Using Integrated Ice Edge Error (IIEE) and Spatial Probability Score (SPS) to assess spread-error relationships in an ensemble sea ice forecast

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and many, many others

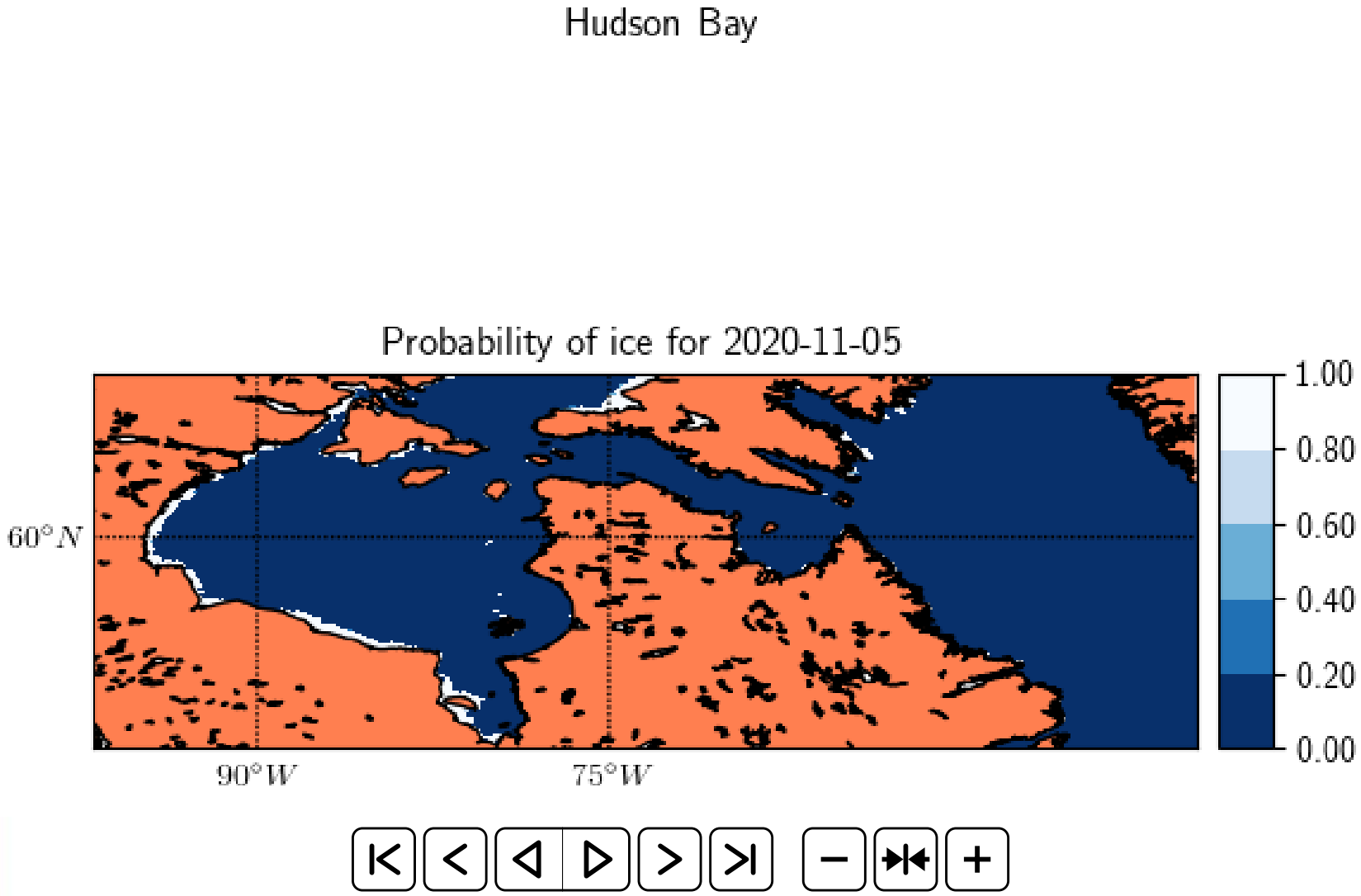
Canada

Rationale

- Newly coupled Ensemble Prediction System (GEPS)
  - Coupled since 3 July, 2019.
  - Medium Range system: 16 day forecast
    - with 32 day forecasts weekly (00Z Thursday)
- Ensemble Perturbations are coming solely from Atmosphere
- What is the spread/error relationship for sea ice in GEPS?
  - In context of Probability of Ice

Probability of Ice: Fraction of Ensemble Members with Sea Ice concentration above threshold of 0.15

Probability Of Ice In Hudson Bay



Forecast/Observed Fields

$$
\begin{aligned}
\text{Forecast Ensemble Member Presence of Ice:} &= f_i(x) \\
&= 0/1 \\
\text{Observed Presence of Ice:} &= O(x) \\
&= 0/1 \\
\text{Forecast Probability of Ice:} &= P = \frac{1}{N}\sum_{N} f_i(x) \\
&\quad 0 < P < 1
\end{aligned}
$$

Metrics Used

Ensemble Mean Integrated Ice Edge Error (IIEE)

$$\begin{aligned} \mathrm{IIEE} &= \frac{1}{N}\sum_{N}\mathrm{IIEE}_i = \frac{1}{N}\sum_{N}\int dA\,|f_i(x) - O(x)| \\ &= \int dA\,|P(x) - O(x)| = \int dA\,(\sigma_{\mathrm{e}}^2) \end{aligned}$$

