Highlights from Recent Publications Describing Climate Projections for the North Pacific

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1. Meehl et al., 2006, Climate change projections for the twenty-first century and climate change commitment in the CCSM3, *Journal of Climate*, 19, 2597-2616.

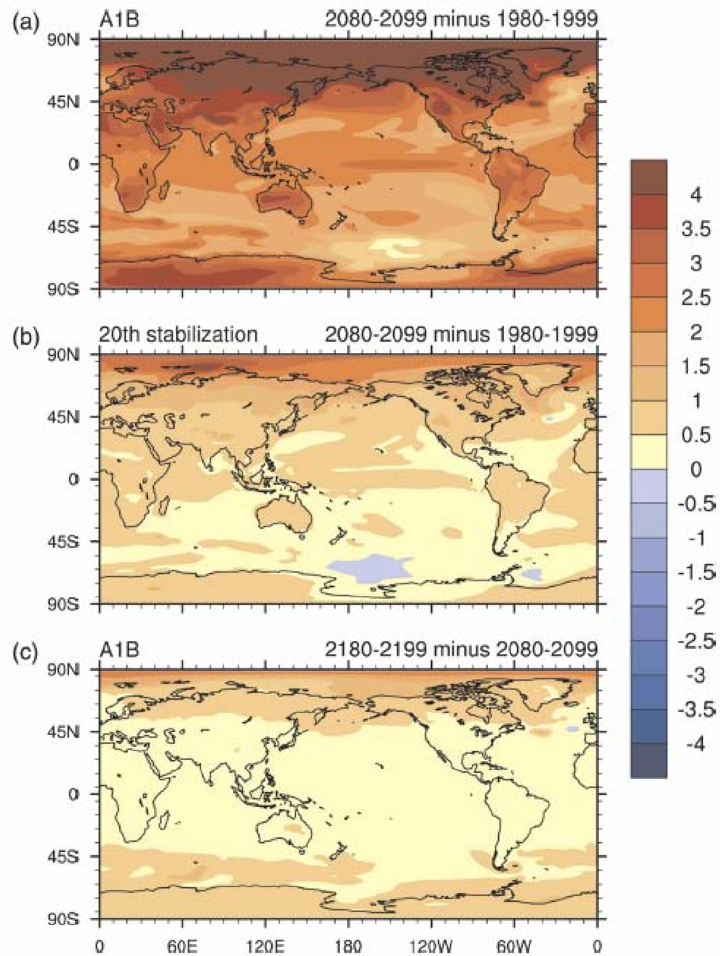


FIG. 5. (a) Geographic plots of annual mean surface air temperature differences (°C) for A1B scenario, 2080–99 minus 1980–99; (b) same as (a) except for twentieth-century stabilization experiment; (c) same as (b) except for twenty-first-century stabilization experiment, 2180–99 minus 2080–99.

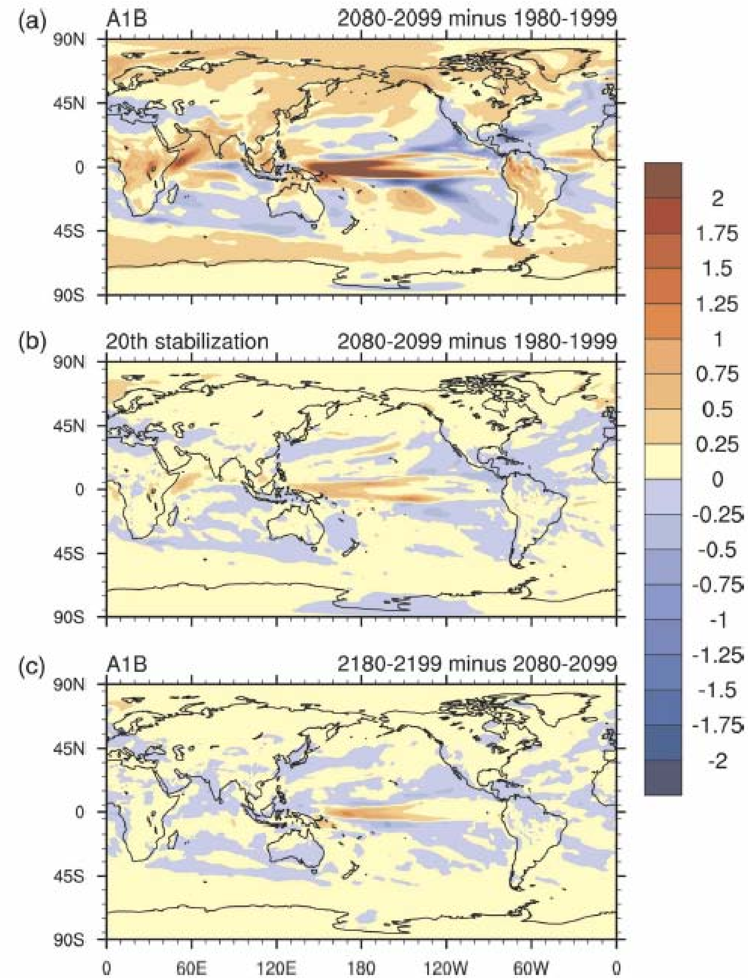


FIG. 6. (a) Same as Fig. 5a except for annual mean precipitation differences (mm day^{-1}); (b) same as Fig. 5b except for precipitation differences; (c) same as Fig. 5c except for precipitation differences.

