Shaping of IAS summer weather by zonal mean momentum

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Outline

• <[u]> a meaningful entity, not just a statistic

• Seasonal: Americas midsummer drying

• Interannual: regressions (ENSO entangled)
  – Tropical cyclones, precip
What is $<[u]>$?

- $[u]$ is zonal mean
  - makes $-\partial \Phi/\partial x$ term ~vanish on RHS
  - $u^*v^*$ are 'eddy' deviations (Starr, Lorenz notation)

- $<u>$ is vertical mean – ‘barotropic’
  - makes $fv$ term ~vanish on RHS

- $<[u]>$ is *barotropic zonal mean momentum*
  - a function of latitude and time only
  - AAM is its (weighted) latitudinal integral
"Meaningful" averaging and $<[u]>$

- $<[u]>$ obeys an equation w/ few terms on RHS
- It thus has an existence *more substantive* than $u$
  - an entity, a player, a climate sub-system
  - more fundamental than a “jet” (isotach) or "pool" (isotherm)

- I'll speak of $<[u]>$ as a wind that "advects" scalars. But of course advection is by local $u(\text{lon, p})$
  - of which $<[u]>$ is one ‘component’...
<[u]> climatology

NCEP R1 climatology
W. Atl. midsummer drying driven ultimately by Asian monsoon, via global zonal momentum dynamics

Kelly and Mapes 2011 obs. (JGR)
Kelly and Mapes 2013 model clincher (J. Climate)
If $<u>$ shapes the anticyclones,

- Pacific too?
- TC steering impacts as well as rain?
Tropical Cyclone Density Climatology

Data: IBTrACS
<[u]> regressed Cyclone Days in each grid cell

Subtropical westerlies negatively associated with IAS region TCs

30x15deg bin size
But wait – ENSO affects $<[u]>$!

JJASO (1979-2014)

Better be careful about attribution/interpretation!
But wait – ENSO affects $<[u]>!$

- In thermal wind sense (EQ-pole T diff mnemonic works)
- Barotropic mean goes as upper levels in that mnemonic
  - Shear goes as $[u]$ in that mnemonic
Attribution to 2 factors

• Pure $<[u]>$ regression: postulate this form:

$$TC = c_u <[u]> + err_u$$

Optimize $c_u$ by minimizing $\text{RMS}(err_u)$
Attribution to 2 factors

• Pure SST regression: postulate this form:

\[ TC = c_T \text{ SST} + \text{err}_T \]

Optimize \( c_T \) by minimizing RMS(\( \text{err}_T \))
ENSO and $<[u]>$ univariate regressions: comparable variance explained
Attribution to 2 factors

- **Joint (partial)** regression: postulate this form:

\[ TC = c_{T,u} \text{ SST} + c_{u,T} \langle [u] \rangle + \text{err}_{Tu} \]

Optimize \( c_{T,u} \) and \( c_{u,T} \) wrt \( \text{RMS(\text{err}_{Tu})} \)

\[
C_{u,T} = \left. \frac{\partial (TC)}{\partial \langle [u] \rangle} \right|_{\text{NinoSST}}
\]
Canceling effects by positively correlated predictors

Pacific SST, for a given $<[u]>$, is positively associated with Pacific TCs

Subtropical westerlies negatively associated with all TCs, for a given Nino34 SSTA
Q: If $<[u]>$ shapes the anticyclones,

- Pacific too?
- TC steering impacts as well as rain?

— A: Not E-W dipoles Not just “steering”!
CMAP rain regressions are even more redundant (or entangled)
CMAP partial regression separates effects very starkly

20x10deg bin size
Precip (CMAP)

(a) JJASO nino3.4 partial regression coeff.

(b) JJASO $<[u]>$ 15-30N partial regression coeff.

native 2.5deg res
Interpretation

• Always a tricky business...

• Source of ENSO variance well understood

• Sources of $<[u]>$ variance other than ENSO not
  – monsoon-driven stationary eddy $[u^*v^*]$?
    • but then monsoon & ENSO are correlated?
Interpretation

• Always a tricky business...

• **Framing** the problem is important and subtle – *a coherent account of the phenomena & mechanisms is essential, not an afterthought*  

• A data analysis will not solve its own framing
  » *but wait -- by variance explained per predictor?*
  » *but then, from a list of candidate predictors: framing again*
Conclusions

• $<[u]>$ is arguably a climate “entity”, not just a statistic
  – its budget has few terms, chiefly $[u^*v^*]$ at upper levels

• $<[u]>$ has regional impacts (Americas and elsewhere)
  – its $y$-shear helps shape the subtropical anticyclone
  – it contributes as a component to $u$ isotach (jet)
  – it discourages TCs, for a given ENSO state

• Part of $<[u]>$ variability is an ENSO signal
  – mustn’t ascribe ENSO effects to one’s pet ENSO-correlated thing

• Might non-ENSO parts of $<[u]>$ include unique predictable signals, or valuable lessons about weather-climate interaction mechanisms?
Extra slides
The case for $\langle [u] \rangle \rightarrow$ MSD

- Mechanism: upper stationary eddy flux $[u^*v^*]$
- Ultimate cause: Asian monsoon

- Obs. evidence: interannual correlations
- GCMs able to reproduce signal
- Model clincher: darker India soil $\rightarrow$ more ✔
<[u>] seen in both shaping of stationary waves and motion of fast disturbances.
shaping of stationary waves

Heating (PV source)

Eddy $Z_{1000}$ no [u]

Eddy $Z_{1000}$ w/ July [u]

Chen, Hosling & Dole 2001
shaping of stationary waves
The case for $\langle u \rangle$ effects

- Further clincher: southern hemisphere
Águas de Março
(dryness of February)

Source: CPTEC Web site

Kelly and Mapes – submitting this week
Typical El Niño influence

More hurricanes due to less vertical wind shear

Fewer hurricanes due to stronger vertical wind shear and trade winds and greater atmospheric stability

WARM, WET

Typical influence of El Niño on Pacific and Atlantic seasonal hurricane activity. Map by NOAA Climate.gov, based on originals by Gerry Bell.
Warm ENSO $\rightarrow$ increase E-P Temp gradient $\rightarrow$ increased Westerly $<[u]>$ in subtropics

Cold ENSO $\rightarrow$ decreased E-P Temp gradient $\rightarrow$ decreased Westerly $<[u]>$ in subtropics