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SEASAR 2012
The 4th International Workshop on Advances in SAR Oceanography

Sentinel-1 Mission Operations Concept

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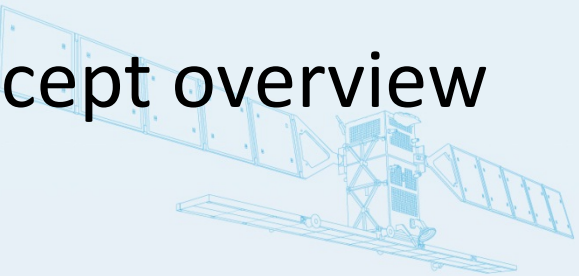
ESA / ESRIN

Outline

- Global Monitoring for Environment and Security (GMES)
- Sentinel operations concept, data policy
- Sentinel-1 mission overview
- Sentinel-1 observation scenario
- Sentinel-1 PDGS operations concept overview
- Concluding remarks



Global Monitoring for Environment and Security

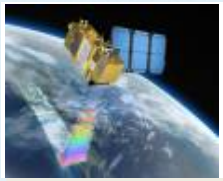
European independence in data sources for environment and security monitoring

Global, timely and easily accessible information in Land, Marine, Emergency response, Atmosphere, Security and Climate Change domains

GMES dedicated missions: Sentinels

Sentinel 1 – SAR imaging
All weather, day/night applications, interferometry

end 2013 / 2015



Sentinel 2 – Multi-spectral imaging
Land applications: urban, forest, agriculture,..
Continuity of Landsat, SPOT

beg 2014 / 2015

Sentinel 3 – Ocean and global land monitoring
Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry

beg 2014 / 2015

Sentinel 4 – Geostationary atmospheric
Atmospheric composition monitoring, trans-boundary pollution

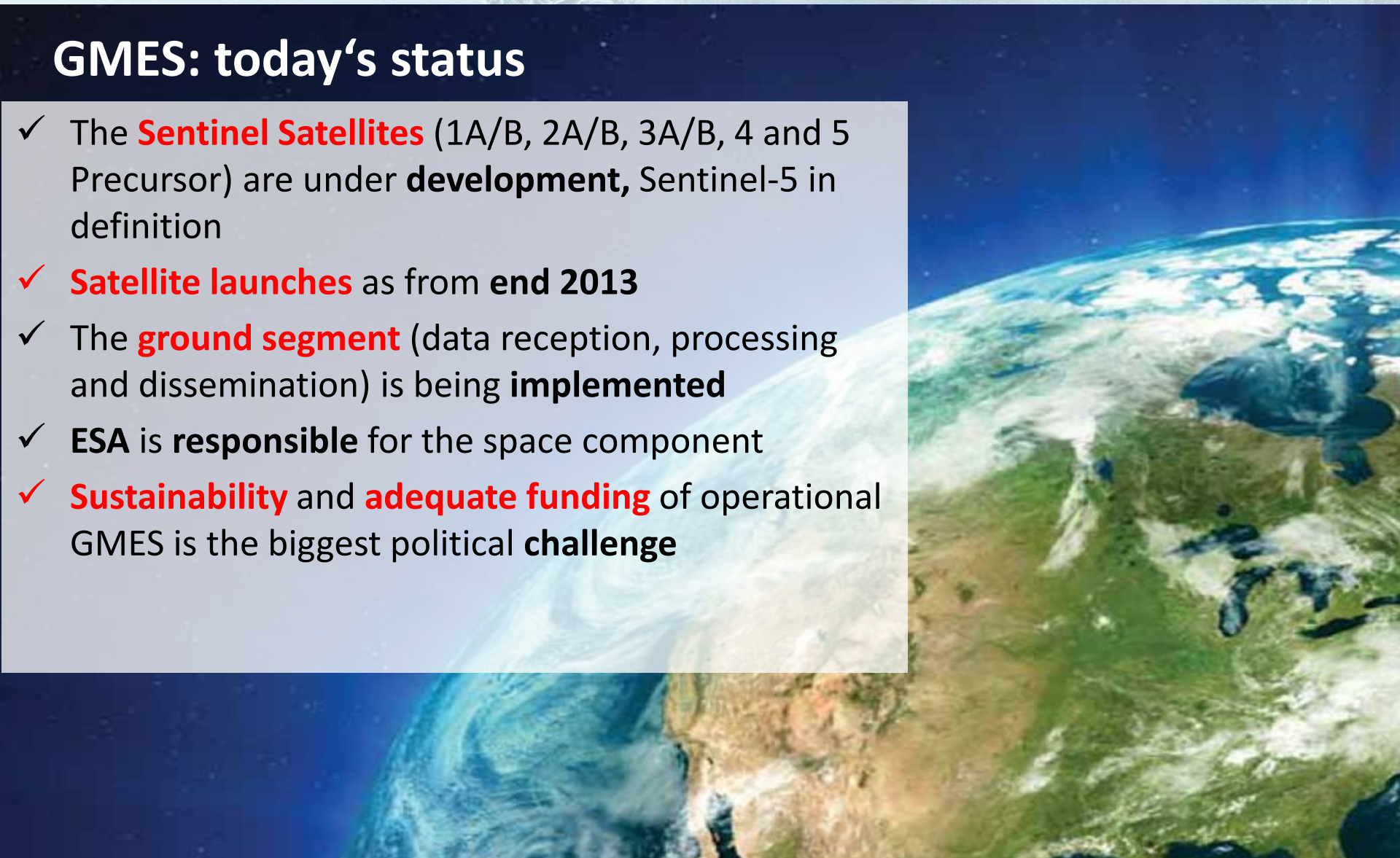
2020

Sentinel 5 – Low-orbit atmospheric
Atmospheric composition monitoring
(**S5 Precursor** launch in **2015**)

2020+

GMES: today's status

- ✓ The **Sentinel Satellites** (1A/B, 2A/B, 3A/B, 4 and 5 Precursor) are under **development,** Sentinel-5 in definition
- ✓ **Satellite launches** as from **end 2013**
- ✓ The **ground segment** (data reception, processing and dissemination) is being **implemented**
- ✓ **ESA** is **responsible** for the space component
- ✓ **Sustainability** and **adequate funding** of operational GMES is the biggest political **challenge**



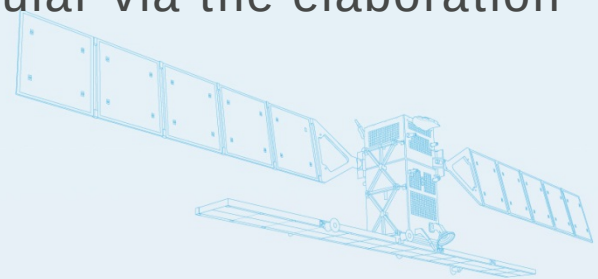
Main objectives of the Sentinel operations strategy

- provide data in priority to GMES services and for utilisation by Member States according to their specified requirements

- ensure systematic and routine operational activities:
  - with a high level of automation
  - with pre-defined operations to the maximum extent possible

- minimize the number of potential conflicts during operations, therefore anticipate conflict resolution, in particular via the elaboration of the mission observation scenarios

  → required for Sentinel-1 in particular



Sentinel Data Policy
=
full and open access to Sentinel data to all users

- Aim for maximum availability of data & corresponding access services
- Support to increasing demand of EO data for
  - → climate change initiatives
  - → implementation of environmental policies

In practical terms:

- Anybody can (has the right to) access acquired Sentinel data
- Licenses for the Sentinel data are free of charge
- Online access with users registration including acceptation of generic Terms and Conditions, at no fees, within the financial limits for operations cost.

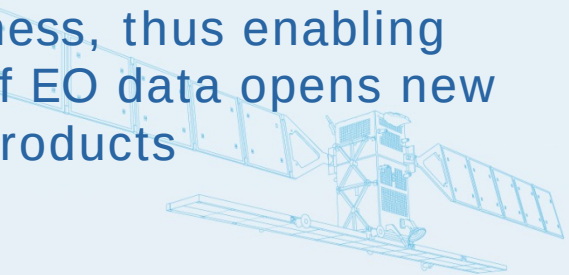
Sentinel Data Policy

What does it mean?

