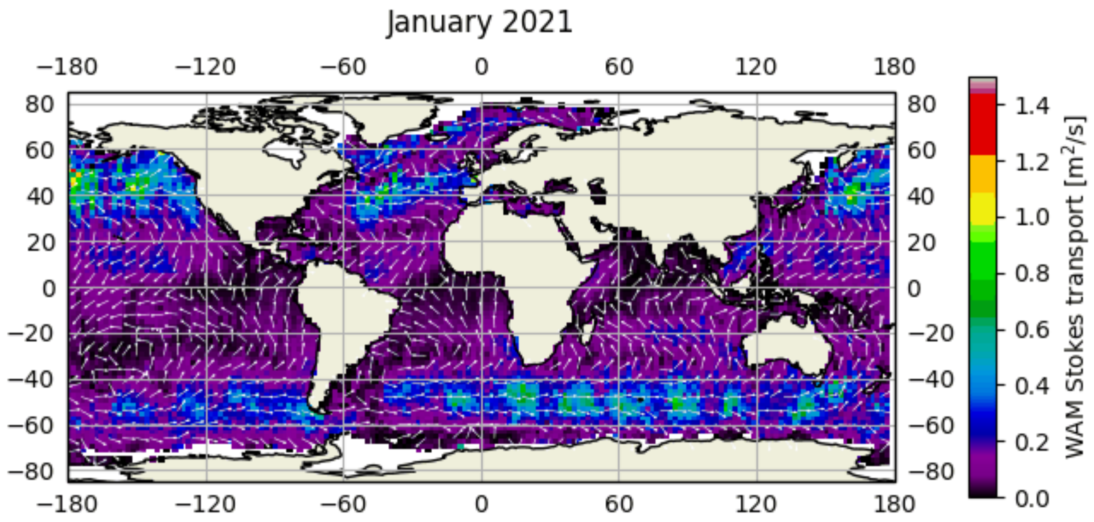
$$\int \dots dk$$

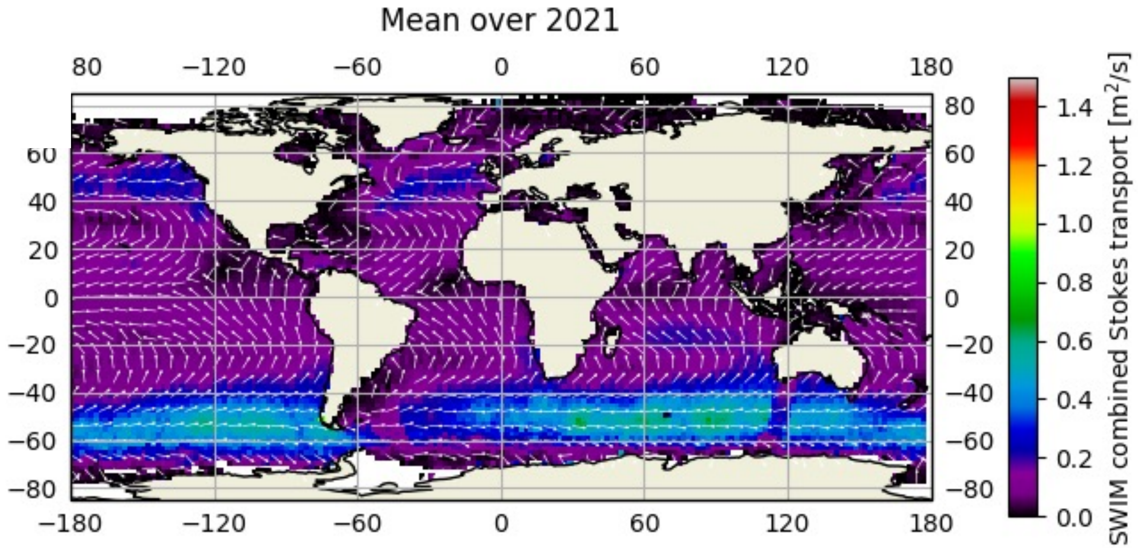
2.9 cm/s

2D transport

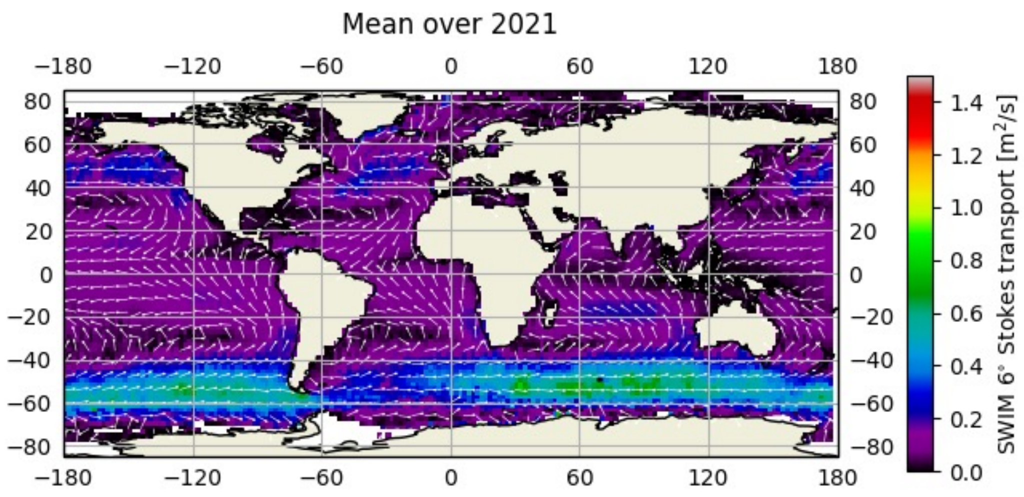


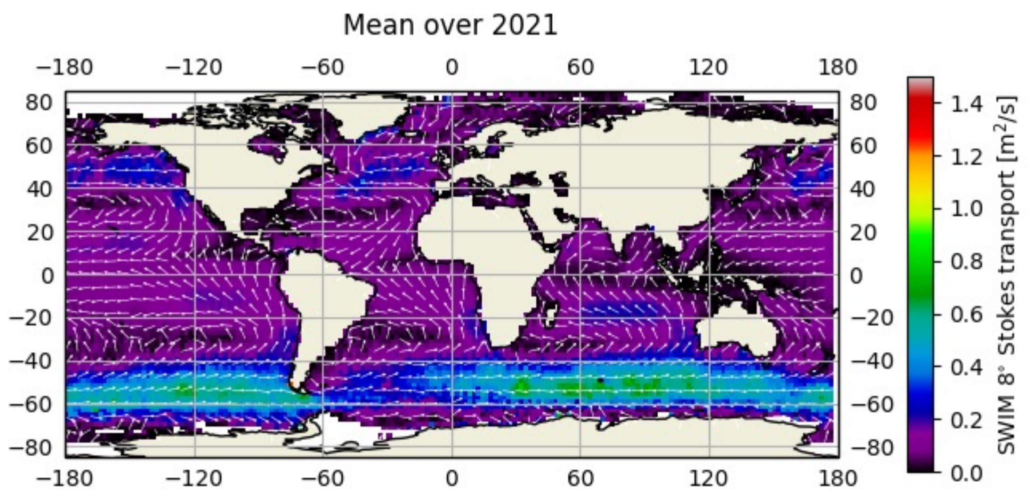
