

Applications of Sentinel-2 and 3 in coastal waters and ocean colour

Presented by H elo ise Lavigne

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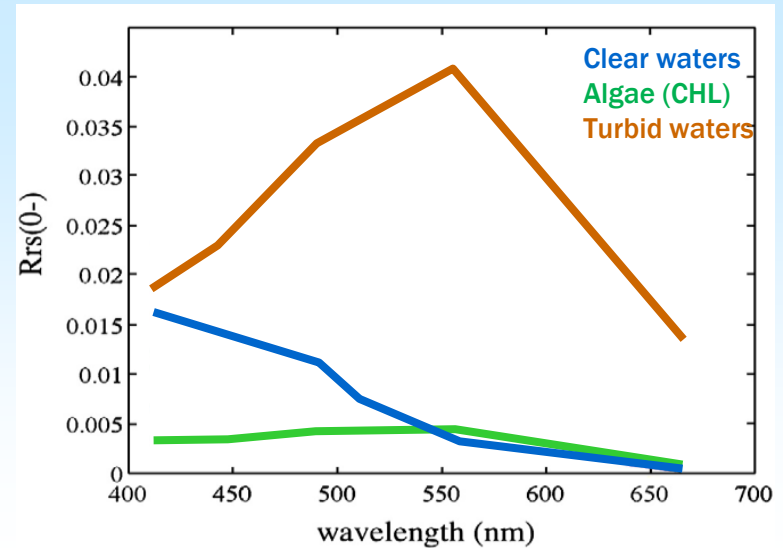
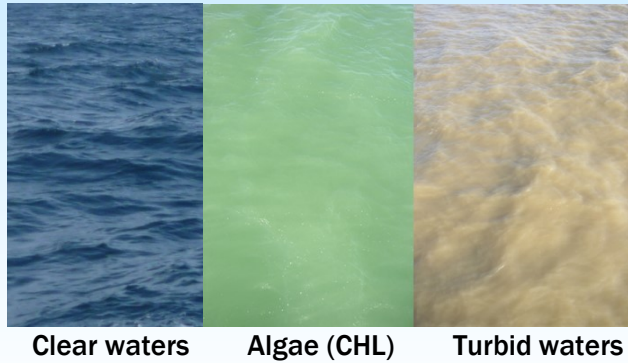
Kevin Ruddick, Bouchra Nechad, Quinten Vanhellemont, Dimitry Van Der Zande

REMSEM (Remote Sensing and Ecosystem Modelling Team)

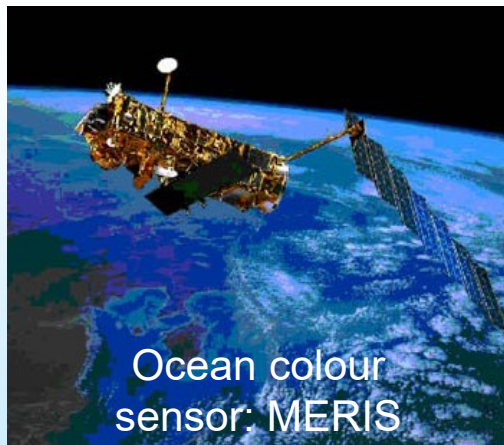
[Operational Directorate Natural Environment](#)

RBINS (Royal Belgian Institute for Natural Sciences)

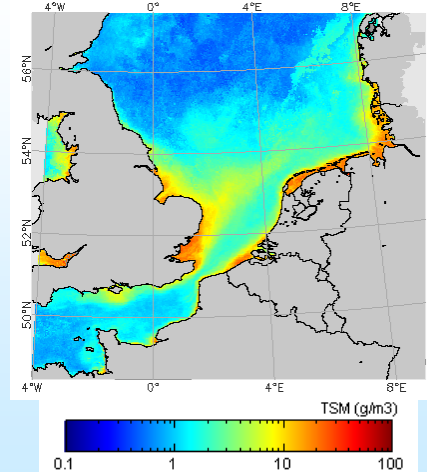
Remote sensing: What is ocean colour?



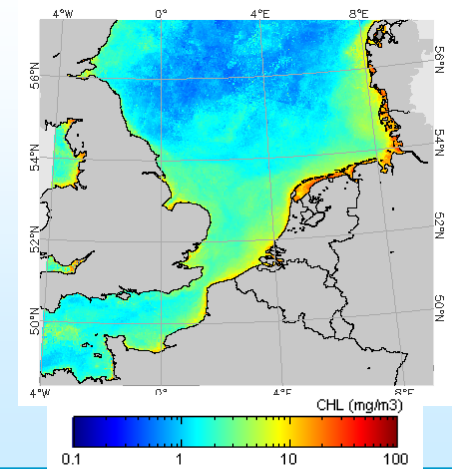
Adapted from Moore et al., 2009



Suspended Particulate Matter (SPM)



Chlorophyll a (CHL)



SPM and Turbidity



clear water

low turbidity



high turbidity

SPM (Suspended Particulate Matter):

Measures the concentration of particulates (often sediments) in water.

Turbidity:

Measures how light is scattered in water (by 90°)

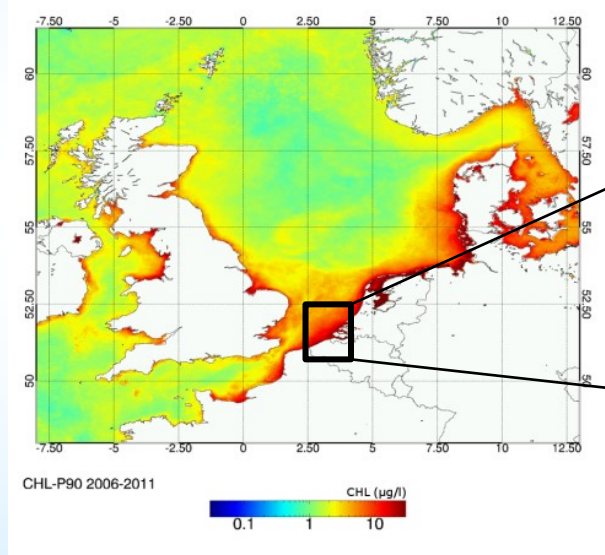
Aquatics Applications – Spectral resolution

	Application	User	Parameter
App1	Coastal water quality (EU MSFD/WFD reporting)	National govt	CHL – Turbidity (TUR)
App2	Harmful Algae Blooms near real-time alert	National govt Fisheries Aquaculture	CHL, phytoplankton type (Harmful algae bloom)
App3	Carbon cycle modelling and Ocean acidification	Ecosystem modelers	CHL, PAR, Kd, euphotic depth
App4	Marine Science support	Marine scientists (esp. biology)	CHL
App5	Coastline/Bathymetry change, dredging/dumping	Sediment transport modelers	SPM, TUR for model val/initial
App6	Offshore construction (environmental impact)	Govt + Offshore industry	SPM, TUR
App7	Diving ops; Detection of subs, mines; marine animal vision	Diving industry Military, Biologists	Underwater visibility