Spatial Probabability Score (Area Integral of Brier Score)

$$\mathrm{SPS} = \int dA\,(\mathrm{BS}) = \int dA\,(P(x) - O(x)))^2 = \int dA\,(\sigma_{\mathrm{m}}^2)$$

Uncertainty / Spread

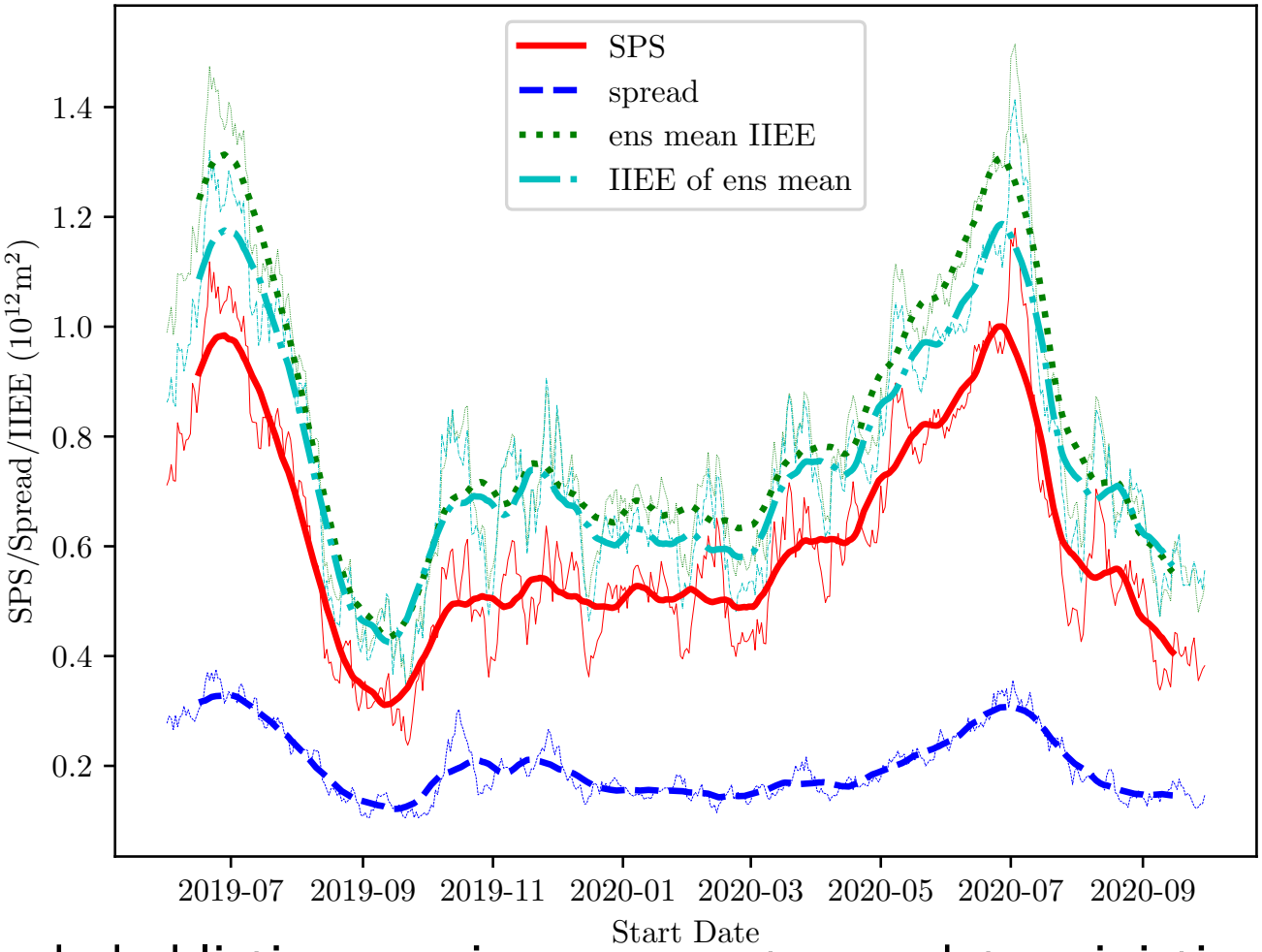
$$\mathrm{IIEE} - \mathrm{SPS} = \int dA\;P(x)\cdot(1 - P(x)) = \int dA\,(\sigma_{\mathrm{v}}^2)$$

