# Ocean color, biological heating and upper ocean thermal structure: A sensitivity analysis


Lead PI: Dr. Avichal Mehra[1]

Co-PI's: Drs. Hae-Cheol Kim[2], Eric Bayler[3], David Behringer[2]

Collaborators: Drs. Jim Cummings[4], Zulema Garraffo[2], Sudhir Nadiga[2], Vladimir Krasnopolsky[1], Carlos Lozano[1], Victoria Coales[5], Seunghyun Son[6]

1: NOAA/NWS/NCEP/EMC; 2: IMSG at NOAA/NWS/NCEP/EMC; 3: NOAA/NESDIS/STAR; 4: SAIC at NOAA/NWS/NCEP/EMC; 5: UMD/HPL; 6: CIRA at NOAA/NESDIS/STAR

# Project Descriptions

(Background)

• The NOAA Ecological Forecasting Roadmap (EFR) for 2015-2019 states that its objective is "to provide dependable, higher quality forecast products, derived from the successful transition of research and development into useful applications…."

• In support of the NOAA-approved roadmap, this project proposes to evaluate approaches and develop a prototype foundational global biogeochemical modeling capability for NOAA's global operational Real-Time Ocean Forecast System (RTOFS-Global) for reliably providing the global modeling fields required to support the ecological forecasts of the EFR technical teams

# Project Descriptions

(Background)

- Specifically,
  - to establish a component for the national modeling 'backbone' that will generate global predictions of the common physical and biogeochemical variables used by ecological forecasts
  - to address key linkages and gaps within the EFR infrastructure framework via JPSS VIIRS ocean color data and physical-biogeochemical numerical modeling because ocean color data from VIIRS provides a unique path toward ecological forecasting through biogeochemical (BGC) analyses and forecasts, facilitating both real-time and scenario-based marine ecosystem applications

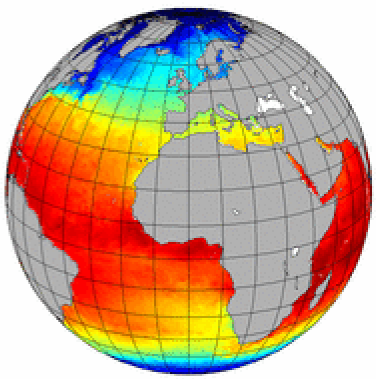
# Scientific Objectives

- Employing coupled BGC-physical modeling to improve NWS forecasting skill at short-term and seasonal scales
  - ➢ by including the effects of biological heating on upper-ocean thermal structure
  - ➢ by exploring the direct assimilation of ocean color products (e.g., VIIRS) in conjunction with radiative transfer (RT) computations using existing validated algorithms (Lee et al., 2005).
- Providing scenario-based forecasting
  - ➢ to predict system responses to potential changes by drivers (natural or through ecosystem management decisions)
- Assessing the effects of carbon dynamics between the atmosphere and the ocean and subsequent changes in the acidity of the global ocean
- Exploring BGC model to support for upper-trophic-level modeling

