Supplemental Material

Alexander et al. 2019, The Response of the Northwest Atlantic Ocean to Climate Change

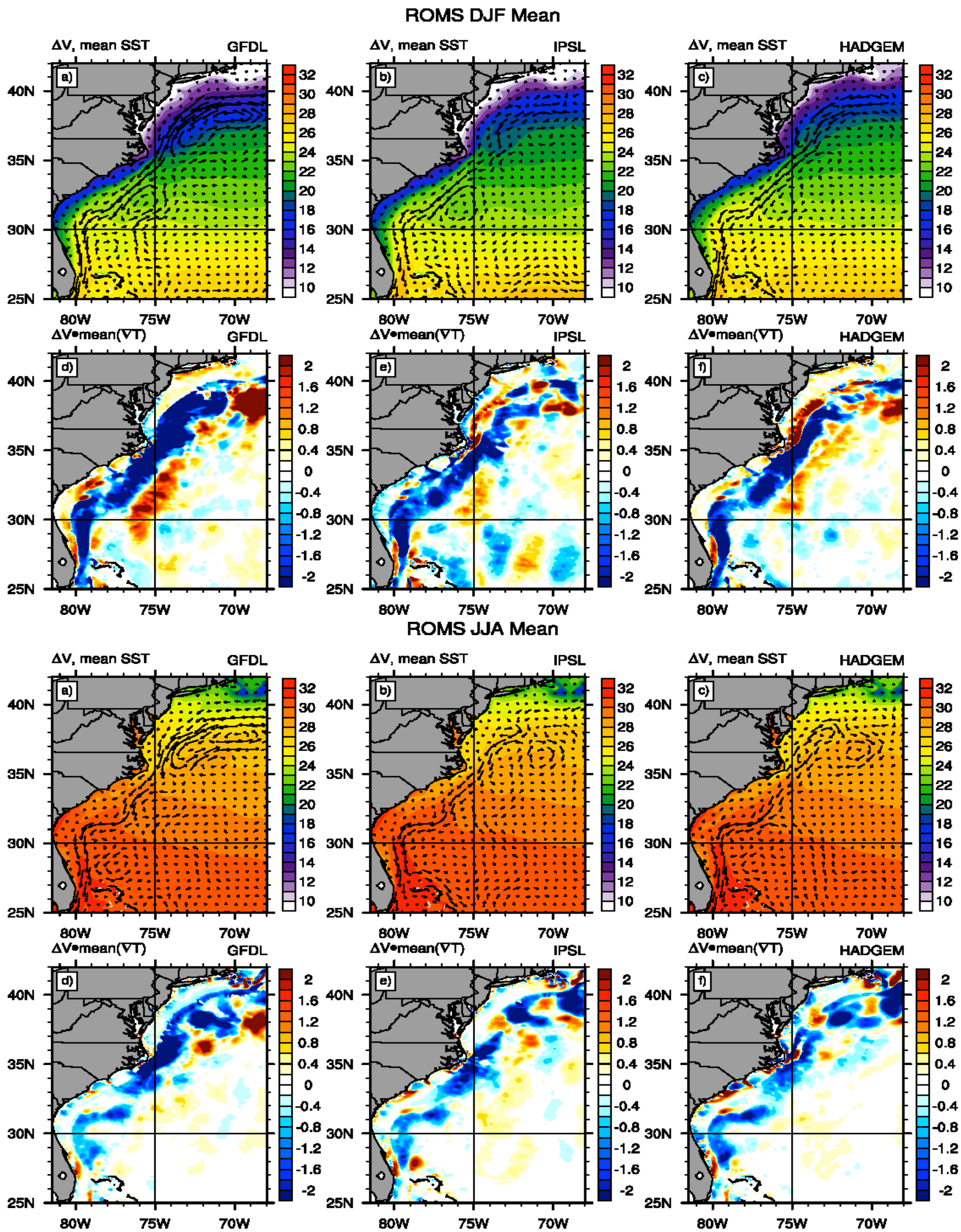

Fig. SM1. The effect of the change in the Gulf Stream on SSTs during DJF and JJA. Top panels show the response of the surface ocean currents to climate change (RCP8.5-CTRL) in the ROMS simulations driven by the GFDL (left) IPSL (center) and HadGEM (GCMs (right), overlaid on the mean temperature field (shaded, interval 1 °C) from the CTRL run. The southwest directed vectors indicate the slowing of the Gulf Stream in the future and as a result, less warm water is advected north. As shown in a budget framework in the lower panels, the anomalous current (RCP8.5-CTRL or Δ) acting on the climatological mean temperature gradient from the CTRL acts to cool the ocean, i.e. $(\Delta \boldsymbol{V} \cdot \nabla \overline{SST}) < 0$, in the Gulf Stream region. The cooling is strongest in the GFDL-ROMS compared to the other two simulations. It is stronger in winter tan in summer in all three simulation, primarily due to a weakening of the meridional temperature gradient.

CMIP5 GCM Response: SST (˚C)
RCP8.5-Hist (shaded), Historical (contour)

