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WRF Simulation of Dividing Streamlines at Granite Mountain

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Overview

- Motivation
- WRF Domain
- Dividing Streamline Theory
- Results from Simulations
- Summary and On Going Work
- Acknowledgements
- Questions

Motivation

- The goal of this work is to investigate synoptically driven stably stratified flows over Granite Mountain and the capability of WRF to capture streamlines, stream surfaces, and ultimately a dividing streamline.

Photo Credit: M.Y. Thompson

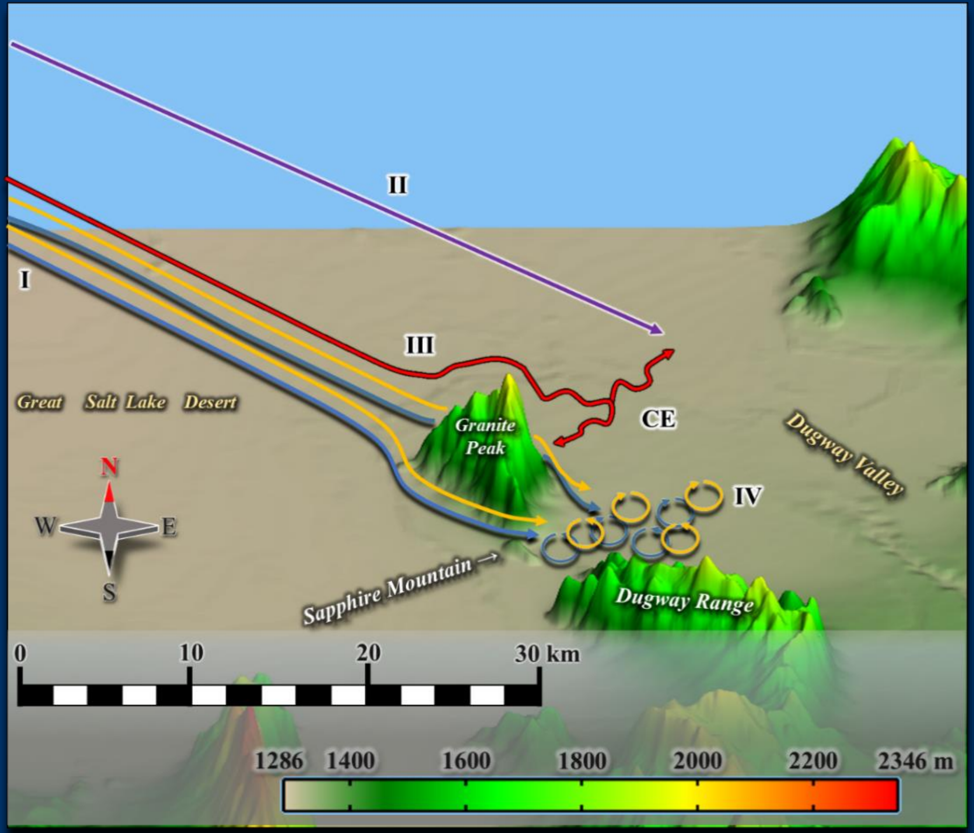
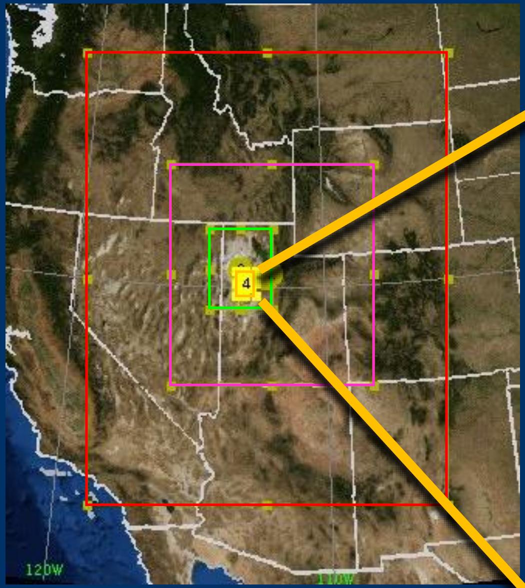


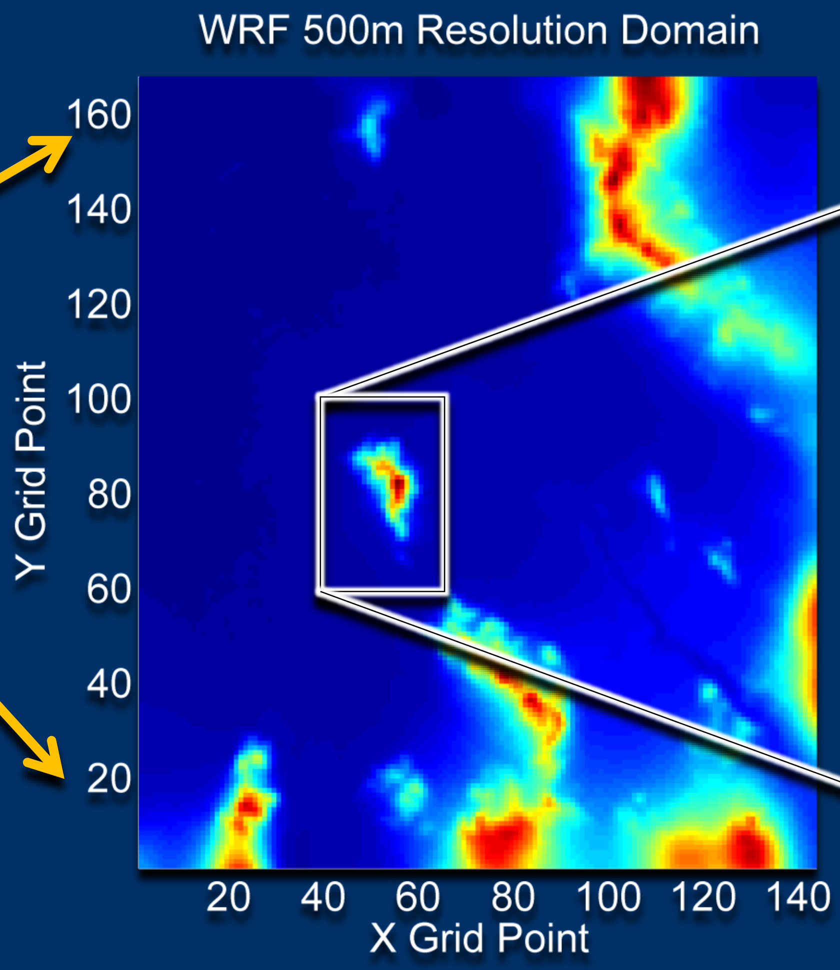
Figure 1 from Fernando et al. 2015 combined with flow features in Brighton 1978

