Simulating Convective GWs forced by Radar-Based, Neural-Network-Predicted Diabatic Heating

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Motivation

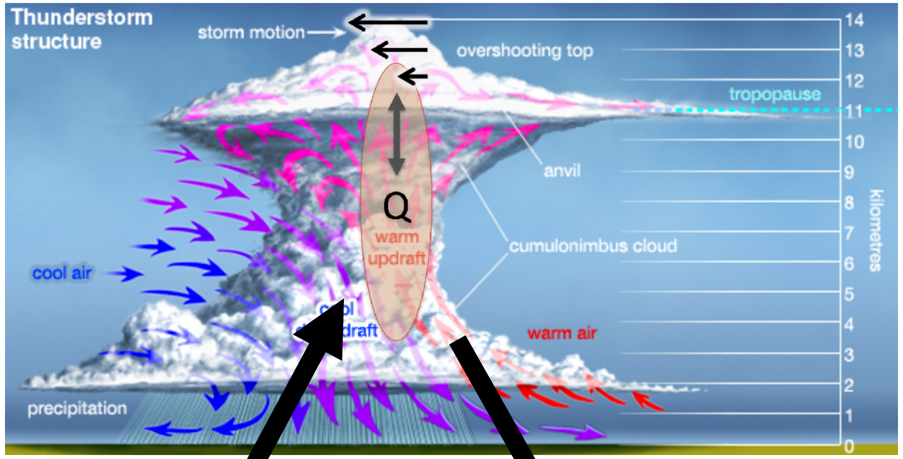
- Convective latent heating, Q, is a significant gravity wave (GW) source via diabatic and mechanical mechanisms
- NWP models cannot reproduce locations and timings of observed convective cells
  - **Prevents direct comparison between observations and models (numerical, parameterizations)**
- Methods to force **observed** convection in a model from weather radar exist (Stephan and Alexander 2015, Bramberger et al. 2020), but are idealized, not general, and do not make use of additional radar observables

Objective:

- Use machine learning to predict convective Q, force models to study the generated GWs and ultimately improve parameterizations

The Method

1. **Train NN** to WRF-simulated Predict Q(z) from simulated radar fields

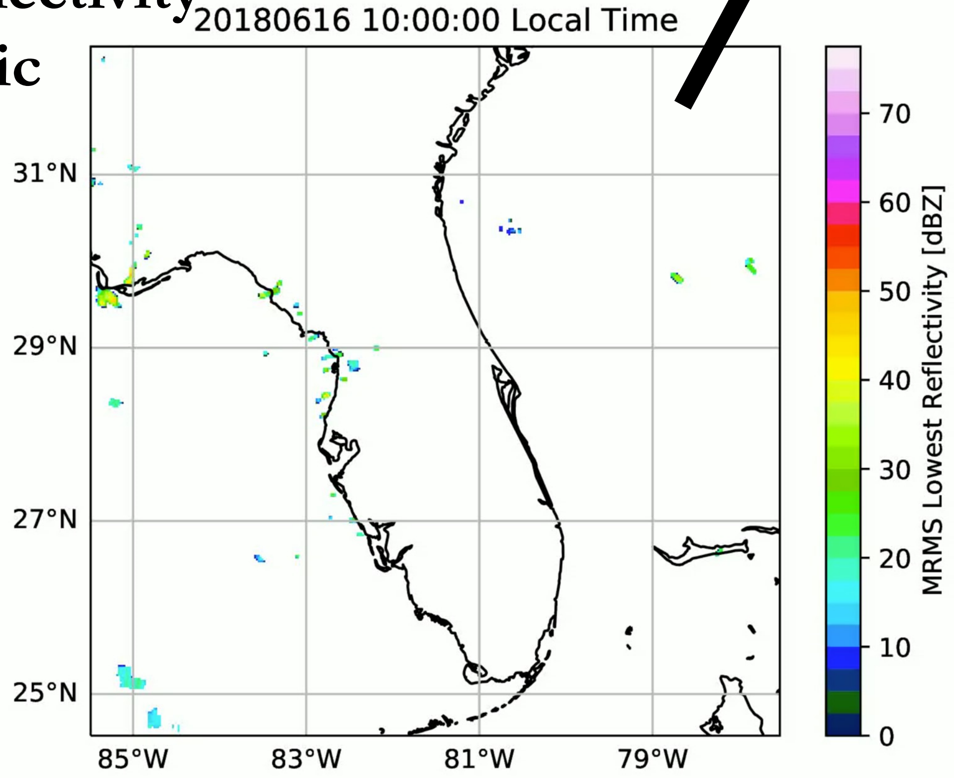


Adapted from Encyclopedia Brittanica 2011.

