Diffusion models for short-term probabilistic forecasting of Antarctic sea ice concentration

Andrew McDonald[1,2]
arm99@cam.ac.uk
@ampersandmcd

Tom Andersson[4*]
tomandersson3@gmail.com
@tom_r_andersson

Richard E Turner[1,6]
ret26@cam.ac.uk
@cambridgemlg

Jonathan Smith[2]
jonsmi@bas.ac.uk
@geologyjon

James Byrne[2]
jambyr@bas.ac.uk
@jimcircadian

J Scott Hosking[2,3]
jask@bas.ac.uk
@scotthosking

Peter Yatsyshin[3]
pyatsyshin@turing.ac.uk
@pyatsysh

María Peréz-Ortiz[5]
maria.perez@ucl.ac.uk
@mperezortiz_

[1]University of Cambridge
[2]British Antarctic Survey
[3]The Alan Turing Institute
[4]Google DeepMind
[5]University College London
[6]Microsoft Research

European Polar Science Week
5 September 2024

AI4ER
UNIVERSITY OF CAMBRIDGE
British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
The Alan Turing Institute
Microsoft Research
UCL
Google DeepMind

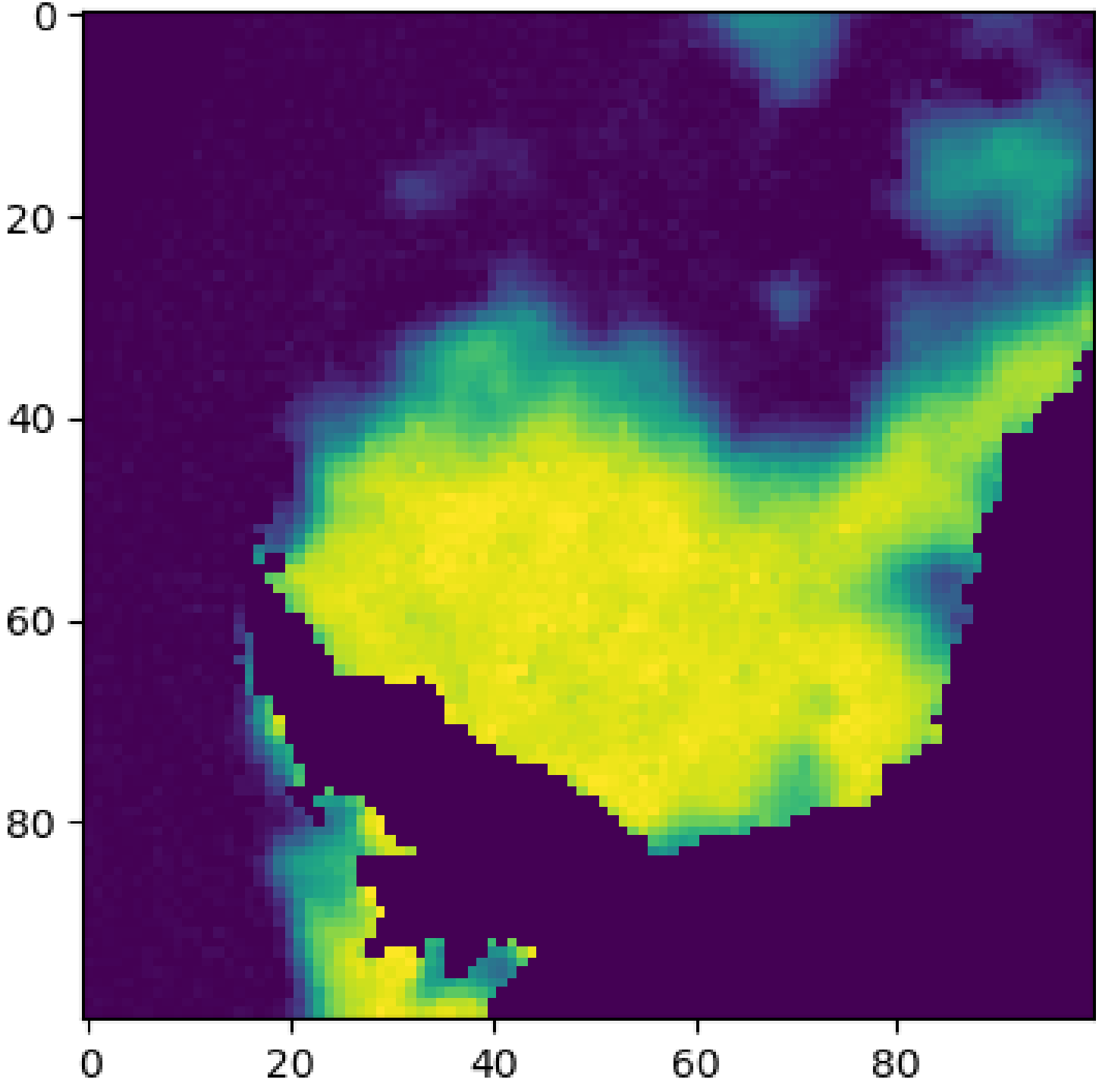
icenet.ai
@icenet_ai

* work completed whilst at BAS

Observation or Forecast?

25 km resolution over the Weddell Sea

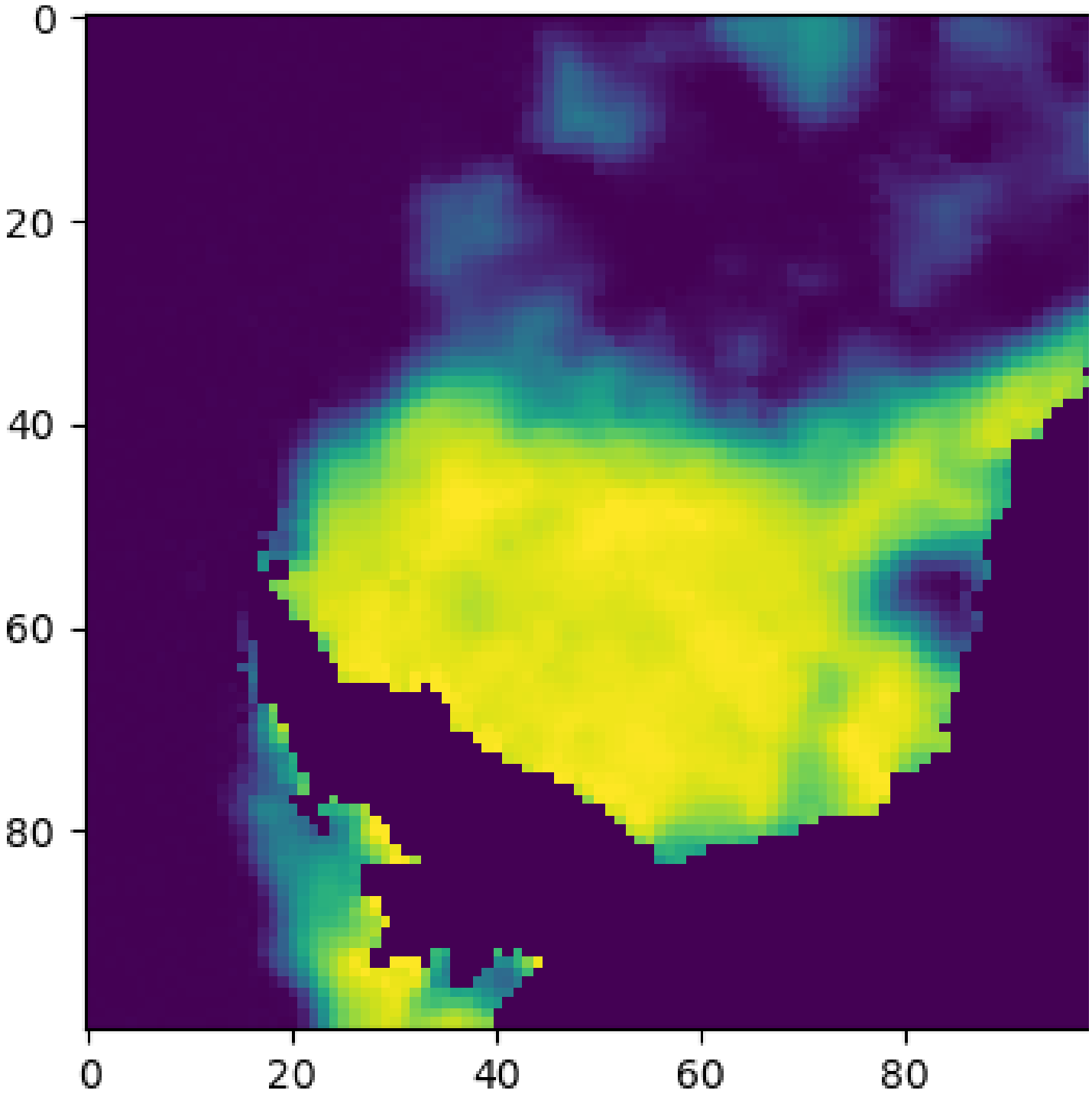
Tile A



Observation or Forecast?