- **North Pacific surface air temperature warmer by 2-4°C**
- **More precipitation (> 9cm/yr) north of 40°N**
- **A1B scenario = medium GHG increase**

1. Meehl et al., 2006, cont'd.

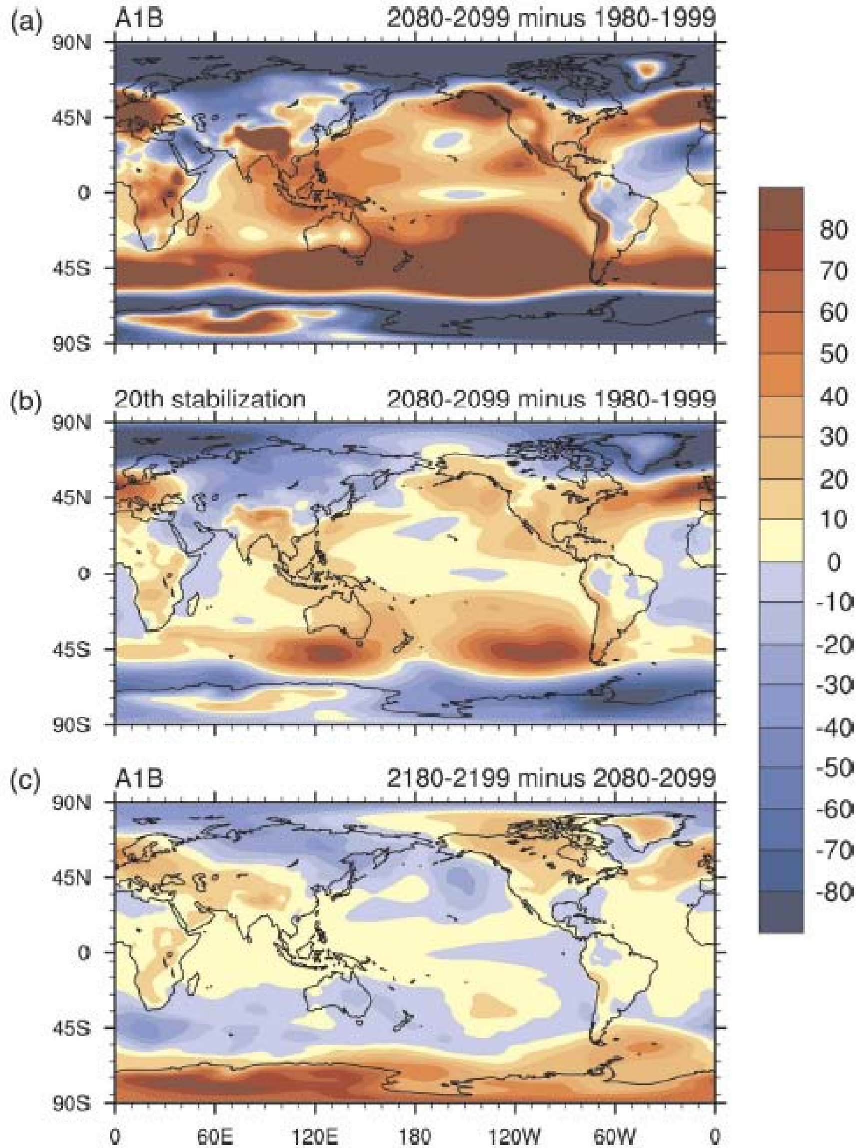


FIG. 7. (a) Same as Fig. 5a except for annual mean sea level pressure (SLP) differences (Pa); (b) same as Fig. 5b except for SLP differences; (c) same as Fig. 5c except for SLP differences.

- sea level pressure increase in Gulf of Alaska
- decrease in Okhotsk & northern Bering Seas
- seasonal differences ?

2. Stouffer et al., 2006, GFDL's CM2 global coupled climate models. Part IV: Idealized climate response, *Journal of Climate*, 19, 723-740.

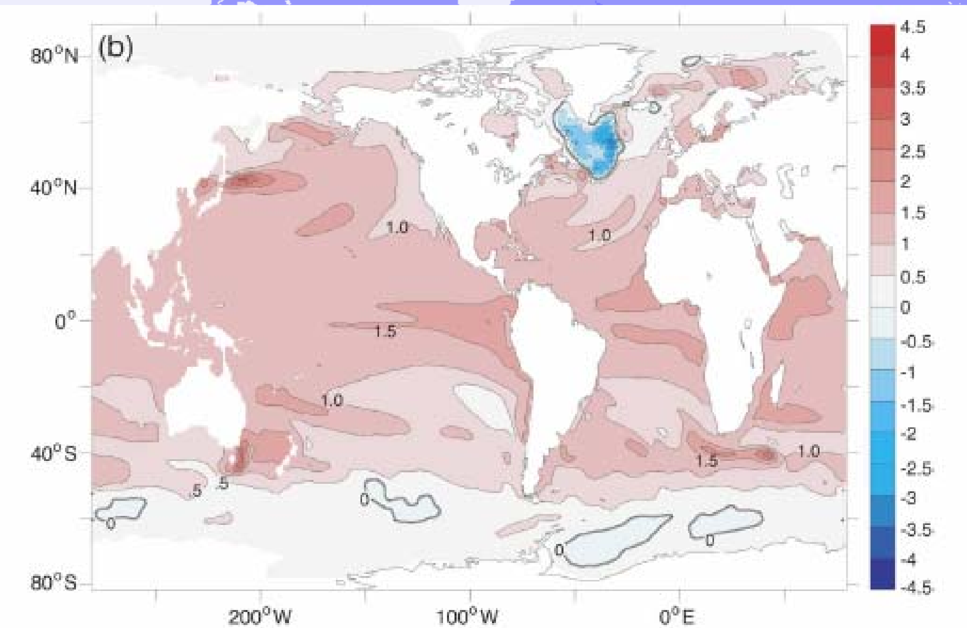


FIG. 8. Maps of annually averaged SST difference (K) for (a) CM2.0 and (b) CM2.1. The differences are constructed by subtracting the 1% integration (model years 61–80) minus 1860 control (model years 1–100).