# Ocean Color and Biological Heating

# Ocean Model

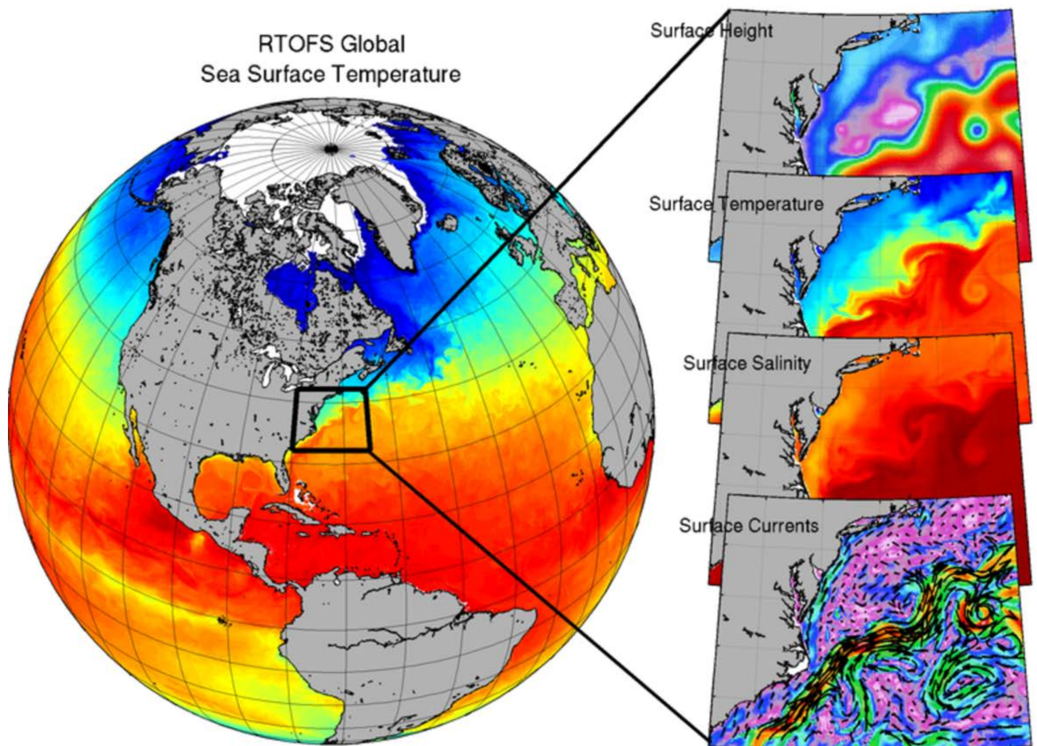
## (HYbrid Coordinate Ocean Model; HYCOM)



Credit: Spindler

- GLBa0.24
  - ➢ Hybrid Coordinate Ocean Model (HYCOM) with 1/4° and 32 layers
  - ➢ iso-pycnal (deep ocean), z-levels (surface), σ (coasts)
  - ➢ Tripole grid (1 at South Pole and 2 from Arctic patches)
  - ➢ Recti-linear (<47°N) and curve-linear (>47°N)

- RTOFS-Global (NCEP's operational)
  - ➢ HYCOM-base (1/12° and 41 layers)
  - ➢ NAVOCEANO daily initialization with MVOI (now 3DVAR) data assimilation from NCODA (Navy Coupled Ocean Data Assimilation)
  - ➢ KPP for vertical mixing
  - ➢ 2-day nowcast (GDAS) and 6-day forecast (GFS)




Credit: Spindler

# Numerical Experiments

| Experiments | Ocean color product | Sensor | Period | Algorithms |
|---|---|---|---|---|
| **KparCLM** | Long-term climatological $K_{dPAR}$ (Son and Wang, 2015) | SeaWiFS | 1997-2009 | Kara et al. (2004) |
| **ChlaCLM** | Long-term climatological Chl-*a* (O'Reilly et al., 1998) | SeaWiFS | 1997-2009 | Lee et al. (2005) |
| **ChlaID** | Interannual mean Chl-*a* (O'Reilly et al., 1998) | SeaWiFS | Each year (2001 – 2009) | Lee et al. (2005) (diurnal variation of solar zenith angle) |
| **ChlaIND** | Interannual mean Chl-*a* (O'Reilly et al., 1998) | SeaWiFS | Each year (2001 – 2009) | Lee et al. (2005) (no diurnal variation of solar zenith angle) |

- KparCLM vs. ChlaCLM: algorithmic differences
- ChlaCLM vs. ChlaID: mesoscale variabilities
- ChlaID vs. ChlaIND: diurnal variabilities and short-term scale effects

# Configurations

- SeaWiFS ocean color data, combined with hourly CFSR (Saha *et al*., 2010) with additional flux correction, were used to hindcast ocean state 2001-2009

- The optical algorithm (CHL) is a two-band scheme for CASE 1 waters (Lee *et al*., 2005) newly implemented in the latest HYCOM source code version (src2.2.98)