WAM 2D transport

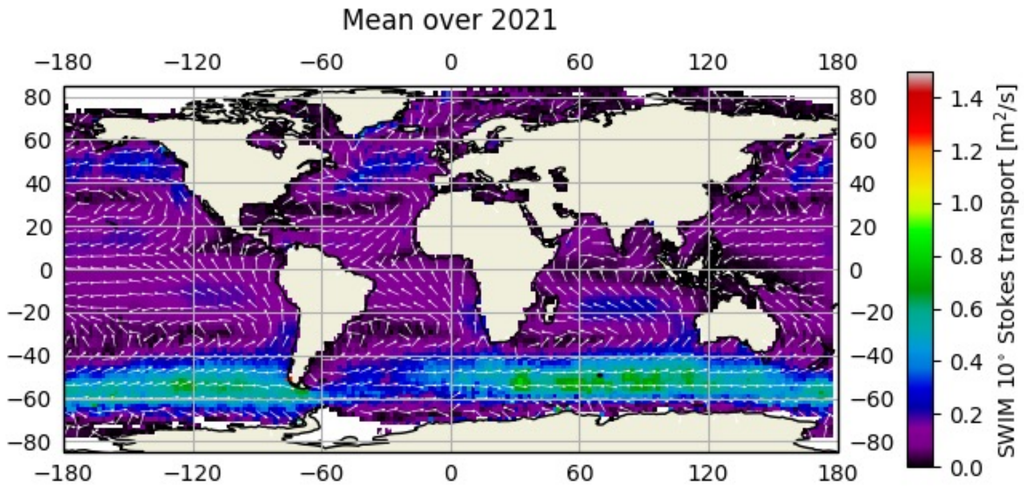


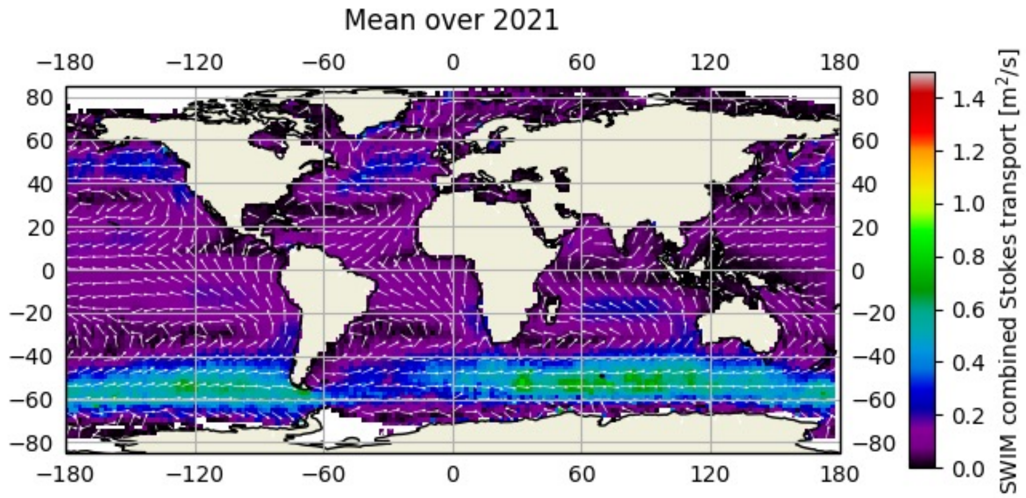


SWIM 2D transport

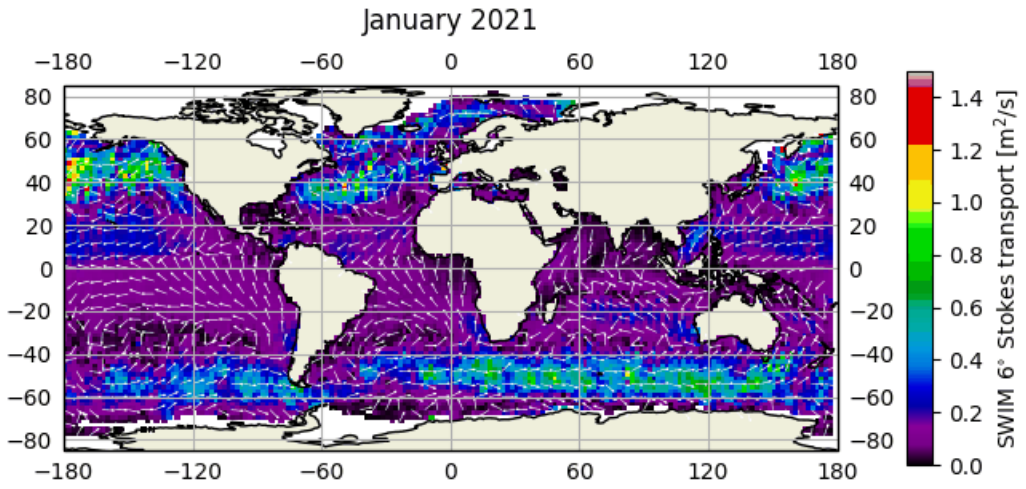


