



# ***Verification of NCODA Assimilation in the HYCOM 1/25<sup>th</sup> degree Gulf of Mexico Domain***

***James A. Cummings***

***Ole Martin Smedstad***

***Naval Research Laboratory  
Planning Systems Incorporated***

***10<sup>th</sup> HYCOM Consortium Meeting***

***COAPS, Florida State University, 7-9 November 2006***



# *Data Assimilation Intercomparison Study*

## **Planned at December 2005 HYCOM Meeting (RSMAS)**

Forecast Model: HYCOM

Domain: Gulf of Mexico, 1/25° resolution (~3.5 km)

Assimilation Time Period: 2004 – 2005

Atmospheric Forcing: 1° NOGAPS

Nesting: climatological boundary conditions (from 1/12° Atlantic)

River Inputs: monthly river flow

## **HYCOM Assimilation Systems**

TOPAZ, ENKF (NRL), MVOI (NCODA), ROIF, SEEK, OI (NCEP)

## **Control Run**

Free run model from 2003 – 2006 forced by 1° NOGAPS



# *Data Assimilation Intercomparison Study*

## **Intercomparison Criteria – Forecasting System**

**Skill of forecasts as compared to free run model**

**Skill of nowcasts as compared to free run model**

Performance measures of assimilation system

Skill of assimilative lateral boundary conditions for downscaling

Prediction of non-assimilated (independent) observations

Prediction Loop Current and Loop Current eddy interactions

## **Intercomparison Criteria – Oceanographic Knowledge**

Water masses at all depths

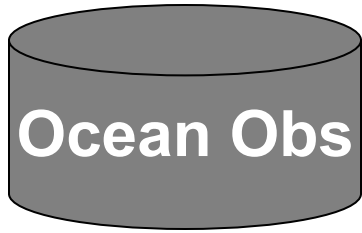
Deep circulation

Barotropic Stream Functions

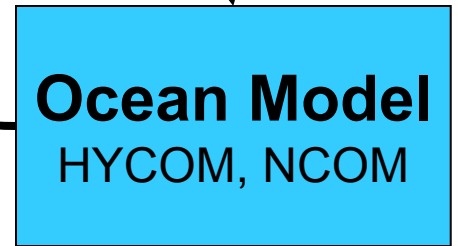
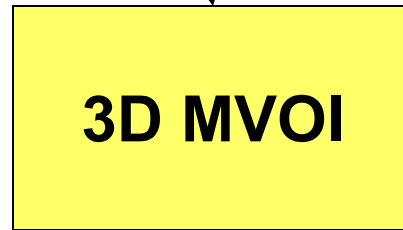
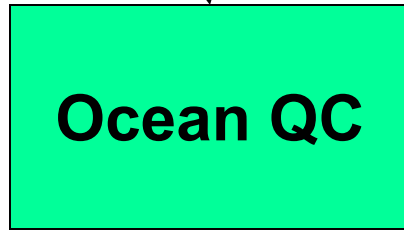
Mass and velocity structure in Yucatan and Florida Straits

# NCODA System Overview

Sequential Incremental Update Cycle  
Analysis-Forecast-Analysis



**SST:** Ship (ERI, Bucket, Hull Contact), Buoy (Fixed, Drifting), AVHRR (GAC,LAC), GOES, AATSR, MSG, AMSR-E  
**Temp/Salt Profiles:** XBT, CTD, Buoy (Fixed, Drifting), Argo Float, Gliders  
**SSH:** Altimeter, T/S profiles  
**Sea Ice:** SSM/I



Forecast Fields  
Prediction Errors

Model forecast fields and prediction errors are used in the QC of newly received ocean observations

Innovations

Increments

First Guess



# ***NCODA Implementation Data Assimilation Intercomparison Study***

## **Observations**

SST - satellite (AVHRR GAC), ship, fixed and drifting buoy

Profile – Argo Float, TESAC, XBT

Altimeter – Jason, GFO, ENVISAT

Synthetics – temperature/salinity profiles from assimilation of altimeter SSH data using Cooper-Haines vertical projection technique

## **Assimilation**

24-hour update cycle – 2 Sep 2003 through 1 June 2006

No forecasts beyond update cycle interval

Incremental Analysis Update (IAU) procedure - increments inserted over 240 model time steps (first 12 hours of forecast)

## **Verification Statistics** – computed as daily averages by depth

OmA – observation minus analysis (residuals)

OmF – observation minus 24 forecast (innovations)

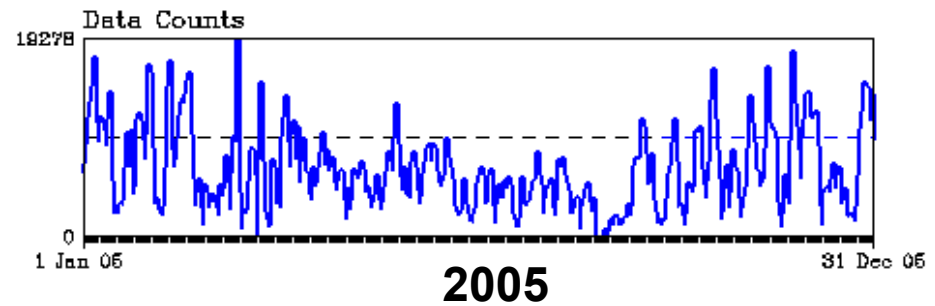
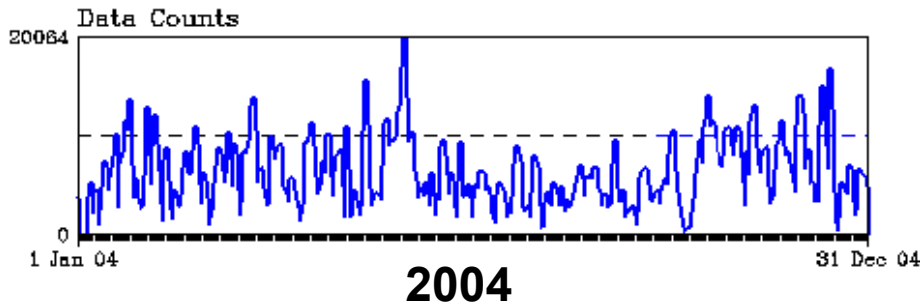
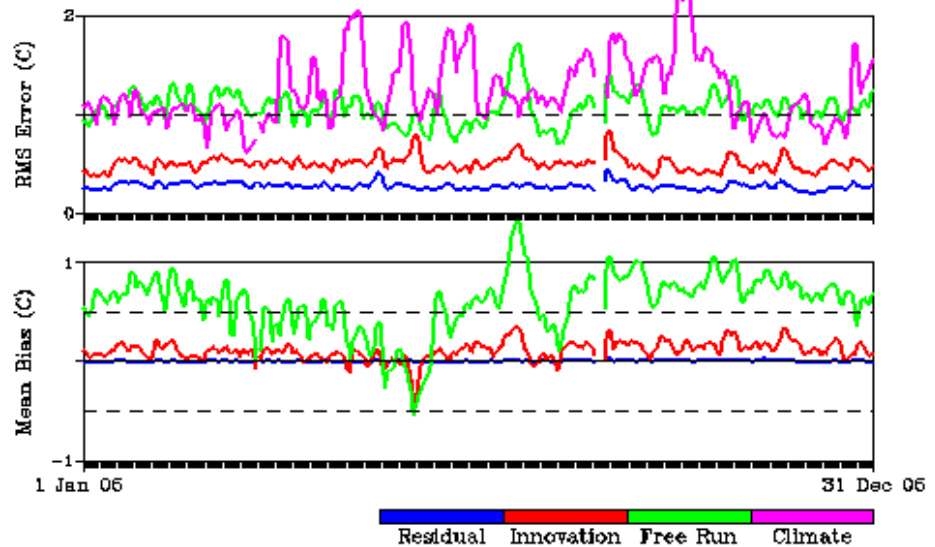
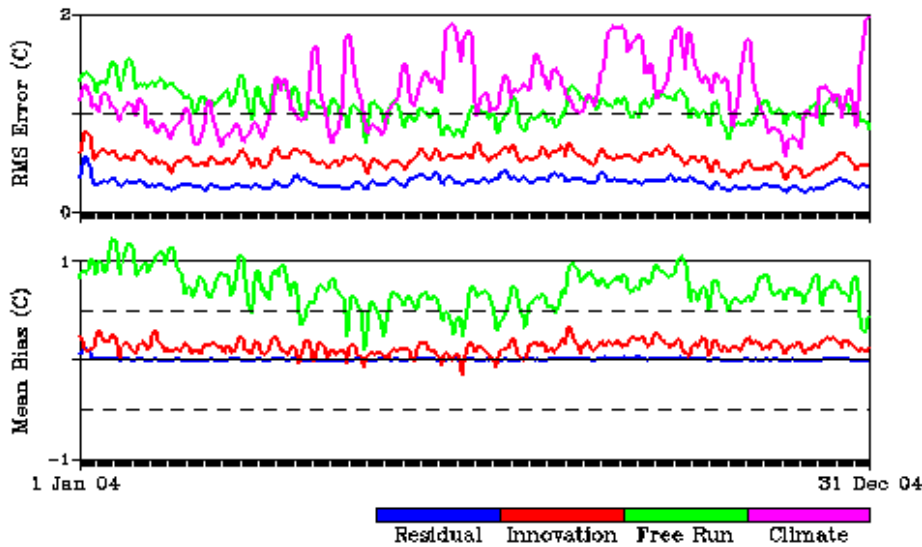
OmM – observation minus free run of model (control)

