Sentinel-1 Mission Operations Concept

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Scope of the presentation

- Sentinel overall operations concept
- Sentinel-1 mission overview
- Status of Sentinel-1 observation scenario
- Concluding remarks

Sentinel overall operations concept

Overall Sentinel operations strategy

Main objectives of the Sentinel operations strategy

- provide data to GMES services and for use by ESA 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 solve anticipated conflicts a priori, in particular in the elaboration of pre-defined mission observation scenarios
  → planned for Sentinel-1 in particular

Sentinel High Level Operations Plan (HLOP)

The aim of the HLOP is:

- to identify the main constraints, limitations and potential conflicts related to the high level operations of the Sentinel missions

- to describe the measures and the strategy to cope with these constraints, reducing to the maximum the potential conflicts during operations

- to provide a high level definition of the Sentinel Operations and Observations Scenarios.

The Sentinel HLOP is a paper to be approved by ESA Member States (PB-EO)

Sentinel Data Policy

ESA Member States have adopted a FREE and OPEN data policy

Anybody can access Sentinel data; no difference is made between public, commercial and scientific use

→ open access

Sentinel data will be made available to the users via a 'generic' online access mode

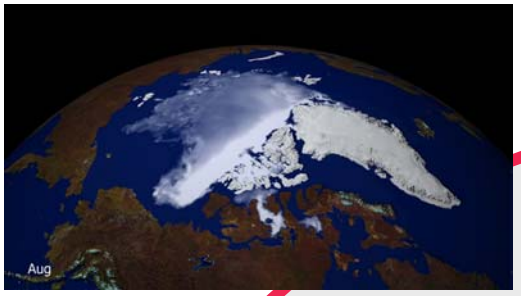
→ free of charge

This Data Policy still needs confirmation on the European Union side, as part of overall GMES data and information policy

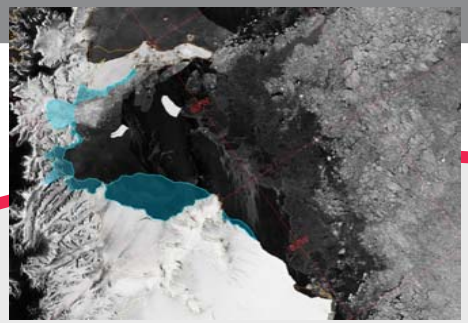
→ security restrictions might be implemented on the data distribution.

Sentinel-1 Mission Overview

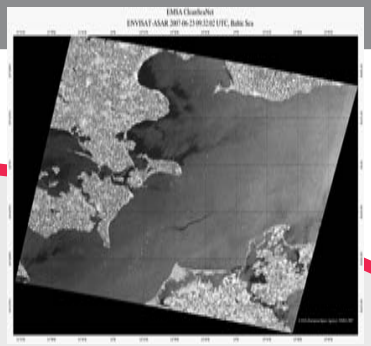
Few examples of Sentinel–1 applications



Arctic ice extent
August 2009
(Credit: MyOcean)

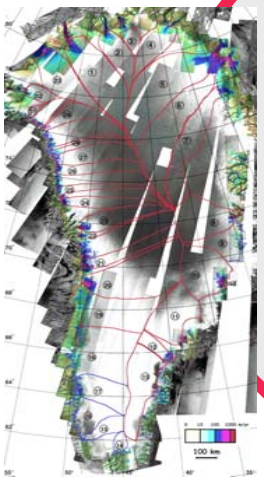


Larsen ice shelf loss between
2002 and 2009
(Credit: Polar View)



Oil spill detection
and Surveillance
(Credit: EMSA)

Ship detection
(Credit: ESA)

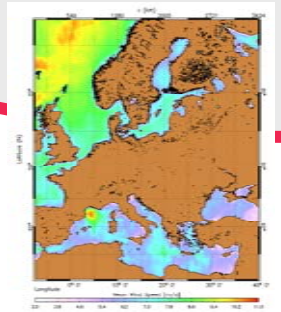


Acceleration of Greenland
glaciers flow
(Credit: Rignot et Al)

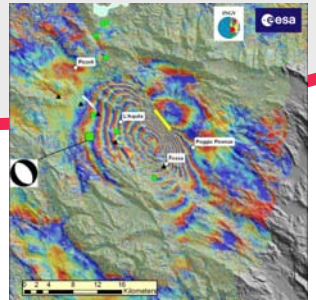
C-band SAR observations support a wide range of applications

Land use
(Credit: ESA)

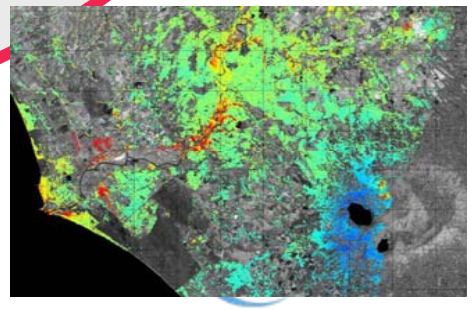
Emergency management:
flooding
(Credit: SAFER, DLR)



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



Earthquake
analysis
(Credit: INGV)



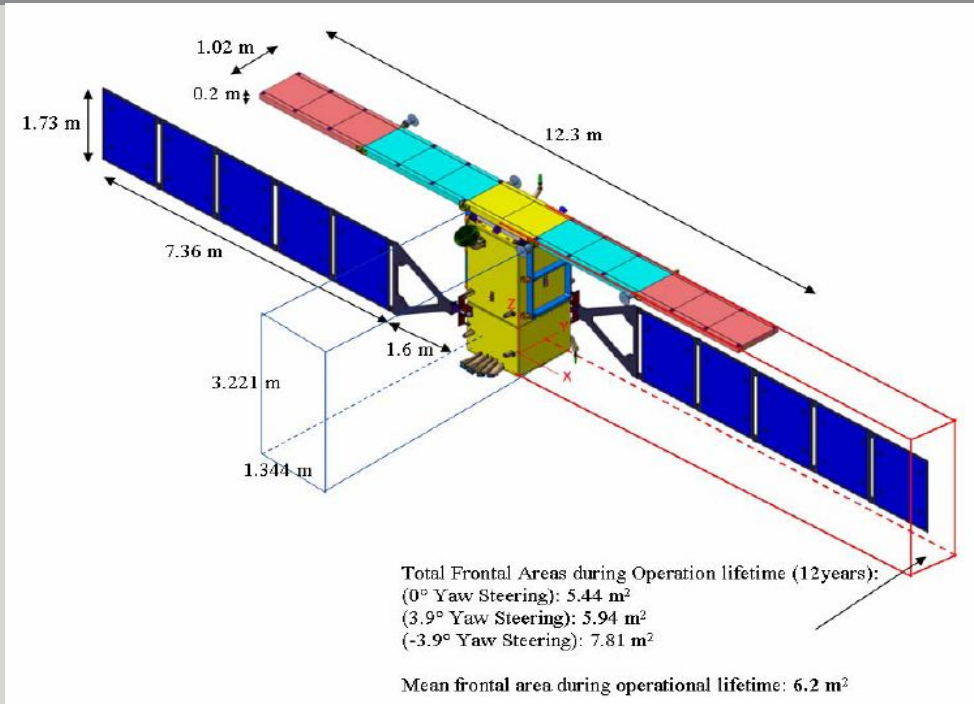
Subsidence map
1992-2006
(Credit: Terrafirma)

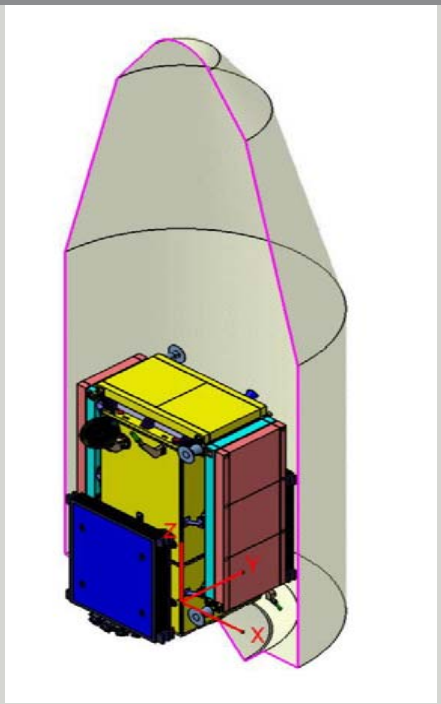
Sentinel–1: C-band SAR mission

- ✓ **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.

The Sentinel-1 mission is based on a constellation of 2 satellites
Sentinel-1A to be launched in May 2013
Sentinel-1B under procurement, launch date is TBD (indicatively 2015)

Sentinel–1 satellite





- 2300 Kg spacecraft mass
- 7 years design life time, consumables for 12 years
- Sun synchronous dawn-dusk orbit at 693 Km mean altitude
- **12 days repeat cycle (1 satellite), 6 days for the constellation**
- **The two satellites are in the same orbit but with an anomaly difference of 180 deg.**
- C-Band SAR Payload with centre frequency 5.405 GHz

Sentinel–1 SAR operational modes
Data recording / transmission capabilities

Four nominal SAR operation modes:

• Strip map	80 km swath, 5x5 m res.
• Interferometric wide swath	250 km swath, 5x20 m res.
• Extra wide swath	400 km swath, 20x40 m res.
• Wave	5X5 m res (TBC), sampled images of 20x20 km at 100 km along the orbit, alternating into 2 incidence angles

Note: above resolutions are single look mode resolutions. Best resolution of image products (GRD) is in the order of 10 meters.

