Narragansett Bay ROMS: Model-Data Comparisons of Currents and Hydrography

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NBC Workshop: Just Another Day on the Upper-Upper Bay
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Background on Modeling Effort

- Model development has been an ongoing process over past 5-10 years.
- Major impetus: CHRP Narragansett Bay Hypoxia project (Funded by NOAA-CHRP and RI-BRWCT).
    - ROMS model used to parameterize material transports in ecological box model of the Bay.
    - For this application, require a realistically forced model that captures the variability in circulation and mixing occurring in NB in response to time-variable forcing (river inflows, wind, heat fluxes, tides, oceanic variability).
- Present version of model run for 2006, 2007, 2010, and 2014.

Use of Field Observations to Assess the Skill of the Numerical Model

- Numerical circulation model is a ***Computer Program***, and as people used to say in the early days of computers regarding programs: ***"Garbage in, Garbage out"***.

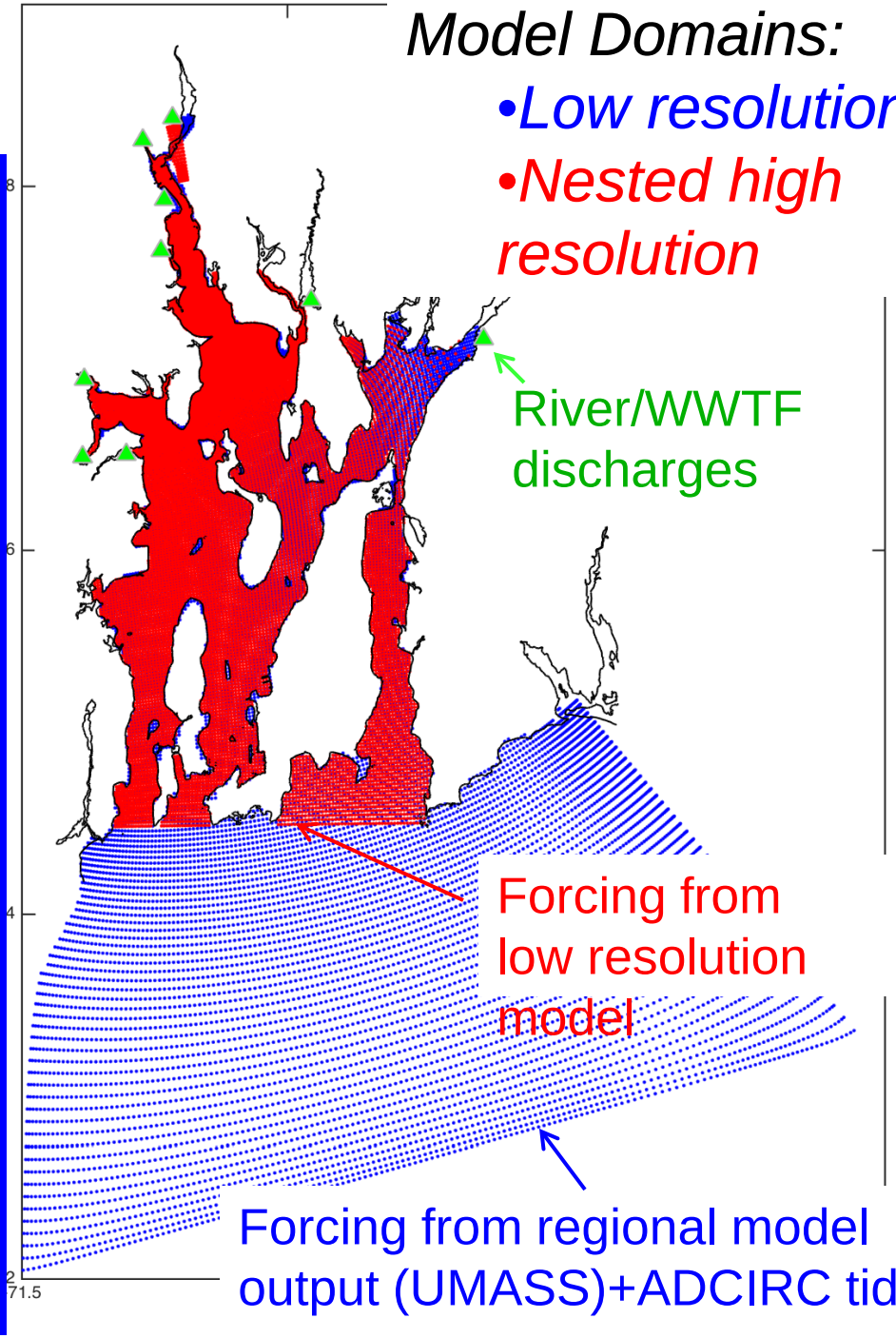
- Before using model output for any application, it is crucial to verify the performance of the model.

- In this presentation, I will evaluate the skill of our ROMS Narragansett Bay model in simulating water surface elevation, currents, hydrography (temperature and salinity), and vertical density stratification using observations.

ROMS N-Bay Circulation Model

Nested (ROMS) configuration:

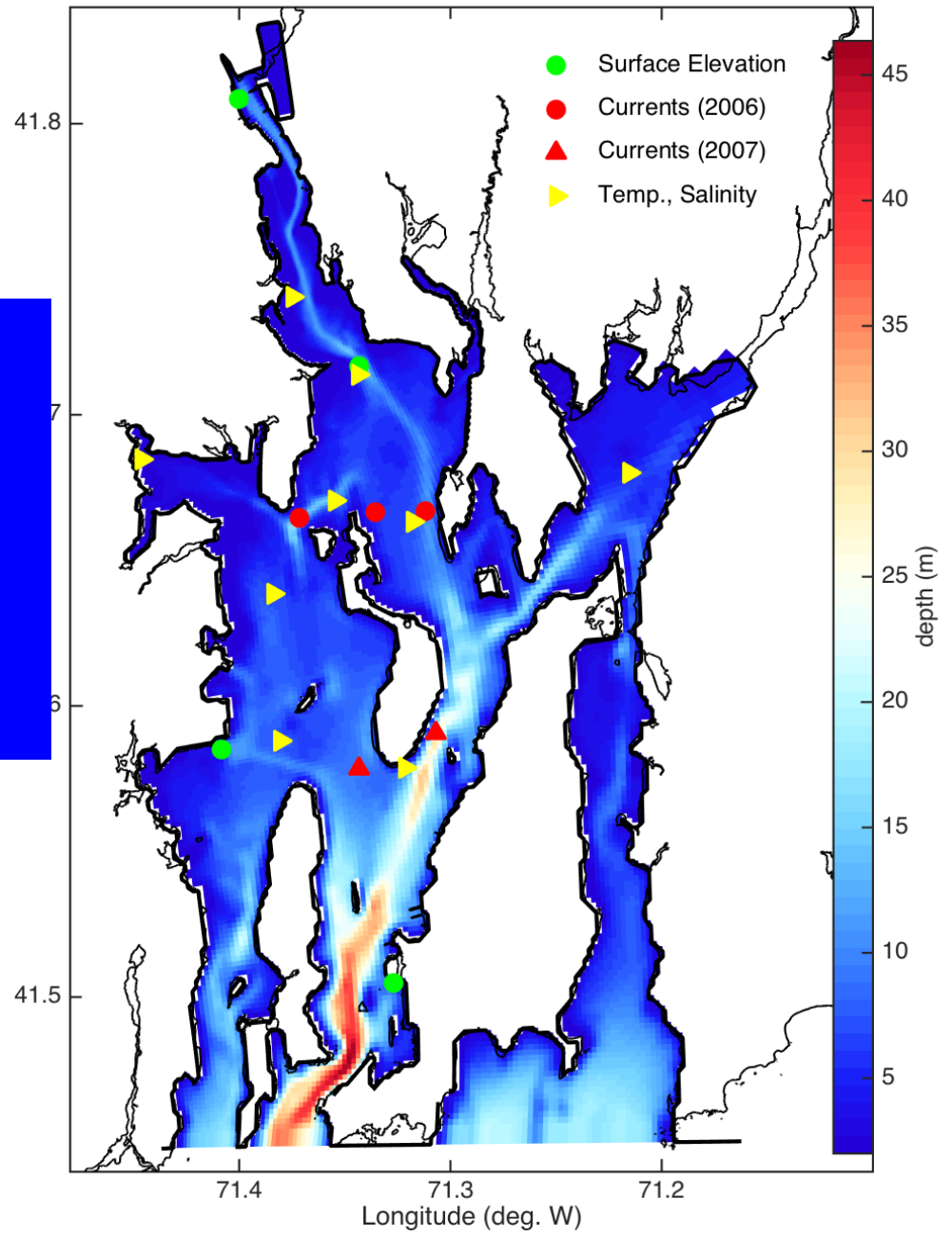
- Low resolution model extending onto continental shelf provides boundary conditions for high-resolution Bay model (50-100m resolution in upper Bay).
- Sigma vertical coordinate (15 levels).
- Vertical mixing parameterized using *k*-ε turbulence closure.
- Horizontal viscosity/diffusivity scaled by grid spacing.
- Forced with:
  - Measured river/WWTF inflows (green symbols).
  - Winds from WRF met. model analysis (UMASS).
  - Radiative forcing from N.A.R.R. (NOAA).
  - Local met. measurements (T.F. Green and PORTS).