25 km resolution over the Weddell Sea

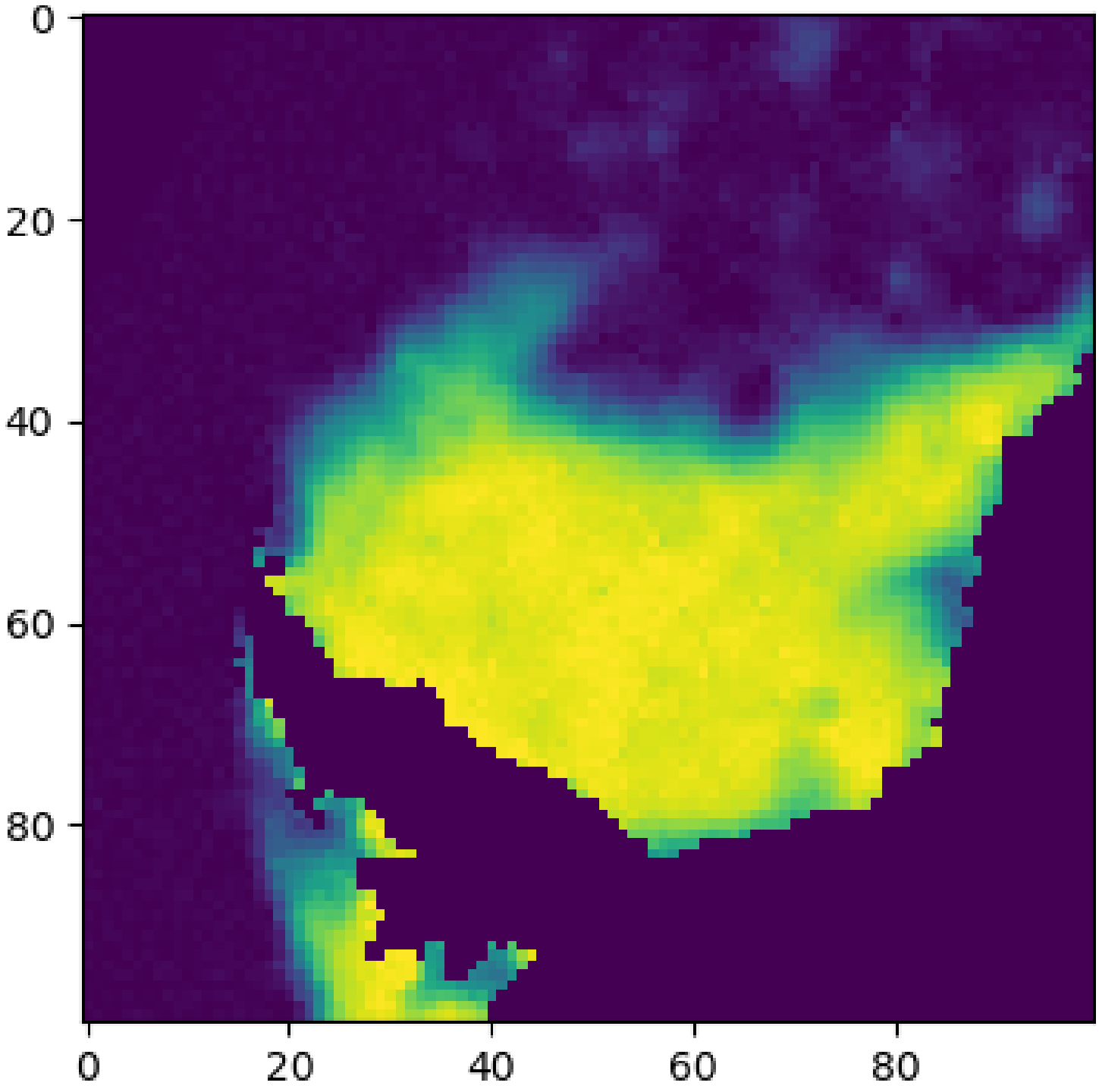
Tile B



Observation or Forecast?

25 km resolution over the Weddell Sea

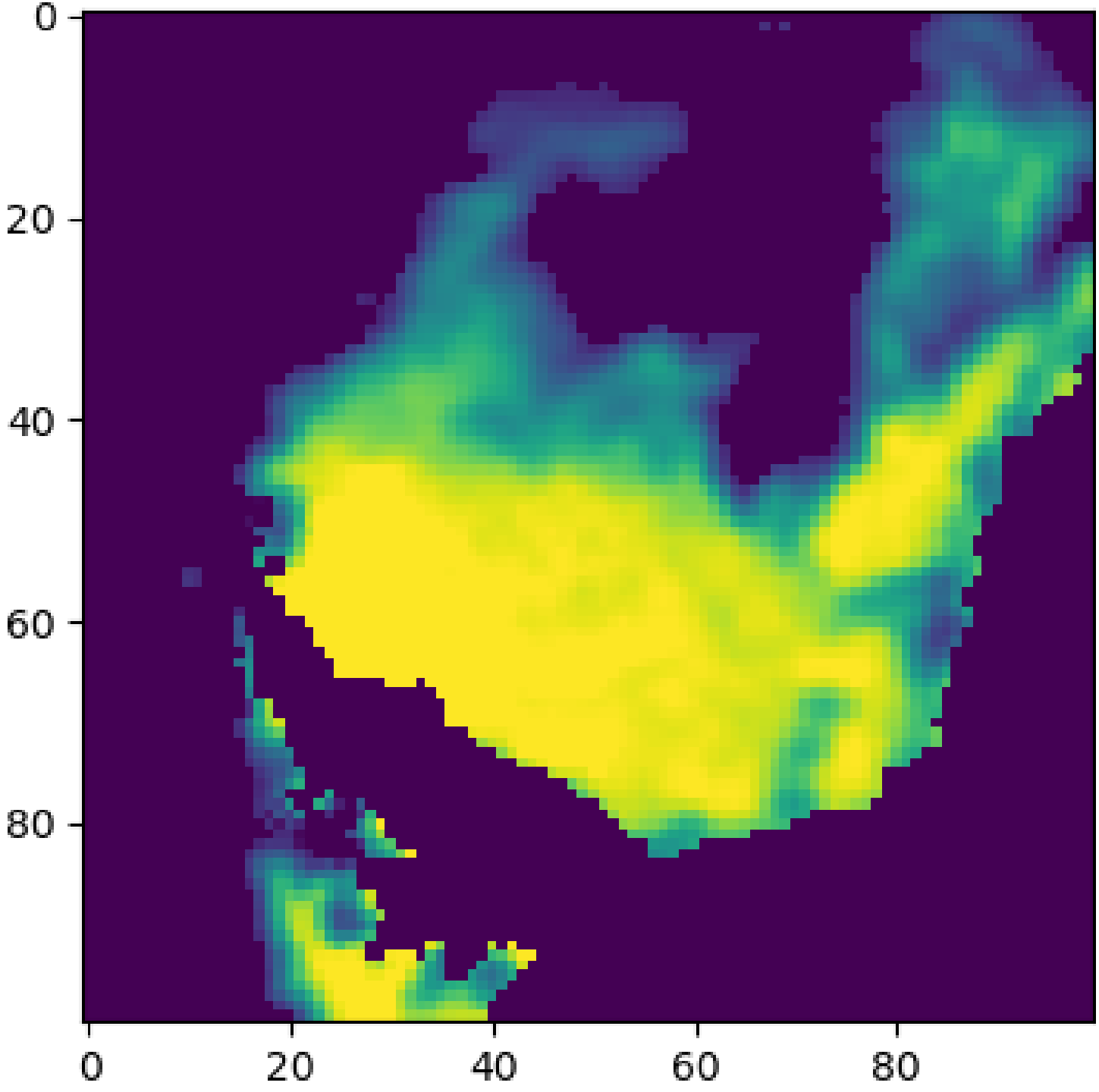
Tile C



Observation or Forecast?

