Leveraging Numerical Weather Prediction and Machine Learning for Local Operational Predictions: Designs, Implementations and Stakeholders

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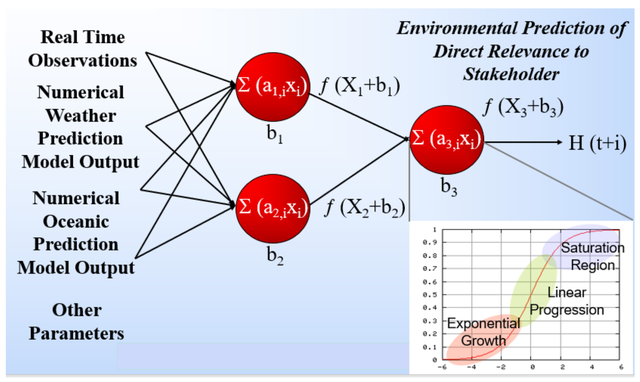
Abstract

Accurate local predictions are important for many stakeholders including ecosystems managers or emergency personnel ahead of impactful events such as coastal flooding or thunderstorms. Stakeholders are often looking for predictions that they can relate to directly (such as data they are regularly consuming) rather than output from gridded numerical models. In addition, variables of interest and/or location may not be covered by gridded models or model resolution is too coarse. For example, operational hydrodynamic models do not yet extend to many bays, estuaries and lagunas of ecological significance. Since the early 2000's the Conrad Blucher Institute has been combining output from operational Numerical Weather Prediction (NWP) models with real-time measurements as input to computationally efficient machine learning models to predict environmental variables at the locations of stakeholders' interests. The predictions have been used to interrupt navigation and coastal works in a laguna ahead of large cold stunning events leading to thousands of turtles rescued. Other predictions have been used ahead of coastal flooding events or are in development for the automated prediction of thunderstorms with lead times of up to 15 hours. The use of AI to build and implement the models will be described along with interactions with stakeholders.

General Approach

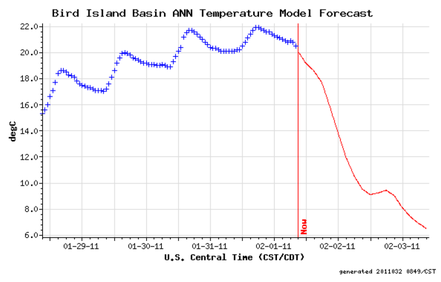


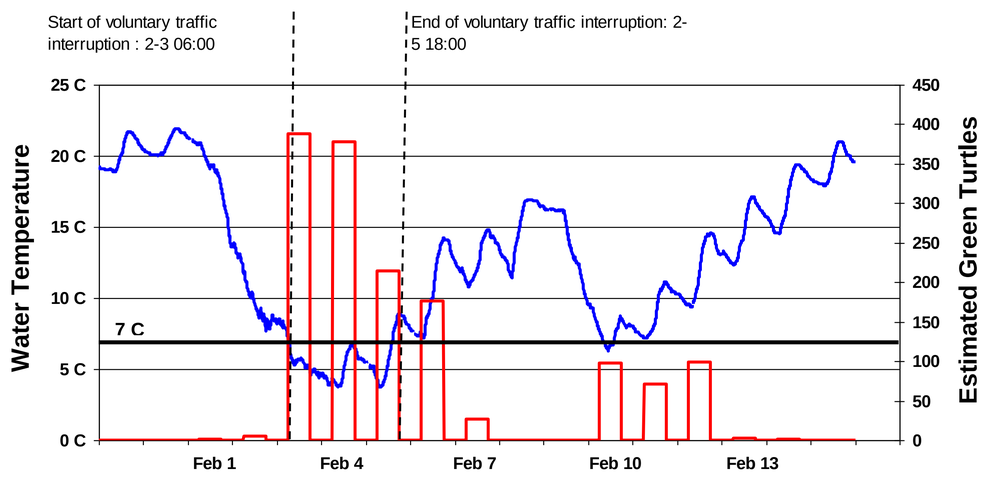
Take advantage of the flexibility and computational efficiency of trained neural nets to extend measurement time series used by stakeholders.

