# Experiments and Analyses with High Resolution Versions of CCSM

Frank Bryan

NCAR/CGD

# Completed and Ongoing Experiments

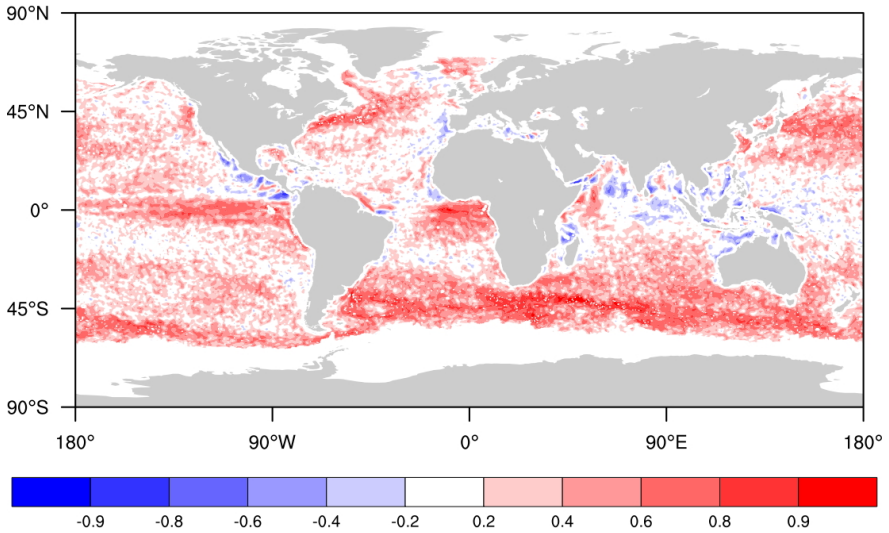
- LLNL Grand Challenge Runs
  - Analysis of frontal scale air-sea interaction
- PetaApps Control Runs
  - Analysis of low-frequency climate variability
- 0.5° CAM5 AMIP-type forced runs
  - Sensitivity of air-sea interaction processes to SST resolution and model formulation
- 0.5° atm/0.1° ocn $CO_2$ ramp experiment
  - resolution dependence of climate sensitivity and response
- CORE forced 0.1°/62 level ocean experiments

# Frontal-Scale Air-Sea Interaction

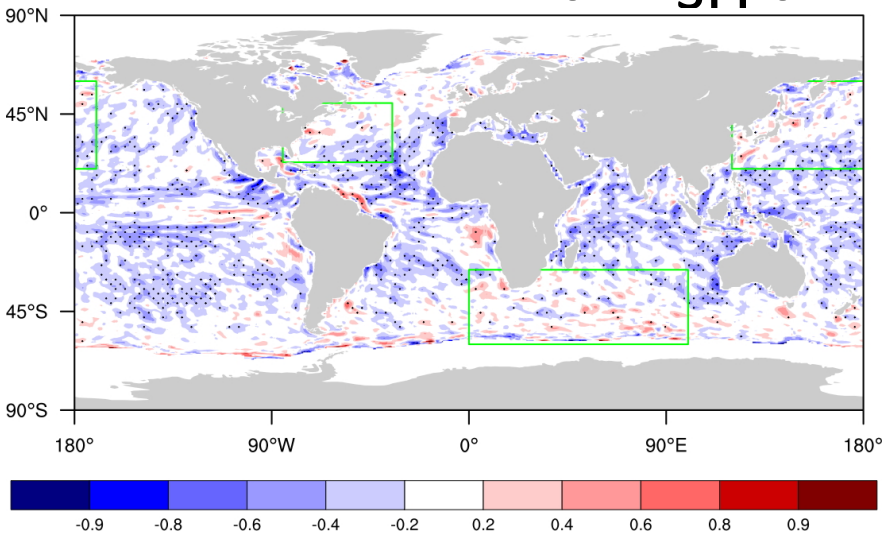
Bryan et al (2010) J. Climate, **23,** 6277-6291

- Local atmosphere-ocean coupling processes at ocean mesoscale
- Observational (primarily remote sensing) and regional model studies have contrasted frontal- scale with basin-scale air sea interaction processes:
  - Basin-scale: high winds associated with enhanced turbulent fluxes, entrainment, Ekman transport leading to cool SSTs
  - Frontal-scale: Warm SSTs force lower atmospheric response leading to higher winds

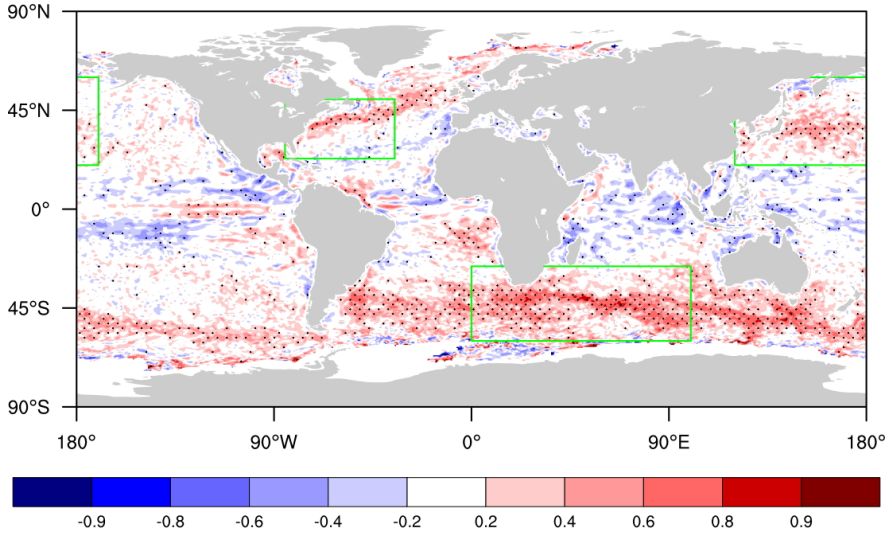
# Correlation High-Pass SST w/ $|\mathbf{U}_{srf}|$