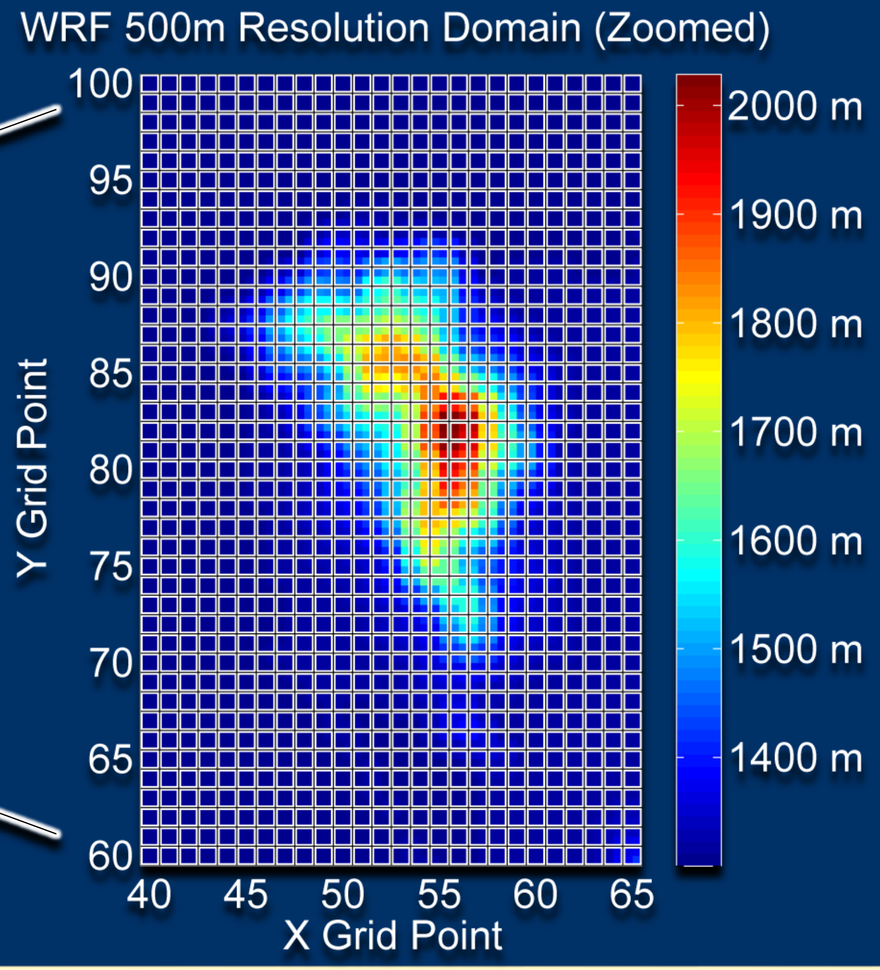
WRF Domain

Domains

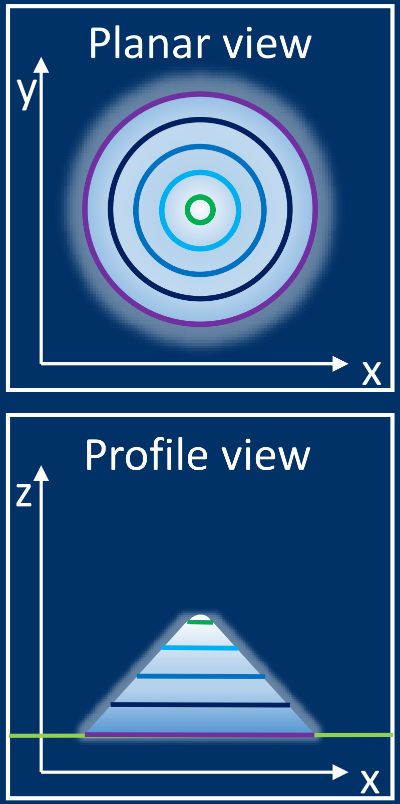


Modeling Domains:
Lambert projection
Utah (113°W, 40°N);
(32km, 8km, 2km, 500m);
Vertical levels: 50





Dividing Streamline



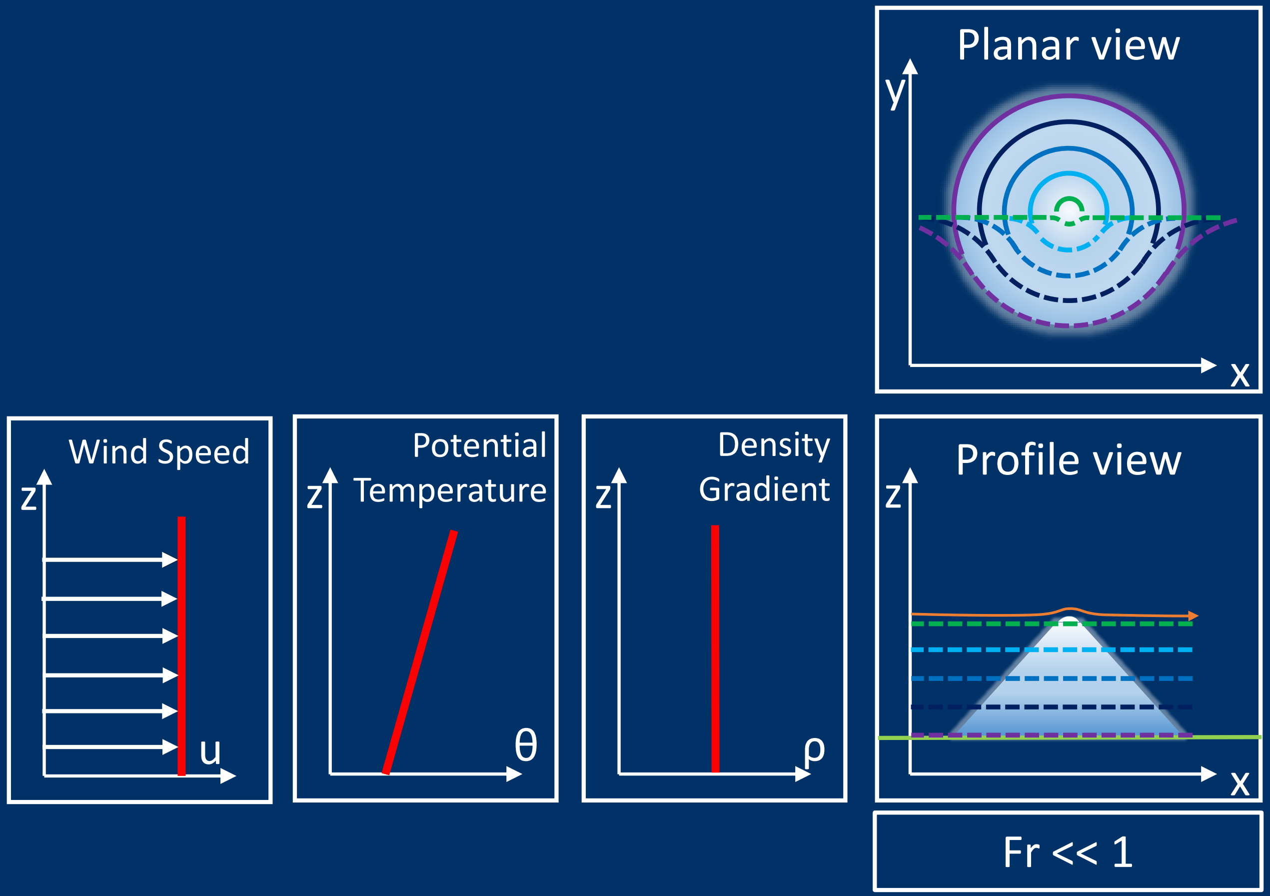
A simple idealized flow obstacle to represent the dividing streamline.