Methods used include neural nets, random forests, self organizing maps (SOM). Operational models are all based on neural nets. Computational efficiency allows ingestion of the latest environmental measurements (often 6 mins) dynamically.

Cold Stunning Event Predictions

Methods: Shallow Neural Network and Random Forests
Goal: predict onset of cold stunning events with at least 24hrs lead time to allow for cessation of activities in water body and staging of response
Stakeholder/Partner: Texas Parks and Wildlife, National Park Service, Coastal Conservation Association Texas, Gulf Intracoastal Canal Association, …





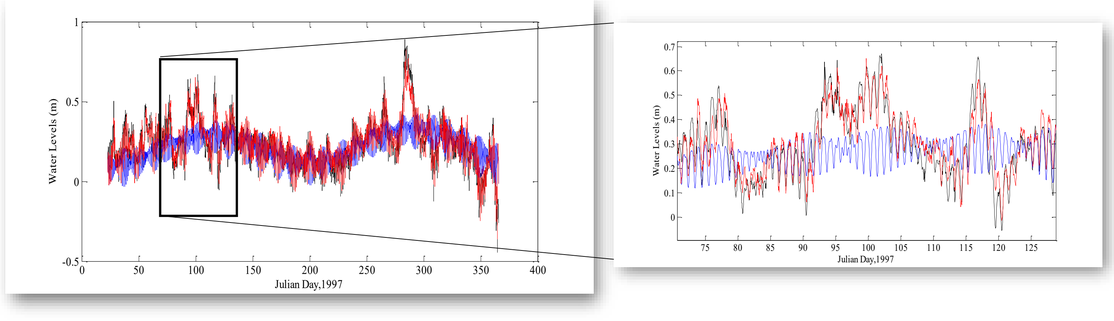
Shaver, D. J., Tissot, P. E., Streich, M. M., Walker, J. S., Rubio, C., Amos, A. F., George, J. & Pasawicz, M. R. (2017). Hypothermic stunning of green sea turtles in a western Gulf of Mexico foraging habitat. PLoS ONE 12(3): e0173920. https://doi.org/10.1371/journal.pone.0173920.

Ball, R., Tissot, P.E., Zimmer, B. & Sterba-Boatwright, B. (2009). Comparison of random forest, artificial neural network, and multi-linear regression: a water temperature prediction case. Proceedings of the 7th Conference on Artificial Intelligence and its Applications to the Environmental Sciences, part of the 2009 American Meteorological Society Annual meeting, Phoenix, Arizona.

Water Level/Flooding Predictions

Methods: Shallow Neural Networks
Goal: predict water levels for up to 72 hrs for locations where tidal predictions do not meet NOAA standards
Stakeholder/Partner: National Weather Service, National Park Service, …

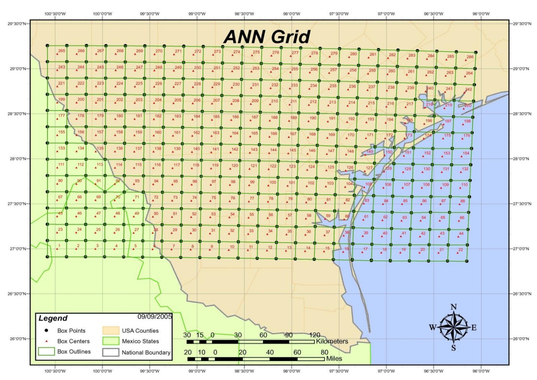
Comparison of 24 h ANN predictions with measurements for Corpus Christi Naval Air Station

