A Spatio-Temporal Model for Arctic Sea Ice

Alison Kleffner, Susan VanderPlas, Yawen Guan
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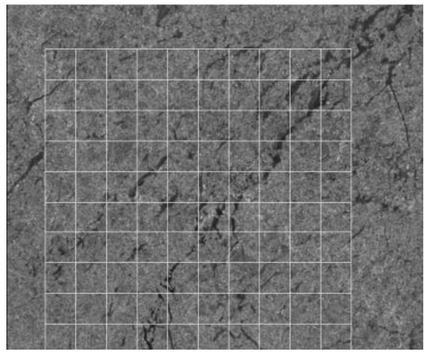
Introduction

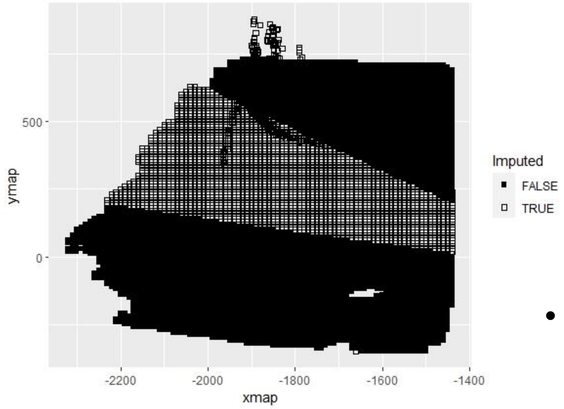
- Sea ice is frozen water in the Arctic Ocean that generally occurs as an ice pack which can drift over the oceans surface
- Cracks, or leads, may form in the ice pack due to dynamic processes
    - Allows for heat from the ocean to be transferred to the atmosphere

- Other Ice Lead detection methods through satellite images
    - Thermal Images
    - Deformation Calculations
- Satellite data can be low in resolution and are affected by atmospheric conditions (clouds, etc.)

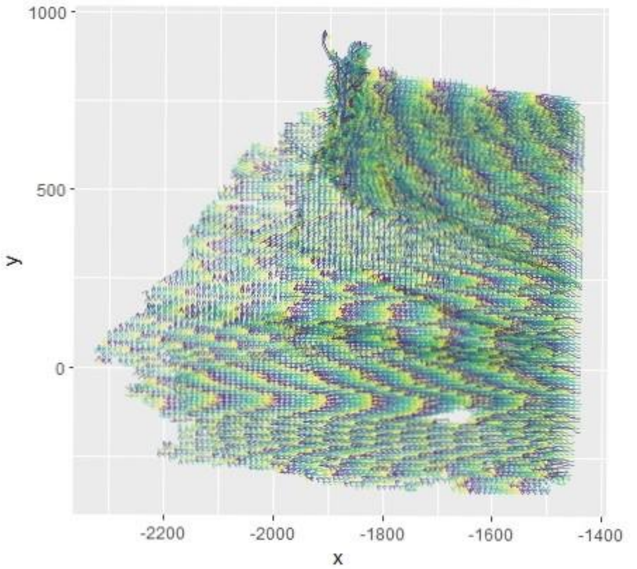
Data

- Used motion data from the RADARSTAT Geophysical Processing System (RGPS)
- The movement of sea ice is tracked in sequential radar images
- Due to this data collection, data may be missing





Method Motivation



- Groups of movement patterns within the ice pack.
- Trajectories in the ice sheet can be grouped together when have similar movement.

Questions? akleffner@huskers.unl.edu

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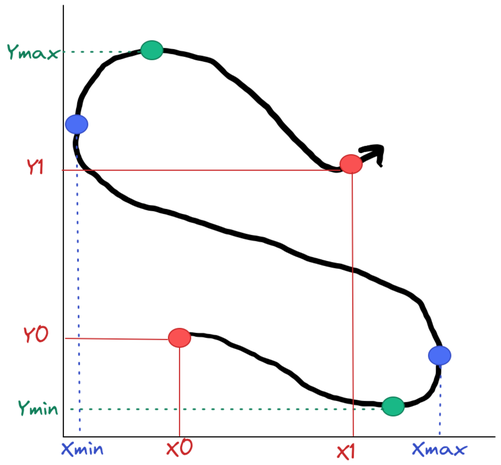
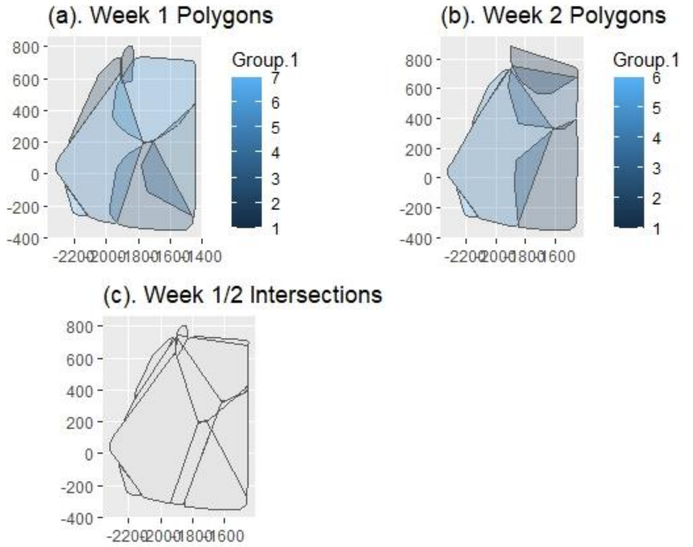
Clustering: Using Bounding Box

