Evaluation of 12 algorithms to estimate Suspended Particulate Matter from OLCI over European coastal waters

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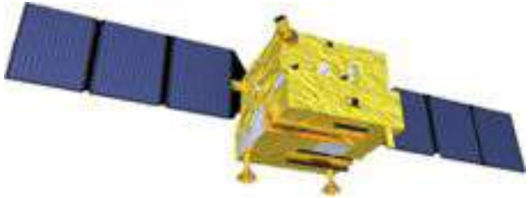
<u>PhD subject</u> : spatio-temporal variability of coastal waters quality in Europe and China using **Sentinel-3** and **Haiyang-1** satellites

River plumes in Bangladesh

Sentinel-3



Haiyang-1

Validation of 12 SPM models to estimate SPM from OLCI over French Coastal waters

<u>Objectives :</u>

- **Validate SPM models** over an in-situ dataset
- Perform a **matchup analysis**
- Compare SPM models **mapping capacities**

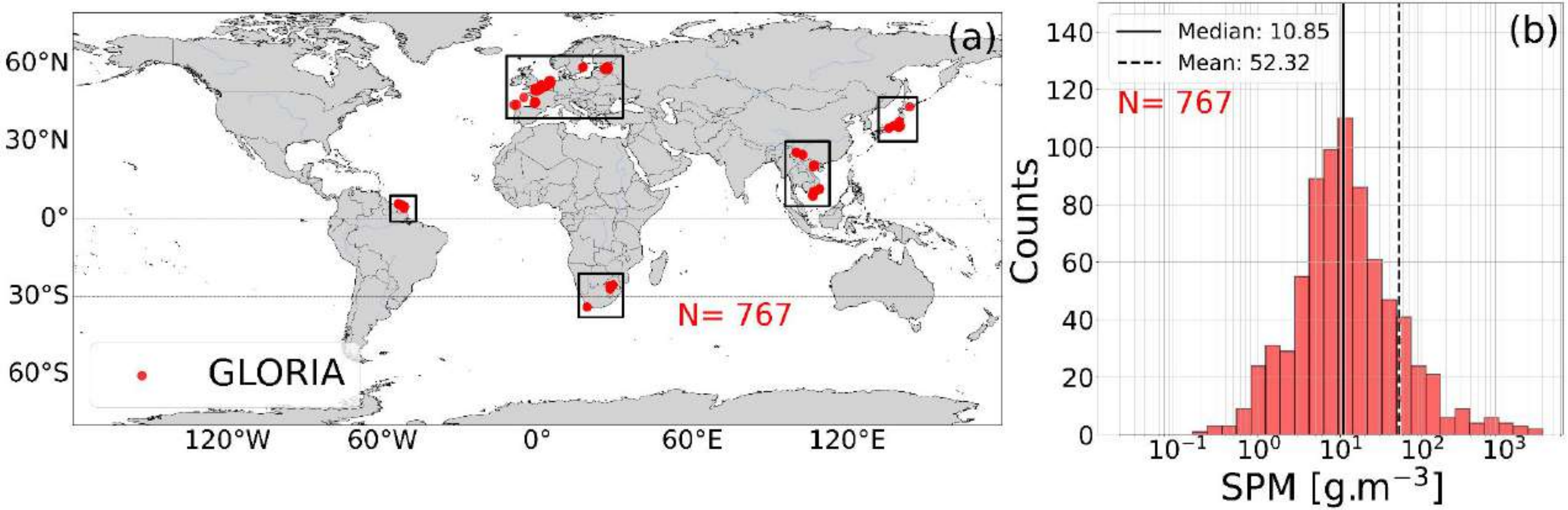
River plumes in Bangladesh

<u>SPM models tested :</u>

- Han et al. (2016) - 2 versions
- Nechad et al. (2010)
- SOLID from Balasubramanian et al. (2020)
- MDN from Pahlevan et al. (2020)
- Novoa et al. (2017)
- Jiang et al. (2021)
- Petus et al. (2010)
- Siswanto et al. (2011)
- Gernez et al. (2017)
- Wozniak et al (2016)
- TSM_NN (standard product from EUMETSAT)

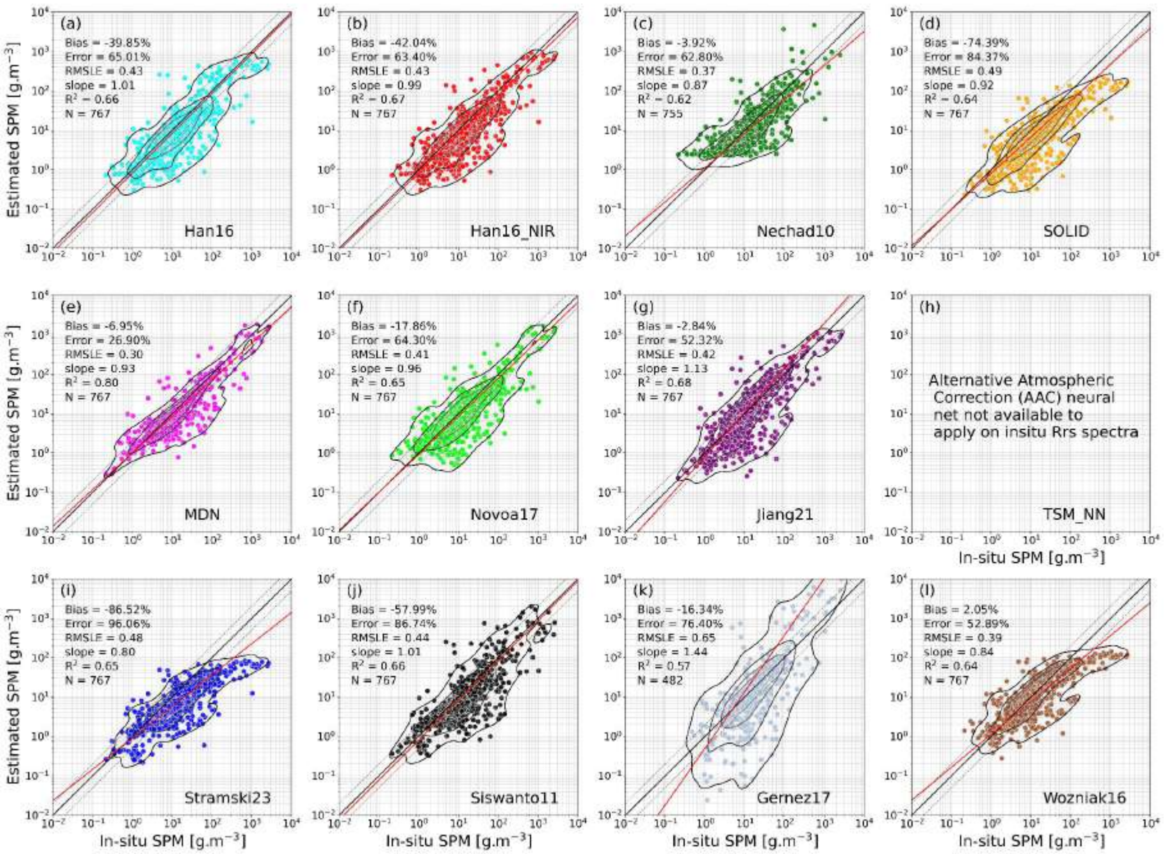
1. Models validation using the GLORIA dataset