- in North Pacific
  - SST increase (1°-3°C)
  - SSS generally decreases

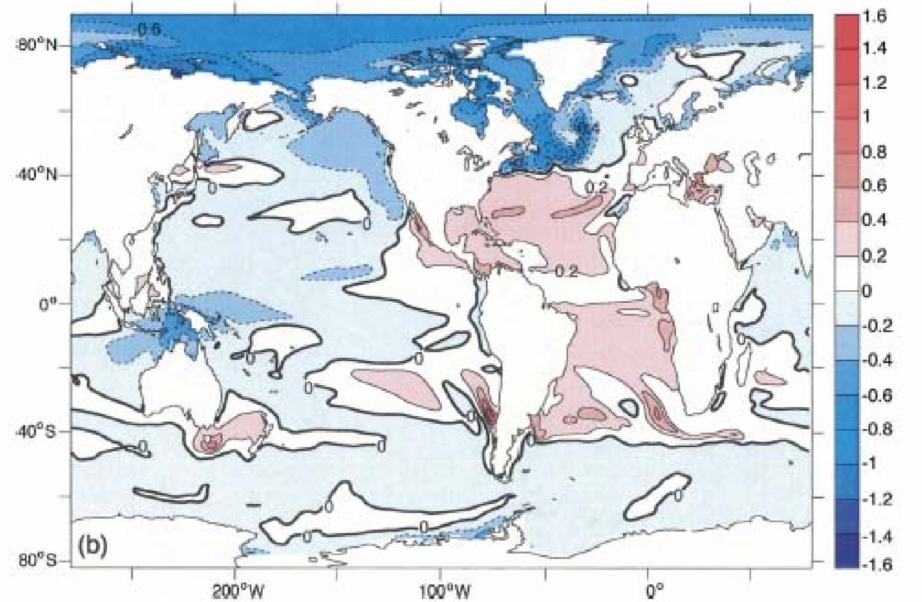


FIG. 9. As in Fig. 8 but for SSS difference (psu).

2. Stouffer et al., 2006, cont'd.

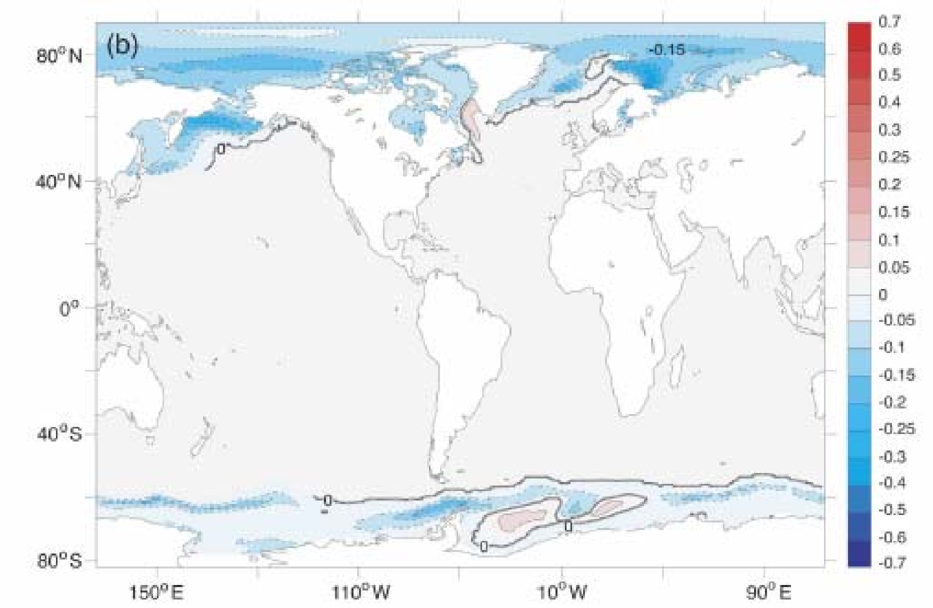


FIG. 4. Maps of annually averaged sea ice extent difference (fraction) for (a) CM2.0 and (b) CM2.1. The differences are constructed by subtracting the 1% integration (model years 61–80) minus 1860 control (model years 1–100). The contour interval is 0.05 (fraction) between −0.3 and 0.3; otherwise it is 0.1.

- Less sea ice extent
  - 20% in Bering
- Warmer sea temps down to 1000m

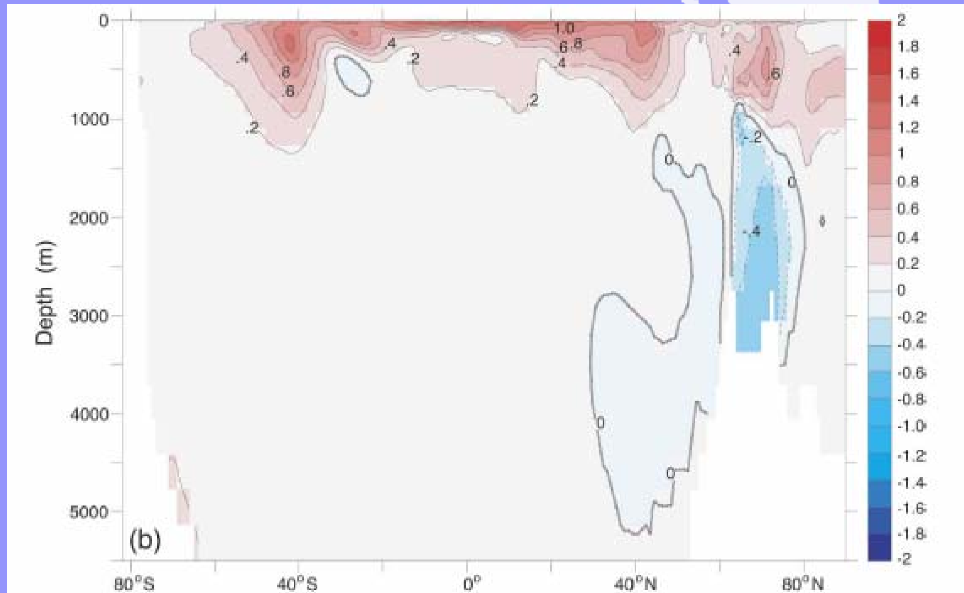


FIG. 12. Latitude–depth sections of the zonally annually averaged temperature differences (K), 1% integration (model years 61–80) minus 1860 control integration (model years 1–100), for (top) CM2.0 and (bottom) CM2.1.

3. Saenko et al., 2005, On the response of the ocean wind-driven circulation to CO2 increase, *Climate Dynamics*, 25, 415-426.

