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Cyclones at Quarter-Degree Resolution:

Updated CAM with Prognostic Vs. Diagnostic Momentum Fluxes, Compared to CAM5 and CAM6

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Prognostic vs. Diagnostic Momentum Fluxes in CAM/CLUBB

CAM5/CAM6

- CAM5 used a “moist turbulence scheme” with downgradient diffusion
- CAM6 used CLUBB, but also with diagnostic momentum fluxes (downgradient scheme), where K=Lscale*sqrt(TKE)

$$\overline{u'w'} = -K_m \frac{\partial \overline{u}}{\partial z}$$

$$\overline{v'w'} = -K_m \frac{\partial \overline{v}}{\partial z}$$

Updated CAM/CAM7

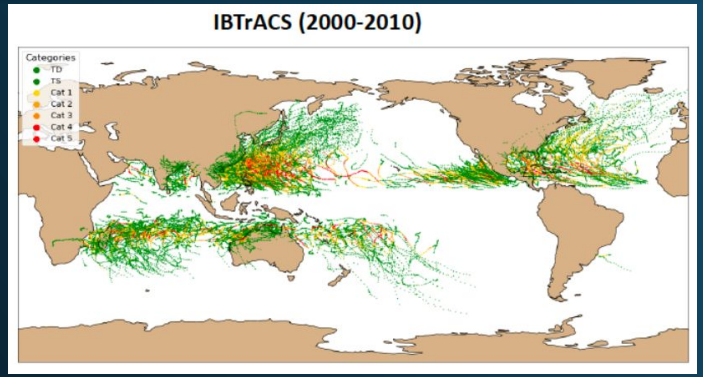
- Will use CLUBB’s prognostic momentum flux code by default. This development work was done under the momentum CPT.
- Can revert to diagnostic momentum fluxes by namelist flag

$$\frac{\partial \overline{u_h' w'}}{\partial t} = \underbrace{-\overline{w}\frac{\partial \overline{u_h' w'}}{\partial z}}_{ma} \underbrace{-\frac{1}{\rho_s}\frac{\partial \rho_s \overline{w'^2 u_h'}}{\partial z}}_{ta} \underbrace{-\overline{w'^2}\frac{\partial \overline{u_h}}{\partial z}}_{tp} \underbrace{-\overline{u_h' w'}\frac{\partial \overline{w}}{\partial z}}_{ac} \underbrace{+\frac{g}{\theta_{vs}}\overline{u_h' \theta_v'}}_{bp}$$

$$\underbrace{-\frac{C_6}{\tau}\overline{u_h' w'}}_{pr1} \underbrace{+C_7 \overline{u_h' w'}\frac{\partial \overline{w}}{\partial z}}_{pr2} \underbrace{-C_7 \frac{g}{\theta_{vs}}\overline{u_h' \theta_v'}}_{pr3} \underbrace{+C_{\text{shr}}^{\text{uu}}\overline{w'^2}\frac{\partial \overline{u_h}}{\partial z}}_{pr4}$$

$$\underbrace{+\frac{\partial}{\partial z}\left[\left(K_{w6}+\nu_6\right)\frac{\partial}{\partial z}\overline{u_h' w'}\right]}_{dp1}$$