25 km resolution over the Weddell Sea

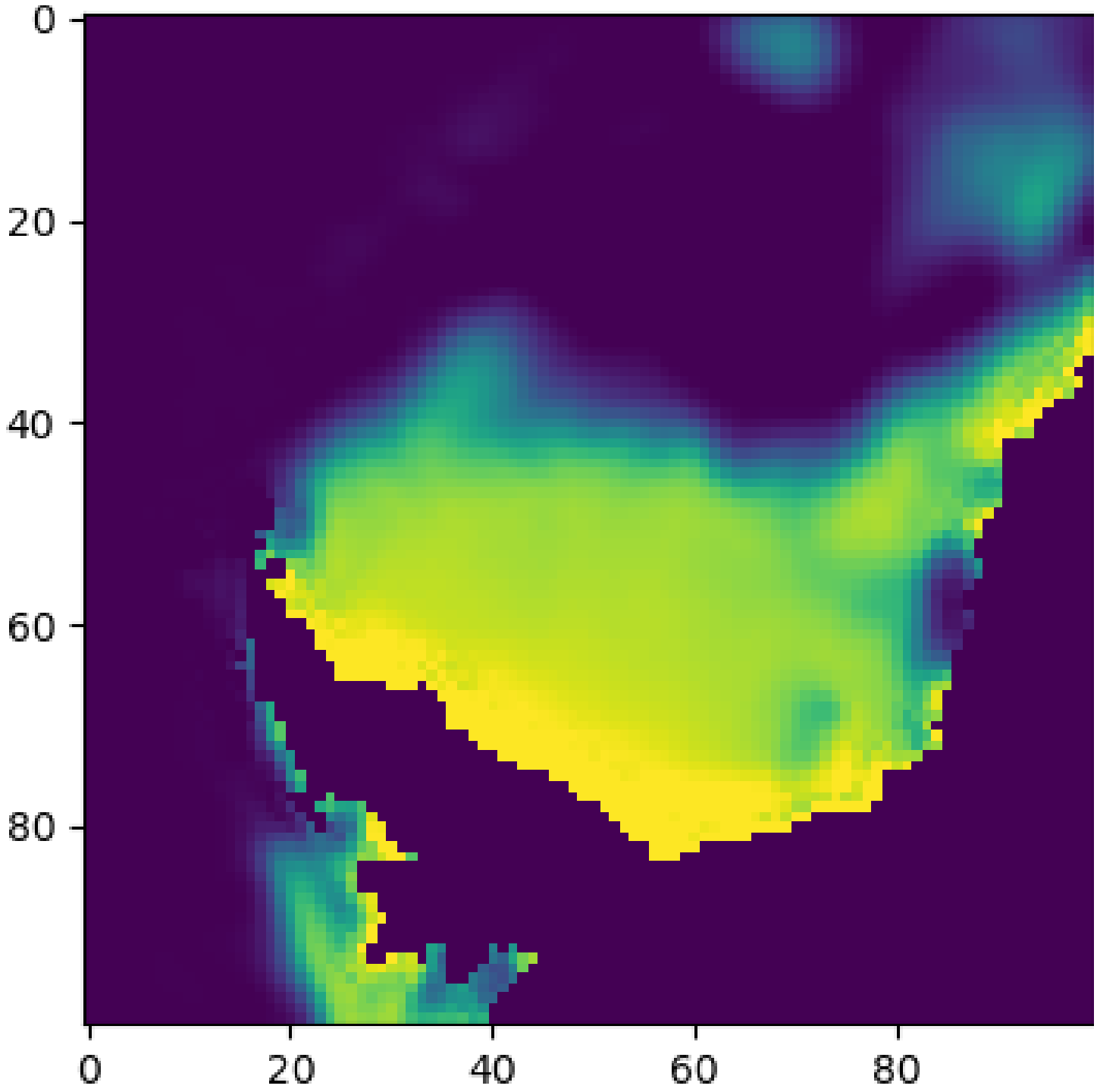
Tile D



Observation or Forecast?

25 km resolution over the Weddell Sea

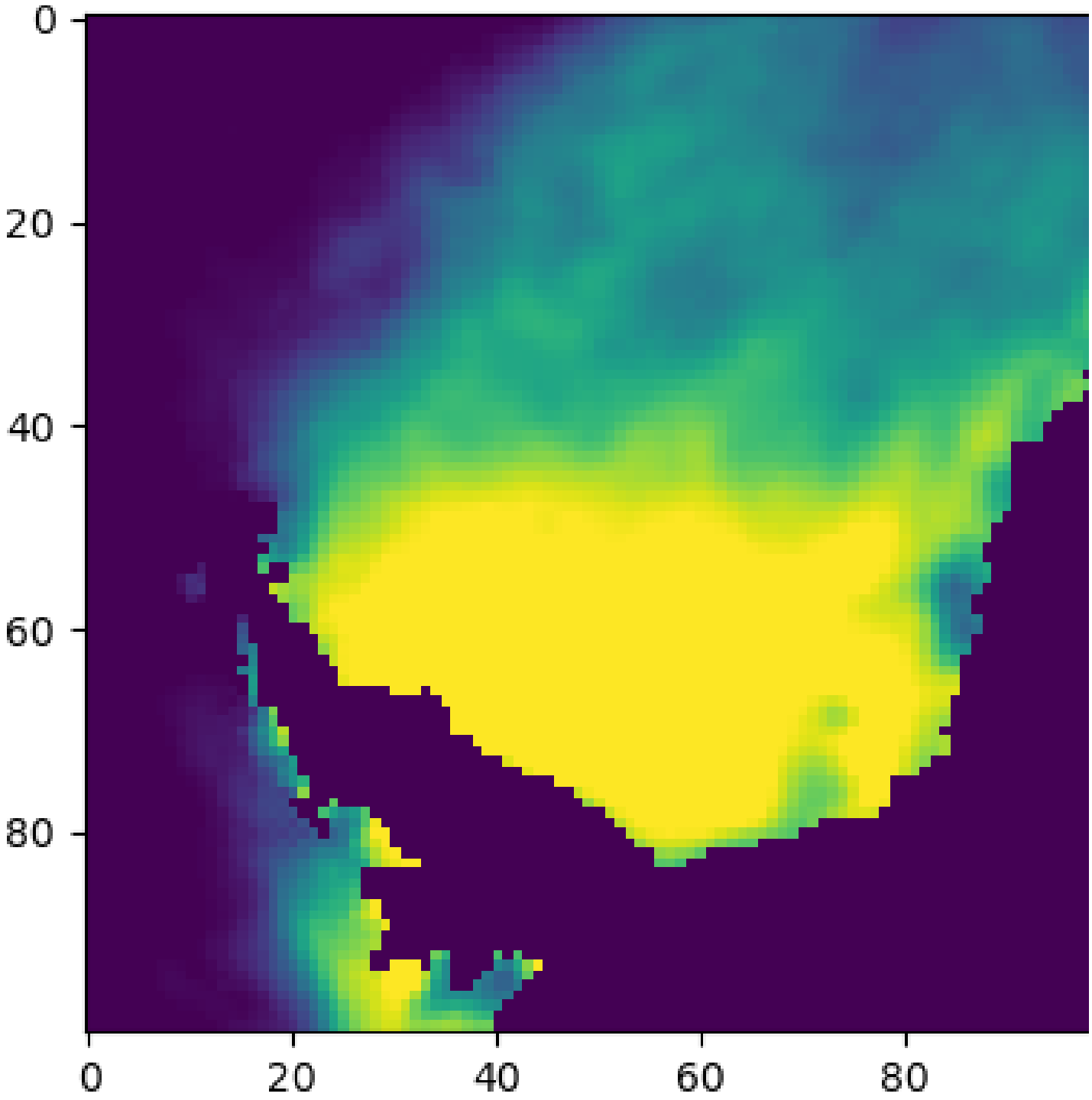
Tile E



Observation or Forecast?