Metrics Used

Note: As defined RMSE(all members) = RMSE(ensemble mean) + ensemble variance

$$\sigma_{\mathrm{e}}^2 = \sigma_{\mathrm{m}}^2 + \sigma_{\mathrm{v}}^2$$

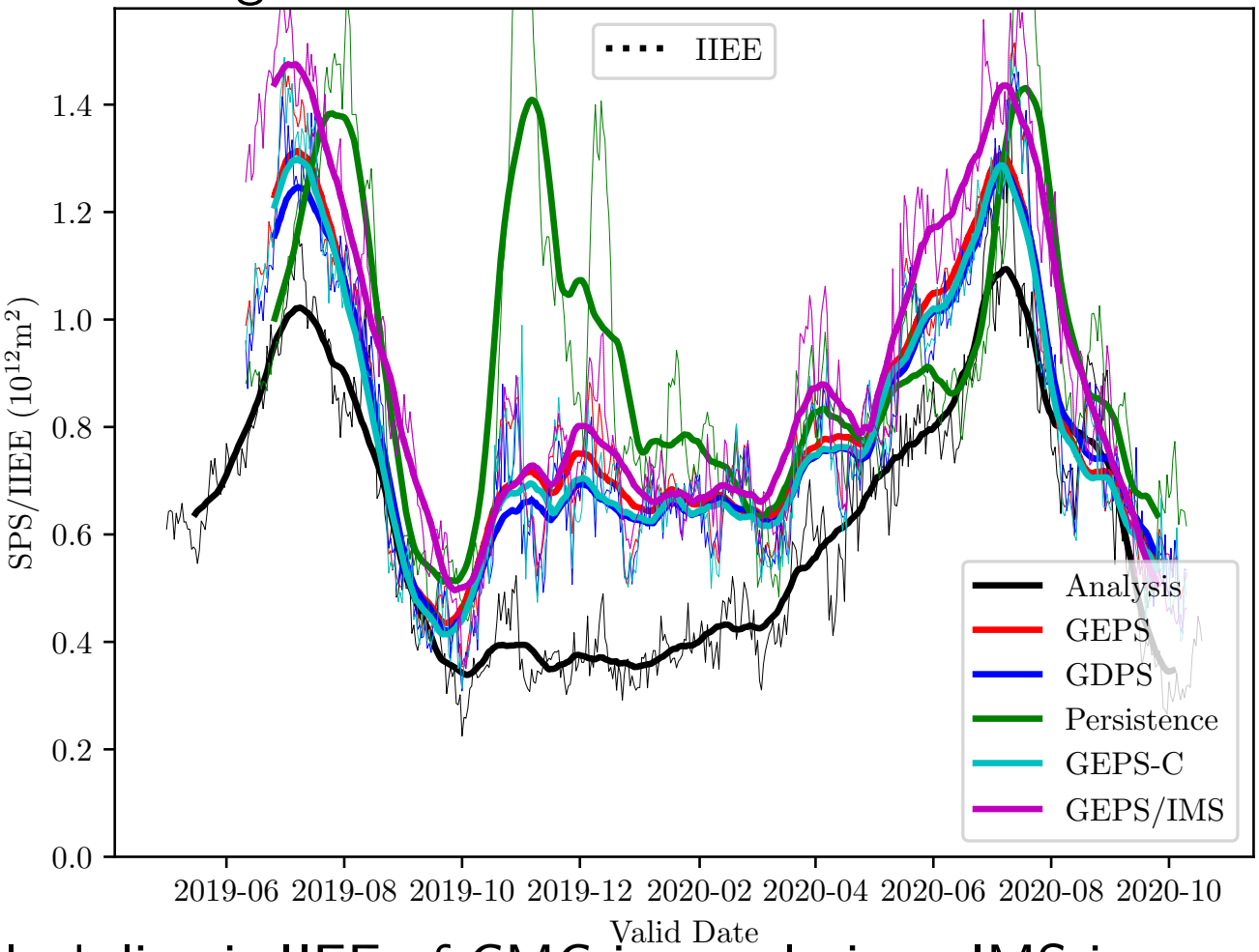
10 Day Lead Results – Year Round



- Probabablistic score improvement over deterministic score.
- But underdispersive – and bad early summer biases.

10 Day Lead Results – mean of IIEE System Comparison

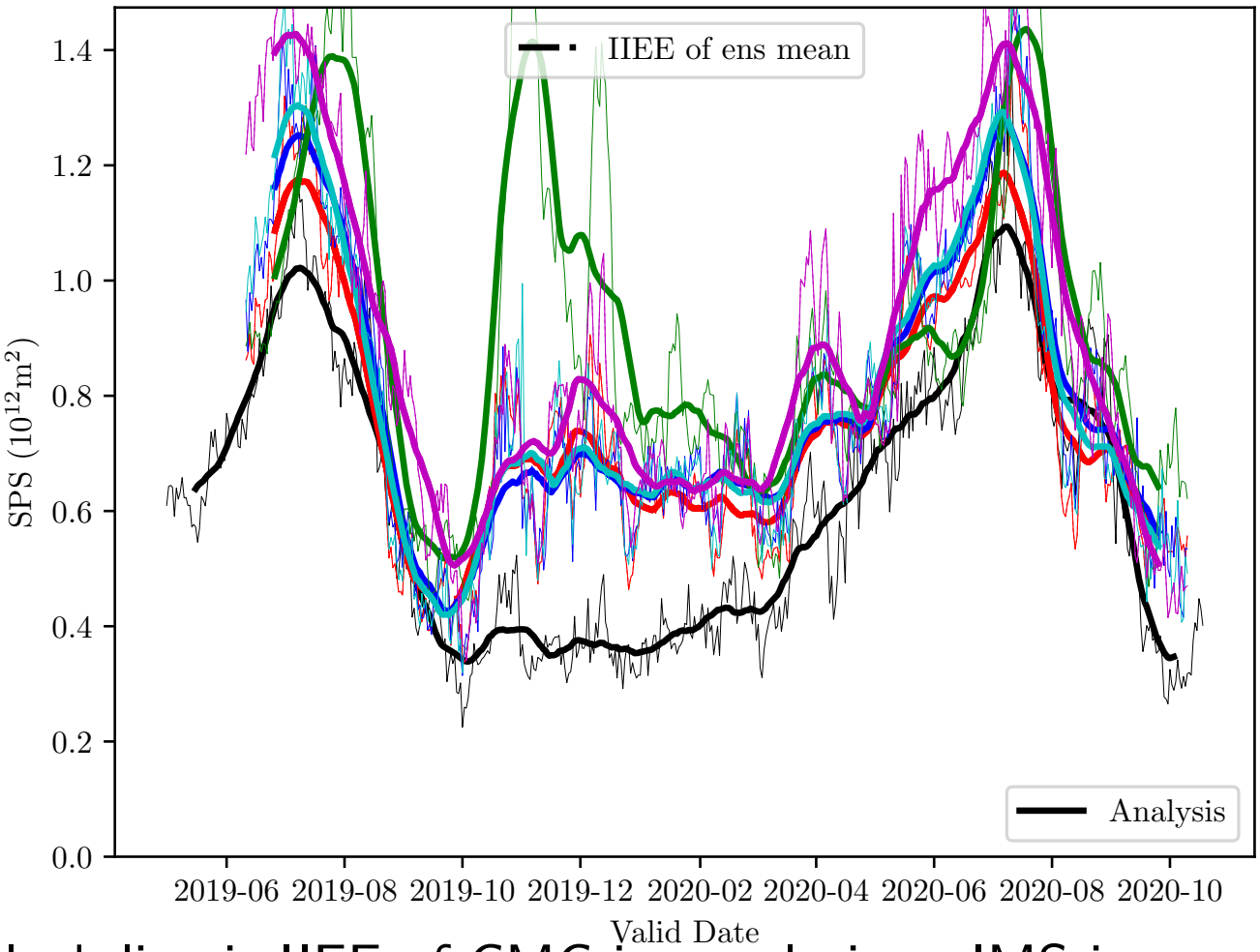
- Calculating Mean Value of IIEE for all members.
- Disadvantages Ensemble