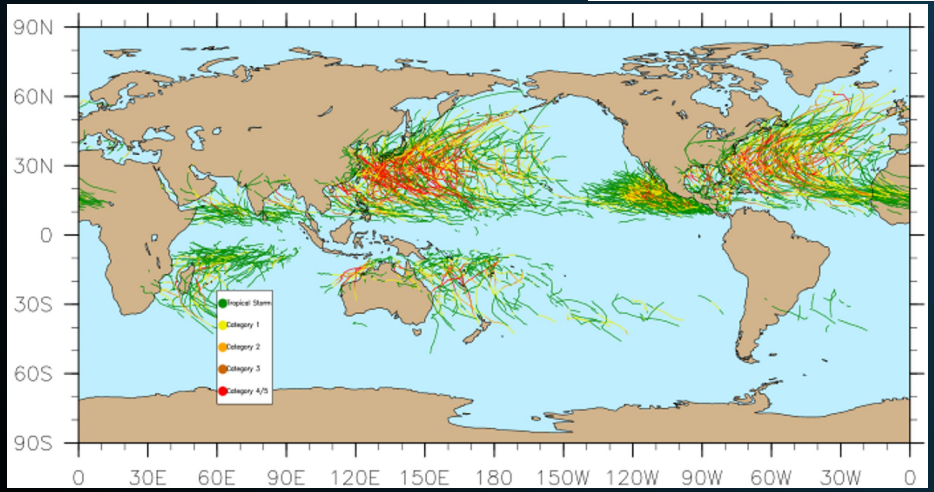
Storm tracks from TempestExtremes



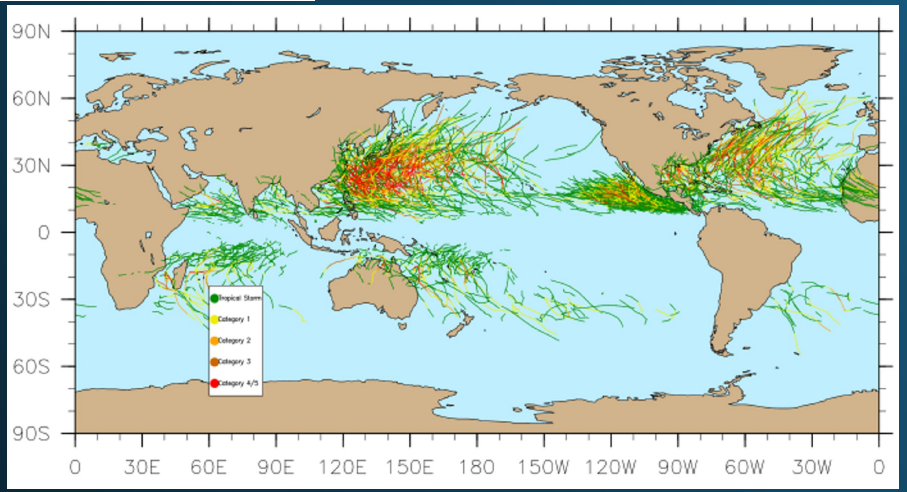
Thanks to Julio Bacmeister for IBTrACS scripts and Peter Lauritzen for the IBTrACS plot; lower plots I created from updated CAM quarter-degree tests using Tempest Extremes–thanks to Colin Zarzycki for help.

Prognostic looks better in East Atlantic

Diagnostic



Prognostic



Colin Zarzycki's takeaways on the large-scale results

The good:

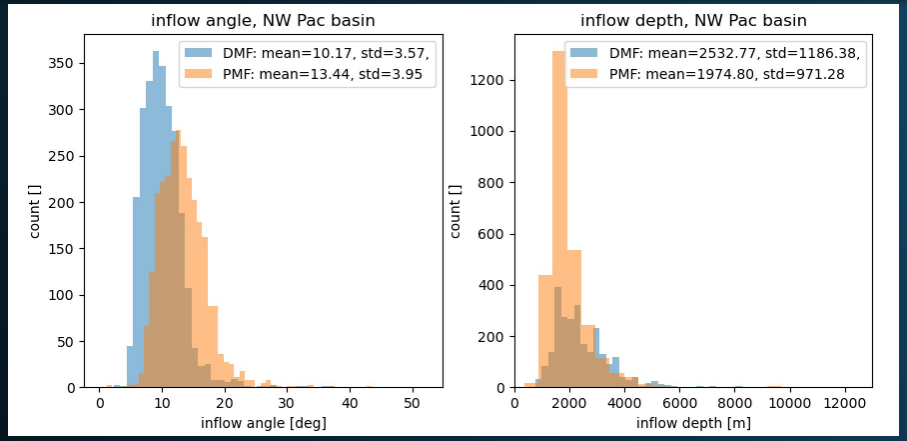
1. DMF is better than CAM5 for spatial patterns of TC count, genesis, and ACE/PACE (integrated intensity). The PMF runs further improve on that.
2. Temporally, the runs seem to better match TC activity globally (i.e., active/inactive months) with the PMF being slightly better than DMF (albeit both aren't great seasonally in the NATL).
3. Both DMF and PMF very much improve the high Central Pacific bias from CAM5 (PMF being a bit better).
4. From a storm-scale perspective (i.e., average duration of TCs, average max intensity, etc.), both DMF and PMF do better than CAM5.

