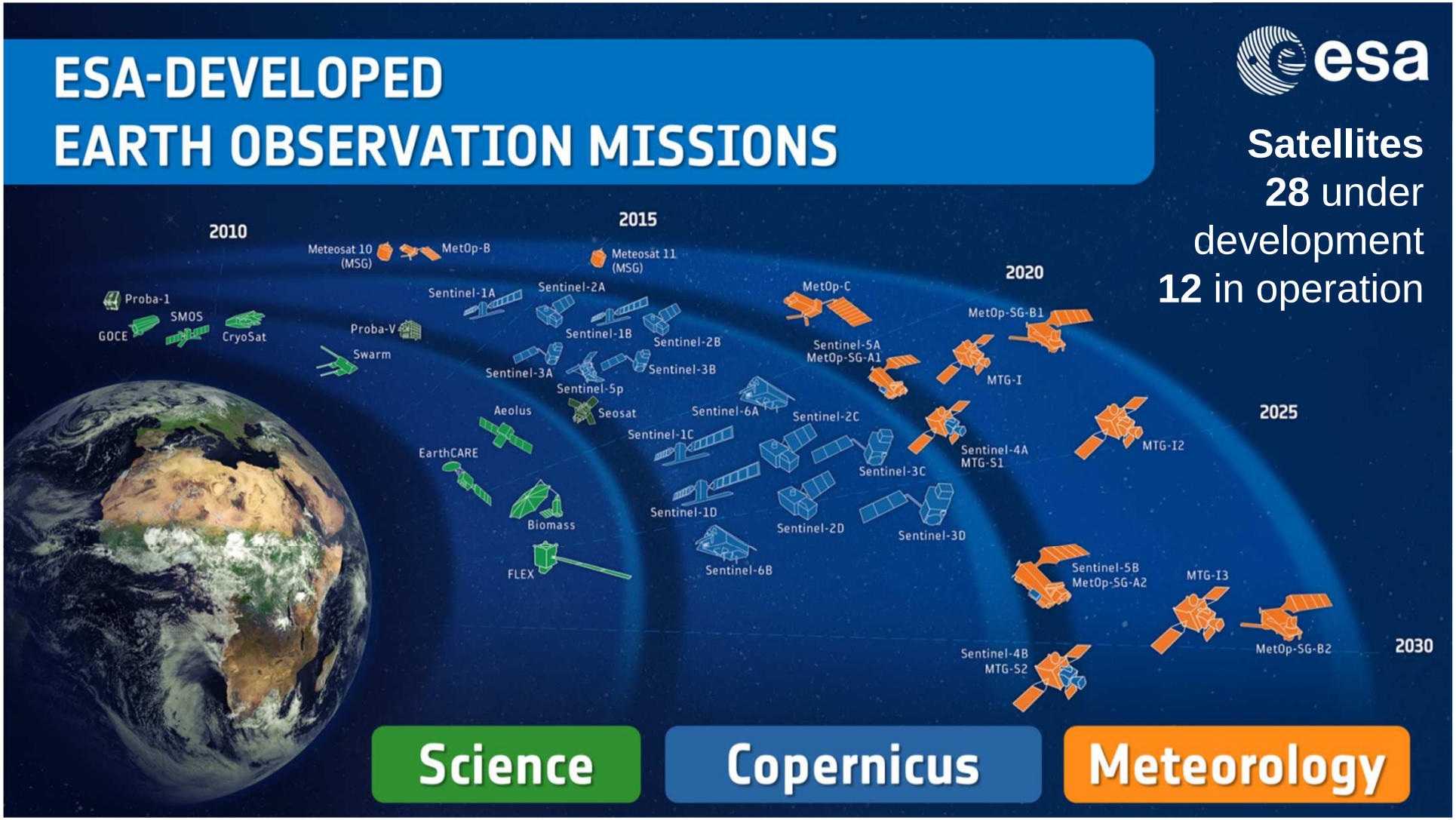
ESA Earth Observation Activities – interest/benefits for Poland

Warsaw,
29 May 2019

Gordon Campbell

Developments in ESA Earth Observation

- Space technology – instruments, systems, structures, mechanics, command and control, software, etc
- Ground segment technology – transmission, command and control, processing
- EO data exploitation (science, applications, services)
- Platform and processing capabilities
- AI/ML, BDA


ESA-DEVELOPED
EARTH OBSERVATION MISSIONS
esa
Satellites
28 under development
12 in operation
2010
2015
2020
2025
2030
Proba-1
GOCE
SMOS
CryoSat
Meteosat 10 (MSG)
MetOp-B
Proba-V
Swarm
Sentinel-1A
Sentinel-2A
Meteosat 11 (MSG)
Sentinel-1B
Sentinel-2B
Sentinel-3A
Sentinel-3B
Sentinel-5p
Seosat
Aeolus
EarthCARE
Biomass
FLEX
Sentinel-1C
Sentinel-6A
Sentinel-2C
Sentinel-1D
Sentinel-6B
Sentinel-2D
Sentinel-3C
Sentinel-3D
MetOp-C
Sentinel-5A
MetOp-SG-A1
MetOp-SG-B1
MTG-I
Sentinel-4A
MTG-S1
MTG-I2
Sentinel-5B
MetOp-SG-A2
MTG-I3
MetOp-SG-B2
Sentinel-4B
MTG-S2
Science
Copernicus
Meteorology

Sentinel Launches

esa

S-1

Radar

A 3 Apr. 2014

B 25 Apr. 2016

S-2

High Resolution Optical

A 23 Jun. 2015

B 6 Mar. 2017

S-3

Medium Resolution Optical & Altimetry

A 16 Feb. 2016

B 25 Apr 2018

S-4

Atmospheric Chemistry (GEO)

A 2021

B 2027

S-5P

Atmospheric Chemistry (LEO)

A 13 Oct. 2017

S-5

Atmospheric Chemistry (LEO)

