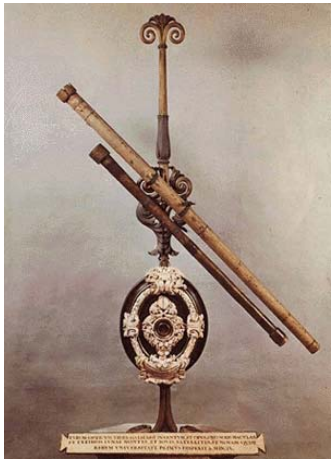
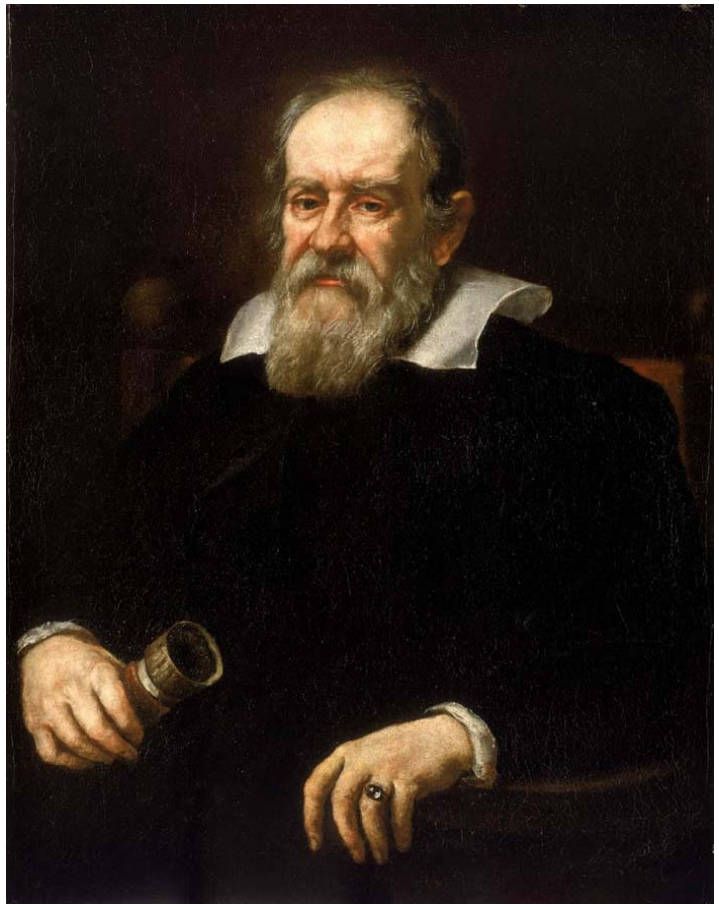
Information, Uncertainty, Decision

18 October 2010

NATO Undersea Research Centre
Ed Gough, Steve Payne,
Jim Hansen, Emanuel Coelho

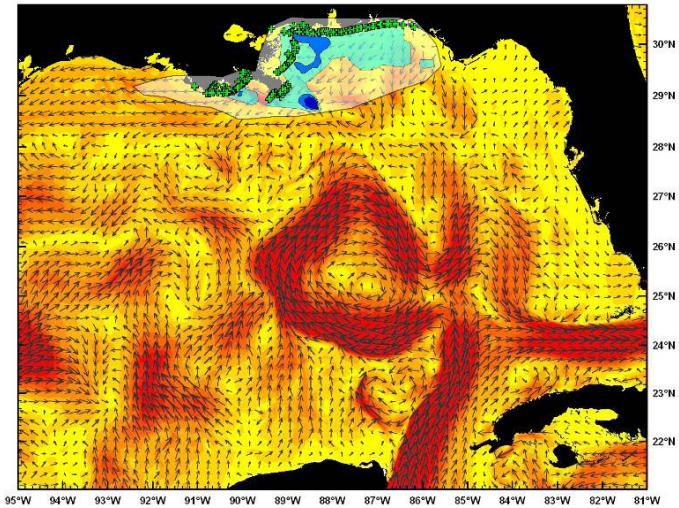
A New Lens

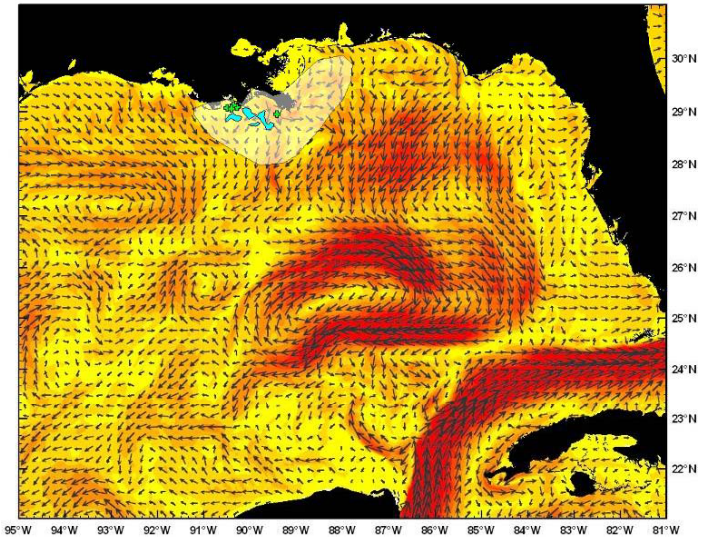




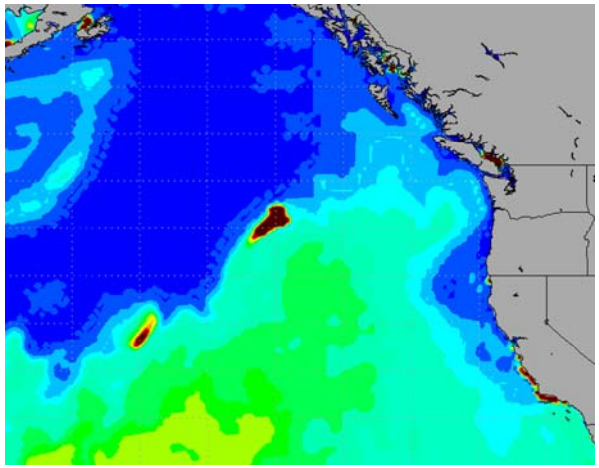
Galileo Galilei

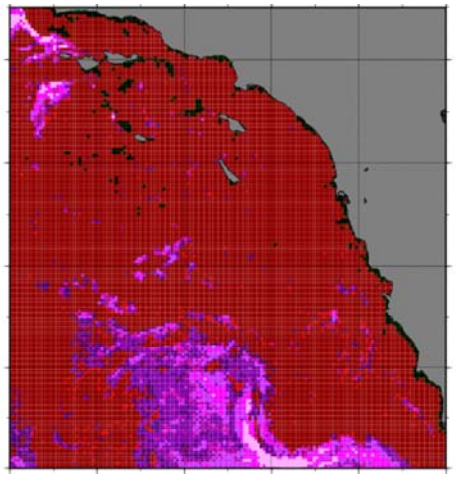
A Mathematical Lens

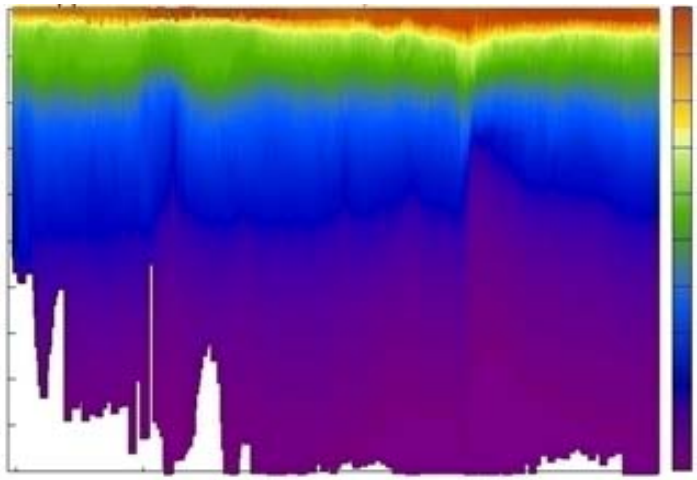




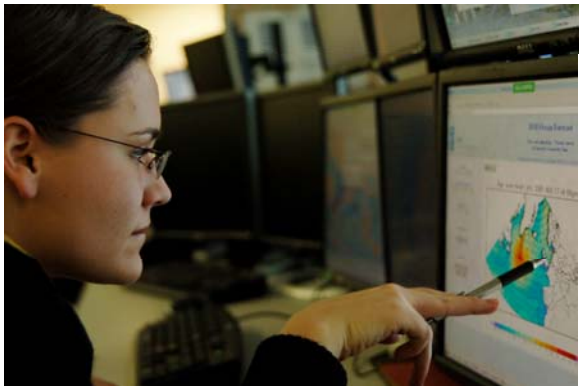
Assimilate Obs



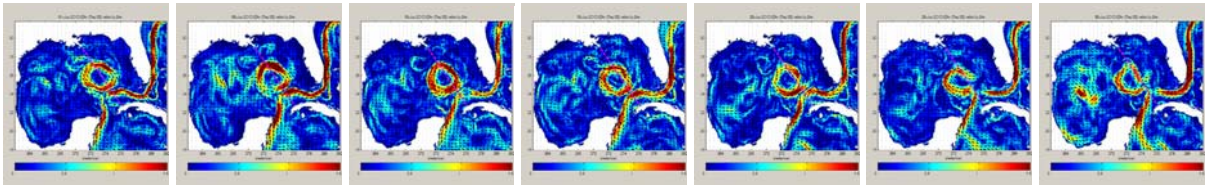




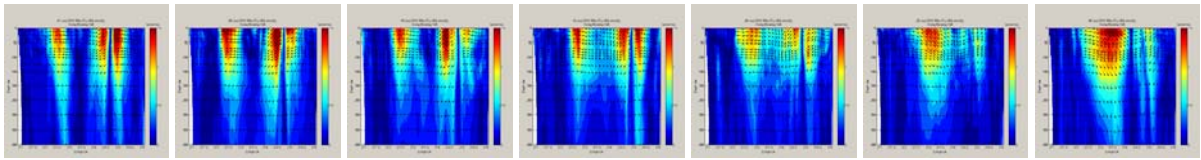
Virtual Observations



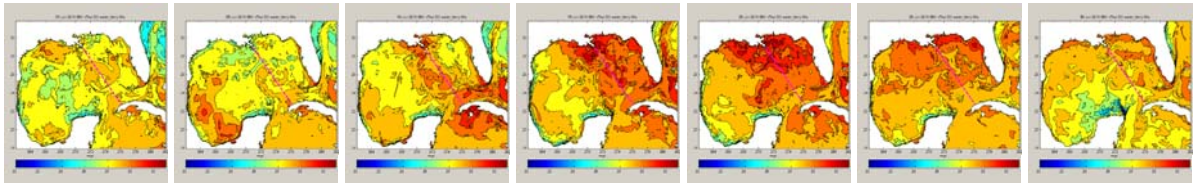
5-DAY Daily AMSEAS Surface Currents and Temperatures at 0m, 10m and 200m, Gulf of Mexico