Skill Assessment: Site Locations

Observations:

- Surface elevation (NOAA tide gauges).
- Currents (URI ADCPs).
- Temperature and Salinity (URI/DEM buoys)



Skill Assessment: Site Locations

Tide Gauges (surface elevation):

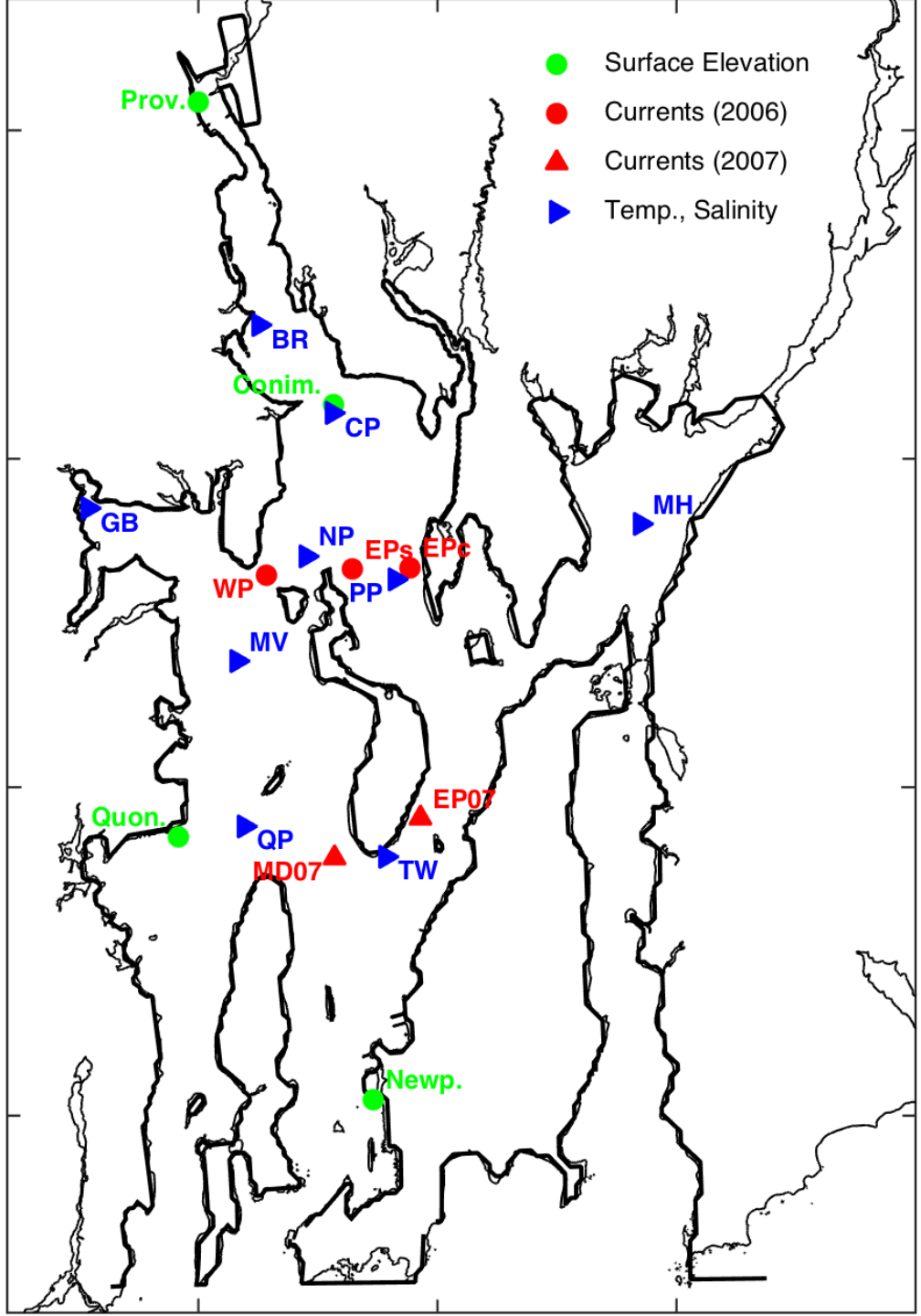
- Providence (Prov.)
- Conimicut (Conim.)
- Quonset (Quon.)
- Newport (Newp.)

ADCPs (current profiles):

- West Passage Channel 2006 (WP)
- East Passage Channel 2006 (EPc)
- East Passage Shoal 2006 (EPs)
- East Passage Channel 2007 (EP07)
- Betw. Prudence and Conanicut 2007 (MD07)

Monitoring Buoys (T and S, surf & bott):

- Bullock Reach (BR)
- Conimicut (CP)
- North Prudence (NP)
- Mount View (MV)
- Quonset (QP)
- Popasquash Point (PP)
- T-Wharf (TW)
- Greenwich Bay Marina (GB)
- Mount Hope Bay (MH)



Evaluation of Model Skill

Use Willmott (1982) Index of Agreement (or Skill):

$$Skill = 1 - \frac{\sum_{i=1}^{N}(T_{mod} - T_{obs})^2}{\sum_{i=1}^{N}(|T_{mod} - \overline{T_{obs}}| + |T_{obs} - \overline{T_{obs}}|)^2}$$

Skill=1: perfect model
Skill=0: useless model

T_{obs} = observed value
T_{mod} = model-predicted value

For surface elevation and currents, skill evaluated for:

A. Raw data.
B. Subtidal signal (low pass filtered, cutoff period =36 h).
C. Tidal signal (Raw-Subtidal).

Reference:
Willmott, C. J., 1982. Some comments on the evaluation of model performance, Bull. Am. Meteor. Soc., 63, 1309-1313

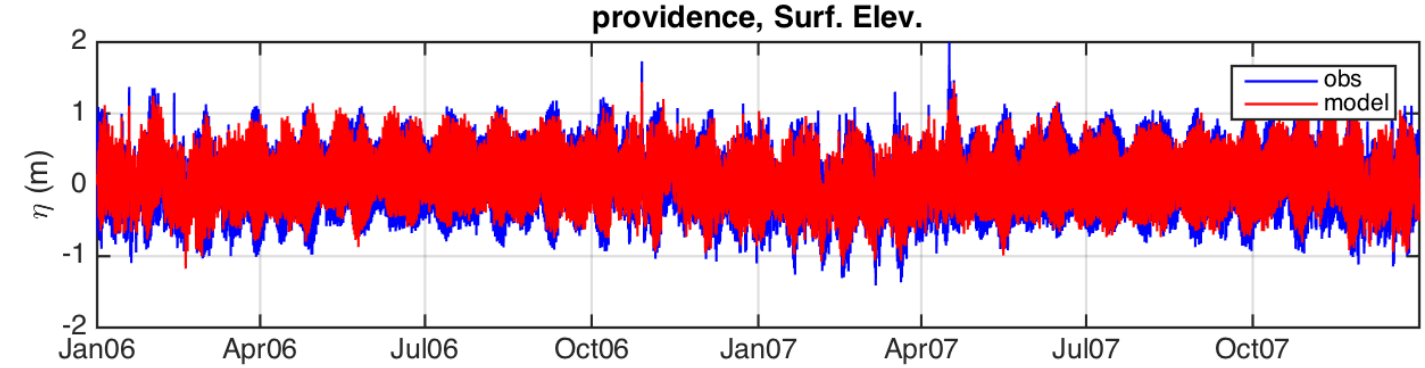
ROMS Model-Data Comparison: Sea Level at Providence (2006-2007)