OmC – observation minus climatology (GDEM v3.0)

# Surface Temperature Validation

HYCOM 1/25 Gulf of Mexico – Surface Temperature

HYCOM 1/25 Gulf of Mexico – Surface Temperature

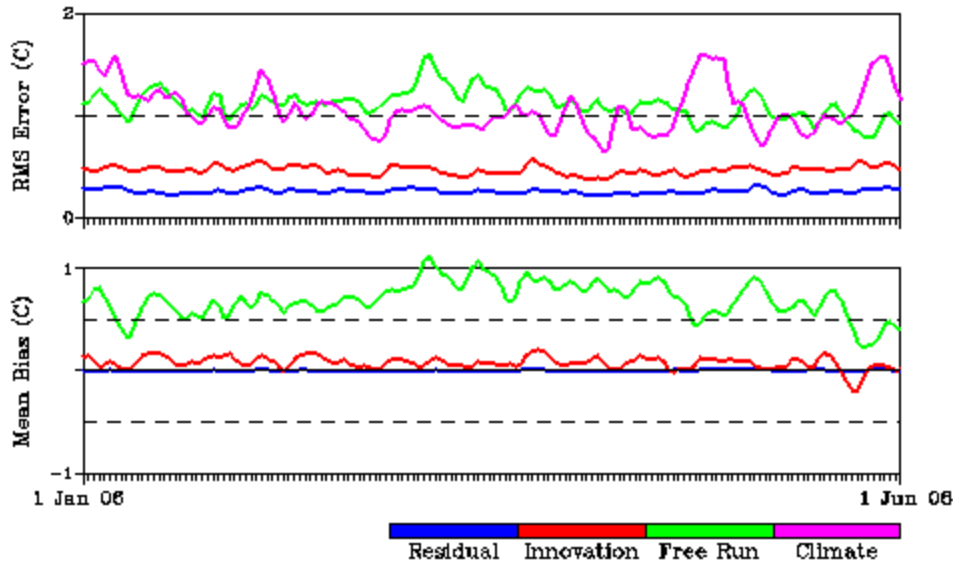


residual error	0.28	bias	0.01 °C
innovation error	0.51	bias	0.13 °C
free run error	1.06	bias	0.71 °C
climate error	1.14		°C

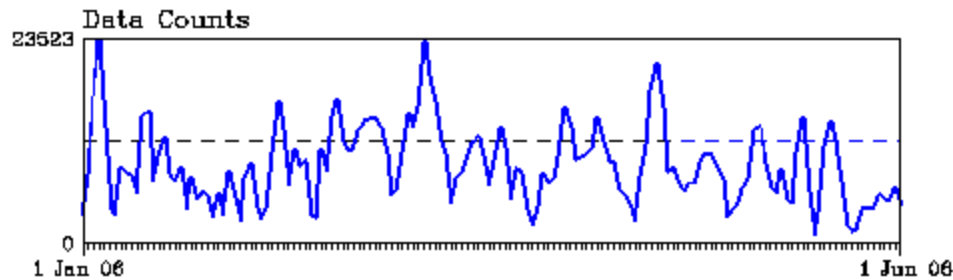
residual error	0.27	bias	0.01 °C
innovation error	0.48	bias	0.10 °C
free run error	1.06	bias	0.58 °C
climate error	1.17		°C

