



# **SST Data Impacts in Global HYCOM**

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# Assimilation: **Observation Data Impacts**

Why do ocean data assimilation?

- correct errors of model forecast with new observations
- generate improved initial conditions for next run of model

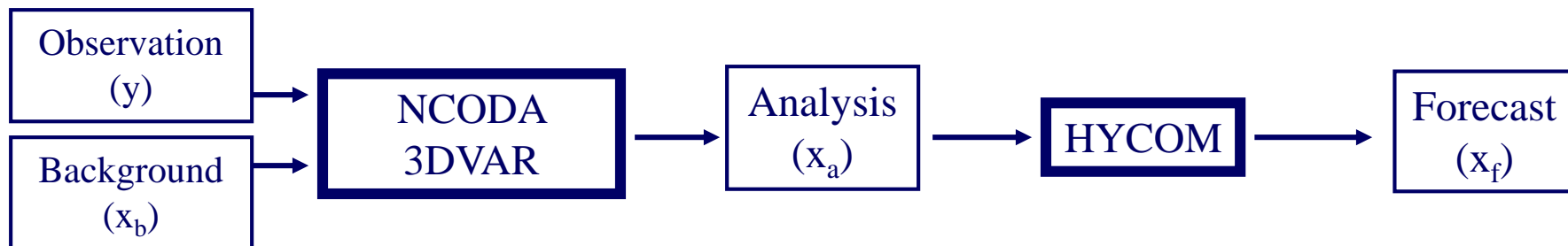
Do all observations assimilated have equal value?

- in terms of reducing ocean model forecast error

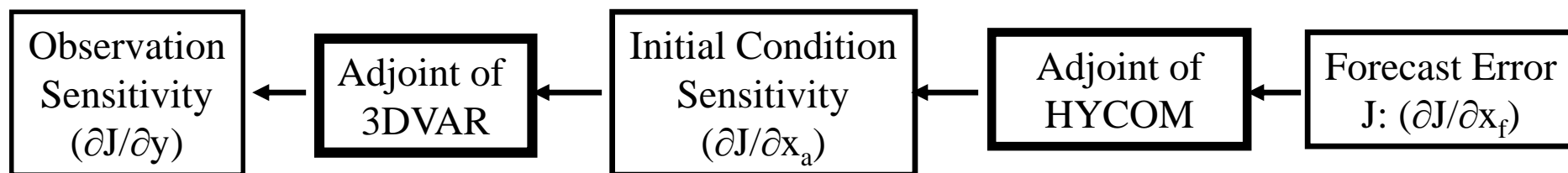
How can we quantify the impact of each observation?

- adjoint-based data impact system
- objective, quantitative, and efficient method
- can be run routinely, regular assessment observation impacts (capture observing system changes)
- impacts of observation subsets easily quantifiable:
  - instrument type (with traceability to individual platforms)
  - measurement variable (temperature, salinity, velocity)
  - geographic region
  - vertical depth level

# Analysis – Forecast System



## Data Impact System



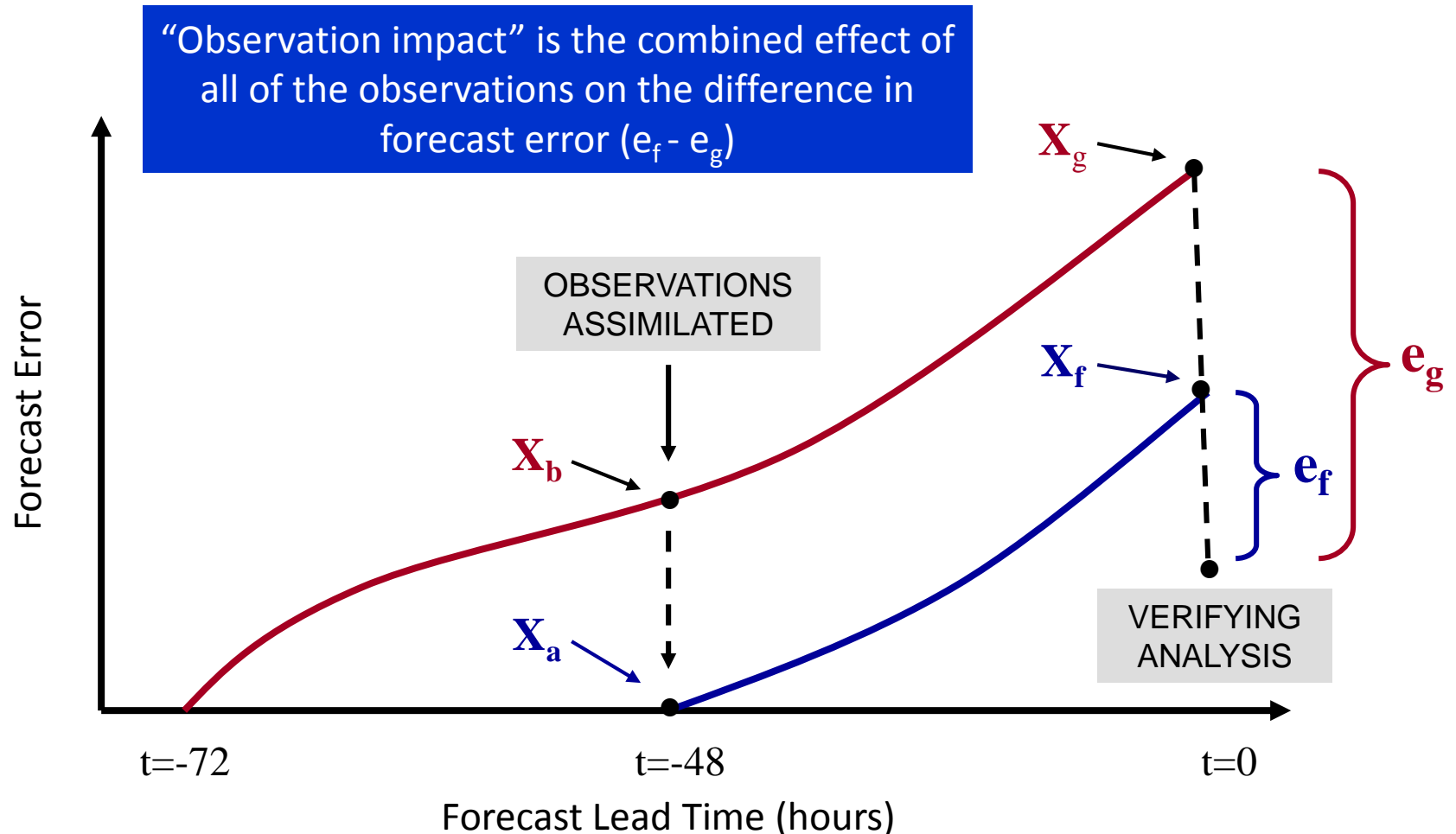
$$\delta e_f^g = \langle (y - Hx_b), \frac{\partial J}{\partial y} \rangle$$

Observation Impact Equation  
(Langland and Baker, 2004)

What is the impact of observations on measures of forecast error ( $J$ ) ?

# Observation Impact: Concept

Observations move the forecast from the **background trajectory** ( $X_b$ ) to the **trajectory starting from the new analysis** ( $X_a$ )



# Observation Impact Equation: Interpretation

For any observation assimilated, if ...

$\delta e_f^g < 0.0$  the observation is **BENEFICIAL** -  
forecast errors **decrease**

$\delta e_f^g > 0.0$  the observation is **NON-BENEFICIAL** -  
forecast errors **increase**

**Non-beneficial** impacts:

- not expected, assimilation should decrease forecast error
- if it occurs, look for problems in data QC, instrument calibration, model error, assimilation statistics (observation error, background error)

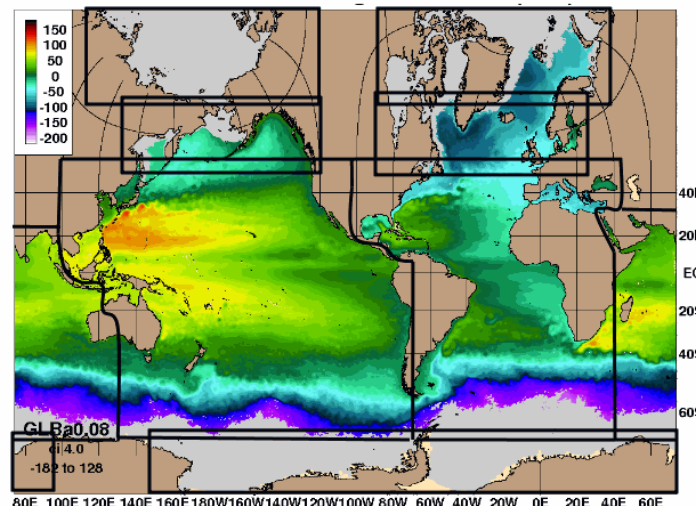
# Observation Impact: **Global HYCOM**

- HYCOM: 1/12° eddy resolving grid (8.8 km at equator)
- NCODA 3DVAR: 24-h update cycle
  - three-dimensional multivariate error covariances: flow-dependent, adaptive - vary with location, evolve with time
  - SST assimilated using hourly FGAT fields (maintain diurnal cycle)
- NCODA adjoint: observation sensitivity and data impacts
  - adjoint projects forecast error fields into observation space

## HYCOM Analysis Domains:

SST data impacts in Atlantic, Indian and Pacific domains reported here

Pre-operational run of system



$\delta e_{48}^{72}$

# Forecast Error: HYCOM Gulf of Mexico

Surface Temperature (C)