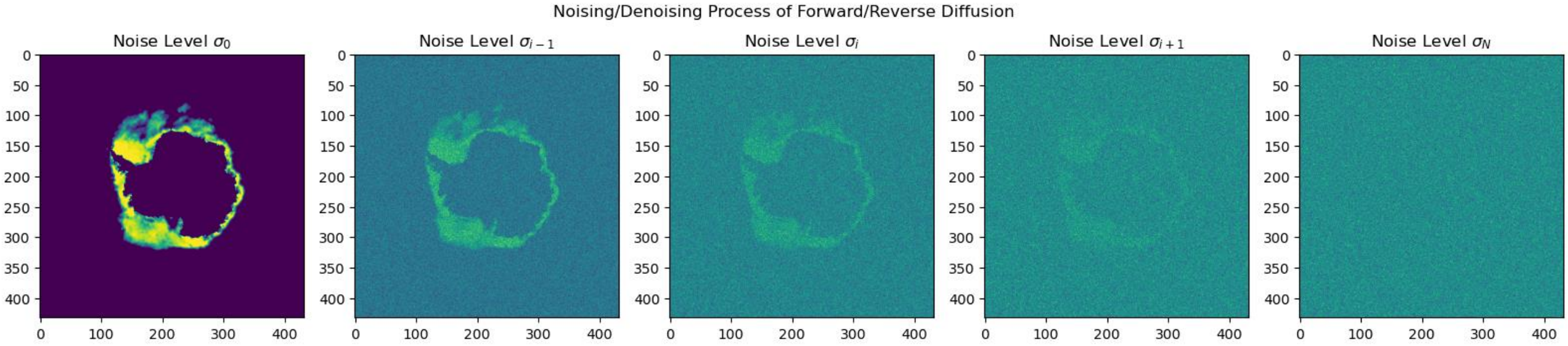
25 km resolution over the Weddell Sea

Tile F



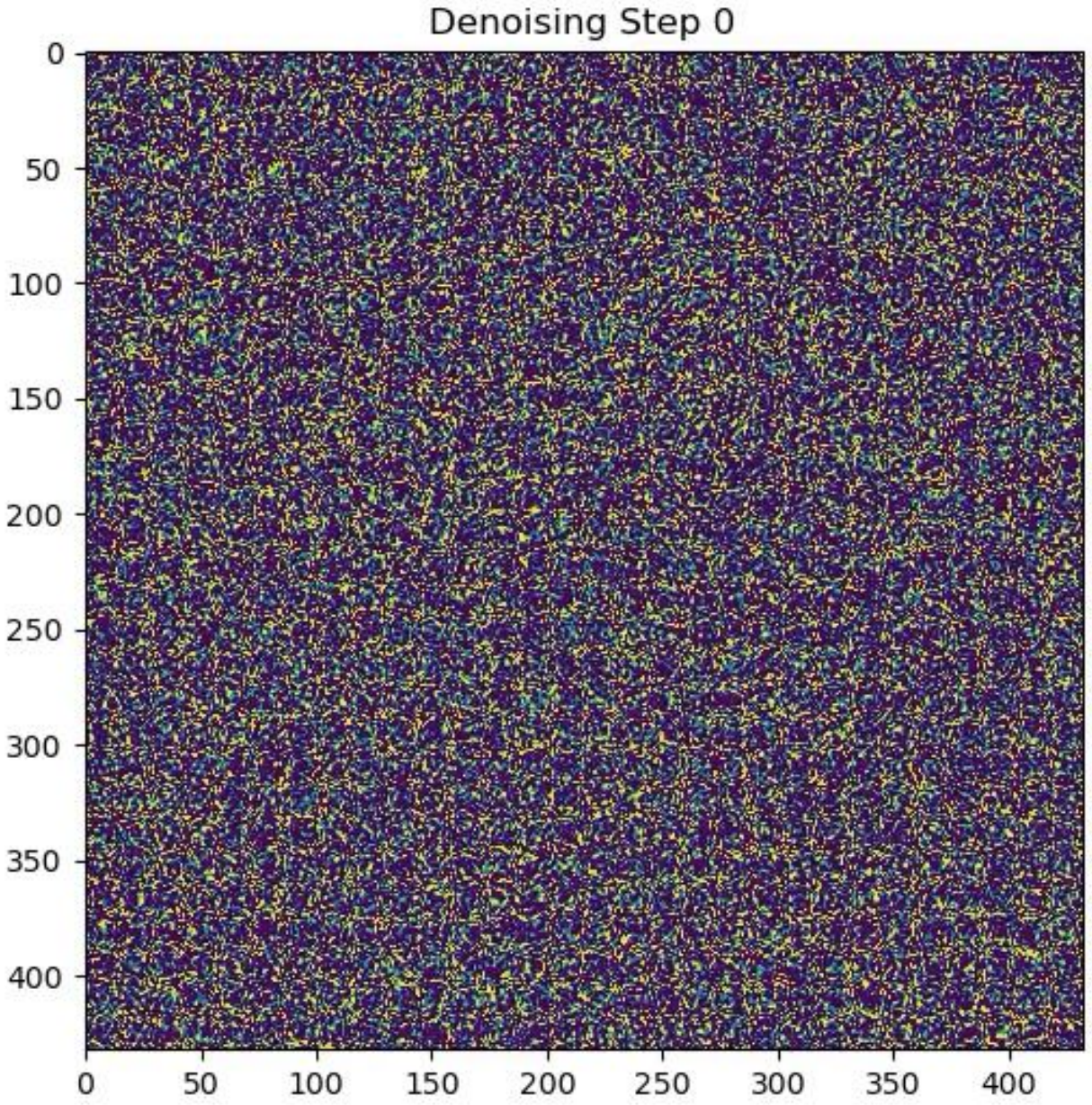
What is Diffusion?

A generative deep learning technique where we progressively denoise a sample.



What is Diffusion?

With a trained model,
we get this.