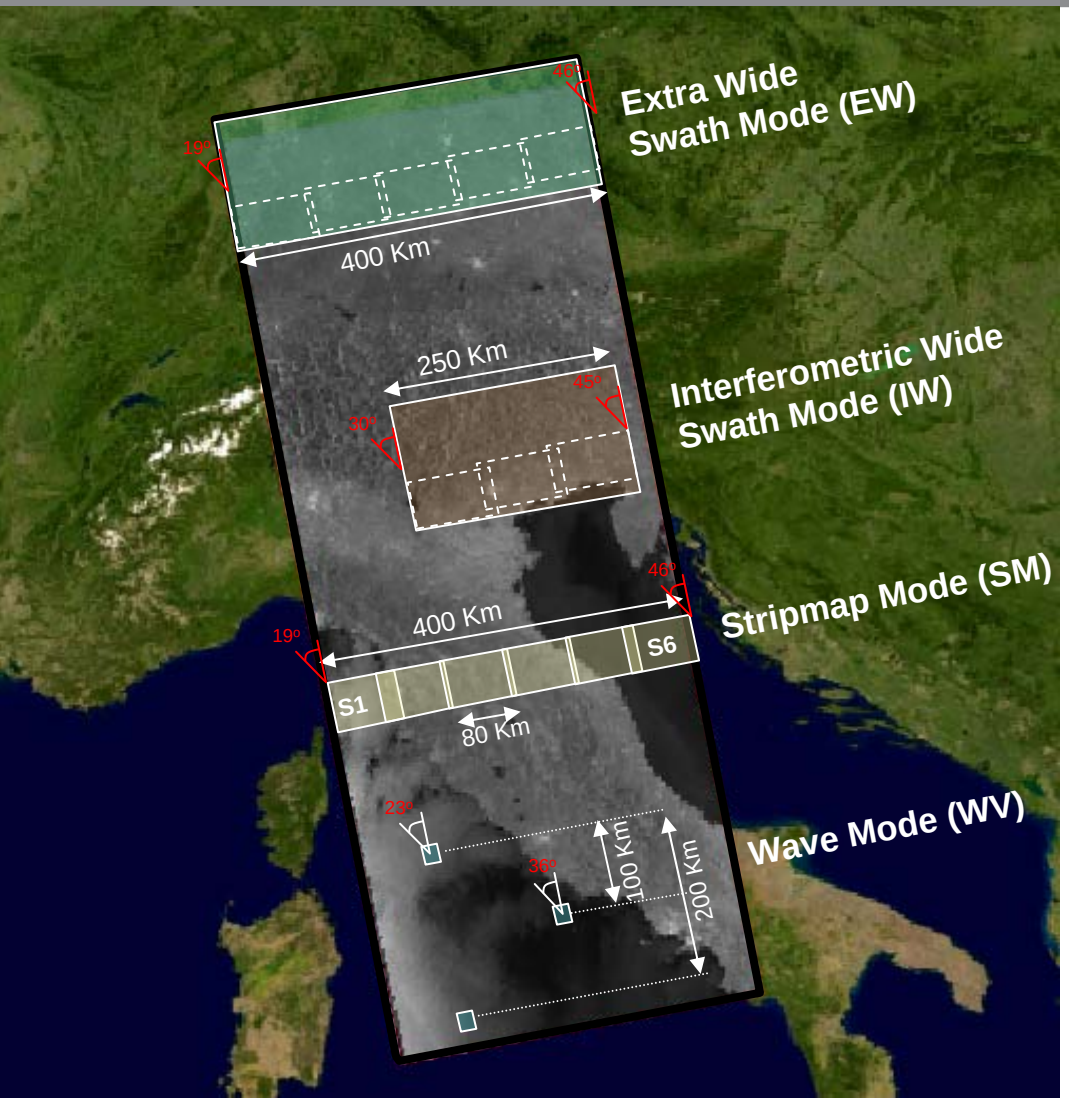
SAR Duty cycle:

→ 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 users.

Sentinel-1 Observation Scenario

Approach, status of observation requirement collection

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 Member States

In addition, on best effort basis and in order to ensure 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

Process

• Bi-lateral discussions with GMES services / EMSA among which potential conflict of observation requirements are expected (i.e. mainly over ocean / sea-ice):

• Bi-lateral or multi-lateral discussions with ESA Member States to review and discuss National requirements not covered by GMES service requirements

• Inputs from the GMES Operations Consultation Group (GOCG) to include the observation requirements of collaborative ground segment initiatives

• Continuity / experience of ERS and ENVISAT, and discussion with:
    • Science community mainly through workshops (e.g. FRINGE, SEASAR, etc.)
    • International Partners.

Sentinel-1 Observation Requirements

Two main categories of services / applications:

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

→ Services / applications over land

In addition, on top of the pre-defined scenario, emergency observations not part of the pre-defined plan may be accepted in exceptional cases.

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 require 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 from sensing
- → 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, earthquake, subsidence, landslides (background mapping)
  - Terrain motion monitoring (subsidence, landslides)
  - Specific security services
  - Global tectonic areas and volcano monitoring
  - Glacier and snow monitoring
  - River and lake ice monitoring
  - Forest mapping
  - Global land mapping (agriculture, soil moisture, land cover & change monitoring, 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 operation cycles)

Sentinel-1 observation scenario

The Sentinel-1 observation scenario is 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 the 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

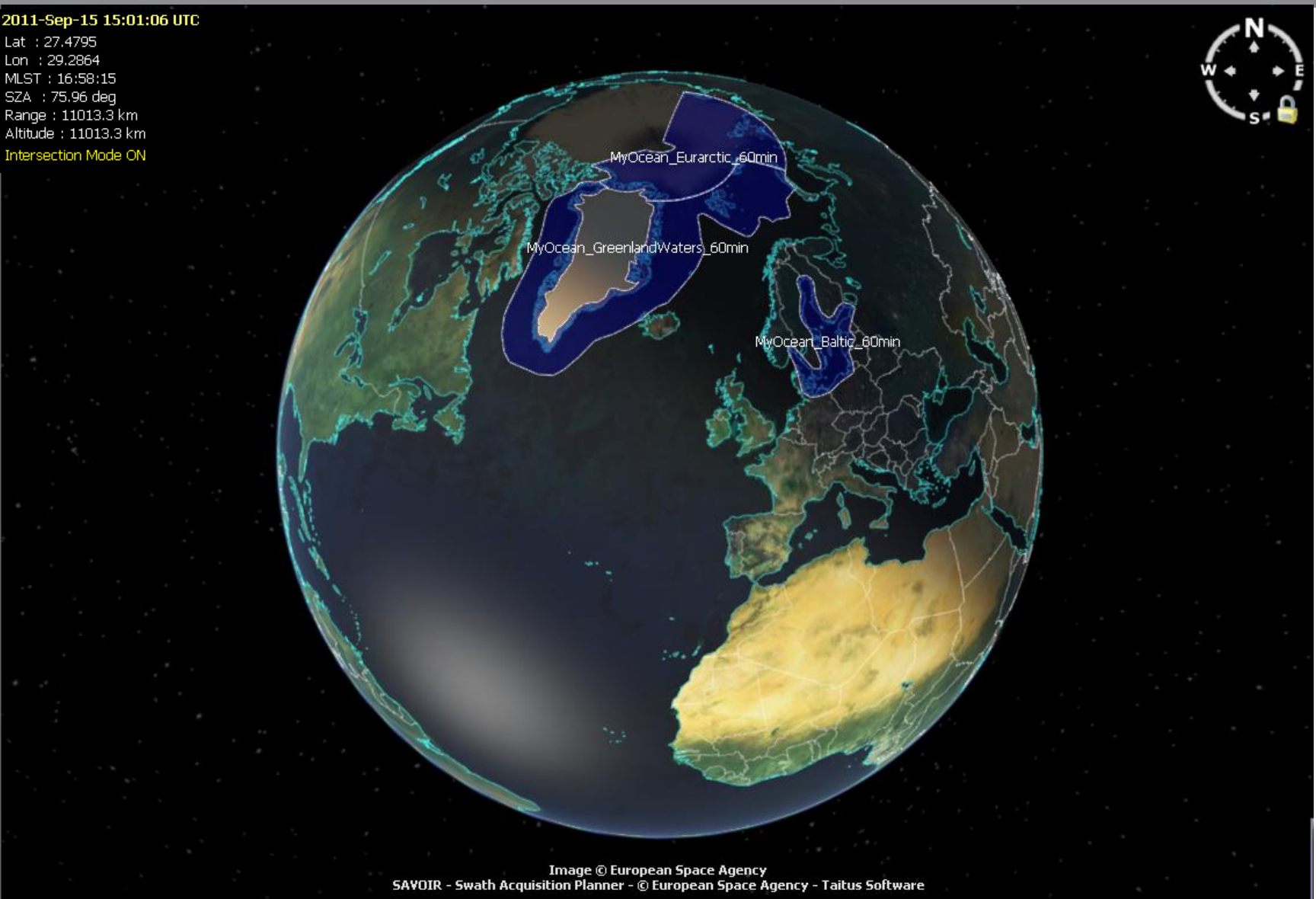
→ Over seas and polar areas, and ocean relevant areas: pre-defined mode is either IWS or EWS

• In exceptional cases only, emergency observation requests may alter the pre-defined observation scenario, with e.g. the use of the Strip Map mode

