Terrain Effects on Wind Speed Enhanced by Atmospheric Stability

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RAM Associates

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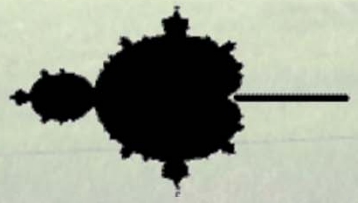
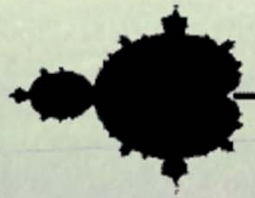
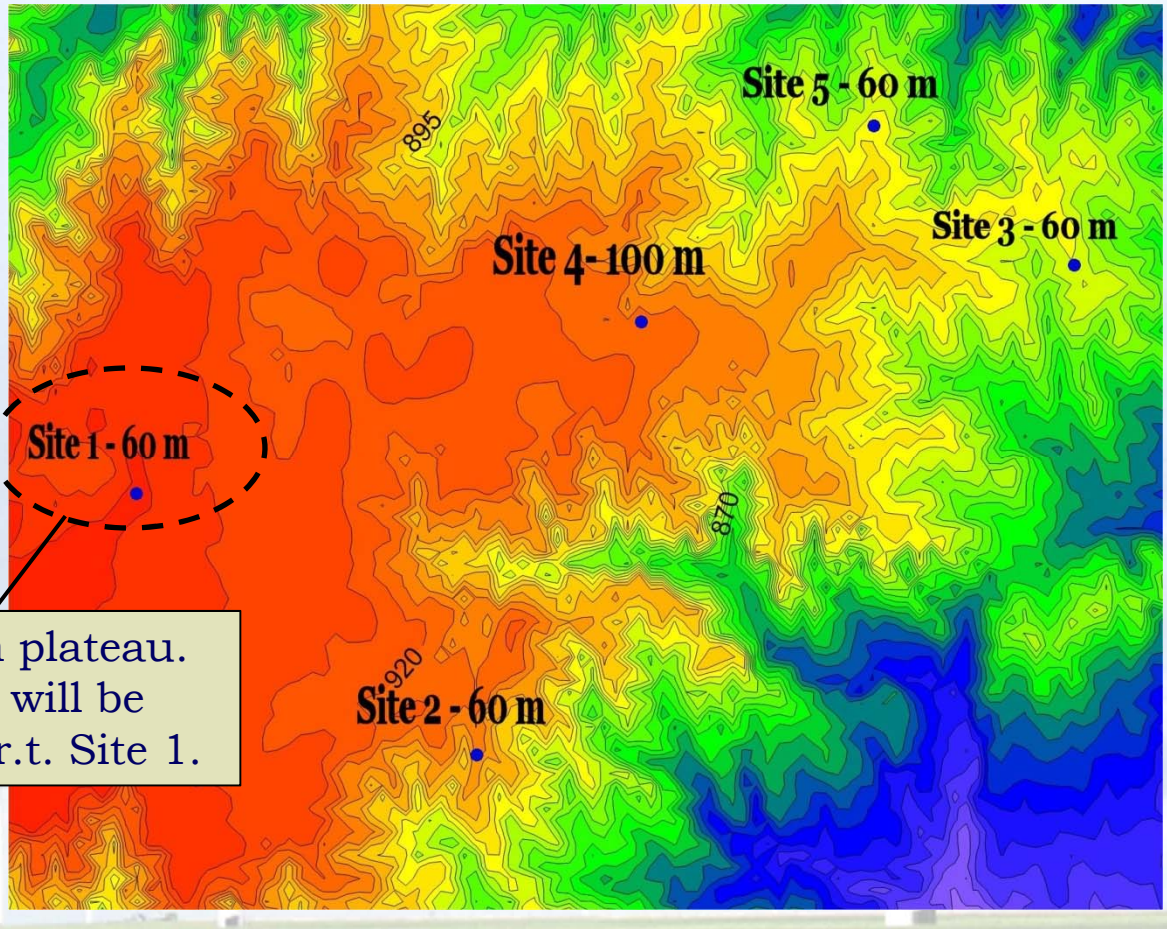


Data Sites

- 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



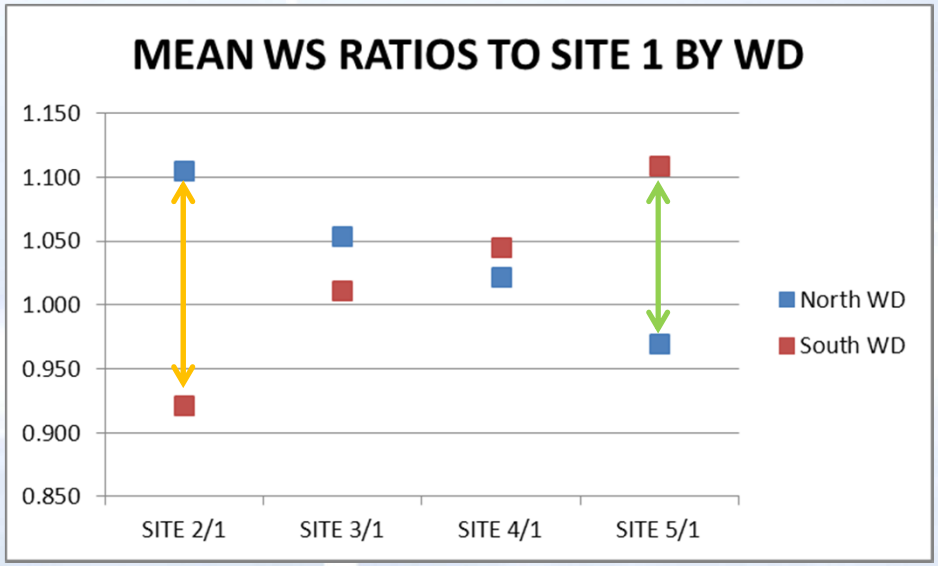
The Site – Southern Great Plains



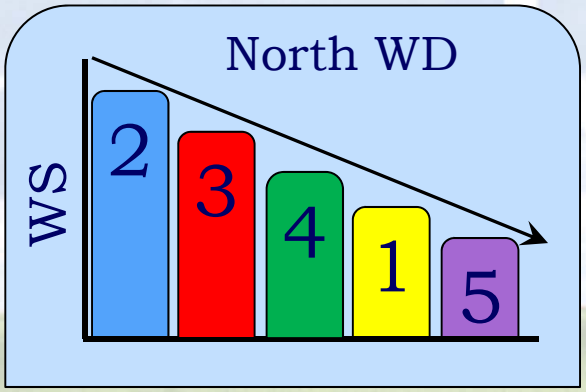
Site 1: On plateau. WS ratios will be shown w.r.t. Site 1.