Models applied to 767 in-situ quality-controlled Rrs spectra, paired with SPM measurements

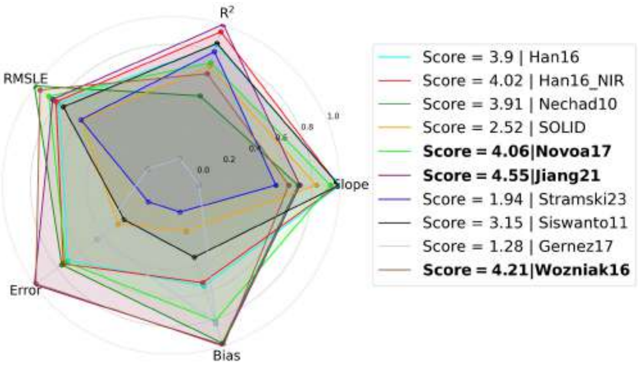


GLORIA in-situ paired Rrs/SPM measurements selected

1. Models validation using the GLORIA dataset



Estimated SPM using in-situ GLORIA Rrs vs. in-situ SPM for 11 models



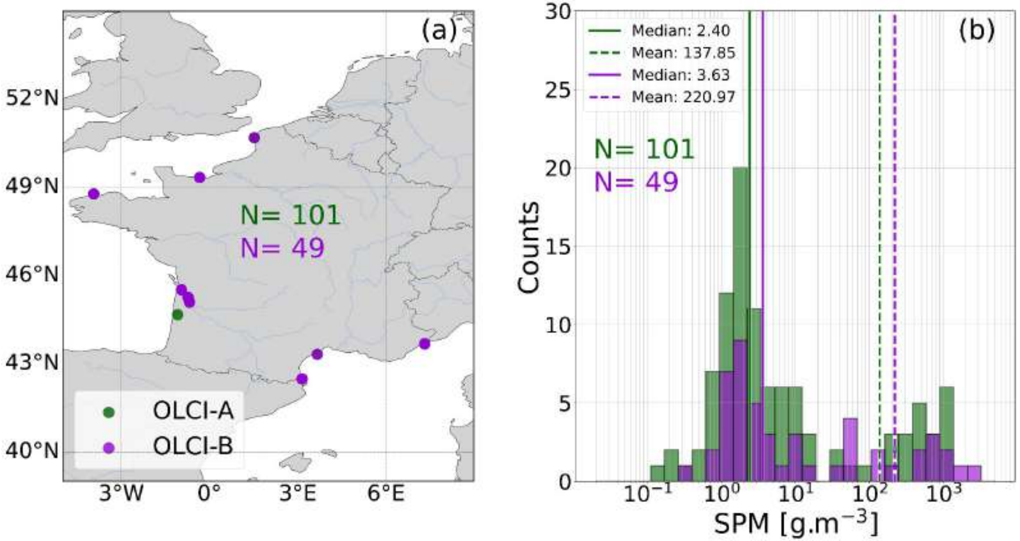
Models normalized metrics and scores

- ➔ **Jiang21** outperforms the other models, showing the best Error, Bias and R^2
- ➔ Han16 and Han16_NIR are ranked 5th and 4th, respectively

