

Brockmann Consult Environmental Informatics • Geoinformation Services

JNCC Using Earth Observation for Water Quality Monitoring

Copernicus sensors, data and products Online, 13.-14.10.2020 Carsten Brockmann

Managing Director Brockmann Consult GmbH, Germany

Copernicus – the European EO programme



European Earth Observation System, led by the EU

> European response to global needs:

- to manage the environment
- to mitigate the effects of climate change
 - to ensure civil security

FULL, FREE AND OPEN ACCESS TO DATA



ATMOSPHERE MONITORING
 MARINE ENVIRONMENT MONITORING
 LAND MONITORING
 CLIMATE CHANGE
 EMERGENCY MANAGEMENT
 SECURITY



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Global & System View by Copernicus







Copernicus Components & Competences



In-situ data are supporting the Space and Services Components

Copernicus – European Leadership in EO





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The Sentinels Explained



Sentinel 1 (A/B/C/D) SAR Imaging	All weather, day/night applications, interferometry
Sentinel 2 (A/B/C/D) Multispectral Imaging	Land applications: urban, forest, agriculture, Continuity of Landsat, SPOT
Sentinel 3 (A/B/C/D) Ocean & Global Land Monitoring	Wide-swath ocean colour, vegetation, sea/land surface temperature, altimetry
Sentinel 4 (A/B) Geostationary Atmospheric	Atmospheric composition monitoring, pollution; instrument on MTG satellites
Sentinel 5 (A/B/C) & Precurso Low-Orbit Atmospheric	or Atmospheric composition monitoring; instrument on MetOp-SG satellites
Sentinel 6 Jason CS (A/B)	Altimetry reference mission

Sentinel Launches





Contributing Missions



Optical High & Very High Optical Medium & Resolution **Low Resolution** DMC Pléiades RapidEye and many SPOT **PROBA-V** more Deimos-2 SPOT (HRS) **Atmosphere** Altimetry Cryosat Jason MetOp MSG **Synthetic Aperture Radar** TerraSAR-X Cosmo Radarsat **Tandem-X** SkyMed

Slide 10

ESA Sentinel 1, Sentinel 2, Sentinel 3 Land

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EUMETSAT

Sentinel 3 Marine & Atmosphere Sentinel 4 5 + 6

Cesa Sentinel Online									
- Sent	inel-2 MSI Introduction	ust	om Search	🗨 EUM	ETSAT	MONITORING WEAT	HER AND CLIMATE FROM SPACE	► REGISTER/SIGN IN	
The Sentinel- acquisition, a each instrum- been harmon on the right o	COCENCUS Europe's eyes on Earth	sa		HOME IMAGES AB		NEWS European Unio			
The categorie	Mission Status Report 164 senting Reference Period: 01-30 September 2020 • colo			+.	• • • •	Programme	Europe's eyes on Earth	EUMEISAI	
Gives a l geophys	Mission Status	Cees	a 🔣	European Union Programme					
Applicat Describe security	 Despite the critical situation in Europe due to the COVID-19, import ensure the continuity of the Sentinel-2 mission operations, which up to n 		. 6		EUMETS	SAT	oduct Notice – OLCI Level-2	Ocean Colour	
Product Describe	 The Copernicus Sentinel-2 mission is nominally performing global and s Since 20 October for Sentinel-2A and 23 October for Sentinel-2B, the extended to acquire the following new areas: 		Cover Co						
Process Describe Resoluti	 Pacific Islands (e.g. Tuamotu, Austral Islands, Kiribati, Juan Ferr Bermuda Island Sargasso Sea. 						and 24. & Sontinal 28		
Defines t • <u>Revisit</u> a	The Sentinel-2 acquisition plans are regularly published at: <u>https://sentinels.copernicus.eu/web/sentinel/missions/sentinel/</u>	S3 Product Notice – OLCI				A & OLCI-B			
Describe of the Se	Level-1C top-of-atmosphere reflectance products are available in all Co Access Hub Services Data Hub Collaborative Data Hub and Internat						2 Ocean Colour OL 2 WFR in NRT and NTC		
 <u>Naming</u> 	available offline through as detailed <u>here</u> .	Mission S3A & S3B				OL_2_WRR in NRT and NTC			
Describe available	 Level-2A surface reflectance products since 13th of December 2018, an region since 26 of March 2018, are available in all Copernicus Data Hub 	Sensor	OLCI						
 <u>Data For</u> Outlines 	The 2019 Copernicus Sentinel Data Access Annual Report has been pu	OL_1_EFR in NRT and NTC Product OL 1_ERR in NRT and NTC					OPS-SEN3/TEN/19/1068317 S3.PN-OLCI-L2M.001		
Software	 Information on data quality is available in two reports, one for L1C produces used the new Since the 04 February, the Constructs Sentinel-2 products used the new Since the 04 February and the new Since the New Sin					3/2019			
Highlight	for Level-1C and 02.14 for Level-2A products. More information here.		\$3.PN-OLCI-L1.05	EUM/OPS-SEN3/DOC/19/1083411					
analysis Anomalysis 	 The Quaternions files for Copernicus Sentinel-2 mission computed by have been made available from the Copernicus Open Access Hub from 	Issue/Rev Date 21/05/2019			01/07/2019		roduct Notice was prepared by EUMETSAT with assistance from the S3		
Provides		Version	1.1				on Performance Centre.		
Definition Provides	 Some Data Hub anomalies and outages impacted the availability of the Please refer to the <u>news</u> page for the list of the single events. As a consequence of a contingency at network level, the nominal available 	Preparation This Product Notice was prepared by the S3 Mission Performance Centre and by ESA and EUMETSAT experts			Centre and	TSAT Mission Management			
	Sentinel-2 Level-2A products has been affected between 25 and 28 missing products is on-going at the time of writing this report. • The following articles related to Sentinel-2 were published during the rep	Approval Joint ESA-EUM Mission Management				2. Constellation of satellites will provide long-term operational measurements of the ocean			
	US West Coast on fire						1		

