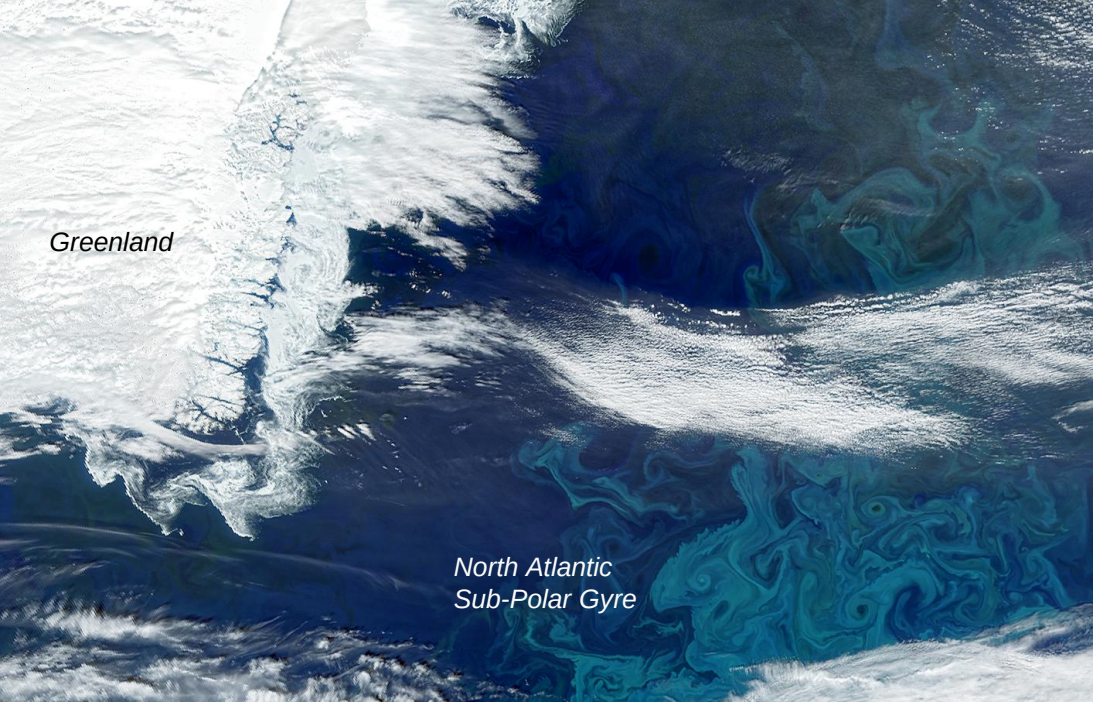

An Early Warning System for Tipping Points in the Greenland Ice Sheet and the North Atlantic Subpolar Gyre: exploring the Edge of the Possible with AEROSTATS

Christine Gommenginger[1], David McCann[1], Adrien C.H. Martin[3], José Marquez Martinez[2], Sam Lavender[4], Christian Buckingham[1], Alice Marzocchi[1], Louis Clément[1], Simon Josey[1]

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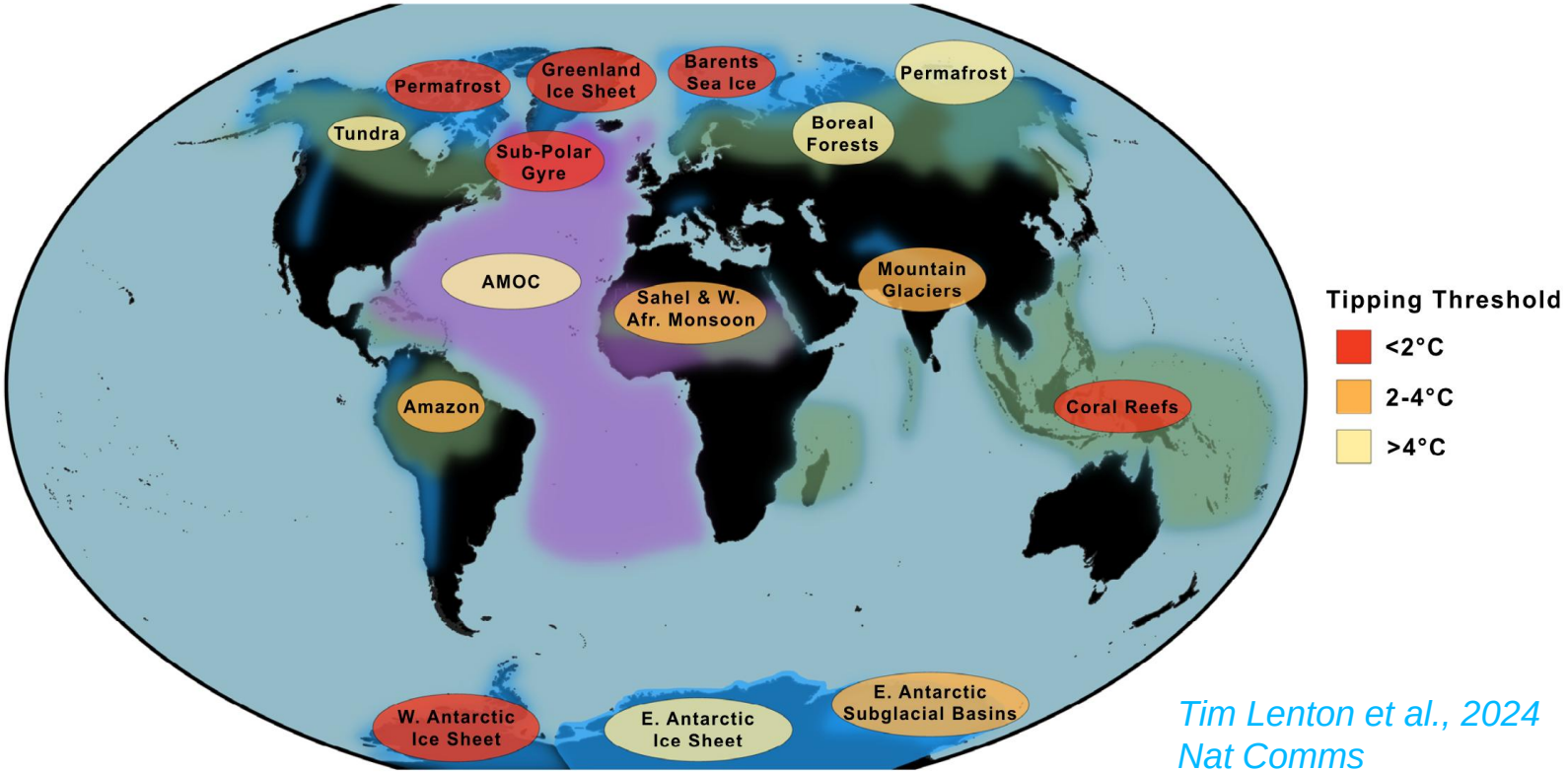
Climate tipping elements and their sensitivity to global warming



