

A Digital Twin for Polar Mission Planning

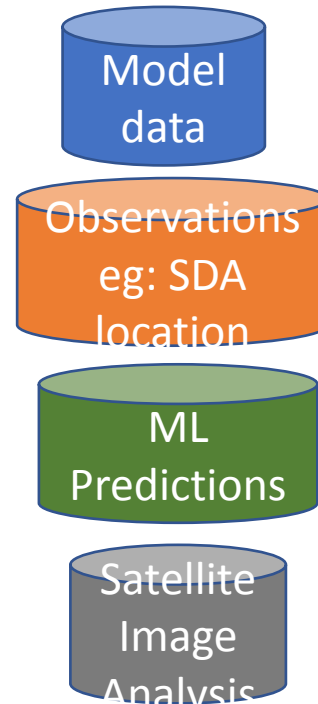
M. Fox, J. Smith, S. Hall, G. Coombs, J. Byrne, M. Thorne



Context of this talk :

Automating Operations of the Royal Research Ship Sir David Attenborough (SDA)

Building a Digital Twin of the Southern Ocean *from the perspective of the SDA*



Objective: optimise fuel and carbon efficiency of science cruises

Data available:

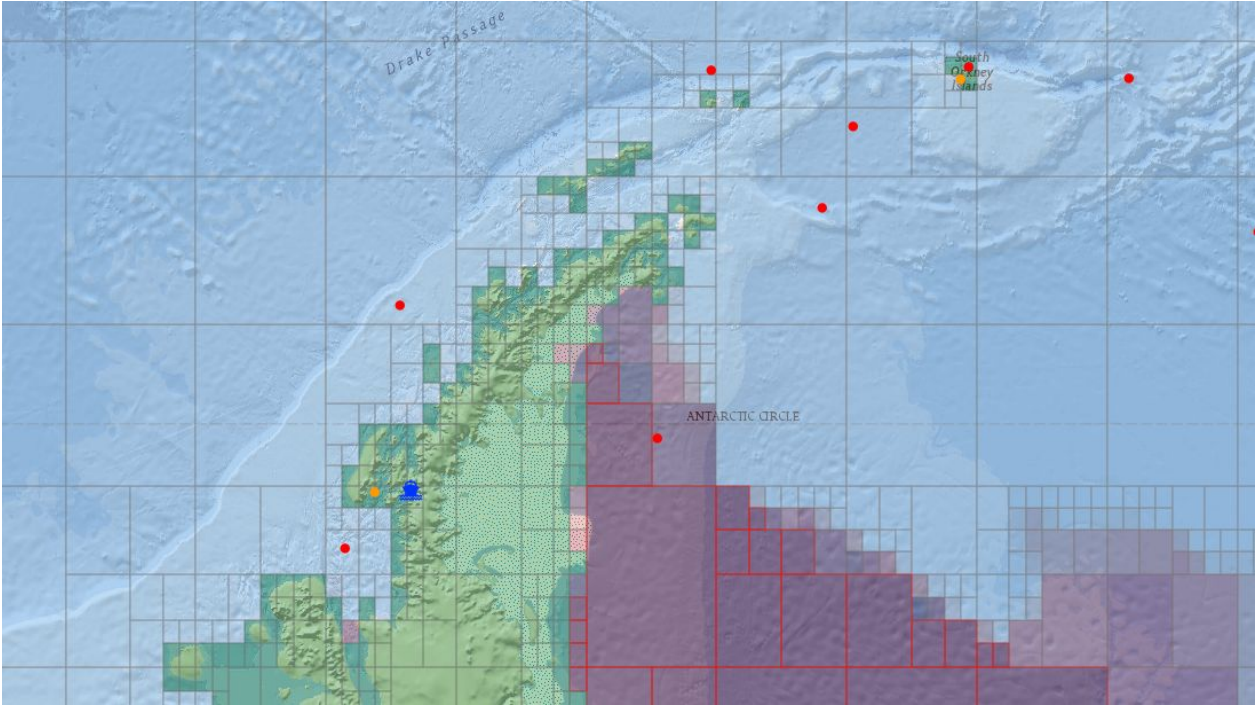
- Historic ice extent
- icebergs: calving, tracking
- Sea ice and weather forecasts
- Satellite imagery
- Previous ship tracks and event logs
- On-board data streams (position, heading, wind speed etc)

To inform:

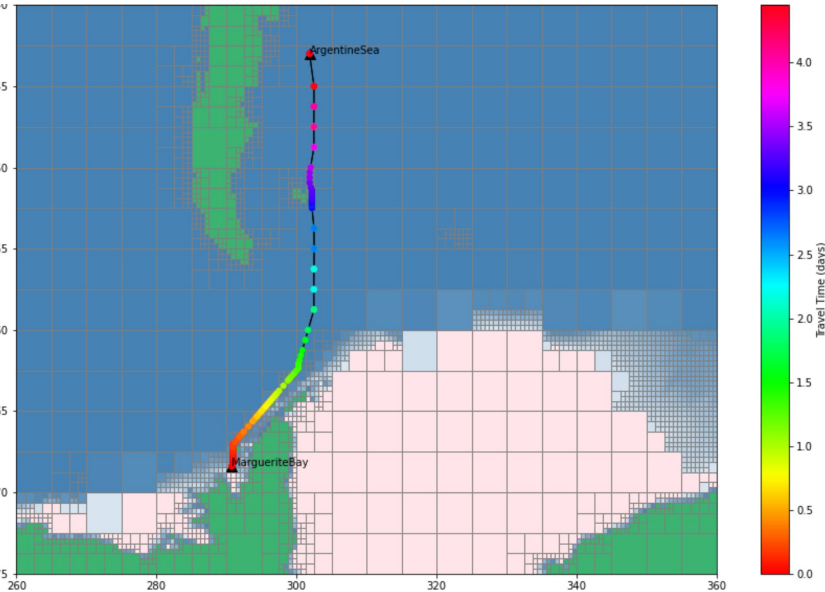
Automated operations planning for the vessel