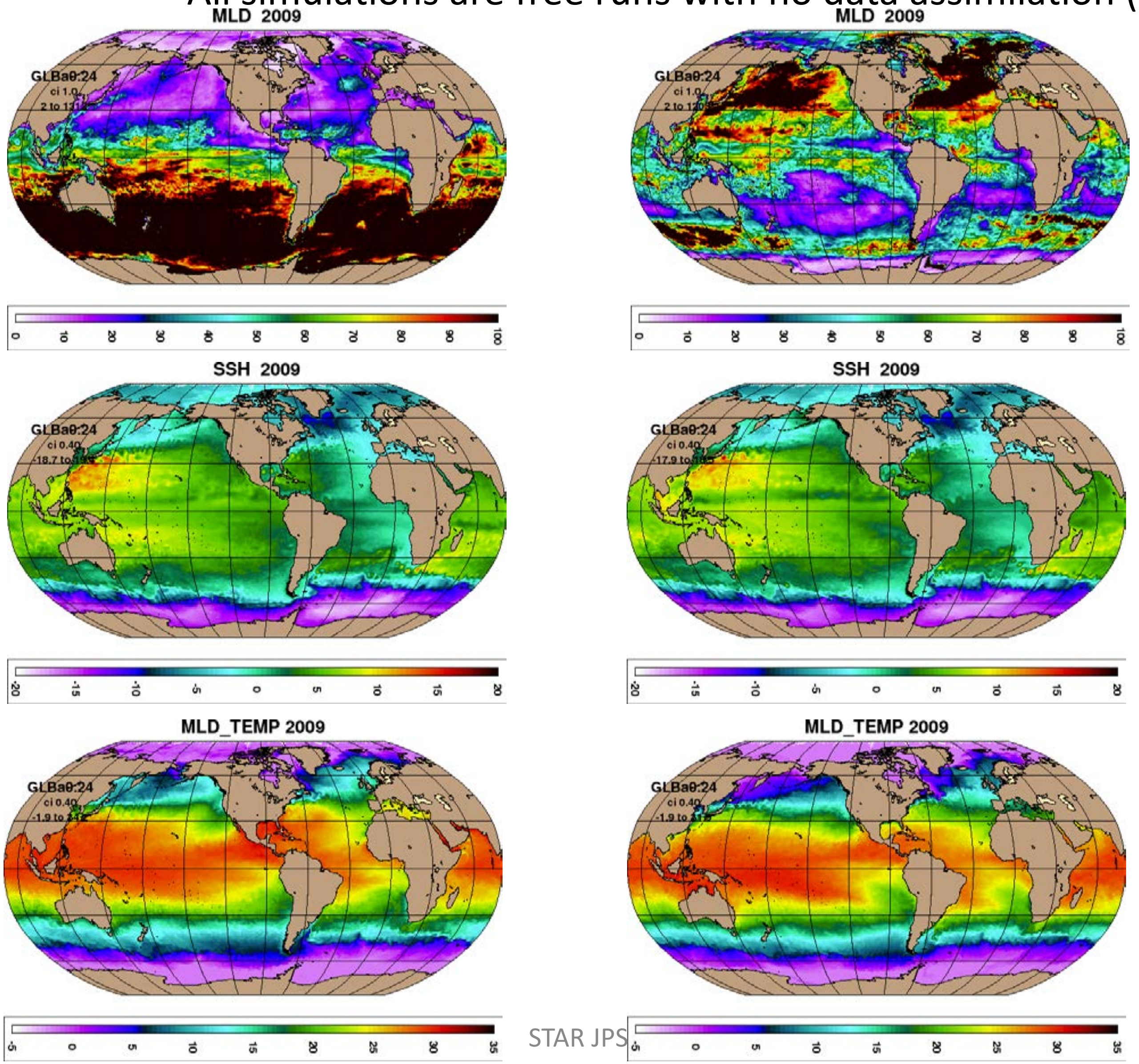
- The two-bands include the visible (VIS; 400-700 nm) and red bands (IR; 700-2000 nm)

- Required input are:

  - Total absorption coefficient at the surface for 490 nm ($a_{490}$, $m^{-1}$)
  - Total backscattering coefficient at the surface for 490 nm ($b_{b490}$, $m^{-1}$)
  - These inherent optical properties (IOP's) are functions of chlorophyll and pure water
  - $K_{VIS}(IOP,z)=K_1(IOP,\theta_a)+K_2(IOP,\theta_a)/(1+z)^{0.5}$
  - $K_{IR}(z,\theta_a)=[0.56+2.304/(0.001+z)^{0.65}](1+0.002\theta_a)$
  - Considered valid for global, basin-scale oceanography