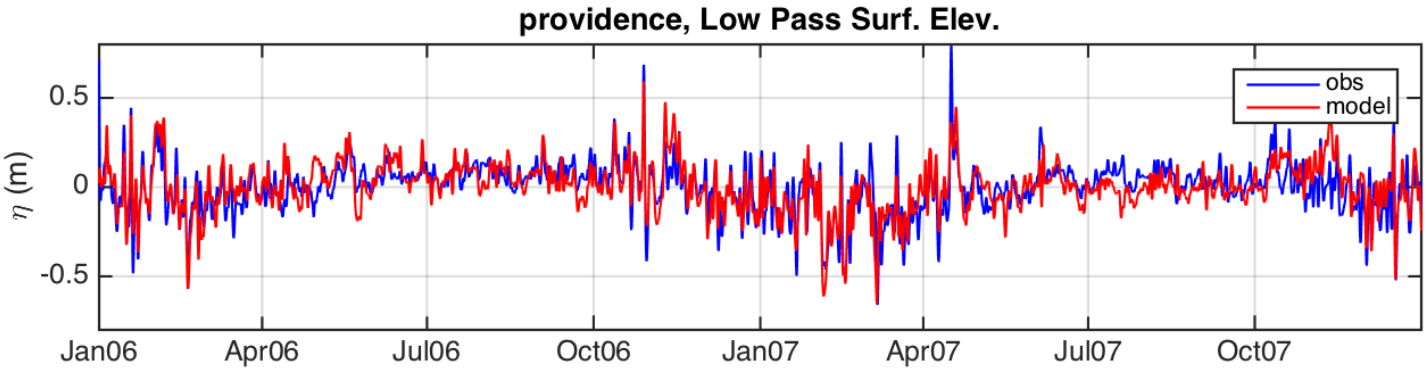
Skill

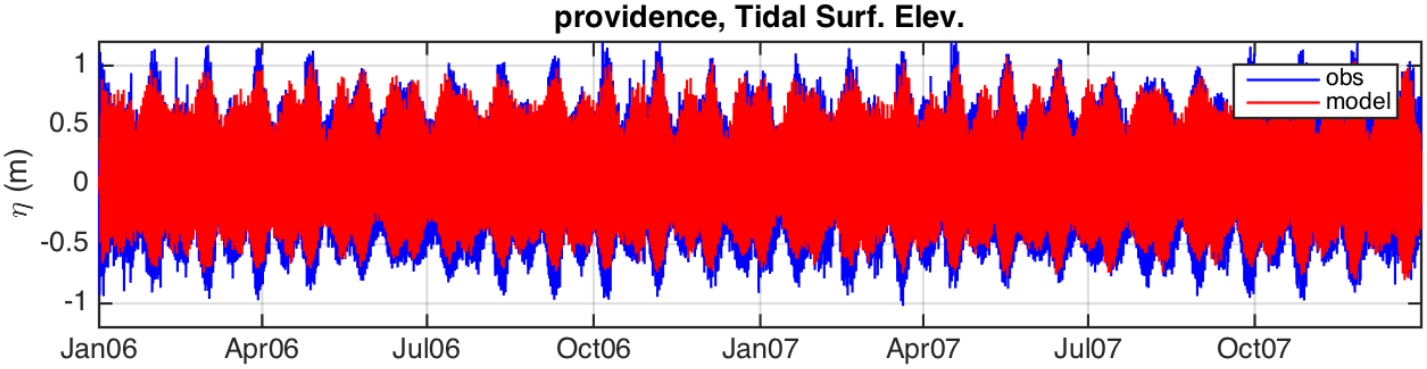
Raw: 0.955

Subtidal: 0.851

Tidal: 0.967







Model Skill: Sea Level 2006-07

Skill Definition:

$$Skill = 1 - \frac{\sum_{i=1}^{N}(T_{mod} - T_{obs})^2}{\sum_{i=1}^{N}(|T_{mod} - \overline{T_{obs}}| + |T_{obs} - \overline{T_{obs}}|)^2}$$

Site	Raw	Subtidal	Tidal
Providence	0.955	0.851	0.967
Conimicut	0.957	0.844	0.970
Quonset	0.960	0.818	0.978
Newport	0.963	0.841	0.980

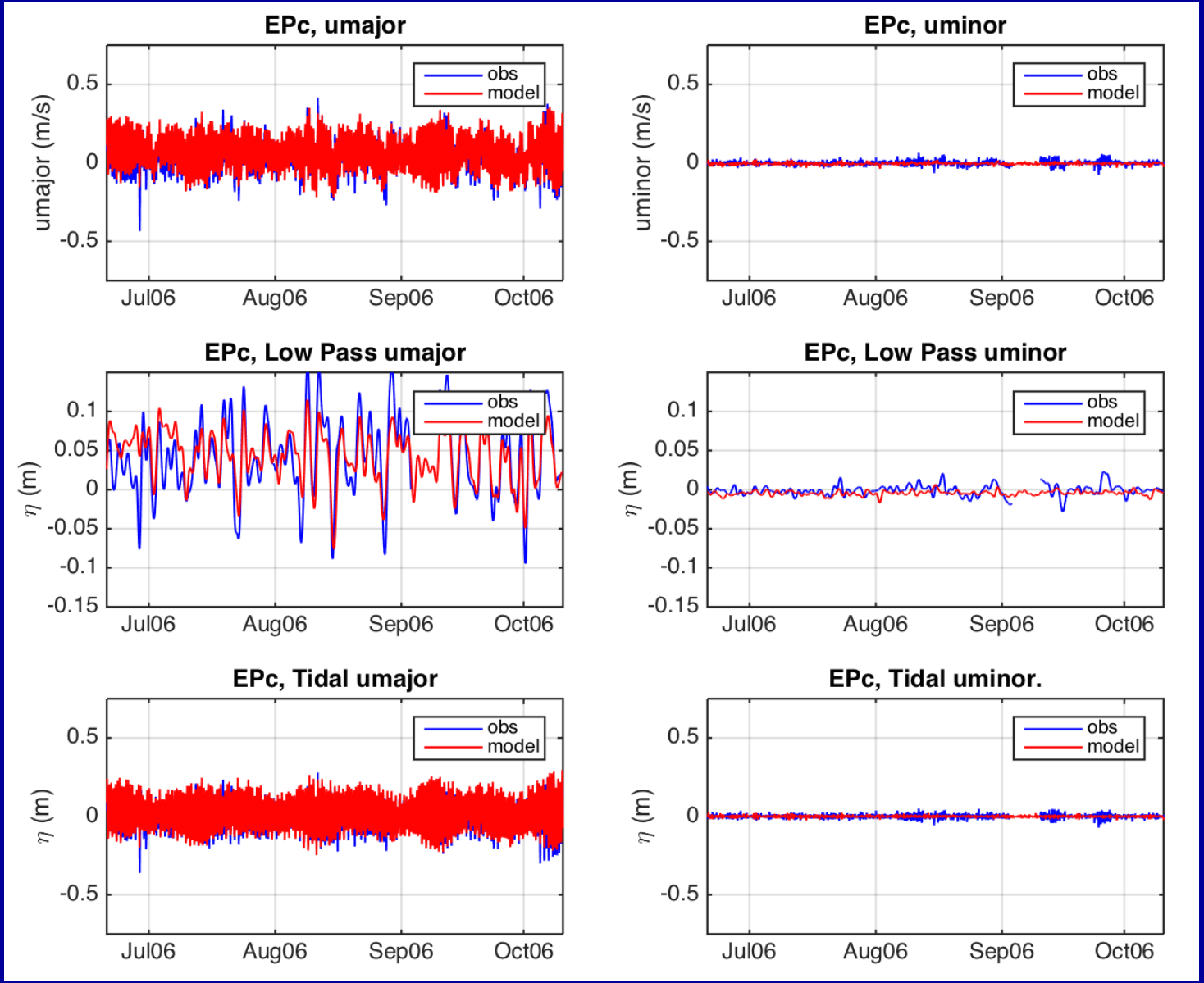
ROMS Model-Data Comparison: Depth-averaged Current at EP Channel (2006)

Skill (major axis current)

Raw: 0.894

Subtidal: 0.846

Tidal: 0.906



Model Skill: Depth-Averaged Major Axis Currents 2006-07

Skill Definition:

$$Skill = 1 - \frac{\sum_{i=1}^{N}(T_{mod} - T_{obs})^2}{\sum_{i=1}^{N}(|T_{mod} - \overline{T_{obs}}| + |T_{obs} - \overline{T_{obs}}|)^2}$$

Site	year	Site ID	Raw	Subtidal	Tidal
West Passage Channel	2006	WP	0.812	0.724	0.812
East Passage Channel	2006	EPc	0.894	0.846	0.906
East Passage Shoal	2006	EPs	0.832	0.512	0.876
East Passage Channel	2007	EP07	0.865	0.737	0.869
Between Prudence and Conanicut Islands	2007	MD07E	0.932	0.617	0.938

Evaluation of Model Skill (Hydrography)

- For *T*, *S*, Δρ compute the mean difference (bias) at each location and then examine skill of demeaned variables (fluctuations about the mean).

$$Bias = \frac{1}{N}\sum_{i=1}^{N} T_{mod} - \frac{1}{N}\sum_{i=1}^{N} T_{obs}$$

Mean of Model - Mean of Obs.

$$T'_{mod} = T_{mod} - \frac{1}{N}\sum_{i=1}^{N} T_{mod}$$

$$T'_{obs} = T_{obs} - \frac{1}{N}\sum_{i=1}^{N} T_{obs}$$

- Use Taylor Diagram as visual aid in evaluating model.