Tim Lenton et al., 2024
Nat Comms

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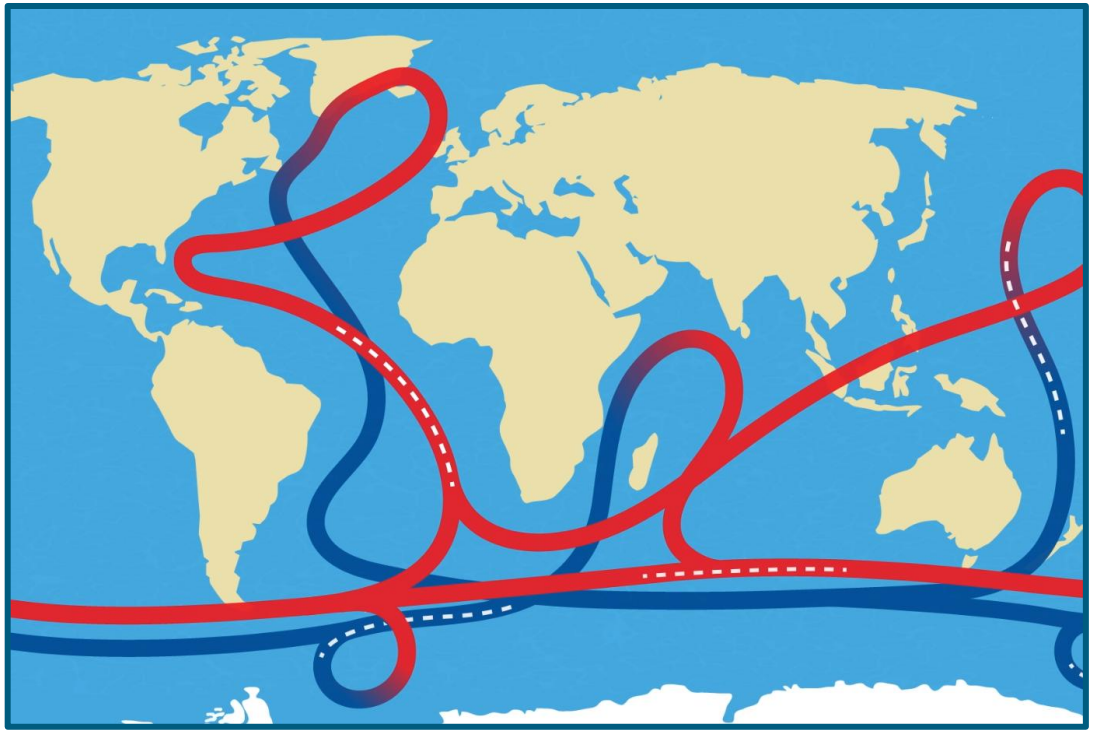
THE GLOBAL THERMOHALINE CIRCULATION



- Global ocean circulation driven by differences in water temperature and salinity (density)
- Two major sites of deep-water formation (‘ocean convection’) in the North Atlantic and the Southern Ocean