- Canadian Centre for Climate Modelling and Analysis model
- Wind stress curl pattern & subtropical gyres move poleward
- Weakening of downward subtropical (10-30°) Ekman pumping
- increase in downward Ekman pumping in subpolar (30-50°) regions

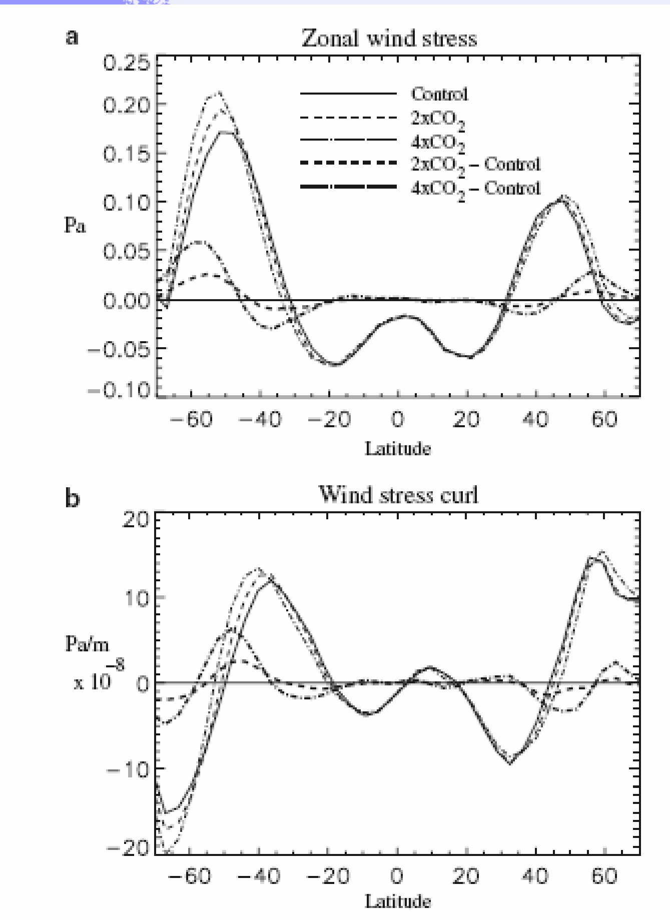


Fig. 2 Zonally-averaged **a** zonal wind stress and **b** wind stress curl in the Control climate, 2×CO_2 climate and 4×CO_2 climate. *Heavy lines* in both panels show the changes (2×CO_2 minus Control; 4×CO_2 minus Control) in the corresponding parameters

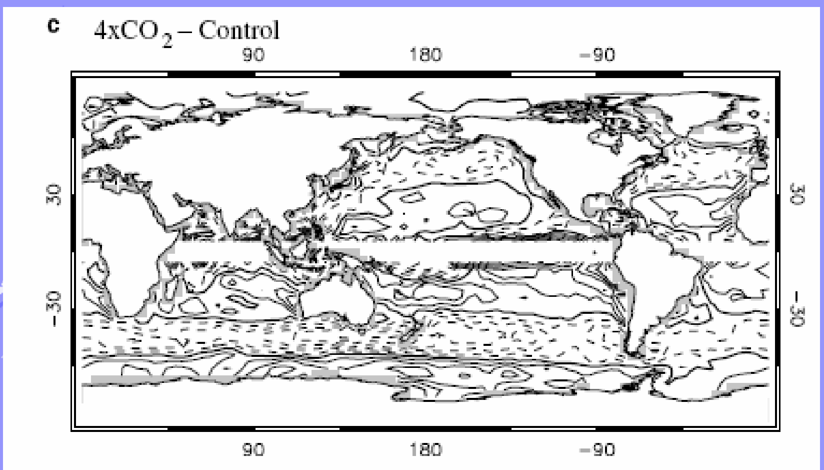


Fig. 5 **a** Ekman pumping in the Control state, **b** Ekman pumping change in the 2×CO_2 state (2×CO_2 minus Control) and **c** Ekman pumping change in the 4×CO_2 state (4×CO_2 minus Control). Negative values are *dashed*; zero line is *bold*; contour interval is 0.4×10^{-6} m/s in **a** and 0.2×10^{-6} m/s in **b** and **c**

4. Yamaguchi & Noda, 2006, Global warming patterns over the North Pacific: ENSO versus AO, *Journal of the Meteorological Society of Japan*, 84, 221-241.

- SS temp, precip, pressure trends for 18 models to 50N
  - Most response patterns related to ENSO & AO natural modes of variability
  - No consensus on relative importance of these 2 mechanisms
  - Most models show subtropical min in ΔSST, increasing poleward of 30N
  - Most models show decrease in precip in subtropics, < 1mm/d increase poleward of 30N

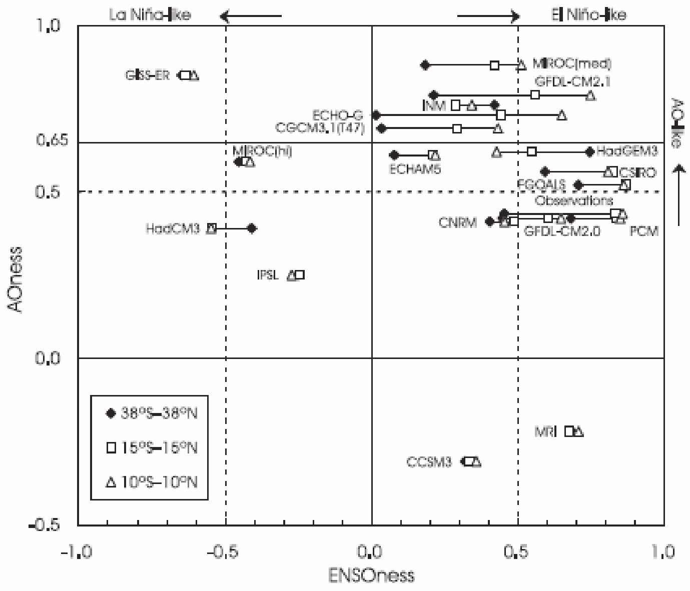


Fig. 9. Scatter diagram of "ENSOness" versus "AOness" for the simulated trend patterns. "ENSOness" and "AOness" are expressed in terms of the pattern correlation shown in Table 2 and Table 3, respectively. The "observations" is based on the historical observations shown in Figs. 1, 5 and 10.

