Terrain Effects on Wind Speed Enhanced by Atmospheric Stability

Jack Kline and Liz Walls
RAM Associates

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Data Sites

- Five Meteorological Towers used
- 4-60 m tilt-up & 1-100 m lattice tower
- 60 m towers have 3 levels of WS – redundant booms SW & SE, upper @ 57m
- Cell tower has WS to 100 m & two temperature sensors @ 99 m & 3 m. Used for shear alpha and delta-T
- Prevailing southerly & some northerly WD
- Wind speed analysis for both WD ranges
The Site – Southern Great Plains

Site 1: On plateau. WS ratios will be shown w.r.t. Site 1.
Average Conditions by WD

- Data period rather brief – March thru August 2012
- Distinct effects of terrain and stability still evident
- Site 1 57m used as reference. Wind speed ratios to Site 1 calculated

**WS ratios w.r.t. Site 1 flip when WD changes from north to south.**
Mean Diurnal Ratios by WD

Day – Unstable
Smallest difference between WS ratios

Night – Stable
Largest difference between WS ratios
Mean Diurnal Alpha & Delta-T by WD

- **Diurnal alpha & delta-T North WD**
  - **Night – Stable:**
    - High Alpha & ΔT > 0
  - **Day – Unstable:**
    - Low Alpha & ΔT < 0

- **Diurnal alpha & delta-T South WD**

➤ **Alpha and ΔT diurnal trends are very similar for both northerly and southerly WDs.**
Shear $\alpha$ vs. delta-$T$: N&S

Relationship between alpha and $\Delta T$ same for both north and south WD.

Alpha is driven by $\Delta T$ in same fashion for both wind directions.
RAMWind Terrain Exposures

Exposure ~ integral of elevation differences between met tower & surrounding terrain, by direction. Weight by WD frequency

Larger values indicate greater overall elevation difference

Upwind exposure – related to terrain in direction wind comes from

Downwind exposure – related to terrain in direction wind is going to
Vertical Profile

[Diagram showing a vertical profile with labeled sites: Site 1, Site 2, Site 5, South, North.]

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Mean WS vs. Exposure - North WD

**WS RATIOS TO SITE 1 vs UW EXPOSURE**

- Decreasing WS with increasing upwind exposure.

**WS RATIOS TO SITE 1 vs DW EXPOSURE**

- Increasing WS with increasing downwind exposure.
WS Ratio Map – North WD
Mean WS vs. Exposure – South WD

- Decreasing WS with increasing upwind exposure.
- Increasing WS with increasing downwind exposure.
- Same type of relationship between WS and exposure for northerly and southerly WDs.
- **Relative WS can change with WD due to UW & DW terrain effects.**
WS Ratio Map – South WD
WS Ratios vs. Exposure by Stability: Hi $\alpha >= 0.20$; Low $\alpha < 0.10$ – North WD

During northerly WD, higher sensitivity of WS to exposure during high atmospheric stability conditions.
WS Ratios vs. Exposure by Stability: Hi $\alpha \geq 0.20$, Low $\alpha < 0.10$ – South WD

> Similarly, during southerly WD, higher sensitivity of WS to exposure during high stability conditions.
High Stability Enhances Terrain Effects

- Sensitivity of WS to terrain defined by slope of WS ratios vs. exposure
- Sensitivity to terrain increases as stability increases
- Stability defined by either $\Delta T$ or shear alpha exponent
- Analyze sensitivity vs. stability ($\Delta T$) for all 24 diurnal WS ratios
During both WD, as stability increases, the sensitivity of WS to UW and DW exposure increases.
Conclusions

• Terrain effects on wind speed highly dependent on atmospheric stability
• Relative WS can change with wind direction, due to UW & DW terrain effects
• Under stable conditions, higher UW exposure impedes wind flow (lower WS), but higher DW exposure enhances flow (higher WS).
• Sensitivity of WS to terrain is directly related to stability