ROMS Model-Data Comparison: T/S at Conimicut

Bias

Tsurf: -0.6 C

Tbott: -0.7 C

Ssurf: 0.3

Sbott: -0.2

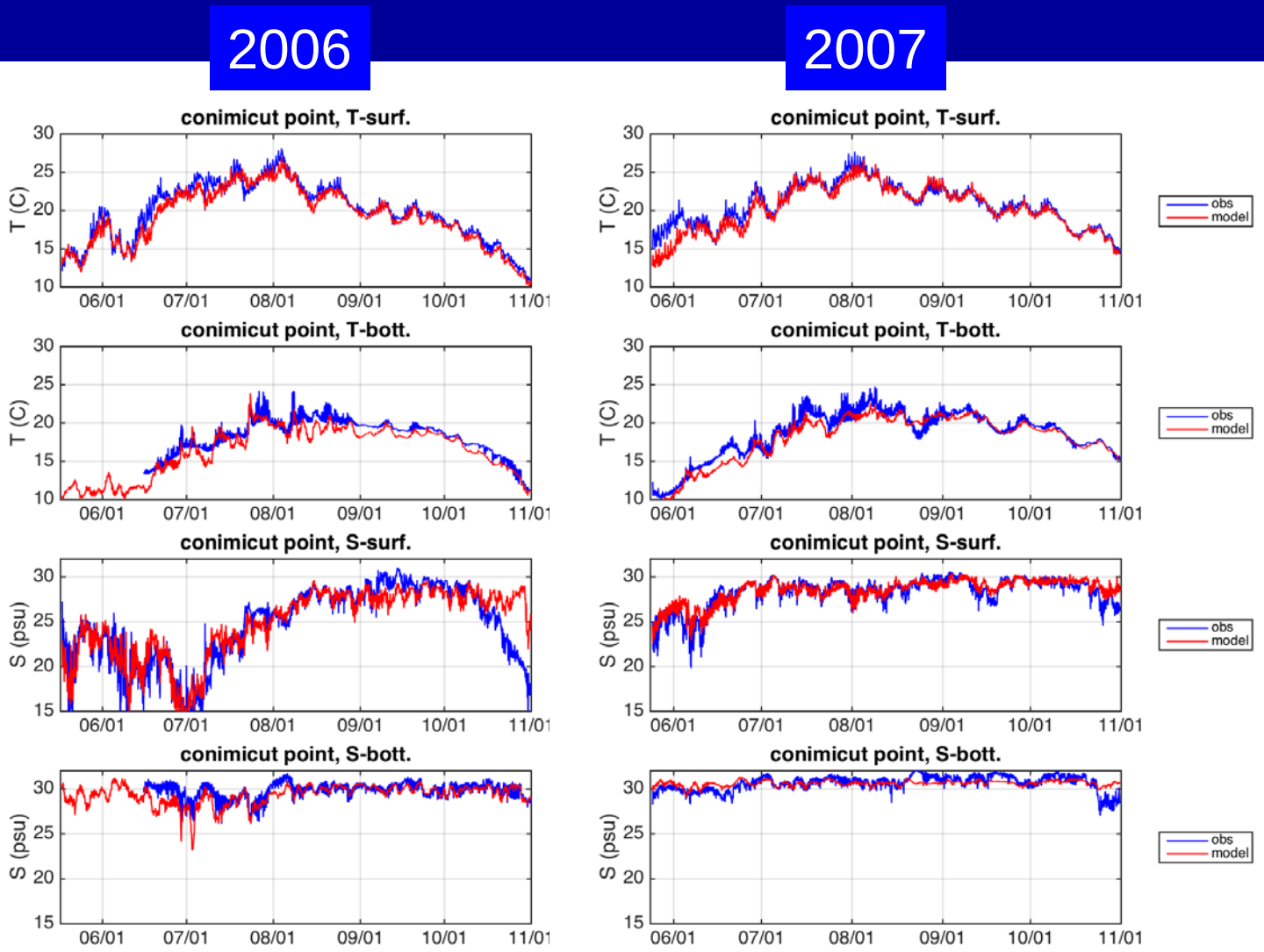
Skill

Tsurf: 0.98

Tbott: 0.98

Ssurf: 0.95

Sbott: 0.81



ROMS Model-Data Comparison: T/S at Bullock

Bias

Tsurf: -0.9 C

Tbott: 0.5 C

Ssurf: -0.2

Sbott: -2.5

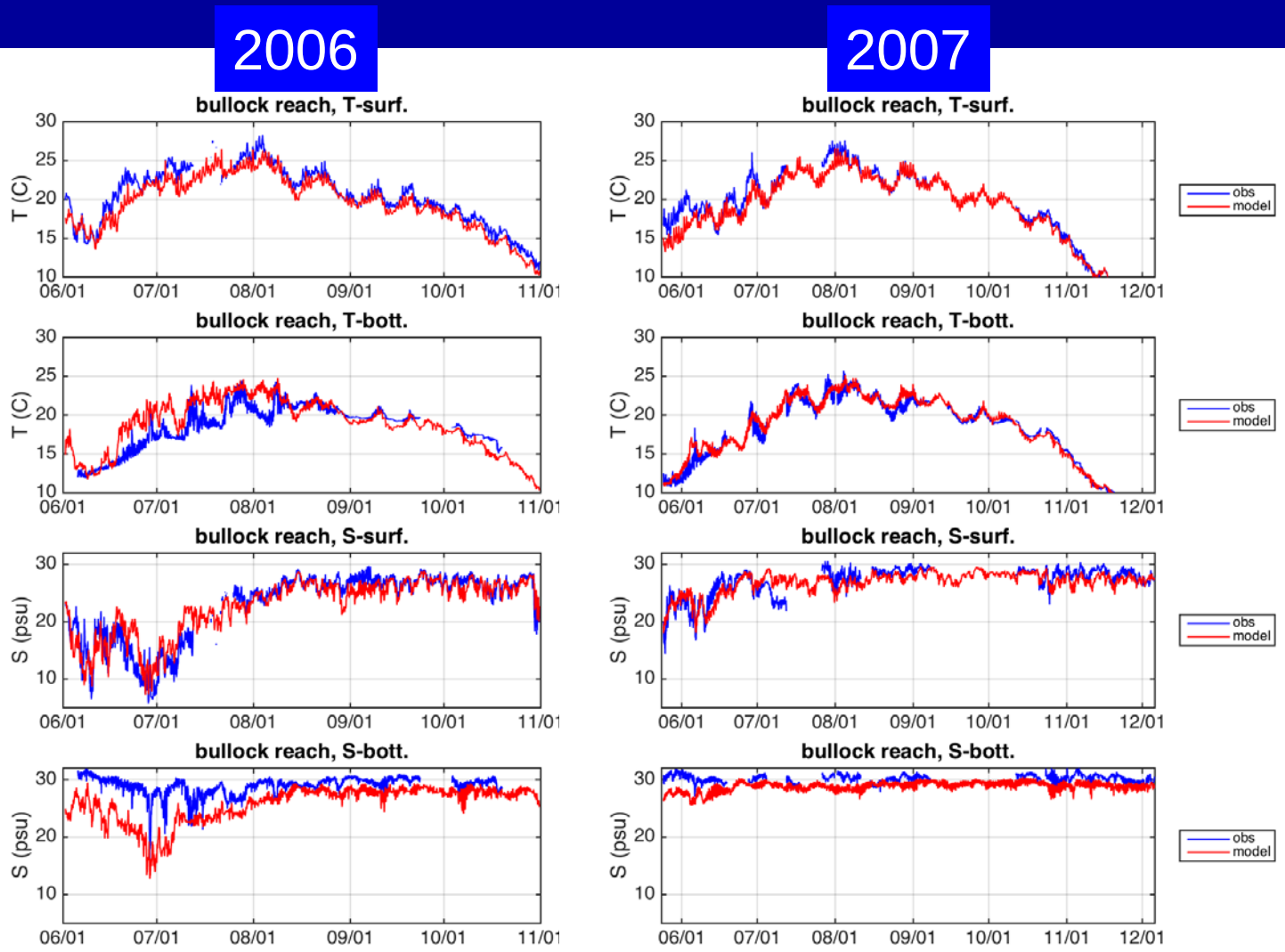
Skill

Tsurf: 0.99

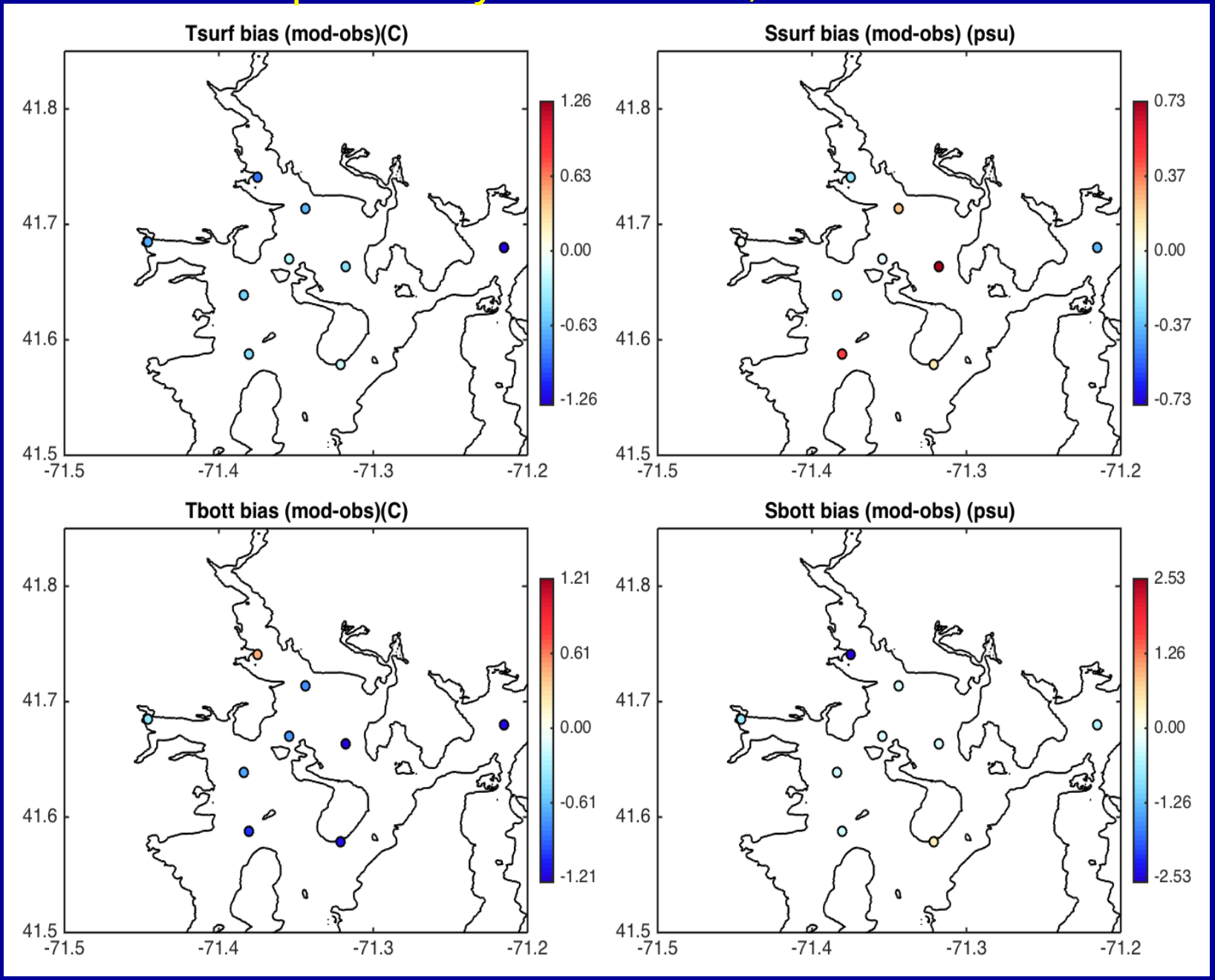
Tbott: 0.97

Ssurf: 0.95

Sbott: 0.68



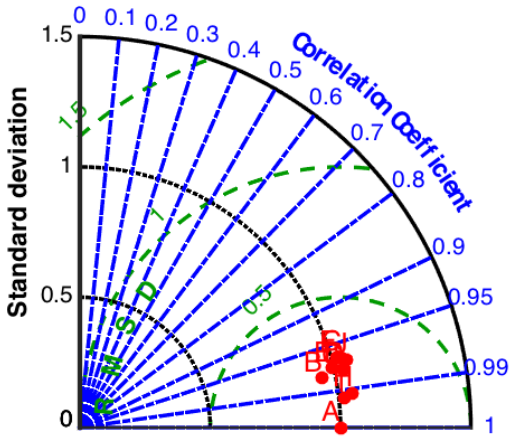
Temp./Salinity Model Bias, 2006-2007



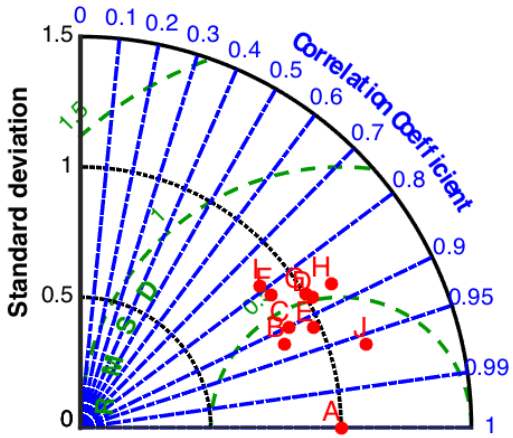