A 2021

B 2027

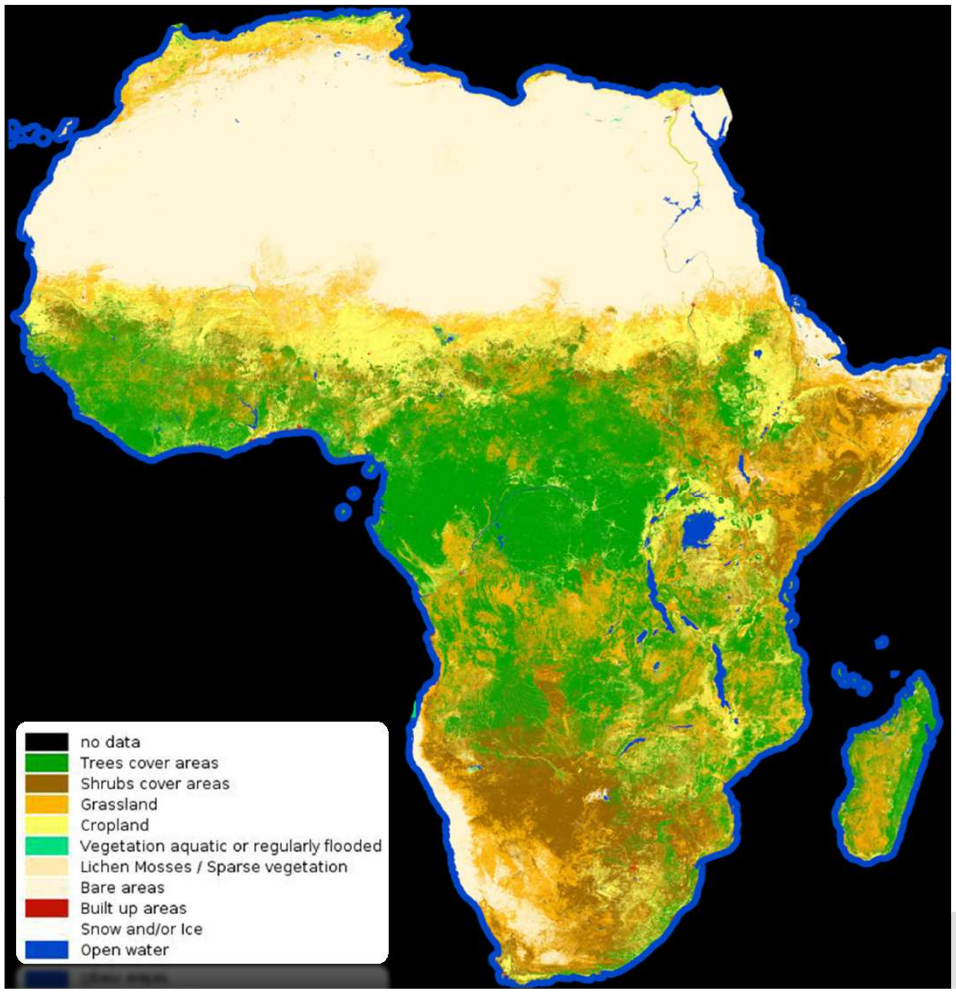
S-6

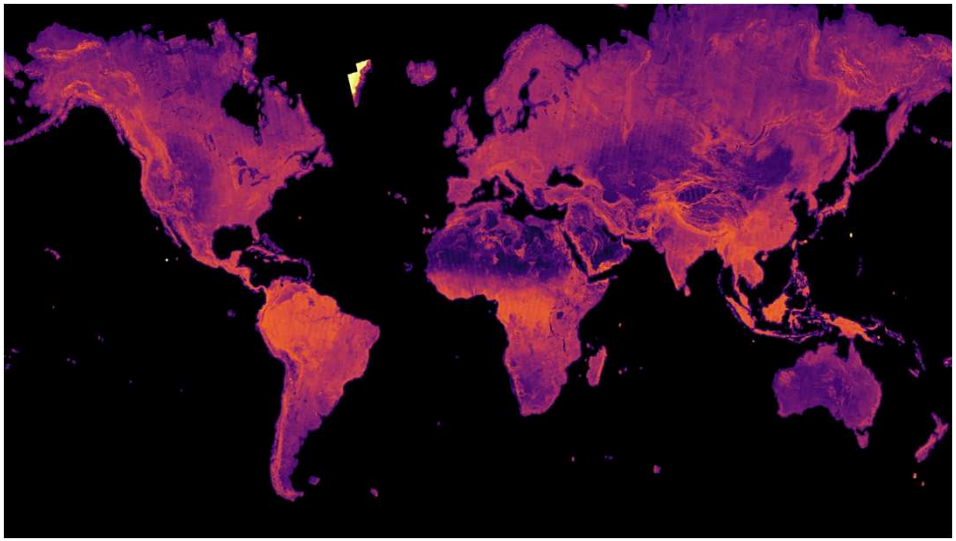
Altimetry

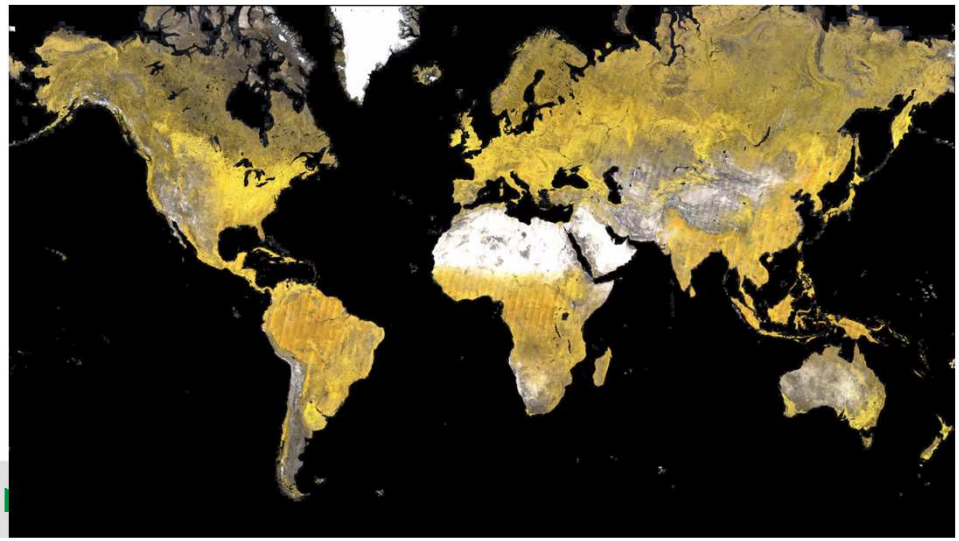
A 2020

B 2025

Sentinels – step change







Science: Earth Explorers

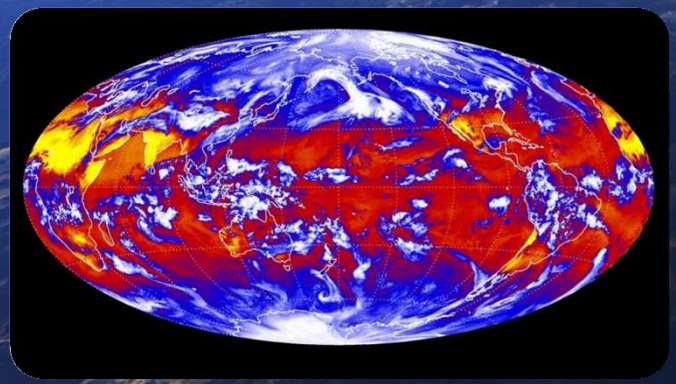
European Space Agency

Earth Explorer 9

Launch around 2025

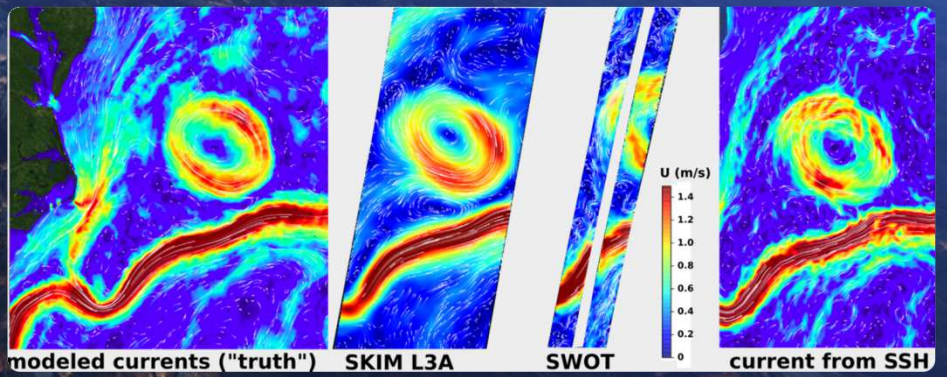
FORUM

Greenhouse Effect / Climate Change



SKIM

Ocean Surface Currents

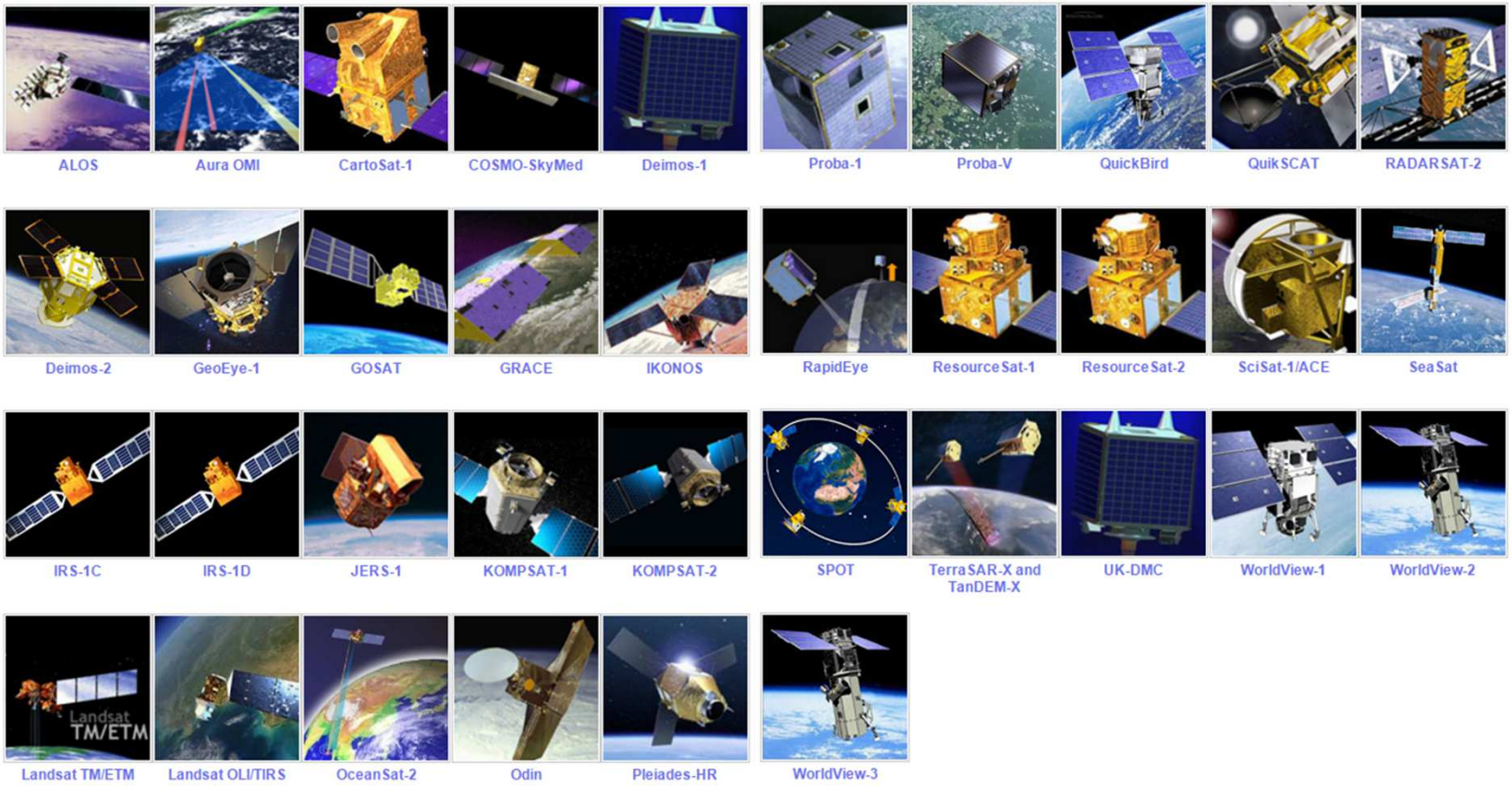


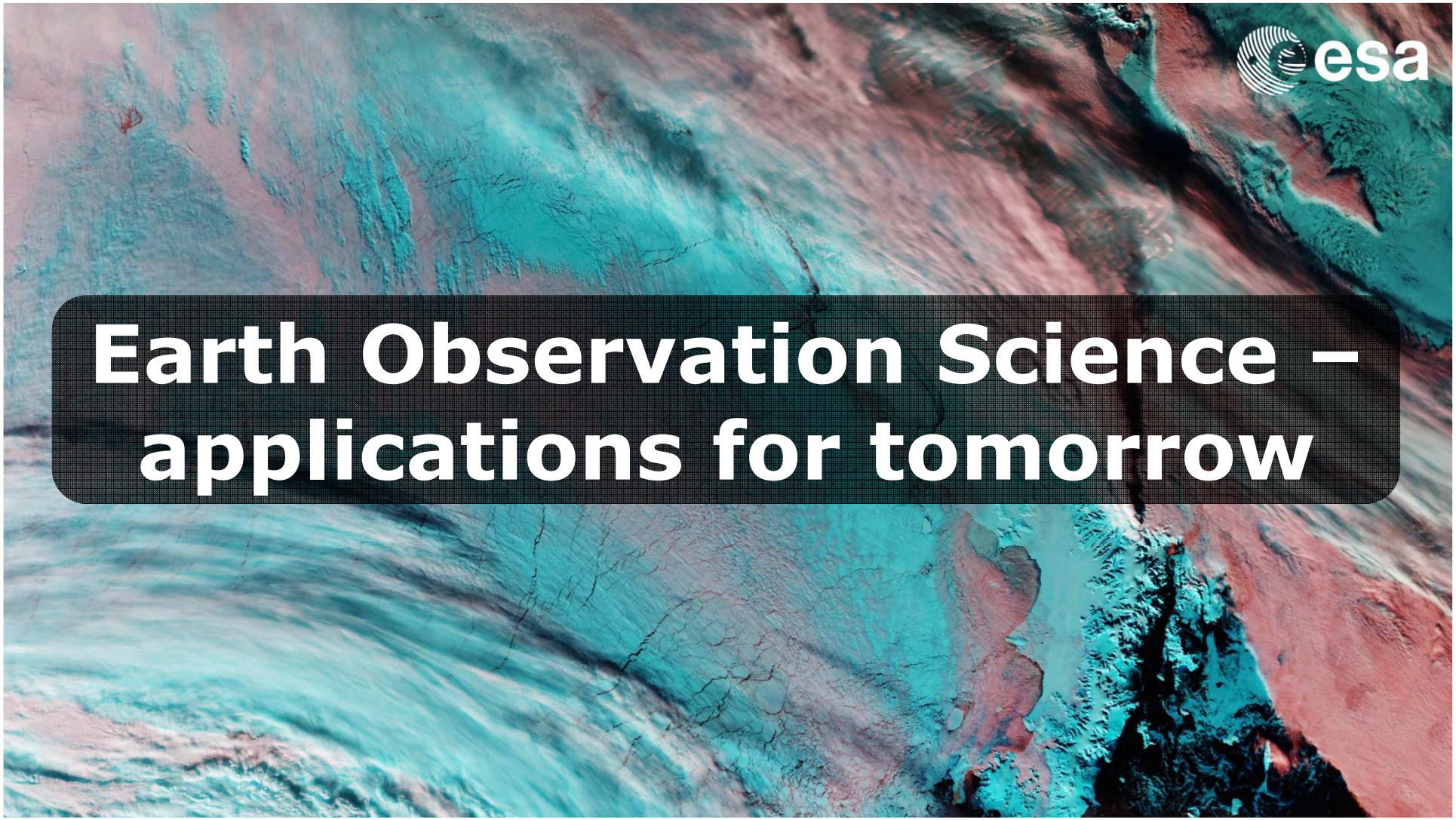
Meteorology

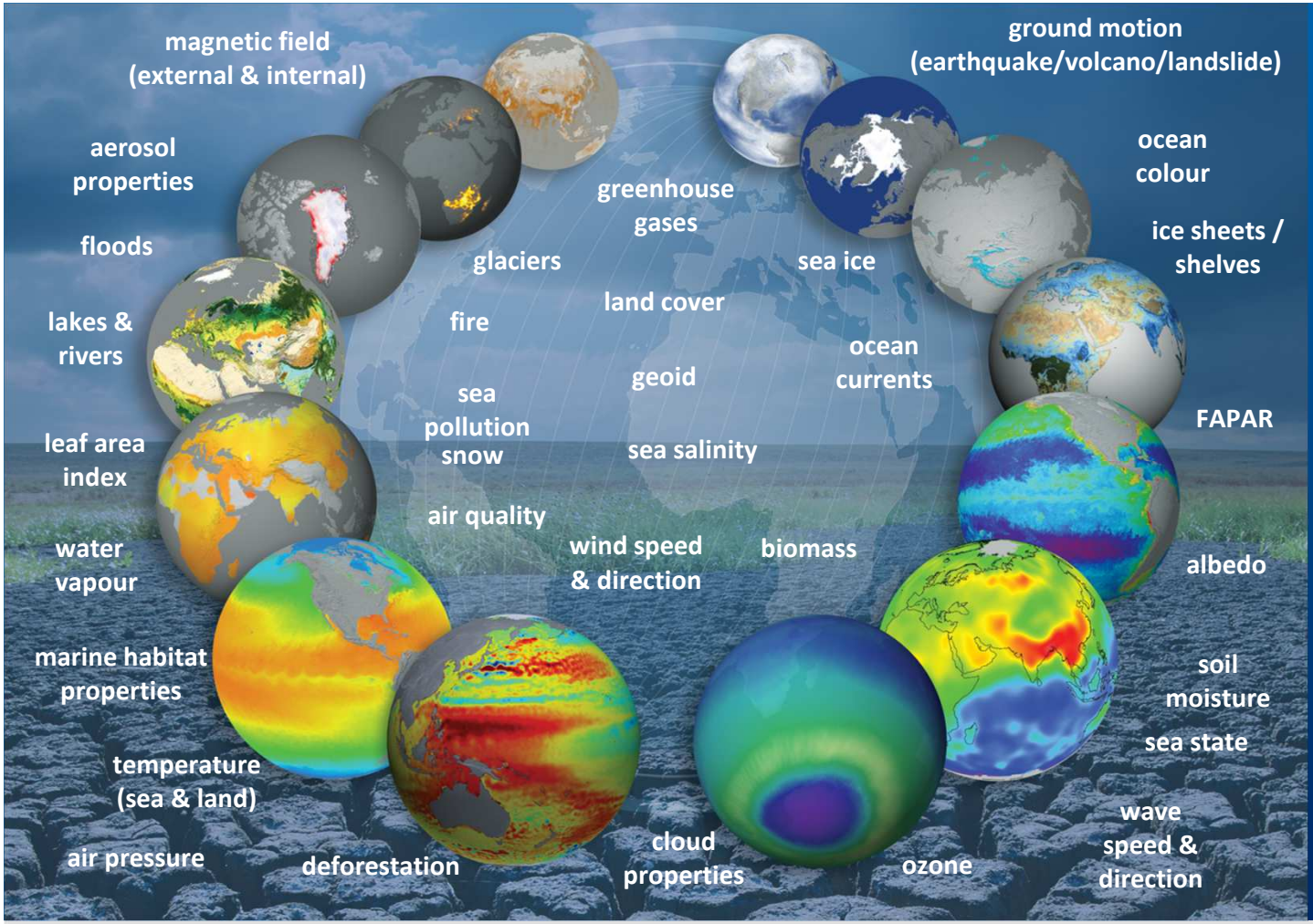
< Current Systems

< Post-2020 Systems

Third Party Missions




esa
Earth Observation Science –
applications for tomorrow

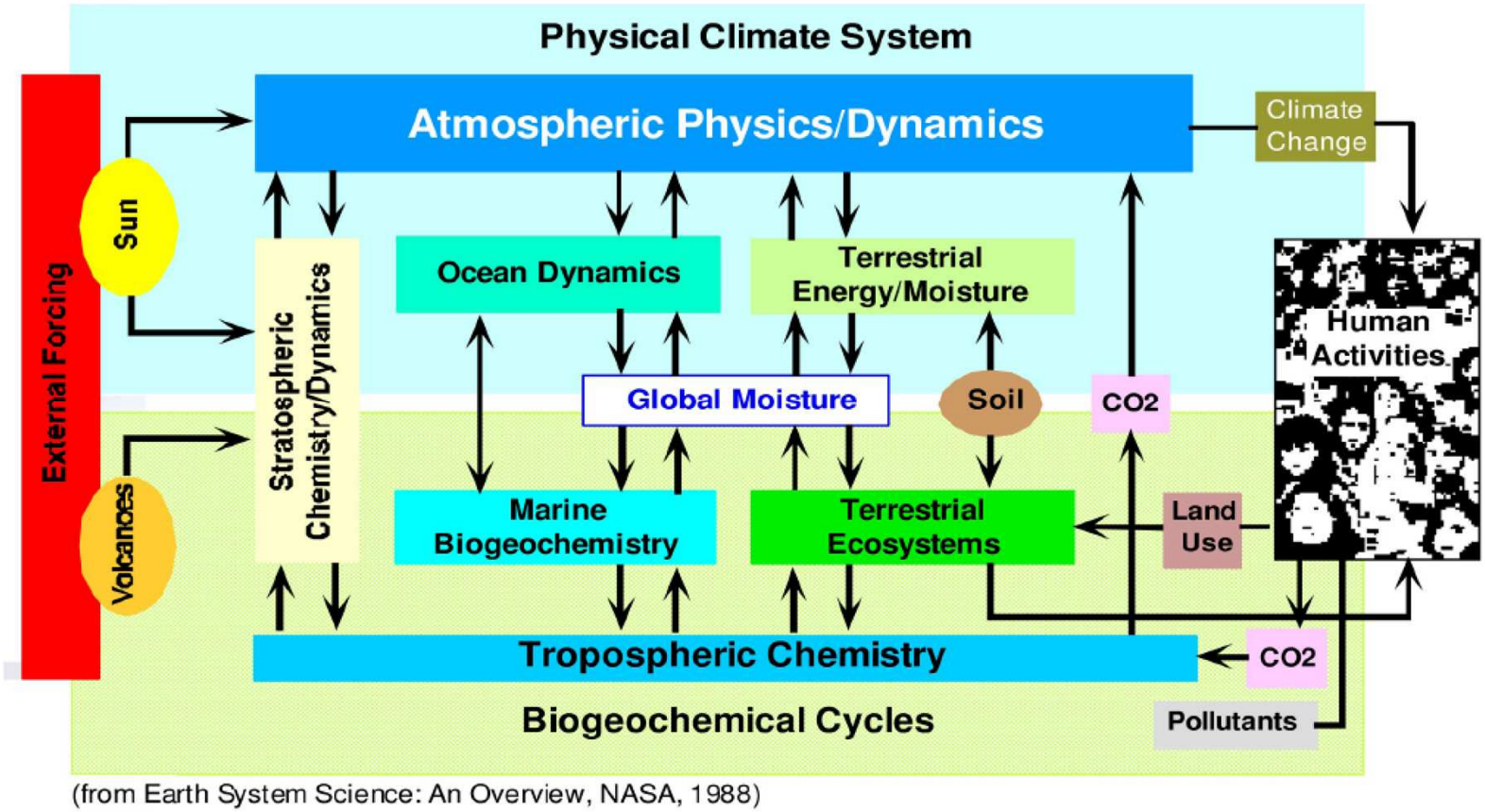


esa

ESA provides EO mission data addressing almost **all** parameters retrievable by EO satellites

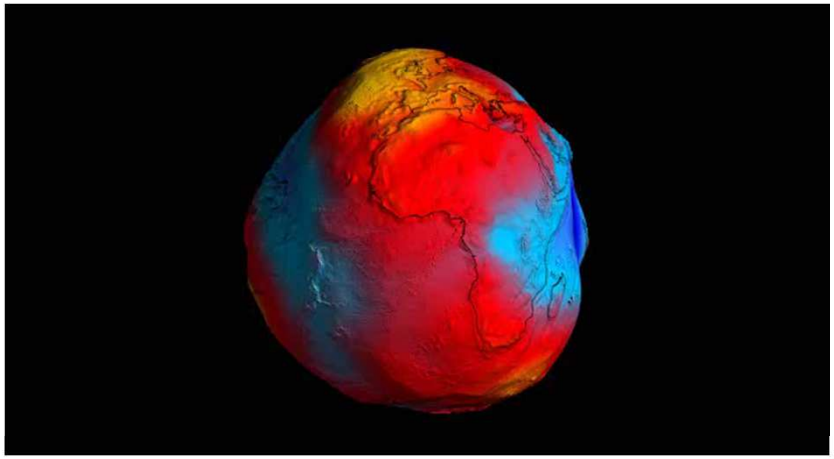
➔ **Extreme user diversity**

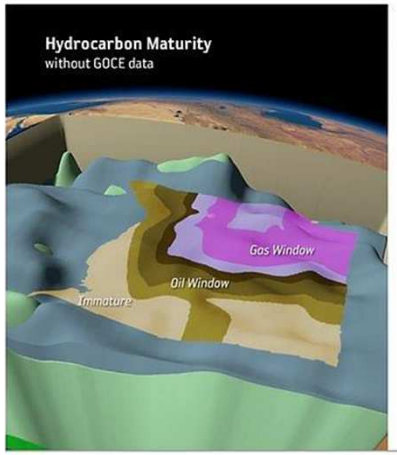
What are we trying to do?

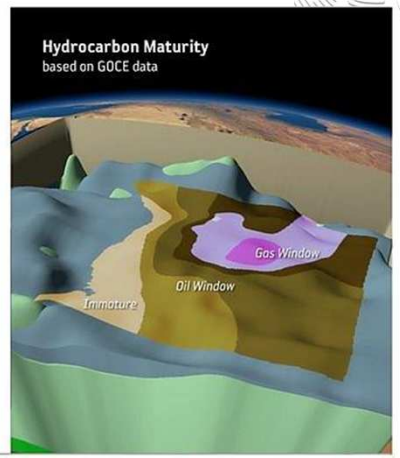


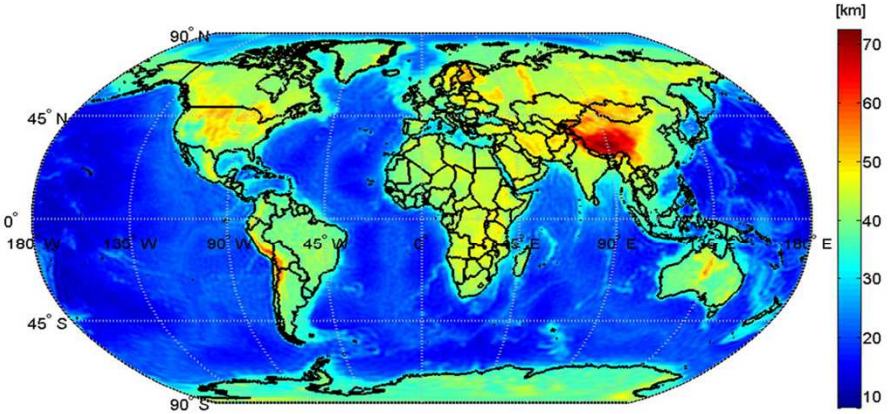
(from Earth System Science: An Overview, NASA, 1988)

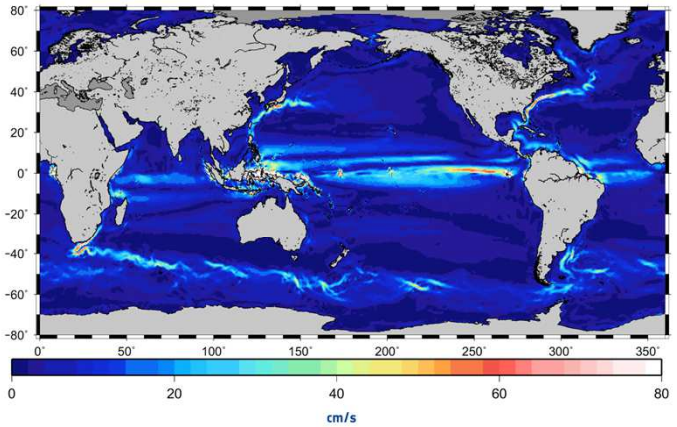
GOCE



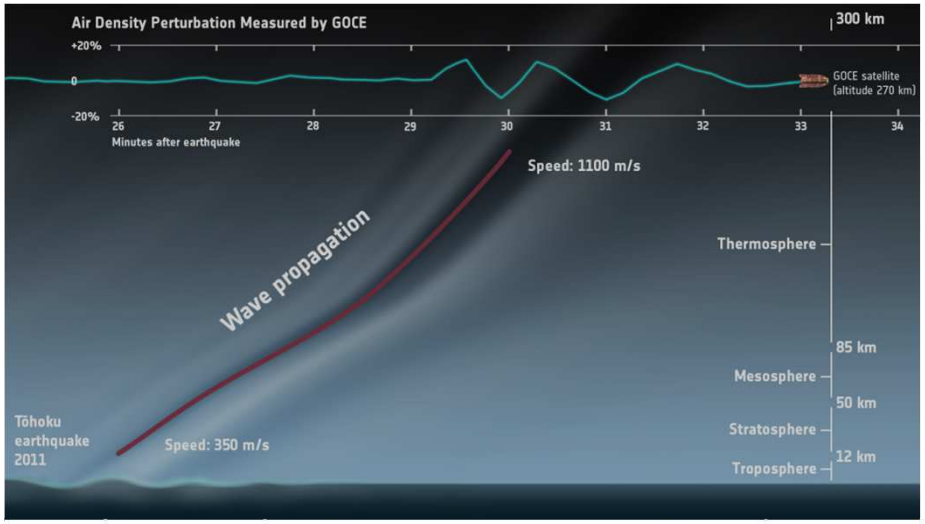

Hydrocarbon Maturity
without GOCE data
Gas Window
Oil Window
Immature

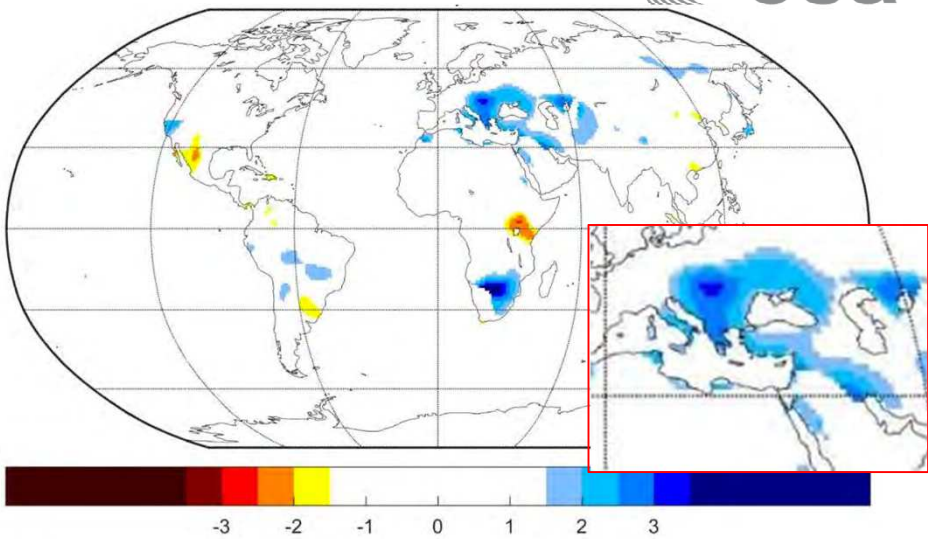

Hydrocarbon Maturity
based on GOCE data
Gas Window
Oil Window
Immature

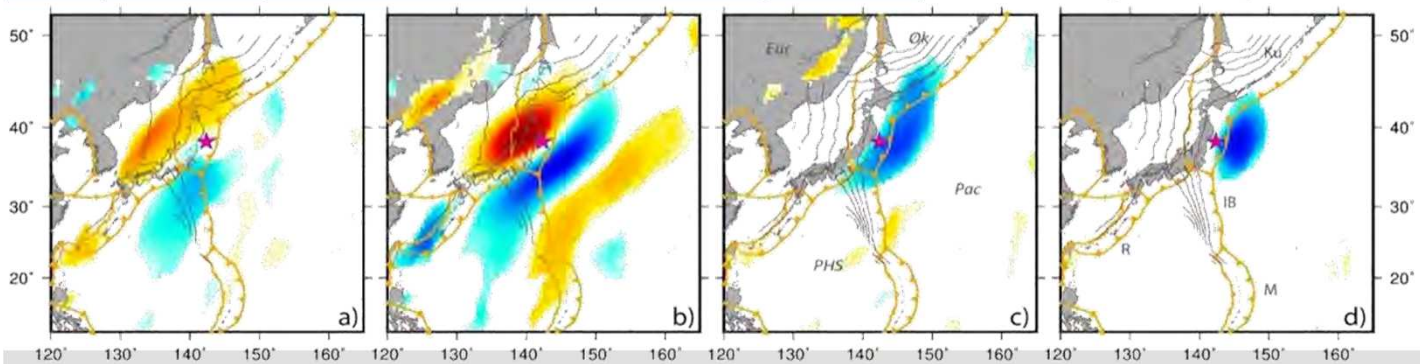

90° N
45° N
0°
45° S
90° S
180° W
135° W
90° W
45° W
0°
45° E
90° E
135° E
180° E
[km]
70
60
50
40
30
20
10

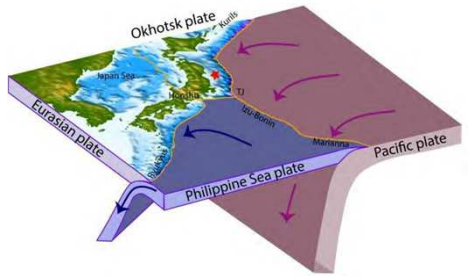

80°
60°
40°
20°
0°
-20°
-40°
-60°
-80°
0°
50°
100°
150°
200°
250°
300°
350°
0
20
40
60
80
cm/s

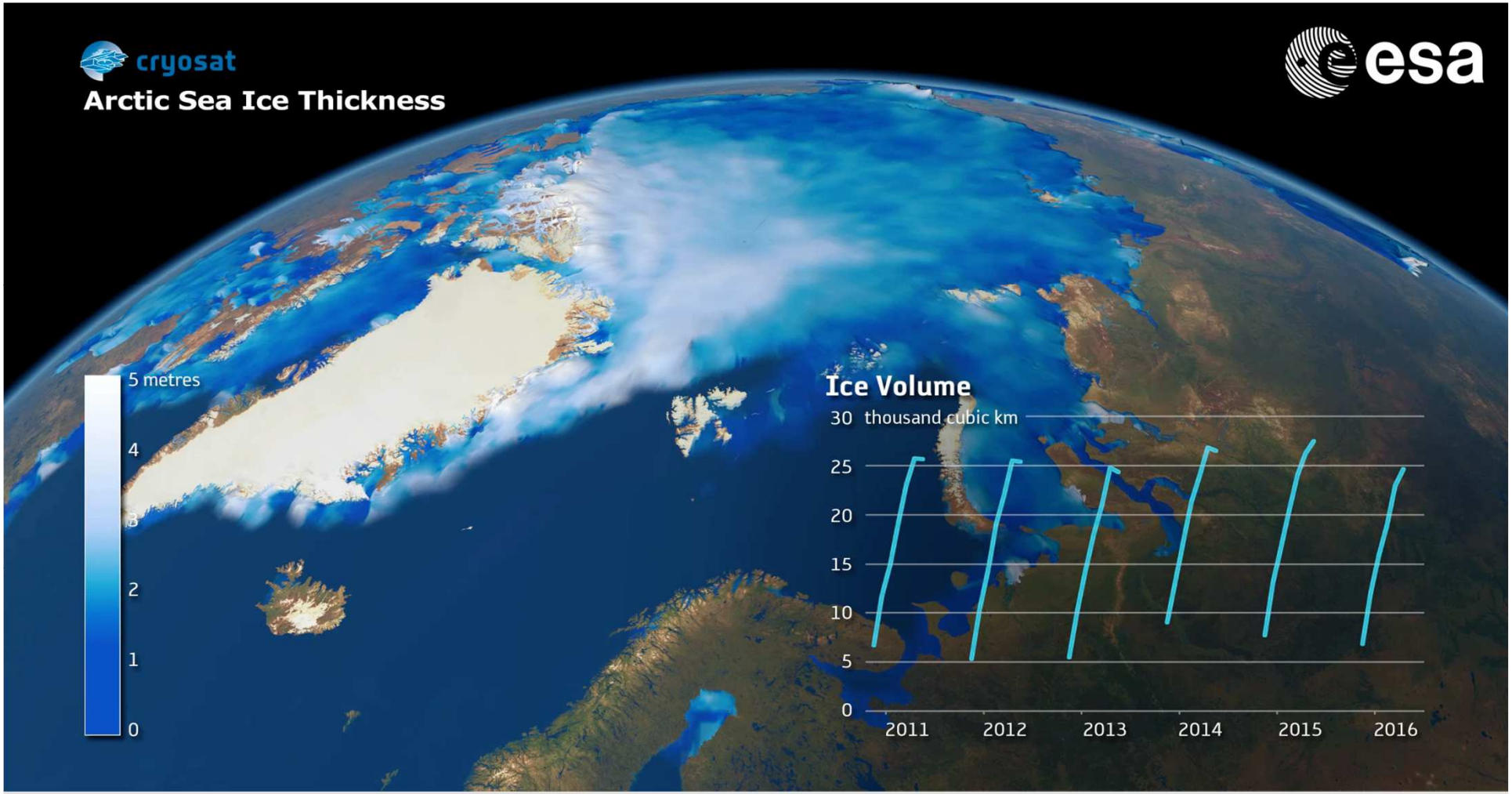
GOCE: the utility of gravity measurements





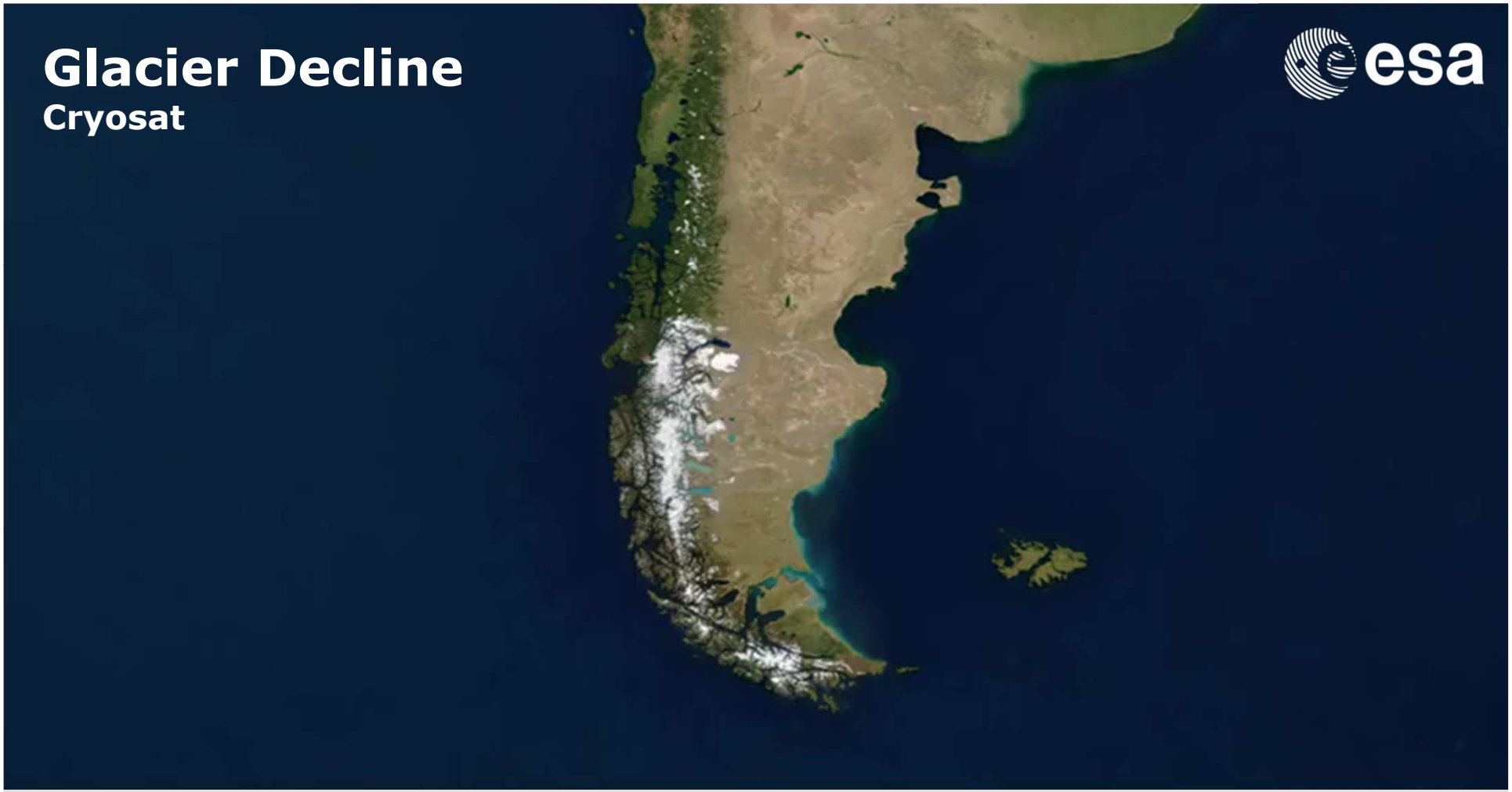





cryosat
Arctic Sea Ice Thickness
esa
5 metres
4
3
2
1
0
Ice Volume
30 thousand cubic km
25
20
15
10
5
0
2011
2012
2013
2014
2015
2016
European Space Agency