- Black line is IIEE of CMC ice analysis vs IMS ice analysis
- Green line is persistence. Magenta line: GEPS validated IMS.

10 Day Lead Results – IIEE of mean System Comparison o

- Calculating IIEE from ensemble mean ice conc.



- Black line is IIEE of CMC ice analysis vs IMS ice analysis
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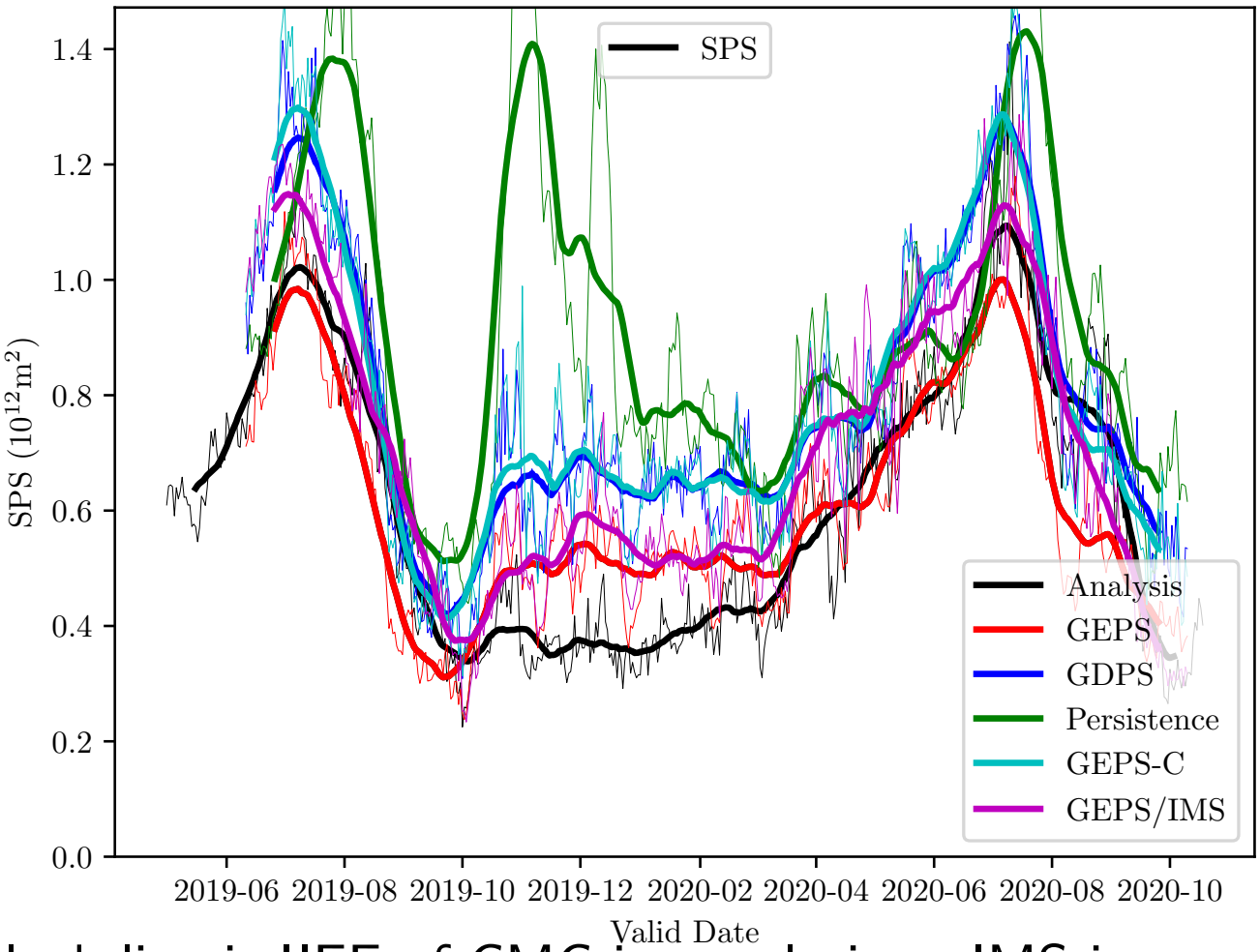
10 Day Lead Results – SPS System Comparison