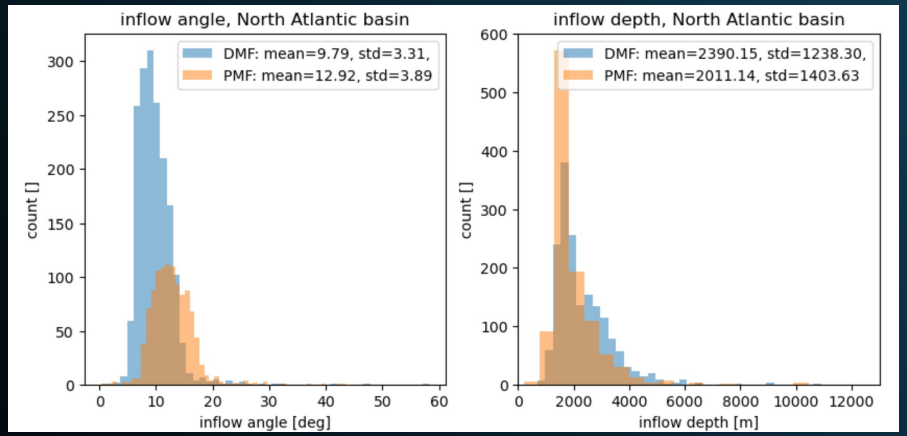
Remaining challenges:

1. Both DMF and PMF produce WAY too many TCs. Globally, this is about 2x what is observed–it's also not just a "weak" TC problem, since the integrated intensity metrics (ACE/PACE) are also way too high.
2. There remain some persistent biases, like the northward bias of TCs in the Western Pacific.
3. Some concern that this occurs even with MG2. Previously, we found that the TC frequency was sensitive to MG1 vs. MG2, and MG2 was an improvement over MG1.

*The **good** news* is that if we could suppress the cyclone counts somewhat (e.g. zm_tau, dt_phys, entrainment,etc.) without really impacting the patterns of activity, updated CAM would be one of the better global models at 25km. It's mostly the TC genesis that's the issue.