U/Nh and Brunt–Väisälä frequency

- Non-dimensional height parameter $= \dfrac{U}{N\,h}$
  - U = wind speed
  - h = mountain height
  - N = Brunt–Väisälä frequency

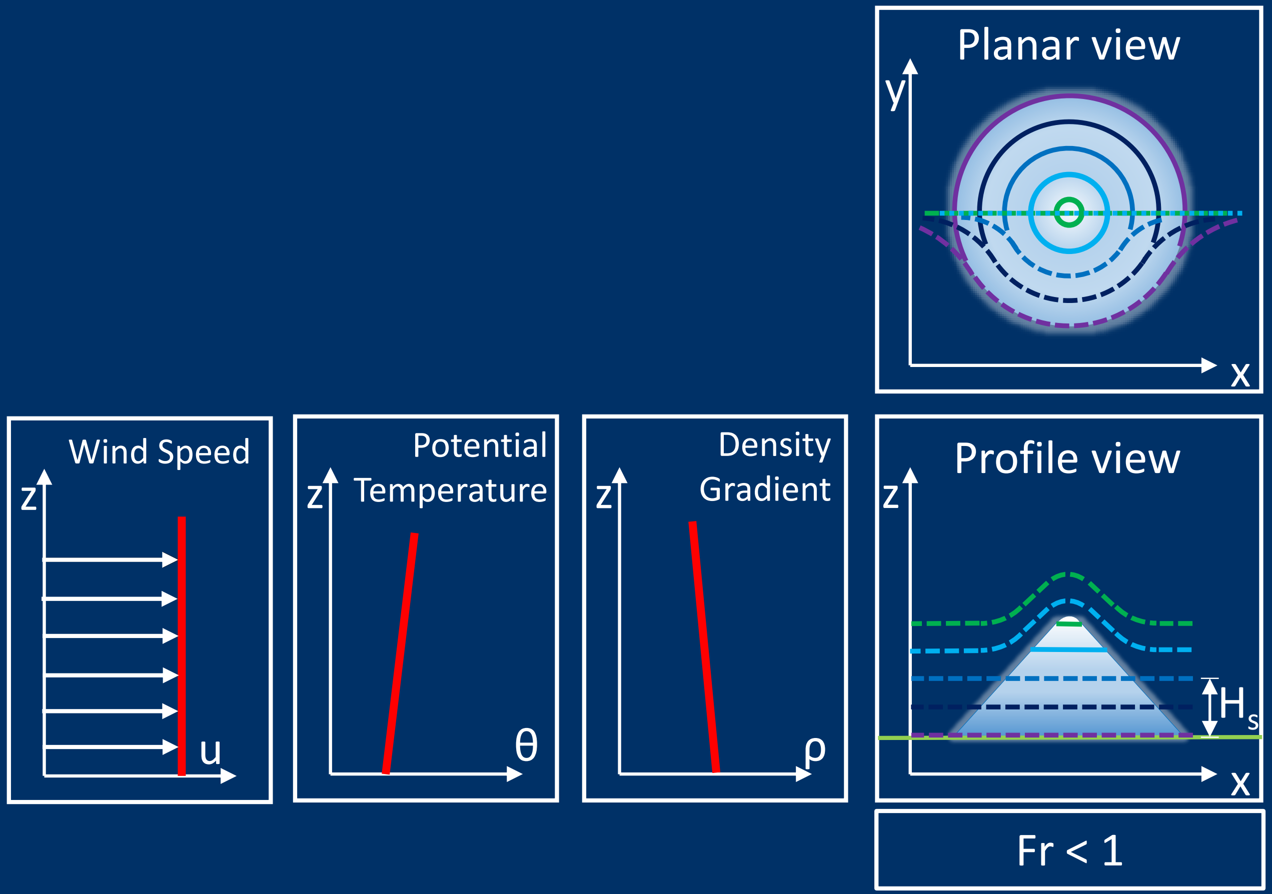
- Brunt–Väisälä frequency: $N = \sqrt{-\dfrac{g}{\rho_0}\dfrac{\partial\rho(z)}{\partial z}}$
  - g = *gravity*
  - ρ = density

U/Nh << 1



A simple idealized obstacle and flow to represent a dividing streamline in 3D

U/Nh ≈ 1



A simple idealized obstacle and flow to represent a dividing streamline in 3D

Sheppard's Equation

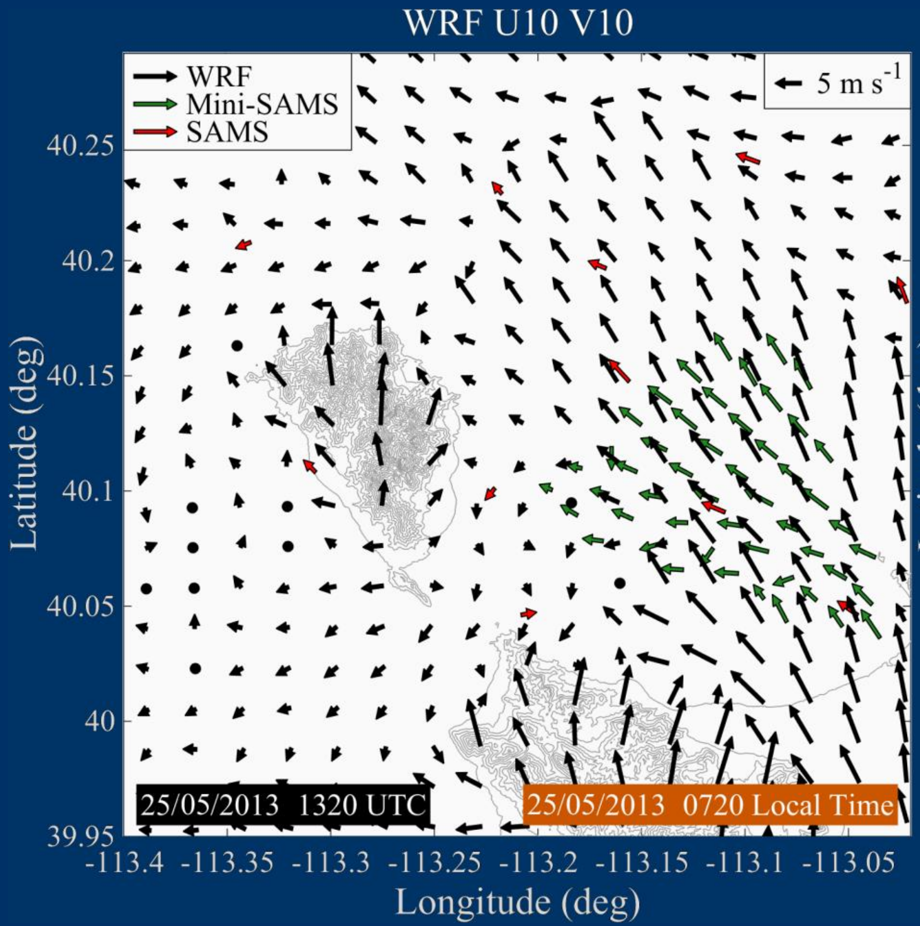
- $\frac{U_\infty^2}{2} = \int_{H_s}^{h} (h - z) N^2(z) dz$
  - h = height of terrain obstacle
  - H_s = height of the streamline
  - U_∞ = upstream velocity
  - ρ = density

