An Ocean Reanalysis Using the 1/12° Global HYbrid Coordinate Ocean Model (HYCOM)

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Ocean Reanalysis

- Atmospheric centers (ECMWF and NCEP) have performed multiple atmospheric reanalyses using a static model and assimilation scheme while ingesting all available QC'ed observational data
- Currently, no long time period eddy-resolving ocean reanalysis exists
- This project addresses that need
- Funded by the DoD Modeling and Simulation Coordination Office (M&S CO)
- Goal: to provide physically consistent environmental scenarios for planning, wargaming and scenarios to support the warfighter

Ocean Reanalysis

- Models and assimilation
  - Ocean: 1/12° global HYCOM
  - Ice: CICE (coupled to HYCOM via ESMF 4.0)
  - Assimilation: NCODA (3DVAR)
  - Waves: WaveWatch 3 (not coupled to HYCOM),
                    NCEP is doing the wave reanalysis

- Forcing
  - NCEP Climate Forecast System Reanalysis (CFSR)
 - 1993-2009 (the satellite altimeter period)

Ocean Reanalysis

- Climate Forecast System Reanalysis (CFSR)
  - New reanalysis from NCEP designed for climate studies
    - Loosely coupled atmosphere and ocean (MOM4: ¼° - ½°)
  - Substantially better than NCEP Reanalysis 1 and 2 and of similar quality to 40-yr ECMWF Reanalysis (ERA-40)
  - Horizontal resolution: 0.3125° Gaussian grid
  - Temporal resolution: 1-hourly
    - Will allow inclusion of an accurate diurnal cycle
  - Processing 1992-2009 complete
    - One year of 1-hrly native grid forcing in HYCOM-ready format = 210 Gb (binary .D files: real*4) or 105 Gb (netCDF: integer*2)
    - Currently being placed on the HYCOM data server

CFSR Daily Forcing – 21 March 2004

Air Temperature at 2 m (K)
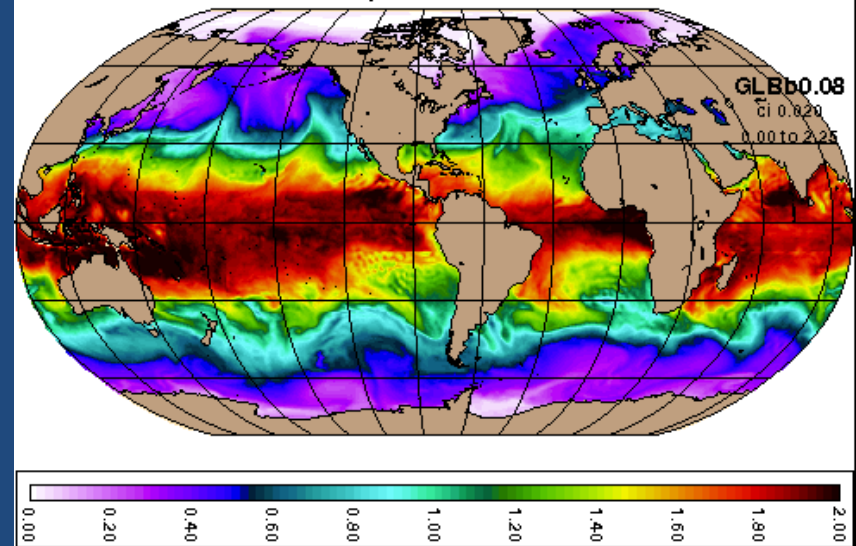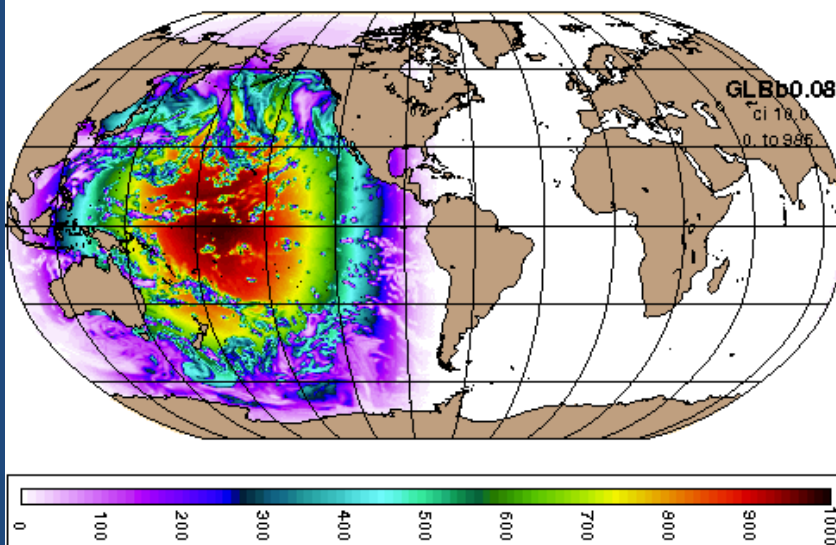