# Simulations (2001-2009)

- All runs are initialized at Jan. 1, 2001
- All simulations are free runs with no data assimilation (2001-2009)




Mixed Layer Depth (MLD)

Sea Surface Height

MLD-averaged Tempearture

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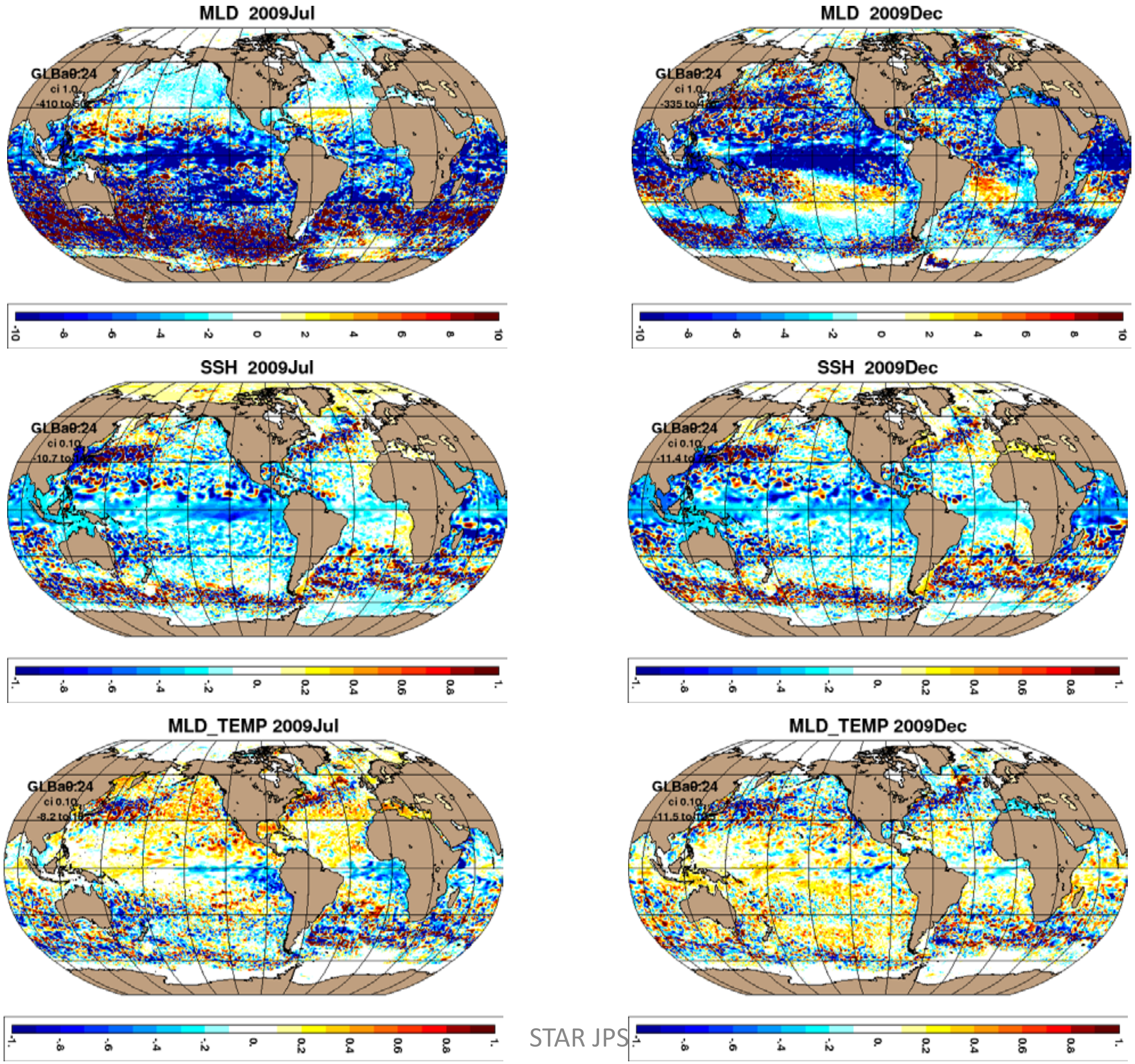
# KparCLM minus ChlaCLM
## (Algorithm Difference)

