

The Malta Council for Science & Technology

Trans-Atlantic Training 2021 (TAT-8) Introduction to ESA Earth Observation 01 June 2021

Francesco Sarti

European Space Agency, Earth Observation Directorate

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The purpose of the series of Trans-Atlantic Training (TAT) courses is to provide training activities for students and early-career scientists in the area of Earth Observation with an emphasis on remote sensing of land-use, land-cover changes and land applications. It is organised jointly by ESA, NASA and the Charles University of Prague. Teachers are leading experts from Europe and the USA.

The 2021 edition is virtually hosted at the Aristotle University of Thessaloniki and is locally organized by the Copernicus Academy Office of AUTh.

The 2021 Topic is CLOUD-BASED METHODS FOR CHANGE DETECTION: SAR & OPTICAL DATA PROCESSING.

Link: https://authgr.zoom.us/j/99778470652



TAT Intro & Welcome Přemysl Štych (CUNI), Efstratios Stylianidis & Antonios Mouratidis	Land classification and change (incl. practicals) Peter Potapov (GLAD)	Overview and status of Copernicus Programme Astrid-Christina Koch	Cloud-based RUS Practicals Miguel Castro Gómez (RUS) (Urban area monitoring with	•eesa
(AUTH)		(European Commission)	Sentinel-1)	Topics include
ESA EO Programmes Francesco Sarti (ESA)		Presentation of RUS Copernicus Cloud-based Service		wildfires, land classification and change, vegetation
		Georgia Karadimod (KOS)		health monitoring,
NASA Intro Garik Gutman (NASA)	Vegetation health monitoring (incl. practicals) Petya Campbell (NASA)	SAR Intro & GEE Demo Antonios Mouratidis (AUTH) & Daniel Paluba (CUNI)		social science for
			BREA	forest applications,
			Cloud-based RUS Practicals	SAR applications to
		Covid Race Dashboard Amalia Castro Gómez (ESA)	Miguel Castro Gómez (RUS) (Flood monitoring with Sentinel- 1)	Gómez (RUS) ng with Sentinel- b) geo-hazards, with several cloud-based practicals on SAR
BI			and the second	processing (urban
Fire lecture Vince Ambrosia (NASA)	BRI	BRE/	Cloud-based RUS Practicals Miguel Castro Gómez (RUS) (Deforestation with Sentinel-1)	monitoring, flood
	Social Science in forest applications Anders Pedersen & Gregory Taff (WRI)			monitoring,
				deforestation) and a
Fire and Emissions Quantification – Data, Methods and Tools		SAR Applications & Geohazards Exploitation Platform Demo		demo of the ESA GEP
Krishna Vadrevu (NASA)		Michael Foumelis (AUTH)		→ THE EUROPEAN SPACE AGENCY

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FACULTY OF ENGINEERING ARISTOTLE UNIVERSITY OF THESSALONIKI











The European Space Agency

The European Space Agency

² 22

Member

States

ce Agency

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Over 80 satellites developed, tested, and operated since 1975

2020 Budget 6.68 billion = 12 per European

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Space for

peaceful

purposes

ESA Activities and Achievements



ESA is active across every area of the space sector

World leader in science and technology

Over 80 satellites developed, tested, and operated since 1975

More than 220 launches from Europe's Spaceport in Kourou

All of this is possible thanks to the collaboration of member states

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ESA Membership

22 Member States

Austria Italy **Belgium** Luxembourg **Czech Republic Netherlands** Denmark Norway Estonia Poland Finland Portugal Romania France Germany Spain Greece Sweden Hungary Switzerland Ireland United Kingdom

Cooperation Agreements 7 other European States & Canada



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ESA BUDGET BY DOMAIN FOR 2020: 6.68 B€



European Citizens' Priorities in Space

Q: In the future, do you believe that priority should be given to space activities that allow us to ... ?

TOP 5 Priorities:



"In the eyes of Europeans, the **primary area of progression** for space activities would be to **foster a better understanding of what is happening on Earth**, particularly regarding the **climate**"







ESA Directorate of EOP

in

ESA EO Vision:



Taking the Pulse of our Planet

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Our Mission



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Develop world-class Earth Observation systems addressing scientific & societal challenges with European and global partners



ESA EOP builds user-driven Missions



Member States

Earth Explorers



Defined by science partners in Member States through Open Calls



- Objectives come from partners & industry
- Mission Definition by ESA with industry, partners & users involved

