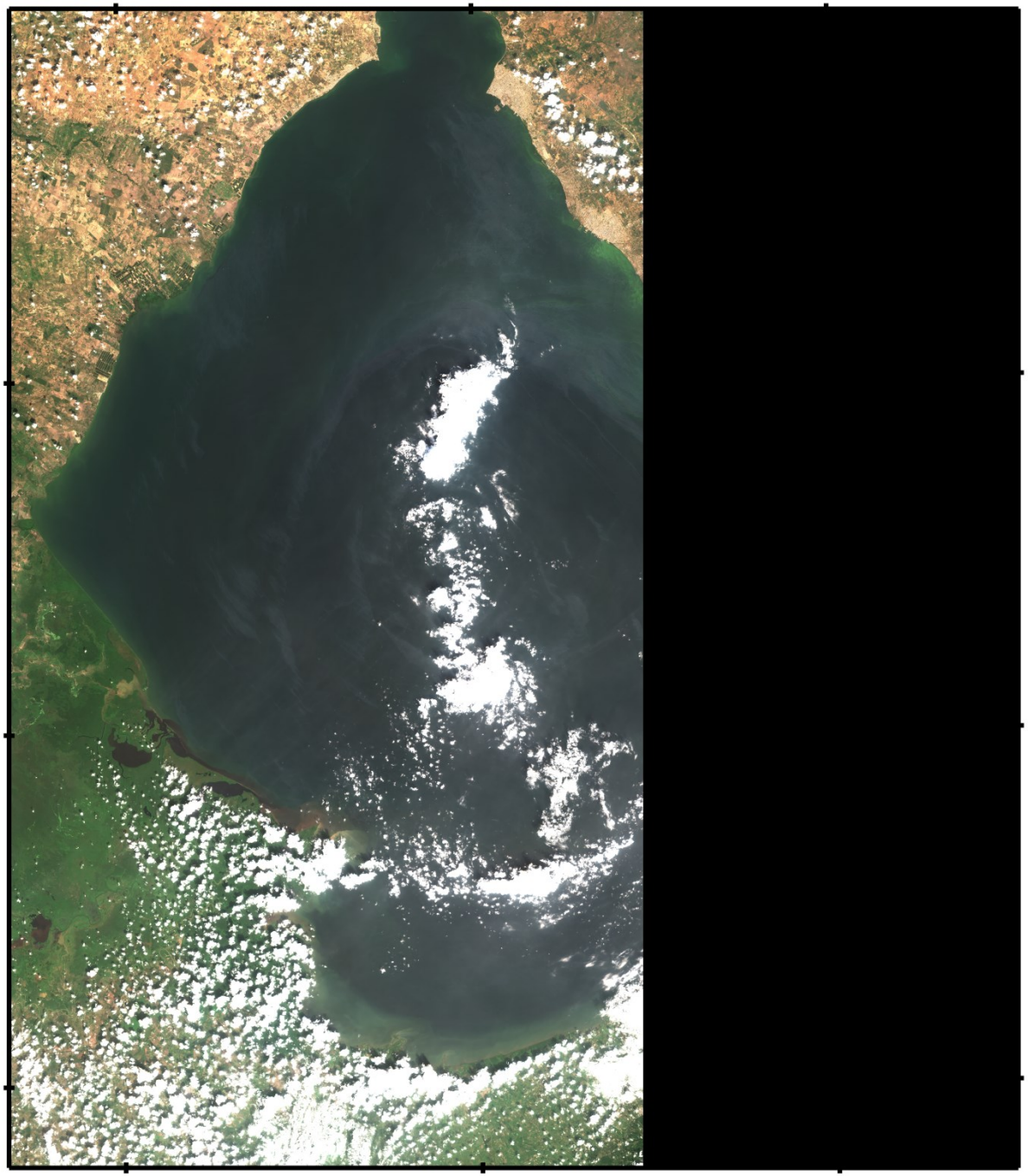
High resolution (1-30m) optical remote sensing of processes in coastal and inland waters – new opportunities and challenges

by Kevin Ruddick and Quinten Vanhellemont
Royal Belgian Institute for Natural Sciences (RBINS)
and
Inputs from: Ana Dogliotti (IAFE), Héloise Lavigne and Dimitry Van der Zande

The Game-Changers!
2013: Landsat-8 (30m, 15m) free of charge from USGS
2015: Sentinel-2A (10-20m) free of charge from ESA
Also Pléiades (2m, 70cm) commercial from Astrium

IWCS?
Presentation at ~~IOCS~~, Lisbon, 15-18.5.2017



S2A, 2015-12-28, 15:24

New Delhi, Yamuna River

ρ_s RGB S2A/MSI 2016-10-22 (05:28 UTC)

New users and applications: e.g. Port of Zeebrugge (~4km)

[Dredgingtoday.com]

Black (anoxic?) sediments

Bird sanctuary

In/Out Water and Sediment flux (and jellyfish … ?)

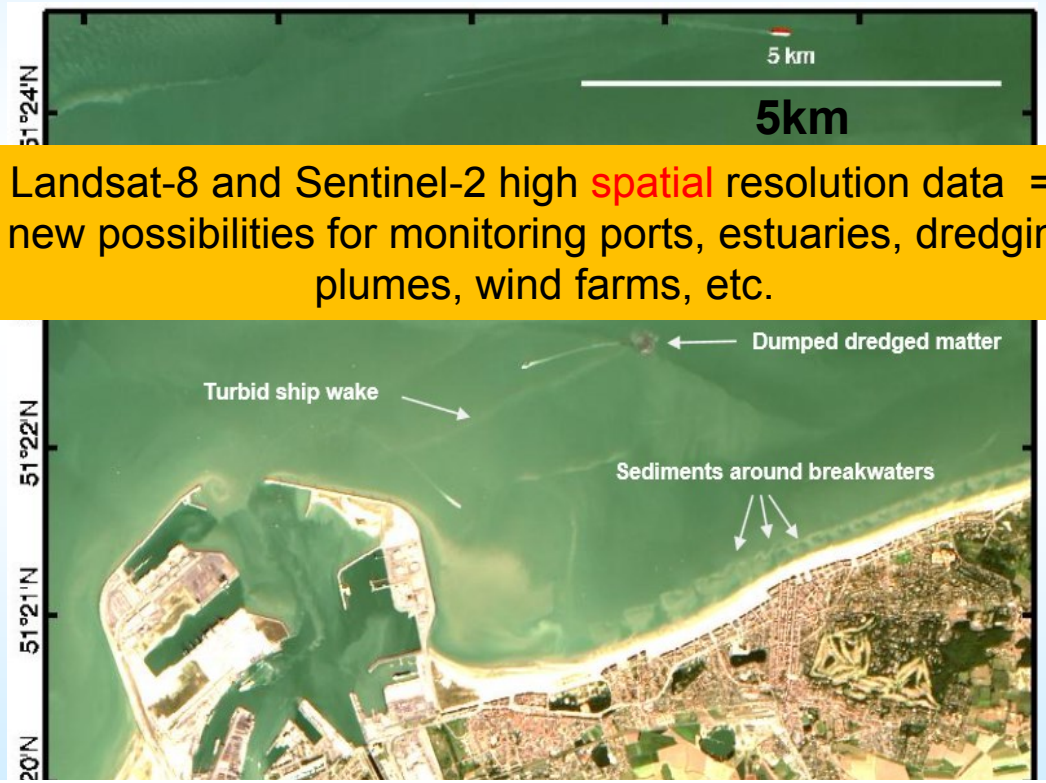
+Around port:

Beach change and tourism

Dumped WWI munitions

Application Opportunities

- Many coastal/inland apps are very nearshore: EU Water Framework Directive 1 n. mile

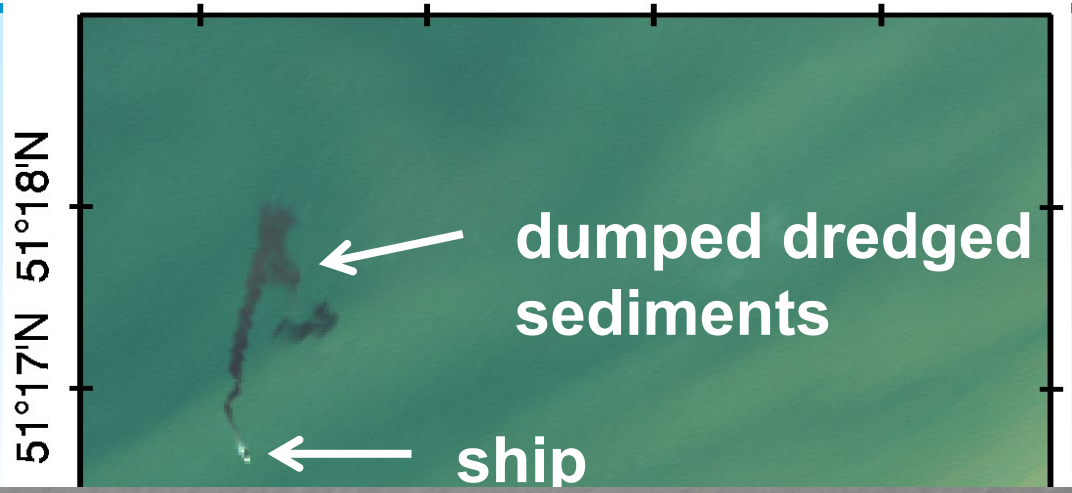


Landsat-8 and Sentinel-2 high spatial resolution data => new possibilities for monitoring ports, estuaries, dredging plumes, wind farms, etc.

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

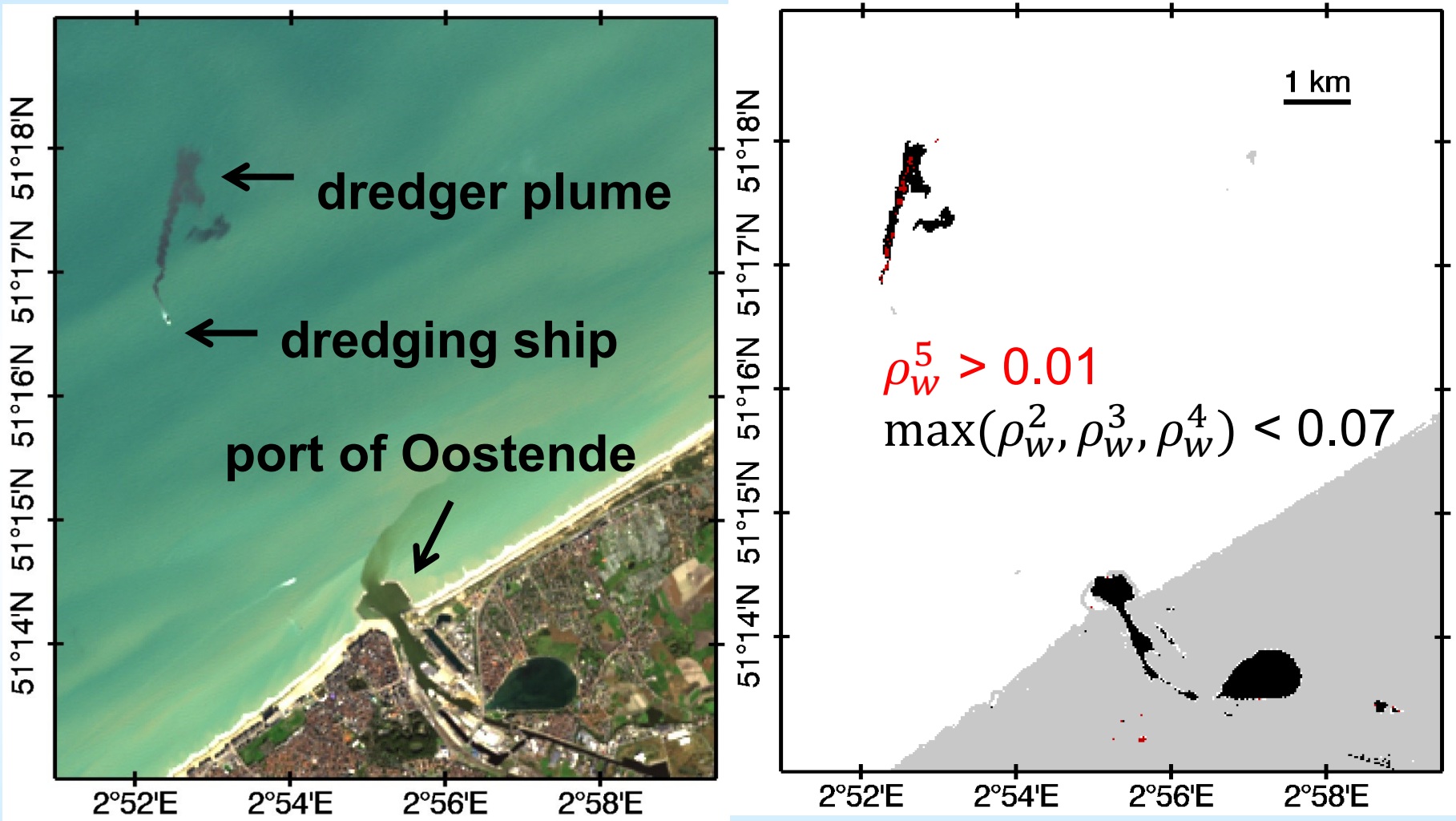
Vanhellemont Q. & Ruddick K. (2014). **Landsat-8 as a Precursor to Sentinel-2: Observations of Human Impacts in Coastal Waters.** Proceedings of the Sentinel-2 for Science Workshop held in Frascati, Italy, 20-23 May 2014, ESA Special Publication SP-726.

Landsat-8/OLI 2013-10-30 Rayleigh corrected RGB

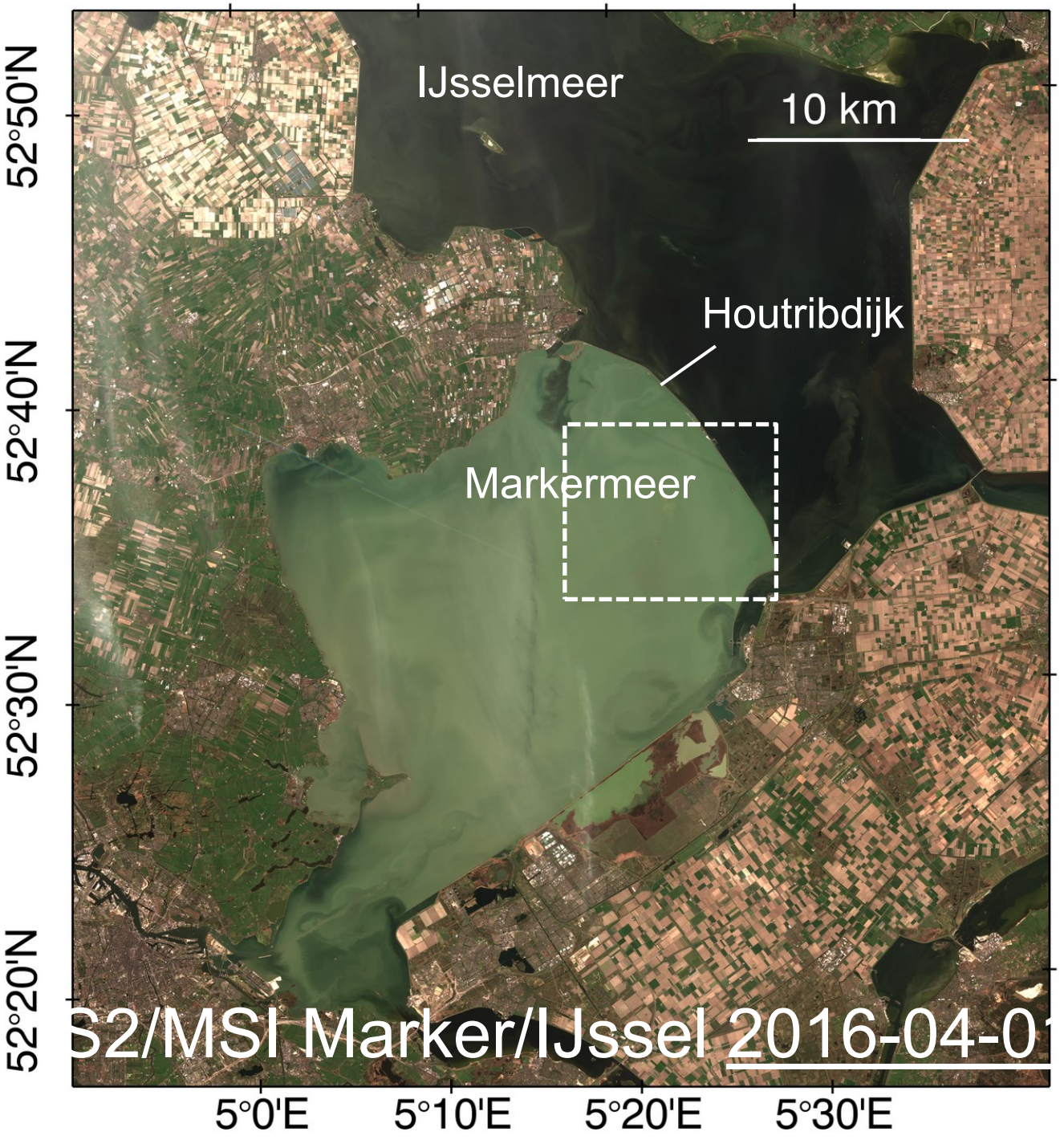


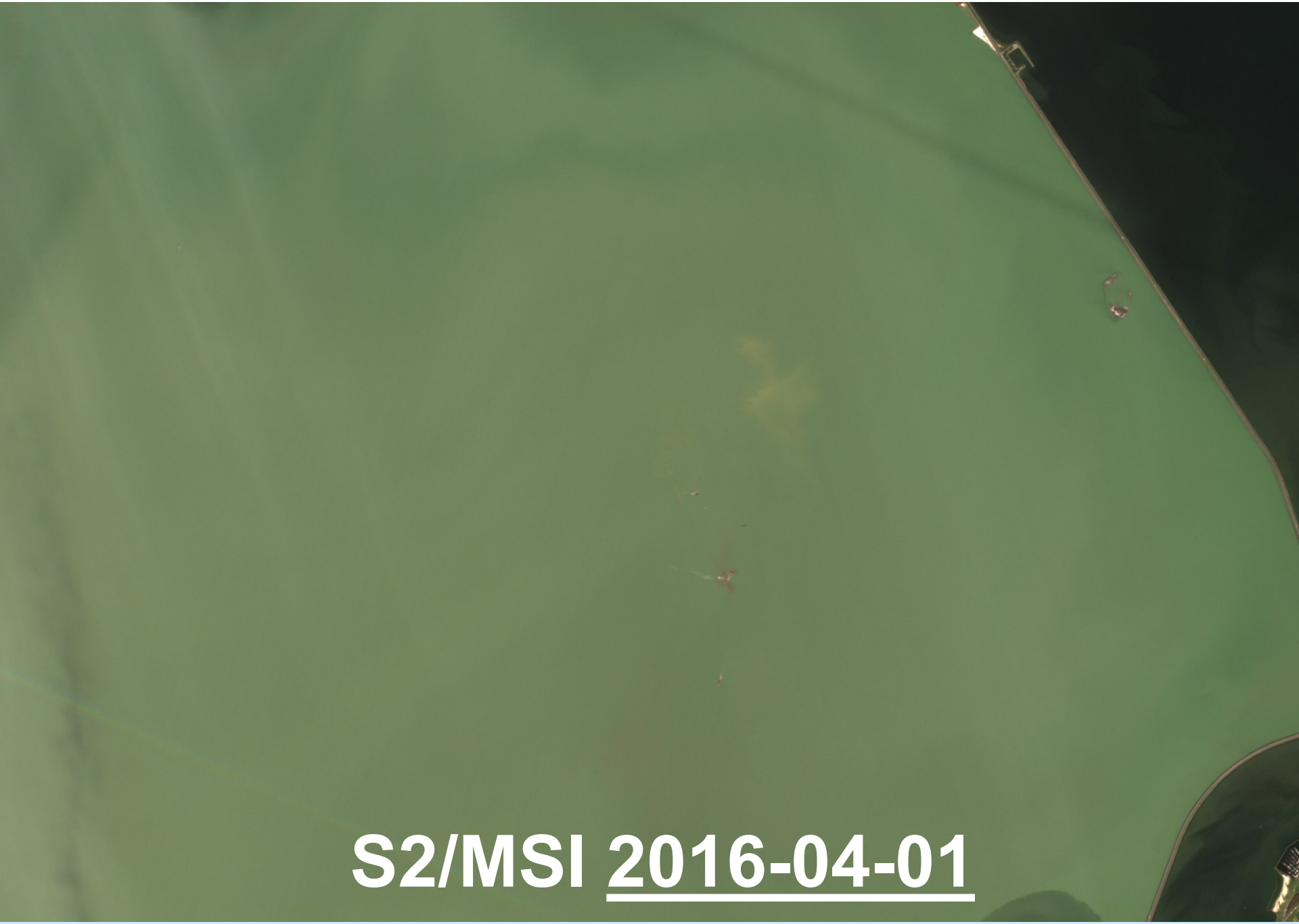
Vanhellemont, Q., Ruddick, K., 2014b. **Landsat-8 as a Precursor to Sentinel-2: Observations of Human Impacts in Coastal Waters.**, in: ESA Special Pub SP-726