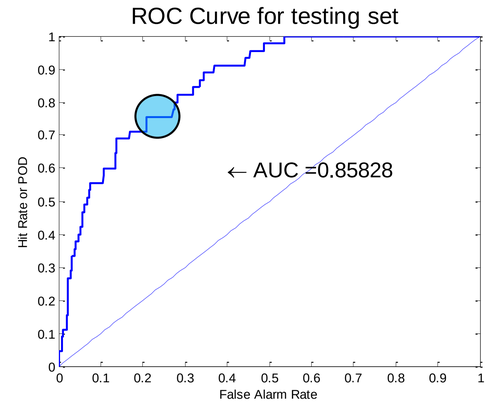


Tissot, P.E., Cox, D.T. & Michaud, P.R. (2003). Optimization and Performance of a Neural Network Model Forecasting Water Levels for the Corpus Christi, Texas, Estuary. Proceedings of the 3rd Conference on the Applications of Artificial Intelligence to Environmental Science, part of the 2003 American Meteorological Society Annual Meeting, Long Beach, California.

Cox, D. T., Tissot, P.E. and Michaud P. (2002). Water Level Observations and Short-Term Predictions Including Meteorological Events for Entrance of Galveston Bay, Texas. Journal of Waterway, Port, Coastal and Ocean Engineering, 128-1, 21-29. doi: 10.1061/(ASCE)0733-950X(2002)128:1(21).

Shallow Neural Network Predictions of Thunderstorms



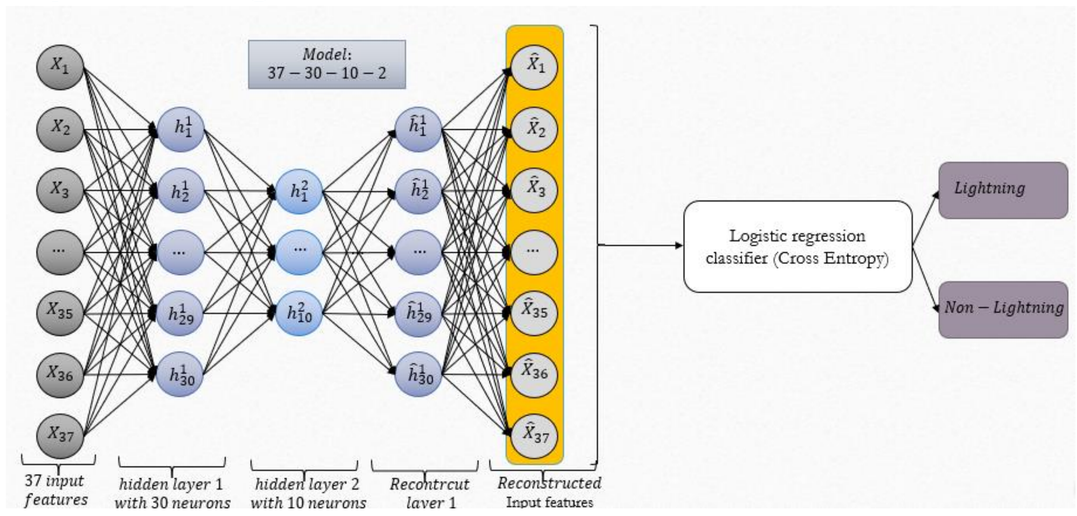


Methods: Shallow Neural Network and Random Forests as non linear MOS
Goal: Predict Thunderstorms 9-15 hours in advance within 400 km^2 box regions in South Texas
Stakeholder/Partner: National Weather Service

Collins, W., & Tissot, P. (2015). An artificial neural network model to predict thunderstorms within 400 km2 South Texas domains. Meteorological Applications, 22(3), 650-665. doi: 10.1002/met.1499.

Tissot, P.E. & Collins, W. (2012). Comparison of Machine Learning Techniques for the Prediction of Thunderstorm Location. 10th Conference on the Application of Computational Intelligence to Environmental Science, part of the 2012 American Meteorological Society Annual Meeting, New Orleans, Ls.