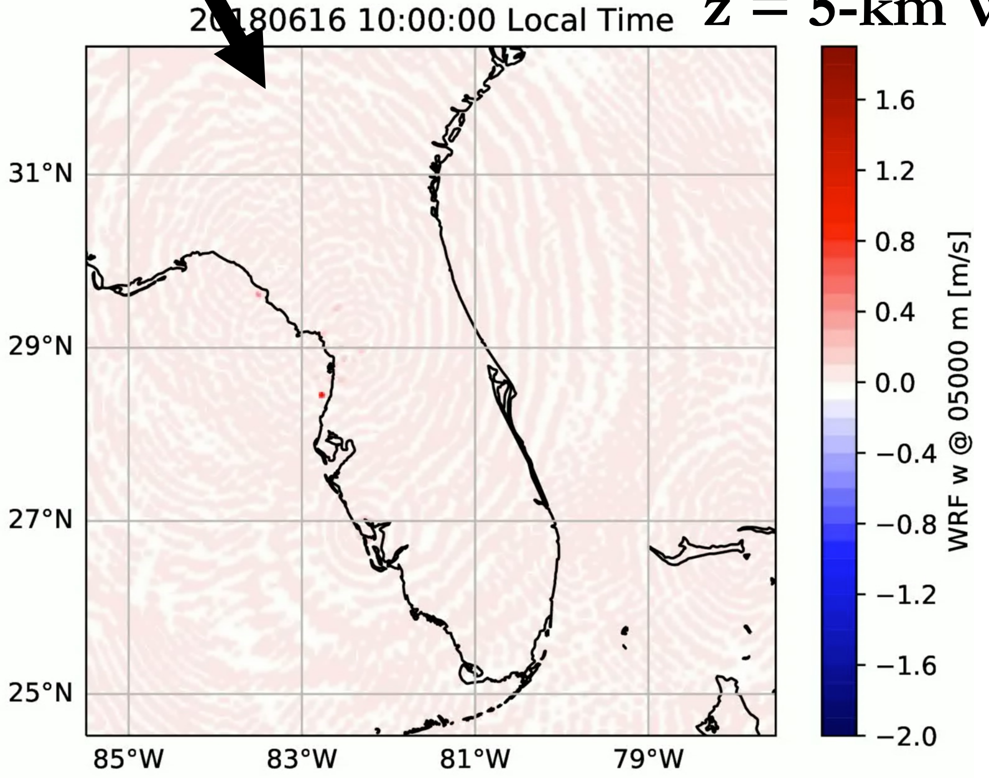
2. **Predict Q(z)** from **observed** radar fields

3. **Force idealized WRF** with Q(z)