Problem Setup

Autoregressive

10-day rollouts

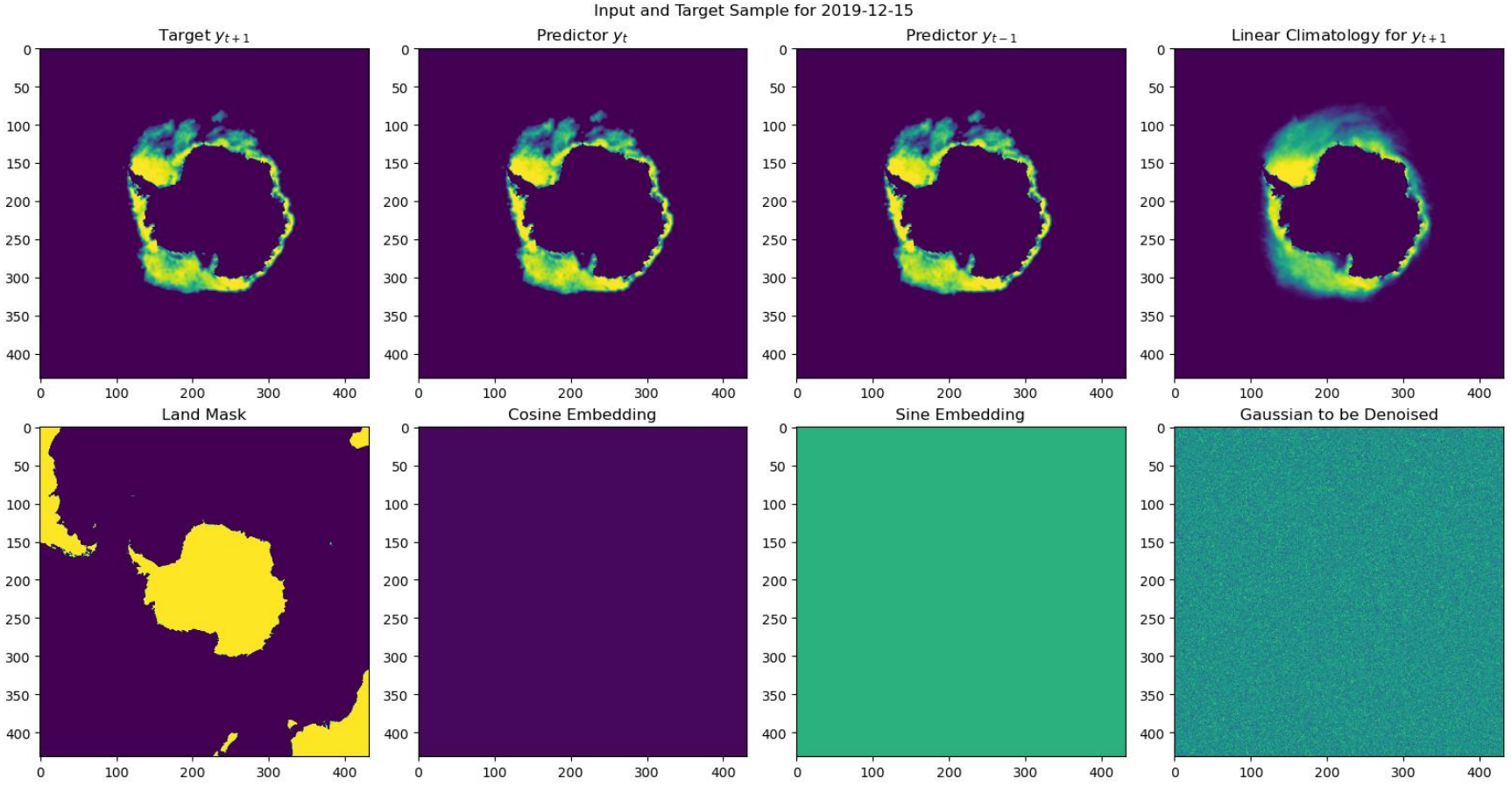
U-Net backbone

14.2 M parameters

HuggingFace `diffusers` library

DDIM scheduler with 20 denoising steps

v-prediction parameterisation

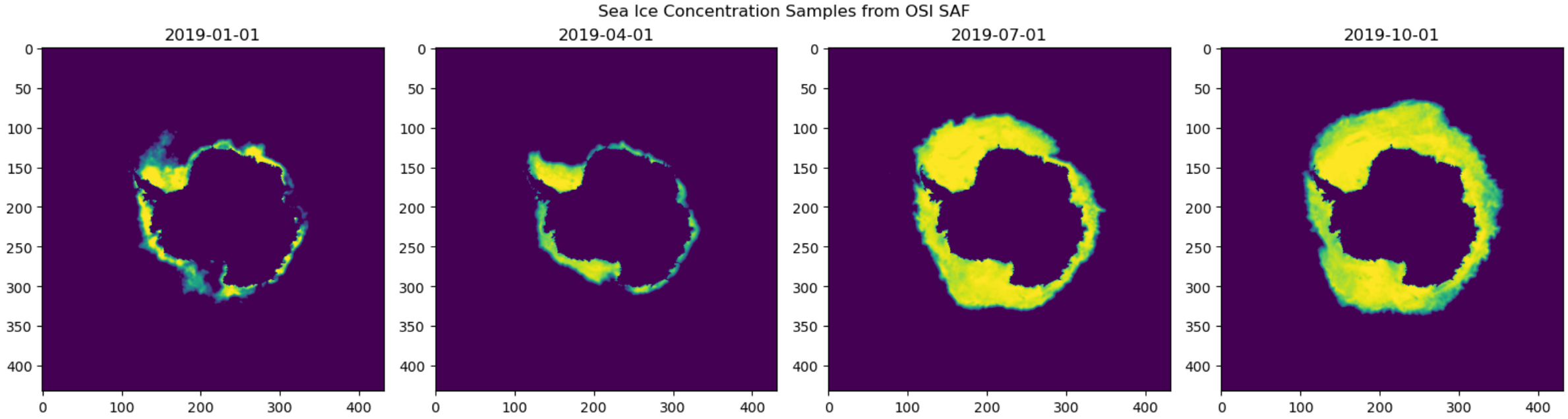


Problem Setup

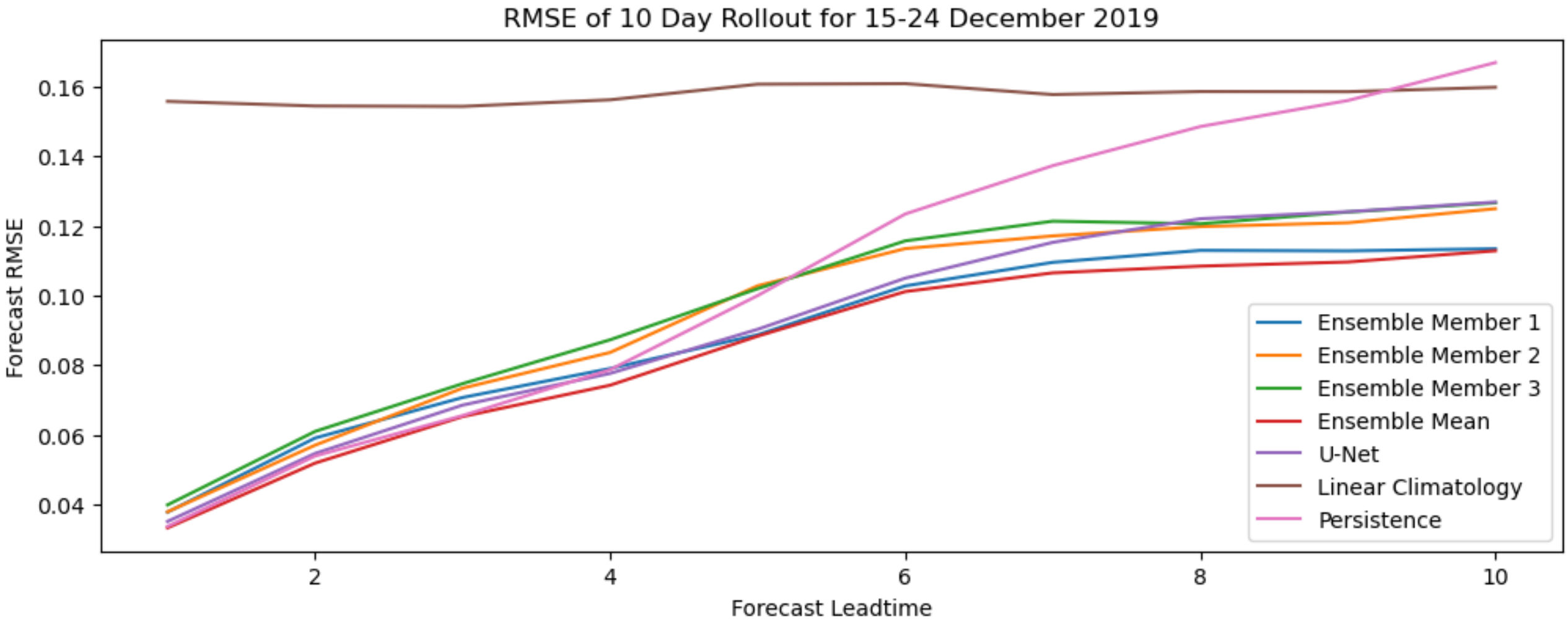
EUMETSAT OSI SAF
25 km SIC data from
SMMR, SSM/I, SSMIS

1988-2016 training
2017-2018 validation
2019-2020 test

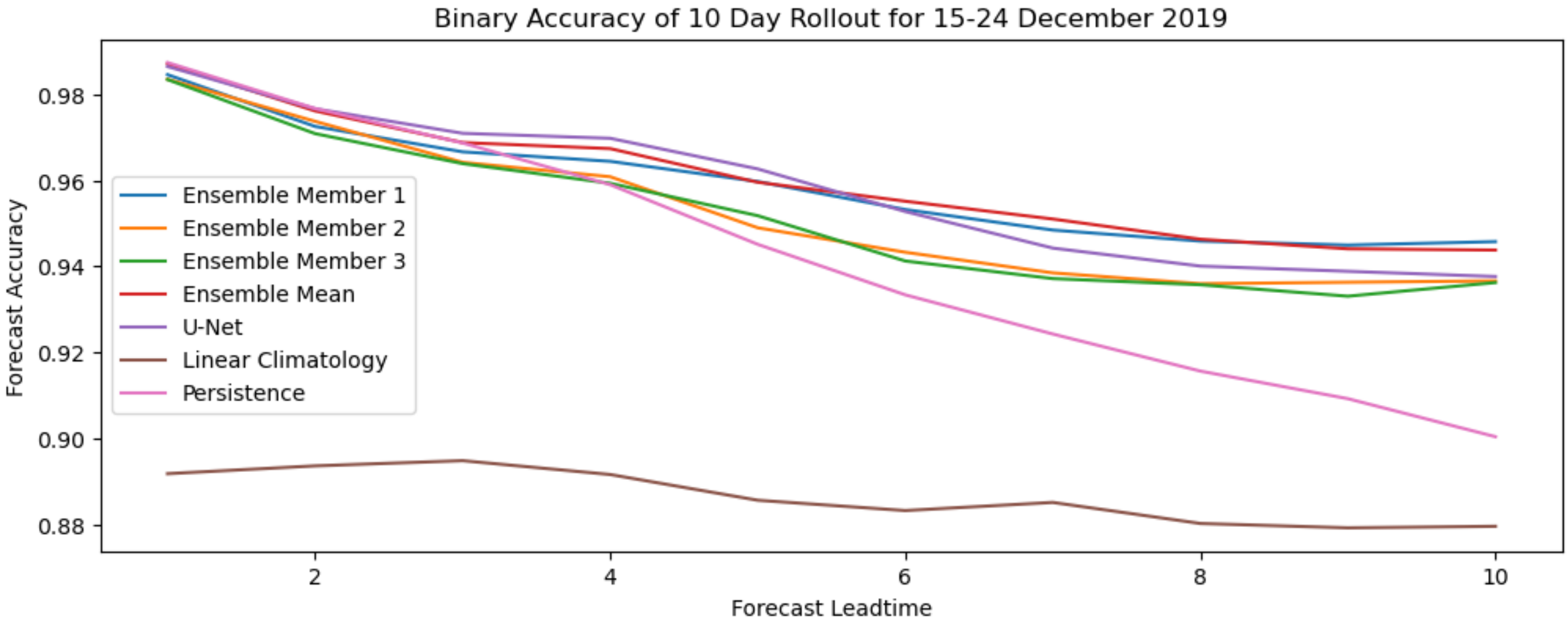
Extensible to other domains and variables