Landsat-8/OLI 2013-10-30



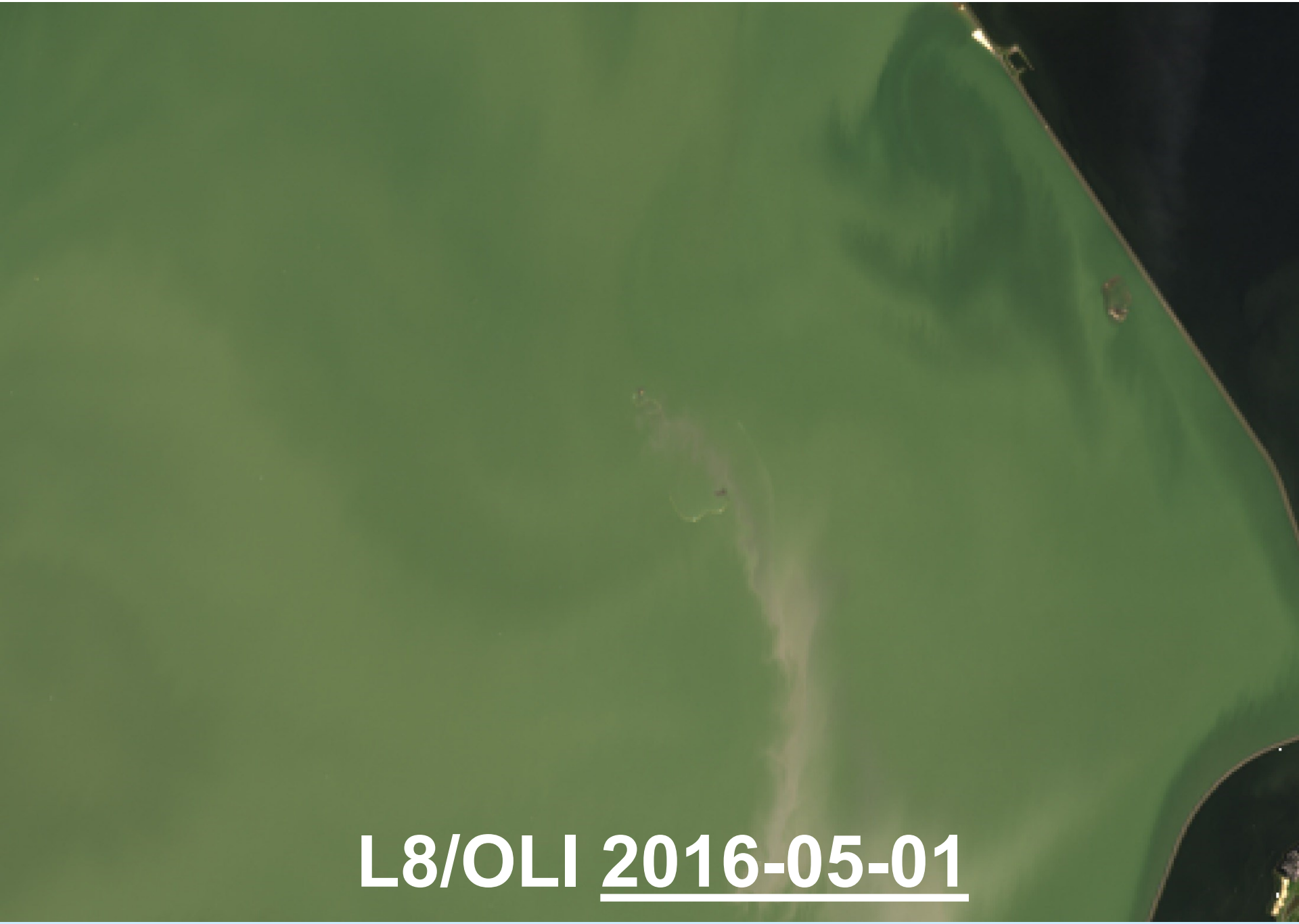
Vanhellemont, Q., Ruddick, K., (2015). **Advantages of high quality SWIR bands for ocean colour processing: examples from Landsat-8.**
http://dx.doi.org/10.1016/j.rse.2015.02.007

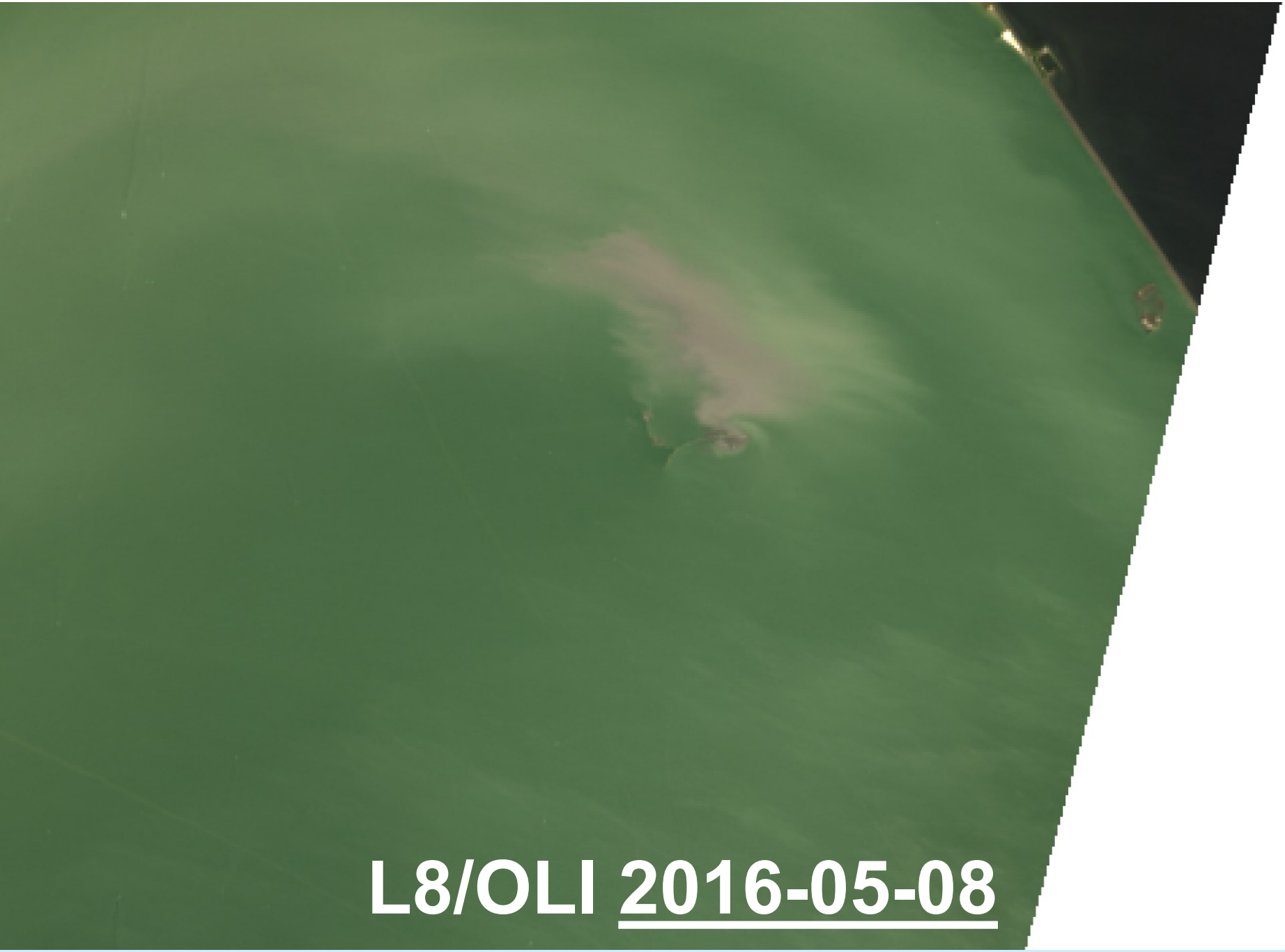

IJsselmeer
10 km
Houtribdijk
Markermeer
52°50'N
52°40'N
52°30'N
52°20'N
5°0'E
5°10'E
5°20'E
5°30'E
S2/MSI Marker/IJssel 2016-04-0



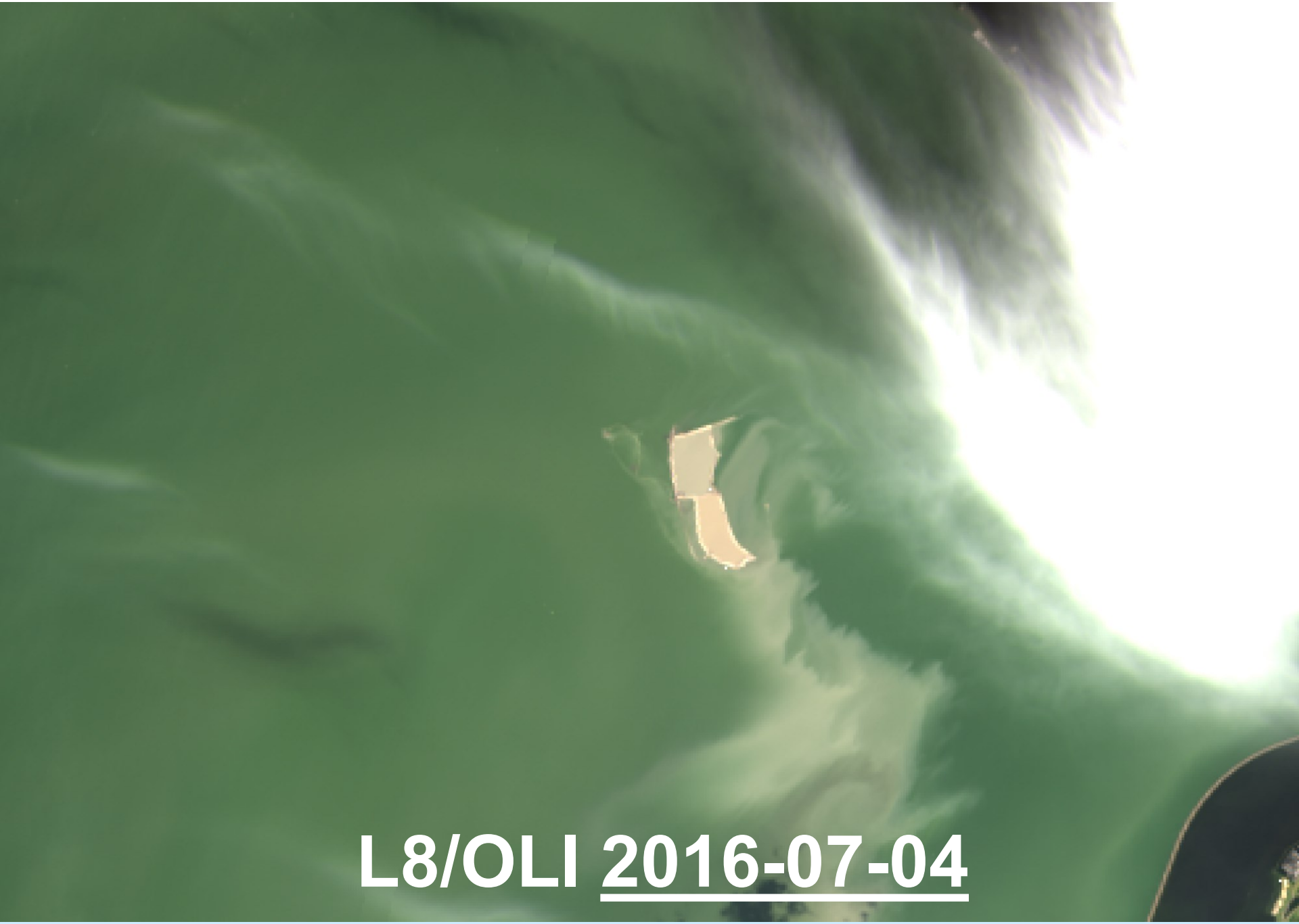
S2/MSI 2016-04-01

S2/MSI 2016-04-11





L8/OLI 2016-05-08

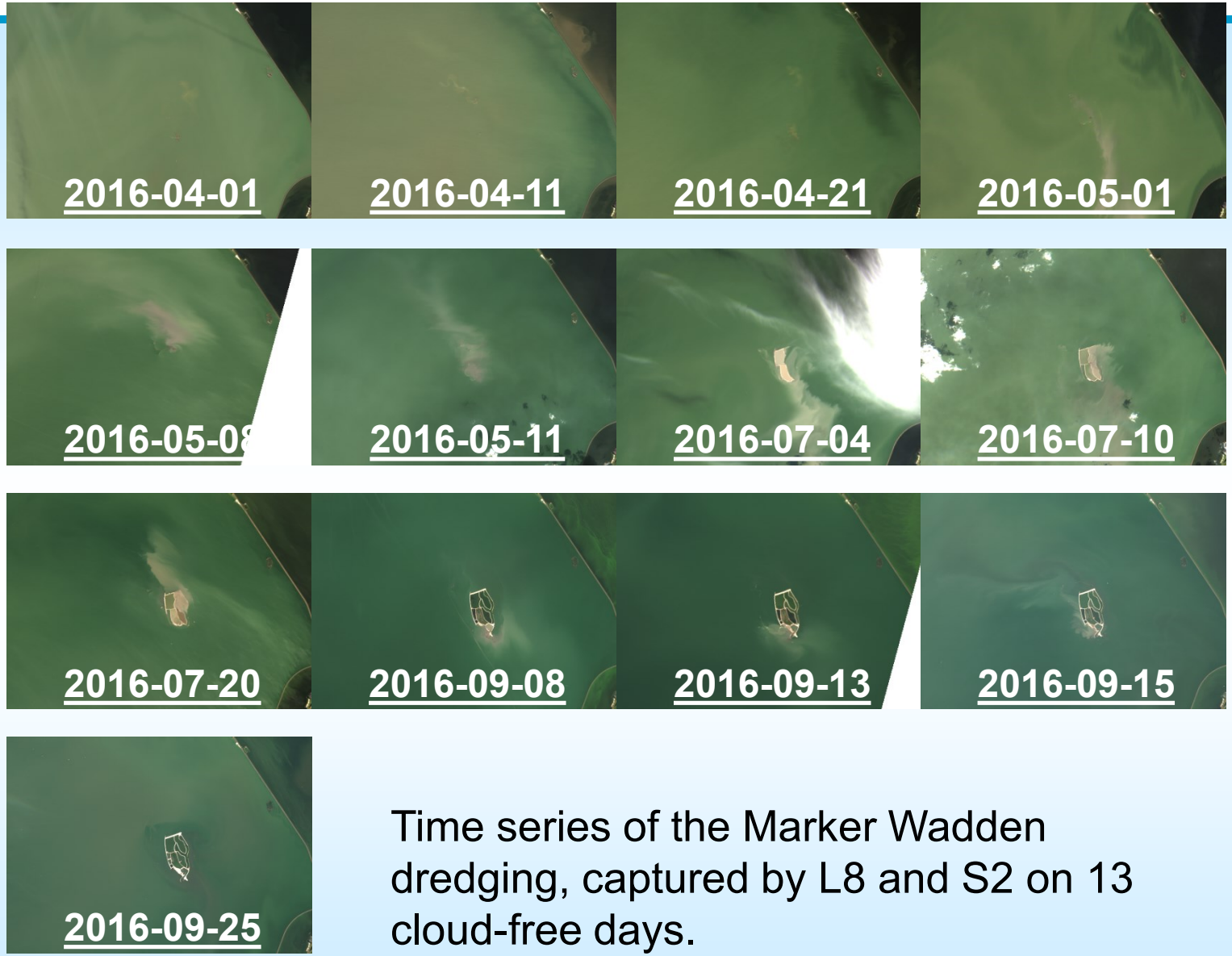


S2/MSI 2016-09-08

L8/OLI 2016-09-13

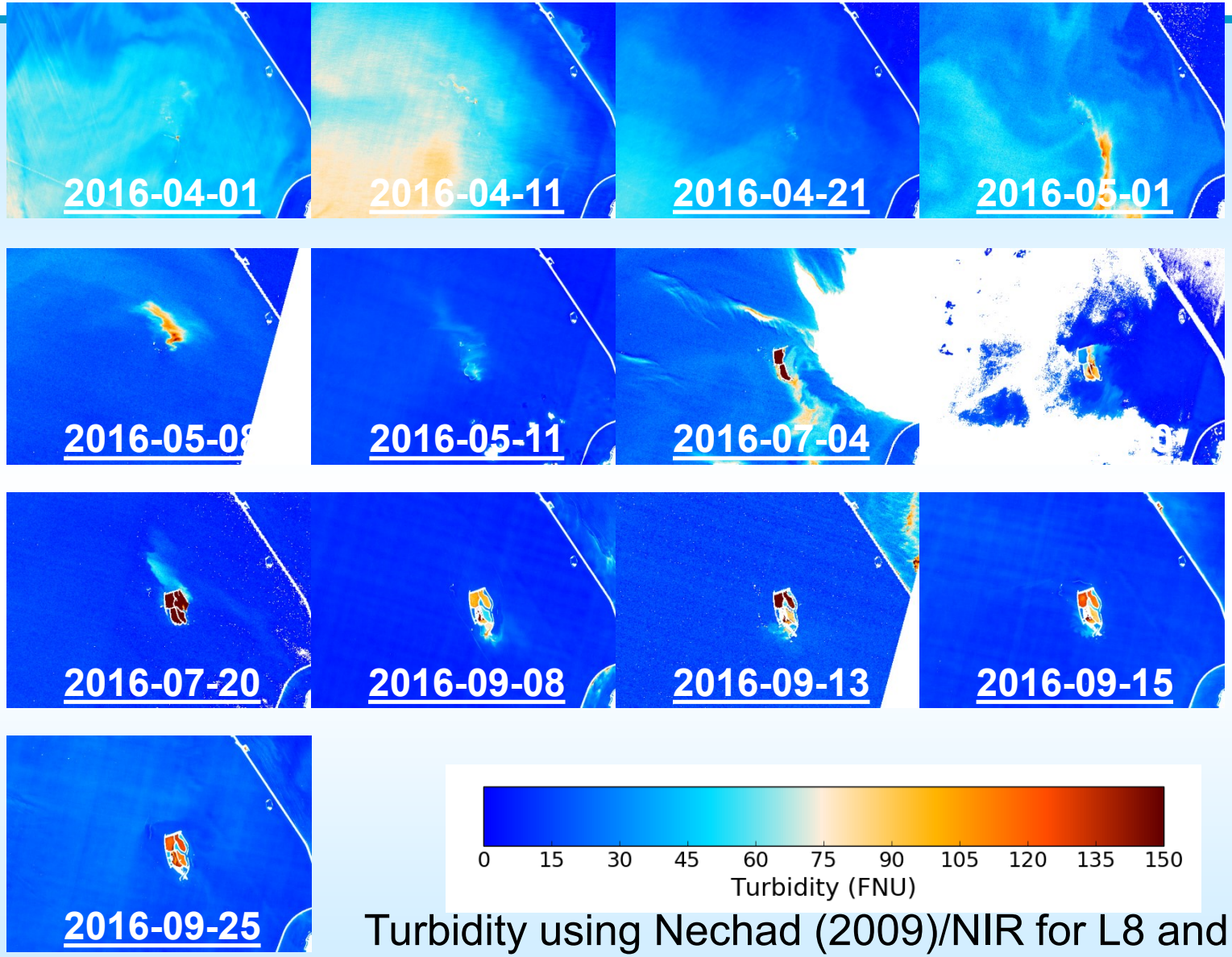
S2/MSI 2016-09-15

S2/MSI 2016-09-25



Time series of the Marker Wadden dredging, captured by L8 and S2 on 13 cloud-free days.