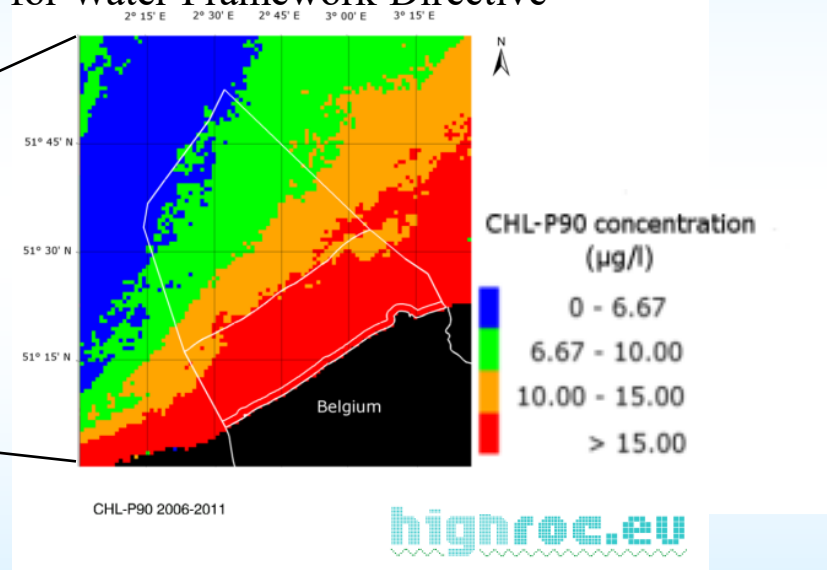
Using satellite to report Belgian water quality to EU

- Satellite-based eutrophication assessment service (OSPAR convention, EU Water Framework Directive, MSFD)

Map of CHL-P90 during March-Oct. periods from 2006-2011 (from MERIS data)



Standard product in Belgian waters for Water Framework Directive

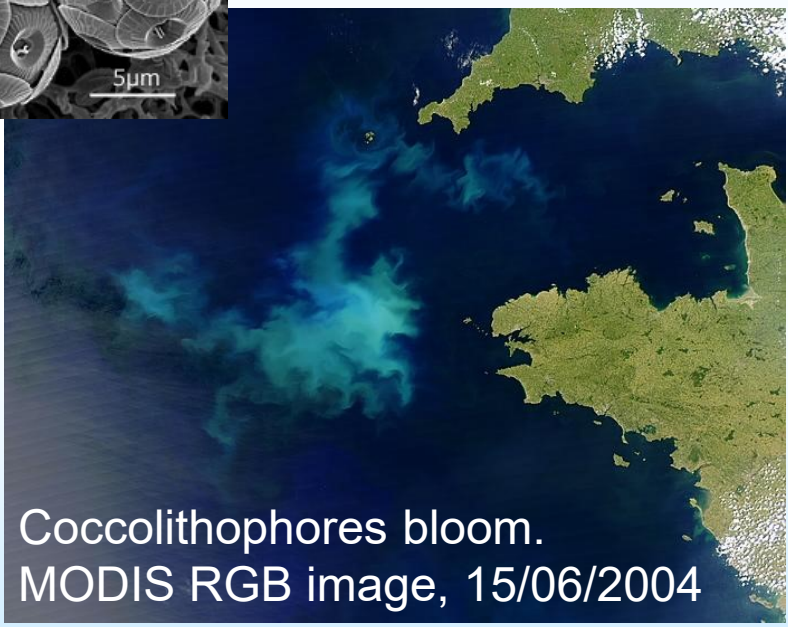
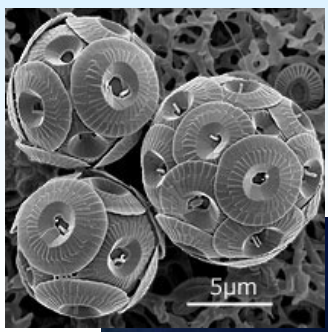


Images from D. Van der Zande

➔ Remote sensing is neutral, transparent, and spatially extensive (cross-boundary)

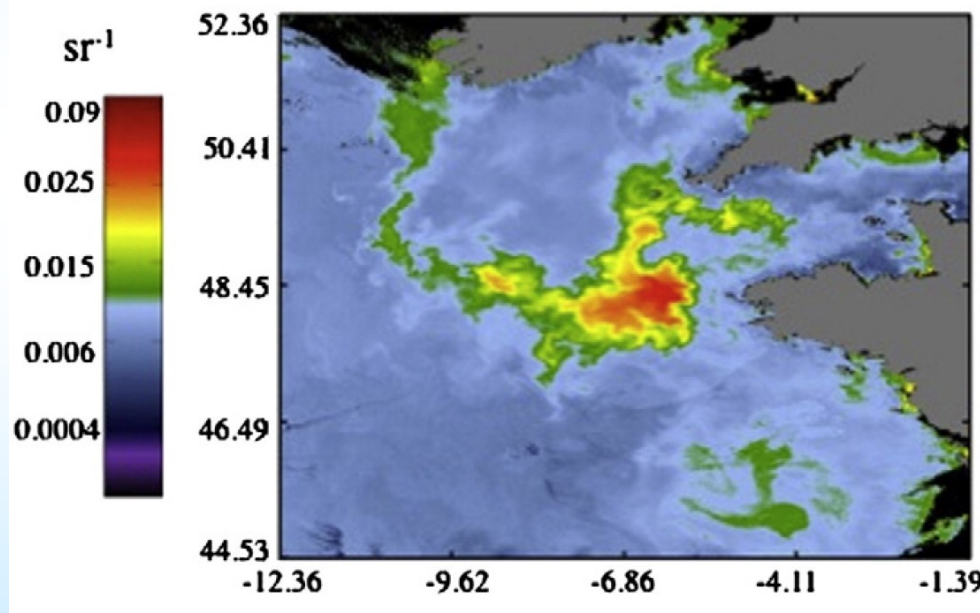
Detection of coccolithophores bloom

- Coccolithophore blooms can be detected from satellite.
- They have a major role in the oceanic carbon pump. They highly contribute to the long-term carbon burial.
- They are also sensitive to ocean acidification.



Coccolithophores bloom.
MODIS RGB image, 15/06/2004

Water leaving reflectance at 555nm



From Moore et al., 2012, *Remote Sensing of Environment*

- Most of coastal/inland human activities are very nearshore: EU WFD 1 n. mile
- Need of very high spatial resolution sensors
 - Landsat 8 / OLI : 30m
 - Sentinel 2 / MSI : 10m
- With HR satellite sensors new sediment transport features become visible
 - ports
 - estuaries
 - dredging plumes
 - turbid wakes in wind farms

App6 Environmental impact of offshore construction (wind farms)

- Legal obligation for offshore wind farm construction to assess environmental impact.
- New environmental impact is visible : turbid wakes in wind farms.