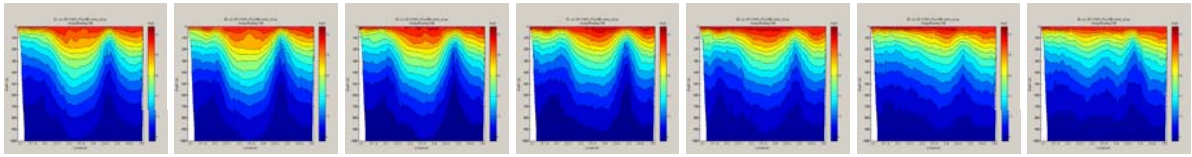
Surface Currents



Currents on Diagonal in Upper 1000m

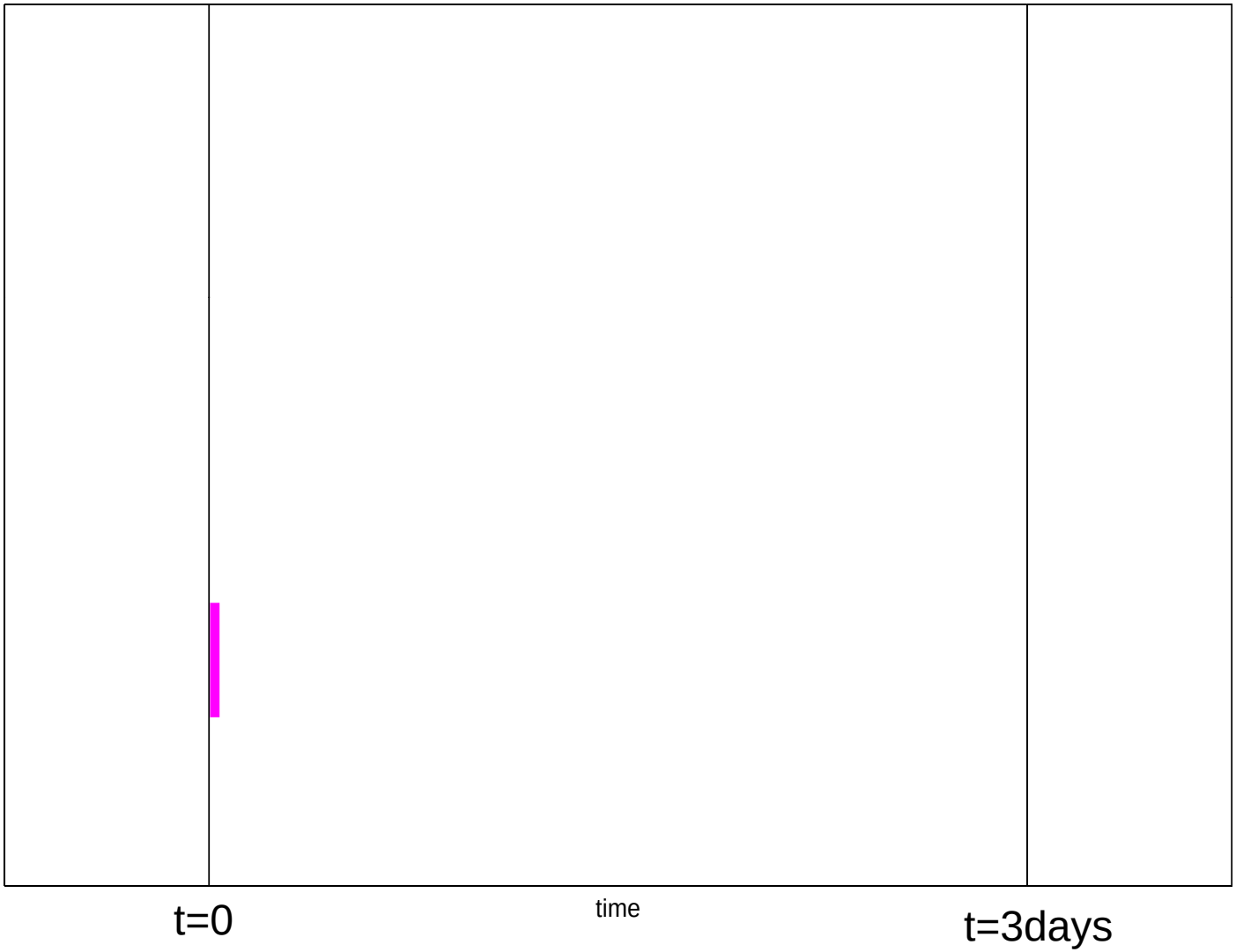


Temperatures at 0m



Temperatures on Diagonal in Upper 1000m

Model Forecast:
Deterministic vs. Probablistic



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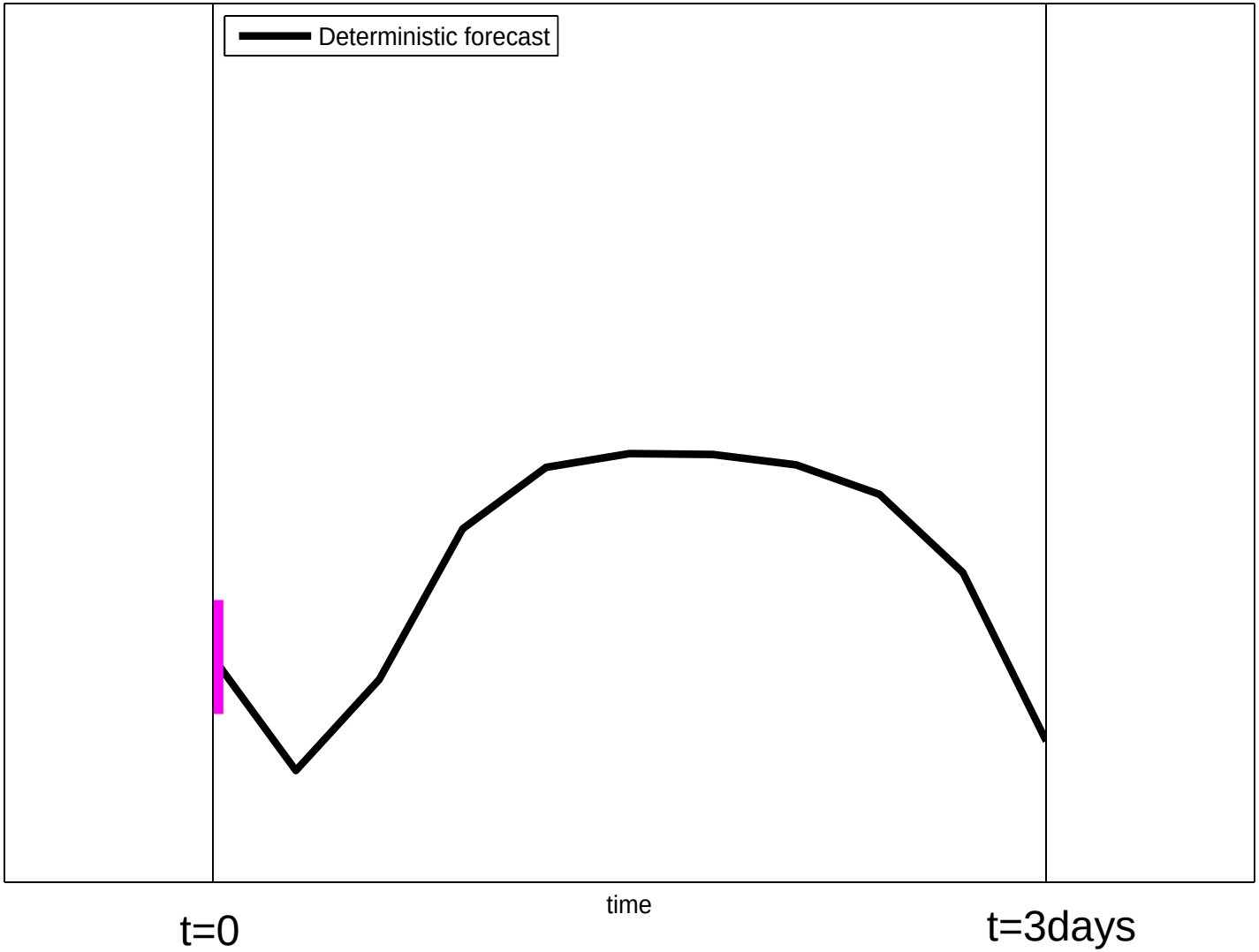
Deterministic vs. Probablistic



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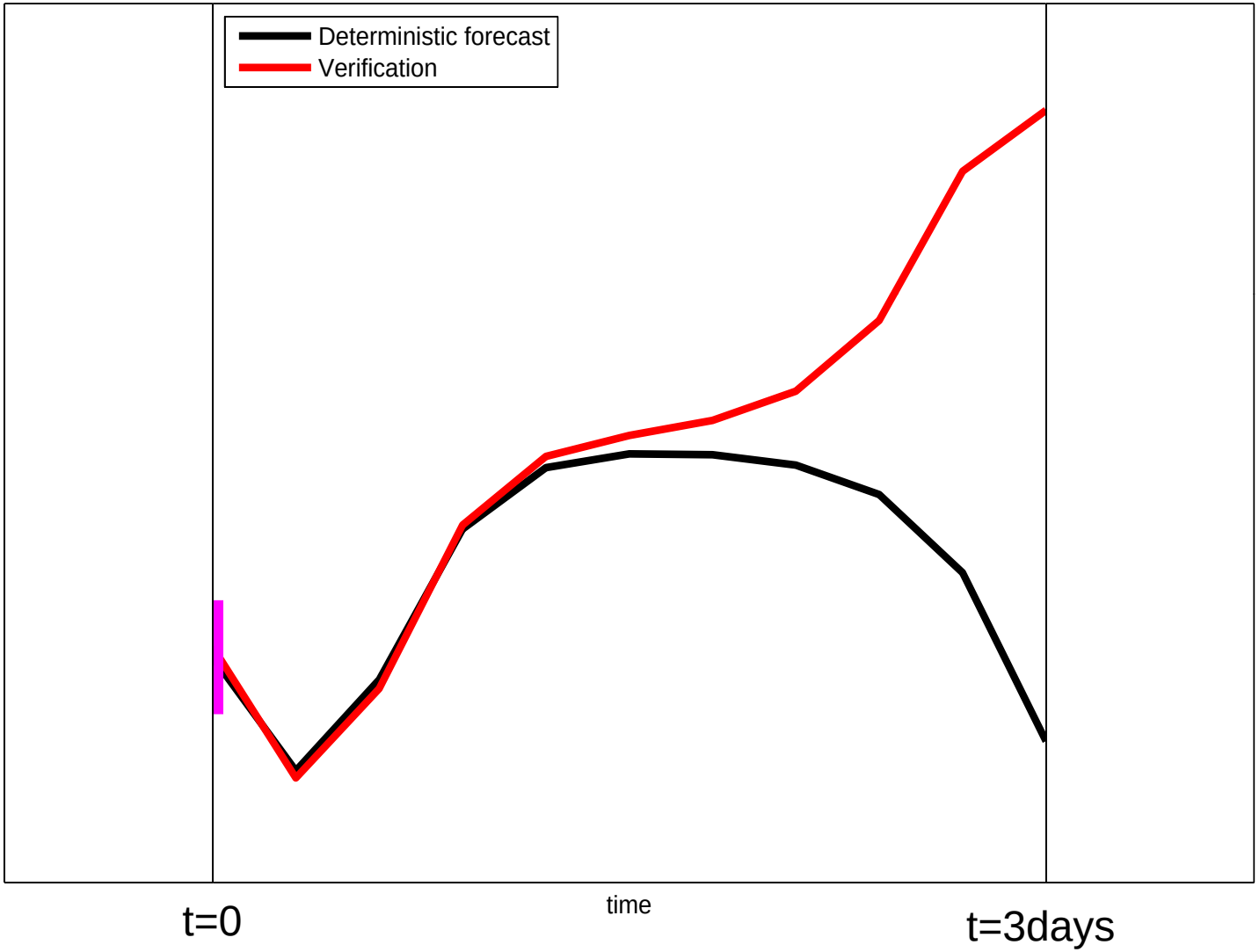

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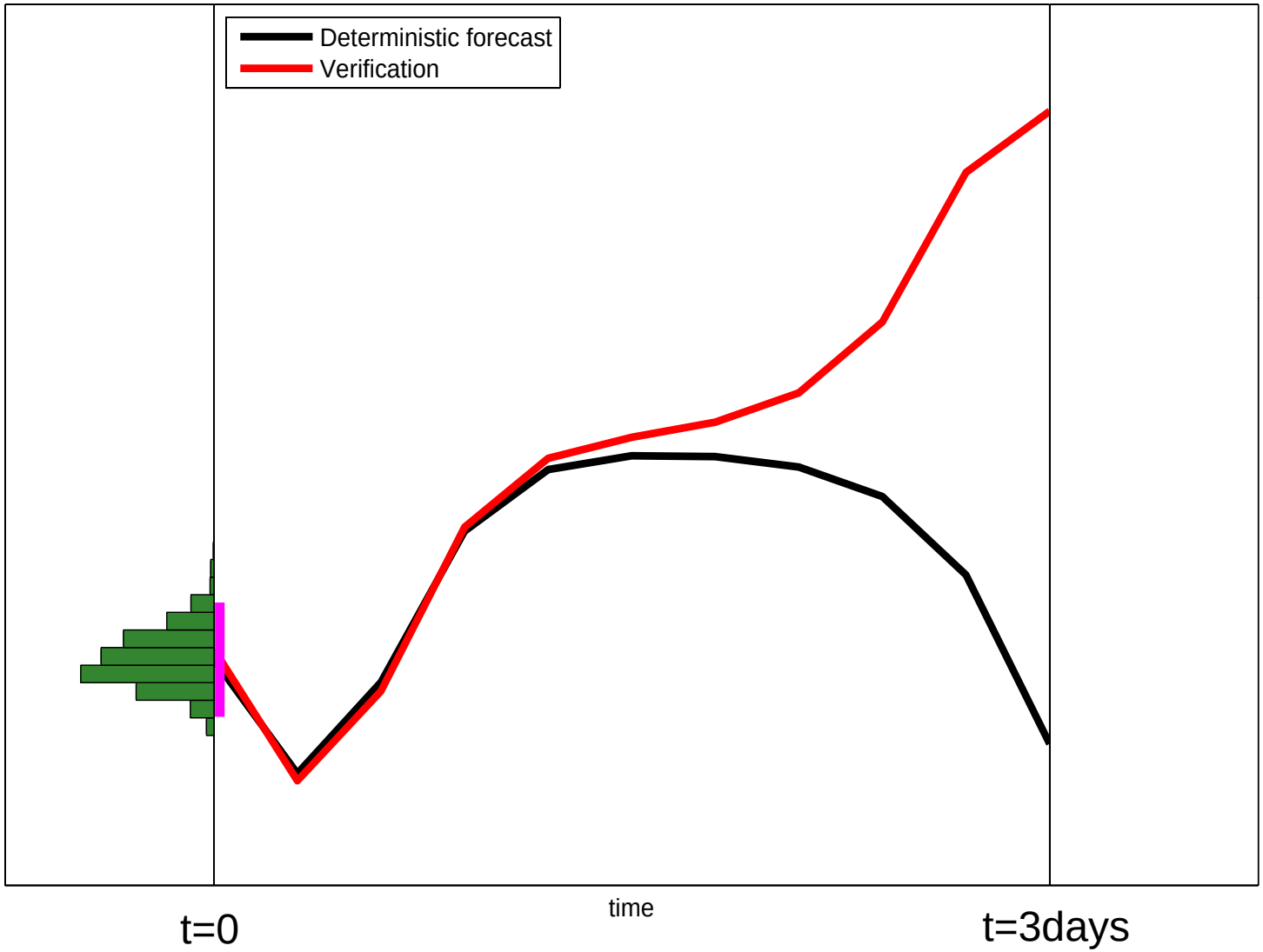
Deterministic vs. Probablistic