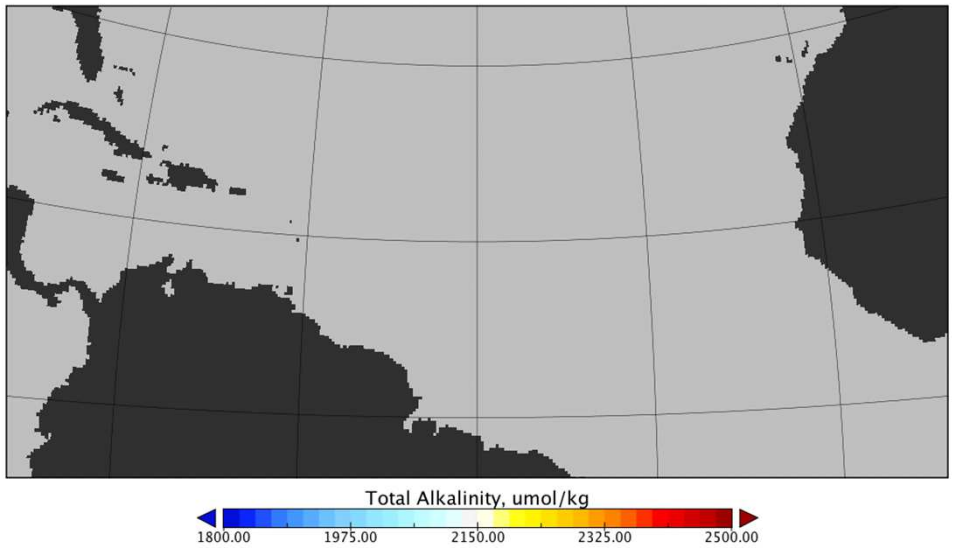
Glacier Decline

Cryosat

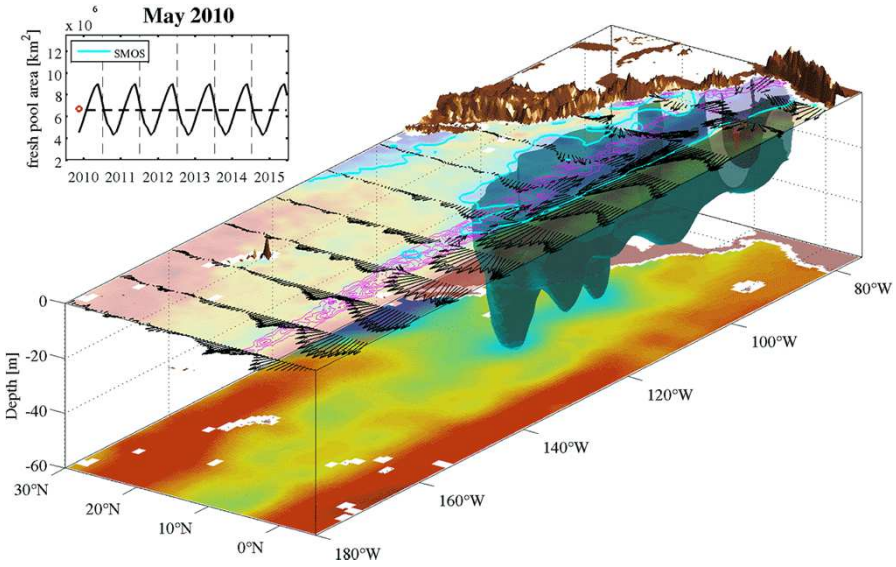


European Space Agency

SMOS: recent results

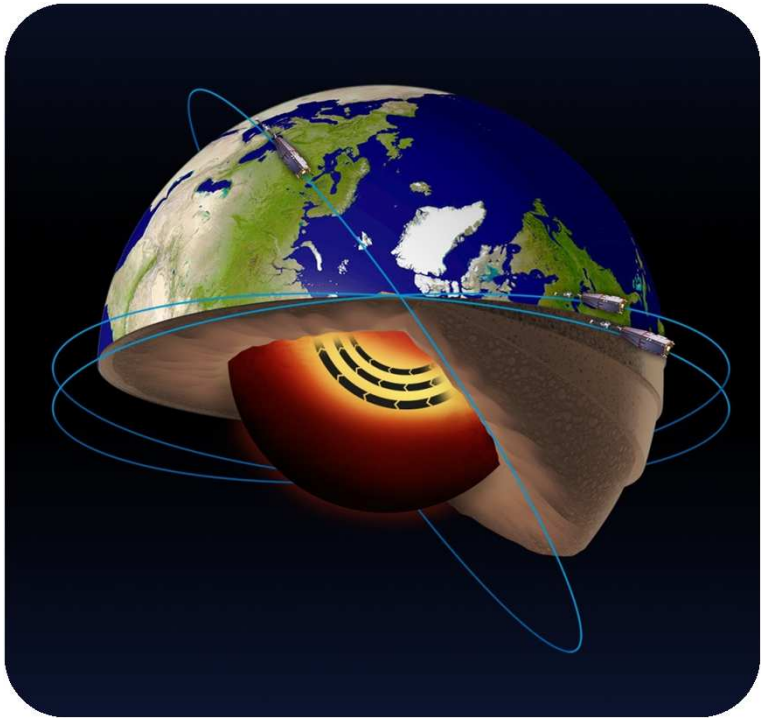


Ocean acidification

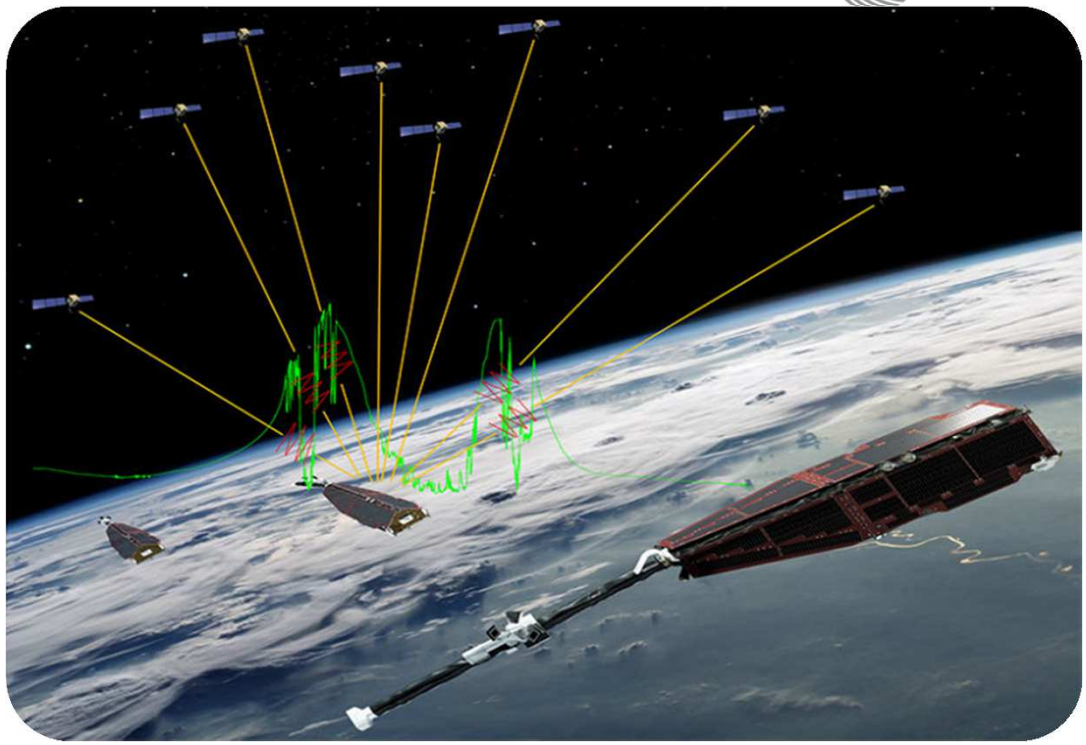


Fresh water inflows

Swarm: Key Discoveries



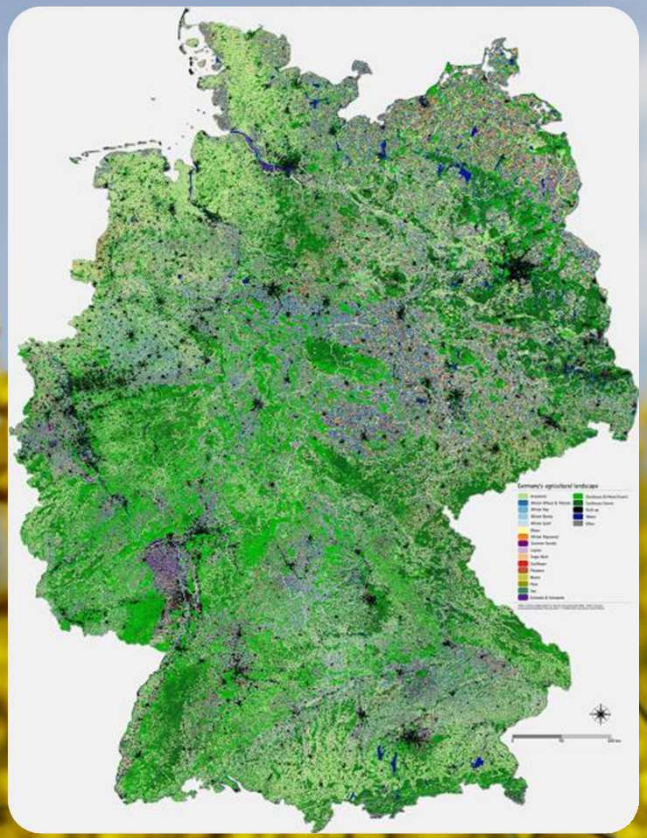
Liquid Iron Jet Stream
3000 km below surface
40 km/year and it is speeding up

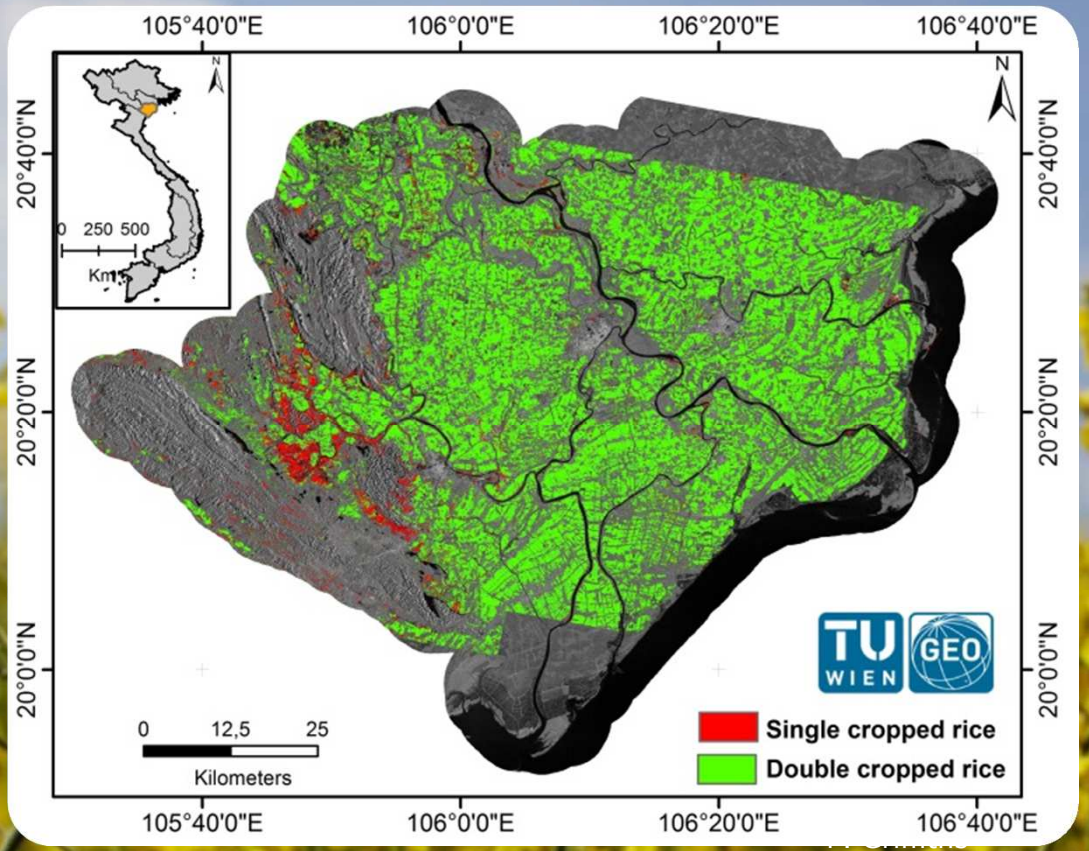


GNSS Blackout Phenomenon due to
'thunderstorms' in the ionosphere

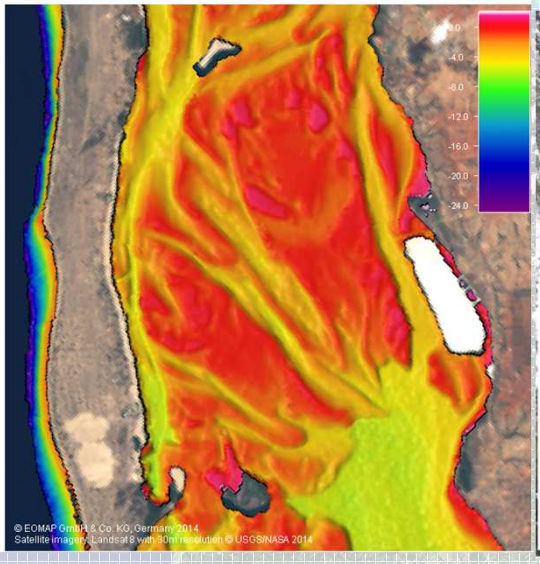

esa
EO applications –
benefits for the citizen

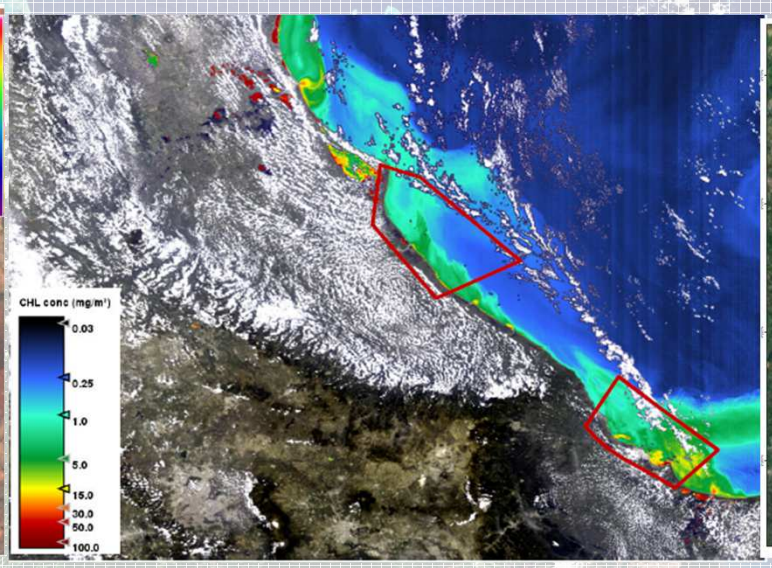
CAP/Ecosystem services/Food Security



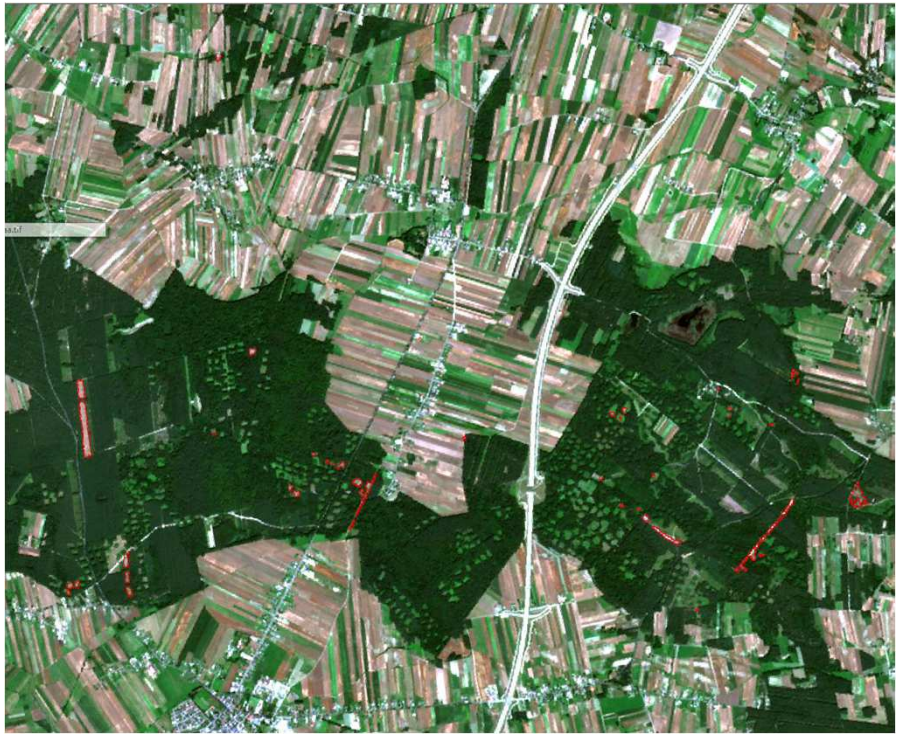


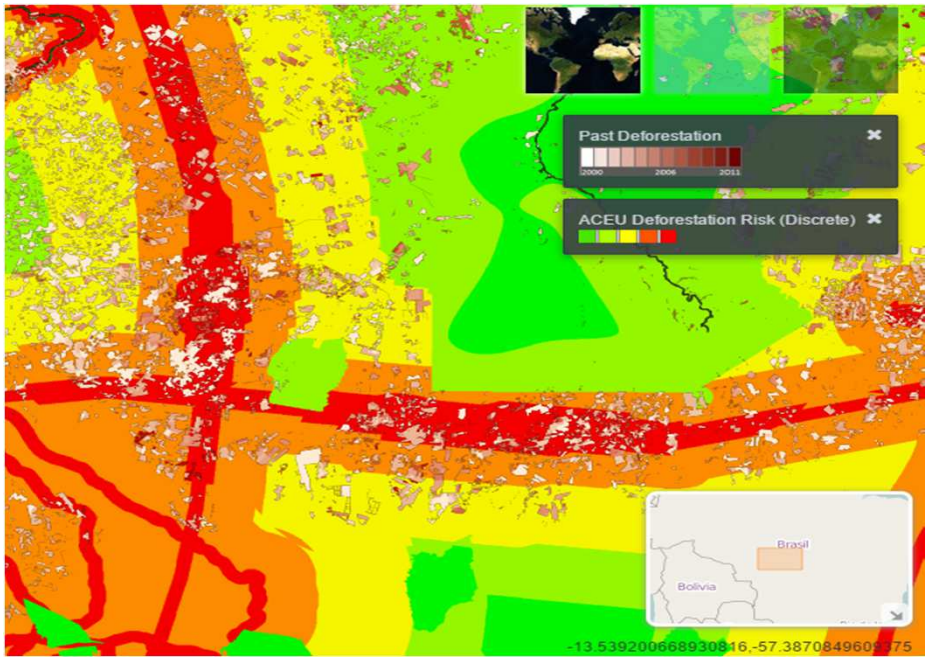
MFSD/WFD


-0.0
-4.0
-8.0
-12.0
-16.0
-20.0
-24.0
© EOMAP GmbH & Co. KG, Germany 2014
Satellite imagery: Landsat 8 with 30m resolution © USGS/NASA 2014