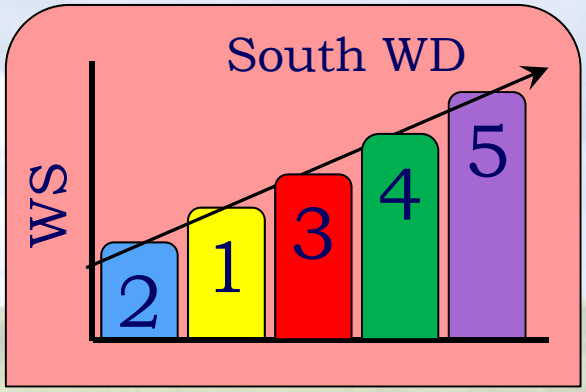
Average Conditions by WD

- 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.**





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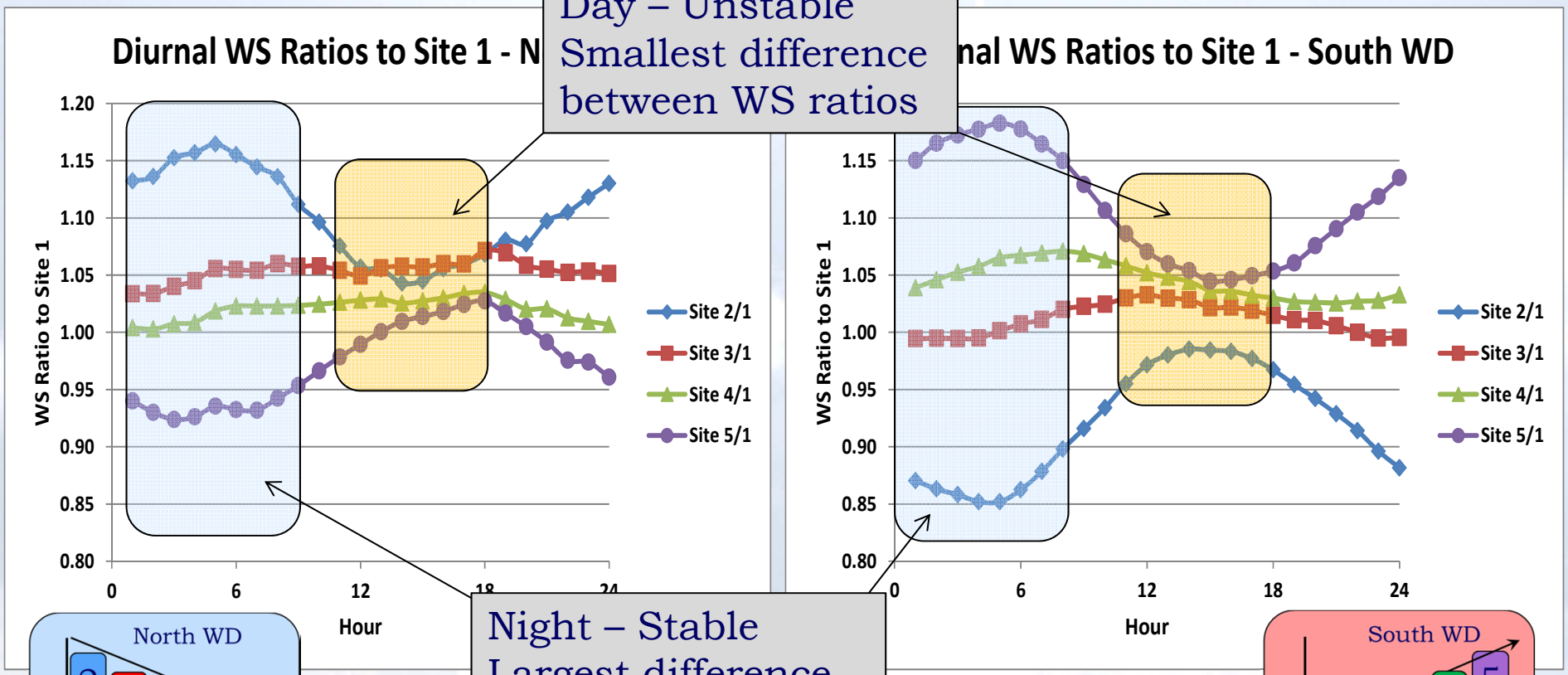
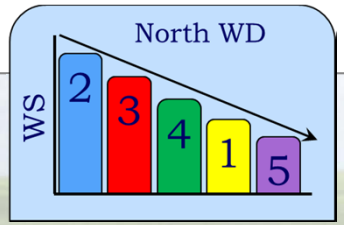
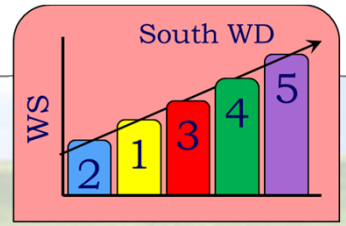
Mean Diurnal Ratios by WD