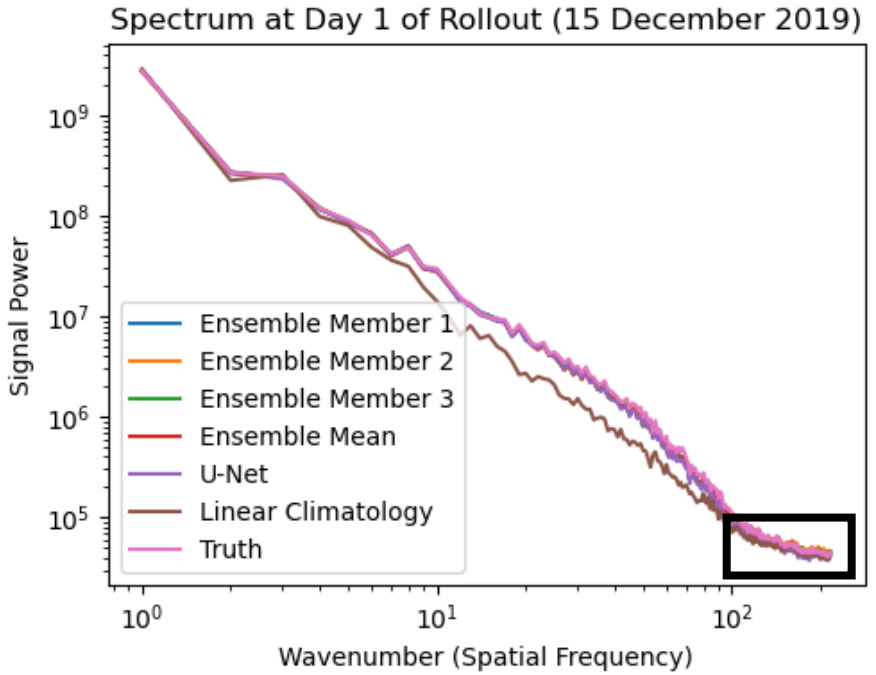
Results

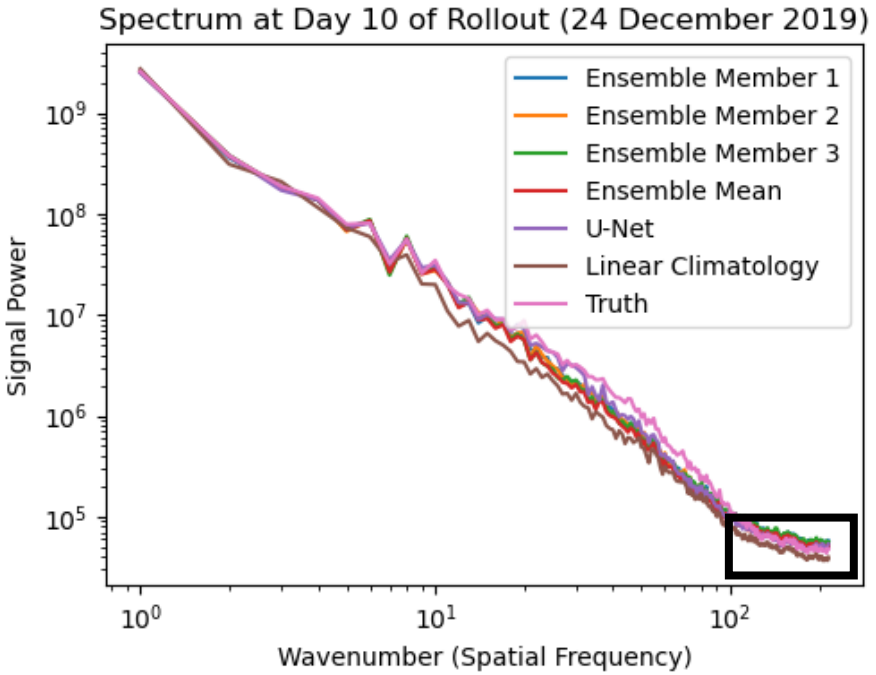

RMSE of 10 Day Rollout for 15-24 December 2019
Forecast RMSE
0.16
0.14
0.12
0.10
0.08
0.06
0.04
2
4
6
8
10
Forecast Leadtime
Ensemble Member 1
Ensemble Member 2
Ensemble Member 3
Ensemble Mean
U-Net
Linear Climatology
Persistence

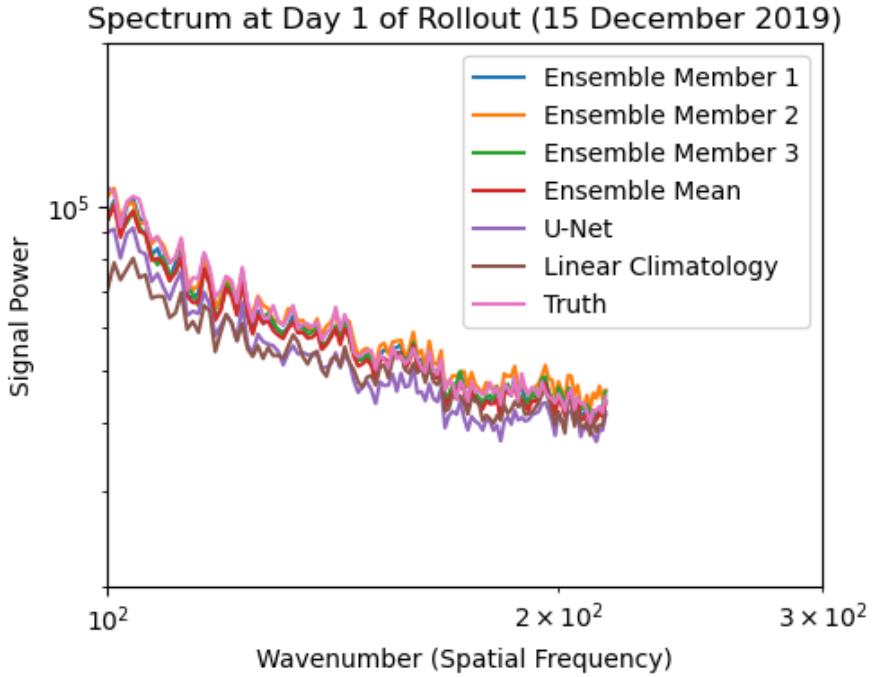
Results

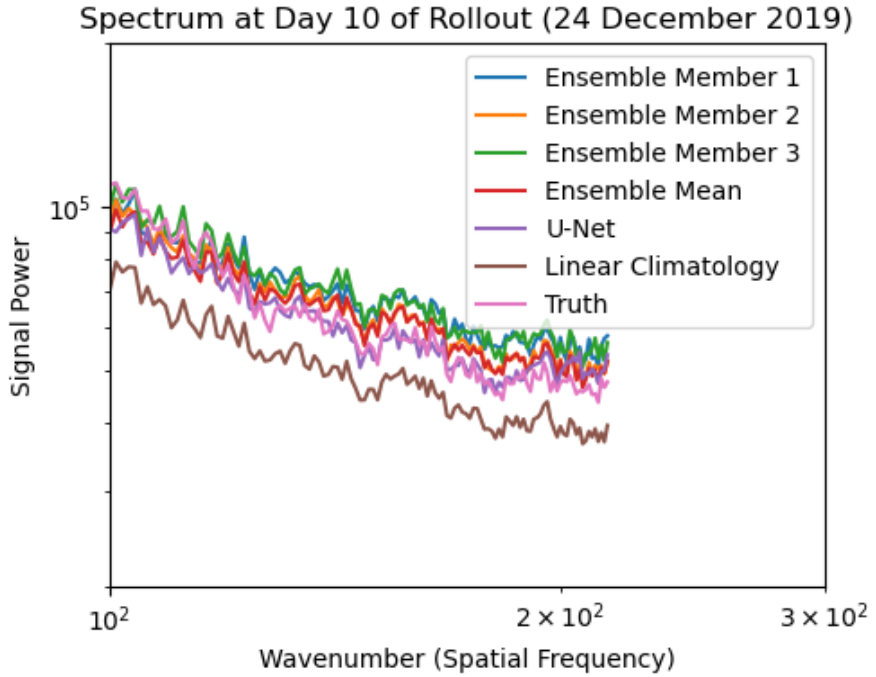

Binary Accuracy of 10 Day Rollout for 15-24 December 2019
Forecast Accuracy
0.98
0.96
0.94
0.92
0.90
0.88
Ensemble Member 1
Ensemble Member 2
Ensemble Member 3
Ensemble Mean
U-Net
Linear Climatology
Persistence
2
4
6
8
10
Forecast Leadtime

Results

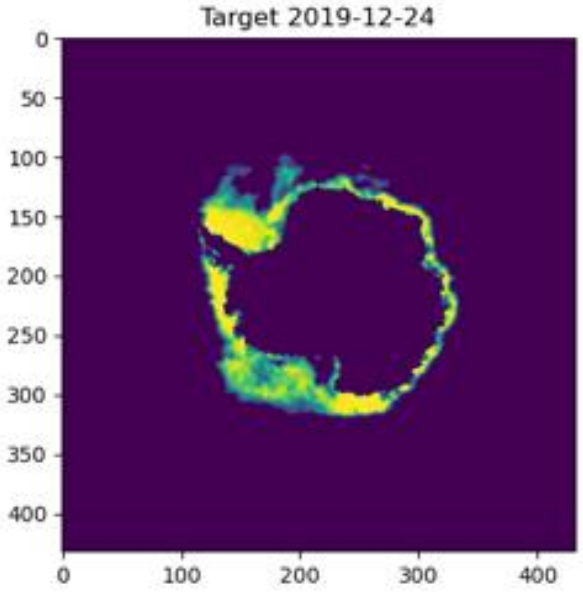

Spectrum at Day 1 of Rollout (15 December 2019)
Signal Power
Wavenumber (Spatial Frequency)
Ensemble Member 1
Ensemble Member 2
Ensemble Member 3
Ensemble Mean
U-Net
Linear Climatology
Truth