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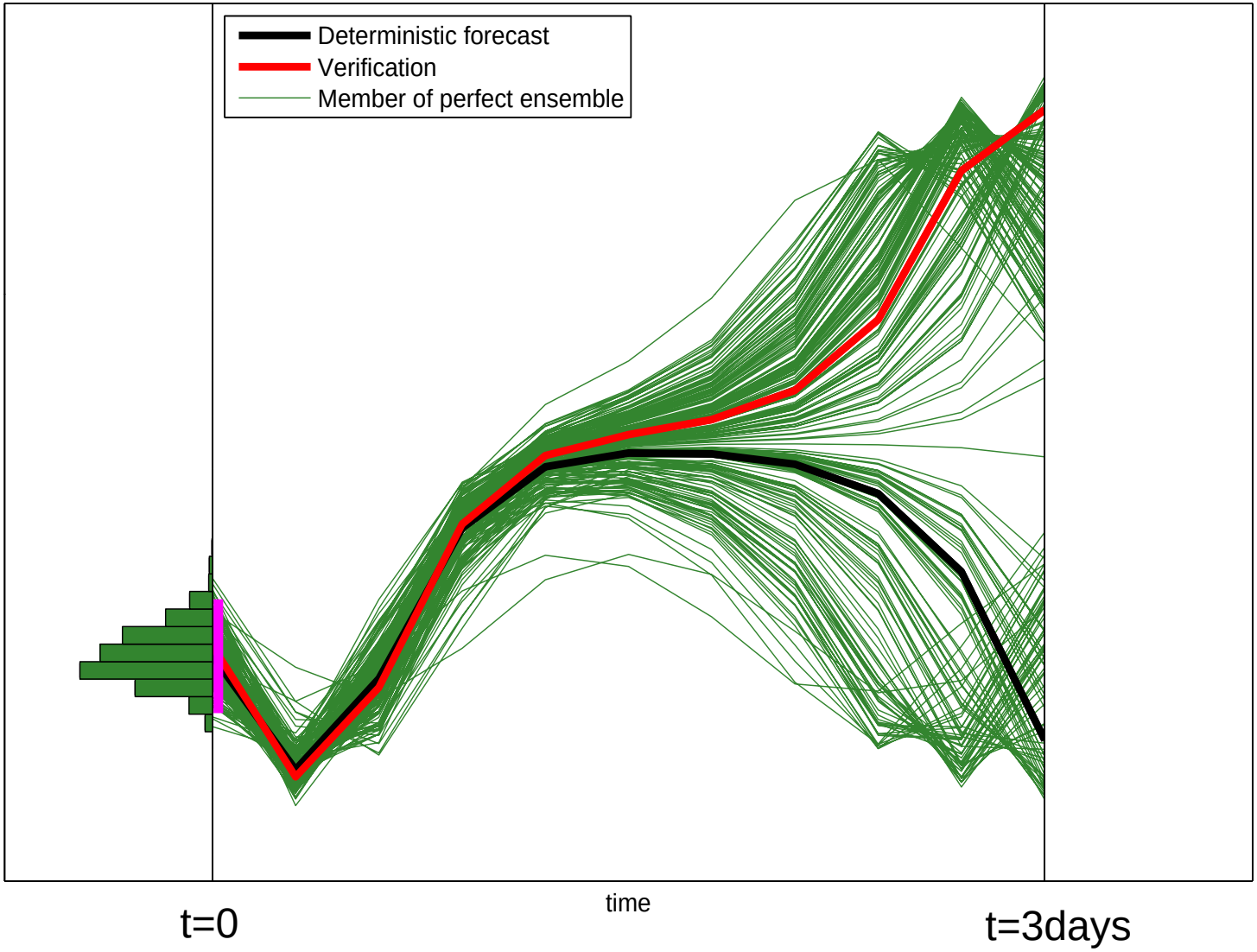

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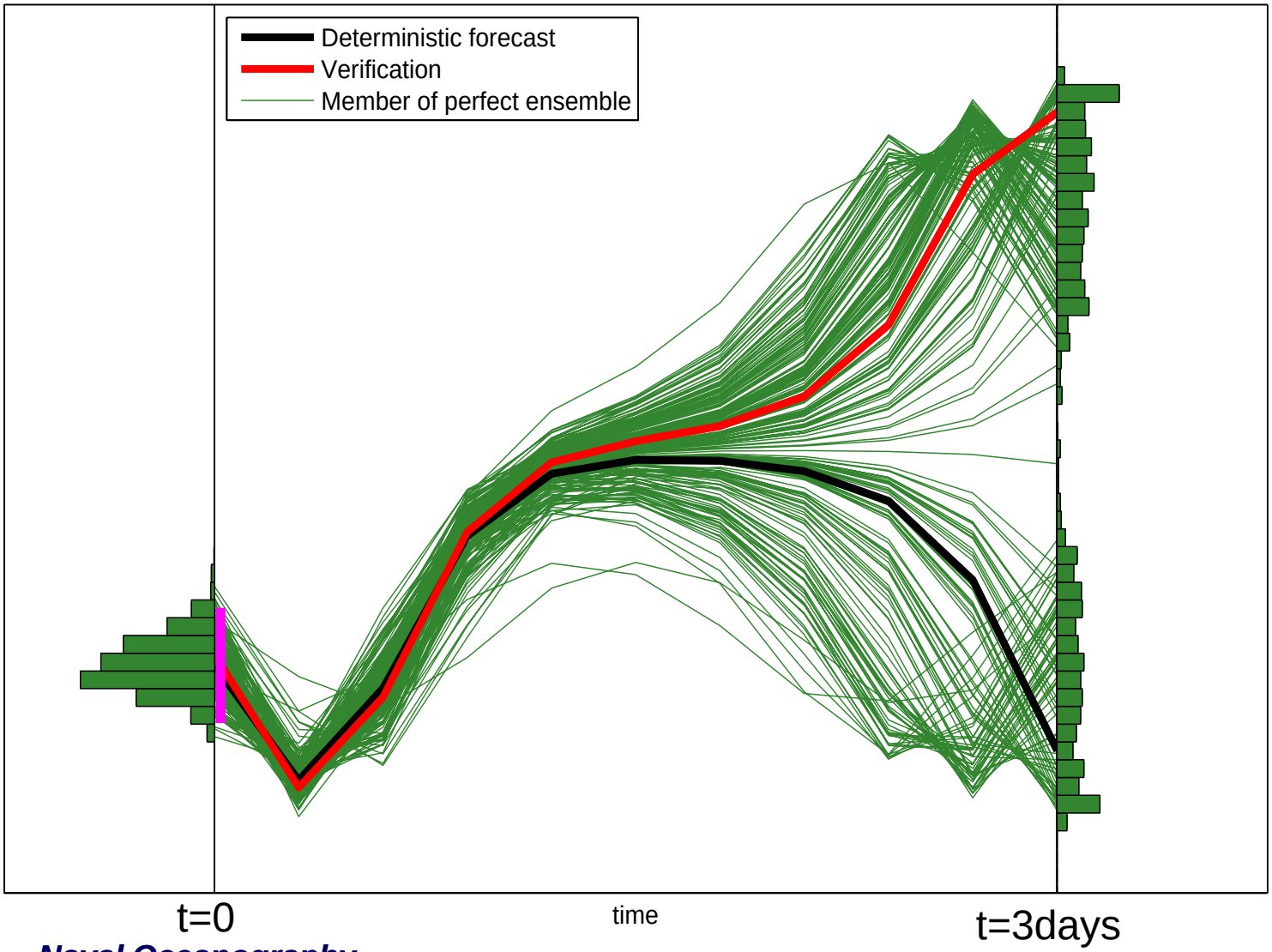
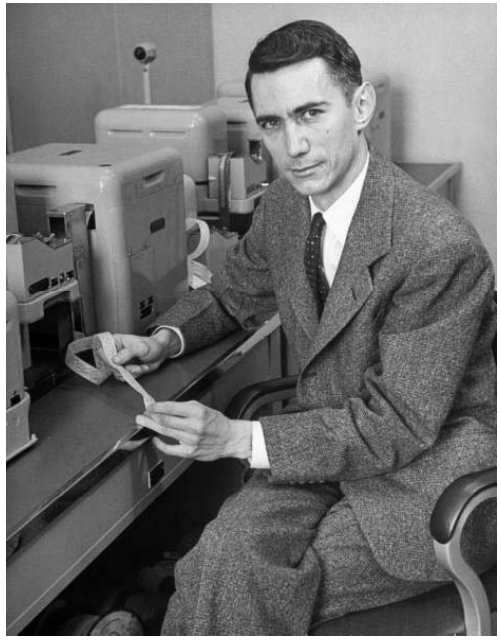
Deterministic vs. Probablistic

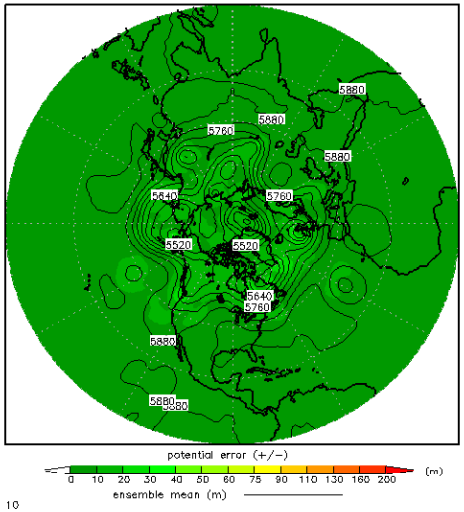


Information Theory

$$H(x) = -\sum p(x) \ln_2 p(x)$$

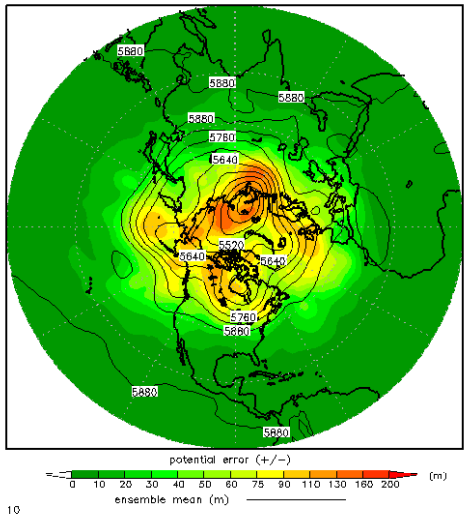


Claude Shannon



VT: Tue 00Z 10 AUG 10
FNMOC NOGAPS (U): 500mb Geopotential Height
Run: 2010081000Z Tau: 0

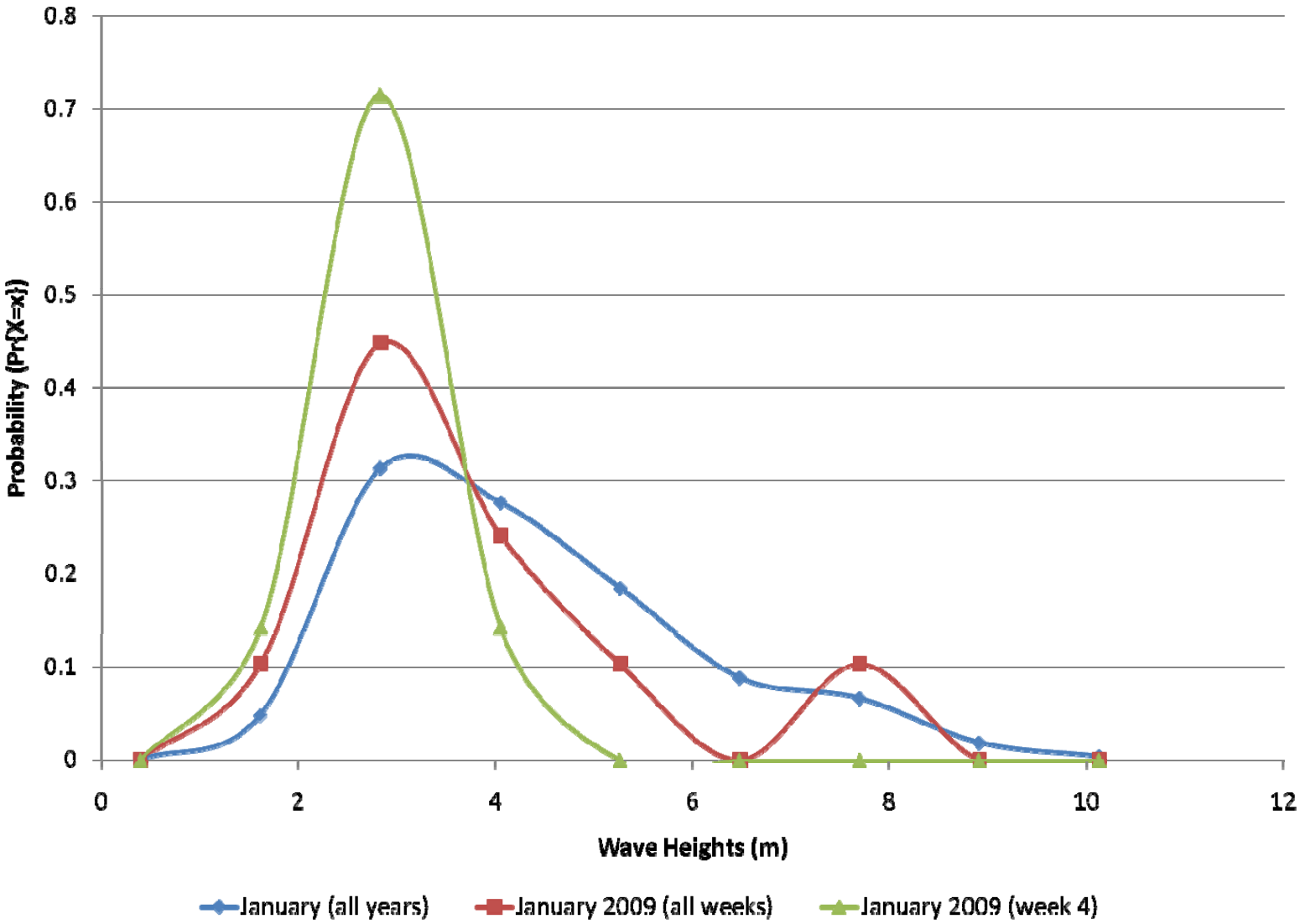
Approved for public access. Distribution is u