Day – Unstable
Smallest difference
between WS ratios



Night – Stable
Largest difference
between WS ratios





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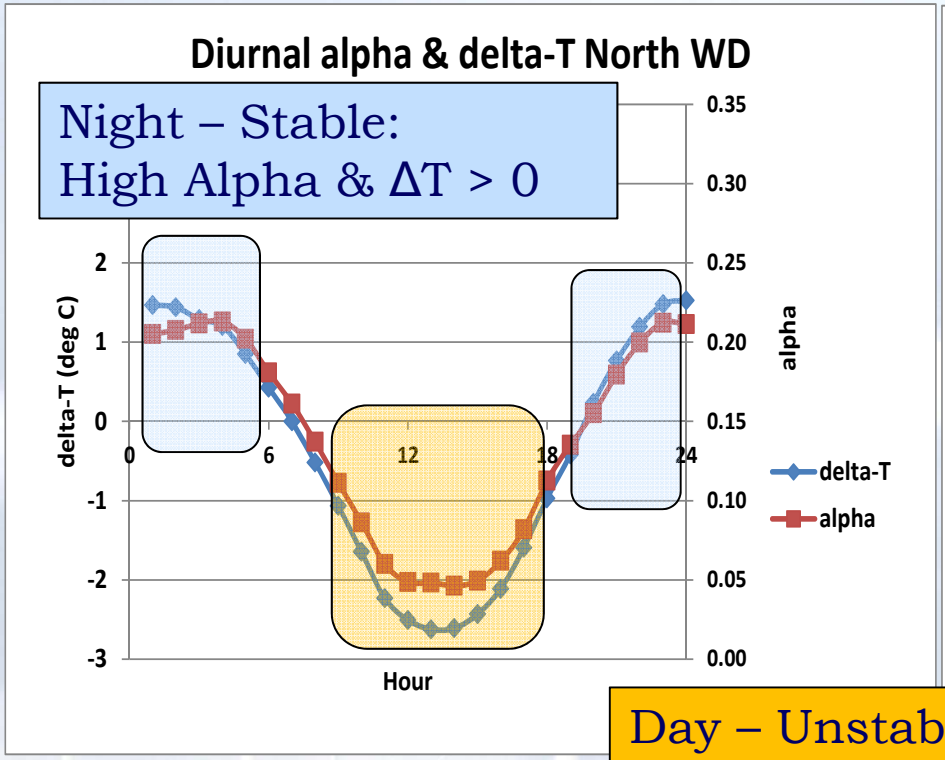
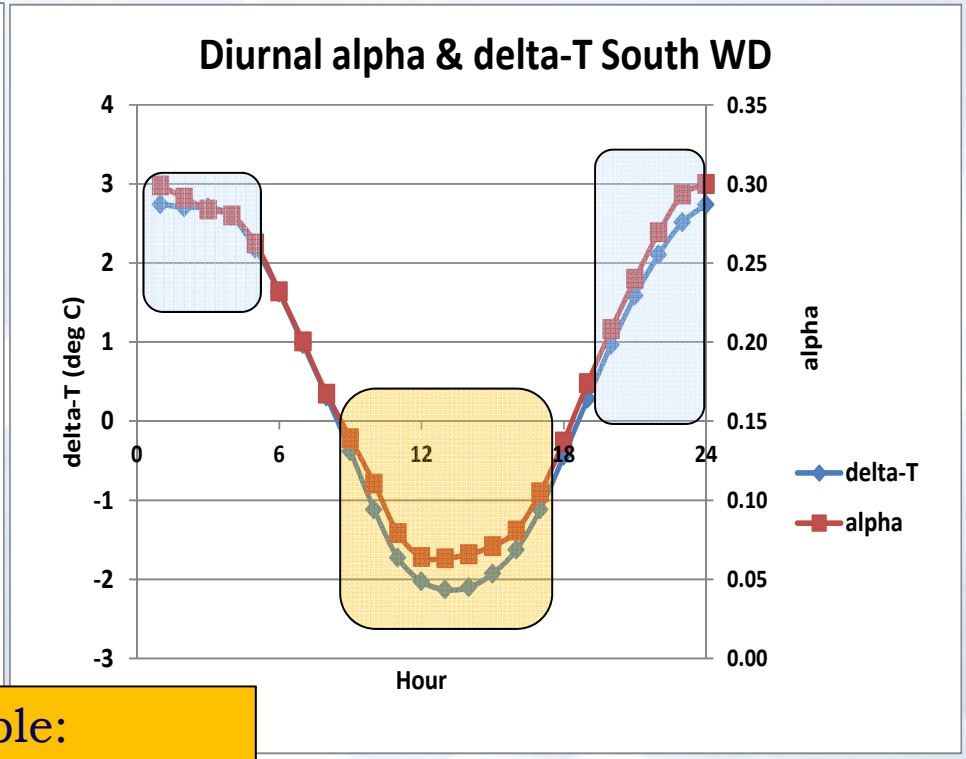
Mean Diurnal Alpha & Delta-T by WD





Day – Unstable:
Low Alpha & ΔT < 0

- Alpha and ΔT diurnal trends are very similar for both northerly and southerly WDs.

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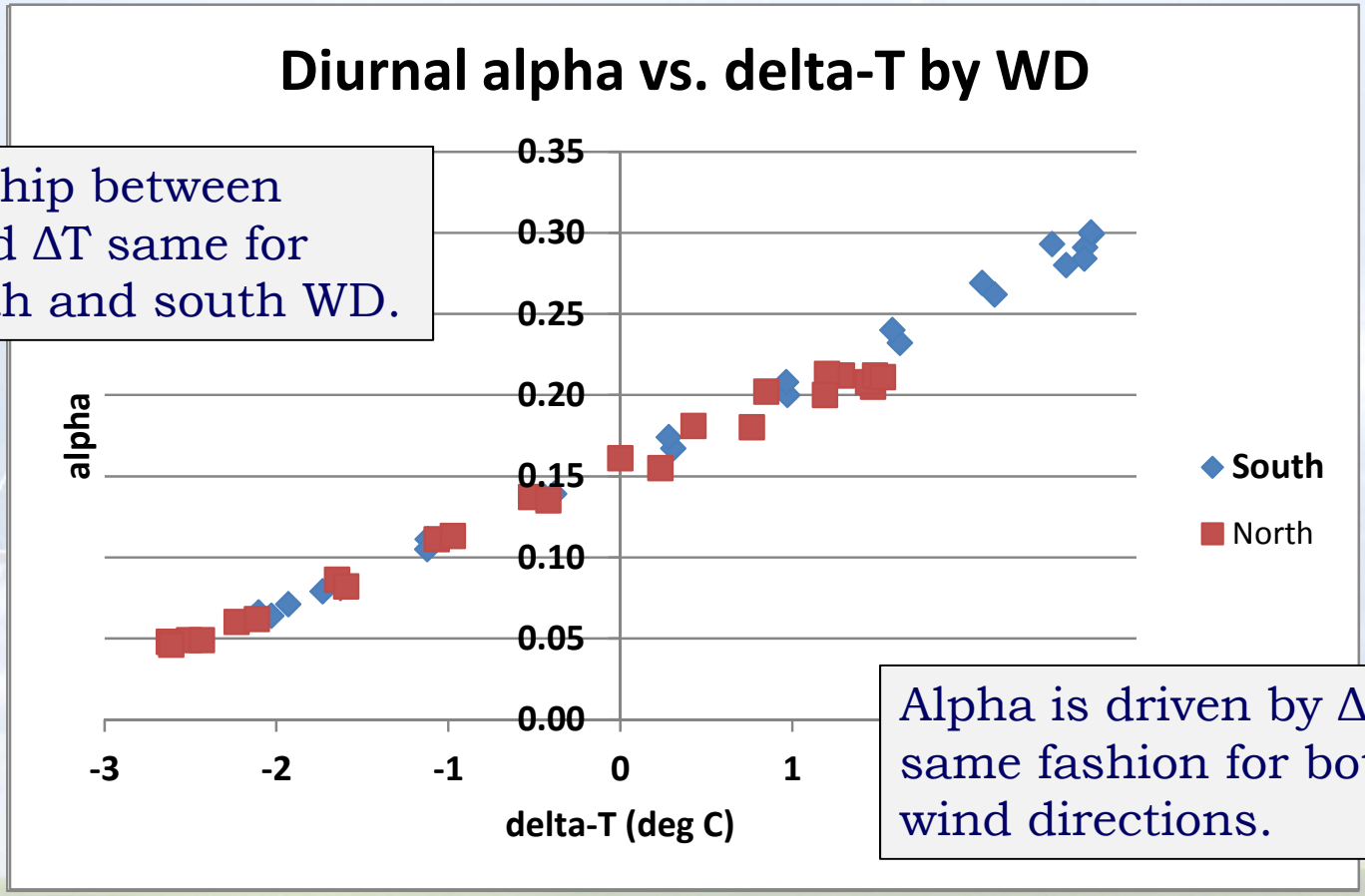
Shear α vs. delta-T: N&S

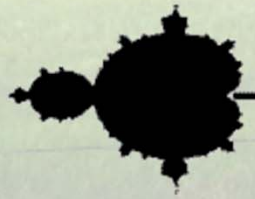


Relationship between alpha and ΔT same for both north and south WD.