Technically: Improved availability and easier access to EO data, simple data dissemination system and interfaces to users

Politically: Continue international trend for full and open access to EO data, in line with GEO data sharing principles, setting context for future data policies

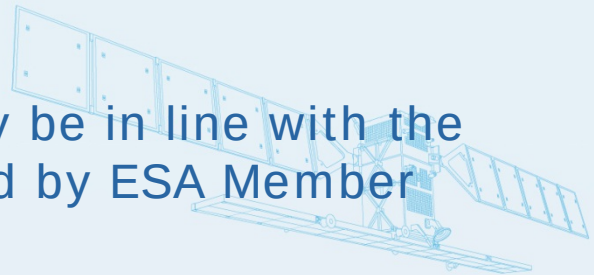
Economically: Supports growth of VACs' business, thus enabling growth and job creation; Increased uptake of EO data opens new markets and supports development of new products



Sentinel Data Policy Status

- The Sentinel Data Policy, based on the previously mentioned principles, was adopted by ESA Member States in 2009
- On the European Union / European Commission side, the Sentinel Data Policy is part of the GMES Data and Information Policy (DIP), which has a larger scope (i.e. covers the whole GMES including the services)
- The European Commission drafted recently a “Commission Delegated Regulation” which among others covers the GMES Data and Information Policy

  → Content-wise the GMES DIP should largely be in line with the Joint Sentinel Data Policy Principles approved by ESA Member States



Sentinel–1: C-band SAR mission

- ✓ **Data continuity of ERS and ENVISAT missions**
- ✓ **GMES radar imaging mission for ocean, land and emergency services**
- ✓ **Applications:**
  - monitoring sea ice zones and the arctic environment
  - surveillance of marine environment (e.g. oil spill monitoring)
  - maritime security (e.g. ship detection)
  - wind, wave, current monitoring
  - monitoring of land surface motion (subsidence, landslide, tectonics, volcanoes, etc.)
  - support to emergency / risk management (e.g. flooding, etc.) and humanitarian aid in crisis situations
  - mapping of land surfaces: forest, water and soil, agriculture, etc.

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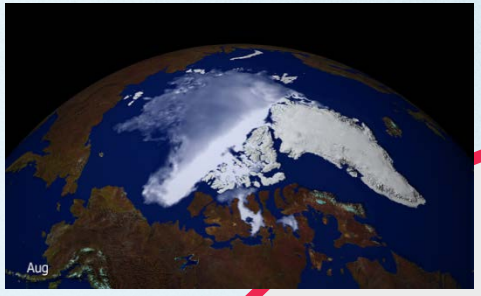
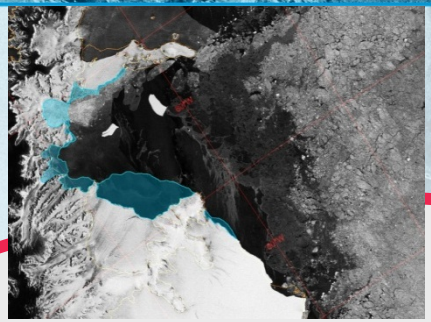
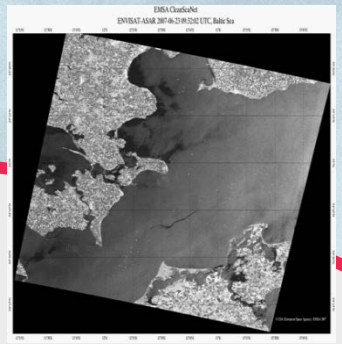


Arctic ice extent
August 2009
(Credit: MyOcean)

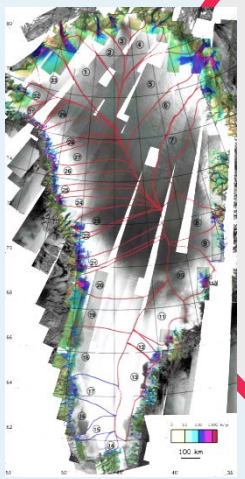


Larsen ice shelf loss between
2002 and 2009
(Credit: Polar View)



Oil spill detection
and Surveillance
(Credit: EMSA)

Ship detection
(Credit: ESA)



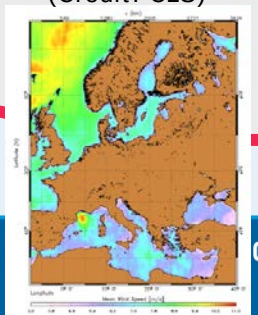
Acceleration of
Greenland glaciers flow
(Credit: Rignot et Al)

C-band SAR observations to support a wide range of applications

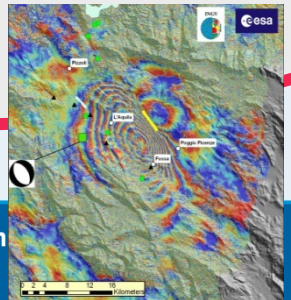
Land use
(Credit: ESA)

Subsidence map
1992-2006
(Credit: Terrafirma)

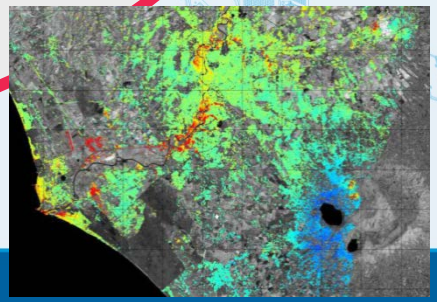
Emergency
management: flooding
(Credit: SAFER, DLR)



Mean wind speed
from 2005 to
2009
(Credit: CLS)

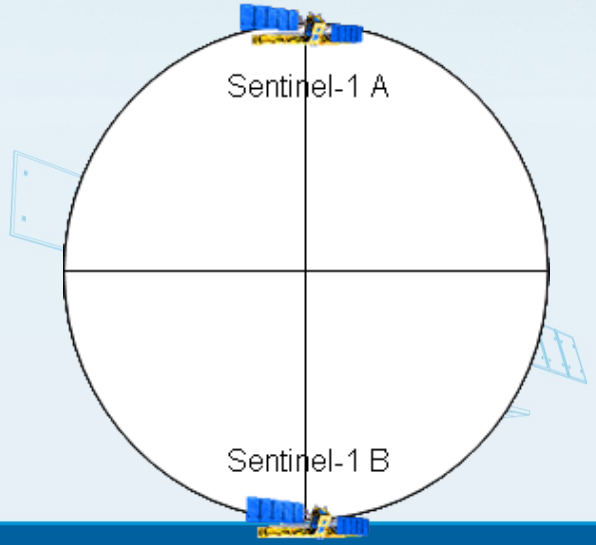


Earthquake
analysis
(Credit: INGV)



Sentinel–1 Mission Facts

- Constellation of two satellites (A & B units)
- Near-Polar sun-synchronous (dawn-dusk) orbit at 693 km altitude
- Both satellites in the same orbit (180 deg. phased in orbit)
- 12 days repeat cycle (1 satellite), 6 days for the constellation
- 7 years design life time with consumables for 12 years
- Launch of Sentinel-1 A scheduled for Oct 2013 followed by Sentinel-1 B about 18 months later



Sentinel–1 SAR operational modes
Data recording / transmission capabilities

SAR operation modes:

Default modes:

- Interferometric Wide Swath (IWS): 250 km swath; level-1 product best res.: 20 m
- Wave (WV): sampled images of 20x20 km at 100 km along the orbit, alternating into 2 incidence angles; level-1 product best resolution: 50 m

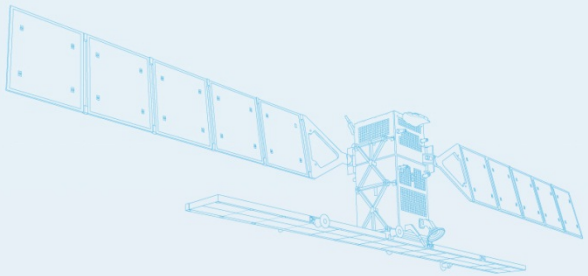
Additional modes:

- Extra Wide Swath (EWS): 400 km swath; level-1 product best res.: 50 m
- Strip Map (SM): 80 km swath, 6 possible incidence angles; level-1 product best resolution: 9 m

(planned to be used exceptionally only)

SAR Duty cycle:

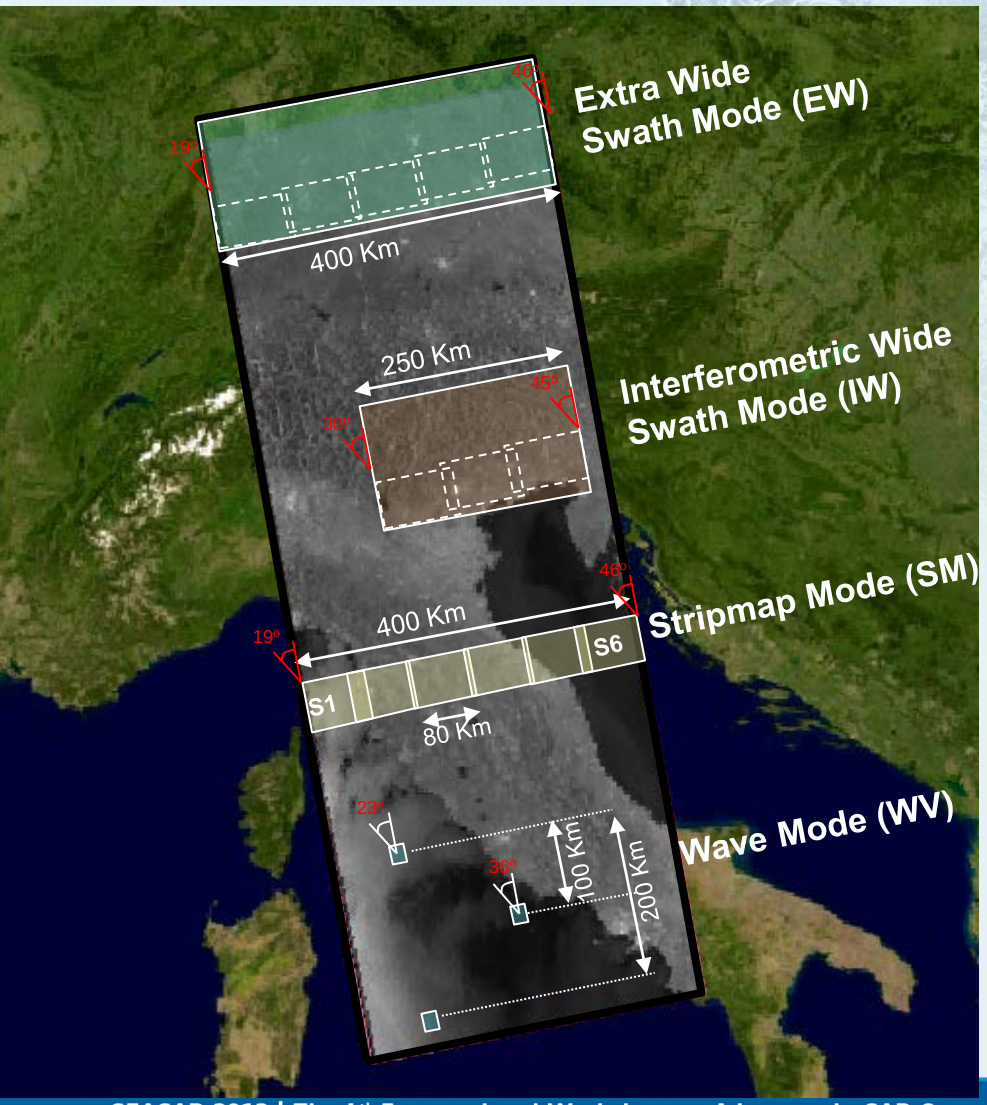
→ up to 25 min/orbit in high rate acquisition modes



Data recording / transmission capabilities :

- On-board data storage capacity of 1400 Gbit
- Two X-band RF channels of 260 Mpbs each
- Equipped with an Optical Communication Terminal for GEO laser link with European Data Relay System

Sentinel-1 SAR Modes



Sentinel-1 SAR can be operated in 4 exclusive imaging modes with different resolution and coverage:

Mode Rate	SAR Mode
High Bit Rate (HBR)	IW
	EW
	SM (S1 → S6)
Low Bit Rate (LBR)	WV

Polarisation schemes for IW, EW and SM:

- single polarisation: HH or VV
- dual polarisation: HH+HV or VV+VH

For Wave mode: HH or VV

For all of these operating modes, the same family of products is available to the users.

Sentinel-1 observation scenario objective

Implement a pre-defined and conflict-free observation plan, aiming at fulfilling, to the maximum feasible extent, the observation requirements from:

- the GMES services
- the use by ESA / EU Member States

In addition, on best effort basis and in order to ensure some continuity of ERS/ENVISAT, requirements from the science community are also considered, as well as contribution to international cooperation activities.

→ Need to find *a priori* the solutions on the potential conflict among users (e.g. different SAR operation modes / polarisation required over same geographical area)

Sentinel-1 observation scenario definition process

- Bi-lateral discussions with GMES services / EMSA to clarify their observation requirements

- Bi-lateral / multi-lateral discussions with ESA Member States (Delegations, GOCG) to discuss National requirements not covered by GMES service requirements

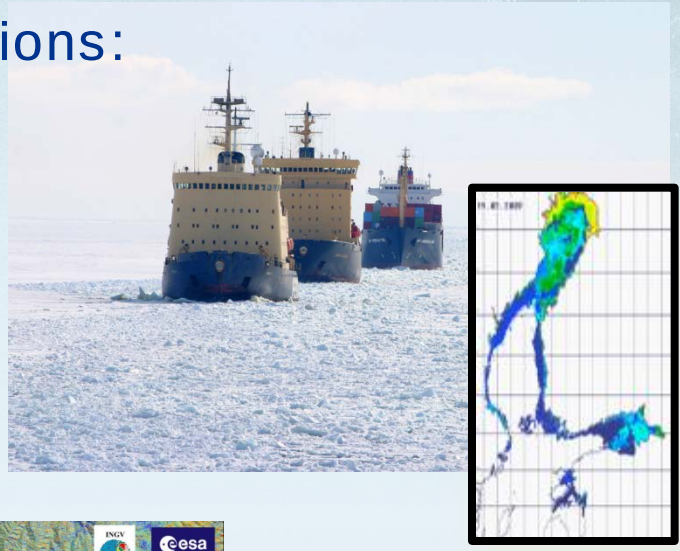
- Continuity / experience of ERS and ENVISAT, discussion with science community mainly through workshops (e.g. FRINGE, SEASAR, etc.)

- Discussion with the Canadian Space Agency on complementary observations with Radarsat Constellation Mission

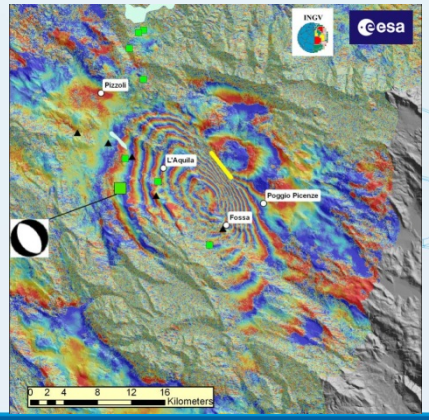
Sentinel-1 Observation Requirements

Two main categories of services / applications:

→ Services / applications over oceans, seas and sea-ice areas

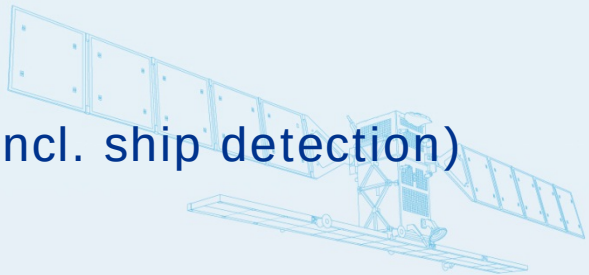


→ Services / applications over land



Sentinel-1 services over oceans, seas and sea-ice areas

- → These services (either in the core or collaborative domain) require quasi real time or near real time data, typically in less than 3 hours, and in some cases in less than 10 min.
- → Quasi real time services or services requiring data within 1 hour from sensing rely on the support from local stations
- → These “monitoring” types of service require systematic or very frequent (e.g. daily) observations
- → These services include:
  - Sea-ice and iceberg monitoring
  - Oil spill monitoring
  - Maritime security information services (incl. ship detection)
  - Wind, wave, current monitoring



Sentinel-1 services and applications over land

→ These services or applications cover a wide range of different thematic domains

→ They do not require data in quasi real time, few of them require data in 3 hours NRT

→ Related data are planned to be recorded on-board and downloaded to the core ground station network

→ These services / applications include:

- risk management in support to flooding
- "security" services in the GMES framework
- land motion / geo-hazard monitoring with InSAR (seismic hazards, volcanoes, landslides, subsidence / inactive mines, coastal lowland and flood defence)
- glacier, snow monitoring
- large ice sheet monitoring (Greenland, Antarctica, in particular to support climate change studies)
- river and lake ice monitoring
- global forest mapping (e.g. in support of REDD / GFOI)
- global / regional land mapping (incl. for food security, crop monitoring, land cover and change monitoring, soil moisture, etc.).