- Black line is IIEE of CMC ice analysis vs IMS ice analysis
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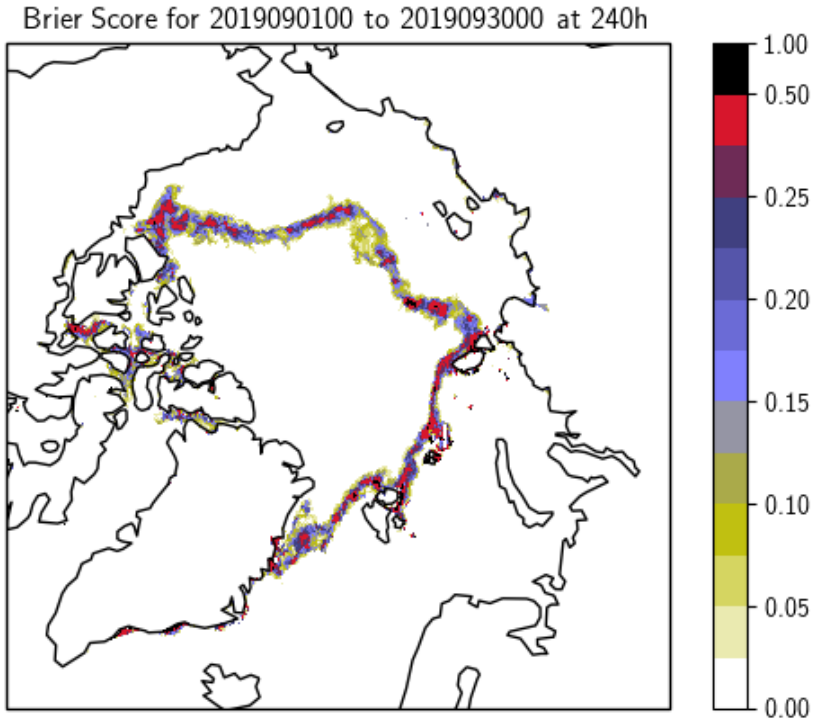
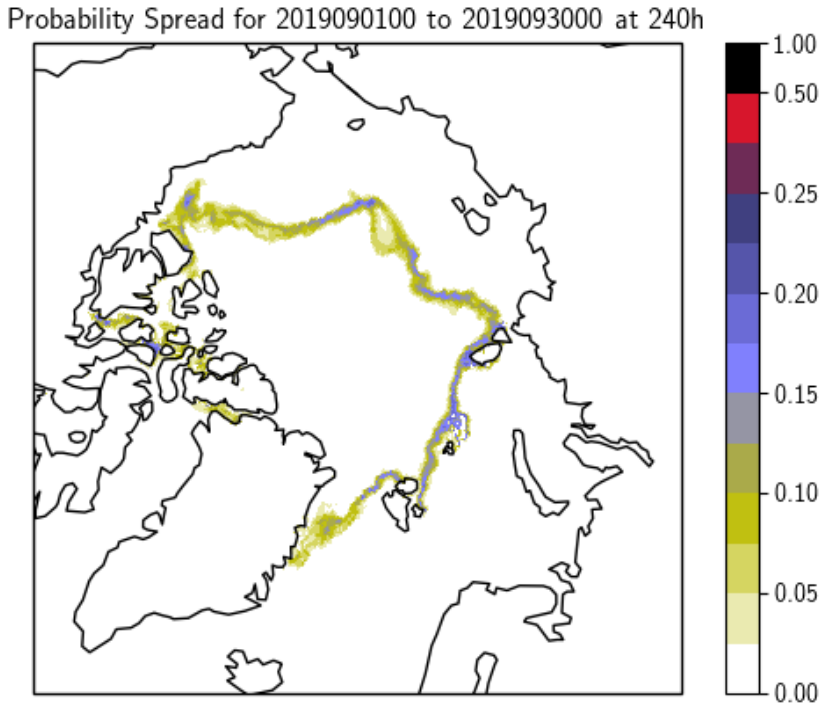
September Error / Spread Relation