Copernicus Dashboard



> 405.000
registered users
= tip of the iceberg





full, free & open data policy



Third Party Missions

















ALOS

CartoSat-1

GOSAT

Deimos-1

Proba-1

Proba-V

QuickBird

RADARSAT-2



Deimos-2







IKONOS

RapidEye

ResourceSat-1

SciSat-1/ACE

Sea Sat





IRS-1C

IRS-1D

GeoEye-1

JERS-1

10-1

KOMPSAT-1

KOMPSAT-2



Terra SAR-X and TanDEM-X



WorldView-1

WorldView-2













SPOT





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QuikSCAT

The Earth Explorers

THE EUROPEAN SPACE AGENCY

Cesa

The Earth Explorers Missions





Science: Earth Explorers



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- Science driven programme
- Mission selection proposed by a peer committee
- On average one mission every 2 years



First Earth Explorer Launched 17 March 2009





GOCE Maps Moho





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Global Ocean Currents





Mean ocean circulation (mean speed of ocean currents in cm/s) derived from GOCE geoid & sea altimetry data





Second Earth Explorer Launched 2 Nov. 2009

Two variables

- Soil Moisture
- Ocean Salinity

SMOS: Root zone Soil Moisture and major droughts (2015)



Monitoring soil moisture in the root zone allows detecting drought and provides information on the water available to plants, particularly relevant for semi-arid regions. **Water shortages can then be predicted several weeks before vegetation is likely to suffer**



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SMOS: Root zone Soil Moisture, May 2016





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SMOS: Soil Moisture

The Netherlands

June 2017

© VanderSat

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SMOS: Alboran Sea Salinity Changes









Third Earth Explorer Launched 8 Apr. 2010

Ice Thickness (cm-level changes)

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Antarctica Ice Melting Impact





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Shifting Grounding Lines





Antarctica

Based on CryoSat data over six years (2010 - 2016)

© CPOM/Leeds/ESA



.Swarm

Fourth Earth Explorer Mission 3-satellite constellation Launched 22 Nov. 2013 Magnetic Signals

Swarm: Earth Core Discovery



esa

Liquid Iron Jet Stream 3000 km beneath the surface

40 km / year

Jet stream is speeding up

© ESA/ATG Medialab
Swarm: Occan Impost on Magnatian (magnatic tidal signals) Cesa

etary Visions 2018

Aeolus



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Fifth Earth Explorer Launched 22 Aug. 2018 Wind Mission First ever UV LIDAR in Space

Aeolus addresses our 'Blind Spot'



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Wind

- Improving NWP Models' forecast accuracy
- Deepening Understanding of Climate Science
- Spurring insight into the atmospheric energy, water, aerosol and chemistry cycles



Aeolus



12 September 2018

© ESA/ECMWF

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Aeolus data is operational and impactful



Aeolus gauges hurricane Lota wind velocities 17 November 2020



Aeolus Data is now operational

Aeolus

Data is now operationally used by ECMWF in its Numerical Weather Prediction models





We could not have hoped for a better start to 2020 than announcing the operational use of wind data from the ground-breaking #Aeolus satellite:

ecmwf.int/en/about/media... A big thank you to @esa @ESA_EO for making Aeolus happen, and Happy New Year to all.



Aeolus data is operational and impactful







Positive impact (red) when assimilating Aeolus winds from 4 April to 19 August 2020 (M. Rennie – ECMWF)

*

ESA/PB-EO/184/RoomDoc(2020)44



Future Earth Explorers



Upcoming Earth Explorers



EarthCARE

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- Clouds, aerosols & radiation
- High performance lidar tech.
- Partnership with JAXA
- Launch planned 2023





Further Earth Explorers





Biomass

- Forest biomass & height estimates
- First P-band SAR in space
- Launch planned 2023

FLEX

- Vegetation fluorescence, indicator of photosynthesis
- Launch planned 2024

Earth Explorer 9 selected: FORUM





Key for climate science

By measuring radiation emitted by Earth into space, FORUM will provide new insight into the planet's radiation budget and how it is controlled

Covers Earth's top-of-atmosphere emission spectrum from 6.25 - 100 micrometer with a spectral resolution of 0.5 cm⁻¹



Copernicus

Copernicus – a new Phase in EO

European Earth Observation System

- Led by the EU
- EU-ESA Collaboration

European response to global needs:

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

European independence, contribution to global system (GEOSS)



FULL, FREE AND OPEN ACCESS TO DATA







European Copernicus Programme

Global leadership in Earth Observation Excellent EU-led cooperation with ESA





sentinel-sp | sentinel-s → GLOBAL AIR MONITORING

sentinel-6 \rightarrow CHARTING SEA LEVEL



Benefits EU-interests, science & applications 67-131 B€value by 2035

Boost European competitiveness & tech innovation **Big data, Al, cloud comp.**

Sentinel Expansion missions will support **European Green Deal**

Copernicus Sentinel Status





The Big Data Revolution



Copernicus is the largest producer of EO data in the world



Global & System View by Copernicus





Copernicus Sentinel Satellites





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 (MF/B/C) & Precursor Low-Orbit Atmospheric Atmospheric composition monitoring; instrument on MetOp-SG satellites



Sentinel 6 Jason CS (A/B)

Altimetry reference mission

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Contributing Missions are key to Copernicus





many more ...

