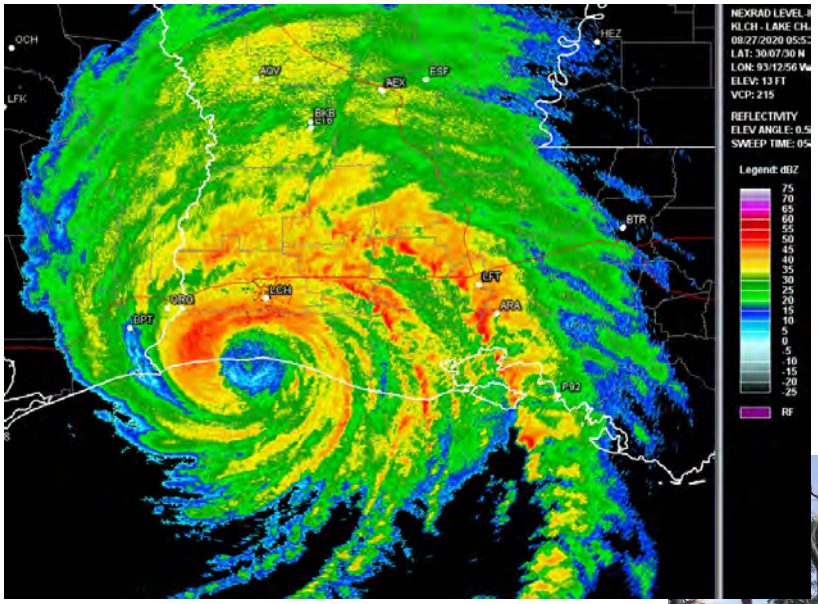
United States Department of Agriculture
Forest Service

Tree Structure Damage Impact Predictive (TreeS-DIP) Modeling Approach



Current Research in Hurricane Disturbed Forests

Monday, October 7, 2024

Robert Chastain, RedCastle Resources, Inc.
360-292-9888
Robert.chastain@usda.gov

Geospatial Technology and Applications Center | GTAC
USDA Forest Service

GTAC Mapping Our Future Together

Talk Summary

- Describe TreeS-DIP approach
- Summarize Phase I work (hurricane Michael)
- Lessons learned from Phase I
- Summarize Phase II work (7 hurricanes)
- Lessons learned from Phase II
- Hurricane Helene application

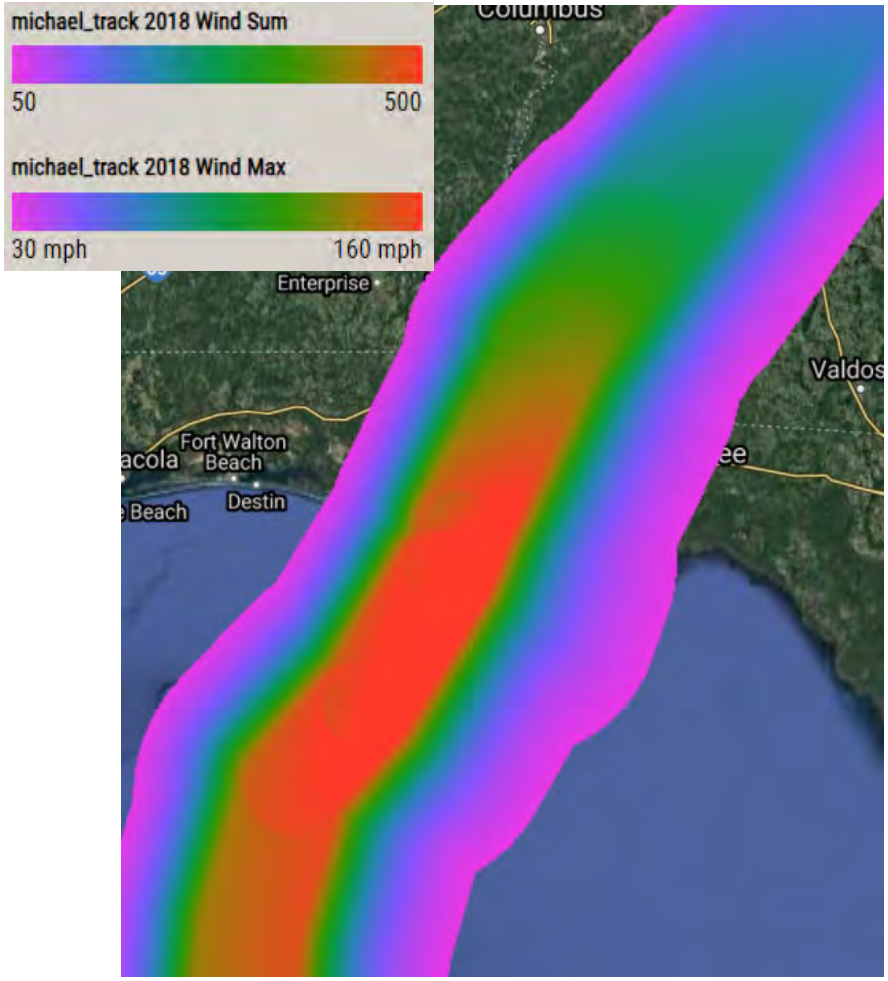
Project Need

The USFS and its Region 8 partners require applications, tools, and spatial products to rapidly and consistently respond to large-scale storm events (i.e., hurricanes). Requests for emergency funding to respond to these events cannot wait until the availability of empirical information from remote sensing or ground observations. The need for a predictive modeling approach is therefore essential to meet these short-term management needs

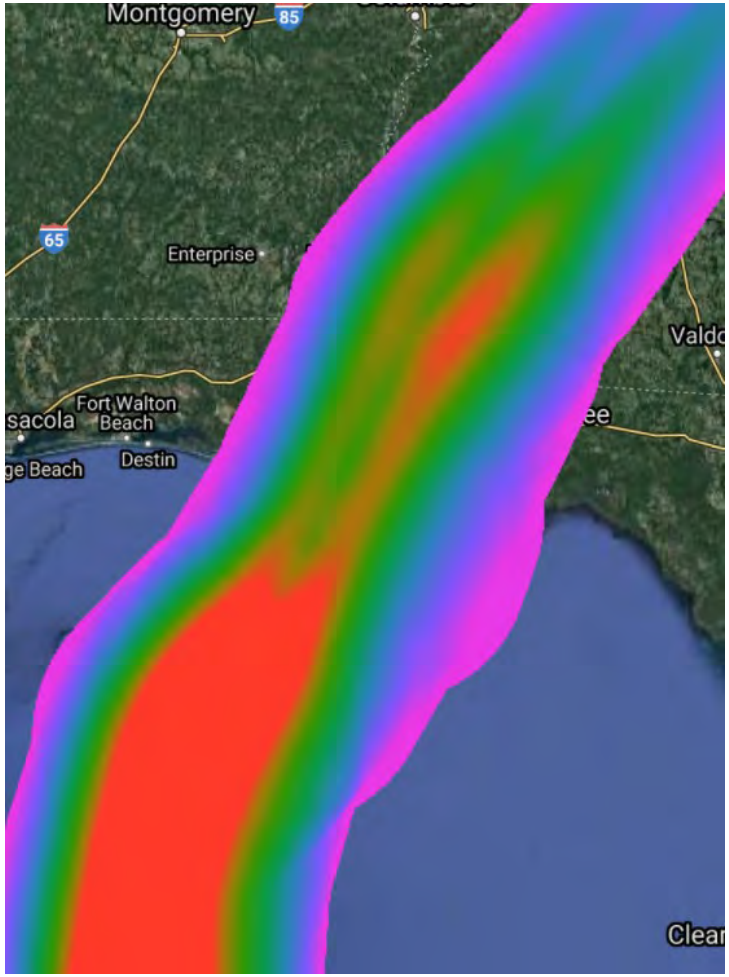
Phase I Goals and Objectives

- Determine feasibility of predicting forest damage using an ensemble modeling approach
  - Coarse scale outputs available 24-48 hours after storm event
  - More time-sensitive requirement than remote sensing or ground-based information can provide
  - Fulfills the need for near-real time strategic information and funding requests, not intended for detailed analysis
- Develop prototype models and workflow to predict tree damage resulting from hurricanes
    - ForestGALES and random forest
    - Hurricane Michael used as retrospective event
- Produce spatial products at resolution of 1 to 3 km