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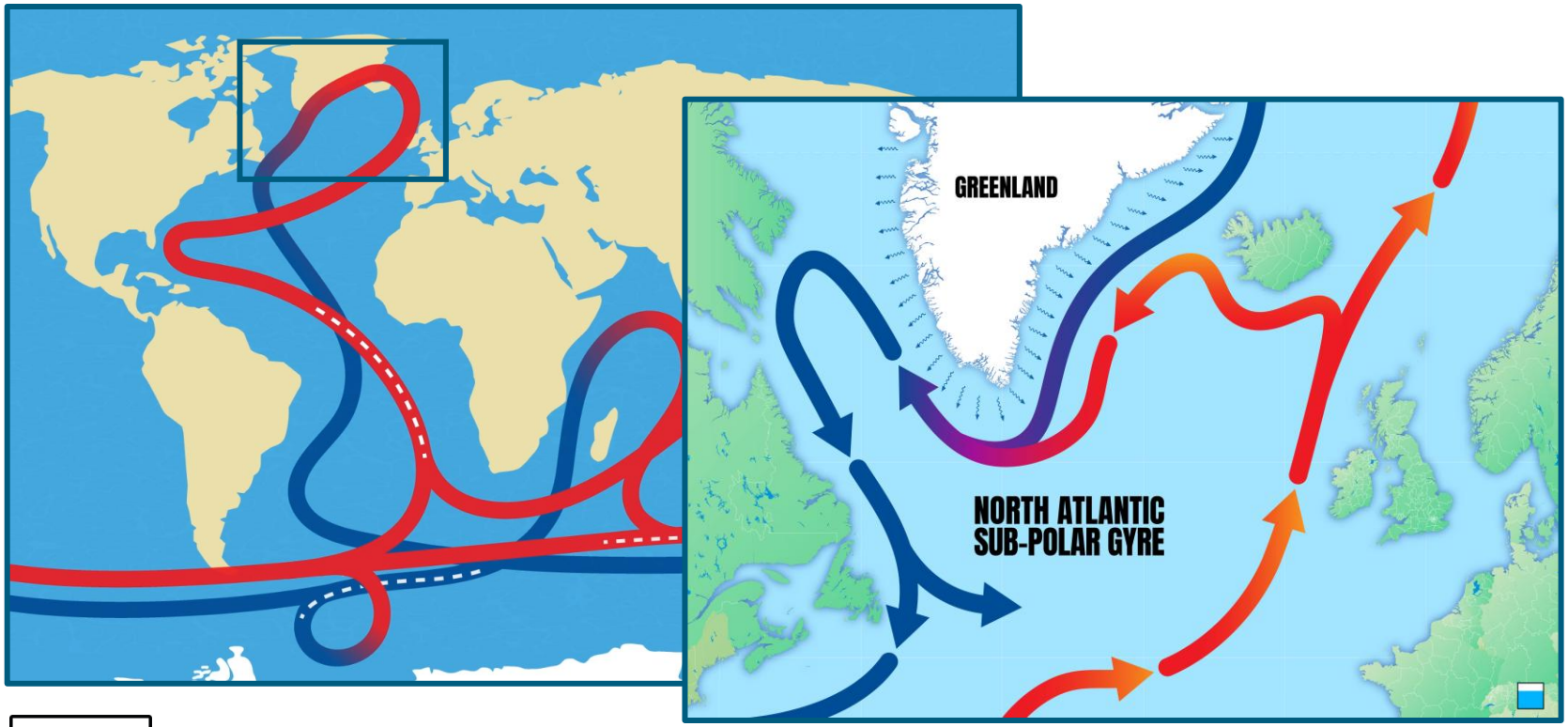
North Atlantic Subpolar Gyre & Greenland Ice Sheet Tipping Points



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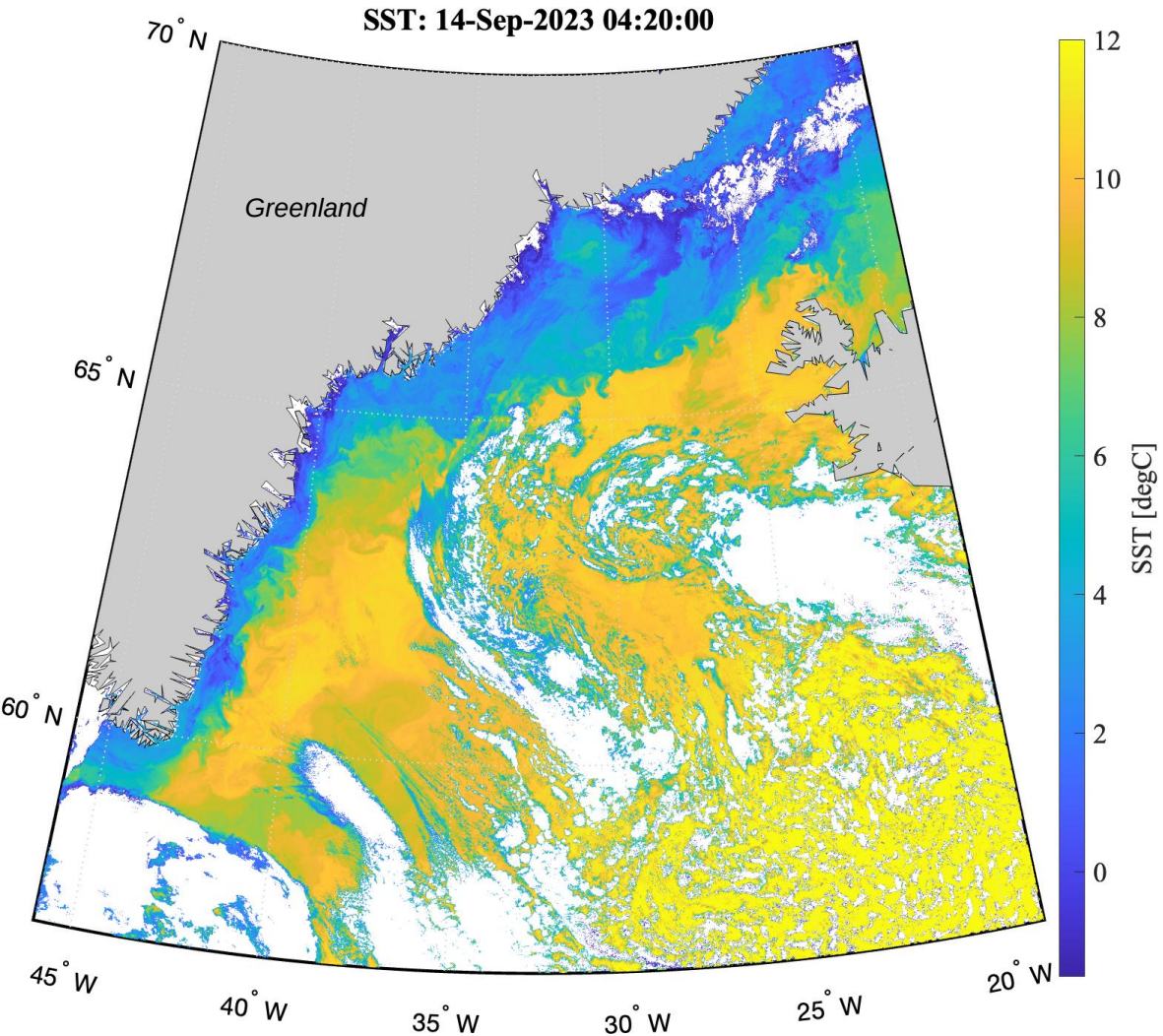