Taylor Diagrams, 2006-2007

A = observations
B = Bullock
C = Conimicut
D = North Prudence
E = Mount View
F = Quonset
G = Popasquash
H = T-Wharf
I = Greenwich Bay
J = Mount Hope Bay

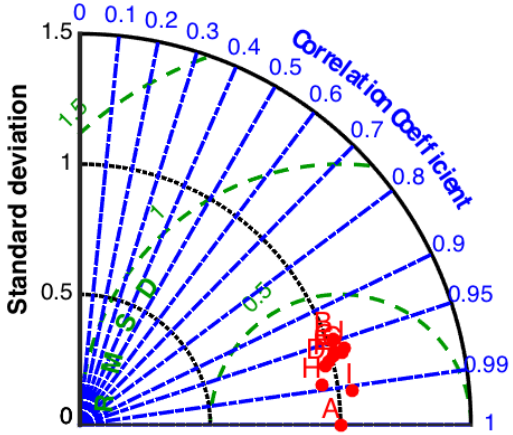
Tsurf



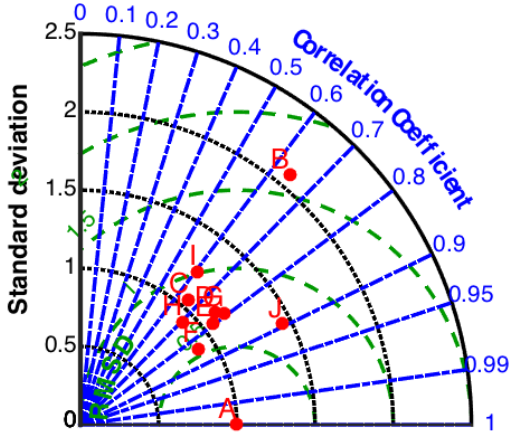
Ssurf



Tbott



Sbott



Model Skill: Hydrography 2006-07

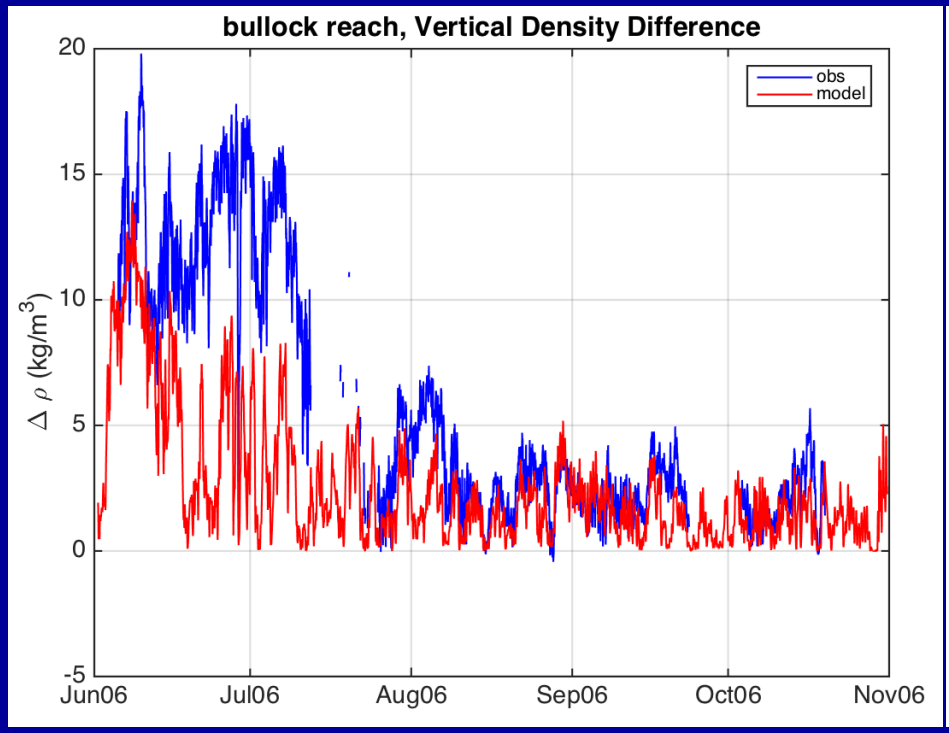
Skill Definition:

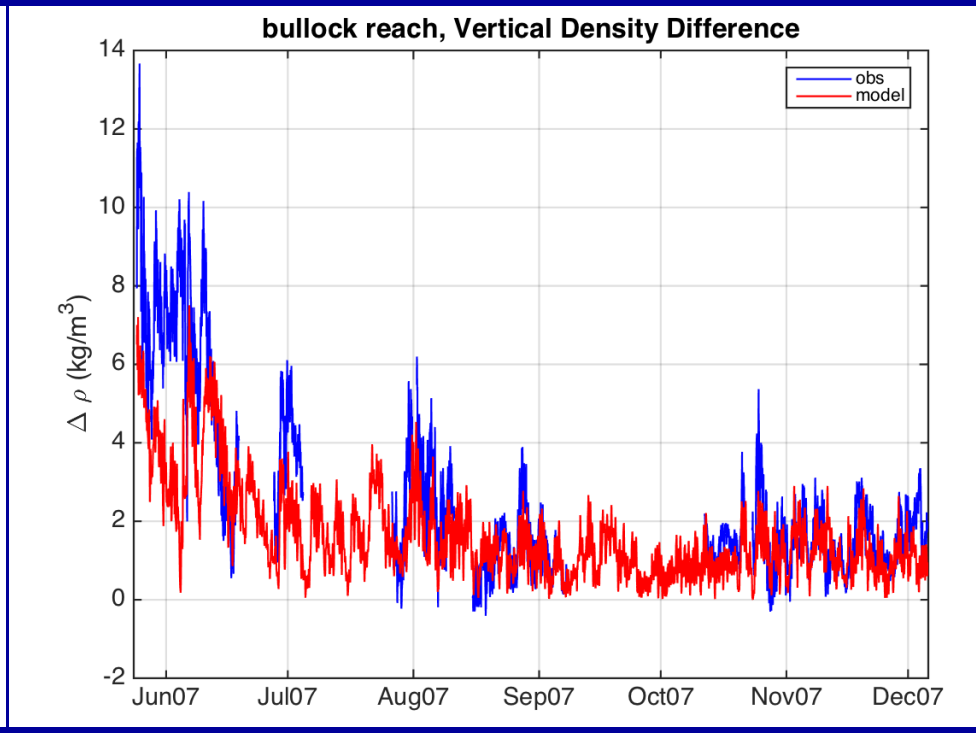
$$Skill = 1 - \frac{\sum_{i=1}^{N}(T_{mod} - T_{obs})^2}{\sum_{i=1}^{N}(|T_{mod} - \overline{T_{obs}}| + |T_{obs} - \overline{T_{obs}}|)^2}$$