Alpha is driven by ΔT in same fashion for both wind directions.

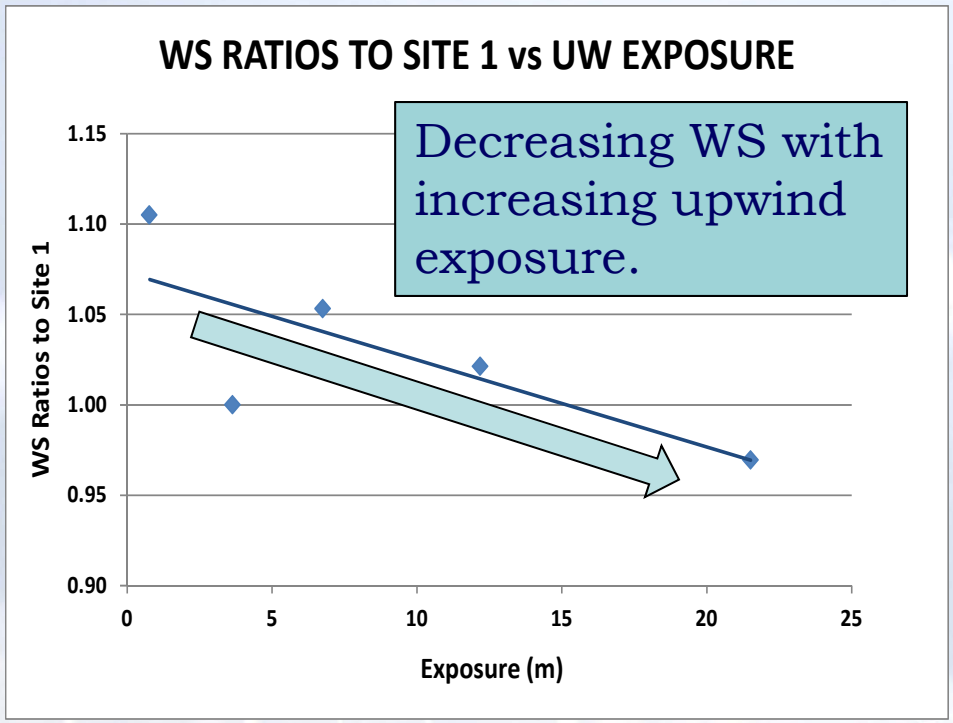
RAMWind Terrain Exposures

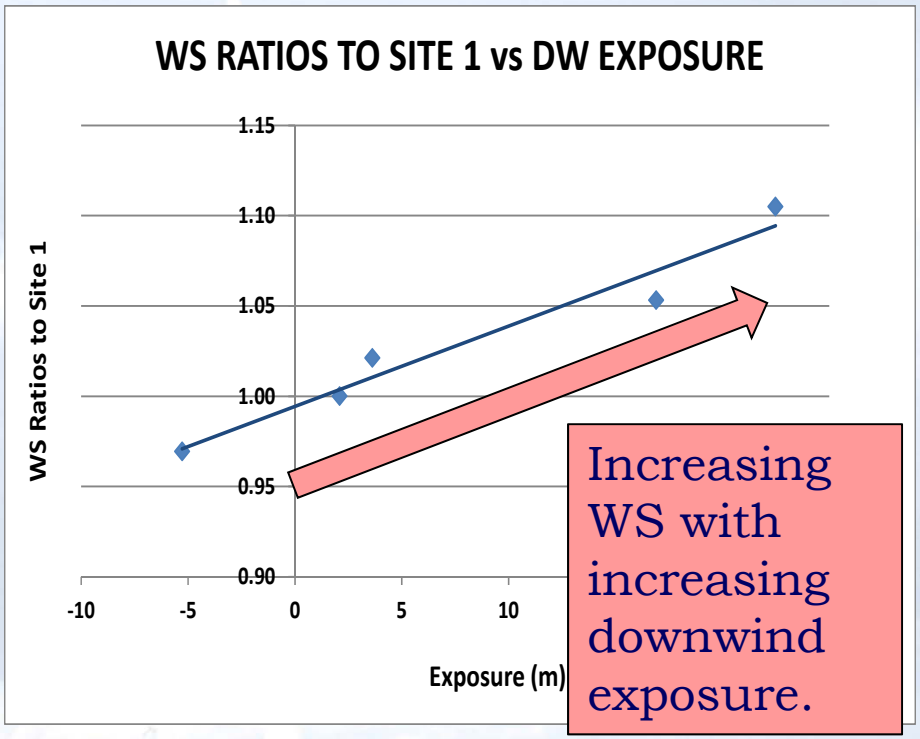
- Exposure ~ integral of elevation differences between met tower & surrounding terrain, by direction. Weight by WD frequency
- Larger values indicate greater overall elevation difference
- Upwind exposure – related to terrain in direction wind comes from
- Downwind exposure – related to terrain in direction wind is going to