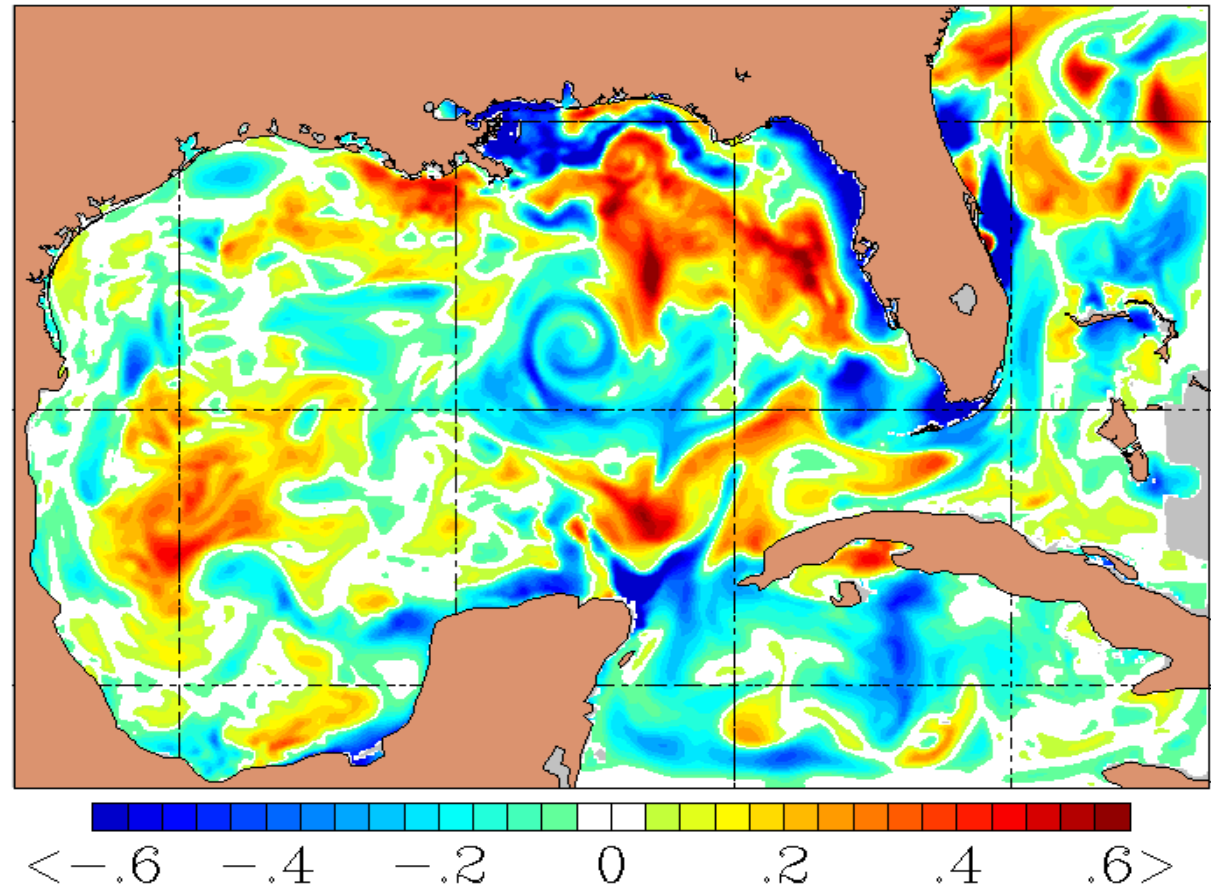
24 July 2012

$$\frac{\partial J}{\partial x_f} = e_f - e_g$$

$$e_f = (x_{48} - x_0)(x_{48} - x_0)$$

$$e_g = (x_{72} - x_0)(x_{72} - x_0)$$

$$\delta e_{48}^{72}$$



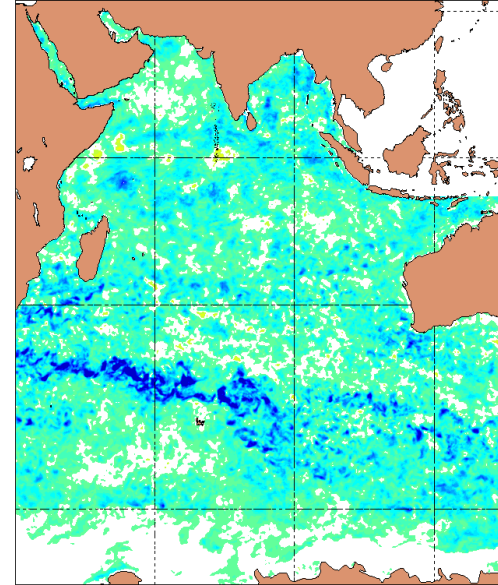
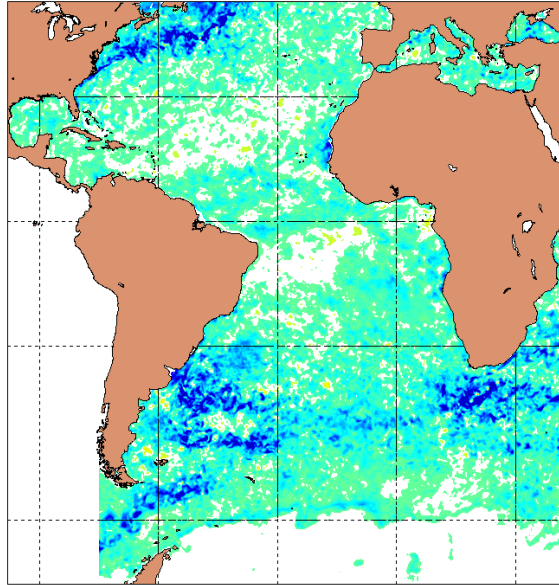
Both positive and negative forecast error values are common

Negative values indicate forecast error reduction

Positive values indicate forecast error growth



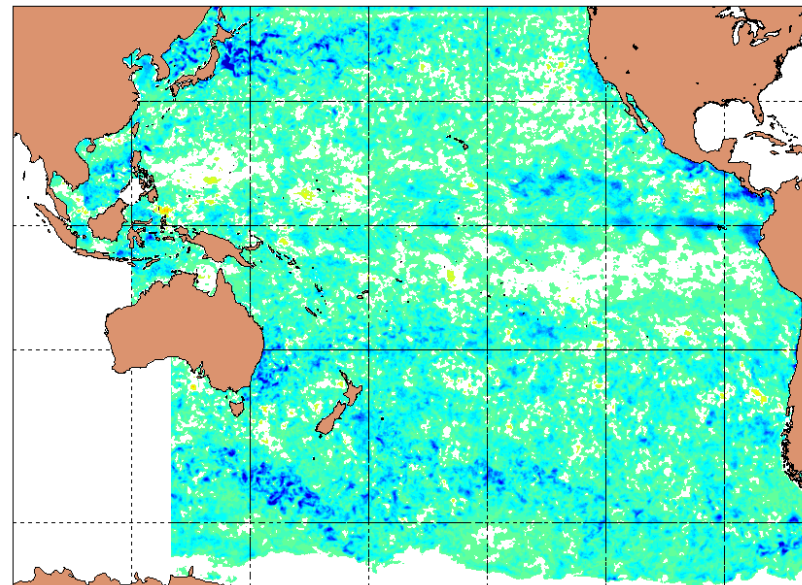
# Forecast Error: Global HYCOM



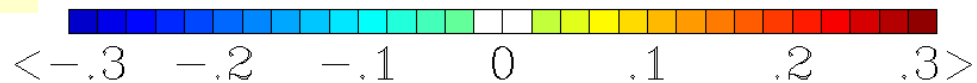
Averaged Surface  
Forecast Errors (C)

November 2012

negative values  
indicate forecast  
error reduction

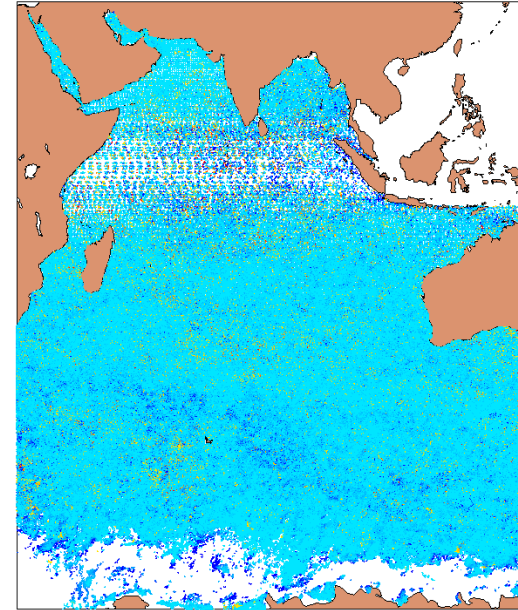
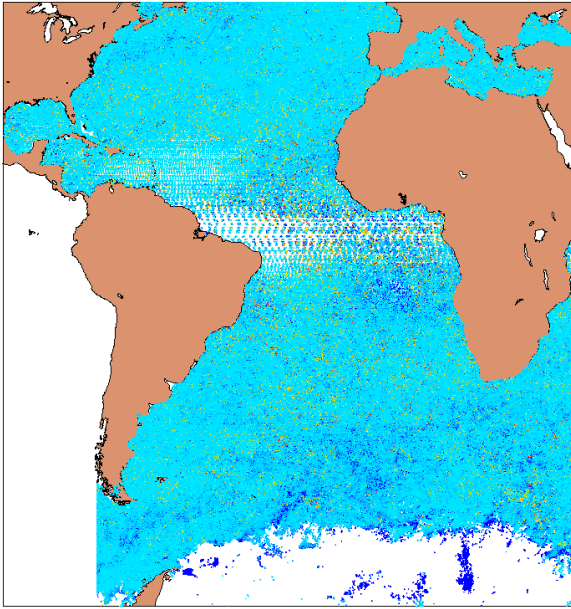