# Surface Temperature Validation – Jan to Jun 2006

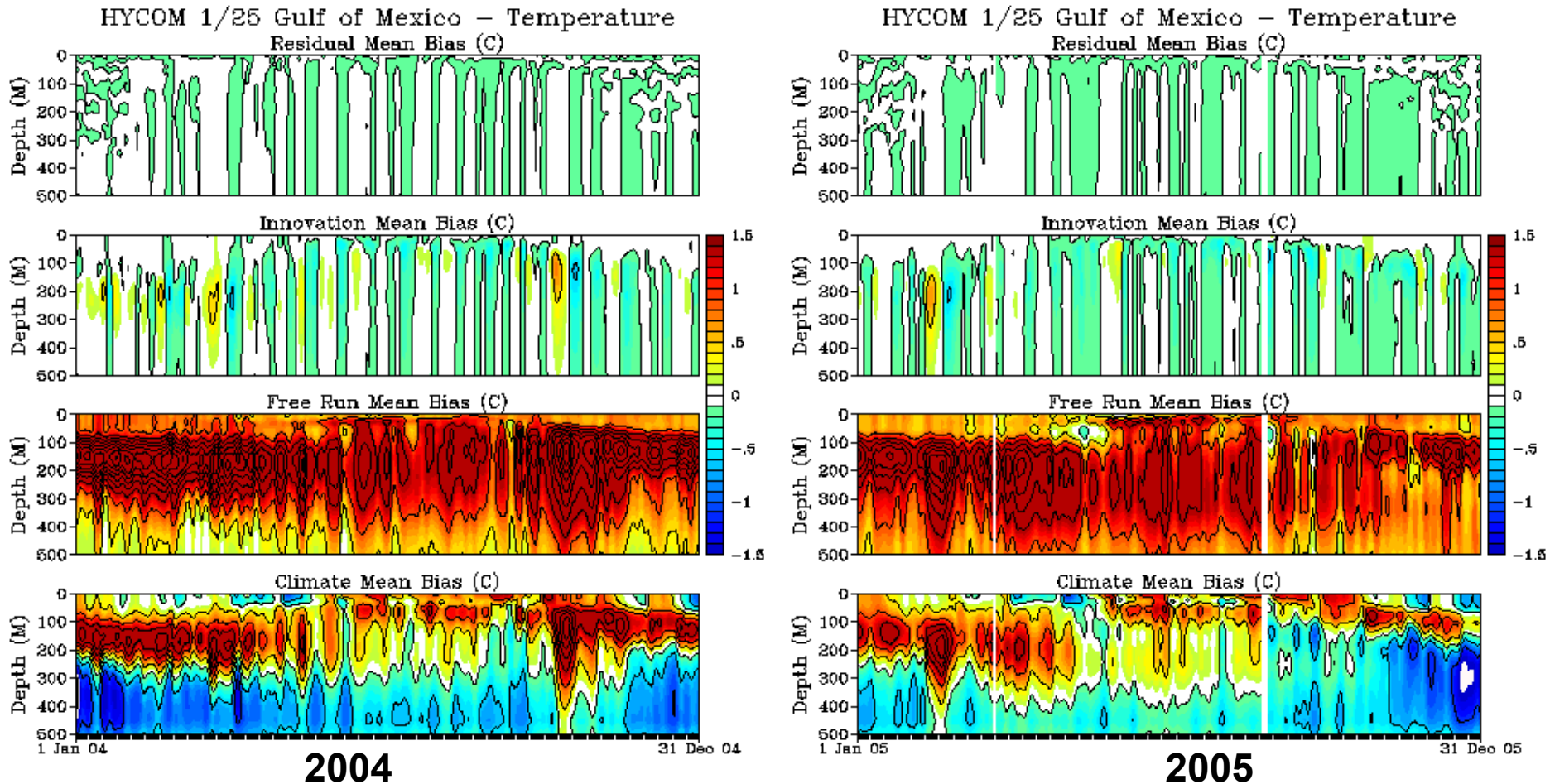
HYCOM 1/25 Gulf of Mexico – Surface Temperature



residual error	0.26	bias 0.01 °C
innovation error	0.46	bias 0.08 °C
free run error	1.15	bias 0.75 °C
climate error	1.04	



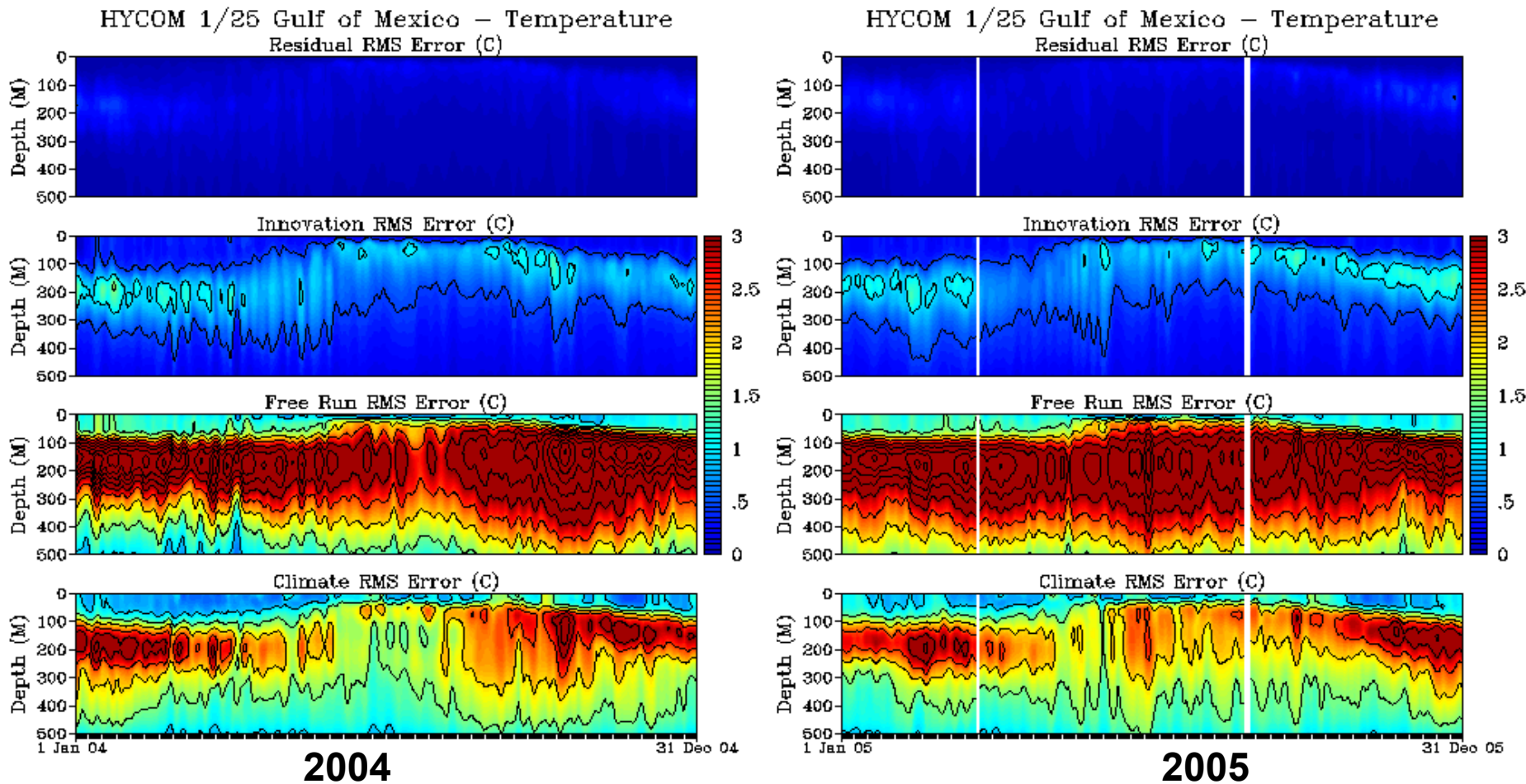
# Temperature Validation – Mean Bias



- analysis residuals biased slightly warm  $\sim 0.08$  °C
- 24-hr forecasts from assimilation run essentially unbiased  $\sim 0.1$  °C
- free running model biased very cold  $\sim 1.0$  to  $>3.0$  °C
- observations (synthetics) biased warm and cold relative to climatology



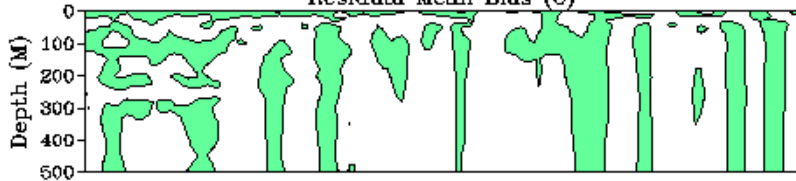
# Temperature Validation – RMS Error



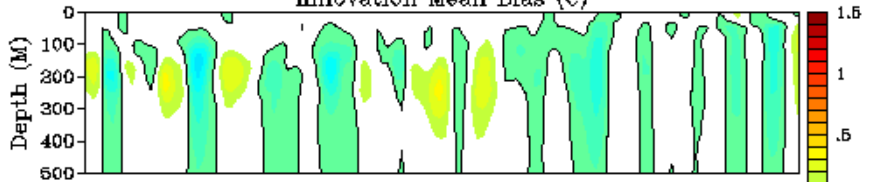
- residual errors very low  $\sim 0.3$  °C
- innovations errors concentrated in thermocline
- free running model errors very large  $\sim 1.0$  to  $>4.0$  °C