ForestGALES Modeling



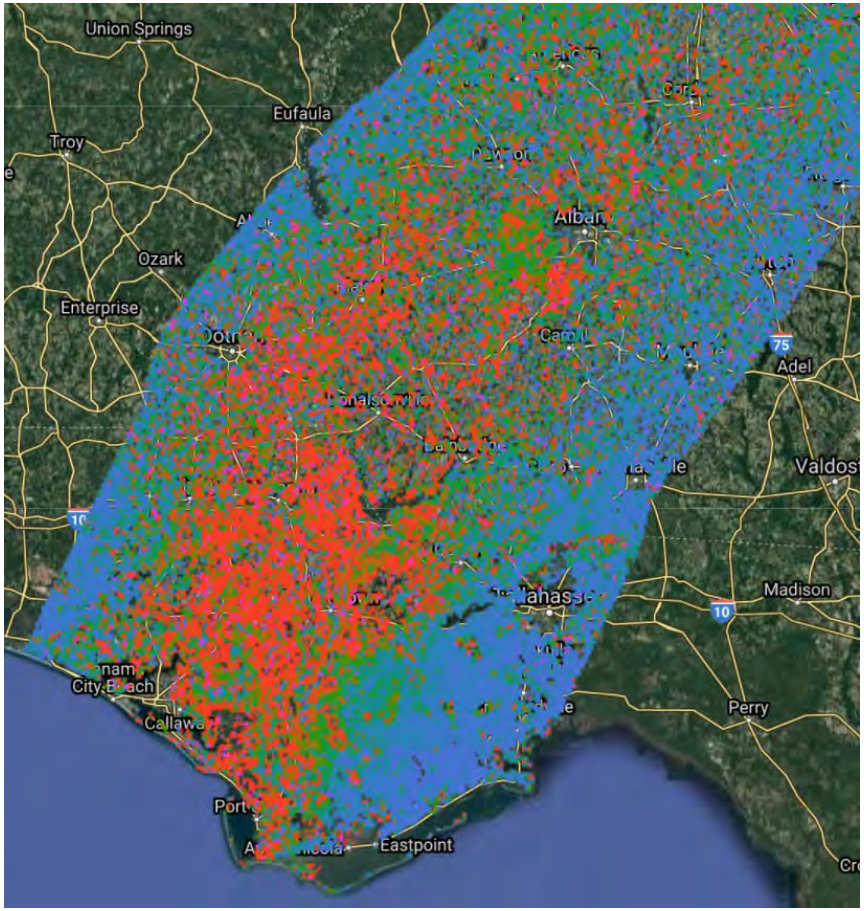
Wind Max



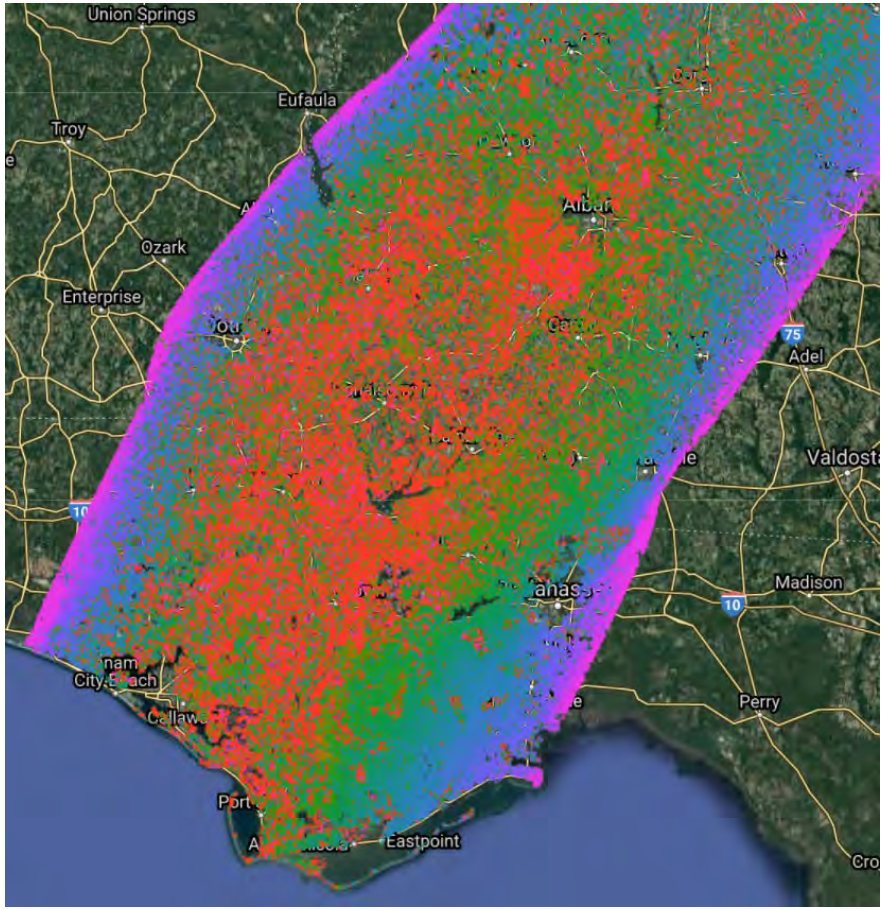
Wind Sum

Michael (2018)