$$\frac{\partial J}{\partial x_f} = e_{48} - e_{72}$$





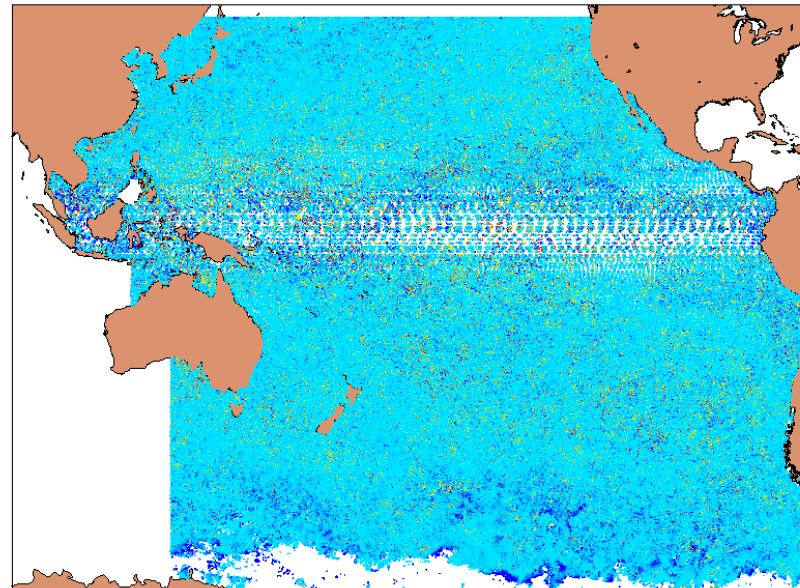
# Observation Impact: SST



Global HYCOM  
Nov 2012

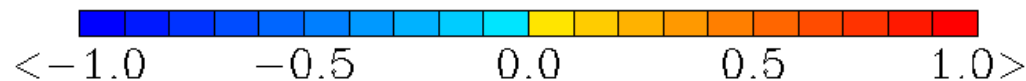
Per Ob Data  
Impacts (C)

(averaged at model  
grid locations)



$\delta e_{48}^{72}$

negative values  
indicate beneficial  
impacts



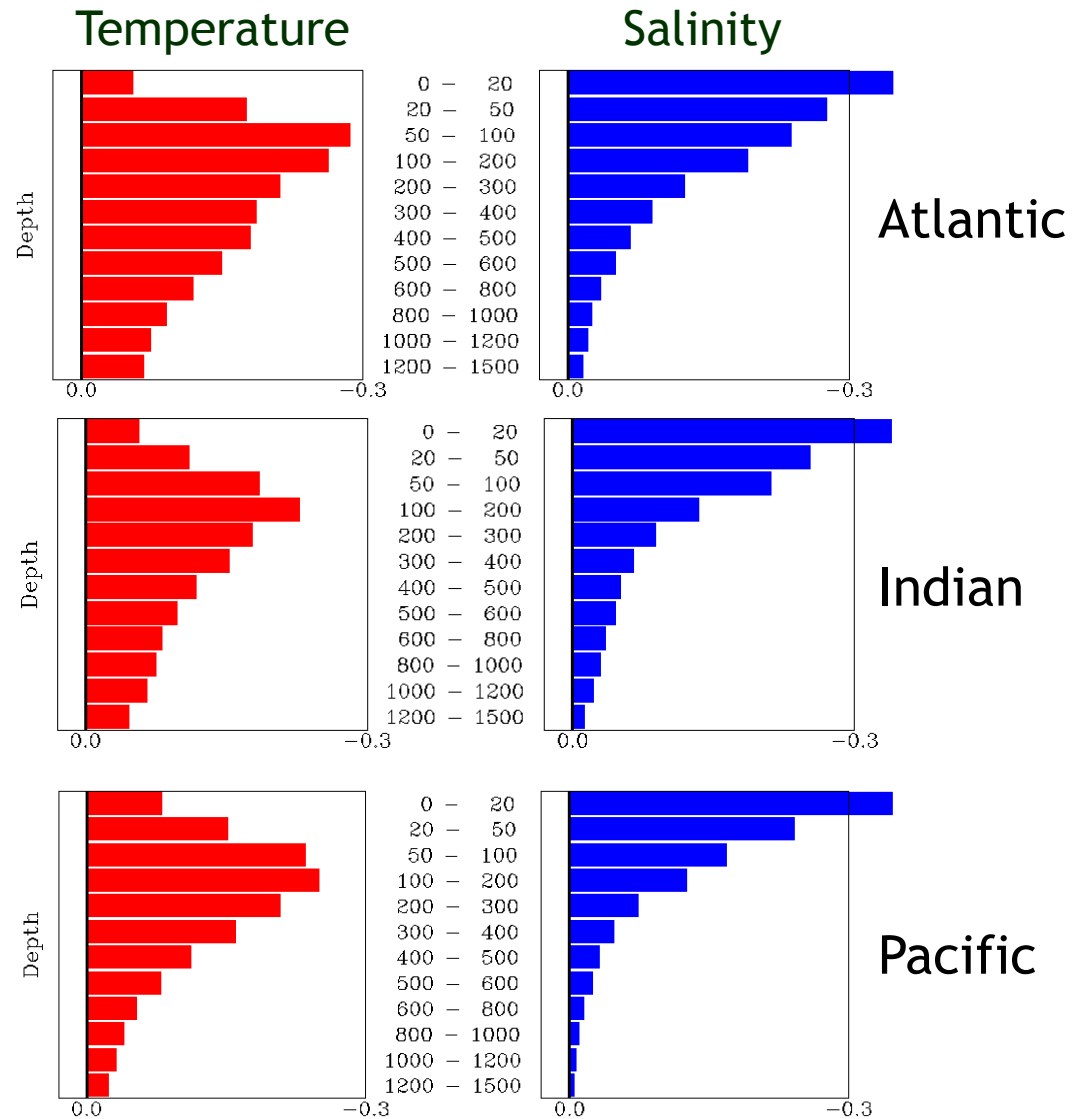
# Observation Impact: SST at Depth

## Argo Data Impacts Global HYCOM Oct-Nov 2012

Infer impact of SST data at depth from reduced impact of Argo temperature profiles in upper ~100 meters

Assimilation of SST corrects HYCOM near-surface error

SST vertical length scales based on model mixed layer depths (vary with location, evolve with time)



$\delta e_{48}^{72}$

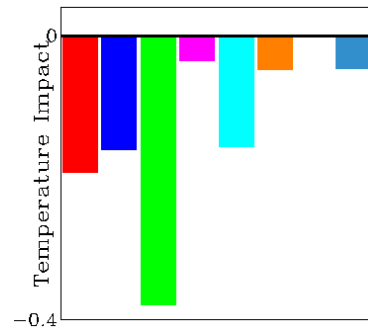
# Data Impact: Temperature Observing Systems

Global HYCOM

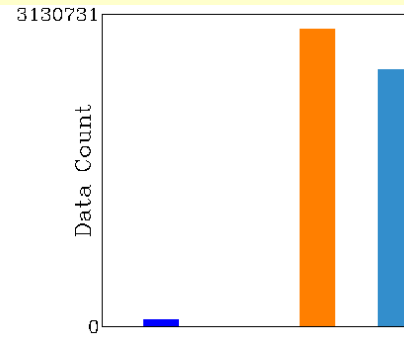
Nov 2012

$\delta e_{48}^{72}$

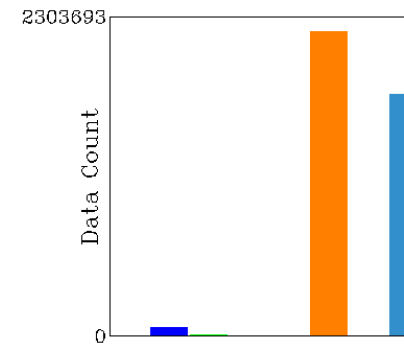
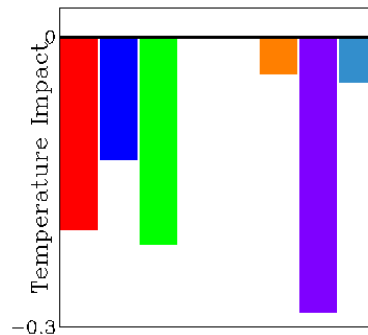
Per Ob Impact



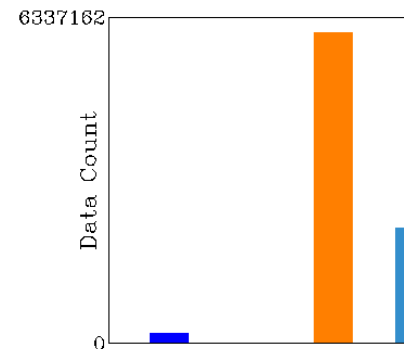
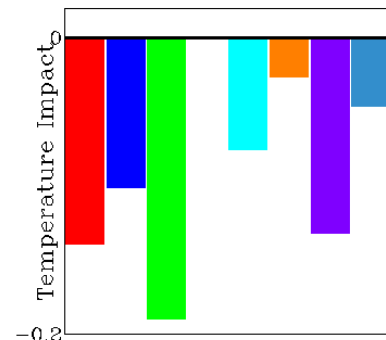
Data Count