[Vanhellemont Q. & Ruddick K. ACOLITE processing for Sentinel-2 and Landsat-8: atmospheric correction and aquatic applications (2016) Ocean Optics, Victoria]



Turbidity using Nechad (2009)/NIR for L8 and S2.

[Vanhellemont Q. & Ruddick K. ACOLITE processing for Sentinel-2 and Landsat-8: atmospheric correction and aquatic applications (2016) Ocean Optics, Victoria]

Intense near-shore bloom observed by Sentinel-2A/MSI in Belgian waters

(red-edge Chl-a absorption – see Vanhellemont & Ruddick VLIZ 2017)

Figure 1 Sentinel-2A/MSI Rayleigh-corrected RGB composite of the Belgian coastal zone on 2016-05-01 (10:53 UTC). Common sampling stations are annotated.

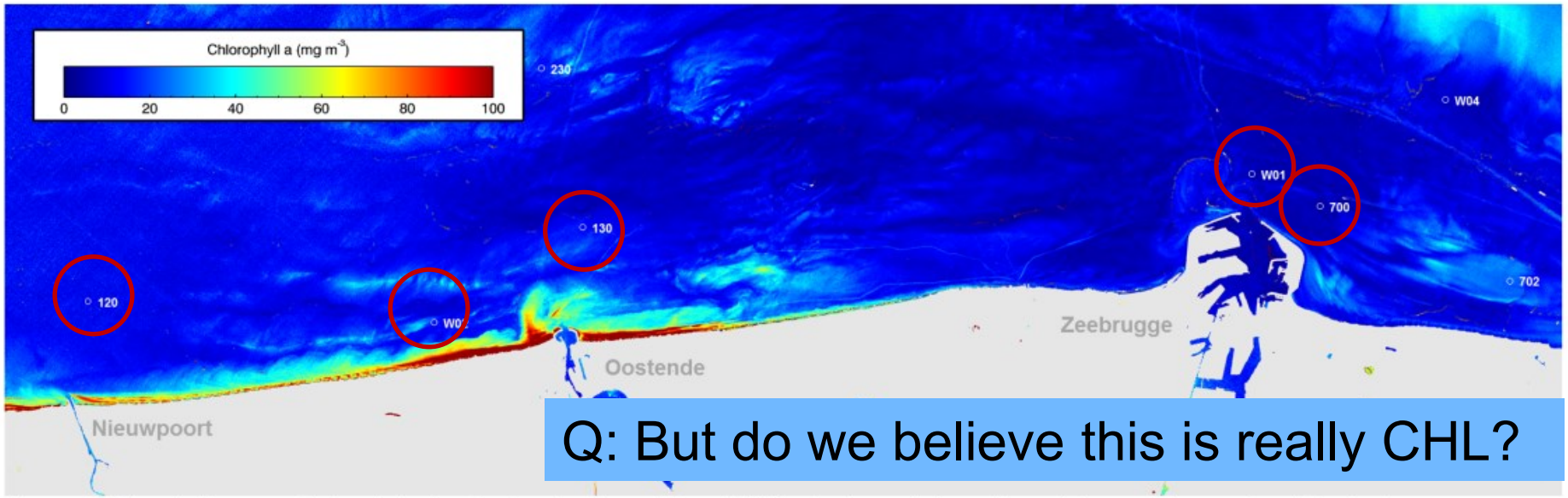


Figure 2 Chlorophyll a concentration derived using the algorithm of Gons (2005), showing an intense bloom between Nieuwpoort and Oostende

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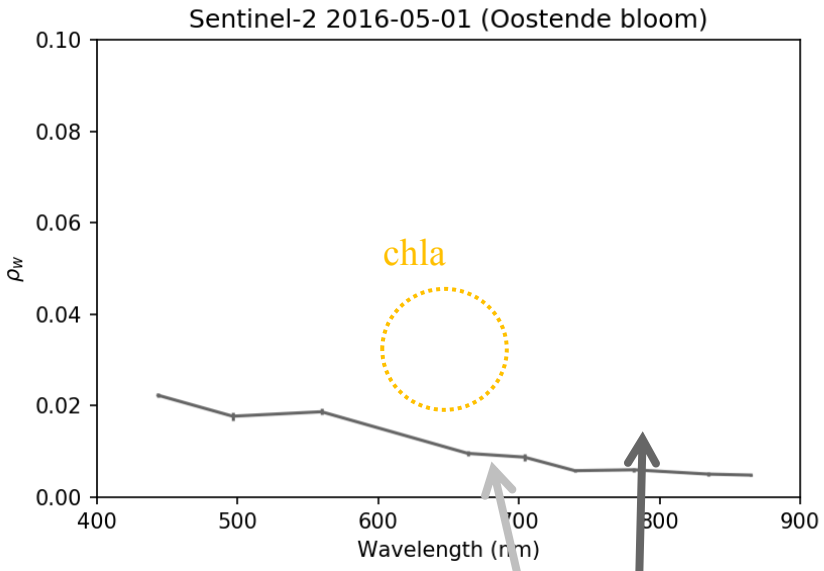
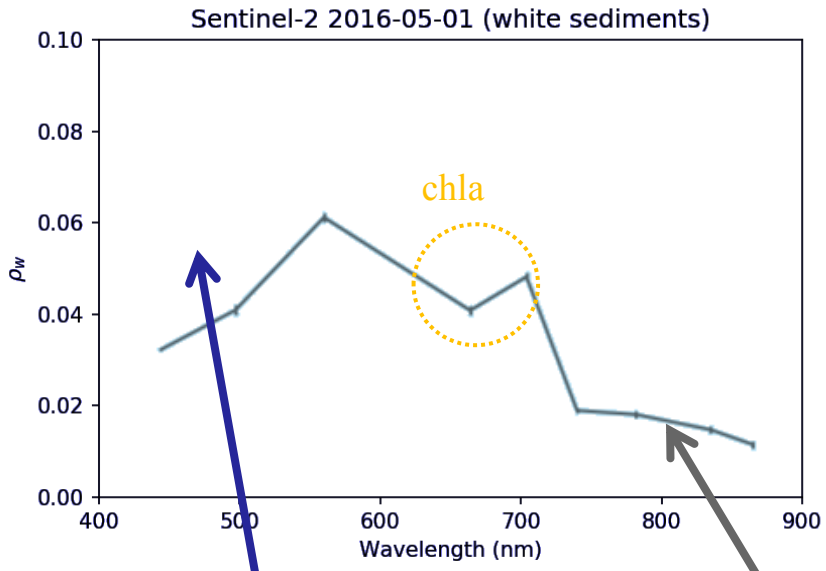




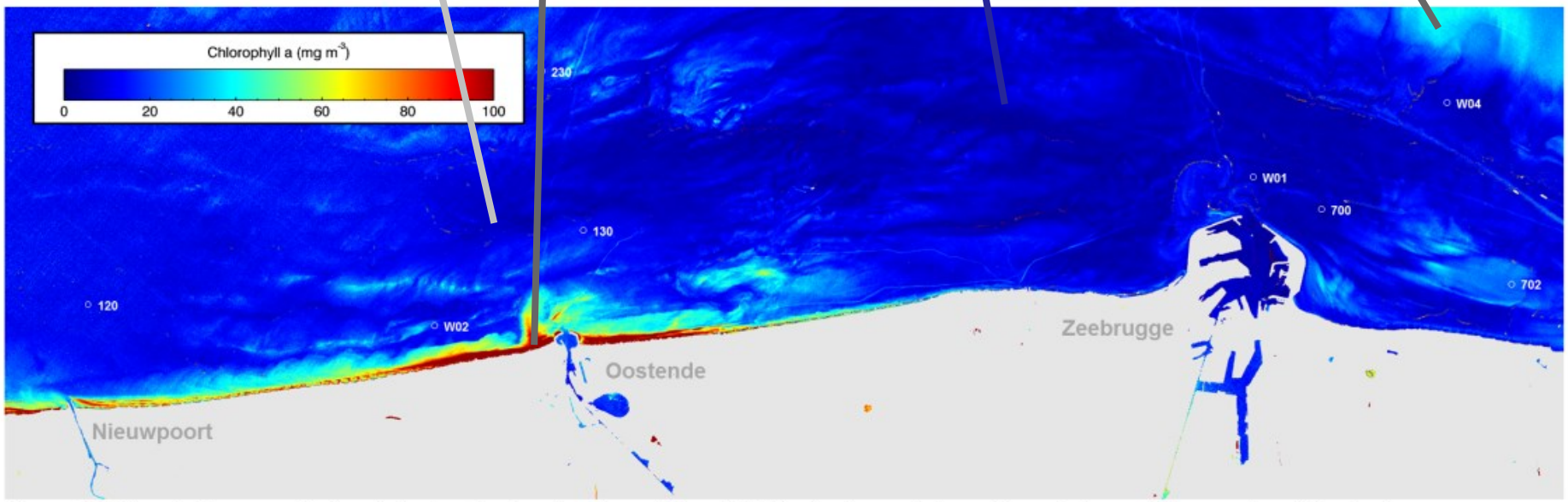
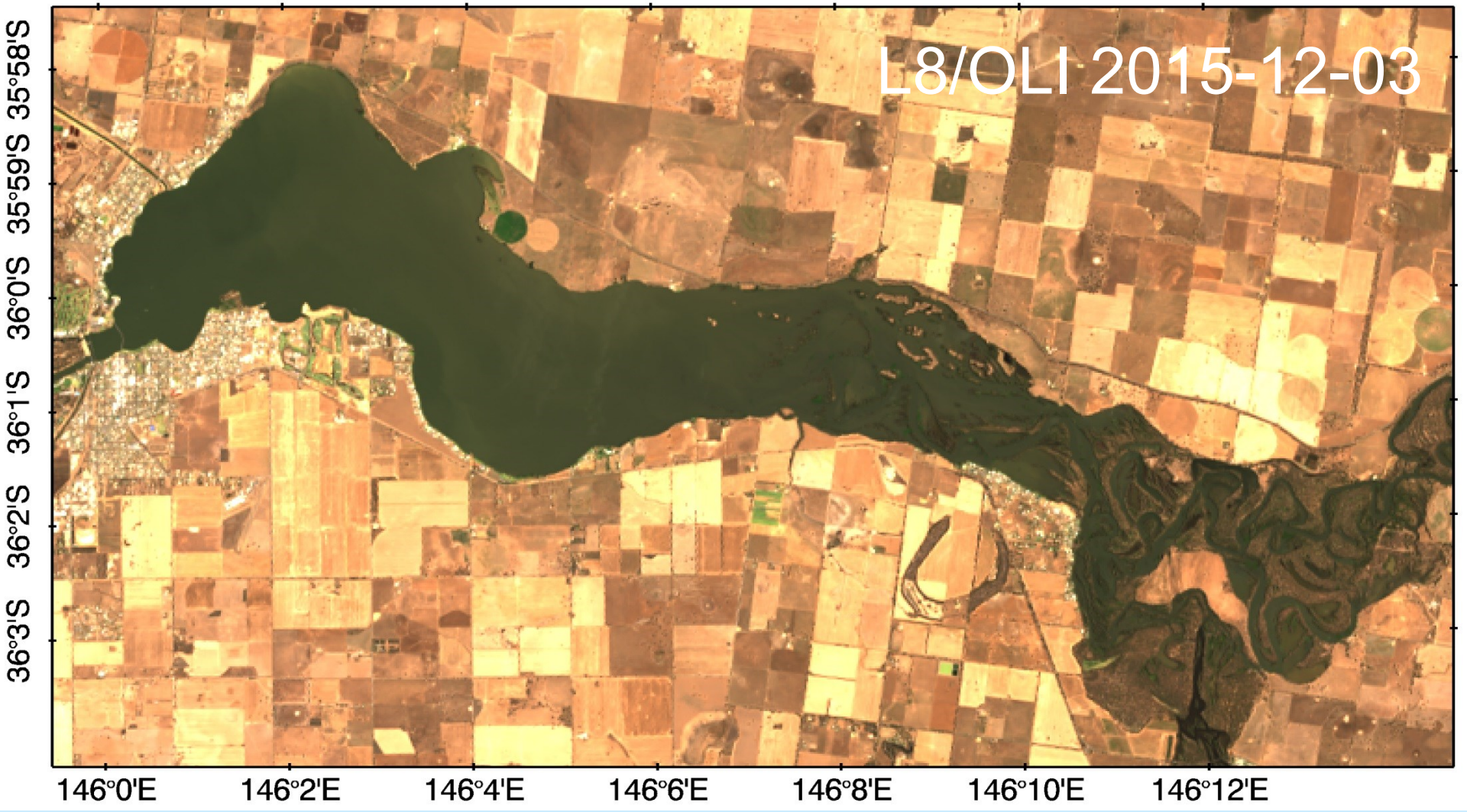


Figure 2 Chlorophyll a concentration derived using the algorithm of Gons (2005), showing an intense bloom between Nieuwpoort and Oostende

Cyanobacterial bloom in Lake Mulwala, Australia

[Vanhellemont Q. & Ruddick K. ACOLITE For Sentinel-2: Aquatic Applications of MSI imagery (2016) ESA Living Planet Symposium held in Prague, ESA SP-740]



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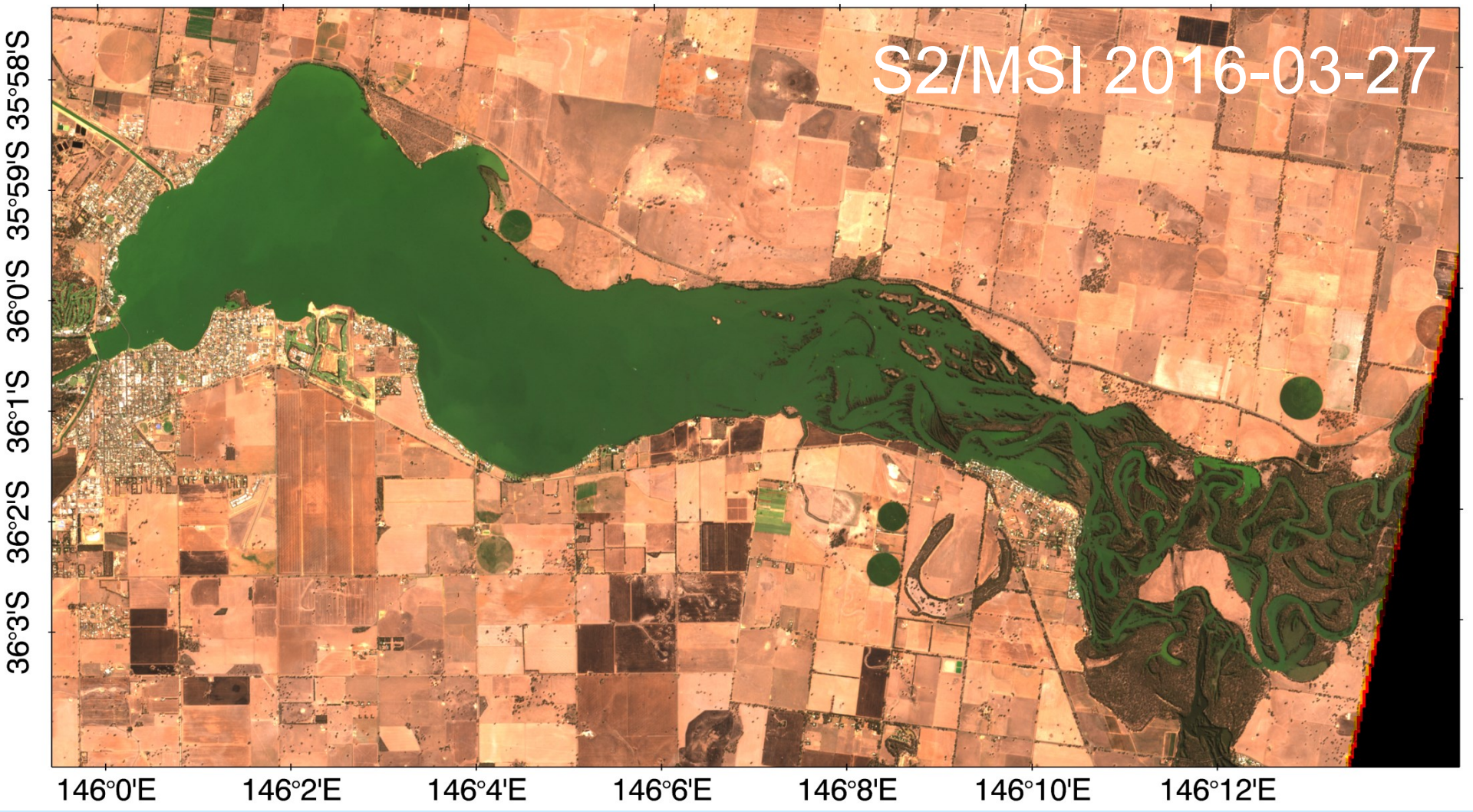