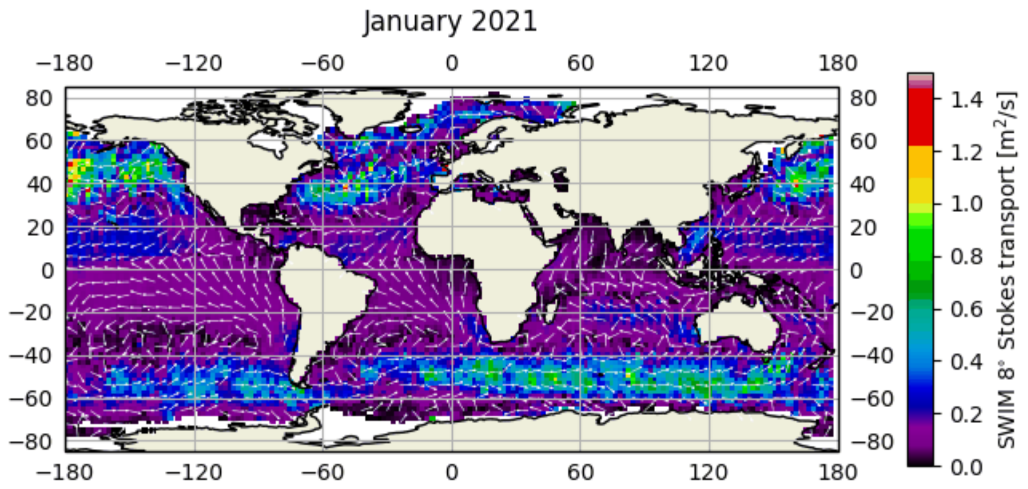


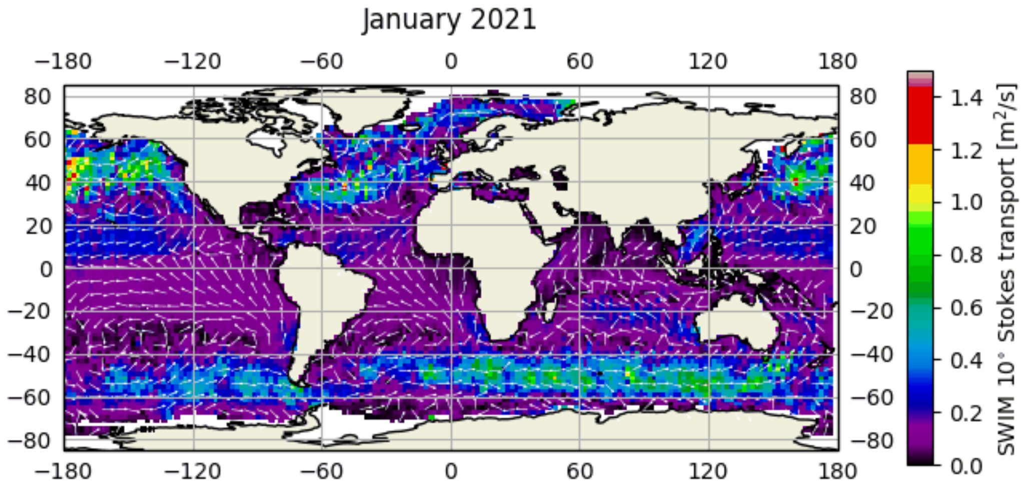


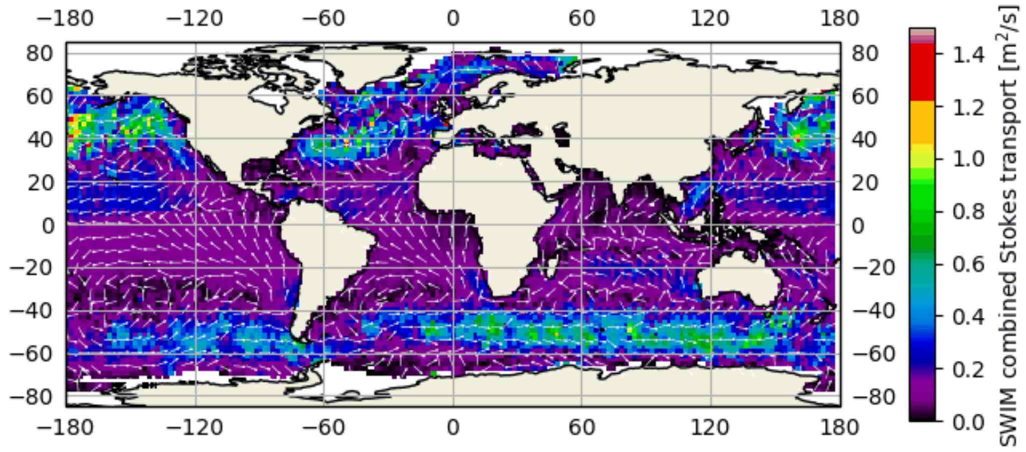


SWIM 2D transport

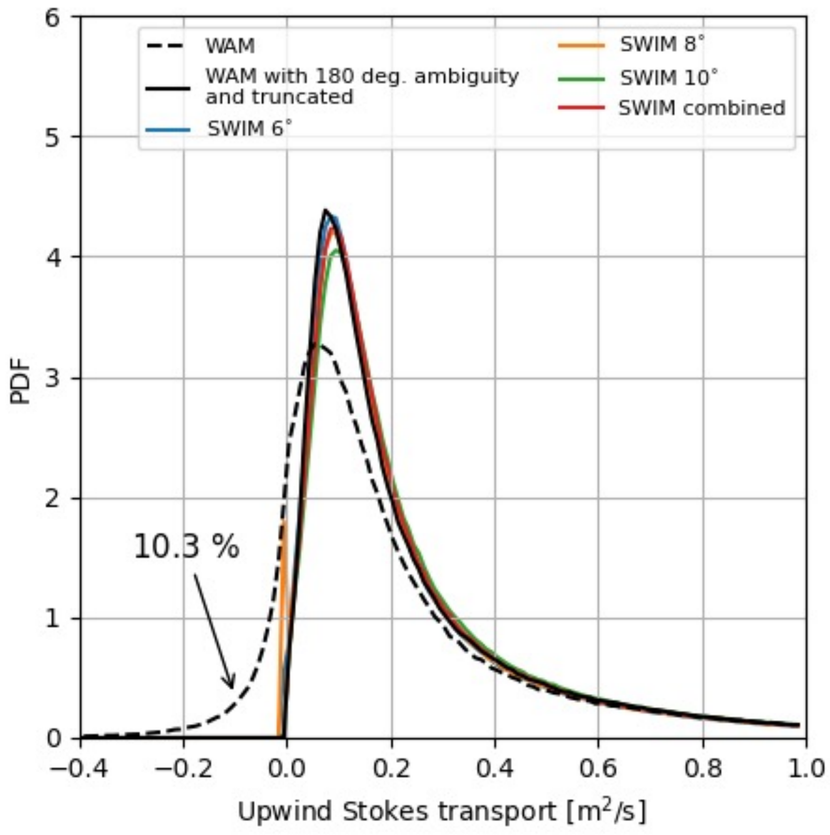