Ground Segment Data relevant for Water Quality

Sentinel 2

• Level 1

- TOA reflectances in 12 spectral bands
- 15 180nm spectral bandwidth
- 10 / 20 / 60 m spatial resolution
- All inland waters and coastal areas (20km)

• Level 2

- Scene classification (land-water-cloud etc)
- Surface reflectances, good for land applications
- No product for water applications
- Water Quality products from downstream service providers

Sentinel 3

• Level 1

- TOA radiances in 21 spectral bands
- 10 20nm spectral bandwidth
- 300m spatial resolution
- Global coverage
- Level 2
 - Scene classification (land water cloud, including water specific classes)
 - Water leaving reflectance (ocean and coastal waters, not suitable for inland waters)
 - Chorophyll and suspended matter concentrations
 - Yellow substance absorption
 - Attenuation coefficient
 - (more in preparation by EUMETSAT)

Sentinel 2

Danube Delta Ground Segment Product

Top of atmosphere RGB



Sentinel 2

Danube Delta Downstream product CyanoAlert

Cloud masking Atmospheric correction Chlorophyll concentration

40.0

< 30.0

25.0

\$13.0



Water Quality Example from Sentinel 3, 25.06.2020



Copernicus Space Segment

Copernicus Services



coordinates





Copernicus Services



land.copernicus.eu

https://land.copernicus.eu/global/products/lwq





Copernicus Global Inland Water Service



Spatial resolution



Lake Surface Reflectances (LSR)

- 300m: Operational products
- 100m: demonstration products 01/19-03/20



Extension of list of lakes





UK Water covered by Copernicus Inland Water Service



Neagh

Lomond

Melvin

Leven

Katrine

Ullswater

Spelga

Camlough Silent-Valley

Lough Ross

Lough Fea

Loch Lochy

None

None

Lough-Mourve

Castlehume Lough

Erne-Lough

Windermere

Macnean-Lough

Bassenthwaite

Derwent-Water

Portmore-Lough

Lough-Island-Reavy

Lough Scolban Lough Gullion



Product Example – Time series Lake Balaton





46.7°

46.6°N

46.6°N



20180521 47° 46.9°N 46.8°N 46.7° 46.6°N 17.5°E 18°E



Lake Balaton - Turbidity

46.7°

46.8°N

46.7°N

46.6°N

17.25°E

18°E









17.5°E

17.75°E

18°E



17.5°E

46.6°N



17.5°E

17.75°E

18°E



17.5°E

17.75°E

18°E

46.6°N

20180821



10

Copernicus Global Land Service, Lake Water Products Processing: Calimnos v.1.1.0, PML, BC Inputdata: MERIS FRS © ESA

Background: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Copernicus Services



Copernicus Marine Service (CMEMS) – Oceans

- Products
 - Chlorophyll-a concentration
 - Optical water properties
 - Reflectances, backscattering coefficient, light attenuation coefficient, absorption coefficient
- Characteristics
 - Per regional sea + global (see figure)
 - Level 3:
 - daily mean
 - 1km x 1km and 4km x 4km
 - New: 100m x 100m based on Sentinel 2 (from 2021)
 - Level 4:
 - Gap-filled
 - daily mean, monthly mean
 - 1km x 1km and 4km x 4km
 - New: 100m x 100m based on Sentinel 2 (from 2021)



CMEMS TSM Product Example, 22.04.2020

Low Resolution Product (1km)



HR-OC Sentinel-2 Product (100m)