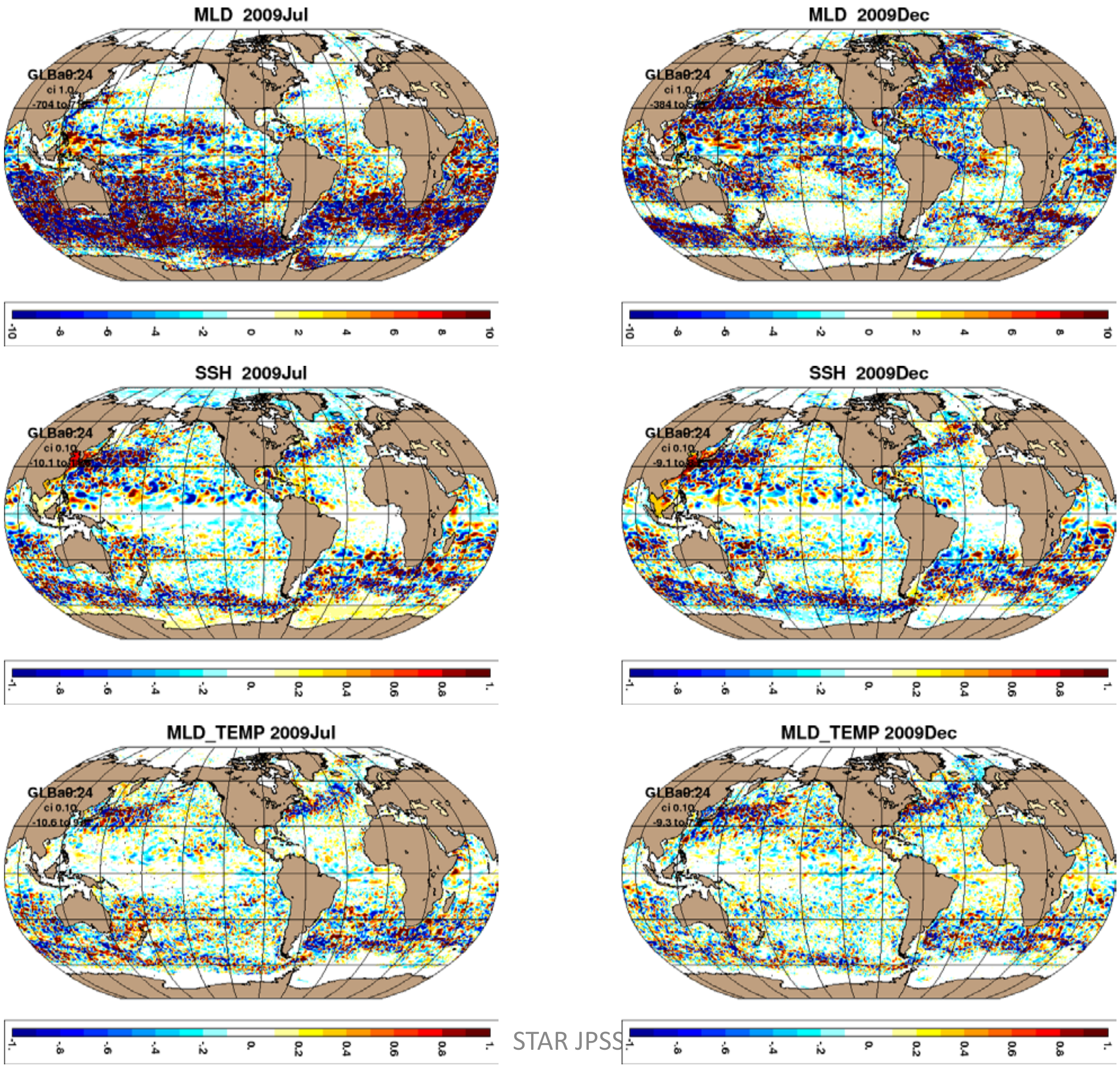



Mixed Layer Depth (MLD)