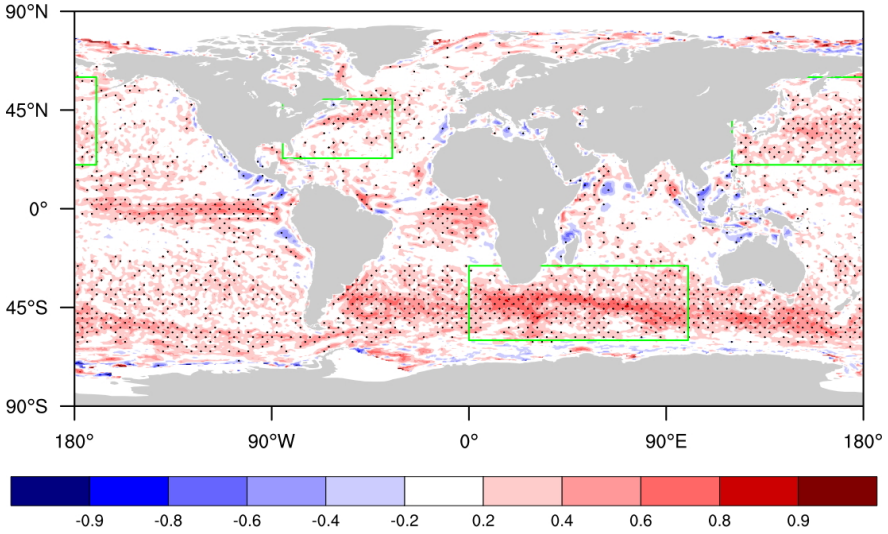

QuickScat + AMSR




CCSM 0.5° atm / 1° ocn

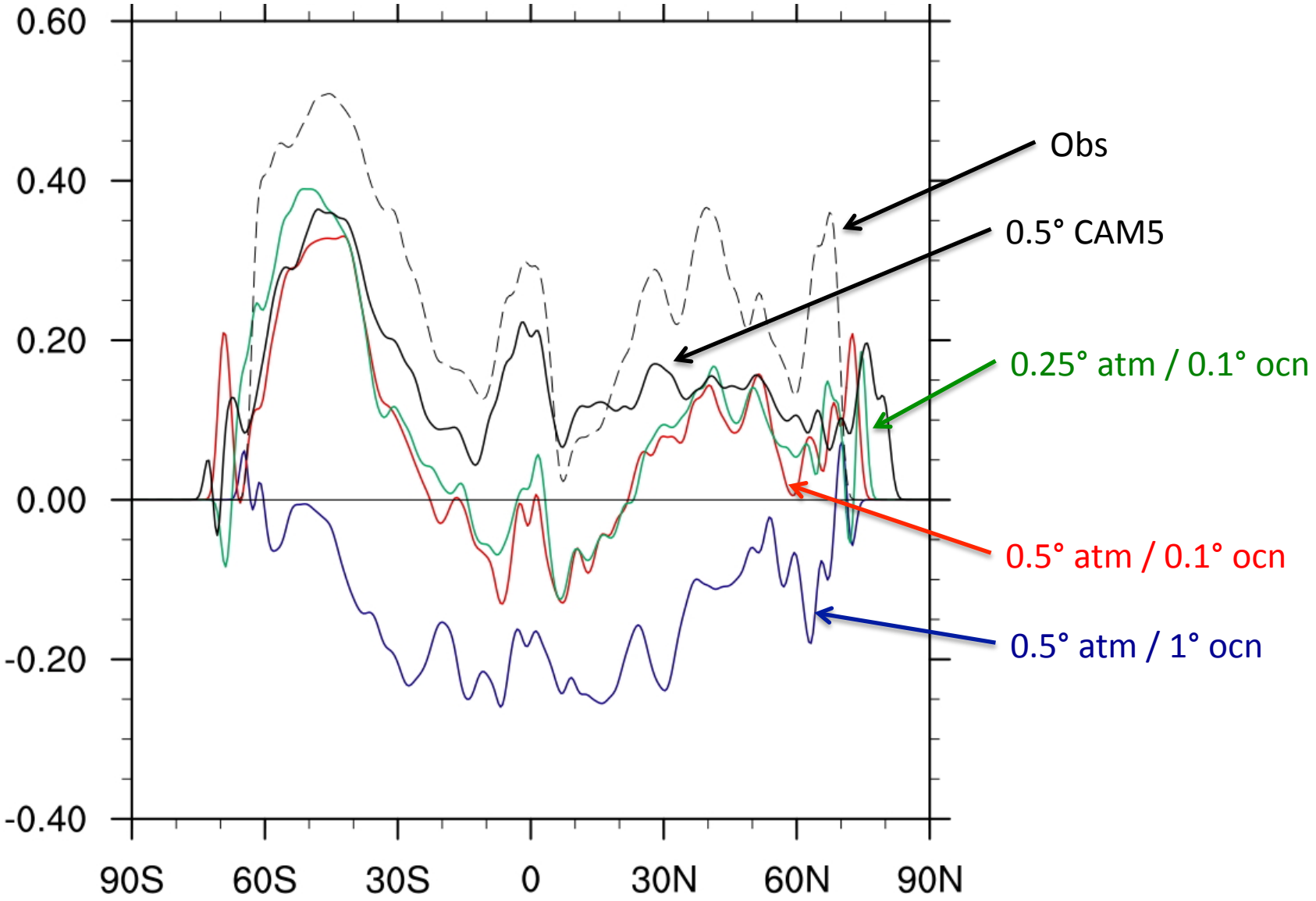


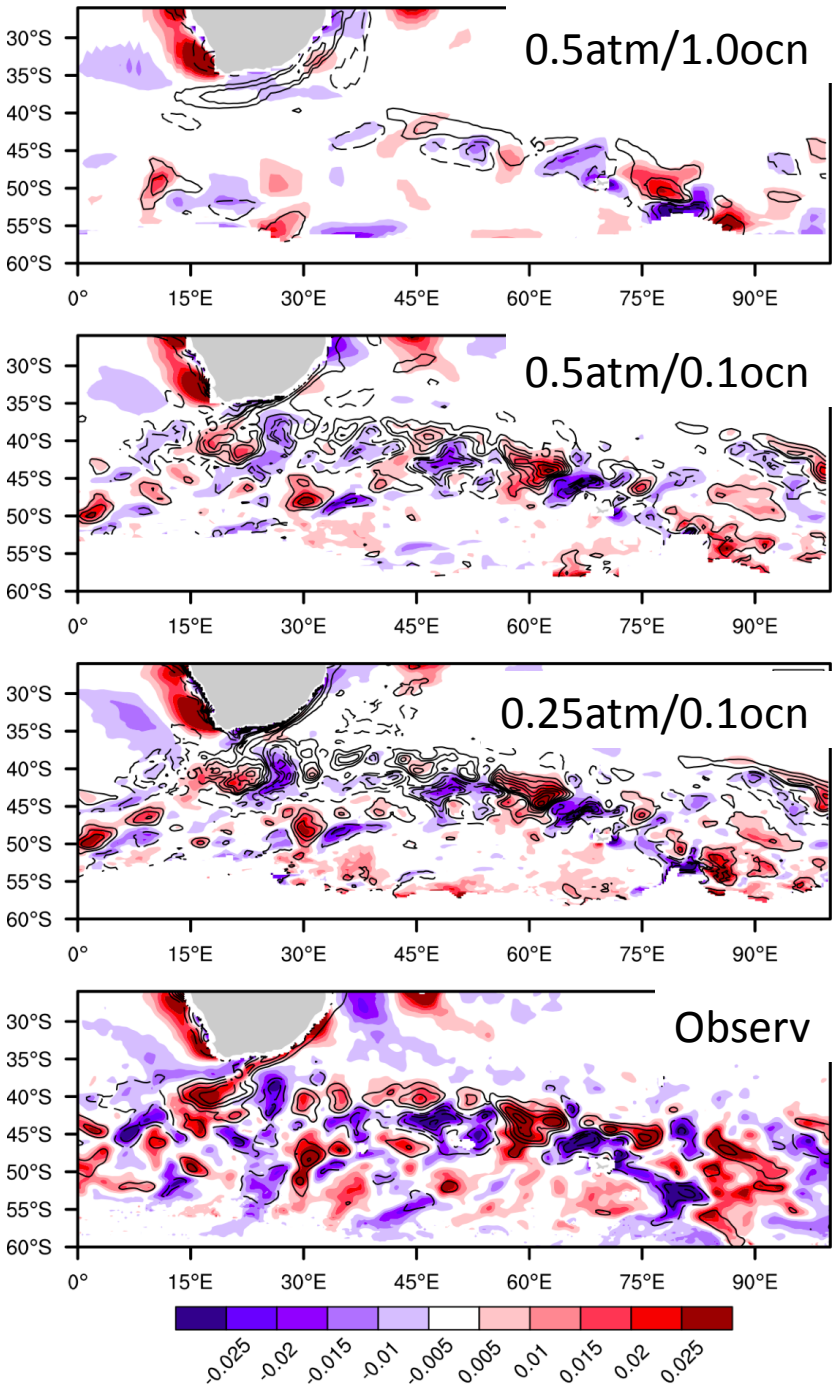

CCSM 0.5° atm / 0.1° ocn



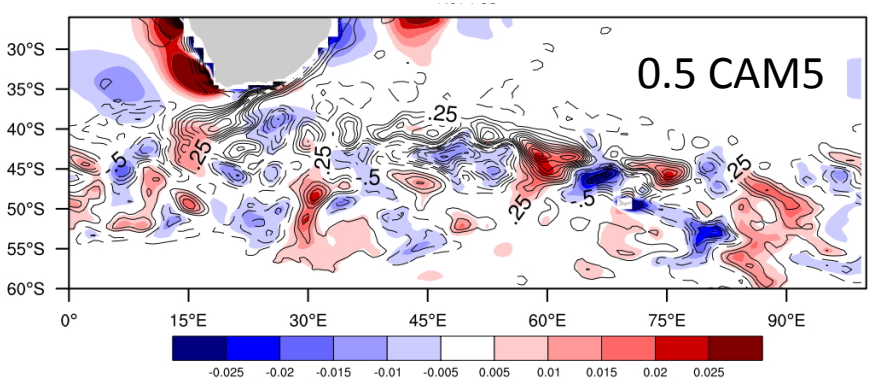

CAM5 0.5° w/ 0.25° SST

# Zonal Avg. Correlation High-Pass SST w/ $|\mathbf{U}_{srf}|$

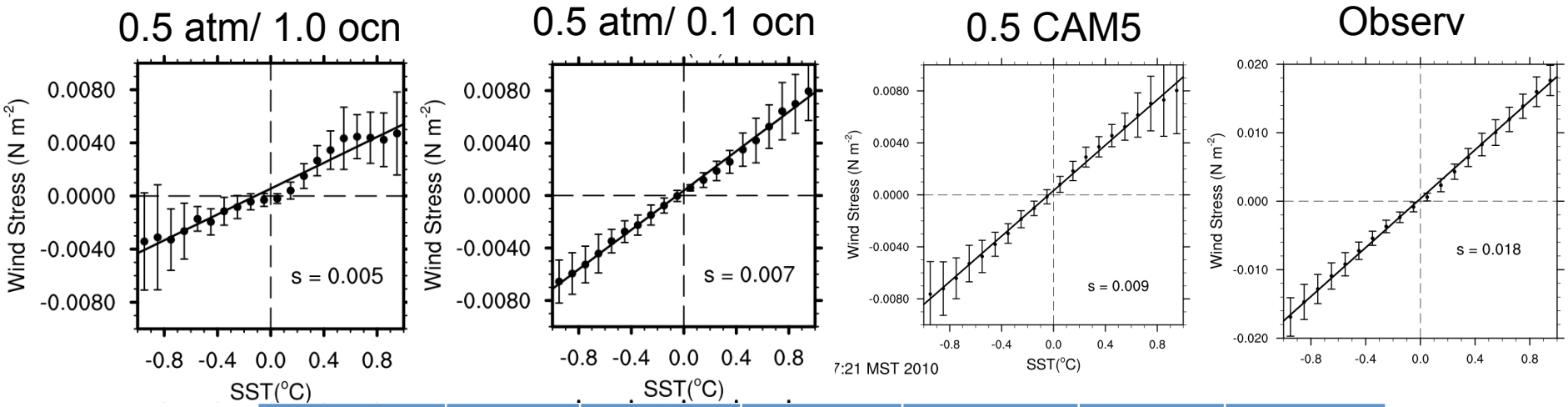





Seasonal Mean
Wind Stress (color)
Vs.
SST( contour)



# Regional SST vs Stress Regressions




| | Region | 0.5A/1.0O | 0.5A/0.1O | 0.25A/1.0O | 0.5A CAM5 | QS/AMSR |
|---|---|---|---|---|---|---|
| \|τ\| vs. SST | KE | 0.007 | 0.008 | 0.006 | 0.007 | 0.010 |
| | ARC | 0.005 | 0.007 | 0.008 | 0.009 | 0.018 |
| | GS | 0.006 | 0.004 | 0.005 | 0.005 | 0.009 |
| div(τ) vs Downwind grad(SST) | KE | -0.16 | 0.83 | 0.75 | 0.84 | 0.64 |
| | ARC | 1.02 | 1.03 | 0.99 | 1.08 | 1.62 |
| | GS | 0.39 | 0.60 | 0.50 | 0.61 | 0.62 |
| curl(τ) vs Crosswind grad(SST) | KE | -0.51 | 0.50 | 0.53 | 0.64 | 0.42 |
| | ARC | 0.75 | 0.82 | 0.84 | 0.77 | 1.33 |
| | GS | -0.37 | 0.29 | 0.33 | 0.37 | 0.38 |