- **Sharp contrasts of temperature and salinity cross-shore**
- **Many small eddies and fronts at 1-10 km scales**
- **Persistent clouds in most seasons**
  - *Problem for high-resolution spaceborne SST & Ocean Colour*

Credits: Christian Buckingham, NOC

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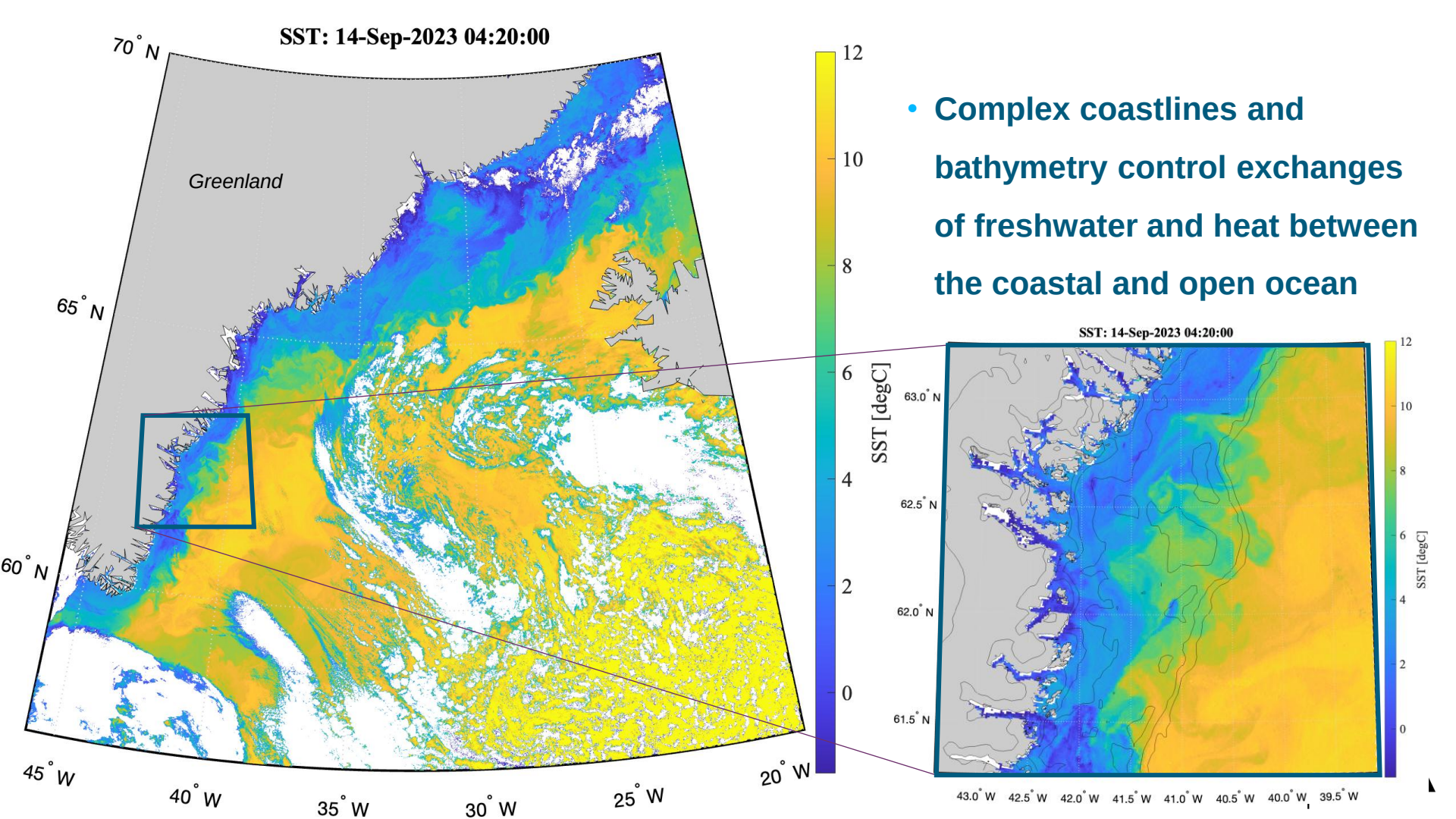
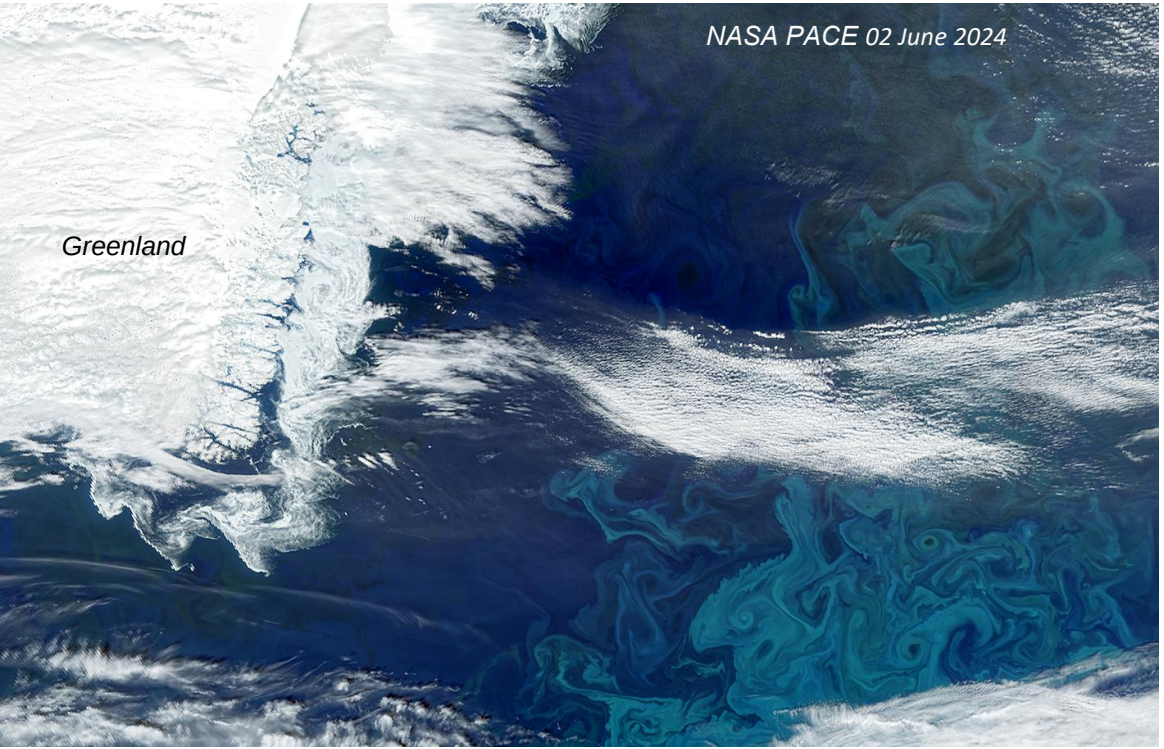