# Temperature Validation – Jan to Jun 2006

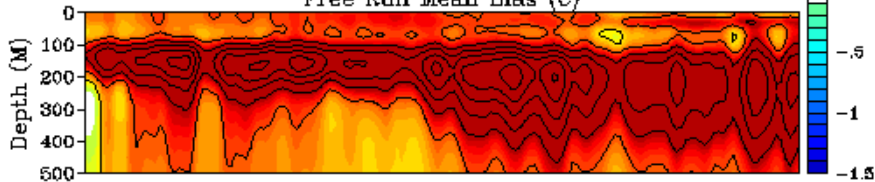
HYCOM 1/25 Gulf of Mexico – Temperature  
Residual Mean Bias (C)



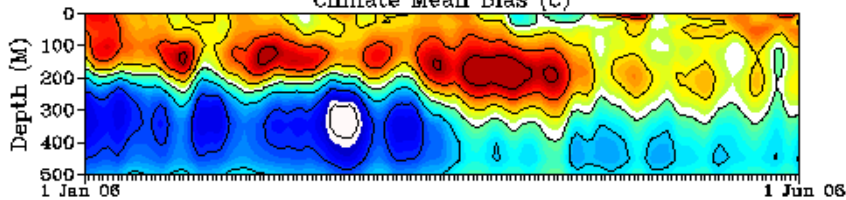
Innovation Mean Bias (C)



Free Run Mean Bias (C)



Climate Mean Bias (C)

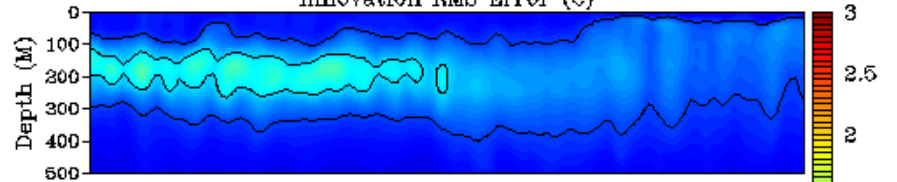


Mean Bias

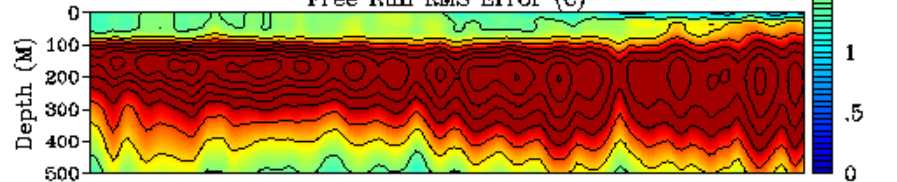
HYCOM 1/25 Gulf of Mexico – Temperature  
Residual RMS Error (C)



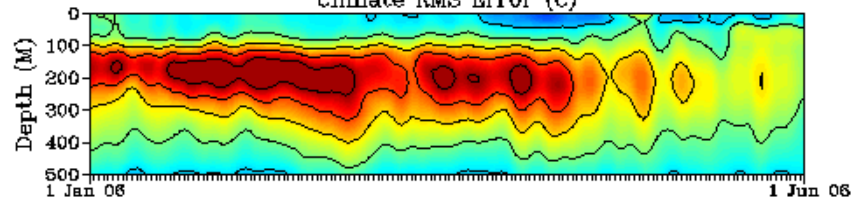
Innovation RMS Error (C)



Free Run RMS Error (C)



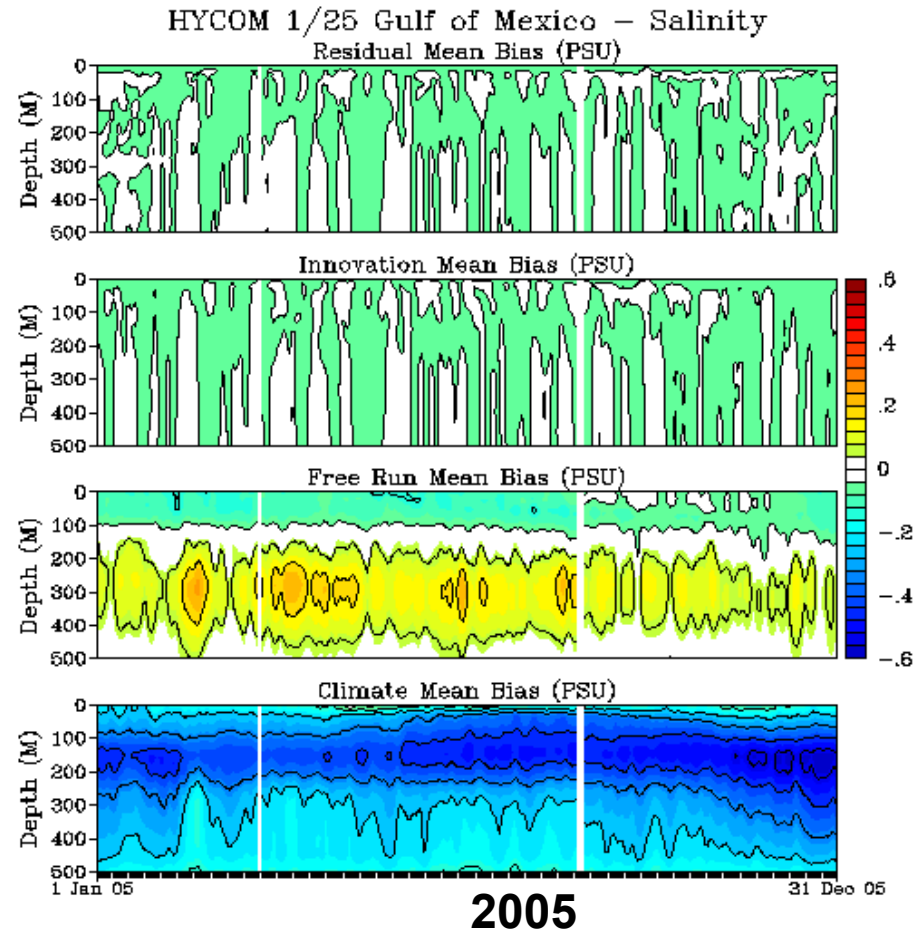
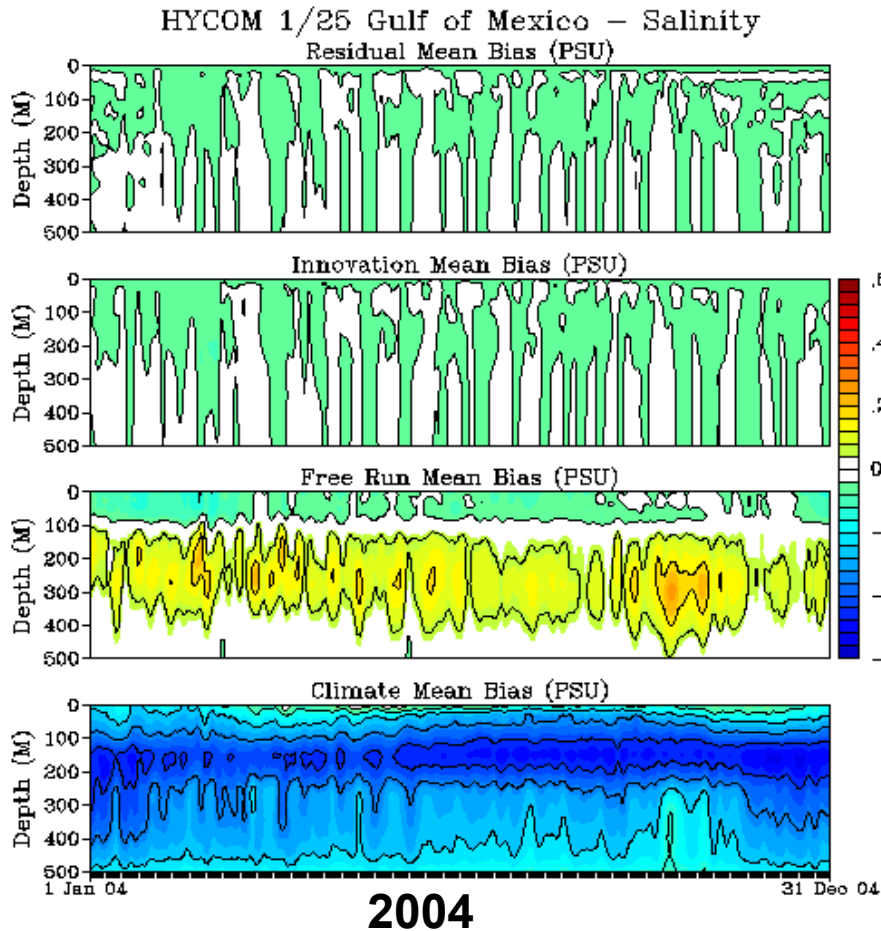
Climate RMS Error (C)