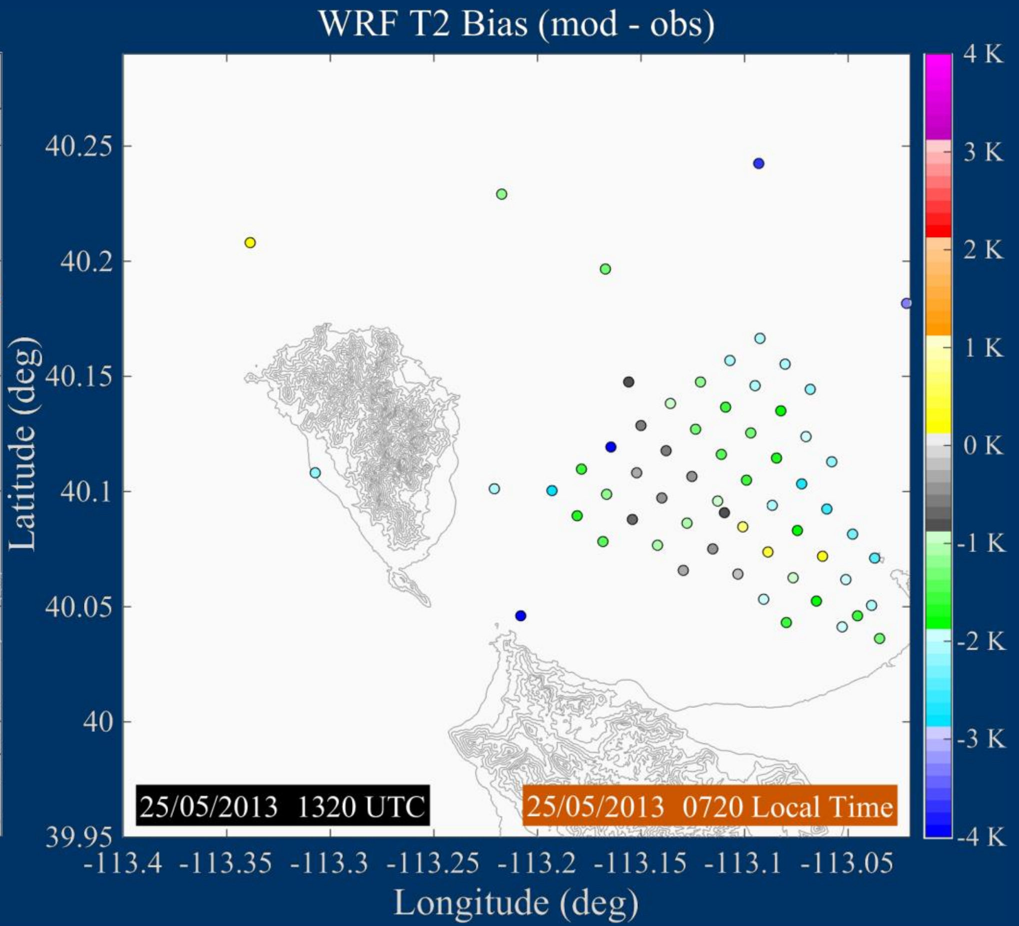
- **This can be simplified to find the height of the dividing streamline:**

  $H_s = h(1 - \frac{U}{Nh})$

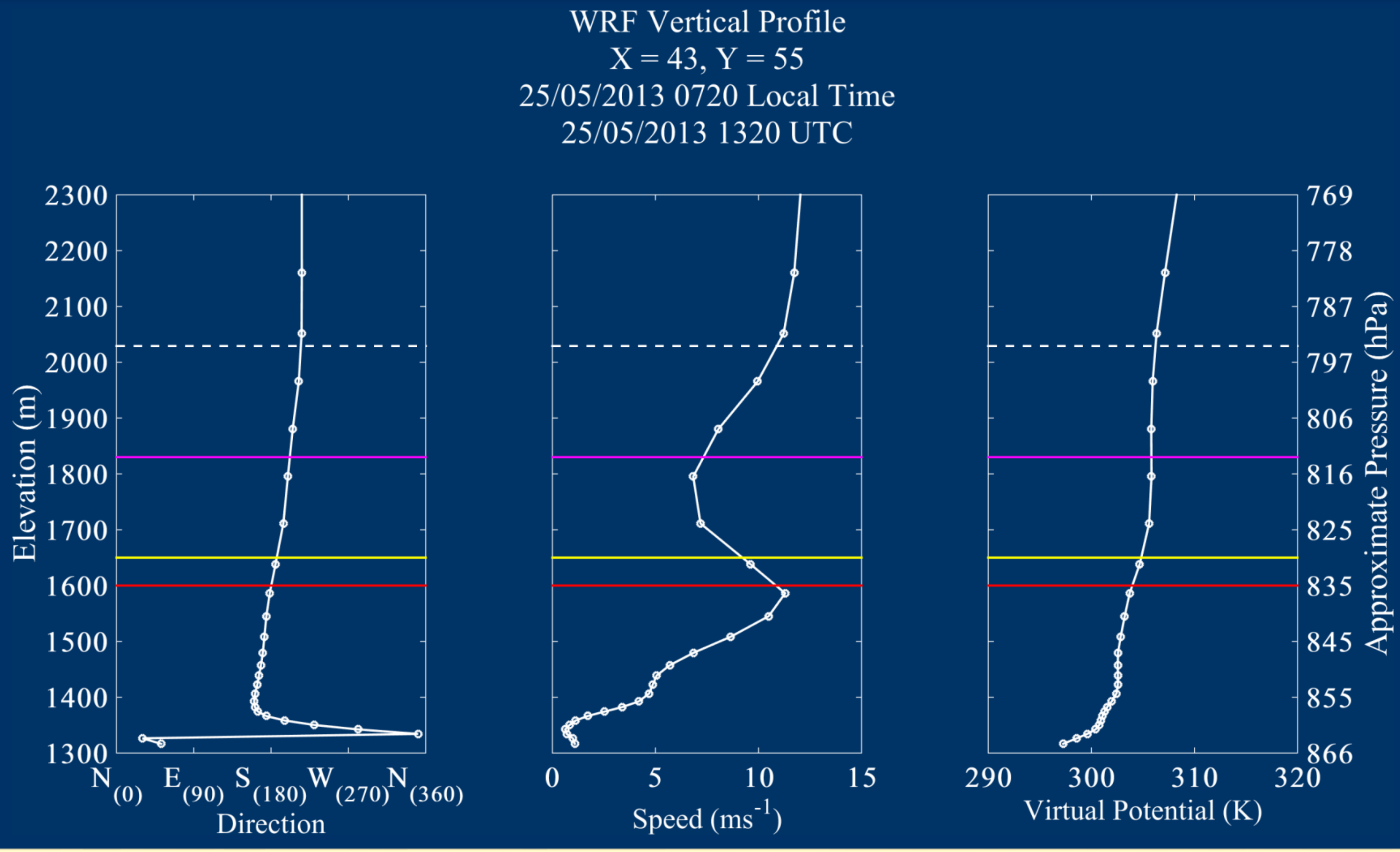
Leo et al. (2015)

