Improvement of the GEOS-5 AGCM upon updating the Air-Sea Roughness Parameterization

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Introduction

- Surface Winds in the Southern Ocean are too strong in the GEOS AGCM.
- Old scheme is based on 30 year old observational data of air-sea exchange over oceans.
- Several other GCMs have biases in Southern Hemisphere jet location and/or strength, and are based on similarly old data.
- We document the improvements in the GEOS AGCM upon updating the surface layer parameterization to reflect more recent observations.
- Pair of 30 year model run in which interactive stratospheric chemistry is included, one with the old, weaker, friction, and one with the new, stronger, friction.
- Additional pairs of experiments have been performed without stratospheric chemistry and at higher resolution to test robustness.

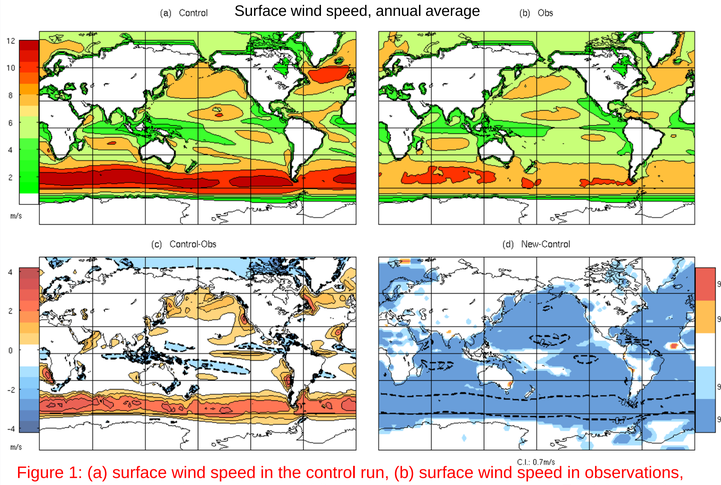

Figure 1: (a) surface wind speed in the control run, (b) surface wind speed in observations, (c) control minus the observations, and (d) the new run minus the control. For (a) and (b), the contour interval is 2m/s and the color scale is on the top left. For (c) and (d), the contour interval is 0.7 m/s. For (c), the color scale is on the left. For (d), regions with anomalies whose statistical significance exceeds 95% are in color. The zero contour is omitted and negative contours are dashed.

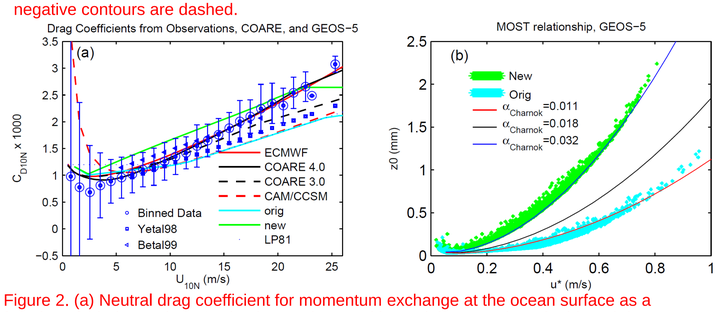

Figure 2. (a) Neutral drag coefficient for momentum exchange at the ocean surface as a function of wind speed at 10m in observations and in models. Error bars for binned data denote 1 standard deviation. (b) Relationship between friction velocity (u*) and roughness length(z_0) over all ocean gridpoints averaged over one day of GEOS-5 model output.

- Surface wind biases are reduced almost everywhere.
- Over the Southern Ocean, biases are reduced by up to 50%, with the largest reduction in wind speed of 1.2m/s.

