Coupled Earth System Components in Data Assimilation: Advantages and Key Challenges

Phil Browne, Patricia de Rosnay, Tracy Scanlon, Alan Geer, Chris Burrows

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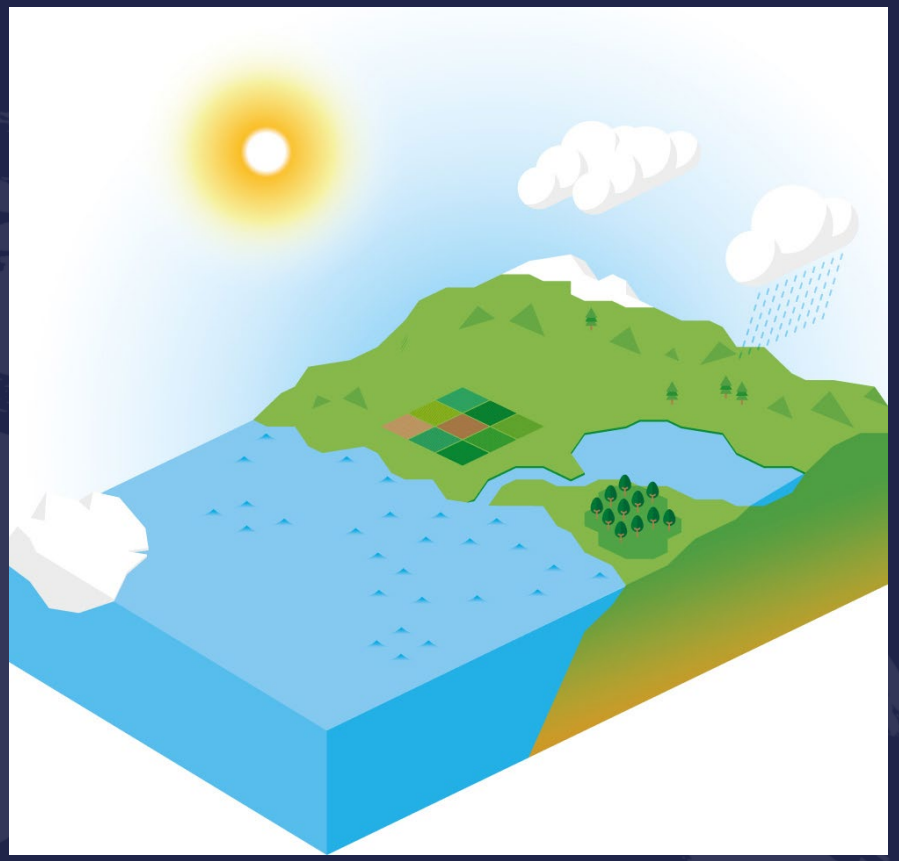
Setting the scene for Coupled DA

Motivation for coupled DA

- ECMWF produces forecasts from 10 days to seasonal timescales
- These are **Earth system** forecasts comprising
  - atmosphere
  - land surface
  - ocean waves
  - ocean
  - sea ice
  - lakes
  - snow
  - chemistry
  - rivers
  - fire
- All of these need initial conditions



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Alternatives to Coupled DA

- Completely ignore all processes in other components
- Use fixed climatology for other components
- Use someone else's analysis of the other components,
  - e.g. Level 4 products as a boundary condition

"Benefits of not coupling"
You can blame all your problems on errors in external products

"Disadvantages of coupling"
You have to correct for errors and biases as they are now internal issues

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Coupled DA

Coupled DA is the **approximations, simplifications and accommodations** we make in order to do data assimilation with coupled models – if these weren't necessary, we would be talking simply about **data assimilation**

A key consideration is that components have vastly different observational networks

- Many remote sensing signals stop at the surface
- People don't tend to live anywhere but the surface
- Technology to measure different components varies
  - e.g. various aerosol constituents, sea ice salinity, snow density etc.

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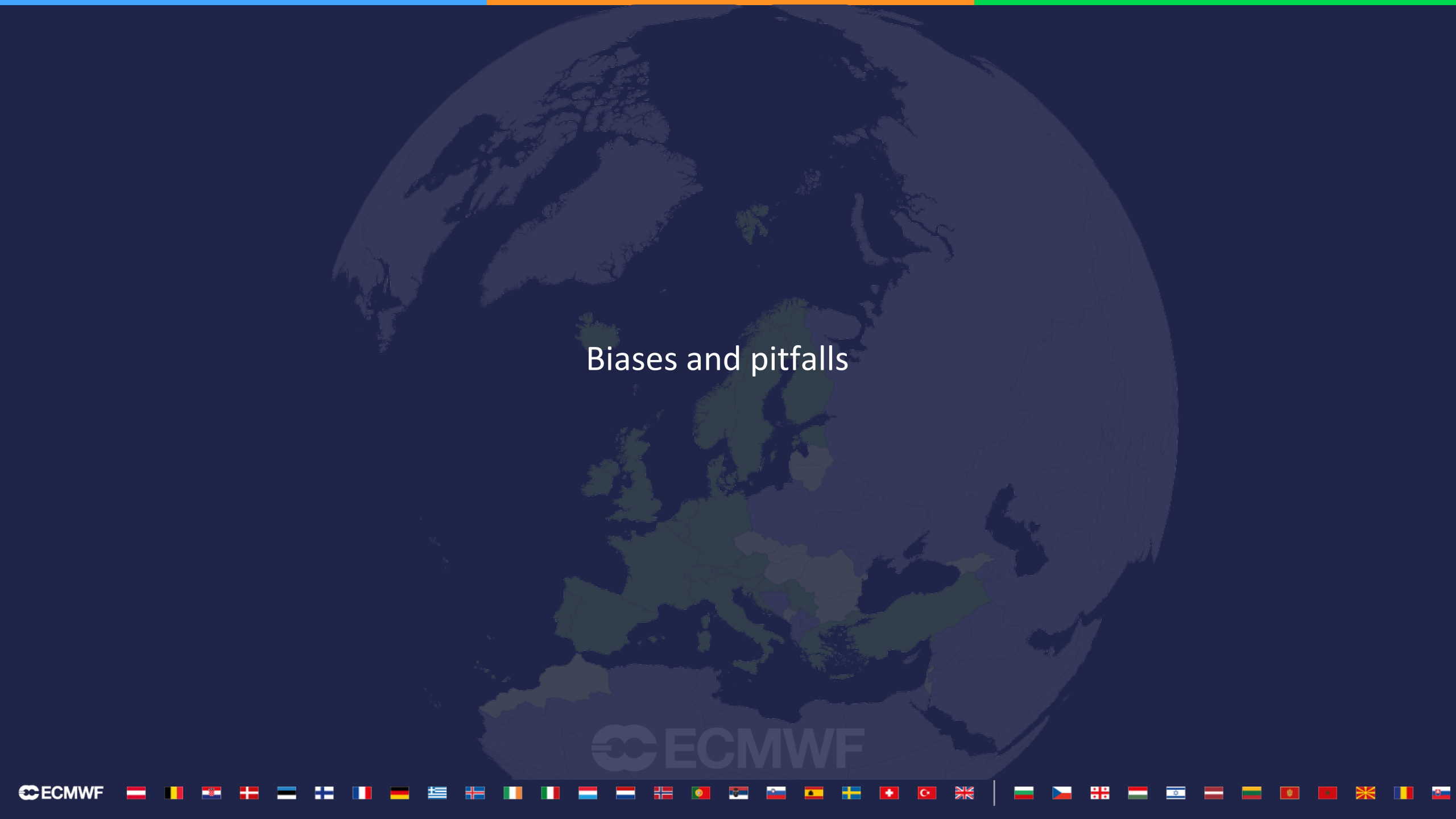
Biases and pitfalls