2. Models validation through a matchup exercise

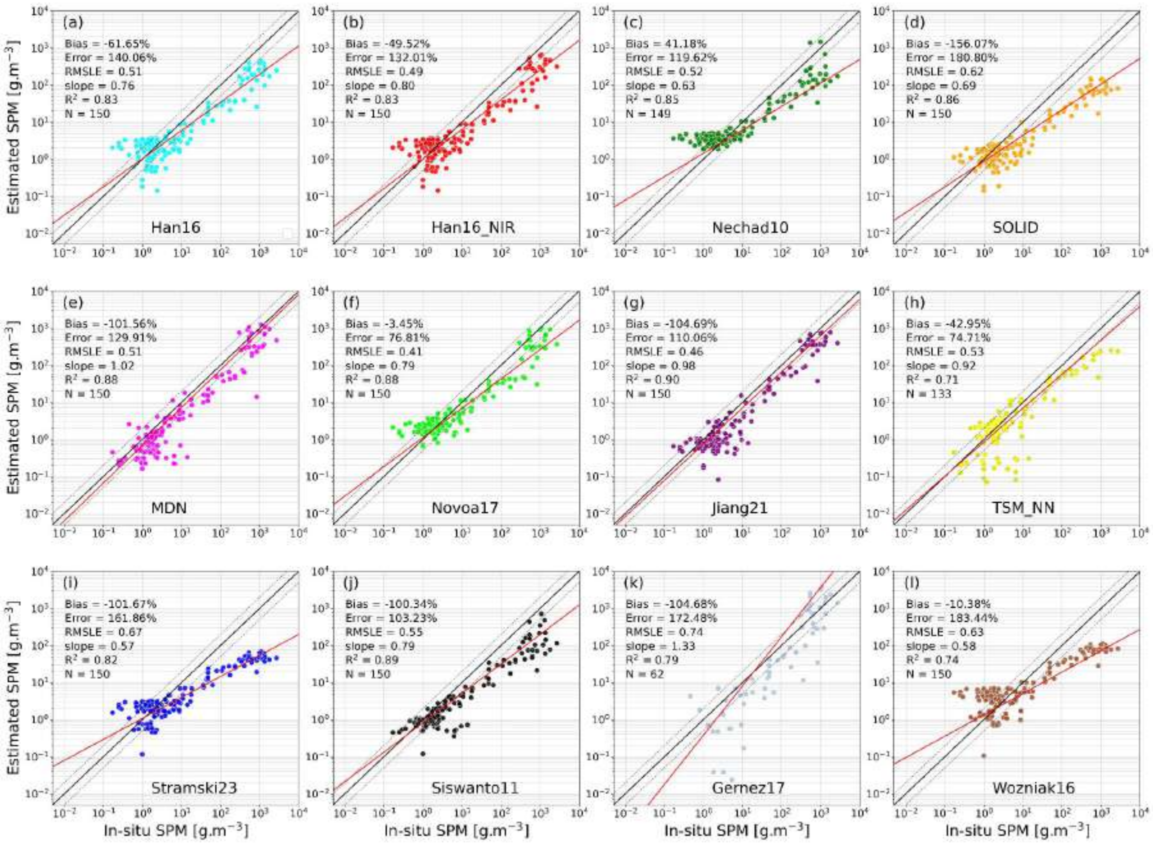
Satellite data : **OLCI L2 standard EUMETSAT product** (IPF procedure for atmospheric correction)

SOMLIT in-situ dataset : French coastal monitoring network used for matchup analysis (150 matchups)

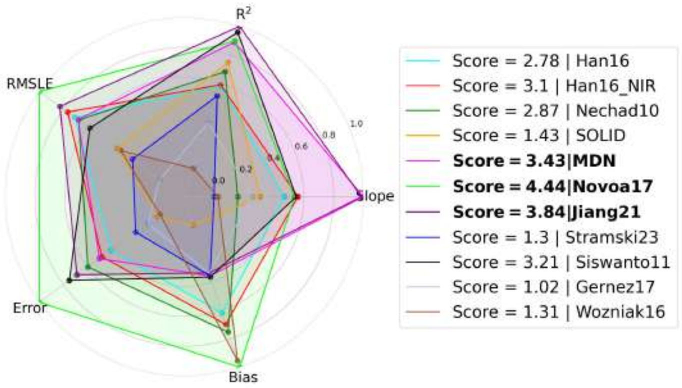


SOMLIT SPM matchups with OLCI

2. Models validation through a matchup exercise



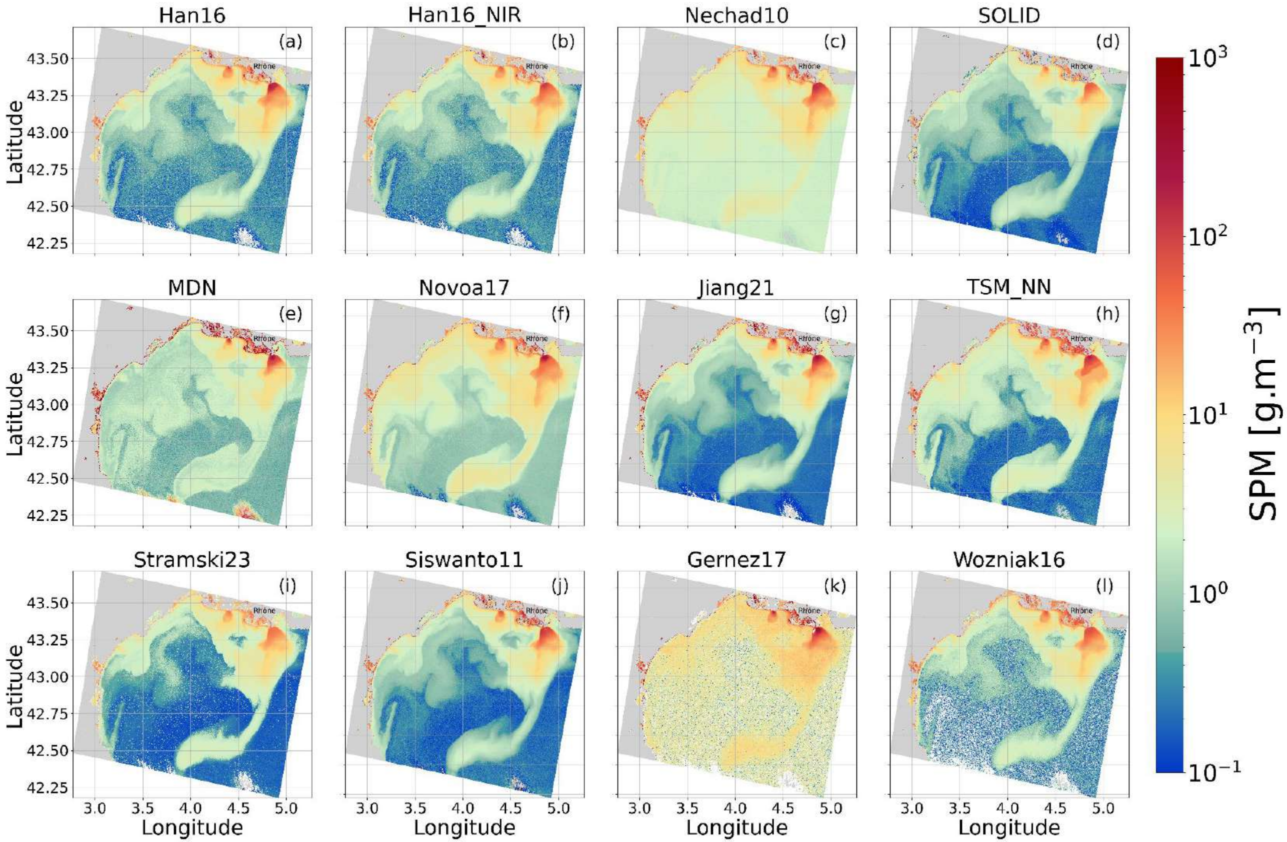
SOMLIT SPM matchups with OLCI standard product for 12 models