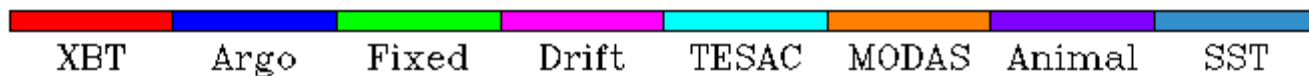
Atlantic



Indian

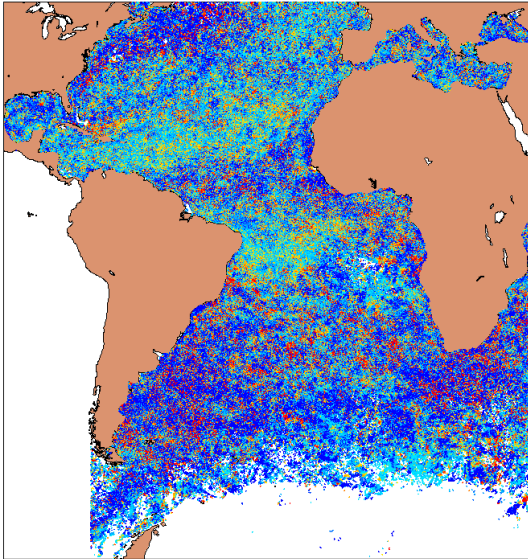


Pacific

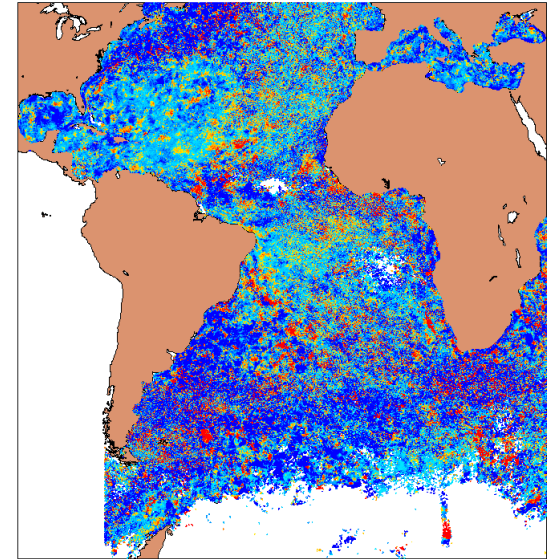


# Satellite SST Impacts: HYCOM Atlantic Ocean

NOAA-18



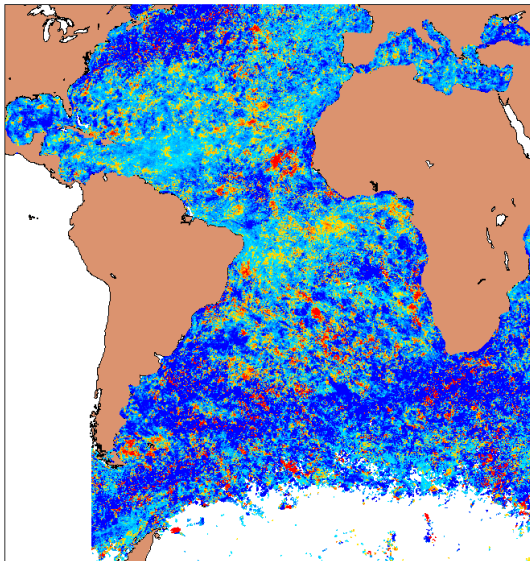
NOAA-19



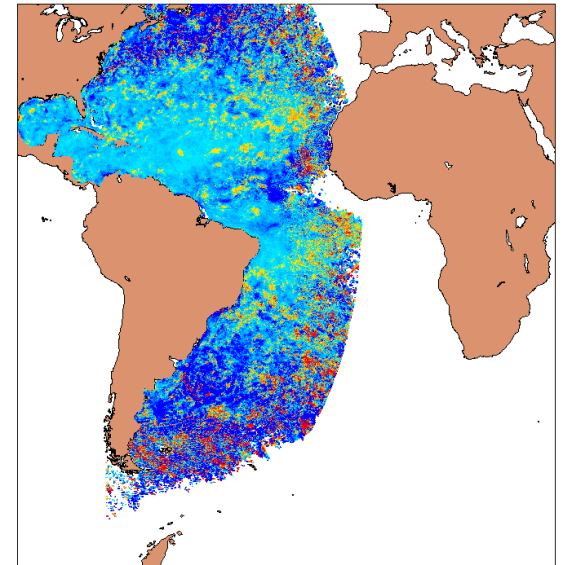
Per Ob Data  
Impacts (C)

(averaged at  
model grid  
locations)

METOP-A



GOES



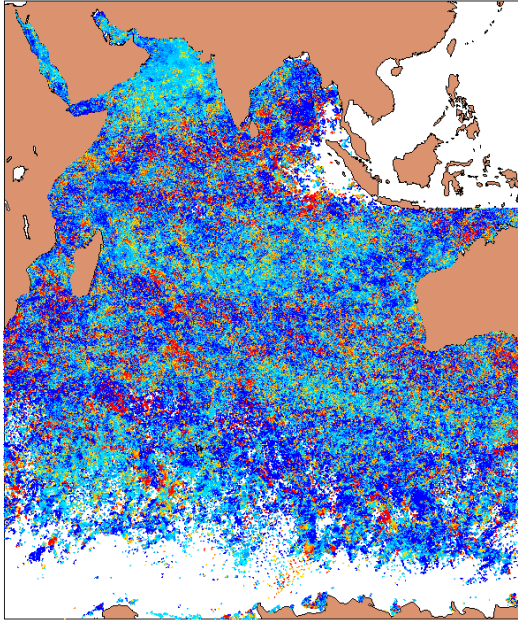
Nov 2012



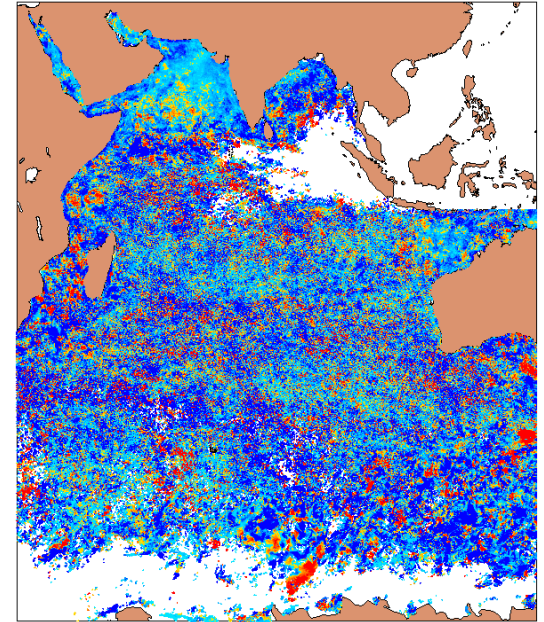


# Satellite SST Impacts: HYCOM Indian Ocean

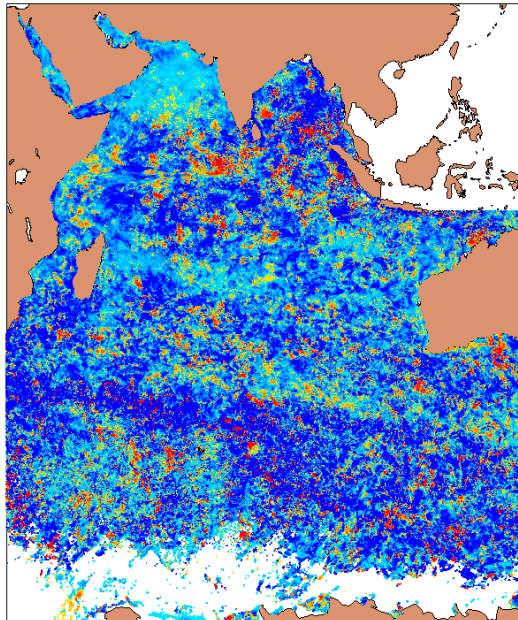
NOAA-18



NOAA-19



METOP-A



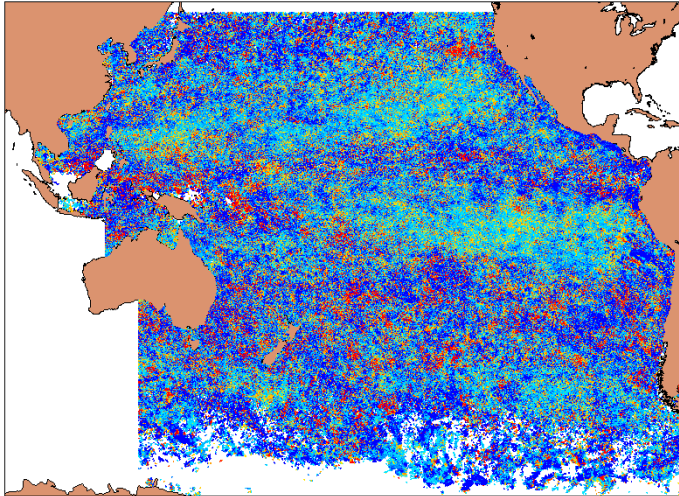
**Per Ob Data Impacts (C)**

(averaged at model grid locations)