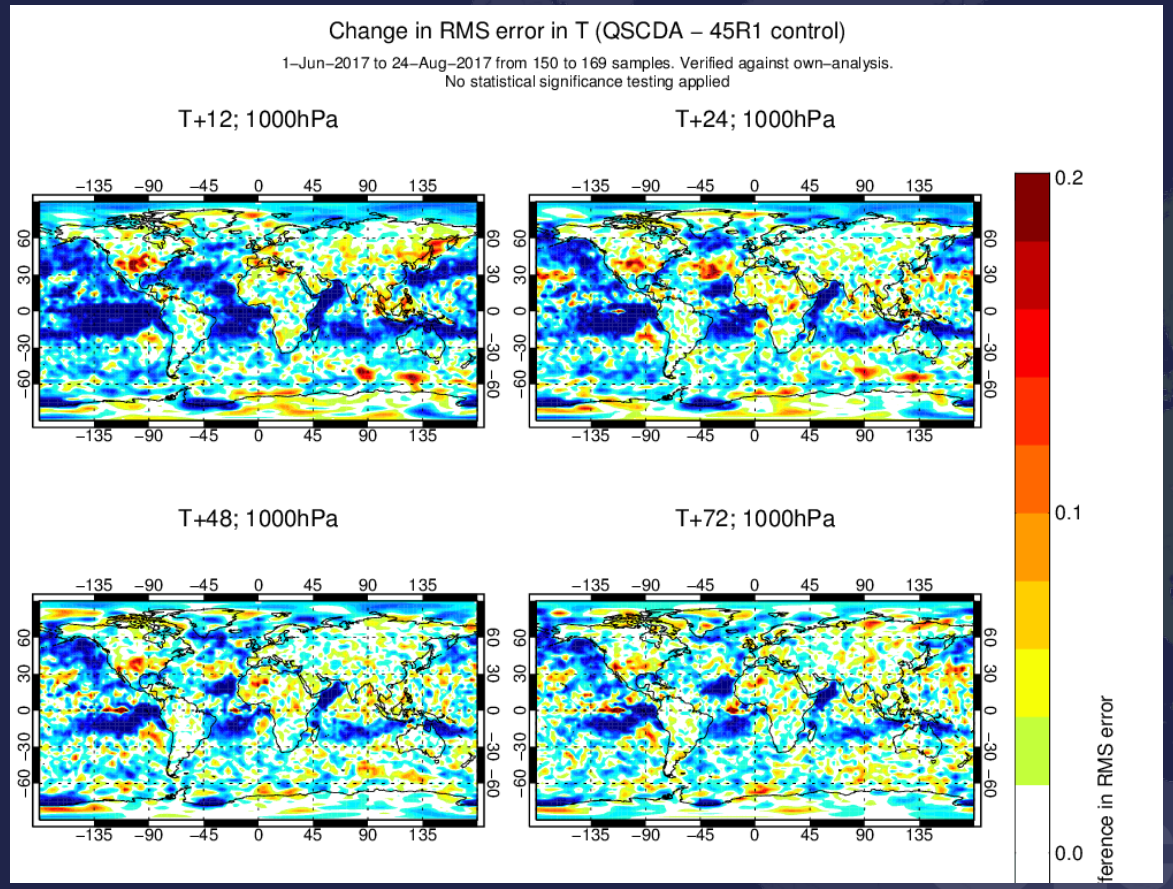


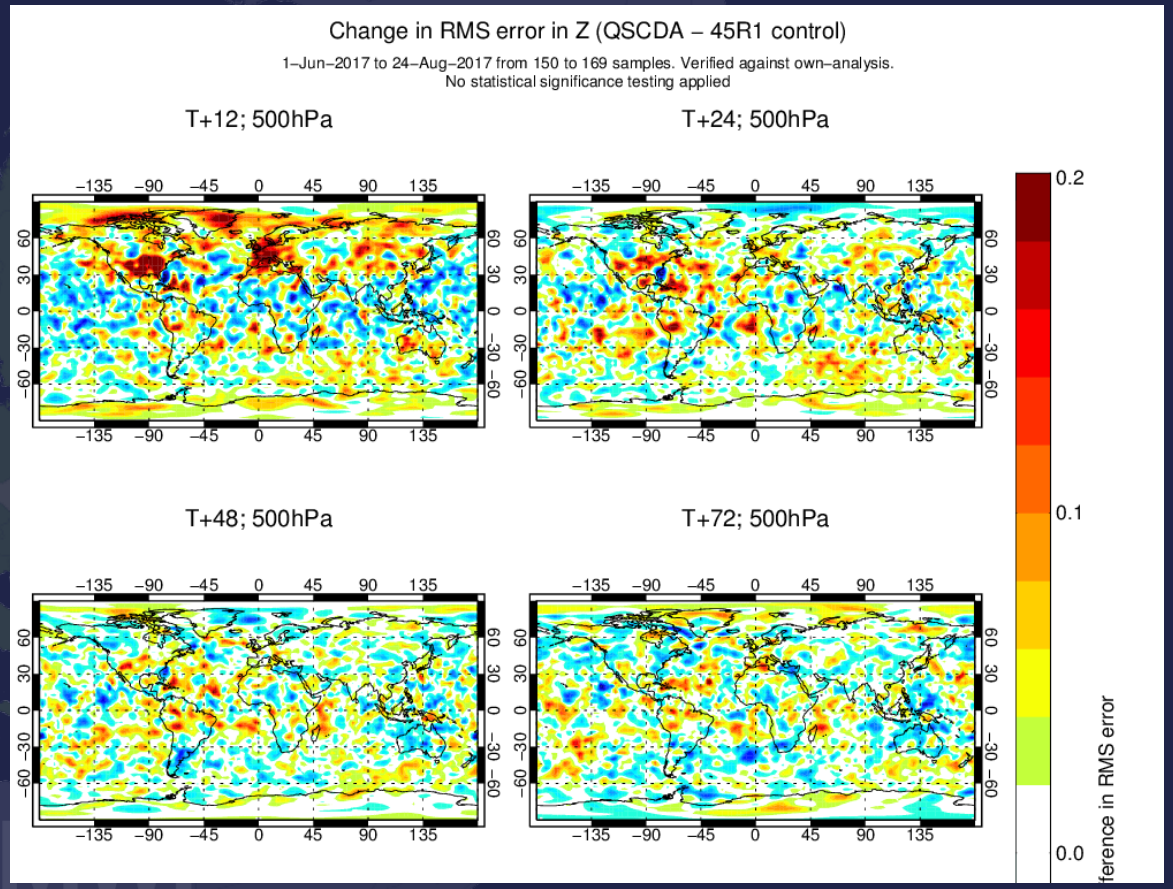
Biases in coupled DA

Every model has its own biases

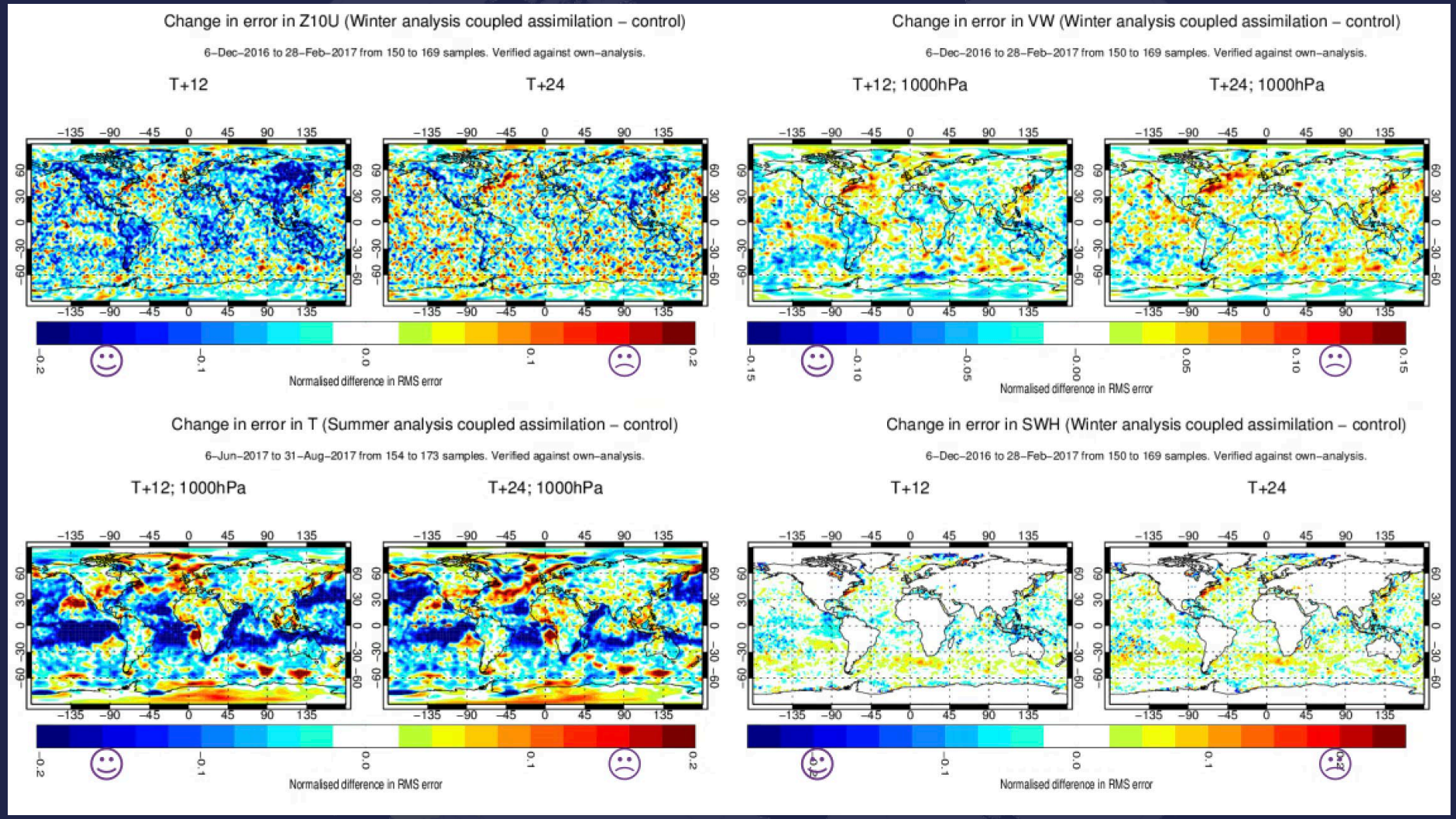
Processes are tuned to a certain state

- More realism does not therefore translate to better performance