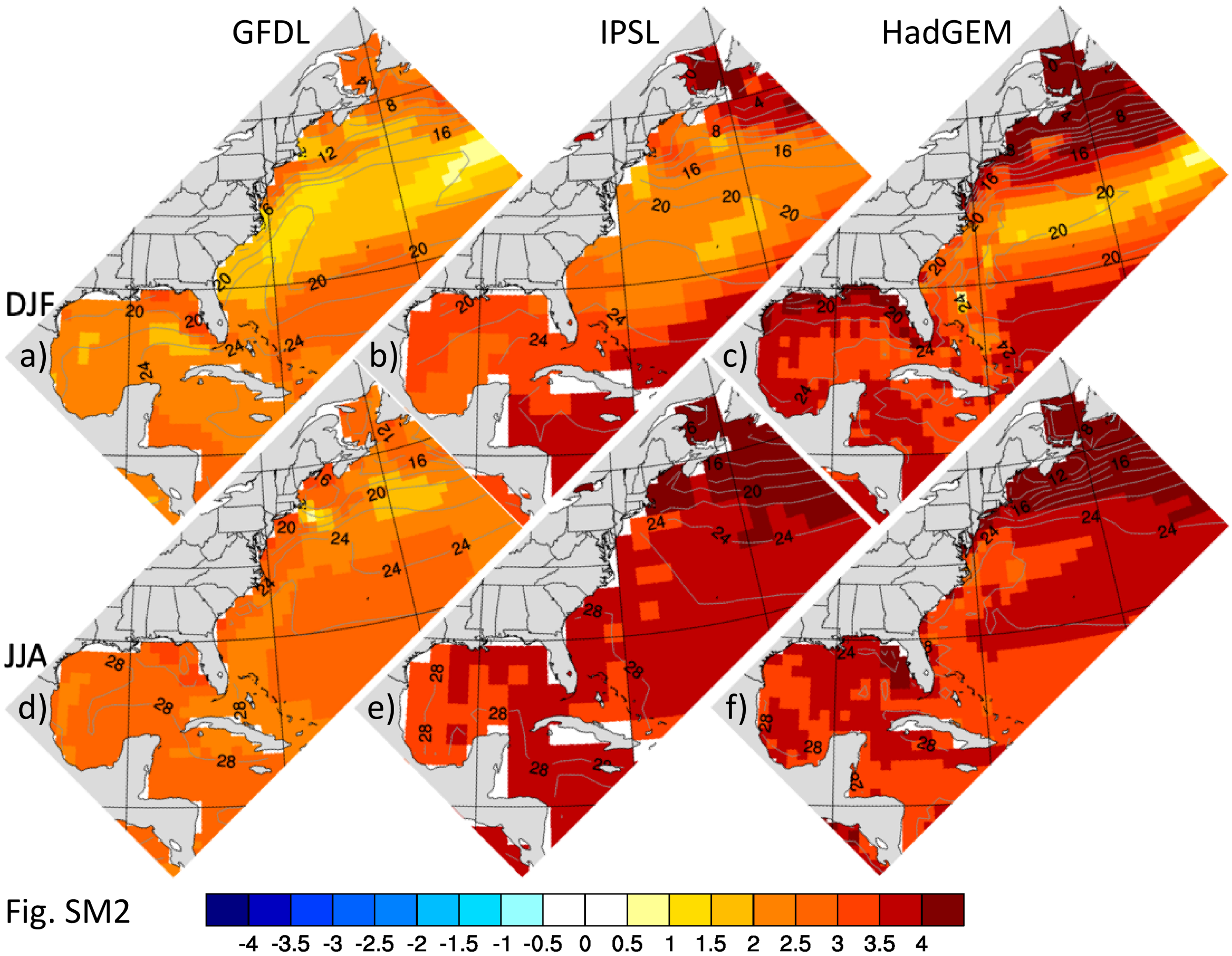

Fig. SM2

Fig. SM2. SST climatology and response to climate change from the IPCC GCMs over the same domain as used in the ROMS simulations. SST during the historical period (1976-2005, contours, interval 2 ˚C) and the SST response (shaded, interval 1.0 ˚C) obtained from the difference between the future (2070-2099 in the RCP8.5 simulations) and the historical period during DJF (top) and JJA (bottom) in the (a) (d) GFDL, (b) (e) IPSL, and (c) (f) HadGEM GCMs.

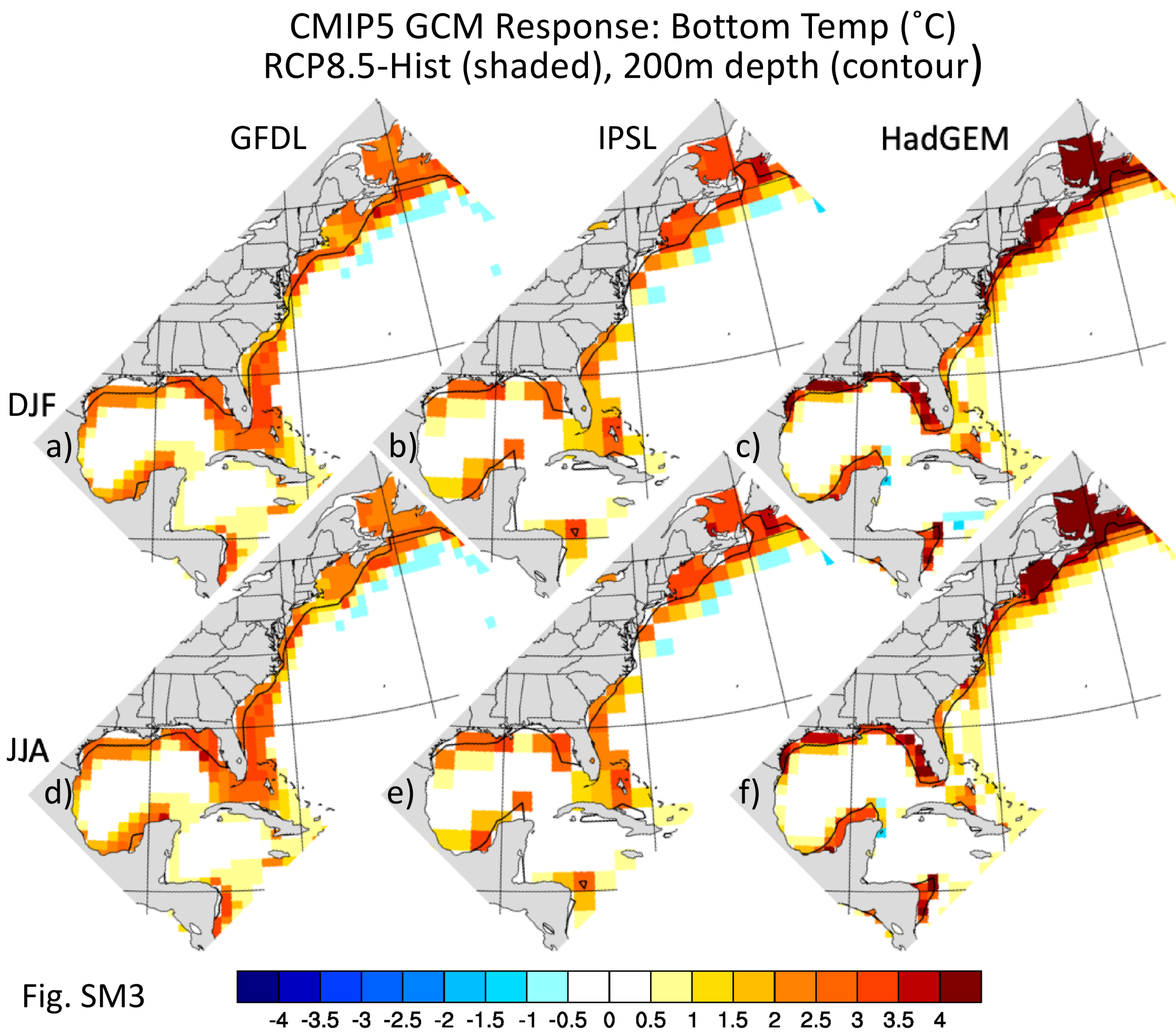

Fig. SM3. Bottom temperature response (RCP8.5 - historical) during DJF (top) and JJA (bottom). Obtained from the (a) (d) GFDL, (b) (e) IPSL, (c) (f) HadGEM GCMs. The 200m isobath, representing the shelf break, is indicated by the black curve.