Models normalized metrics and scores

- ➔ **Novoa17** retrieves SPM with the **best accuracy** and precision, but **saturates** for low concentrations
- ➔ **Jiang21 shows the largest dynamic range**, making it suitable for large scale studies

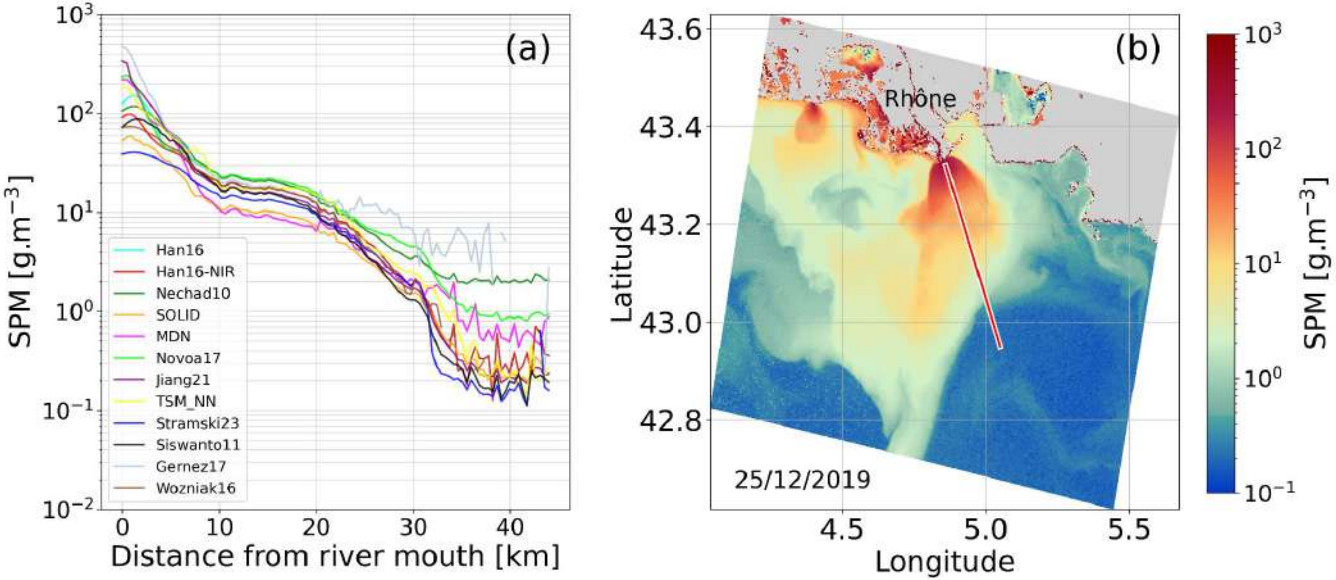
3. Models capabilities in SPM mapping



SPM maps for the 12 models for the same OLCI-B image (25/12/2019, Rhône River plume)

3. Models capabilities in SPM mapping

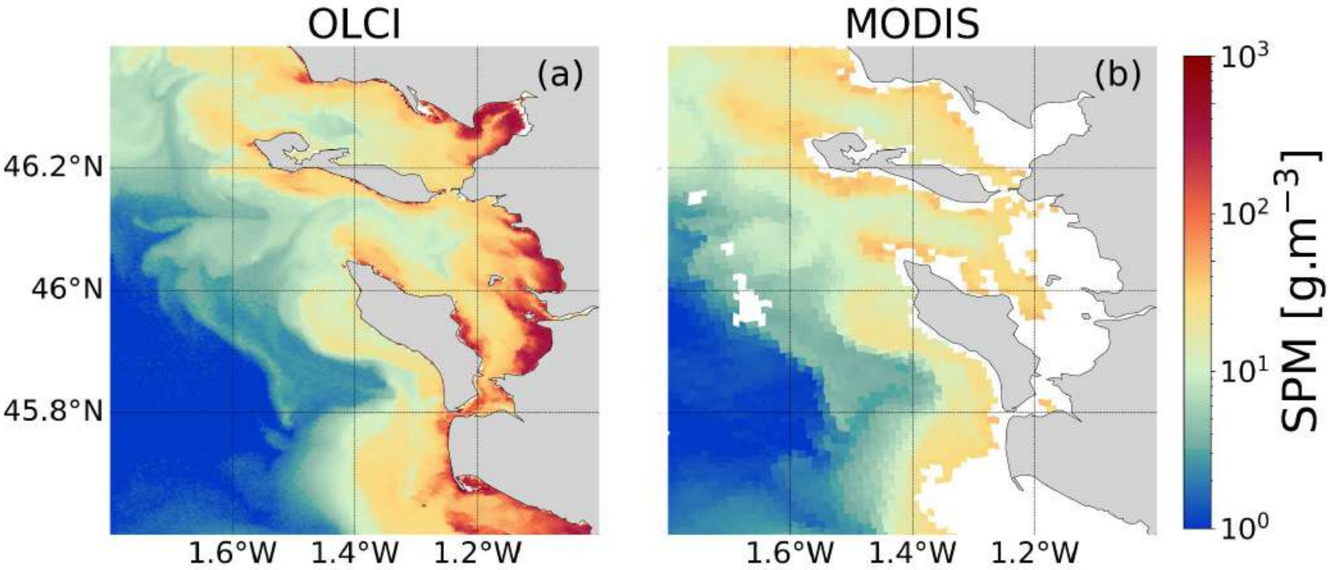
- **Large differences in SPM magnitude** between the models for high and low concentrations (≃ 1 order of magnitude)
- Evidence for **noise presence for low SPM** for some models