CFSR-sea temp2m 20040321 00Z

GLBb0.08
ci 1.0
227. to 305
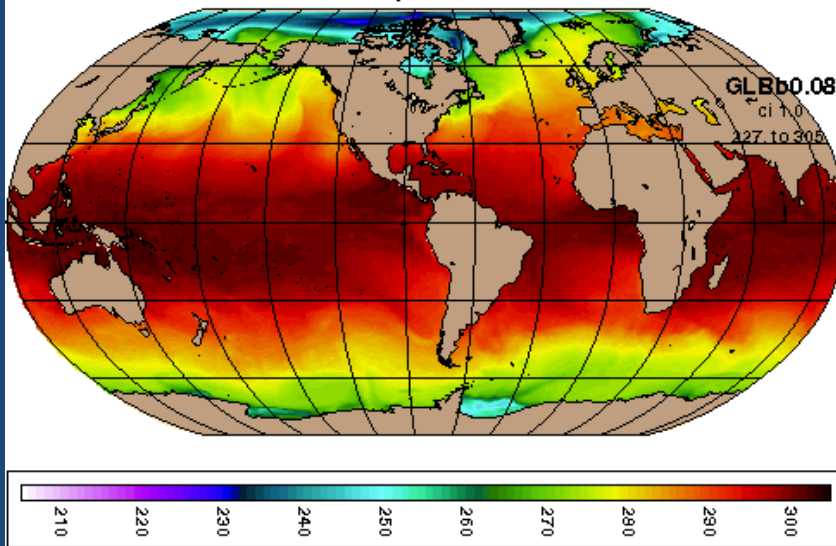
Surface Specific Humidity (kg/kg x 10^2)

CFSR-sea spchum 20040321 00Z

GLBb0.08
ci 0.020
0.00 to 2.25

Net Surface Shortwave (W/m^2)

CFSR-sea solrad 20040321 00Z

GLBb0.08
ci 10.0
0. to 985

Net Surface Longwave (W/m^2)

CFSR-sea longwv 20040321 00Z

GLBb0.08
ci 2.0
-156. to 90
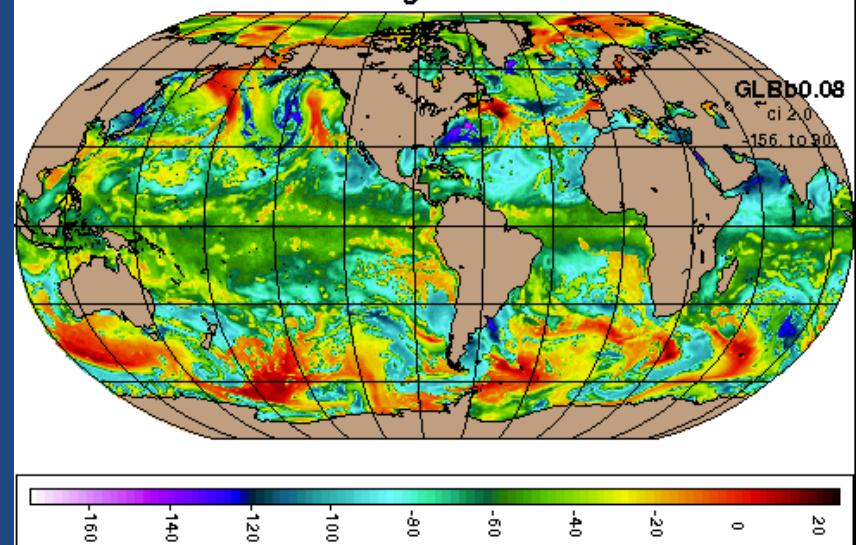
CFSR Daily Forcing – 21 March 2004