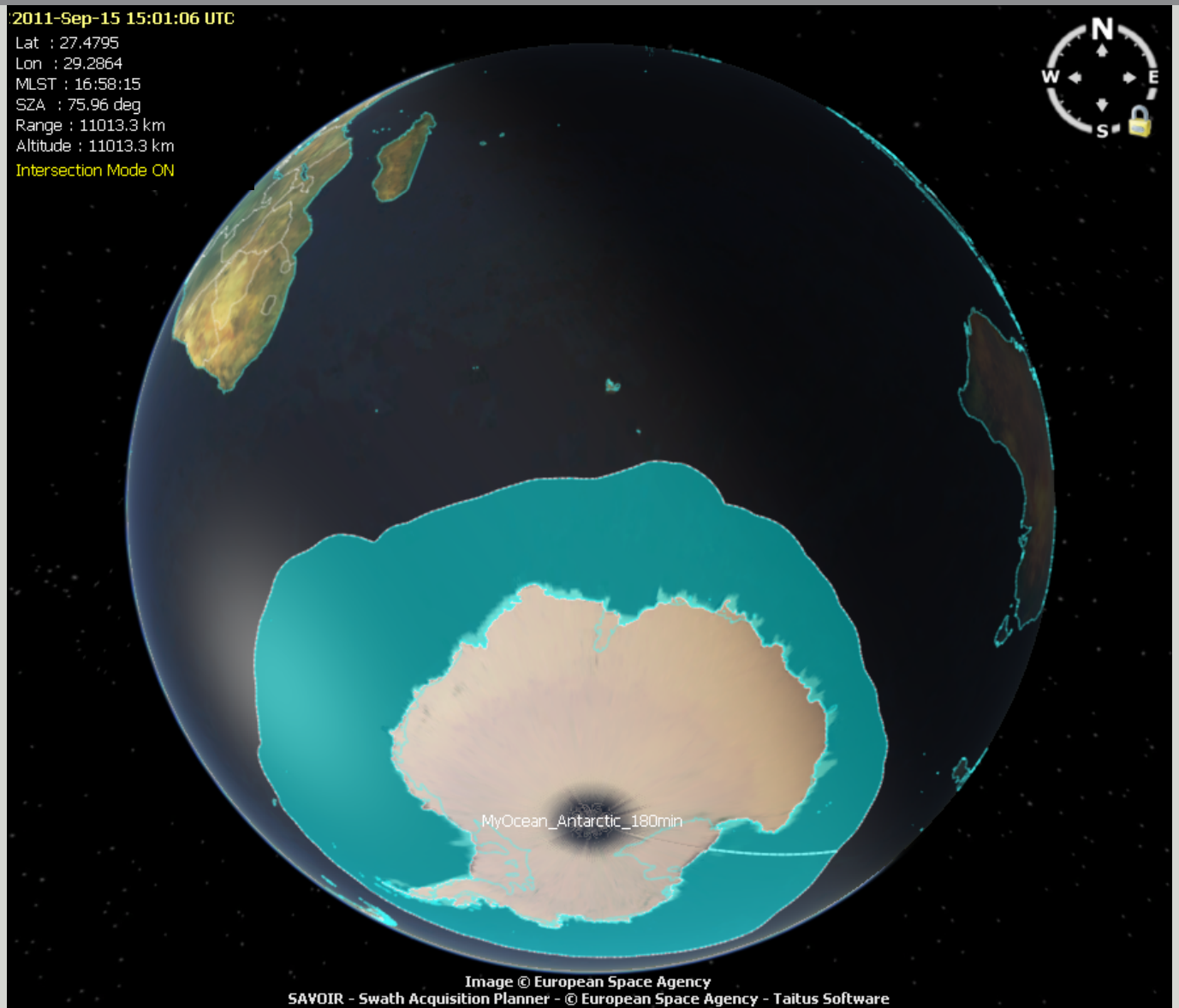
Preliminary observation requirements from MyOcean sea-ice monitoring services

- 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



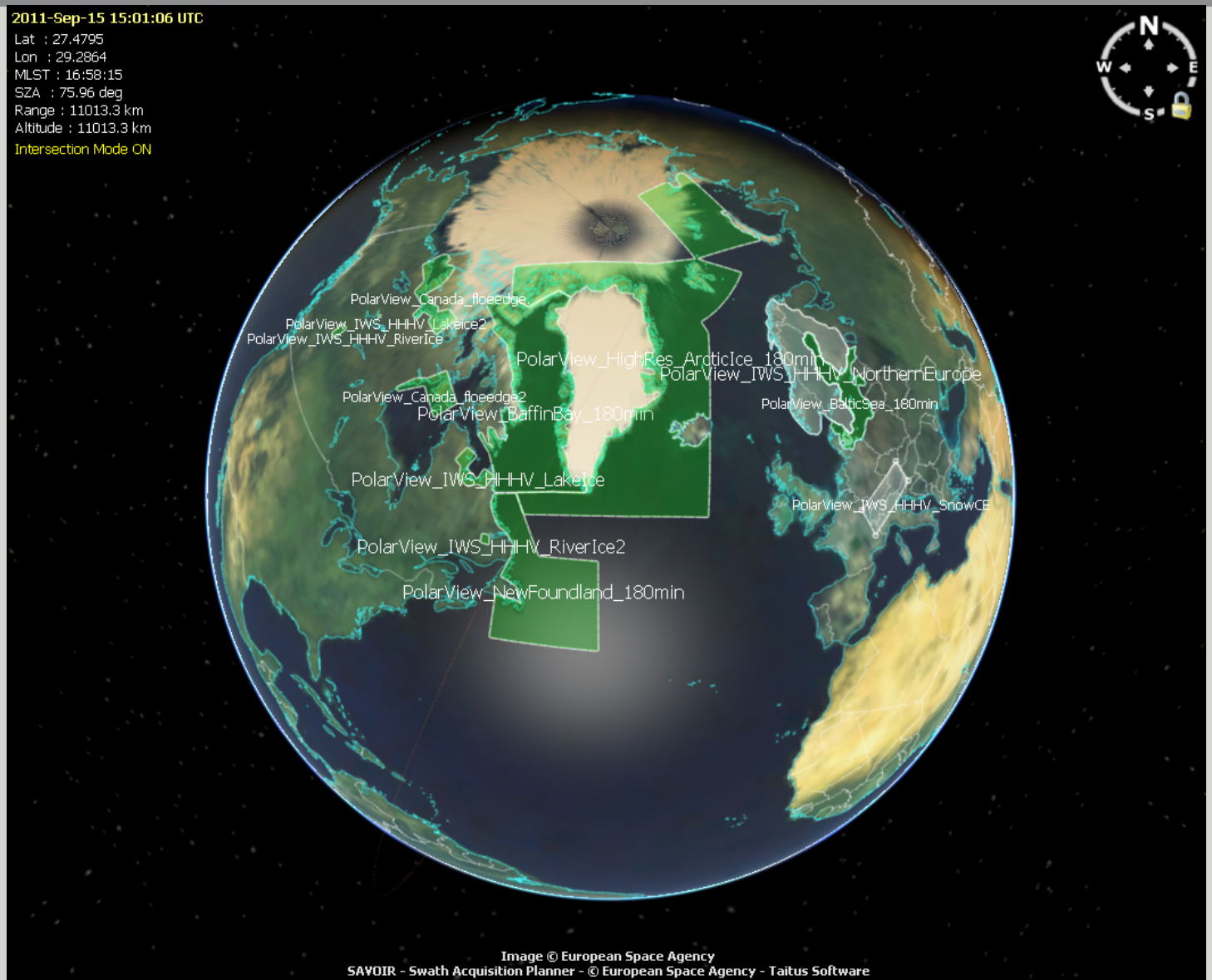
MyOcean sea-ice monitoring services Antarctica



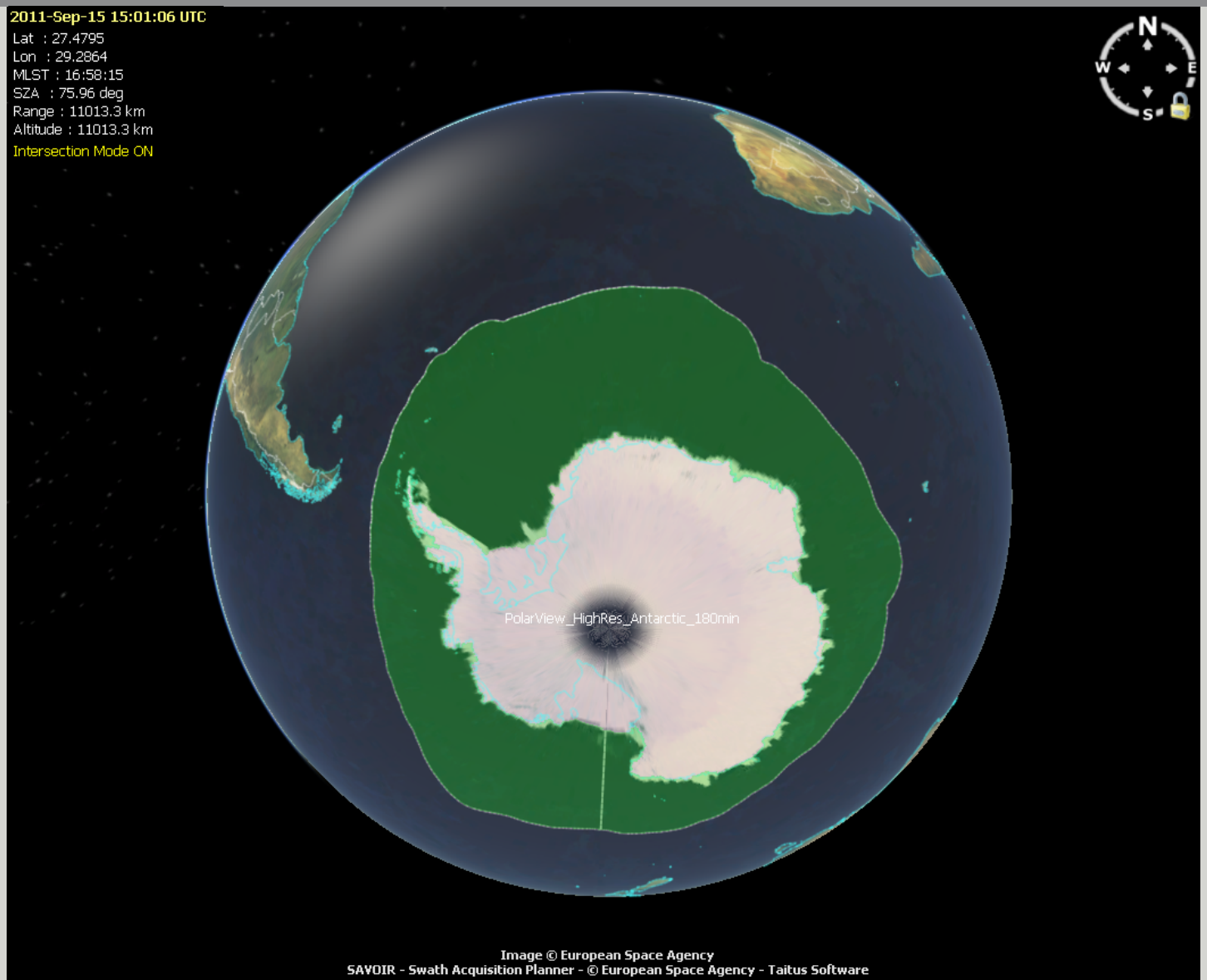
Preliminary observation requirements from Polarview