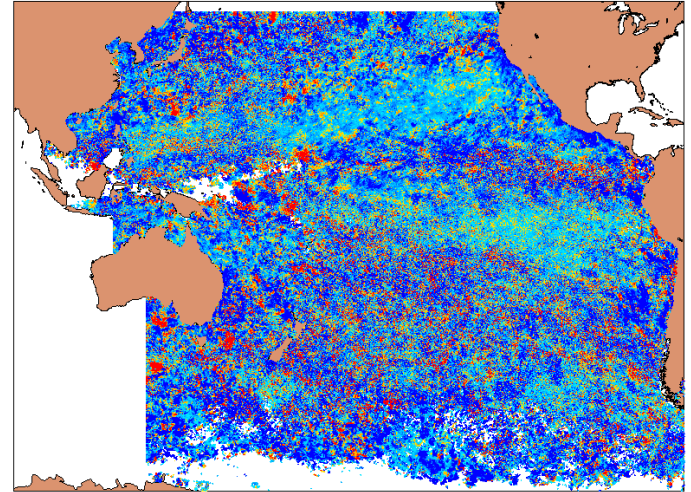
Nov 2012

# Satellite SST Impacts: **HYCOM Pacific Ocean**

NOAA-18



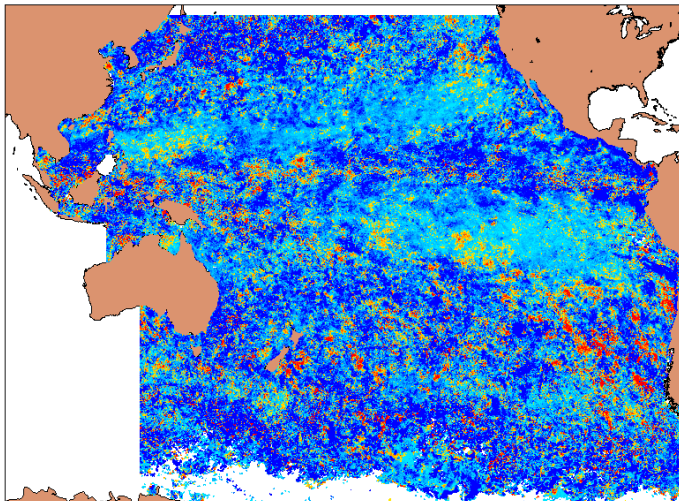
NOAA-19



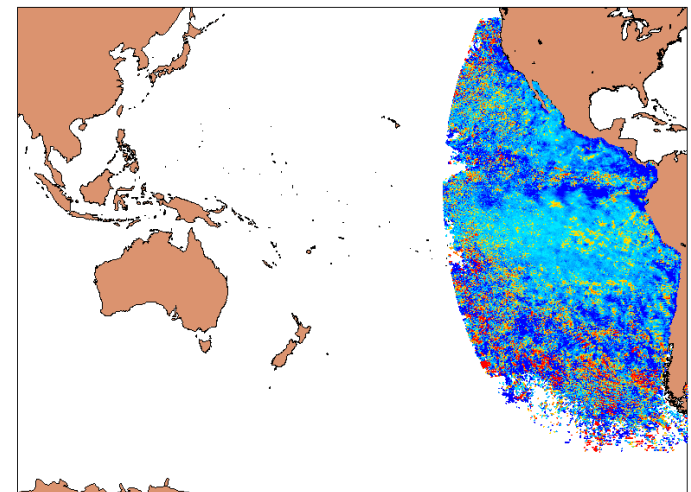
Per Ob Data  
Impacts (C)

(averaged at  
model grid  
locations)

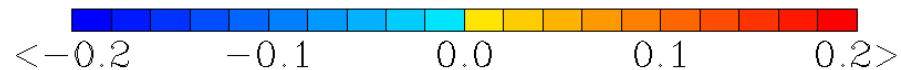
METOP-A



GOES

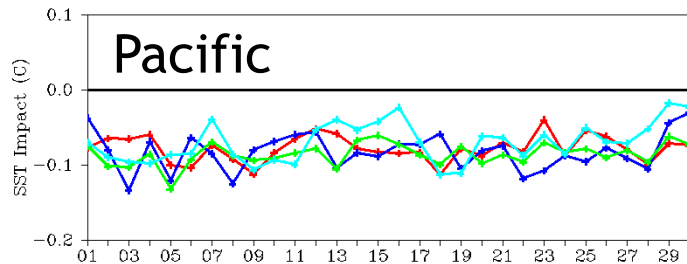
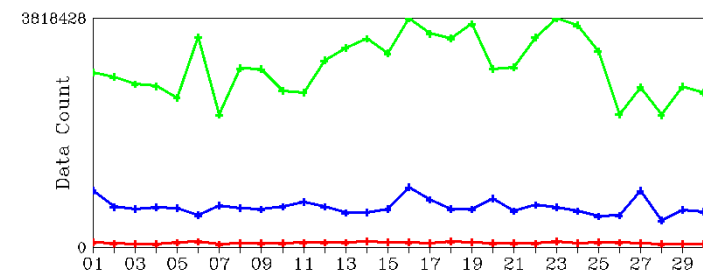
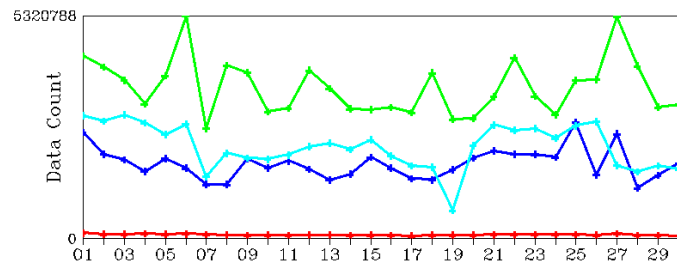
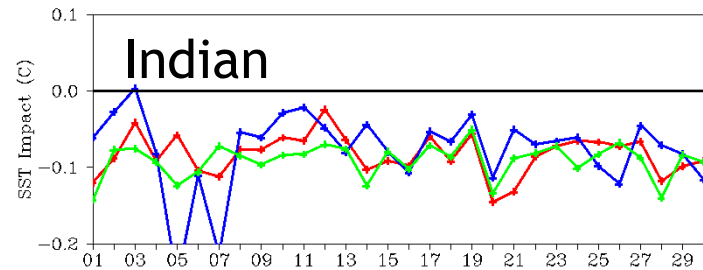
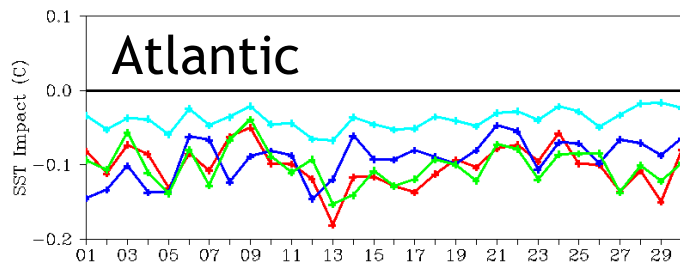