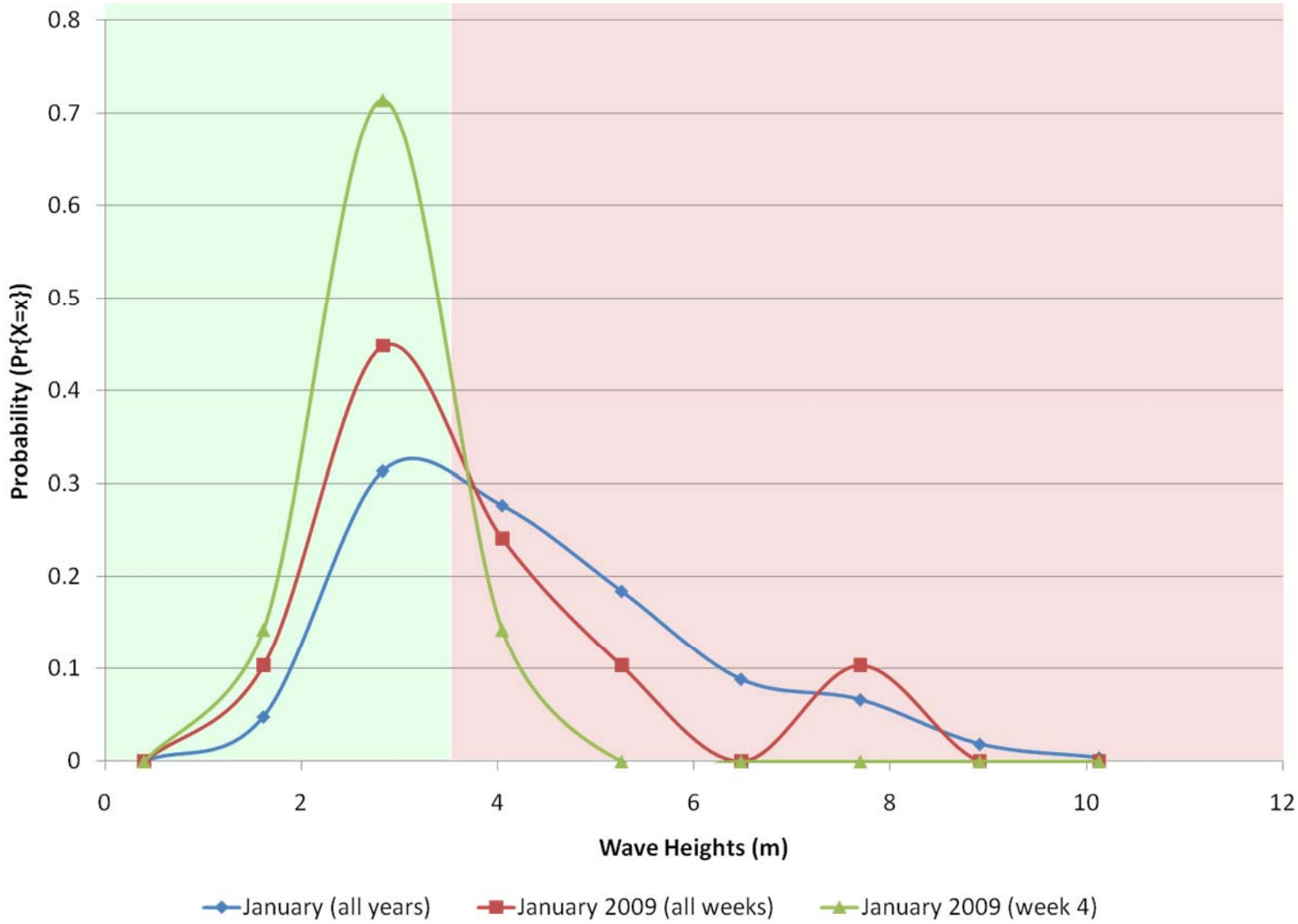
VT: Tue 12Z 17 AUG 10
FNMOC NOGAPS (U): 500mb Geopotential Height
Run: 2010081000Z Tau: 180

Approved for public access. Distribution is unlimited.

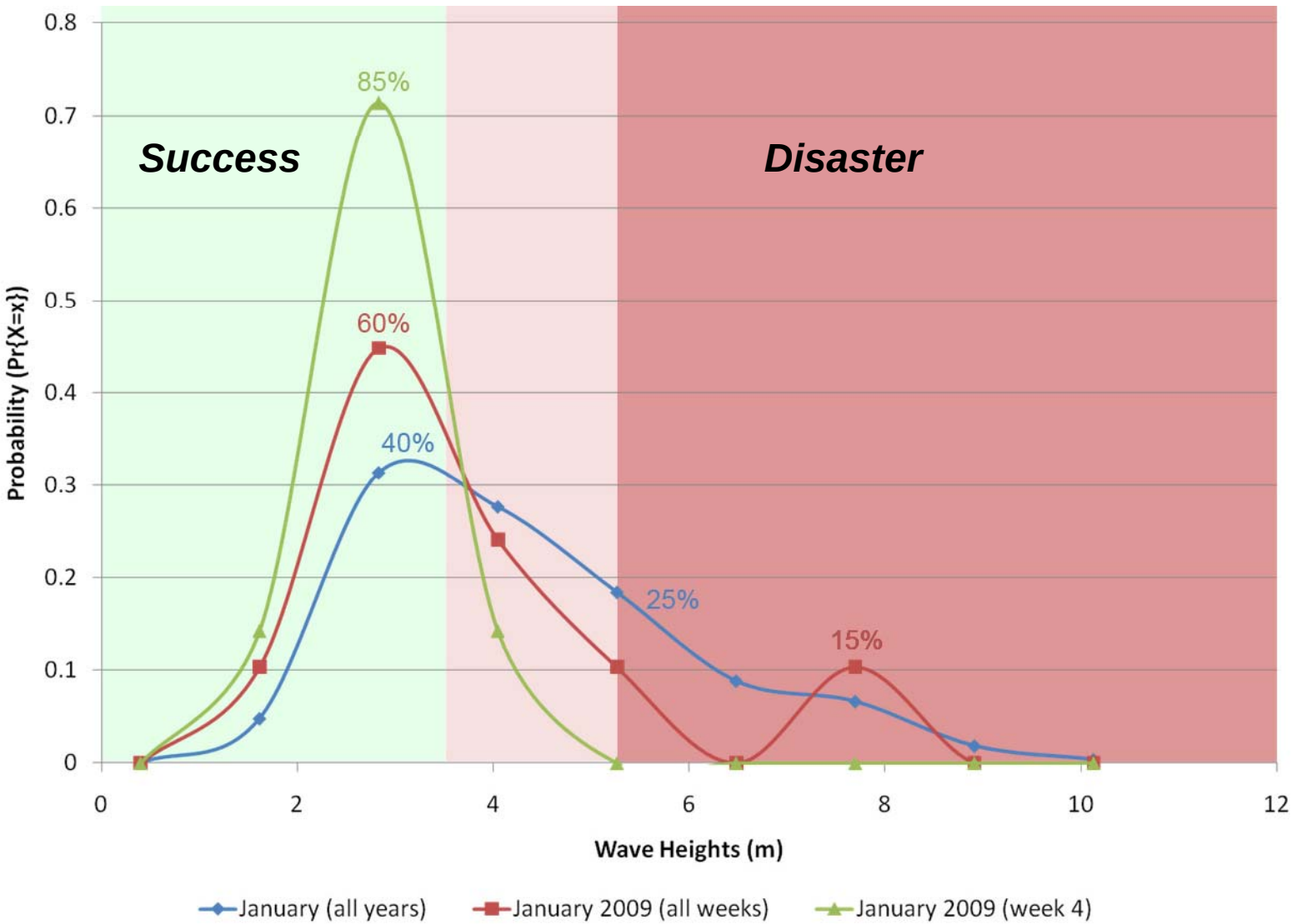
Wave height probability distributions



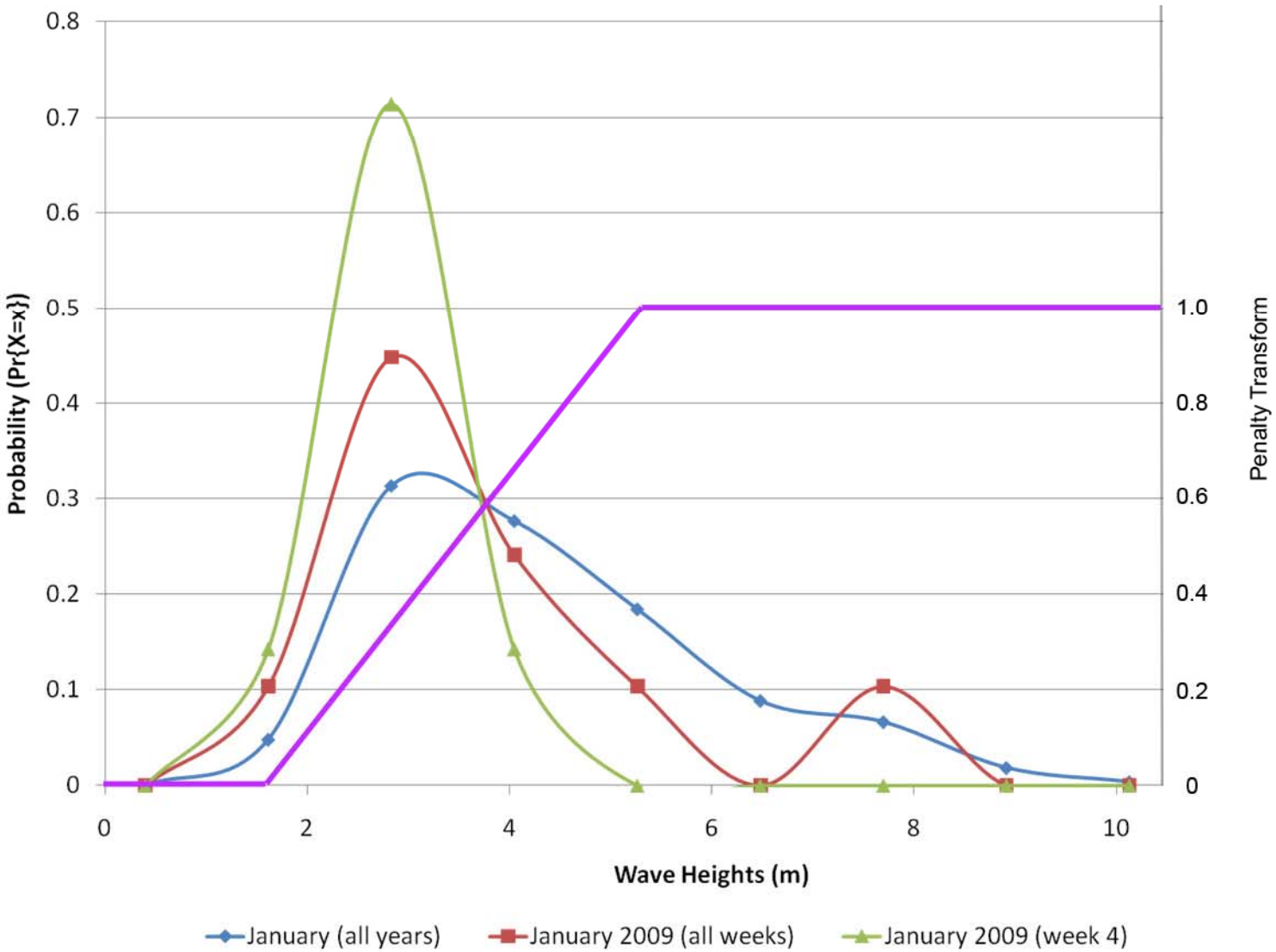
Threshold


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Probability (Pr{X=x})
0
2
4
6
8
10
12
Wave Heights (m)
January (all years)
January 2009 (all weeks)
January 2009 (week 4)