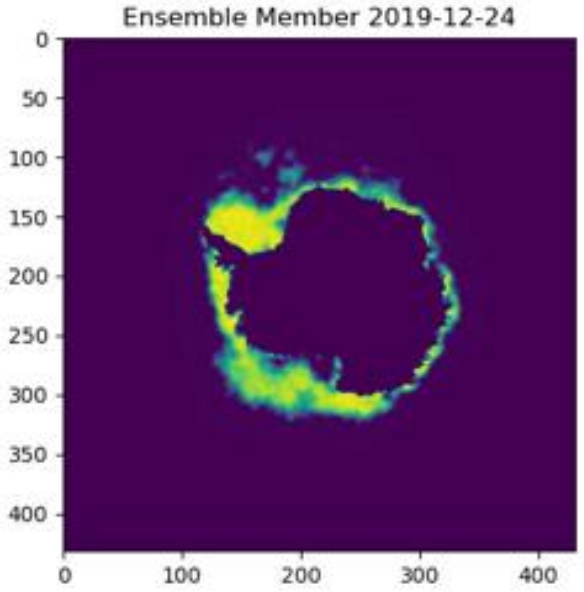

Spectrum at Day 10 of Rollout (24 December 2019)
Signal Power
Wavenumber (Spatial Frequency)
Ensemble Member 1
Ensemble Member 2
Ensemble Member 3
Ensemble Mean
U-Net
Linear Climatology
Truth

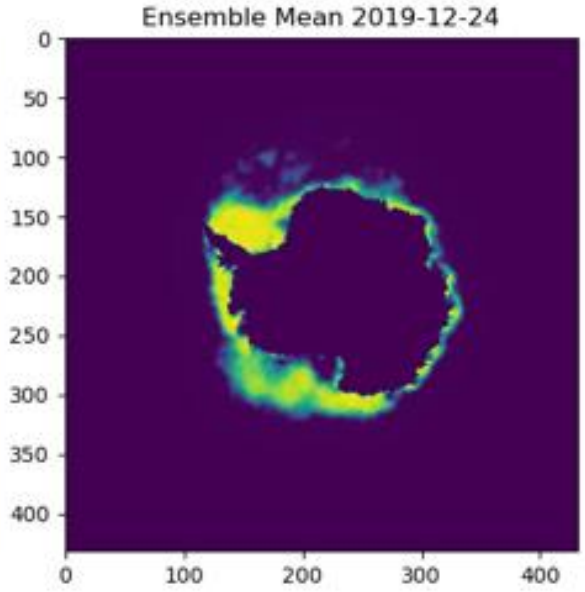

Spectrum at Day 1 of Rollout (15 December 2019)
Signal Power
Wavenumber (Spatial Frequency)
Ensemble Member 1
Ensemble Member 2
Ensemble Member 3
Ensemble Mean
U-Net
Linear Climatology
Truth

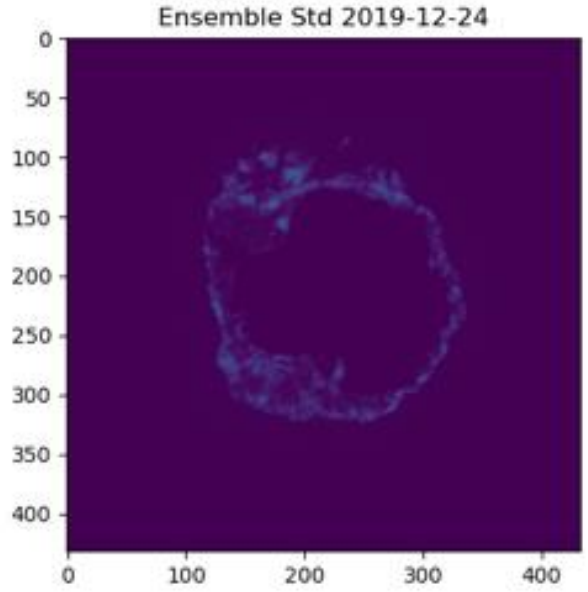

Spectrum at Day 10 of Rollout (24 December 2019)
Signal Power
Wavenumber (Spatial Frequency)
Ensemble Member 1
Ensemble Member 2
Ensemble Member 3
Ensemble Mean
U-Net
Linear Climatology
Truth