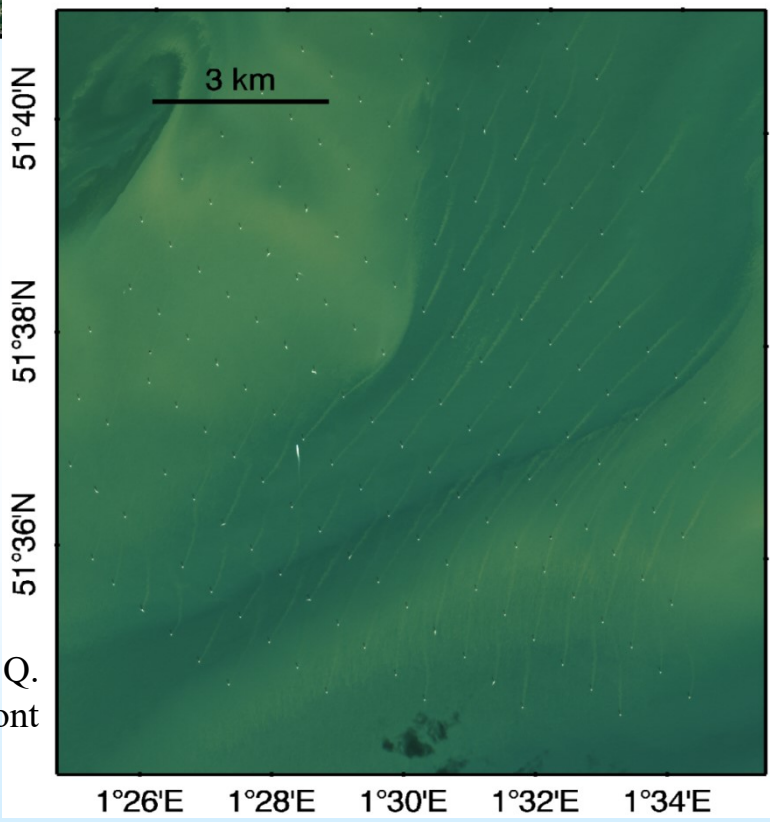
Sediment wakes in direction of tidal current [(c) RBINS, J-P. Vogt]

[Vanhellemont & Ruddick K (2014). Turbid wakes associated with offshore wind turbines observed with Landsat 8. Remote Sensing of Environment, 145, pp. 105–115. Open Access]

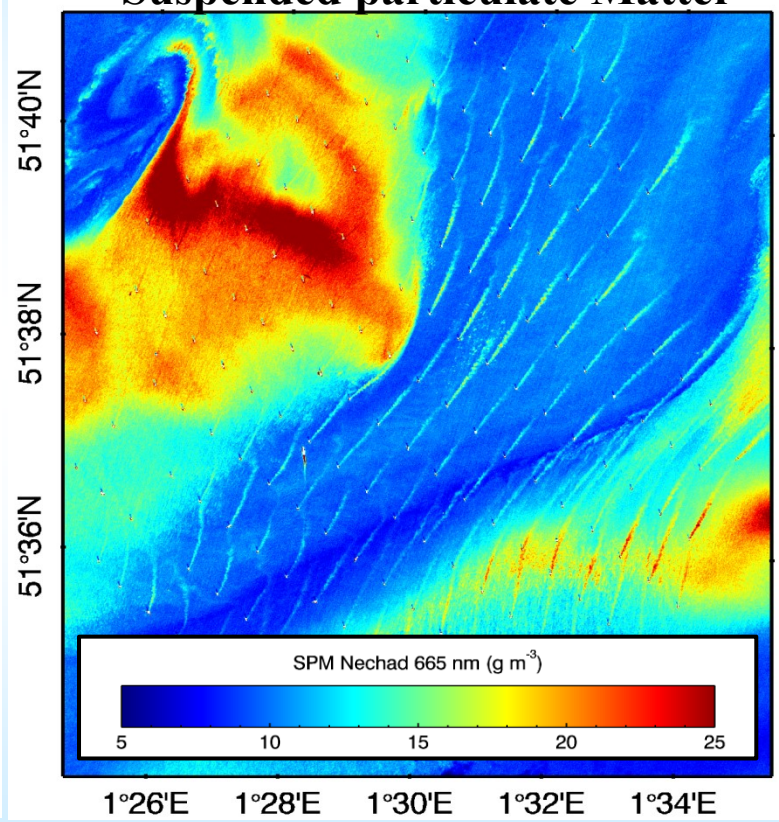
Environmental impact of offshore construction (wind farms)