RMS Error

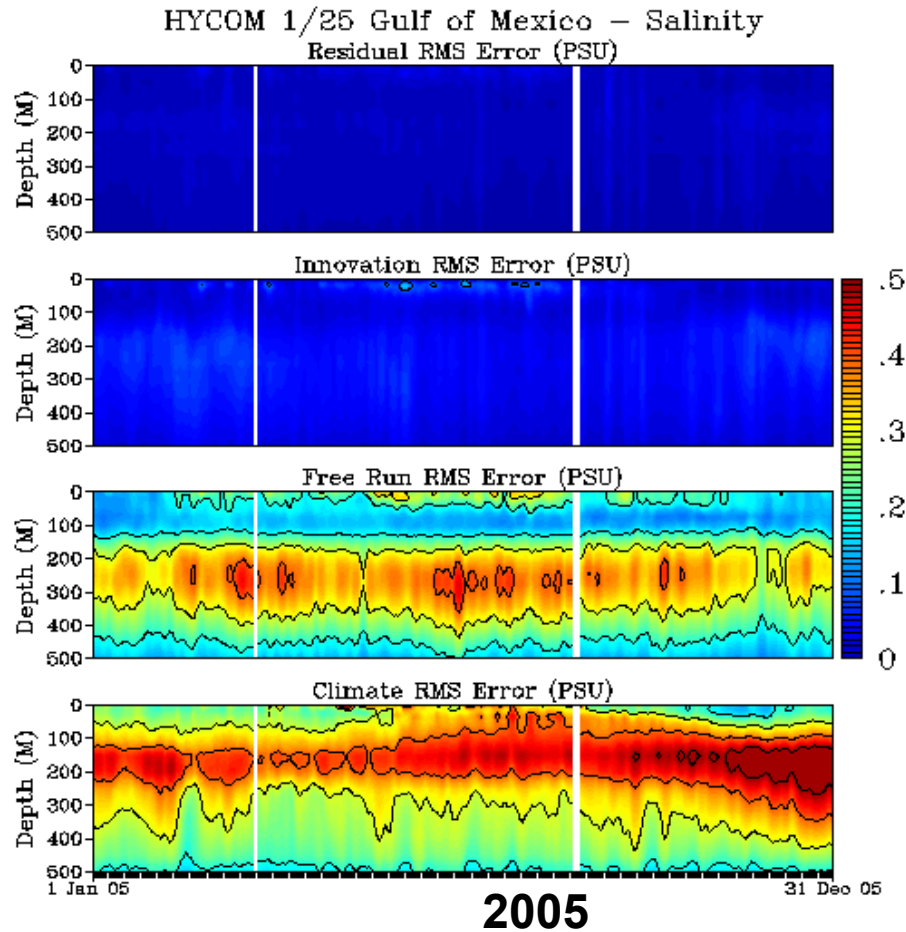
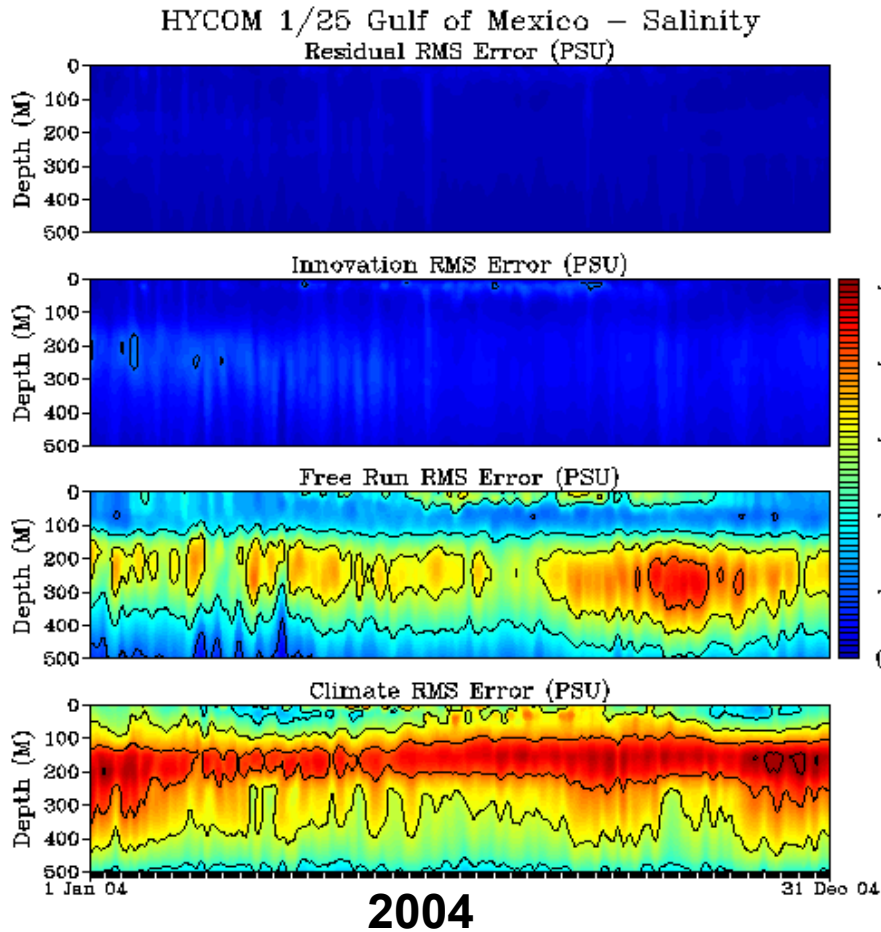
similar error patterns as 2004 and 2005