SPM section for 12 models across the Rhône River plume (25/12/2019)

3. Differences between SPM derived from OLCI and MODIS standard products

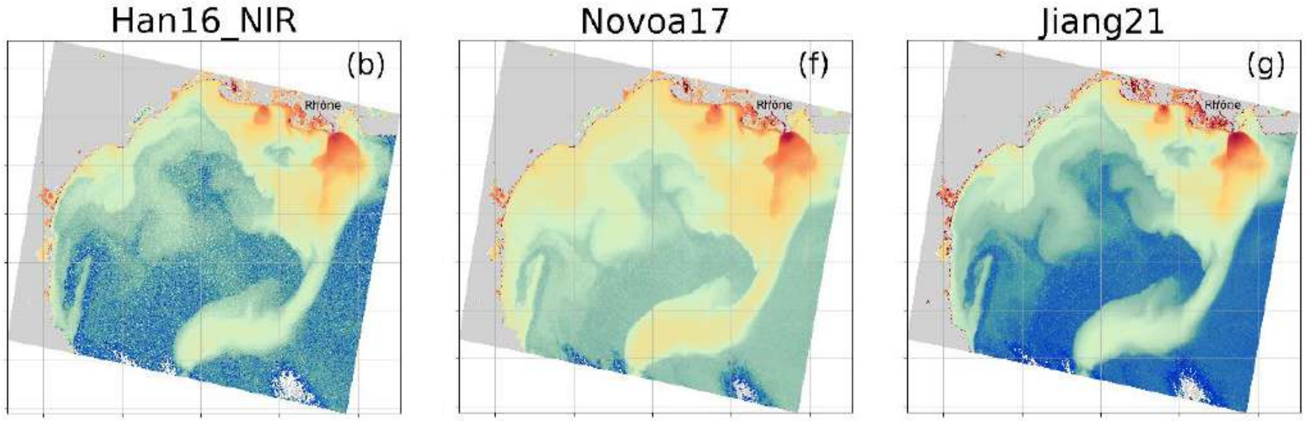
- OLCI resolves **smaller scales features** with its 300m resolution
- MODIS red band **saturate for high turbidity** and/or Bright Pixel mask raised



OLCI (300 m) and MODIS (1 km) SPM (Han16) for Oléron and Ré Islands, France, 15/03/2020

Conclusions

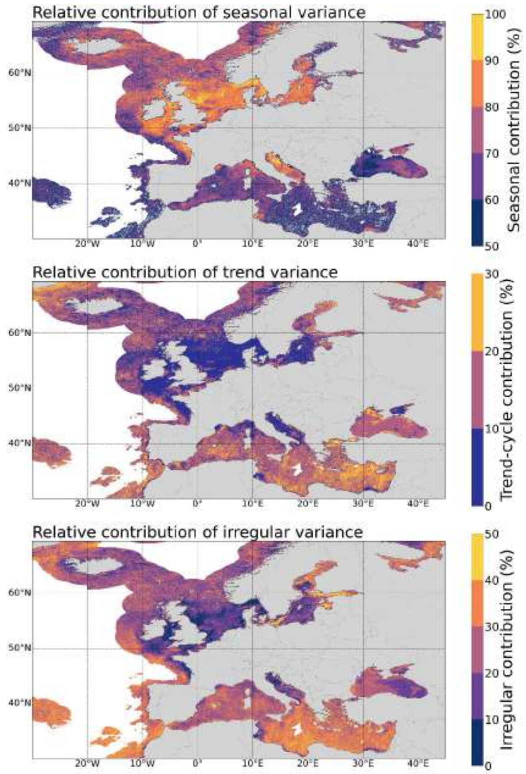
- **Novoa17** and **Jiang21** outperform the other models in terms of statistics
- However, Novoa17 saturates for low SPM concentrations
- **Jiang21** presents the **best mapping capabilities** (larger dynamic range)
- OLCI present advantages compared to MODIS in turbid coastal regions



SPM concentrations in the Rhône River plume on 25/12/2019 from OLCI-B standard product

Perspectives

1. **Optical classification** of coastal waters : method from Tran et al. 2023 (in revision)
2. Application of the best **bio-optical algorithms** by class (MBR, Red/NIR, MDN) to estimate chlorophyll-a concentration
3. **Validation** of SPM products from in-situ measurements
4. Study of **spatio-temporal variability of SPM** : trend, seasonality, residuals (Census X11, melin and Vantrepotte 2011)
5. Definition of **hot-spots**
6. Explanation of changes in water quality : **environmental and anthropic forcings** (Granger causality and random forests)
7. Comparison with other time series (MERIS, MODIS, GlobColour, CCI)
8. Investigation of other parameters (**Chla** et **Kd)**



Relative contributions of the Seasonal, trend and irregular terms to SPM variance

Thank you for your attention

https://oceancolor.gsfc.nasa.gov/

Remerciements

Backup

Methods : statistical metrics

- **Median Symmetric Accuracy** (“Error”) : a percentage error equally penalizing over and under-estimations (while MdAPE doesn’t)

$$Error = 100 \times (10^{median(|log_{10}(SPM^{est}/SPM^{obs})|)} - 1)$$

- **Symmetric Signed Percentage Bias** (“Bias”) : a percentage bias that maintains symmetry between over and under-estimations

$$Bias = 100 \times sign(MdLQ) \times (10^{|MdLQ|} - 1)$$

$$MdLQ = median(log_{10}(SPM^{est}/SPM^{obs}))$$

- **Root Mean Square Logarithmic Error** (RMSLE)

$$RMSLE = \sqrt{\frac{\sum_{i=1}^{n}(log_{10}(SPM_i^{est}) - log_{10}(SPM_i^{obs}))^2}{n}}$$