Sentinel-2/MSI 2015-09-17

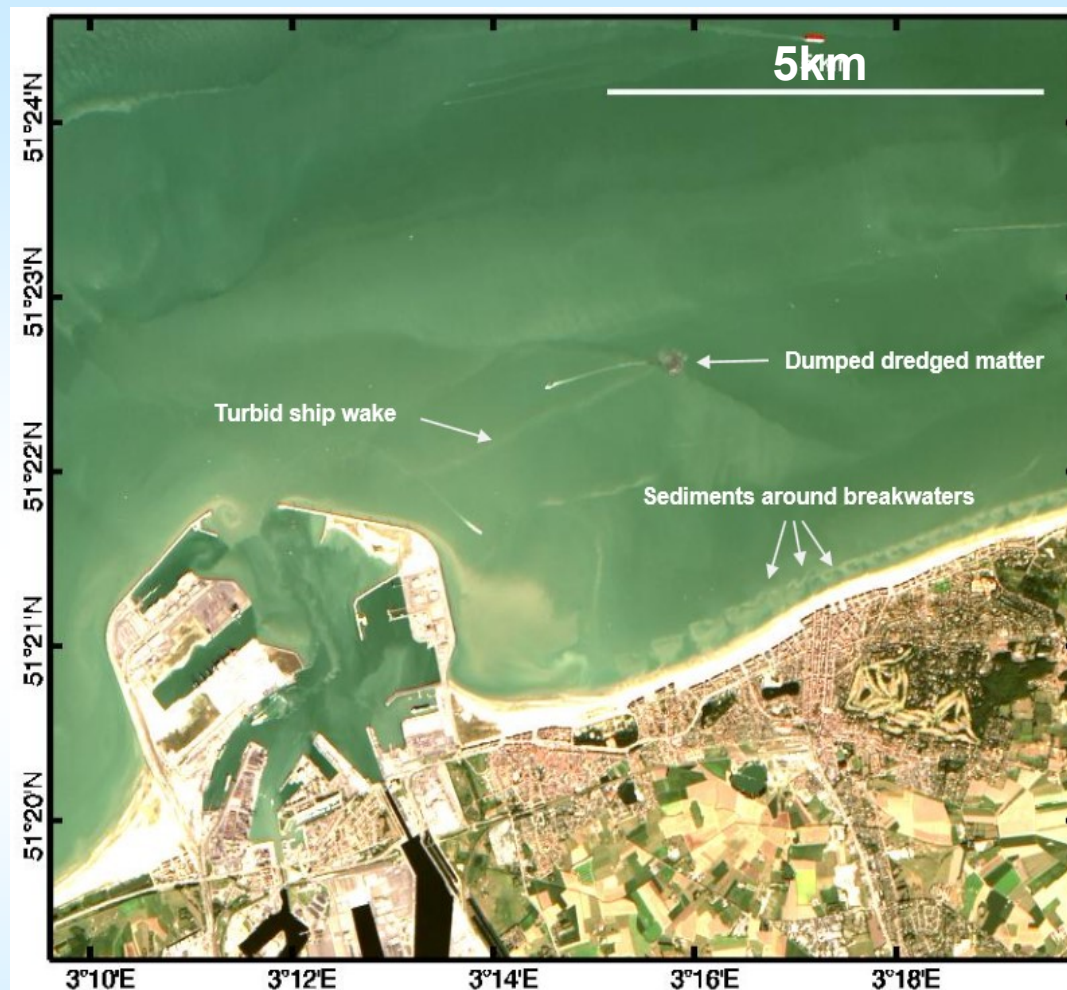


Suspended particulate Matter



Images from Q. Vanhellemont

[Vanhellemont & Ruddick K (2014). Turbid wakes associated with offshore wind turbines observed with Landsat 8. Remote Sensing of Environment, 145, pp. 105–115. Open Access]



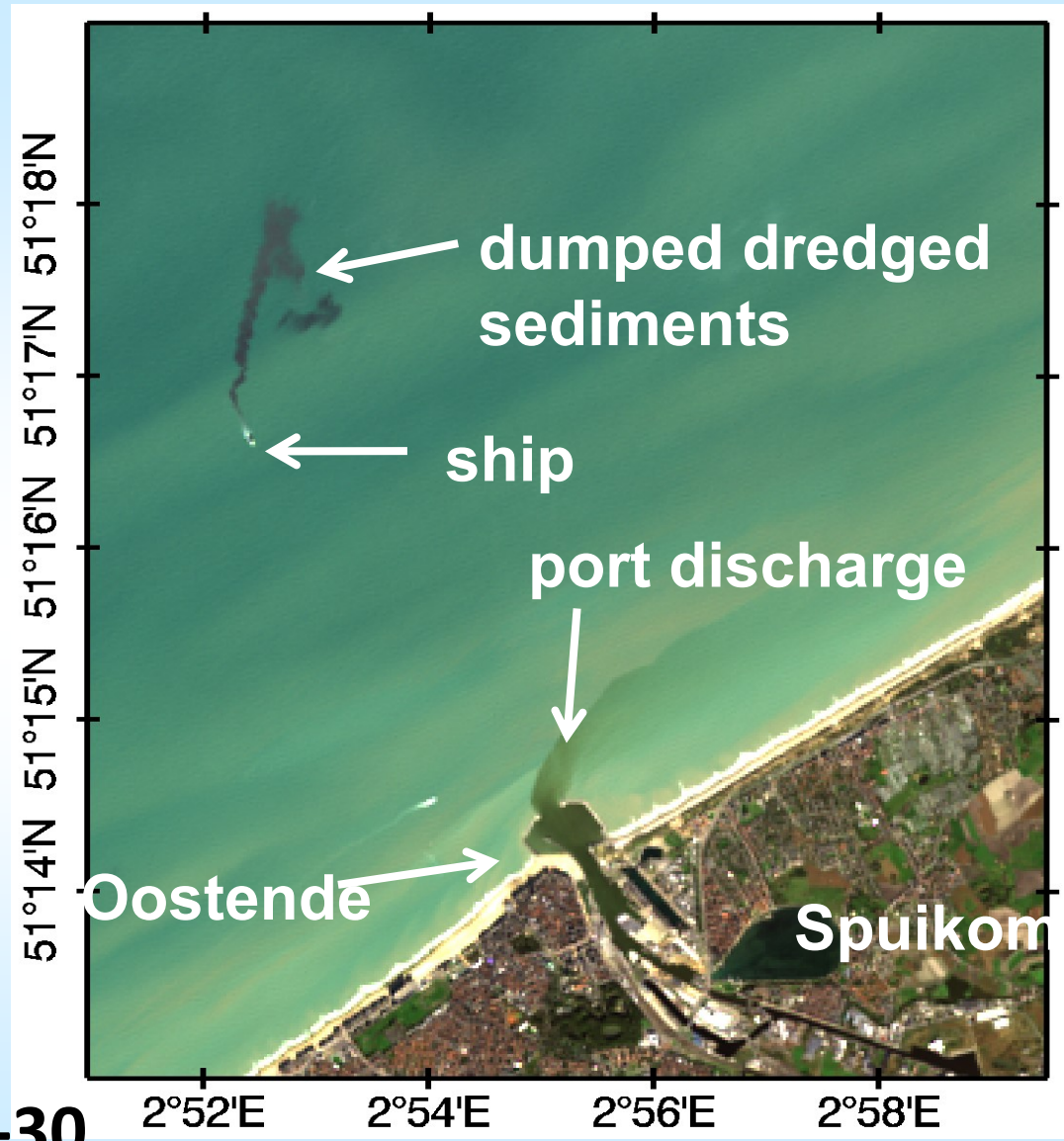
Landsat-8
(30m...15m)
around port of
Zeebrugge

Vanhellemont Q. & Ruddick K. (2014). Landsat-8 as a Precursor to Sentinel-2: Observations of Human Impacts in Coastal Waters. In: Submitted for the proceedings of the Sentinel-2 for Science Workshop held in Frascati, Italy, 20-23 May 2014, ESA Special Publication SP-726.

