CRISTAL, CRISTALair and campaigns: Paving the way for the next generation of cryospheric measurements.

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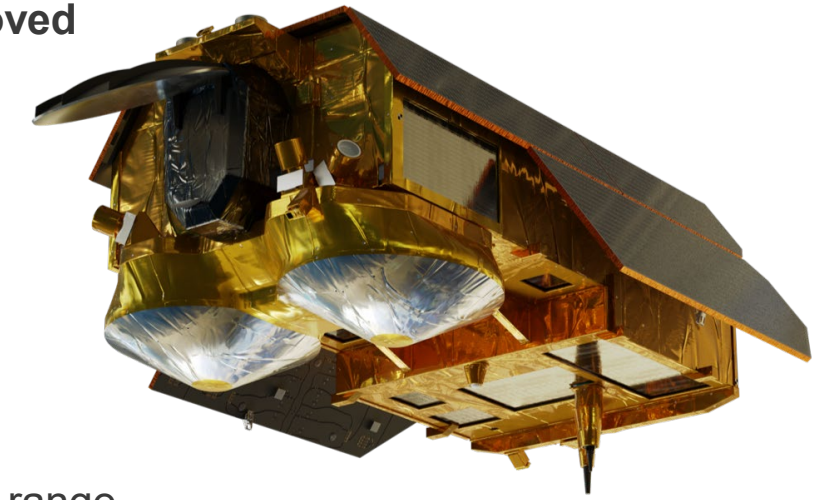
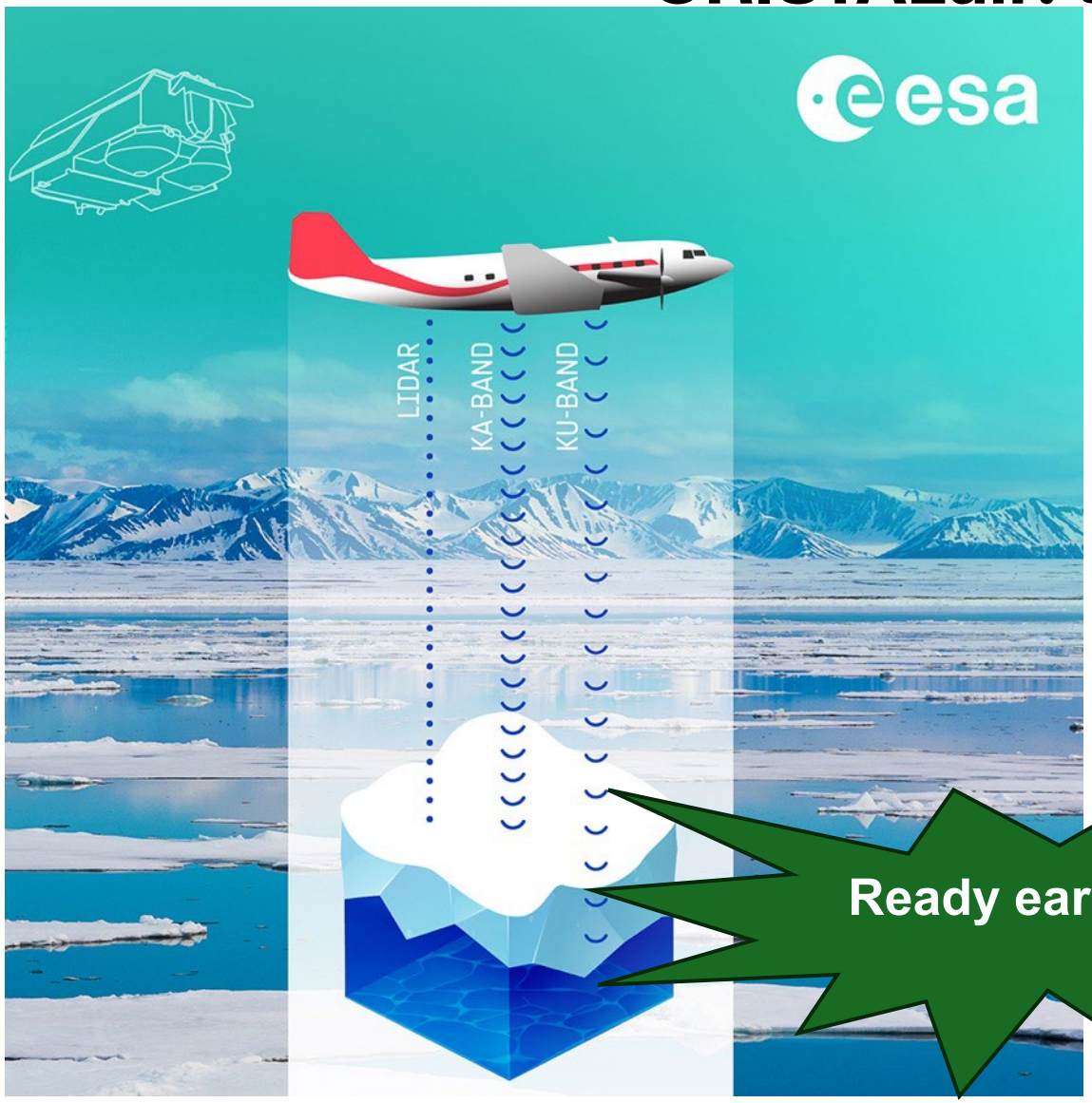
CRISTAL – the operational ice mission for Copernicus