Nov 2012



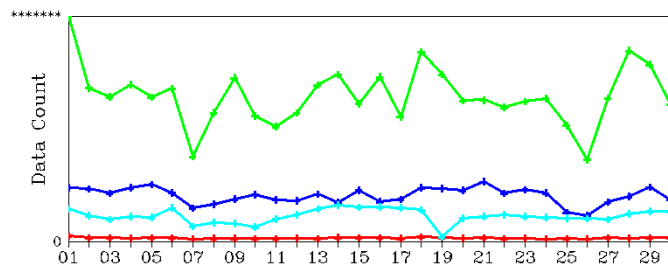


# Satellite SST: HYCOM Daily Impacts



$\delta e_{48}^{72}$

Nov 2012



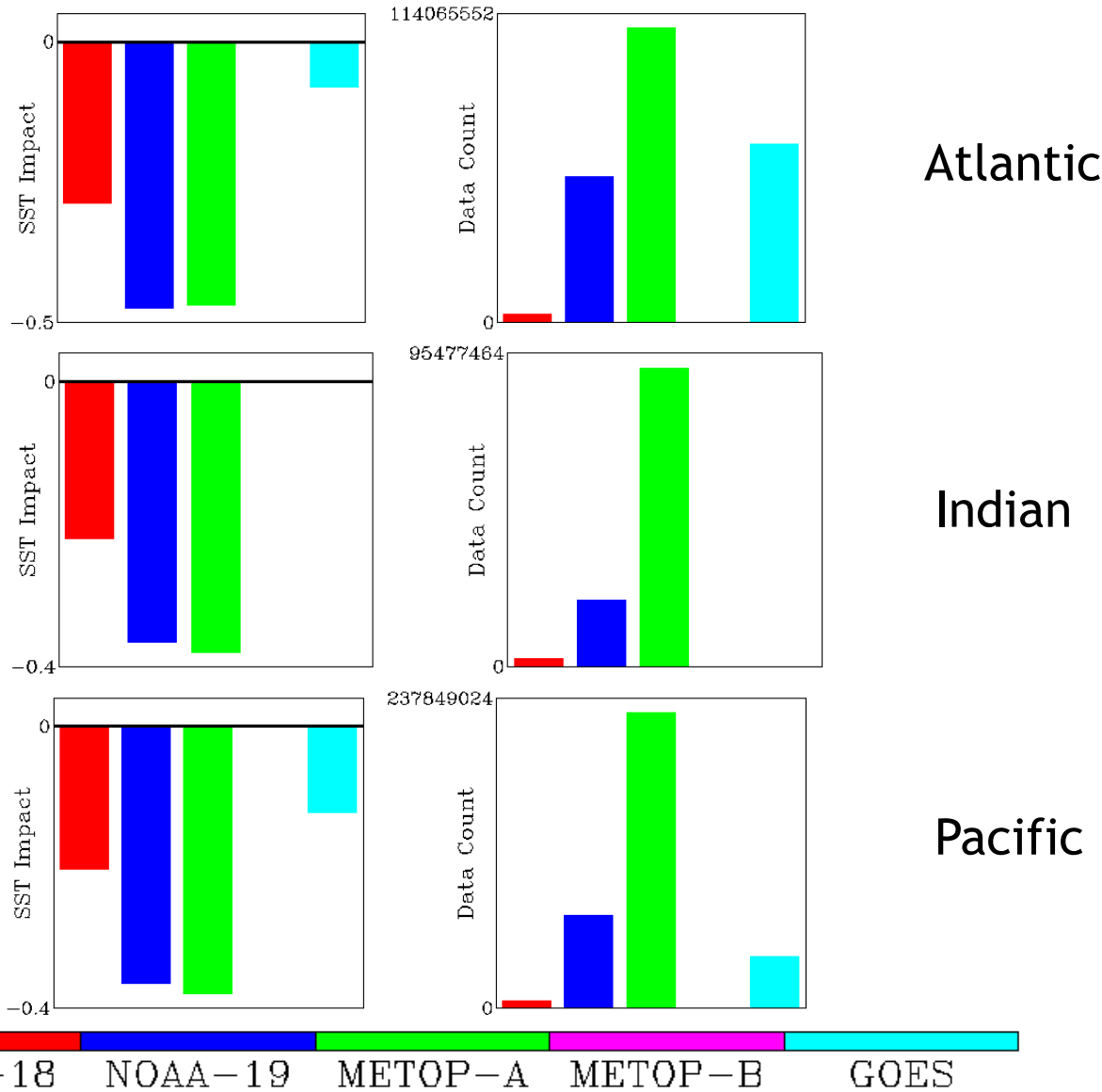


# Observation Impact: HYCOM Satellite SST

Per Ob Impact      Data Count

Nov 2012

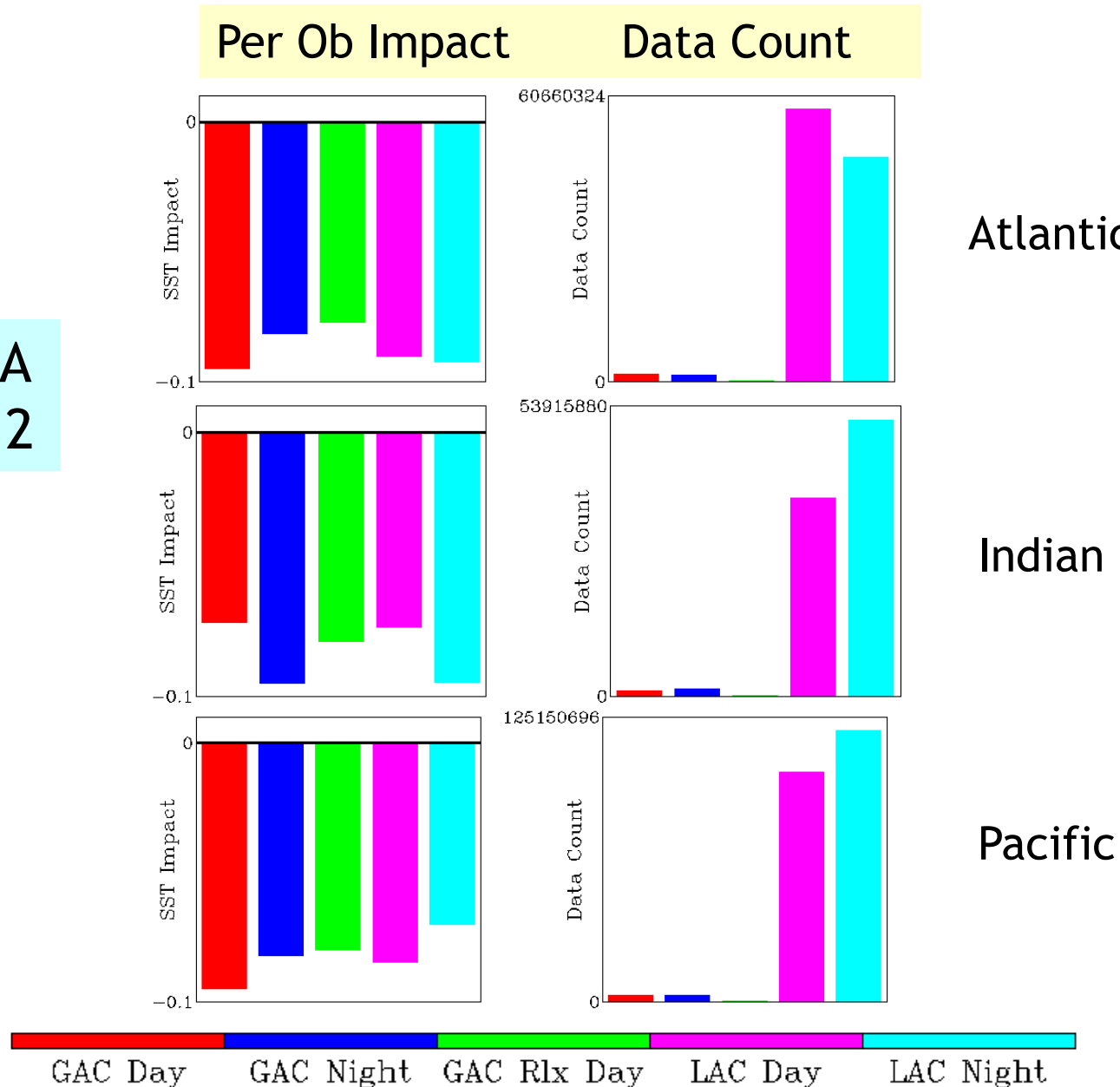
$\delta e_{48}^{72}$



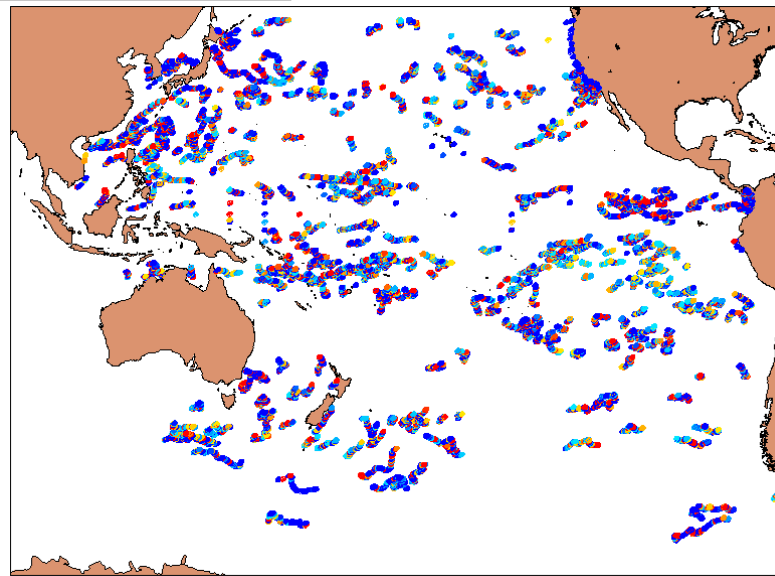
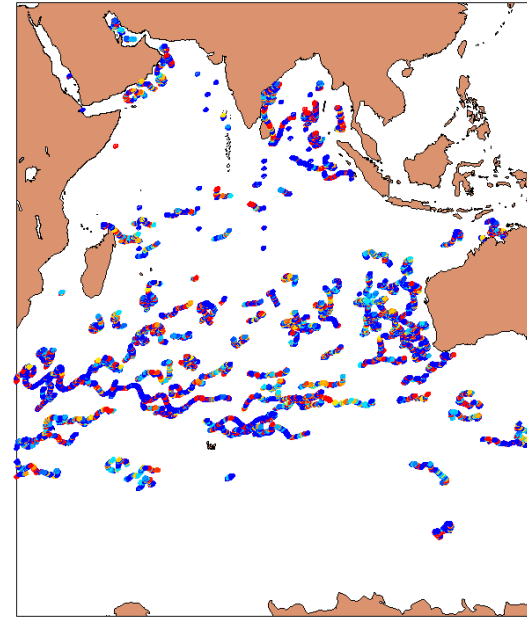
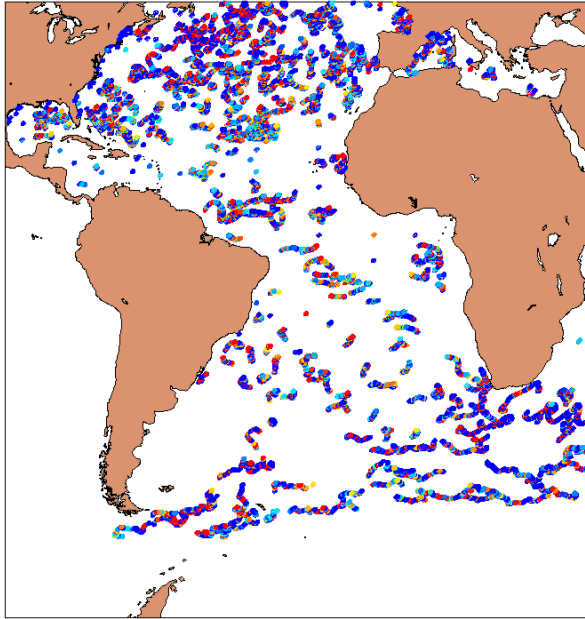
# Observation Impact: Satellite SST Retrieval Type