Sediment transport in near shore environments (dredging activities)



J.P. Vogt (RBINS) 2014-01-24



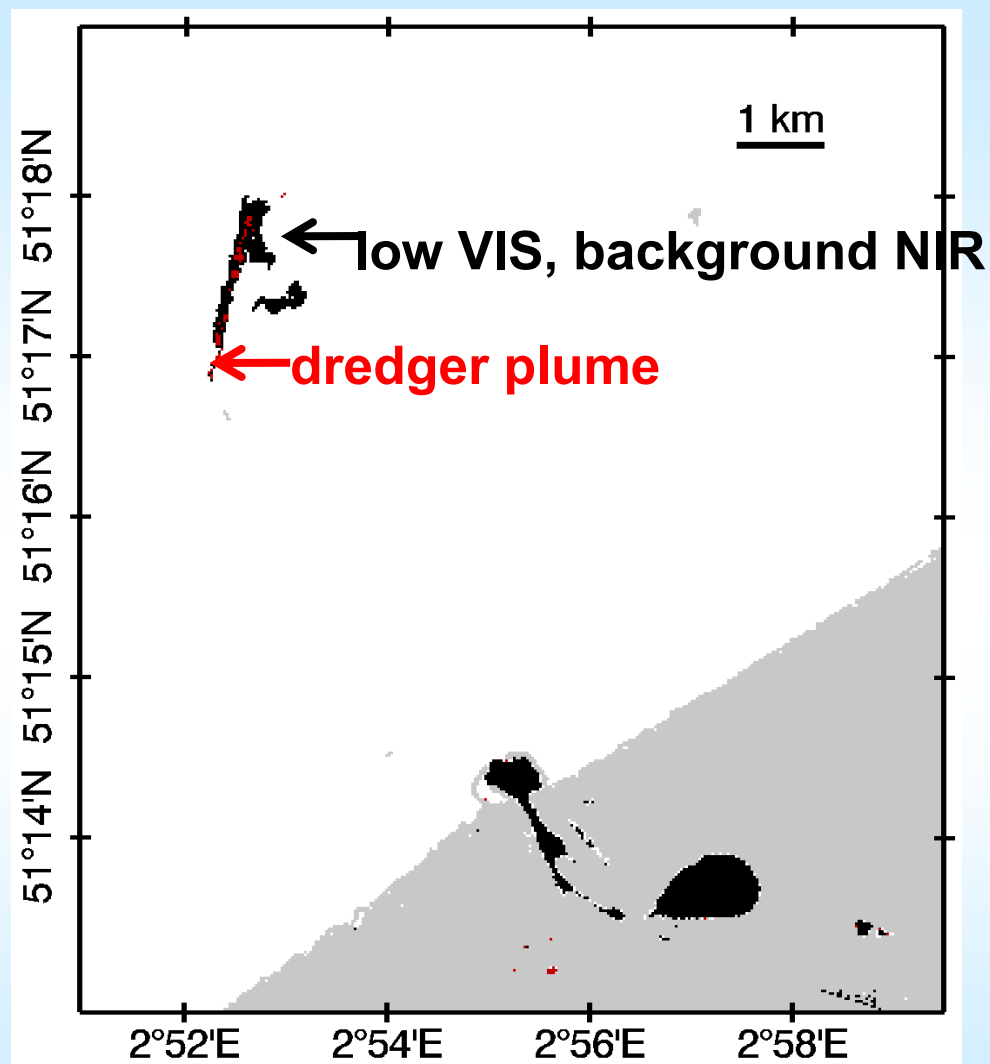
Landsat-8/OLI 2013-10-30

Sediment transport in near shore environments (dredging activities)

Automatic detection of black sediments based on very low reflectance in VIS and high in NIR.

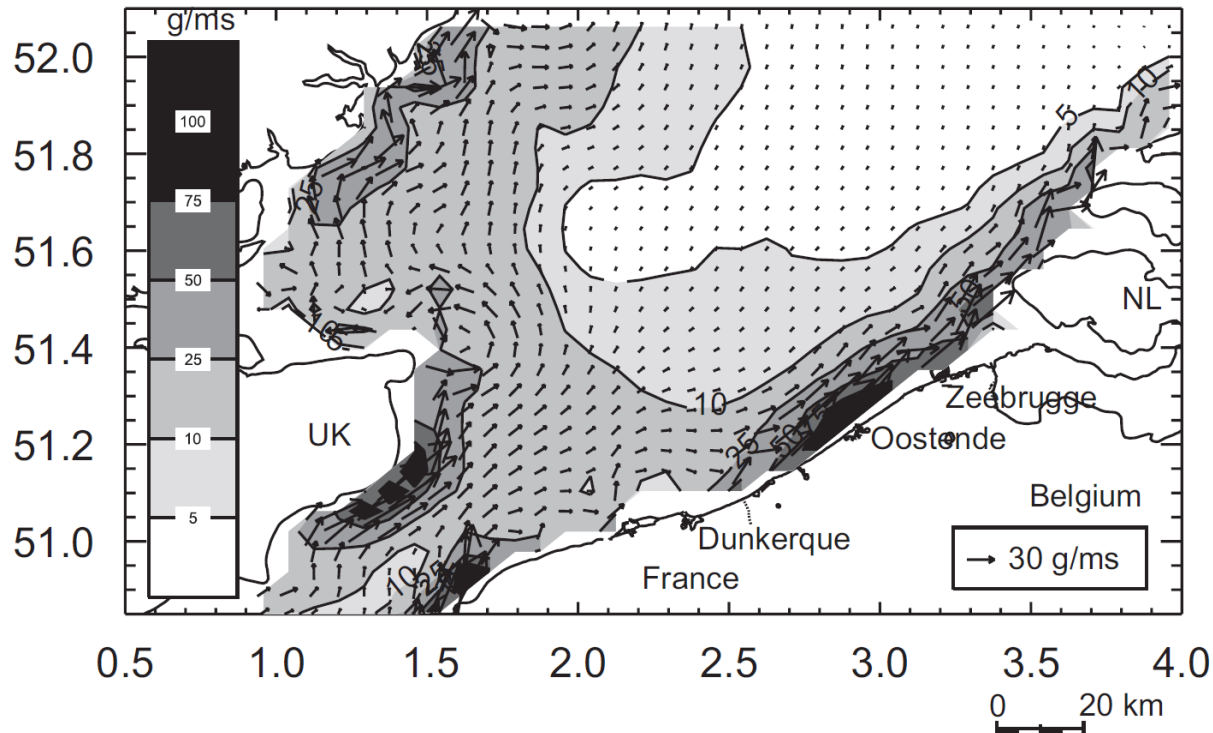
Vanhellemont, Q., Ruddick, K., (2015a).
Advantages of high quality SWIR bands for
ocean colour processing: examples from
Landsat-8.

<http://dx.doi.org/10.1016/j.rse.2015.02.007>



Sediment transport modelling

- E.g. RBINS-SUMO team couple satellite surface SPM maps and 3D hydrodynamic model to simulate sediment transport;
- Remote sensing can be also used for model initialisation and validation



Yearly averaged SPM transport in the Southern North Sea derived from 3D COHERENS model and SPM satellite pictures.