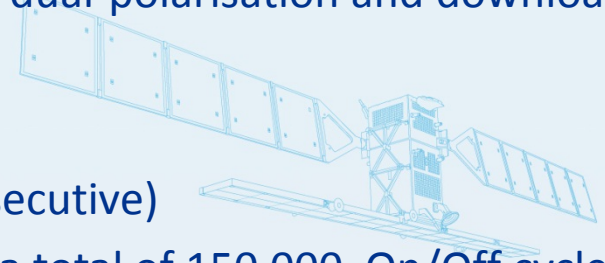
Examples of Sentinel-1 operations constraints (list not exhaustive)

Instrument operations constraints:

- SAR modes exclusivity (incl. polarisation schemes)
- SAR mode transition time (2.4 sec.)
- SAR duty cycle (25 min/orbit for the 3 high rate modes)

Data transmission / acquisition constraints:

- Huge volume of data, potentially up to 2.4 TB/day with the two satellites
- Data rate versus X-band downlink capacity (use of on-board data compression – FDBAQ)
- Data downlink conflict between RT data transmission in dual-polarisation and download of on-board recorded data
- On-board memory sizing (1410 Gbits)
- X-band duty cycle (max. 30 min/orbit, max. 20 min consecutive)
- X-band downlink switches (X-Band system specified for a total of 150,000 On/Off cycles)



Sentinel-1 observation scenario (currently under definition)

High level strategy

• optimum use of SAR duty cycle (25 min/orbit), taking into account the various constraints (e.g. limitation in number of X-band RF switches, mode transition times)

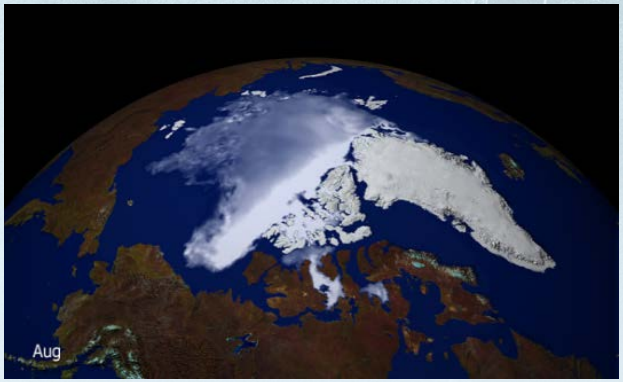
• Wave Mode continuously operated over open oceans, with lower priority w.r.t. the other high rate modes

• IW or EW modes operated over pre-defined geographical areas:

→ Over land: pre-defined mode is IWS

→ Over seas and polar areas, and ocean relevant areas: pre-defined mode is either IWS or EWS

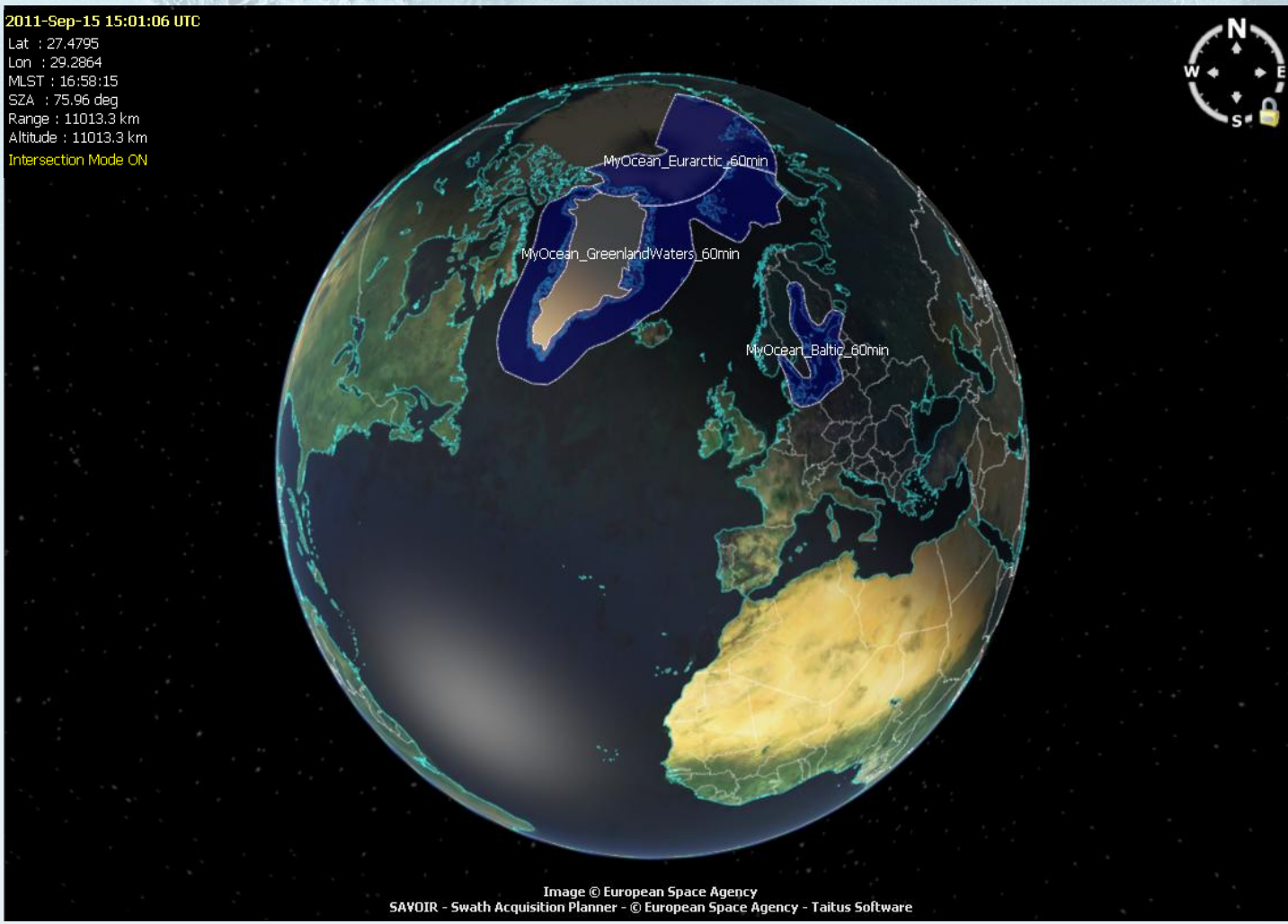
Preliminary observation requirements from MyOcean sea-ice and iceberg monitoring services



- Areas of interest: Eurarctic, Baltic sea, Antarctic
- Data latency from sensing:
  - NRT 1h for Eurarctic, Baltic sea
  - NRT 1h-3h for Antarctica
- Mode / polarisation:
  - EW: 400 km swath, 90m res. (12 ENL)
  - Polarisation:
    - ideally dual-polarisation (HH+HV) for ice charting
    - single polarisation (HH) acceptable for ice drift monitoring in the Arctic Ocean and Antarctic winter season
- Potential conflicts, mainly with:
  - EMSA oil spill monitoring services
  - Ship detection services (Baltic sea)
  - Land requirements regarding coastal zones (mode transition)
  - Other “National” services