5. Merryfield, 2006, Changes to ENSO under CO_2 doubling in a multimodel ensemble, *Journal of Climate*, 19, 4009-4027.

- 15 models
- 3 show statistically significant increases in ENSO amplitude, 5 show decreases
- Mean fractional decrease in ENSO period of 5%
  - may be related to comparable increase in Rossby wave speed

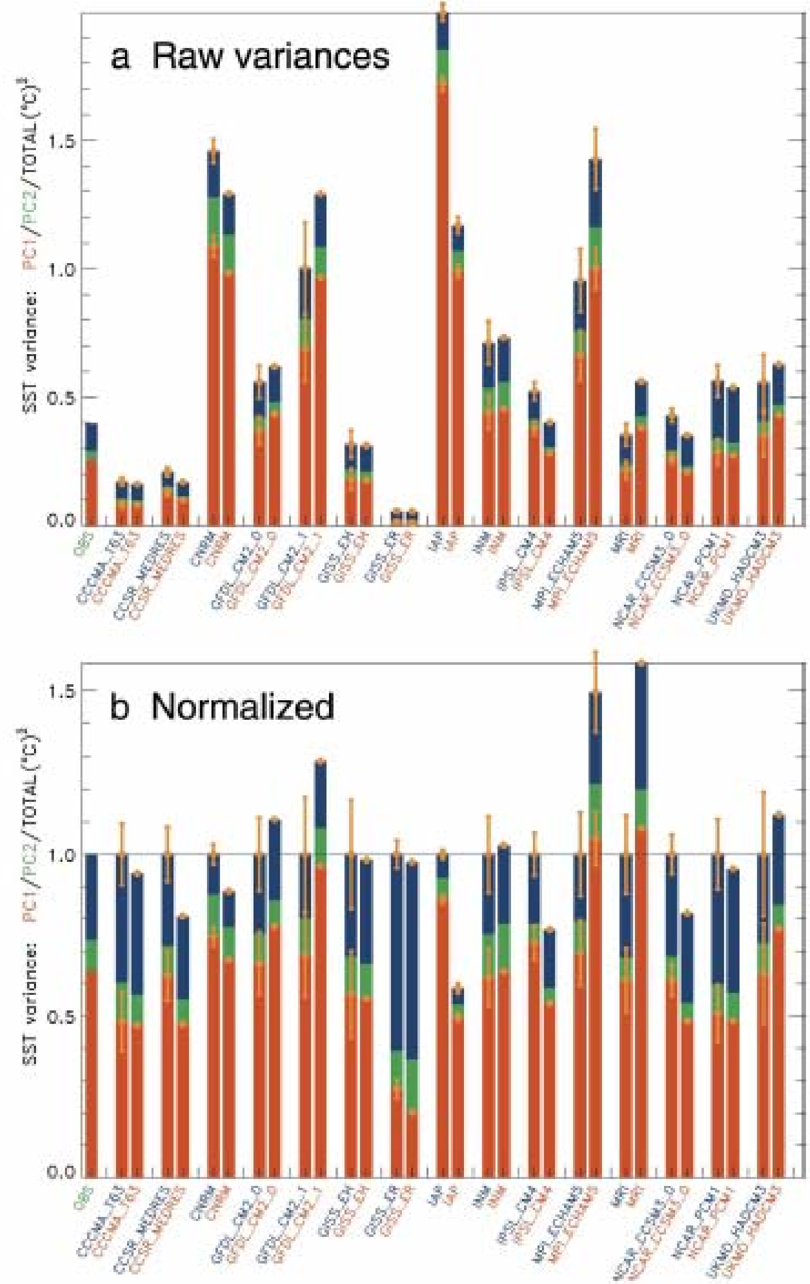
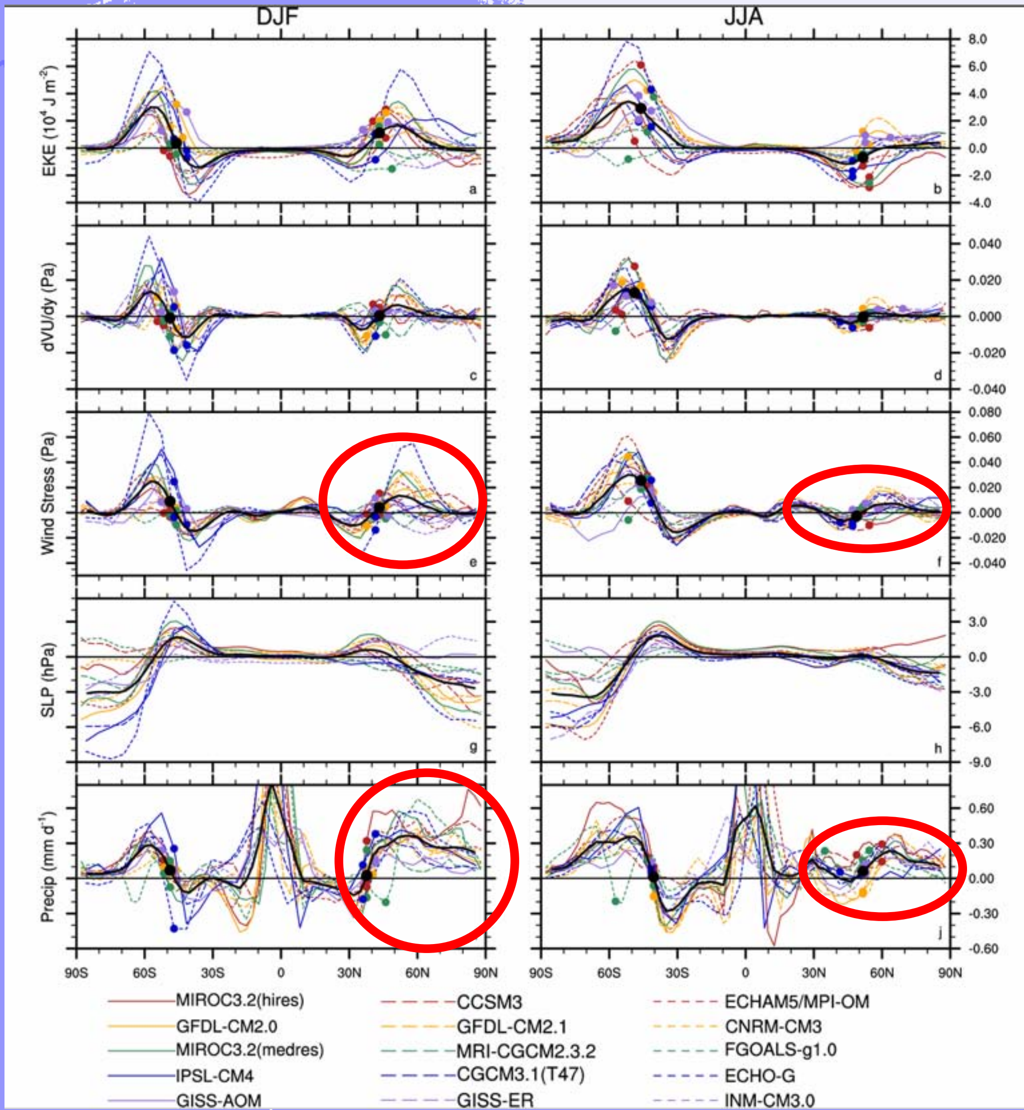