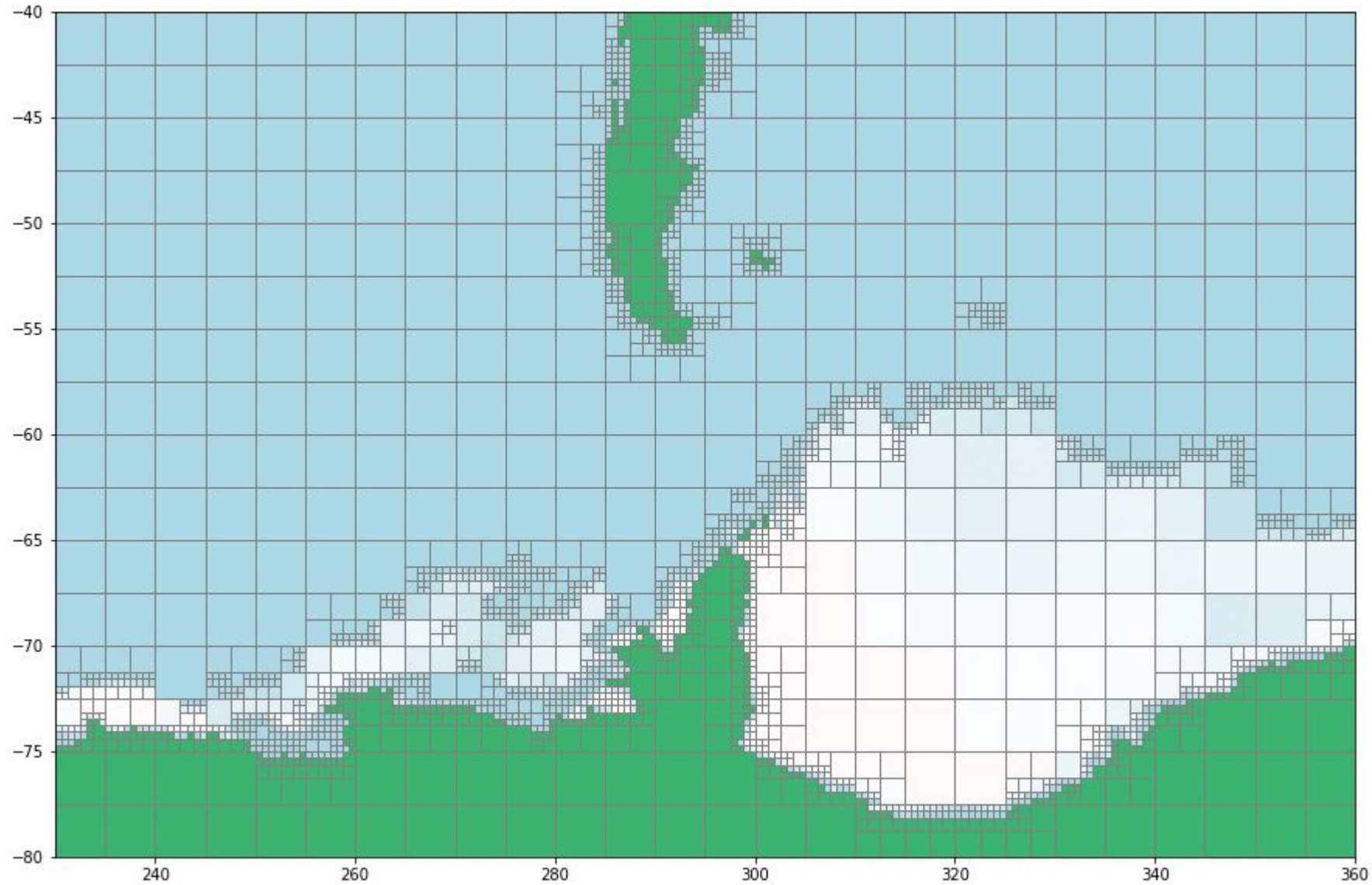
Route Planning



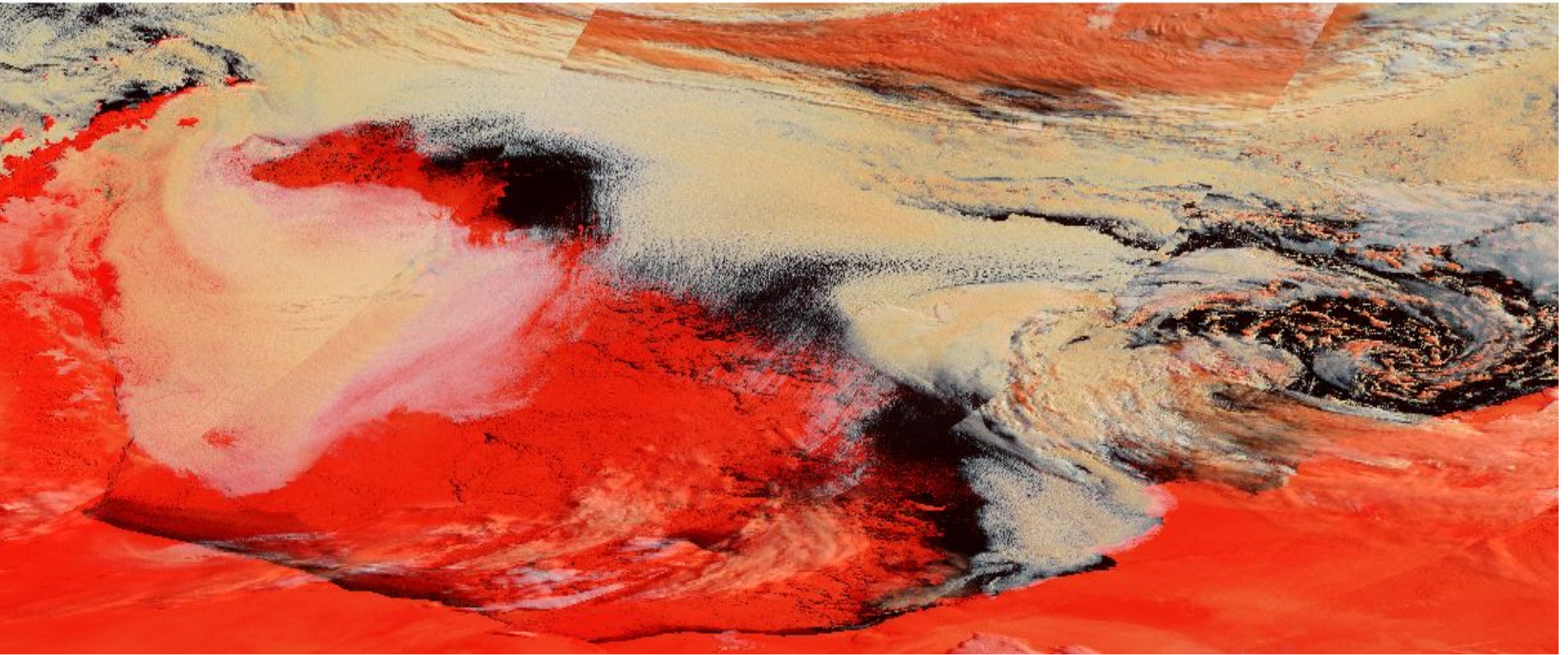
Rothera	4	16 Dec 23	20 Dec 23	First call
Transit	3	20 Dec 23	23 Dec 23	
Signy	4	23 Dec 23	27 Dec 23	Open station
Transit	2	27 Dec 23	29 Dec 23	
KEP	3	29 Dec 23	01 Jan 24	First call
Transit	1	01 Jan 24	02 Jan 24	
Bird Island	4	02 Jan 24	06 Jan 24	First call
Transit	2	06 Jan 24	08 Jan 24	
Falklands	6	08 Jan 24	14 Jan 24	Mob Weddell campaign