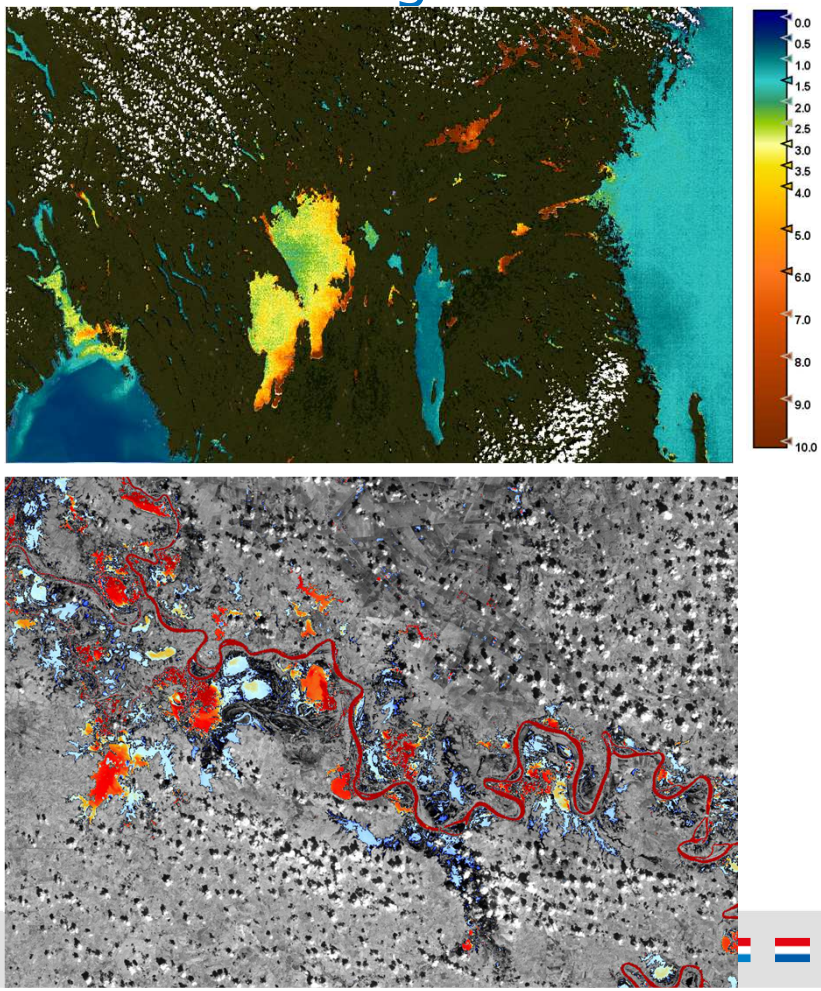

CHL conc (mg/m³)
0.03
0.25
1.0
5.0
15.0
30.0
50.0
100.0

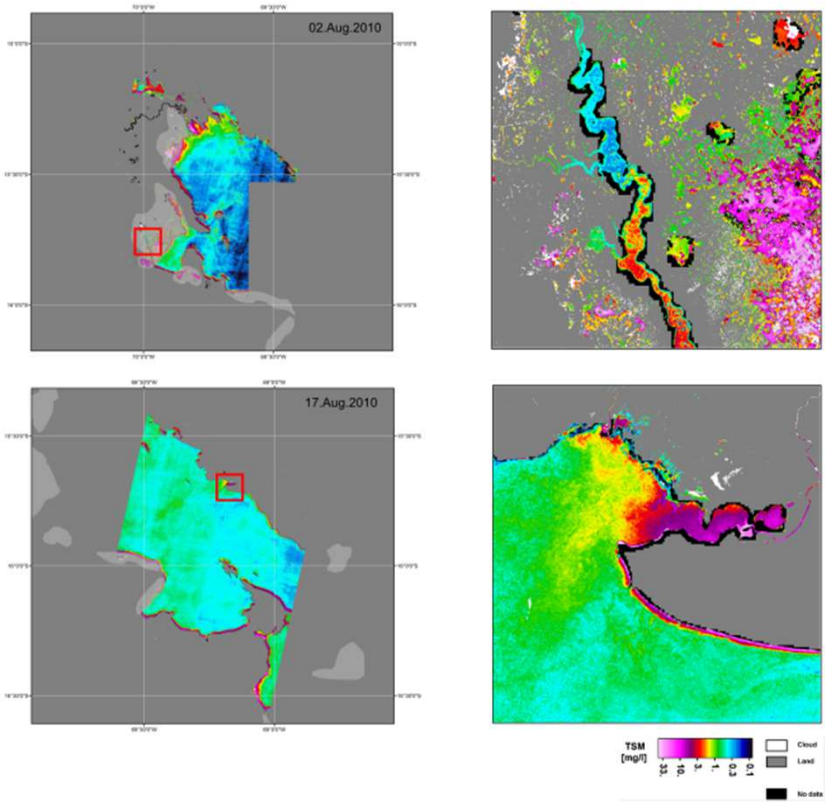
Forest Ecosystem Management



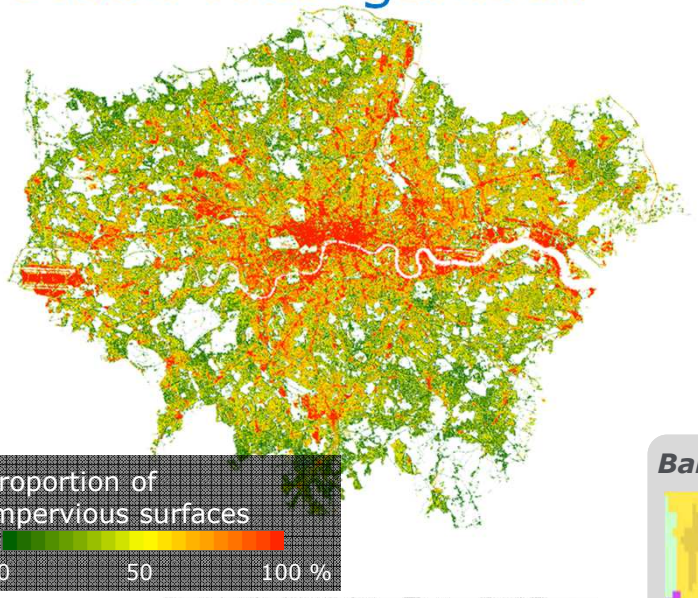


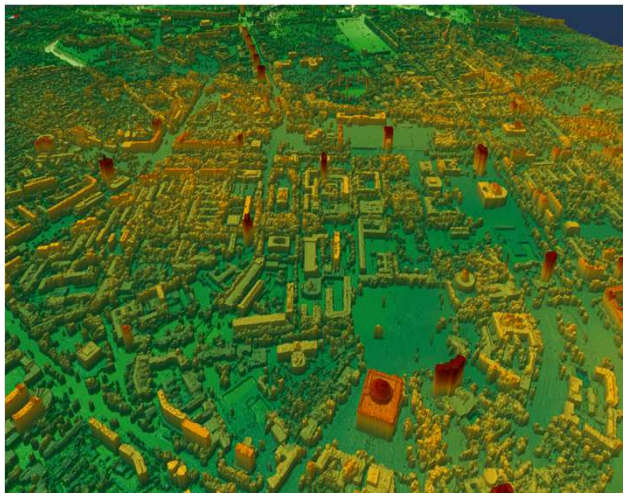
Water management

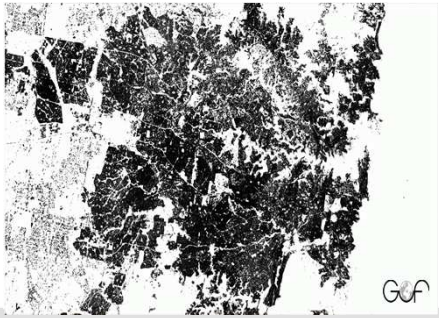




Urban Management

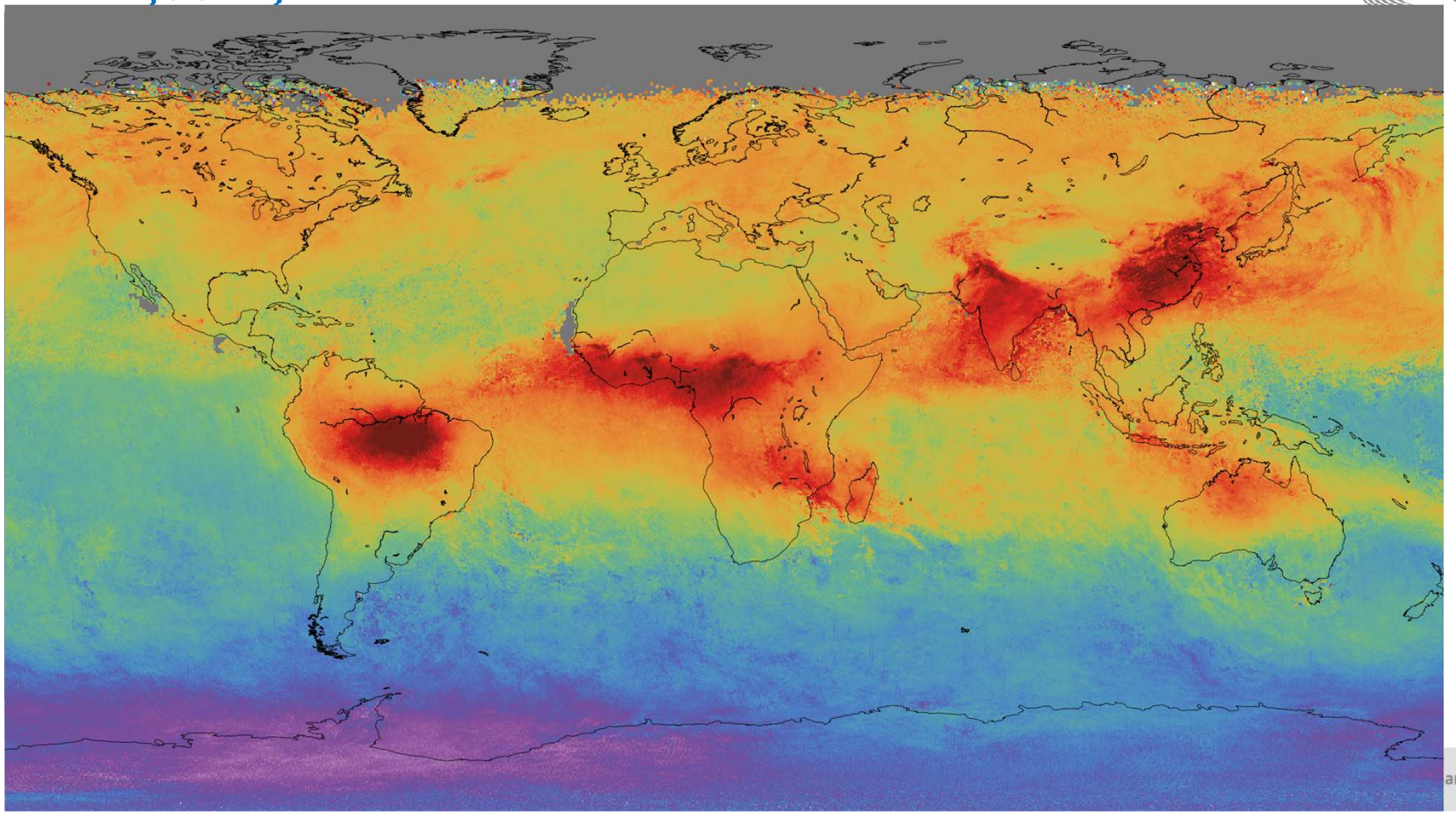




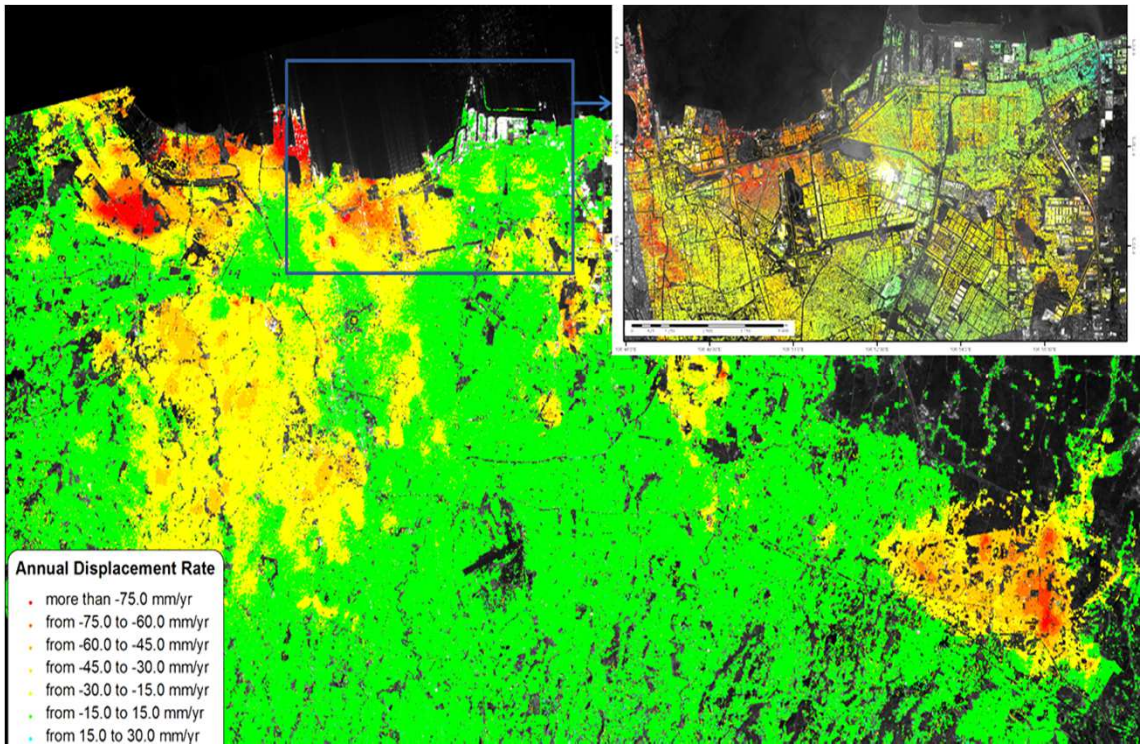


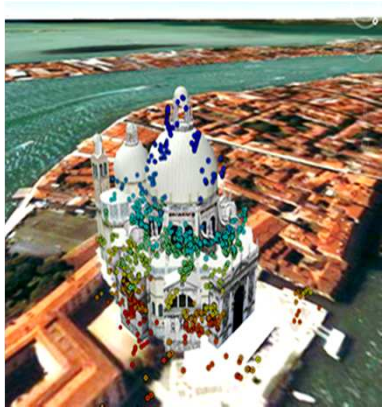
Barcelona: Corine Land Cover v Urban Atlas

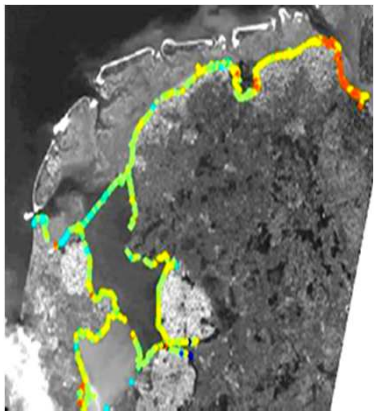
Air quality

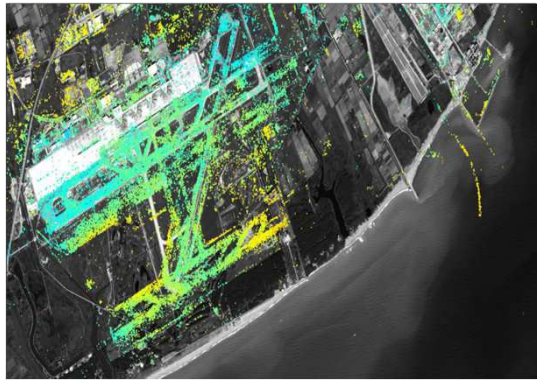


Land subsidence and infrastructure stability

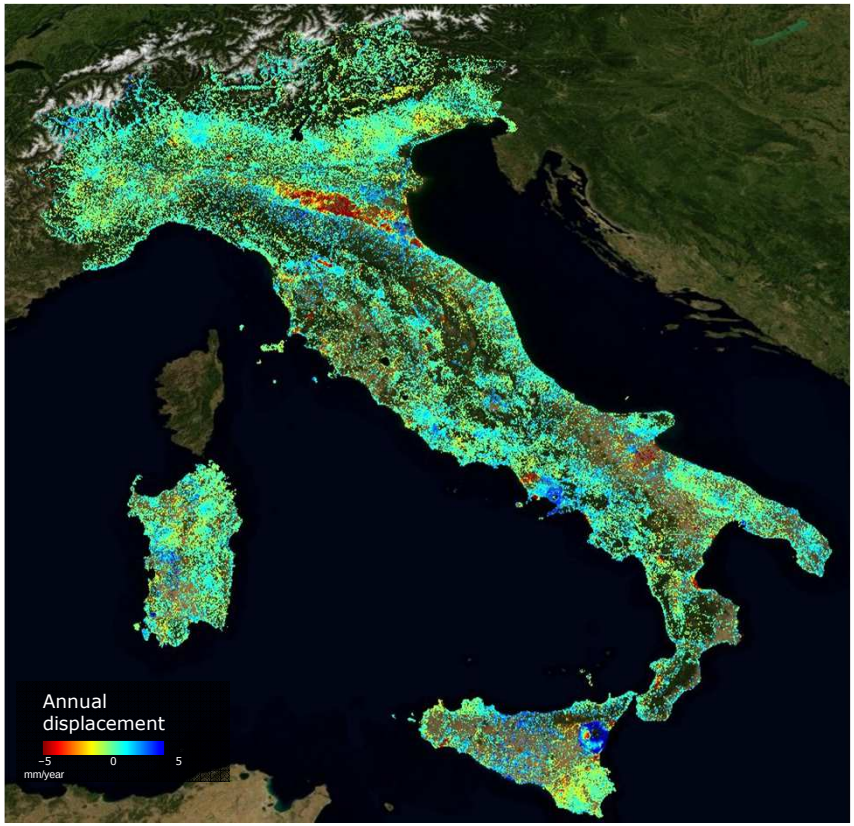


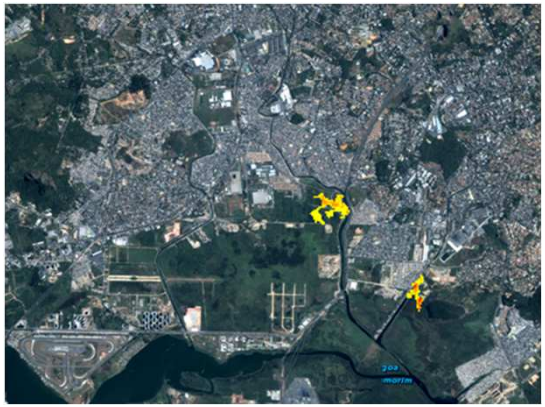


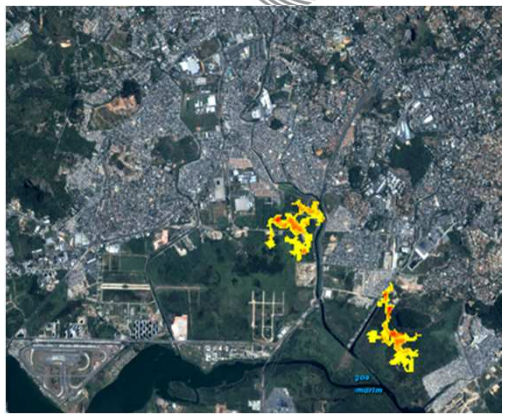


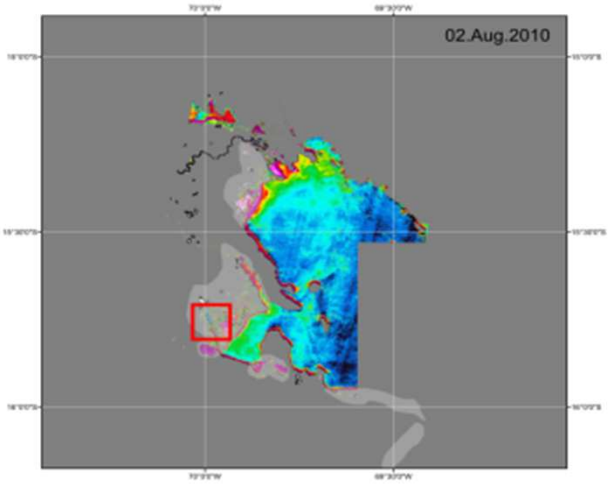


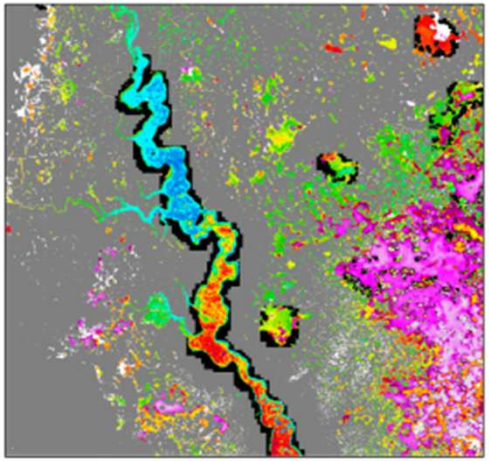
Natural hazards and risk management

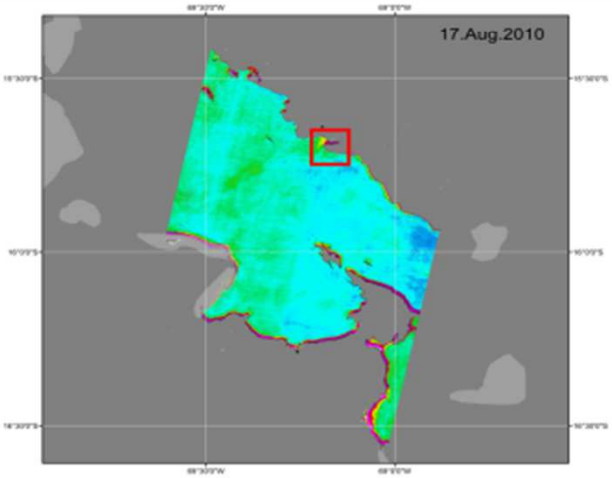







02.Aug.2010

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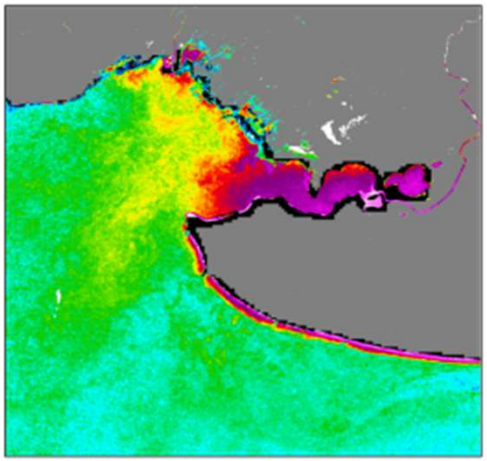
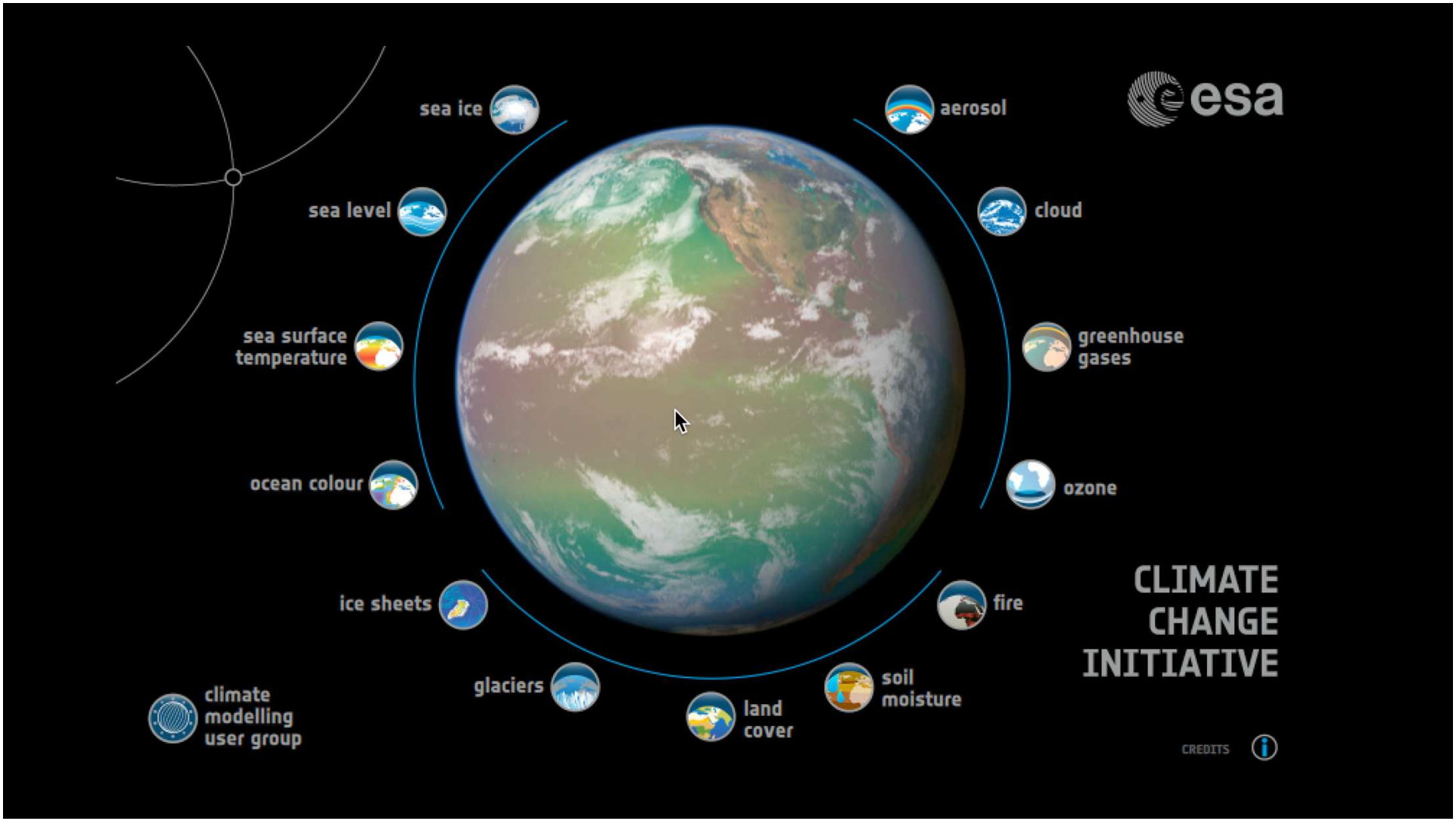


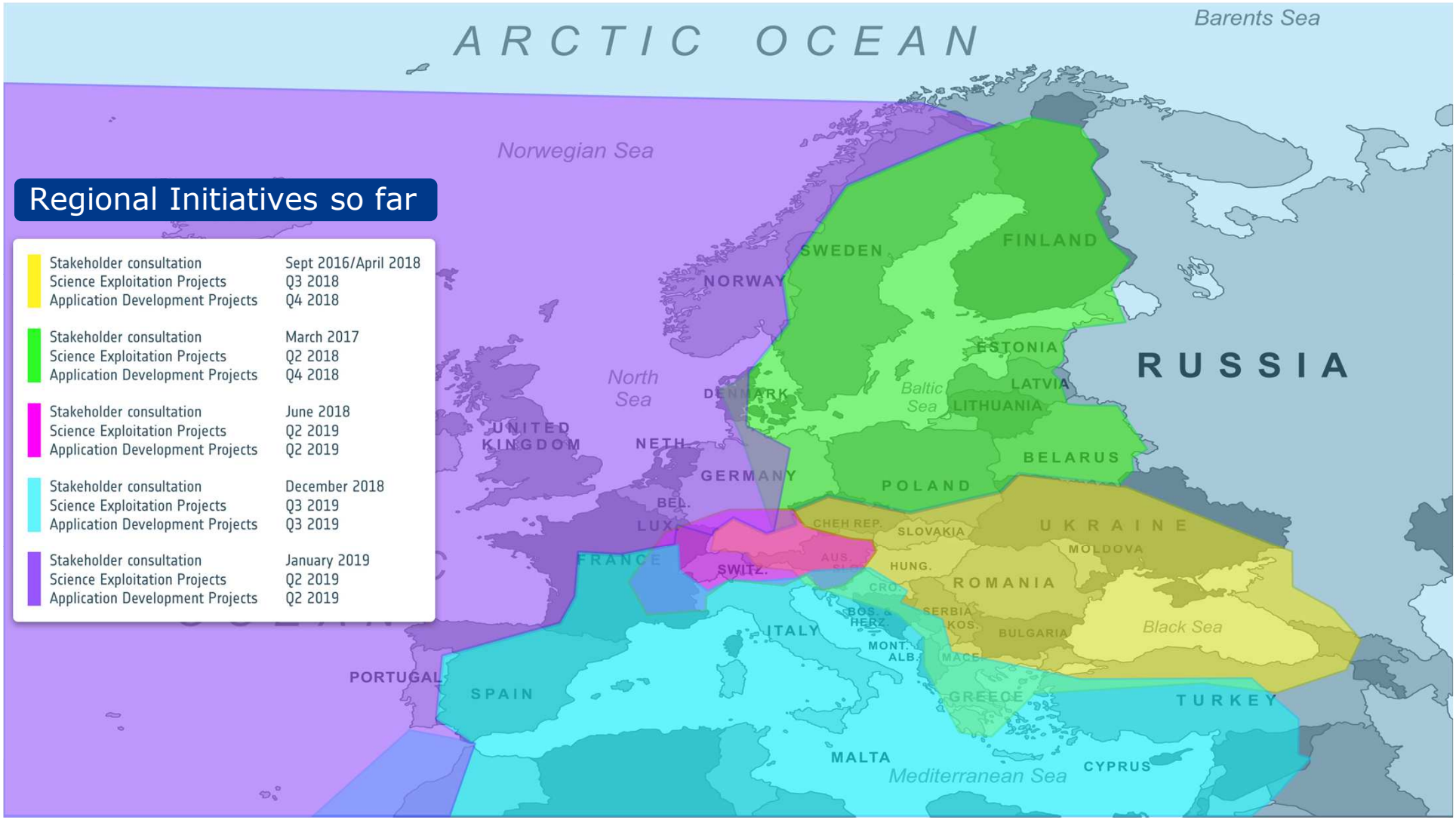

TSM
[mg/l]
33.
10.
3.
1.
0.3
0.1
Cloud
Land
No data


Rzeszów Centralny
Rzeszów
RZESZOW
519


esa
sea ice
aerosol
sea level
cloud
sea surface temperature
greenhouse gases
ocean colour
ozone
ice sheets
fire
glaciers
soil moisture
land cover
climate modelling user group
CLIMATE CHANGE INITIATIVE
CREDITS