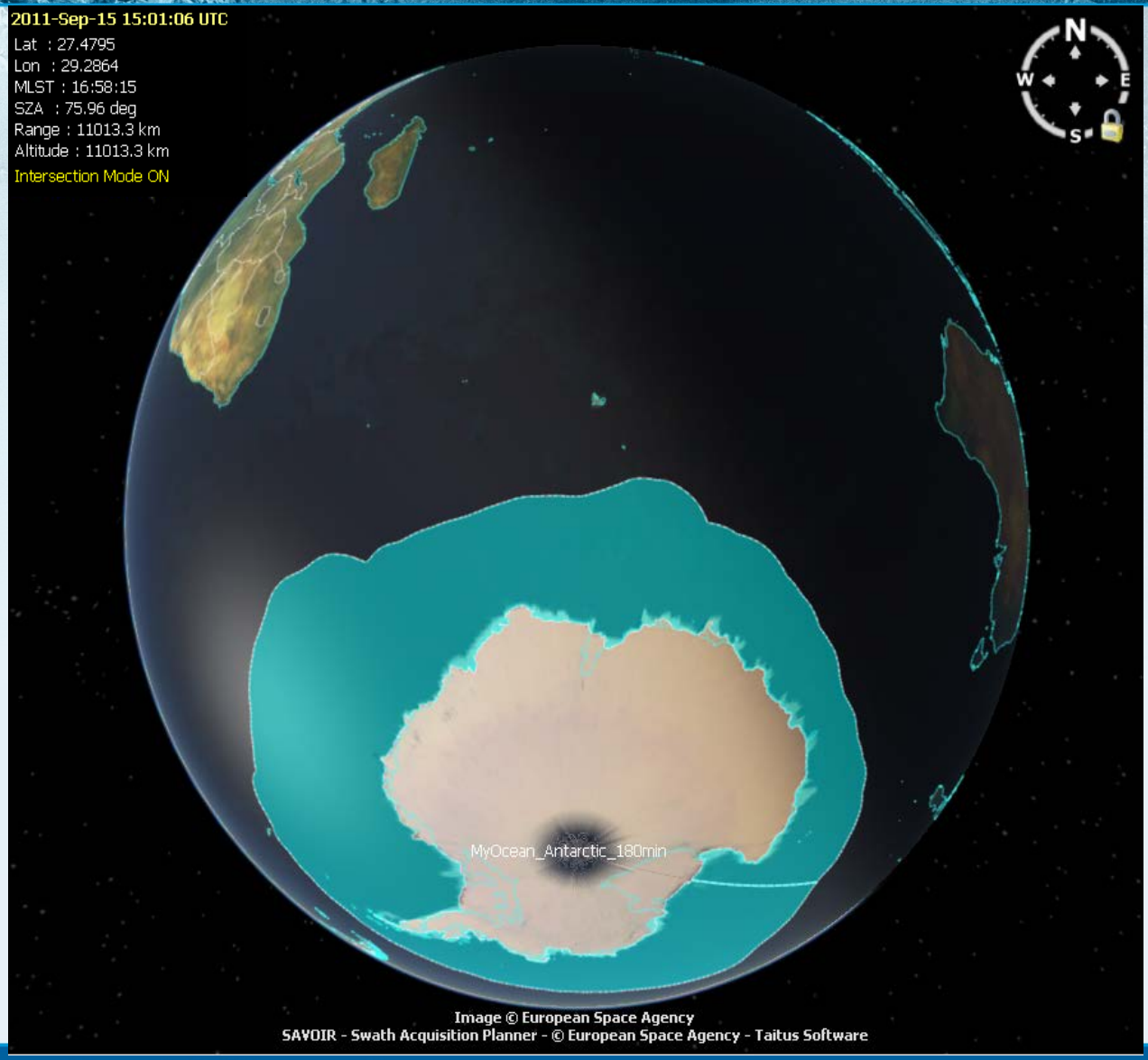
MyOcean sea-ice monitoring services –

North Hemisphere



MyOcean sea-ice monitoring services –

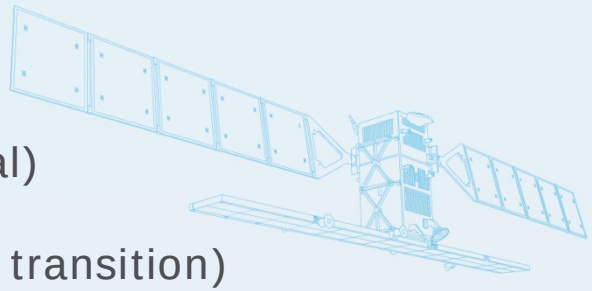
Antarctica



Preliminary observation requirements from EMSA (CleanSeaNet 2nd generation)

- Areas of interest: see next slide
- Data latency: RT / less than 10 min from sensing
- Mode / polarisation:
  - EW: 400 km swath, 50m res, TBC

  → IW mode may be privileged over specific areas to improve ship detection service (part of CleanSeaNet-2), e.g. Mediterranean Sea
  - Polarisation:
    - ideally dual-polarisation (VV+VH) for oil spill monitoring
    - HH+HV might be acceptable in case of conflicts with other services
    - H polarisation better for ship detection
- Potential conflicts, mainly with:
  - Sea-ice monitoring services (MyOcean and National)
  - Ship detection services (National)
  - Land requirements regarding coastal zones (mode transition)
  - Other “National” services



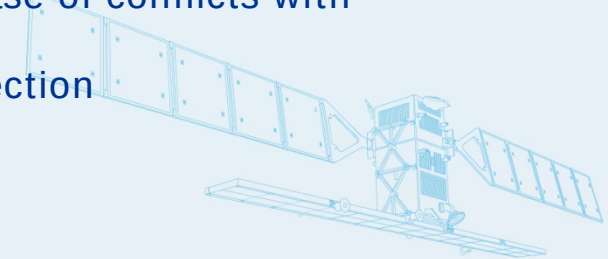
Sentinel-1 Real Time (10 min) requirements from EMSA (CleanSeaNet 2nd generation)

High level strategy to fulfil European observation requirements for services over oceans, seas, sea-ice during Full Operational Capability

→ Systematic (or very frequent) monitoring of European waters and sea-ice areas to support operational quasi or near real time services:

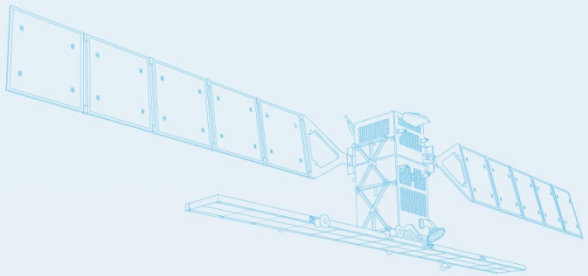
- Sea-ice and iceberg monitoring
  - Mode: EWS (or IWS for iceberg monitoring)
  - Product resolution: 90m (or 50m / 20m (IWS) for iceberg monitoring)
  - Polarisation:
    - HH+HV for ice charting
    - HH acceptable for ice drift monitoring (Arctic, Antarctic)

- Oil spill monitoring (and simultaneous ship detection) - EMSA
  - Mode: EWS (or IWS in critical areas for ship detection or to avoid mode switch)
  - Product resolution: 50m (or 20 m with IWS)
  - Polarisation:
    - ideally VV+VH for oil spill monitoring
    - HH+HV might be acceptable in case of conflicts with other services
    - H polarisation better for ship detection

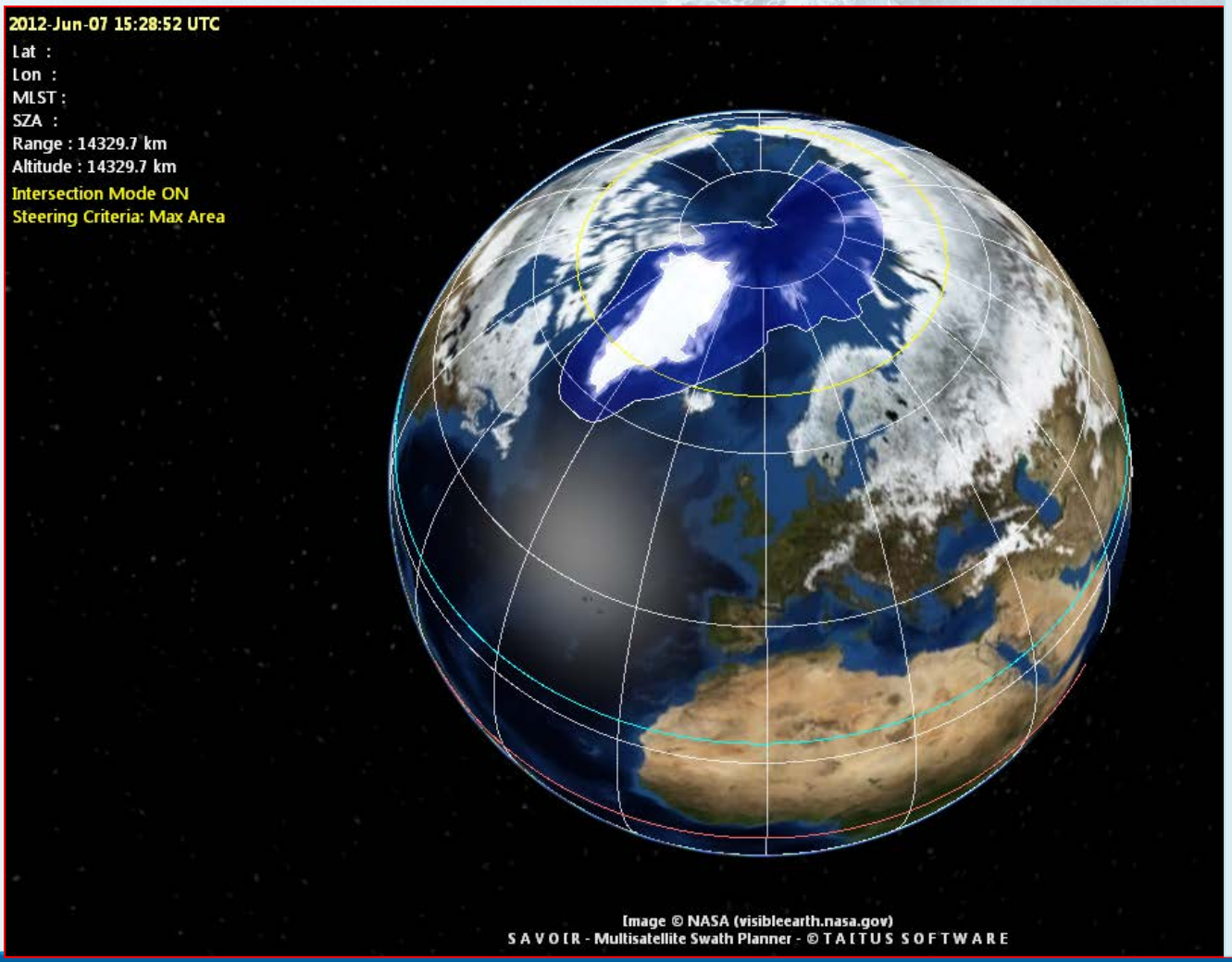


- Wind, wave, current monitoring
  - Mode: EWS
  - Product resolution: 50m
  - Polarisation: VV+VH