ForestGALES Modeling



ForestGALES Damage Max



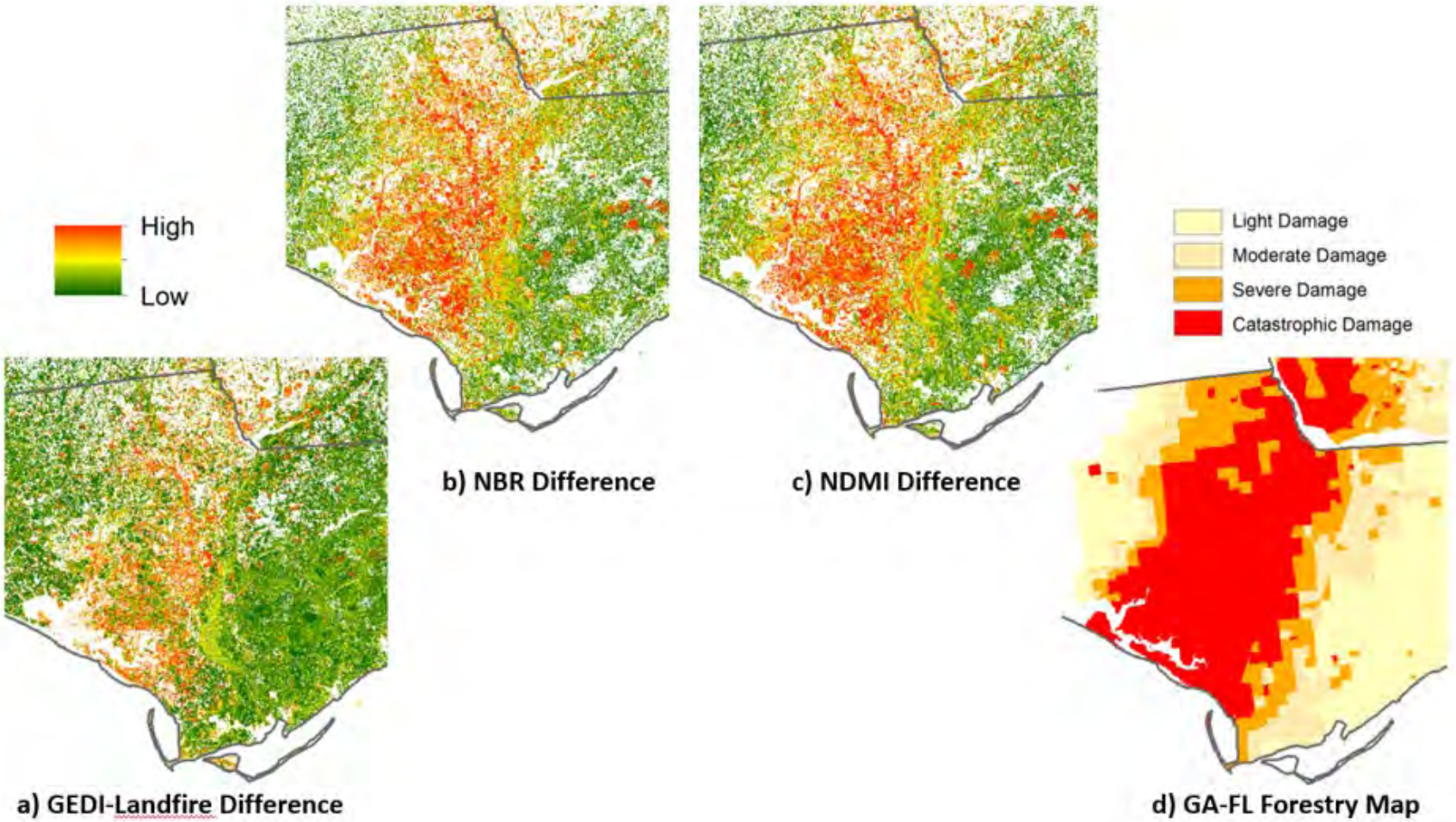
ForestGALES Damage Sum

Michael (2018)

Random Forest Modeling

Variable	Resolution	Source	Date	Latency	Modeled?
Soil moisture	3 km	NASA LIS	Near-real time	Every 6 hrs	Yes
Total basal area	30 m	NIDRM	2012	Static	Yes
Stand density index	30 m	NIDRM	2012	Static	Yes
Canopy cover	30 m	NLCD	2016	Static	No
Elevation	30 m	NED	Accessed in 2020	Static	No
Wind exposition	30 m	NED	Accessed in 2020	Static	Yes (SAGA)
Effective airflow hts	30 m	NED	Accessed in 2020	Static	Yes (SAGA)
Soil Windfirmness	10 m	gSSURGO	Accessed in 2020	Static	Yes (NRCS SQL)
Tree height	30 m	Landfire	2001, 2016, 2019	Static	No
Precipitation	~5 km	NOAA	Near-real time	Hourly	No
ForestGALES wind max	30 m	HURDAT2	Near-real time	Hourly	Yes
ForestGALES wind sum	30 m	HURDAT2	Near-real time	Hourly	Yes

Reference Data



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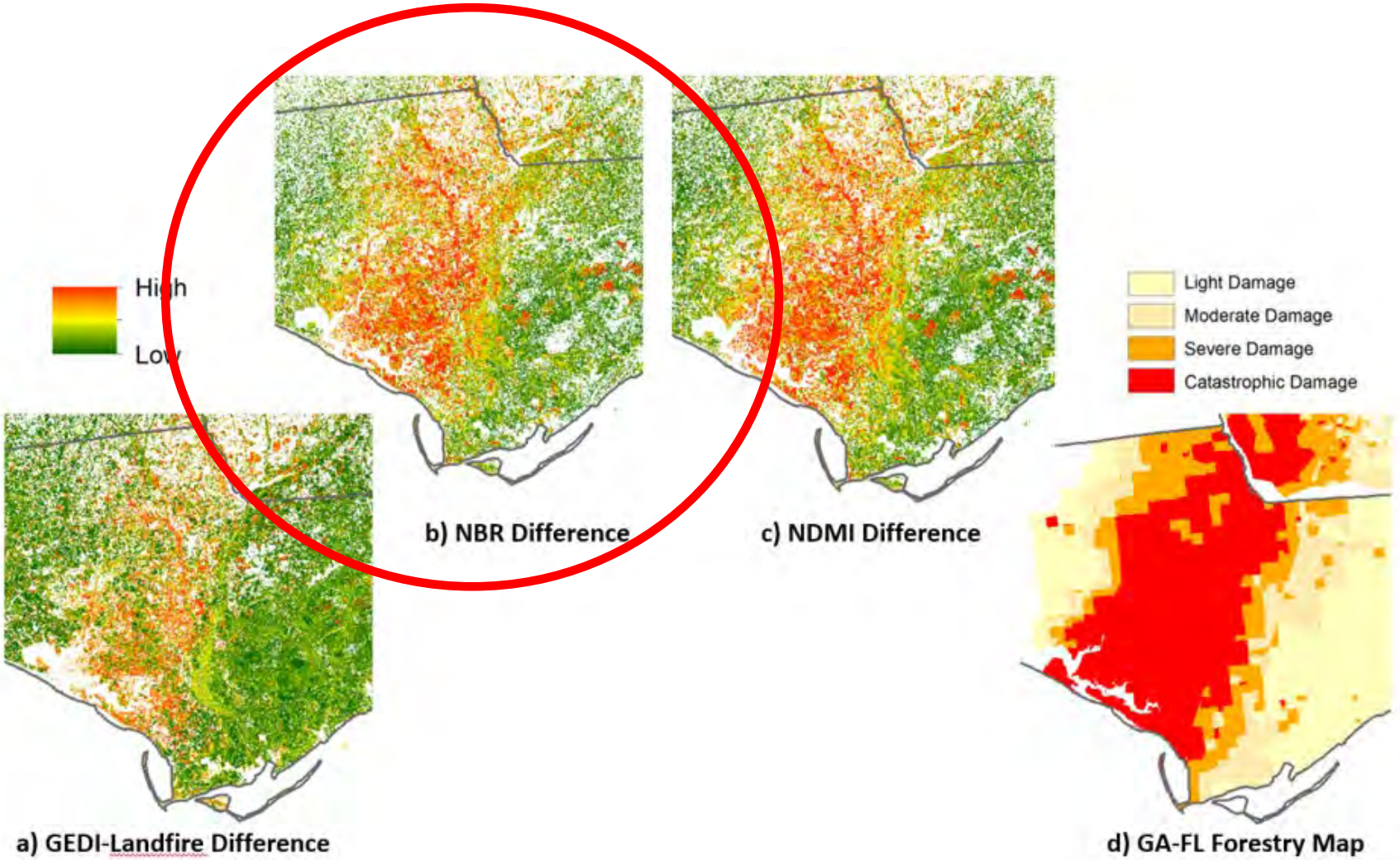
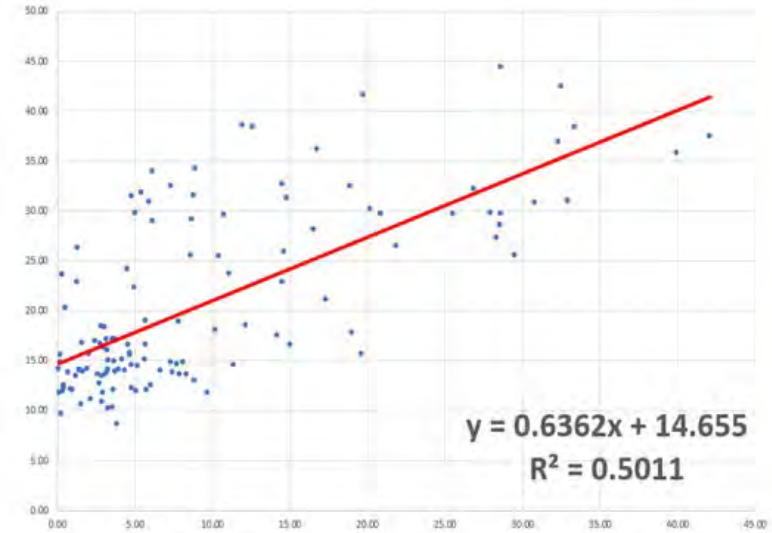
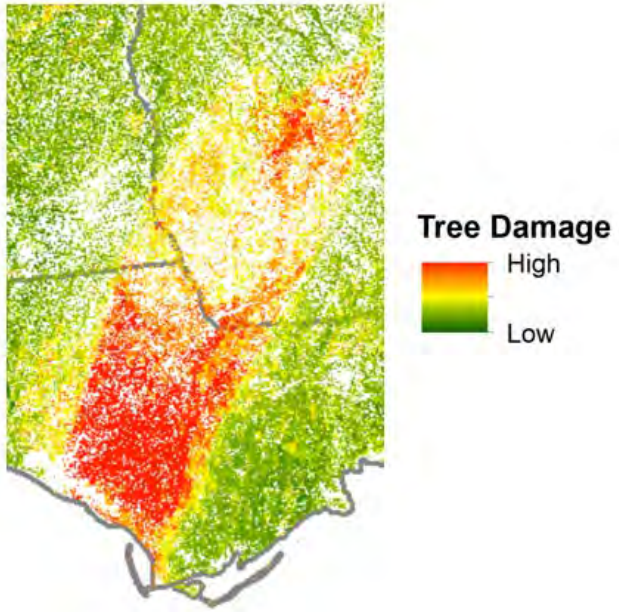