- **Complex coastlines and bathymetry control exchanges of freshwater and heat between the coastal and open ocean**



- **Seasonal sea ice cover, highly dynamic and variable**
- **Many small-scale eddies and fronts also visible offshore**
  - *High marine productivity*
- **Persistent cloud cover also problematic for spaceborne ocean colour**

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Climate predictions of Sub-Polar Gyre convection collapse?

- **Risk of North Atlantic SPG convection shutdown remains uncertain**
- **Many CMIP6 models predict no shutdown**
- **High-res models better represent key processes and tend to show convection shutdown**
- **Those models predict abrupt convection shutdown around 2040**
  - *major impacts on Western Europe and marine productivity in the North Atlantic*

Overall, based on CMIP6 models, the likelihood of SPG convection collapse in the next 20 years is 45%

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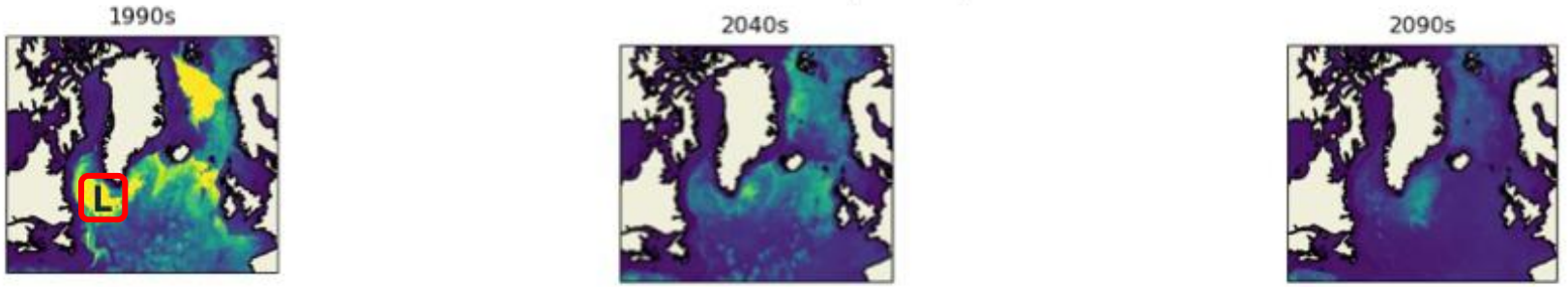
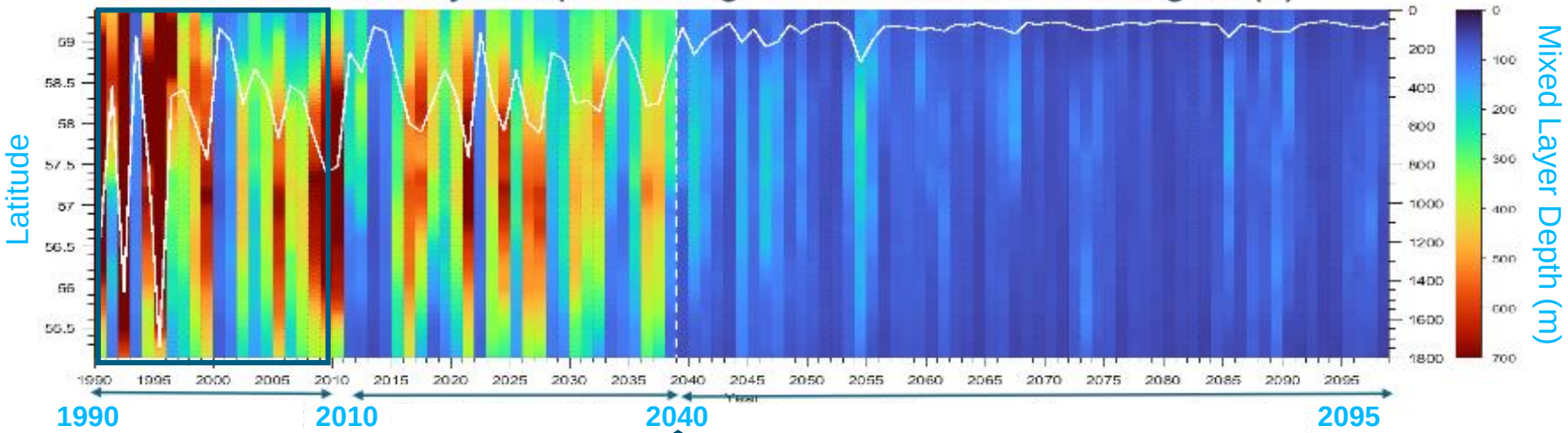
NEMO-CICE-MEDUSA simulation (1/12°) under SSP370 scenario



winter mixed layer depth averaged over Labrador Sea region (L)



Credits: Alice Marzocchi, NOC

The ARIA Forecasting Tipping Points programme

Opportunity space: Scoping Our Planet | Programme: Forecasting Tipping Points | Opportunity seeds: Scoping Our Planet

Forecasting Tipping Points

Advanced Research + Invention Agency ARIA

Backed by £81m, this programme within the Scoping Our Planet opportunity space aims to enhance our climate change response by developing an early warning system for tipping points.

Technical Area 1