Precipitation (m/s x 10^6)
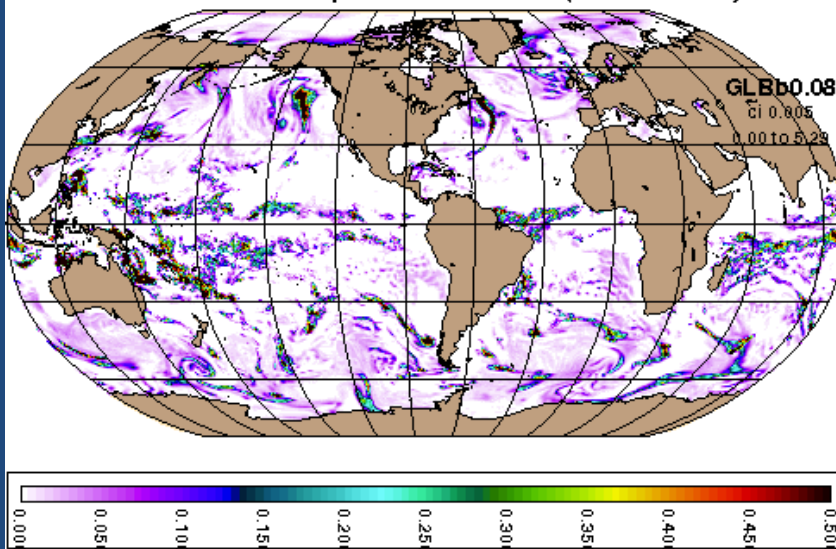
Surface Temperature (K)
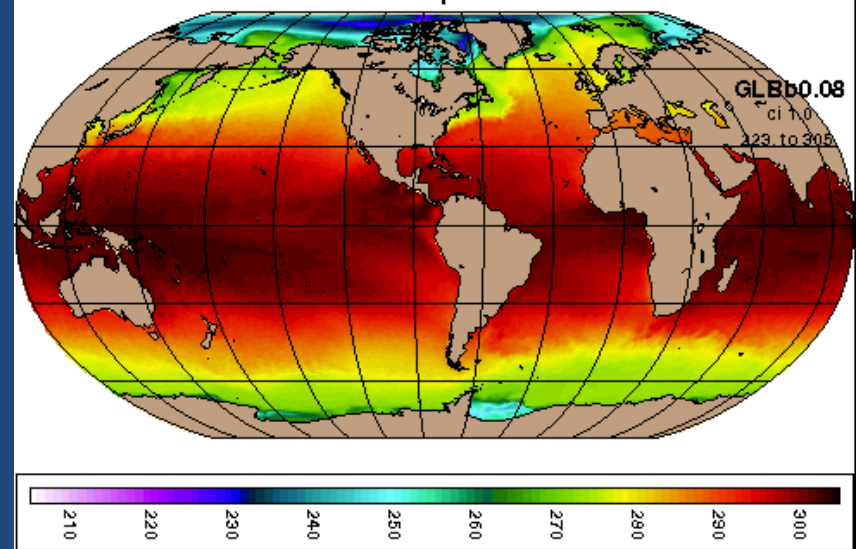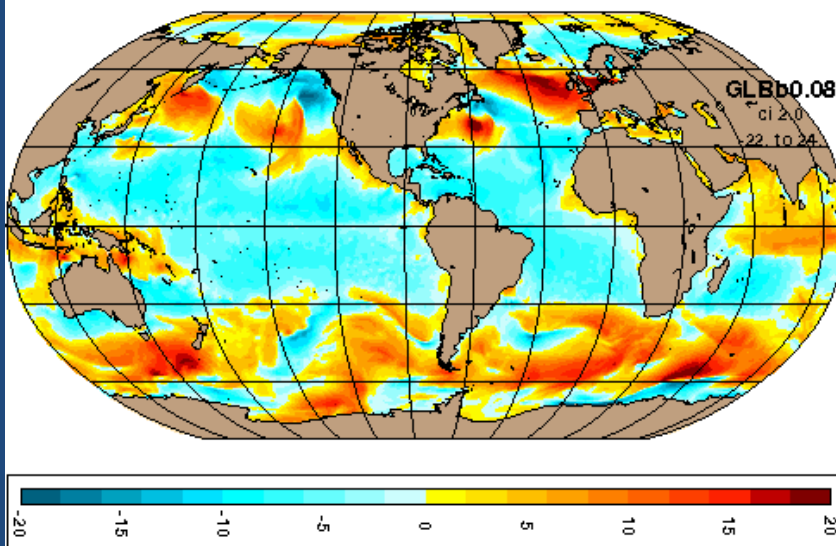
10 m Zonal Winds (m/s)