Exchange of biases between components – a bad gulf stream



Soil moisture – a tool for correcting atmospheric biases

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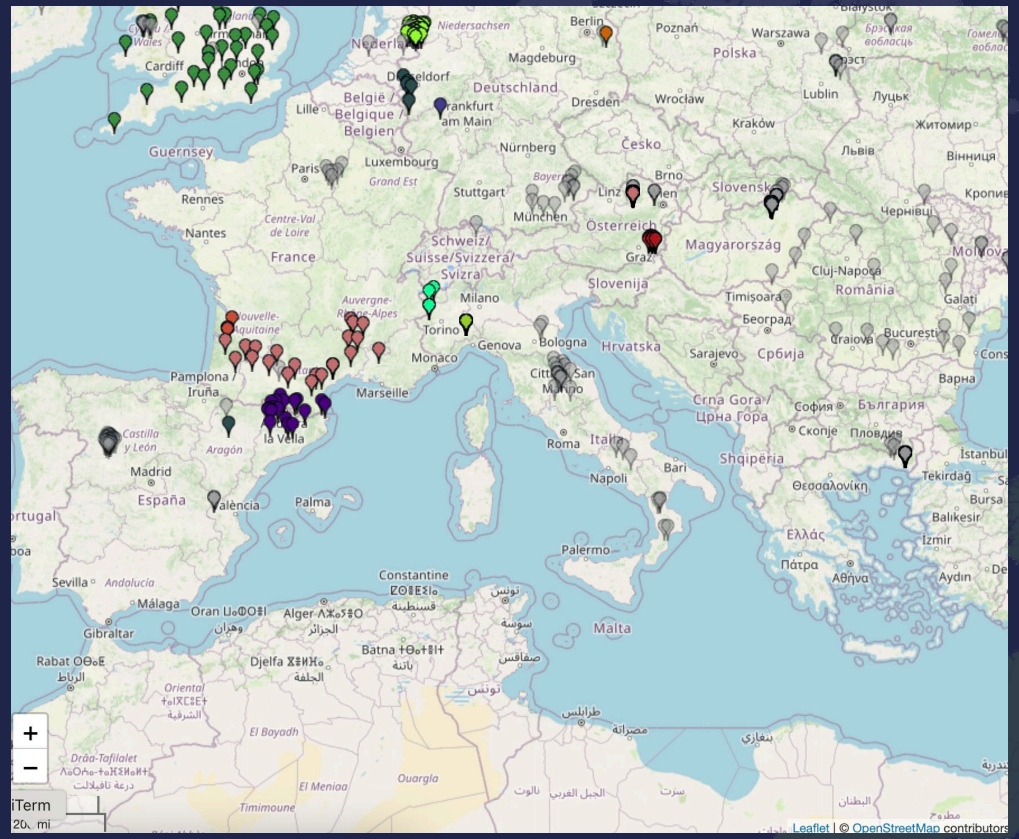
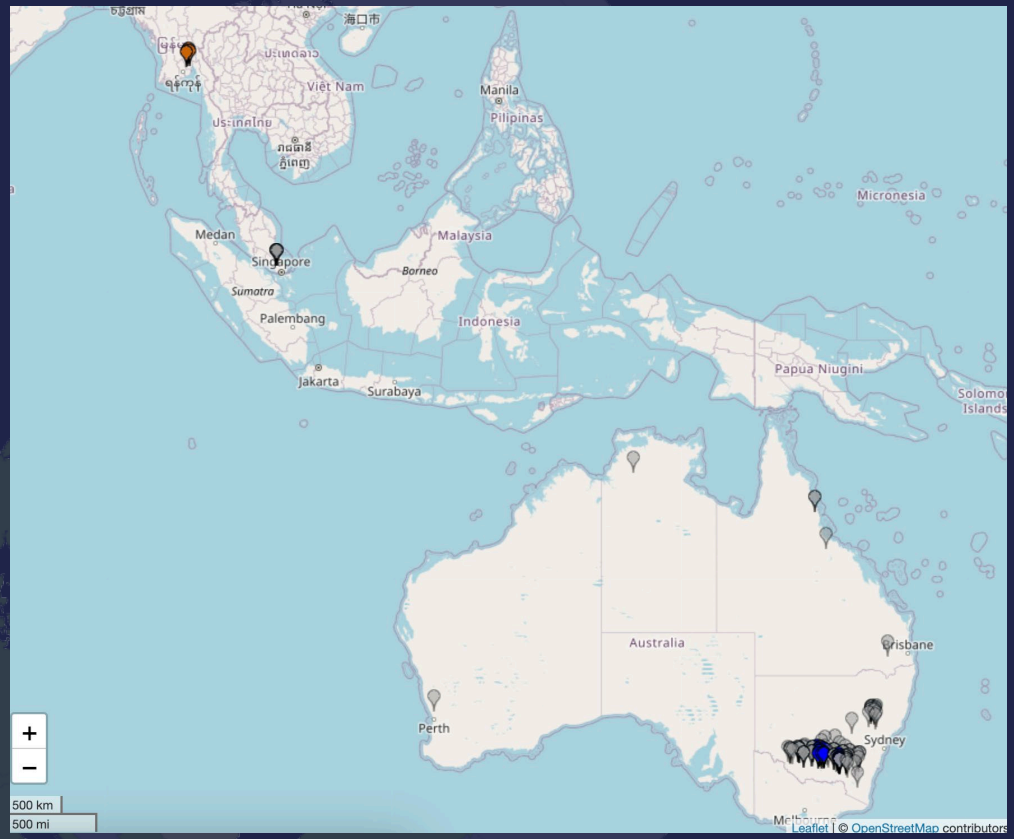
Soil moisture observational network at depth since 2020