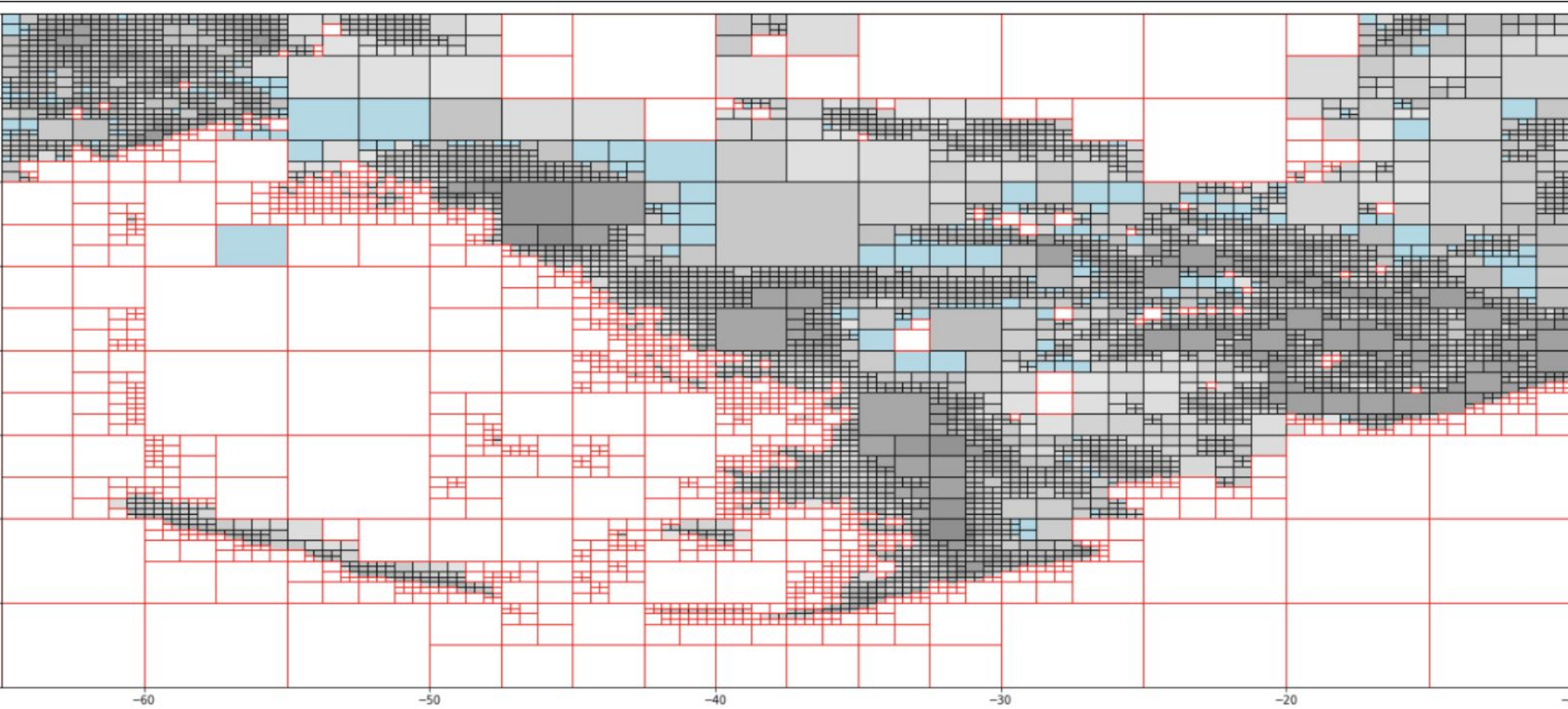
Digital Environment



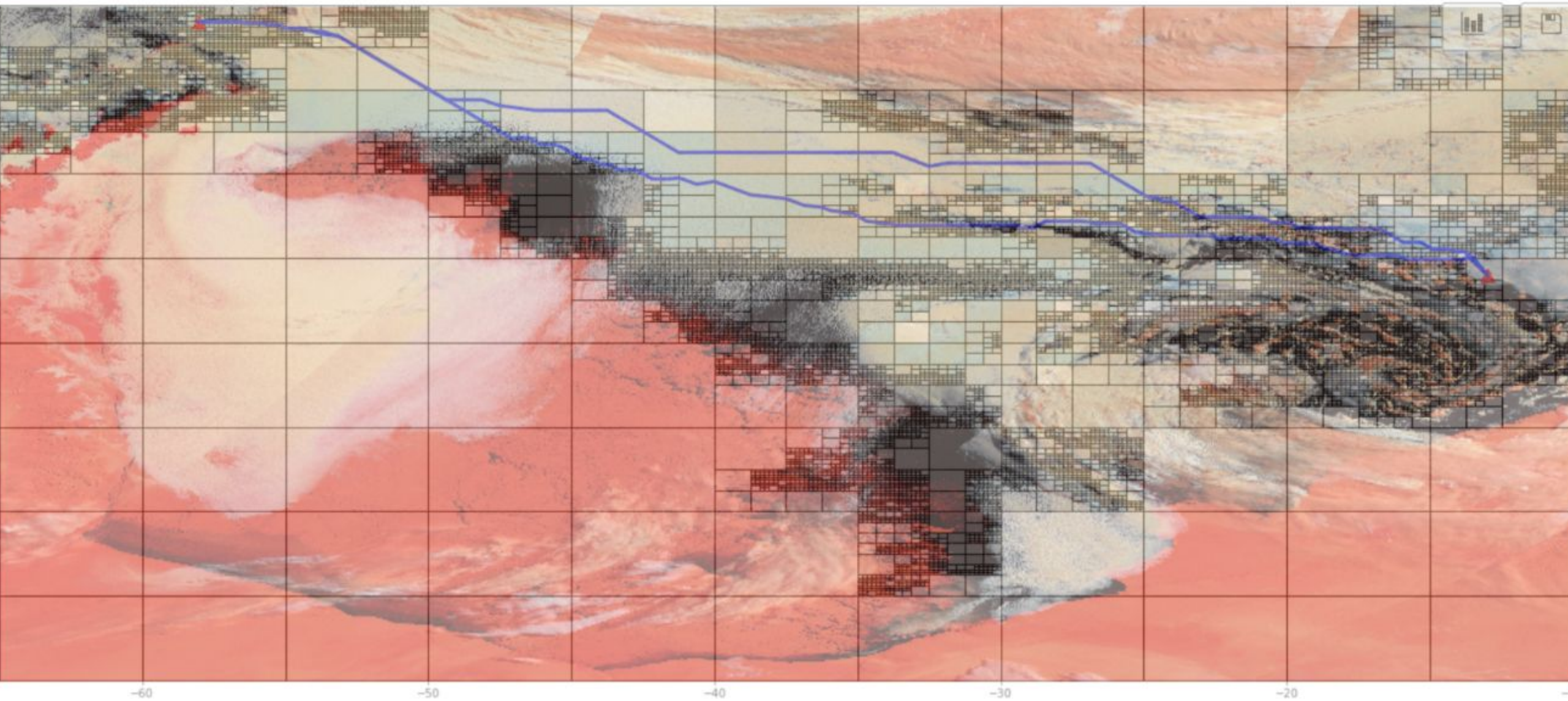