- Created a bounding box around each trajectory, to represent the movement of the trajectory over time.
- Features used:
  - Length of x/y traveled (between max and min location)
    - $x_{max} - x_{min}, y_{max} - y_{min}$
  - Difference in x/y from latest to earliest observation
    - $x_1 - x_0, y_1 - y_0$
  - Angle of movement
  - Average x/y value
  - Sub-trajectories – previous time information
- Then used K-means clustering
  - Number of clusters found using Silhouette Statistic



Spatio-Temporal Interpolation

- Define the spatio-temporal neighbors for each missing point, using our previously made clusters



- Member of an intersection are considered spatio-temporal neighbors, because in similar geographic region over time.
- Created univariate models for x and y using the GpGp package in R, which uses the Vecchia's approximation, using the exponential space-time covariance function. Output is the MLE of mean and covariance parameters.
- Use Model to predict missing locations and on the grid.

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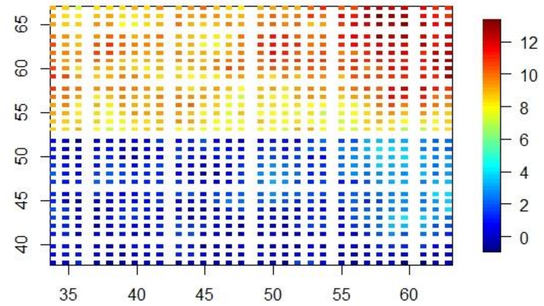
Simulation Study

1. Generate Underlying Process:

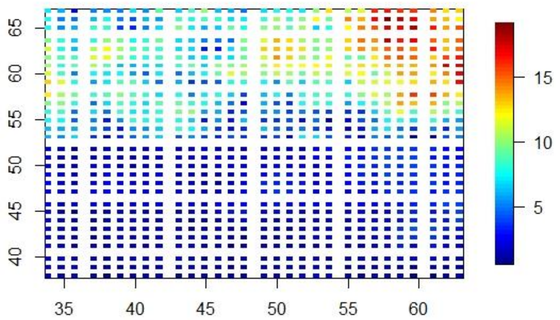
$$U_{d,c}(s,t) \sim GP\left(\mu_{d,c}, C_{d,c}(\theta)\right),$$
$$C_{d,c}(\theta) = \sigma^2 e^{-||D^{-1}(x-y)||},$$

d=x,y c = 1,2

Movement in X



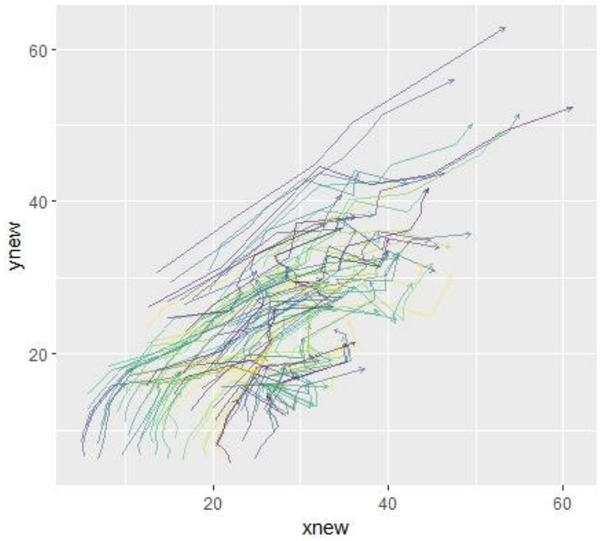
Movement in Y



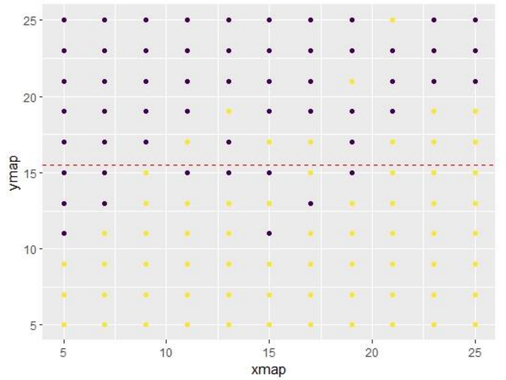
2. Generate Trajectories using Underlying Process