Taken from
https://ismn.earth/en/dataviewer/

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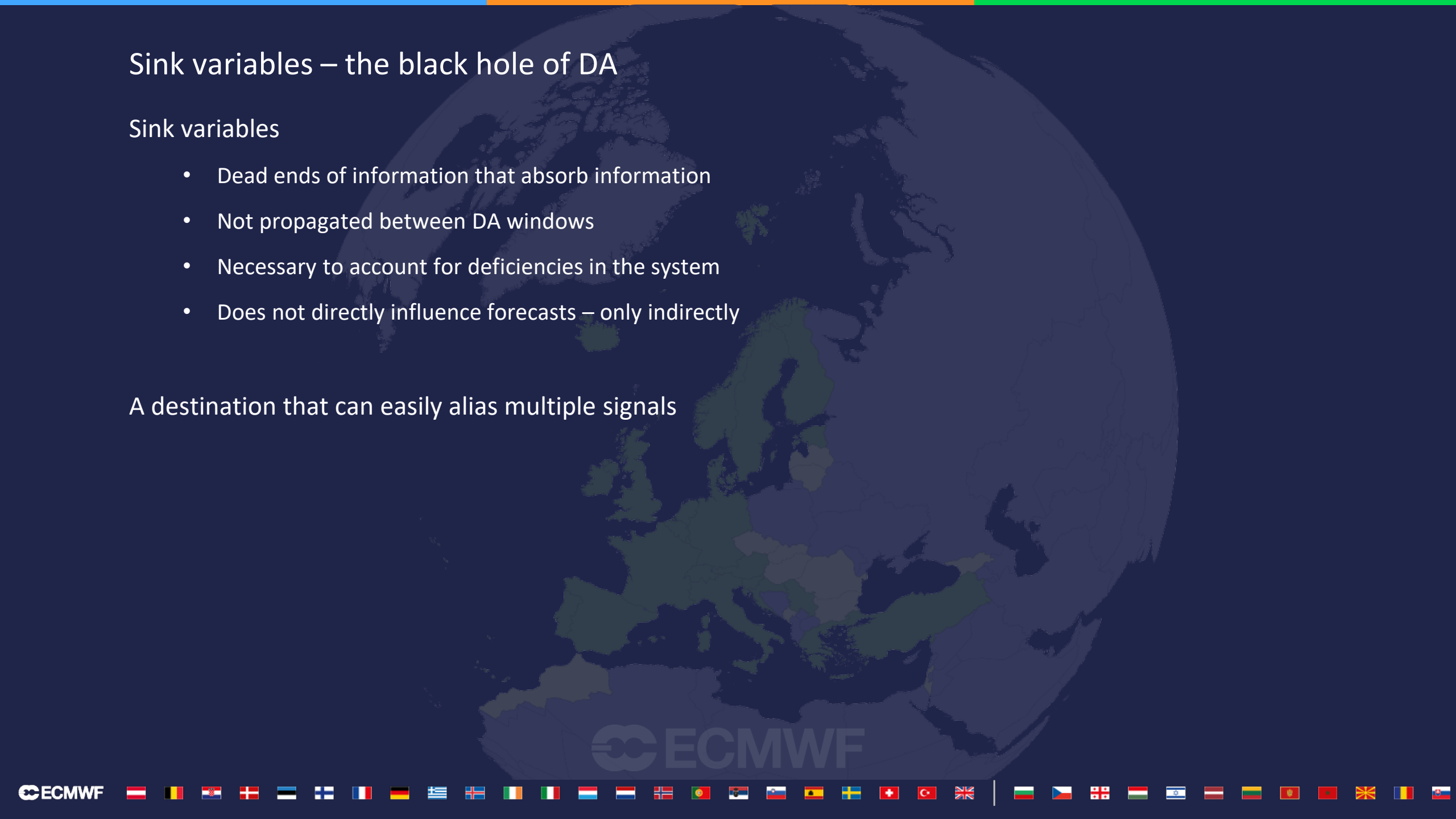
Sink variables – the black hole of DA

Sink variables

- Dead ends of information that absorb information
- Not propagated between DA windows
- Necessary to account for deficiencies in the system
- Does not directly influence forecasts – only indirectly

A destination that can easily alias multiple signals



Removing sink variables – retaining the information

Some sink variables may contain valuable information

- Instead of losing this information we want to keep it
- We want that information to also impact the forecast (and improve it!)

How do we do this?

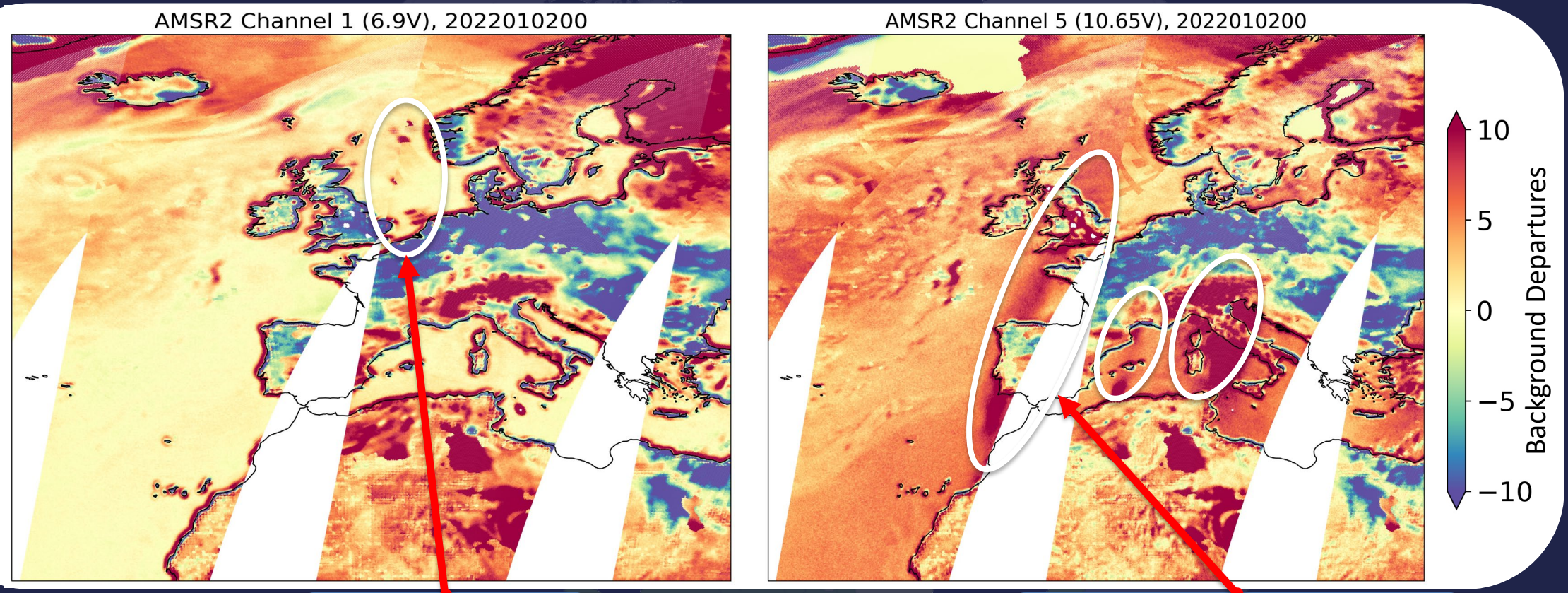
- Carefully!

Pass the information from a sink variable to to different component for them to cycle the information:

- Skin temperature
- Effective sea ice concentration
- Sea surface height

- The vertical retention of the information is dealt with by the DA/model in the other components (for ocean/sea-ice/land applications)

RFI in AMSR2 observations



Oil platforms?