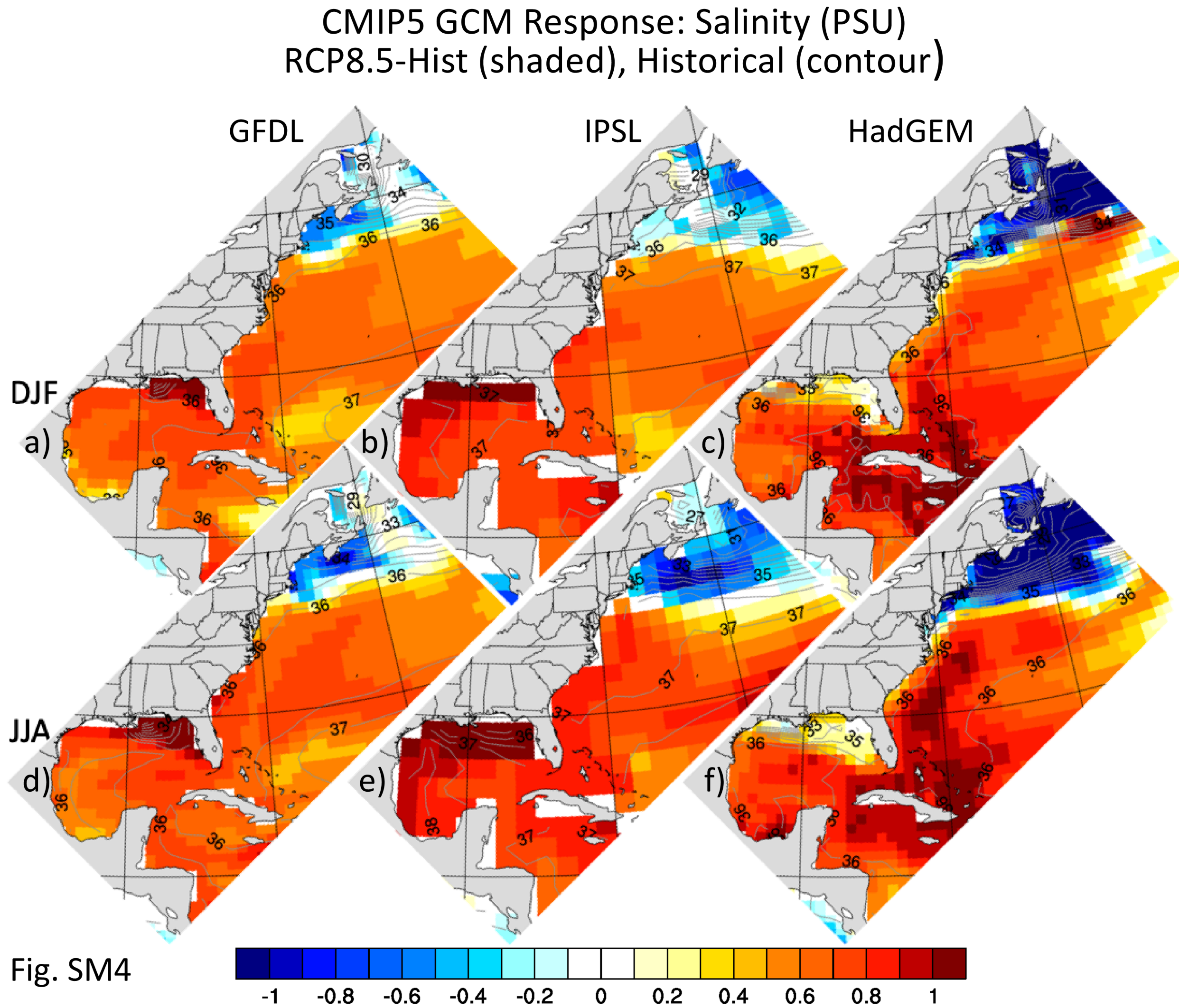

Fig. SM4. Sea surface salinity (SSS) during the historical period (1976-2005, contours, interval 1 PSU) and the SSS response (RCP8.5-historical, shaded, interval 0.1 PSU) during DJF (top) and JJA (bottom) in the (a) (d) GFDL, (b) (e) IPSL, and (c) (f) HadGEM GCMs.

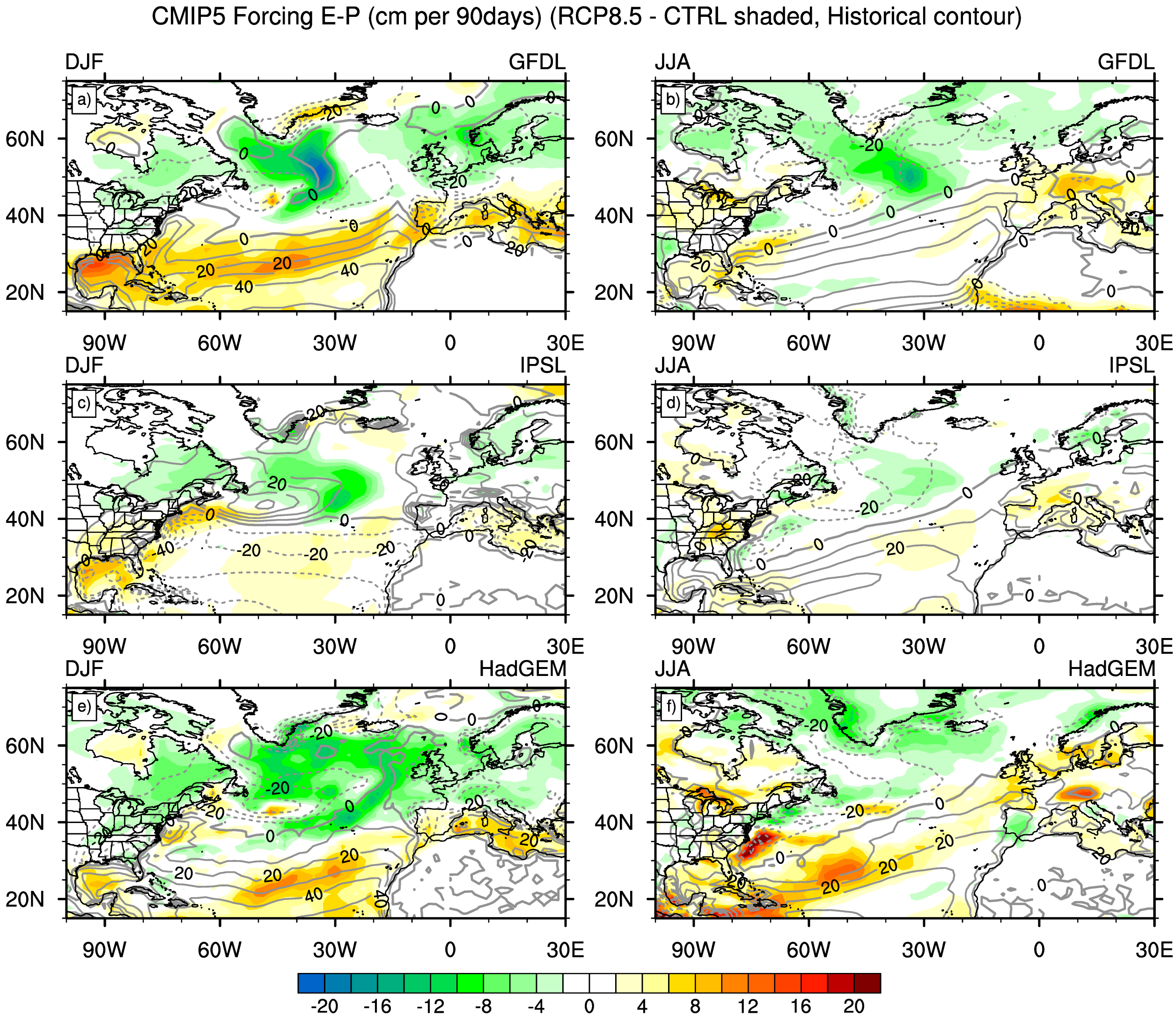

Fig. SM5. Surface evaporation minus precipitation (E-P) during the historical period (1976-2005, contours, interval 20 cm per 90 days) and the E-P response (RCP8.5-historical,shaded, interval 20 cm per 90 days) during DJF (left) and JJA (right) in the (a) (b) GFDL, (c) (d) IPSL, and (e) (f) HadGEM GCMs. Note 90 days is the length of the winter and summer seasons.

CMIP5 GCM River Runoff (10^{-5} kg m^{-2} s^{-1}) (RCP8.5-Historical)

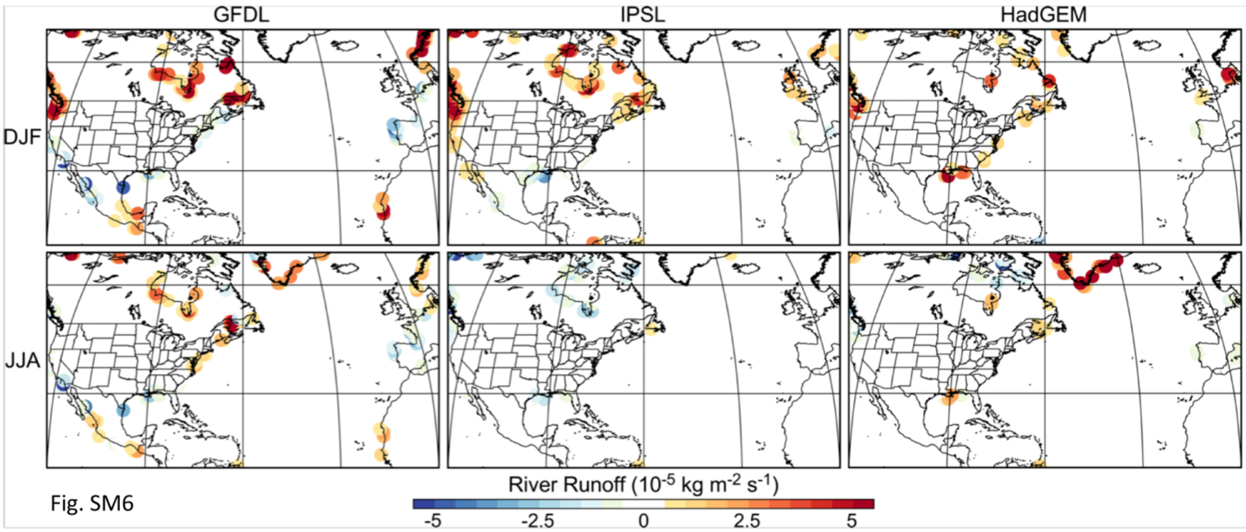

Fig. SM6. Response in river runoff (RCP8.5-historical, shaded, interval 5×10^{-6} kg m^{-2} s^{-1}) during DJF (top) and JJA (bottom) in the (a) (d) GFDL, (b) (e) IPSL, and (c) (f) HadGEM GCMs. Runoff is given at the locations of where rivers enter the ocean as indicated by Dai et al. 2009.