Site	Tsurf	Tbott	Ssurf	Sbott
Bullock	0.99	0.97	0.95	0.68
Conimicut	0.98	0.98	0.95	0.81
North Prudence	0.99	0.99	0.93	0.87
Mount View	0.99	0.98	0.96	0.89
Quonset	0.98	0.98	0.90	0.91
Popasquash	0.99	0.98	0.93	0.88
T-Wharf	0.99	0.99	0.93	0.83
Greenwich Bay	0.99	0.99	0.88	0.77
Mount Hope Bay	0.98	0.98	0.97	0.91

ROMS Model-Data Comparison: Vertical Density Difference at Bullock, 2006-2007

$$\Delta\rho = \rho_{bott} - \rho_{surf}$$



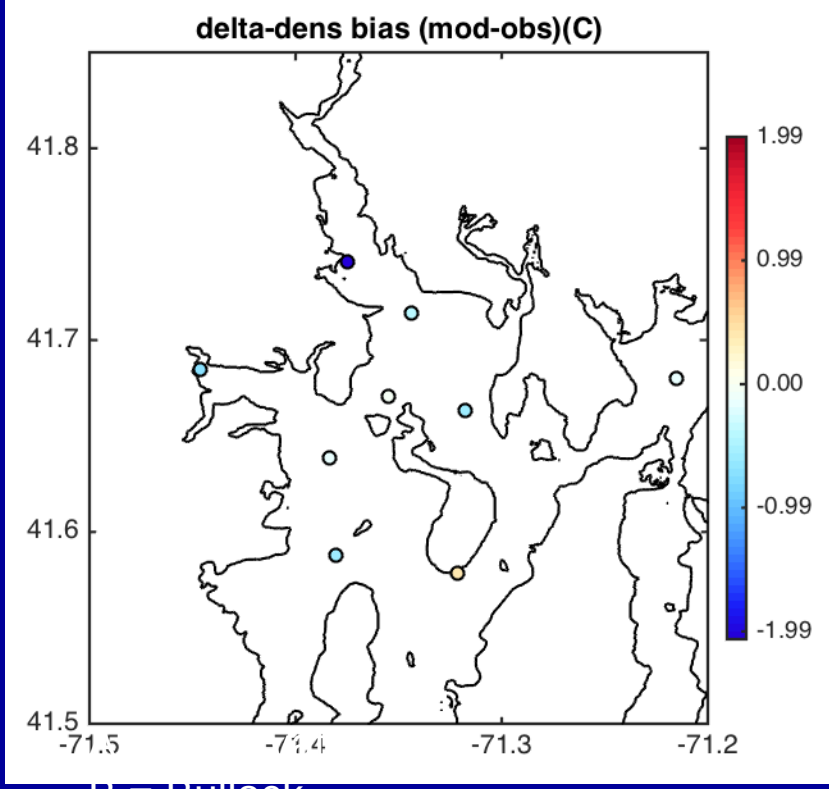


Bias = -2 kg/m^3

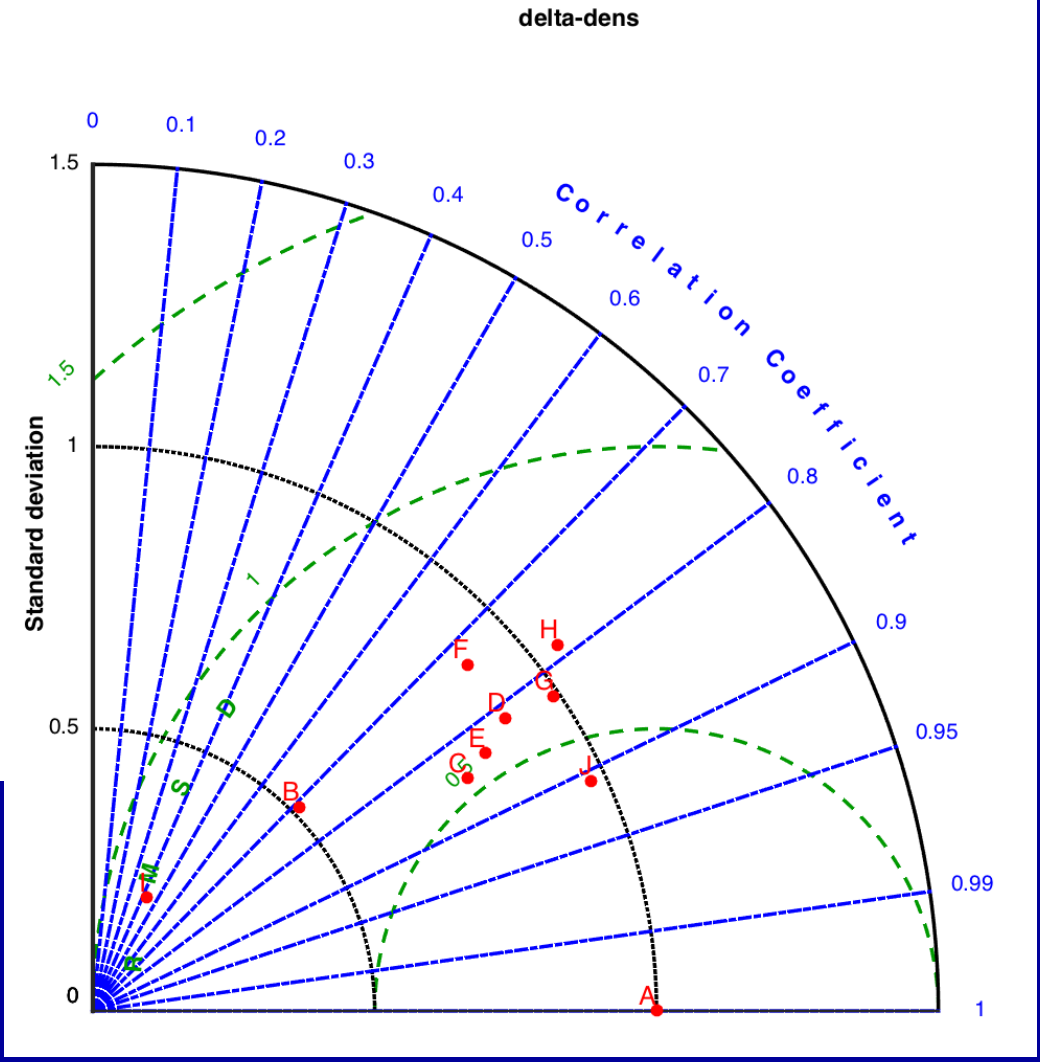
Skill = 0.75

Vertical Density Difference, 2006-2007

Bias



Taylor Diagram



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J = Mount Hope Bay

Model Skill: Vertical Density Difference 2006-07

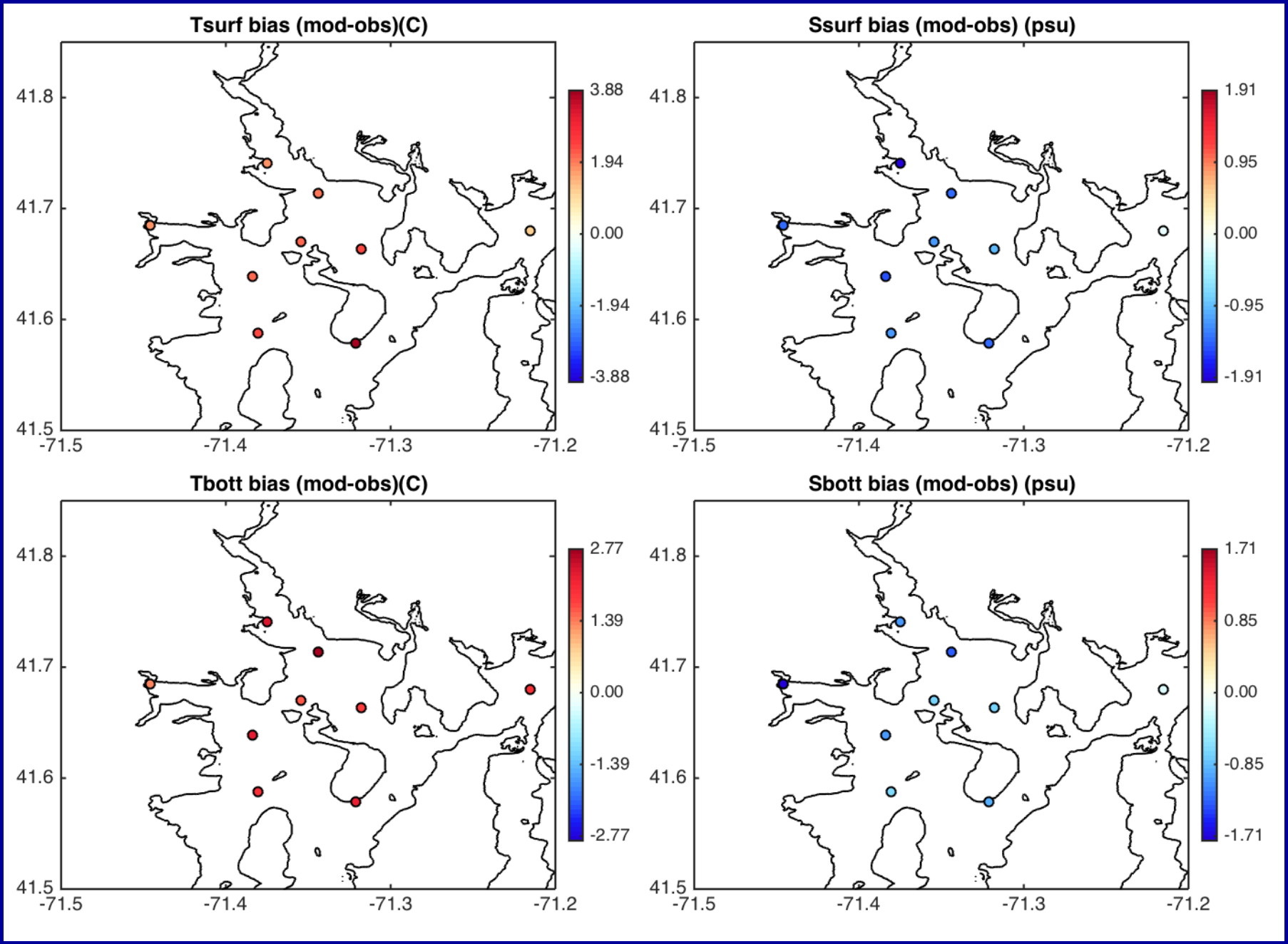
Skill Definition:

$$Skill = 1 - \frac{\sum_{i=1}^{N}(T_{mod} - T_{obs})^2}{\sum_{i=1}^{N}(|T_{mod} - \overline{T_{obs}}| + |T_{obs} - \overline{T_{obs}}|)^2}$$

Site	Skill (vertical density diff.)
Bullock	0.75
Conimicut	0.91
North Prudence	0.90
Mount View	0.90
Quonset	0.86
Popasquash	0.91
T-wharf	0.88
Greenwich Bay	0.36
Mount Hope Bay	0.95

2010 Hydrography Model Evaluation

Model Bias, Temperature/Salinity 2010



Taylor Diagrams, Temperature/Salinity 2010

A = observations
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H = T-Wharf
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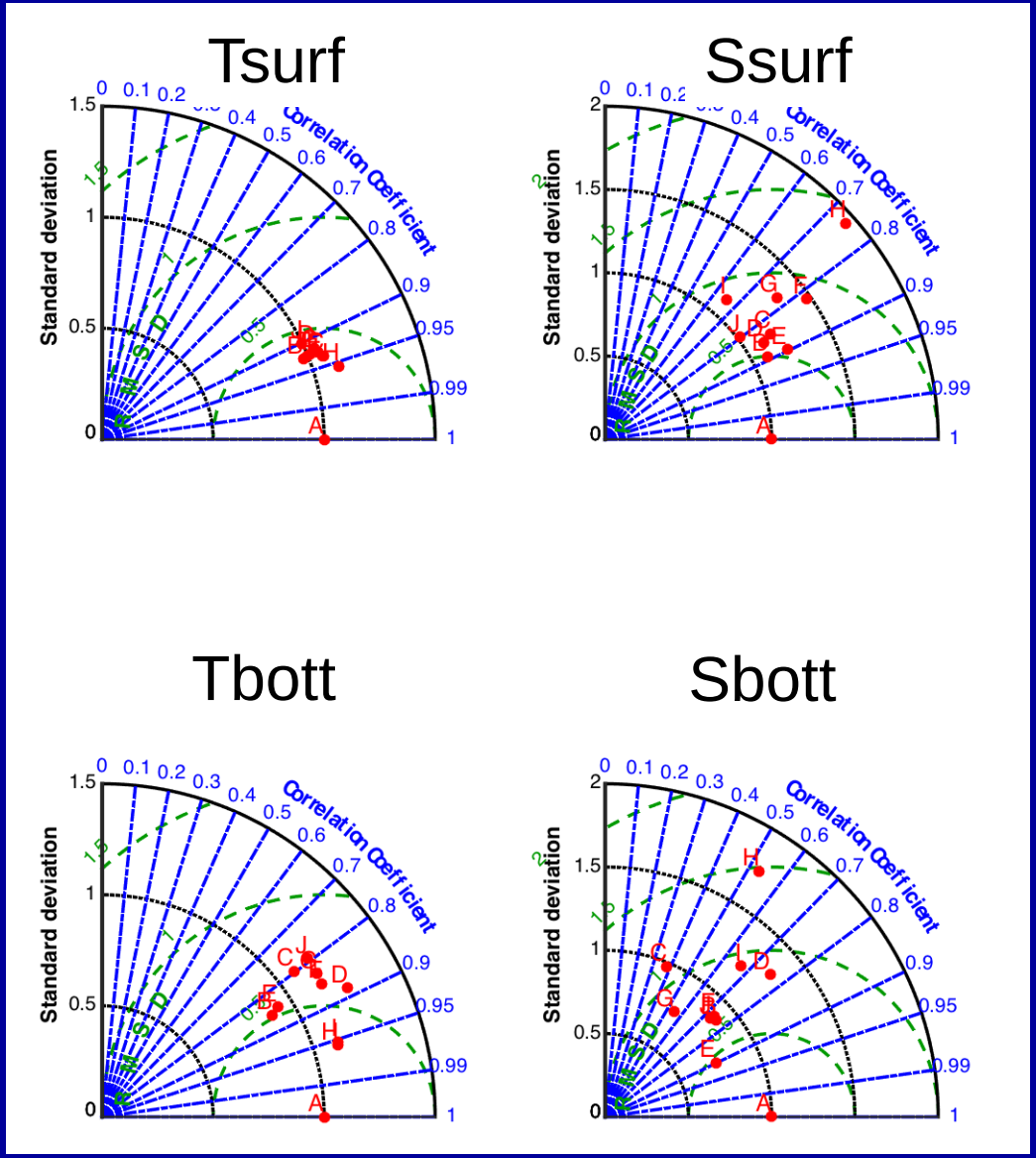


Model Skill: Hydrography 2010

Skill Definition:

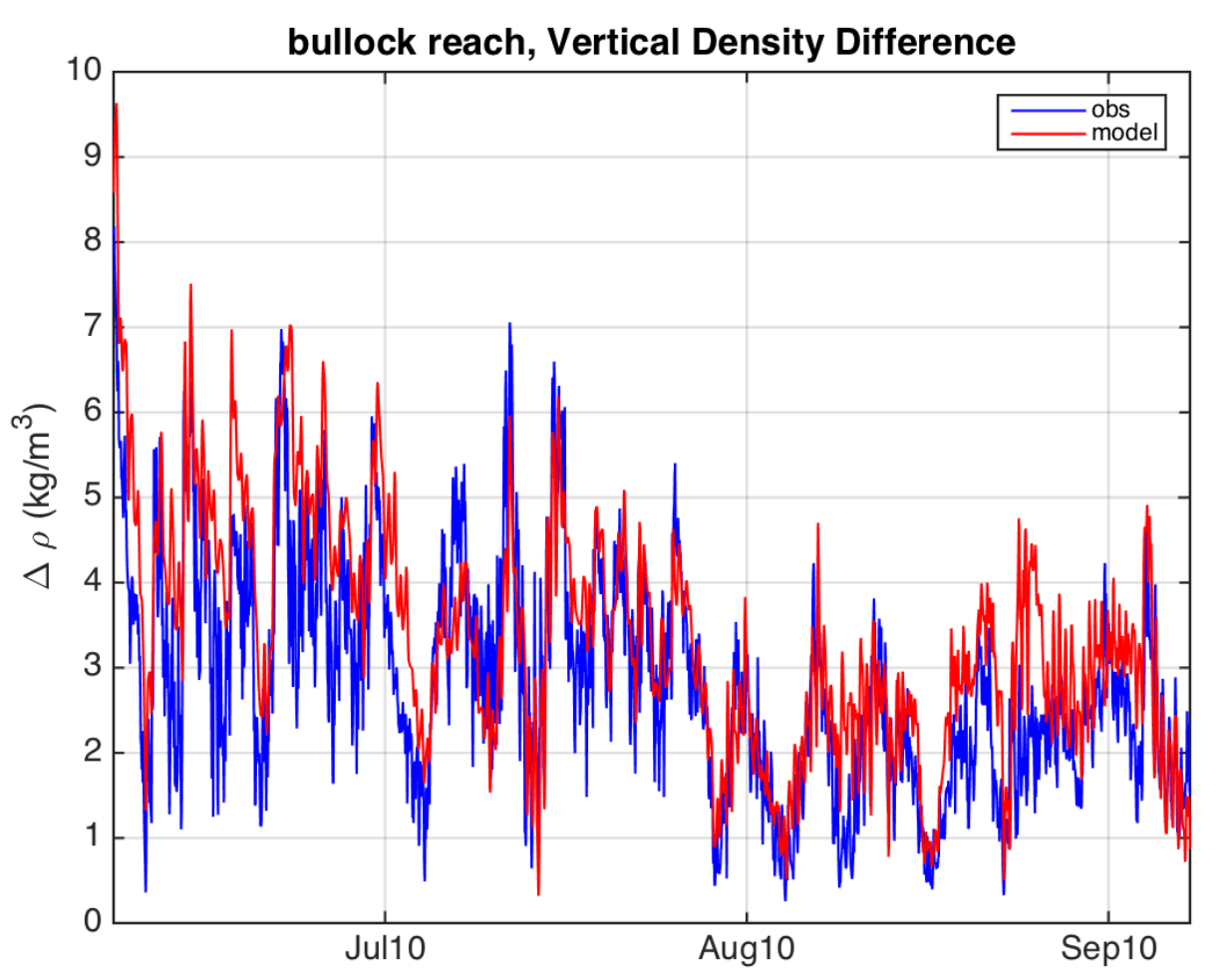
$$Skill = 1 - \frac{\sum_{i=1}^{N}(T_{mod} - T_{obs})^2}{\sum_{i=1}^{N}(|T_{mod} - \overline{T_{obs}}| + |T_{obs} - \overline{T_{obs}}|)^2}$$