MODIS Satellite imagery



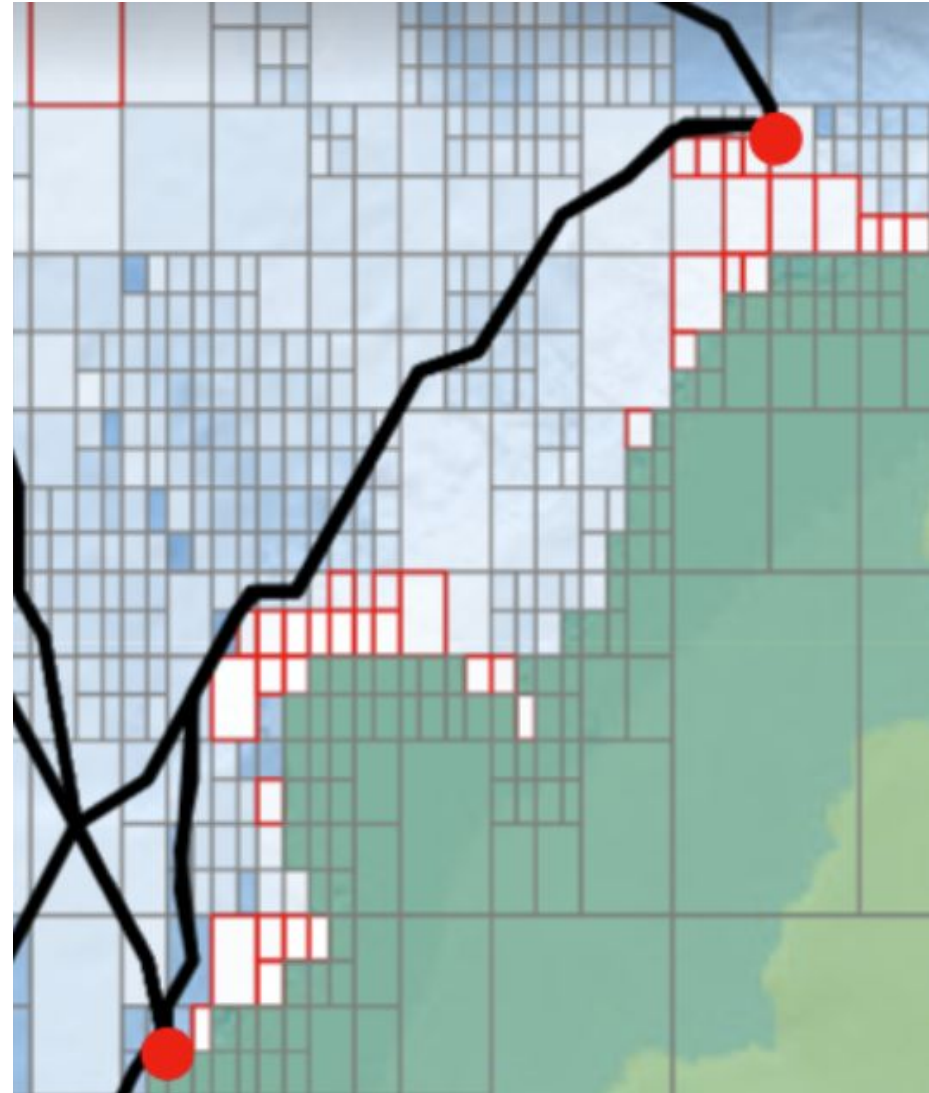
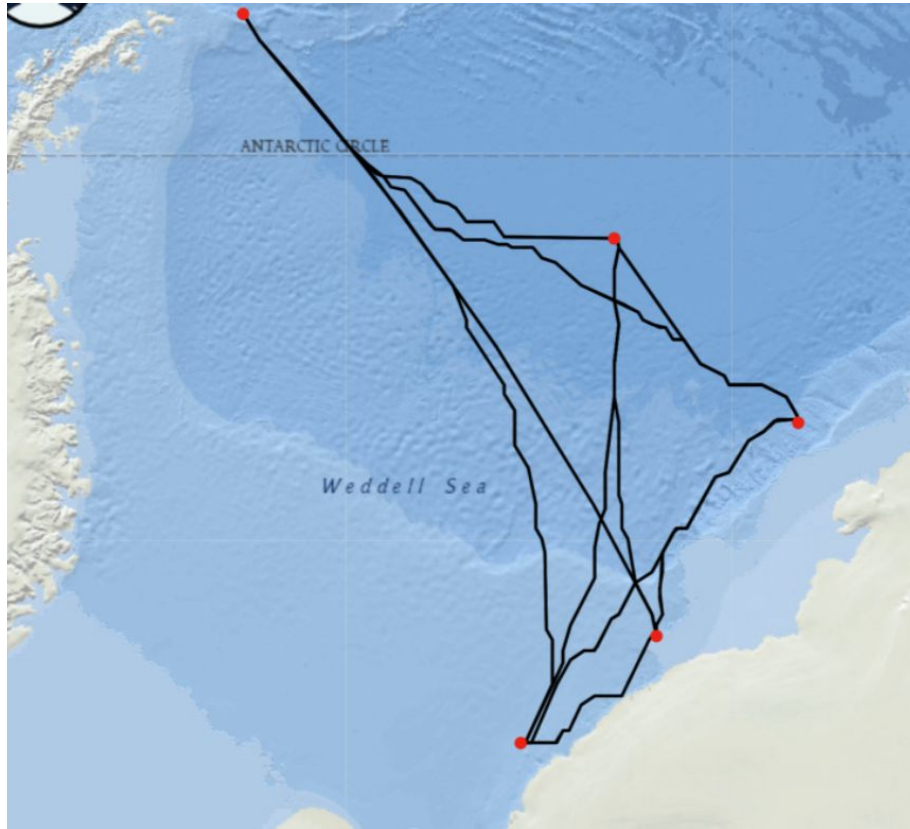
Mesh Representation



