Exploring a Dynamic Weighting Method to Improve the Accuracy of AI models for Atmospheric Profile Retrieval

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Objectives

- To improve the accuracy of predictions on atmosphere profiles using:
  - Residual Networks
  - Multi-output attention
  - Custom Weighted MSE Loss
- Show results and depict improvement between the current model and a basic model
- Compare current model with NOAA MiRS data product

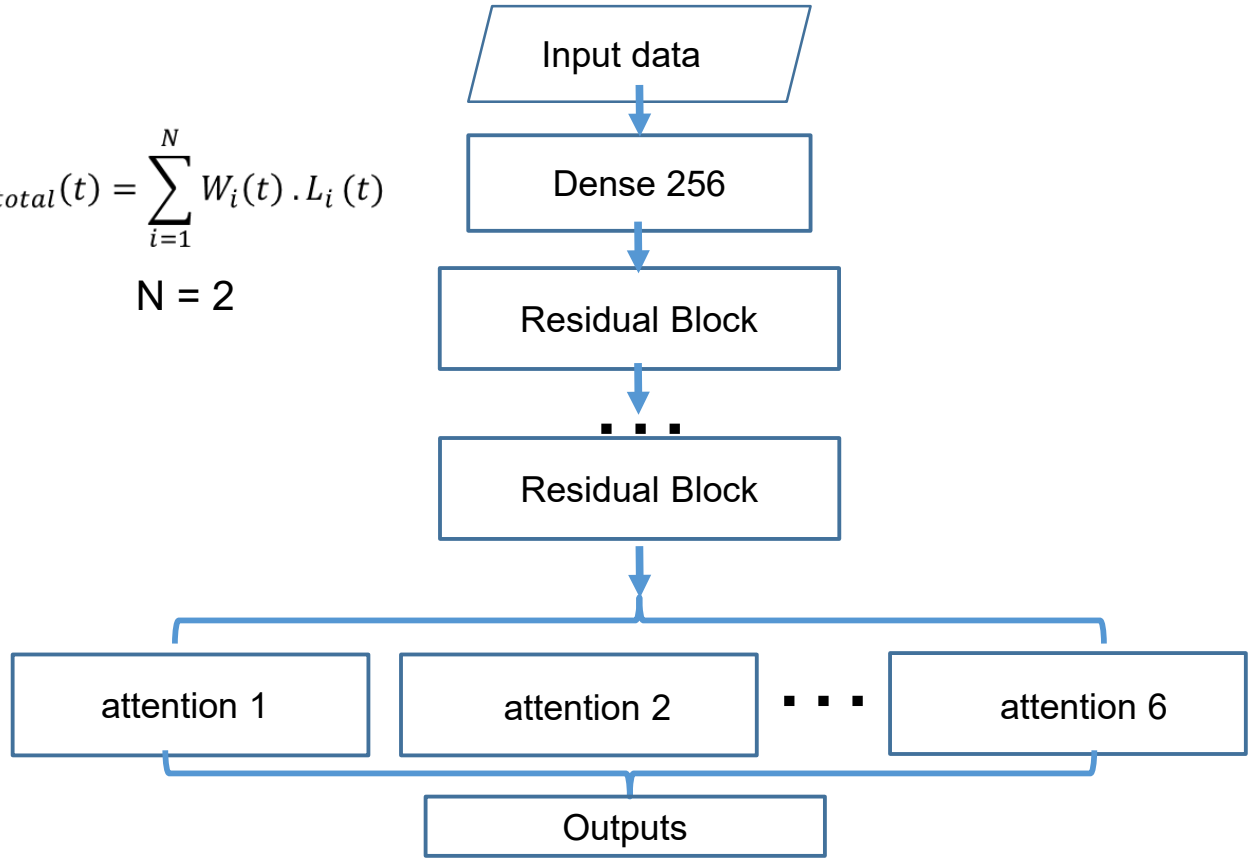
Data Used

- Inputs: ATMS SDR and GEO fields:
  - Sensor Zenith Angle, Surface Pressure, ATMS BTs, latitude, and longitude
- Output labels: ECMWF fields collocated with ATMS SDR data at the pixel level
- Output: 91-layer temperature profile and 91-layer water vapor profile
- Data covers 2019 to 2020, one day per month, separated to training, test, and validations sets in a 8:1:1 ratio