- Areas of interest: see next slides
- Data latency from sensing: NRT 3h
- Mode / polarisation:
  - for sea-ice: similar to MyOcean, i.e. EW, polarisation HH+HV
  - for river-ice and lake-ice monitoring: IW, polarisation HH+HV
- Potential conflicts, mainly with:
  - EMSA
  - Ship detection services
  - Land requirements (regarding Polarview river-ice)
  - Other National services

Polarview observation requirements
North Hemisphere



Polarview observation requirements
South Hemisphere



Preliminary observation requirements from MARISS (collaborative)

- Areas of interest: see next slides

- Data latency: RT / few minutes from sensing (similar to EMSA) or 1 hour from sensing, depending on the area

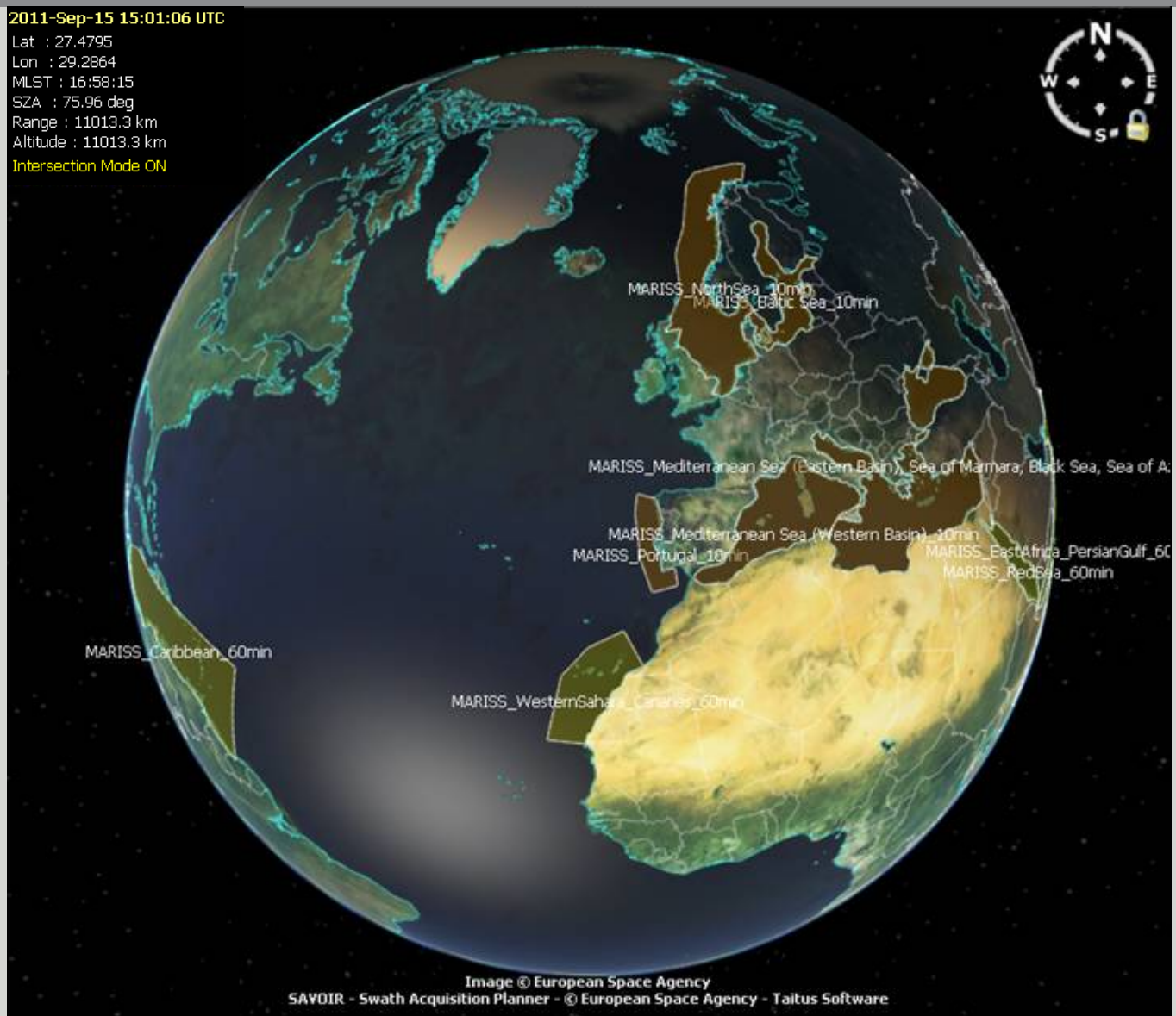
- Mode / polarisation:
  - IW, polarisation HH+HV

- Potential conflicts, mainly with:
  - EMSA
  - MyOcean sea-ice service, Polarview
  - Other National services

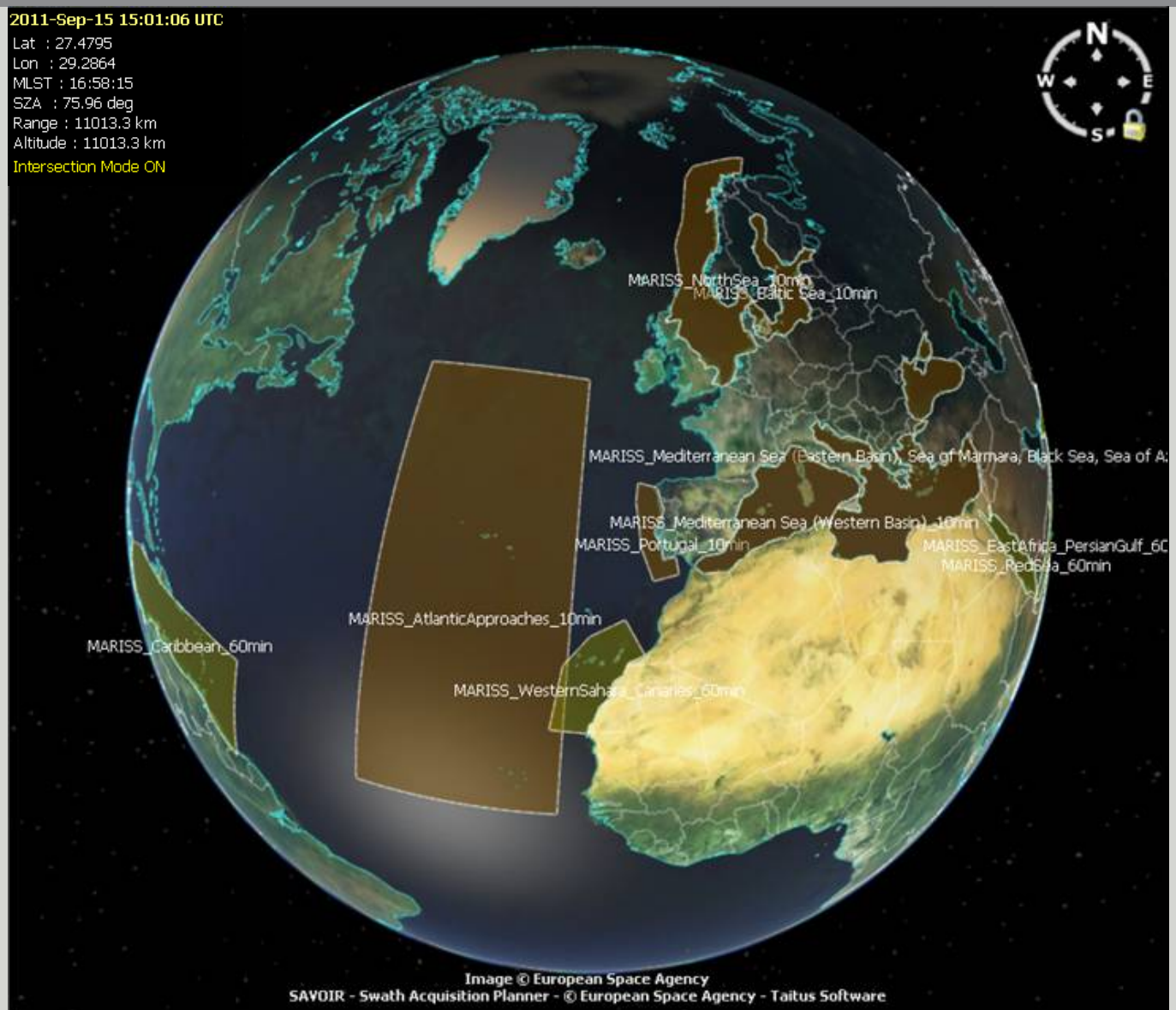
→ *Discussion required to further consolidate mode/polarisation and area extent*

→ *Ship detection service requirements is expected to be a main issue for defining the overall observation scenario*