Surface Observations Comparison with WRF

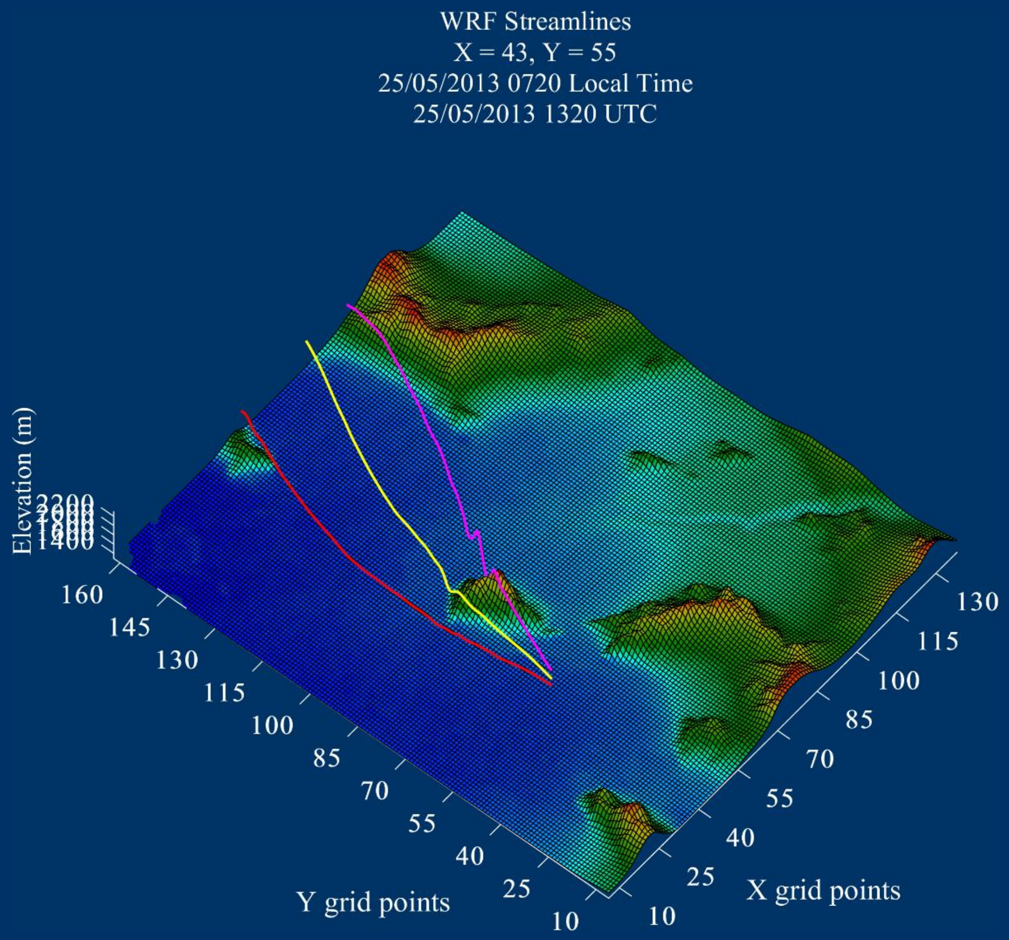




WRF Vertical Profile



Vertical Release of Streamlines

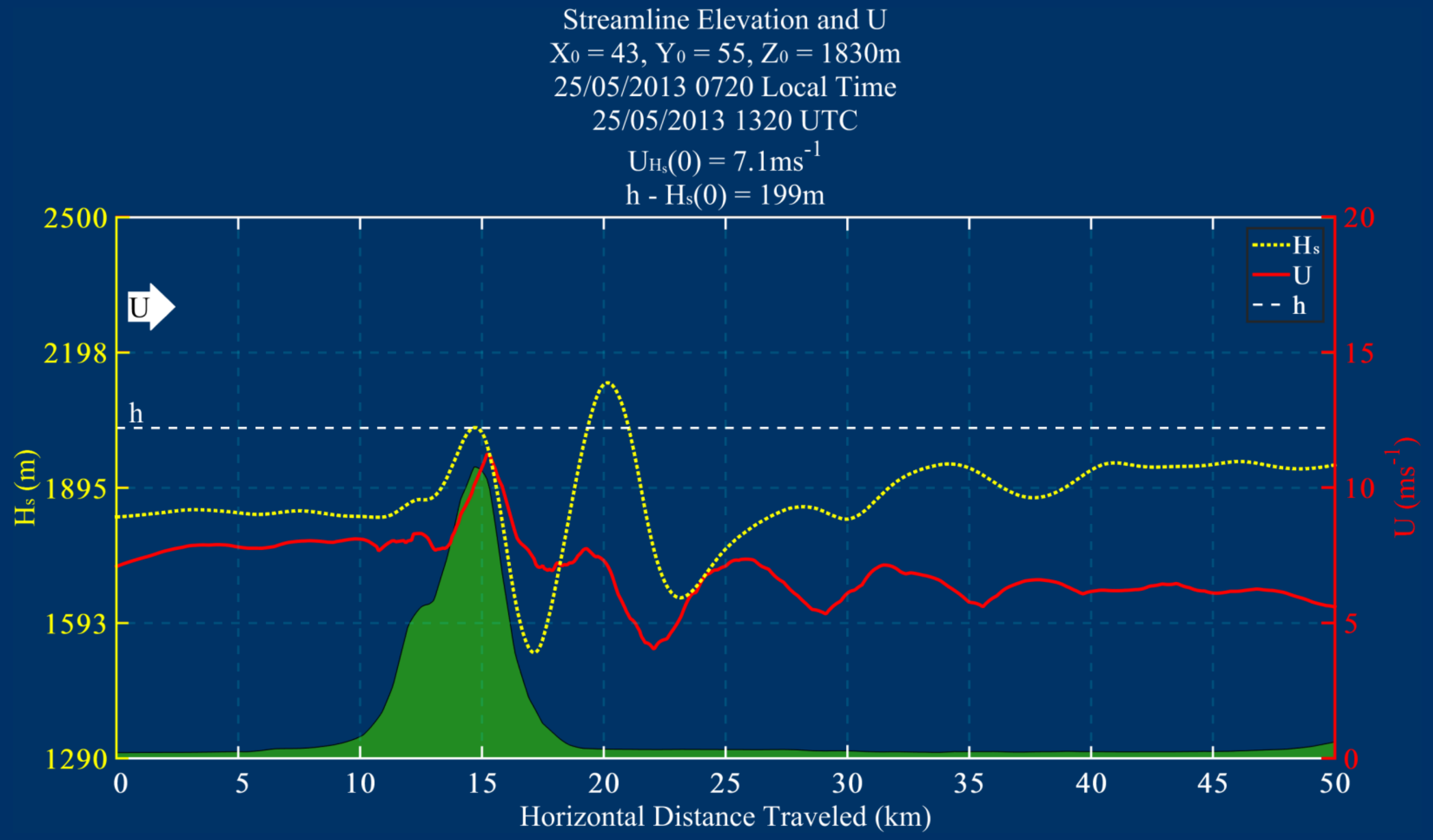


Simple Application of Sheppard's Equation

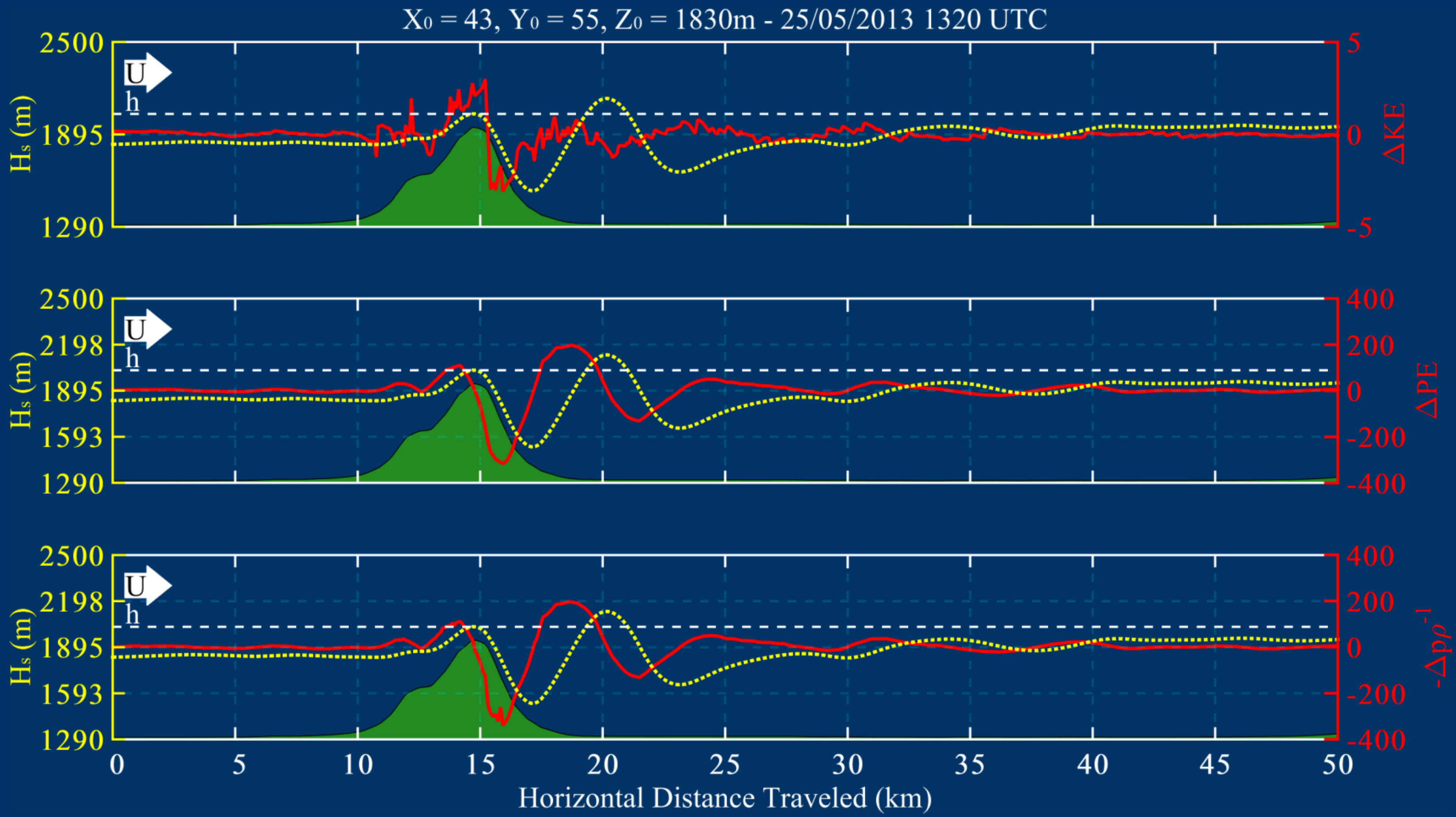
- $H_s = h(1 - \frac{U}{Nh})$
  - $\frac{U}{Nh} \approx 0.35$
  - $h = 720m\ (relative\ to\ the\ surrounding\ surface)$
- H_s = 468m (720m – 468m = 252m below the peak)
- Since the actual peak is 2029m above sea level the dividing streamline height should be equal to 1777m above sea level.
- The actual dividing streamline height is approximately 1830m (a difference of 53m)