Reference Data

Model	GEDI reference	NDMI Reference	NBR Reference	4-Class Map Reference
FG - WindMax	0.0916	0.2445	0.2707	**0.5952**
FG - WindSum	0.0763	0.1605	0.1713	0.4206
RF - 10var - WindMax	0.1188	0.4507	0.4709	**0.6788**
RF - 10var - WindSum	0.1161	0.4332	0.4841	**0.6246**
RF – 9var - Windmax	0.1248	0.4676	**0.5211**	**0.6128**
RF – 9var - Windsum	0.1092	0.4665	**0.5199**	**0.6118**
RF – 8var - Windmax	0.1363	0.4621	**0.5098**	**0.6400**
RF – 8var - Windsum	0.1321	0.4769	**0.5226**	**0.6421**
RF – 5var - Windmax	0.1120	0.4007	0.4357	**0.6820**
RF – 5var - Windsum	0.0895	0.4427	**0.5011**	**0.6339**

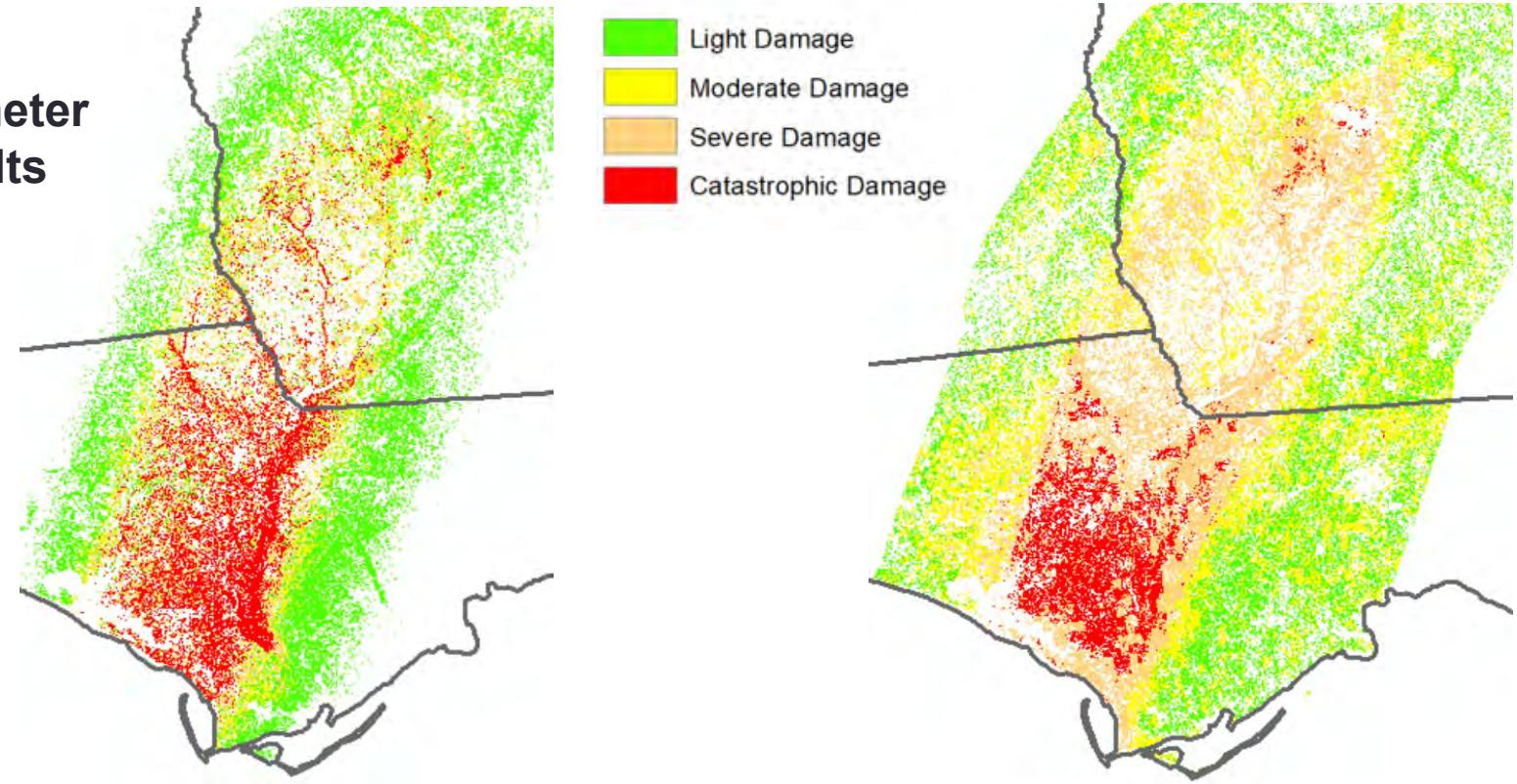


RF 5-variable Wind Sum model with FIA sample NDMI Difference



Results

30-meter results