MRMS Reflectivity Mosaic



z = 5-km WRF w



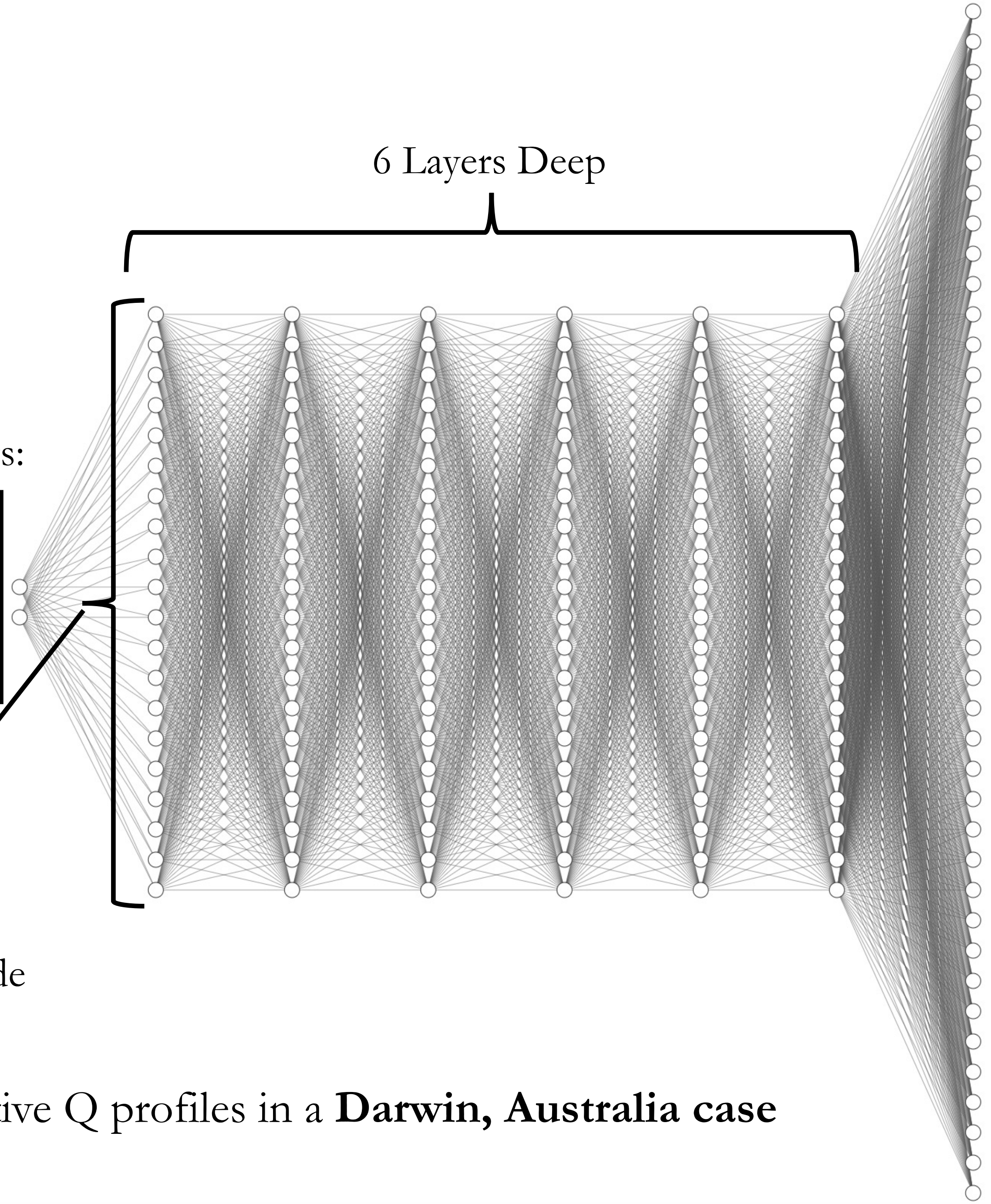
The NN

6 Layers Deep

5 Input Parameters:

$$\begin{bmatrix} RR \\ Z(T = 0C) \\ Z(T = -10C) \\ Z(T = -20C) \\ ET \end{bmatrix}$$

(Z = reflectivity)