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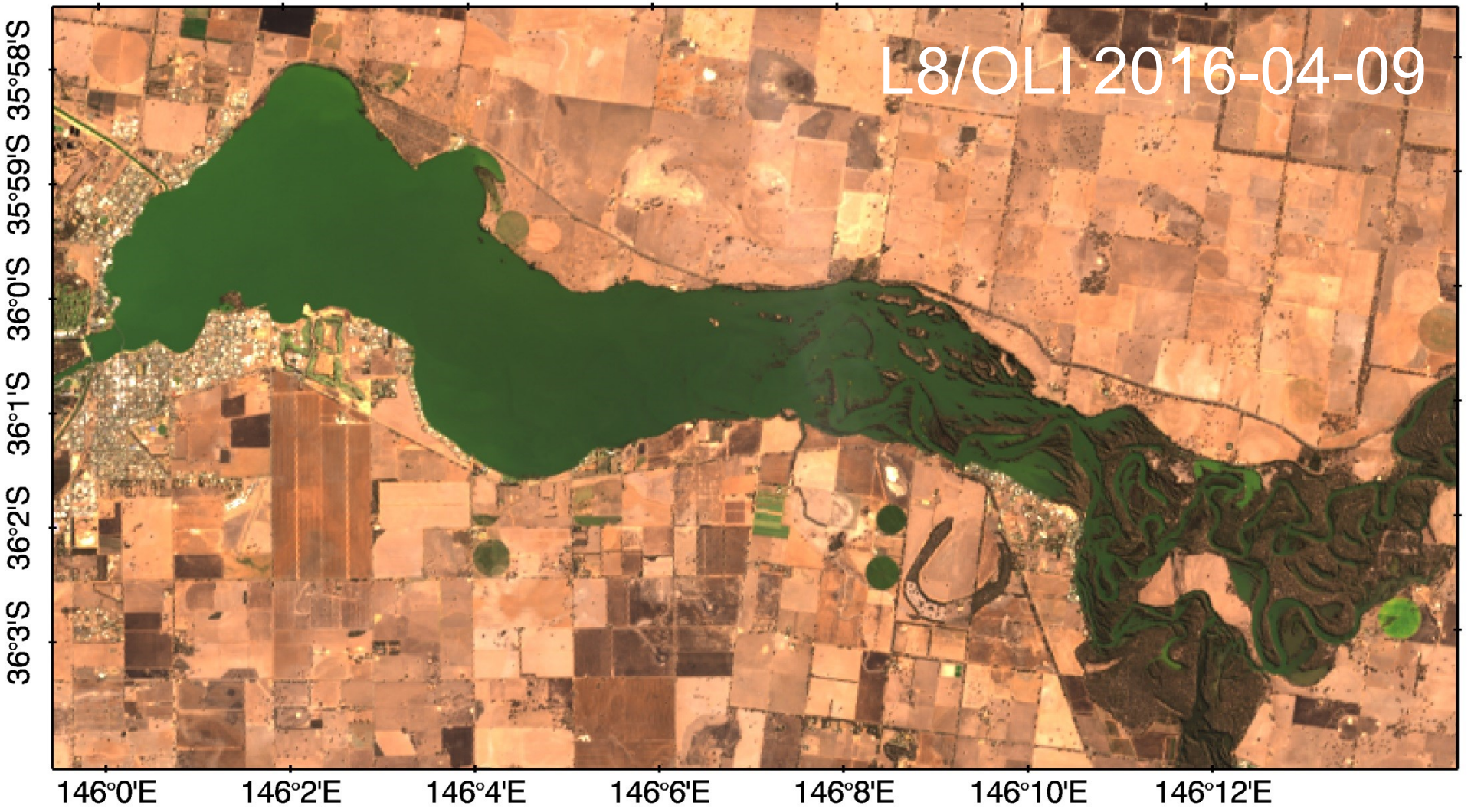

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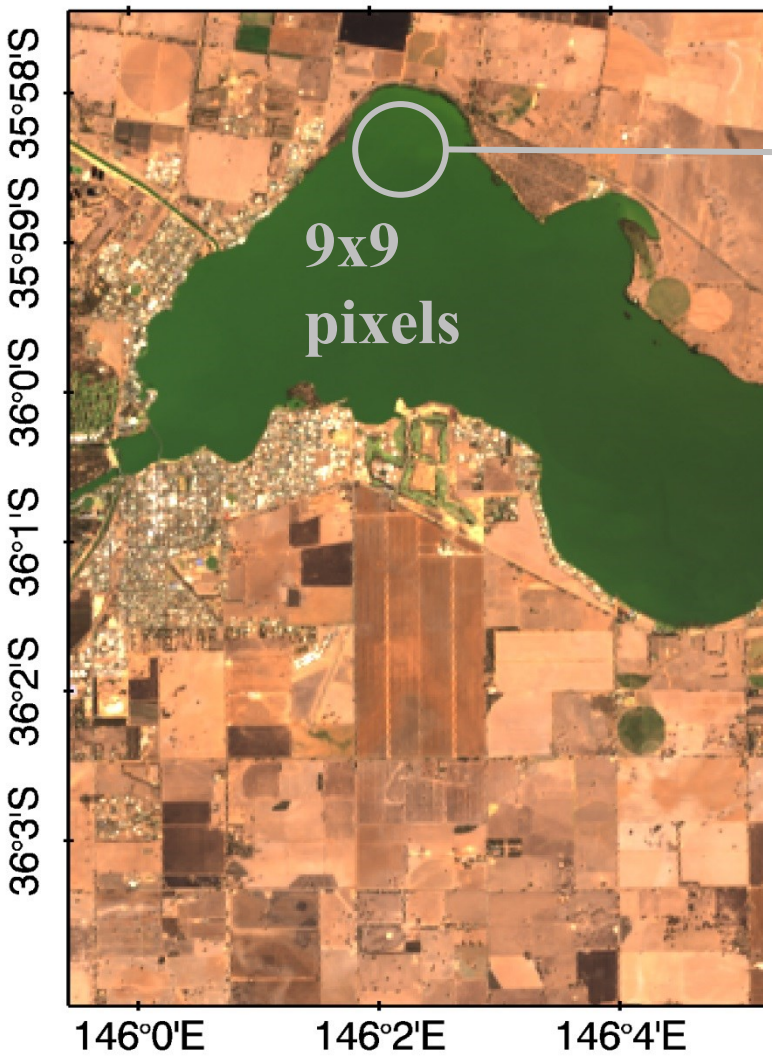

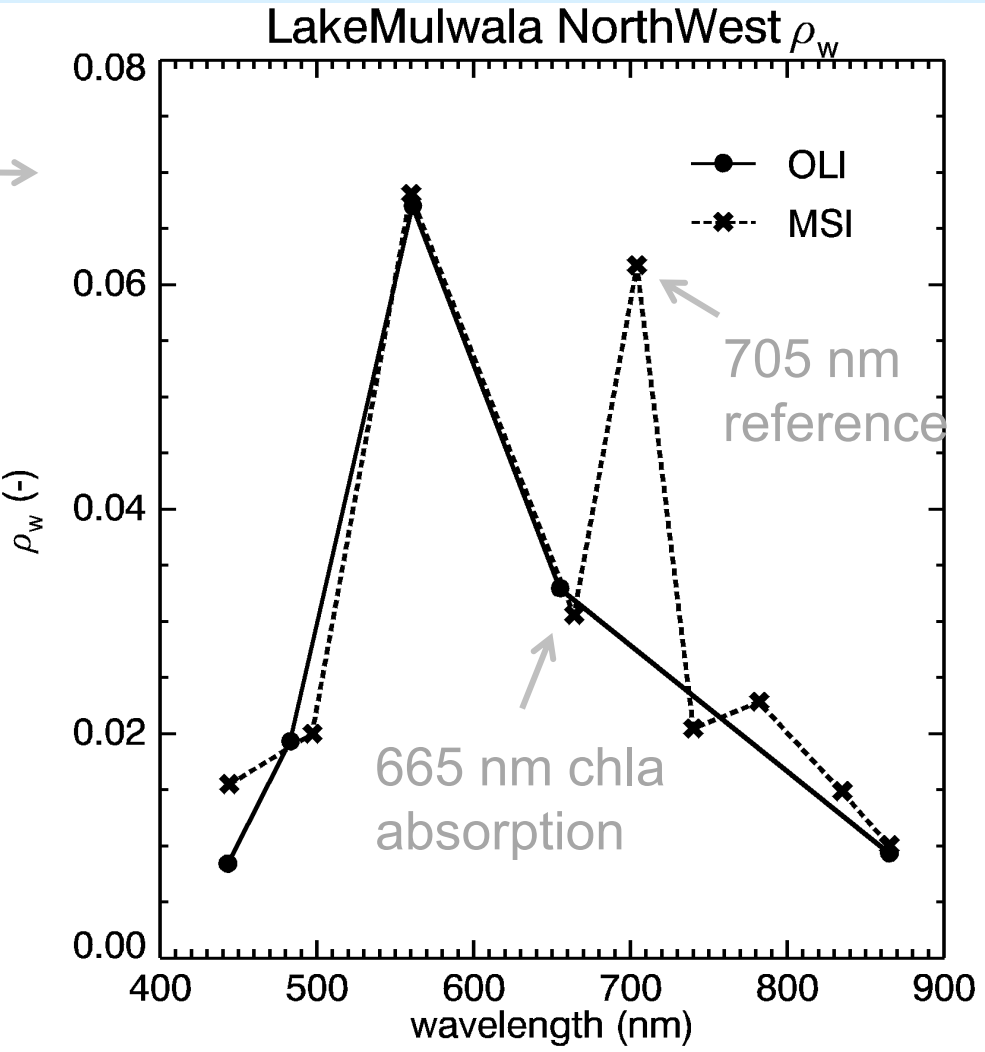

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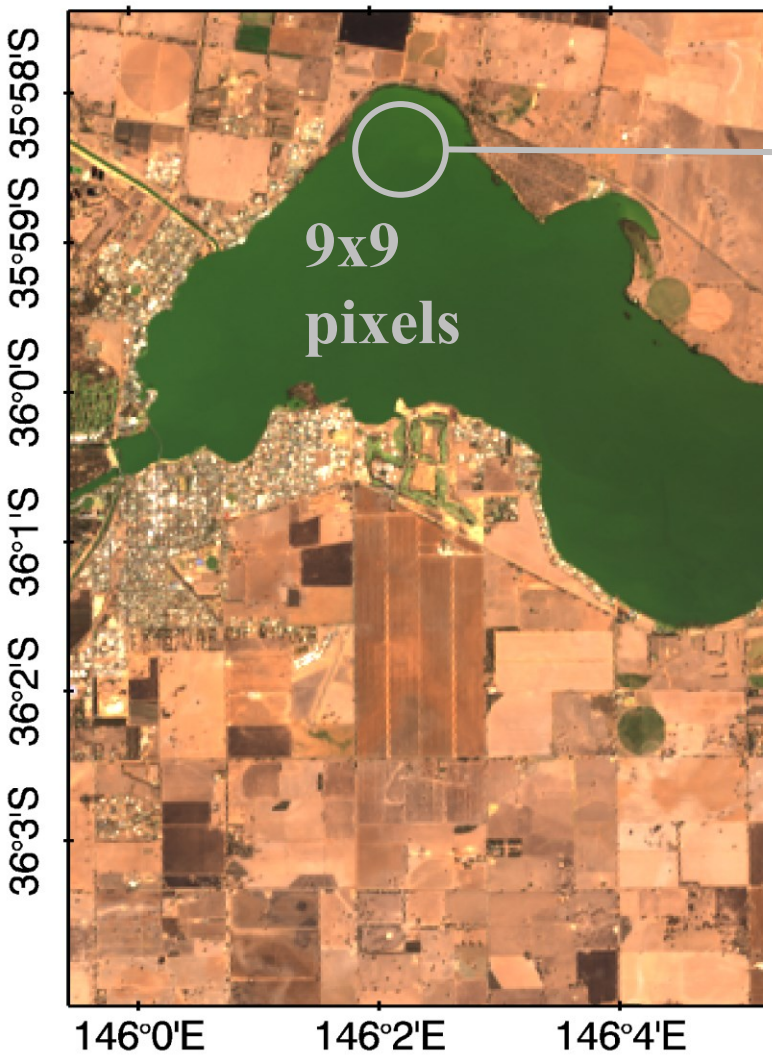
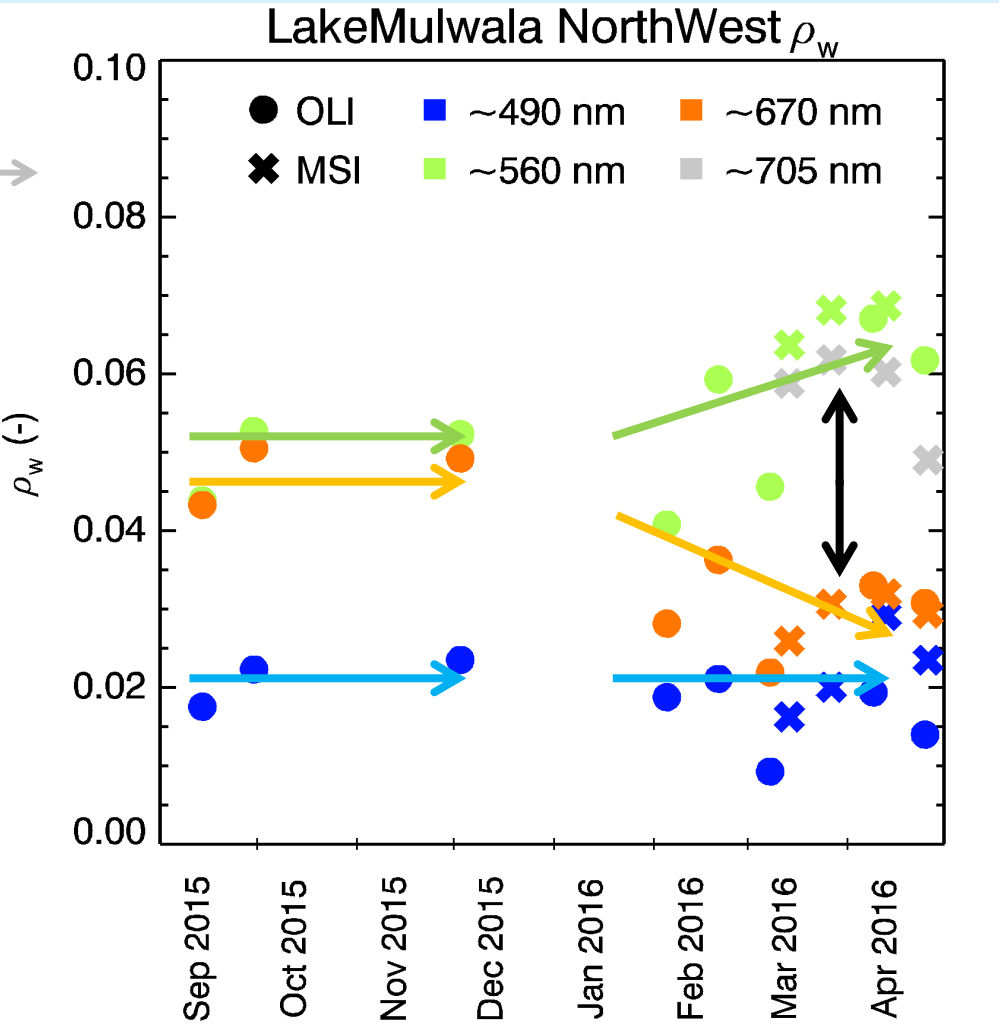
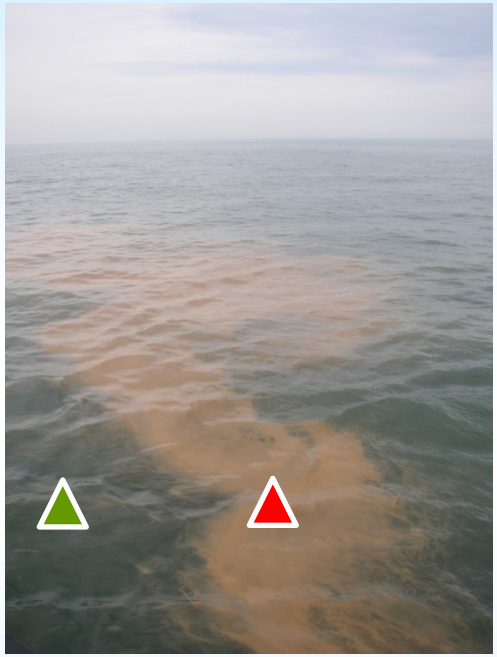


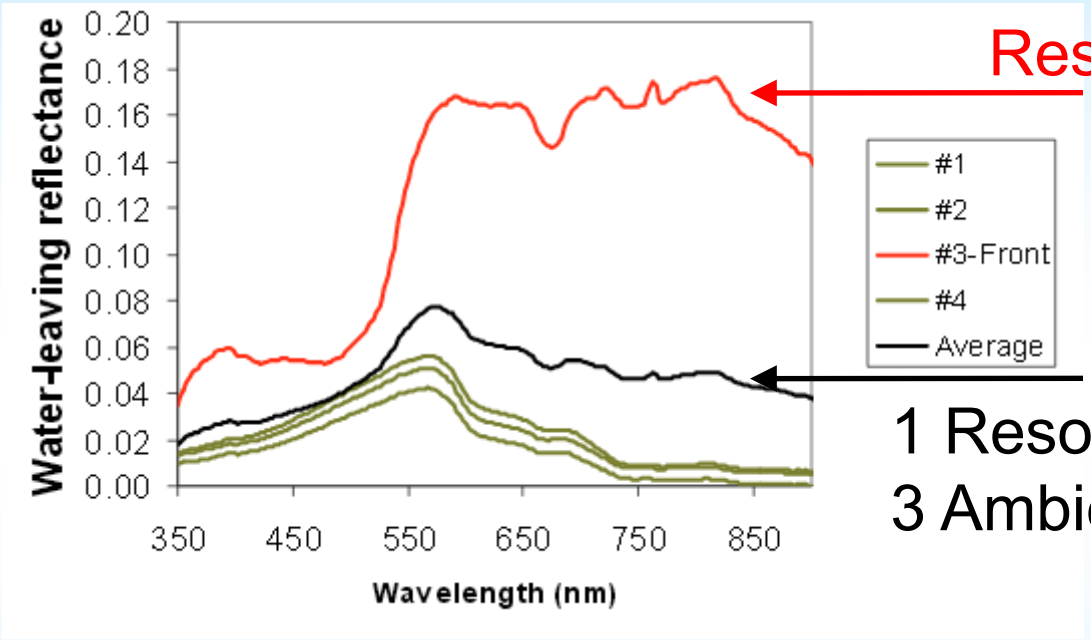


Patchy marine biology – seen better at high res

~5m

Spatial Resolution => Spectral Constrast





Resolved

1 Resolved +
3 Ambient

[Van Mol B., Ruddick K., Astoreca R., Park Y. & Nechad B. (2007). **Optical detection of a Noctiluca scintillans bloom**. EARSeL eProceedings, 6, 130–137]