1 NO POVERTY
2 NO HUNGER
3 GOOD HEALTH
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 RENEWABLE ENERGY
8 GOOD JOBS AND ECONOMIC GROWTH
9 INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE AND JUSTICE
17 PARTNERSHIPS FOR THE GOALS
THE GLOBAL GOALS
For Sustainable Development
European Space Agency


esa
EO for European Regions


Regional Initiatives so far
Stakeholder consultation Sept 2016/April 2018
Science Exploitation Projects Q3 2018
Application Development Projects Q4 2018
Stakeholder consultation March 2017
Science Exploitation Projects Q2 2018
Application Development Projects Q4 2018
Stakeholder consultation June 2018
Science Exploitation Projects Q2 2019
Application Development Projects Q2 2019
Stakeholder consultation December 2018
Science Exploitation Projects Q3 2019
Application Development Projects Q3 2019
Stakeholder consultation January 2019
Science Exploitation Projects Q2 2019
Application Development Projects Q2 2019
ARCTIC OCEAN
Barents Sea
Norwegian Sea
North Sea
Baltic Sea
Black Sea
Mediterranean Sea
RUSSIA
FINLAND
SWEDEN
NORWAY
ESTONIA
LATVIA
LITHUANIA
BELARUS
POLAND
DENMARK
UNITED KINGDOM
NETH.
GERMANY
BEL.
LUX.
FRANCE
SWITZ.
AUS.
CZECH REP.
SLOVAKIA
HUNG.
UKRAINE
MOLDOVA
ROMANIA
CRO.
BOS. & HERZ.
SERBIA
KOS.
BULGARIA
MONT.
ALB.
MACE.
GREECE
TURKEY
ITALY
PORTUGAL
SPAIN
MALTA
CYPRUS

Regional Initiatives: overview

Objectives

Concrete embedding of EO capabilities within regional Earth science programmes, regional environmental protection agreements and regional sustainable development strategies

In each region:

- Connect innovative EO R&D, application and service developments with the required underlying customized platform and processing capabilities
- Augment connectivity between EO and conventional Earth science, environmental protection and natural resources management practices

Scope - separate but coordinated actions for each region:

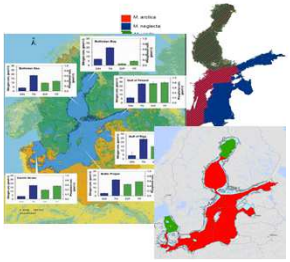
Project Office:
stakeholder engagement, communication and planning

Science projects
connect with regional Science programmes

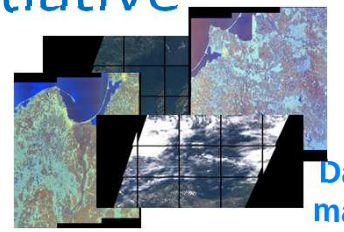
Application projects
Integrate EO in ecosystem assessment & sustainable growth

Customized platform and processing resources

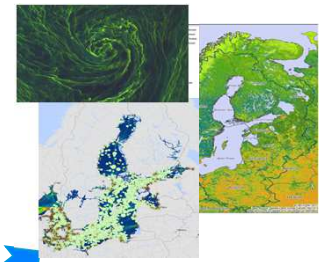
Baltic Regional Initiative



Support to National & Regional Monitoring/ Reporting

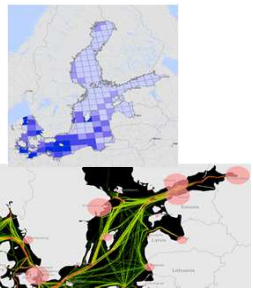


Data access, management & processing

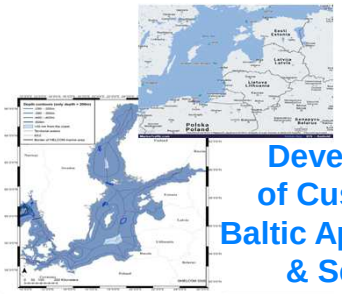


Routine Monitoring & Analysis/ Reference Datasets

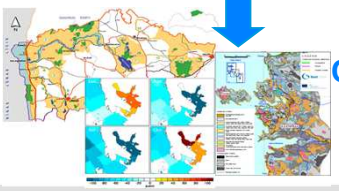
Communication, Education and Citizen Engagement



Support to Baltic Management Actions/Plans



Development of Customized Baltic Applications & Services

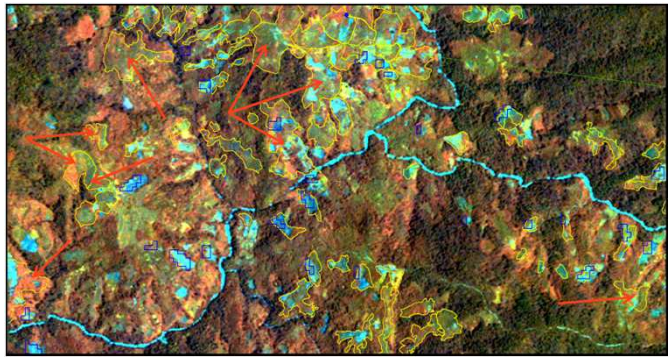


Support to Cooperative Baltic Research

Support to Regional Baltic Initiatives/networks

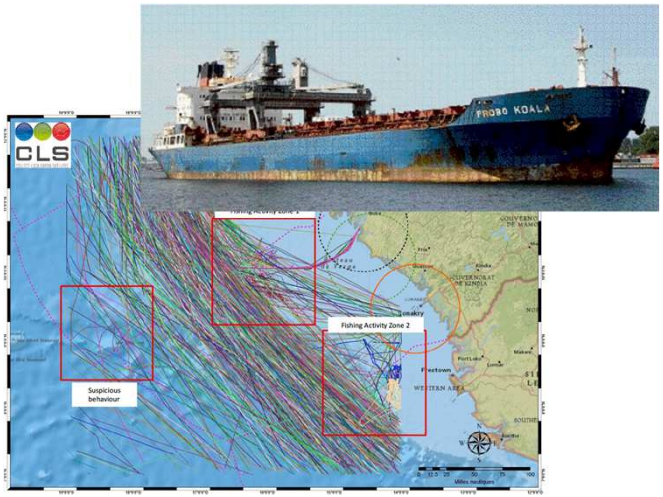

esa
EO for security and law enforcement

Security and Law enforcement

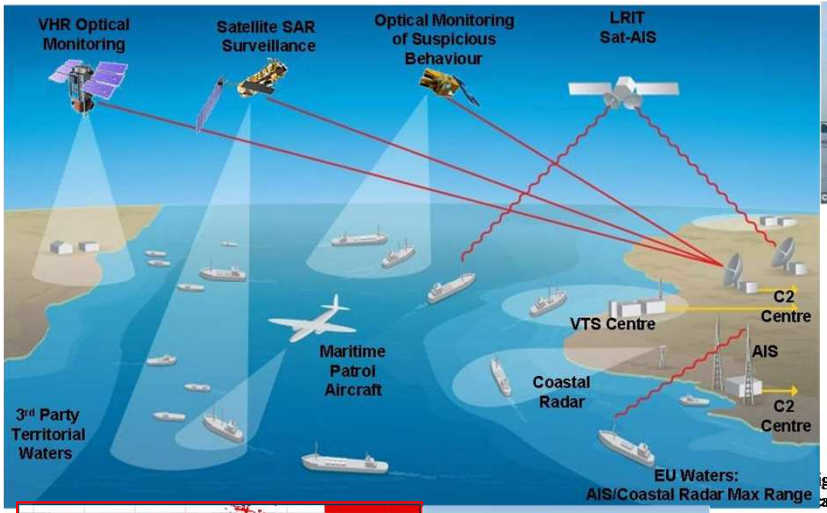


Use of civilian systems means:

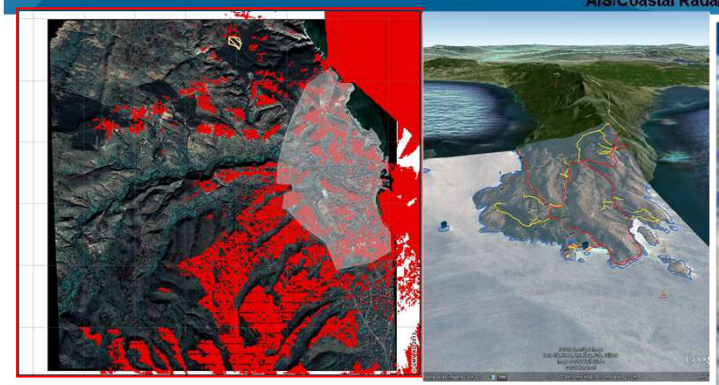
- Information is open source
- Information is shareable
- Data are traceable

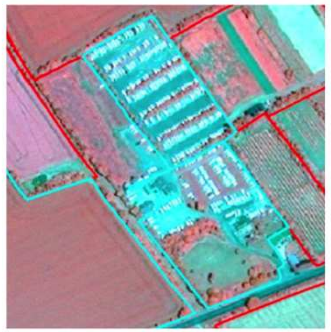


Security and Law Enforcement – operational capabilities



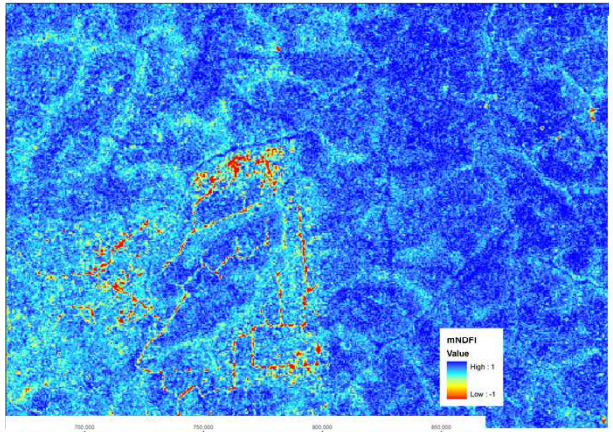
igure 1: a) and b) Rendez-vous between ships observed by SAR. c) a
ale and zoomed)

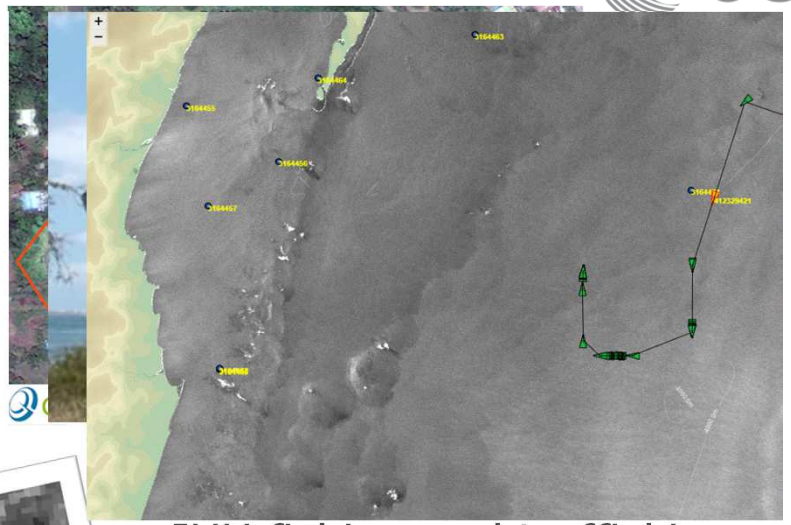


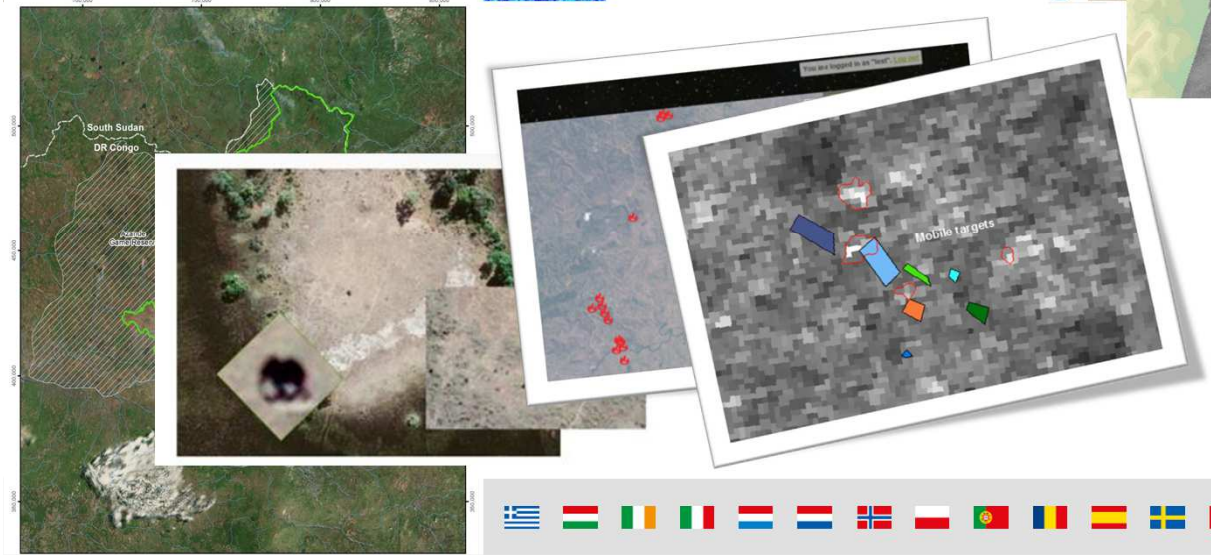


European Space Agency

Security and law enforcement – environmental crime







IUU fishing and trafficking
Ivory poaching and trafficking
Timber poaching and trafficking
Wildlife trafficking
Waste trafficking and dumping
Illegal/illicit mining

Security and law enforcement – crimes against humanity

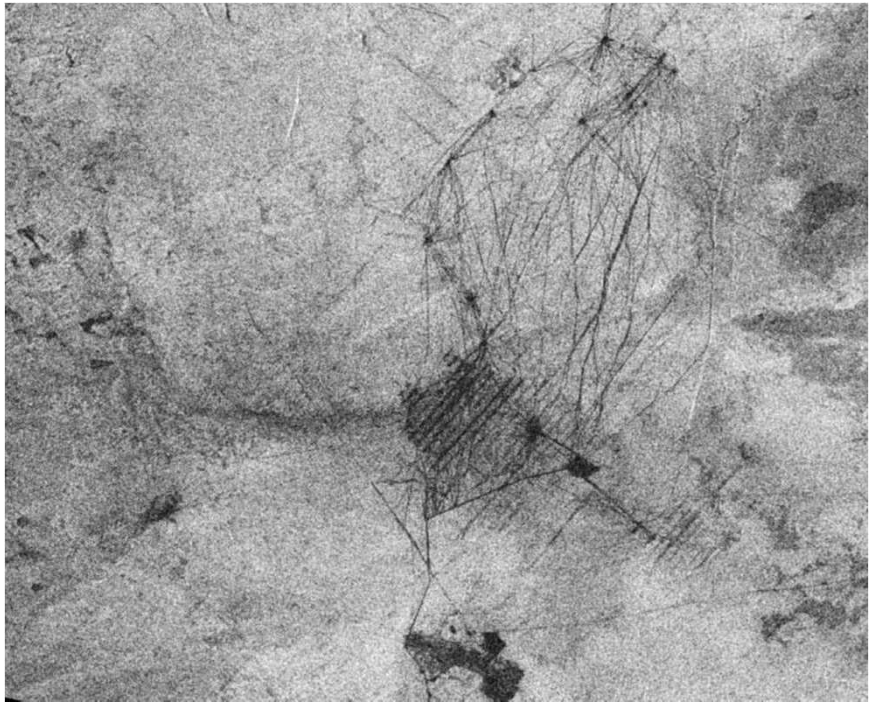
War crimes

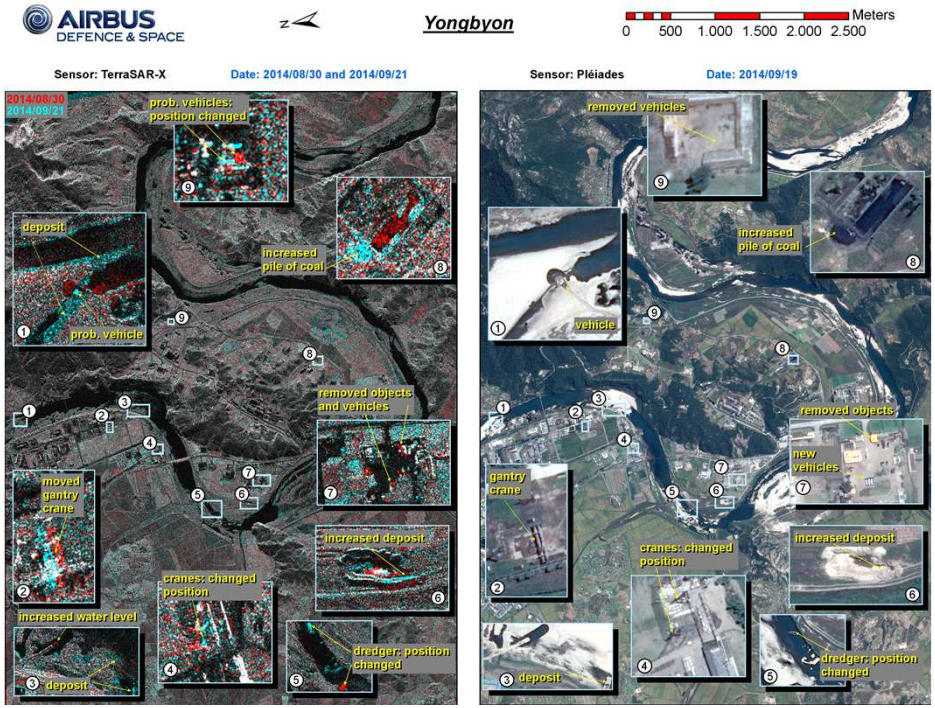
Ethnic cleansing

State involvement in irregular conflict

Violence against minorities

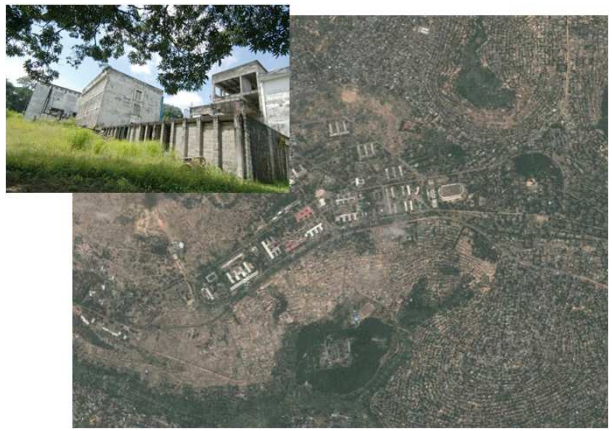
Security and law enforcement – counter-proliferation





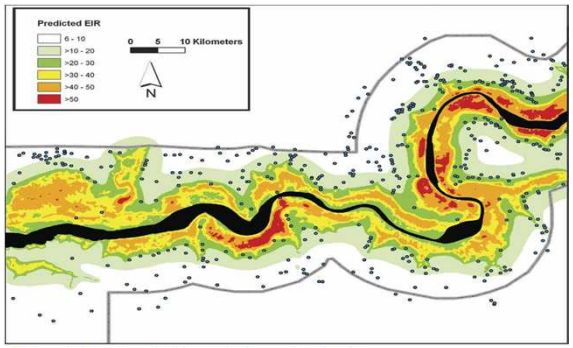
- Unlicensed/irregular materials production
- Unlicensed/irregular facility operations
- Unlicensed/irregular trafficking of controlled materials
- Facility safety against non-state actors
- Use of WMD

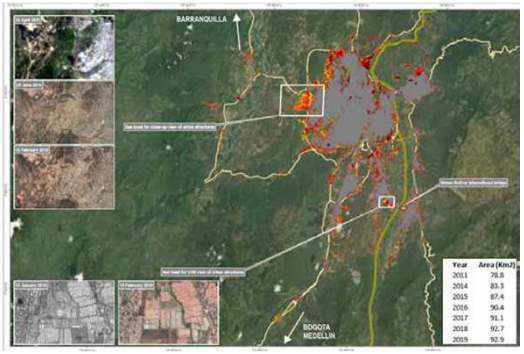
Security and law enforcement – terrorism/organized crime



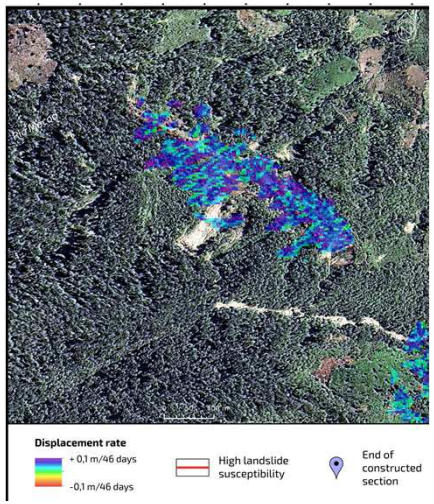
Weapons trafficking
Safety of critical facilities
Irregular fighters training camps
Returning FTFs

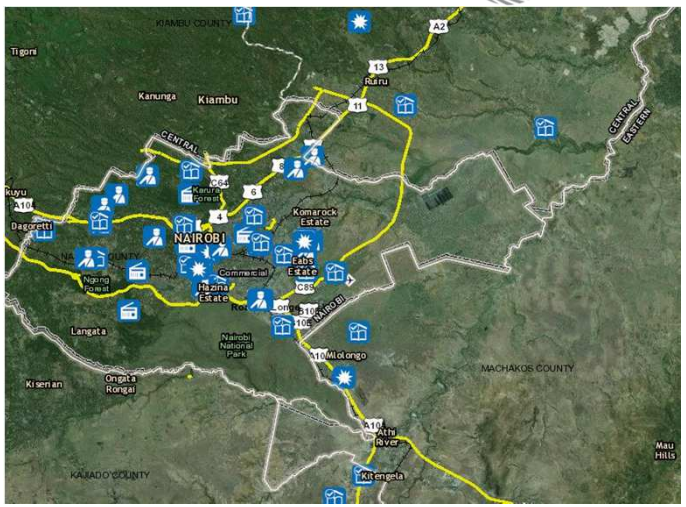
Security and law enforcement – fragility, conflict & violence





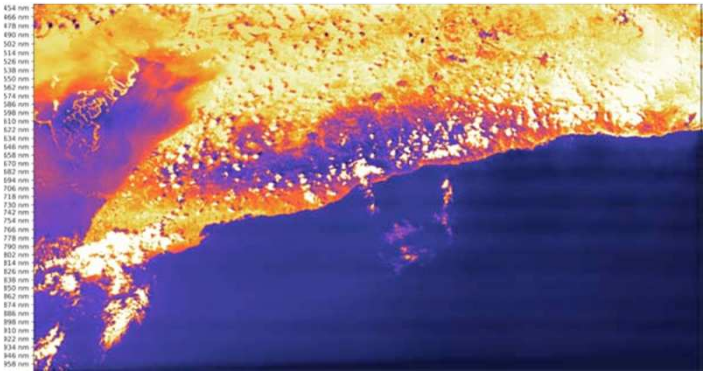
Colombia - landslide risk characterization