CMIP5 GCM Response: Bottom Salinity (PSU)

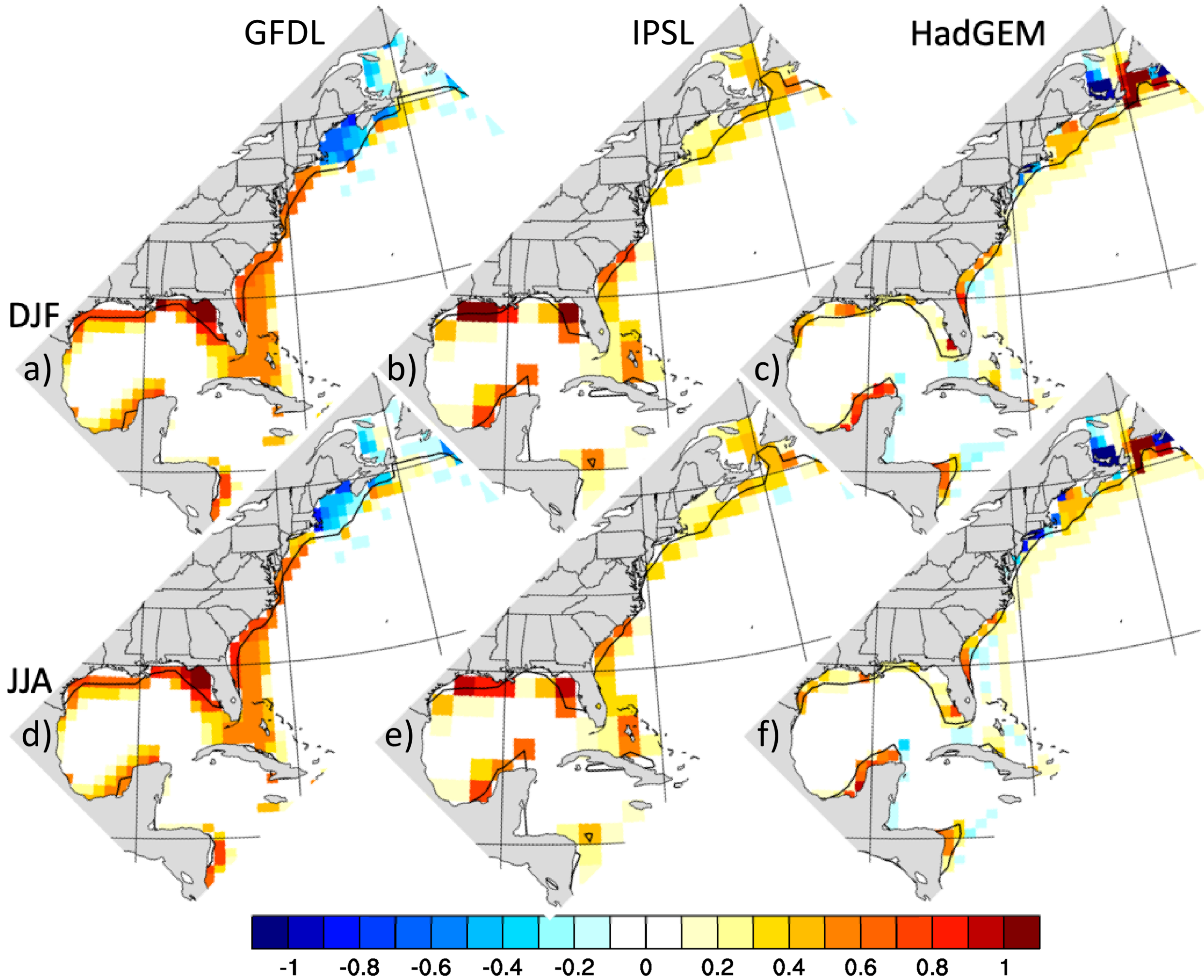

Fig. SM7. Bottom salinity response (RCP8.5 – historical, shaded, interval 0.1 PSU) during DJF (top) and JJA (bottom) in the (a) (d) GFDL, (b) (e) IPSL, and (c) (f) GCMs. The 200 m isobath is indicated by the black curve.