Vertical Profile

Mean WS vs. Exposure - North WD





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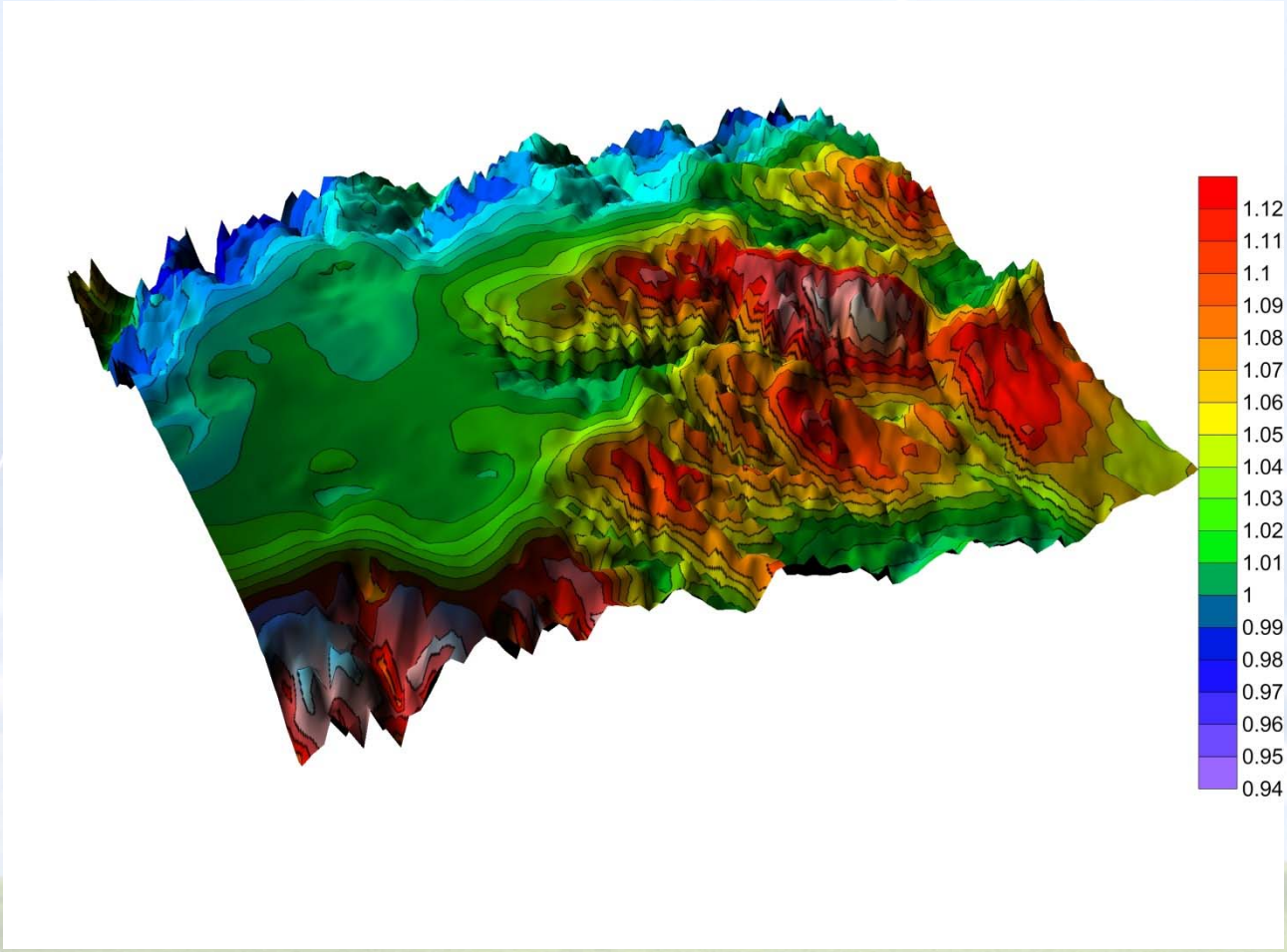
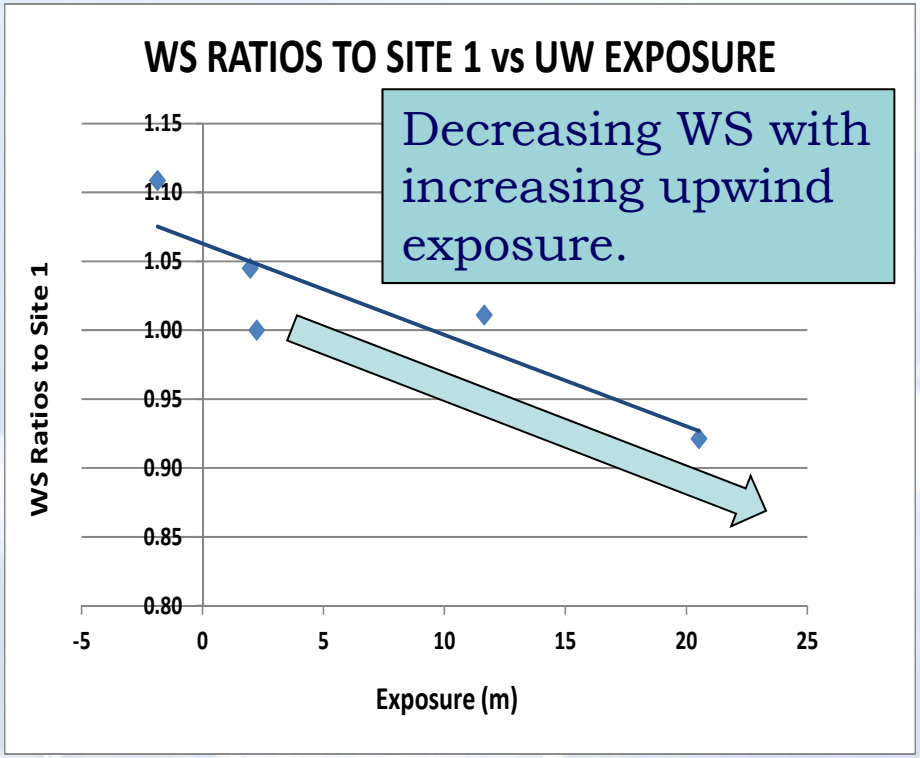
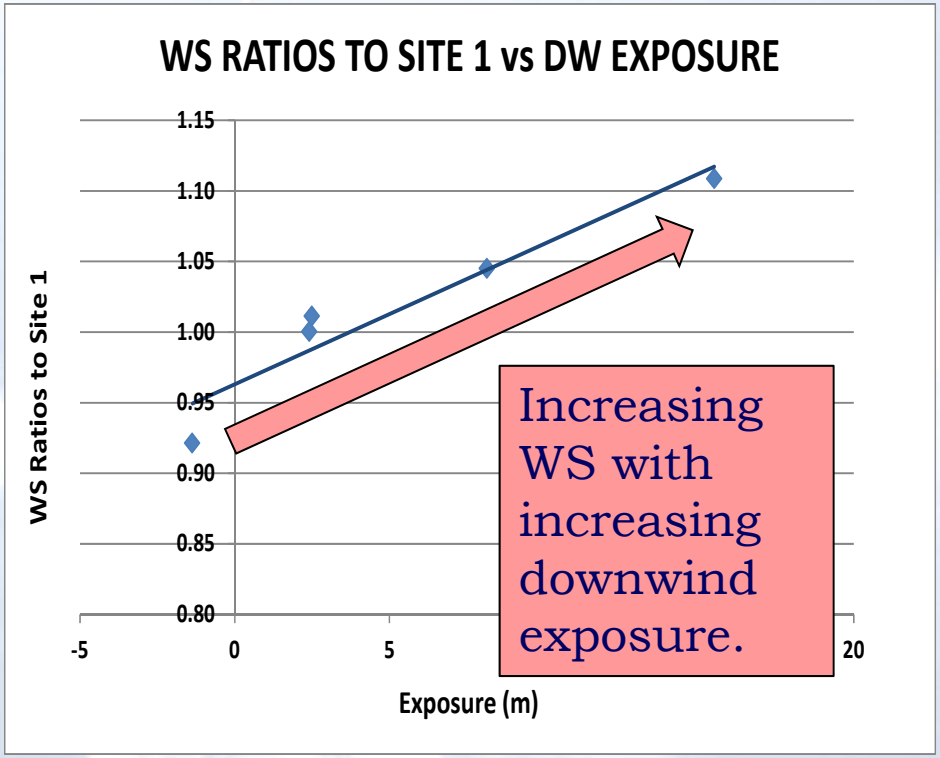
WS Ratio Map – North WD