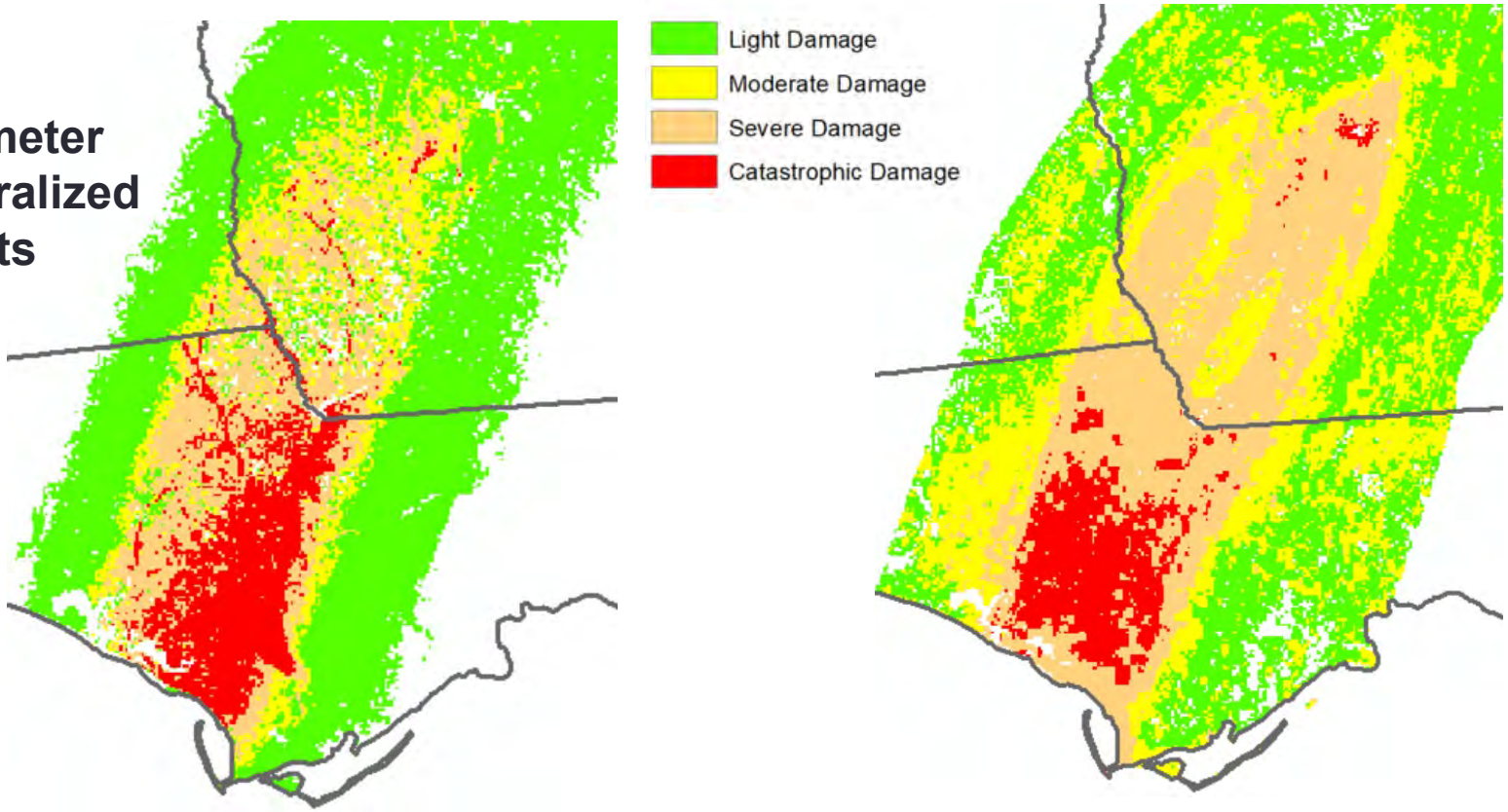


ForestGALES Wind Max Tree Damage Model

Random Forest Wind Sum Tree Damage Model

Deliverables

900-meter generalized results



ForestGALES Wind Max Tree Damage Model

Random Forest Wind Sum Tree Damage Model

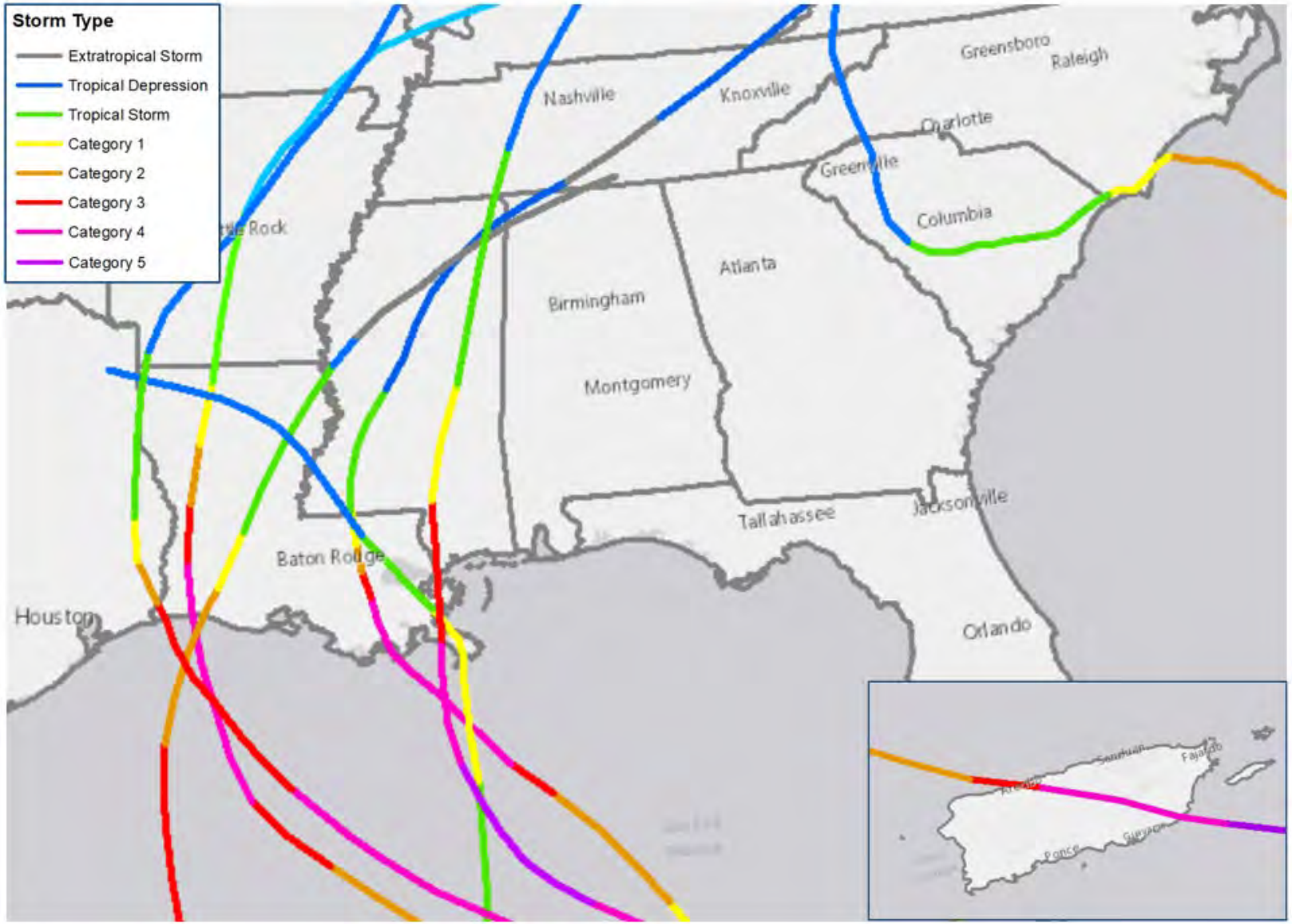
Lessons Learned

- ForestGALES tends to overpredicts tree damage, whereas random forest yields relatively conservative predictions
- TreeS-DIP approach predicts spatial patterns of tree risk for this singular windy hurricane event
- Other storms with differing characteristics will need to be investigated to further understand value and/or limitations of TreeS-DIP approach
- A second year of model and workflow development likely needed