Leo et al. (2015)

Speed Along a Streamline $H_s(0) = 1830\text{m}$



Energy Changes Along a Streamline



Equation of Energy Along a Streamline

- Equation of energy:

$$-\frac{\partial \boldsymbol{p}}{\rho} = \partial\left(\frac{1}{2}\boldsymbol{u}^2 + \boldsymbol{g}\boldsymbol{z}\right)$$

Sheppard (1956)

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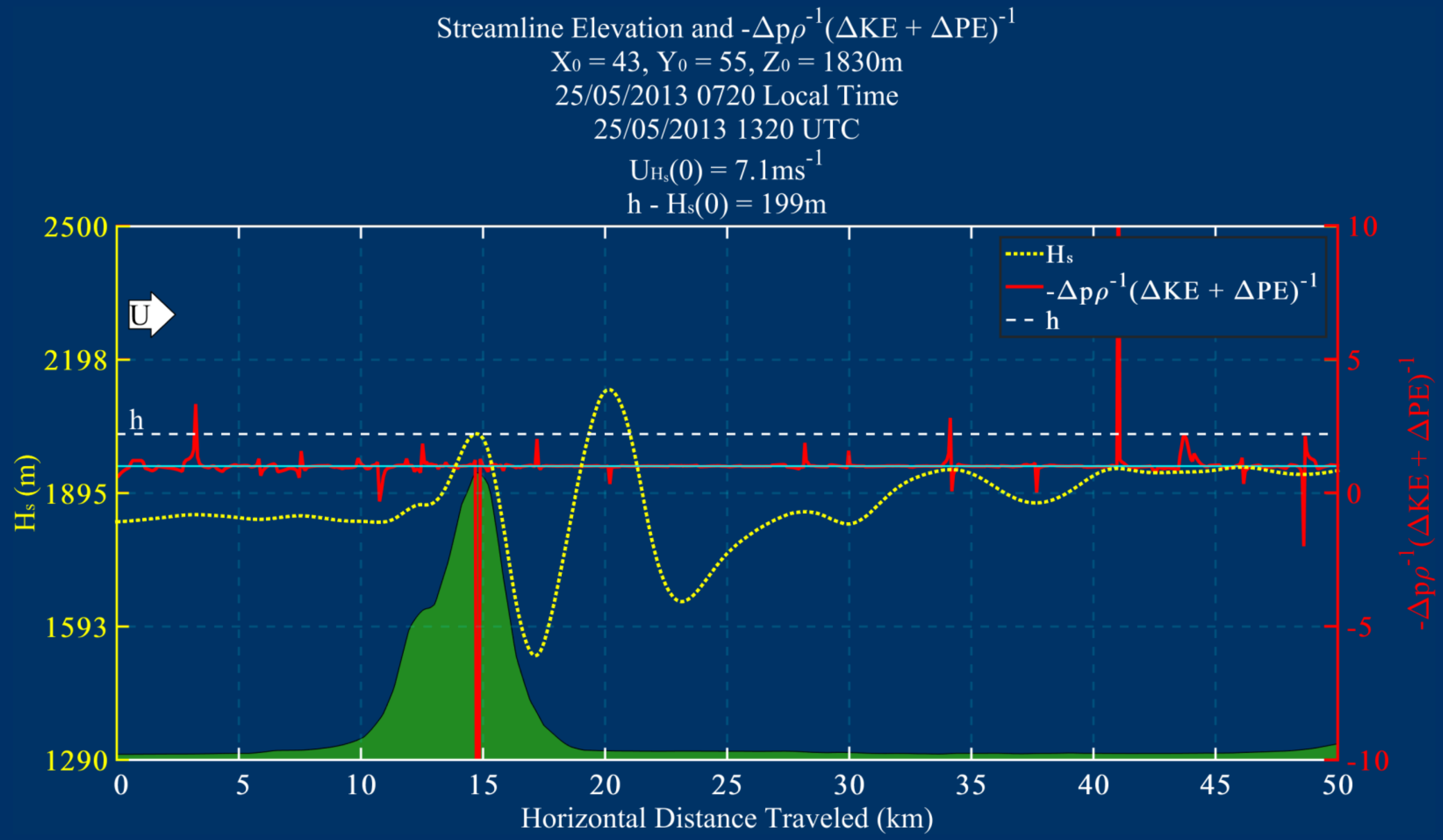
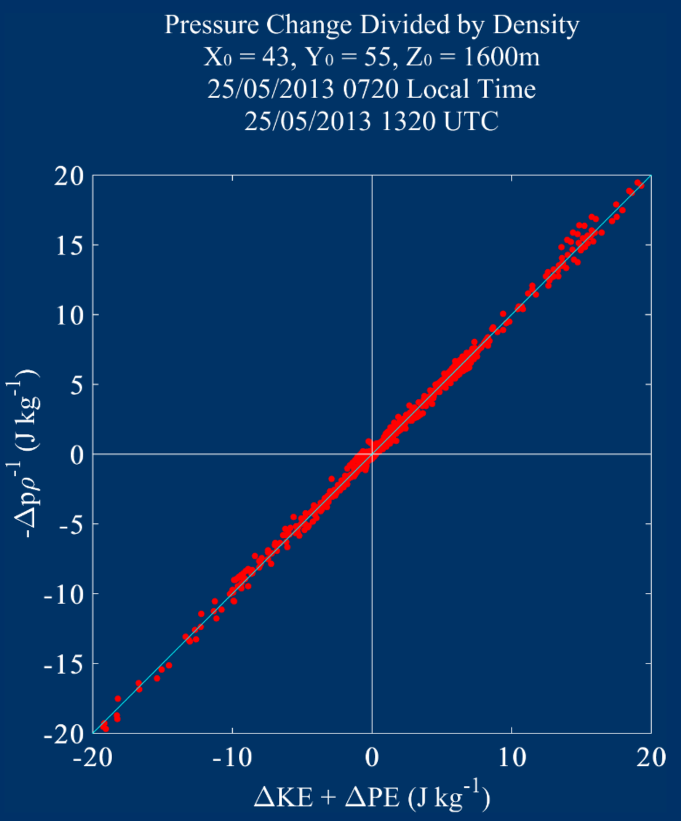
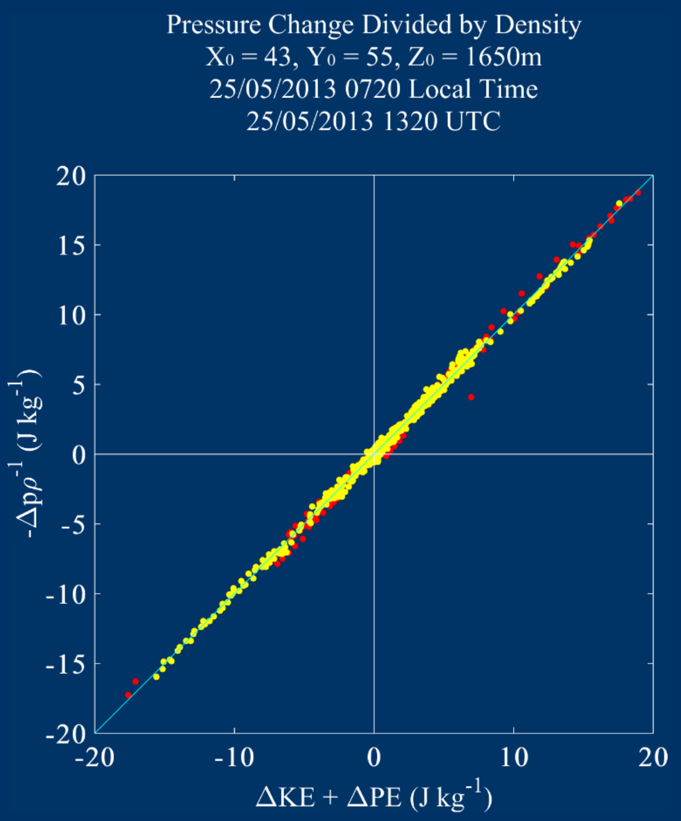
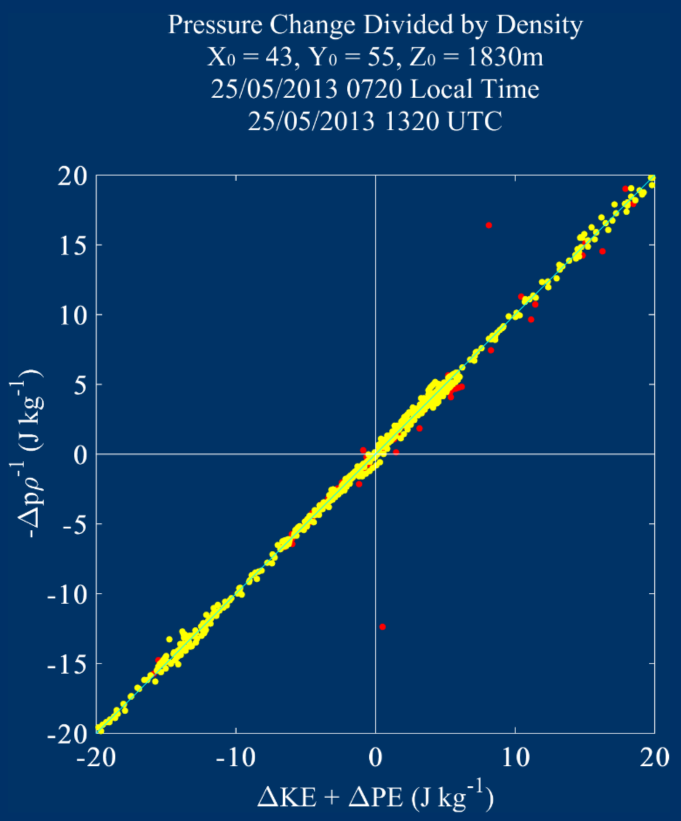
Energy Variations Along a Streamline