Brier Score



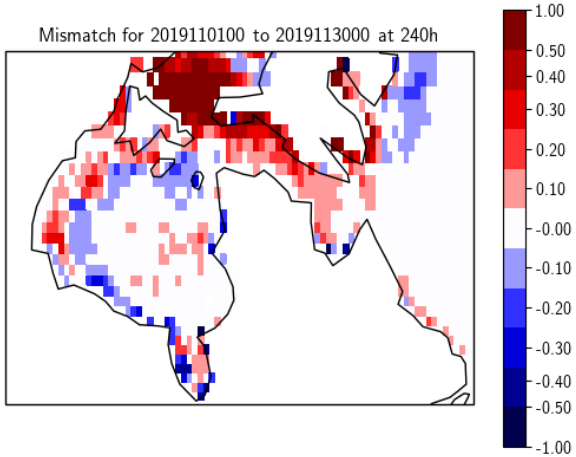
Ensemble Spread



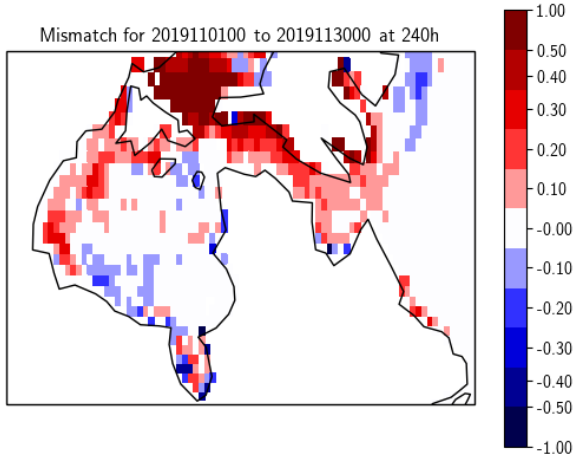
- Spread is respectable (Max. Spread = 0.25)
- But system has bias (BS is large)