Fettweis et al., 2007, Continental Shelf Research

Potential for the exportation of methods

Sediment transports around artificial islands



Palm island Dubai, [Google Earth]

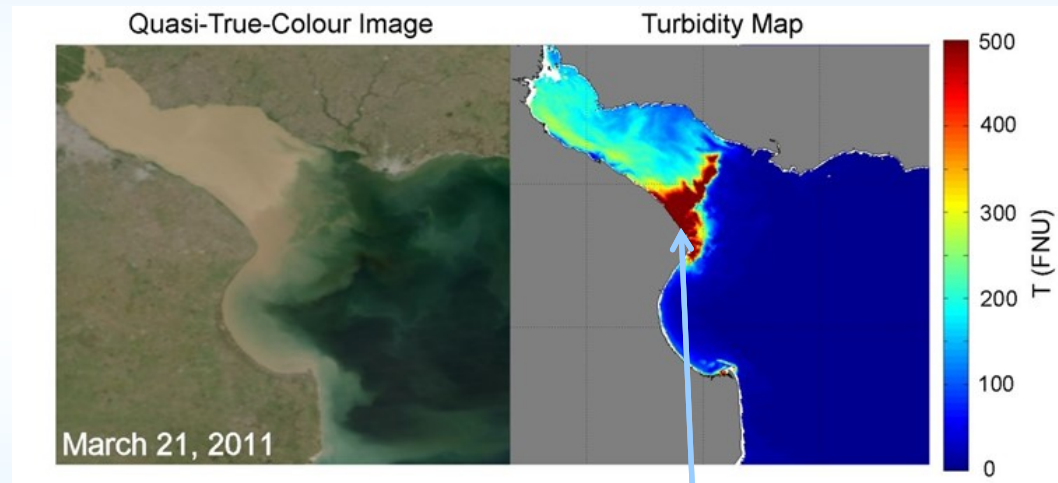
Underwater visibility applications

For humans (diving operations)

... and other marine animals

RBINS receives requests for visibility predictions (“optimal diving window”) for various diving operations.

La Plata turbidity mapping [Dogliotti et al, 2011]



300km

From: [Subsea World News] “Specialist divers battling strong tides and zero-visibility have completed a year-long project to cover parts of an exposed underwater pipeline in the Humber estuary.”

Visual predators cannot see here, safe haven for prey, e.g. fish larvae

Multi-mission context for SPM and CHL (not exhaustive!)

Satellite/Sensor	Period	Spatial Resolution	Temporal Resolution	SPM / TUR	CHL offshore	CHL coastal
Dedicated to ocean colour						
SeaWiFS	1997-2010	1000m	Daily	YES	YES	NO
MODIS-TERRA	1999+	1000m	Daily	YES	YES	NO
MODIS-AQUA	2002+	1000m	Daily	YES	YES	NO
ENVISAT-MERIS	2002-2012	300m	~4/week	YES	YES	YES
VIIRS	2011+	1000m	Daily	YES	YES	NO
Sentinel-3/OLCI	2015-2035	300m	2 days (2 sats)	YES	YES	YES

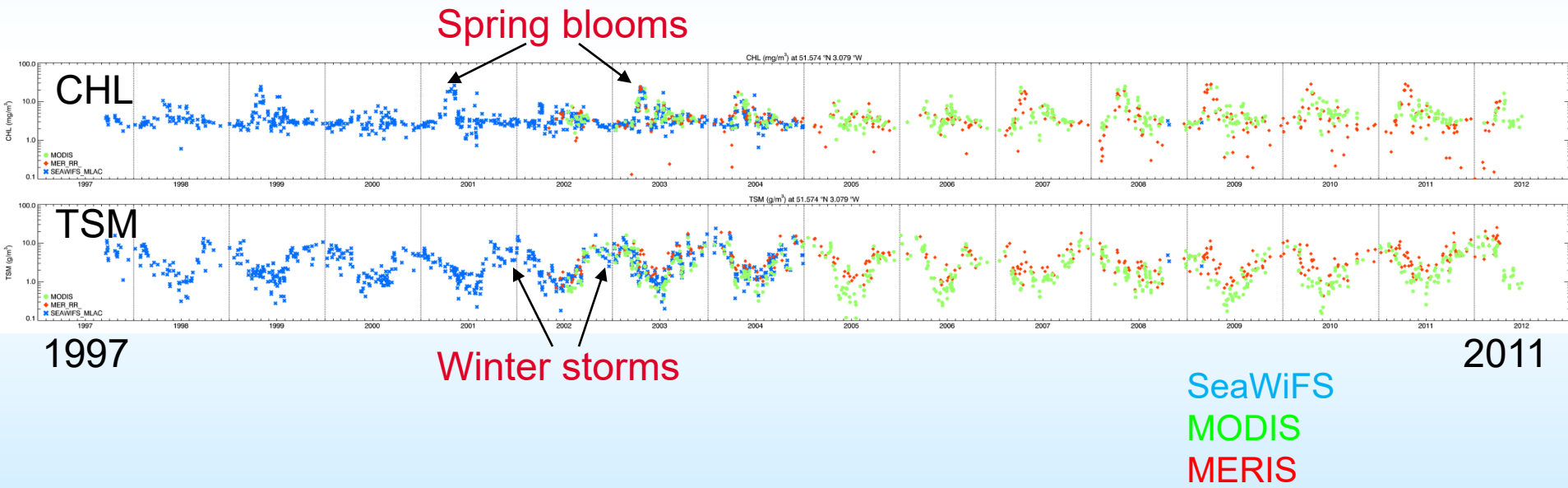
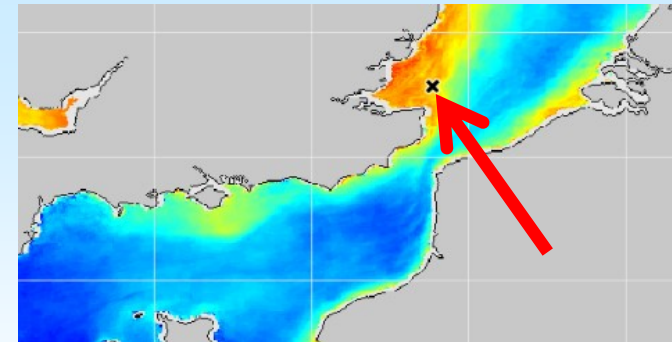
Other missions

PROBA-V	2013+	100m	Every 5 days	YES	NO	NO
Landsat-5	1984-2013	30m	Every 16 days	YES	NO	NO
Landsat-8	2013+	30m	Every 8 or 16 days	YES	NO	NO
Sentinel-2/MSI	2015-2035	10m	~5days (2 sats)	YES	YES	YES
Pléiades	2011+	2m/70cm	On demand	YES	NO	NO
SEVIRI-MSG	2004+	5000m	Every 15 minutes	YES	NO	NO

Multi-mission Exploitation : GRIMAS software

[Vanhellemont and Ruddick, 2011]

- Online time-series extraction tool
 - “SNC” region
 - SeaWiFS/MODIS/MERIS
 - 1997 – 2015 archive