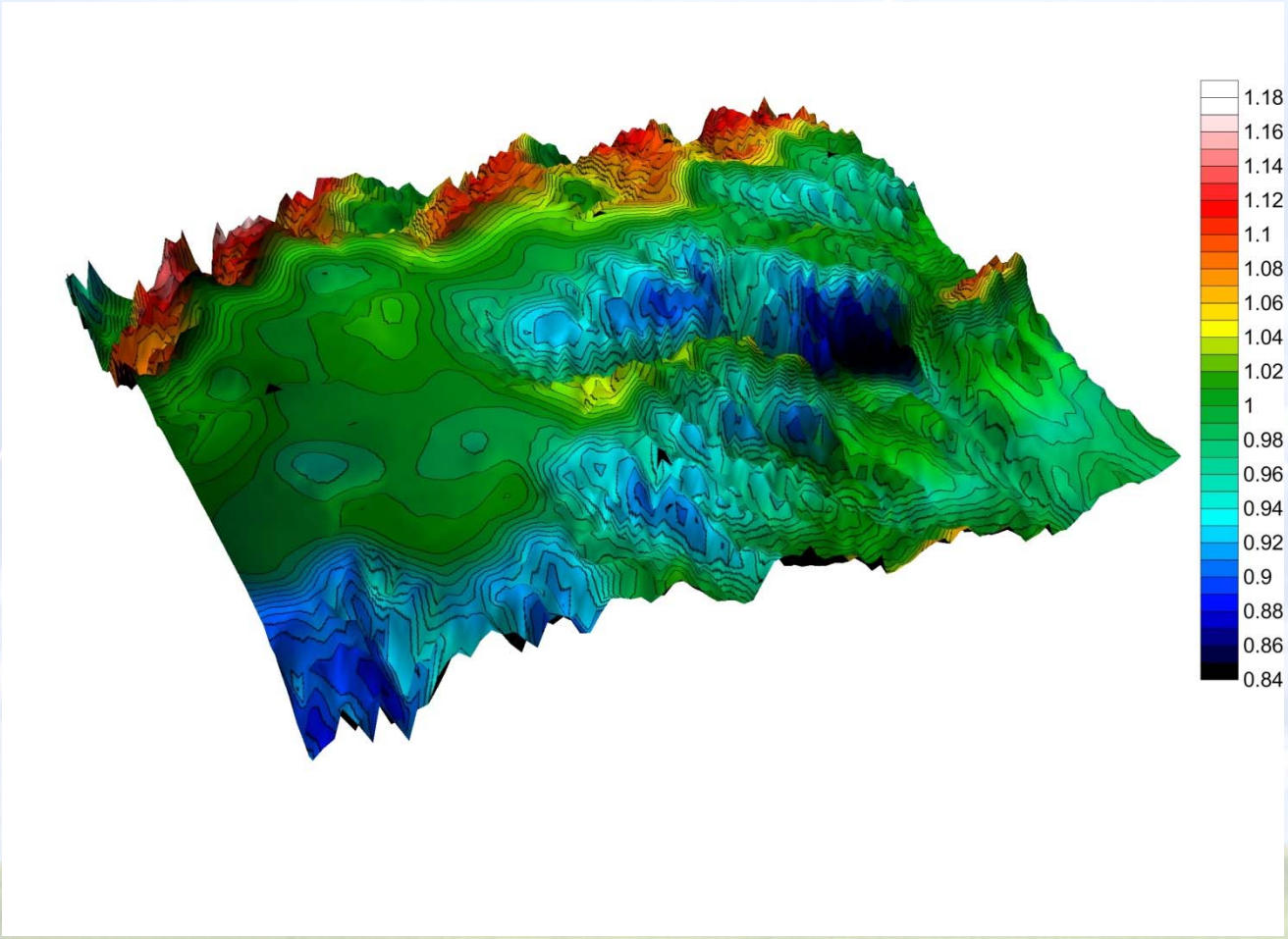
Mean WS vs. Exposure – South WD



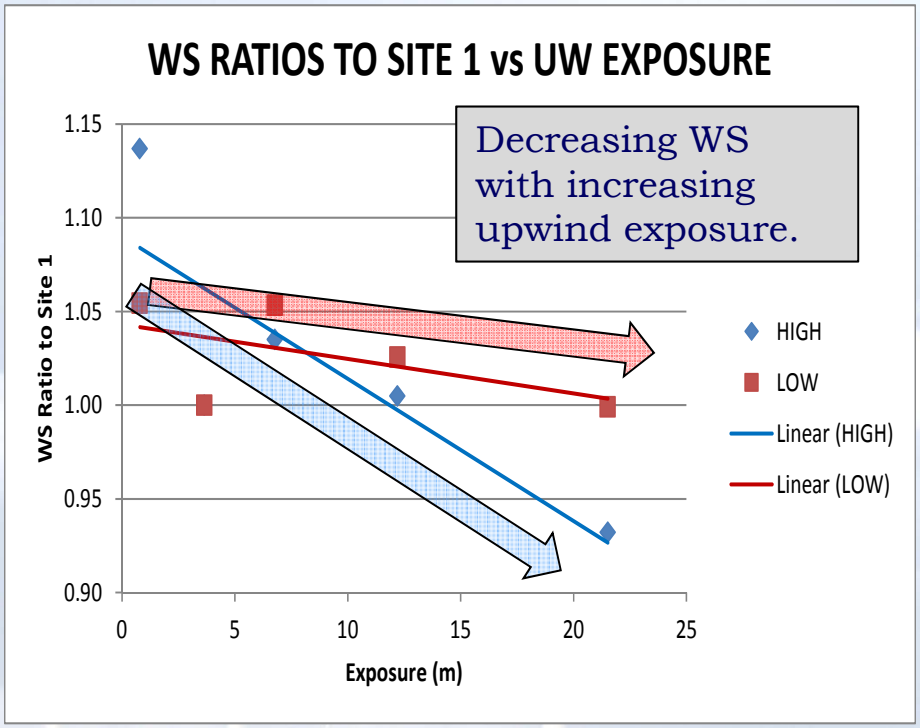


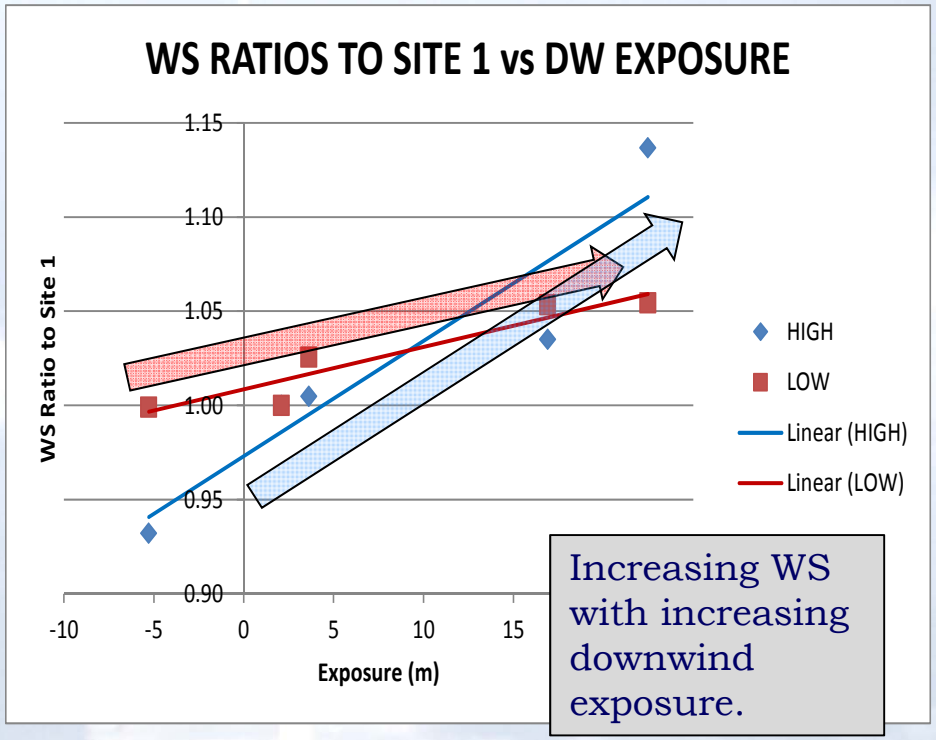
- Same type of relationship between WS and exposure for northerly and southerly WDs.
- **Relative WS can change with WD due to UW & DW terrain effects.**

WS Ratio Map – South WD



WS Ratios vs. Exposure by Stability: Hi α >= 0.20; Low α < 0.10 – North WD