Streaks of high background departures, always in the descending overpass

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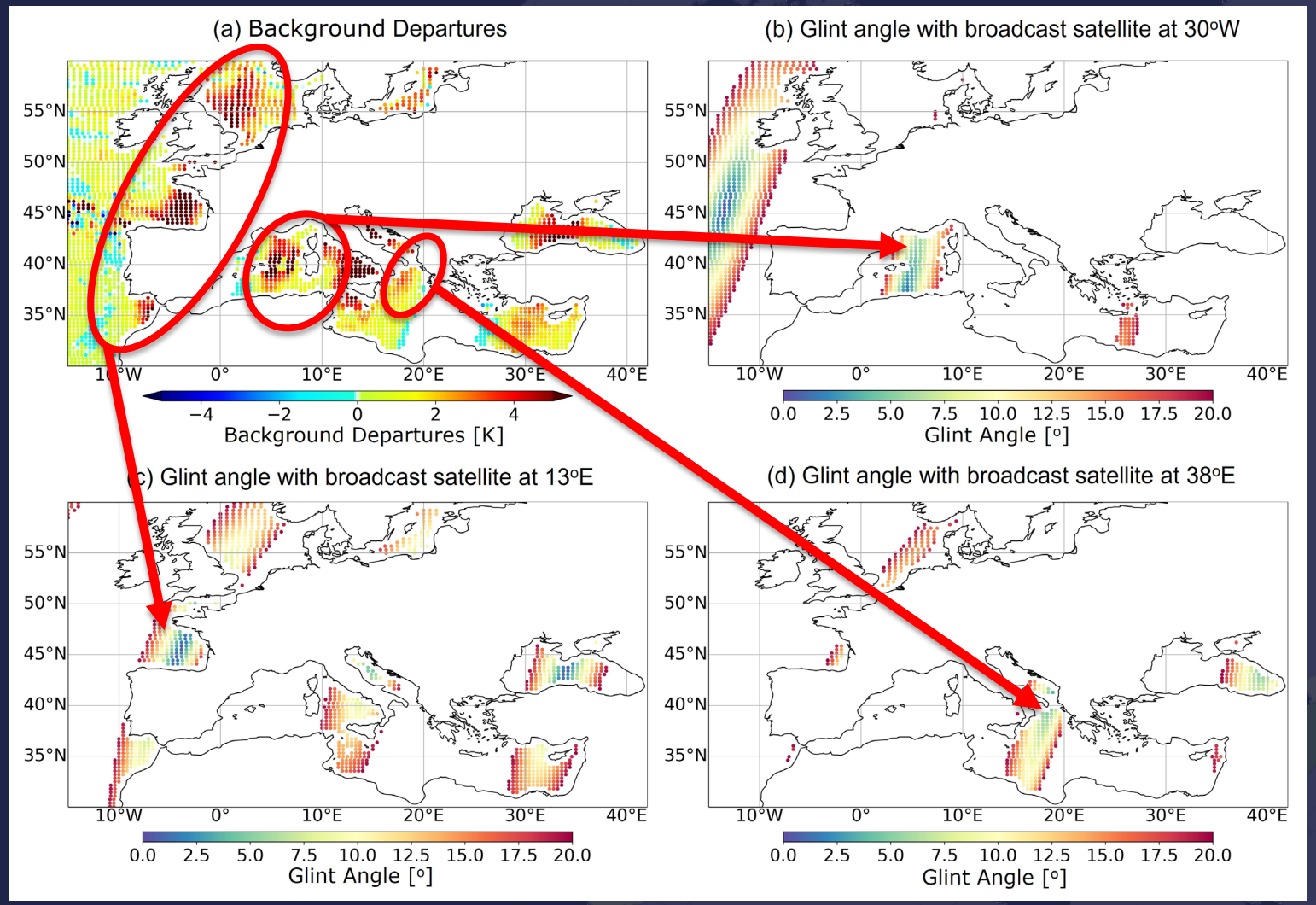
RFI at 10.65 GHz – Glint angles from identified sources



Identified sources can be linked to the patterns we see in the background departures.

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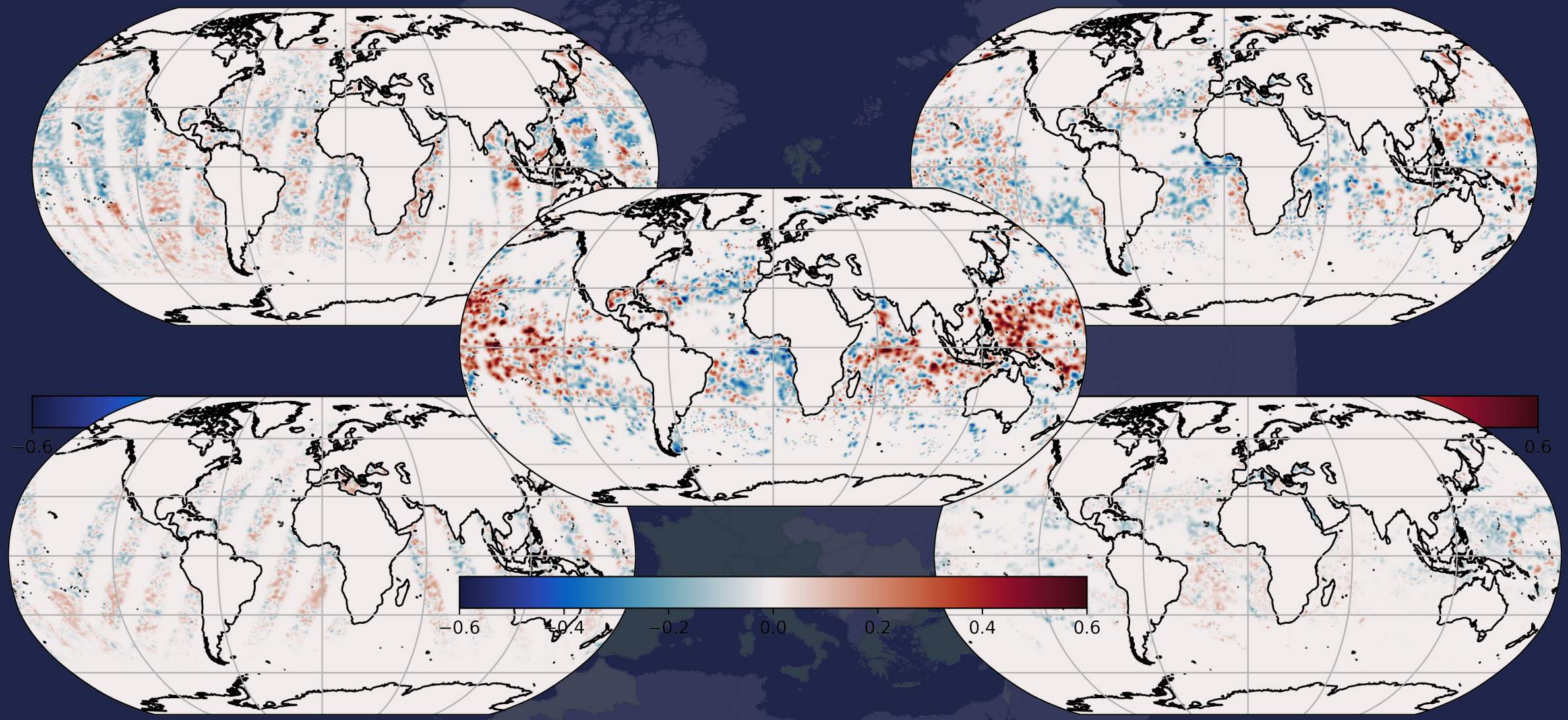
Identifying biases with coupled DA – IASI skin temperature increments