Mesh and image overlaid



Explaining Route Plans



Icebergs and in-ice features

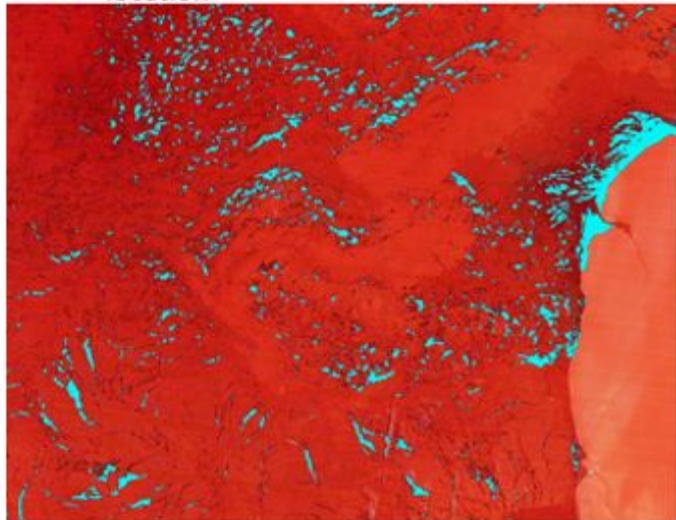
Detecting in-ice lead and polynya features in Modis visible imagery using unsupervised classification
marrog@bas.ac.uk