- During northerly WD, higher sensitivity of WS to exposure during high atmospheric stability conditions.

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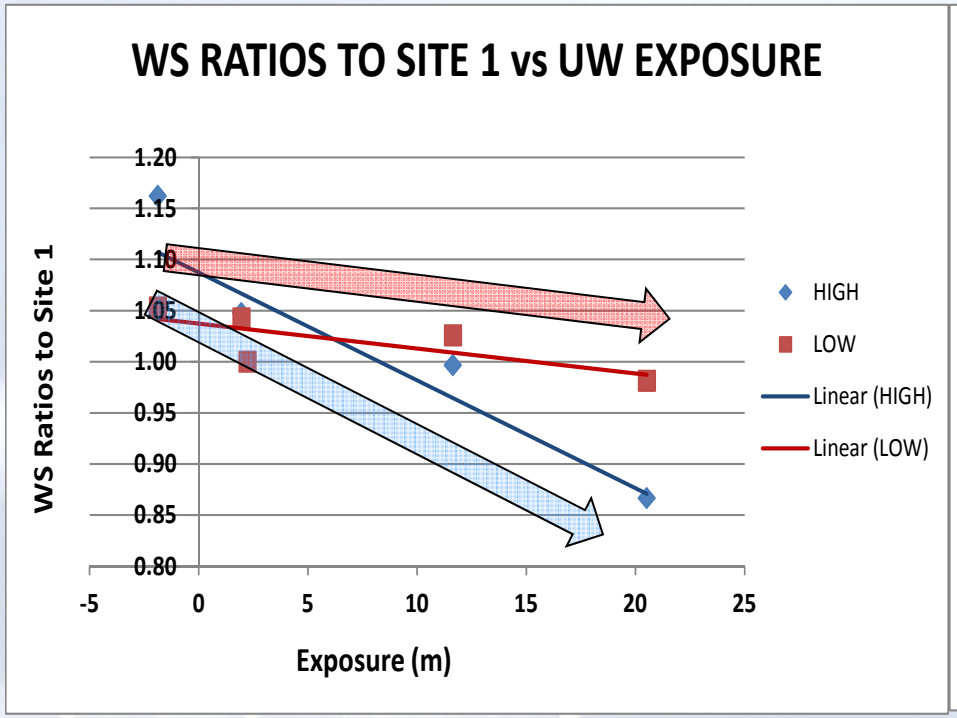
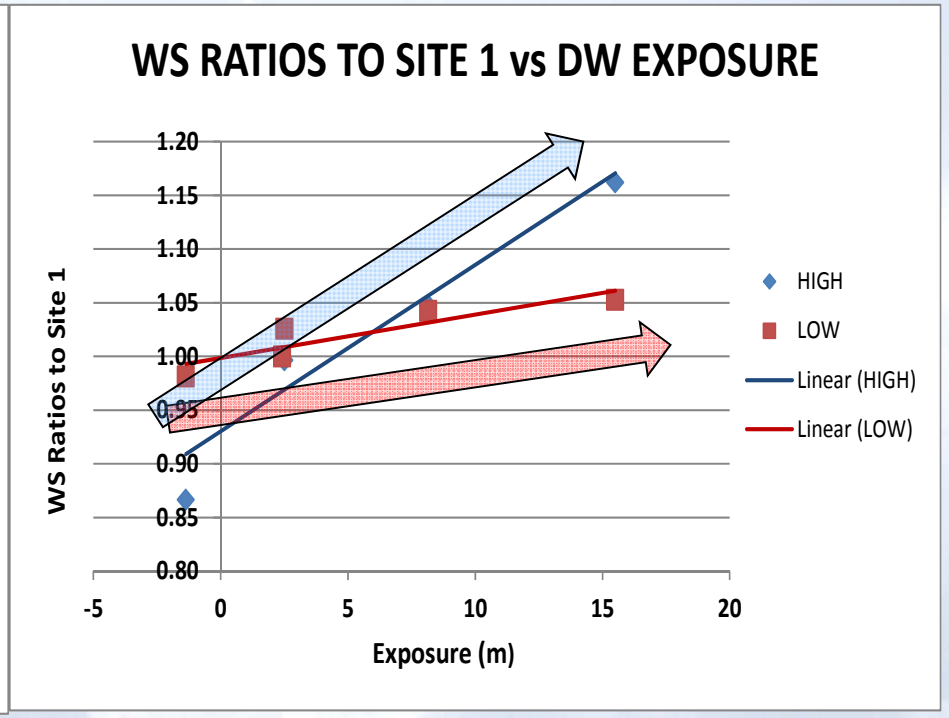
WS Ratios vs. Exposure by Stability: Hi α >= 0.20, Low α < 0.10 – South WD





- Similarly, during southerly WD, higher sensitivity of WS to exposure during high stability conditions.