METOP-A  
Nov 2012

$\delta e_{48}^{72}$

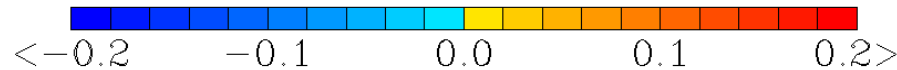


# Buoy SST Impact: HYCOM - Nov 2012

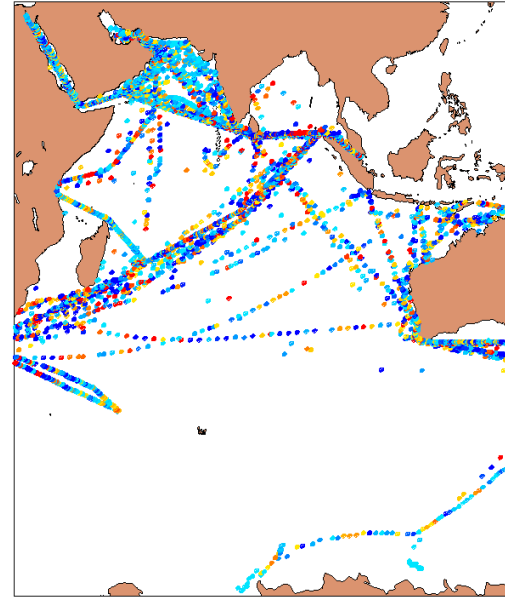
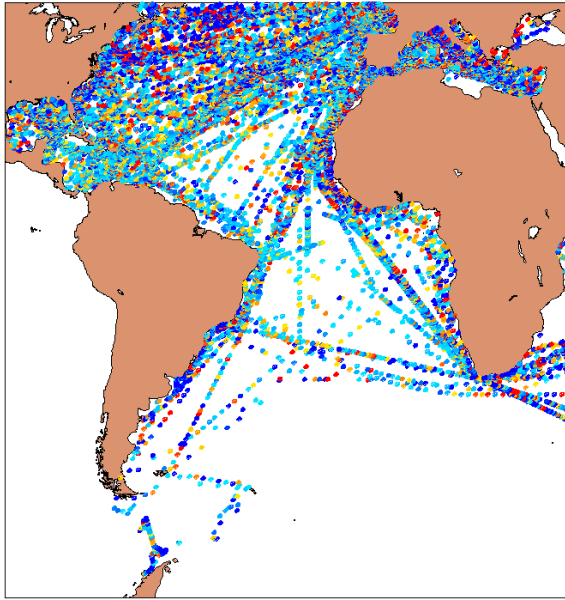


negative values  
indicate beneficial  
impacts

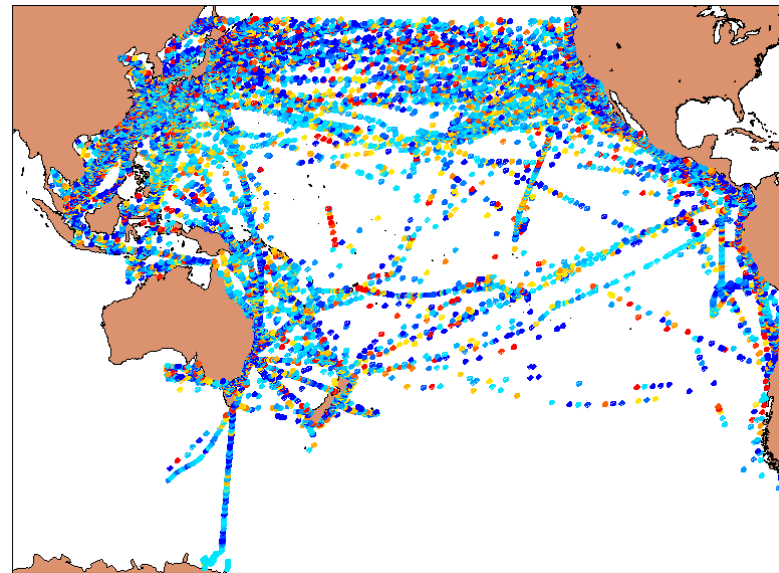
$\delta e_{48}^{72}$



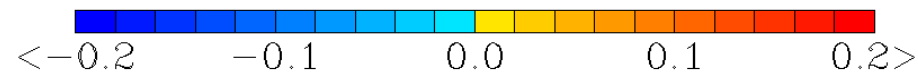
# Ship SST Impact: HYCOM – Nov 2012



negative values  
indicate beneficial  
impacts



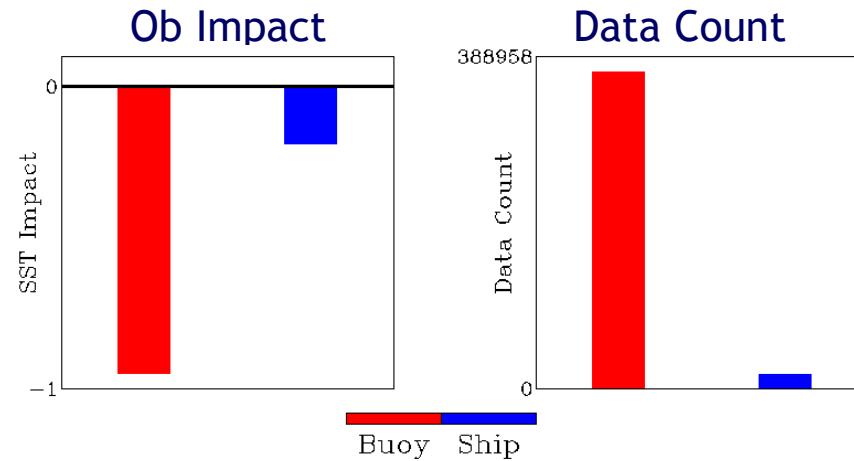
$\delta e_{48}^{72}$



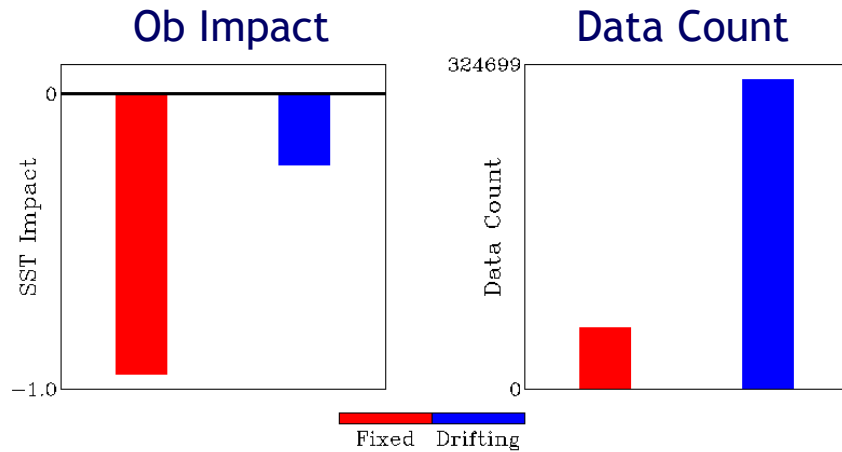
# SST Data Impact: HYCOM Ship and Buoy

Pacific Ocean

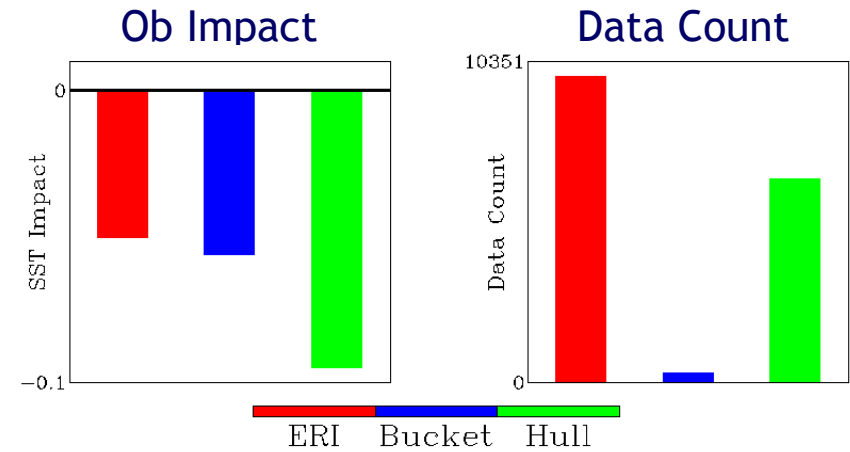
Nov 2012



Buoy >> Ship



Fixed buoy >> Drifting buoy



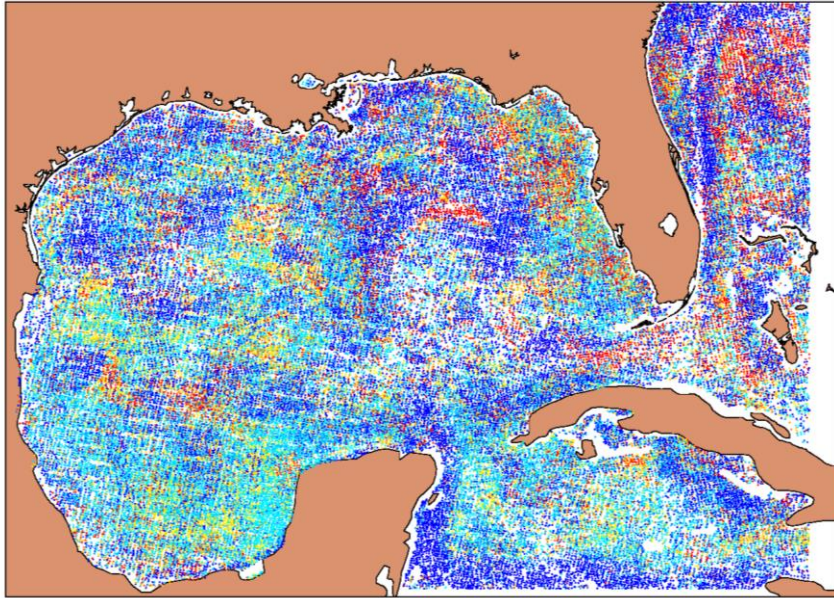
Hull contact > ERI or bucket

# SST Data Impact: Quality Control Aspects

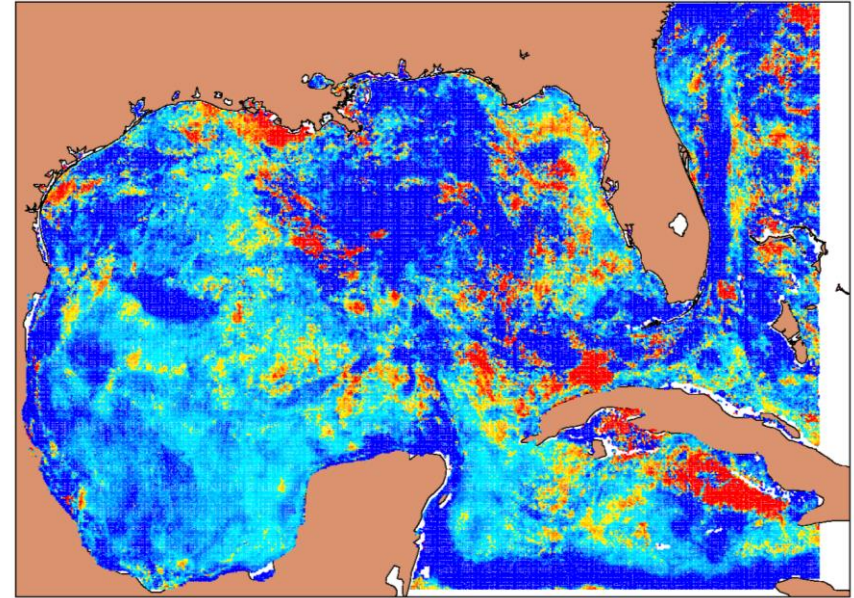
NOAA-18 vs. NOAA-19 SST Data Impacts (C)