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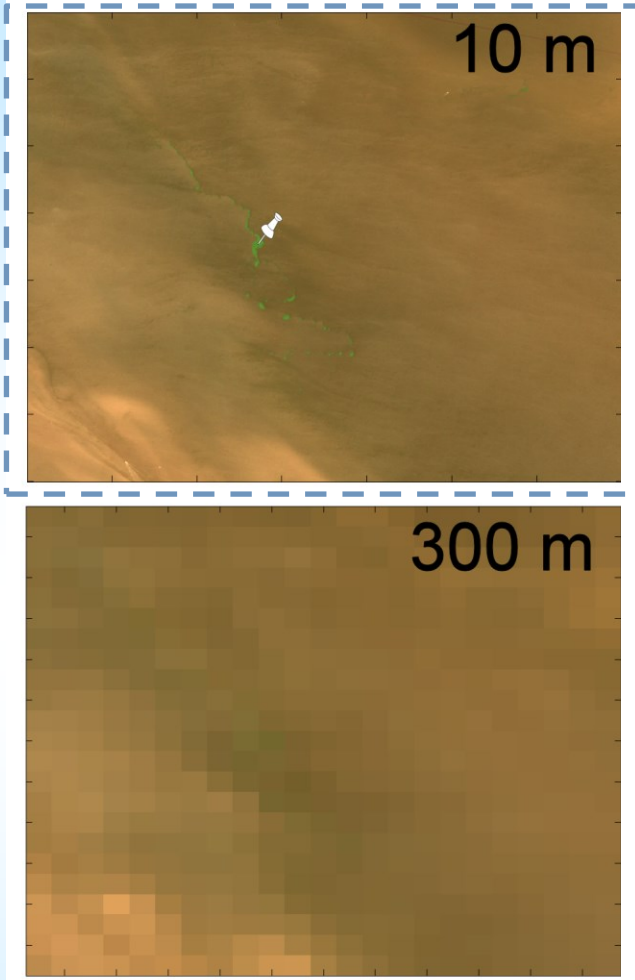
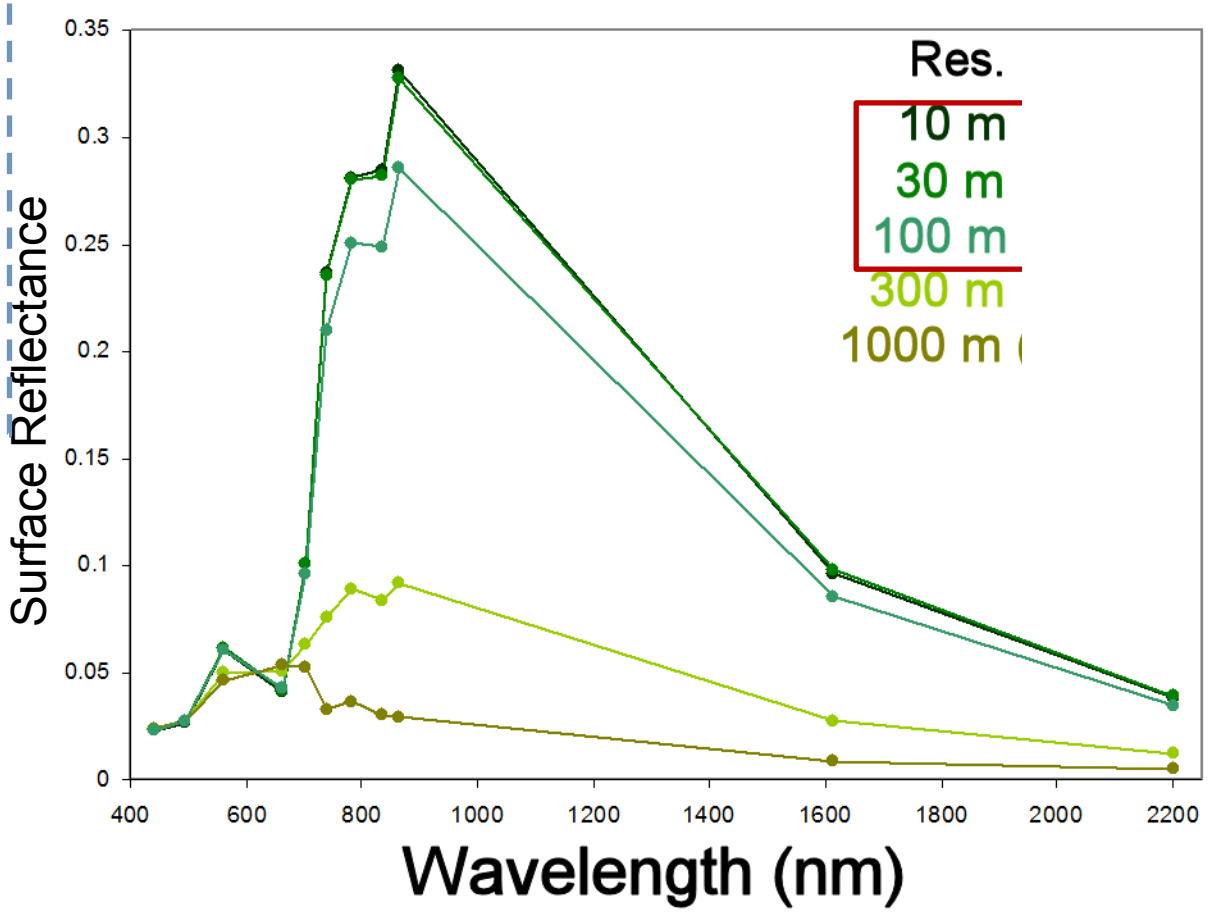




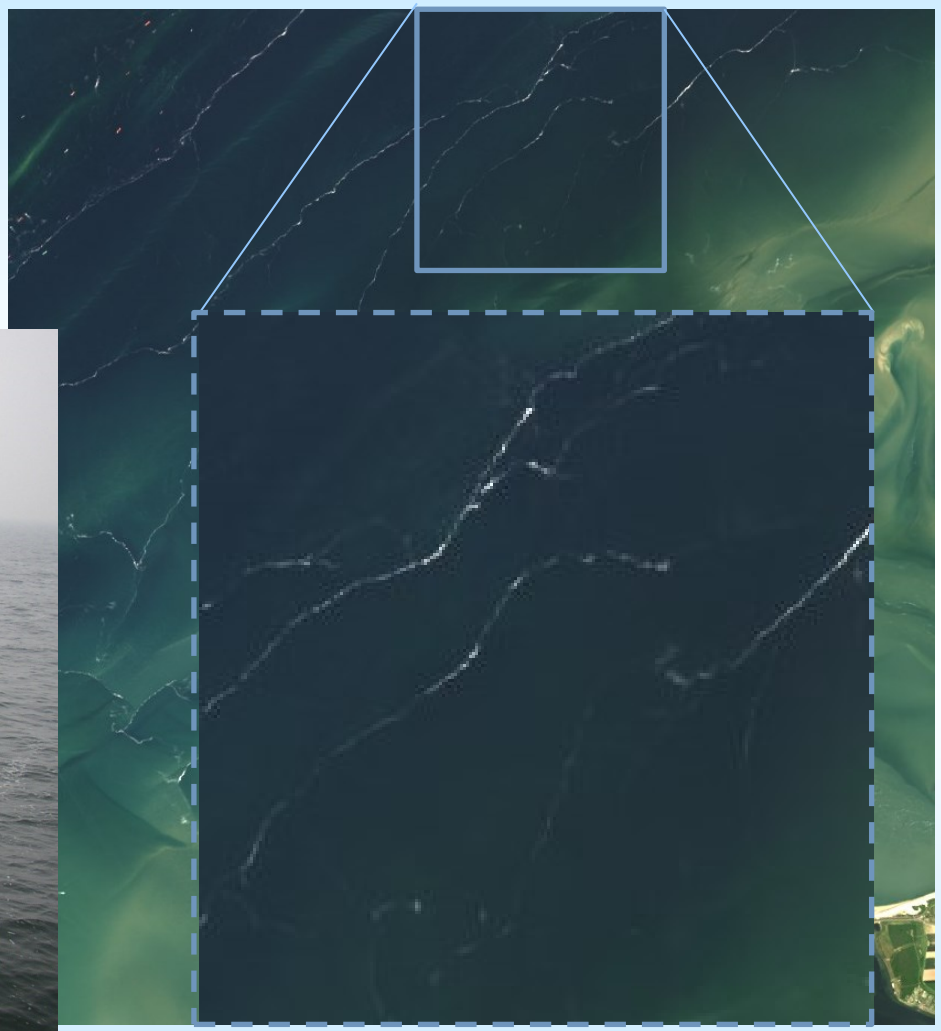
Detected at 10-100m, not at 300m

[Dogliotti, Gossn, Vanhellemont and Ruddick, "**Large invasion of floating aquatic plants in the Río de la Plata estuary!**" Ocean Optics 2016]

Scientific Opportunities – biological foam

Photo of *Phaeocystsis globosa* foam, Belgica cruise 2003-04-24

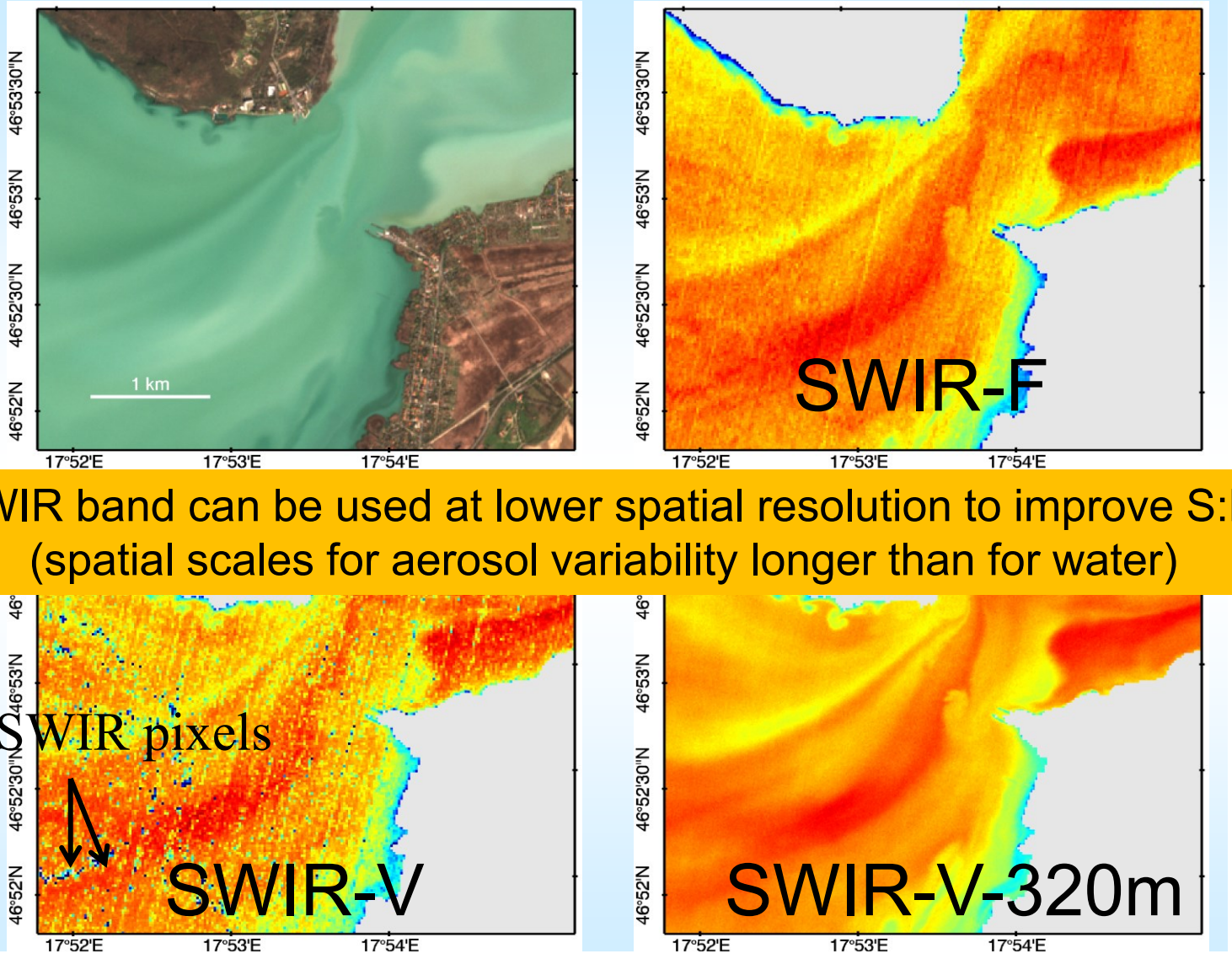
L8, 2014 J139



~ 40km

Atmospheric Correction using SWIR bands

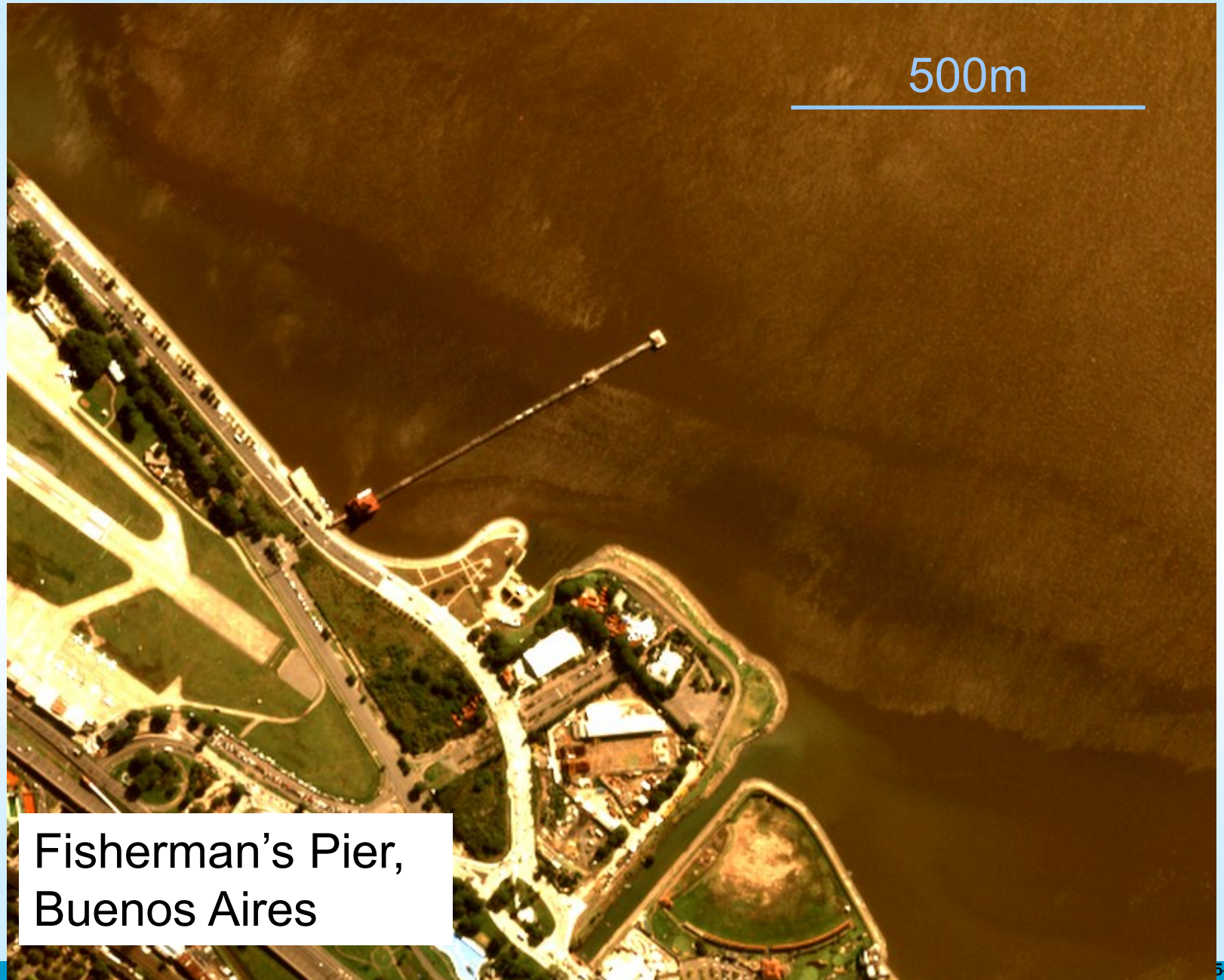
S2/MSI Lake Balaton on 2016-03-14



SWIR band can be used at lower spatial resolution to improve S:N
(spatial scales for aerosol variability longer than for water)

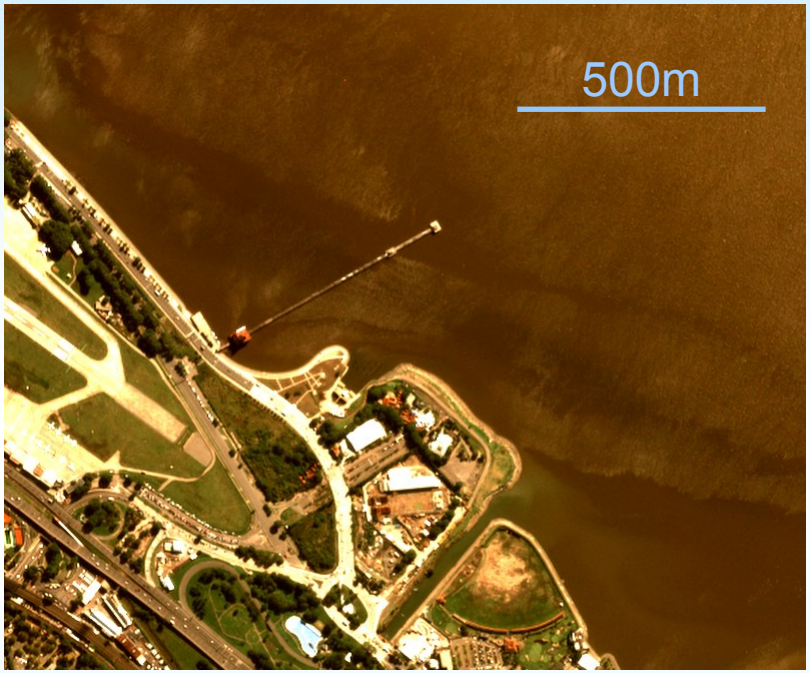
[Vanhellemont Q. & Ruddick K. ACOLITE For Sentinel-2: Aquatic Applications of MSI imagery (2016) ESA Living Planet Symposium held in Prague, ESA SP-740]