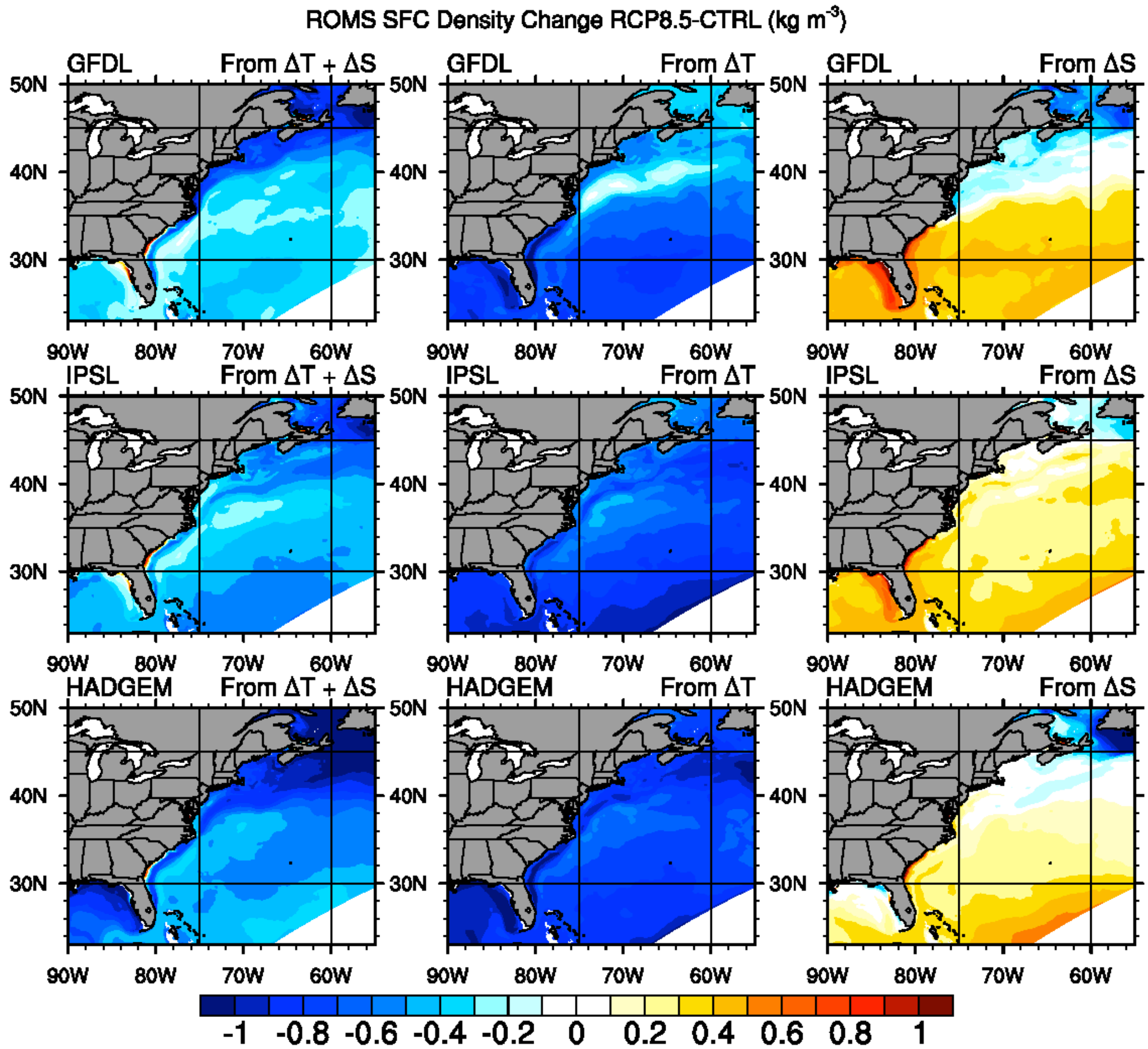

Fig. SM8a. The annual mean density response (left column) and its decomposition into its temperature (center) and salinity (right) components at the surface (shading interval 0.1 kg m^{-3}) for the GFDL-ROMS (top), IPSL-ROMS (middle), and (c) (f) HadGEM-ROMS (bottom). The density change due to a change in temperature dominate the density change due to salinity except in the northern part of the domain.

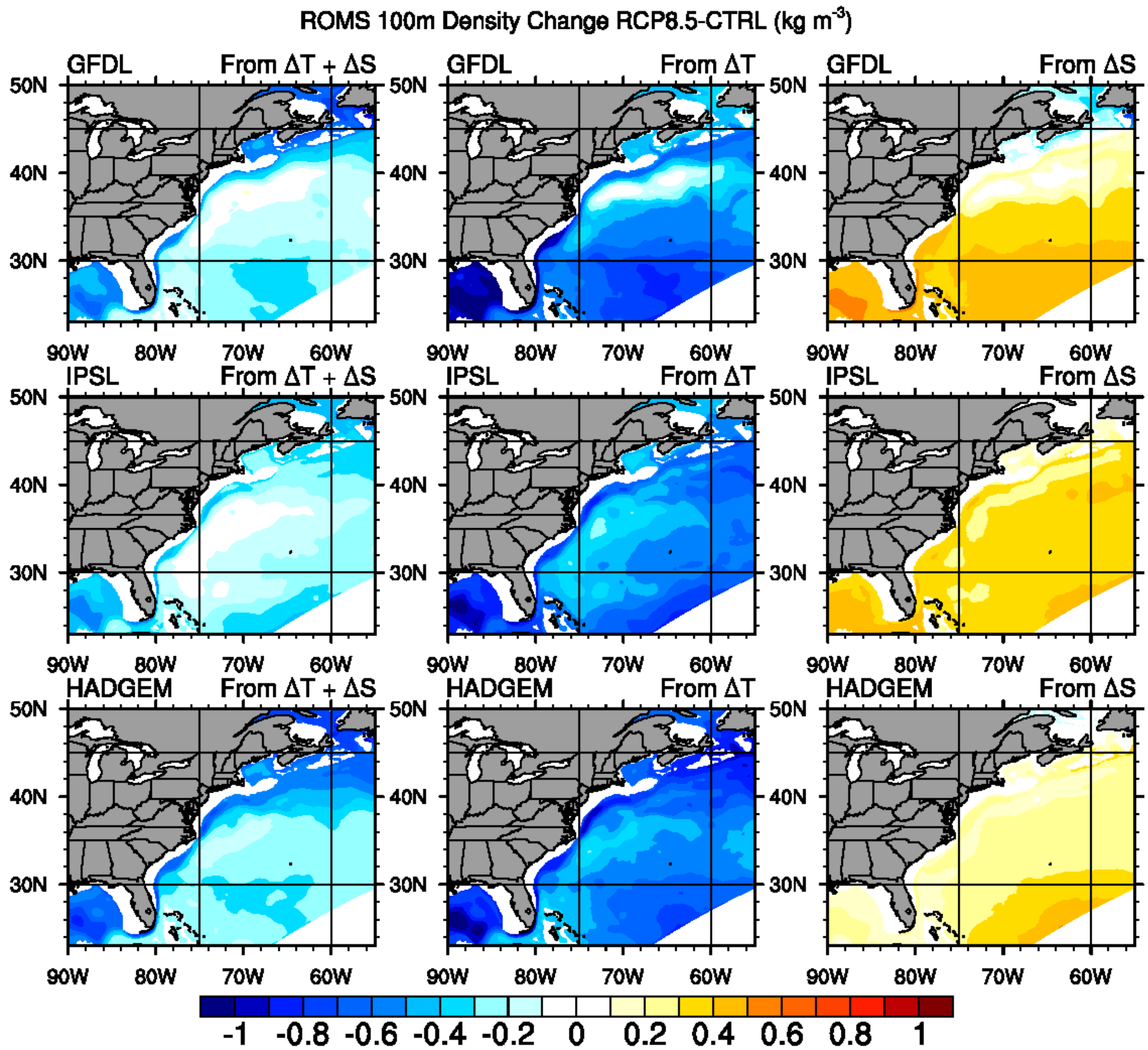

Fig. SM8b. The total annual mean density response (left column) and its decomposition into its temperature (center) and salinity (right) components at 100 m depth (shading interval 0.1 kg m^{-3}) for the GFDL-ROMS (top), IPSL-ROMS (middle), and (c) (f) HadGEM-ROMS (bottom). The nonlinear contributions to the change in the equation of state were negligible and thus the temperature and salinity contributions to the change in density could be seperated.