- The **Slope** and **R^2** from a type II linear regression :

$$log_{10}(SPM^{est}) = slope \times log_{10}(SPM^{obs}) + intercept$$

Methods : statistical metrics

- All 5 metrics are normalized based on the min and max values for all models :

$$Error_{norm}(i) = \frac{Error(i) - max(Error(i)_{i=1,k})}{min(Error(i)_{i=1,k}) - max(Error(i)_{i=1,k})}$$

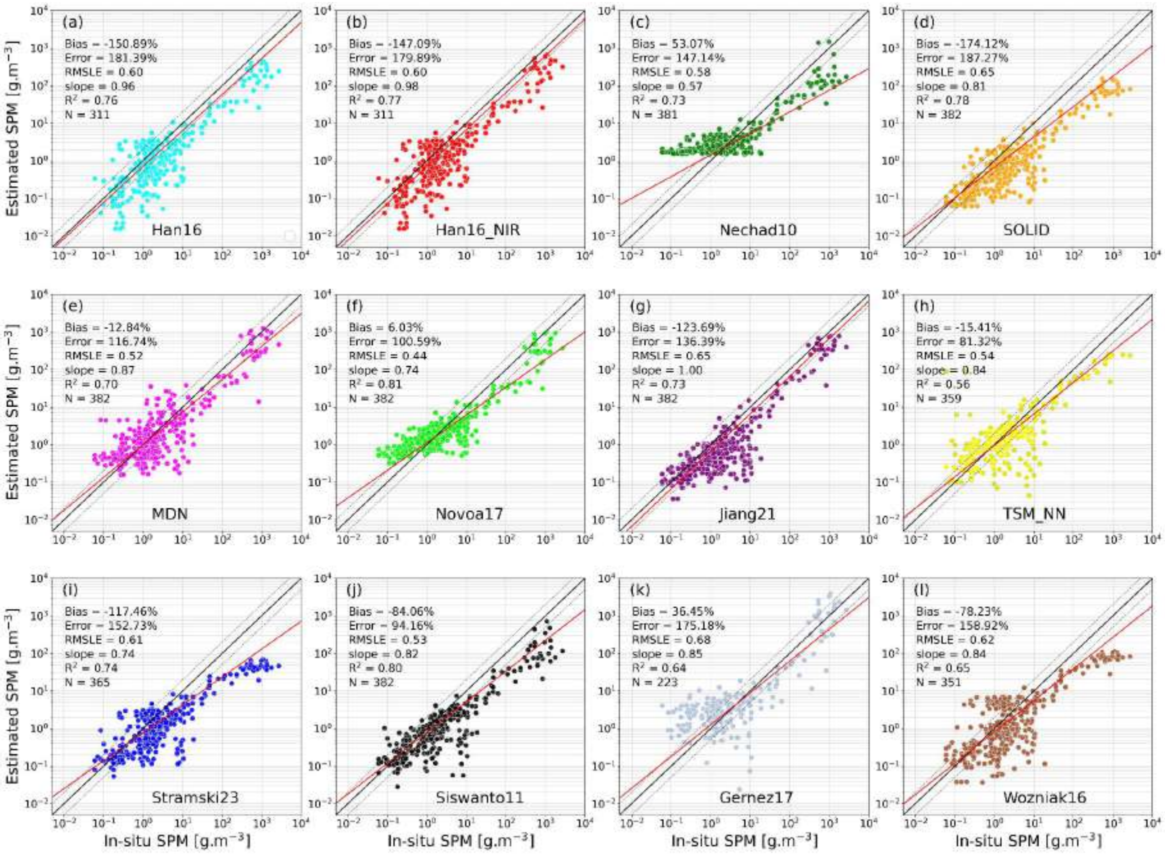
- The score for a model i is computed by summing its normalized metrics :

$$Score(i) = Bias_{norm}(i) + Error_{norm}(i) + RMSLE_{norm}(i) + Slope_{norm}(i) + R^2_{norm}(i)$$

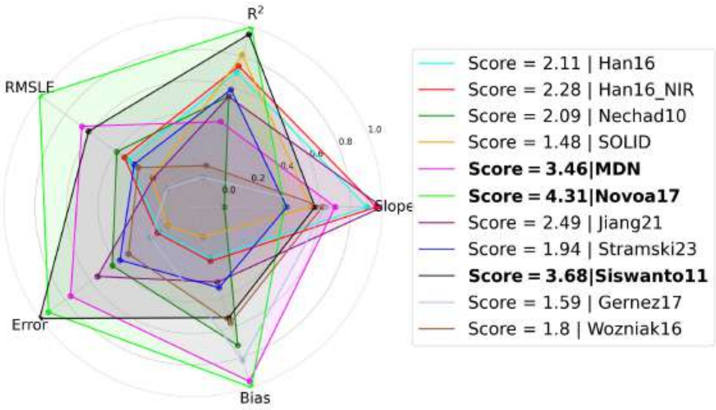
Methods : Matchup protocol

- 3x3 windows centered on the in-situ measurement
- At least 5/9 valid pixels
- A Coefficient of Variability (CV) of Rrs(560) < 20%
- 3h difference between measurement and satellite overpass
- OLCI Spetra with at least on negative Rrs value removed