Inflow Angle and Depth

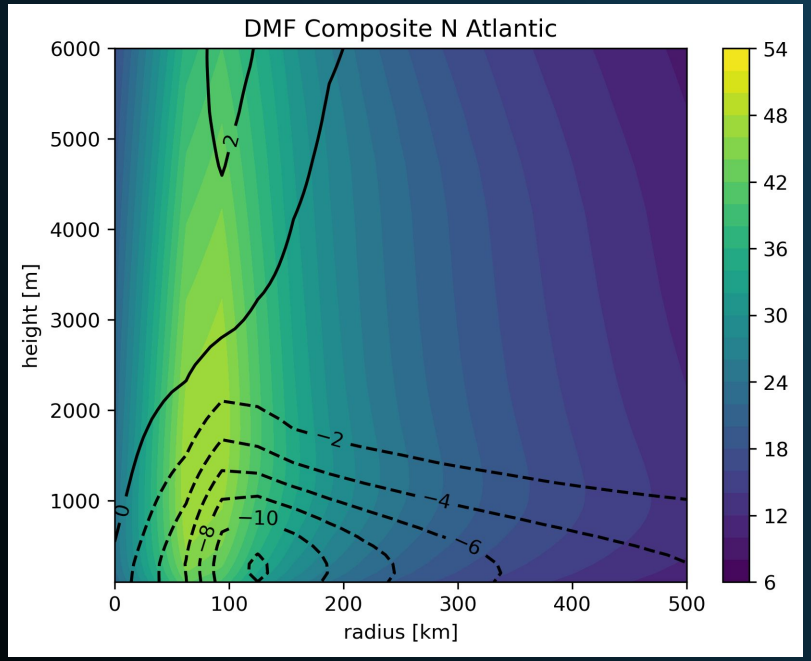


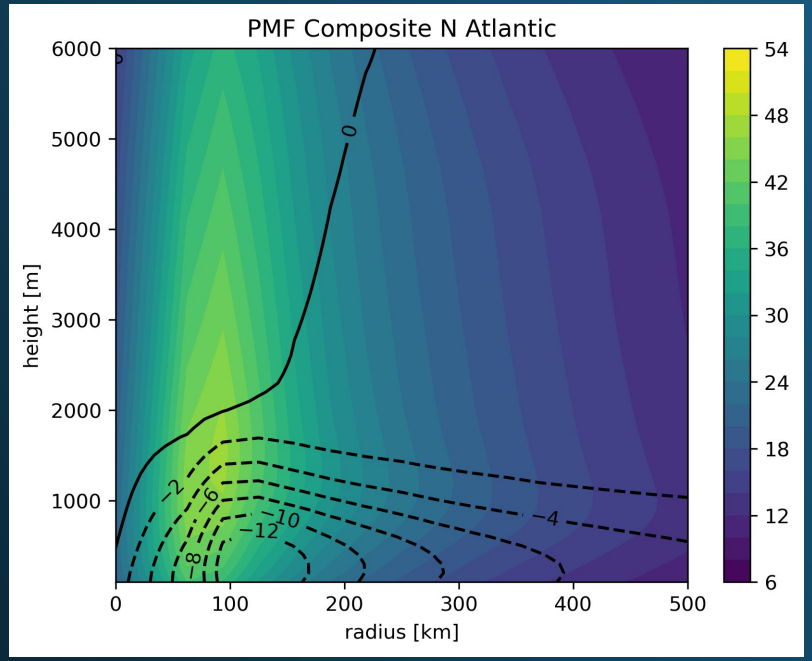


The mean inflow angle has improved with respect to CAM6 (where we think it was closer to 10 degrees). Observationally it should be perhaps 20-22 degrees, so we are still low, but using prognostic momentum fluxes shows a clear improvement over diagnostic. The inflow angle and inflow depth also show the correct (anticorrelated) relationship.

Wind Contours – N Atlantic

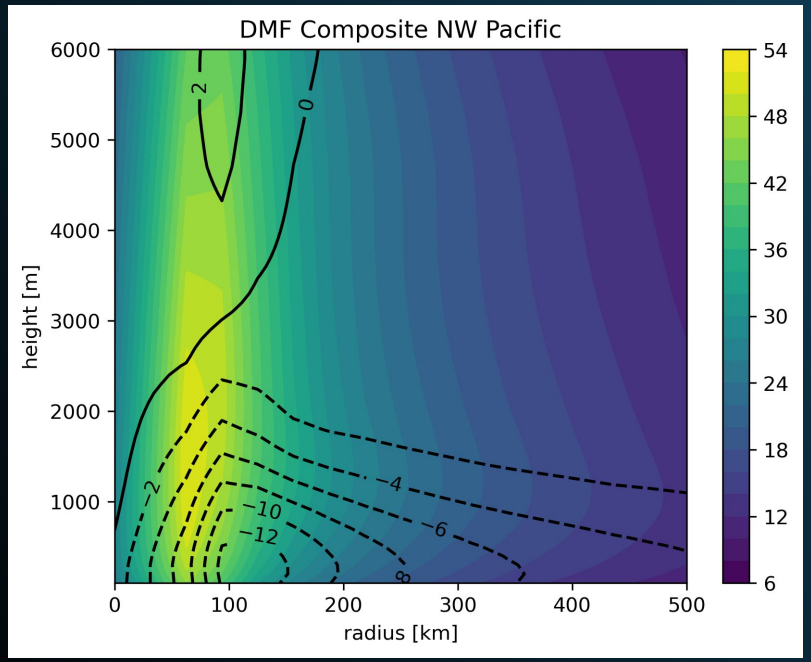
Diagnostic momentum flux (left) vs. prognostic momentum flux (right) wind contours for the North Atlantic. Color contours are for tangential wind, black contour lines are for radial winds. The maximum winds are confined to a lower region in the prognostic momentum test, a strength over the diagnostic test; however, the maximum winds should ideally be closer to the surface.