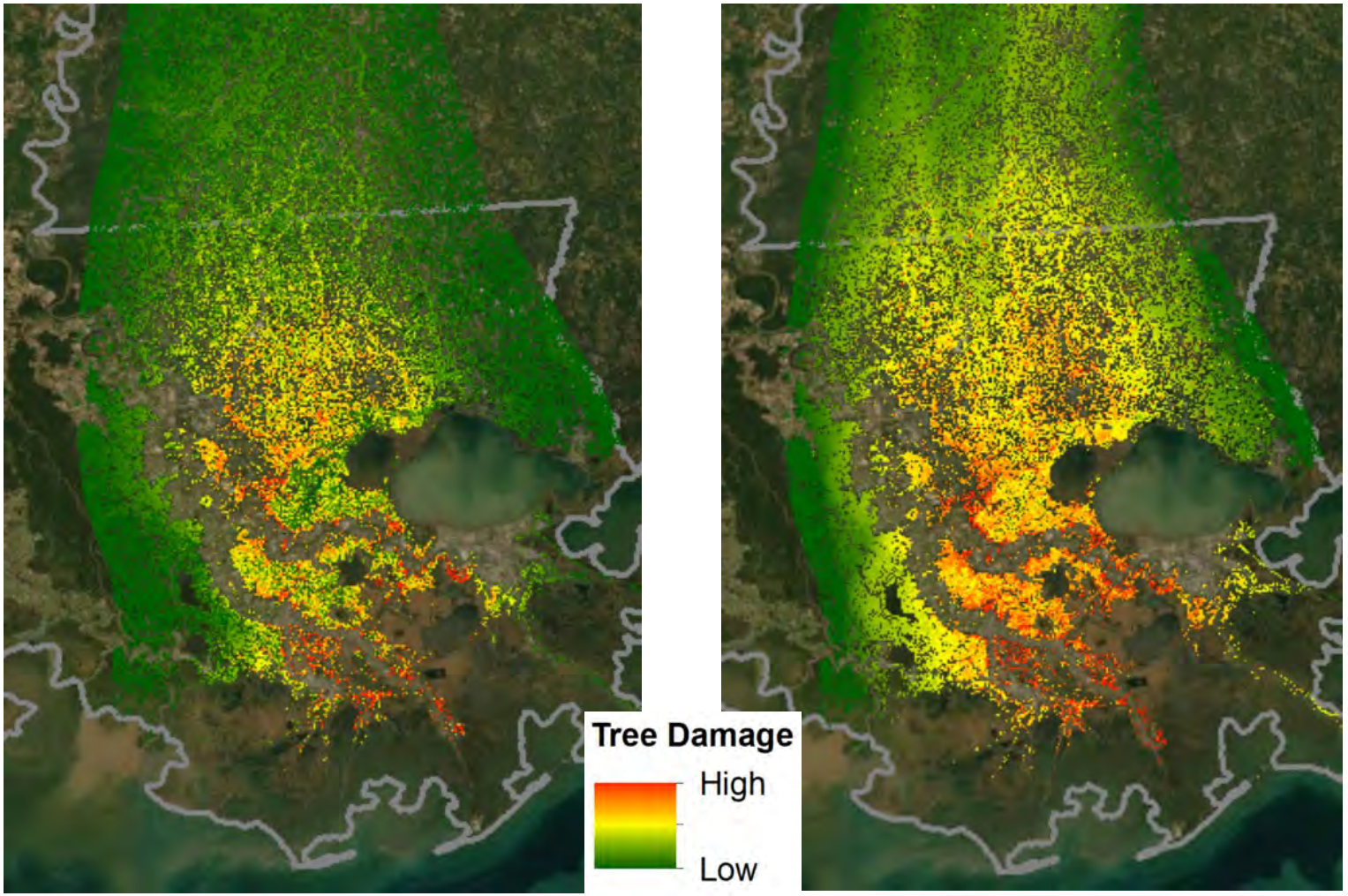
TreeS-DIP Phase II Objectives

- Use multiple hurricanes as a retrospective events to further assess predictive modeling approach
- Hurricanes include:
  - Ida (2021) – windy and wet
  - Laura and Delta (2020) – serial events
  - Florence (2018) – wet event
  - Maria (2017) – windy event impacting Puerto Rico
  - Katrina (2005) – very large, historically impactful storm
  - Rita (2005) – damaging due to soil moisture after Katrina
- Develop predictive models
  - ForestGALES (enhanced!) and random forest

TreeS-DIP Phase II Hurricanes



ForestGALES Implementation

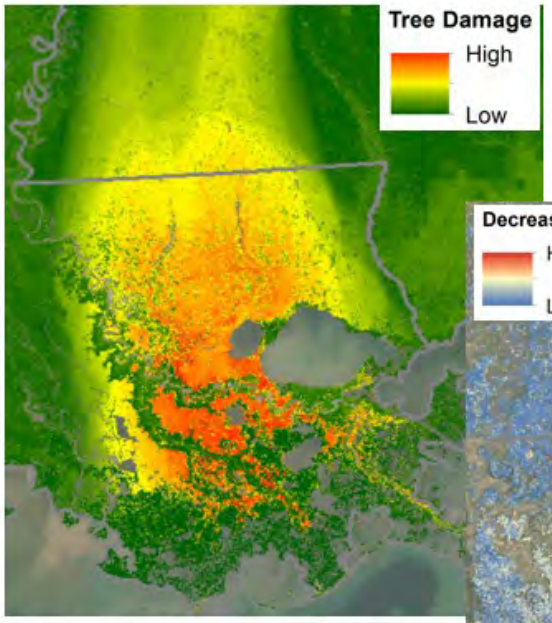


ForestGALES Damage Max

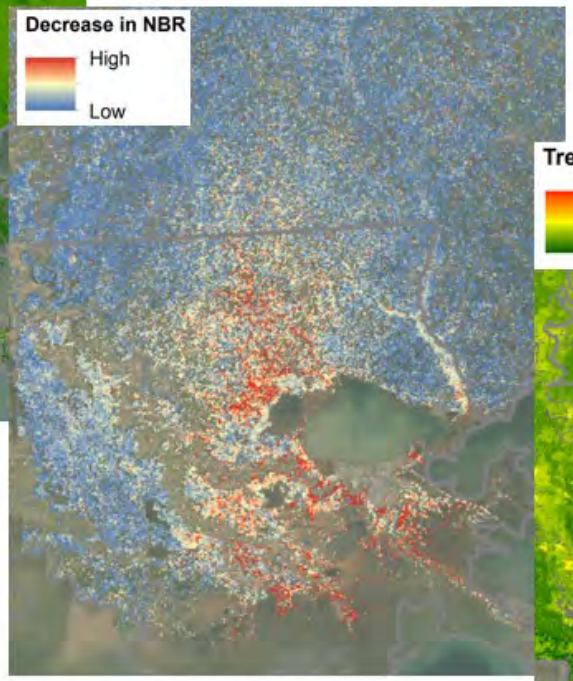
ForestGALES Damage Sum

Separate Moduli of rupture for loblolly, water tupelo, and oak

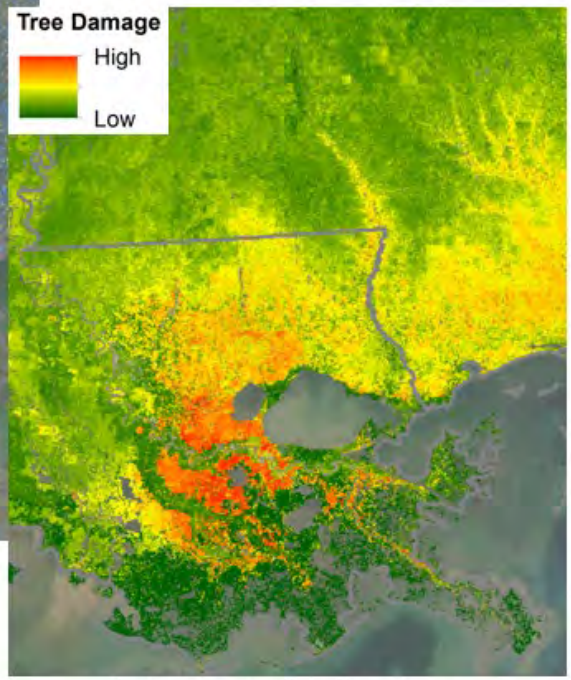
TreeS-DIP Phase II



Eleven Variable Random Forest (Wind Sum)



NBR Difference



Eight Variable Random Forest (Wind Sum)