Models sensitivity to atmospheric correction procedure



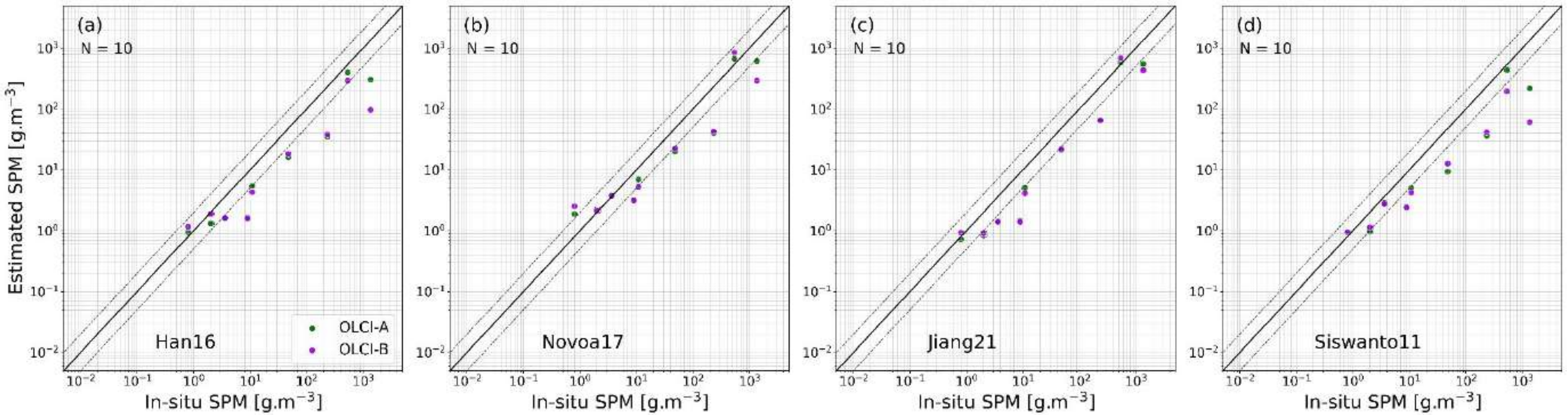
SOMLIT SPM matchups for the 12 models



- ➔ **Novoa17** still retrieves SPM with the **best accuracy** and precision, but **saturates** for low concentrations
- ➔ **Jiang21** more sensitive to AC procedure

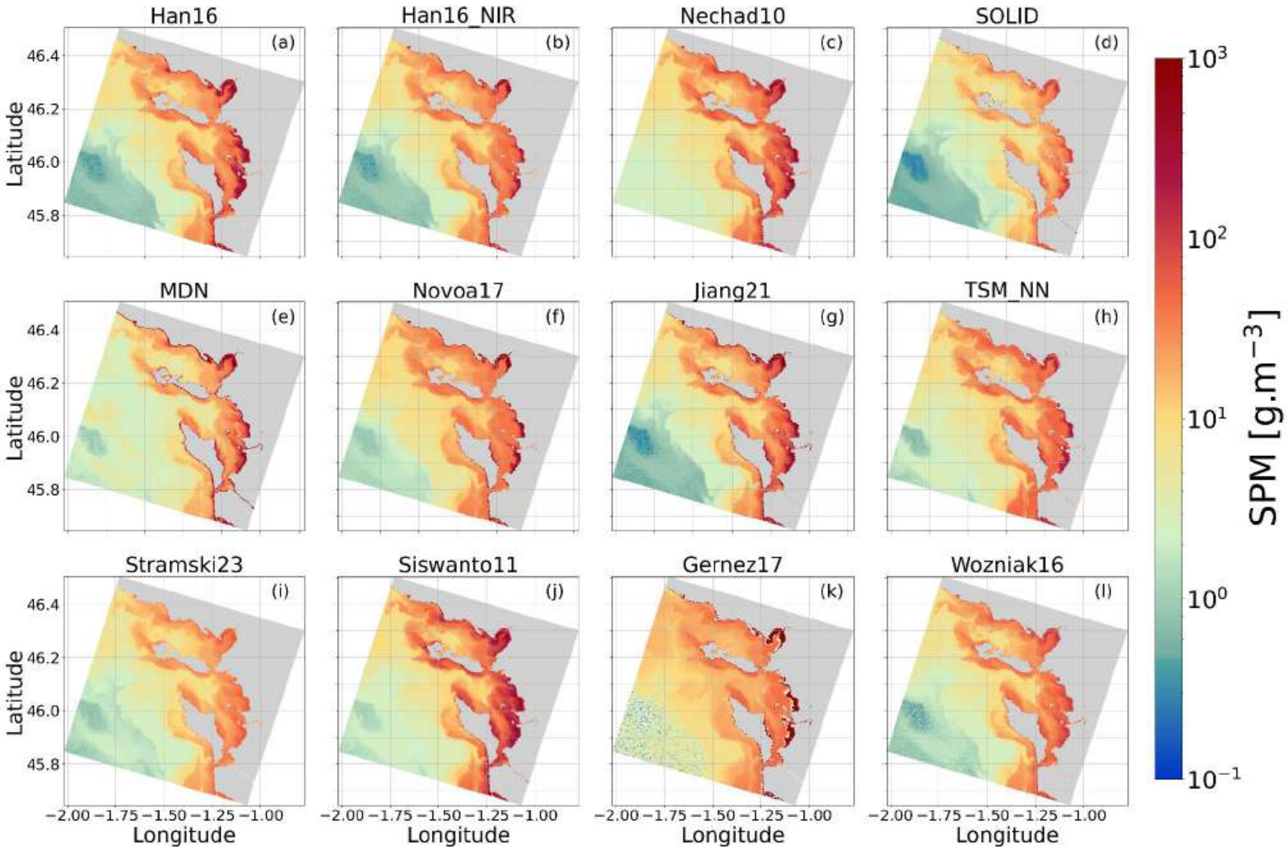
Differences between OLCI-A and OLCI-B

- 10 common matchups between OLCI-A and OLCI-B for the SOMLIT dataset
- **Jiang21** gives more similar results with S3A and S3B than the other 3 models



