**Evaluation of PBL simulation in the GFDL AGCM**

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**Introduction**

### Diurnal cycles (DCs) in the planetary boundary layer (PBL)

- The DCs in the PBL impact on life cycles of weather and climate systems by altering surface fluxes, cloud processes, air quality, and etc.
- Correctly simulating the DCs remains challenging for state-of-the-art weather and climate models.
- The DCs of the PBL parameters have received less attention in GCM studies, compared to the variations at monthly, seasonal and annual time scales.

This presentation contains:

- evaluation of the performance of the GFDL AGCM in simulating the annual-mean and DC climatologies of PBL parameters: T2 (2-m temperature), U10 (10-m wind speed), and PBLH (PBL height)
- comparison of two PBL schemes in simulating the PBL parameters and the DCs

### Model Setup

- 10-year climatology runs driven by prescribed SST and sea ice were conducted using the GFDL AGCM with two PBL parameterization schemes.
- Horizontal resolution: about 100 km / Vertical resolution: 33 interface levels (32 grid-center levels) with the lowest model level height at around 33 m
- Two PBL parameterization schemes in the GFDL AGCM compute:
  - Vertical transport (mostly) in the PBL: \( \frac{\partial \theta}{\partial t} = -K_c \frac{\partial w}{\partial z} \), where \( w \) is the vertical flux

  \[(1) \text{K-profile scheme based on Lock et al. (2000): KPP}\]

  \[K_c = K_{\text{wind}}^0 + \frac{K_{\text{rad}}^0}{\text{Pr} \sqrt{\frac{z}{z_0}}} + K_{\text{sh}}^0 + \frac{K_{\text{rad}}^0}{\text{Pr} \sqrt{\frac{z}{z_0}}} \]

  - Prescribed K-profile in the mixed layer
  - entrainment parameterization based on local Ri, from the SFC to the model top
  - This is the standard option in the GFDL AGCM.

  \[K_c = q \frac{\sqrt{TKE}}{S_c} \quad \text{where} \quad q = \sqrt{\text{Pr} \text{TKE}} \]

  - **TKE scheme based on Mellor and Yamada (1974, 1982): TKE**

  \[K_c = q \frac{\sqrt{TKE}}{S_c} \]

- Recently implemented into the GFDL model (J.-C. Golaz, H. Guo, B. Xiang, M. Zhao).
- It showed promise of improved simulations in stratocumulus regions, while degradations were introduced elsewhere.

**Reference data**

- T2, U10, and PBLH: a reanalysis ensemble (ANL) was generated by combining four reanalysis sets (ERA-20C, ERA-Interim, NCEP CFSR and NASA MERRA) and used as a reference.
- The ensemble spread could provide information on the uncertainty of the parameters.
- The ensemble shows better statistical scores than the individual reanalysis sets, when they are evaluated against the CRU T2 observations.
- Surface turbulent fluxes and Vertical profiles: ERA-20C is used.
- The diurnal cycles of temperature and wind profiles in ERA-20C resemble those observed best among the four reanalysis sets, at the highest vertical and temporal resolutions.

**Concluding remarks**

- This study is the first attempt at documenting the performance of the GFDL AGCMs in the representation of the diurnal cycle climatologies of the PBL parameters. Several systematic biases were found compared to the reanalysis ensemble, and the problems in the PBL parameterization schemes and in the current vertical resolution were identified.
- Based on the findings of this study, we plan to implement a non-local transport term in the PBL schemes for increasing the vertical mixing in the convective PBLs and refine the vertical resolution in the surface layer for better resolving the stable PBLs.

**Results – Temperature**

- **Annual means**

- **Seasonal means**

- **Diurnal amplitude (DA) of T2**

- **Role of vertical mixing in dry PBLs: the Sahara region**

**Results – Winds**

- **Annual-mean U10**

- **Diurnal amplitude of U10**

- **Role of vertical mixing in dry PBLs: the Sahara region**

(a) The increase in U10 during the morning transition is not captured by KPP and TKE, consistent with the systematic underestimation in T2 and DA (the global maps above).

(b) The DA is underestimated over land.

(c) There is no much difference between KPP and TKE.

(d) The models underestimate DAs of T2 in the arid and semi-arid regions.

(e) The PBL cools more quickly in TKE, due to the weaker mixing.

(f) ERA is cooler than KPP/TKE, due to the less efficient heat transport in TKE.