Scientific Challenges – Sunglint in 2m imagery



Scientific ~~Challenges~~ – Sunglint in 2m imagery Opportunity

Sunglinted



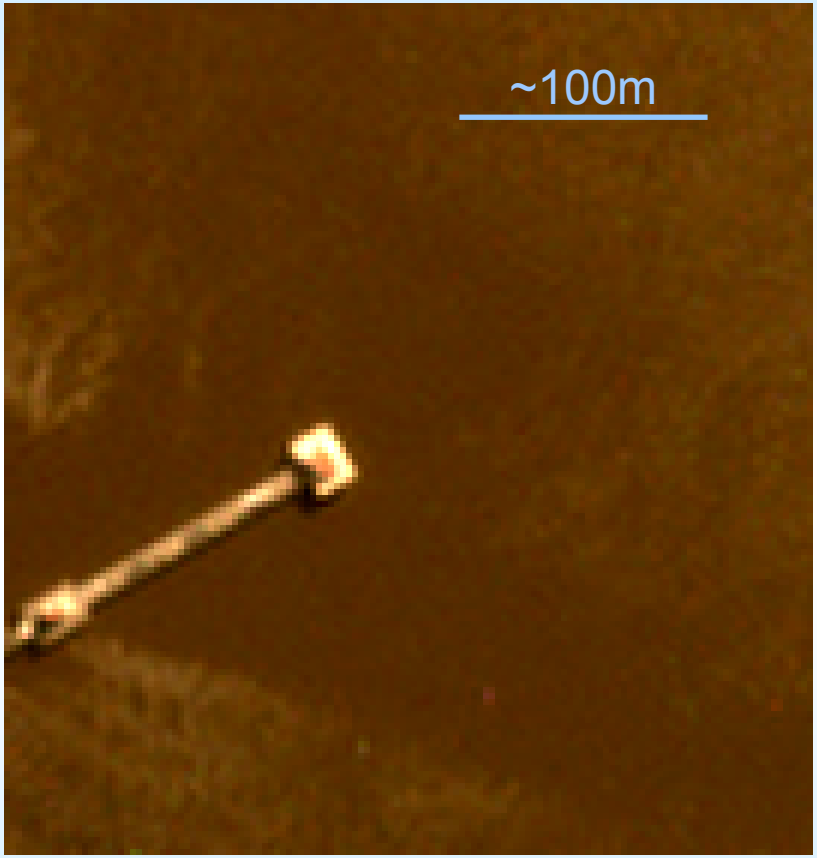
Pléiades, 2016-04-21, 14:05:39
(20.3° VZA into sun)

Not Sunglinted

Pléiades, 2016-04-21, 14:04:37
(19.6° VZA away from sun)

Scientific ~~Challenges~~ – Sunglint in 2m imagery Opportunity

Sunglinted



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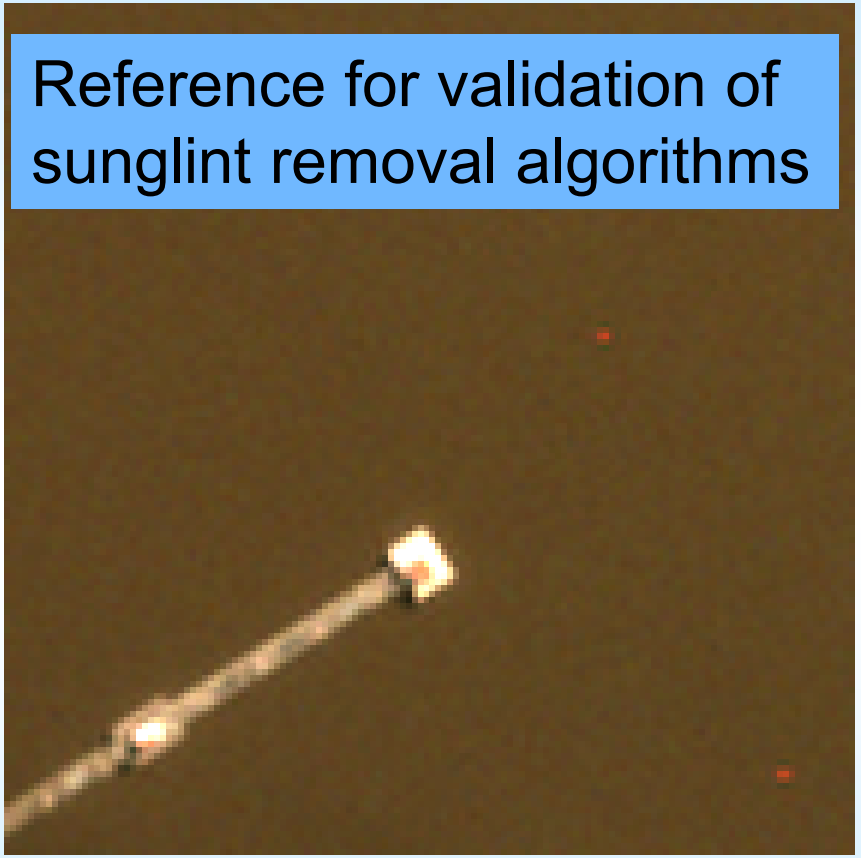
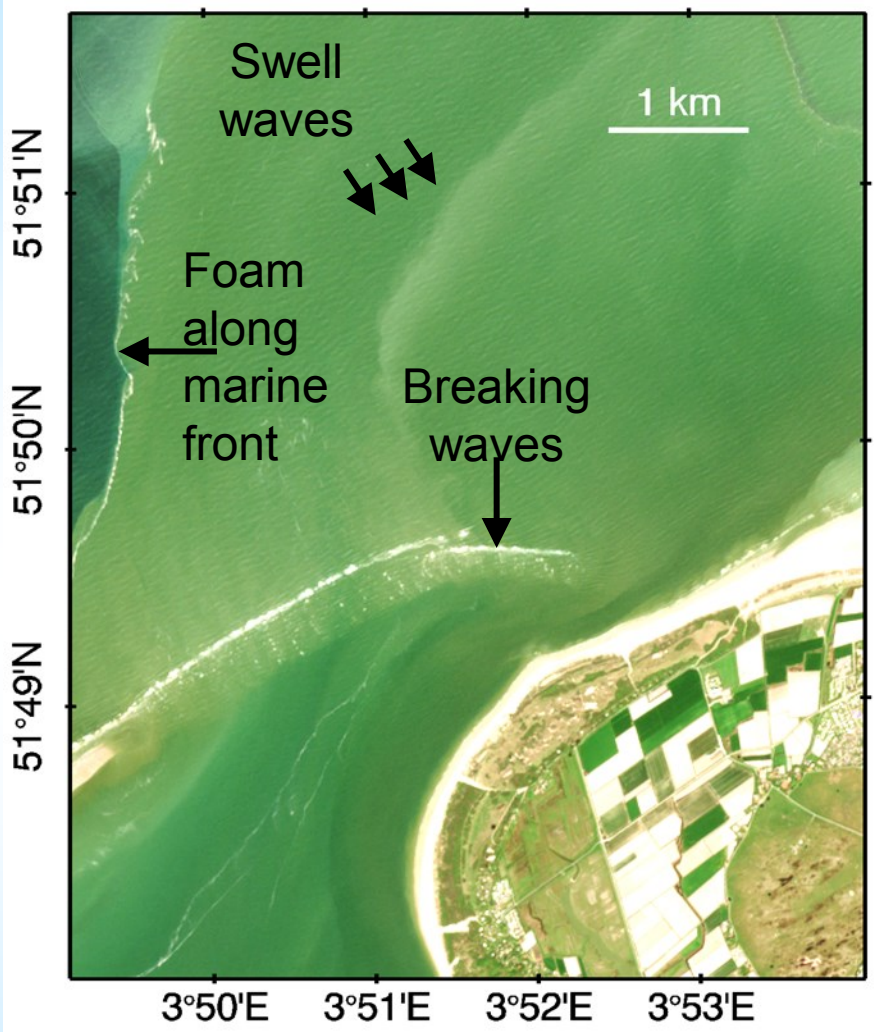
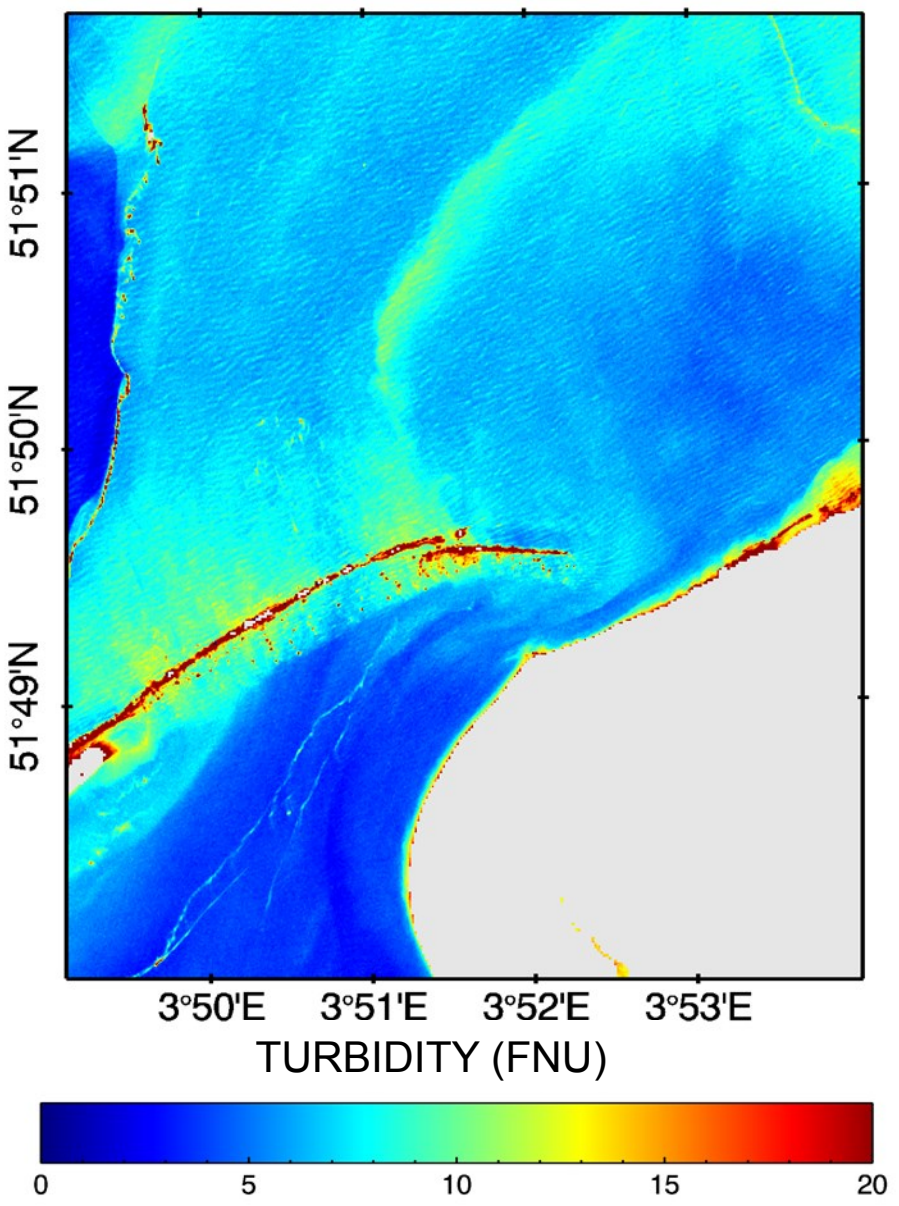


Pléiades, 2016-04-21, 14:04:37
(19.6° VZA away from sun)