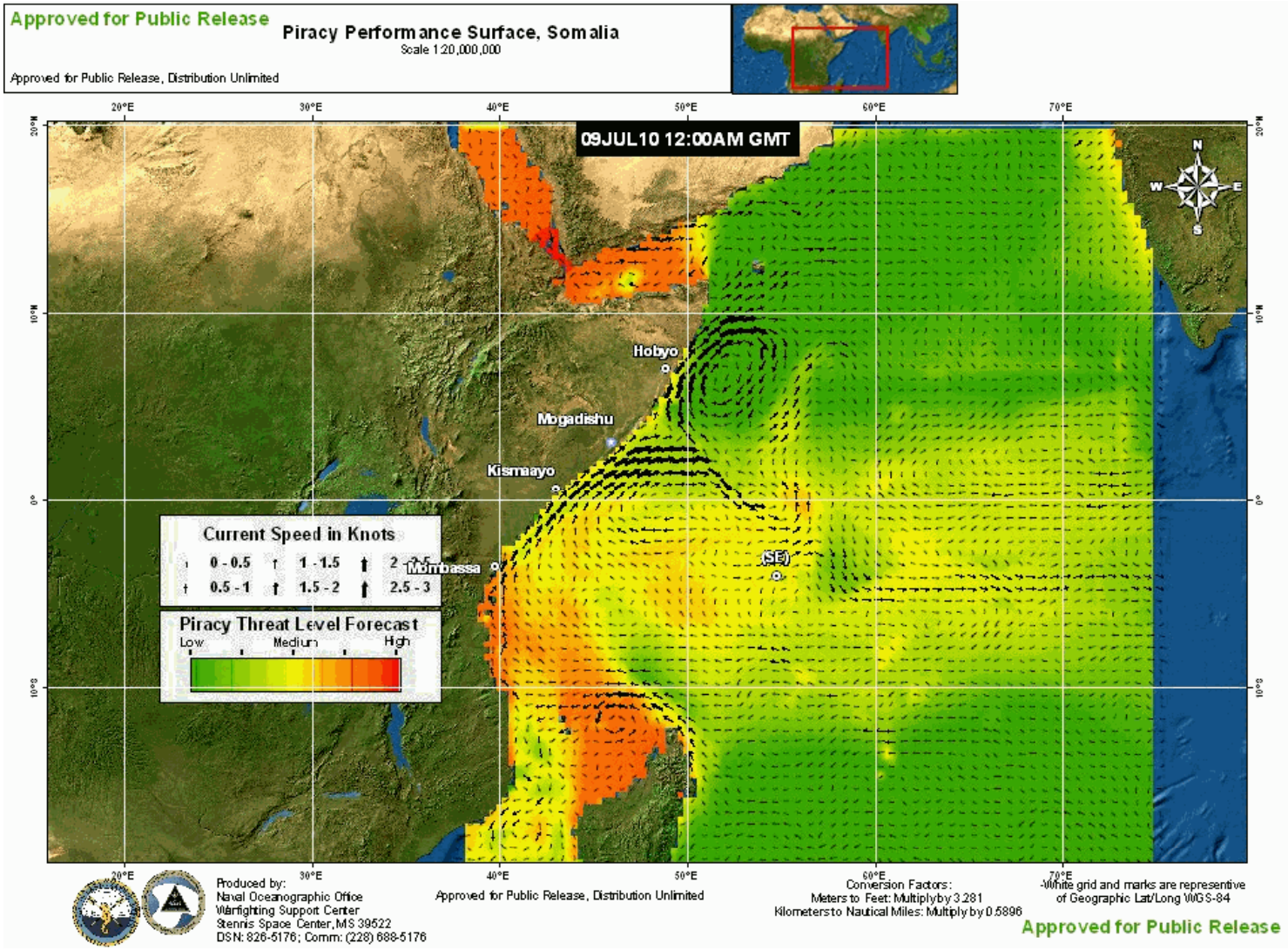
Threshold


Success
Disaster
85%
60%
40%
25%
15%
Probability (Pr{X=x})
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
Wave Heights (m)
January (all years)
January 2009 (all weeks)
January 2009 (week 4)