# Tropospheric Response along 40°S

$\theta$

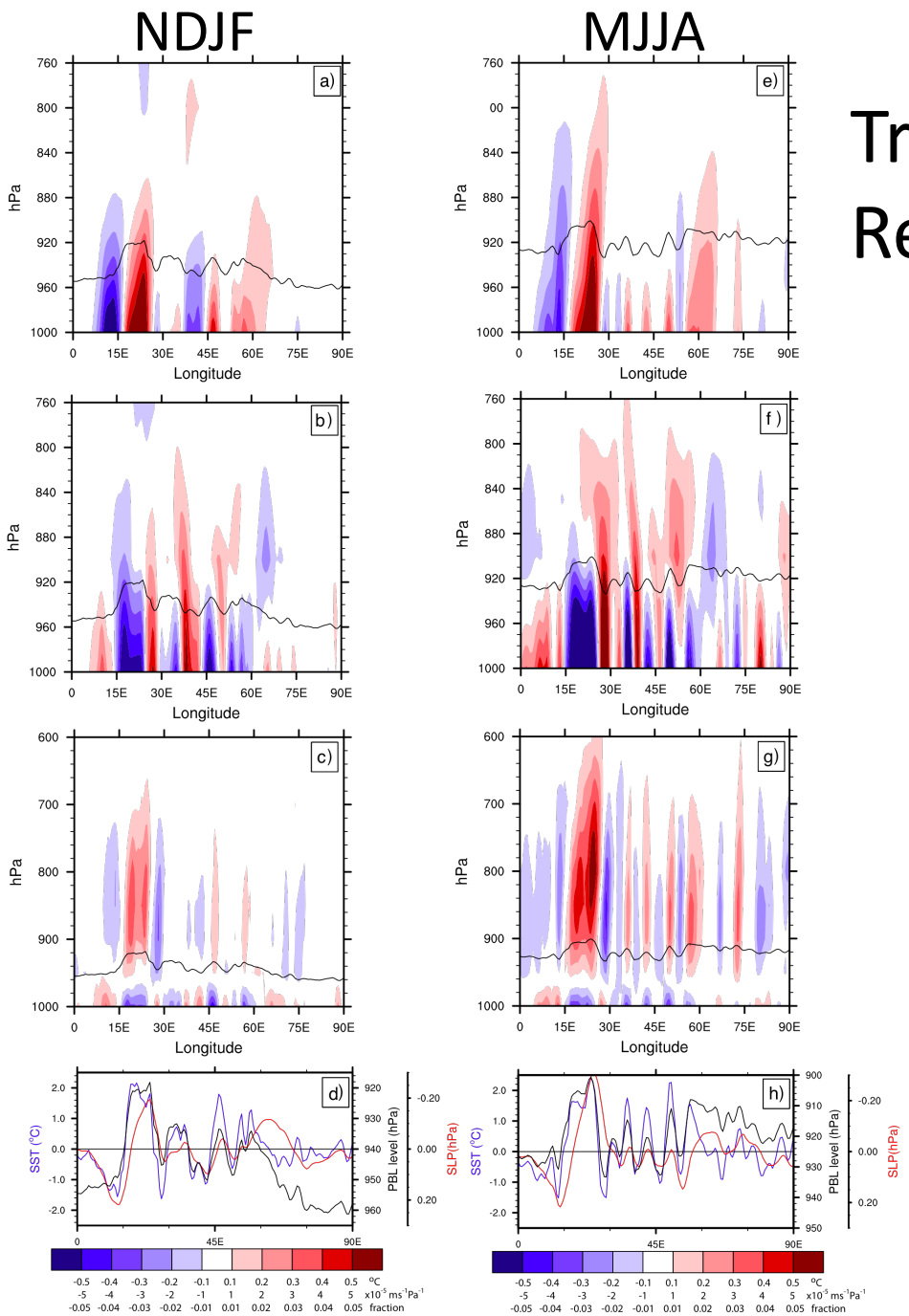
$-\frac{\partial u}{\partial p}$

Cld Frac

SST

SLP

$H_{BL}$



# Forcing of Low-Level Convergence

- For linearized momentum balance in PBL:

$$-fV = -\frac{\partial P}{\partial x} - \varepsilon U$$

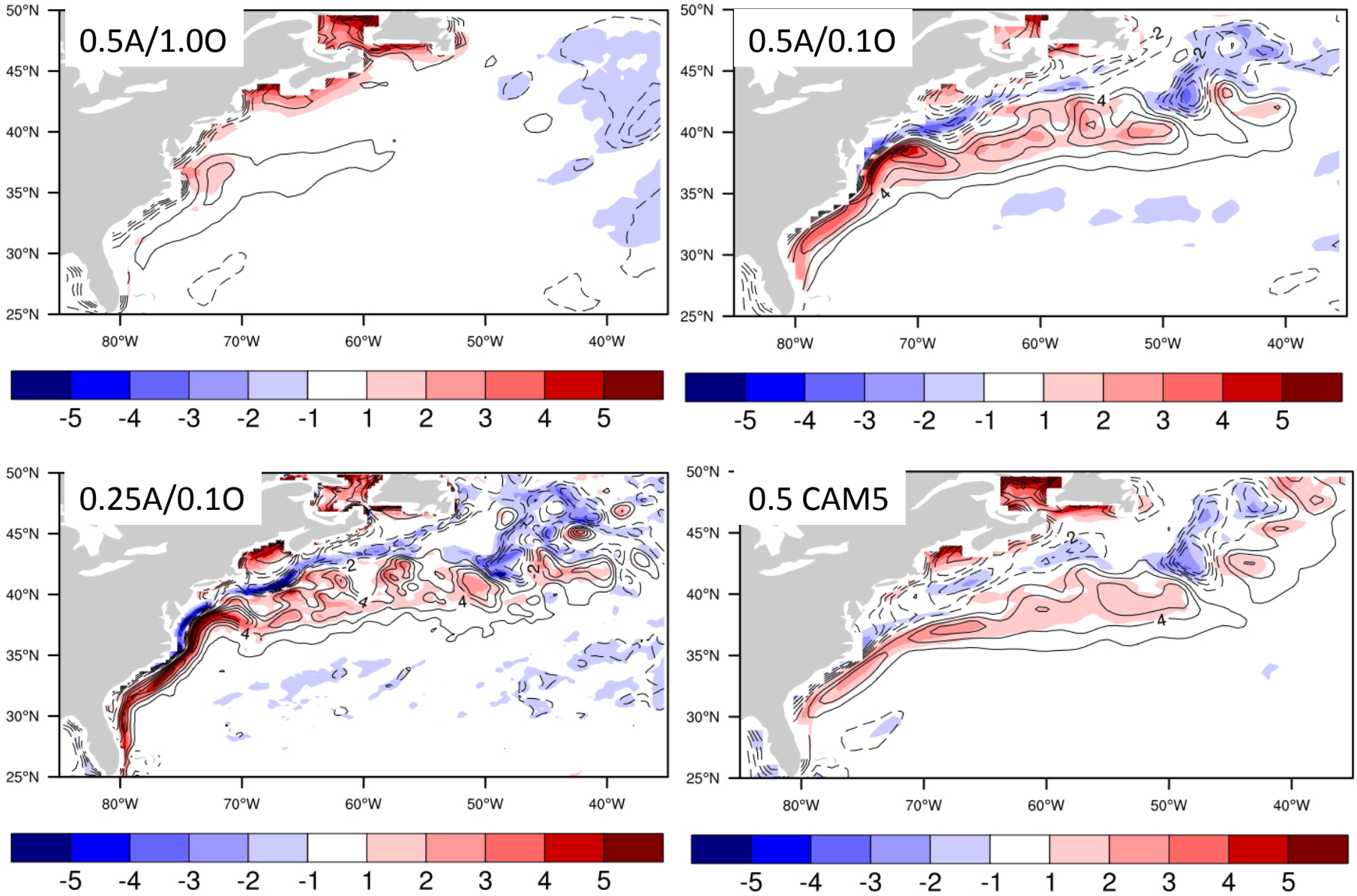
$$fU = -\frac{\partial P}{\partial y} - \varepsilon V$$

- Convergence ~ Laplacian pressure

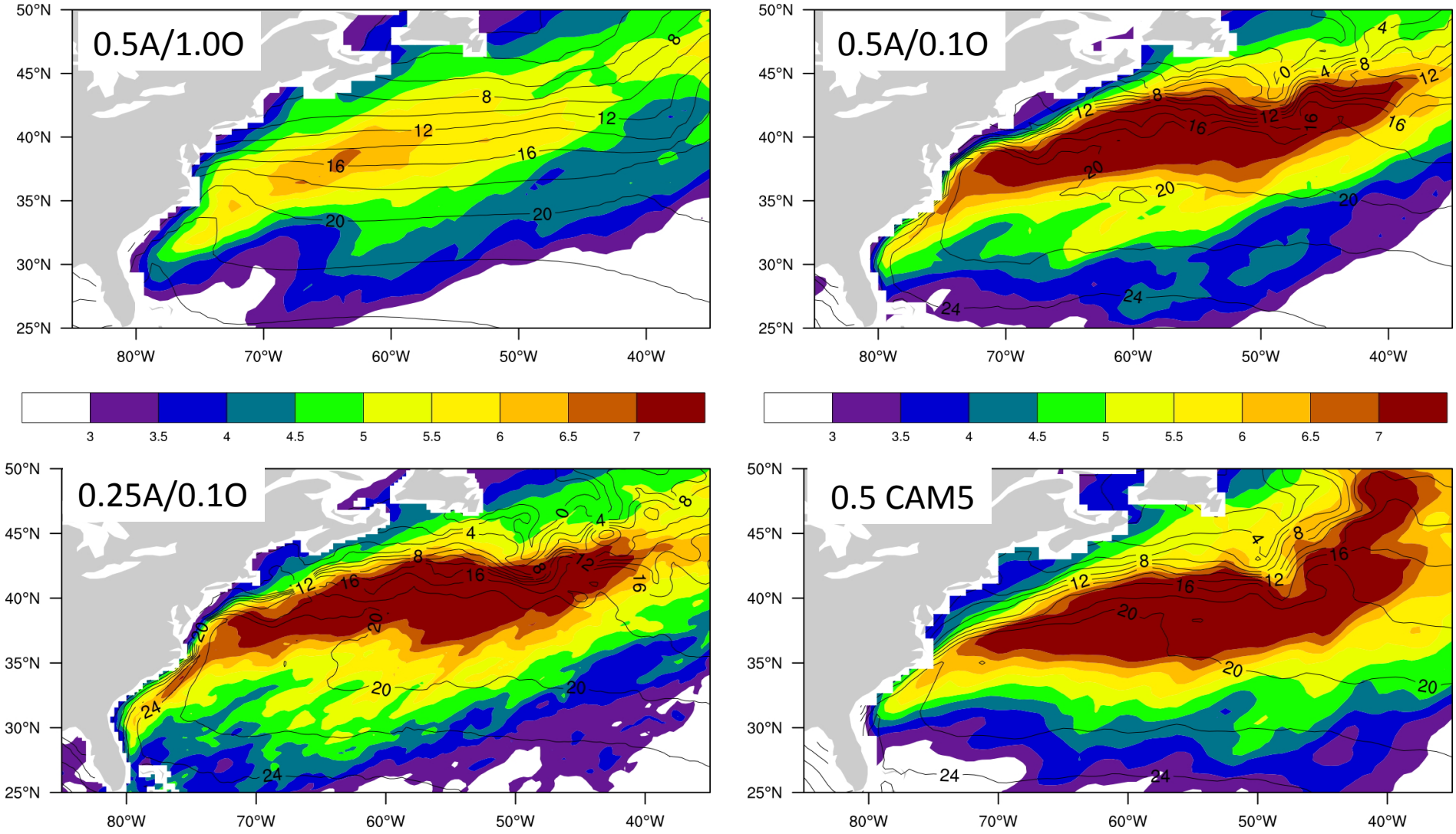
$$-\nabla \bullet \vec{U} \approx \frac{\varepsilon}{\varepsilon^2 + f^2} \nabla^2 P$$