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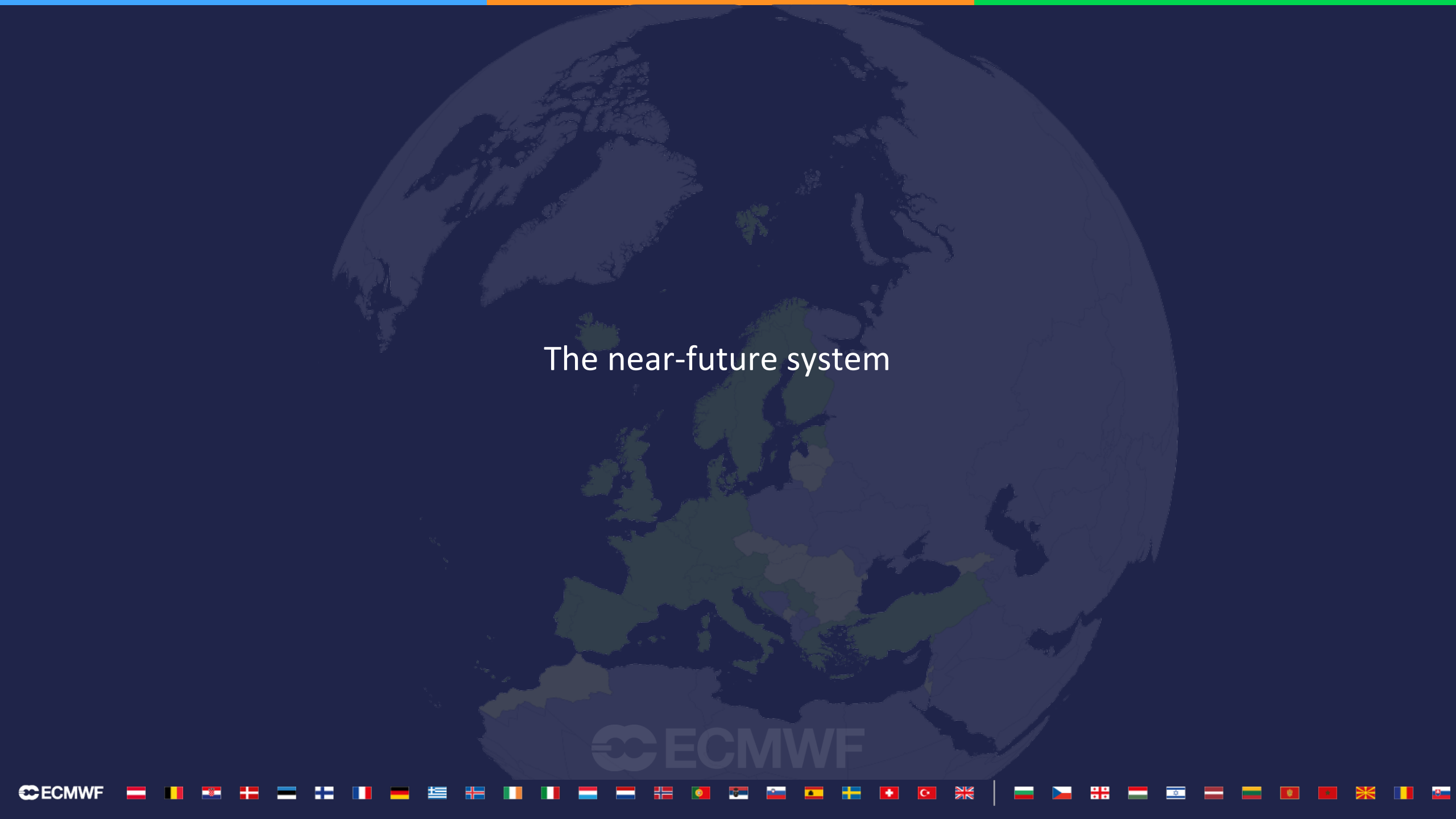
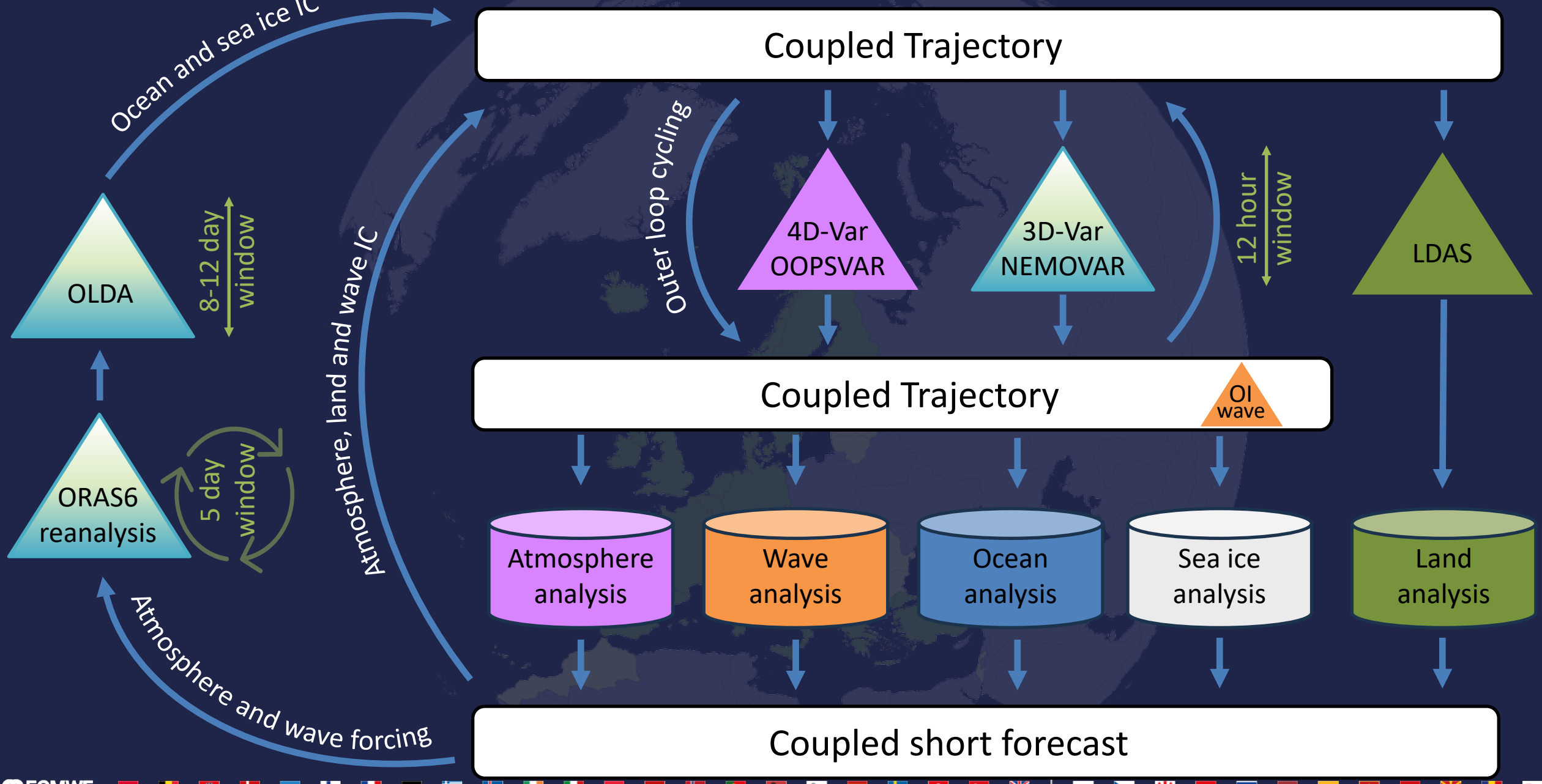

The near-future system

Future operational configuration (IFS CY50R1)



Why do we need the reinitialization?

1. Observations!
    - ORAS6 system assimilates L4 SST data
    - The L4 SST data contains observational information not used in the outer loop coupling analyses
        - Drifting buoy temperature measurements
        - SLSTR – the reference SST sensor
    - We need more time to add these observations (including QC) and assess their impact
2. Testing and consistency for the reforecasts
    - The analyses can only diverge so far from ORAS6
    - By design, we have no long term drifts greatly reducing the computational load of the testing requirements
    - This short leash keeps an element of consistency with the reforecasts needed to calibrate forecast systems