MARISS observation requirements

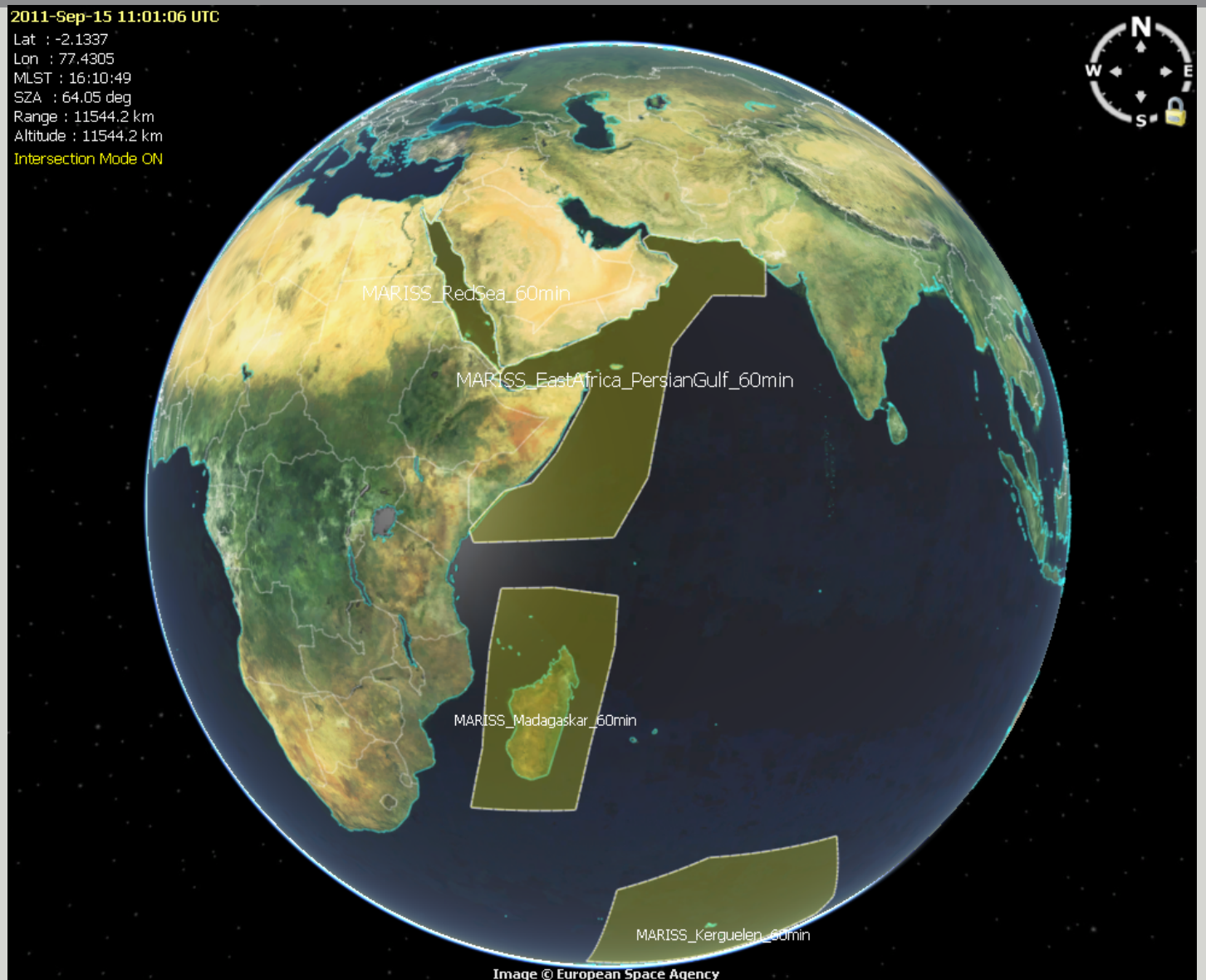


MARISS observation requirements
(incl. Atlantic approaches)

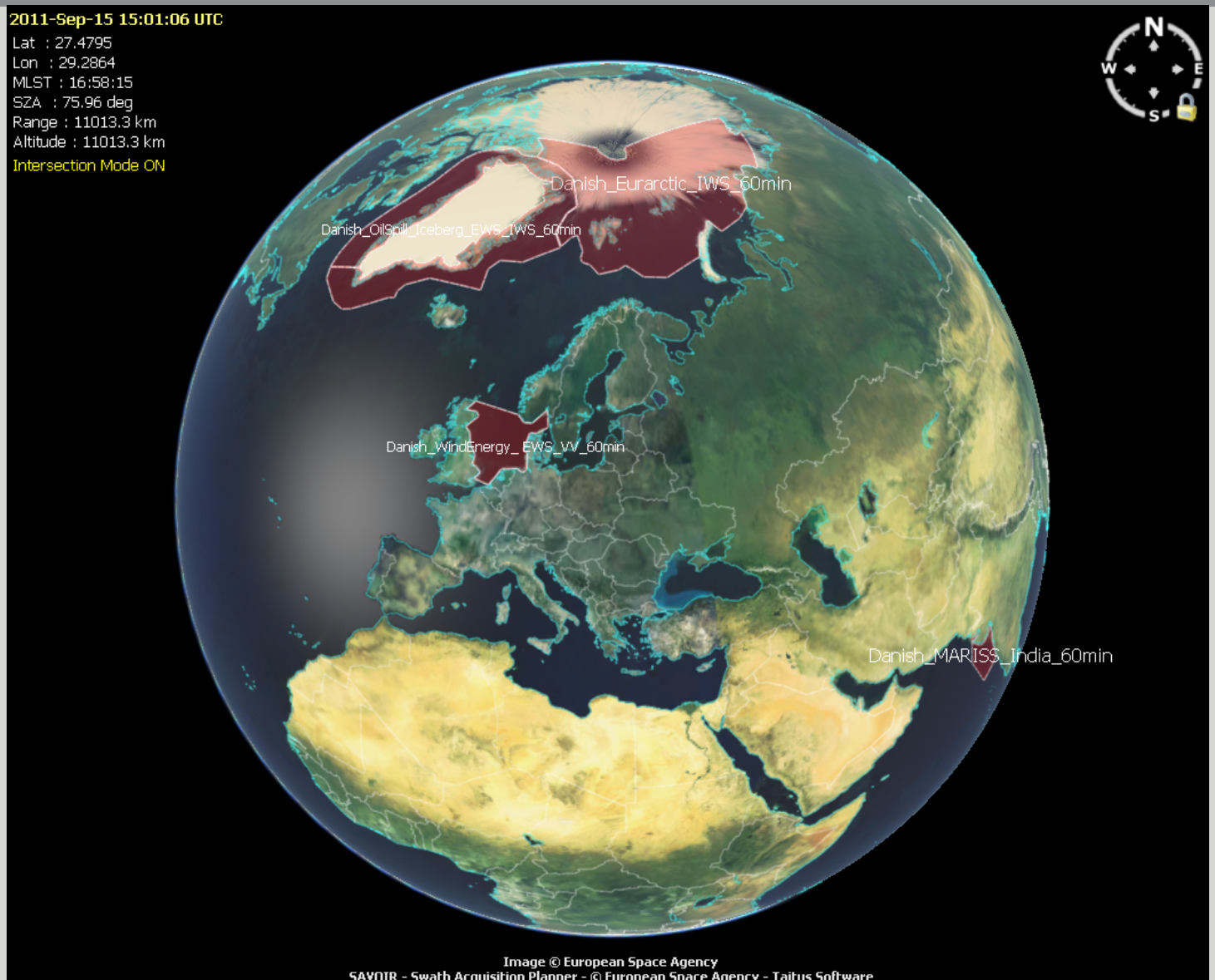


MARISS observation requirements

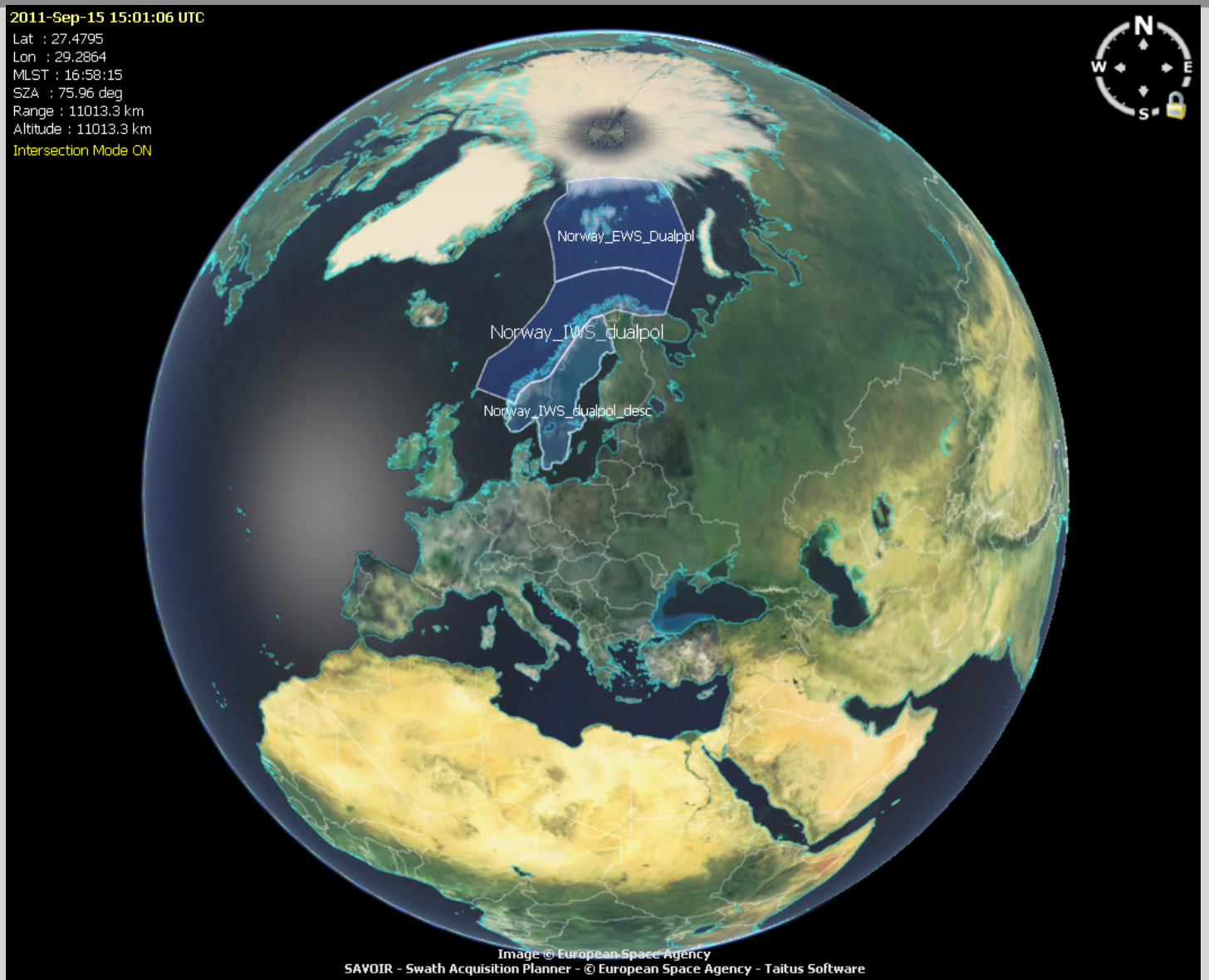
(Red Sea, East Africa, Persian Golf, Madagascar, Kerguelen)



National Requirements - Denmark



National Requirements - Norway



Preliminary observation requirements from EMSA for CleanSeaNet 2nd generation (collaborative)

- 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

→ *Further discussion required with EMSA*

Sentinel-1 RT (10 min) requirements from EMSA (CleanSeaNet 2nd gen.)