- Objectives: Monitor sea ice, icebergs, land ice, glaciers (primary), but also ocean, coasts and all inland waters
- **High inclination mission (92 deg), continues the legacy of CryoSat-2, with improved performance**
- **Dual-frequency Ku/Ka SAR altimeter, Ku is interferometric**
- **Improved bandwidth: 500 MHz in both Ku and Ka**



- SARin over all ice surfaces
- Open burst over sea ice and icebergs → improved azimuth (along-track) resolution & range precision
- Flexible open loop/closed loop tracking everywhere
- AMR-CR radiometer with HRMR for oceanography, coastal altimetry, ice classification, snow parameters

CRISTALair: the airborne demonstrator for CRISTAL



Interferometric Dual-Frequency Airborne Altimeter Instrument

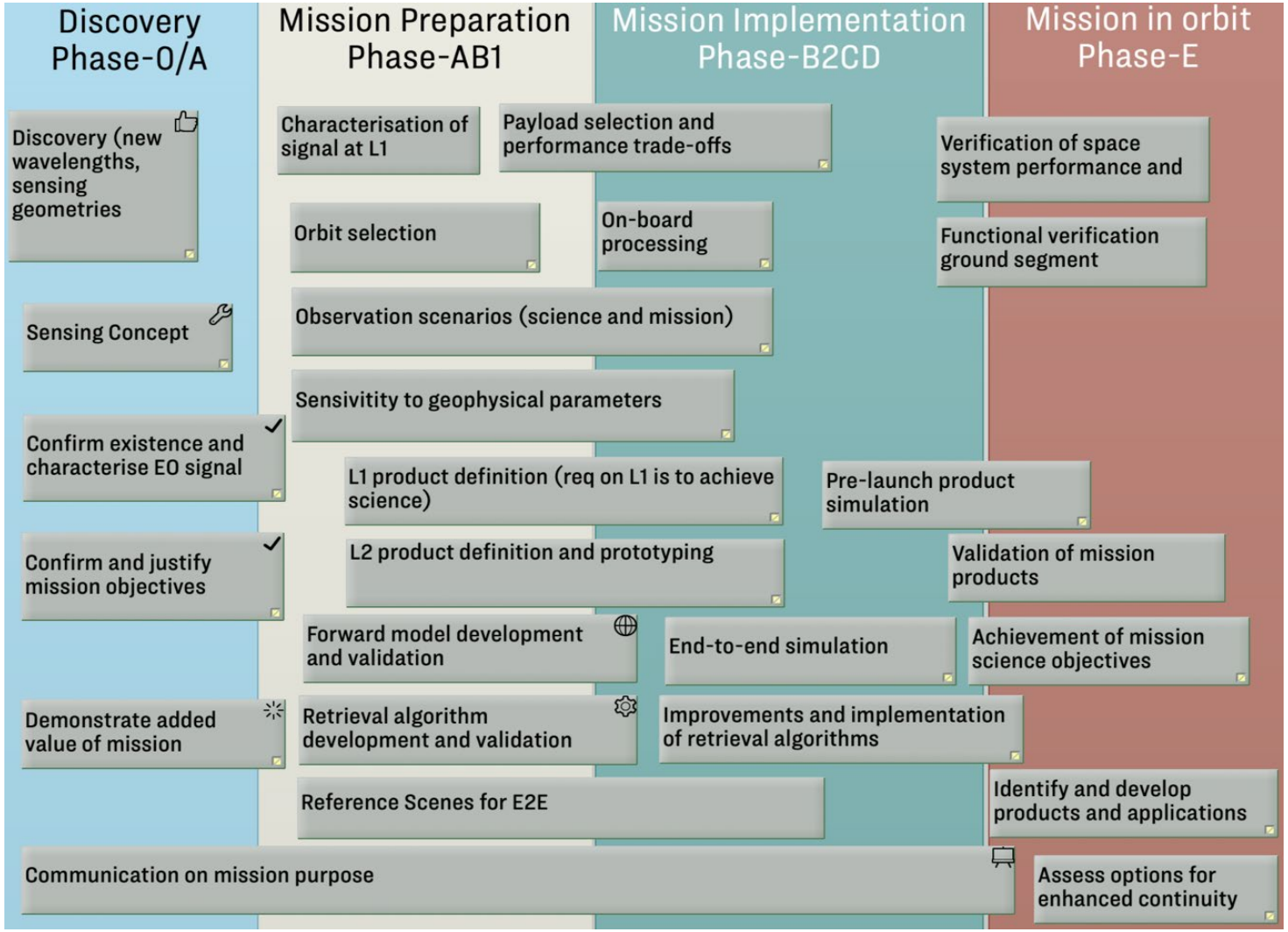
- Interferometry in both Ku- **and** Ka-band
- 1 GHz bandwidth (sampling of full bandwidth)
- Range window: 300 m
- Altitude range: 1000 m – 4000 m (AGL)
- Currently optimized for Twin-Otter aircraft
  - We will also get it certified for Basler aircraft