Original image

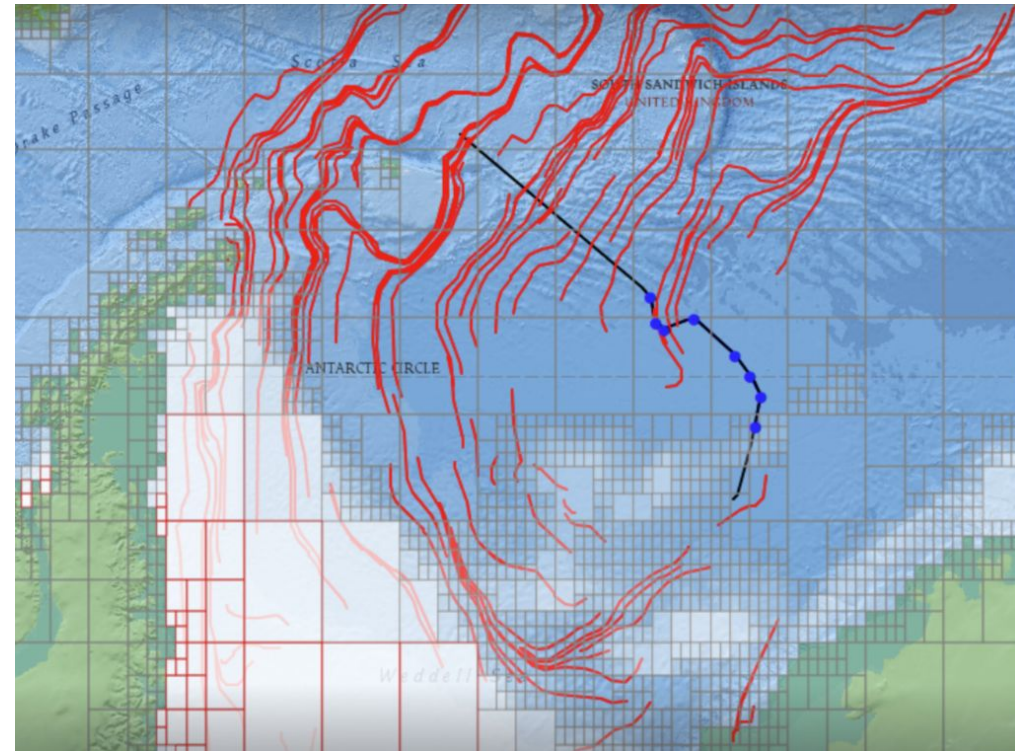


Lead/ polynya location 0 20 40 km

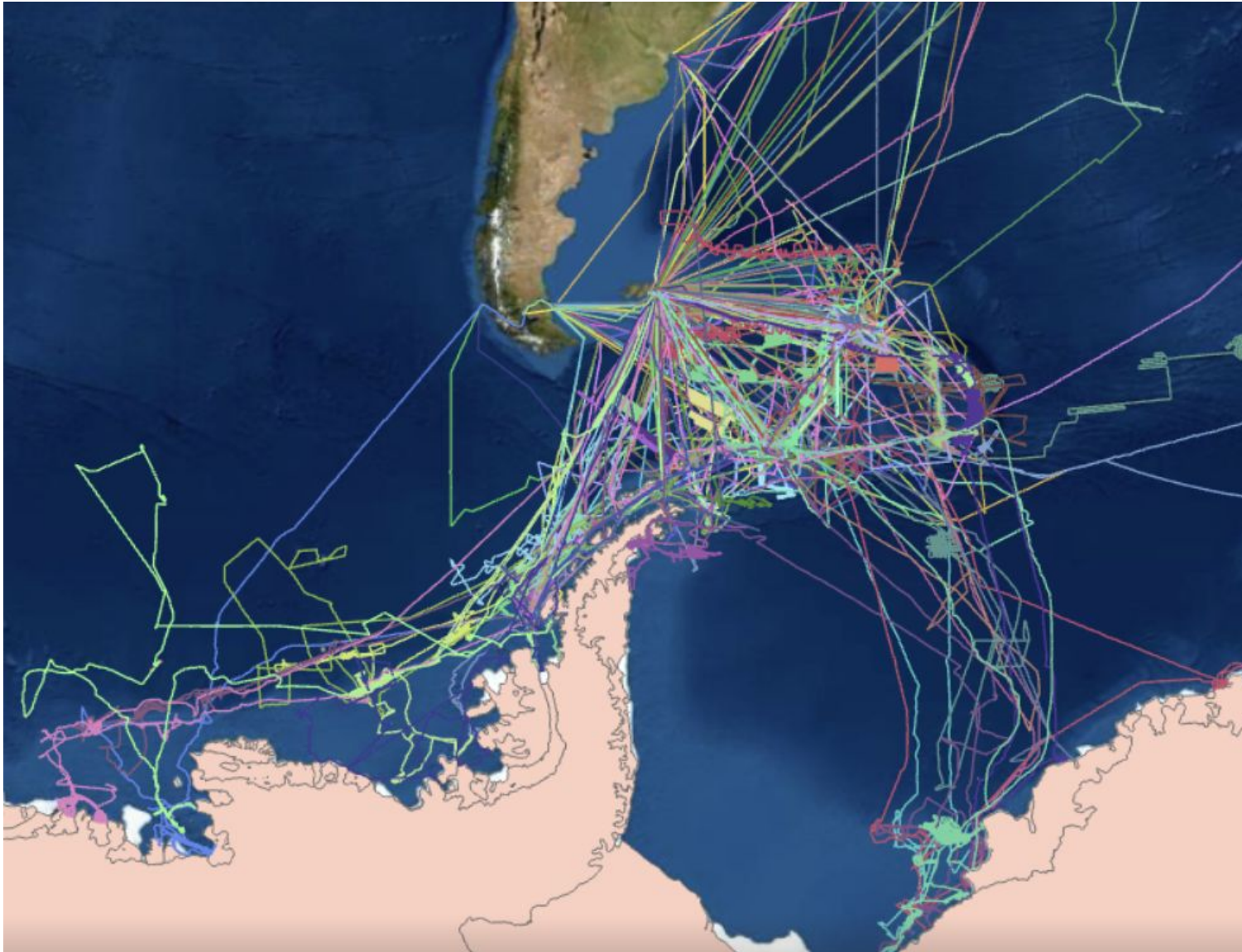
Classification output



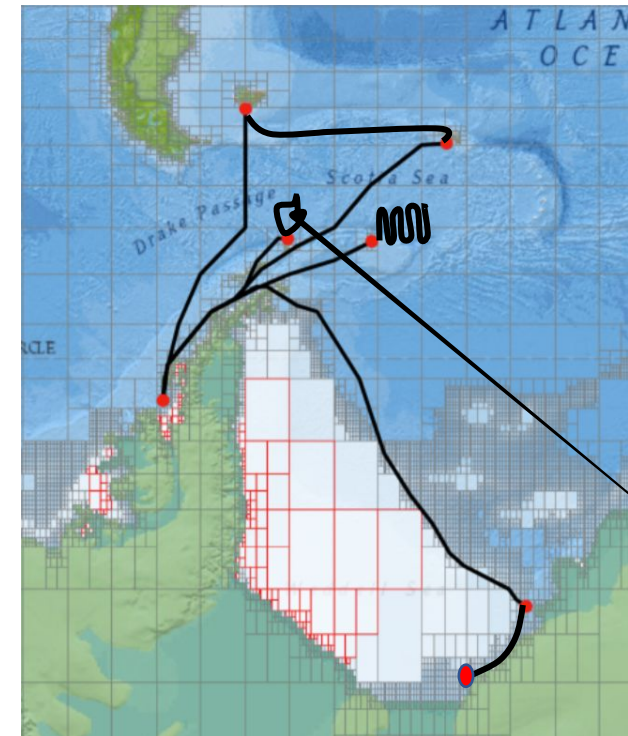
Inferring likely pathways of small icebergs moving with current



High Resolution Track Data for Previous Vessels



Rothera	4	16 Dec 23	20 Dec 23	First call
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How to maximise science gain at minimum cost?



Automated Mission Planning

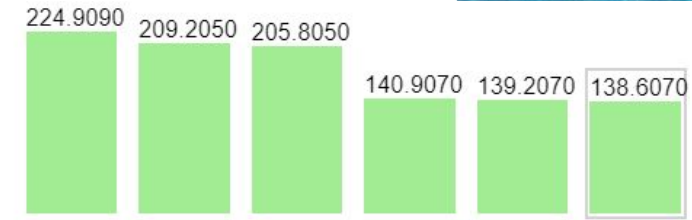
```
20
21 )
22
23 (:predicates
24 (started_hotel) 2
25 (SDA_at ?w - waypoint) 6 1?
26 (done_experiment_at ?w - waypoint) 1
27 (supplied_station ?w - waypoint)
28 (open ?w - waypoint)
29 (vessel_operational)
30
31 )
32
33 > (:durative-action hotel_fuel_burn
48 )
49
50 > (:durative-action
73 )
74
75 do_experiment...
97
98
99 > (:durative-action supply_station...
122 )
123
124
125 )
126
127
128
```

Domain model

```
179
180 (= (transit_time BellingshausenSea NorthernWeddellSea) 6.9)