10 m Meridional Winds (m/s)
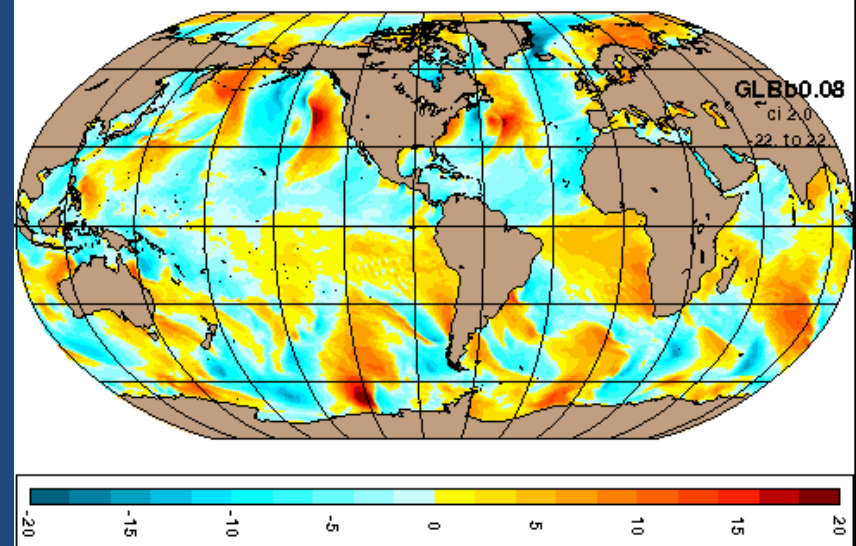
CFSR Filename Nomenclature

- **cfsr-std:** Standard CFSR files with no modification

- **cfsr-sea:** Sea-filled CFSR forcing, i.e. extrapolate ocean values onto atmospheric land points
  – Do this to avoid land contamination near the coasts

- **cfsr-sec:** Sea-filled and correct wind speed (but not direction) to QuikSCAT scatterometer wind speed via linear regression
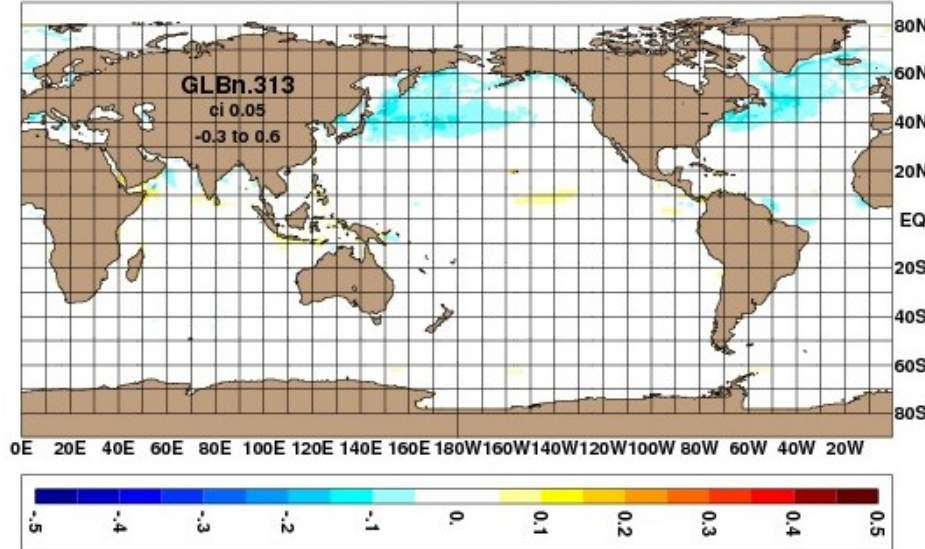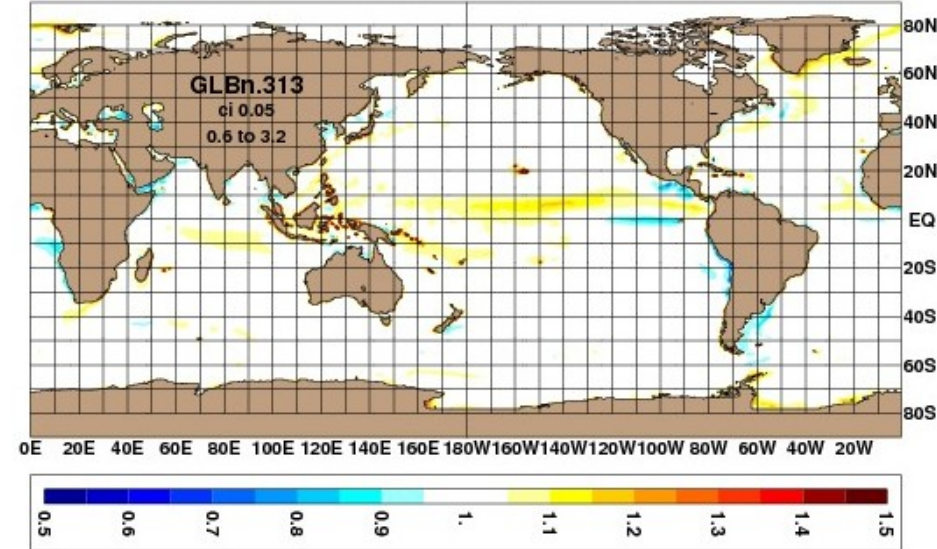
Modifications to CFSR Forcing