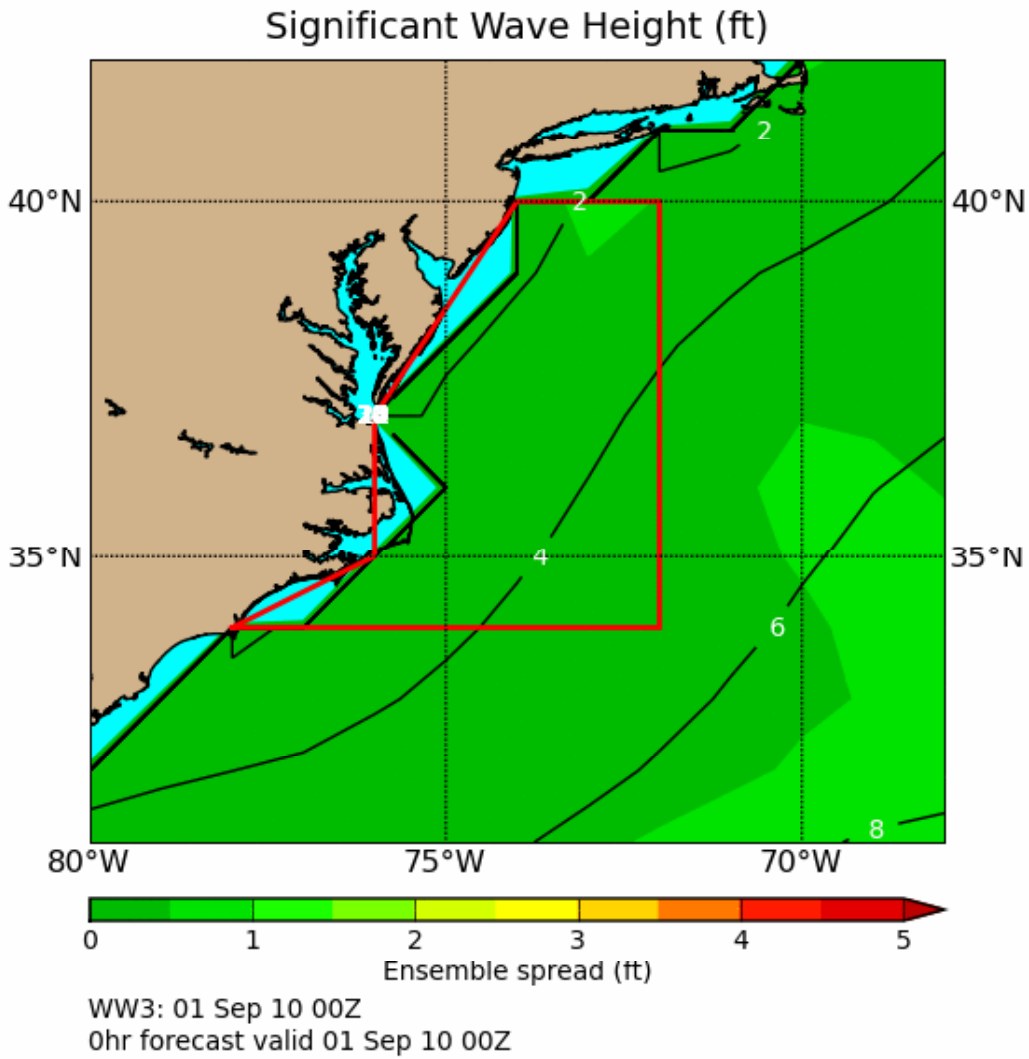
Penalty Function Transform



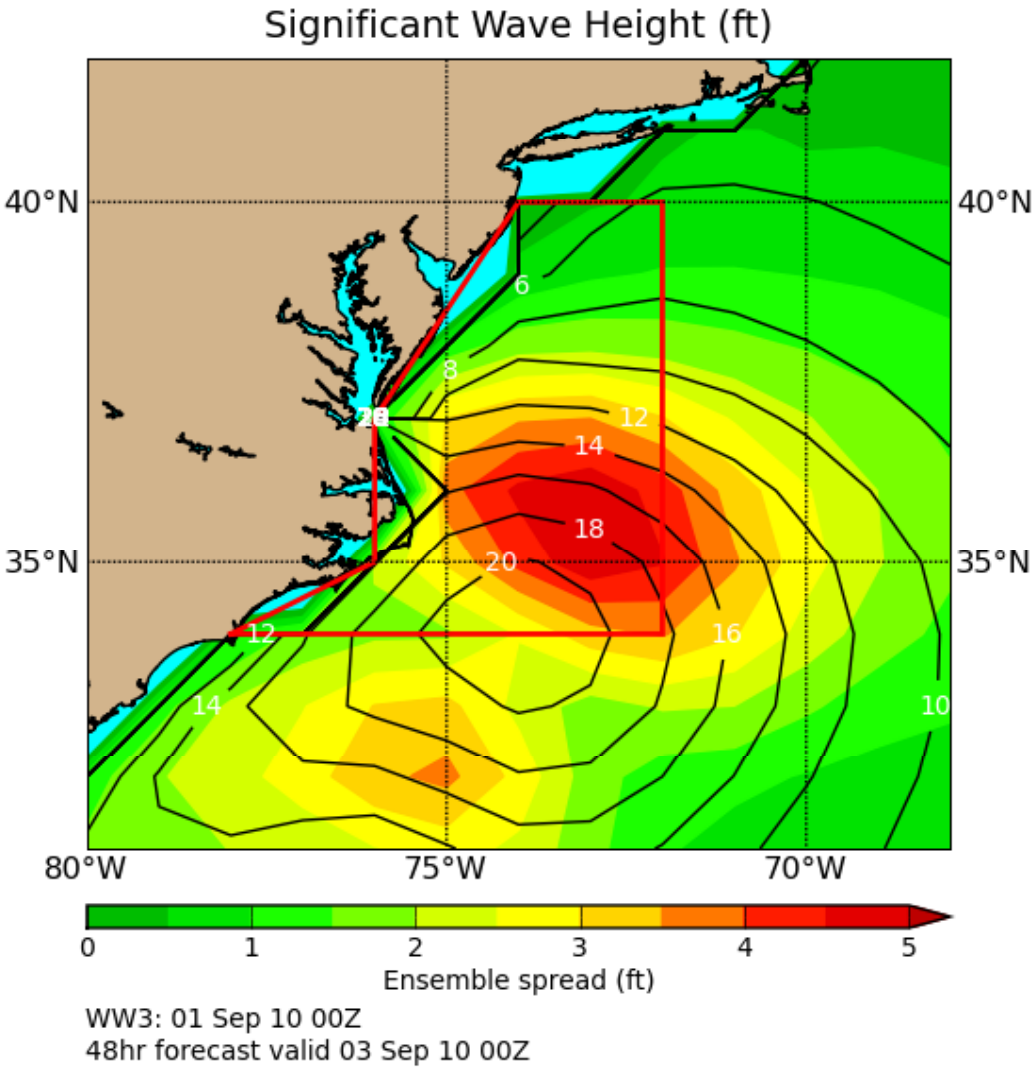
Piracy Performance Surface



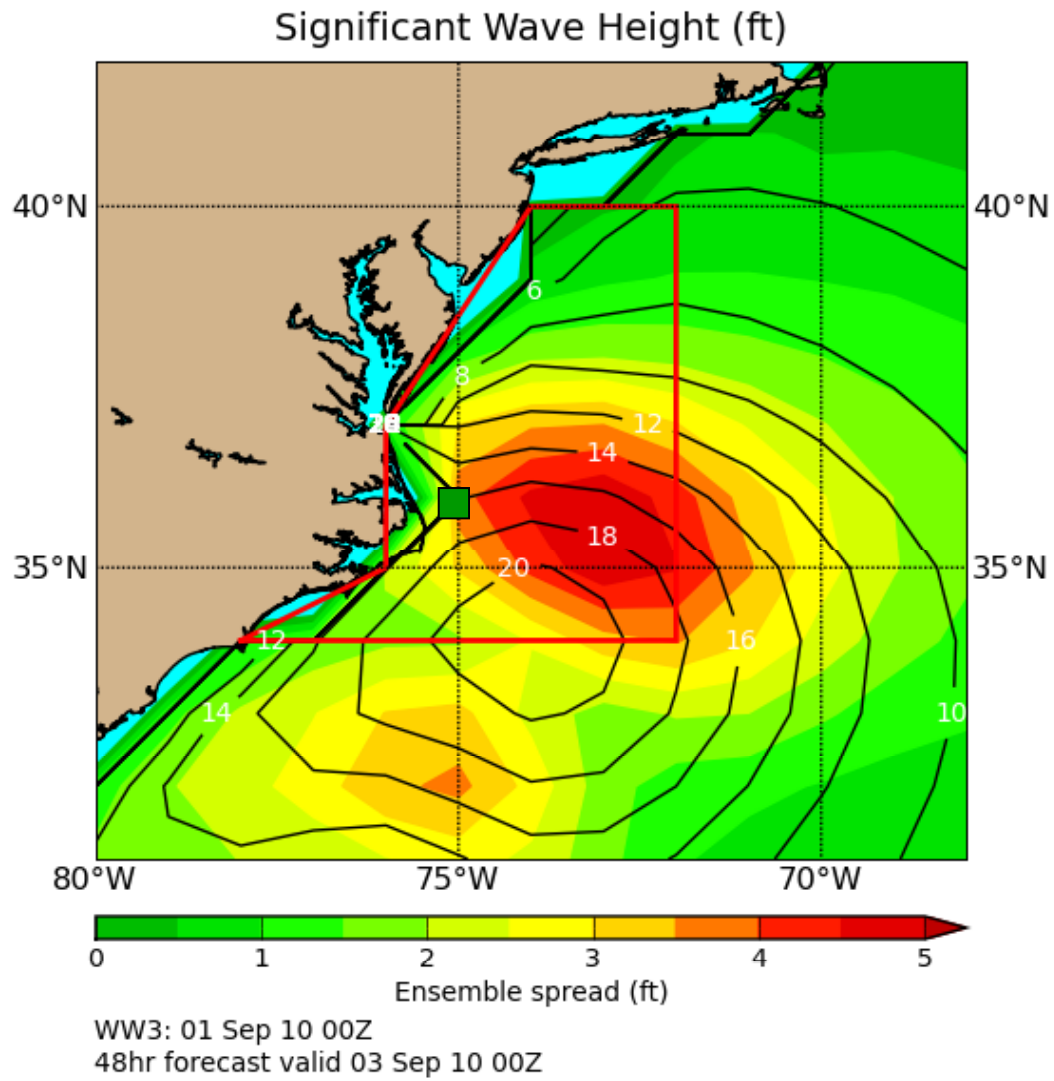
Hurricane Earl – Dynamic Uncertainty



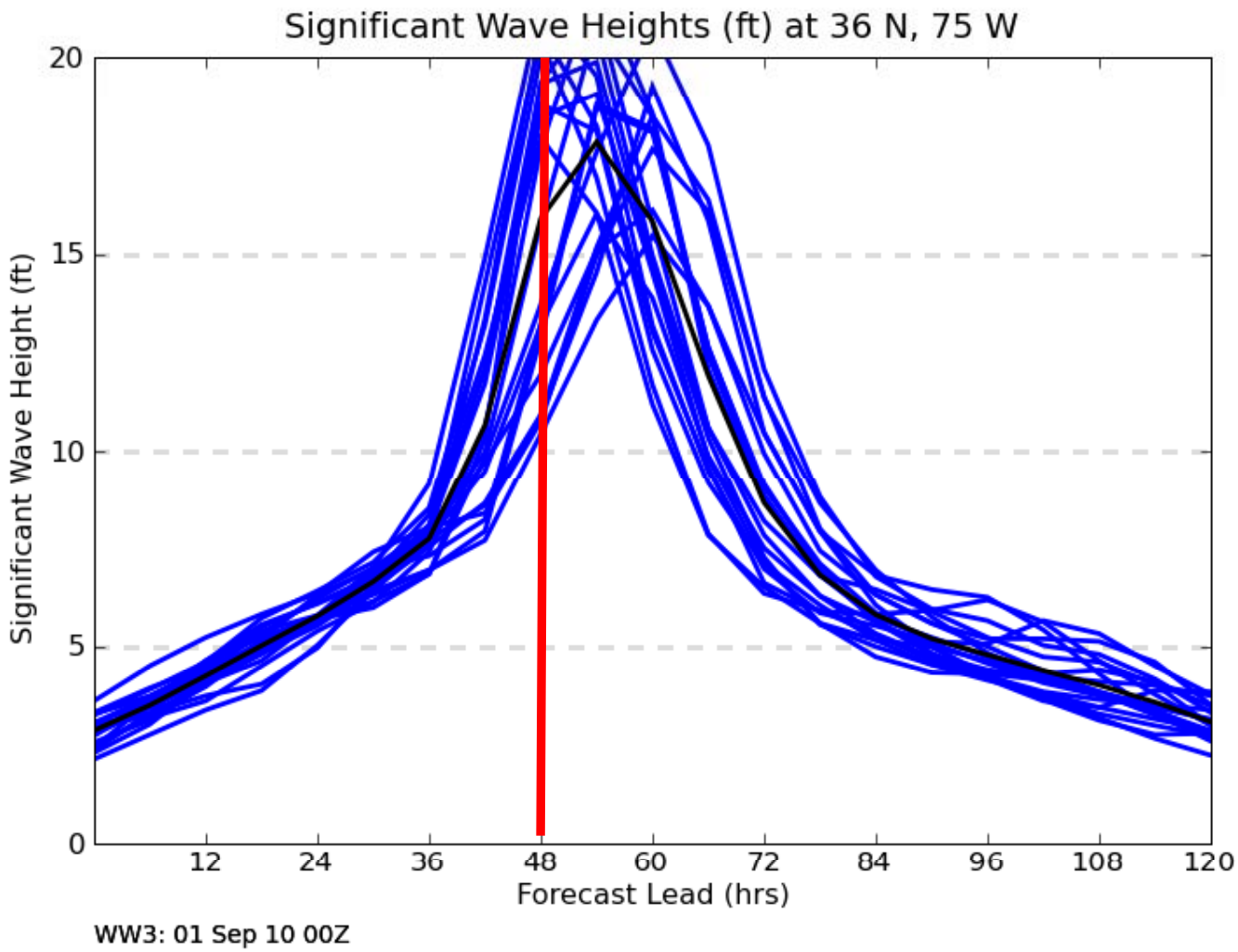
Hurricane Earl – Closest Approach



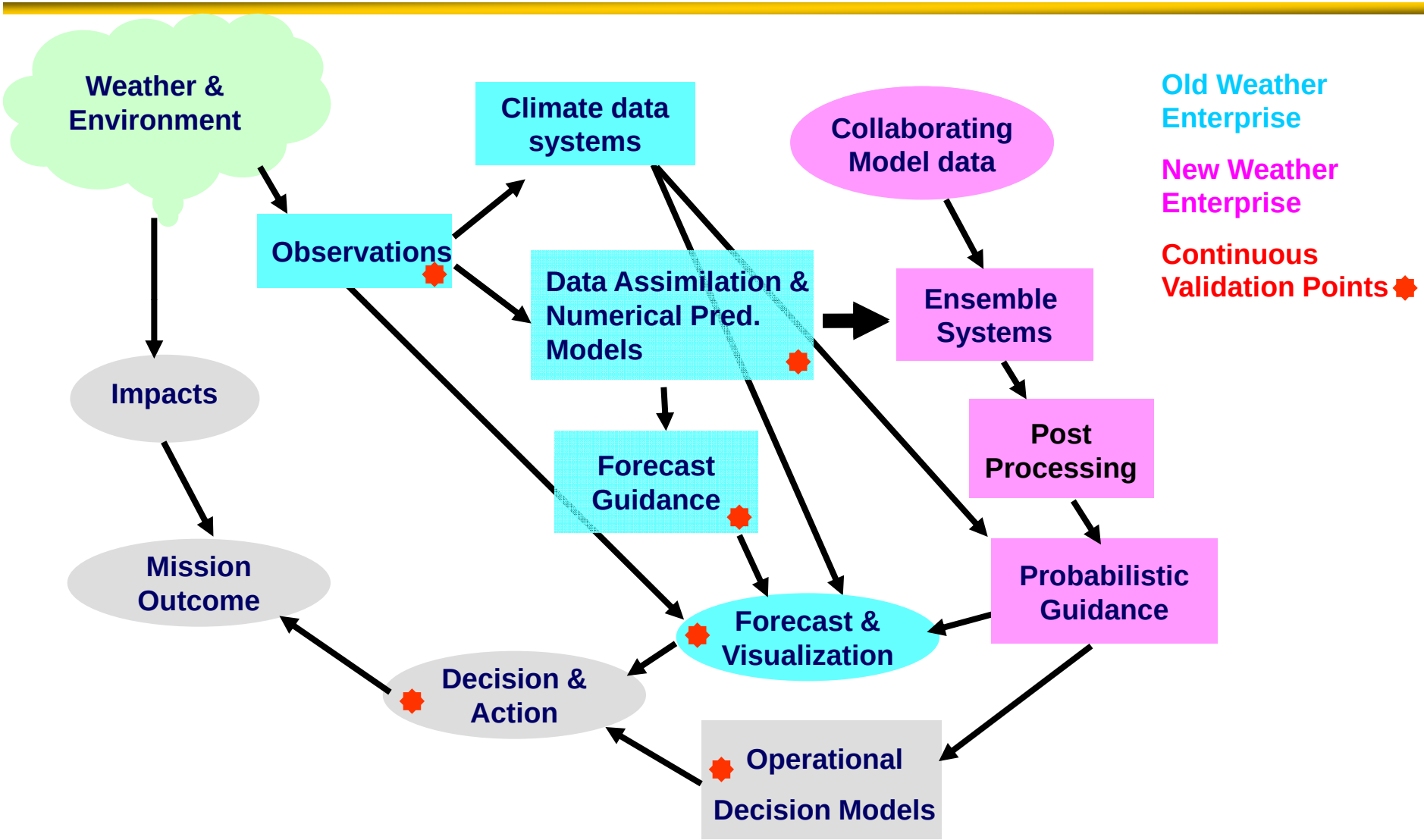
Hurricane Earl – Closest Approach



Ensemble Time Series

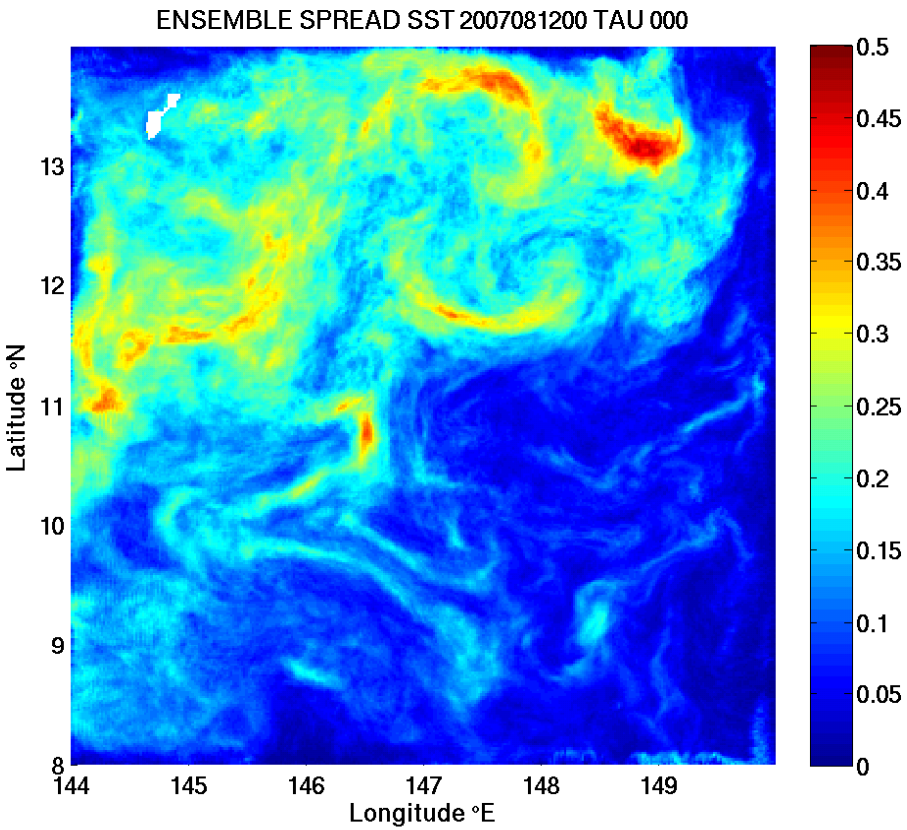


Adding Uncertainty to the Forecast



Ensembles - Ocean Circulation

- *Currently supporting Navy ops*
  - *32 members of regional model with perturbations of surface fluxes and initial conditions*
  - *Ensemble Transform Kalman Filter (EnTKF) approach*
  - *Primary application: adaptive sampling, i.e. where to direct measurement assets, such as gliders*
- *Current Navy R&D*
  - *Mesoscale & coastal focus*
  - *Expansion of perturbations to include boundary conditions and bathymetry*
- *Future*
  - *Coupled models (esp. regional / mesoscale) are viable candidates for ensemble methodologies*



Thank You

Future Automated Optimum Ship Routing

Ship's Navigator

Initial Route Request

METOC Parameters

- **Navigation Data**
- **Winds/Seas/Vis**
- **High Res Currents**

Interactive Web Interface

METOC Inputs

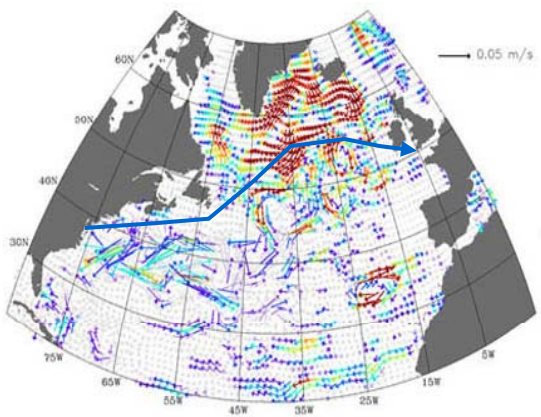
SME Ship Router

"Proposed" Optimum Ship Track

Route Builder

Uncertainty Information from Ensembles

Expert Checks METOC Data Validity and Provides Advice to Ship's Navigator as required



- **Ship/Tactical Limits**
  "Acceptable Risk"
- **Fuel Consumption**
- **SOE Events**