Illustration of potential conflicts (not exhaustive) on European waters / polar areas

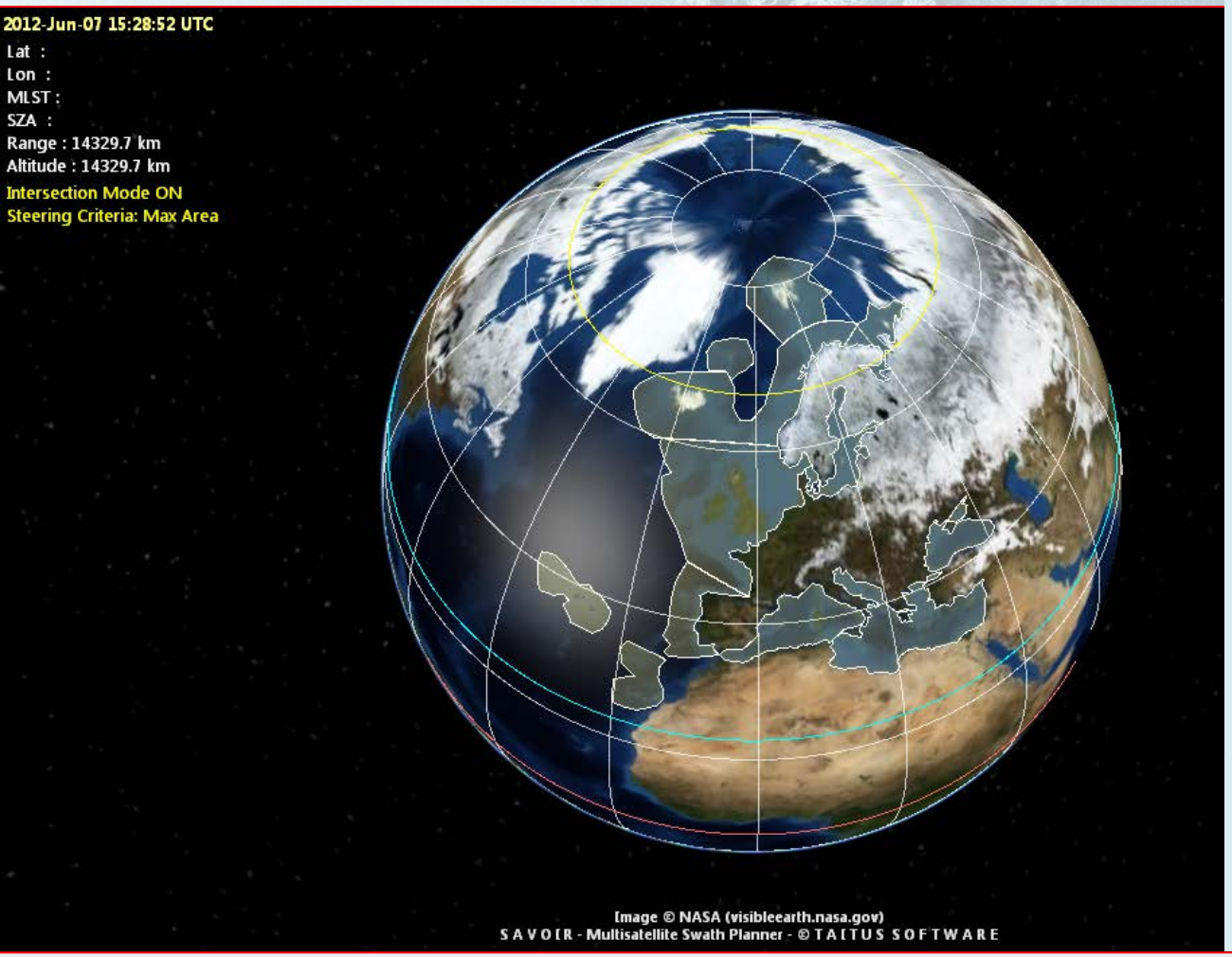


Requirements MyOcean



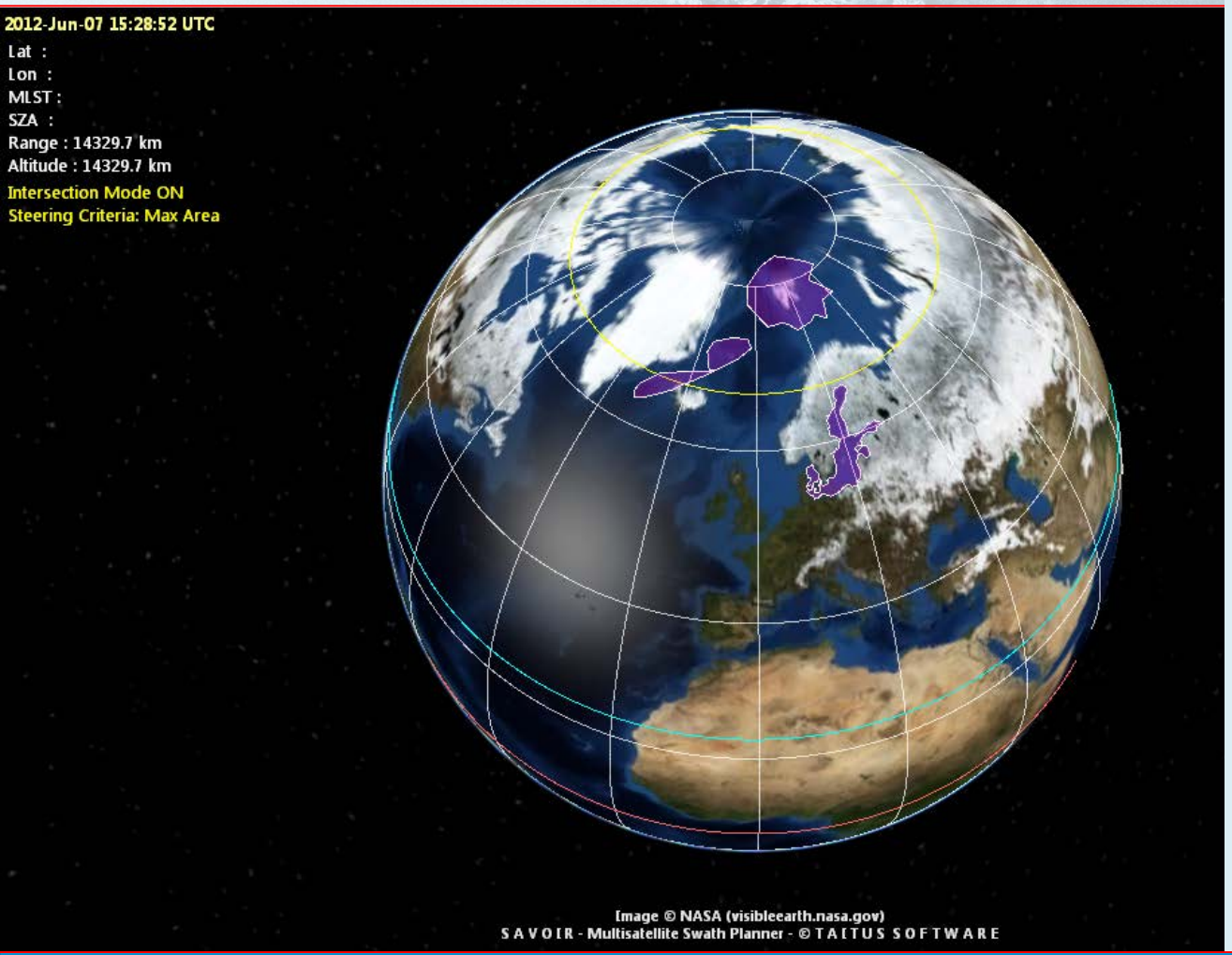
Sea Ice Monitoring
Mode: EWS HH-HV

Requirements EMSA



Oil spill Monitoring
Mode: EWS VV-VH

MyOcean-EMSA Areas of Conflict



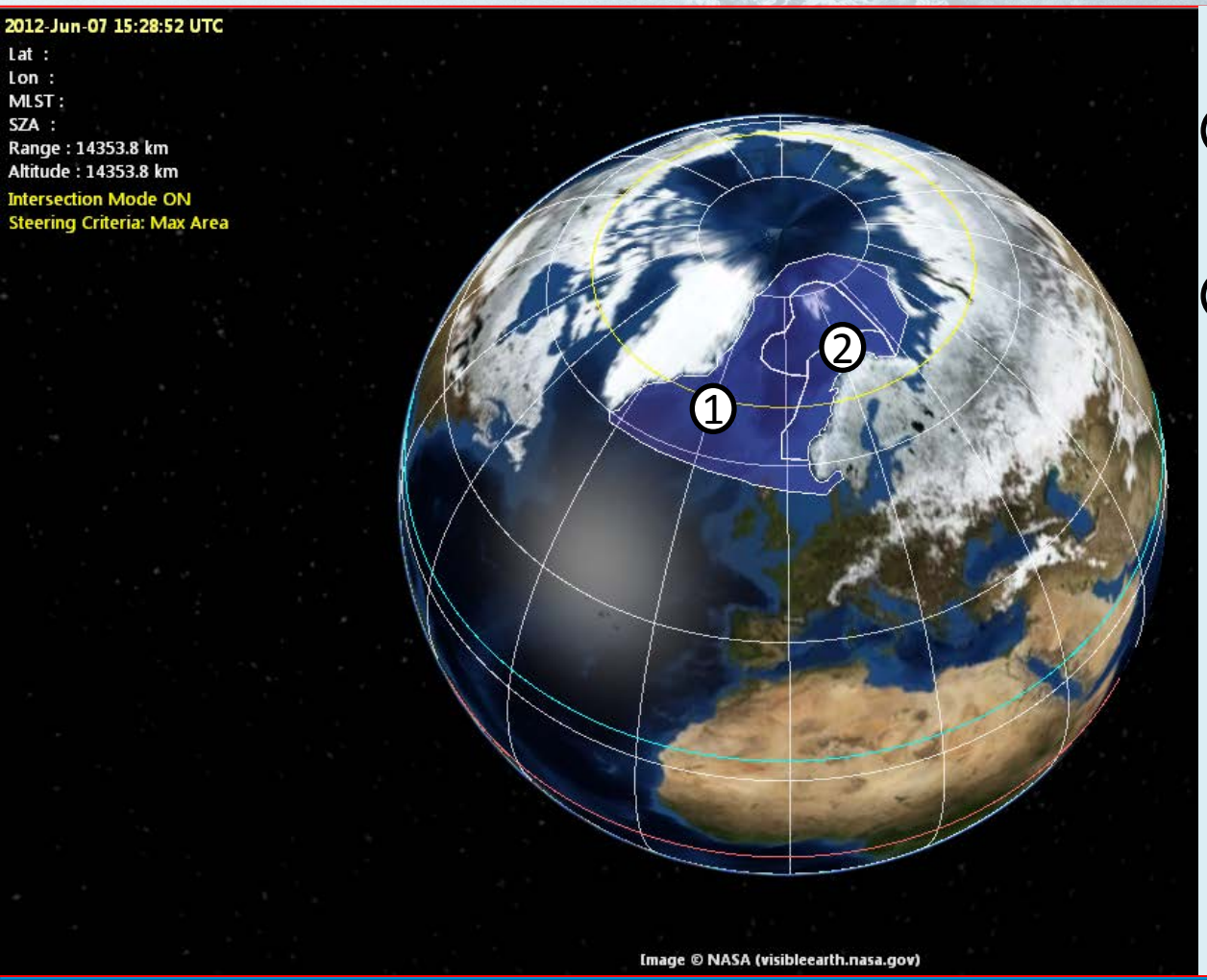
Areas of conflict (different polarisation) between:

- MyOcean
- EMSA

<u>Conflict mitigation for conflicting areas:</u>

- Use HH-HV for oil spill monitoring
- Sampling rather that full systematic mapping for EMSA
- “play” on ascending /descending passes
- Consider seasons

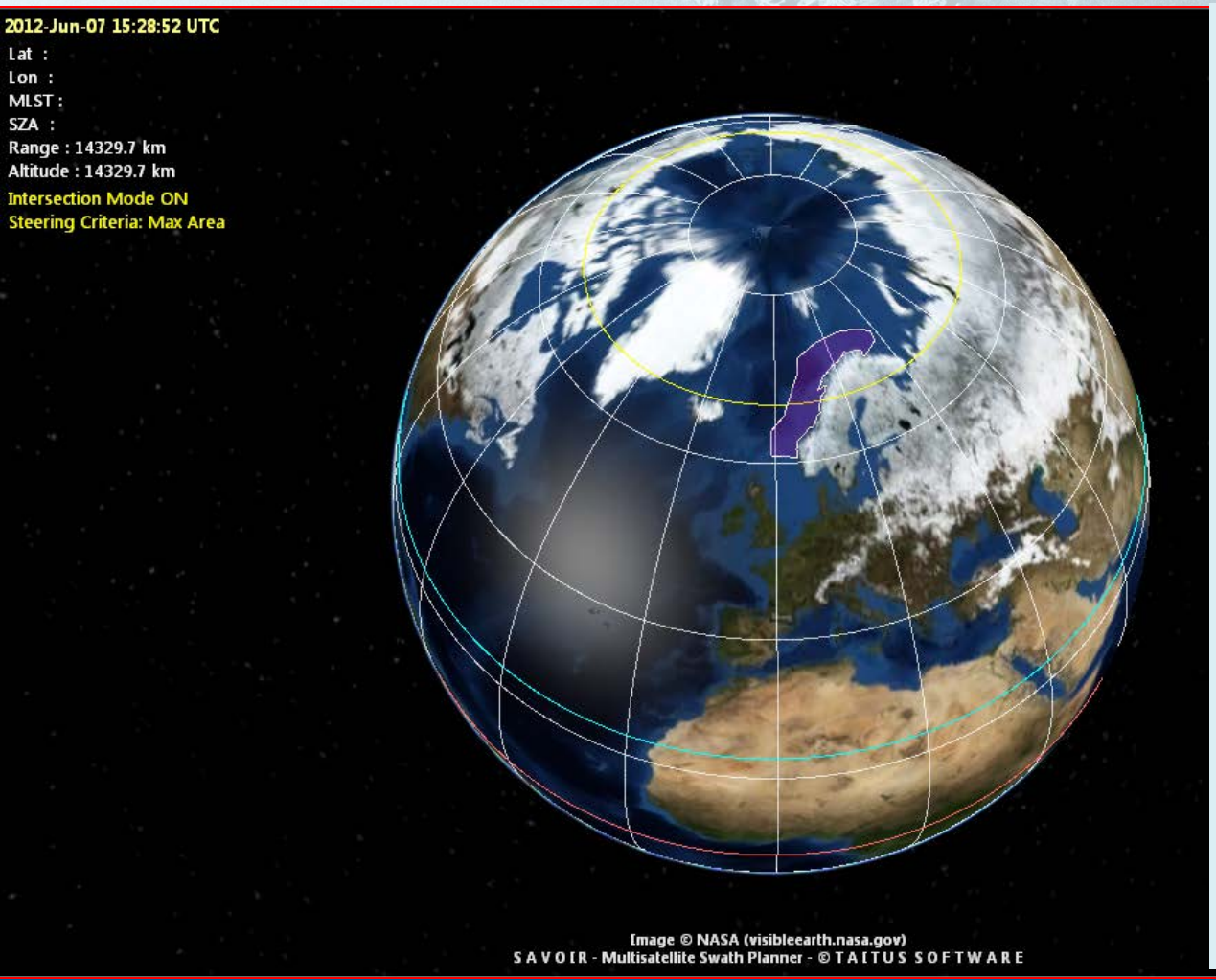
National Requirements-Norway



① Operational Monitoring Mode EWS HH-HV

② Coastal Monitoring Mode IWS dual pol

Norway - Areas of conflict with EMSA



Conflict between EMSA Mode EWS VV-VH and Norway IWS dual pol on Norwegian Coast

<u>Conflict mitigation for conflicting areas:</u>

- Use IWS by EMSA
- Sampling rather that full systematic observation for EMSA
- “play” on ascending /descending passes

→ Discussion required

Example of other observation requirements to be considered: Land motion Europe

Example of other observation requirements to be considered: Land motion Asia / Africa - America

For information: High level strategy to fulfil observation requirements for services over LAND during Full Operational Capability

• Systematic (or very frequent) mapping of tectonic / subsidence / landslides / volcano areas to support operational services based on INSAR

→Need to provide pairs in both ascending / descending passes

• Regular mapping of areas prone to risks to acquire strategic background data (e.g. for flood)