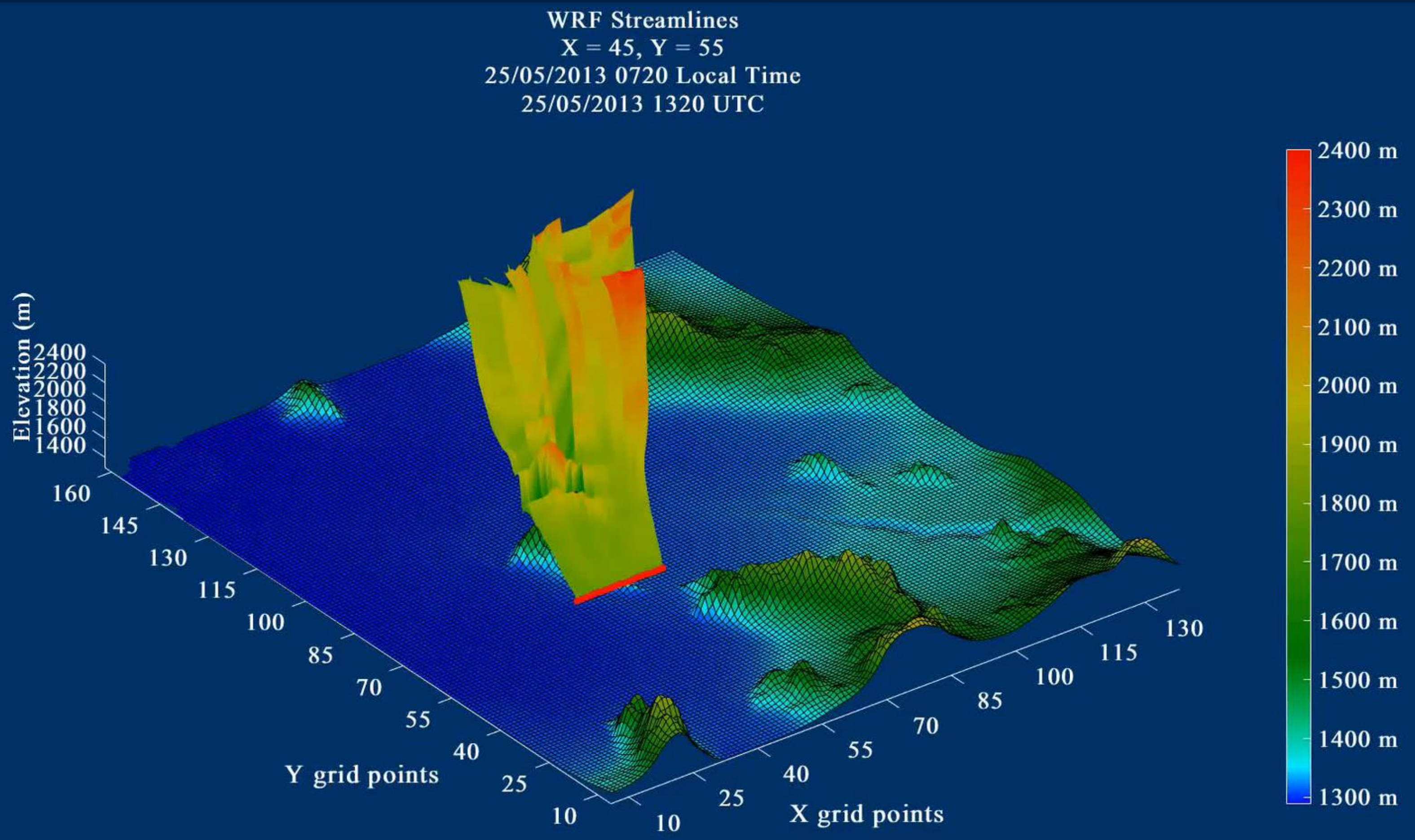
Energy Scatter Plots







Streamline Surface Released at $H_s(0) = 1830\text{m}$



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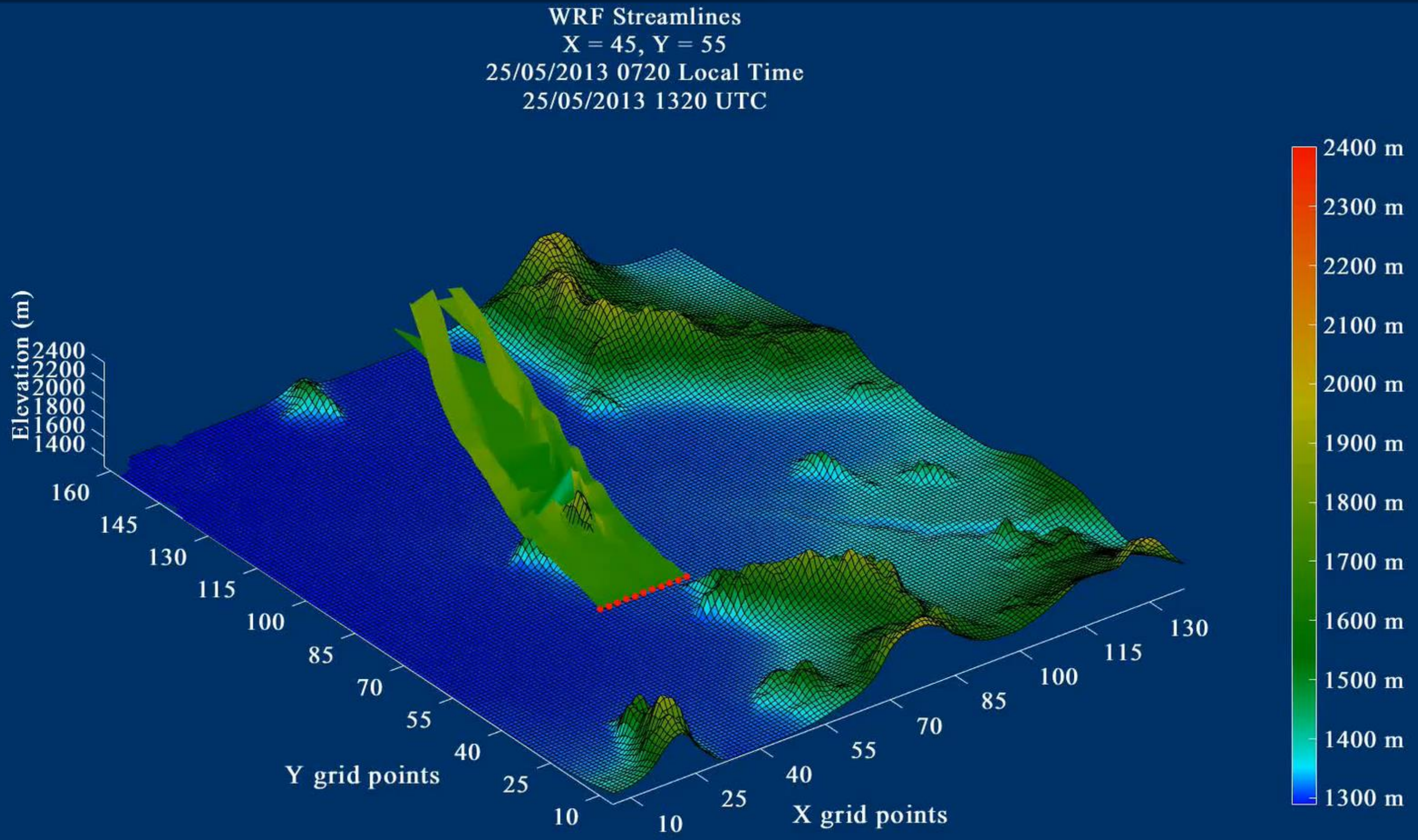
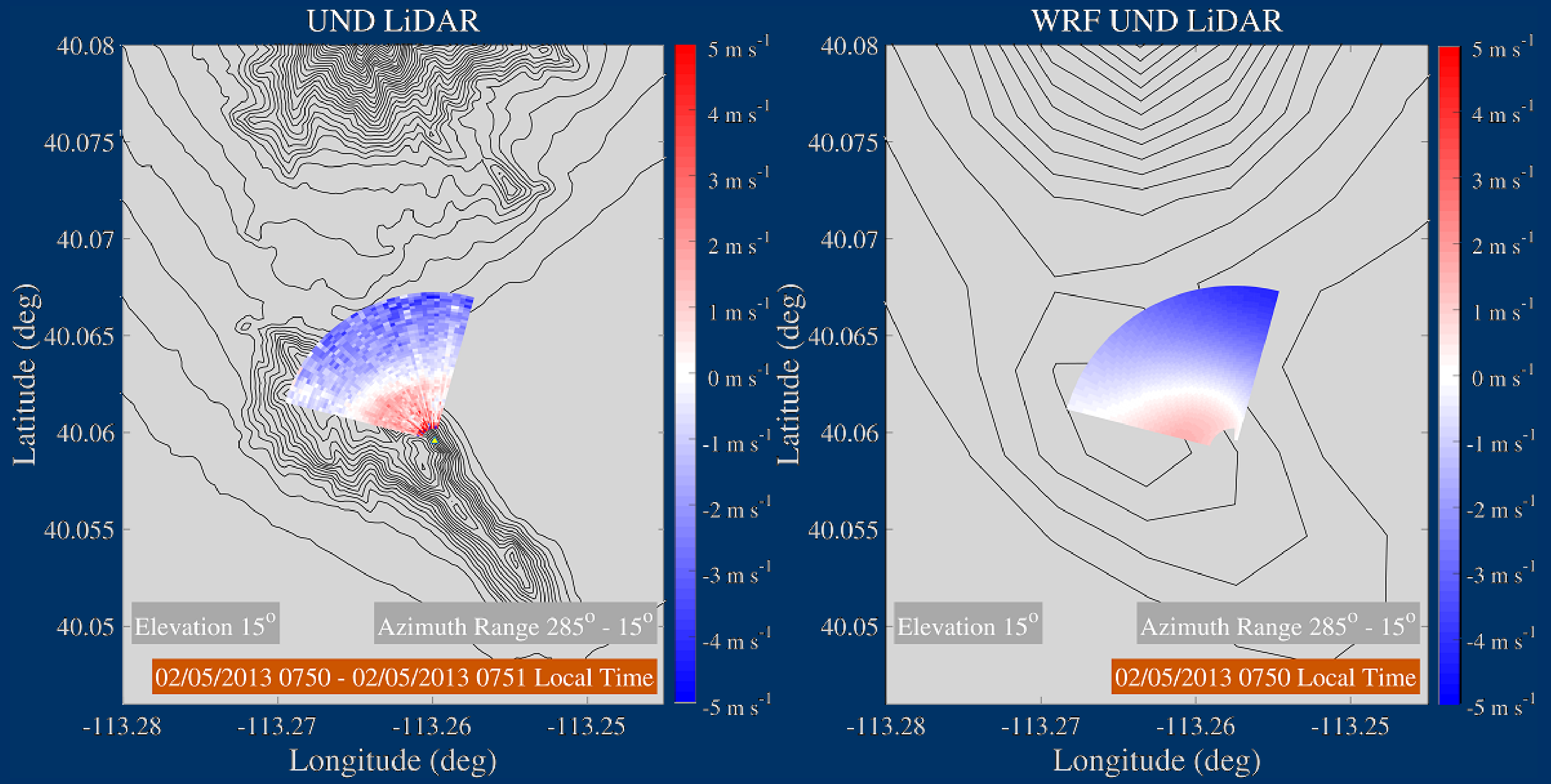
Streamline Surface Released at $H_s(0) = 1650\text{m}$



LiDAR Located on Sapphire Mountain

Photo Credit: Laura Leo

WRF Comparison with LiDAR



Summary and Future Work

- WRF is able to capture a dividing streamline
- The equation of energy in general applies along simulated streamlines
- Continue to investigate stream surfaces
- Further investigation of how properties change over a stream surface
- Understand the role of pressure perturbations on determining the height of the dividing stream line (or surface)
- Utilize the available LiDAR results to compare with WRF results

Acknowledgements

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Thank you!