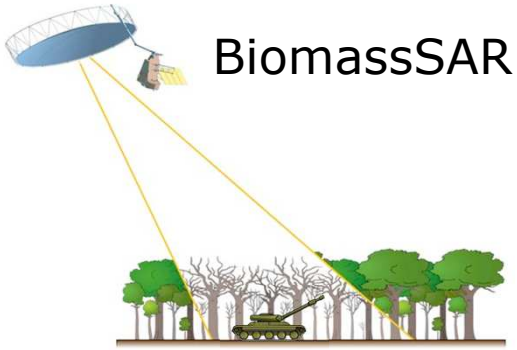


Natural resources management
Environmental Protection
Post conflict reconstruction support
Justice and rule of law
Onset of violence precursors
Epidemic prevention

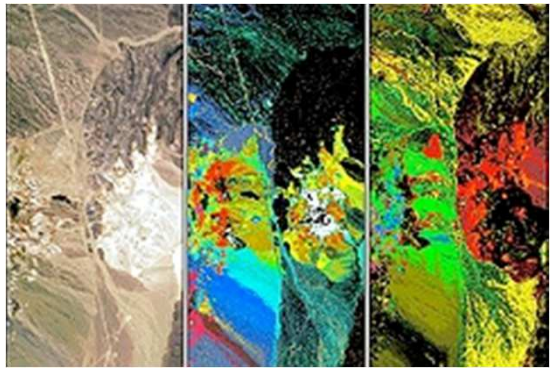
Security and law enforcement – new EO data sources



HyperScout

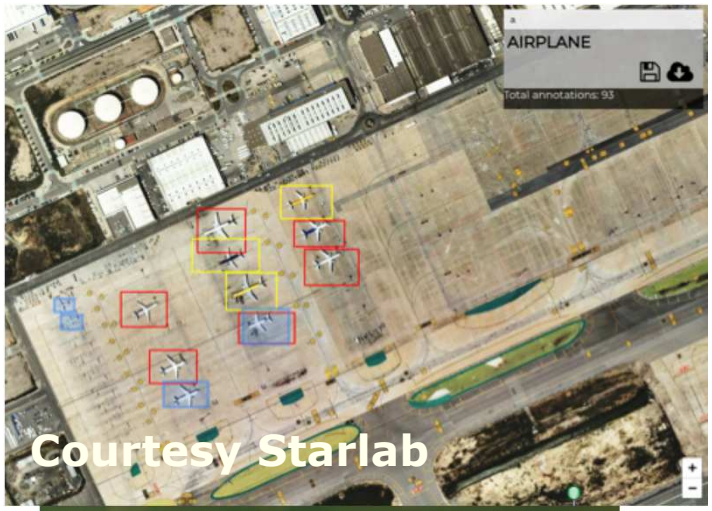


BiomassSAR



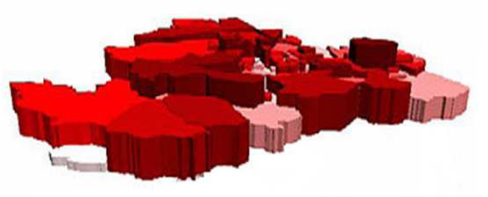
Prisma

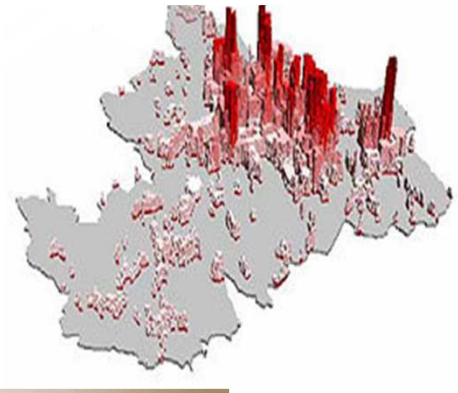
Security and law enforcement – new AI capabilities