• Regular mapping of areas to support GMES security services

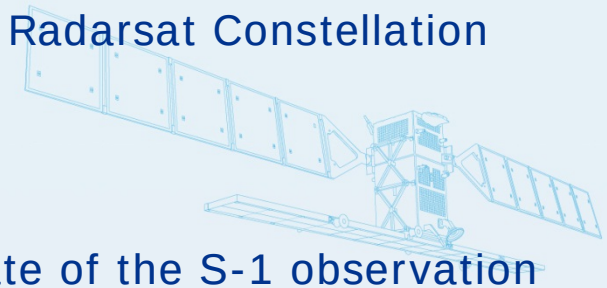
• Regular mapping or ice sheets (Greenland, Antarctica), polar coastal regions and of relevant areas for glacier and snow monitoring (based on season)

• Regular global/regional coverage of all land areas (frequency TBD), supporting among others forest mapping (e.g. REDD), land cover change, crop monitoring, soil moisture, etc. based on seasonal requirements

→ Baseline mode of operations: IW, if possible in dual-polarisation (HH+HV). Single polarisation HH however sufficient for INSAR applications

Sentinel-1 observation scenario evolution during the operations phase

- The inclusion of the 2nd Sentinel-1 satellite leading to the Full Operational Capacity of the missions with the 2-satellite constellation
- The gradual use of the EDRS system to complement the data downlink capacity
- The evolution of the requirements from the services (GMES, National, etc.)
- The constraints on the space and ground segment resources (e.g. core and collaborative ground station networks)
- The contribution of (and interoperability with) the Radarsat Constellation Mission from CSA



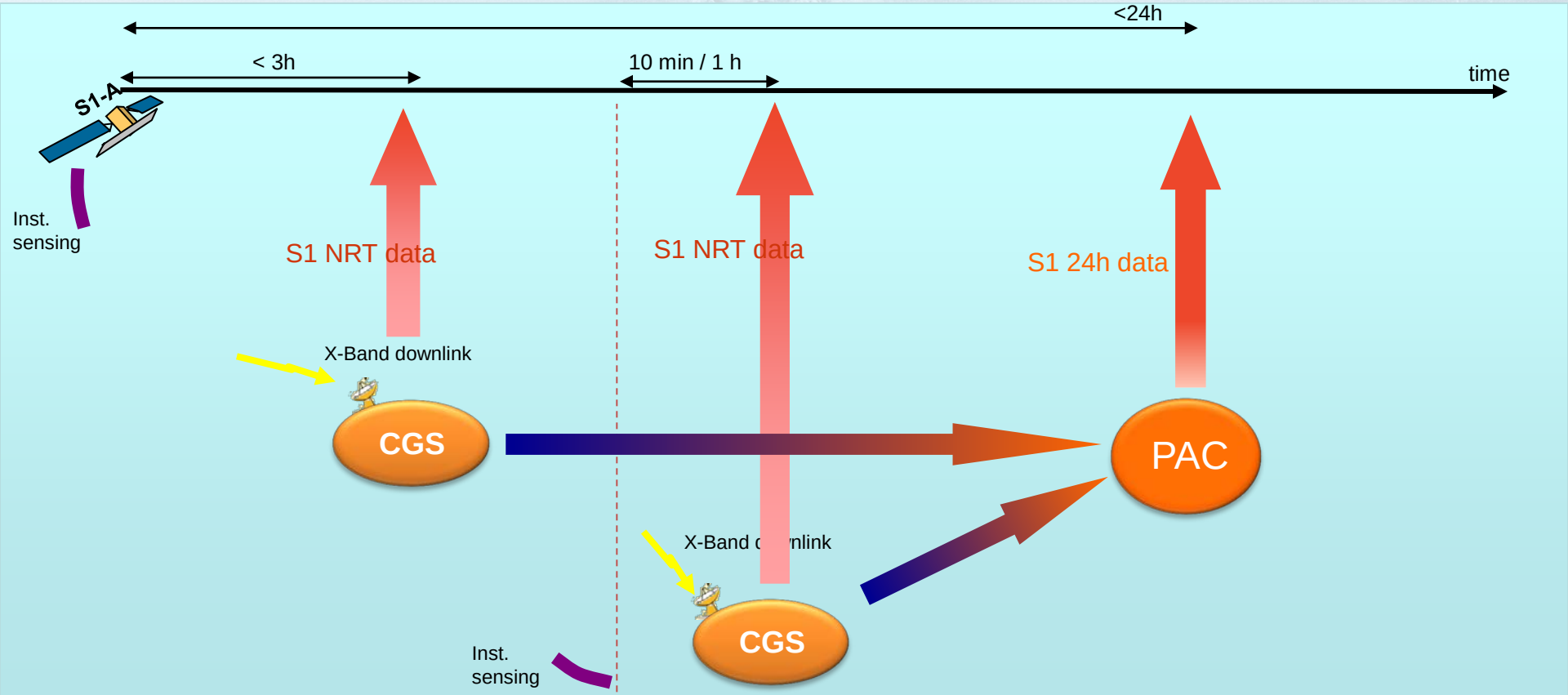
➔ It is planned to set up a procedure for a regular update of the S-1 observation plan during routine operations

Sentinel-1 PDGS(*) Data Timeliness

Data access to systematically generated products is provided according to the following timeliness:

- Standard timeliness: within 24h from sensing for all systematic products
- NRT timeliness:
  - < 3h from sensing (within 1h from downlink)
  - < 1h from sensing for data acquired in direct downlink over specific areas (e.g. European waters).

(*) Payload Data Ground Segment



Processing concept

Processing Concept	Instrument mode	Product Type	Timeliness (availability after sensing)	Comment
Systematic Global	SM, IW, EW	SAR L0 SAR L1 GRD	<24h	All acquired data
	WV	SAR L2 OCN	<3h	All acquired WV mode data (oceans areas)
Systematic Regional	SM,IW,EW	SAR L2 OCN	<3h	For regional maritime surveillance areas in HBR mode defined through High Level Operations Plan (HLOP)
		SAR L0 SAR L1 GRD SAR L1 SLC	<3h	Data available in 3h from sensing from the core PDGS for regional areas defined through HLOP
		SAR L1 SLC	<24h	Data available in 24h from sensing from the core PDGS for regional areas defined through HLOP
Systematic Local	SM,IW,EW	SAR L0 SAR L1 GRD	<10 min	Only for data acquired in direct downlink over the S-1 Core Ground Stations when not addressed by collaborative stations
Archive	SM,IW,EW, WV	SAR L0 SAR L1 GRD SAR L1 SLC SAR L2 OCN	Offline	All systematically generated data is available on-line on a Non Time Critical basis (e.g. nominally ˜24h) Products non systematically generated (e.g. SLC outside the systematic regional areas) can be requested from L0

Global: Applies to all acquired data
Regional: Applies to data acquired over well defined geographical areas, including areas required in NRT, (cf. HLOP)
Local: Applies to well defined geographical areas fulfilling specific constraints (e.g. within the stations coverage area) (cf. HLOP)

Synergy Sentinel-1 / RCM

- CSA-ESA discussions on-going to explore synergies between Sentinel-1 and Radarsat Constellation Mission and in view of a certain level of interoperability between the missions

- RCM – Sentinel-1 interoperability would bring strong benefits to users

- The following interoperability items are explored:
  - Joint / integrated pre-defined observation plans (complementarities in observations / modes, increased revisit, etc.)
  - Level 1 Product format
  - Harmonisation of catalogue interface
  - Development of common tools
  - Harmonised communication, joint publications etc.

- A joint calibration working group is being set up

Concluding remarks

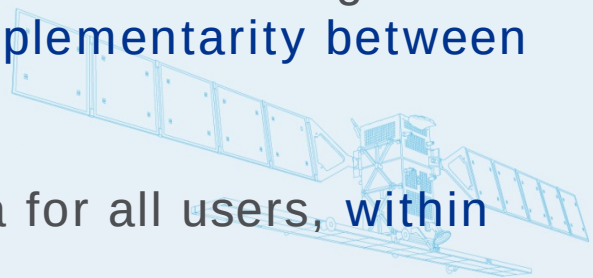
- The Sentinel-1 mission will provide continuity to ERS and ENVISAT C-band SAR with improved performance and revisiting

- Sea-ice monitoring, marine environment protection, pollution surveillance, maritime security etc. are objectives part of GMES, to which Sentinel-1 will largely contribute

- Sentinel-1 will be operated with a predefined routine observation plan currently under definition

- Cooperation with Canadian Space Agency is planned with the goal to achieve a certain level of interoperability and complementarity between Sentinel-1 and RCM

- Towards a free and open access to Sentinel data for all users, within technical and budget constraints / restrictions.



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Thank you for your attention !