181 (= (transit_time BellingshausenSea NorthPeninsula) 5.4)
182 (= (transit_time BellingshausenSea Brunt) 7.9)
183 (= (transit_time BellingshausenSea SouthGeorgia) 10.7)
184 (= (transit_time BellingshausenSea AmundsenSea) 1.8)
185 (= (transit_time BellingshausenSea Signy) 6.2)
186 (= (transit_time BellingshausenSea SorkneyIslands) 6.5)
187 (= (transit_time BellingshausenSea SouthSandwichTrench) 8.2)
188 (= (transit_time BellingshausenSea Falklands) 5)
189 (= (transit_time BellingshausenSea Rothera) 1.1)
190 (= (transit_time BellingshausenSea MaudRise) 10.3)
191
192 (= (fuel_burn_rate) 24)
193
194 (at 50 (open Rothera))
195 (at 100 (open Signy))
196
197 )
198
199
200 (SDA_at Falklands)
201 (supplied_station Rothera)
202 (supplied_station Signy)
203
204 (done_experiment_at AmundsenSea)
205 (done_experiment_at Brunt)
206 (done_experiment_at SouthGeorgia)
207 (done_experiment_at NorthernWeddellSea)
208 )
209 )
210 )
211 (:metric (minimize (fuel_burn)))
```