November Error in Hudson Bay

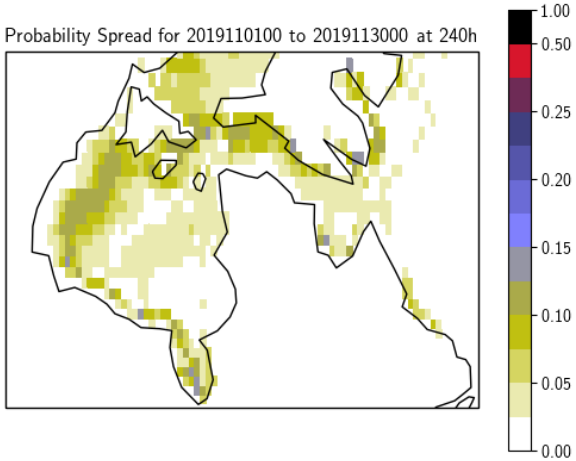
GDPS



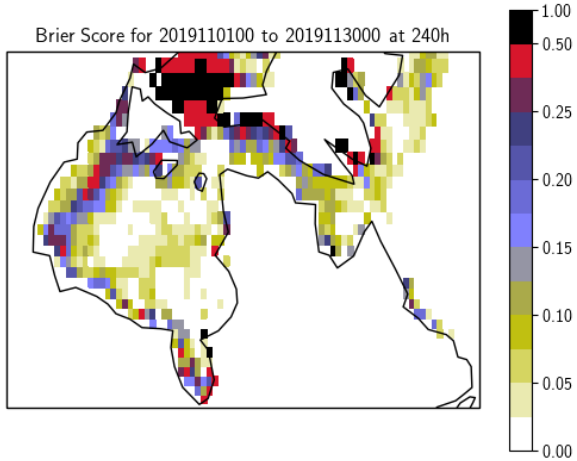
GEPS



Ensemble Spread



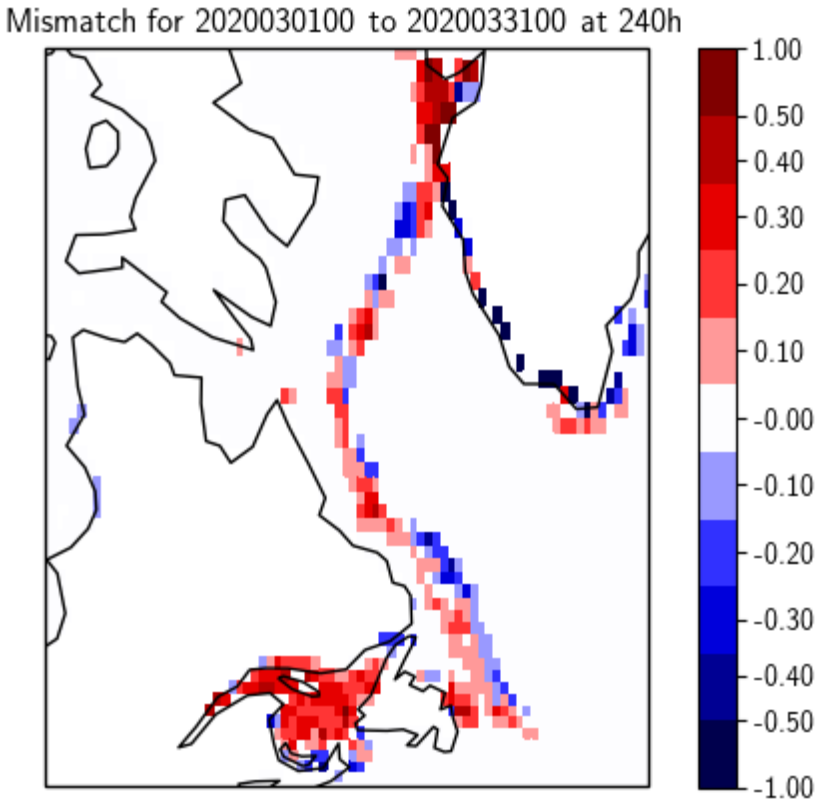
Brier Score



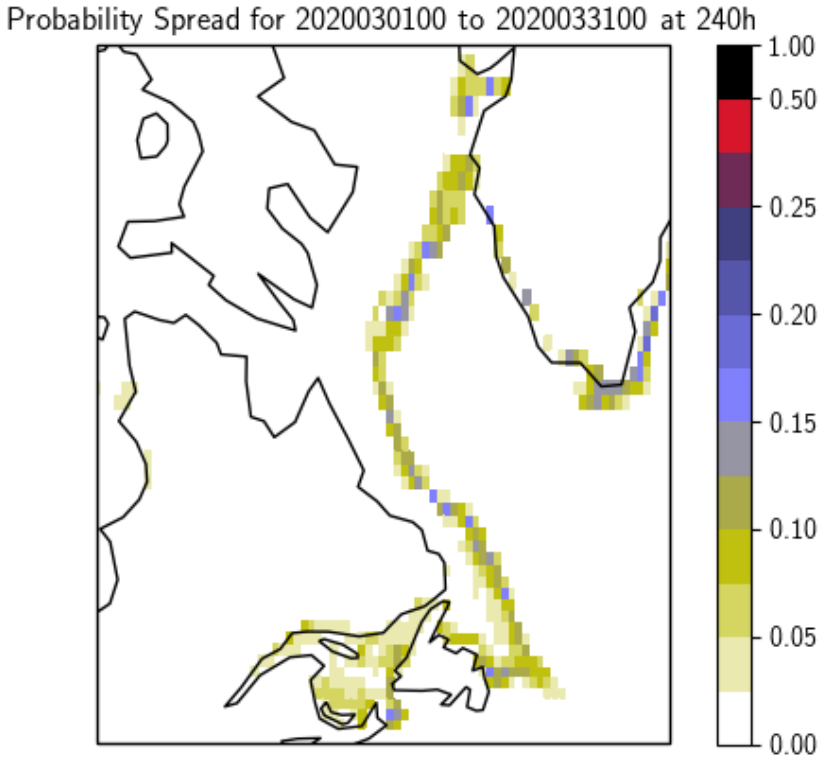
- Ice in ensemble system advances/advects into interior