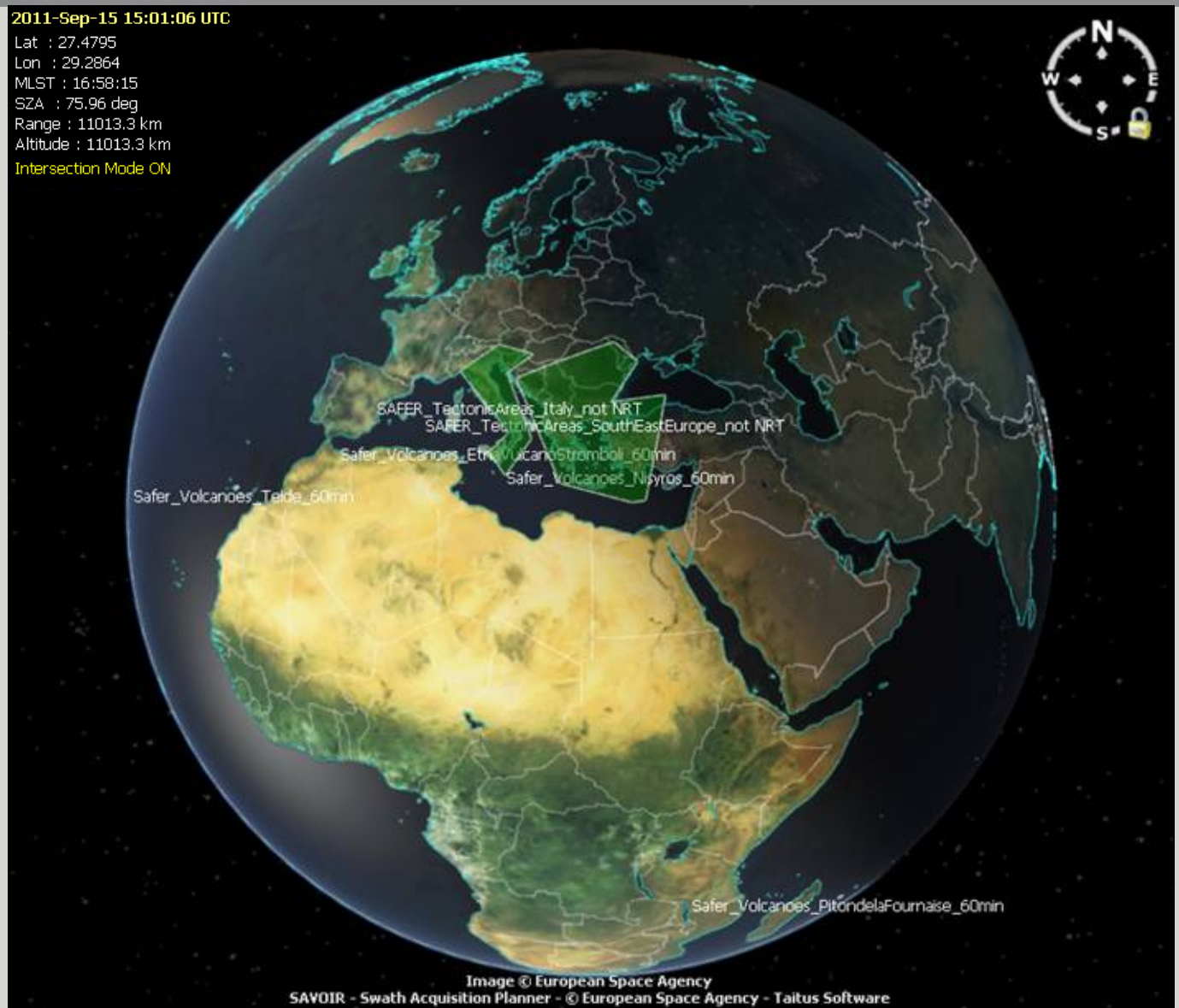
Sentinel-1 RT (10 min + 60 min) requirements from EMSA (CleanSeaNet 2nd gen.)

Observation requirements for services over land

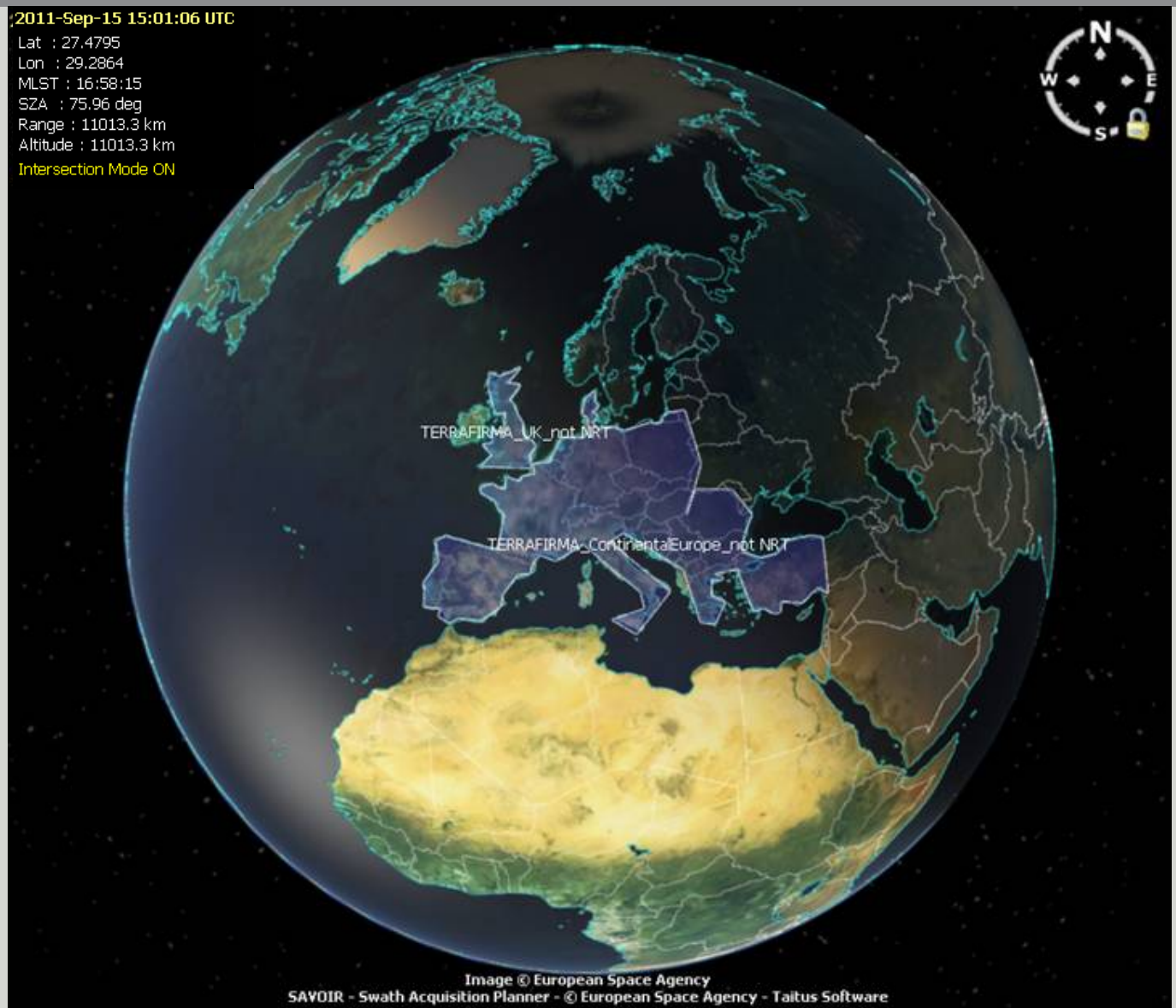
Main existing or planned land services, or source of requirements (list not exhaustive):

- SAFER: Flood Service, Earthquake, background mapping for land subsidence monitoring, Landslides service, Asset Mapping, Historical Assets map
- G-Mosaic: crisis Indicators, exploitation of natural resources, critical assets monitoring, illegal mining
- TerraFirma, DORIS: terrain motion monitoring
- Monitoring of global tectonic areas, Volcano (EVOSS), global land subsidence
- POLARVIEW: Glacier, snow cover monitoring
- Forest Mapping: e.g. support to REDD (GEO Forest Carbon Tracking task)
- GMFS: Crop mapping
- Global land mapping (agriculture, soil moisture, land cover & change monitoring, etc.)