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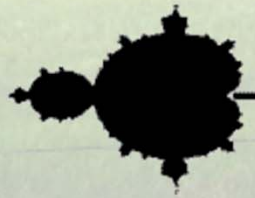
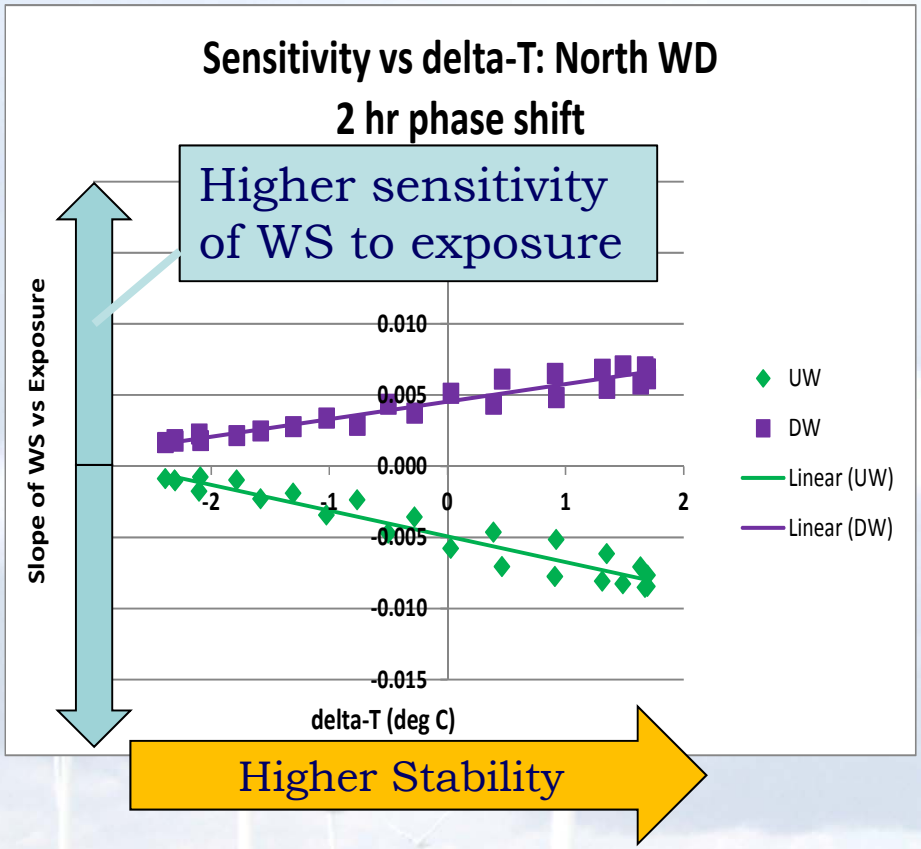
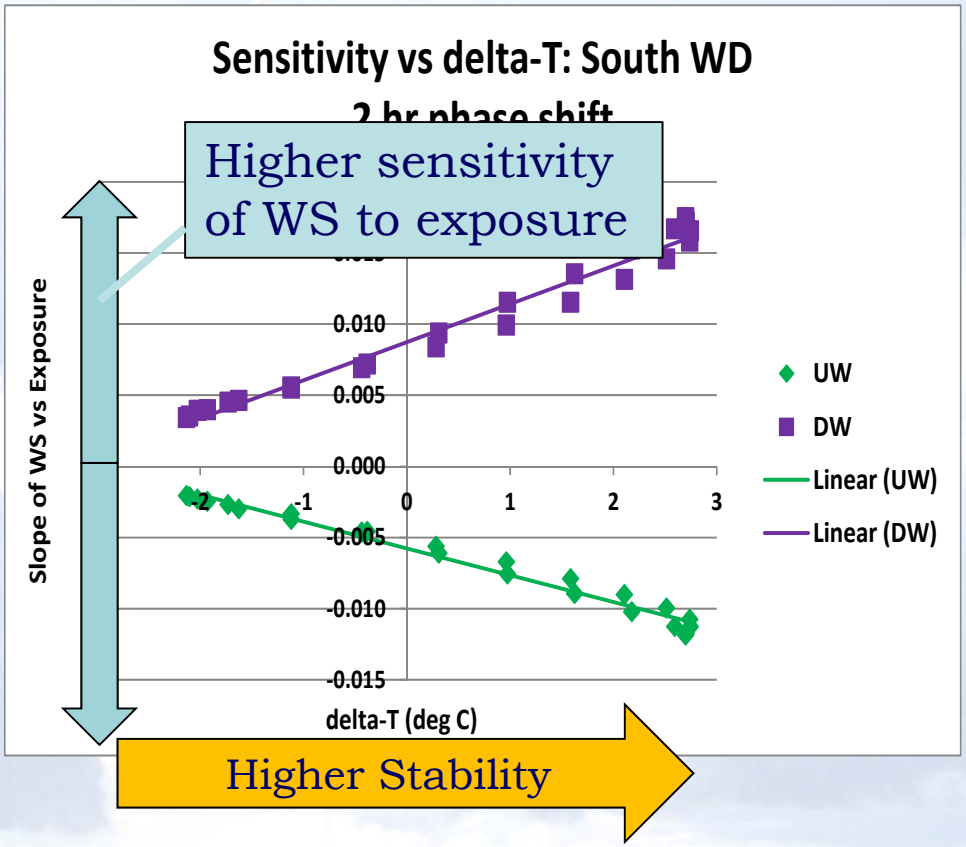
High Stability Enhances Terrain Effects

- Sensitivity of WS to terrain defined by slope of WS ratios vs. exposure
- Sensitivity to terrain increases as stability increases
- Stability defined by either ΔT or shear alpha exponent
- Analyze sensitivity vs. stability (ΔT) for all 24 diurnal WS ratios



Diurnal WS Sensitivity to Terrain





- During both WD, as stability increases, the sensitivity of WS to UW and DW exposure increases.

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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