QuikSCAT Scaling

Offset   Bias
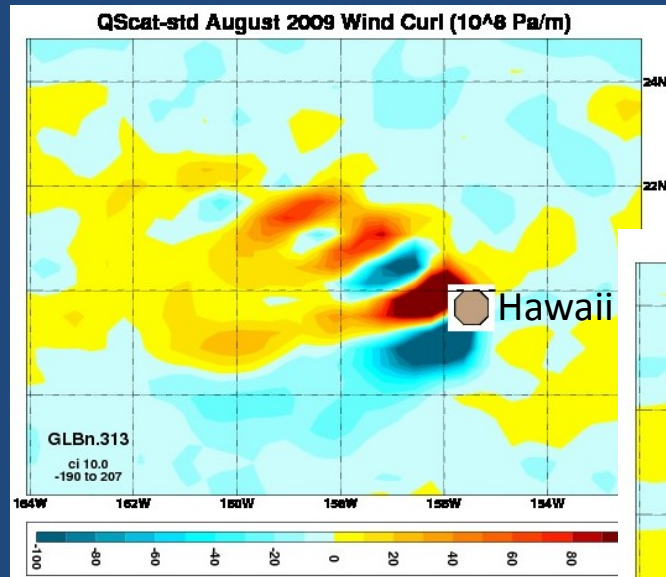

Based on 11 years (1999-2009) of
contemporaneous CFSR and QuikSCAT data

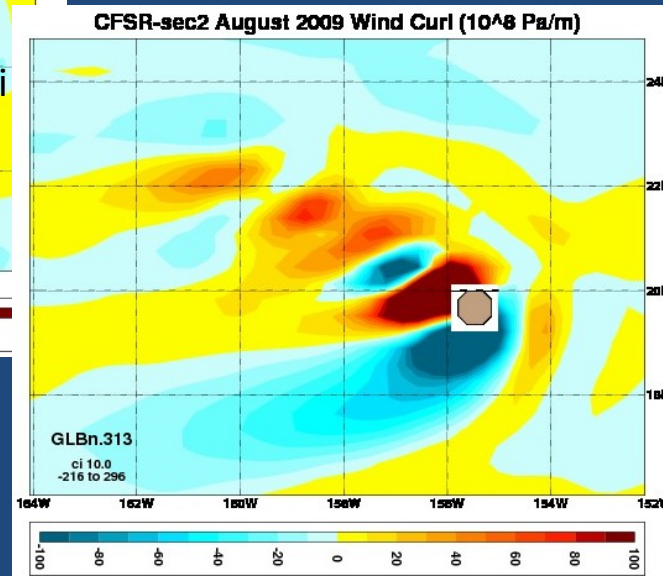# Modifications to CFSR Forcing
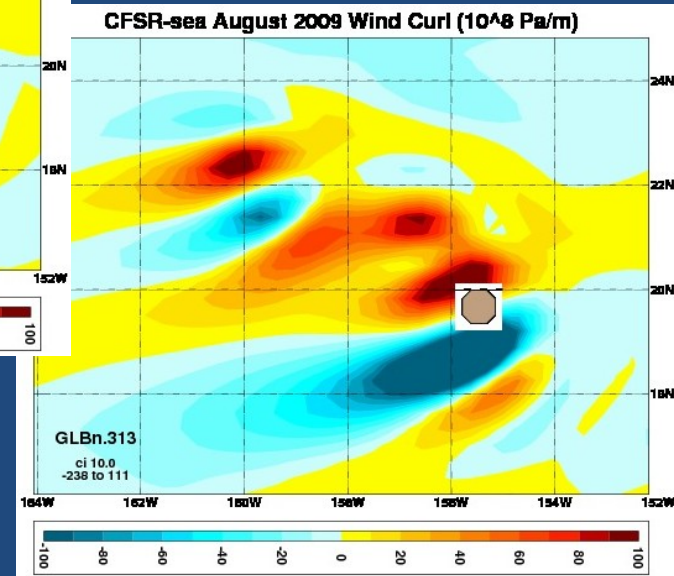## Wind Stress Curl – August 2009

QuikSCAT

