Using High Quality SST Products to determine Physical Processes Contributing to SST Anomalies

A First Step

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November 8, 2010
Methodology

Goal: to determine which physical processes are important in controlling SST in different areas of the North Atlantic.

First step: How much influence does surface forcing have on interannual SST anomalies?

Run 1-d vertical ocean model
  • Surface forcing of heat, freshwater and stress
  • Include horizontal geostrophic and Ekman advection
Model Domain

- North Atlantic ocean
- 1 degree grid
- Daily fields
- 1500 m deep

March mean SST from Observations
Price, Weller, Pinkel
1-d Ocean Model

1500 m

Temperature profile

Salinity profile

Climatology

Density profile

Price, et al. 1986
Price, Weller, Pinkel
1-d Ocean Model

- Short and longwave fluxes
- Stress
- Turbulent heat flux
- Freshwater (P-E) flux
- Temperature profile
- Salinity profile
- Density profile
- SST obs
- 1500 m
- 1500 m
Price, Weller, Pinkel
1-d Ocean Model

Short and longwave fluxes

Freshwater (P-E) flux

Stress

Turbulent heat flux

1500 m

Temperature profile

Salinity profile

Density profile

Vertical mixing:
• static instability

SST obs
Price, Weller, Pinkel

1-d Ocean Model

- Short and longwave fluxes
- Turbulent heat flux
- Freshwater (P-E) flux
- Stress

Temperature profile
Salinity profile
Density profile

Vertical mixing:
- static instability
- wind mixing

1500 m

* SST obs
Price, Weller, Pinkel
1-d Ocean Model

- Short and longwave fluxes
- Turbulent heat flux
- Freshwater (salt) flux
- Stress
- Temperature profile
- Salinity profile
- Vertical mixing:
  - static instability
  - wind mixing
  - vertical advection
  - vertical diffusion
- Density profile
- 1500 m

• SST obs
Data Sets

- Temperature, Salinity profiles - WOA 2009
- SST - NOAA OI with microwave
- Wind stress, Curl - QuikSCAT winds
- Turbulent heat flux - OAFlux
- Radiant heat flux - ISCCP
- Freshwater flux
  - Precipitation - GPCP
  - Evaporation - OAFlux

Time Period of data overlap: 2003 - 2007
Experiments

*Surface forcing only, no advection*

- Climatological runs
  - 1 year
  - climatological fields

- Continual run
  - 5 years
  - actual data fields
  - relax to monthly climatological temperature and salinity profiles, temperature profile modified by observed SST
Climatological Run
Baseline

Gulf Stream: missing temperature advection

Labrador Current: missing salinity advection

Southeast: lacking some of both temperature and salinity advection

RMS SST Error
Calculate heat deficit

Heat = \sum \left[ (T_{\text{mod}} - T_{\text{clim}}) \cdot dh \right] \cdot \rho \cdot c_p \cdot \text{time} \quad \text{W/m}^2
Calculate heat deficit

Heat = \sum [(T_{\text{mod}} - T_{\text{clim}}) \times dh] \times \rho \times c_p / \text{time} \quad \text{W/m}^2

Observations
Model

Missing heat
Calculate heat deficit

Heat = \sum [(T_{\text{mod}} - T_{\text{clim}}) \times dh] \times \rho \times c_p / \text{time} \quad \text{W/m}^2
Calculate freshwater deficit

$$\text{Freshwater} = \sum \left[ (1 - \frac{S_{\text{mod}}}{S_{\text{clim}}}) \times dh \right] / \text{time} \quad \text{cm/yr}$$
Calculate freshwater deficit

$$\text{Freshwater} = \sum \left[ (1 - \frac{S_{\text{mod}}}{S_{\text{clim}}}) \times dh \right] / \text{time} \quad \text{cm/yr}$$
Calculate freshwater deficit

$$\text{Freshwater} = \sum [(1-S_{\text{mod}}/S_{\text{clim}}) \times dh]/\text{time} \quad \text{cm/yr}$$

Observations
Model

Missing freshwater

Excess freshwater

Adjust freshwater flux:
+ 16 cm/yr
Heat flux

- Deficit flux

Freshwater flux
Heat flux

Freshwater flux

- Deficit flux

Annual Mean

Annual Mean: Advection balances surface flux
RMS SST Error for Climatological Runs

Run 5 cases: adjust the surface heat and/or freshwater.

½ Heat

½ Freshwater

½ Heat, ½ Freshwater

¾ Heat

¾ Freshwater

½ Heat, ½ Freshwater
Which correction gives the smallest SST Error?
Which correction gives the smallest SST Error?
RMS Error in SST for best case

Errors still large in the Gulf Stream and the Labrador Current

RMS SST Error for Baseline run
Five year run, 2003-2007

- Daily forcing fields as input
- Adjust surface fluxes with best deficit estimate of heat and/or freshwater.
- Relaxing to climatological profiles 1/month.
- Monthly means
Monthly SST time series show two types of errors:

1. Drift
2. Seasonal bias
SST Anomalies: observed (blue), modeled (red)

Removed seasonal signal and the trend
How well does surface forcing only predict interannual SST anomalies?

Skill = 1 - (error/ std dev)^2
Conclusions

Mean heat flux important in subtropical gyre and Gulf Stream.

Mean freshwater flux important in subpolar gyre.

Skill of model in predicting observations indicates that interannual anomalies in SST are not controlled by surface forcing alone.

Ocean circulation must play a part.
What’s next?

- Develop profiles of currents
- Develop profiles of gradT and gradS
- Apply advection
- Go to longer runs with inferior (?) fields
Bottom Topography, Smith and Sandwell
Mean surface currents, AVISO