March Error in Labrador Sea

Mean Error

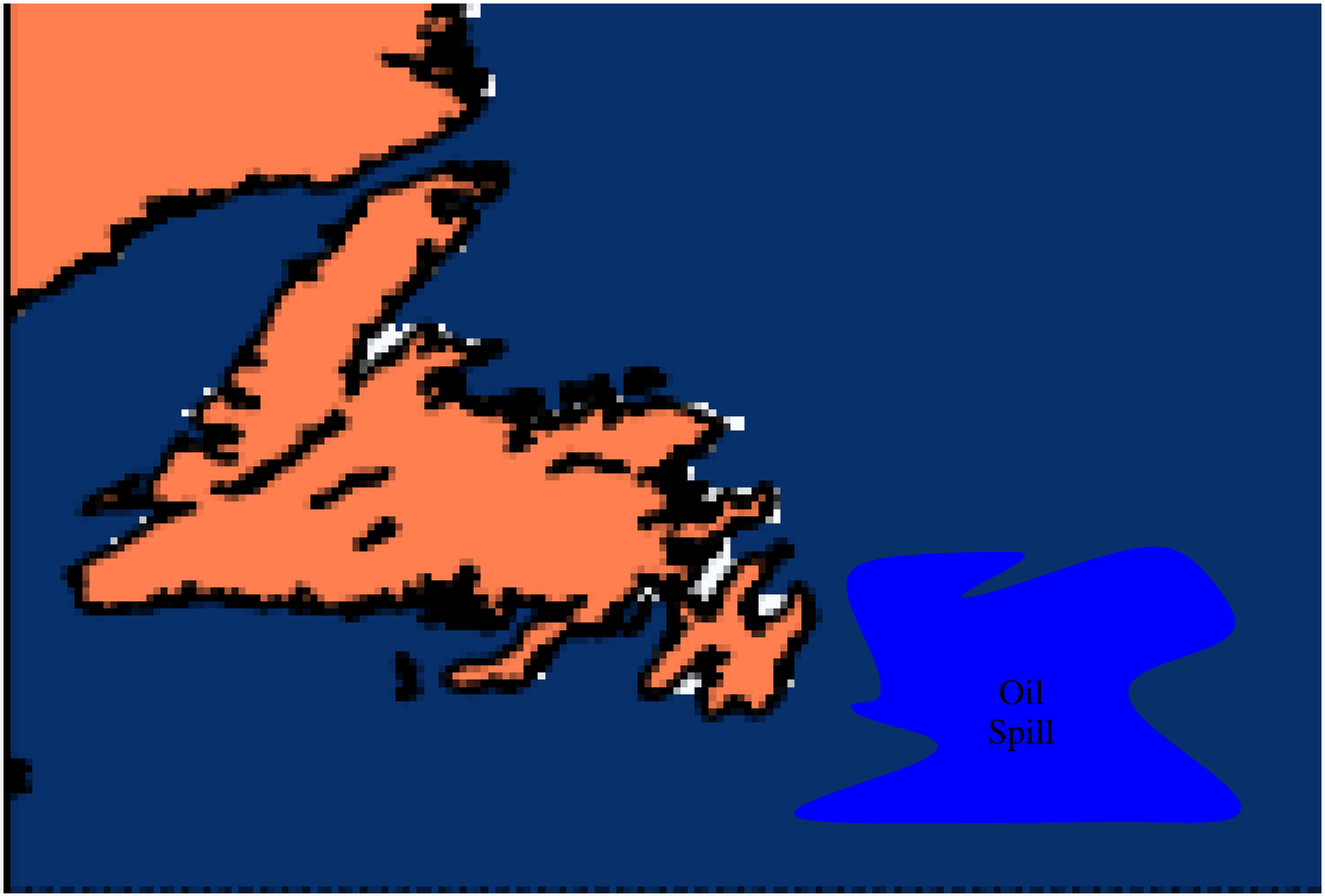


Ensemble Spread

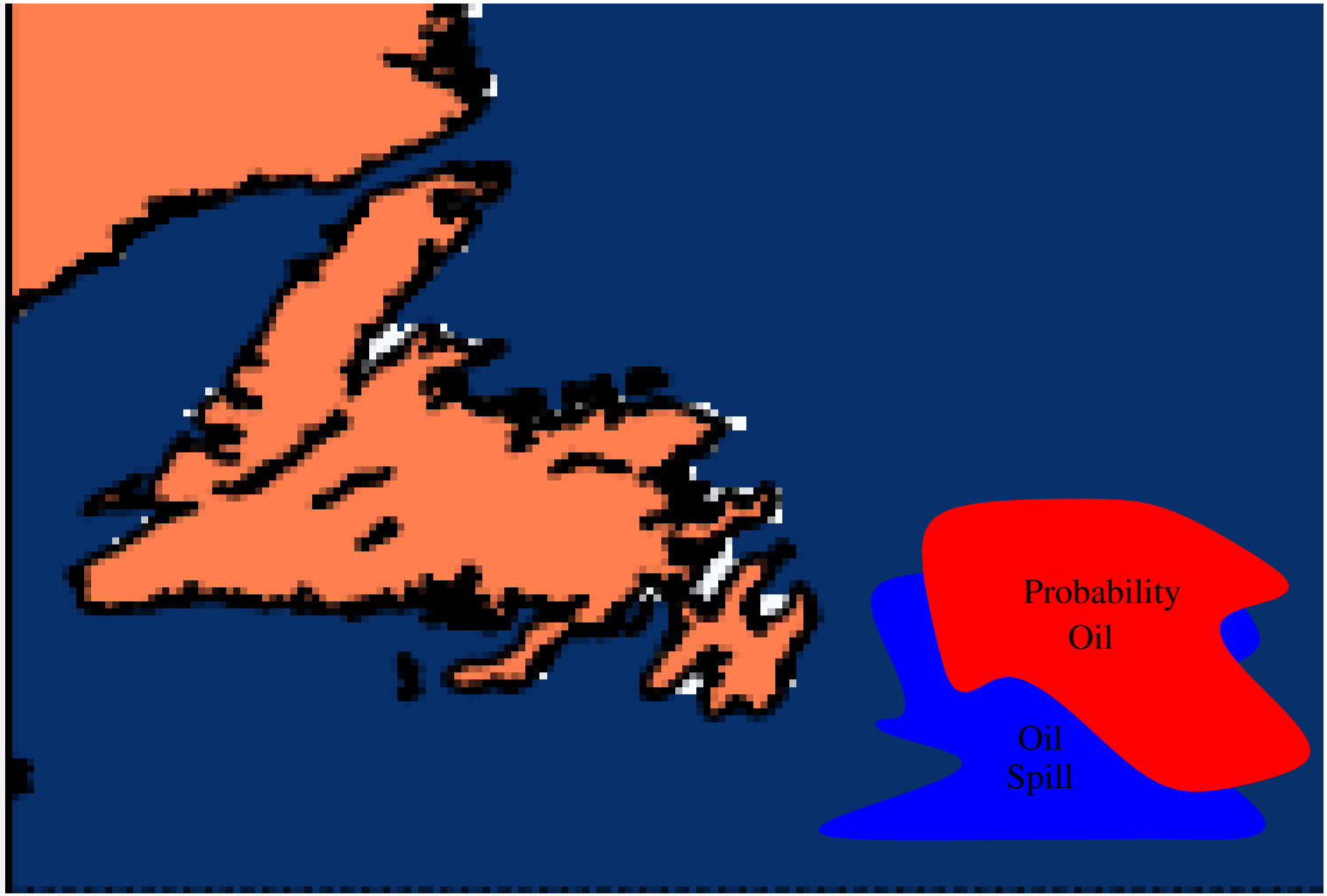


- Spread is in wrong place (or too narrow).
- Ice edge in wrong position.
  - Observed Ice Edge propagates eastward through month.
  - Forecast Ice Edge stays put.

Application to Ensemble Oil Spill Verification



Application to Ensemble Oil Spill Verification



Summary

- Applied IIEE and SPS metrics to Ensemble Sea Ice Forecast.
- Needed an estimate of Spread/Error Relationship
  - And skill benefits over deterministic system.
- IIEE minus SPS gives spread.
- System is underdispersive.
  - Perturbations solely from atmosphere.
- Can demonstrate added value of Ensemble
- More skillful then persistence.
- Large uncertainties in initial conditions.
  - Skill verification against initializing analysis.
  - Likely needs incorporation into ensemble uncertainty.
- Soon to be submitted: *Understanding Sources of Uncertainty and Forecast Error in a Medium Range Coupled Ensemble Sea Ice Prediction System* in **The Cryosphere**