More realistic curl over Hawaii after QuikSCAT correction

CFSR-sec

CFSR-sea

Wind stress curl plotted over Hawaii on the 0.3125° CFSR grid

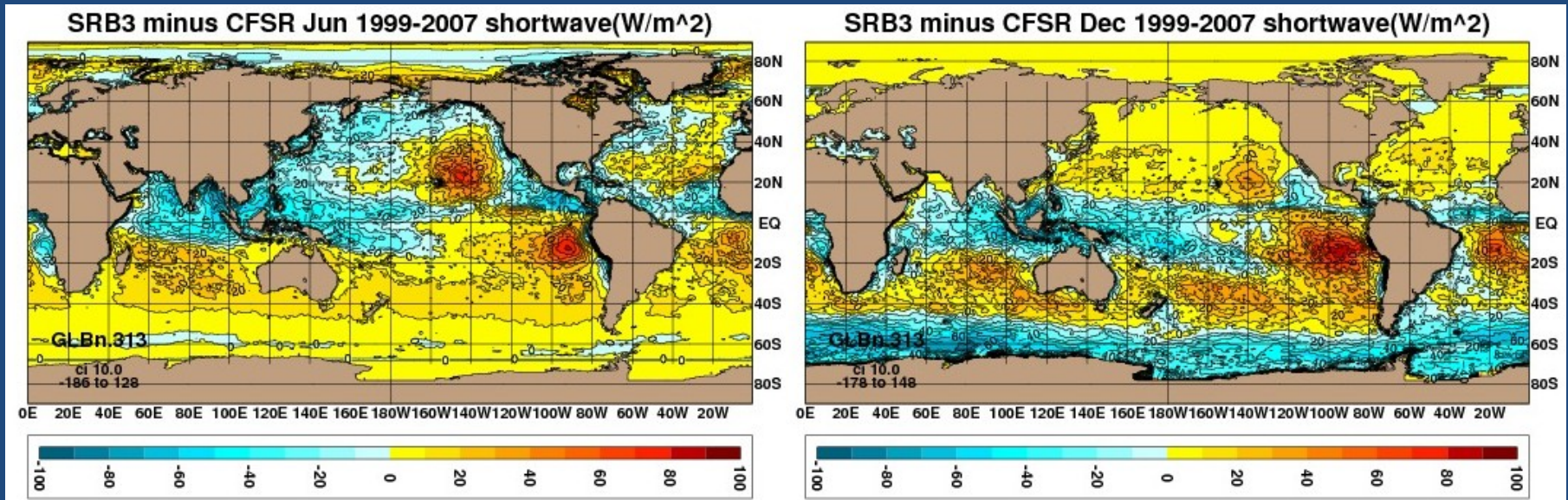# CFSR Radiation Forcing

Net Surface Shortwave Radiation Difference
Surface Radiation Budget (SRB) Release 3 minus CFSR