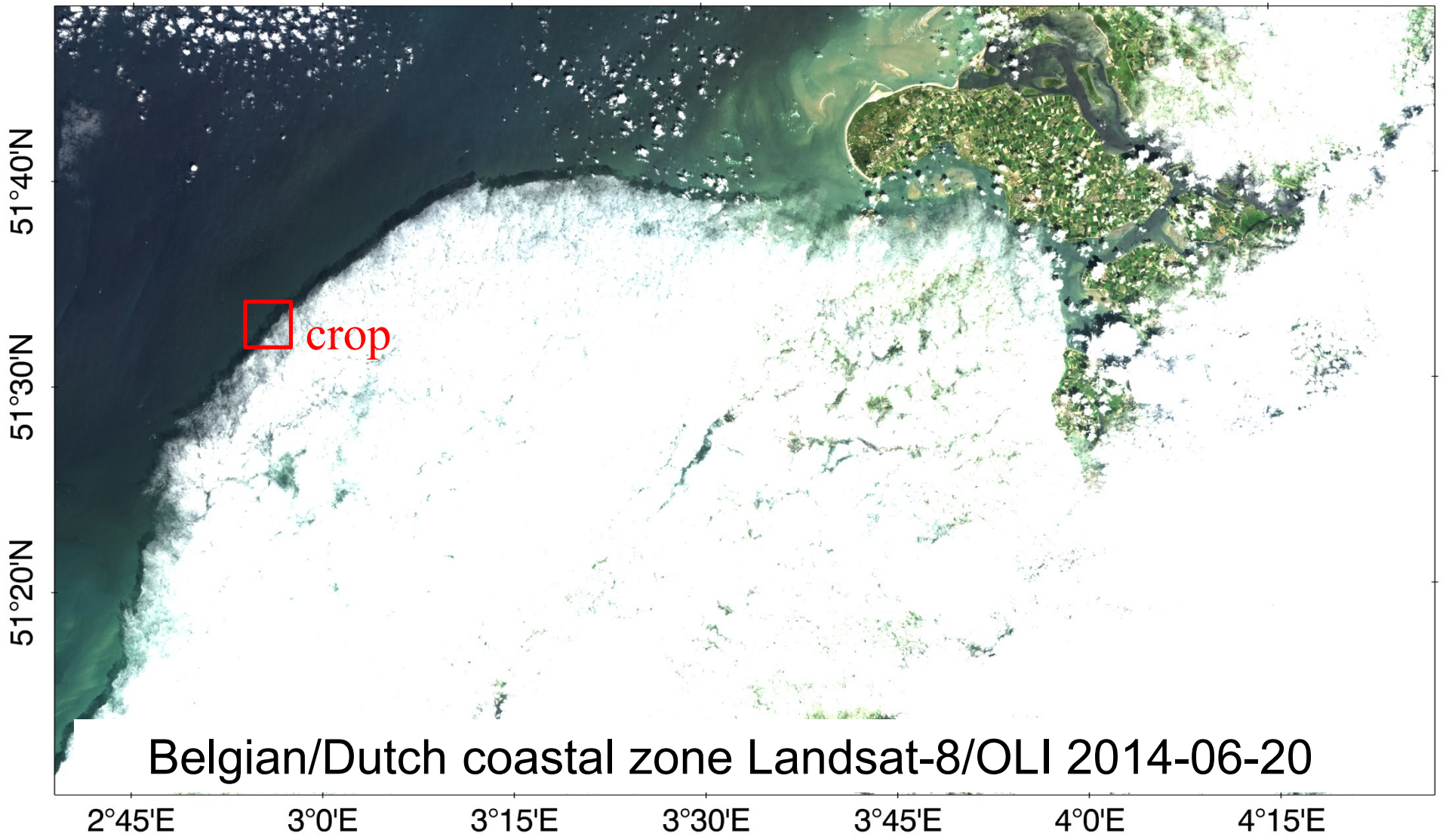
Other surface effects

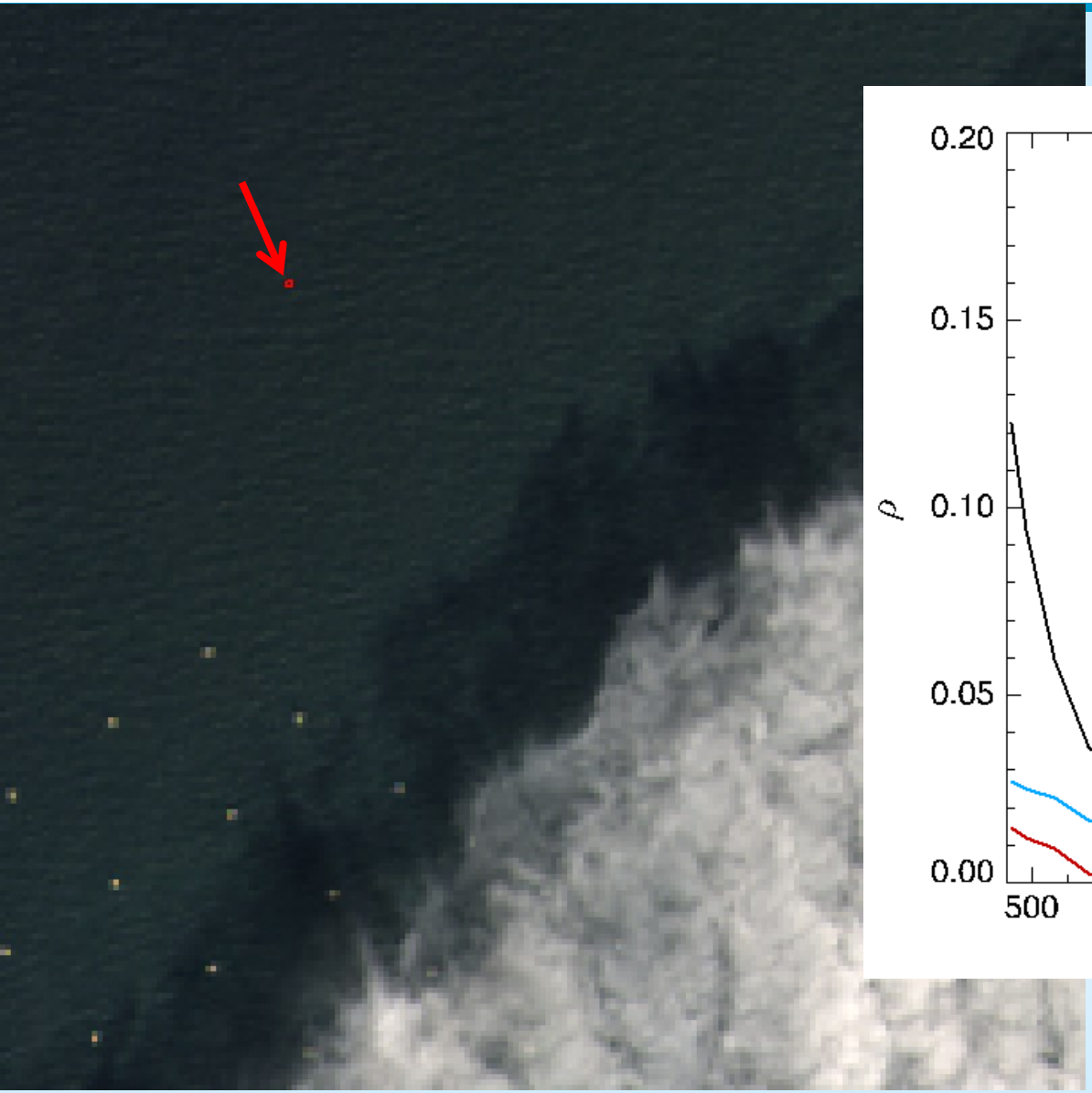


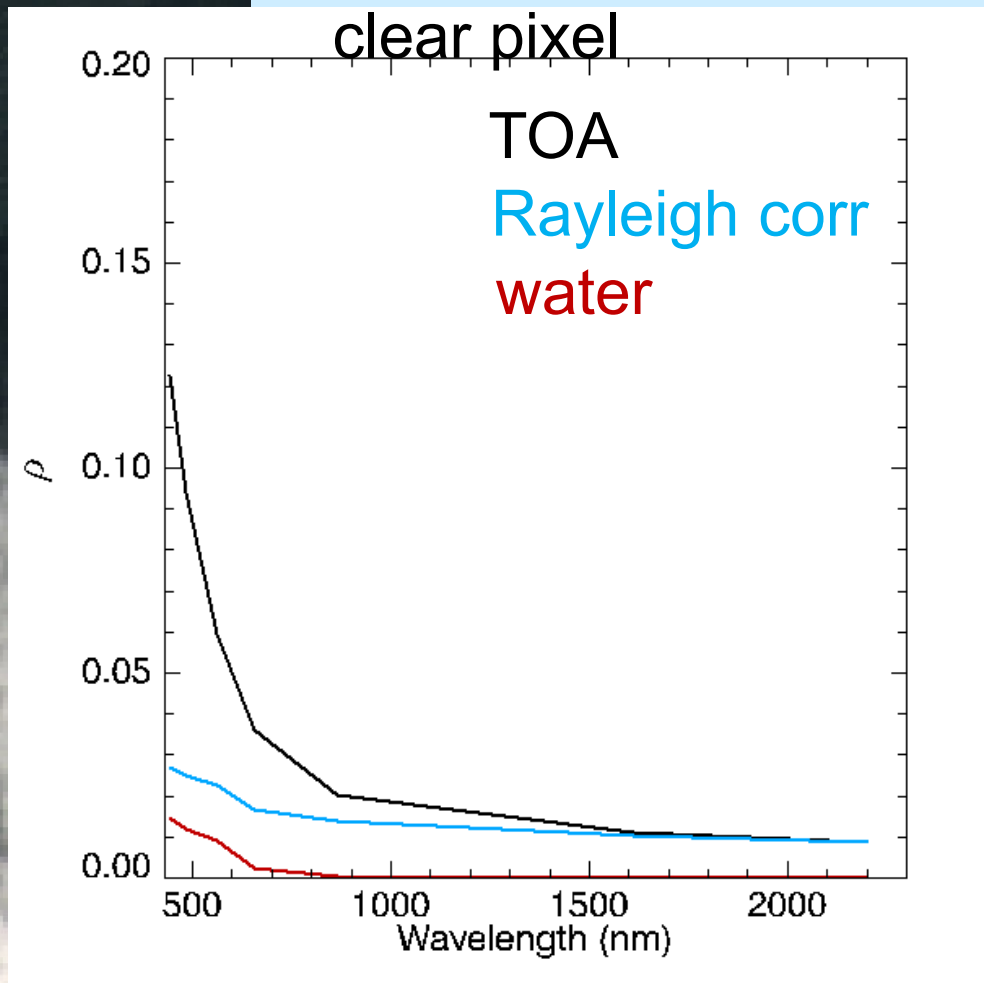
Sentinel-2A 2016-05-01 (Netherlands)

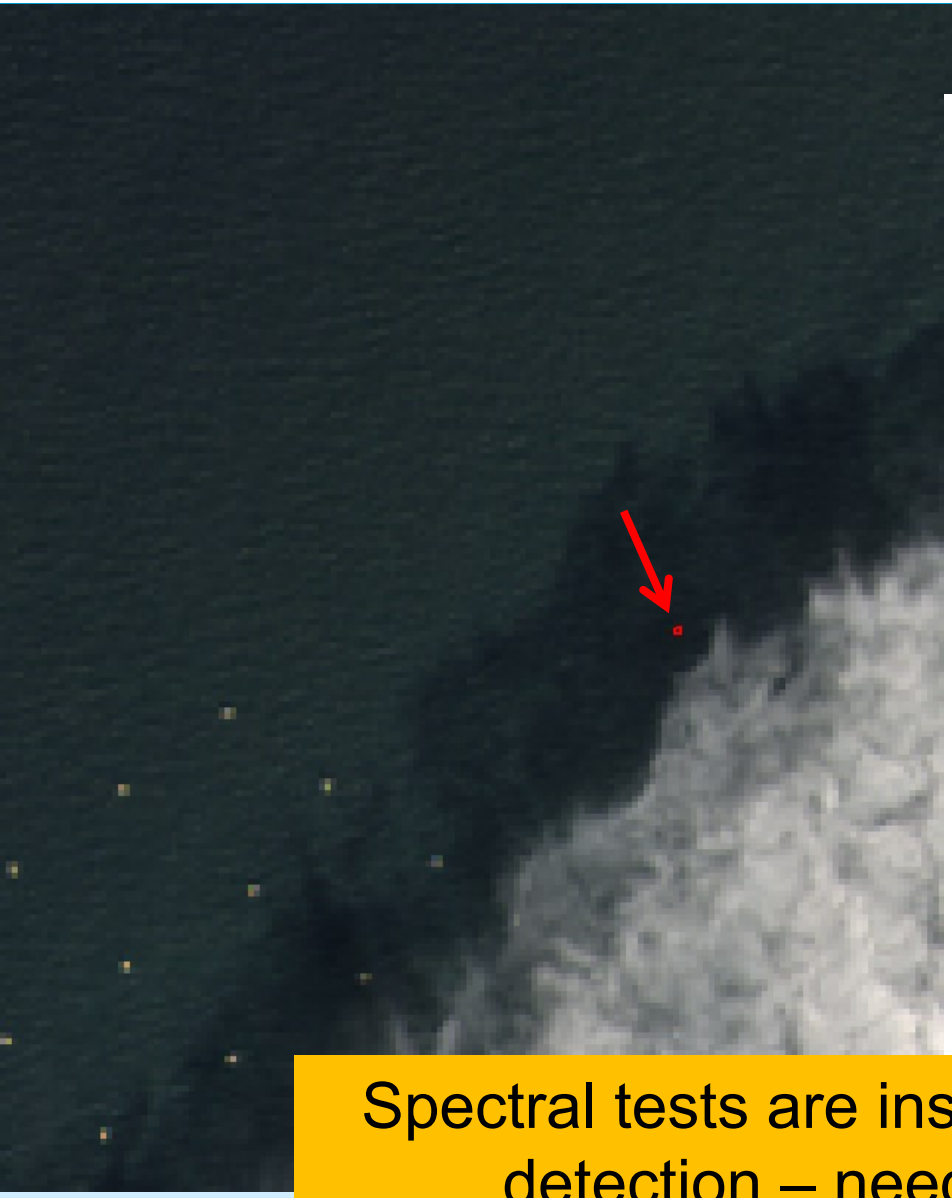


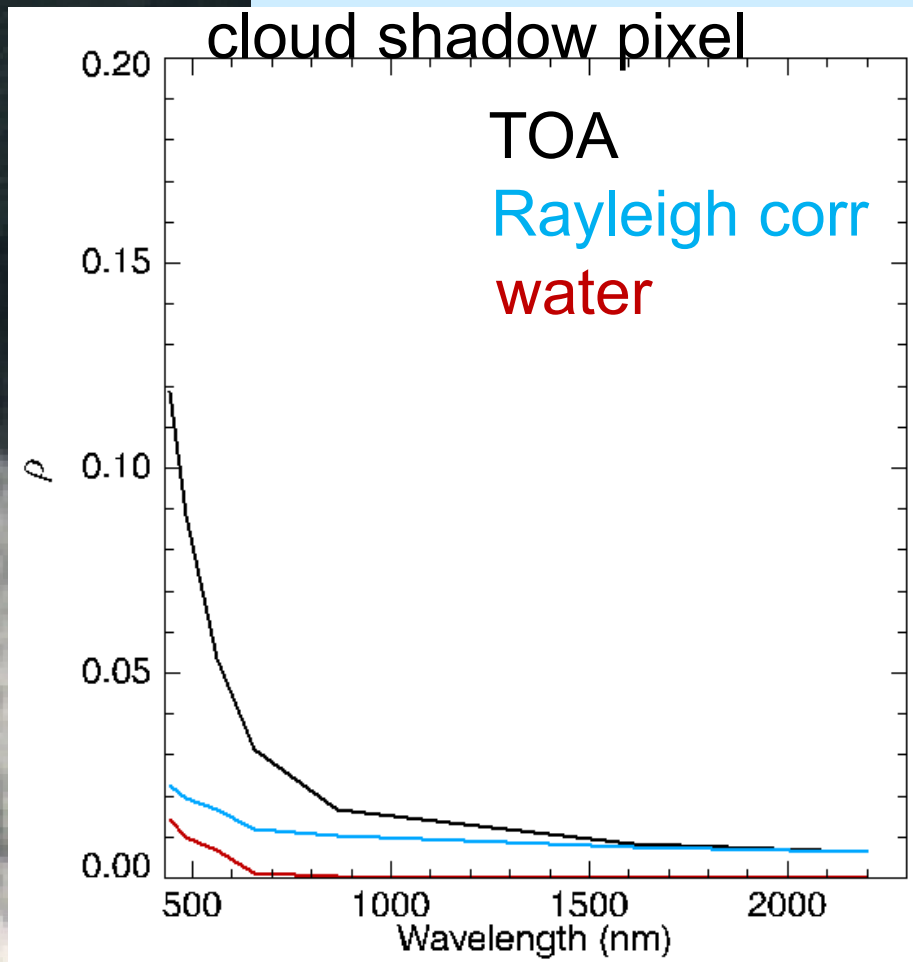
Scientific Challenges - Shadows





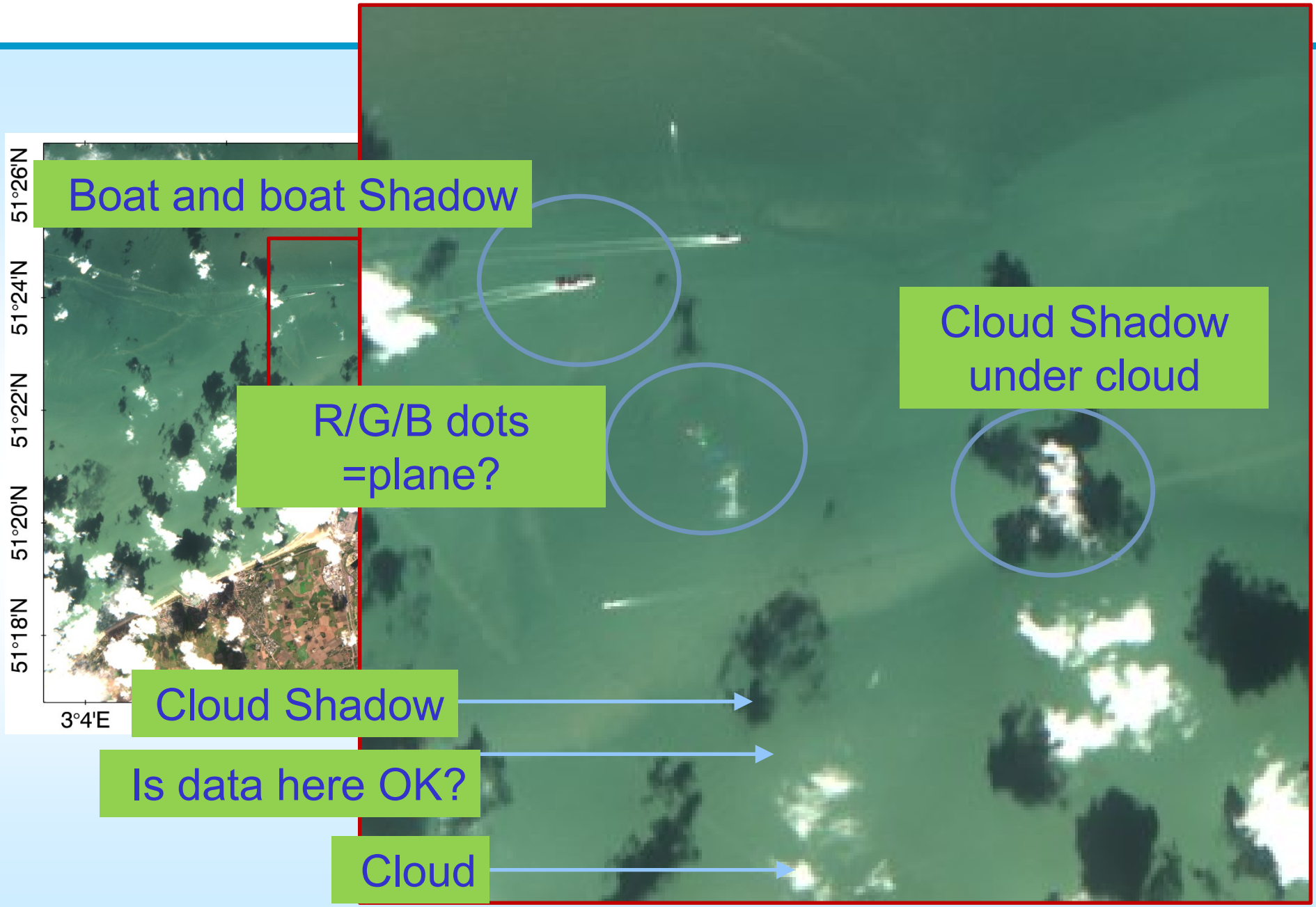






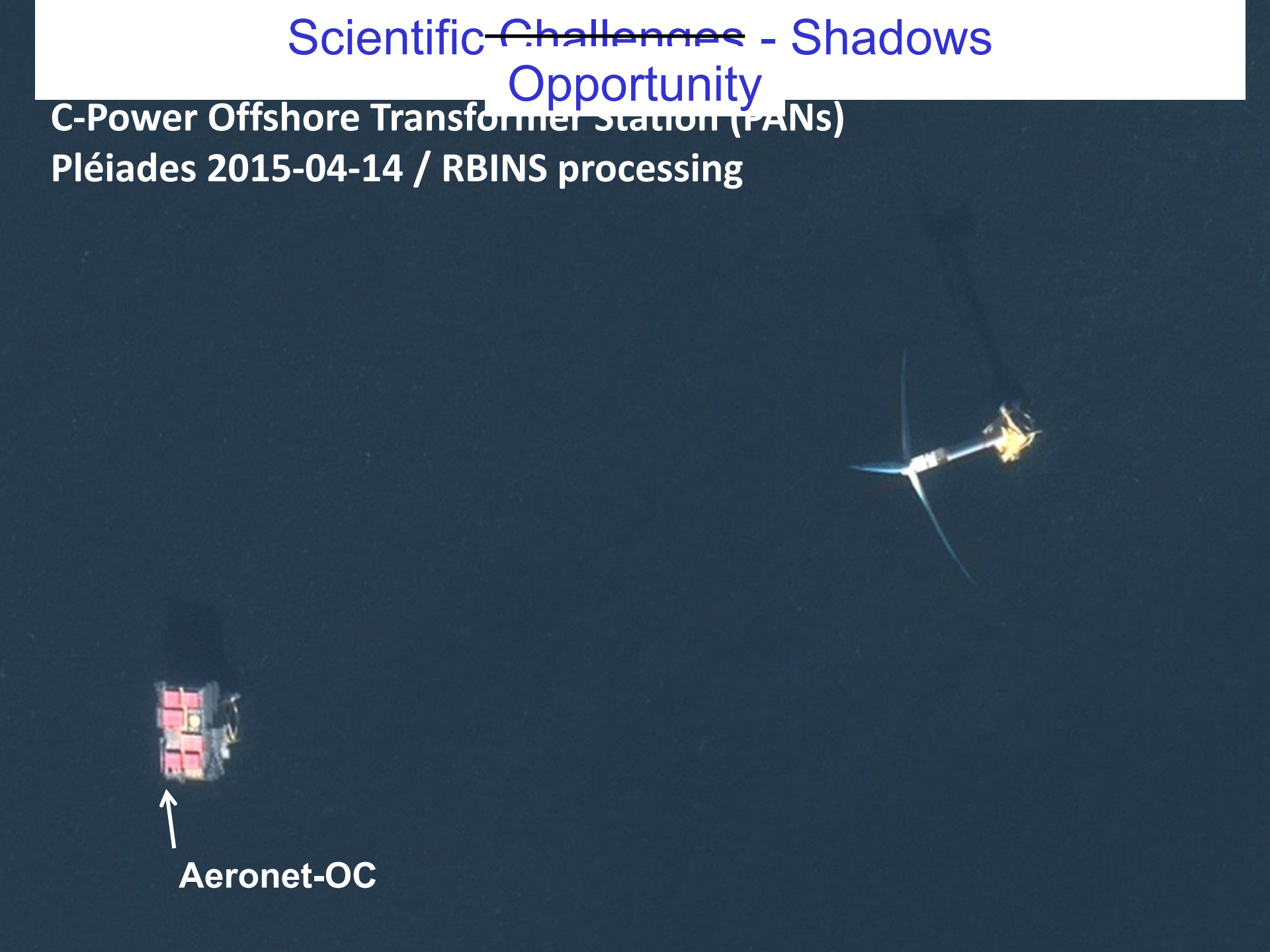
Spectral tests are insufficient for cloud shadow detection – need also spatial context

Also shadows from mountains, boats,buildings and cranes, …



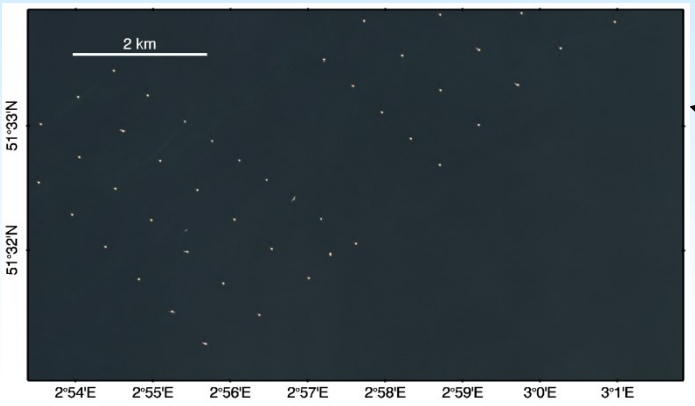
Scientific ~~Challenges~~ - Shadows Opportunity

C-Power Offshore Transformer Station (PANs)
Pléiades 2015-04-14 / RBINS processing



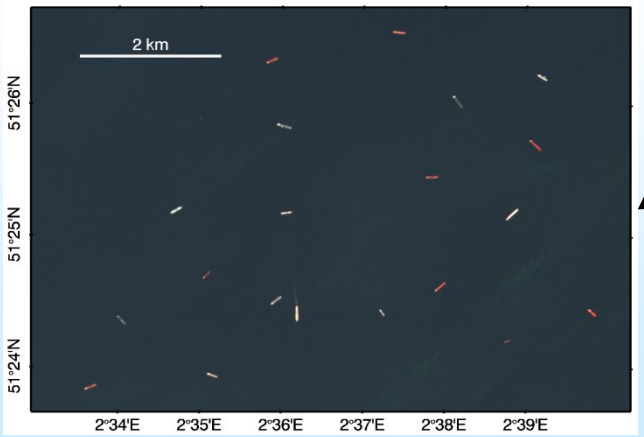
Direct impact of platform signal on TOA pixel (Example from OLCI / Sentinel-3A)

