Predicting Critical Biogeochemistry of the Southern Ocean for Climate Monitoring

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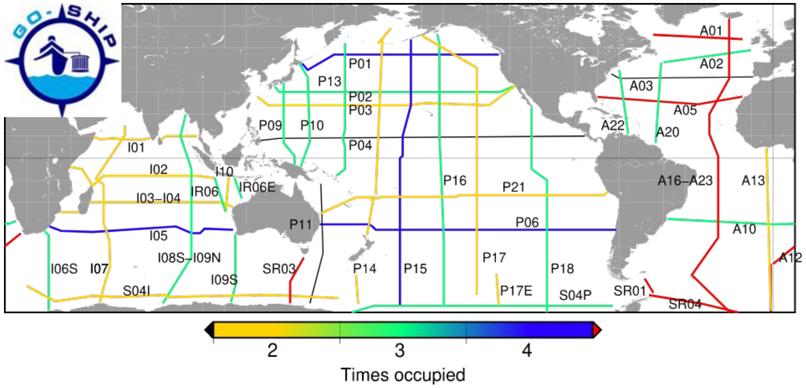
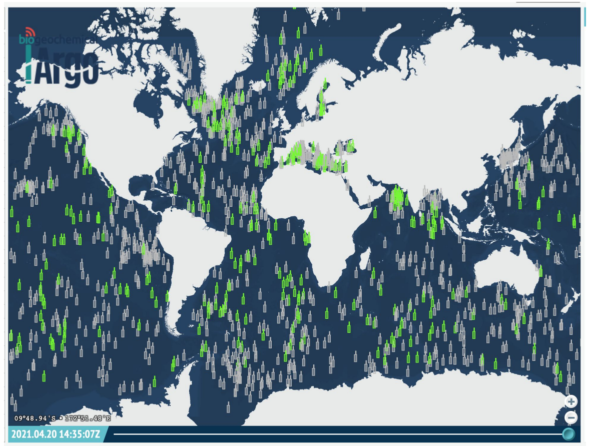
Introduction

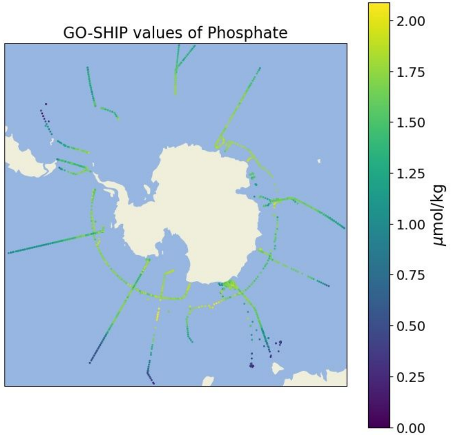
- Ocean plays an important role in the Earth’s climate system
- How do we currently measure and monitor the oceans?
  - Ship surveys, autonomous floats and vehicles
  - Moored-arrays, satellite remote sensing
- Limitations: time, space, measured variables, cost
- Data sets
  - Global Ocean Ship-Based Hydrographic Investigations Program (GO-SHIP)
  - Biogeochemical Argo floats (BGC-Argo)

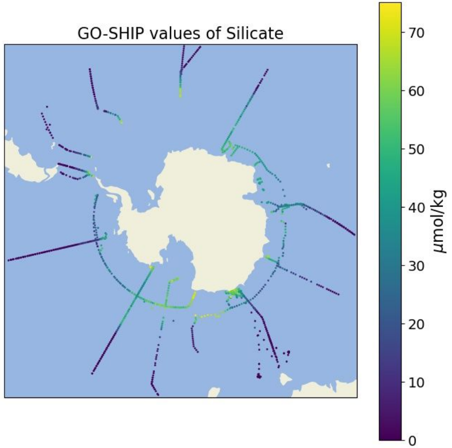




Project Goals

- Can we use ML to predict phosphate and silicate concentrations in the Southern Ocean from a limited number of features?
  - Measured by GO-SHIP, not by BGC-Argo
  - Phosphate: limiting nutrient for phytoplankton production
  - Silicate: diatoms, informative for biogeography
  - Southern Ocean: global carbon sink, BGC-Argo floats, seasonally inaccessible
- Relevance to climate change