40 Neurons Wide

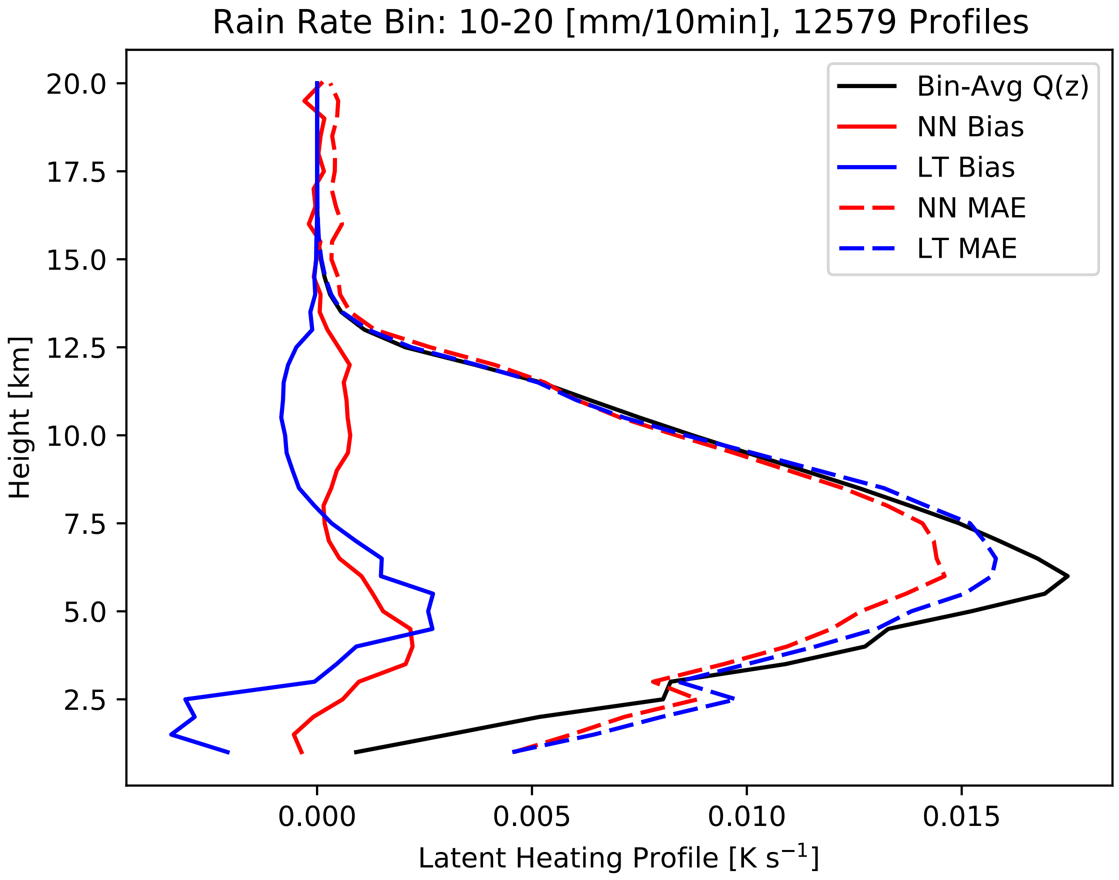
Output Q Profile:

$$\begin{bmatrix} Q(z = 1.50\ km) \\ Q(z = 1.75\ km) \\ Q(z = 2.00\ km) \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ Q(z = 20\ km) \end{bmatrix}$$

- Trained on WRF convective Q profiles in a **Darwin, Australia case**

Evaluation of Latent Heating Predictions

- NN performance marginally better/comparable to the composited lookup-table method of Bramberger et al. (2021)
- For both methods, errors are O(100%) on average…
  - Still, this method does appear to force waves similar to those observed (Stephan et al. 2015, Bramberger et al. 2021)