Common matchups between OLCI-A and OLCI-B for 4 different models

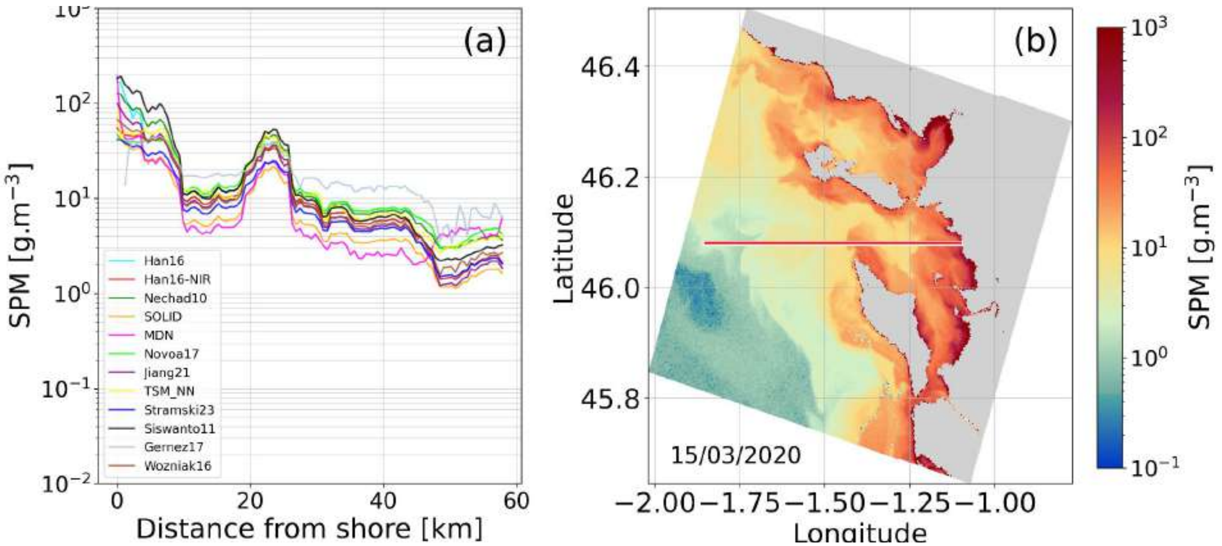
3. Models capabilities in SPM mapping



SPM maps for the 12 models for the SAME OLCI image (15/03/2020, Îles d'Oléron et de Ré)

SPM section across the Rhône River plume on the 25/12/2019

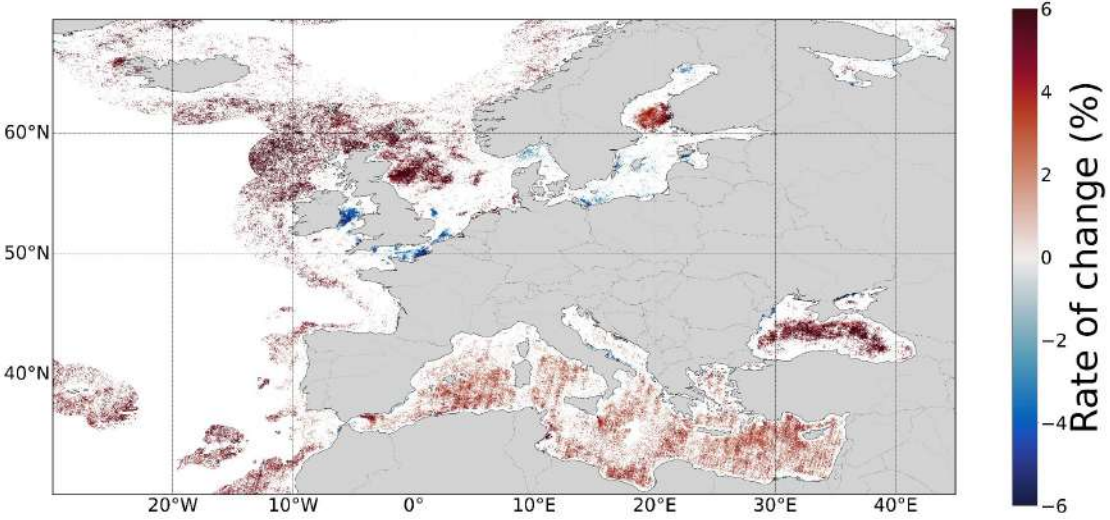
- **Large differences in SPM magnitude** between the models for high and low concentrations (≃ 1 order of magnitude)



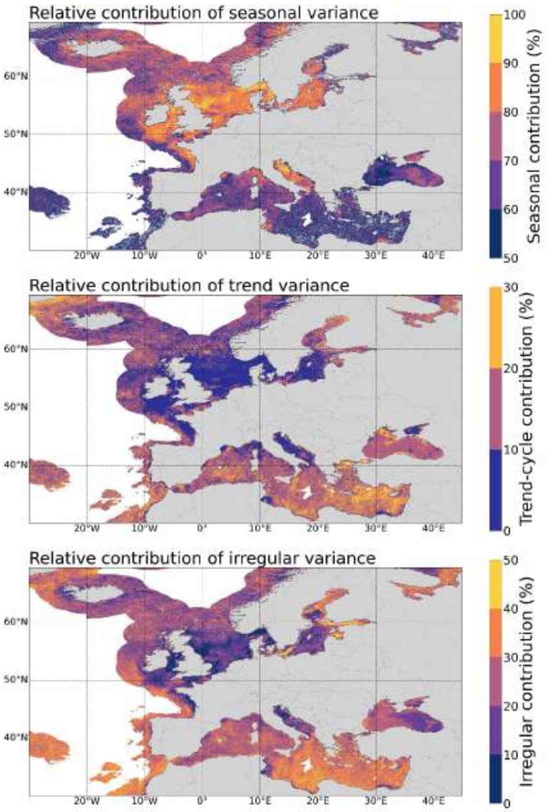
SPM section for 12 models across the Rhône River plume (25/12/2019)

SPM OLCI time series decomposition with Census X-11

- Variability of SPM in European coastal waters investigated
- Hot spots to be defined based on those results



Significant monotonic SPM trend detection (p-value < 0.05)



Relative contributions of the 3 different terms to SPM variance

SPM climatology in Europe from OLCI (Han16)