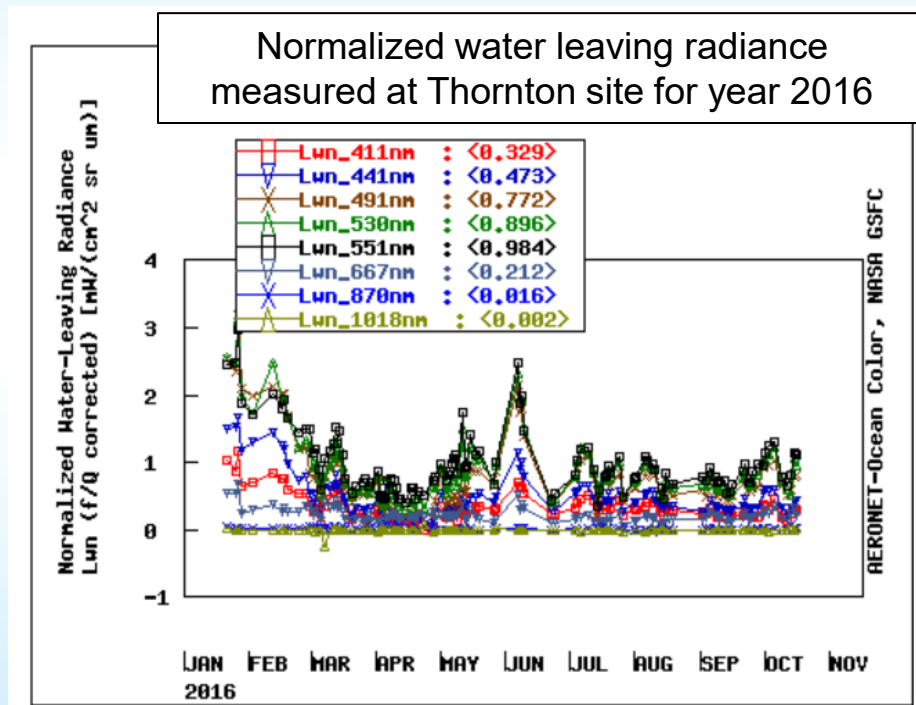
Multi-mission Validation Two AERONET-OC stations

[Ruddick et al., 2014]

- AERONET-OC is the ocean color component of the **Aerosol Robotic Network**
- **Two new AERONET-OC stations** have been installed in Belgian waters for the validation of ocean colour sensors.
 - **nearshore turbid water location** (Zeebrugge-MOW1 site)
 - **offshore in clearer water** (Thornton site)



CIMEL-SeaPRISM installed on the Zeebrugge-MOW1 site [courtesy Afdeling Kust]



Extracted from

http://aeronet.gsfc.nasa.gov/cgi-bin/type_piece_of_map_seaprim_new?level=2

Conclusion

- Ocean colour remote sensing is an essential tool to observe ocean in offshore but also coastal regions.
- There are many applications (only few are presented here).
- With high spatial resolution sensors (S2, L8) small scale features are visible.
- In the multi-mission context temporal resolution is increased.
- Sentinel-2/MSI and Sentinel-3/OLCI data represent an important contribution to ocean colour.

References

REMSEM Publications

- available from <http://odnature.naturalsciences.be/remsem> (or Google “REMSEM publications”)

References mentioned in this presentation

- Dogliotti A.-I., Ruddick K., Nechad B., Lasta C., Mercado A., Hozbor C., Guerrero R., Riviello López G., Abelando M. Calibration and validation of an algorithm for remote sensing of turbidity over La Plata River estuary, Argentina, EARSeL eProceedings, Vol. 10 pp. 119–130, 2011.
- Fettweis, M., Nechad, B., Van den Eynde, D., An estimate of the suspended particulate matter (SPM) transport in the southern North Sea using SeaWiFS images, in situ measurements and numerical model results, Continental Shelf Research 27 (10), 1568-1583, 2007.
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- Ruddick K., Van der Zande D., Vanhellemont Q. Multi-sensor ocean colour validation in Belgian waters (2014) Proc. Ocean Optics XXII Portland, USA, 26-31 October 2014
- Vanhellemont Q., Ruddick K. Advantages of high quality SWIR bands for ocean colour processing: Examples from Landsat-8, Remote Sensing of Environment, Vol. 161 pp. 89–106, 2015.
- Vanhellemont Q., Ruddick K. Landsat-8 as a Precursor to Sentinel-2: Observations of Human Impacts in Coastal Waters, Submitted for the proceedings of the Sentinel-2 for Science Workshop held in Frascati, Italy, 20-23 May 2014, ESA Special Publication SP-726, 2014
- Vanhellemont, Q., Ruddick K, Turbid wakes associated with offshore wind turbines observed with Landsat 8. Remote Sensing of Environment, 145, pp. 105–115. 2014
- Vanhellemont Q. & Neukermans G. & Ruddick K. High frequency measurement of suspended sediments and coccolithophores in European and African coastal waters from the geostationary SEVIRI sensor. Submitted to the proceedings of the EUMETSAT Meteorological Satellite Conference 2013.

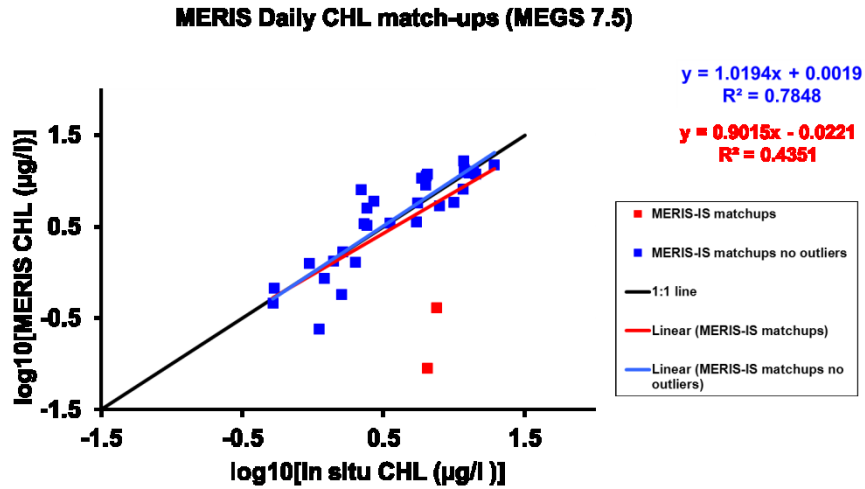
Acknowledgements

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 - European Community (FP7, HIGHROC project).
 - Belgian Science Policy Office (JELLYFOR- BE project)
 - European Space Agency (GMES Marcoast project)
- **The Sentinel program**

Thank you for your attention

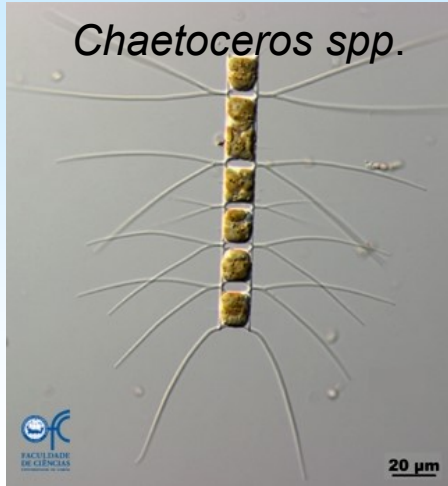
Validation data

CHL MERIS

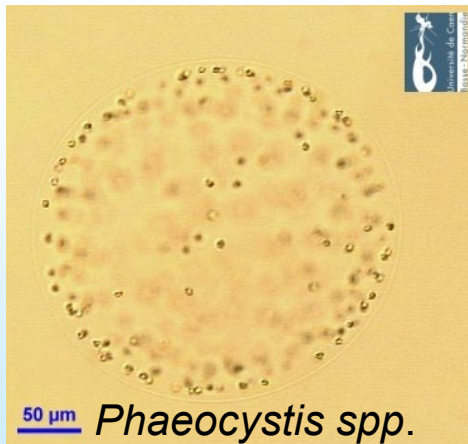


Remote Sensing: What is ocean colour?