Atmosphere



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ESA buys large volumes of non-ESA EO data



Copernicus Sentinel Data Policy



Sentinel data are available:

✓ Free, Full and Open*
✓ Over very long term
✓ Systematically, Operationally

and Growth Legal notice on the use of Copernicus Sentined Data and Service Inform The access and use of covernous Sential that and Service Information is regulated and EU faw," in particular, the law provides that soors shall have a faw, indicated access to Copernicus Sentiard Data of territor Information without and, there and a sonator, sociadou as recends quality and establish for any memory. EU law practs free access to Coperations Sentened Data and Service Info purpose of the following use in so far as it is lawfut* adaptation, modification and combin any combination of points (a) to (d). mation with other data and information stores for specific interations of access and use in the ra-protection of third party rights or task of service disruption. takense of access and use in the rare cases of secur Southerd Data we Sorvice Information for user Administration shall be a A new applicable to him her and that the user resonances to any chims for Attom are applicable to bins her and that the over resonances to any chains for ages agains. The disc European chains and the previders of the and Data bear armanian. The coordinates are compared with the start of the start Data bear do not chains that market be filed to court in white attoms of any other start market be filed to court in white attoms of the start chains. Antomoto, Labo cope or this watter encompasses may dispute, including control and secto chains. Mari might be filed in court, in achievation or in any other fiest for the user communicates to the public or distribution Coperation Stratistical Data and # Information, heither shall inform the recipients of the source of that Data and source how source or followerse or yours. penucus Sentinel data [Year] for Sentinel data, and/or Coperances Service information [Vear] for Coperances Service Where the Copyonics Sensed Data and Service Information have been adapted of

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* ESA Sentinel Data Policy (Sep 2013) and EU Delegated Act on Copernicus Data and Information Policy (Dec 2013)

ESA and COPERNICUS Earth Observation DATA ACCESS (see



dedicated presentation available)

- ESA (ERS & ENVISAT and EEs) and ESA TPM Missions and data access
 - HERITAGE Missions (ENVISAT, ERS) and EEs
 - Access to ESA and ESA TPM and Visualization tool
 - Data policy and EO Sign In registration
 - Access via EO-CAT
 - Other data access mechanism examples (free and restricted)
 - EEs access, AOs and visualization tool
- Access to Copernicus Sentinels Data (focusing on Copernicus hub)
 - Data Policy and use typologies (focusing on scientific users)
 - Sentinel Data data hub (registration, search and download)
 - Sentinel 3 and EUMETSAT CODA hub
 - DIAS and other hubs to access Sentinels data
- RUS service introduction
 - (small video)
- ESA Toolboxes and App

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DIAS – Creating an EO Data Ecosystem

 Copernicus Data and Information Access Services (DIAS)

 Common DG-GROW-ESA approach to EO data exploitation with Copernicus at its core

• Started in June 2018

Copernicus Space Component Evolution





Copernicus: Sentinel Expansion Missions, under study 📀 esa

CO2M - Anthropogenic CO₂ Monitoring



Causes of Climate Change

LST – Land Surface Temperature Mission Agriculture & Urban Management

CRISTAL – Polar Ice & Snow Topography



Effects of Climate Change **CHIME – Hyperspectral Imaging Mission**



Food Security, Soil, Minerals, Biodiversity

CIMR – Passive Microwave Radiometer



Sea: Surface Temp. & Ice Concentration

ROSE-L – L-band SAR Mission



Vegetation & Ground Motion & Moisture



CO2M Anthropogenic CO₂ Monitoring Mission



Supporting the Paris Agreement from space



CRISTAL Copernicus polaR Ice and Snow Topography Altimeter Mission



Monitoring the effects of climate change

CIMR – Science and Applications



Polar Oceans are fundamental to understanding the global environment

Support the EU Arctic Policy

 Measure the Polar regions every ~6 hours with 95% global daily coverage

 Enhance all Copernicus Services



Monitoring many polar ocean parameters

Sea Ice Concentration, Sea Surface Temperature, thin Sea Ice Thickness, Sea Surface Salinity, Wind Speed, Snow Water Equivalent, Soil Moisture

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LSTM Land Surface Temperature Monitoring Mission