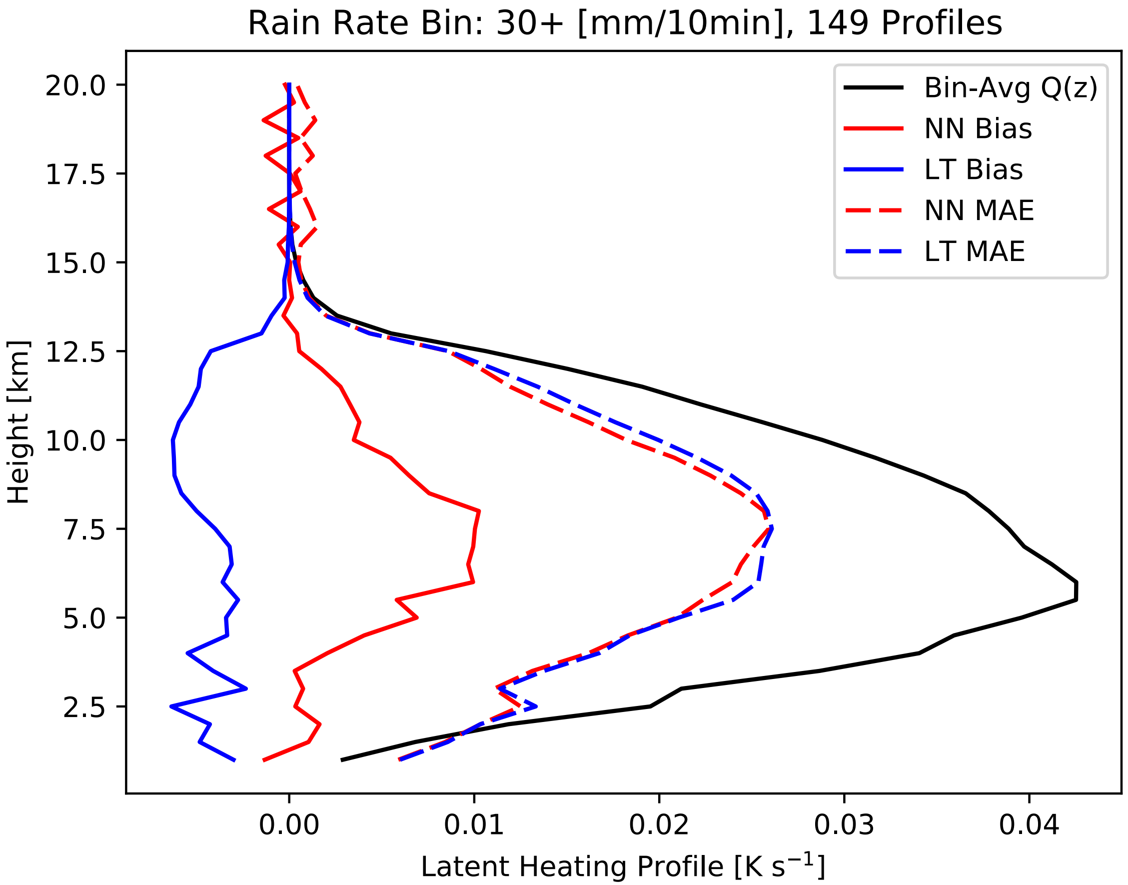
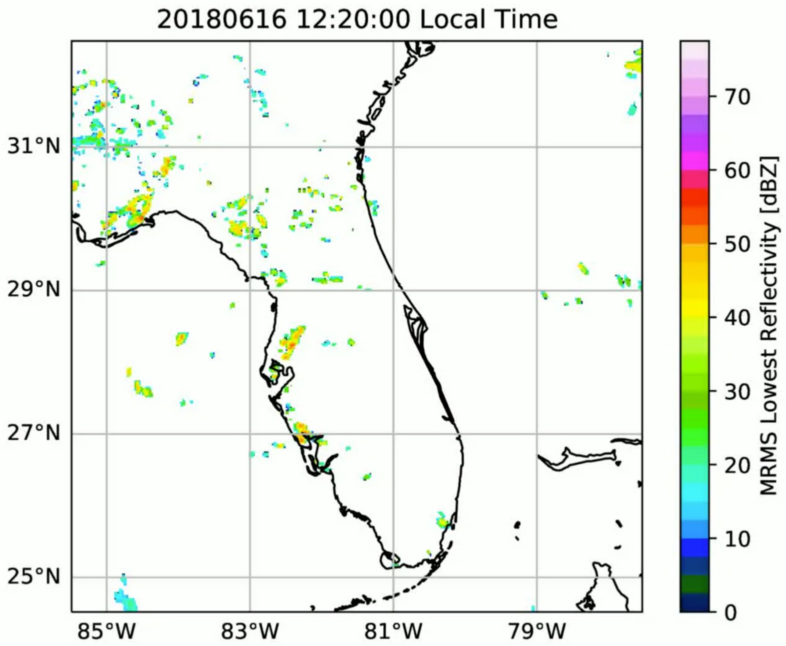
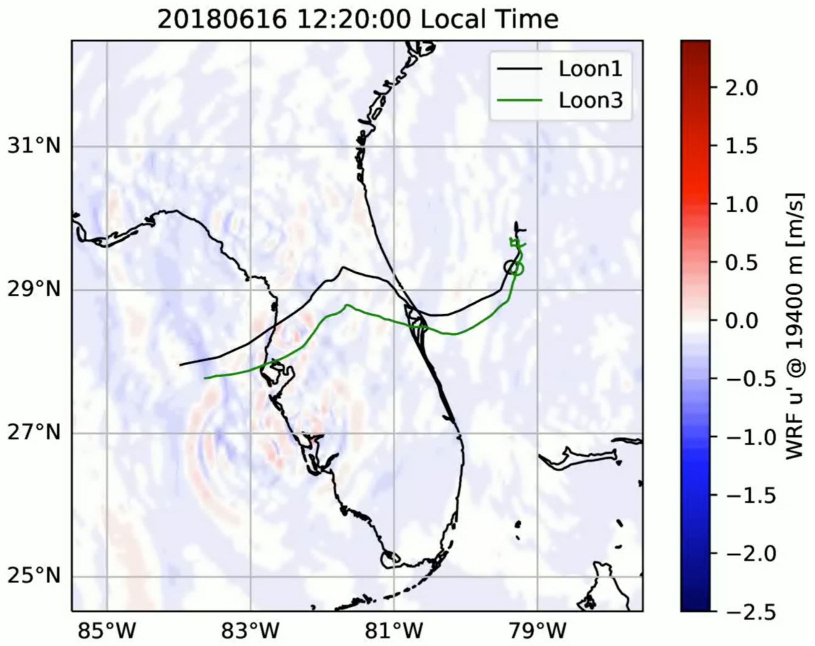