Ready early 2025

- Included:
  - LIDAR (rented)
  - Colour infrared camera
  - Stabilized platform
  - Inertial Measurement Unit
  - GNSS receiver

The role of EO campaigns

- Campaigns contribute to all phases of EO missions (Earth Explorer, Copernicus and Met. Missions)
- Different project phases require different inputs (from discovery to in-orbit validation of operational mission products)
- Campaigns contain full end-to-end simulation aspects of EO missions
  - Level-0 data from payload
  - Level-1 (engineering units)
  - Level-1 to Level-2 (geophysical units)
- Also supports development of Cal/Val concepts for missions prior to launch and their implementation



CRISTAL context for 2024 to 2026 campaigns

- CRISTAL is the first altimetry satellite mission operating simultaneously at both Ku and Ka frequencies. In principle, the difference in penetration of the two frequencies allows the derivation of the Snow Depth (SD), which is crucial to retrieve reliable Sea Ice Thickness (SIT), one of the key geophysical variables for the CRISTAL mission.
- Despite recent progress, the few existing SD processing algorithms are not yet fully mature. They need to be refined and thoroughly validated to meet mission requirement at In-Orbit Commissioning Review (IOCR) and enable a full operational exploitation of CRISTAL dual-frequency capabilities.
- SD over sea ice is itself a variable of strong interest (and ECV) playing a crucial role in the sea ice growth/melt cycle and therefore in the polar (and global) climate system. Currently, studies on SD retrievals are critically lacking validation data, therefore campaigns are urgently needed to collect the necessary SD and SIT validation datasets.
- All the campaigns proposed below, will allow to build an extensive dataset which is necessary to develop, test and improve retrieval algorithms aiming at delivering reliable operational data by the time CRISTAL launches.
- These campaigns also lay the foundations on which to build the CRISTAL post-launch cal/val activities during and after the commissioning phase. They are expected to provide guidance for the design of activities to collect Fiducial Reference Measurements (FRMs) and develop the necessary Cal/Val tools for the CEM in the polar domain.