Developing new sensing systems

Technical Area 2

Pushing to rapid deployment in campaigns

Technical Area 3

Uniting models and measurements to create an early warning system

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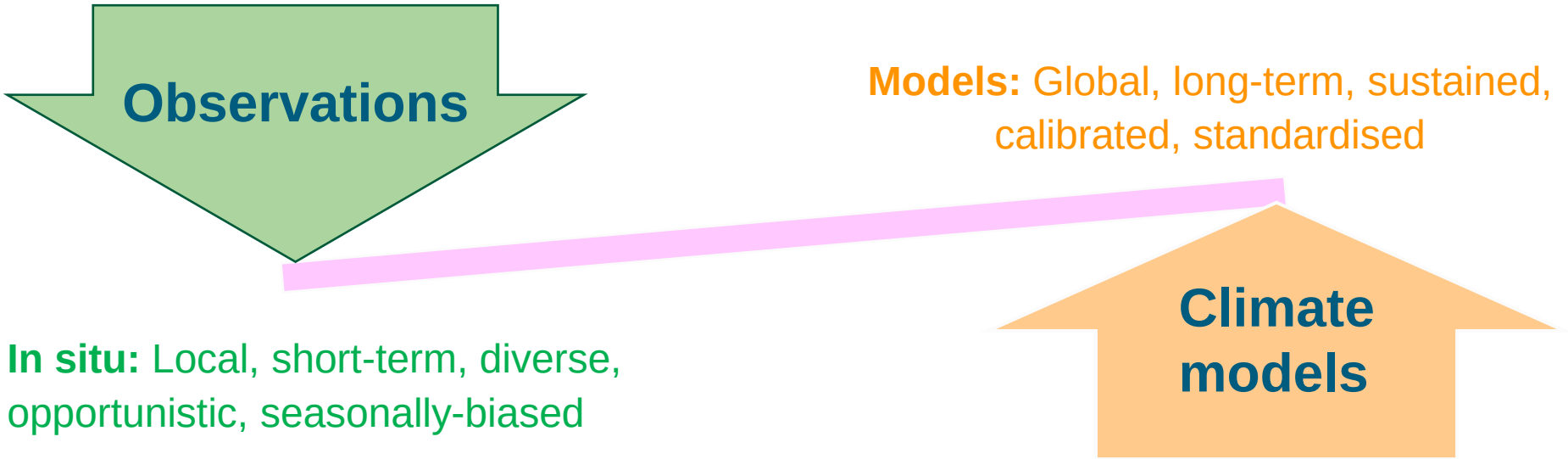
Addressing critical gaps between observations and climate models



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THE ARIA AEROSTATS PROJECT

- **A new 5-year project to better observe exchanges of freshwater and heat between the ocean, atmosphere and cryosphere in the Greenland/SPG region**
  - *focus on fine spatial and temporal scales (< 1 km, < 1 day)*

Three key objectives for Earth Observation in AEROSTATS

1. To demonstrate affordable long-term low-carbon EO monitoring with new airborne platforms like airships, HAPS or drones
2. To develop a new compact high-resolution imager of total ocean current and wind vectors (SEASTARair)
3. To demonstrate year-round observations of ocean colour and high-res SST, including in cloudy and winter conditions

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WP1 Define airborne platform and flight opportunities (T0, T0+24)

- **Review technical capabilities of airborne platforms**
  - *focus on airships, HAPS and drones*
- **Review availability, accessibility, regulatory constraints and cost for a possible deployment in a field campaign in Greenland/SPG in 2028/29**
- **Key considerations for airborne platforms**
  - *Payload mass/power capacity, range, high winds operations*
  - *Availability/certification by 2028*

Are you building, operating or know about airships, HAPS or suitable drones? Please get in touch !