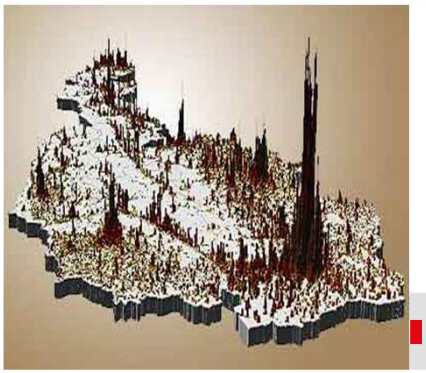


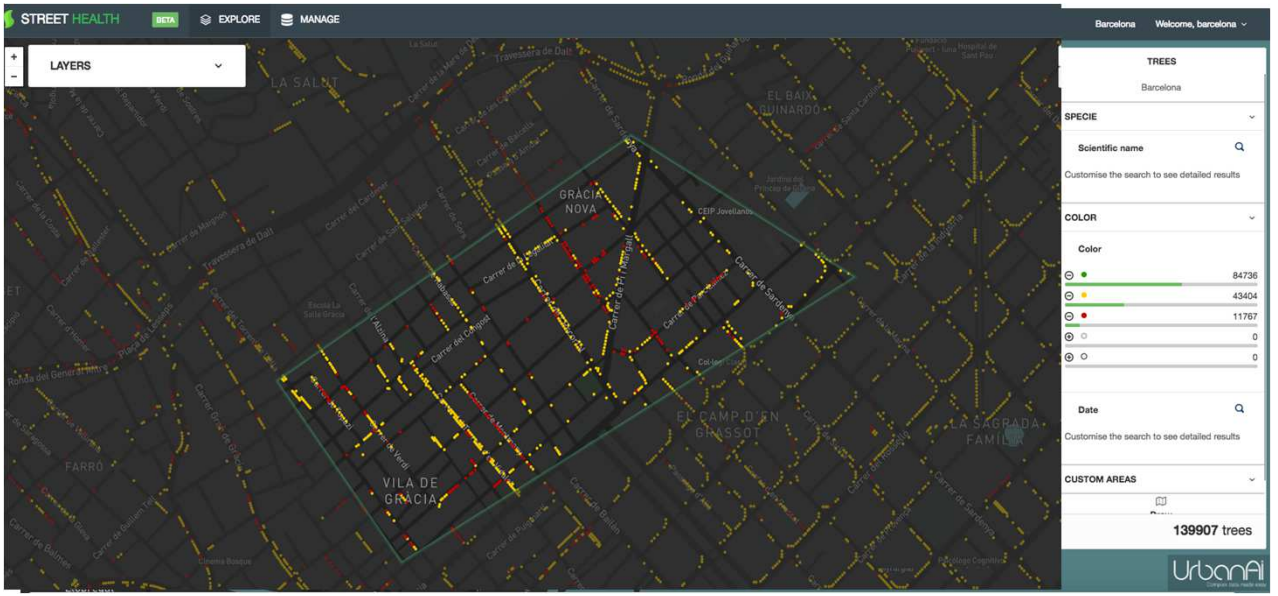

esa
EO services –
Enabling industrial growth

Geomarketing and urban information

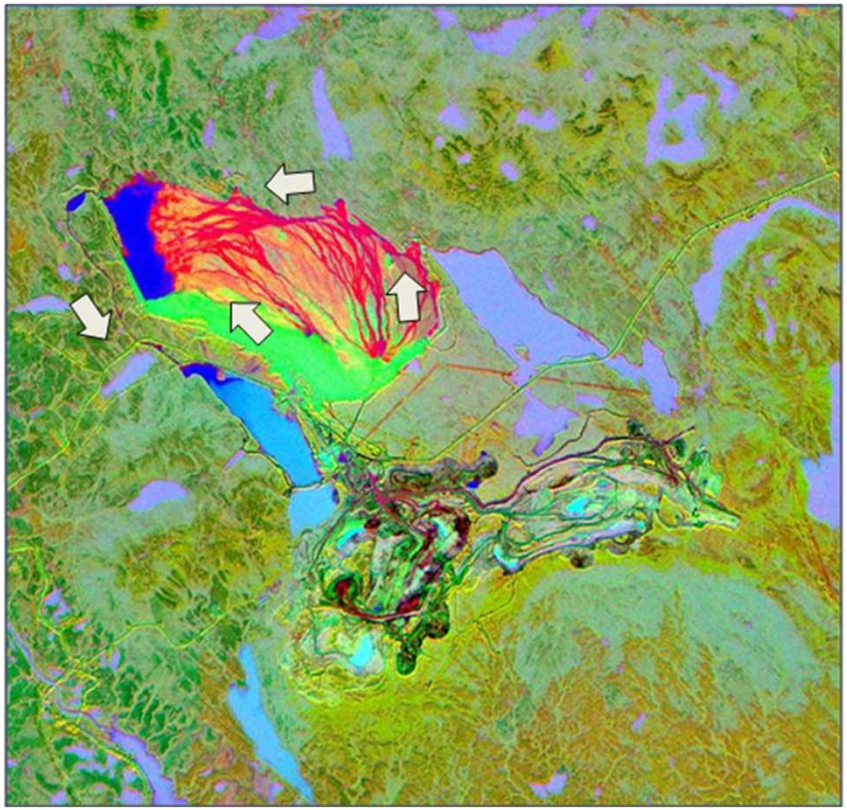




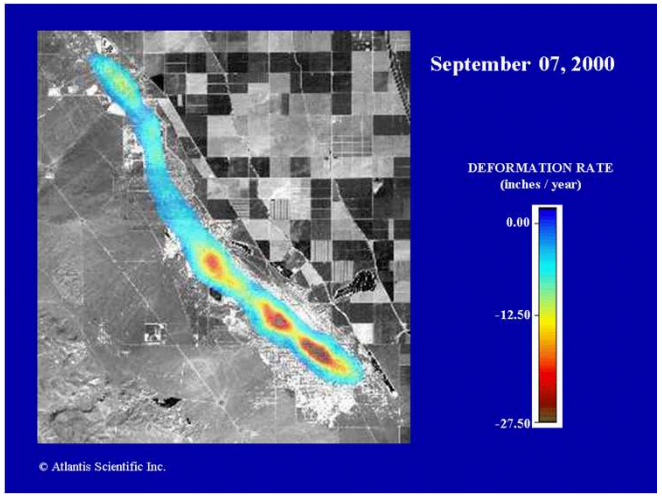




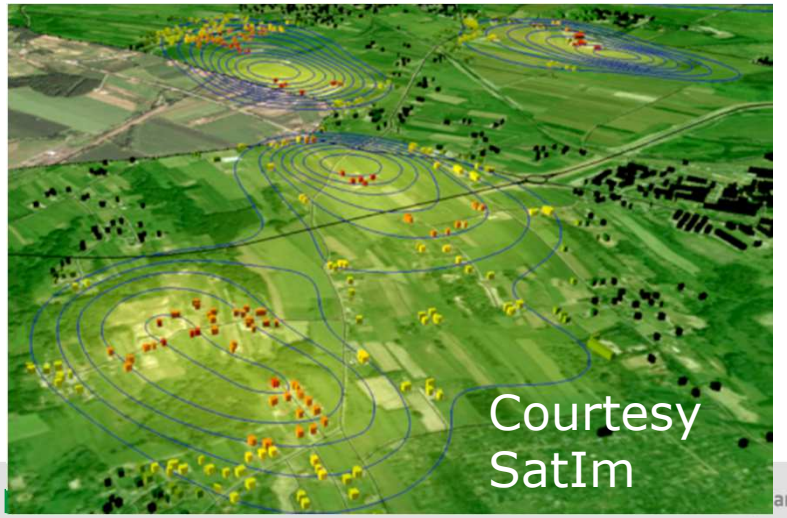
Extractives management



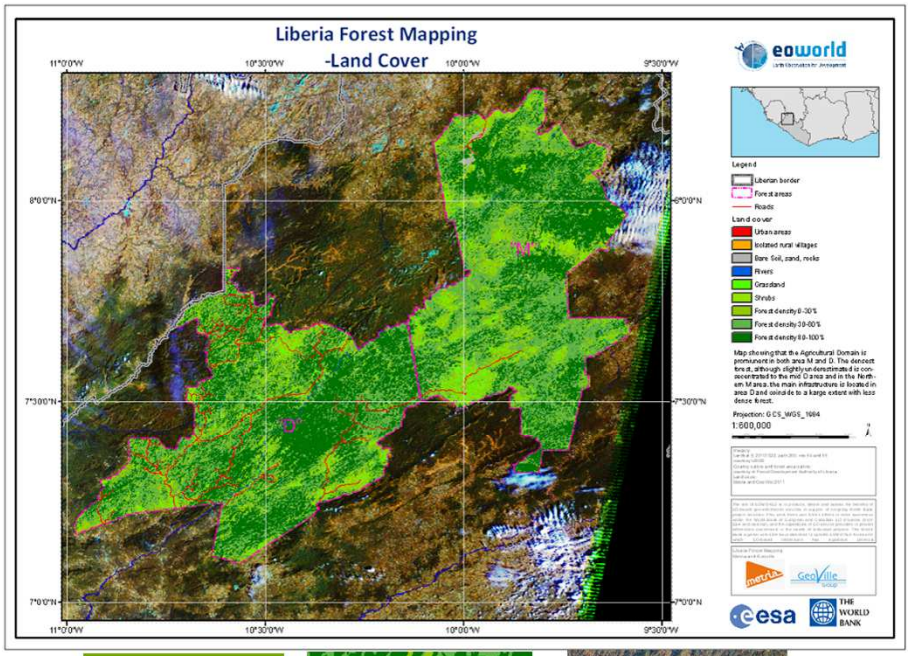
Courtesy EffeGIS

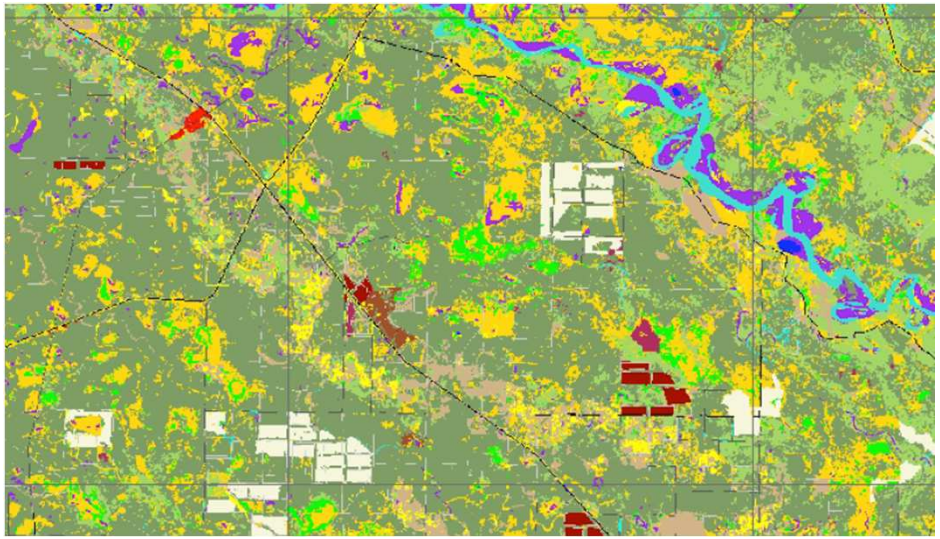


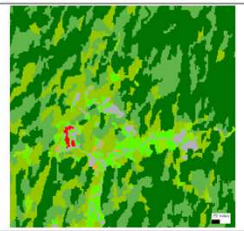
Courtesy Atlantis Scientific

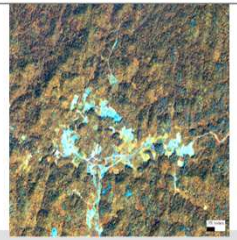


Renewable resources management

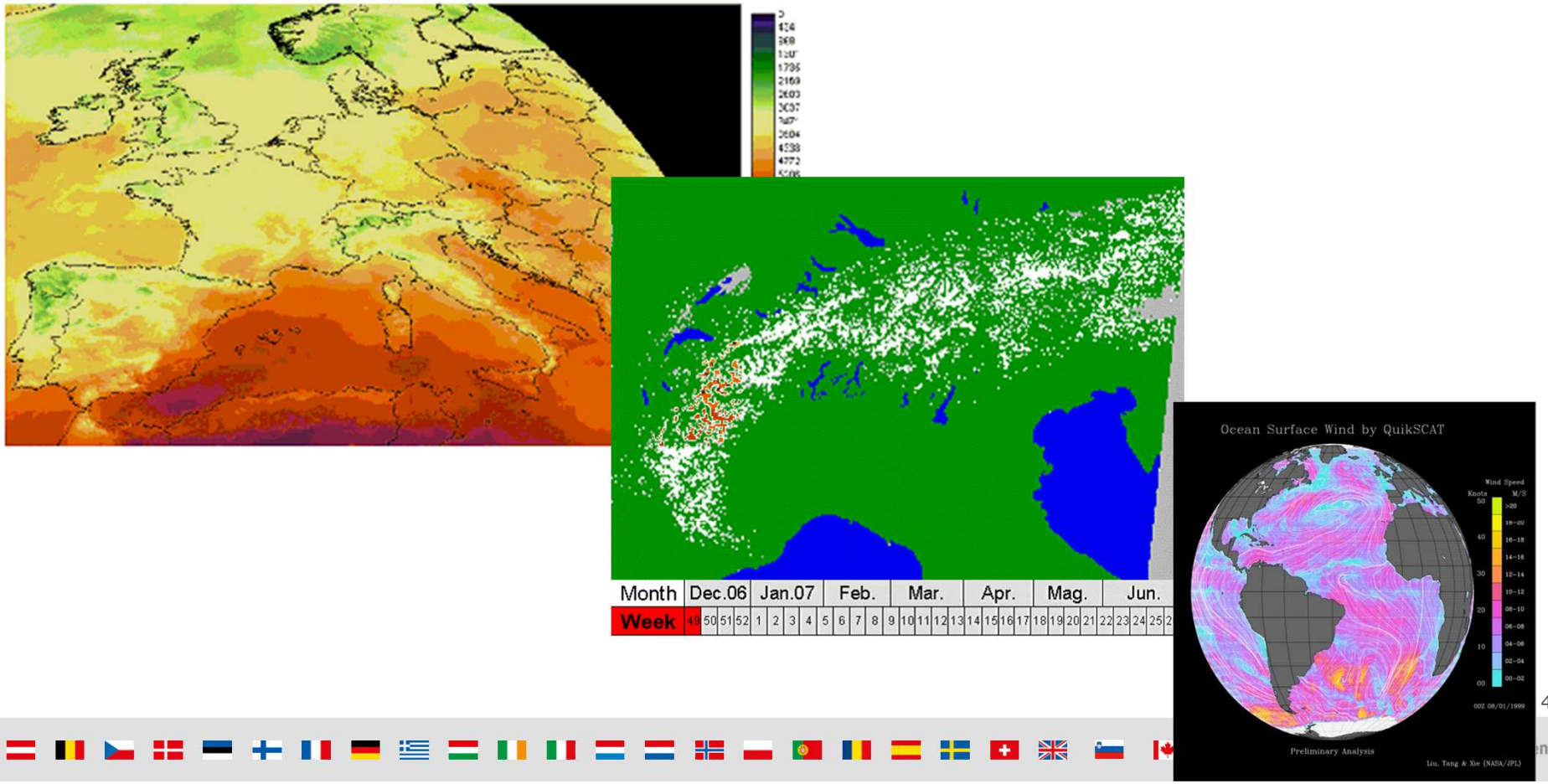




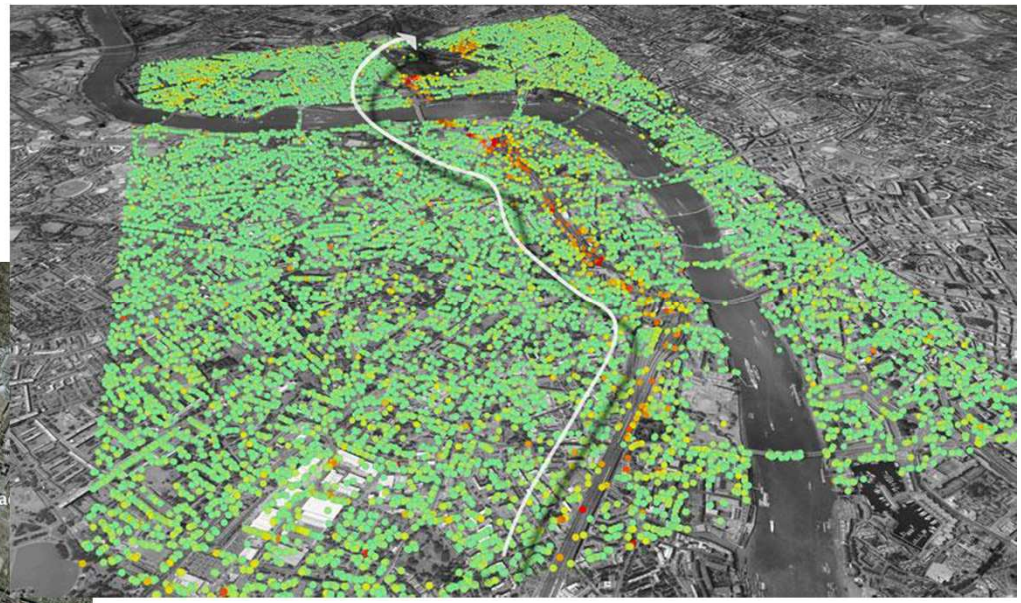




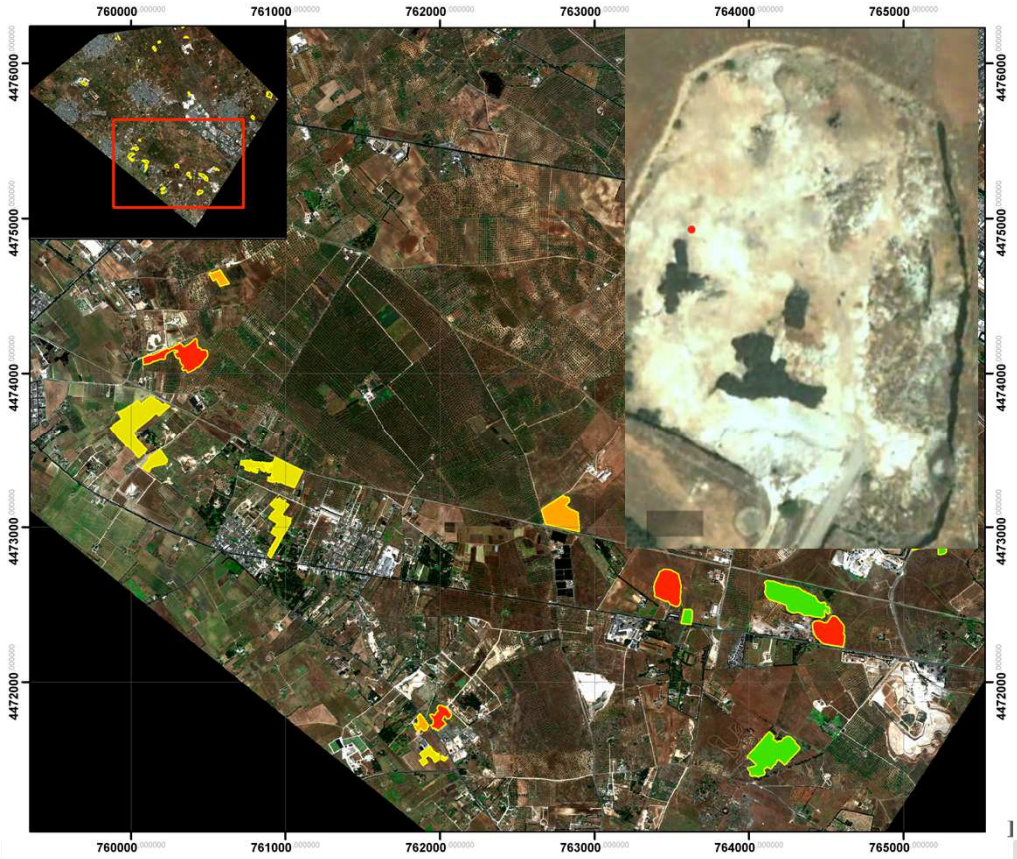
Renewable energy

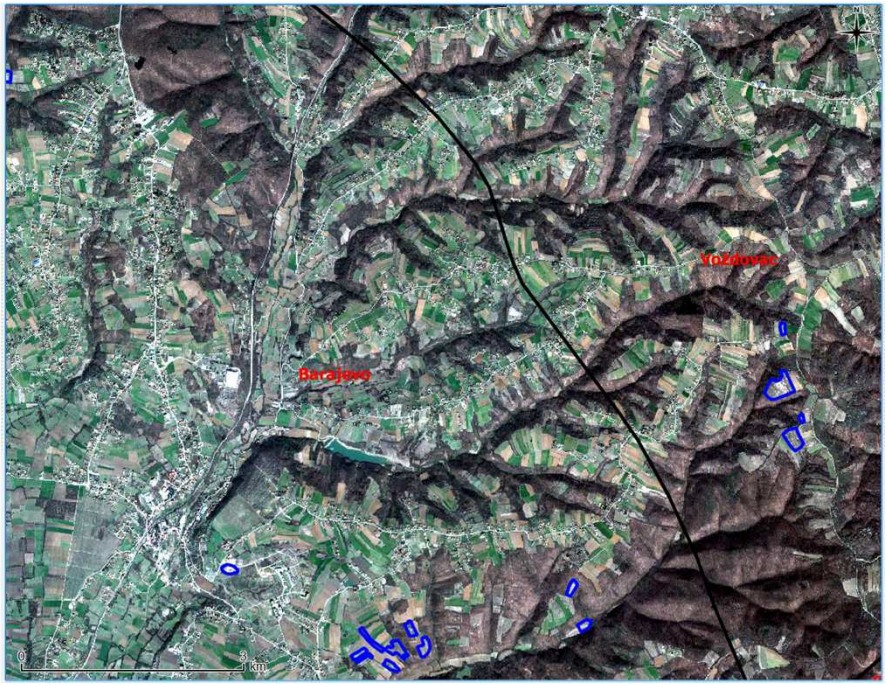


Insurance and risk management

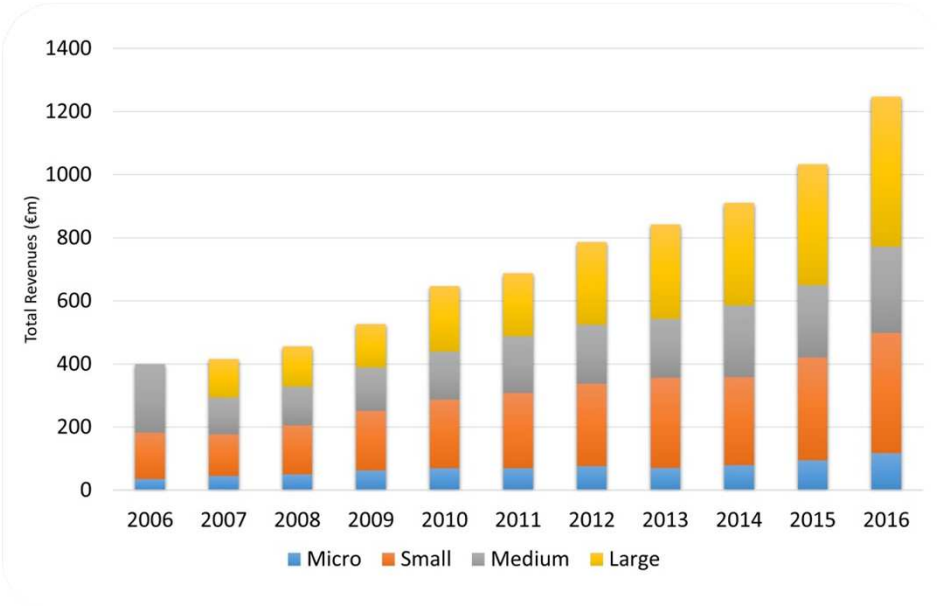


Increasing business –waste management support



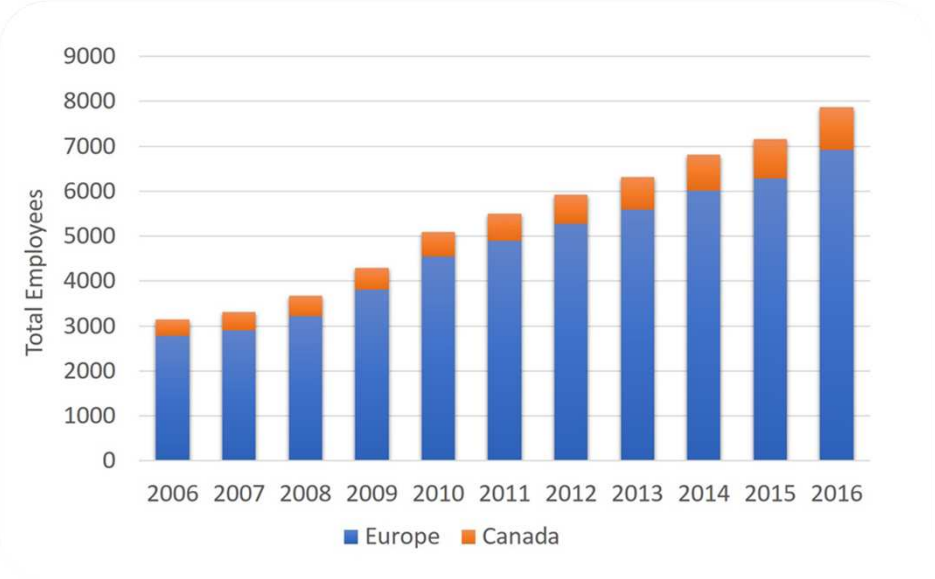


EO market development



European & Canadian EO Service Companies Revenue growth

(EARSC, 2017)



European & Canadian EO Service company employment growth

(EARSC, 2017)

EOEP Block 4 dashboard

INNOVATION

Number of contracts with	science	applications	industry
new capability	87	19	36
expanded application	18	20	82
study/support development	48	2	18

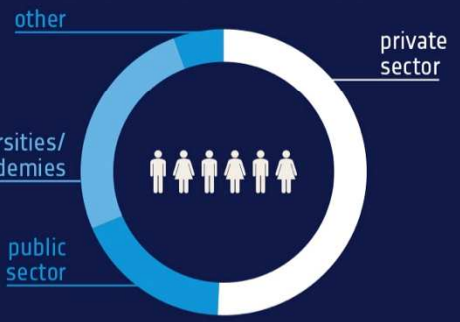
43%
of EOEP contract address innovative new developments

On average, **24** contracts per year are placed under the Permanently Open Call

EMERGING MARKETS ENABLED BY EOEP

developing sector	estimated value [Bn €]
Agro-Insurance	17
Agro-chemicals	239
payment for Ecosystem Services	35
Renewable Energy	280

WHO WE WORK WITH



WHERE WE WORK

ENHANCED PORTFOLIO

Application performance improvement:

information content	1.5 - 4
update times	2 - 10
cost per hectare	2 - 5
spatial resolution/scale	10 - 30

FOCUS ON SMEs

40% of industrial contractors are SMEs

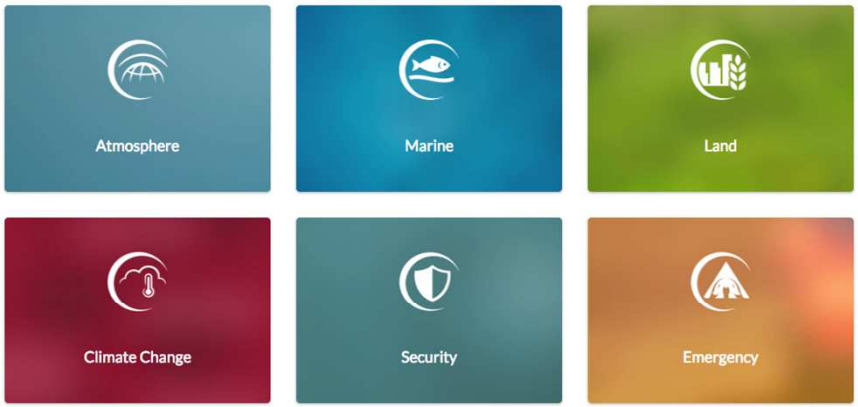
64% of all industrial spend with SMEs

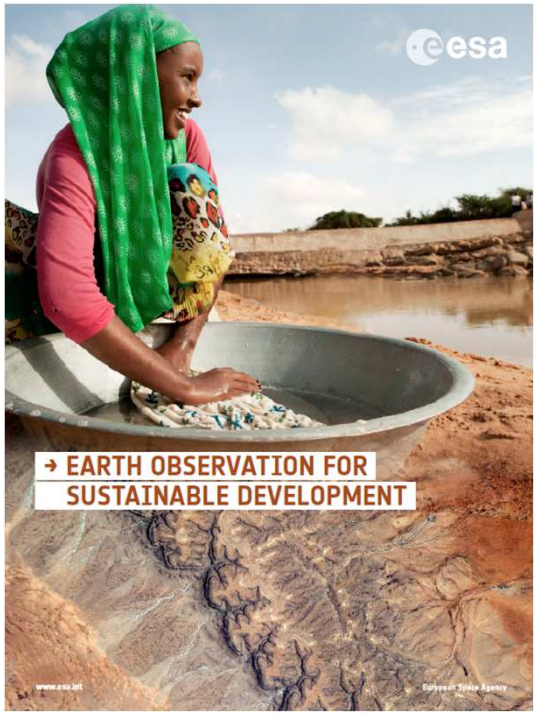
since 2013	science	applicat.	industry growth
No. of contracts involving SMEs	95	37	225
Contract spend with SMEs [M€]	7.7	5.1	23.5
Industrial spend with SMEs	67%	71%	75%
Industrial spend with SMEs	25%	27%	63%

PARTNERSHIPS

since 2013	Contract Value	
	>250 k€	>400 k€
average number of countries involved per contract	3.4	4.1
average number of partners involved per contract	4.7	5.9

Outcomes – what happens after ESA EO projects?





OGP International Association of Oil & Gas Producers

PERILS
Excellence in Insurance Industry Benchmarks

THE WORLD BANK

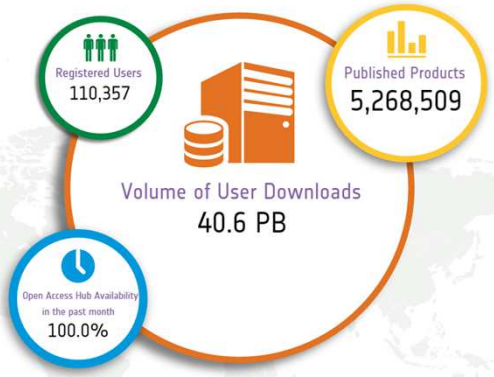
IFAD

ADB

IDB
Inter-American Development Bank

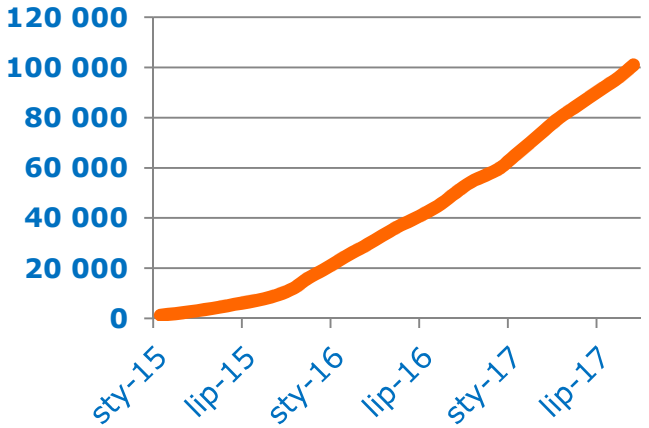
gef GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

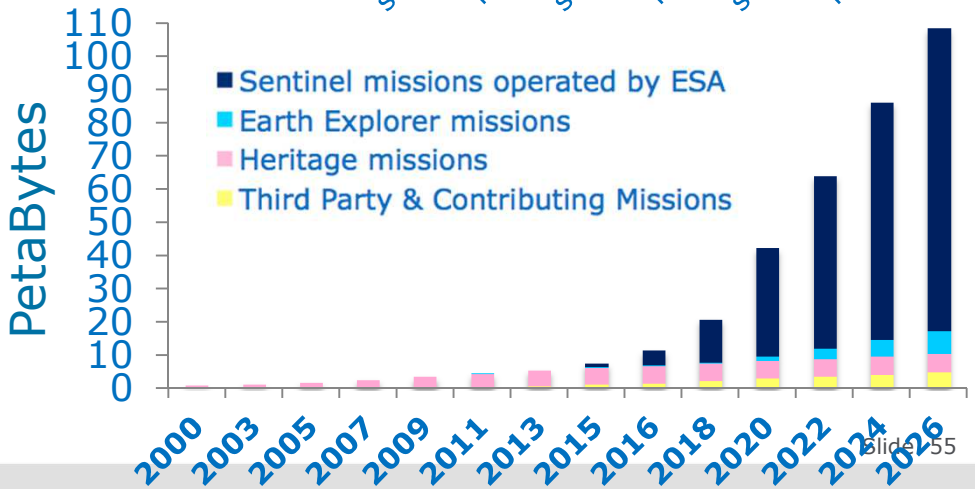
Booming Statistics

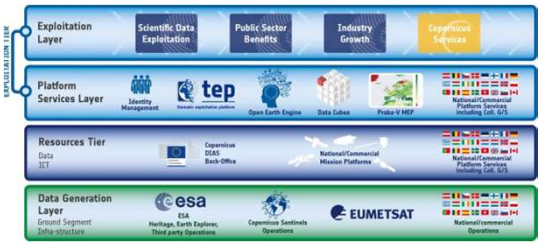


Copernicus Data Statistics
4 Dec. 2017

Sentinel Registered Users



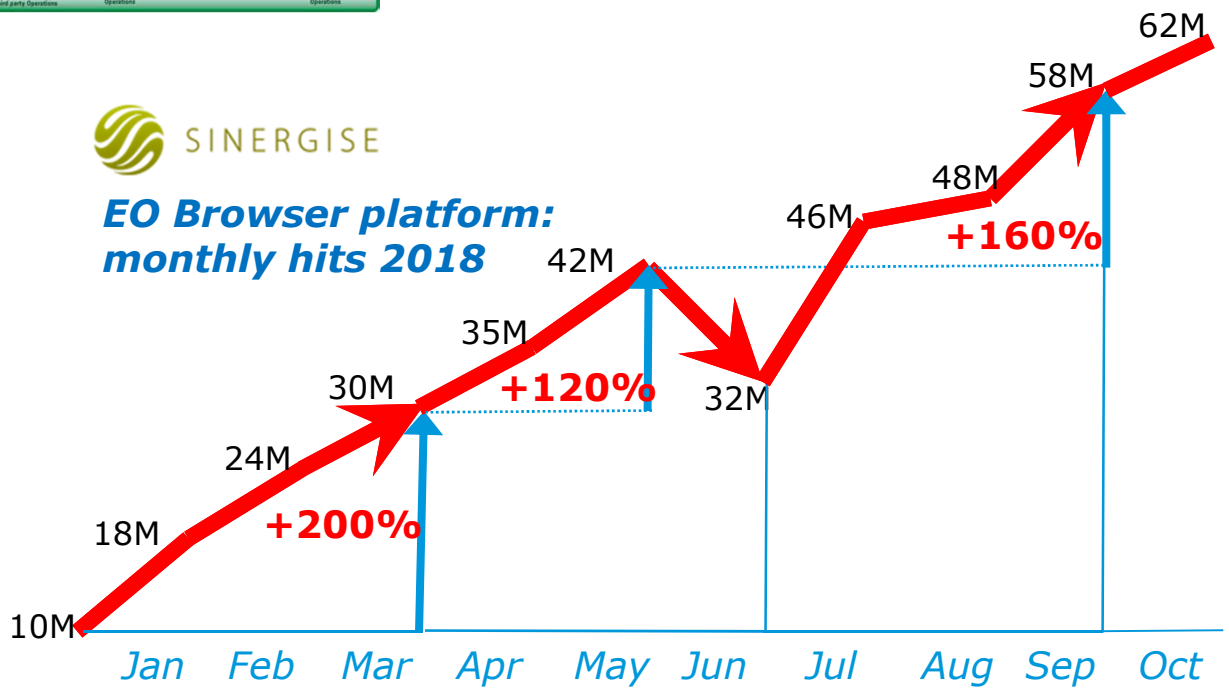




Can European Industry compete in the "hit-based" Digital Platform Ecosystem ?

SINERGISE

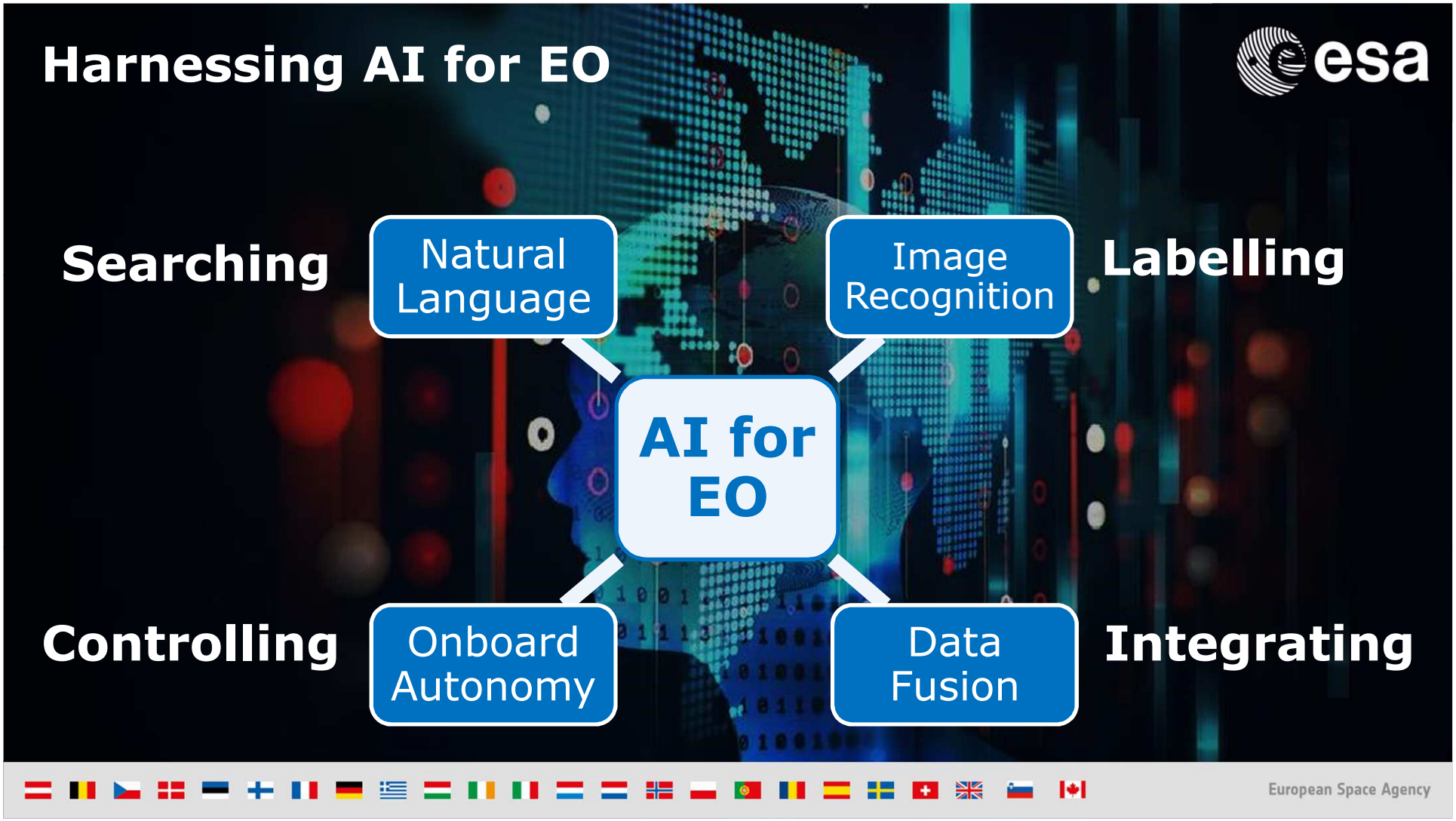
EO Browser platform: monthly hits 2018



>20.000 active users each month

a global success


esa
Embracing AI and Big Data and NewSpace


Harnessing AI for EO
esa
Searching
Natural Language
Image Recognition
Labelling
AI for EO
Controlling
Onboard Autonomy
Data Fusion
Integrating
European Space Agency

Some questions we are addressing

1. (science) How can AI and Big Data developments foster new/improved understanding of Earth system processes, their interaction, their responses to anthropogenic forcing (and the consequences for us)?
2. (applications) What are the new applications or the improved analyses made possible with AI and Big Data Developments?
3. (industry) how are the AI/Big data developments enabling enhanced fusion of spatial information with mainstream commercial information services, what opportunities does this create for Europe and what developments should ESA be supporting?
4. (industry) how does the increased use of mainstream AI/big data/ICT in EO result in EO being just another dataset and what industrial opportunities does this create?
5. How can AI and new ICT capabilities enhance data collection and data fusion to support the responses to the above?

Moving with the times – evolution in science

Experimental

Last Millennia

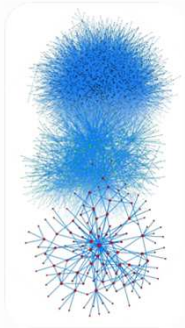
Observation and Description of Natural Phenomena

$$F = \frac{GM_1M_2}{r^2}$$

Theoretical

1600 - ...

