Physics of the Ocean-Atmosphere Coupling in Extreme Winds

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Objectives:
(1) Characterize coherent turbulent structures (CTS) in the PBL
(2) Role of CTS in ocean-atmosphere coupling; satellite footprint
IWRAP Data and Cases

Retrieval Products
- U,V,W/reflectivity/derivatives on 3D grid
- Grid spacing, along-track/across-track/vertical
  - 125 m/125 m/30 m

Guimond et al. (2014), JTECH; Guimond et al. (2018), JAS

Storm Cases for Focused Analysis:
- Hurricane Laura (2020), RI case
  - 8/25 (Cat-1, I); 8/26 (Cat-3, I)
- Hurricane Teddy (2020)
  - 9/17 (Cat-4, S); 9/18 (Cat-3, W)
- Hurricane Delta (2020)
  - 10/06 (Cat-4, S)
  - 10/08 (Cat-2, I); 10/09 (Cat-3, W)

Cal/Val 2020

RMSE = 2.03 m/s or 7.05%
Corr. Coef. = 0.99

RMSE = 0.95 m/s or 62.73%
Corr. Coef. = 0.81

RMSE = 1.79 m/s or 7.38%
Corr. Coef. = 0.99
IWRAP Examples - Teddy

Tangential Windspeed (m/s), file = 202009171640

Horizontal Windspeed (m/s), file = 202009171640

Vertical Windspeed (m/s), file = 202009171640
Energy Transfer in the Hurricane Boundary Layer
Mathematical Methodology


IWRAP swath

See also:
Guimond et al. (2020), JAS
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Azimuthal sector

Storm center

2 km

FIGURE 3. KE spectra for the three radial passes of IWRAP data analysed in this paper.

\[ \tau_{ij} = \tilde{u}_i \tilde{u}_j - \tilde{u}_i \tilde{u}_j = L_{ij} + R_{ij} + C_{ij} \]

\[ L_{ij} = \tilde{u}_i \tilde{u}_j - \tilde{u}_i \tilde{u}_j \]

\[ R_{ij} = \tilde{u}_i \tilde{u}_j - \tilde{u}_i \tilde{u}_j \]

\[ C_{ij} = \tilde{u}_i \tilde{u}_j + \tilde{u}_j \tilde{u}_i - \tilde{u}_i \tilde{u}_j - \tilde{u}_i \tilde{u}_j \]

\[ S = \frac{1}{2} \begin{bmatrix}
\frac{2}{r} \frac{\partial \tilde{u}}{\partial r} + \frac{\partial \tilde{v}}{\partial r} - \tilde{v} & \frac{\partial \tilde{u}}{\partial r} + \frac{\partial \tilde{v}}{\partial z} \\
\frac{\partial \tilde{v}}{\partial r} - \frac{\tilde{v}}{r} & \frac{2}{r} \frac{\partial \tilde{v}}{\partial r} + \frac{\partial \tilde{w}}{\partial z}
\end{bmatrix} \]
**Energy Transfer Breakdown**

*Hurricane Rita (2005)*

Data

\[ \mathcal{P} = -\tau_{ij} \tilde{S}_{ij} \]

**Stress Tensor ($\tau$) Correlations to $\mathcal{P}$**
- Radial-vertical ($\tau_{13}$) 79%
- Azimuthal-vertical ($\tau_{23}$) 49%
- Sign of $\mathcal{P} \rightarrow$ Sign of $\tau \rightarrow$ Sign of $\partial \psi / \partial r$ (vertical velocity)
TKE Budgets in HBL

- Energy transfer term (“2P”) contributes on average ~ 30% to “eddy scale” time tendency
- Backscatter affects larger-scale waves, which can feed energy to mean flow
- HBL has large non-conservative effects
Key Findings for OVWST

- **How does kinetic energy (wind) change in the PBL?**
  - Turbulence models (Smag, TKE; downscale only)
    - HBL contains organized KE backscatter
    - Driven by coherent structures ~ 2 km wavelength
    - Secondary circulations, esp. vertical fluxes
      - Small-scale waves
      - Larger-scale waves
      - Mean flow

- **OVWST applications**
  - role of CTS in ocean-atmosphere coupling
    - Currents and ocean mixing
    - Surface fluxes, convection, storm intensity change
  - Relevant for satellite footprints and OVW data
IWRAP Examples - Teddy

Tangential Windspeed (m/s), file = 202009171750

Radial Windspeed (m/s), file = 202009171750

Vertical Windspeed (m/s), file = 202009171750