Hurricane Ida

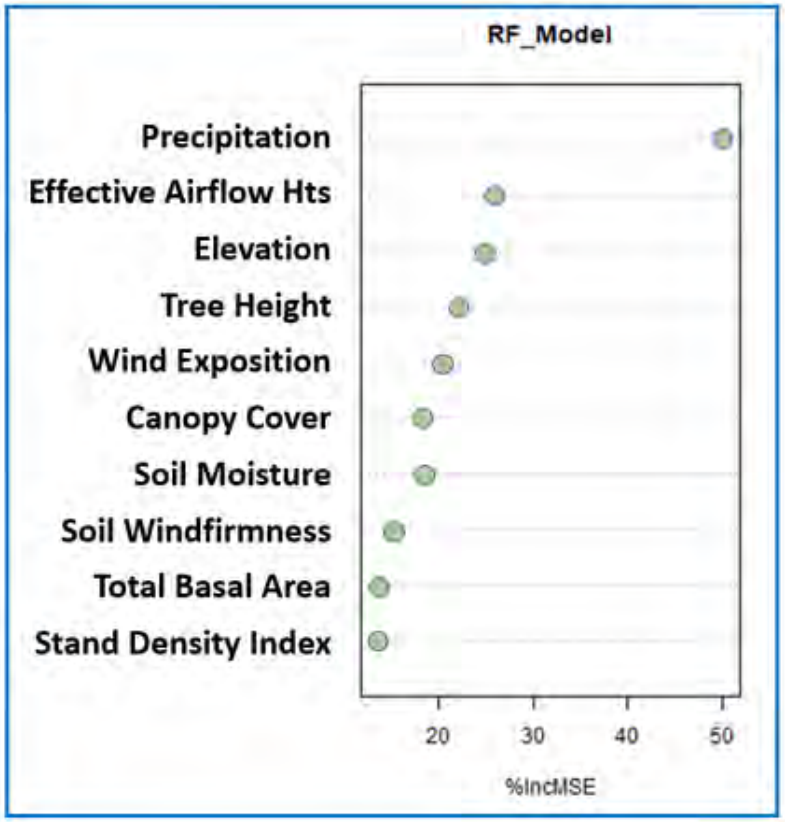
TreeS-DIP Phase II

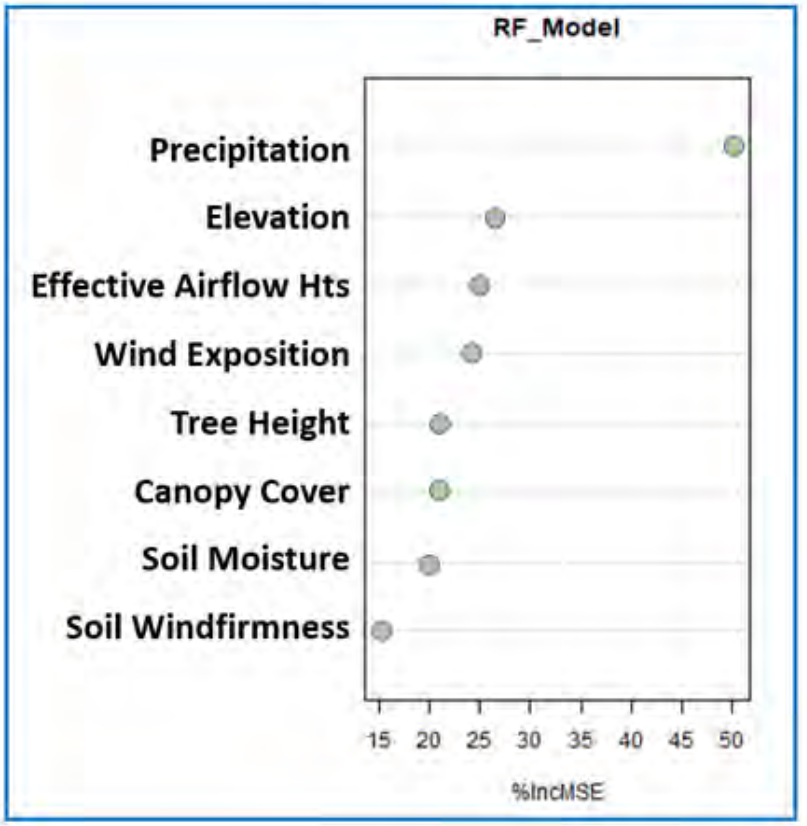
Model	Ida*	Florence	Maria	Laura	Delta	Laura + Delta	Katrina	Rita
ForestGALES with Wind Max	0.5268	**0.4613**	**0.7783**	0.5583	**0.5625**	0.5453	0.5252	**0.5392**
ForestGALES with Wind Sum	0.5421	0.3551	0.7664	**0.5850**	**0.5120**	**0.6106**	**0.6100**	**0.5348**
Random Forest 11 variable (Wind max)	0.5361	0.2742	0.7707	0.5287	0.2139	0.4513	0.5168	0.3902
Random Forest 11 variable (Wind sum)	**0.6228**	0.3753	0.7528	**0.5638**	0.3201	0.5151	0.5023	0.3840
Random Forest 10 variable (Wind max)	0.5196	0.3753	0.7706	0.4999	0.3662	0.4856	0.6006	0.5192
Random Forest 10 variable (Wind sum)	0.6047	0.3969	0.7515	0.5451	0.3509	**0.5493**	**0.6109**	0.5299
Random Forest 7 variable (Wind max)	0.5165	0.3826	0.7687	0.4943	0.3561	0.4848	0.5889	0.5158
Random Forest 7 variable (Wind sum)	**0.6051**	0.3930	0.7520	0.5361	0.3401	0.5474	0.5996	0.5296
Random Forest 5 variable (Wind max)	0.5142	**0.4011**	**0.7816**	0.4805	0.3589	0.4793	0.5923	0.5116
Random Forest 5 variable (Wind sum)	0.5912	0.3916	0.7661	0.5080	0.4438	0.5402	0.6093	0.5206

TreeS-DIP Phase II Lessons Learned

- The highest levels of agreement (R-squared) between ForestGALES and random forest models were seen in hurricanes where high winds was the primary characteristic.
  - Hurricanes Maria, Katrina and Laura
- The lowest highest levels of agreement (R-squared) were seen in hurricanes that were not as windy, but moister events.
  - Hurricanes Florence, Delta, and Rita
- ForestGALES results yielded the highest R-squared values in more than half of the top two results for each storm (8 out of 14 times)

TreeS-DIP Phase II





TreeS-DIP Phase II Lessons Learned

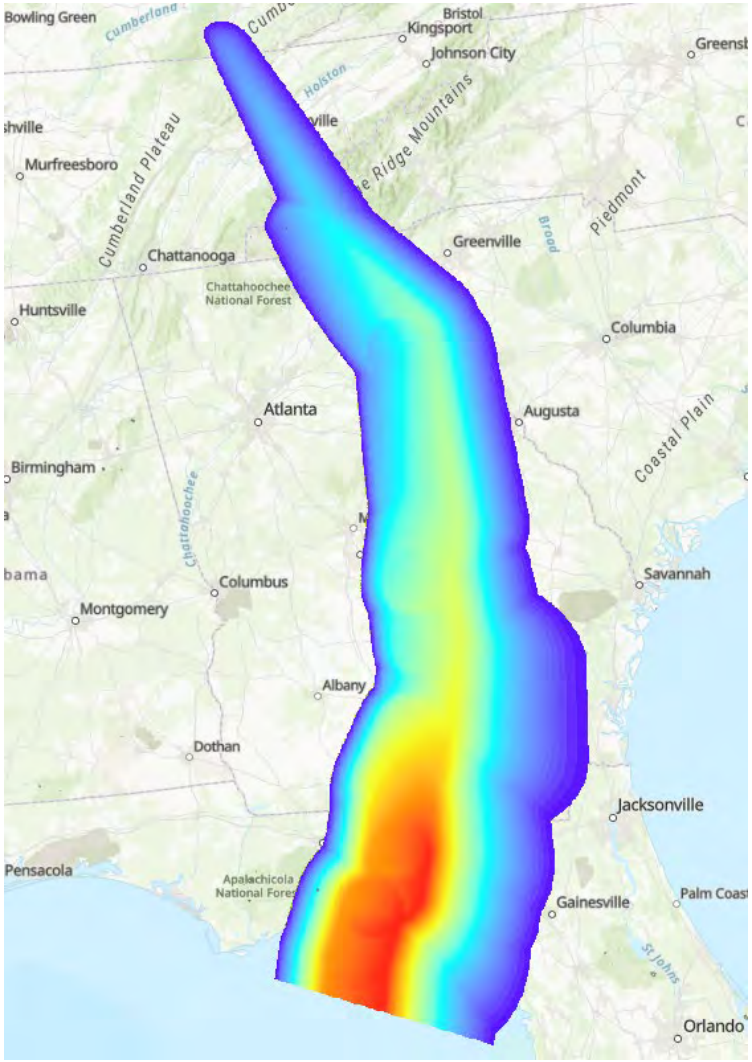
- The highest overall importance of the independent variables selected in random forest models in Phase II are Landfire tree height, NLCD canopy cover, precipitation, NASA SPoRT LIS soil moisture, elevation, and effective airflow heights
- The least important variables are total basal area, stand density index, wind exposition, and soil windfirmness