# Salinity Validation – Mean Bias



- residual and innovation salinities biased salty  $\sim 0.05$  PSU
- free running model salinities biased salty at surface ( $\sim 0.05$  PSU), fresh at depth ( $\sim 0.2$  to  $0.3$  PSU)
- observations (synthetics) biased fresh relative to climatology

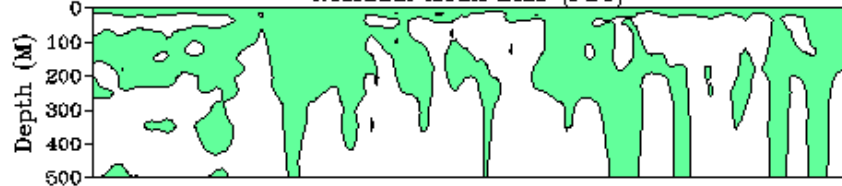
# Salinity Validation – RMS Error



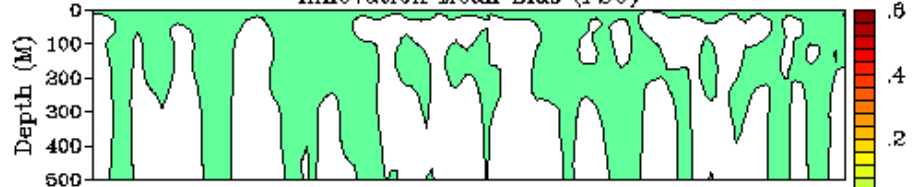
- 24-hr forecast RMS errors very low ( $\sim 0.1$  PSU)
- free running model RMS errors  $\sim 0.2$  to  $0.4$  PSU

# Salinity Validation – Jan to Jun 2006

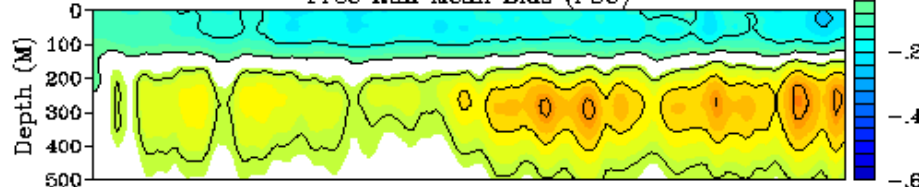
HYCOM 1/25 Gulf of Mexico – Salinity  
Residual Mean Bias (PSU)



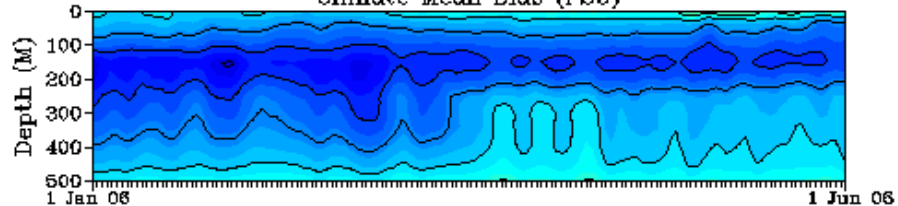
Innovation Mean Bias (PSU)



Free Run Mean Bias (PSU)



Climate Mean Bias (PSU)

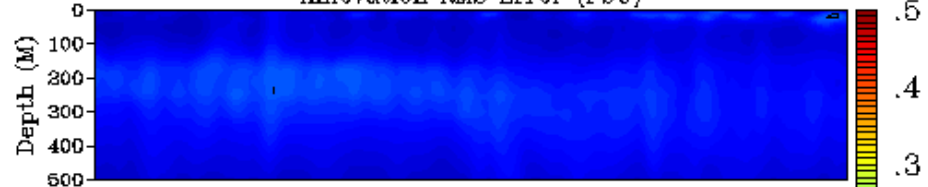


Mean Bias

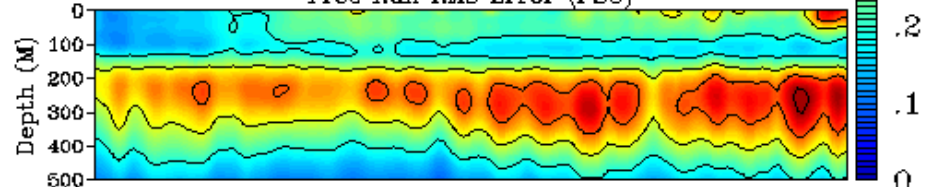
HYCOM 1/25 Gulf of Mexico – Salinity  
Residual RMS Error (PSU)



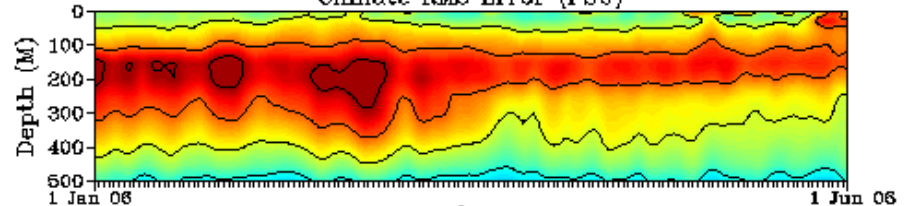
Innovation RMS Error (PSU)



Free Run RMS Error (PSU)



Climate RMS Error (PSU)