Determined by the route-planner

Problem Description



hotel_fuel_burn

navigate Falklands SouthGeorgia

do_experiment SouthGeorgia

navigate SouthGeorgia NorthernWeddellSea

do_experiment NorthernWeddellSea

navigate NorthernWeddellSea Brunt

do_experiment Brunt

navigate Brunt AmundsenSea

do_experiment AmundsenSea

navigate AmundsenSea Rothera

supply_station Rothera

navigate Rothera Signy

supply_station Signy

navigate Signy Falklands

Plan

waypoint

AmundsenSea

Rothera

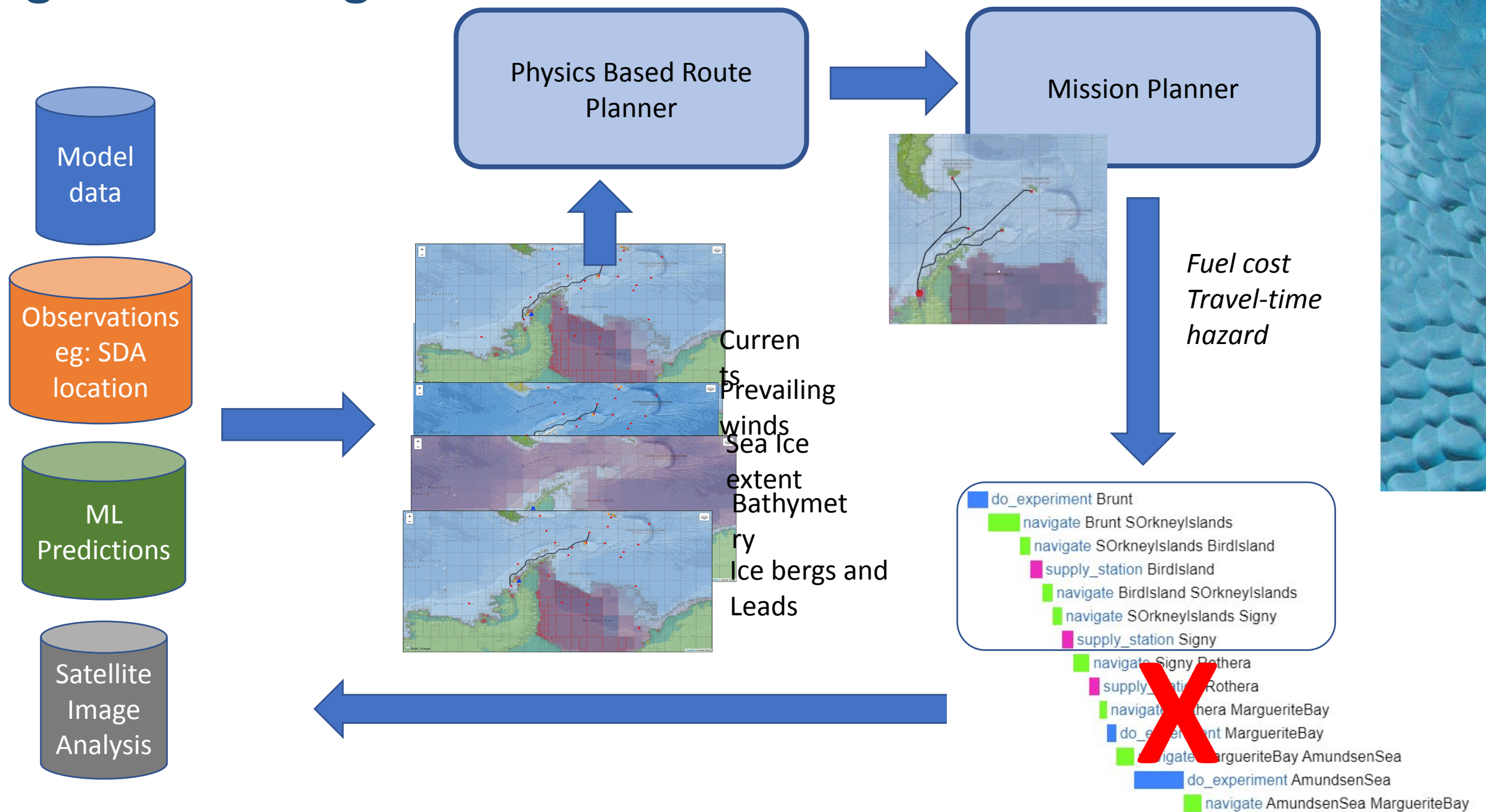
NorthPeninsula

Brunt

Signy



Digital Twinning



Summary

- We are building a *Digital Twin* of the Southern Ocean environment from the operational perspective of the SDA
- Multiple data sources can be combined to provide detailed input to decision-making
 - Sea ice extent
 - Icebergs classification and tracking
 - In-ice features for navigation
- Route-planning in ice
- Mission-planning to save fuel and carbon



Thank you for listening!

