Influence of wind speeds on flux exchange across water-atmosphere interface under different stability conditions

Wind-classes and Atmospheric Stability Ranges

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The energetic life over inland water bodies systems

• Understanding air-water interactions of inland water bodies is critical to ascertain the role inland water bodies have in regulating local and regional weather and its impact to the hydrological balance.

• Wind is one of the main drivers of energy exchange between the atmosphere and water bodies.

• High-wind weather events would dramatically increase energy exchanges (latent heat, LE, and sensible heat, H, fluxes) by 100-200%.
The noisy relationships between LE & H and its drivers

\[ LE = (\rho_a L_v) C_E U \Delta q \]
\[ H = (\rho_a C_p) C_H U \Delta T \]

- Simple linear relationships between LE & H and its drivers through the bulk transfer equations
- Possible correlations between drivers, U and \( \Delta q \) and \( \Delta T \)
- Atmospheric stability, \( \zeta \), influence on both \( C_E \) and \( C_H \) while \( U \) (\( u^* \)) would affect \( \zeta \)
- \( U \) is central to the inter-relationships between LE & H and its drivers
The study location, instrumentation, and dataset

- **Location:** Ross Barnett Reservoir, Mississippi, 134 km², depth 4 – 8 m.
- **Duration:** 174 days (August 24, 2007 to March 5, 2008)
- **Cold front days:** 12 days
- **Warm front days:** 5 days
Wind-classes I, II, III, & IV

To classify, more than 50% of half-hourly $U$ in the below wind ranges:

- Wind-class I: $U < 2.316$ m s$^{-1}$
- Wind-class II: $2.316 \leq U < 3.693$ m s$^{-1}$
- Wind-class III: $3.693 \leq U < 5.125$ m s$^{-1}$
- Wind-class IV: $U > 5.125$ m s$^{-1}$
Atmospheric stability, $\zeta$, ranges

Categorized atmospheric stability, $\zeta$, into 10 classes of ranges:

1. $-10 \leq \zeta < -1$ (557) – **very unstable**
2. $-1 \leq \zeta < -0.5$ (636)
3. $-0.5 \leq \zeta < -0.1$ (2519)
4. $-0.1 \leq \zeta < -0.05$ (648)
5. $-0.05 \leq \zeta < 0$ (589) – **near-neutral**
6. $0 \leq \zeta < 0.05$ (687) – **near-neutral**
7. $0.05 \leq \zeta < 0.1$ (333)
8. $0.1 \leq \zeta < 0.5$ (796)
9. $0.5 \leq \zeta < 1$ (204)
10. $1 \leq \zeta < 10$ (118) – **very stable**

More unstable

More stable
Diurnal changes in $LE$, $H$, & its drivers part 1

- Wind has been reported to change the influence of $\Delta e$ and $\Delta T$ on $LE$ and $H$.
- $H$ closely follows the diurnal pattern of $\Delta T$ in contrast to $LE$.
- Diurnal $\Delta e$ changes with wind-class – it decreased in high wind-classes.
- Diurnal $\Delta T$ did not behave the same as $\Delta e$. 
Diurnal changes in $LE$, $H$, & its drivers part 2

- Diurnal $\Delta e$ was relatively constant in wind-class IV.
- $LE$ and $H$ doubled in wind-class IV compared to wind-class I.
- Persistent wind conditions changes the atmospheric drivers of $LE$ and $H$ above water surfaces.
Increased wind-class enhances $LE$ & $H$

- For positive gradients, higher wind-classes would increase the correlation between $LE$ and $\Delta e$ and between $H$ and $\Delta T$.
- Negative $\Delta e$ and $\Delta T$ cases would not behave the same as positive $\Delta e$ and $\Delta T$.
- Regression slopes would dramatically increase after wind-class III.
- Wind-class III is the initial point where $LE$ becomes more correlated with $\Delta e$. 
Slopes of \( LE/\Delta e \) & \( H/\Delta T \)

\[
LE/\Delta e = (\rho_a L_v) C_E U \\
H/\Delta T = (\rho_a C_p) C_H U
\]

- In wind-class IV, \( LE/\Delta e \) was greatly influenced by atmospheric stability.
- In other lower wind-classes, atmospheric stability did not play an important role in changing \( LE/\Delta e \).
- Persistent high wind conditions and atmospheric stability enhanced the role of \( UC_E \) on \( LE \).
- Under both unstable and stable conditions, \( H \) was influenced by \( UC_H \) but with increased effect in wind-class IV.
Atmospheric stability ranges on $LE$ & $H$

- Maximum $LE$, $U\Delta e$ and $H$, $U\Delta T$ occurred in moderately unstable conditions due to maximum $U$.
- $LE$ under unstable conditions are dependent on persistent wind conditions compared to stable conditions or $H$.
- Under weakly unstable conditions, $LE$ and $H$ in wind-class IV more than doubled in magnitude than in wind-class I even when $\Delta e$ or $\Delta T$ is elevated.
- $U$ interacts and enhances $C_E$ to increase $LE$ only under unstable conditions.
- $U$ interacts and enhances $C_H$ to increase $H$ under both unstable and stable conditions.
Bulk transfer coefficients

• The bulk transfer coefficients ($C_E$ and $C_H$) behaved similarly in all wind-classes and $\zeta$ ranges.
• The increase in $LE$ under weakly unstable conditions are due to the interaction of $U$ and $C_E$.
• The increase in $H$ under both unstable and stable conditions are due to the interaction of $U$ and $C_H$.
Conclusions

• Persistent wind speed conditions would modify the atmospheric drivers of $LE$ and $H$ and increased the correlation between them.

• Evaporation ($LE$) and $H$ would be greatly promoted when sufficient wind conditions are met by 2.5 and 2 times, respectively.

• The increase in $LE$ under weakly unstable conditions are due to the interaction of $U$ and $C_E$.

• The increase in $H$ under both unstable and stable conditions are due to the interaction of $U$ and $C_H$. 
Thank you