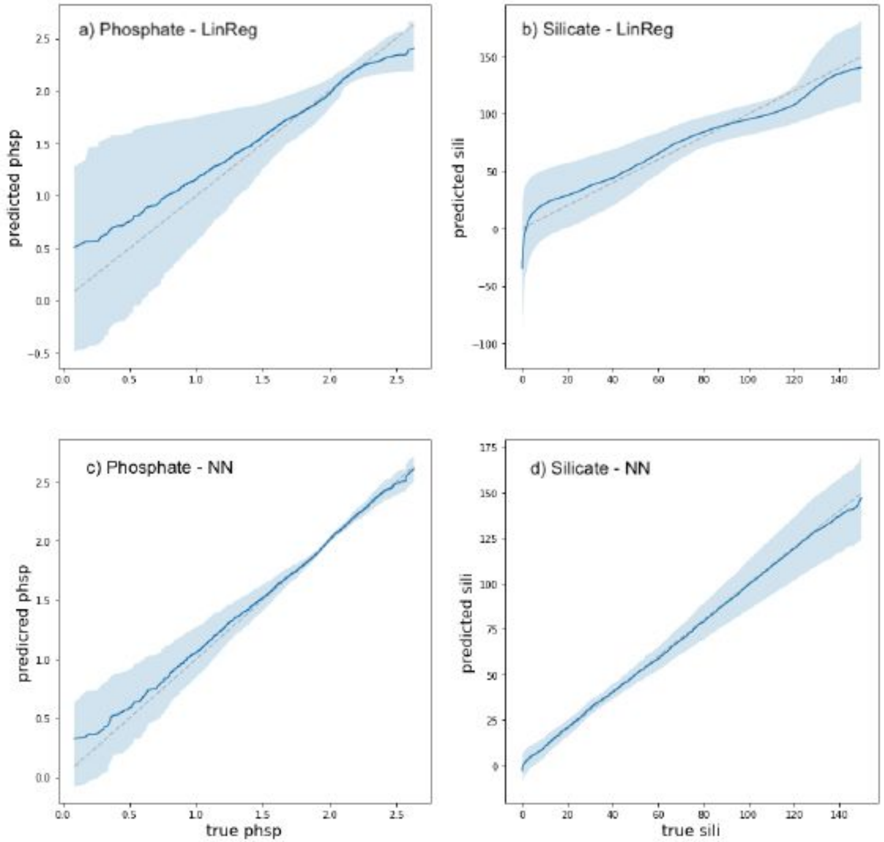
Input Features: T, S, P, O_2, NO_3, Lat, Lon → ML Model → **Output Features:** PO_4, SiO_4 ⇒

Apply ML model to:
1. Earth system model (ESM) data
2. BGC-Argo data

Model & Results

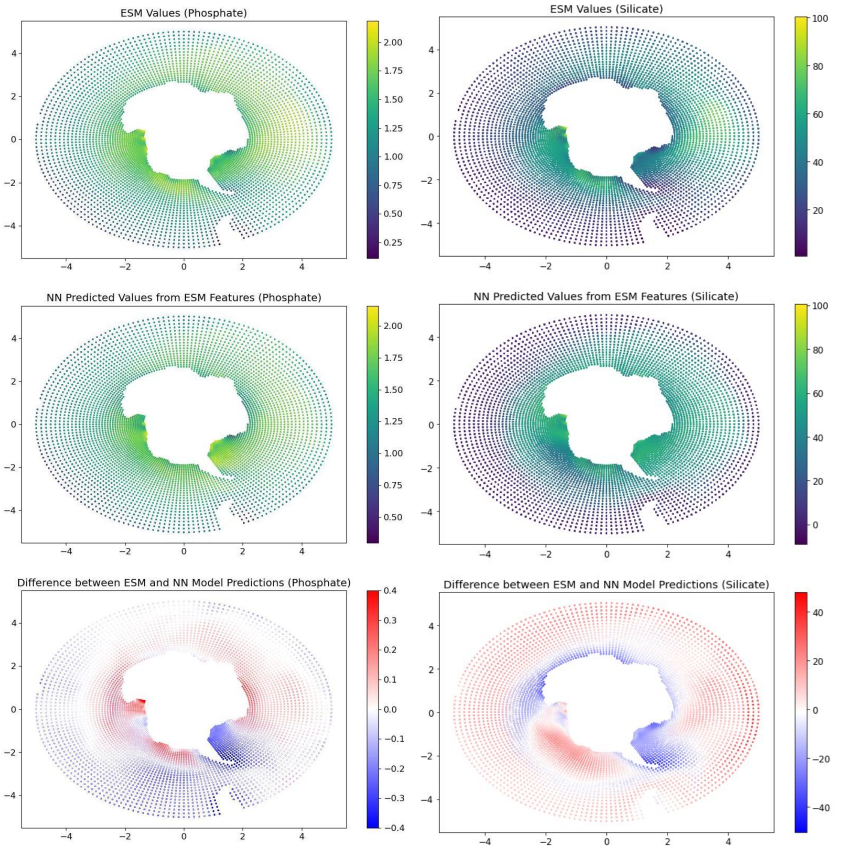
- **Model**
  - 1 layer NN (linear regression)
    - 1 layer, feed-forward, linear activation
  - Neural Network
    - 2-layers, feed-forward, 64 hidden units, ReLu Activation
  - Trained on 42,412 points - 9:1 train/test split
  - Uncertainty bounds via dropout (p=0.2)
- **Results**
  - NN had lower error and smaller uncertainty