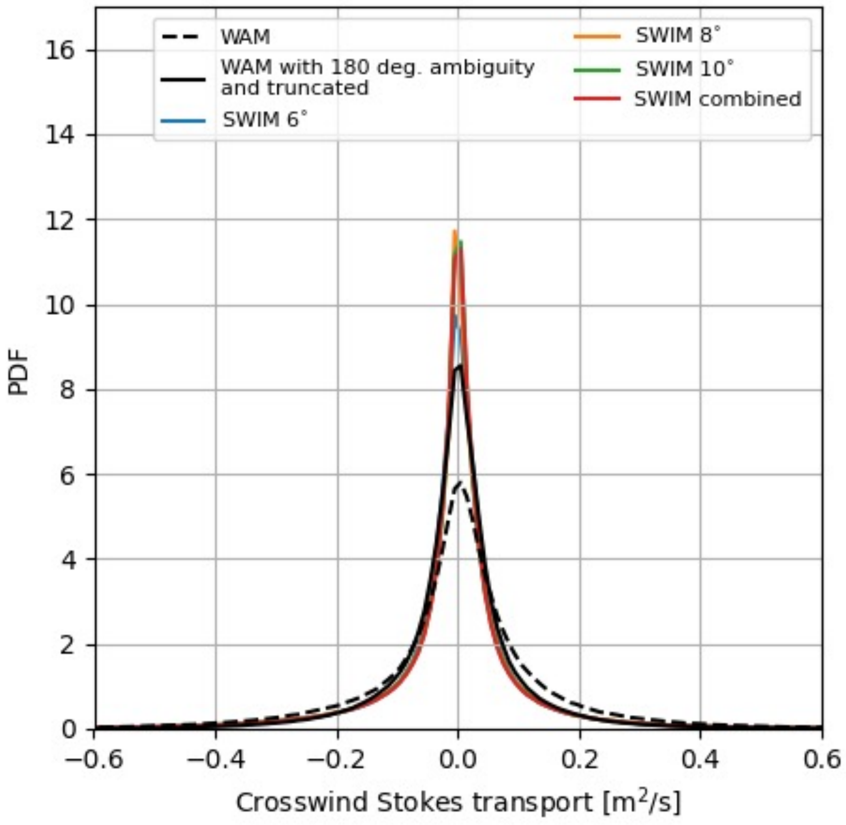




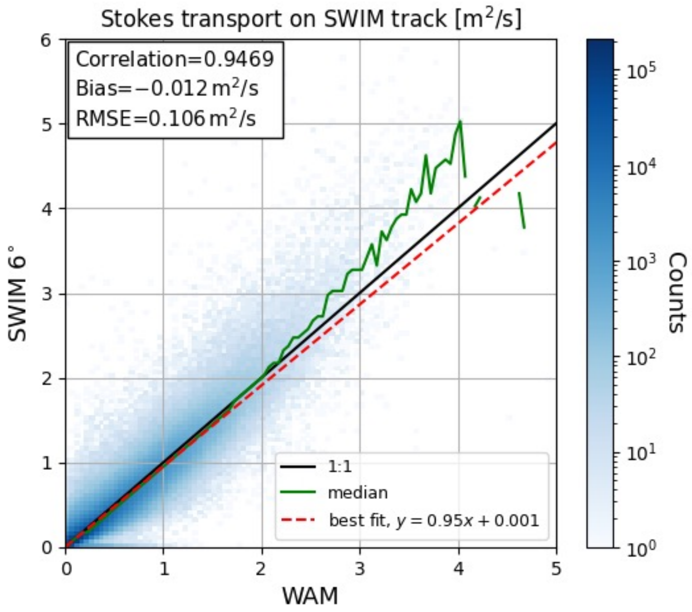


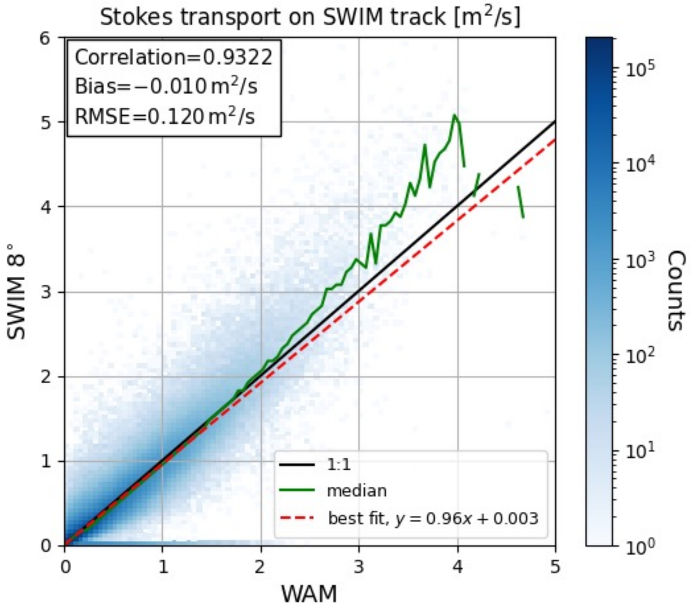
2D transport

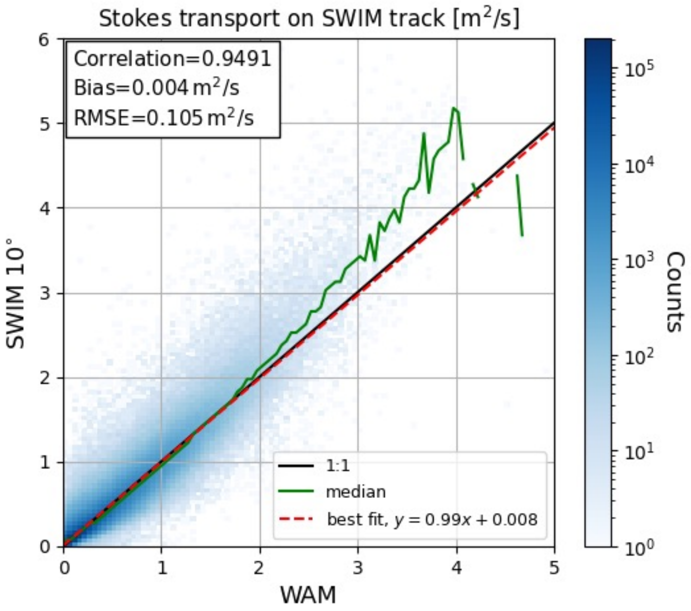