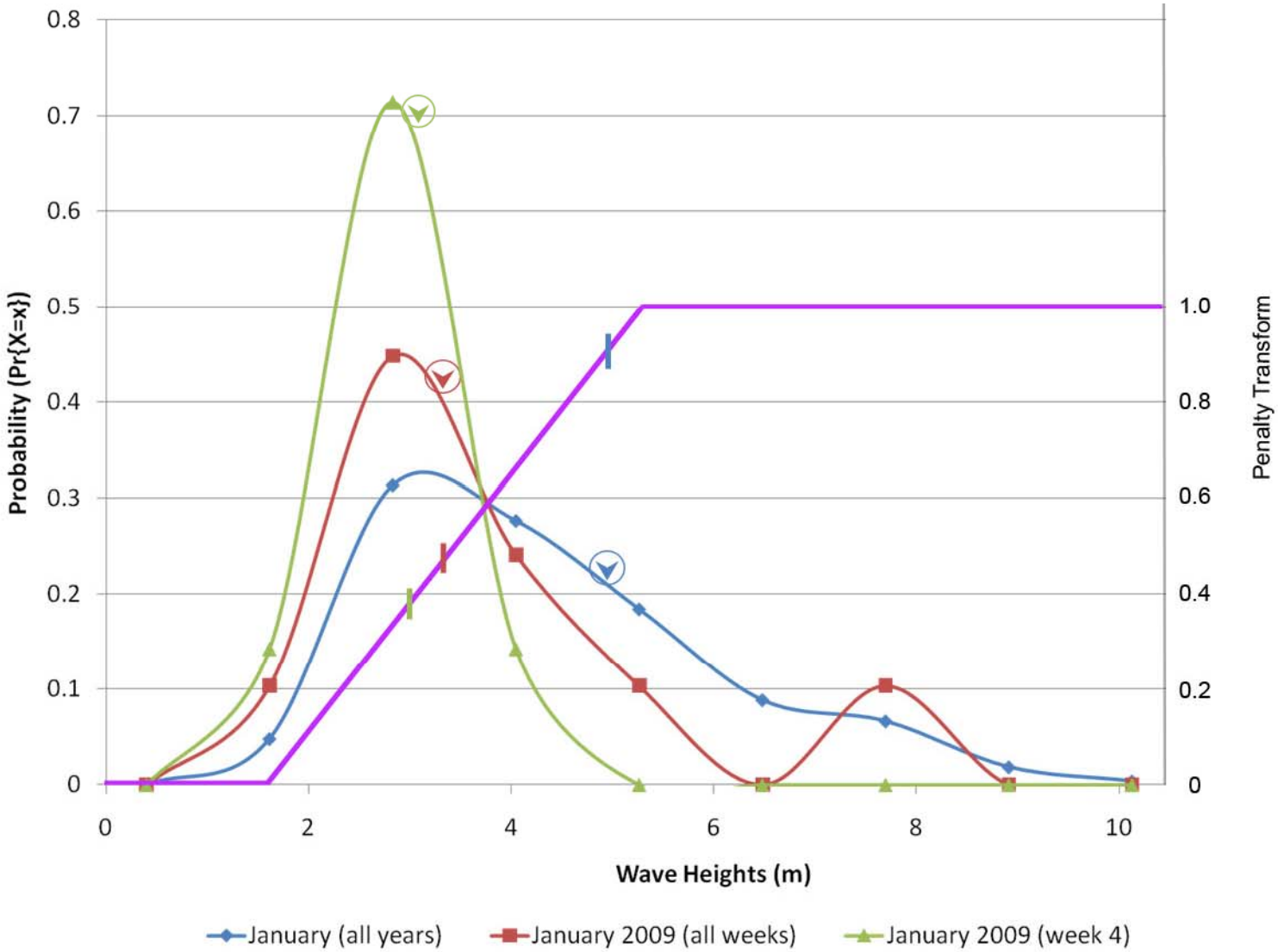
Route Parameters

Parameters adjustable based on meeting mission needs

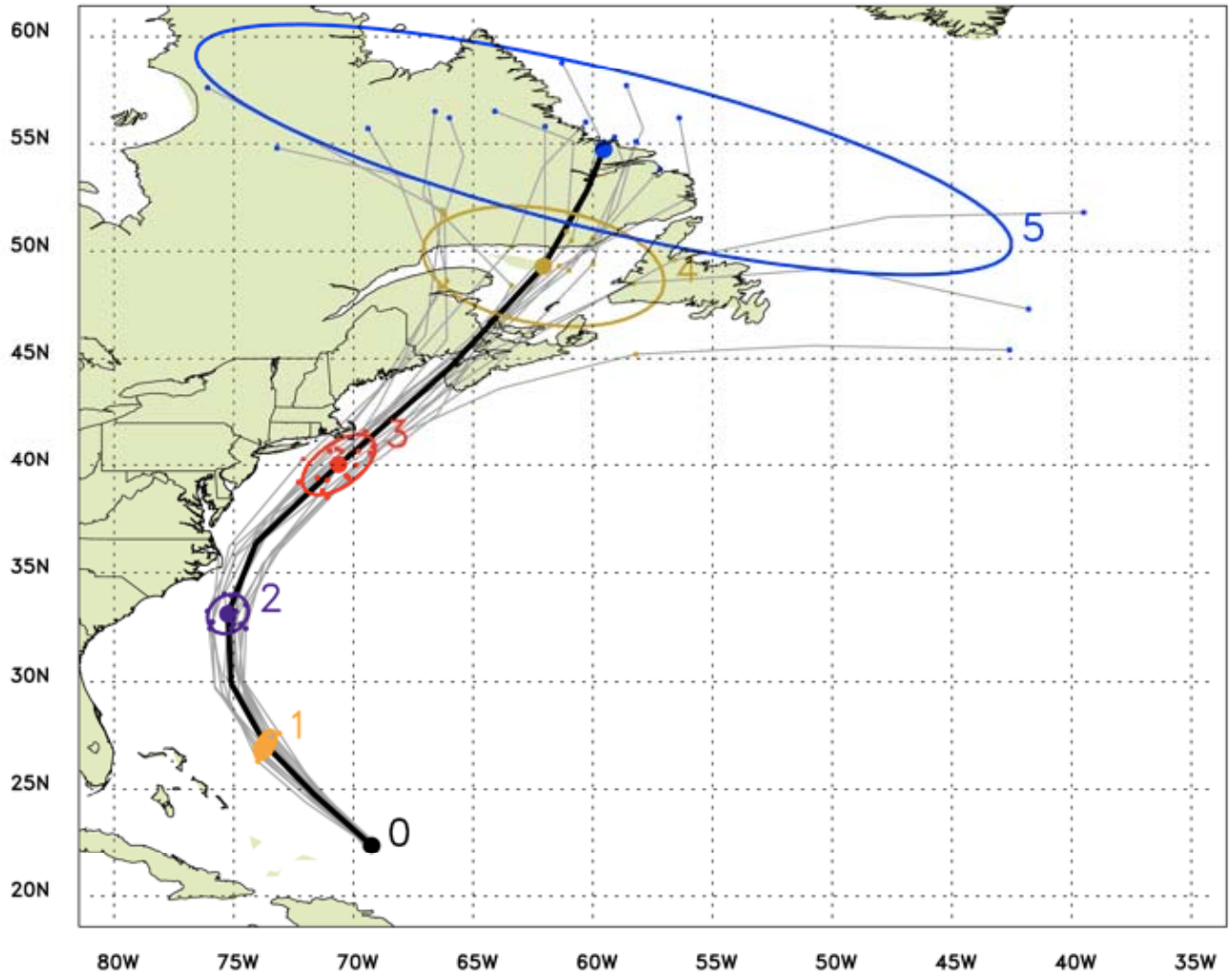
Final Decision

MOVREP Issued

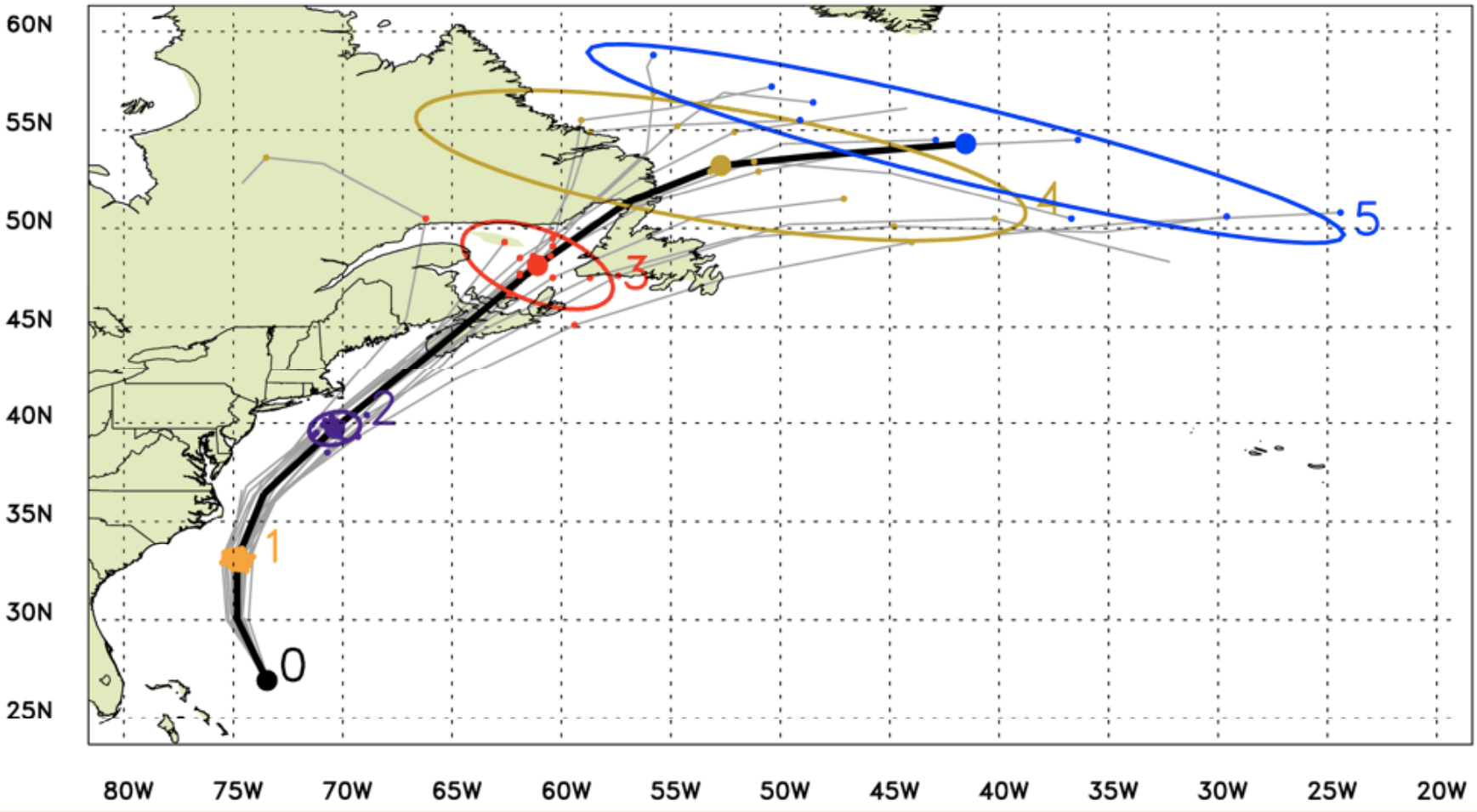
Transform Moves Peaks



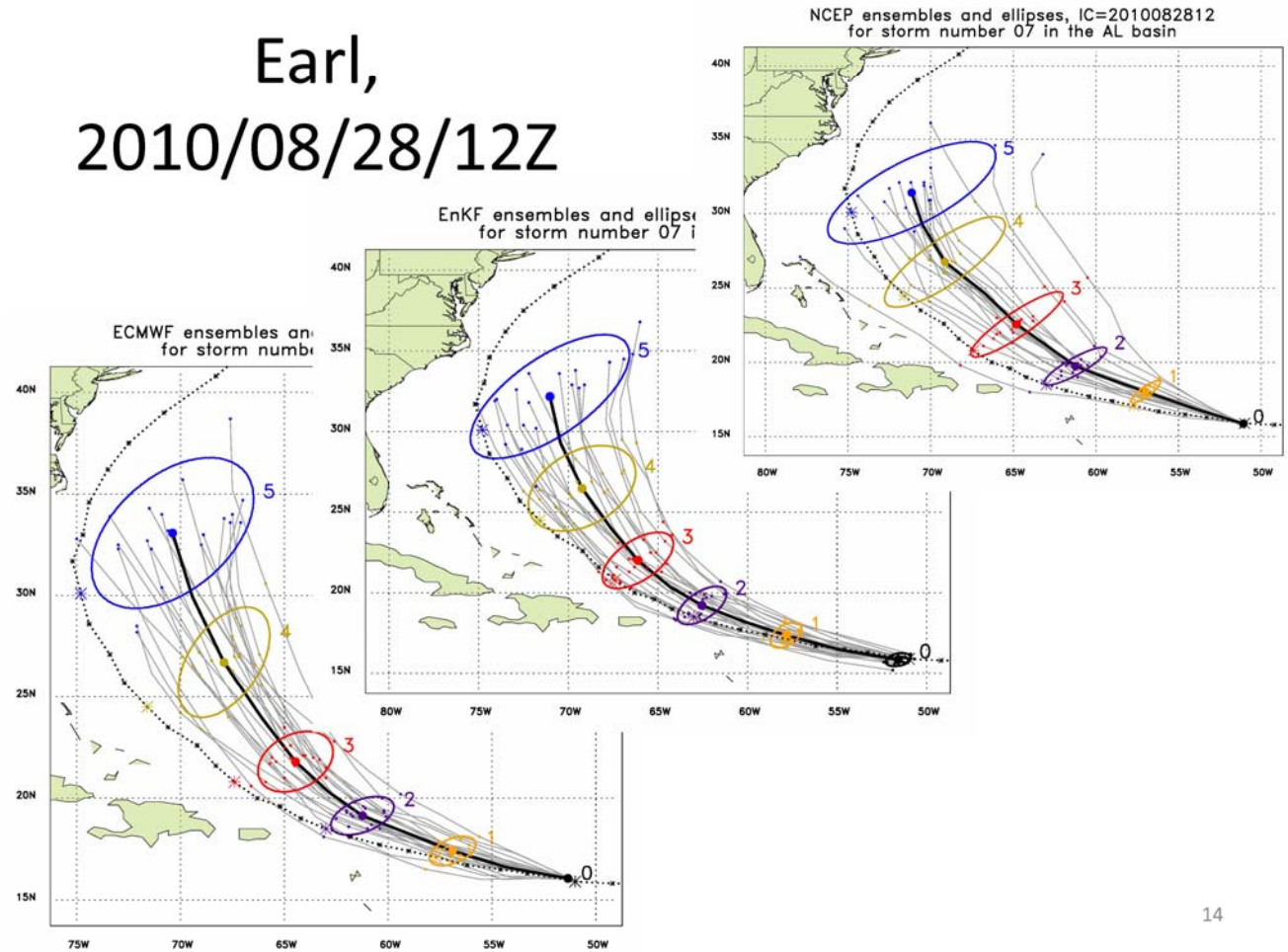
GFS/EnKF ensembles and ellipses, IC=2010090100
for storm number 07 in the AL basin