CRISTAL pre-launch campaigns summary schedule

Campaign	Objectives	Time / Duration	SSP activities & Mission Obj.s
CRISTAL pre-validation campaign	- *De-risk arctic campaign by using CRISTALair in a preliminary testing campaign* - *Detect multiple surfaces in the Ka/Ku radar ecograms by sensing different surfaces over an alpine lake* - *demonstrate that CRISTALair can detect the air/snow, the snow/ice and the ice/water interfaces in a frozen lake acquisition (not a driver)*	March 2025	SP07, SP08
CRISTALair Functional Flight Campaign in the Arctic	- *Cal/sync flights* - *Radiometric / elevation accuracy / slope /point target response and other req verifications* - *Flights over corner reflectors* - *Antenna pointing verification* - *Performance evaluation over altitude* • *Verification of the CRISTALair Level1 ground processor*	TBD / 4 days *(~20 hours over 4 flights)*	SP07, SP08
CRISTALair Functional Campaign add-on in the Arctic *(Station Nord)*	- *Collocated snow measurements to validate snow depth* - *Drone/aircraft snow radar measurements*	TBD	SP03, SP07, SP08
CRISTALair for AWI	*Certification of CRISTALair in AWI aircraft*	TBD	
CRISTAL first Science Campaign in the Arctic *(or Svalbard)*	- *Snow, sea/land ice measurements to develop & consolidate snow depth measurements* - *Characterize radar return at both frequencies* - *Validate snow retrievals*	TBD	SP06, SP07, SP08
Copernicus Synergy Campaign (Arctic)	*Collocated measurements of CRISTALair, CIMRair, snow radar, radiometer (airborne) with ground measurements*	Spring 2026	SP06, SP07, SP08
CRISTAL Science Campaign in Antarctica	*Additional measurements for developing retrieval methods based on Antarctica snow conditions which differ considerably from Arctic snow*	TBD	SP01, SP02,SP06 SP08

CRISTAL pre-validation campaign	- *De-risk arctic campaign by using CRISTALair in a preliminary testing campaign* - *Detect multiple surfaces in the Ka/Ku radar ecograms by sensing different surfaces over an alpine lake* - *demonstrate that CRISTALair can detect the air/snow, the snow/ice and the ice/water interfaces in a frozen lake acquisition (not a driver)*	**March 2025**

- Location: Suitable frozen lake close to Milan (or easily accessible).

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CRISTALair Functional Flight Campaign in the Arctic

- ***Cal/sync flights***
- ***Radiometric / elevation accuracy / slope /point target response and other req verifications***
- ***Flights over corner reflectors***
- ***Antenna pointing verification***
- ***Performance evaluation over altitude***
- ***Verification of the CRISTALair Level1 ground processor***

TBD
/ 4 days
(~20 hours over 4 flights)

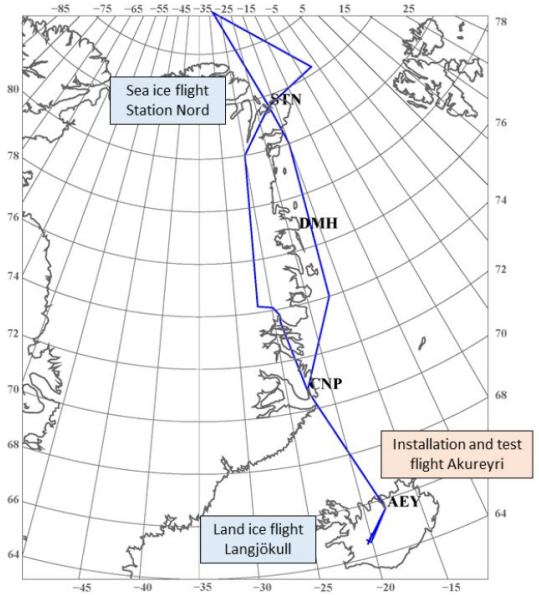

Figure 18. Tentative flights for functional flight campaign. Airports/bases: AEY: Akureyri; CNP: Constable Pynt; STN: Station Nord; DMH: Danmarkshavn.