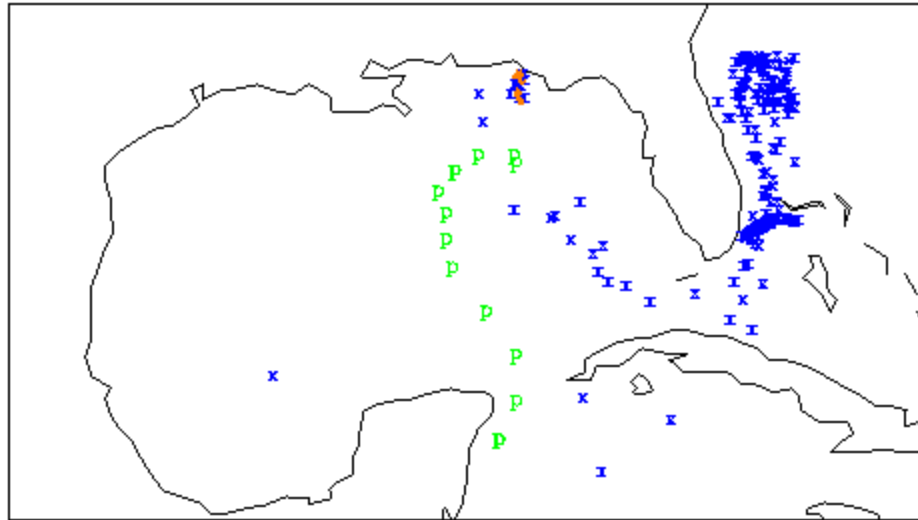


RMS Error

similar error patterns as 2004 and 2005



## *In Situ* Profile Locations January 2004 through June 2006



**P** – Argo profiling float (13)

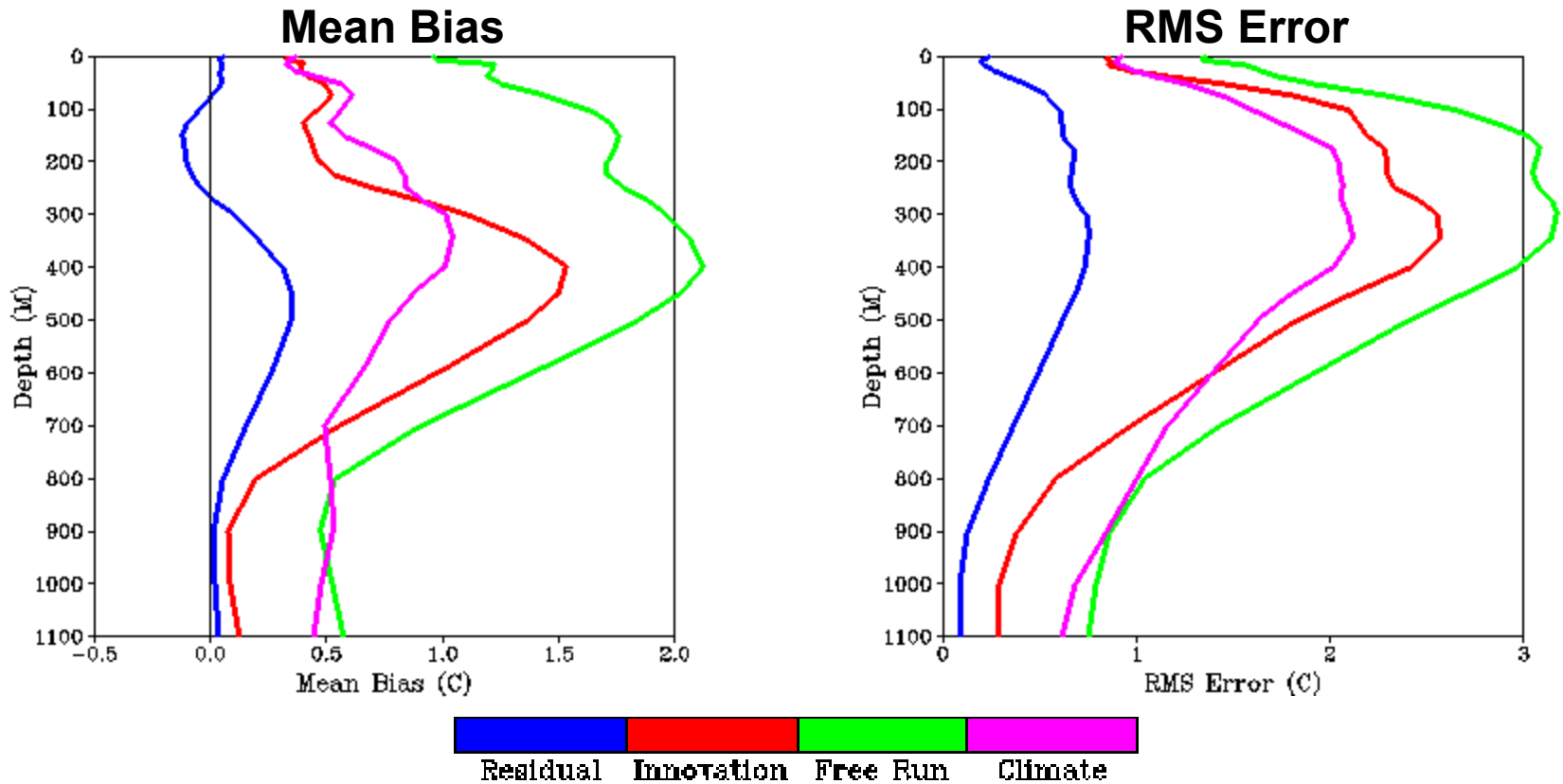
**T** – TESAC salinity-temperature-depth profile (15)

**X** – eXpendable BathyThermograph (222)

**250 Total !**

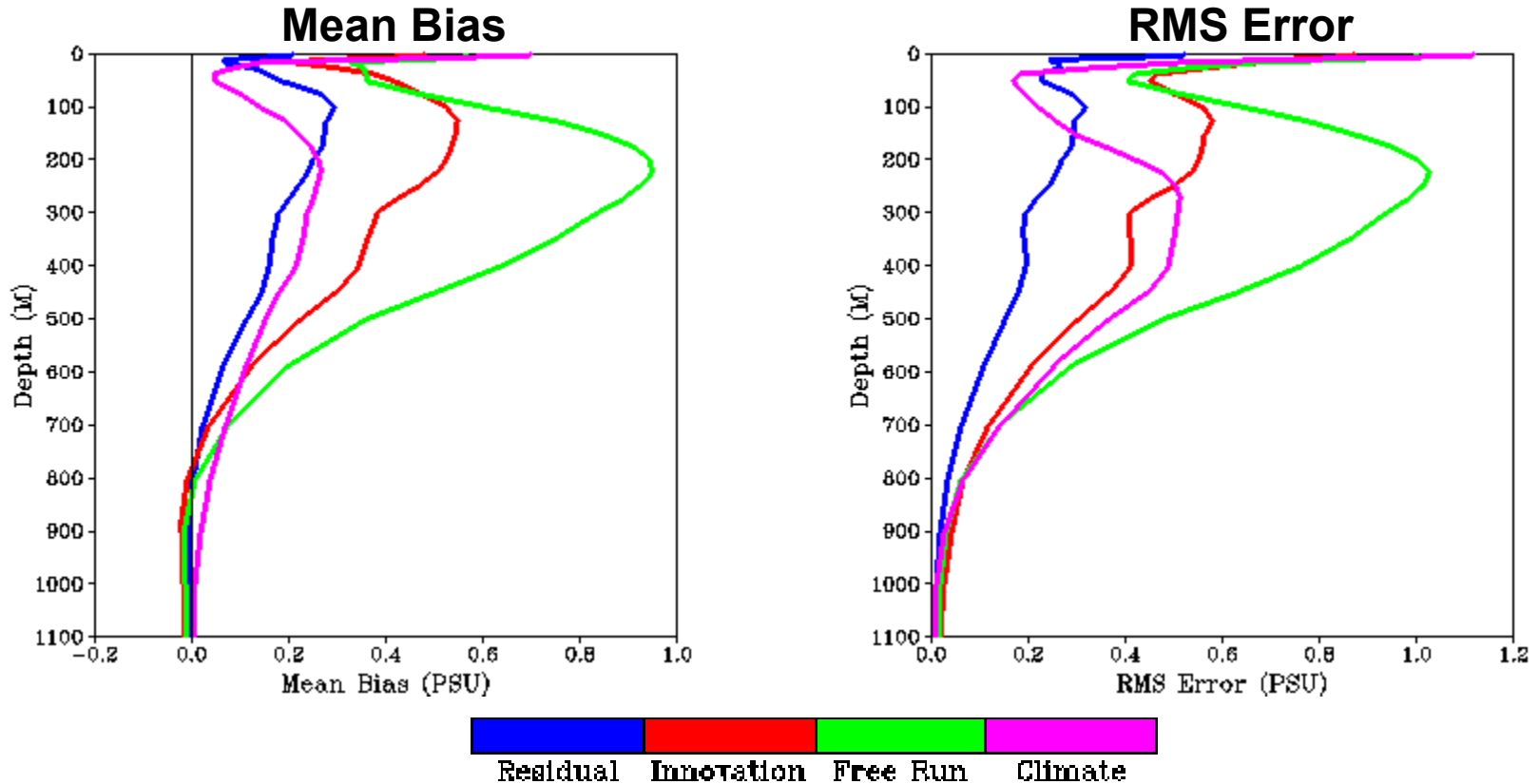
**28 measured salinity !**

# *In Situ* Profile Temperature Verification



- residuals unbiased, magnitude residual RMS errors similar to obs errors
- 24-hr forecast innovations biased cold, maximum errors in thermocline
- model free run biased very cold at all depths (0.5 to 2.2 °C)