[R. Mendes]



[J-P. Vogt]



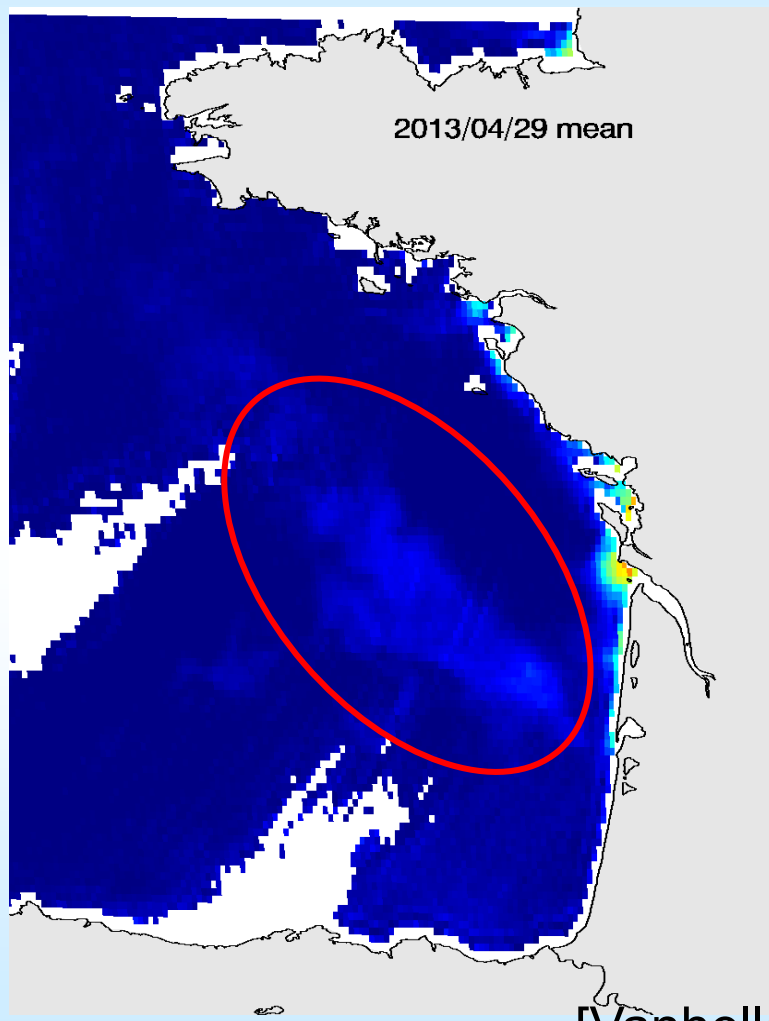
[F. Jouenne]

Multi-mission context for sediment transport (not exhaustive!)

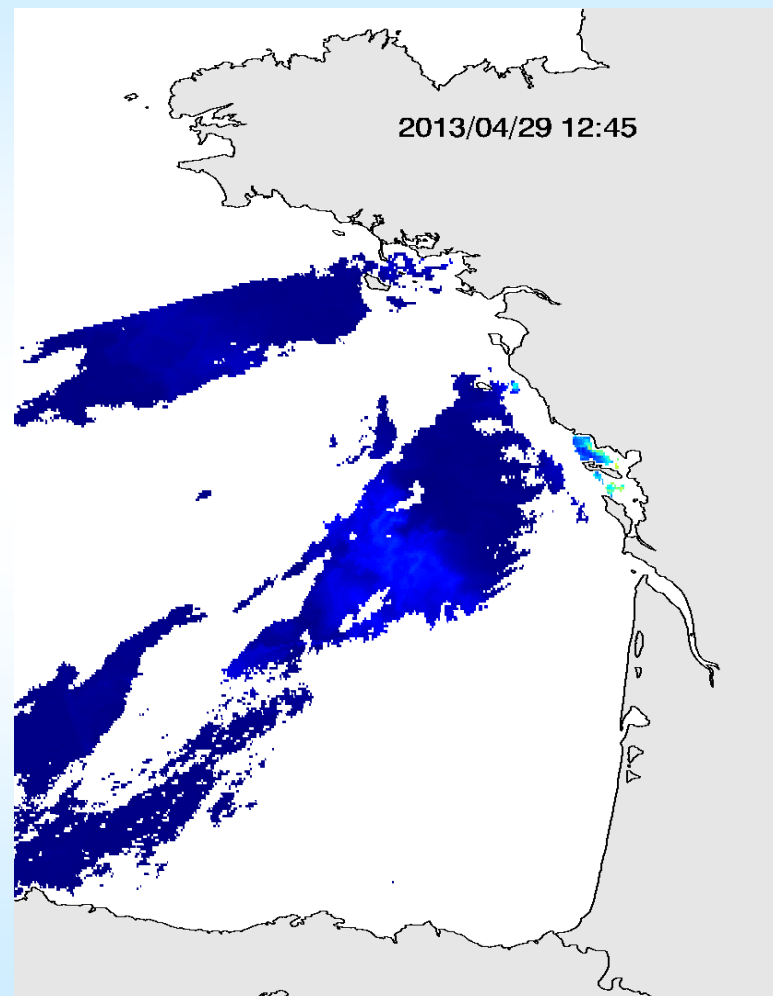
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SeaWiFS	1997-2010	1000m	Daily	Standard Water Products exist	
MODIS-TERRA	1999+	250m			
MODIS-AQUA	2002+	250m			
ENVISAT-MERIS	2002-2012	300m	~4/week		
VIIRS	2011+	1000m	RBINS/	ACOLITE multi-mission atmospheric correction	
Sentinel-3/OLCI	2015+	300m			
PROBA-V	2013+	100m			
Landsat-5	1984-2013	30m	Every 16 days		

Detection of coccolithophore blooms

SEVIRI 2013/04/29
Daily mean (~40 images averaged)



MODIS 2013/04/29
Only one image



[Vanhellemont et al., 2013]