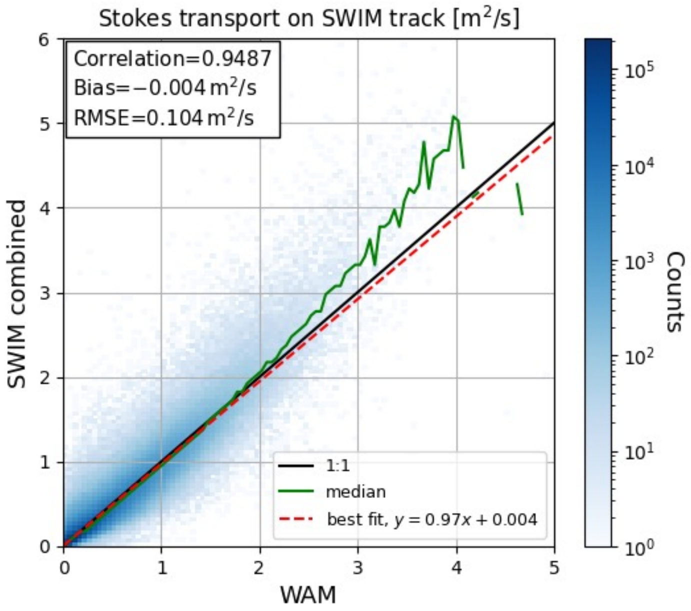


2D transport







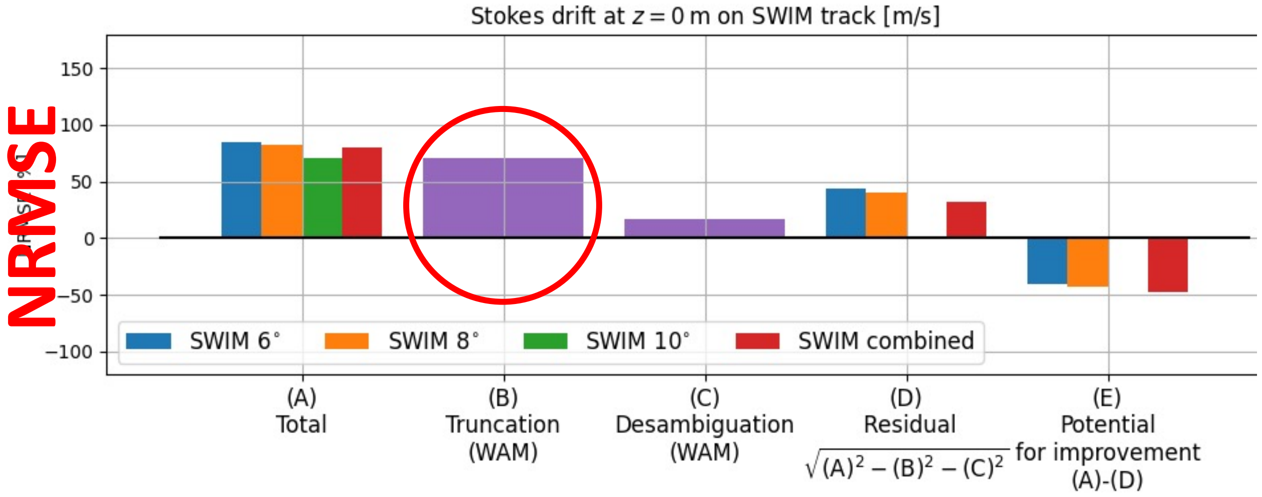


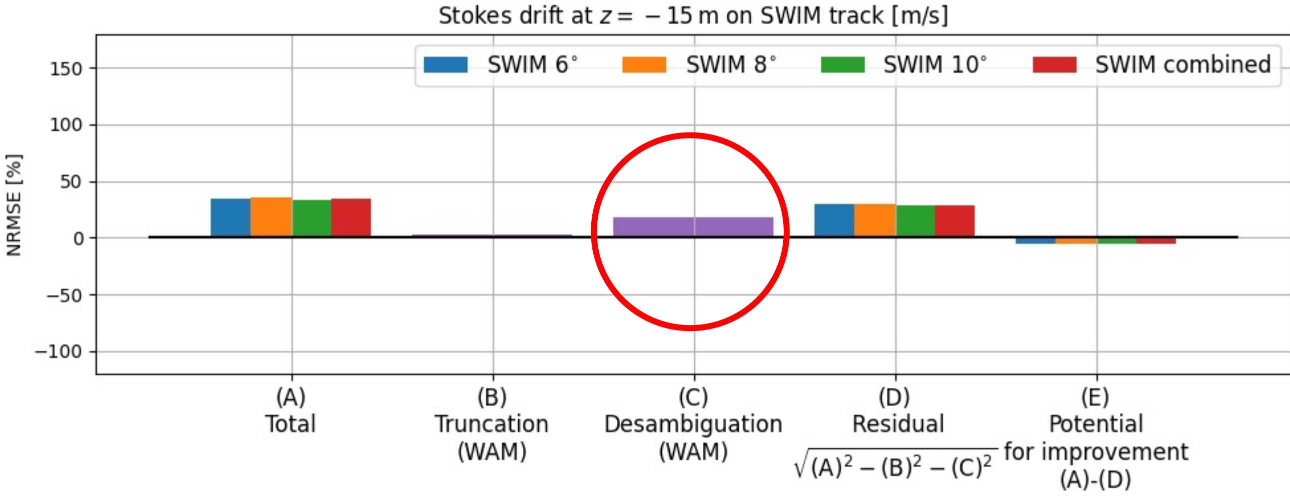
Performances - error budget with respect to WAM