June   December

- Means computed over 1999-2007
- General pattern of too much CFSR shortwave in Indian Ocean and western Pacific, too little west of South America/east of Hawaii

Ocean Reanalysis

- Observations to be assimilated
  - Satellite altimeter and SST data
  - Profile data (Argo profiling floats, XBTs, CTDs)
  - SSM/I ice concentration
  - Surface drifters (near surface T and S)
  - All processed for the 1993-2009 time period and in NCODA-ready format
  - Attempted to locate and process as much available observational data as possible within the constraints of the project

Observations to be Assimilated via NCODA

SSH Observations
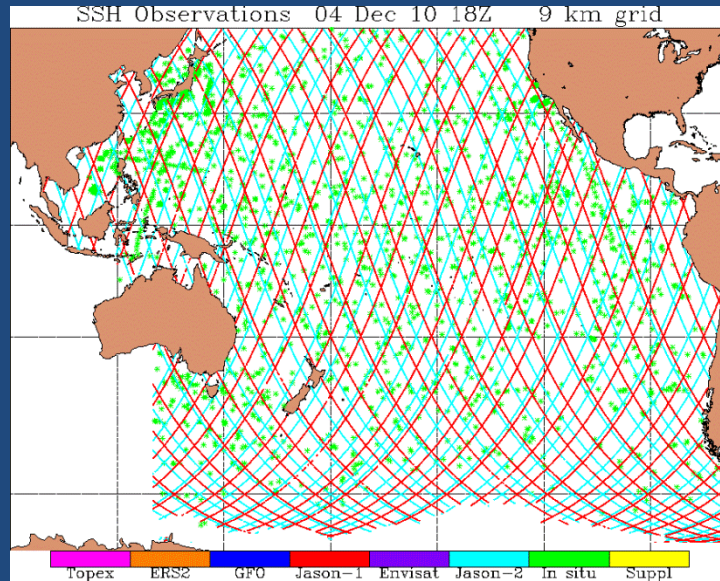
SST Observations
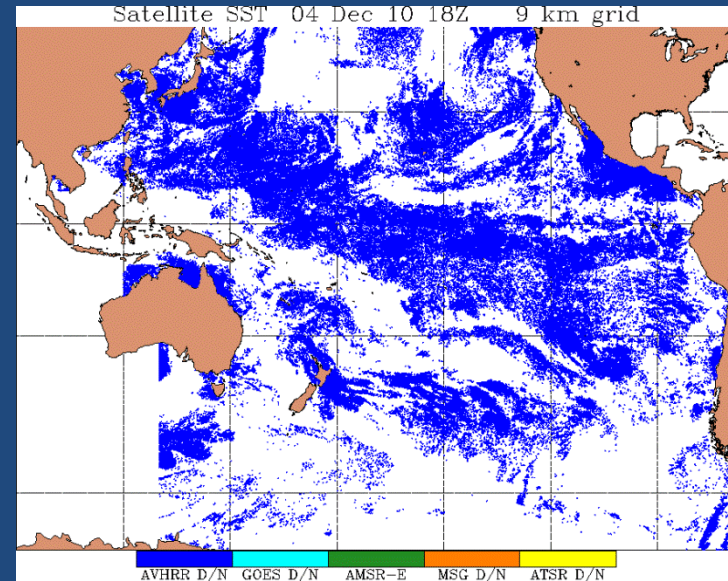
In-situ SST
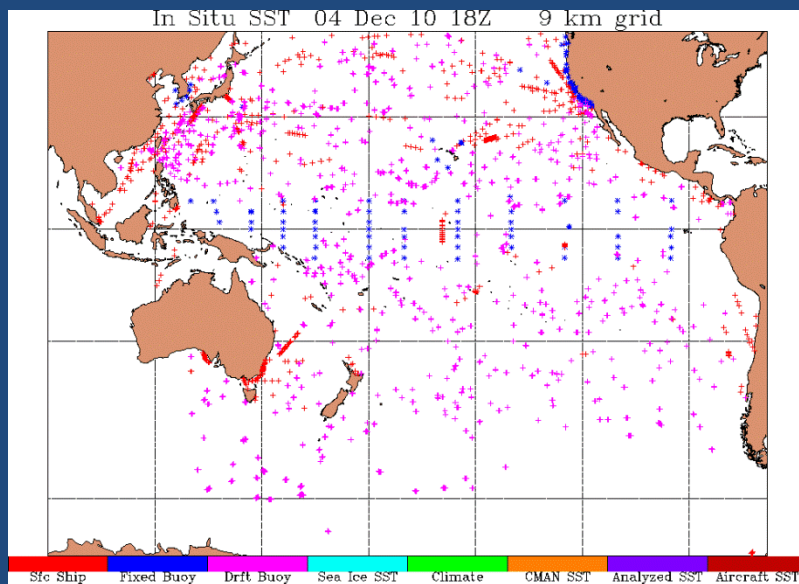
Profile Observations
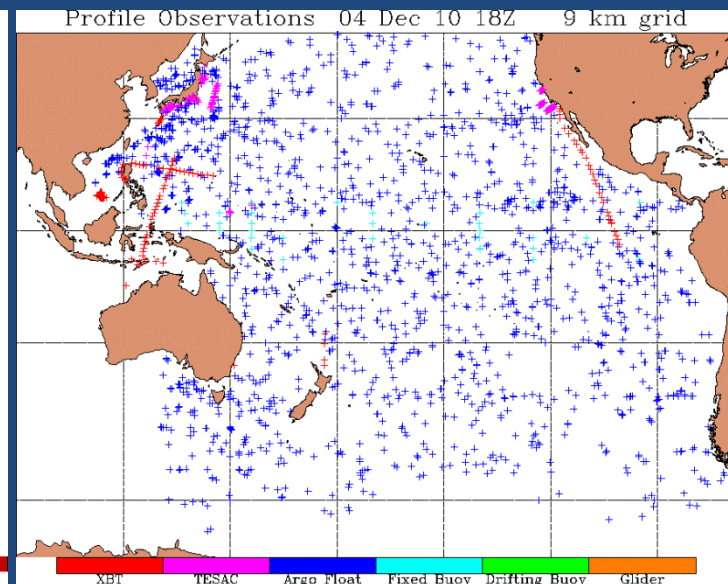
Pre Spin-up Simulations