Support agriculture management services, water and food security

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CHIME – Science and Applications

Support the European Green Deal and EU environmental policies

- Sustainable agricultural and biodiversity management, sustainable mining and environmental preservation
- Through <u>routine hyperspectral</u> <u>measurements</u>
- Support food security, agriculture, soil management

Hyperspectral data cube (courtesy DLR) •eesa



Physiological diversity of a temperate forest

(Airborne imaging spectroscopy APEX data -Schaepman, Jehle et al. 2015)



ROSE-L Radar Observing System for Europe L-band Better services for disasters & geohazards, forests & agriculture management

ROSE-L – Science and Applications

Improve services for Disasters & Geohazards, Forests, Agriculture and high-resolution monitoring of Arctic & Cryosphere



- L-band SAR has strong all-weather capabilities
- Improve disaster mitigation: earthquakes and volcanoes, landslides, flooding etc.
- Land use and agriculture as well as snow and ice applications



Temporal variations in Soil moisture & Crop type



Mapping fast subsidence rates of Semarang (Indonesia) using point scatterers at L-band & C-band



Copernicus' Applications



Safe & Efficient Shipping



East Greenland Ice Chart

Based upon Sentinel-1 A & B data

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Earthquake in France, ground displacement

Interferogram Based on Copernicus Sentinel-1

6 and 12 November 2019

Contains modified Copernicus Sentinel data (2019), processed by ESA



Landslides





Highway 1 California U.S.

Based on Sentinel-1 data (2015–17), processed by Norut

####
Monitoring Rice Yields



Duong Delta Nothern Vietnam

Based on Sentinel-1 Data © TU Wien, GEO



Sentinel-2



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Land Cover Typology

180.000 Sentinel-2A images Dec. 2015 – Dec. 2016





Agricultural Land Use

Distinguishing 15 crop types Germany

Mixed Sentinel-2 and Landsat-8 Data

 © Humboldt University Berlin P. Griffiths



Agricultural Landscape in Belgium





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1 Jan. – 15 June 2018

© VITO

Volcanic Eruptions



Etna Sicily, Italy 16 March 2017

Sentinel-2A

"Countries with limited volcano monitoring resources will benefit most from this Copernicus application"

BBC WORLD NEWS

BBC News 19 April 2017

The Sentinels allow us to monitor every single volcano on Earth

Marine Life



Fiji – South Pacific Sentinel-2B 28 Sept. 2017

Forest Fires in Urban Areas





Mount Vesuvius Naples, Italy Sentinel-2B 12 July 2017

Wildfires in Russia



Sentinel-2 Amur Oblast 9 May 2018

War - Burning Oil Wells

Al Qayyarah Iraq

3 November 2016 Sentinel-2A



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Rainforest Clearing Rondonia, Brazil

Landsat 5

8 July 1989

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Floods in Greece

22 November



Attica before and after floods Copernicus Sentinel-2

22 and 25 November 2019

Contains modified Copernicus Sentinel data (2019), processed by ESA, CC BY-SA 3.0 IGO

Sentinel-3



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Drought

Western Europe (after) 25 July 2018 Copernicus Sentinel-3



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Hurricane Monitoring



< Temperature at the top of Harvey as the storm approaches Texas

Based on Sentinel-3A data 25 August 2017

© BY-SA 3.0 IGO

Top of atmosphere 0 -60 -80 brightness temperature (°C)

250 km

Earth Surface Heat





Sea Surface Temperature





Plant Growth in Spring



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Vegetation Index Based upon Copernicus Sentinel-3A data (2017) © University of Southampton–J. Dash/Brockman Consult (S3-MPC)

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Sentinel-5P



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Nitrogen Dioxide from Sentinel-5P

April 2018 average

© KNMI / NSO

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Shipping Lanes: Air Pollution







Rainforest Burning

Copernicus Sentinel-5P Carbon monoxide (CO) August 2018 (average)

10 15 molec.cm-2



Copernicus modified data (2018 - 2019) → THE EUROPEAN SPACE AGENCY



Regional Scale methane over Africa





Low Ozone Concentrations over Antarctica





Training & Education https://eo4society.esa.int/training-education





- Successful series of Advance training events engaging more than 1000 students worldwide
- Successful introduction of new ICT in training activities through the **MOOCs** involving in average more **6,000 registered students** worldwide per MOOC

Recent training courses:

https://eo4society.esa.int/training-education/scientists-advanced-training-by-theme-oceanland-atmosphere/

https://eo4society.esa.int/training-education/universities-and-young-professionals/

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Thank you for your attention!

www.esa.int eo4society.esa.int https://eo4society.esa.int/training-education/

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