NRMSE = Normalized Root Mean Square Error

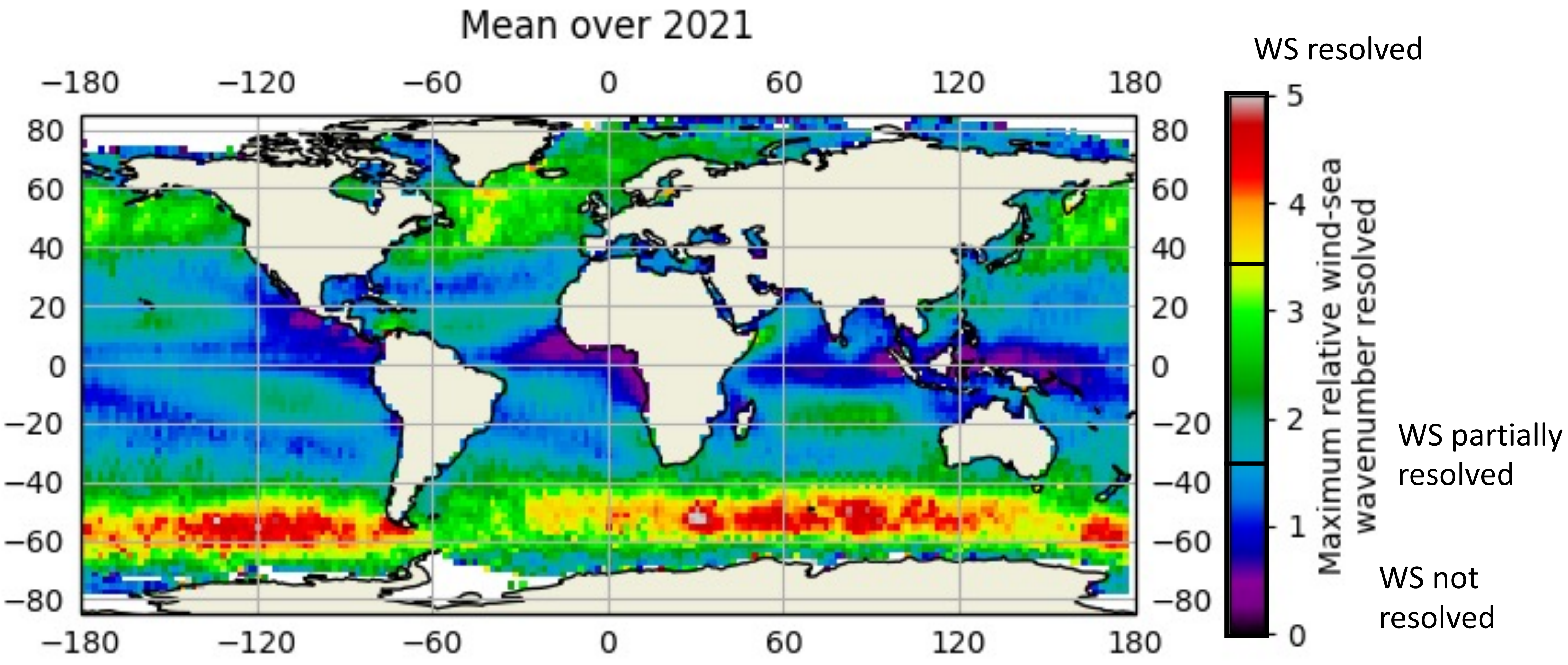
z = 0 m

z = -15 m



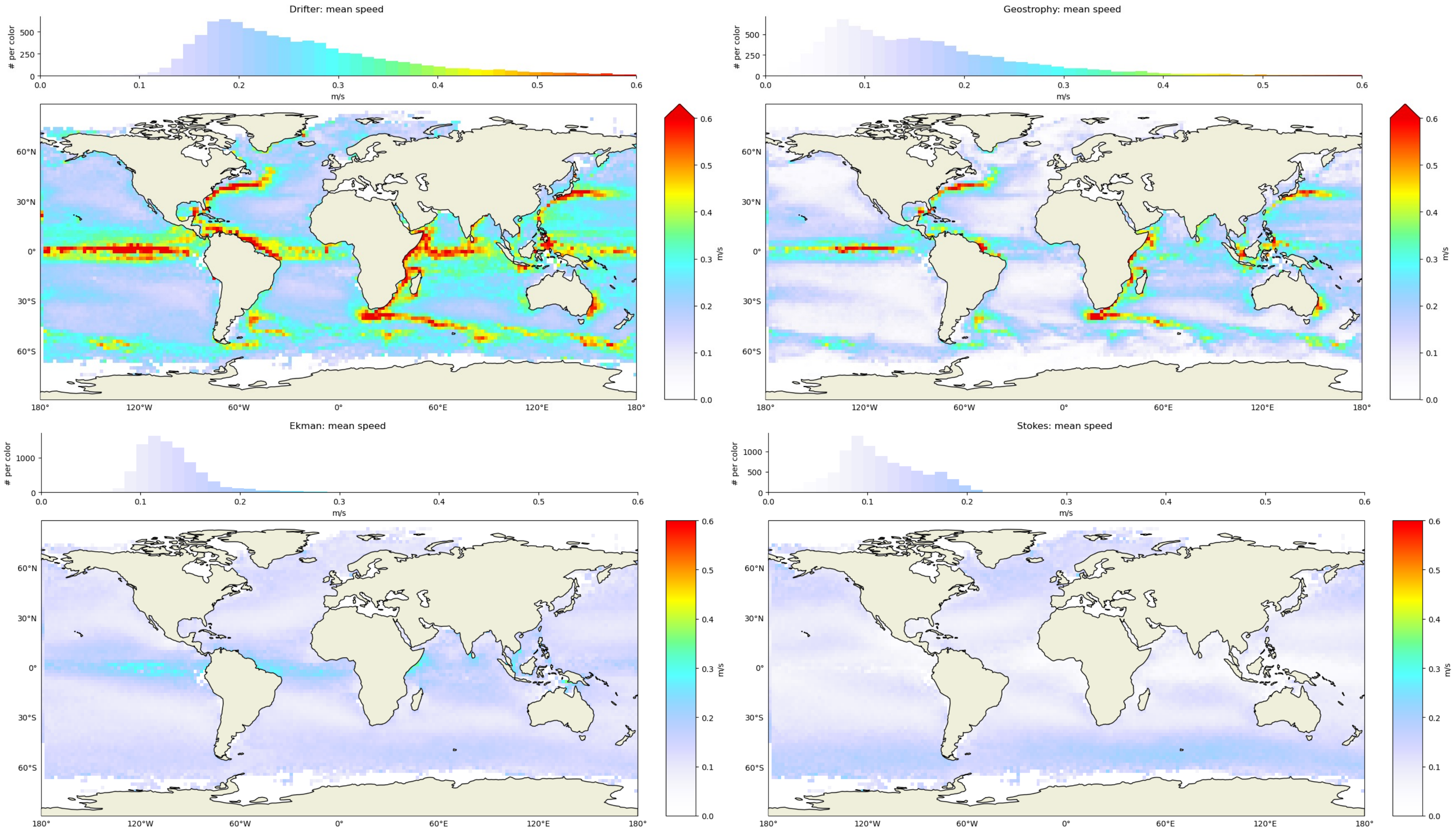


Correction proposition at the surface