Results

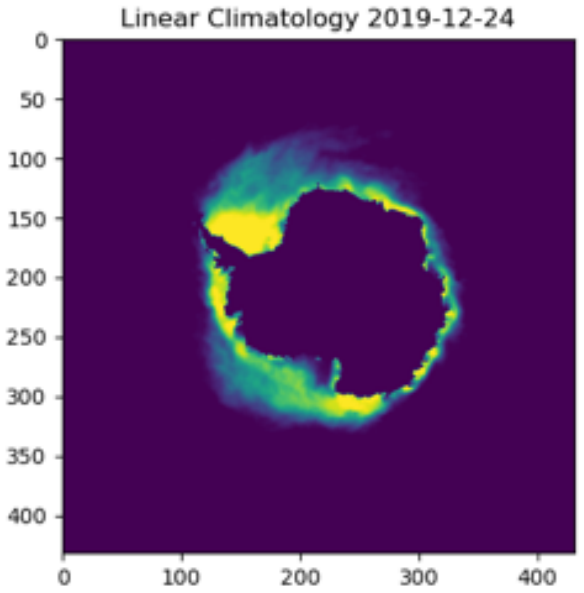


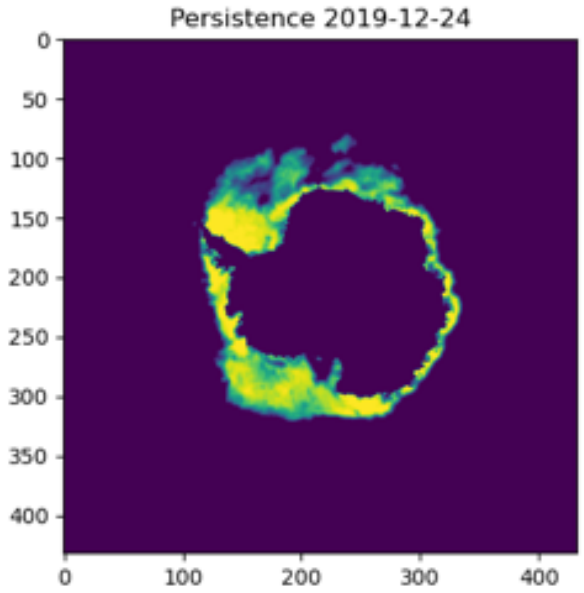


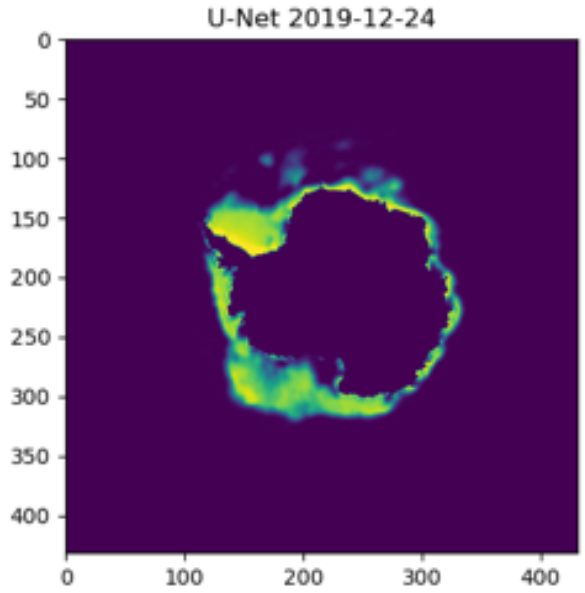




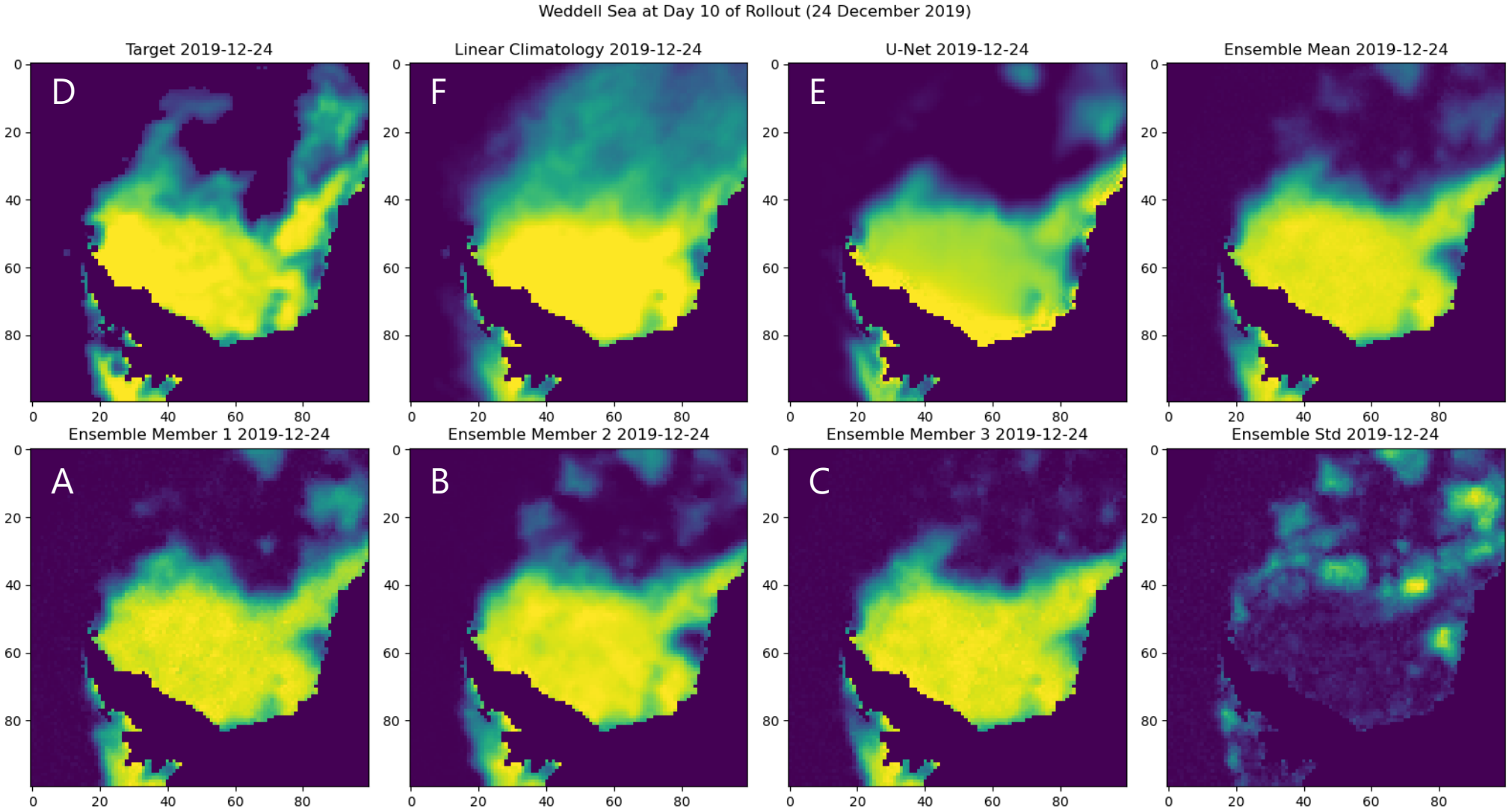
10 Day Rollout for
15-24 December 2019







Results (and answers to Observation or Forceast? quiz)



Future Directions

Better metrics

Longer lead times

AMSR-2 and ice chart data

Latent diffusion

Joint / video diffusion

Vision transformers

Other sea ice variables

Other domains

Downstream integration

Further Reading

[1] L. Weng. “What are diffusion models?” lilianweng.github.io, 2021. https://lilianweng. github.io/posts/2021-07-11-diffusion-models/

[2] T. R. Andersson et al., “Seasonal Arctic sea ice forecasting with probabilistic deep learning.” Nature Communications, 2021.

[3] I. Price et al., “GenCast: Diffusion-based ensemble forecasting for medium-range weather.” *arXiv preprint*, 2023.

[4] T. S. Finn et al., “Towards diffusion models for large-scale sea-ice modelling.” *arXiv preprint*, 2024.

[5] T. S. Finn et al., “Generative diffusion for regional surrogate models from sea-ice simulations.” *Authorea Preprints*, 2024.

Advertisements

POSTER LIST

DAY 3 Thursday | 5 September 2024

	mass change events in Greenland?		
98	Investigation of tidal grounding line migration using SAR line-of-sight offset time series	Sindhu Ramanath Tarekere	German Aerospace Center
99	CryoRad - An innovative radiometric mission for the cryosphere	Marion Leduc-leballeur	Ifac-cnr
100	The Untapped Potential of Using Expedition Ships in the Polar Regions as a Platform for Science & Education	Henry Evans	Hurtigruten Expeditions (HX)
101	Monitoring supraglacial lake dynamics in Antarctica with machine learning	Celia Baumhoer	German Aerospace Center (DLR)
102	SnowDrone - Measuring snow depth on sea ice using a drone-based snow radar	Robert Ricker	NORCE Norwegian Research Centre
103	Iron availability dynamics in Antarctic coastal lakes: insights into yeasts tolerance to Fe by studying RNA adaptation response	Maria Papale	ISP-CNR
104	Deep Sea Learning: Detection of Southern Ocean Taxa Using Computer Vision	Cameron Trotter	British Antarctic Survey
105	DiffIceNet: Forecasting sea ice with conditional latent diffusion	Andrew McDonald	University of Cambridge
106	Arctic ASAP – an uncrewed airship for polar science	Skipper Darlington	Arcticasap.org

Polar observations, models and data

The current state and forthcoming changes in the polar regions

THE REAL-WORLD IMPACT OF AI IN THE POLAR REGIONS

European Polar Science Week

11:00 - 12:30, Friday 6th September 2024

The Queen's Hall, The Black Diamond, Copenhagen

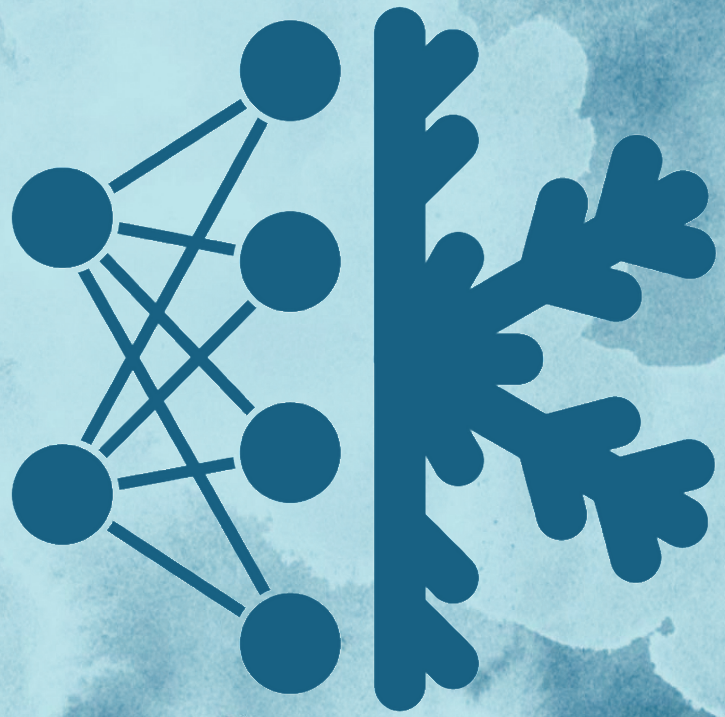
Session organised by

British Antarctic Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

ML4Cryo

A Community for Machine Learning & Cryospheric Scientists



Join the community today!

0. Scan the QR-Code or go to **www.ml4cryo.github.io**
1. Sign up for the Slack Space
2. Introduce yourself on #intros
3. Start collaborating! :)

www.ml4cryo.github.io

www.x.com/ml4cryo

www.linkedin.com/ml4cryo

Diffusion models for short-term probabilistic forecasting of Antarctic sea ice concentration

Andrew McDonald[1,2]
arm99@cam.ac.uk
@ampersandmcd

Tom Andersson[4*]
tomandersson3@gmail.com
@tom_r_andersson

Richard E Turner[1,6]
ret26@cam.ac.uk
@cambridgemlg

Jonathan Smith[2]
jonsmi@bas.ac.uk
@geologyjon

James Byrne[2]
jambyr@bas.ac.uk
@jimcircadian

J Scott Hosking[2,3]
jask@bas.ac.uk
@scotthosking

Peter Yatsyshin[3]
pyatsyshin@turing.ac.uk
@pyatsysh

María Peréz-Ortiz[5]
maria.perez@ucl.ac.uk
@mperezortiz_

[1]University of Cambridge
[2]British Antarctic Survey
[3]The Alan Turing Institute
[4]Google DeepMind
[5]University College London
[6]Microsoft Research

European Polar Science Week
5 September 2024

AI4ER
UNIVERSITY OF CAMBRIDGE
British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
The Alan Turing Institute
Microsoft Research
UCL
Google DeepMind

icenet.ai
@icenet_ai

* work completed whilst at BAS