CPower Windfarm



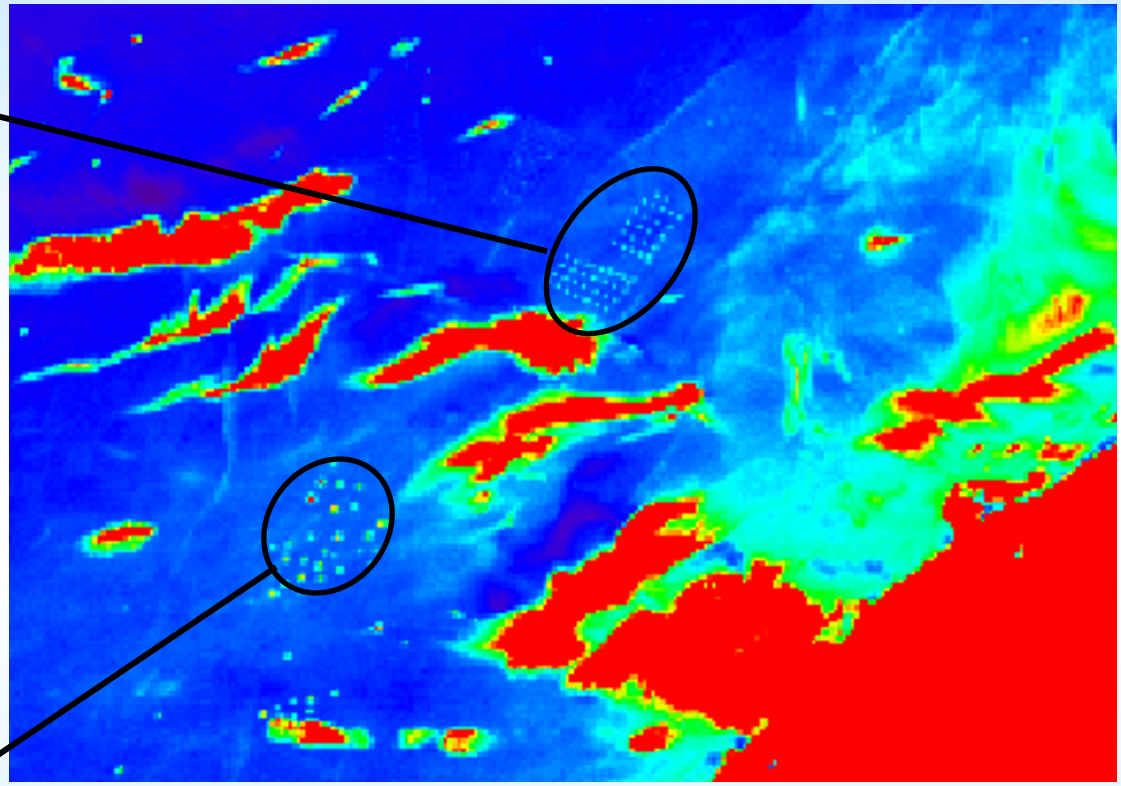
S2A/MSI 2016-09-08

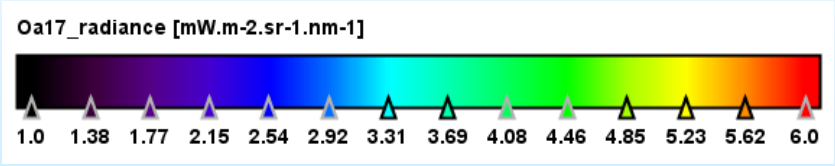
Ship Anchorage



S2A/MSI 2016-09-08

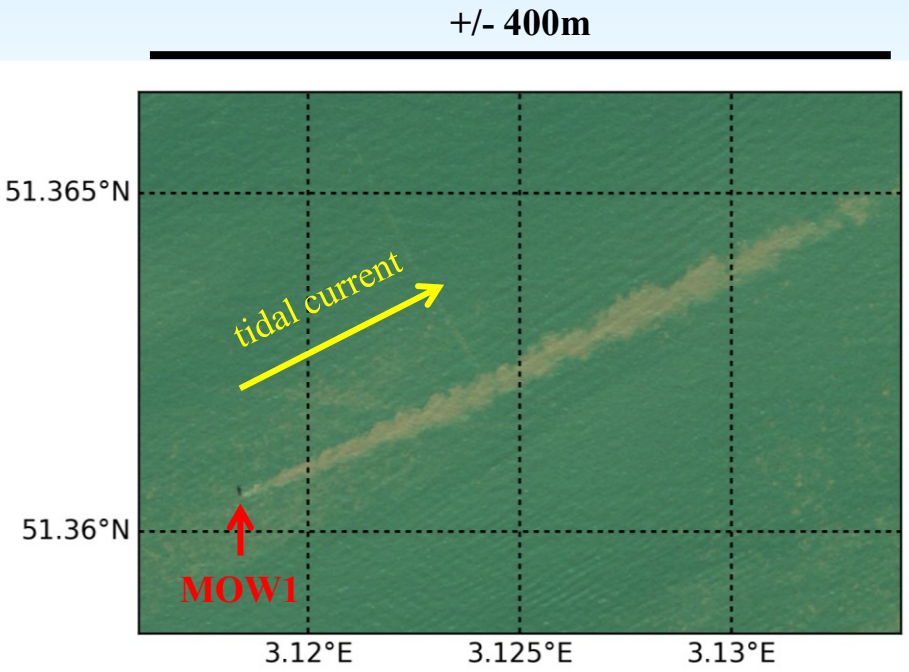
Belgian Coastal Zone 2016-07-18
OLCI TOA radiance 865nm



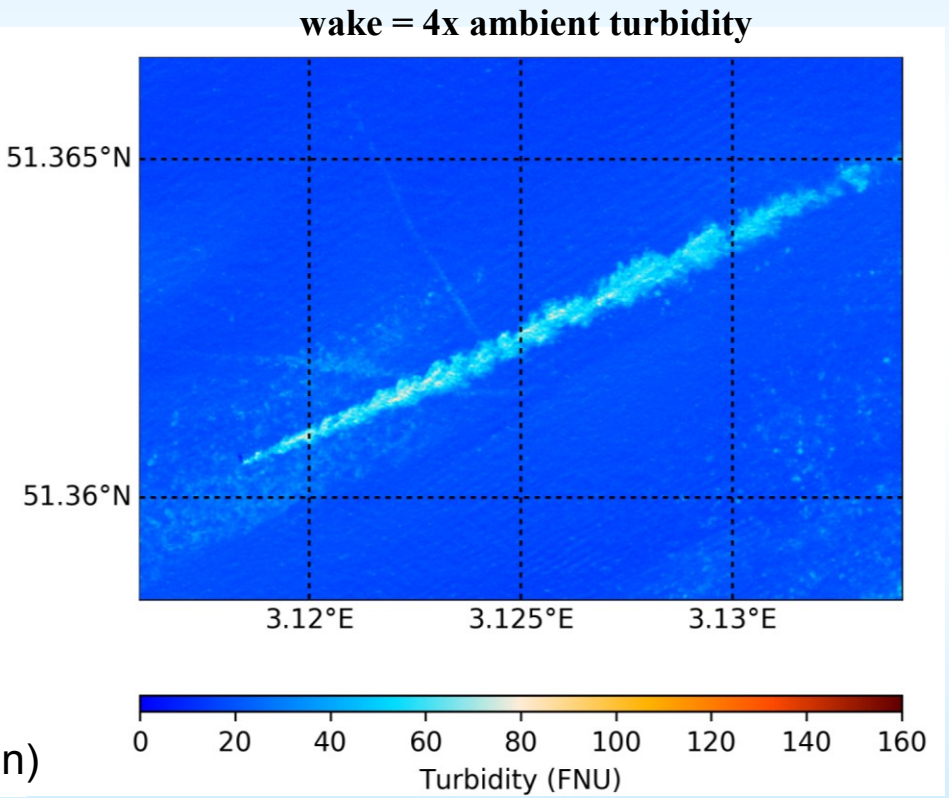


(presented by Héloïse Lavigne at S3VT)

Impact of platform modifying environment (Example from Pléiades)

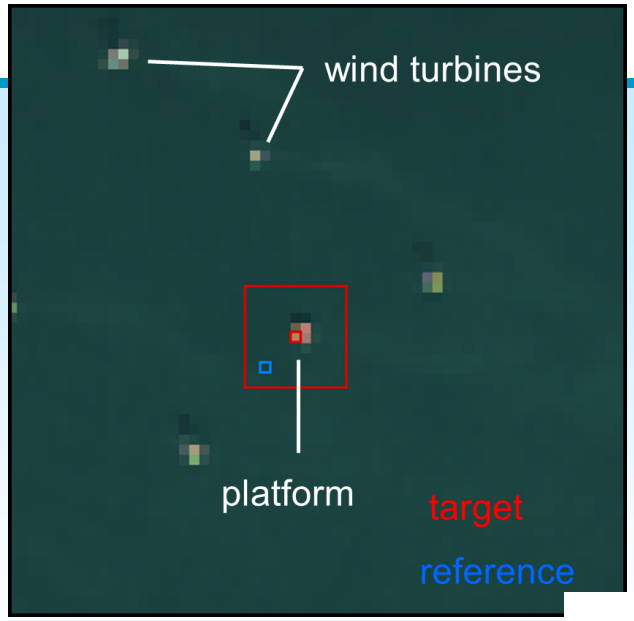


Pléiades image of Zeebrugge/MOW1 measurement pole (AERONET-OC station)



Vanhellemont Q. & Ruddick K. (poster IOCS 2017)

Platform impact on moderate resolution (MODIS/MERIS/OLCI) pixel



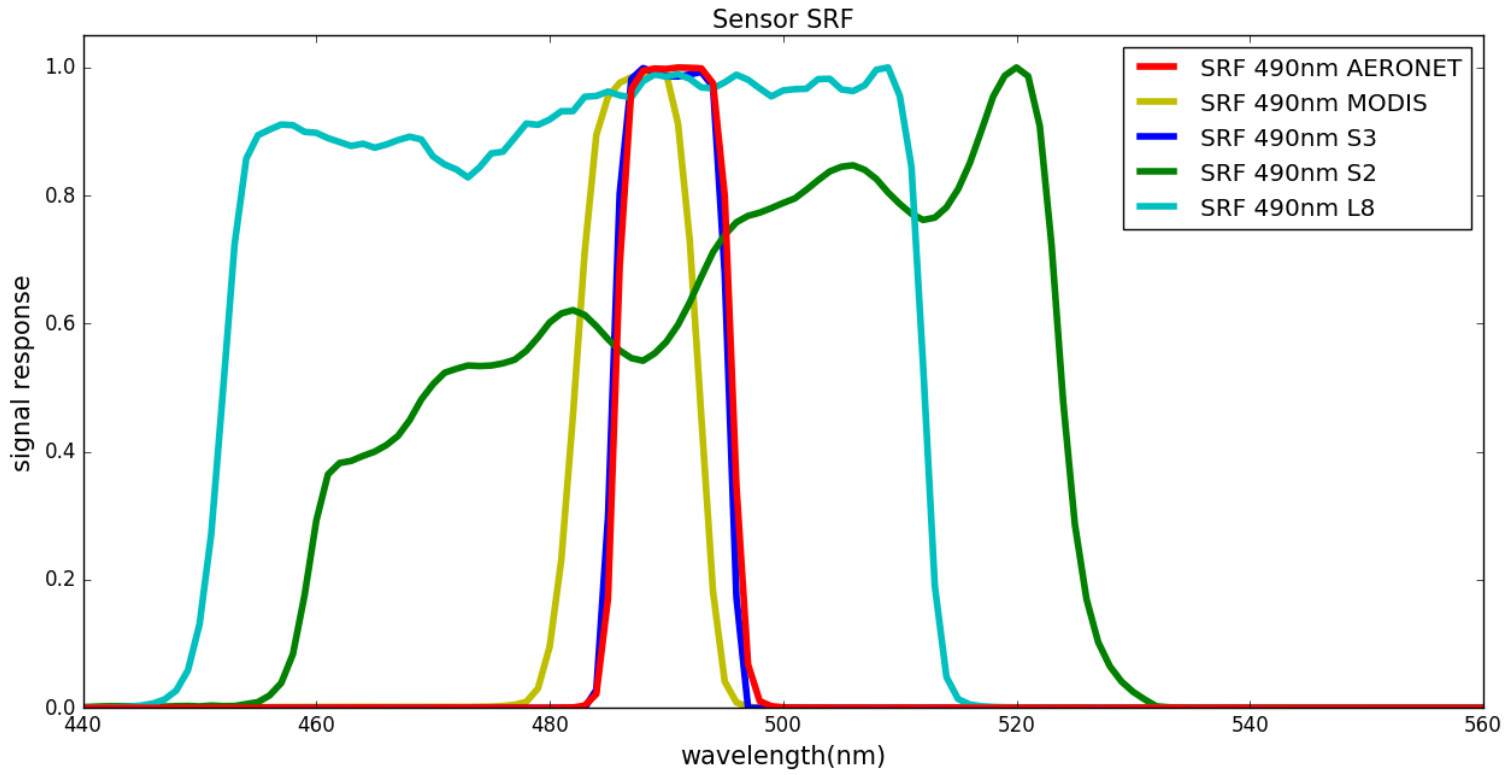
Landsat-8/OLI data

TOA and Ray-corr. ATM and WATER refl

Vanhellemont Q. & Ruddick K. (2015b) **Assessment of Sentinel-3/OLCI sub-pixel variability and platform impact using Landsat-8/OLI** Proceedings of the Sentinel-3 for Science Workshop, ESA Special Publication SP-734

“490nm” spectral band of MODIS, S3/OLCI … L8/OLI and S2/MSI (and AERONET-OC)

=> Algorithms (OC2, etc.) must be recalibrated



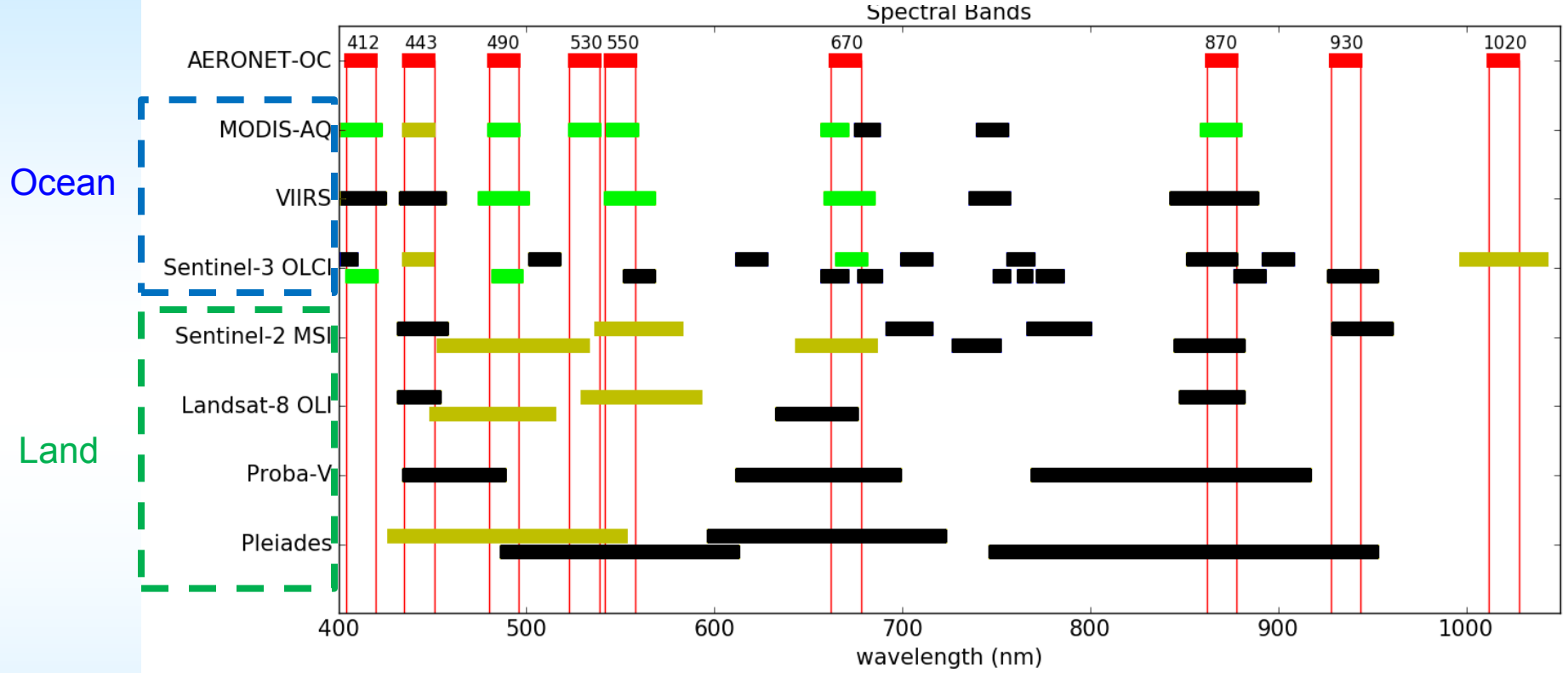
Validation

MAPE < 3% → 12 bands

3% < MAPE < 5% → 8 bands

MAPE > 5% → 36 bands

[Van der Zande D. et al. Validation of Landsat-8/OLI for ocean colour applications with AERONET-OC sites in Belgian coastal waters (2016) Ocean Optics, Victoria, BC]



1. Need band-shift algorithms to improve matching
2. … motivation for parallel hyperspectral network (HYPERNET-OC)

3. Hi res sensors lower frequency => need more AERONET-OC
4. Multi-mission value of AERONET-OC!

CONCLUSIONS (1/2) - New users and applications

- Human impacts are more evident at higher resolution:
  - Sediment transport – ports, offshore constructions, dredging/disposal
  - … Environmental Impact Studies
  - Inland waters, estuaries, ports are often small
  - Better spectral contrast for patchy distributions (Algae, floating veg , corals…)

- Support for medium res OC sub pixel variability
  - platform effects, sunglint, etc.

CONCLUSIONS (2/2) - New data processing challenges

- Using land missions for water applications
  - low spectral resolution, broad bands (need to adapt OC algos), even panchromatic bands
  - low SNR – (need spatial binning eg for SWIR A/C)
  - low temporal revisit
  - vicarious calibration and validation challenges
  - Spectral co-location of moving targets including waves (detector timing and viewing angle)

- Need improved Algorithms for
  - Sun glint correction
  - sky glint correction
  - cloud shadowing
  - adjacency effects (esp. inland waters, e.g. Pléiades NIR)
  - Per pixel processing … spatial context

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- BELSPO FWI TURBINET project (BL/58/FWI10)