Prediction of Bayesian Intervals for Tropical Storms

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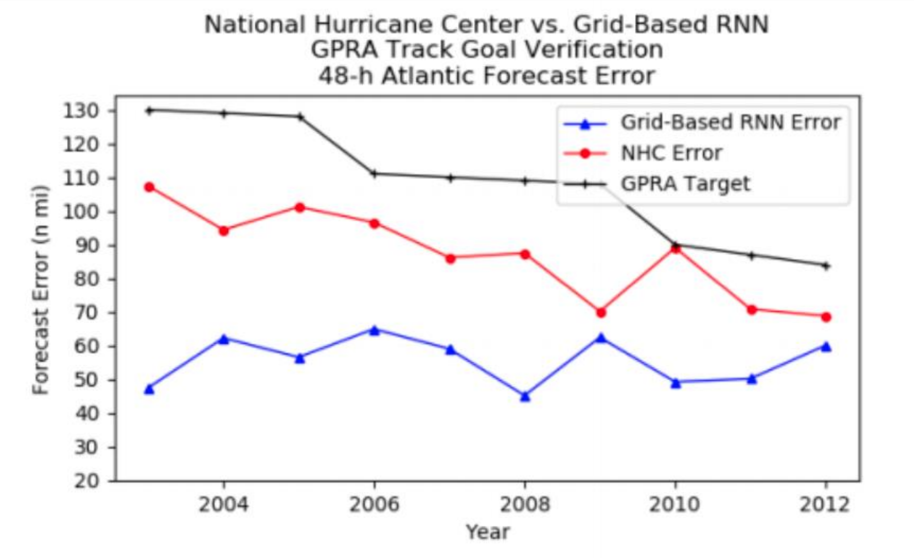
Max Chiswick (Independent) and Sam Ganzfried (Ganzfried Research)

Tropical Storm Prediction with RNN

- Dataset:
  - Tropical storms in the Atlantic Ocean
  - 500 storms from 1982-2017
  - 6 hour timesteps
  - Prediction features: latitude, longitude, maximum surface wind (kt), minimum sea level pressure (hPa)
- Alemany (2019) used an RNN to show forecast error (blue line) superior to the National Hurricane Center (NHC) and Government Performance and Results Act (GPRA) targets for recent years



Uncertainty Cones

- National Hurricane Center (NHC) builds uncertainty cone such that ⅔ of historical forecast errors over the previous 5 years fall within the circle
- Our uncertainty interval instead uses fundamental Bayesian techniques and can use a variety of interval ranges up to 99%

Adding Uncertainty with Bayesian RNN

- Use dropout in both training and testing passes to model uncertainty (Gal, Ghahramani 2016)
- Every forward pass in the testing/prediction phase results in a different output
  - Sample from a Bayesian approximation probabilistic distribution
  - Evaluate the distribution of many predictions to give a Bayesian interval

Adding Uncertainty with Bayesian RNN

$$p(w \mid x, y) = \frac{p(x, y \mid w)\, p(w)}{\int p(x, y \mid w)\, p(w) dw}$$

Posterior of weights is intractable
Assume Gaussian prior ***p(w)* = *N***(0, 1)

$$p(y^* \mid x^*, X, Y) = \int p(y^* \mid x^*, w) p(w \mid X, Y) dw$$

Predictive distribution for new input point ***x****

$$q_\theta(y^* \mid x^*) = \int p(y^* \mid x^*, w) q_\theta(w) dw$$

Approximate predictive distribution
Use ***q(w)*** as approximating variational distribution and minimize KL(***q***(*w*)|***p***(*w*/***X,Y***))

$$q_\theta(y^* \mid x^*) \approx \frac{1}{T} \sum_{t=1}^{T} p(y^* \mid x^*, w_t)$$

Approximation at prediction time

Experiments

- Implemented RNN model with dropout on predictions
- Experiments with 100 and 400 predictions at different levels of dropout
- Created intervals based on mean, standard deviation, and Z-score for each timestep. We used Z-scores to represent intervals of 67%, 90%, 95%, 98%, and 99%.
- Using a dropout of 0.2, we show the true percentage of points within each of the interval bands over every timestep of that sample

0.2 dropout test set	67%	90%	95%	98%	99%
100 Latitude	61.1	82.0	87.0	90.9	93.0
400 Latitude	61.2	82.4	87.3	91.2	93.4
100 Longitude	66.3	84.3	88.6	92.2	93.9
400 Longitude	66.2	84.6	88.8	92.0	94.1

Hurricane Katrina

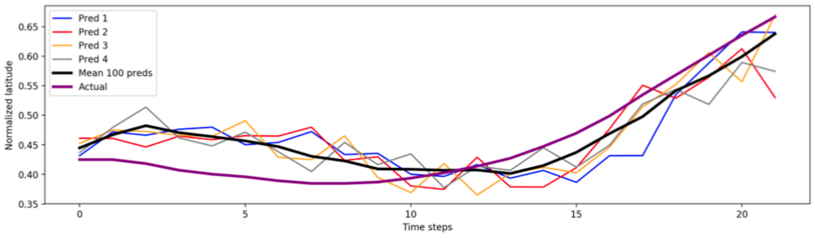


Figure 7: Katrina latitude predictions

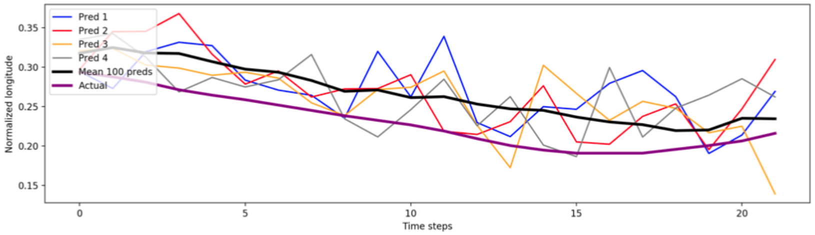


Figure 8: Katrina longitude predictions

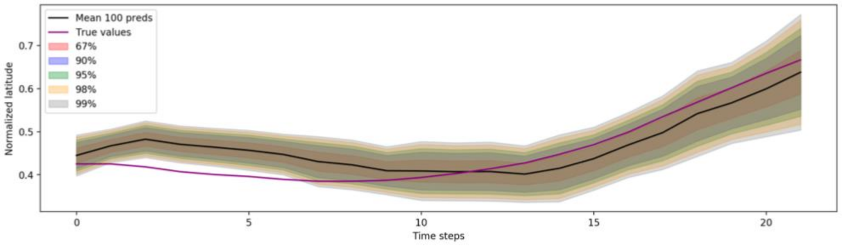


Figure 9: Katrina latitude intervals

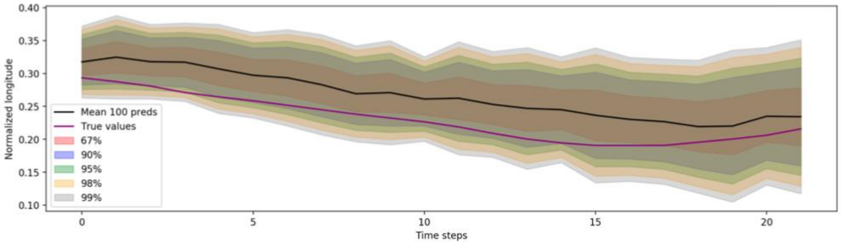


Figure 10: Katrina longitude intervals