# *In Situ* Profile Salinity Verification



- residuals biased fresh, magnitude residual RMS errors similar to obs errors
- 24-hr forecast innovations biased fresh, large errors near surface
- model free run biased fresh in upper 700 m water column, low errors at depth





# Conclusions and Future Plans

## Conclusions

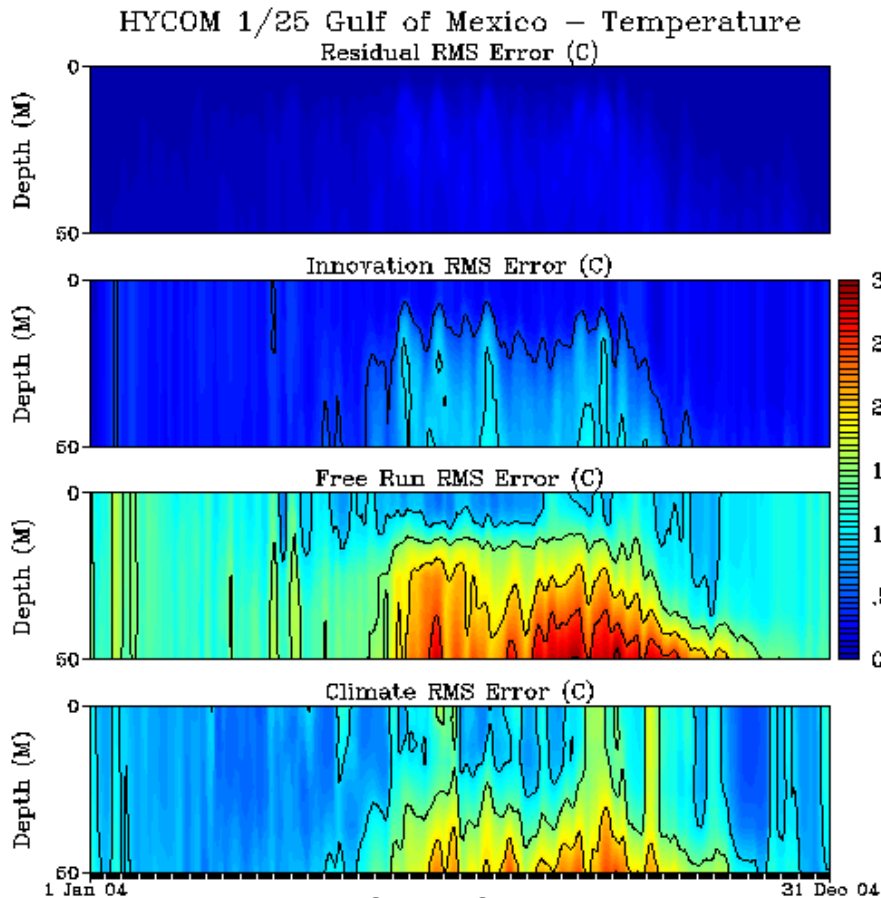
- successive reduction in error from assimilation
  - model free run >> 24-hr assimilative forecast > analysis nowcast
- no spurious time dependent model adjustments to data corrections
- model appears to be biased cold (all depths) and fresh (at depth)
  - difficult for assimilation to correct systematic model errors
  - conclusion based primarily on synthetic profiles at depth
  - need more *in situ* observations, better sampling in space and time

## Plans

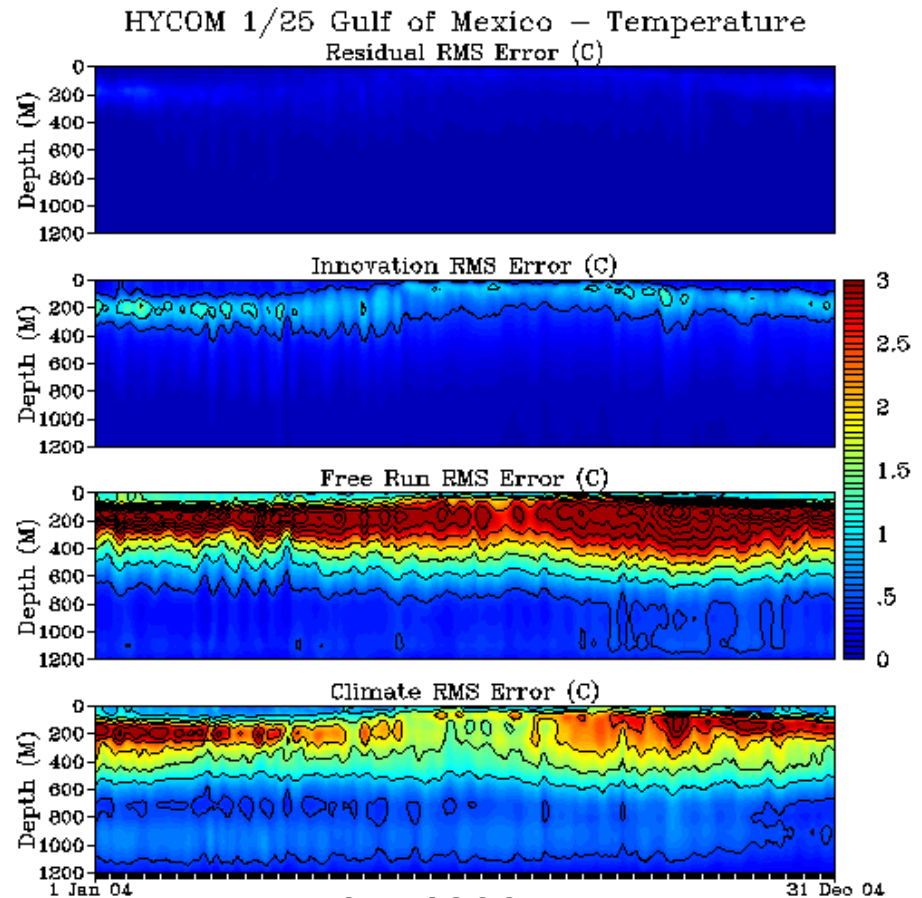
- compute analysis performance measures from innovation and residual time series
- prediction of independent data – MEDS, oil platform observations, etc
- examine oceanographic aspects of assimilative and model free runs

# Temperature Validation – RMS Error

## Expanded Depth Ranges



**0 – 50 m**



**0 – 1200 m**

- innovation errors in (C) in upper 50 m show small corrections in mixed layer
- innovation and forecast error corrections in upper 1200 m are restricted to depths shallower than ~600 m

***END***