FIG. 1. (a) PC1 (red), PC2 (green), and total variances (blue) of monthly near-equatorial Pacific SST under preindustrial conditions (blue labels) and stabilized 2 × CO_2 conditions (red labels) for each of the 15 models considered. Observed variances based on monthly GISST SST data for 1955–94 are indicated at the far left. The error bars represent standard deviations σ obtained from samples of centennial time series in cases where three or more centuries of model output are available. (b) Same as in (a) but the variances are normalized according to (total preindustrial SST variance) = 1.

6. Yin, 2005, A consistent poleward shift of the storm tracks in simulations of 21st century climate, *Geophysical Research Letters*, 32, L18701,doi:10.1029/2005GL023684.

- Ensemble of 15 models
- Poleward shift in mean latitude of cyclones
  - Accompanied by similar shifts in wind stress & precip
- Fewer cyclones but more intense



7. Lambert & Fyfe, 2006, Changes in winter cyclone frequencies and strengths simulated in enhanced greenhouse warming experiments: results from models participating in the IPCC diagnostic exercise, *Climate Dynamics*, doi:10.1007/s00382-006-0110-3.

- **15 CGCMs**
- **All models show fewer but more intense cyclones**
- **No shift in storm tracks (< grid spacing)**

8. Diffenbaugh, 2005, Response of large-scale eastern boundary current forcing in the 21st century, *Geophysical Research Letters*, 32, L19718, doi:10.1029/2005GL023905.

- **Ensemble of 18 CGCMs**
  - **Fine scale processes like coastal upwelling not well resolved**

- **Considered sea level pressure in subtropical highs, equatorward winds in 4 EBC regions (Benguela, Canary, California, Humbolt)**
  - **Relaxation in strength & variability of equatorward wind forcing**

- **Projected changes physically significant but not sufficiently consistent among models to constitute robust signal**

9. Saenko, 2006, Influence of global warming on baroclinic Rossby radius in the ocean: A model intercomparison, *Journal of Climate*, 19, 1354-1360.

- 8 model comparison
- Northern hemisphere Rossby radius increases by ~ 10-40%
    - Length scales of mesoscale eddies, boundary currents, fronts may increase
- Northern hemisphere Rossby wave speed increases by ~ 20-80% at 30-60N
    - Time scale for ocean adjustment may decrease

