Kinetic Energy generation in cross-equatorial flow and Somali Jet
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Motivation:
How is KE generated in monsoon flow?

- Maximum Kinetic Energy in Somali Jet
- Hot-spots for KE generation (refilling stations)

Jet peak moves upwards away from coast

Hourly ERA5 suggests an important role for orographic KE generation

Surface Contribution + Atmospheric Contribution = Total

Small-scale KE gen. through upslope and downslope march of flow
Atmospheric contribution is small but increases with height
Cross-isobaric meridional flow contributes most
1. Is KE generated in-situ or advected from adjacent regions?

2. KE maximum is closer to E African orography at 950 hPa, but occurs over wide area over open ocean at 850 hPa

3. Small inter-annual variability in KE associated with cross-equatorial flow. We can learn about the key drivers of KE generation by analyzing a particular representative year (we choose 2019)
Intricate vertical structure of Somali Jet

- Zonal cross-sections suggest that the depth of cross-equatorial flow and KE is substantial (~2.5 km)

- The altitude of jet maximum occurs just offshore the East African slopes suggesting important role of orography in KE generation

- The altitude of jet maximum shifts upwards over open ocean
Merits in using *hourly* ERA5 reanalysis

Relative difference = \[ \frac{\text{KE}_{\text{Hourly\_Winds}} - \text{KE}_{\text{Monthly\_Winds}}}{\text{KE}_{\text{Monthly\_Winds}}} \]

- One could make a significant error in estimations of KE generation using monthly averaged wind data especially over land
Horizontal KE budget

\[
\frac{D}{Dt} \left( \frac{1}{2} U_H^2 \right) = \frac{1}{\rho} \nabla_H p \cdot \vec{U}_H - 2\Omega \cos \theta \vec{u} \vec{w} + \vec{F}_H \cdot \vec{U}_H
\]

1. Material derivative of KE
2. Generation through cross-isobaric flow
3. Generation due to Coriolis force (negligibly small when calculated)
4. KE Dissipated through turbulent diffusion and molecular friction (Residue)

Expectation:

1. This will allow us to identify “hot-spots” where Generation term #2 is large but dissipation term #4 is small.

2. If Generation (#2) is small but Material Derivative term #1 is large, then the KE is advected
Kinetic Energy Budget (Hot-Spots★)
A simple model for KE generation

- Using hydrostatic approximation, pressure gradients at the pressure level of interest ($p$) can be written in terms of Surface pressure ($p_0$), Surface Geopotential ($z_0$) and virtual temperature in the air layer between $p$ and $p_0$

$$G_{KE} = \left(-R\frac{T_v}{p_0} \left(\nabla_H p_0\right) \circ \vec{U_a}\right) - \left(g \frac{T_v}{T_v_0} \left(\nabla_H z_0\right) \circ \vec{U_a}\right) + \left(T_v \int_{p}^{p_0} \frac{1}{\rho} \left(\nabla_H \frac{1}{T_v}\right) dp \circ \vec{U_a}\right)$$

$G_{KE,1}$ = Due to surface pressure gradients

$G_{KE,2}$ = Due to orography gradients

$G_{KE,3}$ = Due to gradients of inverse virtual temperature
Surface KE generation is most dominant

- Small scale KE generation due to surface pressure and surface geopotential gradients drive KE in Somali jet
Intricate upslope and downslope KE generation at hot-spots
Cross-isobaric meridional flow up-slope of East African highlands is unique feature.
Conclusions

• Maximum KE generation in cross-equatorial flow occurs at 3 hot-spots: 1. Madagascar, 2. East African Orography, 3. Western Ghats

• Resolving small-scale interaction of cross-equatorial flow with African orography can be crucial to accurately simulate monsoon flows

• Monsoon flow accumulates both up-slope and down-slope generated KE to ultimately feed and sustain Somali Jet