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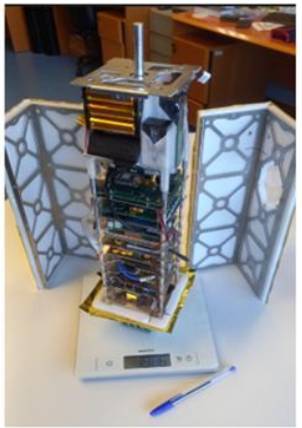
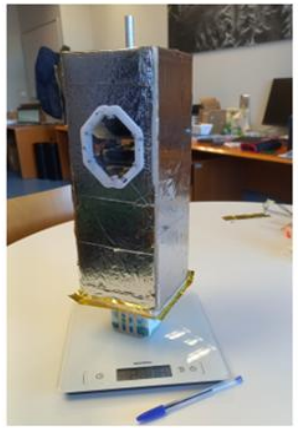
WP2 New EO Payload: SEASTARair

- **New imaging sensor for Total Surface Current and Wind Vectors at < 1 km resolution**
  - *not available from satellites, challenging in situ*
  - *Based on the SeaSTAR 3-azimuth SAR ATI concept and OSCAR aircraft demonstrator*
- **New SEASTARair instrument**
  - *low Size, Weight, Power and Cost (SWaP-C), CubeSAR-based*
  - *Airship, HAPS and drone compatible*
- **Key considerations for SEASTARair**
  - *Low mass and power*
  - *optimizing for platform altitude and velocity*





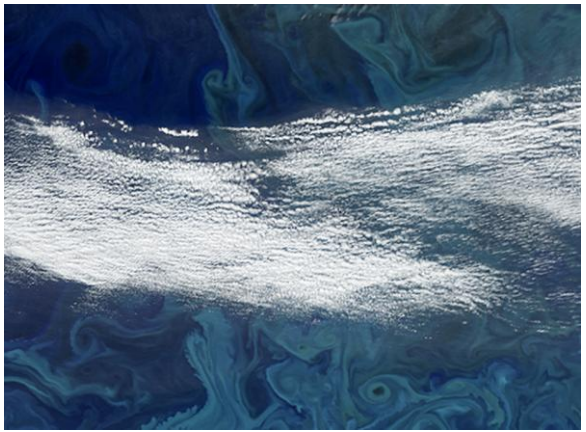
Credits: Jose Marquez, Radarmetrics

Funded by ARIA

WP3 EO Payload: Ocean Colour

Pixalytics

- **Ocean colour as an indicator of marine productivity**
  - *OC changes as early warning of ocean convection shifts ?*
- **Key considerations for Ocean Colour in SPG**
  - *Persistent cloud cover, low light and sun angles, particularly in winter*
  - *Preference for platforms that can fly below clouds*
  - *OC spectral bands, mass, sensor/platform stability, known geometry (atmospheric correction)*
  - *Identify existing OC payloads compatible with deployment in the SPG campaign*



👍 **Are you working on ocean colour sensors relevant to this? Get in touch !**

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Radarmetrics Seeing through.

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WP3 EO Payload: Sea Surface Salinity

- **L-band microwave radiometers ~ 1.4GHz (L-band)**
  - *Operate day/night, all-weather (cloud-independent)*
- **Key considerations for salinity**
  - *SSS instruments are large (antenna), R&D focused, not autonomous*
  - *Currently not compatible with HAPS or drone - airship only*
- **If no airship is available for the 2028/29 field campaign, AEROSTATS will coordinate with international efforts e.g. for CMIR, CRISTAL, CryoRAD**


M. Brogioni, CNR-IFAC

Are you developing or operating an L-band radiometer we could use for this ? Get in touch !