Site	Tsurf	Tbott	Ssurf	Sbott
Bullock	0.96	0.92	0.94	0.86
Conimicut	0.97	0.89	0.91	0.65
North Prudence	0.96	0.93	0.92	0.86
Mount View	0.97	0.92	0.94	0.93
Quonset	0.96	0.92	0.87	0.85
Popasquash	0.96	0.90	0.86	0.73
T-Wharf	0.97	0.98	0.76	0.67
Greenwich Bay	0.96	0.97	0.80	0.80
Mount Hope Bay	0.95	0.88	0.89	0.85

ROMS Model-Data Comparison: Vertical Density Difference at Bullock, 2010

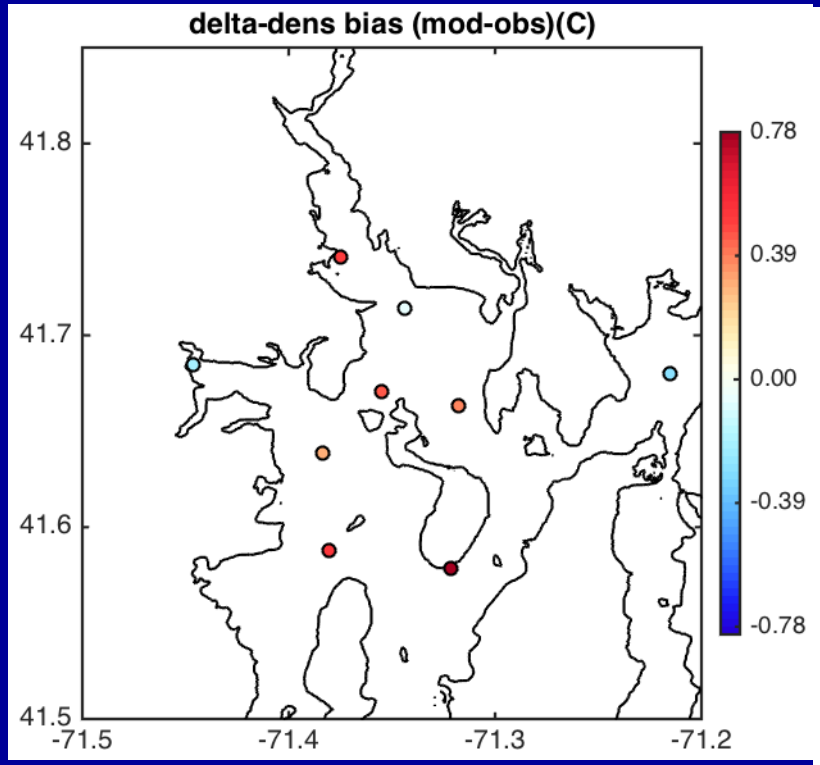
$$\Delta\rho = \rho_{bott} - \rho_{surf}$$

Bias = 0.5 kg/m^3
Skill = 0.89



Vertical Density Difference, 2010

Bias



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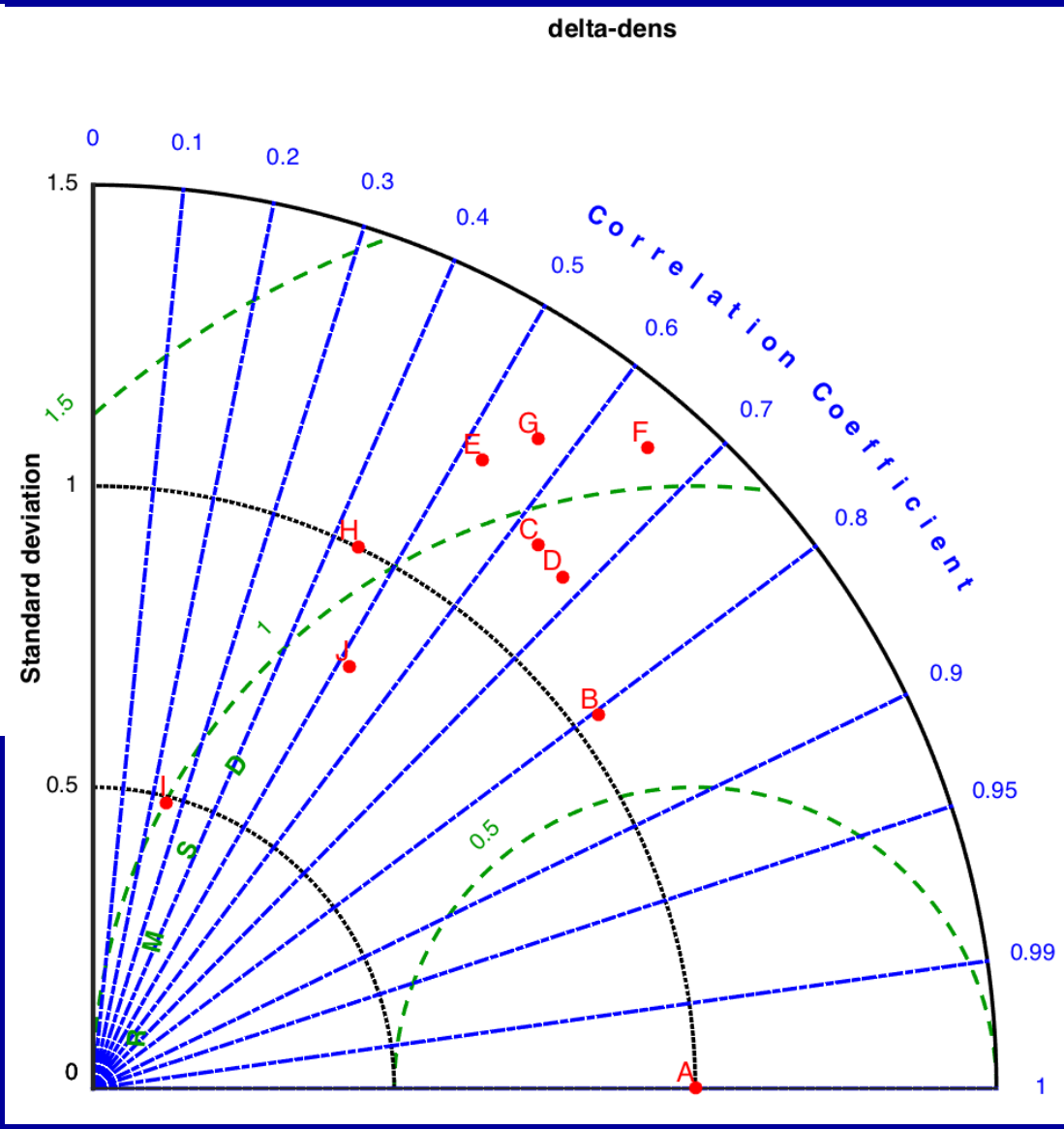
Taylor Diagram



Model Skill: Vertical Density Difference 2010

Skill Definition:

$$Skill = 1 - \frac{\sum_{i=1}^{N}(T_{mod} - T_{obs})^2}{\sum_{i=1}^{N}(|T_{mod} - \overline{T_{obs}}| + |T_{obs} - \overline{T_{obs}}|)^2}$$

Site	Skill (vertical density diff.)
Bullock	0.89
Conimicut	0.79
North Prudence	0.81
Mount View	0.72
Quonset	0.78
Popasquash	0.73
T-wharf	0.66
Greenwich Bay	0.47
Mount Hope Bay	0.71

Model Skill Assessment, Summary

Sea Level and Currents

Tidal timescales:

- Elevation skills > 0.9
- Current skills > 0.8
- Slight under-prediction of tides.

Subtidal timescales:

- Elevation skills > 0.8
- Current skills > 0.6 (except at EPs s~0.5)
- Subtidal fluctuations under-predicted.

Hydrography and Stratification

- Temperature generally simulated well.
  - Significant bias (1-3 deg) during some years.
  - Skills generally > 0.9.
- Model performance for salinity more variable (spatially).
  - Biases of 1-3 psu at some sites.
  - Skills > 0.65.
- Density stratification simulated well at some sites/fair at others.
  - Skill generally > 0.7
  - Model underestimates stratification during high discharge.

Model Skill Assessment, Summary

- Model provides a reasonably accurate simulation of time variable circulation and hydrography.

- Iterative process underway to improve model fidelity:
  - Need to prescribe vertical structure of river inflows?
  - Background vertical mixing too high?
  - Problems with Bay mouth boundary conditions?