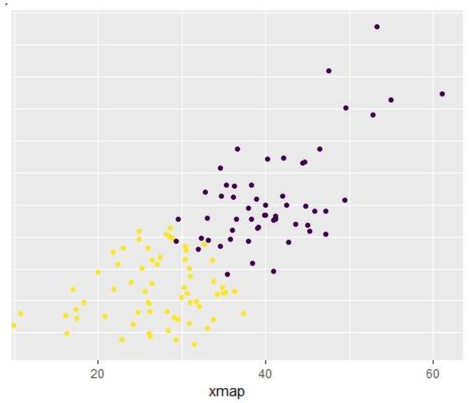
$$(x_{t,j}, y_{t,j}) = (U^X_{t-1,c,g}, U^Y_{t-1,c,g}) + (x_{t-1,j}, y_{t-1,j}),$$

j = 1,…,121 t =1,…7 g = 1,…900



3. Results





RMSE for Interpolation Methods

	Intersection Model		Linear Interpolation		No Intersection Model	
	X	Y	X	Y	X	Y
Overall	**1.388**	**1.304**	2.7	1.83	1.441	1.493
Cluster 1	**1.38**	**1.16**	3.1	2.18	1.457	1.664
Cluster 2	1.402	1.53	**1.39**	**0.35**	1.423	1.261

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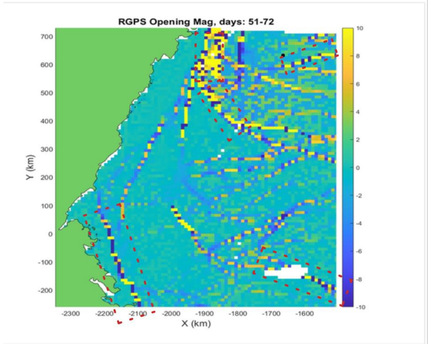
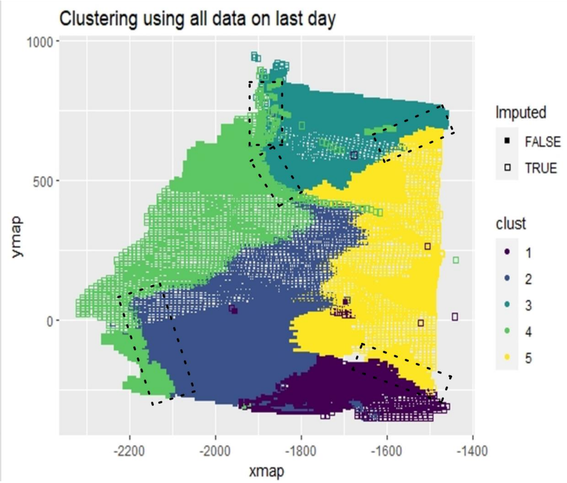
Ice Data Results

- Clustering:





- Interpolation Cross Validation :
  - Used data in intersection from day before and day after to develop model
  - Compared to Linear Interpolation, and running the model using all the data from the week (no intersections)

RMSE for Interpolation Methods

	Intersection Model		Linear Interpolation		No Intersection Model	
Week	X	Y	X	Y	X	Y
1	3.156	3.24	**1.52**	4.098	**3.093**	3.067
2	3.142	3.062	**1.984**	**1.399**	3.198	3.151
3	3.178	3.093	**0.987**	**1.189**	3.19	3.15

RMSE for Week 1 by Cluster

	Intersection Model		Linear Interpolation		No Intersection Model	
Cluster	X	Y	X	Y	X	Y
1	3.018	4.333	3.199	13.042	**2.515**	**3.41**
2	4.376	4.633	**0.187**	**0.359**	4.258	4.106
3	2.641	3.144	**1.314**	**3.066**	2.163	2.883
4	3.024	2.873	**1.396**	**2.442**	2.46	2.777
5	3.925	3.586	**0.74**	**3.036**	3.895	3.241
6	3.143	**3.08**	1.876	5.459	2.597	3.098

Conclusion

- Bounding Box method is limited by pre-defined number of clusters, but seems to discover large ice leads. Should be used in conjunction with other ice lead detection methods
- Intersection Interpolation Method shows promise over linear interpolation when data is not linear. Some issues in model creation – like if not enough known data in that intersection for a given time, large temporal range, etc.

References

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