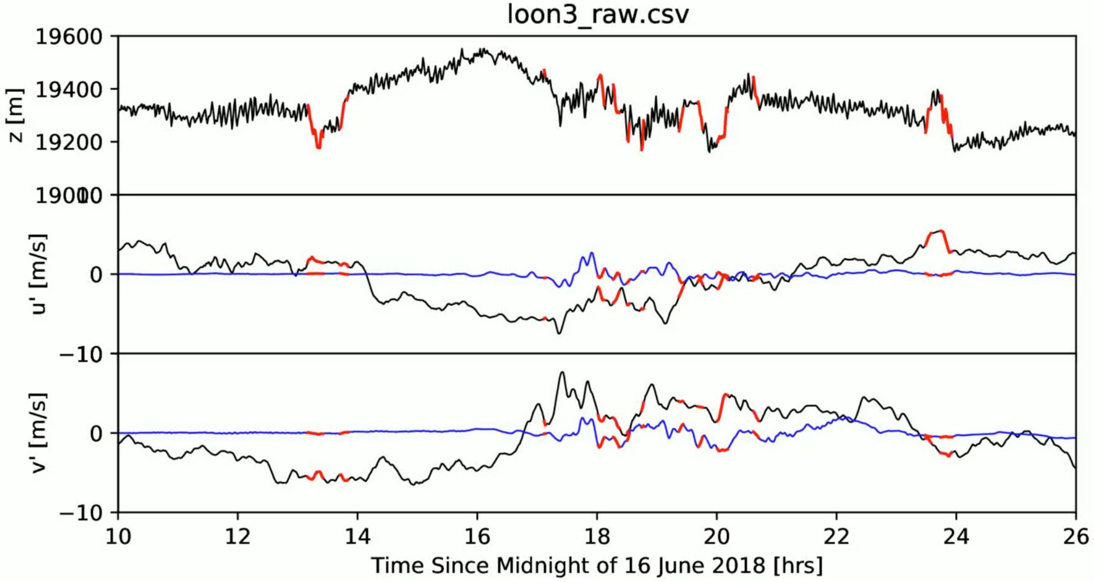
Figure: Average Q(z), Bias, and Mean-Absolute Error (MAE) for the NN, Lookup Table (LT) for two rain-rate bins

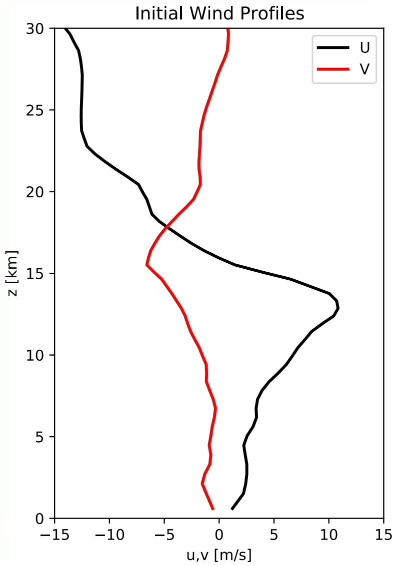
Are Loon-Observed CGWs Reproduced?

- Kind of…
- Timing of arrival of convective GWs looks correct
- Phases do not match, amplitude too low
- Why?
    - Trained on a tropical case, not applicable for a sub-tropical case?
    - NN just not good for this use case? (Does the Bramberger lookup table do better?)









Preliminary Summary

- A NN can predict convective latent heating at least as well as conventional methods
- The Darwin-trained NN can still reproduce Florida convective GWs in ≈correct place, time for comparison with super-pressure balloons

Research questions to be answered:

- How does the Bramberger lookup table method compare to the NN method?
- Can spatial, convolutional NNs better handle spatial mismatching of the radar observations at different levels and increase performance?
- How generally can a NN trained on a single case be? Performance increased with more training data (e.g. a model run over Florida)?