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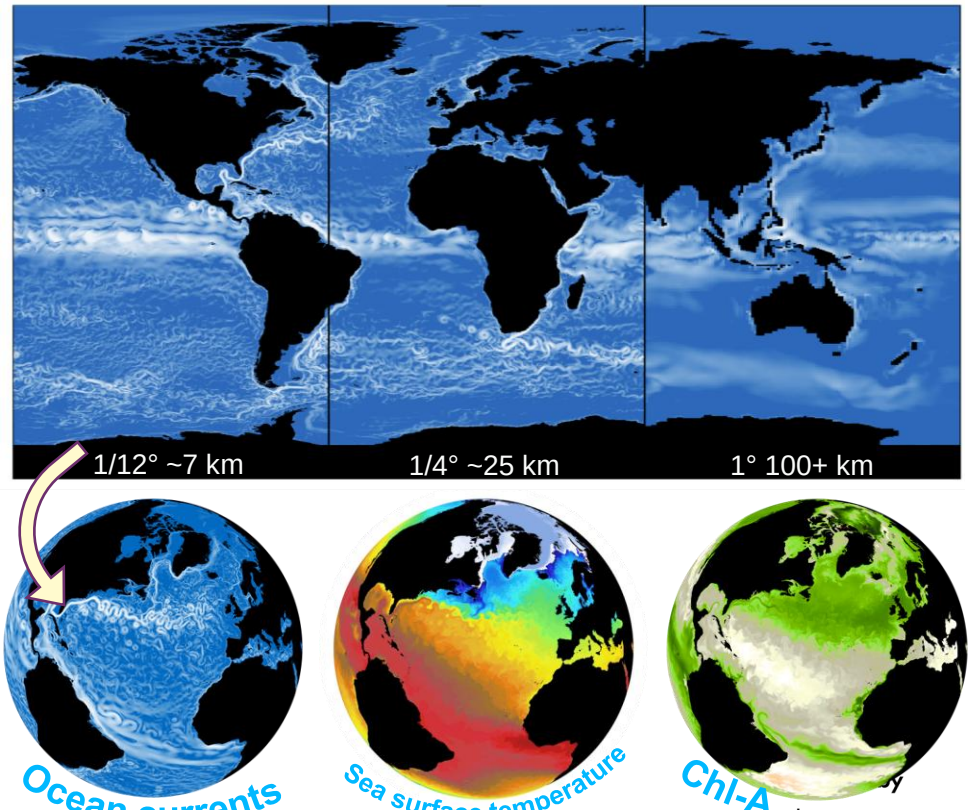
AEROSTATS PHASE 2: SPG FIELD CAMPAIGN AND DATA/MODEL SYNTHESIS

- **Field campaign in SPG in 2028/29**
  - *Airborne campaign with validation against in situ observations from coincident sensors (gliders, AUVs, ASVs)*
- **Data-model synthesis to evaluate heat and salt exchanges in models**
  - *in situ, airborne and satellite observations*
  - *digital tools and a hierarchy of ocean-ice models with different horizontal resolutions, biogeochemical or atmospheric coupling*



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SUMMARY

Large uncertainty around Greenland Ice Sheet and Sub-Polar Gyre Tipping Points

- Susceptible of abrupt change, the risk of North Atlantic SPG convection shutdown remains uncertain
- Some models predict convection shutdown by 2040, impacting Western Europe and marine productivity
- UK ARIA is funding major research to develop an early warning system

AEROSTATS Phase 1 (2025-2027)

- Improve observations of freshwater and heat exchanges in the Greenland/SPG region
- Assess airborne platforms (airships, HAPS, drones) for affordable long-term low-carbon EO monitoring
- Develop new high-resolution imager for total ocean currents and winds
- Investigate year-round monitoring of ocean colour and temperature, including below clouds and in winter

Now seeking partners to join the Greenland/SPG field campaign in 2028/29

- Looking for capability in deploying/operating airborne platforms, ocean colour and L-band salinity sensors

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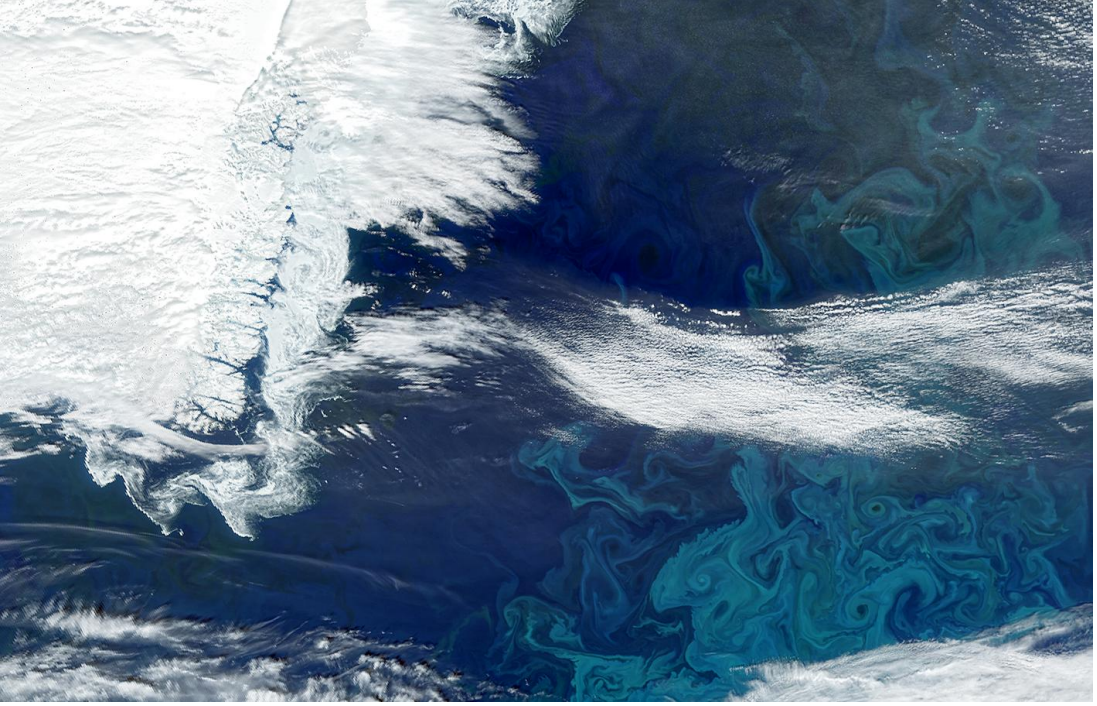

Thank you

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