Minobe, Takatama (2008,2010)

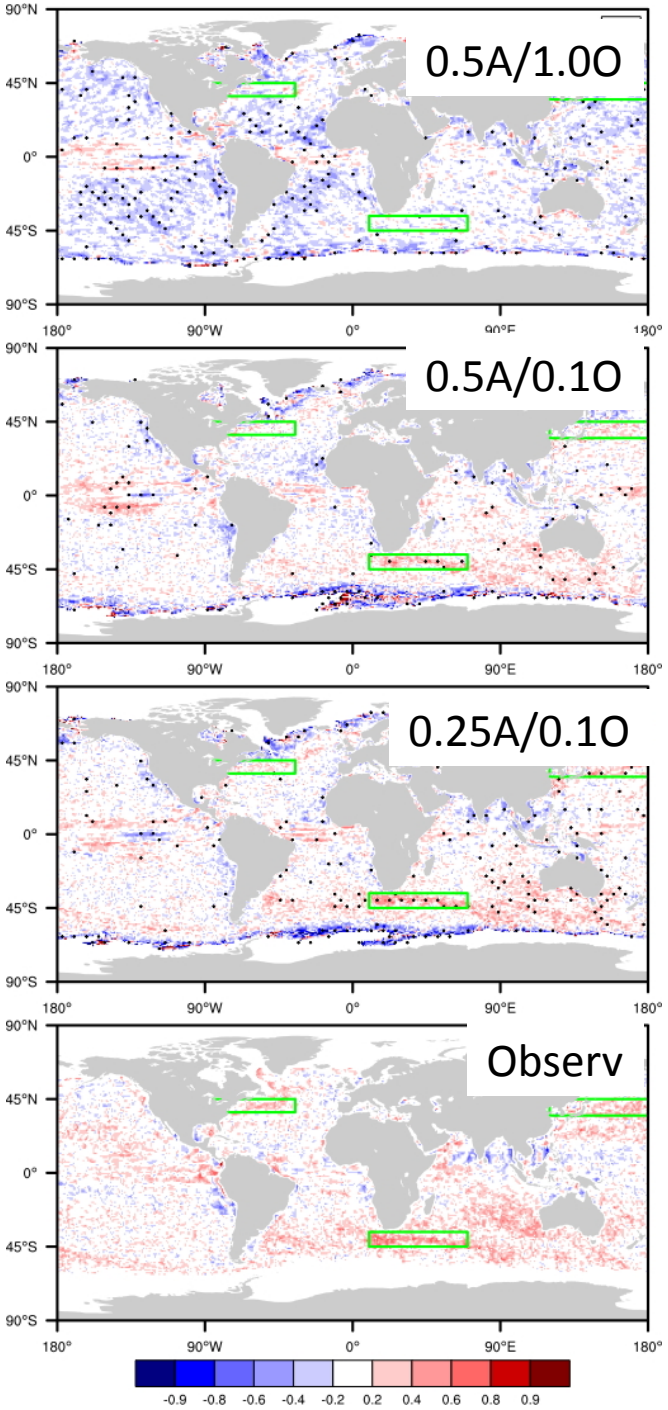
# Lapalacian Pressure (color) vs. Convergence (contours)

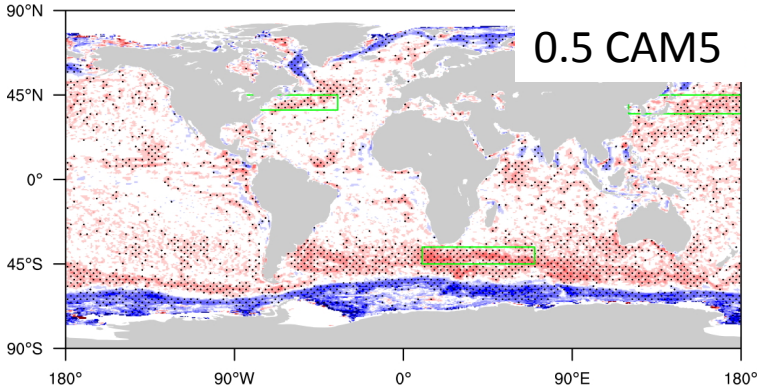


# Winter Mean Precipitation



# Planetary Scale Impact on Energy Balance: Correlation High-Pass SST vs. All Sky Albedo



# Low Frequency Variability

- Do the local frontal-scale interactions influence basin- to global-scale modes of variability?
- Do new modes of variability arise when fluids on both sides of the air-sea interface are turbulent?