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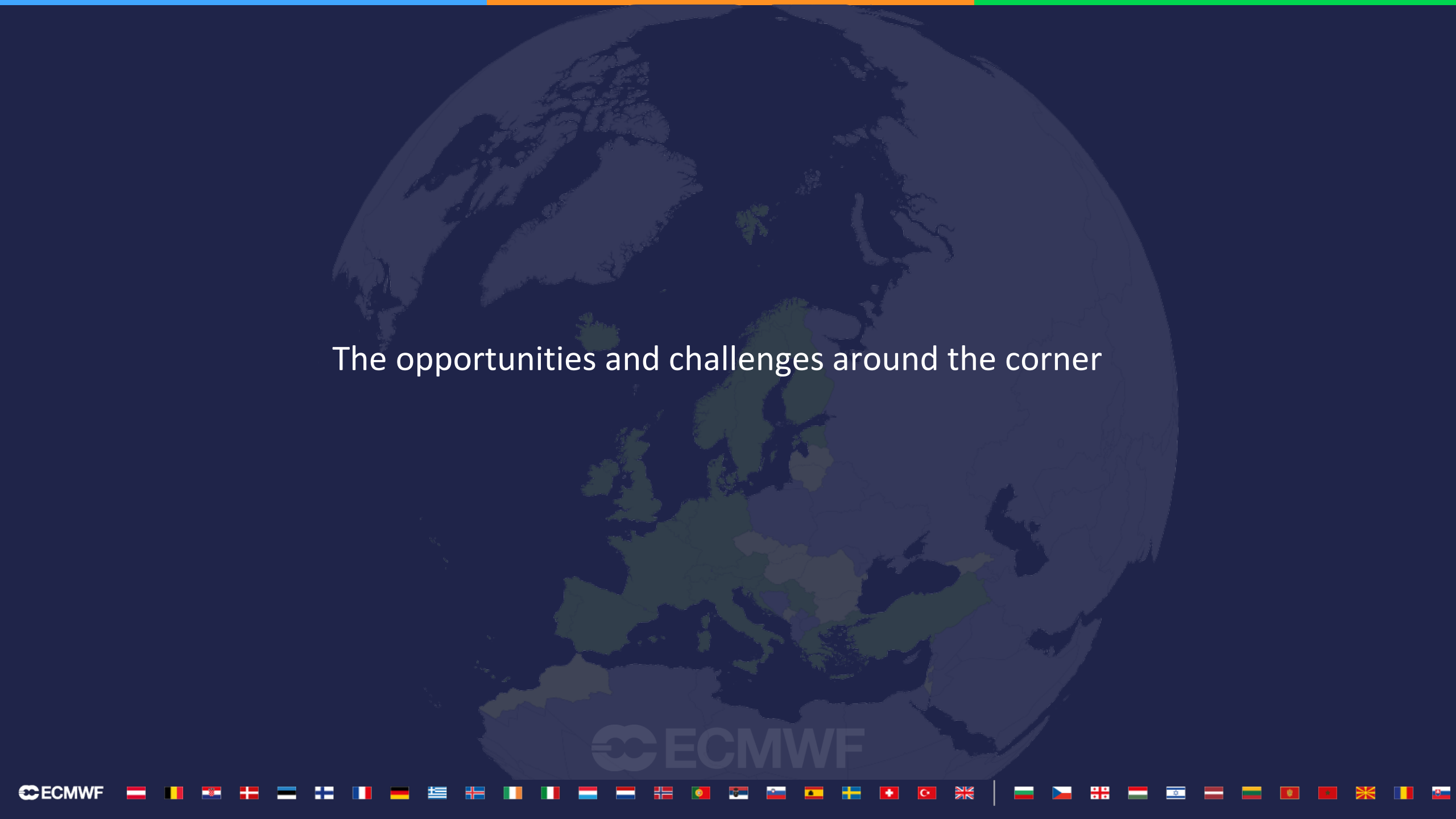
The opportunities and challenges around the corner
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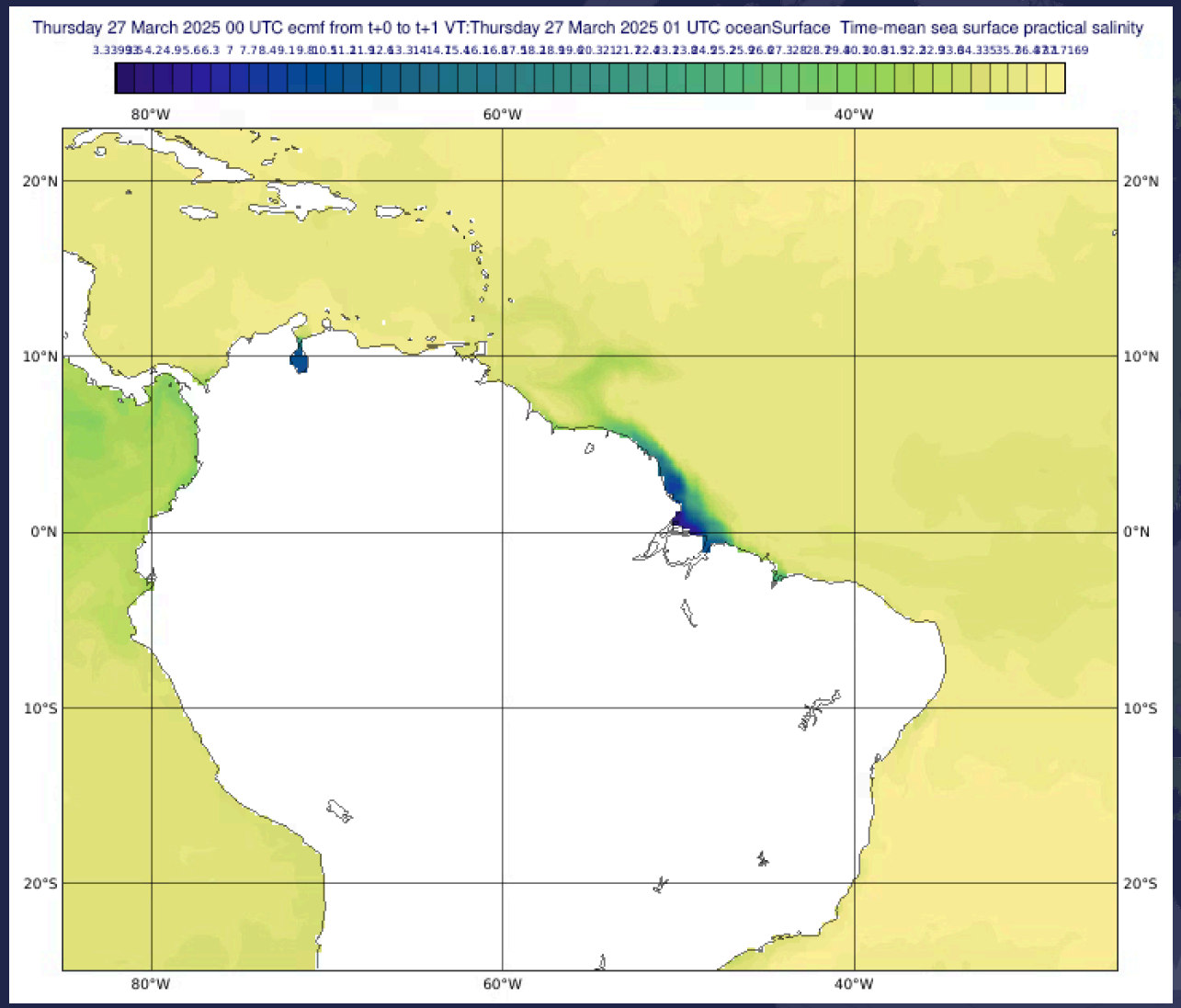
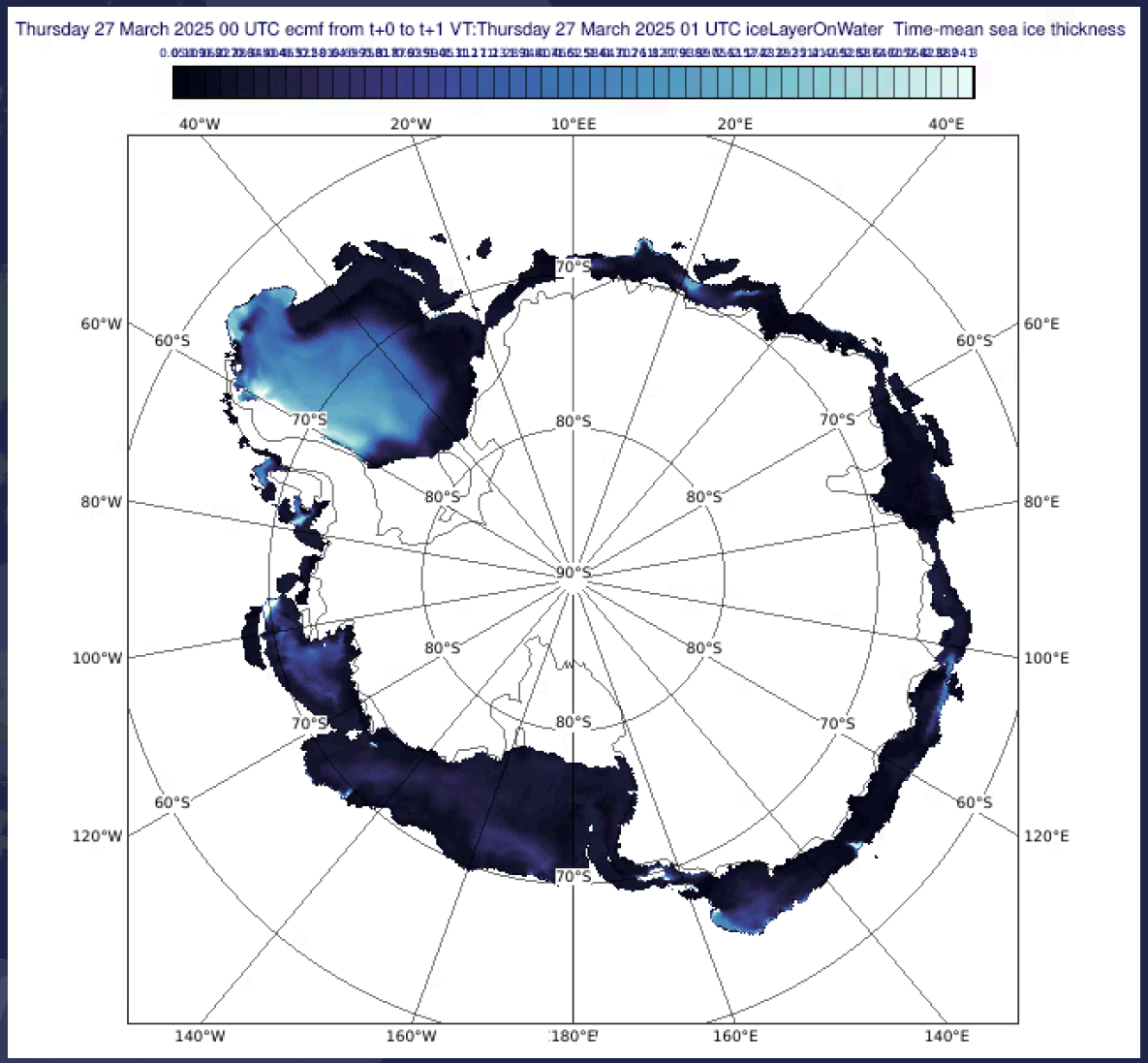
A new dimension of opportunities to be explored – coupled observation operators