Response in Troposphere

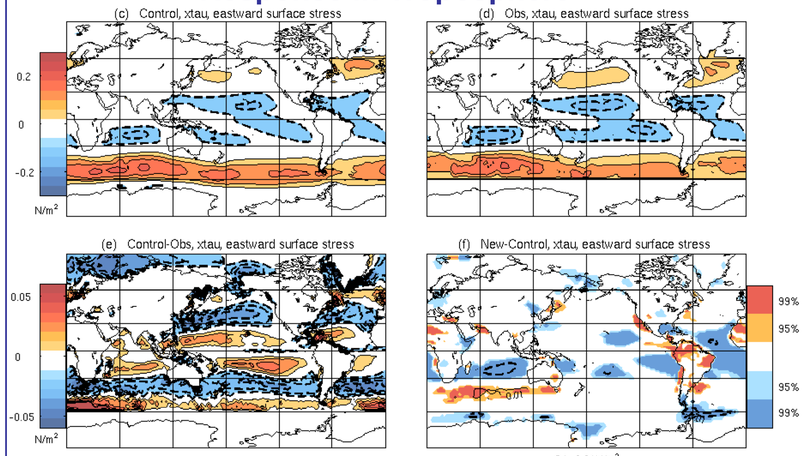

Figure 3: (c-f) Eastward surface stress at the surface in the control run (c), observations (d), control-observations (e), and new-control (f). Contour interval is 5 · 10^{-2} Nm^{-2} for (c) and (d) and 10^{-2} Nm^{-2} for (e) and (f). Regions with anomalies whose statistical significance exceeds 95% are in color in (b) and (f). The zero contour is omitted and negative contours are dashed.

- Change in surface stress. Implied changes in eddy momentum convergence aloft.

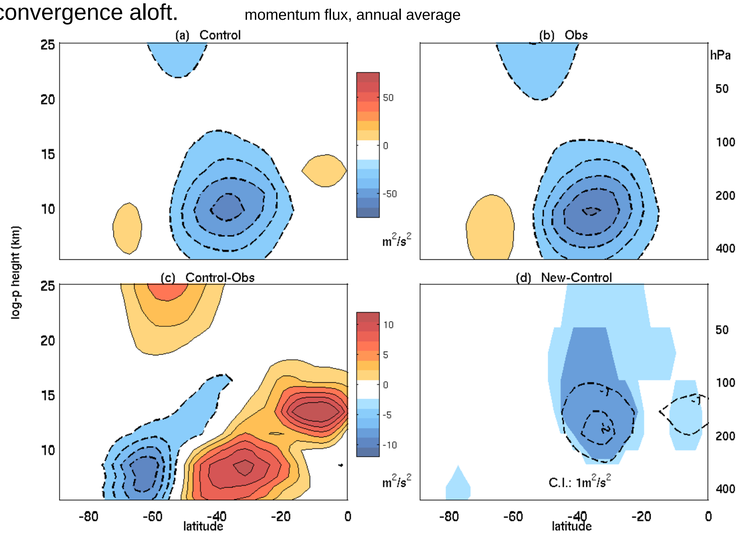

Figure 4: Latitude-height cross section of the poleward westerly momentum flux ($u'v'$). Contour interval is 12.5m^2 s^{-2} for (a) and (b), 2m^2 s^{-2} for (c), and 1m^2 s^{-2} for (d). The zero contour is omitted and negative contours are dashed. Regions with anomalies whose statistical significance exceeds 95% (99%) are in light(dark) blue in (d).

Concluding remarks

1) Old scheme in GEOS AGCM is based on 30-year old observations. Other models are also based on similarly old data. Newer observations suggest oceans are rougher.
2) Increasing the ocean roughness reduces biases in surface wind, surface stress, momentum flux, SH stratospheric polar vortex breakup, SH polar ozone, SH stationary waves, and SH stratospheric heat flux.
3) Barotropic governor (James 1987, James and Gray 1986) arguments are insufficient to explain the response. The relevant dynamics are under investigation (see Barnes and Garfinkel, submitted).

Overall Conclusion – Other modeling group should re-evaluate their surface layer scheme!!