$\delta e_{48}^{72}$

NOAA-18 Launched May 2005



NOAA-19 Launched Feb 2009



  
<-0.12 -0.08 -0.04 0.00 0.04 0.08 0.12>

Lack of coherent structure in NOAA-18 data impacts imply sensor-noise issues as satellite approaches end-of-life

Averaged at grid locations: 15 Apr to 15 May 2012

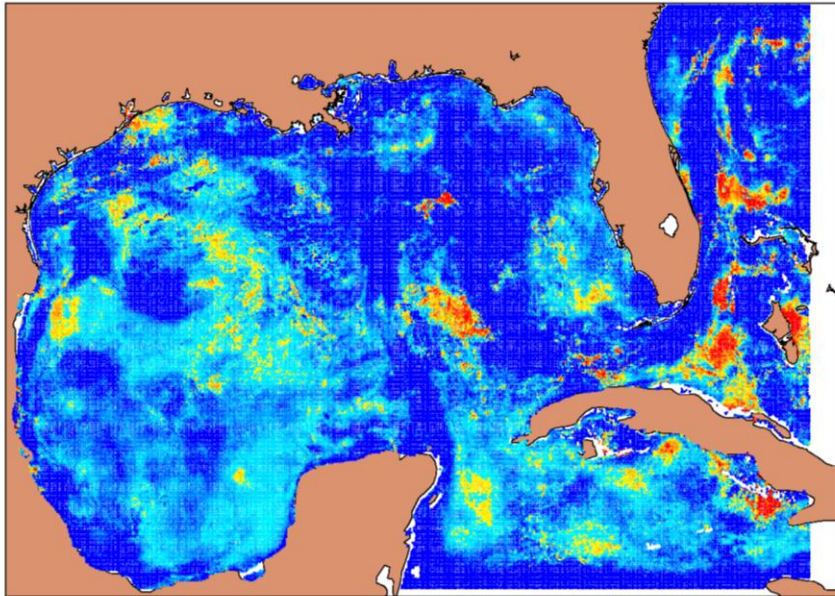


# SST Data Impact: Effect of Forecast Lead Time

## HYCOM Gulf of Mexico: METOP-A Data Impact (C)

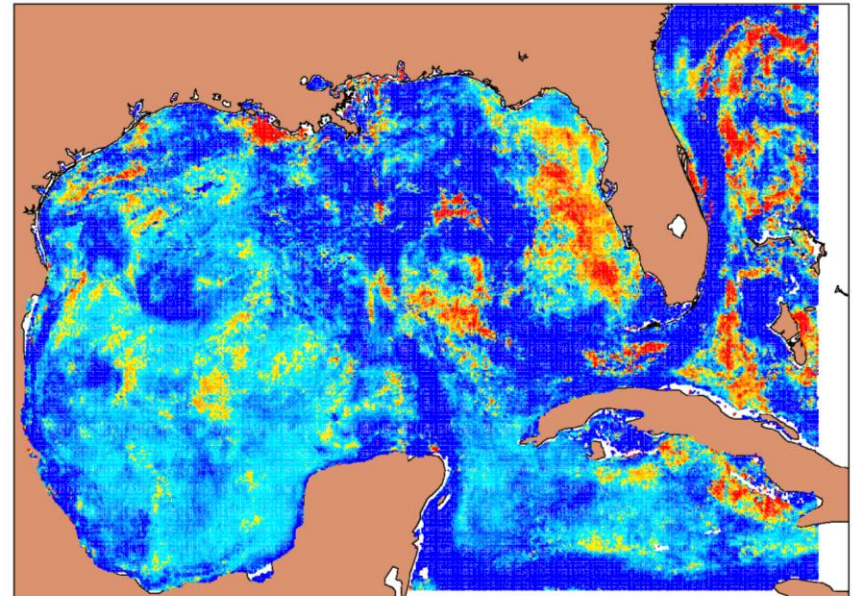
$\delta e_{24}^{48}$

24-hour forecast errors



$\delta e_{48}^{72}$

48-hour forecast errors



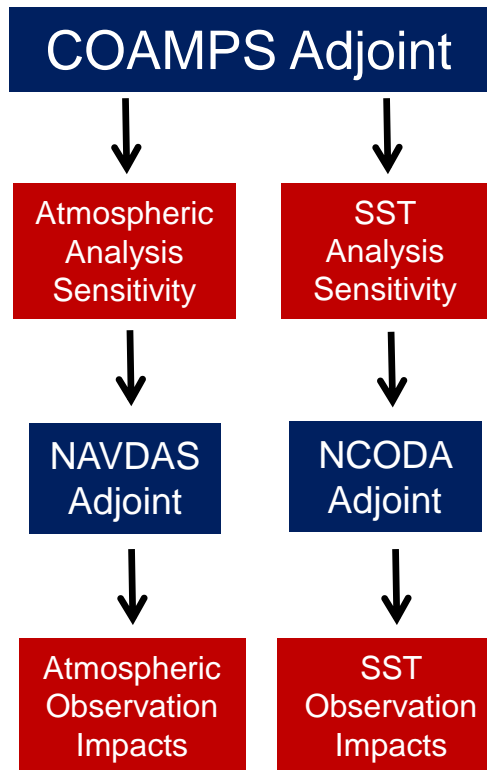
$\begin{array}{cccccccccccc} \text{blue} & \text{blue} & \text{blue} & \text{blue} & \text{blue} & \text{cyan} & \text{cyan} & \text{yellow} & \text{yellow} & \text{orange} & \text{orange} & \text{red} & \text{red} \\ <-0.12 & -0.08 & -0.04 & 0.00 & 0.04 & 0.08 & 0.12 & & & & & & & \end{array}$

Magnitude of beneficial impacts decrease when forecast errors are computed using longer lead times

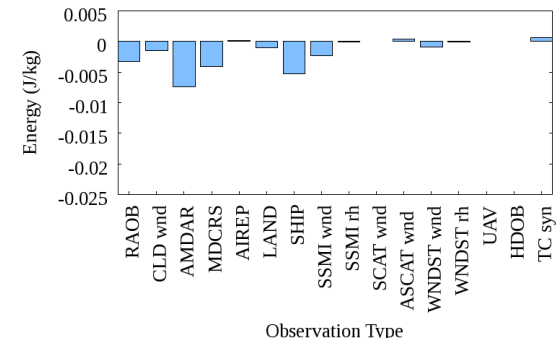
15 Apr to 15 May 2012



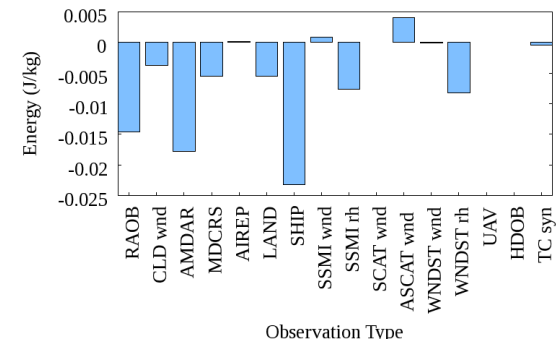
# SST Data Impact: Atmospheric Model



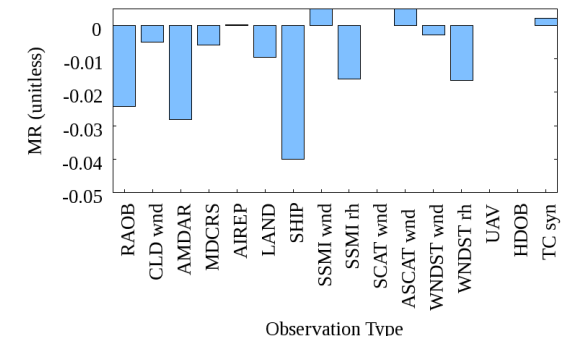
Dry Energy



Moist Energy



Modified Refractivity



- NCODA adjoint integrated into COAMPS data impact system
  - multiple COAMPS forecast error metrics available
- Impact of SST on reducing atmospheric model forecast errors

# SST Data Impact: **Conclusions**

- **Adjoint-based data impact system integrated with Navy global ocean forecast model (HYCOM)**
  - data impact system cannot be used in operations since NRL SSC management forces HYCOM to assimilate 12-days of data every day
  - data impact results make no sense after repeated assimilation of the same observations over and over again
- **In pre-operational run (data assimilated only once) all sources SST data found to reduce HYCOM 48-h forecast error:**
  - NOAA-19, METOP-A >> NOAA-18, GOES
  - fixed buoy >> drifting buoy
  - ship hull contact sensor > ERI and bucket measurements
  - SST data impacts extend to depth of mixed layer
- **Future applications:**
  - impact of SST observations on reducing atmospheric model errors
  - extend adjoint method to include observing system design and targeted observing (variants of core data impact system)

END

Questions?