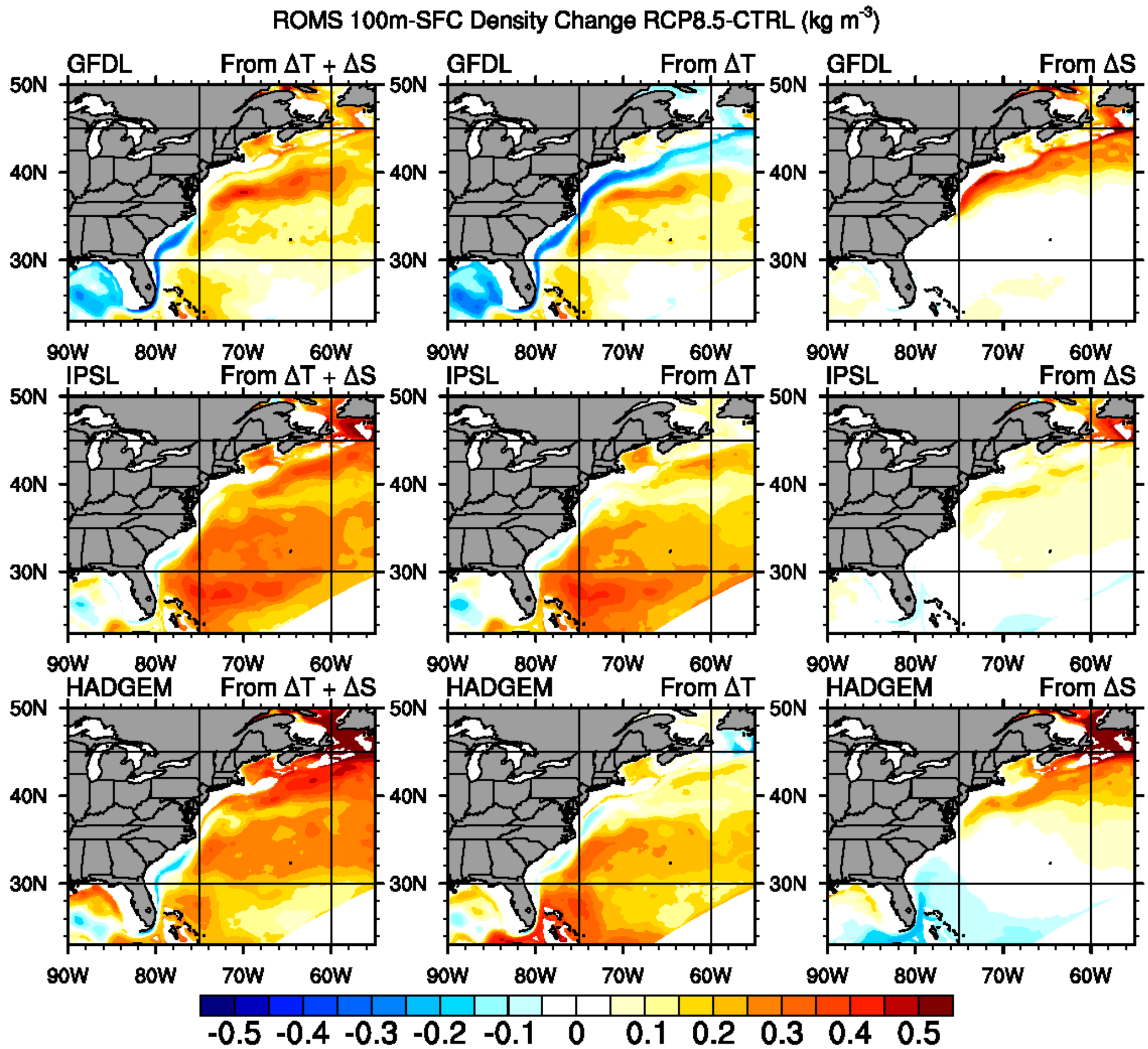

Fig. SM8c. The annual mean total stratification response given by the density difference between 100 m and the surface (left column) and its decomposition into its temperature (center) and salinity (right) components (shading interval 0.1 kg m^{-3}) for the GFDL-ROMS (top), IPSL-ROMS (middle), and (c) (f) HadGEM-ROMS (bottom). Positive values indicate an increase in the stability of the water column and thus increased stratification.

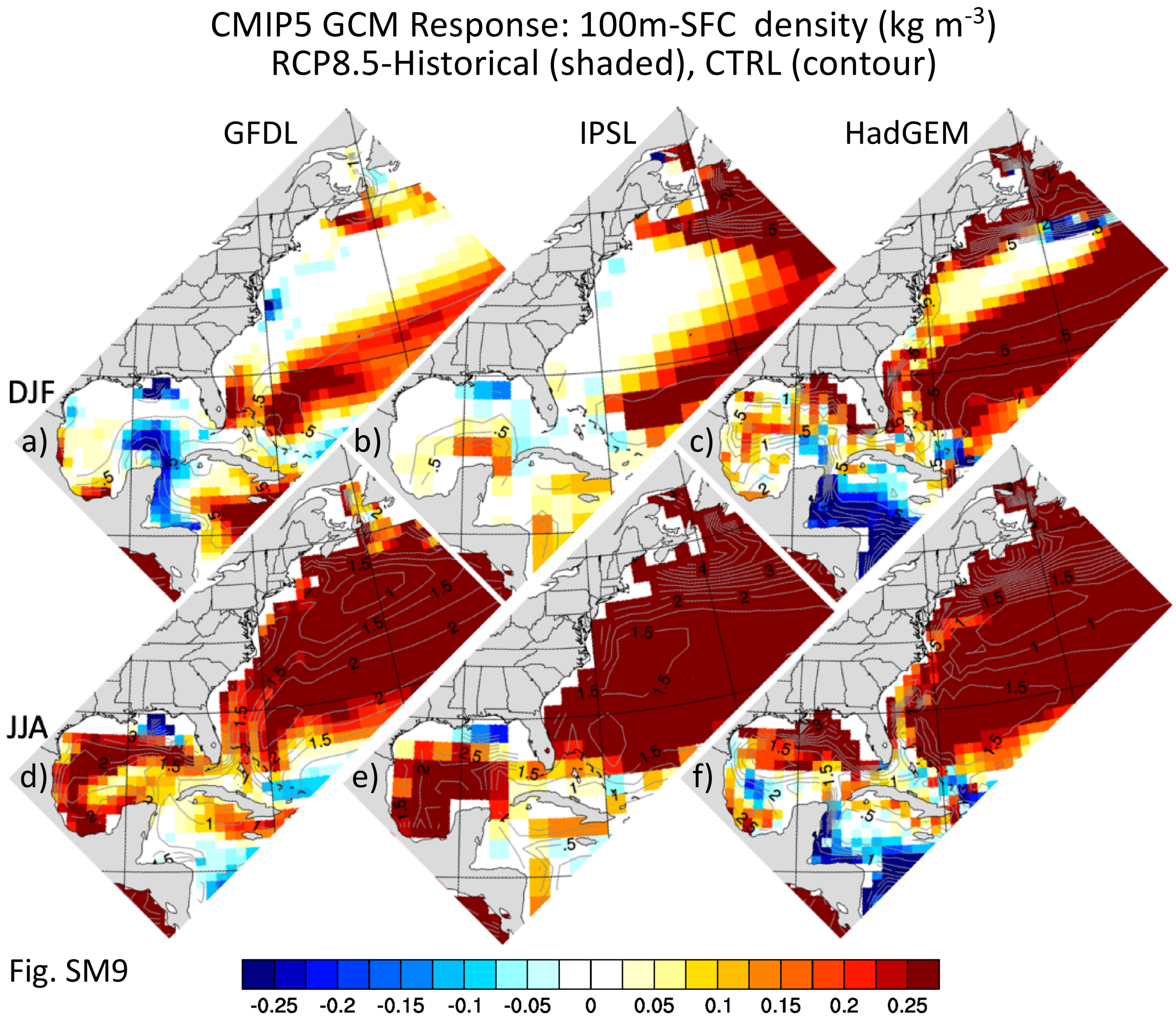

Fig. SM9. The stratification, indicated by the 100m - surface density, in the CTRL (0.25 kg m^{-3} contour) and the stratification response (RCP8.5 – Historical, shaded, interval 0.025 kg m^{-3}) during DJF (top) and JJA (bottom) in the (a) (d) GFDL, (b) (e) IPSL and (c) (f) HadGEM GCMs.