Model Mean Squared Error		
	Linear Regression	Neural Network
PO_4	0.019	0.0031
SiO_4	240	50



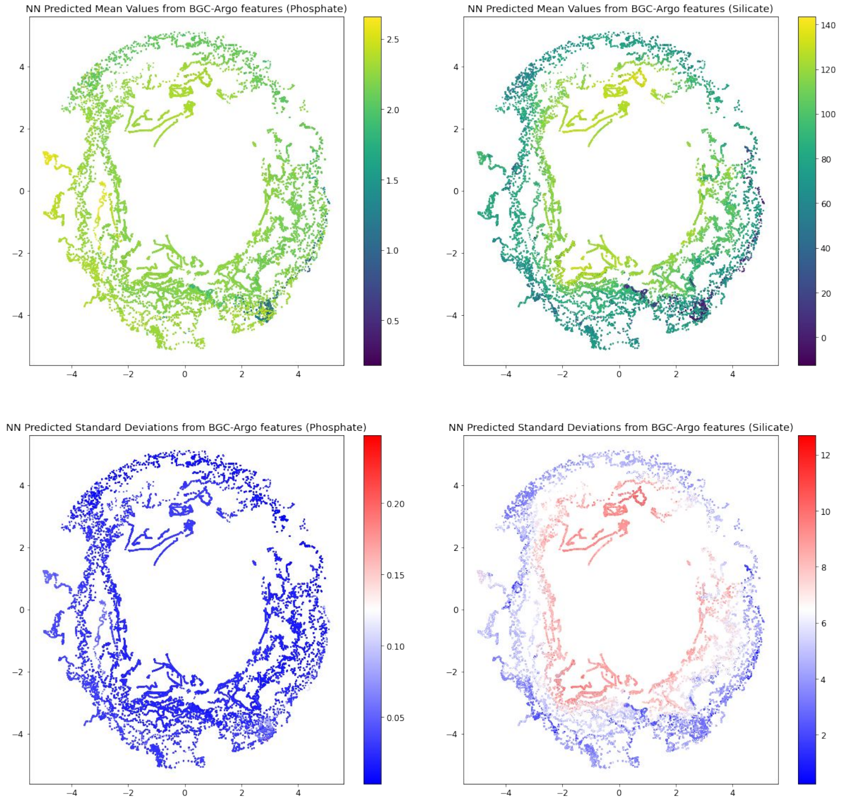
Neural Networks for ESM data

- Compared the ESM output values of phosphate and silicate to our predicted values from applying our neural network to the ESM features
- Results
  - Phosphate: NN predicts greater values away from continent
  - Silicate: NN lower values away from the Antarctic continent
- Conclusion
  - NN generally able to capture the spatial variations in both phosphate and silicate



Neural Networks for BGC-Argo data

- NN predicts a similar spatial pattern to that of the GO-SHIP data
- For silicate, high uncertainty near continent
  - Possibly ice dynamics causing higher variance as well as a latitudinal dependence
- Additional factors: data quality control



Limitations

- Lack temporal component and spatial relations
- Model improvements
  - Spatio-temporal graph neural network
  - Train models on a subset of GO-SHIP data

Conclusion

- Successful neural network predictions of phosphate and silicate in the Southern Ocean including calculation of uncertainty bounds
- Application of neural network to different datasets highlighted areas for model improvement
- Application for climate monitoring