- Flight 1: Test flight in Akureyri (airport runway)
- Flight 2: Land ice flight (glacier, Iceland)
- Flight 3: Sea ice flight (from Station Nord)
- Flight 4: Flight over ocean during transit flight (between Akureyri and Station Nord)

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CRISTALair Functional Campaign add-on in the Arctic *(Station Nord)*	- *Collocated snow measurements to validate snow depth* - *Insitu, drone/aircraft snow radar measurements*	**TBD**
CRISTALair for AWI	***Certification of CRISTALair in AWI aircraft***	**On-going**
CRISTAL first Science Campaign in the Arctic	- *Snow, sea/land ice measurements to develop & consolidate snow depth measurements* - *Characterize radar return at both frequencies* - *Validate snow retrievals*	**TBD**
CRISTAL Science Campaign in Antarctica	*Additional measurements for developing retrieval methods based on Antarctica snow conditions which differ considerably from Arctic snow*	**TBD**

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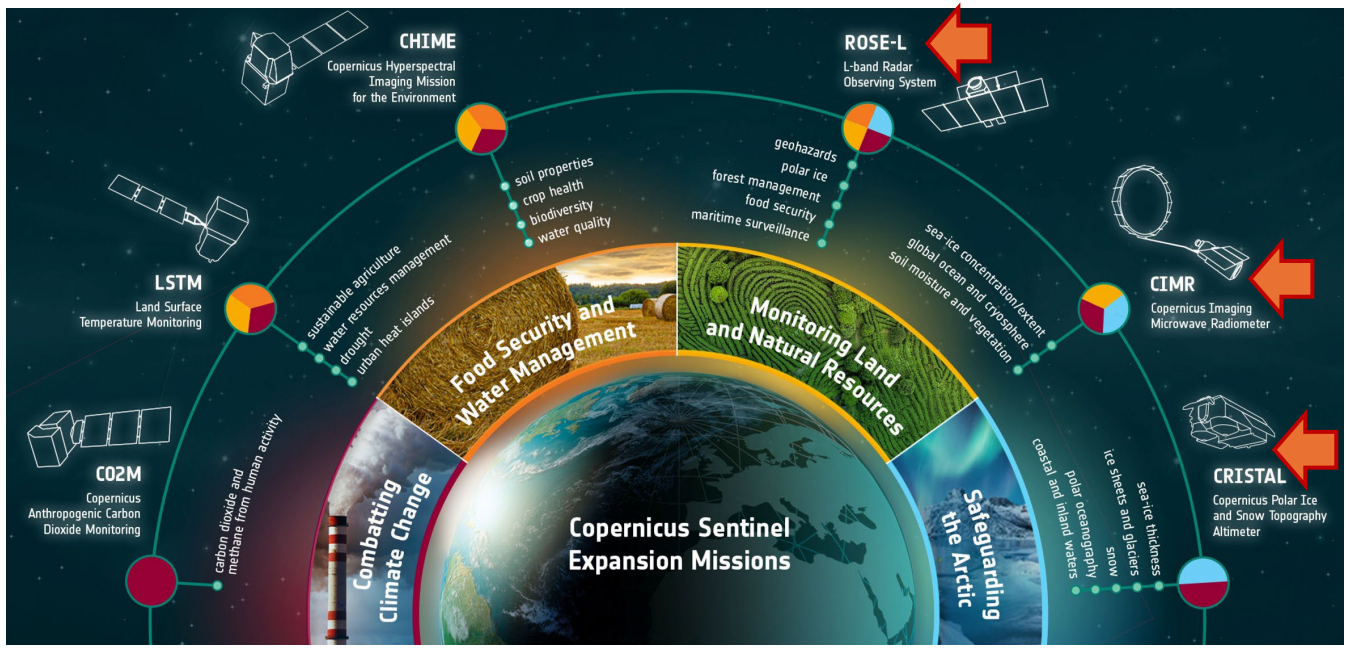
Copernicus Synergy Campaign (Arctic)	*Collocated measurements of CRISTALair, CIMRair, snow radar, radiometer (airborne) with ground measurements*	Spring 2026



- **Timeline & Location**

Spring 2026, Arctic Sea-Ice and Land-ice, with full suite of ground measurements in Cambridge Bay

Objectives

- Building on the MOSAIC legacy, the main objective is to obtain collocated FRM measurements of CRISTALair, CIMRair, snow radar, radiometer (airborne, from **NASA/JPL**) together with a full suite of ground measurements over first year ice

- Acquisition of a unique dataset to support the cryospheric scientific community research, contributing to the understanding of the uncertainties of the retrieved products and improve the current forward models

Questions?