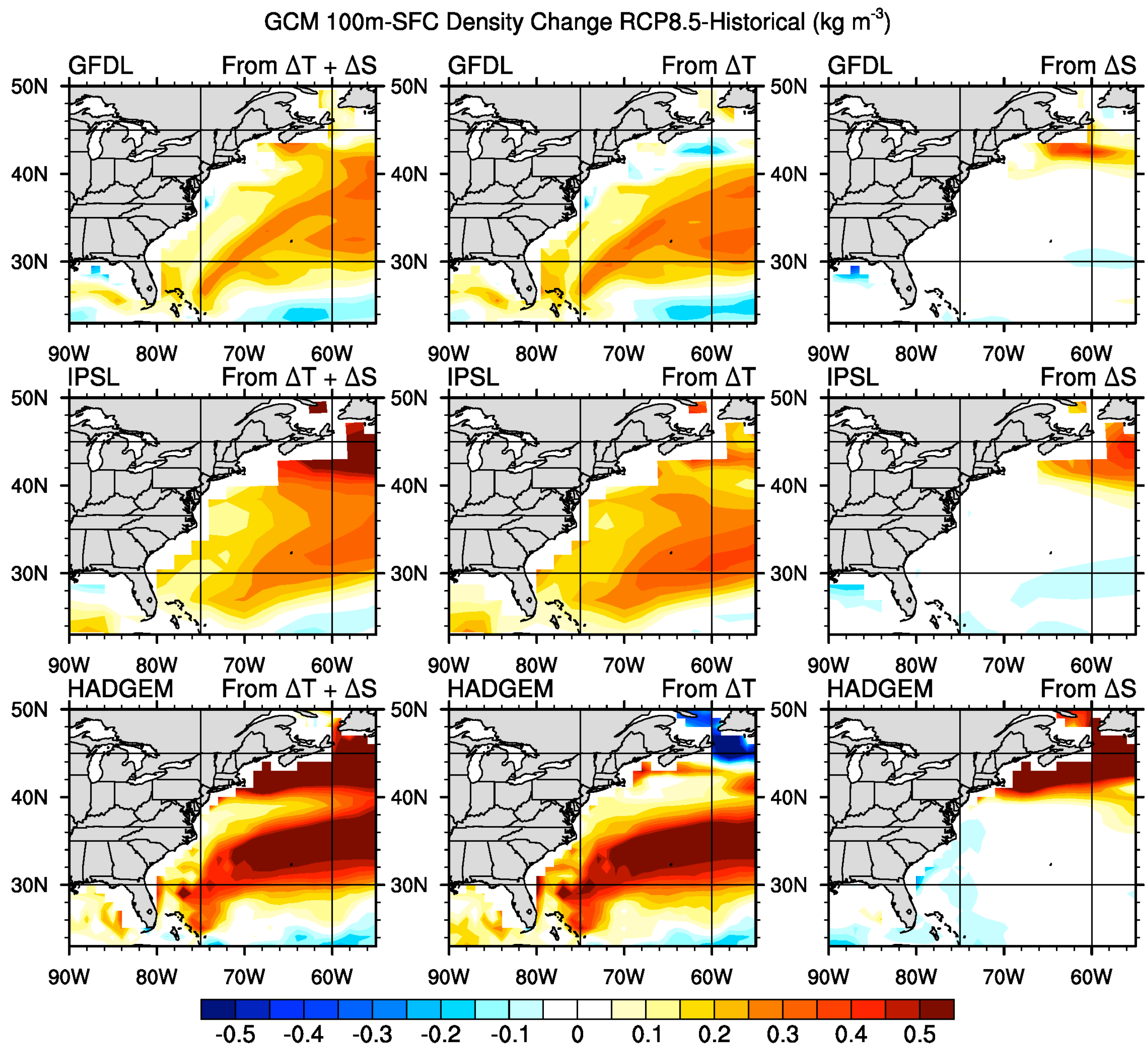

Fig. SM10. The annual mean total stratification response given by the density difference between 100 m and the surface (left column) and its decomposition into its temperature (center) and salinity (right) components (shading interval 0.05 kg m^{-3}) for the GFDL (top), IPSL (middle), and HadGEM (bottom) GCMS. Positive values indicate an increase in the stability of the water column and thus increased stratification.

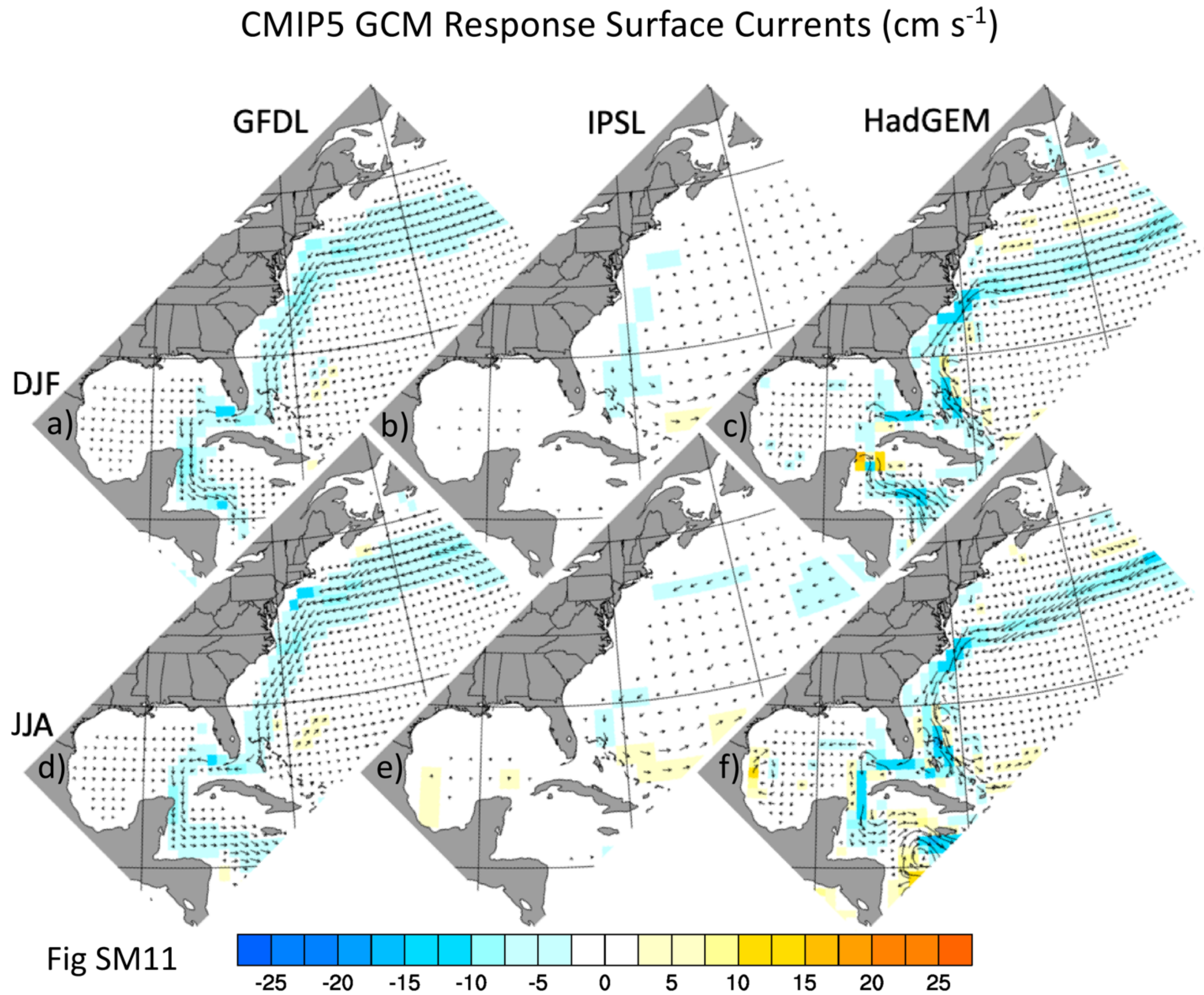

Fig. SM11. The surface current response (RCP8.5 – Historical, speed shaded, interval 2.5 cm s^{-1}) during DJF (top) and JJA (bottom) in the (a) (d) GFDL, (b) (e) IPSL and (c) (f) HadGEM GCMs.