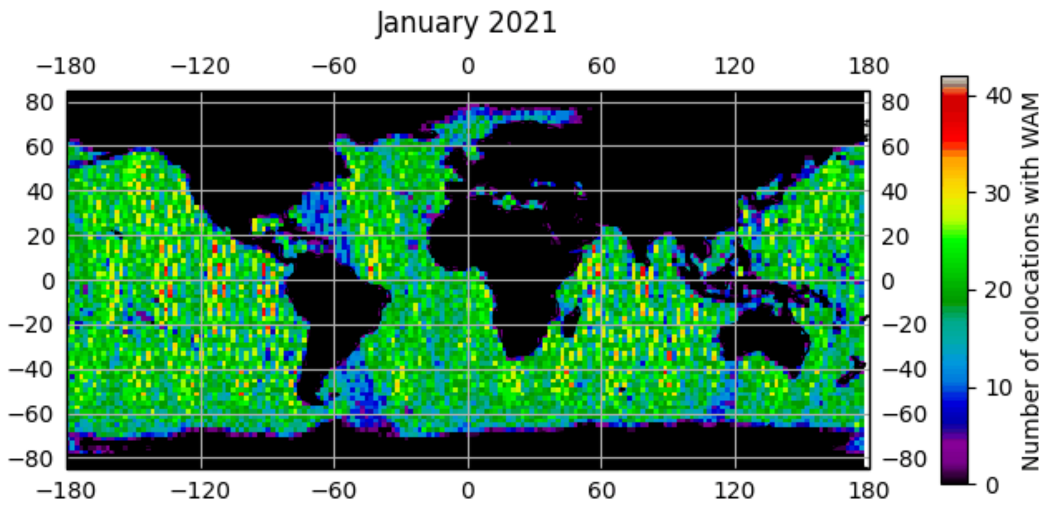


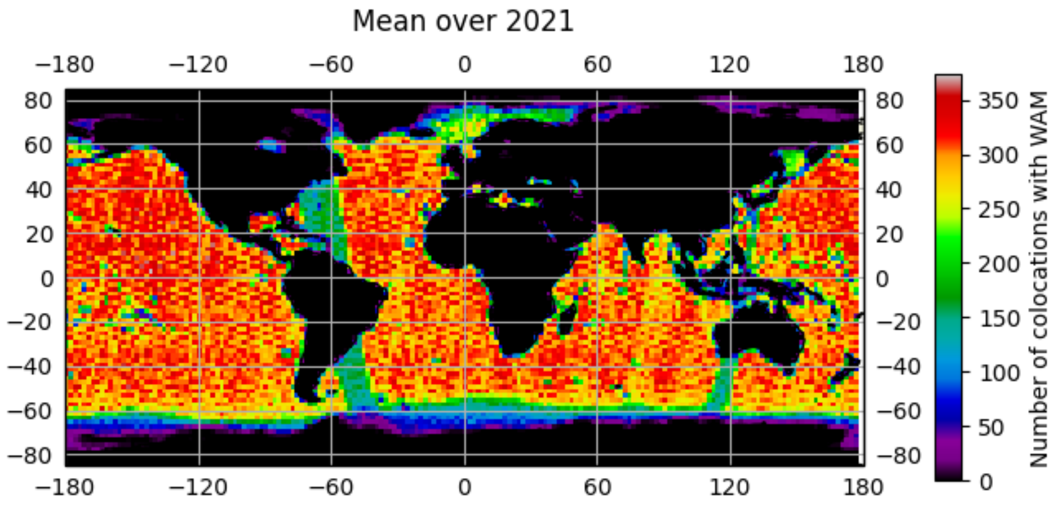
Assuming wave age = 1

Introduction – Stokes drift

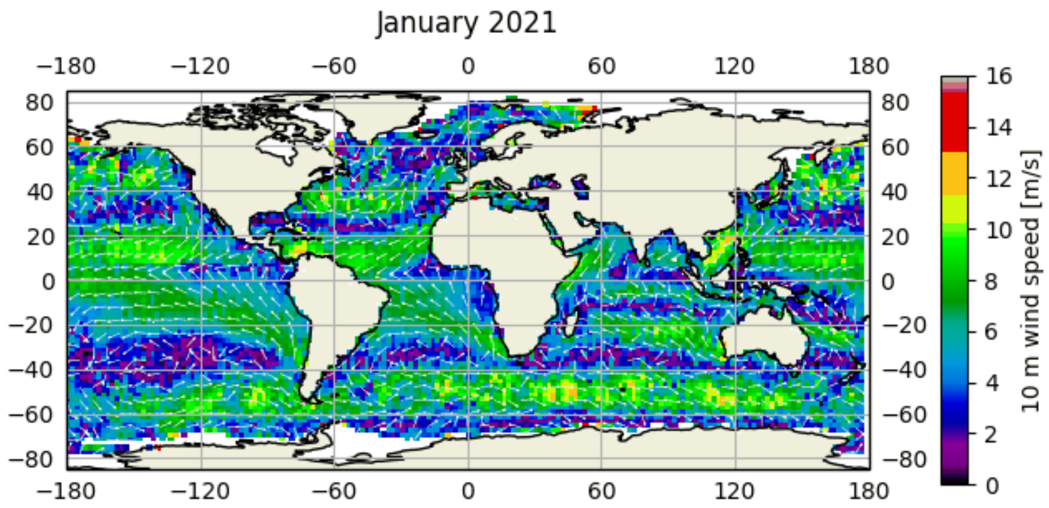