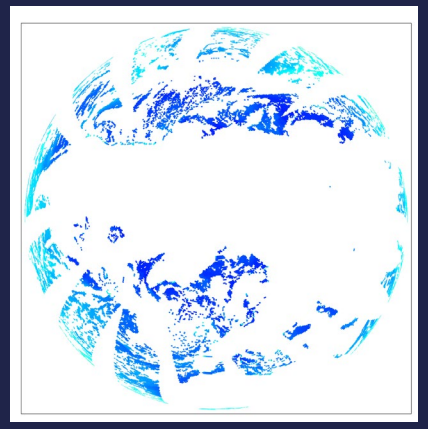
Salinity

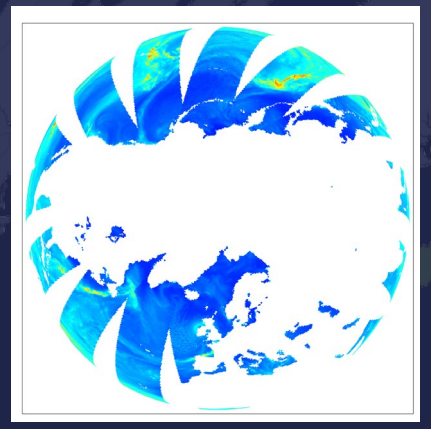


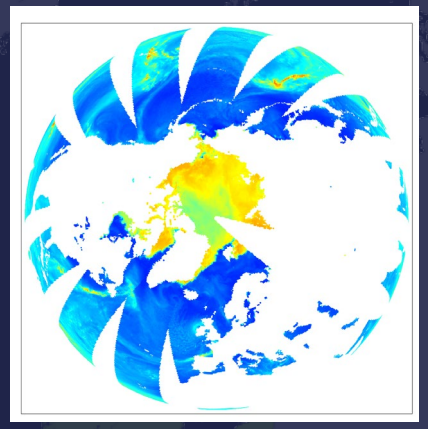
Ice thickness

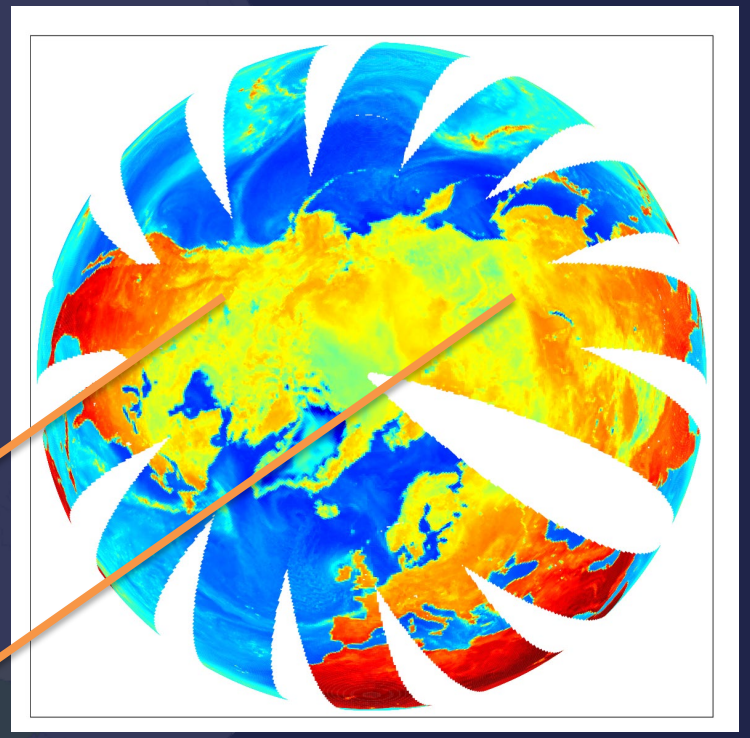


Coupled surface processes to go towards all-surface radiance assimilation



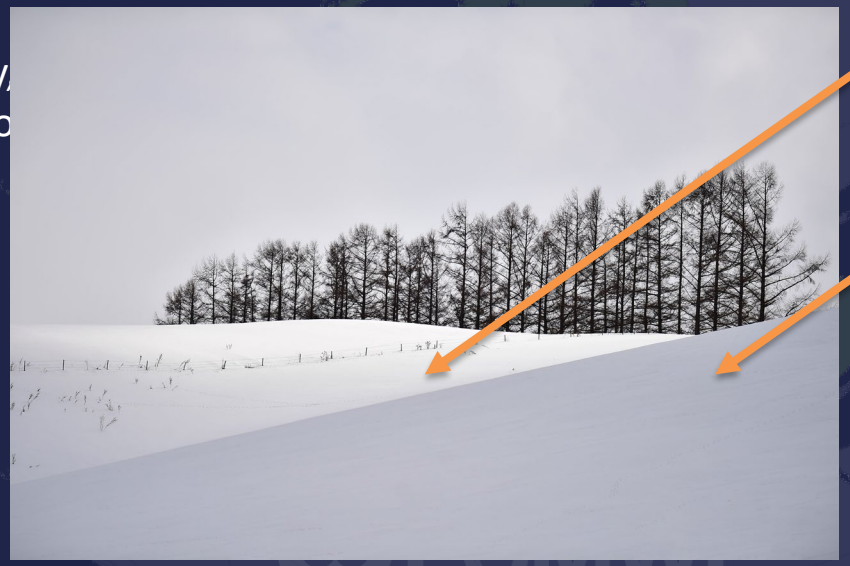






Clear-sky, open ocean
1990s onwards

All-sky,
2009 o



And then further constrain these surfaces directly with these surface sensitive radiances

All-sky, all-surface radiance assimilation – the **penultimate goal**