Newton's laws, Maxwell's equations



Computational

Last Decades

Simulation of Complex Phenomena

Data Intensive

Now & Future

Unify theory, experiment & simulation with multidisciplinary data & distributed communities

Big Data

Volume

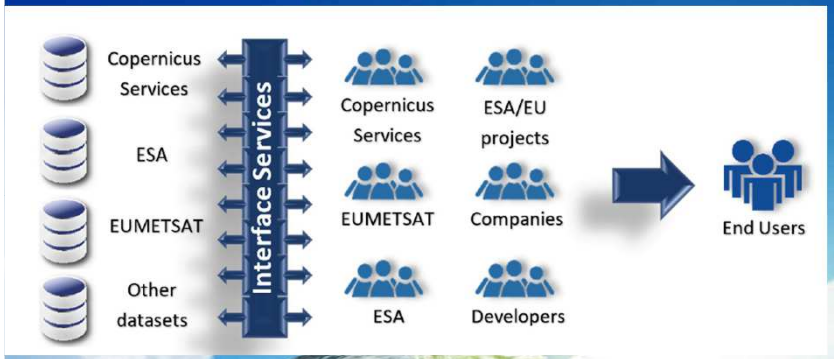
Velocity

Variety

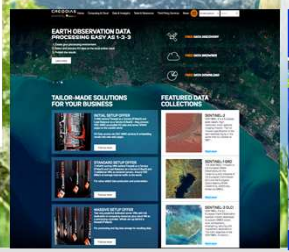
Veracity

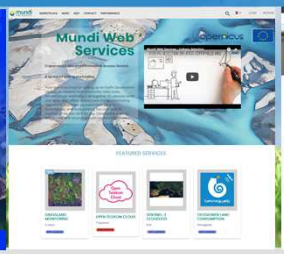
Value

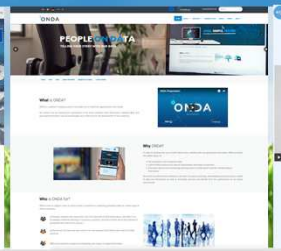
DIAS – Creating an EO Data Ecosystem



- Copernicus **D**ata and **I**nformation **A**ccess **S**ervices
- Common DG-GROW-ESA approach to EO data exploitation with Copernicus at its core
- Create & enable European EO Data ecosystem for research & business
- Starts in June 2018

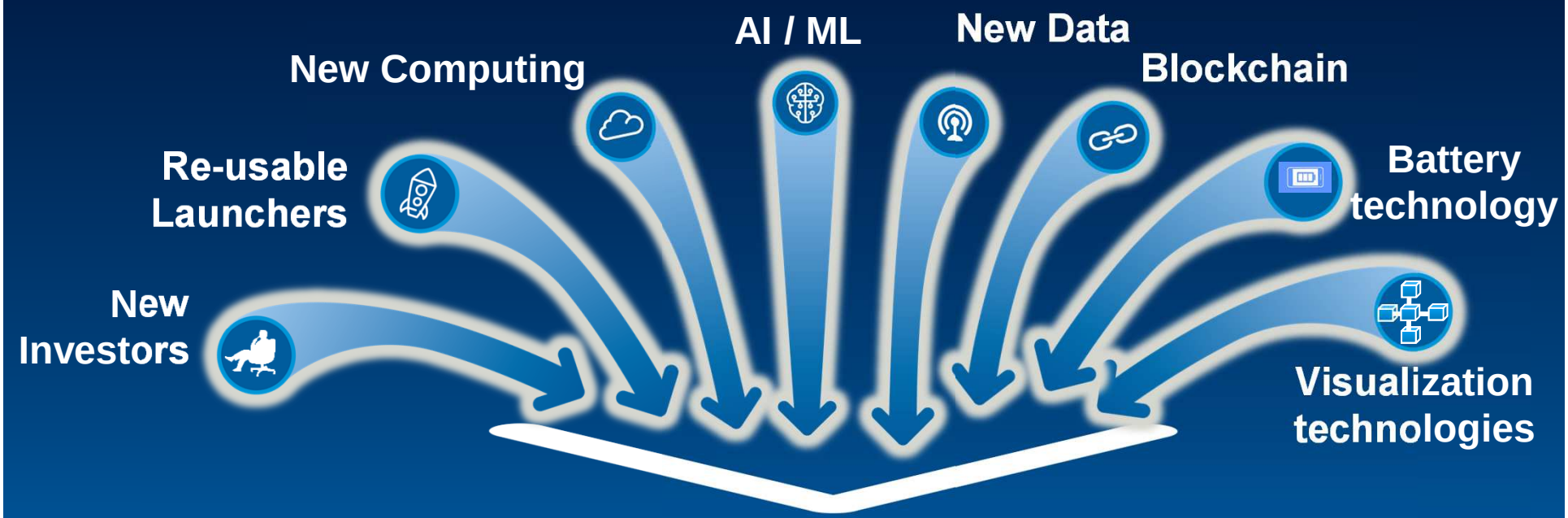







Earth Explorers
esa
cryosat
swarm
smos
goce
Meteo Sat.
msg
metop
mtg-i
metop-sg-b
earthcare
biomass
flex
Sentinels
sentinel-1
sentinel-2
sentinel-3
sentinel-4
sentinel-5
sentinel-5p
sentinel-6
Small Sat Constellations
HAPS
Drones
HAPS
Drones
IoT
IoT
IoT
European Space Agency

External developments to build on



NewSpace industry that is:
- innovative
- World leading
- Sustainable

Opening up opportunity for European SMEs

Global Geospatial Analytics Market

US$ 72.21 Bn by 2020

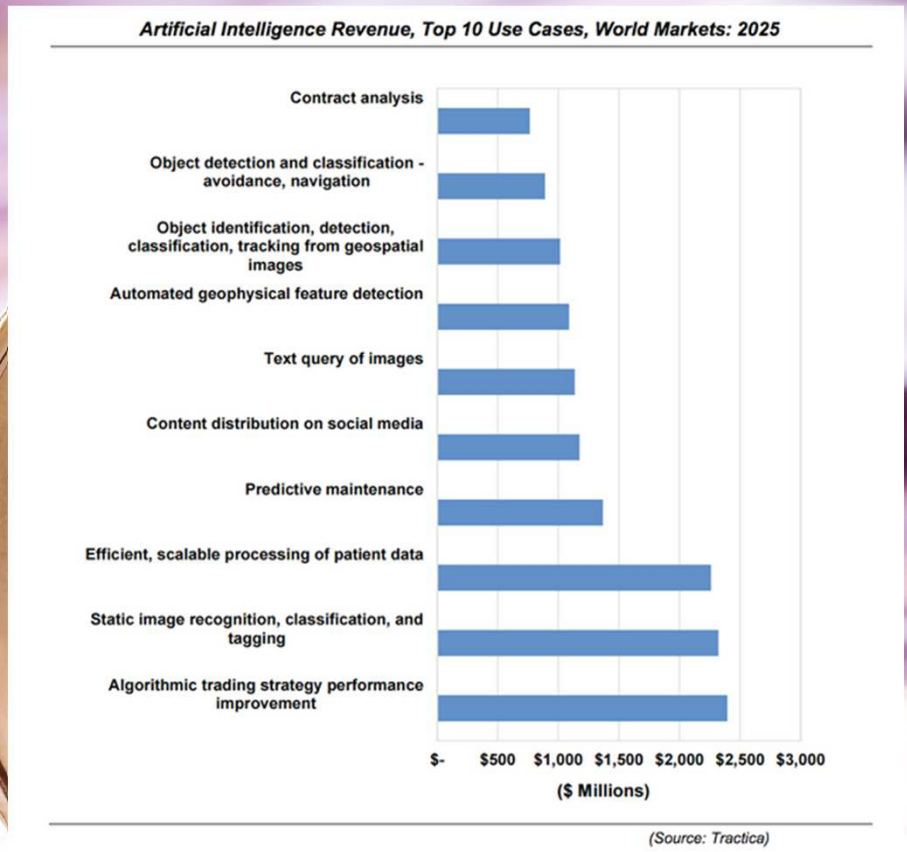
→ 3x increase in 5 years
Research and Markets, 2016

Global revenue from direct & indirect application of AI

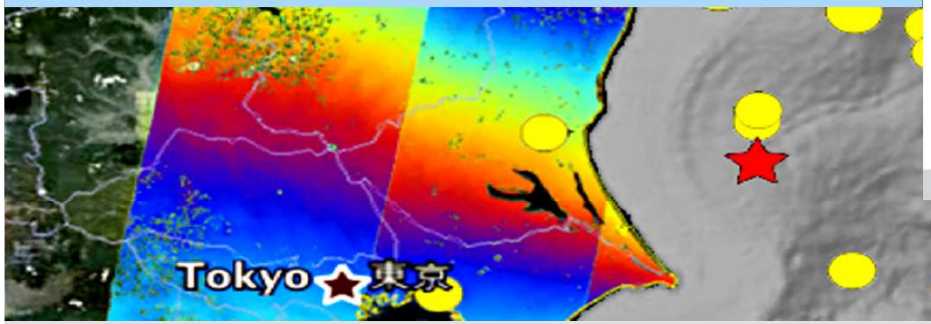
US$36.8Bn by 2025

CAGR of 56.8%.
(Tractica)

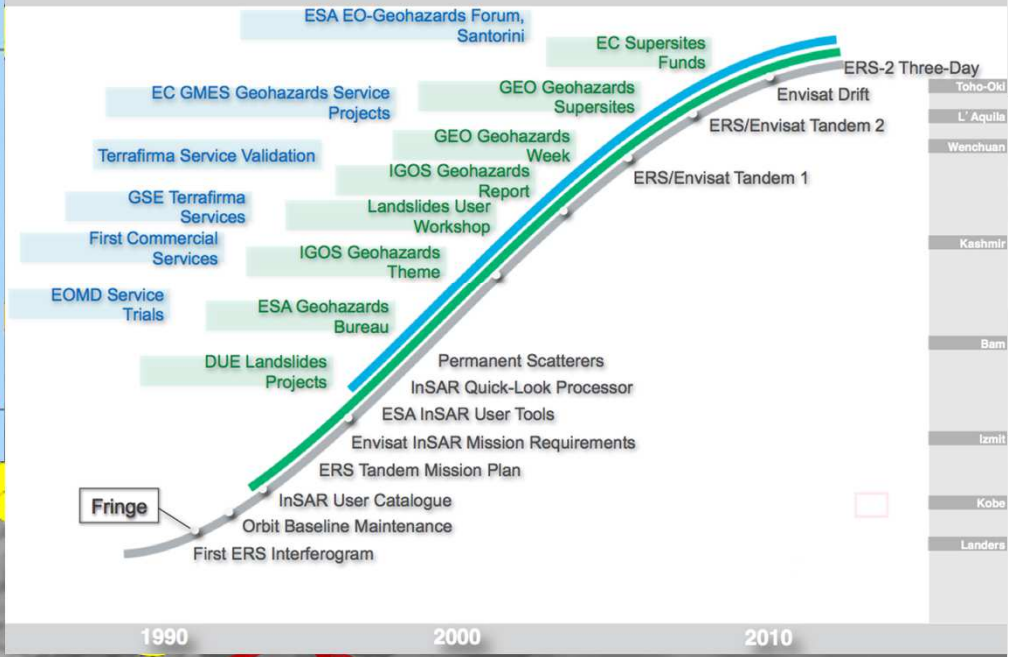
"Over 2000 EO smallsats expected by 2026"



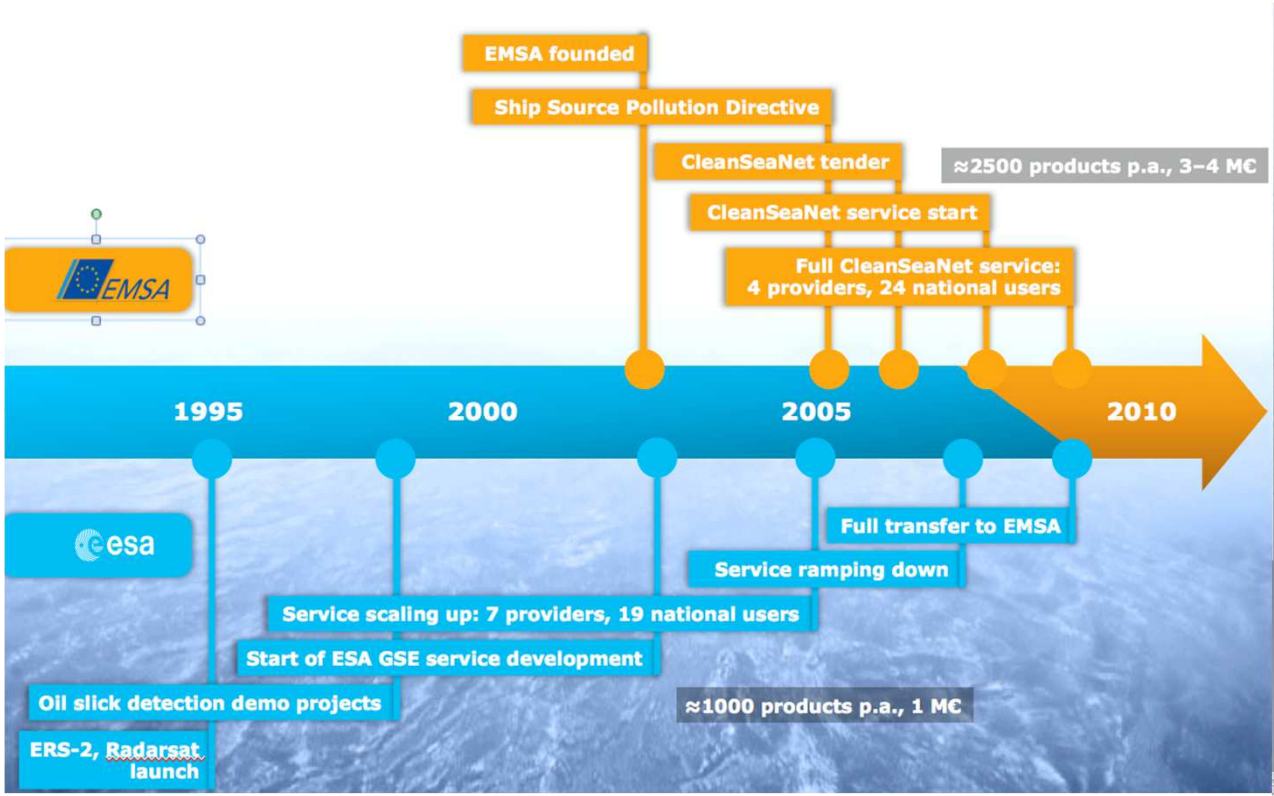
No easy answers, no magic solutions



Science ➔ Applications ➔ Services



And even when it goes to plan there are difficulties...

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Moving forward together:
Future EO

FutureEO – Structured around 4 Blocks

Future Flagships & Systems

1. Foundations, Concepts & Technology

2. Research Missions

FORUM or SKIM

Operation & Exploitation

3. Mission Management

4. Earth Science for Society

FutureEO – 21st Century Innovation

Hardware & Technology

Big & Small

HAPS

Operations

Increased Data Diversity & Volumes

BIG DATA

EO AFRICA

21st Century EO

Software & Applications

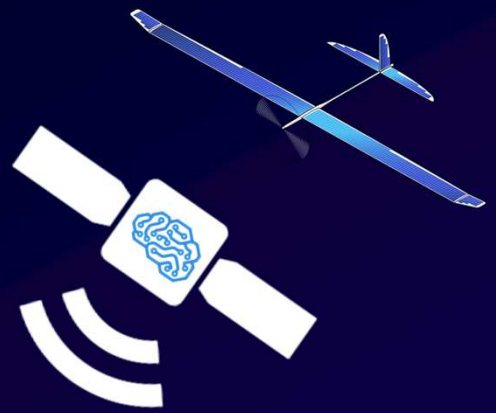
Machine Learning

Artificial Intelligence
Data Analytics
Internet of Things

Cloud Computing

Block 1 – Foundations, Concepts and Technology

End-to-end preparation of EO missions – incl. tech developments and science activities to raise TRL/SRL and mitigate risks



- Call for Innovative Early (Mission) Concepts
- Early phases of EE-11, Sentinel-1/2/3-topo/3-opt NG, future Meteo Missions, Mission of Opportunity, including related IPD and science/campaign activities
- Other Instrument Pre-developments
- Cross-cutting technology pre-developments, e.g. for small instrument concepts, platforms (equipment miniaturisation, standardisation, ...) and new enabling technologies

Block 2 – Research Missions

Completion of Earth Explorer-9

Earth Explorer-10 phase B1

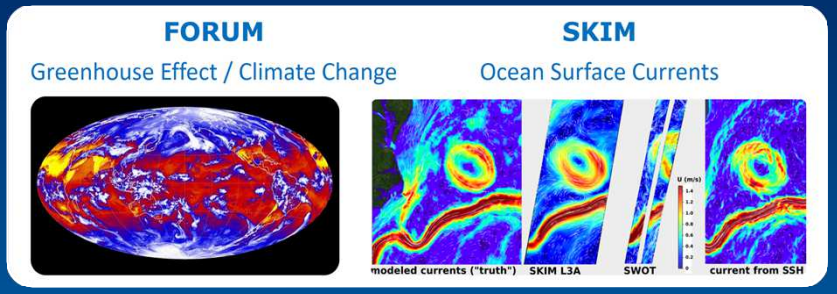
Up to 2 Explorer ‘Scouts’ (‘smallsats’)

- Valuable science for ~30 M€
- Challenge issued in early 2019
- Mission(s) selected after Space19+, for development and launch within 3 years

Timely early development activities

- A future operational wind measurement mission

Phase A/B1 Industrial Teams



Block 3 – Mission Management

smos cryosat swarm aeolus earthcare biomass flex + EE-9 + EE-10

Mission Operations

- Phase E2 of Earth Explorer missions (Phase F if relevant)
- Extension before PBEO in 2022 and part of 2023

Generic Fiducial Reference Measurements

Payload Data Ground Segment

Generic elements and Services for data accessibility, archiving, network, etc.

Geophysical Products

- Development & maintainance of ‘Level 2’ products
- For missions in Phases B/C/D/E (9), including cal/val campaigns

Block 4 – Earth Science for Society

- Address Grand Science Challenges (incl. ESA-EC/RTD Initiative)
- Bring EO Solutions for:
  - Environmental Threats (adaptation, mitigation, resilient society)
  - Sustainable Development (targets & indicators)
- Pioneer AI for EO (Big Data)
- Consolidating the Regional Initiatives (focus on user needs)
- EO for Security Actors
- EO Africa (users engagement & uptake of EO solutions)

Regional Initiatives

Earth System Science

SDG Indicators

Platforms & AI

EO for Security

EO for Resilient Society

Grand Science Challenges: Implementation

Implemented through dedicated **Joint Flagship Activities**: Set of coordinated calls and ITTs by ESA and EC focused on key science challenges where the unprecedented European EO capabilities (e.g., EEs, Sentinels, national missions,..) may contribute;

Flagship joint actions will be supported by:

- **Science Clusters** of ESA and EC projects promoting coordination, Knowledge/data sharing collaboration and cross-fertilization among projects;
- **Joint workshops,** reviewing progress and defining science roadmaps;
- **Joint communication and training;**
- **Open Science Tools** (e.g., Virtual Labs) maximizing the impact of new IT capabilities for open science;
- Coordinated **contribution to major international science endeavors**
- **Fostering transfer of science results** into new solutions for society

EO Solutions for a Resilient Society: **Environmental Threats** - Context

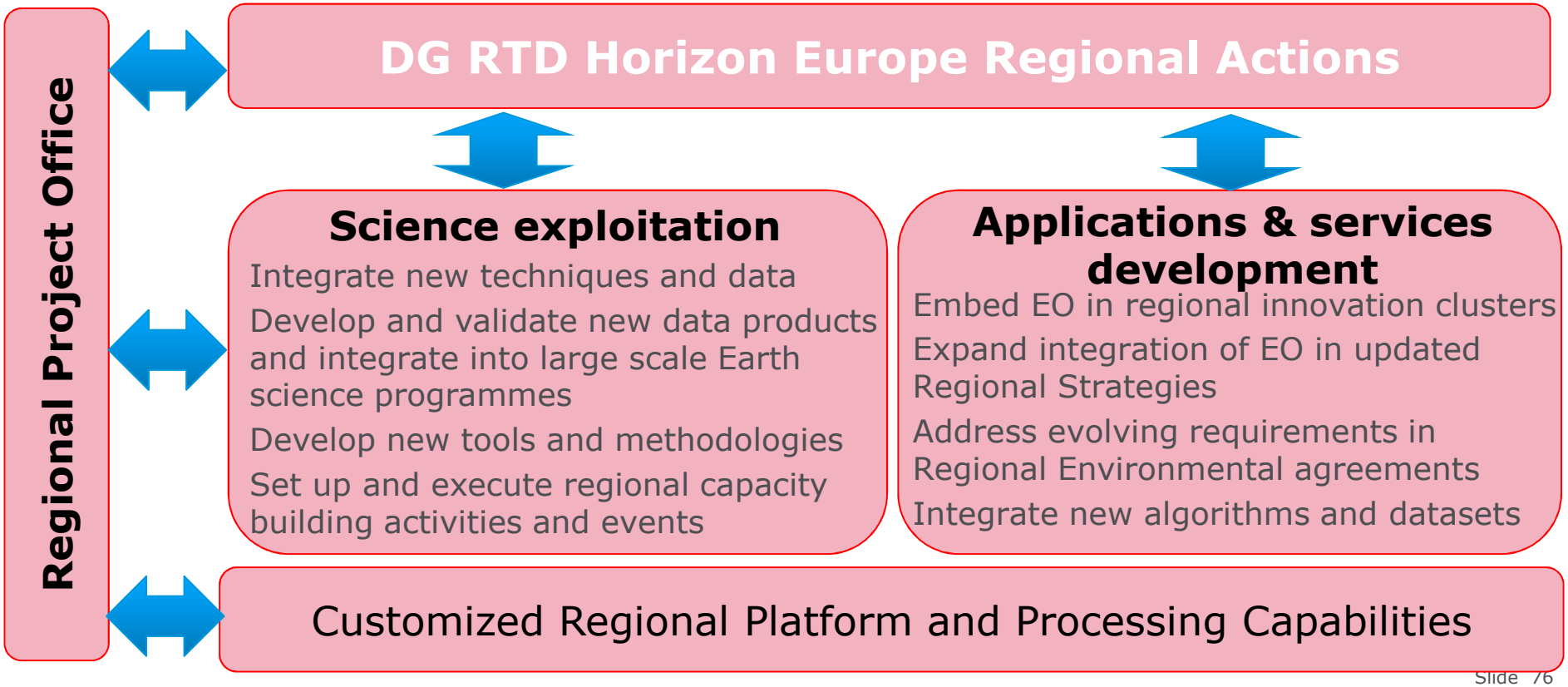
This element responds to COP-21 (2016, Article 7) Paris Agreement, EEA (EEA Report No 15/Oct.2017) and World Economic Forum Global Risks Reports (2017, 2018)

It will support the definition and implementation of actions to address diverse threats such as climate change natural disasters, management of scarce natural resources and economic disruption.

It will address

- environmental resilience (e.g. mitigation of geophysical risk),
- social and economic resilience (e.g. protection of critical infrastructure operations),
- natural resource (e.g. ensuring equitable access to water/energy/materials)
- regional stability (e.g. monitoring compliance with regional stability agreements)

Regional Initiatives 2021 onwards – Future EO1



EO4Security: Exploitation

Scaling up support to Law Enforcement and FCV

- Environmental crimes
- Crimes against humanity
- Counter-proliferation
- Terrorism/Organized Crime
- SDG16

Verification of new EO datasets

- Feature/process detection capability (Earth Explorers, national missions, small satellites)
- Data collection reliability
- Information delivery reliability
- Augmented system effectiveness

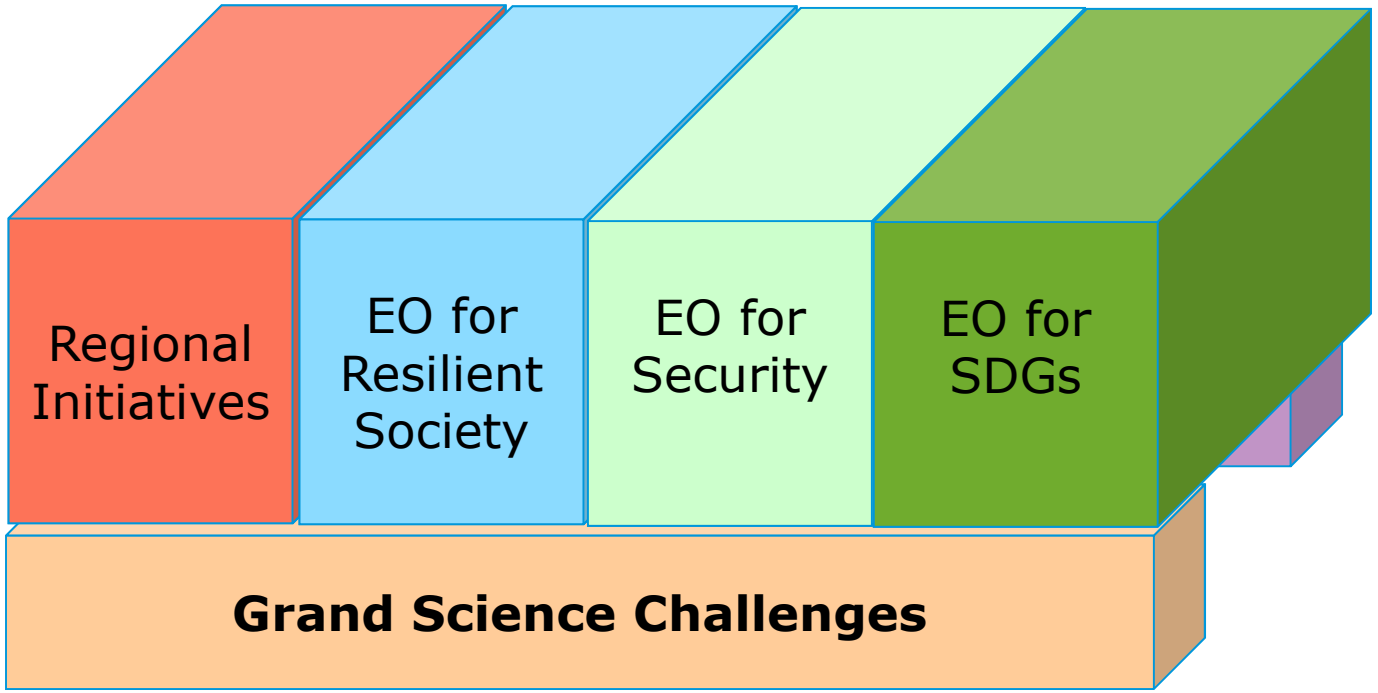
Stakeholder engagement

- Awareness and acceptance
- Working practices
- Legal and regulatory constraints
- Fitness for purpose

Infrastructure requirements consolidation

- Data collection and processing
- Data fusion and combination
- Data storage
- Data analytics
- Visualization

Overall coherence



Take home messages

- Europe is a world leading EO player – continue being part of the growth
- ESA EO activities support full development cycle:
  - New instruments, systems etc, ground segment and exploitation
  - science to operational and commercial applications
- Evolution in ICT etc creates new opportunities – important to ensure agility:
  - Rapid support, facilitation and enabling for short term opportunities
  - Staying power to support longer term developments
- Evolution in EO and ICT is accelerating potential for wider operational EO uptake
  - EU legislation etc (CAP, environment directives)
  - SDGs
  - Industrial and commercial services
  - Citizen engagement
- ESA is at the service of Member States:
  - Ensuring relevant customized support to strategic priorities
  - Leverage complementary national/regional investments
- Hello opportunity!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Thanks!
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European Space Agency