- 1-layer barotropic linear 1/16° NLOM simulation using the CFSR climatology to determine the 1st order Sverdrup response to the wind forcing

- 0.72° and 0.24° global HYCOM (non-assimilative) using the CFSR climatology

- Compared these against existing simulations forced with different atmospheric products and found no gross errors in ocean model response

Spin-up and Reanalysis Simulations

- Spin-up 1/12° non-assimilative global HYCOM with CFSR climatology (~6 model years then iterate with a new offlux file)
  - Started this simulation in January 2011
  - 30 layers
  - Energy loan ice model during spin-up
- Extend climatological spin-up with 1-hourly CFSR forcing using 1/12° global HYCOM/NCODA/CICE
  - Start system in October 1992 (first altimeter data) and allow model to adjust to assimilation
  - Use 1993 as the first valid year of ocean model output

Computational Requirements

- Computer time via the DoD High Performance Computing Modernization Office
- Integrate the hindcast on the Navy DSRC IBM Power 6
- Use 759 processors
  - NCODA takes ~1.5 wall hours per model day
  - HYCOM/CICE takes ~0.6 wall hours per model day
- If assimilate every day
  - 450K processor hours per model year
  - One calendar month per model year
- If assimilate every three days
  - 225K processor hours per model year
  - Two calendar weeks per model year

Storage Requirements

- HYCOM (compressed) archive files:
  - Single day: 5.7 Gb
  - 1 per day: 2 Tb / model year
  - 24 per day: 50 Tb / model year
- Store every 2nd gridpoint, 4x reduction
- Store on a z-grid, 2x increase (30 to >60 levels)
- Store packed, 2x reduction (16 bits vs. 32 bits)
- Subset of the output to be placed on HYCOM server (TBD)

Schedule

- CFSR output in HYCOM-ready format — completed
- Simulations using 1993-2009 CFSR climatology at coarser resolution (0.72° and 0.24°) — completed
- 1/12° non-assimilative HYCOM spin-up using climatological CFSR forcing — started
- 1/12° non-assimilative HYCOM using 1-hrly 1993-2009 CFSR forcing – expected start date late February 2011
- HYCOM/NCODA/CICE reanalysis — expected start date March 2011
- Expect completion of reanalysis by end of 2012