Number of colocations

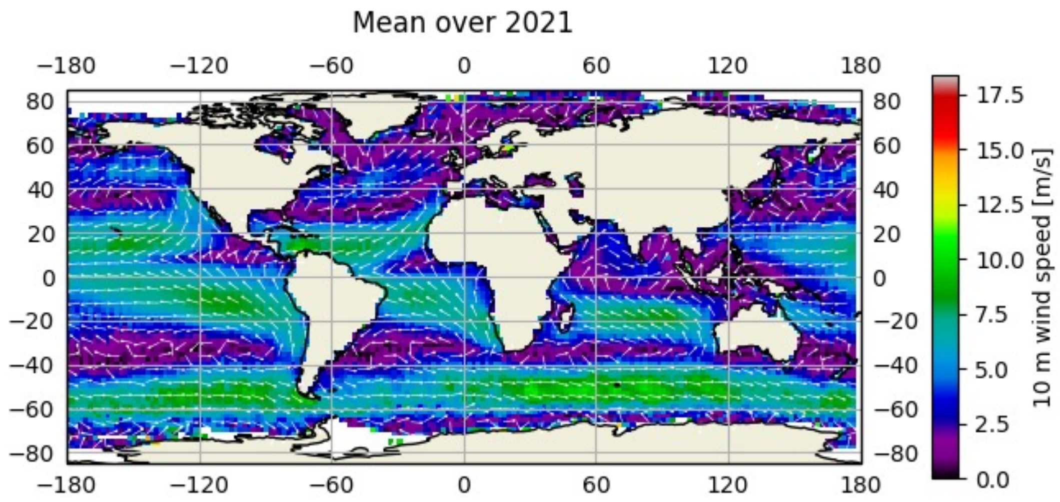




Wind vector



January 2021
10 m wind speed [m/s]



Mean over 2021
10 m wind speed [m/s]