Outline of Proposed Model

$$L_{total}(t) = \sum_{i=1}^{N} W_i(t) \, . \, L_i(t)$$

N = 2



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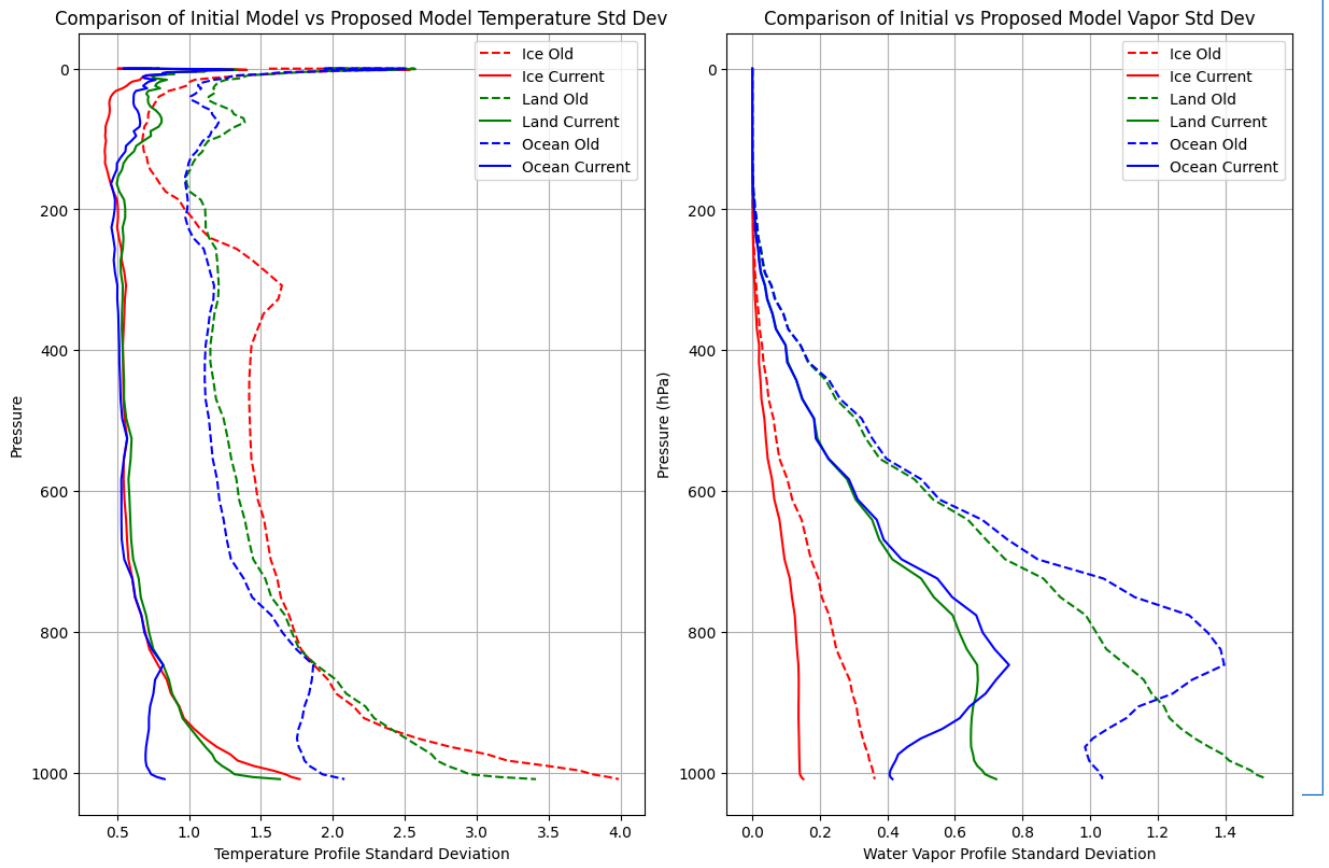
Model Architecture

- The initial model for comparison is a simple 4-layer DNN Model that utilizes:
  - Batch Normalization
  - Dropout
  - LeakyReLU
- The proposed model utilizes these function as well as:
  - Residual Network
    - Adds shortcut connections that bypass one or more layers, allowing gradients to flow directly and enabling effective training of very deep networks.
  - Custom Weighted MSE
    - Automatically adjusts the loss weights of both the temperature and water vapor profile so that they converge at similar rates during training
  - Task Specific Output Heads
    - Splits outputs into Temperature and Water Vapor; further splits to 6-attentions to allow for more focused training in high error regions