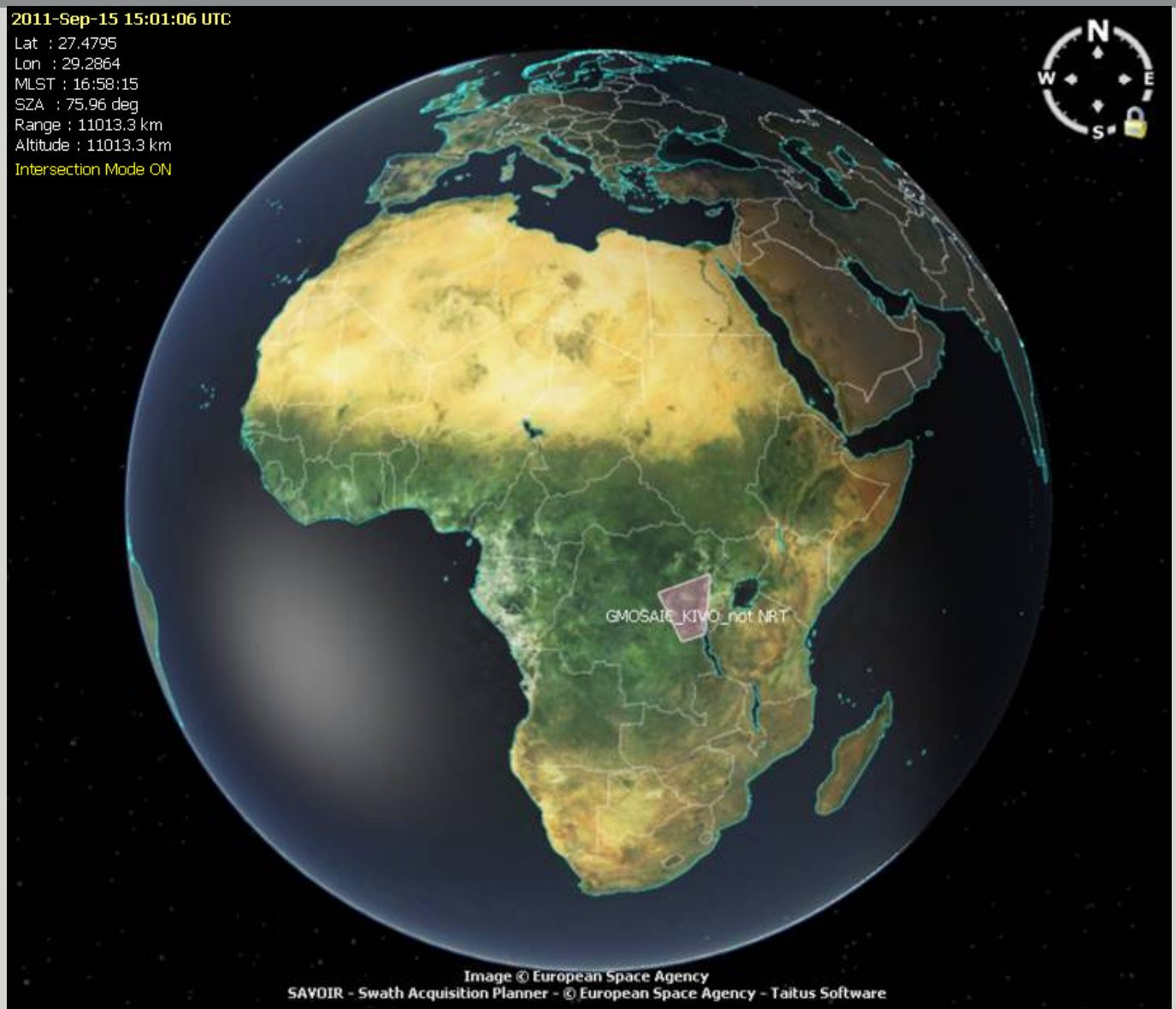
SAFER- European Targets



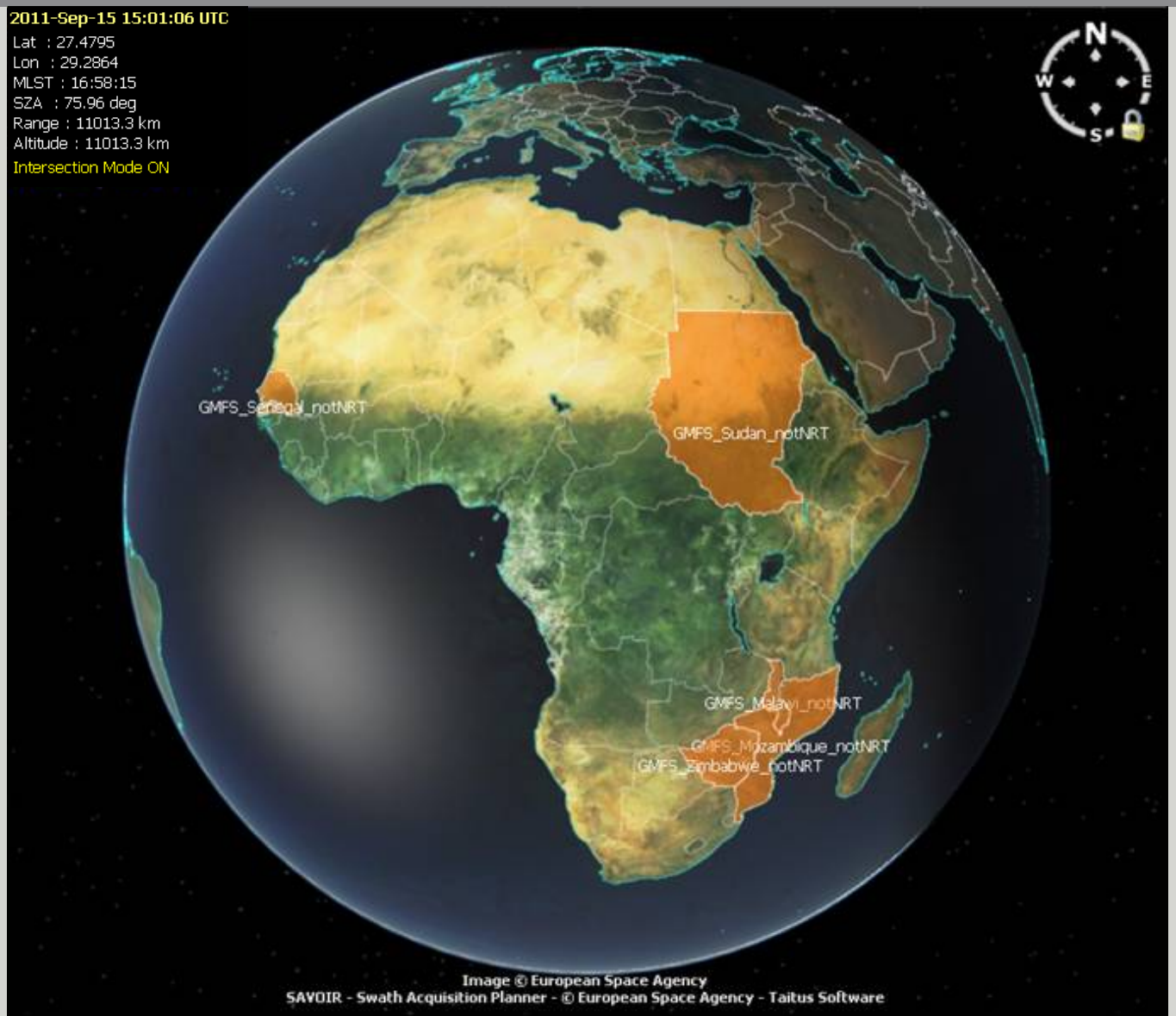
Terrafirma Europe



G-Mosaic - Kivu Province



GMFS Crop Mapping

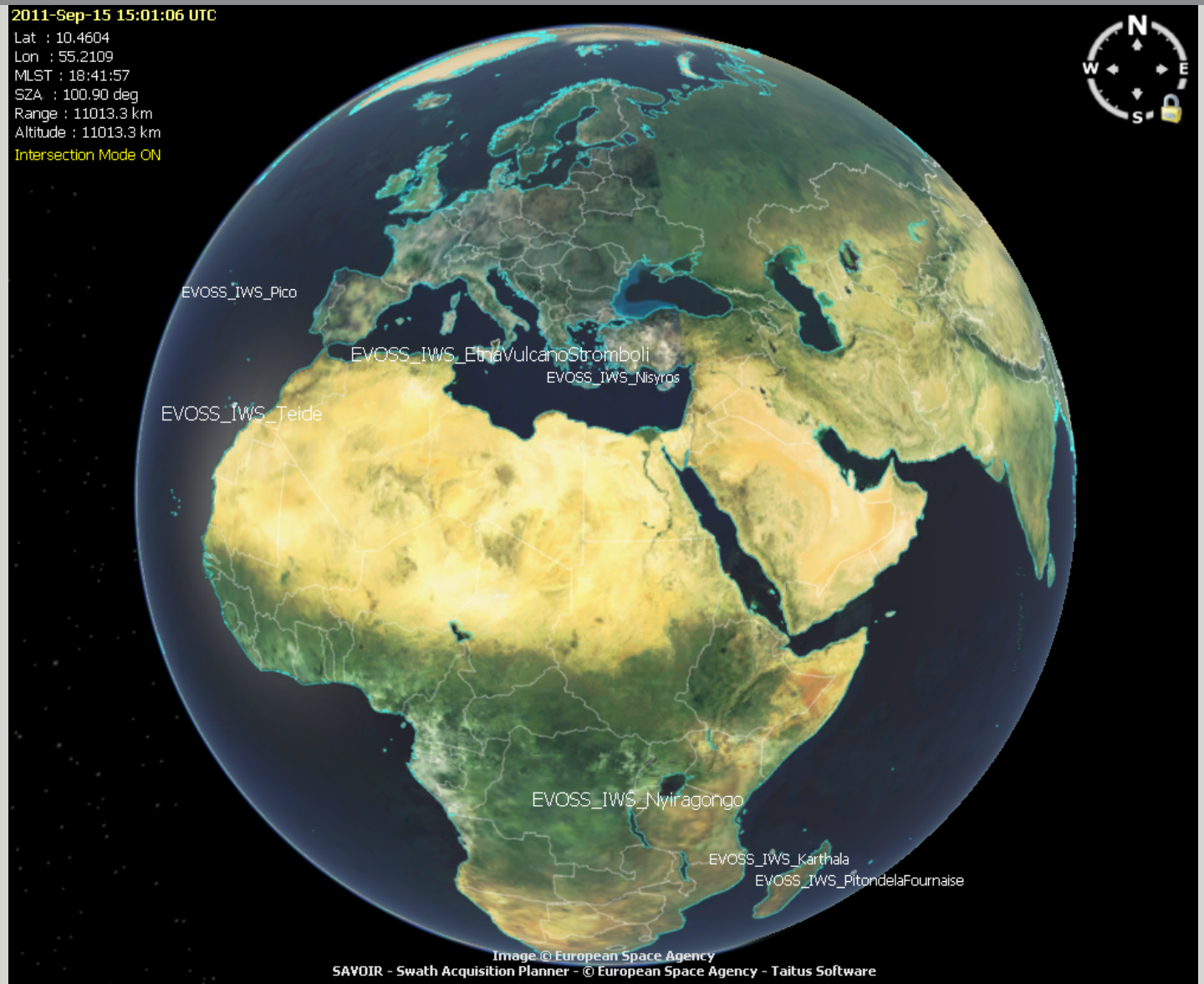


REDD Participating Countries America

REDD Participating Countries Africa and Asia

PolarView, snow monitoring

EVOSS - Global Volcanoes Europe and Africa

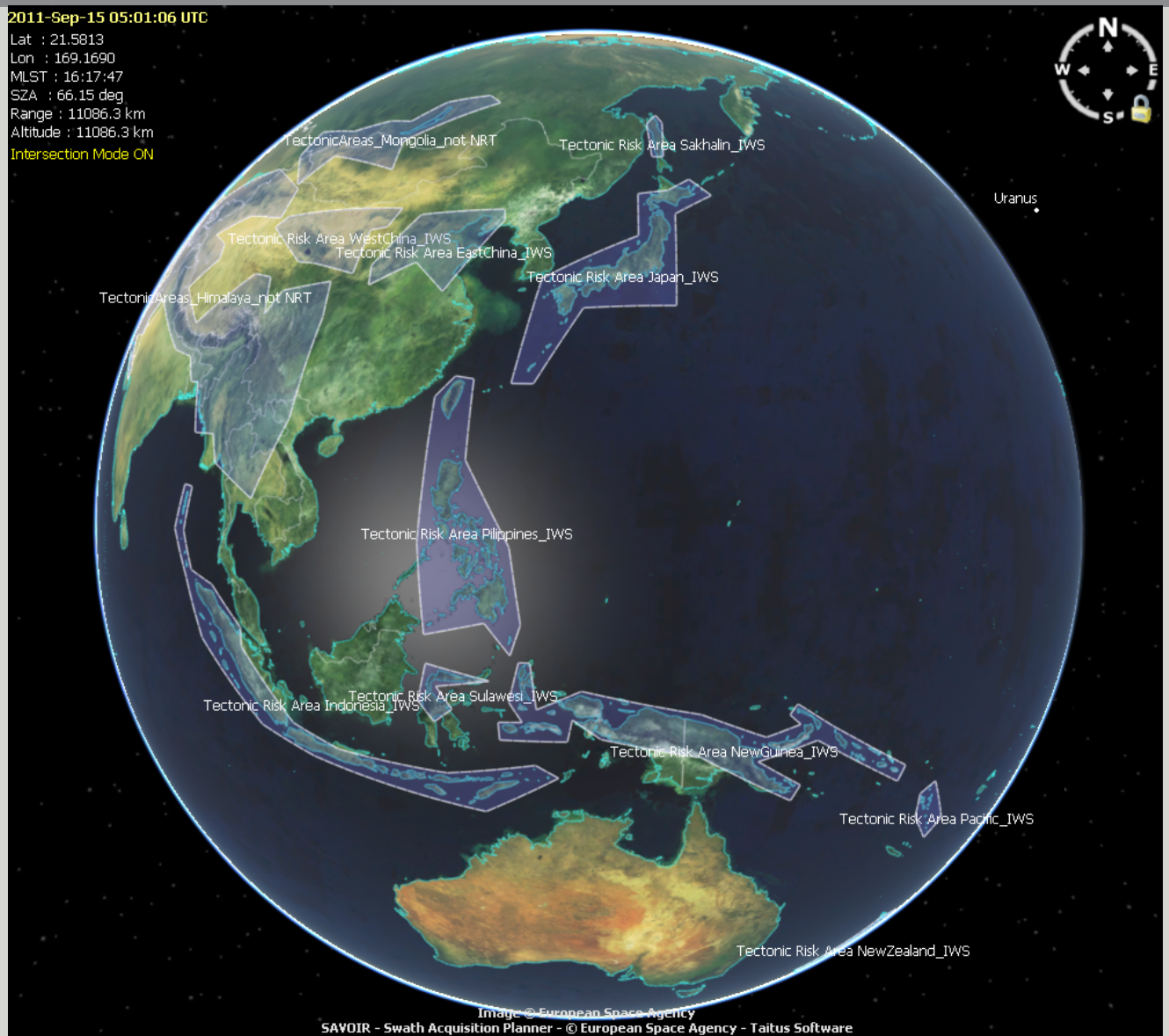


EVOSS - Global Volcanoes America

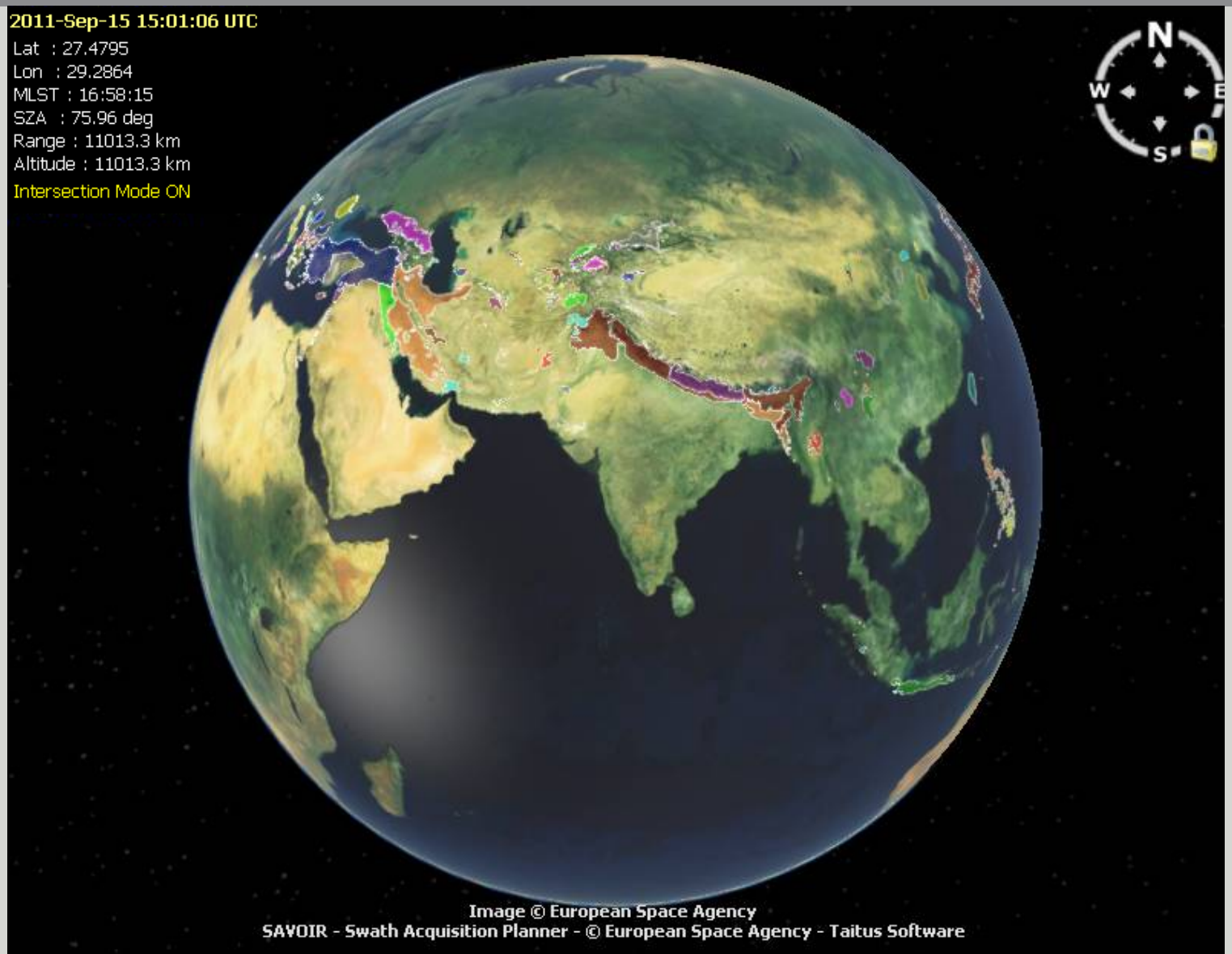
Global tectonic Risk Areas Eurasia (coarse shapes)

Global tectonic Risk Areas America (coarse shapes)

Global tectonic Risk Areas Asia (coarse shapes)



Global tectonic Risk Areas Europe and Asia (detailed)



Global tectonic Risk Areas North and South America (detailed)

Overall strategy to fulfil observation requirements for services over land

During Full Operational Capability operations

• Systematic (or very frequent) mapping of tectonic / subsidence / landslides / volcano areas to support operational services, “operational science” and scientific studies 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 (G-Mosaic)

• Regular mapping (based on seasons) of areas for glacier and snow monitoring

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

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

Initial Sentinel-1 observation scenario & evolution

From Commissioning phase to FOC

- a very basic observation / operations scenario will support the Commissioning phase

- Ramp-up phase: the scenario will gradually evolve from initial operations up to Full Operational Capability (FOC) during the EU Operational Programme (2014+) with the 2-satellite constellation.

Evolution during GSC operational phase, to cope in particular with:

- The main system capacity scenarios (incl. inclusion of the 2nd Sentinel-1 satellite, use of EDRS)

- The evolution of the requirements from the services, the evolution of the “perimeter” of the GMES services as defined by the EC

- The constraints on the space and ground segment resources (e.g. core and collaborative ground station networks), including the available operations funding

- The contribution of (and interoperability with) the Radarsat Constellation Mission (RCM)

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

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

- Towards a free and open access to Sentinel-1 data for all users

- Requirements from the InSAR community represent a main driver for observations over land