Total Suspended Matter [g/m³]

d 100.0

CMEMS TSM Product Example, 22.04.2020





25

Copernicus Services ٩ Marine Land Atmosphere **Climate Change** Security Emergency



C3S Ocean Colour Products

Ocean Colour products are level 3 daily maps with a global extent at a 4-km resolution from 1997 until the present time



Chlorophyll-a ECV (OC-CCI version 3.1) composite data for July 2003



03-04/09/2020

C3S_312b_lot5 ARM | VC

Downstream Service



World | Africa | Asia | Australia | Europe | Latin America | Middle East | US & Canada

Botswana: Mystery elephant deaths caused by cyanobacteria

🕲 21 September



Toxins made by microscopic algae in water caused the previously unexplained deaths of hundreds of elephants in Botswana, wildlife officials say.





Chl from Sentinel 3 OLCI and Sentinel 2 MSI

Sentinel-2 – 06.08.2018

Sentinel-3 OLCI – 07.08.2018



Downstream Service for local authorities

Water Service offered by Brockmann Consult to local management authority, based on Sentinel 2



Chlorophyll Concentration InSitu measurements



Chlorophyll Concentration Sentinel-2





Water colour = Spectral Water Reflectance



Dissolved and suspended matter in coastal water



Absorption spectra of plant pigments



Courtesy: Stramski, IOCCG training course 20918



scattering & absorption =

Inherent Optical Properties (IOPs) of opticall active substances in water and atmosphere determine the water colour

 $a_{total} = a_w + a_{Chla} + a_{tsm} + a_Y$ $b_{total} = b_{b,w} + b_{b,Chla} + b_{b,tsm}$

Pigment absorption and Chlorophyll concentration



Conversions: Chl. a [mg m-3] = 21 * a_pig_442 ^1.04

Water colour = Spectral Water Reflectance



Courtesy: Doxaran, IOCCG training course 20918

Atmosphere



Water (Lwat)

Atmospheric Contribution to Measure Signal



Figure courtesy of R. Doerffer, HZG

Interpreting the measured signal

The radiative transfer equation is a non-linear integral equation

$$I_{\nu}(\tau_{\nu}) = I_{\nu}^{0} e^{-\tau_{\nu}} + \int_{0}^{\tau_{\nu}} S_{\nu} e^{-(\tau_{\nu} - \tau'_{\nu})} d\tau'_{\nu}$$

1. Atmospheric correction $I \rightarrow R^* \rightarrow Rrs$

2. Water reflectance Rrs \rightarrow Lw / Ed

3. Bio-optical inversion Rrs \rightarrow IOPs respectively concentrations of Chl-a, TSM ...

The problem of inversion of the Top of atmosphere signal is underdetermined.

Sentinel 3 OLCI and Sentinel 2 Spectral Bands

Sentinel 2 MSI

12 spectral bandsBand positions optimised for measuring land surfaces10-20-60m spatial resolution of a single pixel

<u>Sentinel 3 OLCI</u> 21 spectral bands Band positions optimised for measuring water colour 300m spatial resolution of a single pixel





Top-of-atmosphere reflectance



After AC: Water leaving reflectance



After bio-optical inversion: Total suspended matter concentration



After bio-optical inversion: Yellow-substance absorption



After bio-optical inversion: Chlorophyll concentration



Copernicus – what's next?

Copernicus Space Component Evolution





High Priority Candidate Missions

Sentinel Expansion (Phase A/B1 studies)

Applications



Anthropogenic CO_2

Climate Change (Causes)



Polar Ice & Snow Topography

Climate Change (Effects)



Passive Microwave Imaging

Sea Surface Temperature & Sea Ice Concentration

Sentinel Expansion (Phase A/B1 studies)



High Priority Candidate Missions



High Resolution Land Surface Temperature Applications

Agriculture & Urban Management Services



HyperSpectral Imaging

L-band

SAR

Agricultural Management & Food Security, Soil & Mineral Resources

Soil, Vegetation, Food Security & Ground Motion



Copernicus Constellation Deployment Schedule



Summary

- The Copernicus Programm is European response to global needs: to manage the environment, to mitigate the effects of climate change and to ensure civil security
- The Copernicus Space Segment consists of a growing fleet of the Sentinel satellites, complemented by contributing missions. Sentinel 2 and Sentinel 3 provide data for water quality monitoring.
- The Copernicus Services build of the data from the space segment and provide fit-for purpose higher level products. The Land Monitoring Service, Marine Monitoring Service and Climate Change service deliver data from inland, costal and oceanic waters.
 - Optimisation and harmonisation across the different services is an ongoing R&D topic.
- Downstream services start from Sentinel and Services data, combine with additional data, and provide tailor-made water quality services for public and proviade customers.