GFS/EnKF ensembles and ellipses, IC=2010090200
for storm number 07 in the AL basin



Earl, 2010/08/28/12Z



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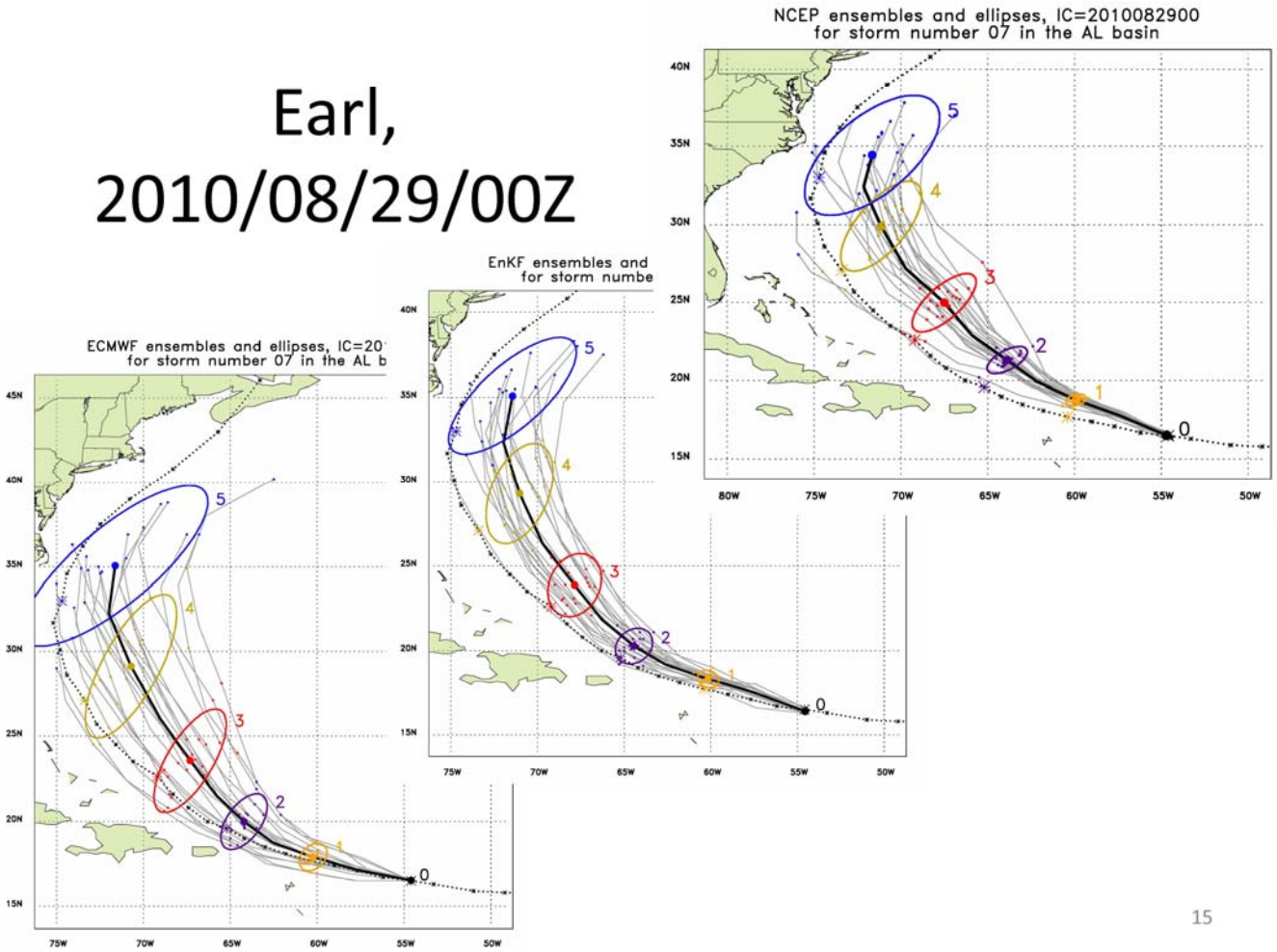
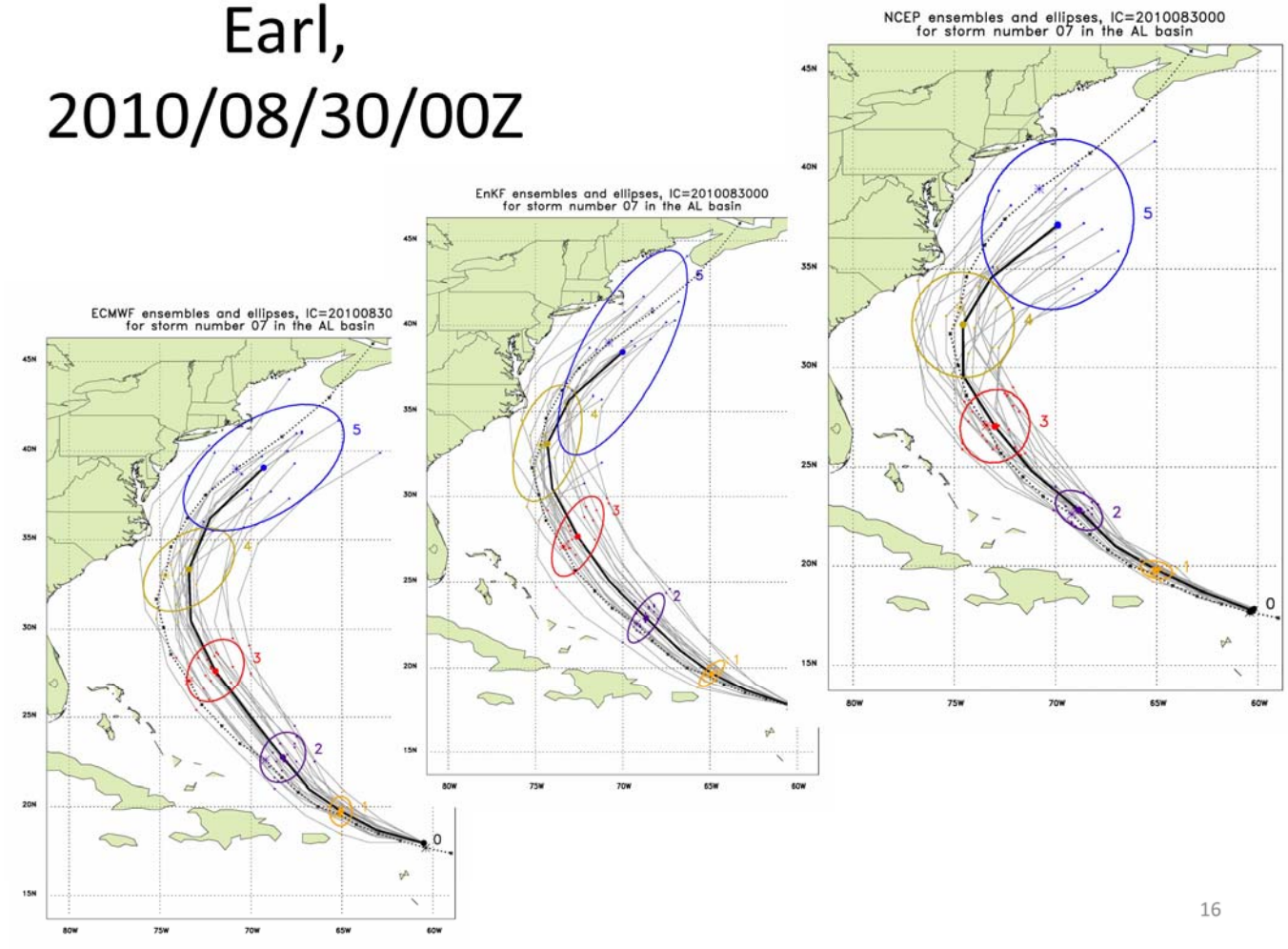
Earl, 2010/08/29/00Z



Earl, 2010/08/30/00Z



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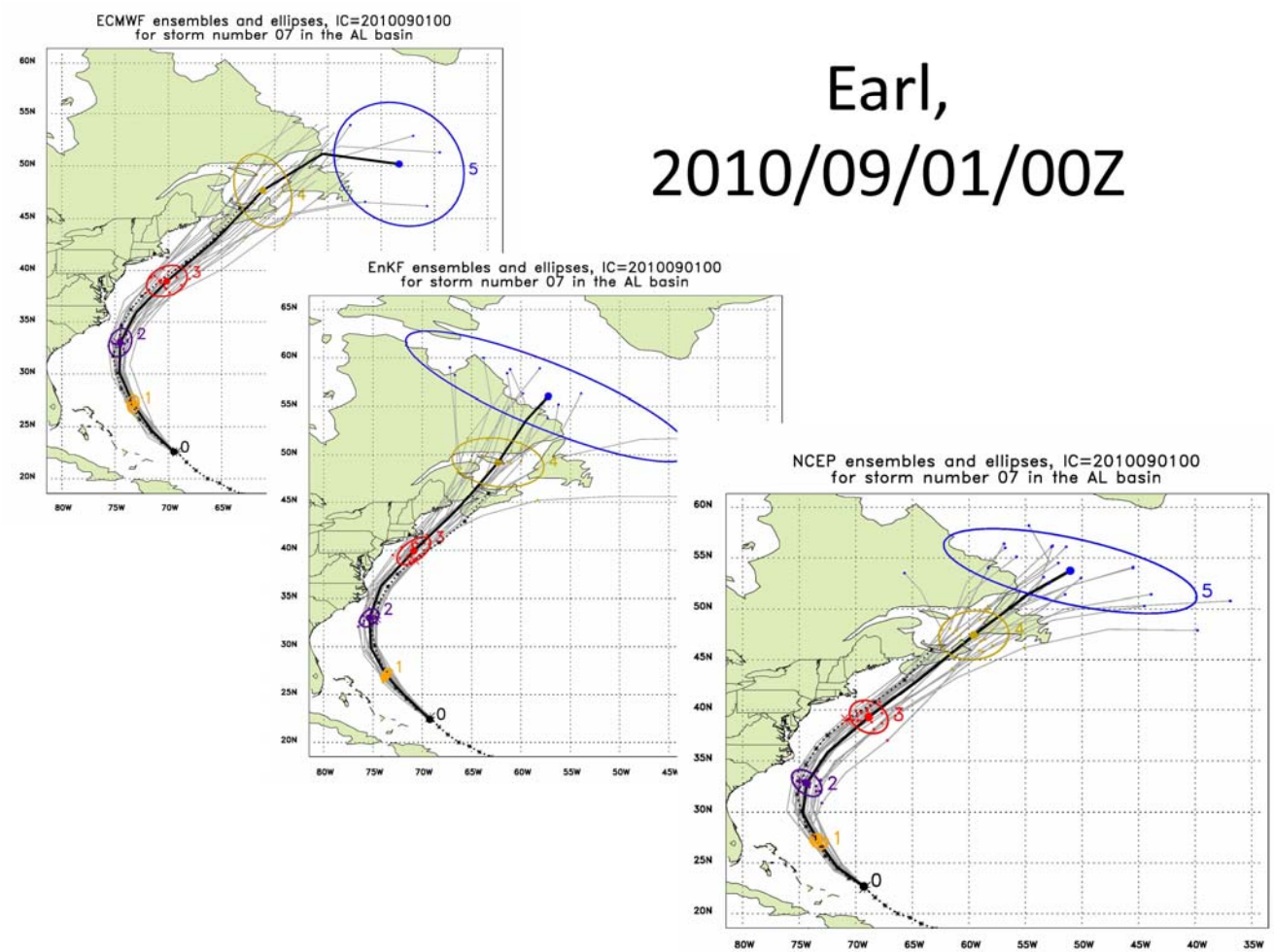
Earl, 2010/09/01/00Z