Response in Stratosphere

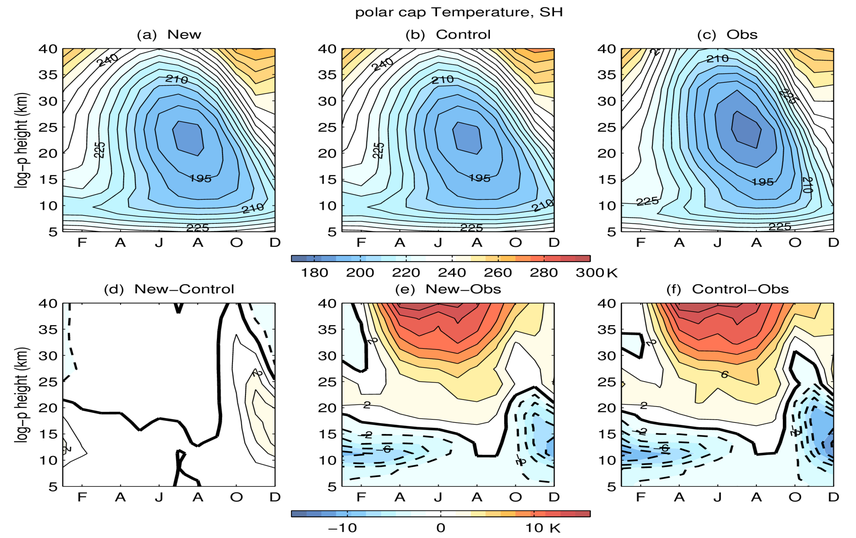

Figure 5: 70S and poleward area weighted temperature as a function of time of year and height. (a), New (b), Control (c), Obs (d), new-control (**e**), New-obs, (f), control-observations**.** Contour interval is 5K for (a)-(c), 1K for (d), and 2K for (e) and (f). The zero contour is bolded in (d)-(f) and negative contours are dashed.

- Vortex breaks up earlier; more planetary wave driving of the vortex; reduced ozone bias (not shown); all three effects are statistically significant.
- Transition to easterlies at 60^{o}S advanced by a week.

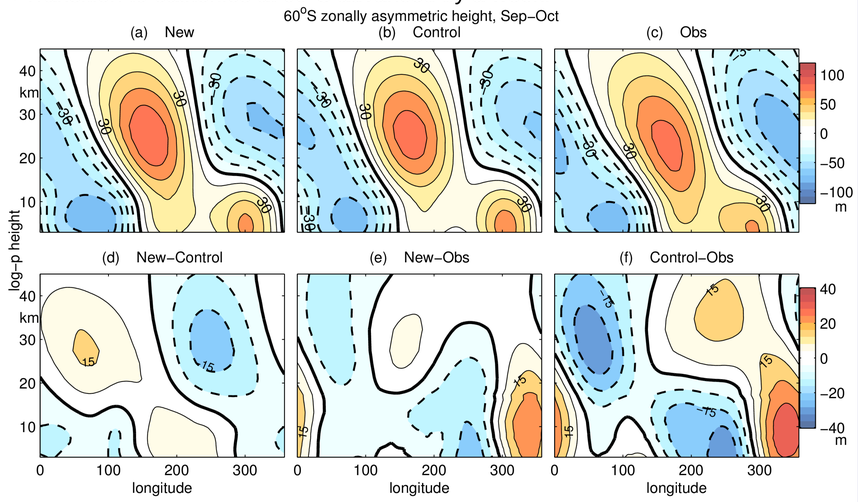

Figure 6: Zonally asymmetric component of geopotential height at 60S as a function of longitude and height. Heights are normalized by the square root of pressure. (a), New (b), Control (c), Obs (d), new-control (**e**), New-obs, (f), control-observations**.** Contour interval is 15m for (a)-(c) and 7.5m for (d)-(f). The zero contour is bolded and negative contours are dashed.

References

Garfinkel, C.I., A. M. Molod , L.D. Oman , I-S. Song(2011), Improvement of the GEOS-5 AGCM upon updating the Air-Sea Roughness Parameterization, GRL, 38, L18702, doi:10.1029/2011GL048802.

Barnes, E. A. and Garfinkel, C. I.(submitted), Barotropic eddy-jet coexistence and the response to surface friction, JAS.