Comparisons of Initial v.s. Proposed Model



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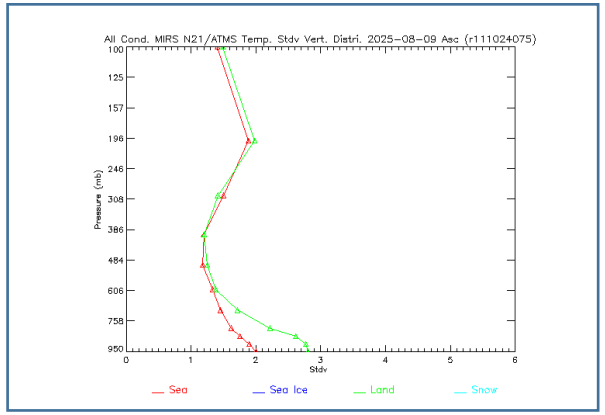
Temperature Profile Results

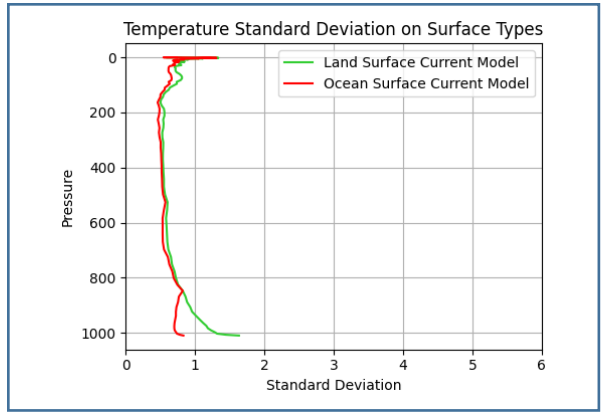
- Since our model inputs and outputs are similar to the NOAA MiRS product (www.star.nesdis.noaa.gov/mirs/geonwp.php), we can roughly compare our model predicted T. and WV profiles with the MiRS retrieval results.

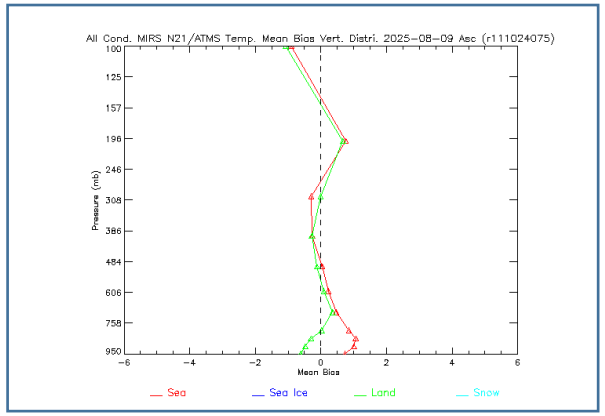
- Compared to the NOAA MIRs operational model we make significant improvements
  - For temperature standard deviation, our model stays below 1 for most altitudes, while the NOAA MiRs model always has Std Dev. >1
  - Our model stays noticeably closer to 0 and contains less divergence from 0 in bias
  - Our model predicts pressure levels up to pressures of 0 hPa while MiRs is limited to 100 hPa

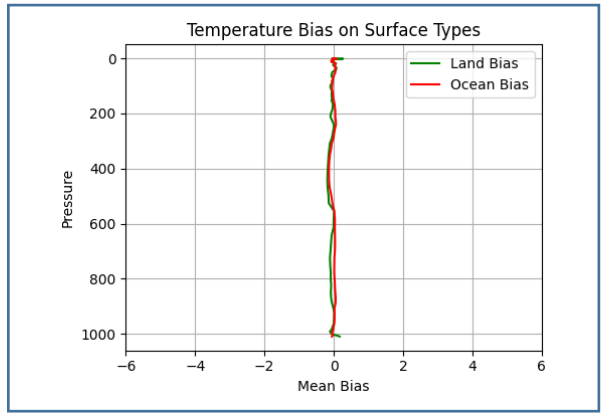
- However, the evaluation results of the test set may not generalize to other dates; the model's generalization performance still needs investigation.

NOAA MiRs Model vs Proposed Model









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Water Vapor Profile Results

- Compared to the NOAA MIRs operational model we make significant improvements
  - Our model has maximum STD error ~25% while the MiRs model reaches up to 45% STD error
  - Our model never exceed 3% mean bias error while the NOAA MiRs operational model exceeds 5% multiple times
  - Our model predicts pressure levels up to pressures of 0 hPa while MiRs is limited to 200 hPa

Conclusion

- Developed a model utilizing ResNet, dynamic loss weighting, and multi-output attention to predict atmosphere profiles utilizing ATMS and ECMWF data
- Model accuracy improved greatly when utilizing the ResNet and dynamic weight based model as compared to a simple 4-layer DNN Model
- By comparison, the current model is significantly more accurate than the NOAA MiRs operational model, but needs further validation using data from different dates

NOAA MiRs Model vs Proposed Model