Deep Learning Predictions of Thunderstorms

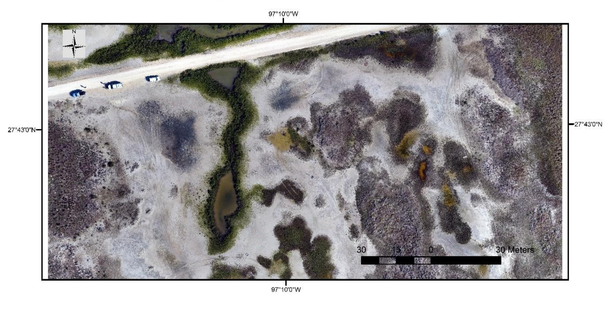


Methods: Stacked autoencoder with logistic regression classifier
Goal: Predict Thunderstorms 9-15 hours in advance within 400 km^2 box regions in South Texas
Stakeholder/Partner: National Weather Service

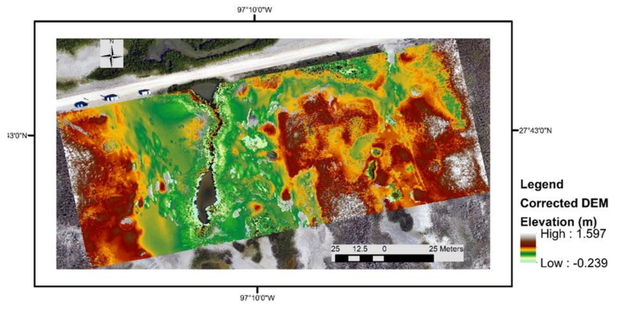
Ensemble Neural Net for DEM Corrections with Tolerance Interval

Methods: Ensemble neural networks (SOM used for other parts of project)
Goal: Predict the difference between remote sensing (Lidar, UAS/Photogrammetry) generated DEMs with reference ground measurements while estimating tolerance intervals
Stakeholder/Partner: Researchers and coastal stakeholders monitoring marshes

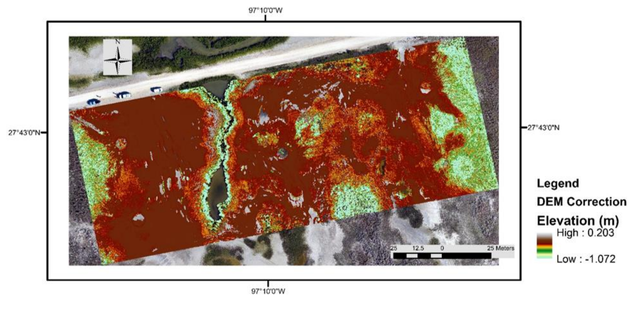
Mustang Island (Texas) Marsh



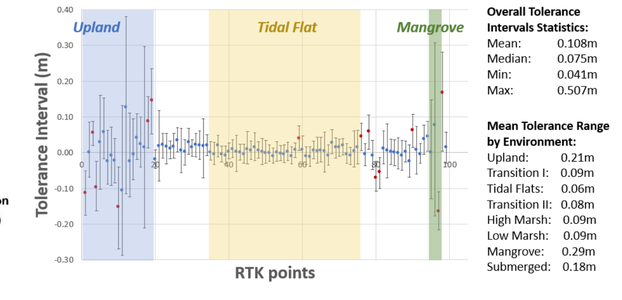
DEM Corrected with Ensemble ANN Model



Map of DEM Correction Magnitude



Corrections & Tolerance for 100 Independent RTK Points



Nguyen, C., Starek, M. J., Tissot, P., & Gibeaut, J. (2018). Unsupervised Clustering Method for Complexity Reduction of Terrestrial Lidar Data in Marshes. Remote Sensing, 10(1), 133. doi:10.3390/rs10010133

Cai, Xiaopeng, Tissot, P.E. (presenter), Nguyen, C. & Starek, M.J. (2019). Estimates of Spatial Variability of Digital Elevation Models from Ensemble Neural Networks. 18th Conference on Artificial and Computational Intelligence and its Applications to the Environmental Sciences, part of the 2019 American Meteorological Society Annual Meeting, Phoenix, Az.

Acknowledgements:

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