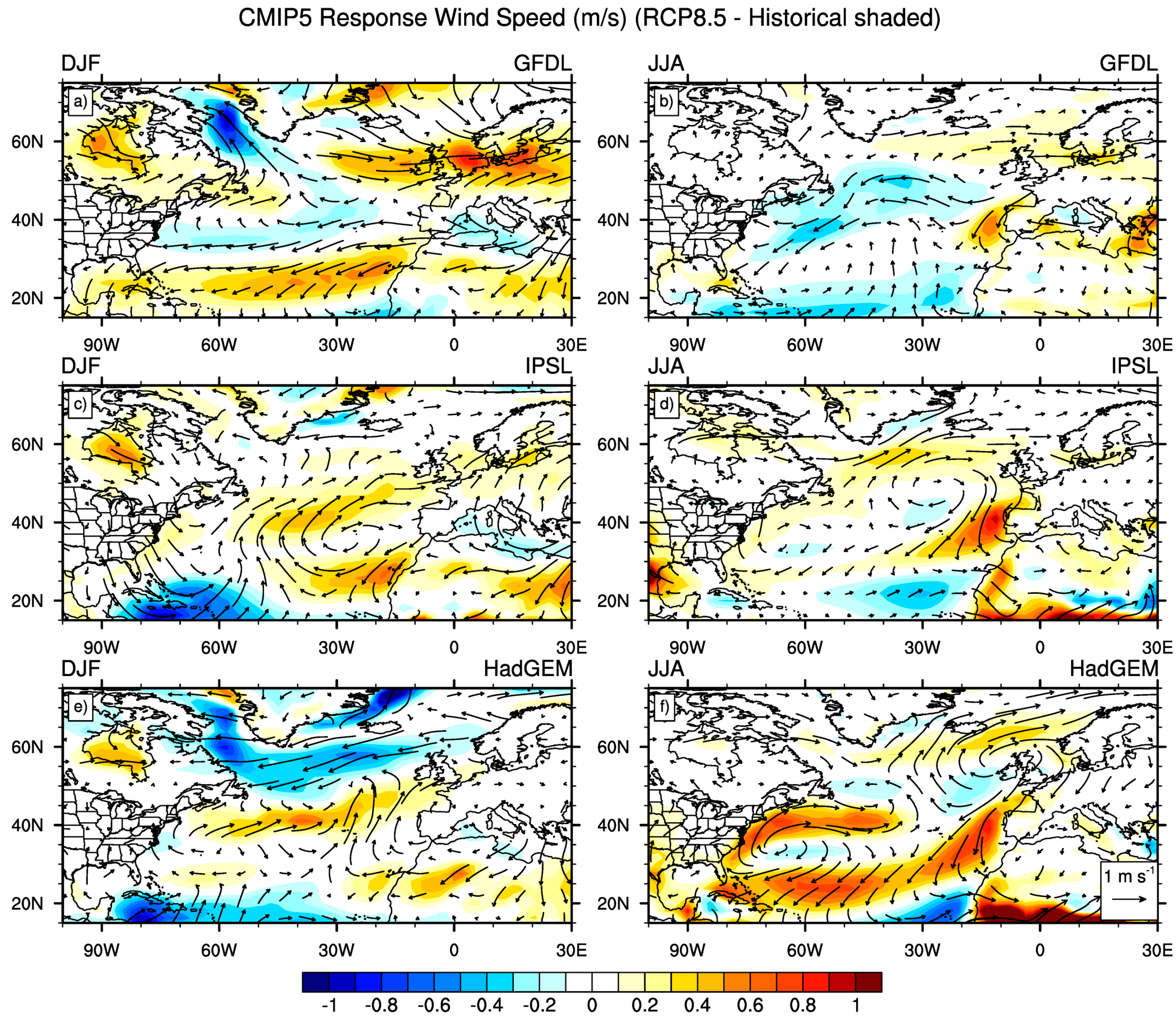

Fig. SM12. The surface wind response (RCP8.5 – Historical, speed shaded, interval 0.1 m s^{-1}, vector scale shown in the lower right panel) during DJF (left) and JJA (right) in the (a) (b) GFDL, (c) (d) IPSL and (e) (f) HadGEM GCMs. The Velocity computed from four times daily zonal and meridional wind components.

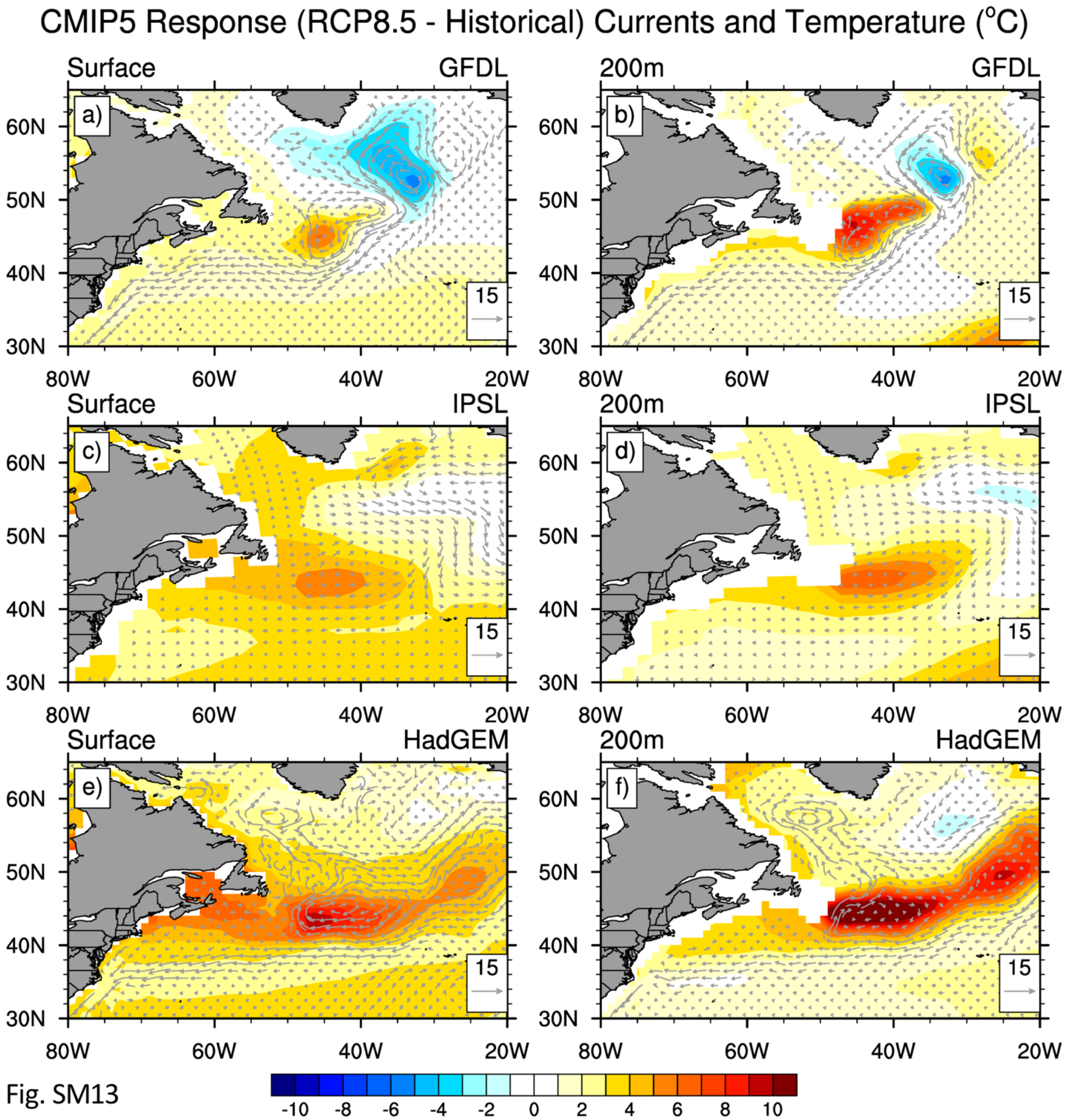

Fig. SM13

Fig. SM13. The annual mean response (RCP8.5 – Historical) in temperature (shaded, interval 1°C) and currents (cm s^{-1}, scale in lower right) at the surface (top) and 200 m (bottom) in the (a) (b) GFDL, (c) (d) IPSL and (e) (fls) HadGEM GCMs. Velocity computed from 5-day averages of the zonal and meridional currents.