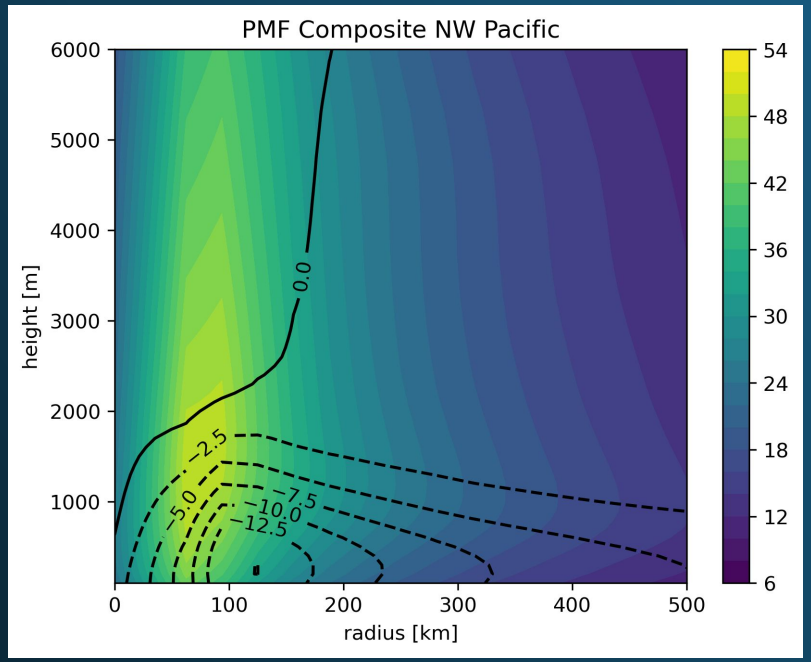




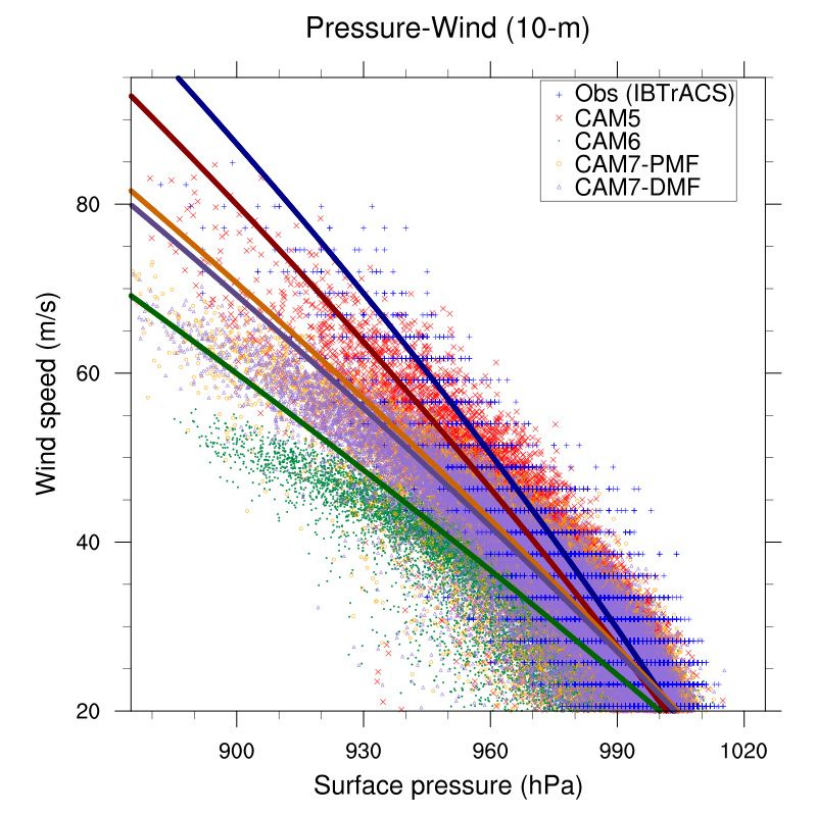
Wind Contours – NW Pacific

Diagnostic momentum flux (left) vs. prognostic momentum flux (right) wind contours for the NW Pacific. Color contours are for tangential wind, black contour lines are for radial winds. While the diagnostic test shows stronger winds, the maximum winds are confined to a lower region in the prognostic momentum test. But in both cases, the maximum winds should ideally be closer to the surface.





Pressure-wind relationship



While CAM5 was the most skillful of recent CAM versions with respect to the pressure-wind relationship, CAM6 showed a degradation. The updated version of CAM, both with and without prognostic momentum fluxes, does better, but prognostic momentum fluxes are slightly better than diagnostic.

Plot by Colin Zarzycki