Sea Surface Height

MLD-averaged Tempearture

# ChlaCLM minus ChlaID
## (mesoscale variabilities)

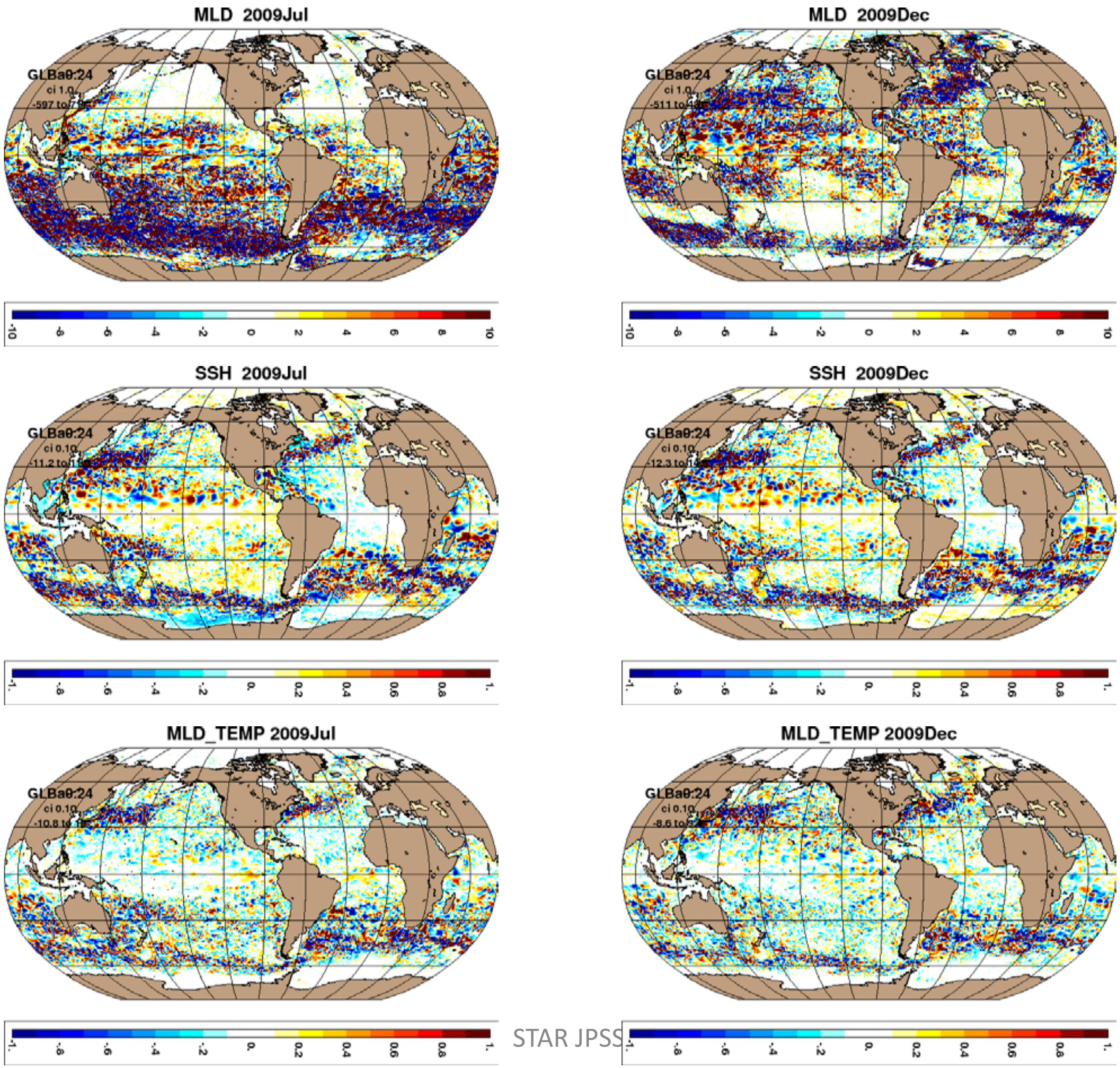



Mixed Layer Depth (MLD)