# Correlation Annual Avg. SSH vs. LHFLX

0.5atm/1.0ocn

REDACTED

REDACTED

0.5atm/0.1ocn

# Timeseries Annual SSH vs. LHFLX

Agulhas 0.5atm/0.1ocn 0.5atm/1.0ocn

SAF

REDACTED REDACTED

Malvinas

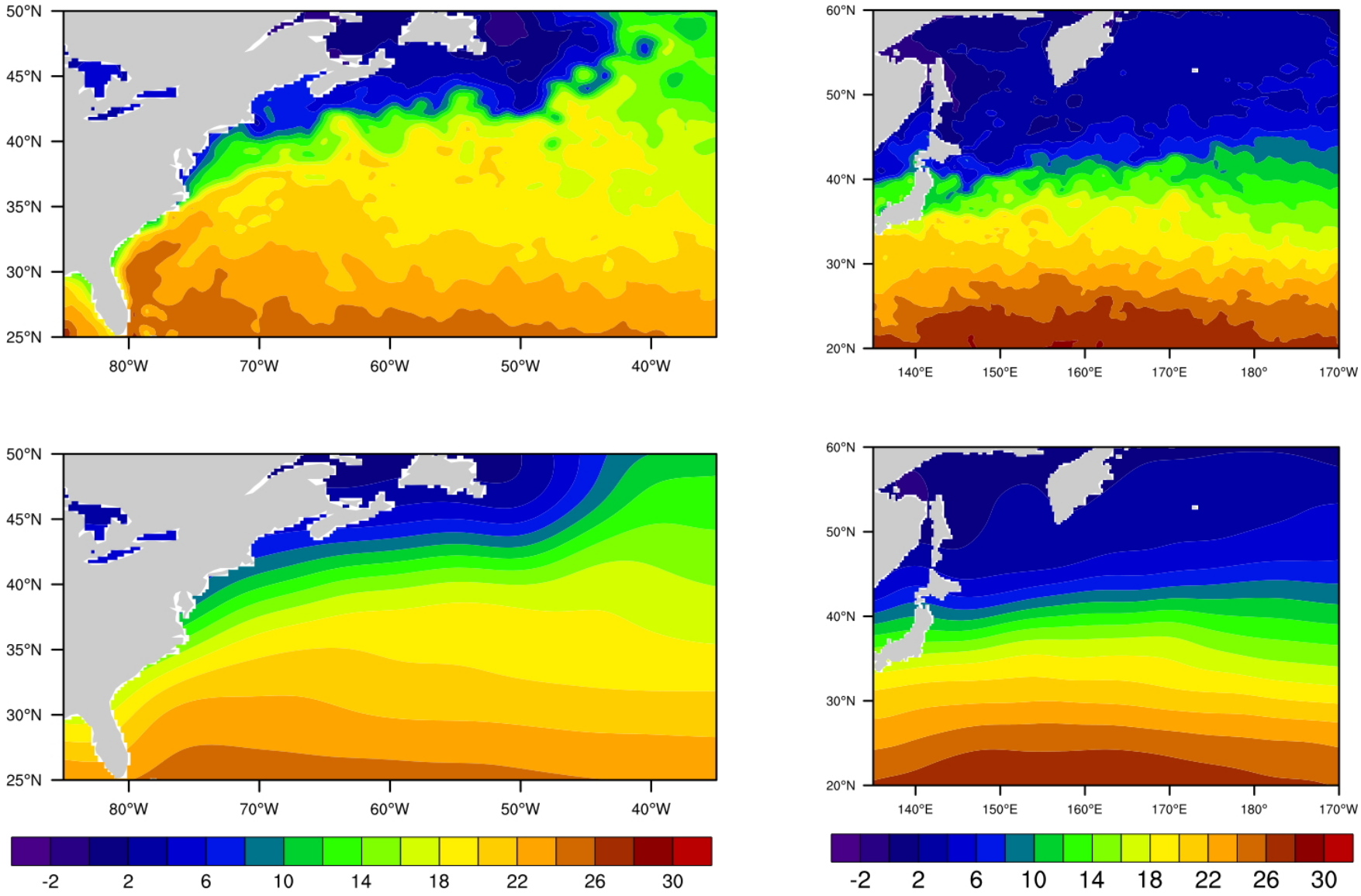
Kuroshio

GS

# Planned CAM5 Experiments

- Sensitivity to Scales Resolved in SST
  - Reproduce Minobe et al experiments w/ CAM5
- Sensitivity to Boundary Layer Parameterization
  - Holtslag-Boville vs. Bretherton-Park
  - Stability function
- More quantitative low-level momentum budgets

# Sensitivity to Scales in SST



# Planned Forced Ocean Experiments

(Experiments running as “C” comp-set through coupler)

- Vertical resolution
  - 62 level vertical grid (from 1° model)
- Sub-grid scale closure
  - Sub-mesoscale parameterization (Fox-Kemper et al)
  - Anisotropic GM
- Windstress surface current coupling
  - Damping mechanism for excessive EKE?