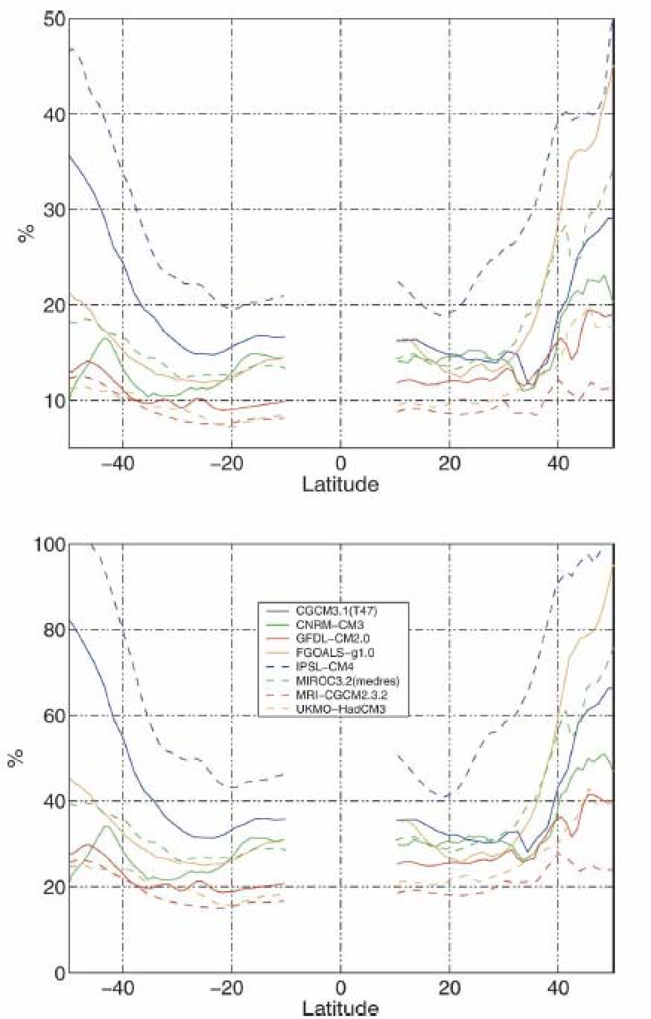
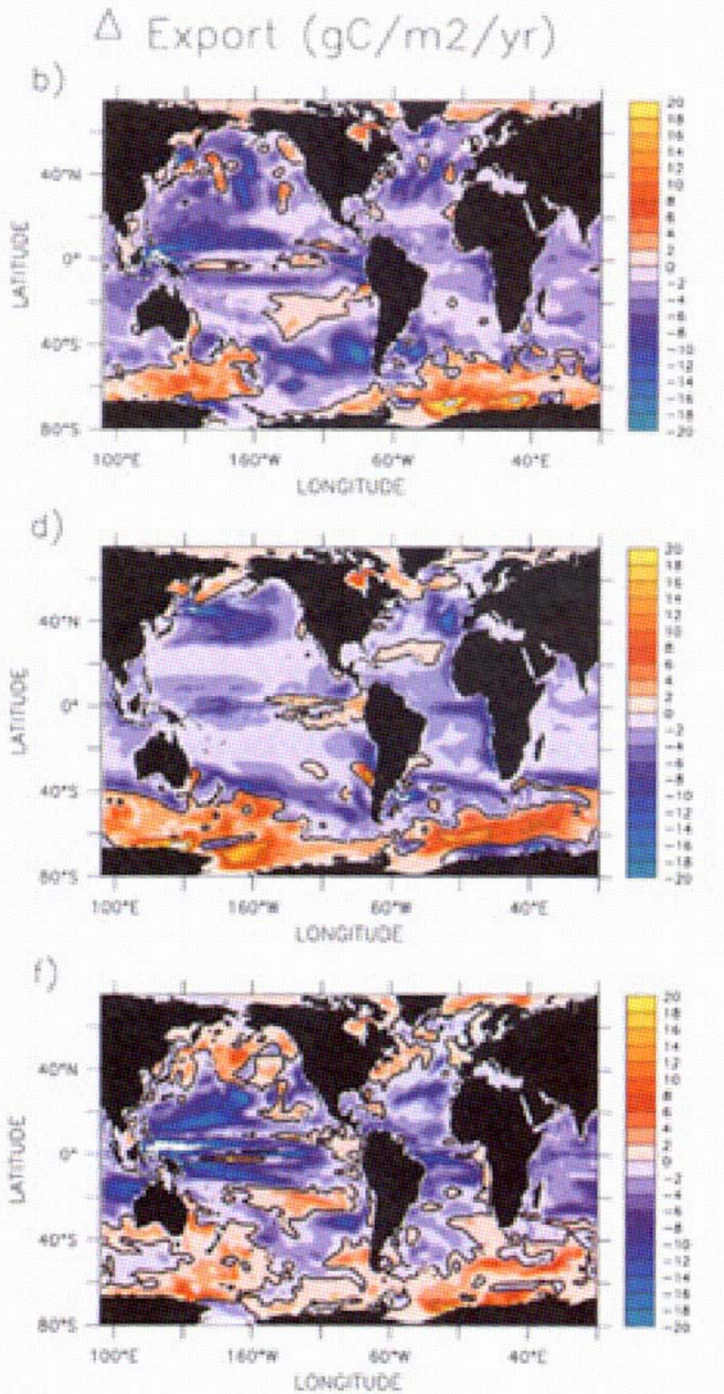


FIG. 4. (top) Relative changes in zonally averaged first baroclinic Rossby radius of deformation and (bottom) its squared values.

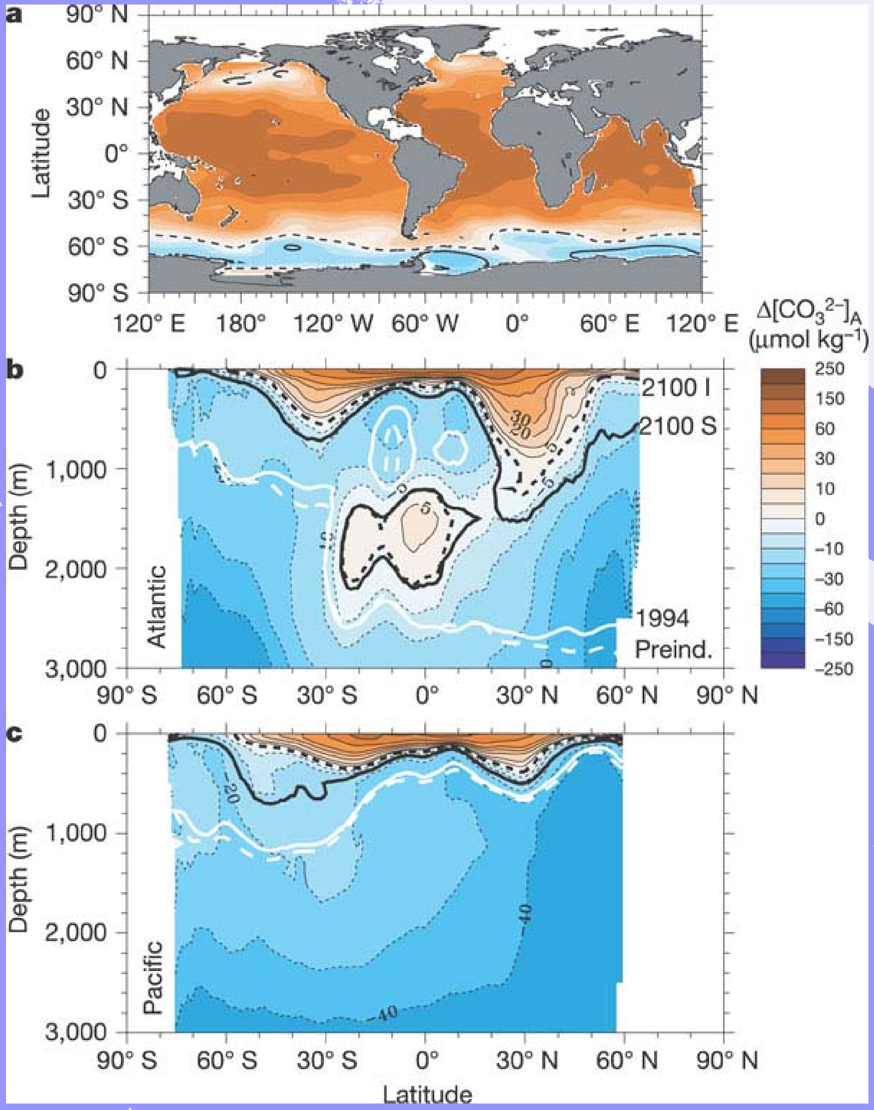
10. Bopp et al., 2001, Potential impact of climate change on marine export production, *Global Biogeochemical Cycles*, 15, 81-99.