Sea Surface Height

MLD-averaged Tempearture

# ChlaID minus ChlaIND
## (diurnal variabilities of solar zenith angle)

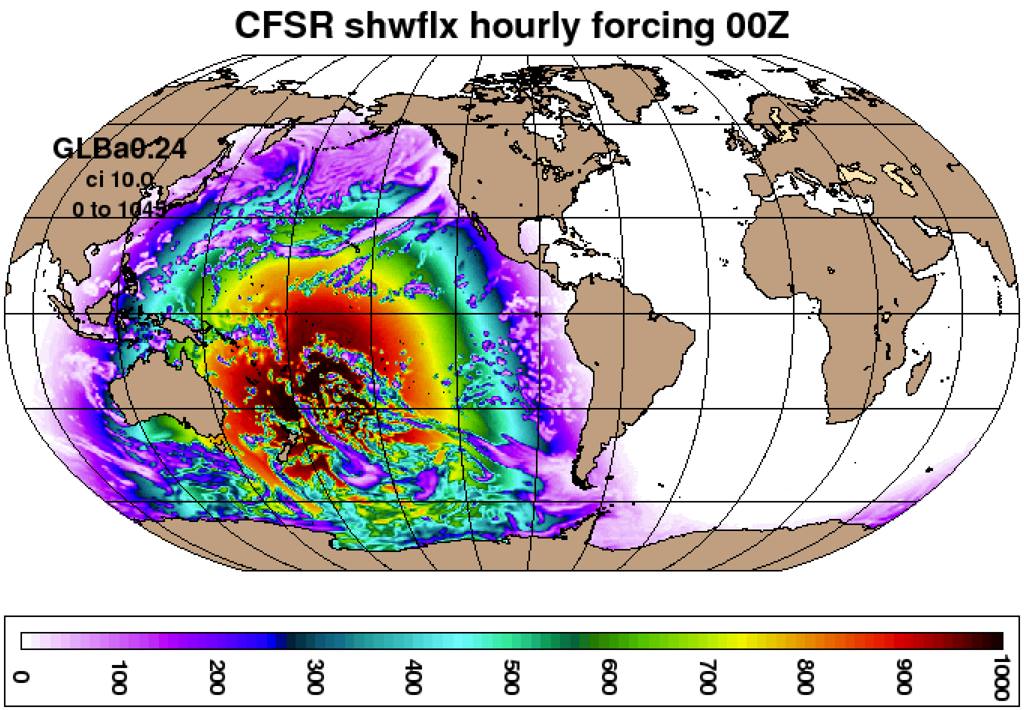


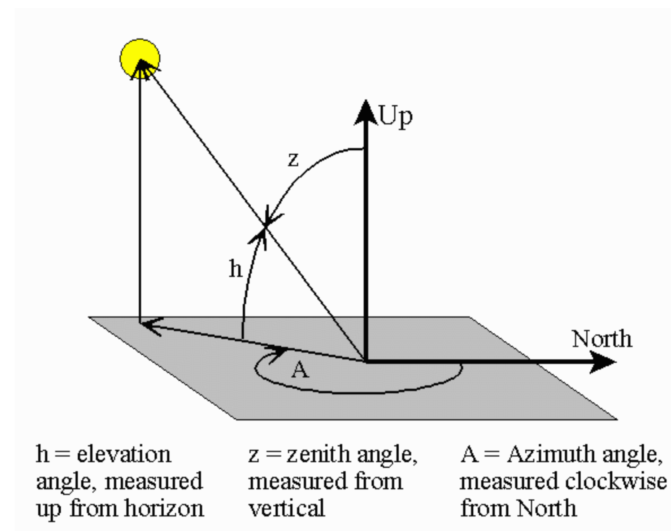

Mixed Layer Depth (MLD)

Sea Surface Height

MLD-averaged Tempearture

# Diurnal variation of surface forcings




Credit: ESRL (www.esrl.noaa.gov)

- Diurnal variation effect of in-water solar zenith angle is significant and should be considered (especially, when high frequency forcings are used)