- compared two climate models and two biology models
- regional trends are sensitive to choice of model formulations
- no clear trend to greater/smaller regional mean export



11. Orr et al., 2005, Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms, *Nature*, 437, 681-686.

- calcite/aragonite saturation horizon shoals due to anthropogenic CO_2
- circulation changes could accelerate the process
- saturation depth is already very shallow in the North Pacific
- shoaling of under-saturated waters into the euphotic zone will make it impossible for calcifying organisms to grow



12. Doney et al., 2006, Natural Variability in a Stable, 1000-Yr Global Coupled Climate/Carbon Cycle Simulation. *J. Climate* 19: 3033-3054.

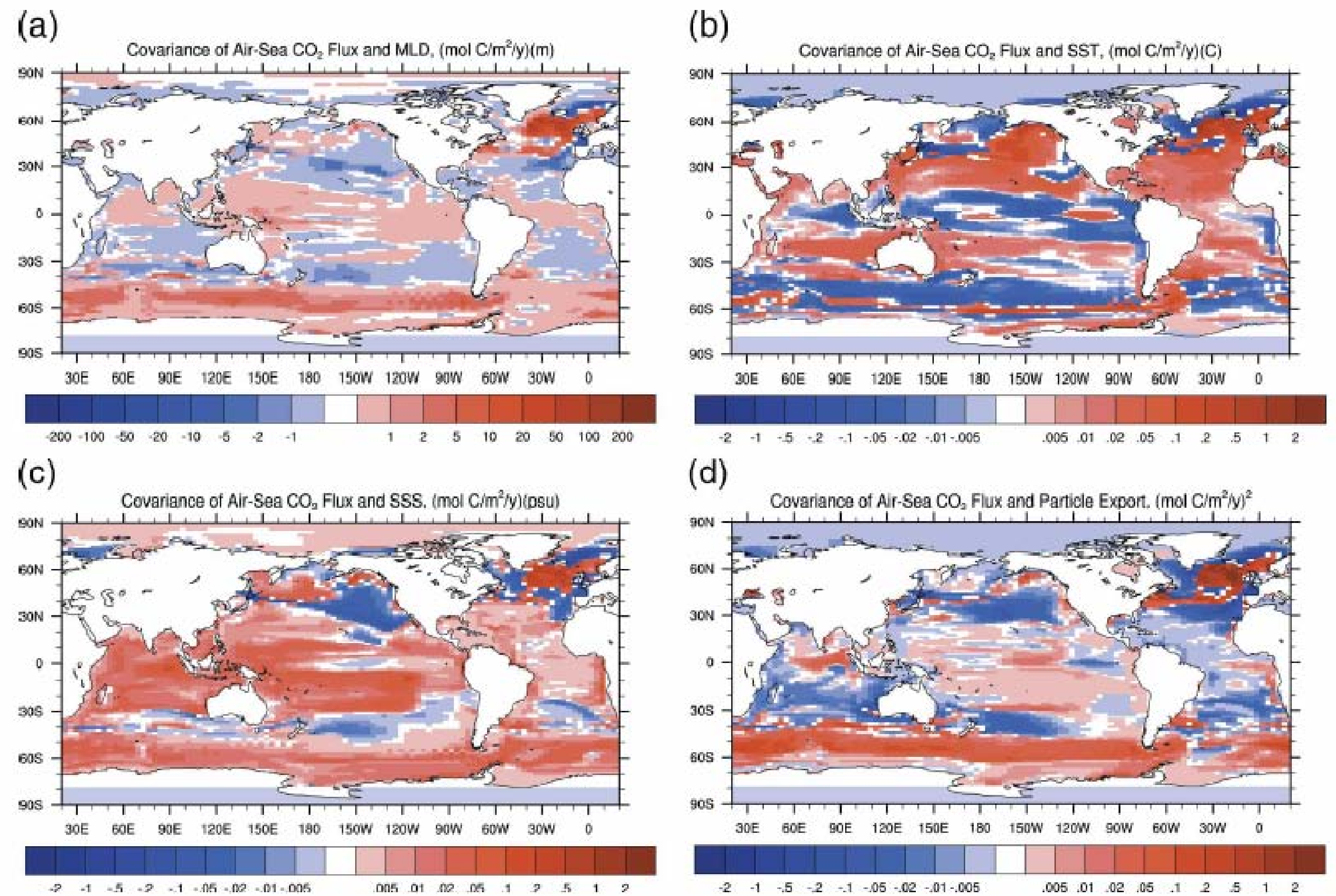


FIG. 13. Spatial covariance maps of annual mean air–sea CO_2 flux (positive out of the ocean) and biological and physical forcing factors including (a) mixed layer depth, (b) SST, (c) SSS, and (d) export production.

- **Not global warming scenario, but shows how CO_2 flux correlates with biophysical factors in coupled carbon model**

Summary

- SST warming generally increases northward
- Precipitation: increases (*decreases*) north (*south*) of 40N
- SSS generally decreases
- Mixed layer depth shallows
- Northward shift of wind patterns & subtropical gyre
- Subpolar downward Ekman pumping increases
- Rossby wave propagation speed increases
- Rossby radius & horizontal eddy scales increase
- No clear trend for Eastern boundary current upwelling
  - models need more resolution
- Biological consequences
  - Difficulties for calcifying organisms