RF Models	TBA	SDI	Tree Ht	TCC	Precip	Soil Moisture	Elev	Airflow	Wind Exp	Windfirmness
7-Var WM	1	2	6	6	7	7	7	6	3	4
7-Var WS	2	3	5	7	6	7	7	6	4	3
5-Var WM	0	0	5	5	7	6	7	4	0	1
5-Var WS	0	1	5	6	6	6	6	5	1	0
Totals	**3**	**6**	**21**	**24**	**26**	**26**	**27**	**21**	**8**	**8**

TreeS-DIP Lessons Learned

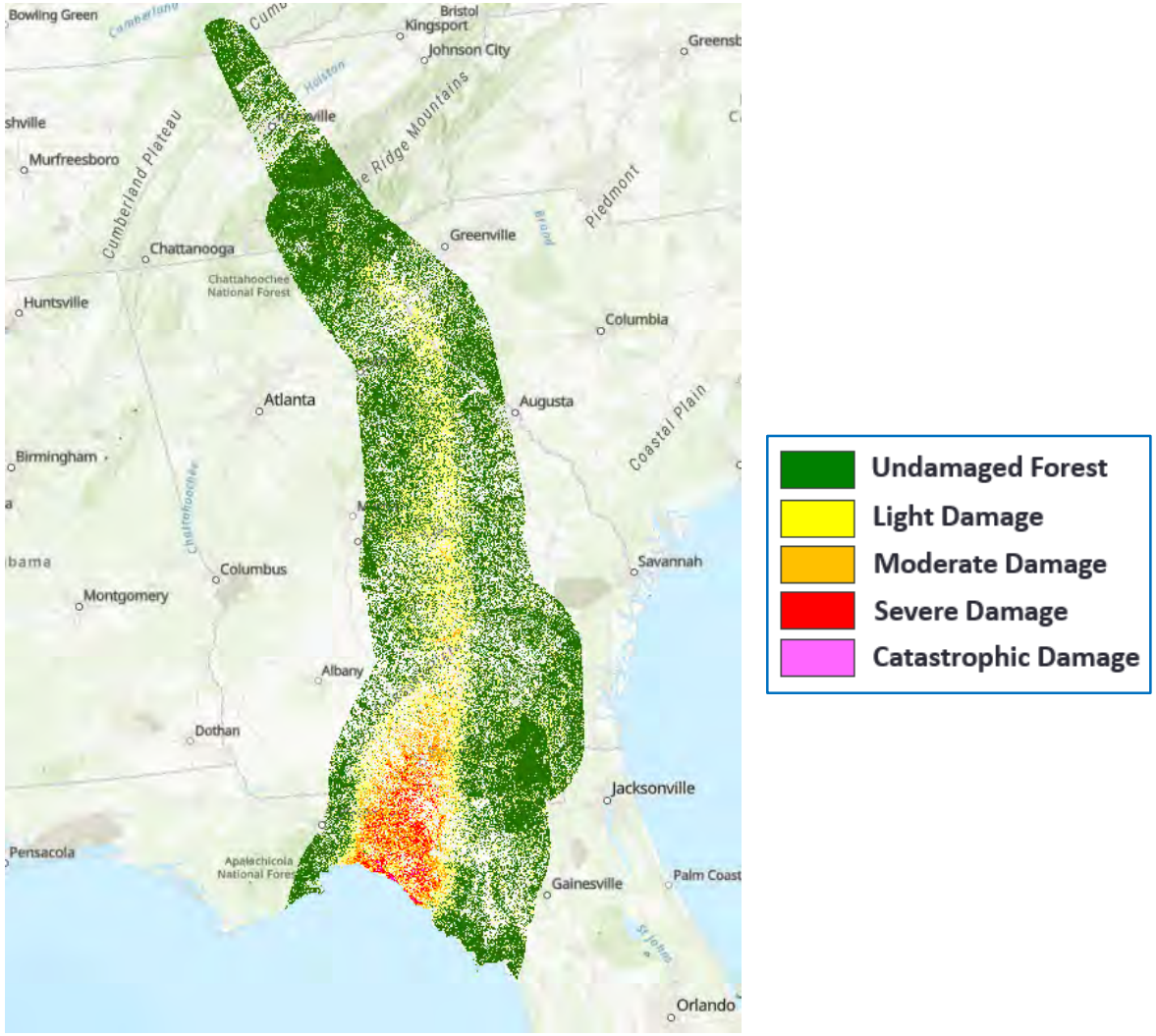
- TreeS-DIP approach feasible for near-real time coarse scale predictions after hurricane event
- Predictions for windy storms are more reliable compared to hybrid events (i.e., moist conditions)
- Independent variables for random forest modeling should be pared down
  - Tree height
  - Canopy cover
  - Precipitation
  - Soil moisture
  - Elevation (and airflow heights)

Maximum Wind Field



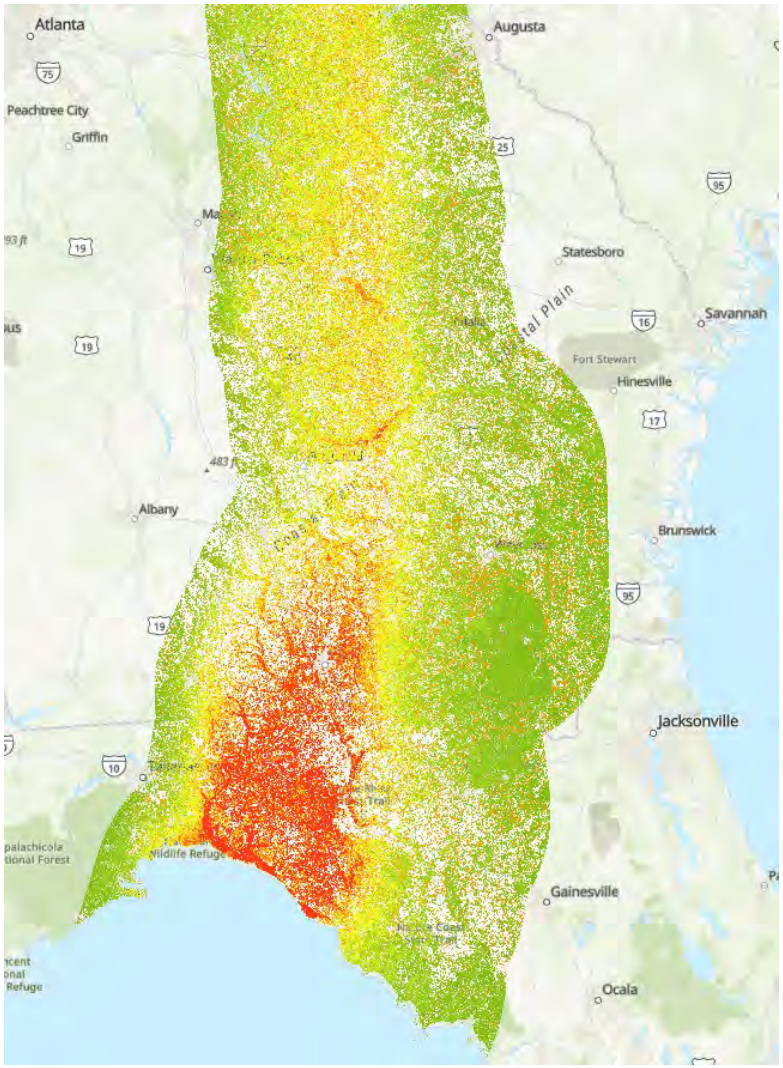
Hurricane Helene

ForestGALES Result



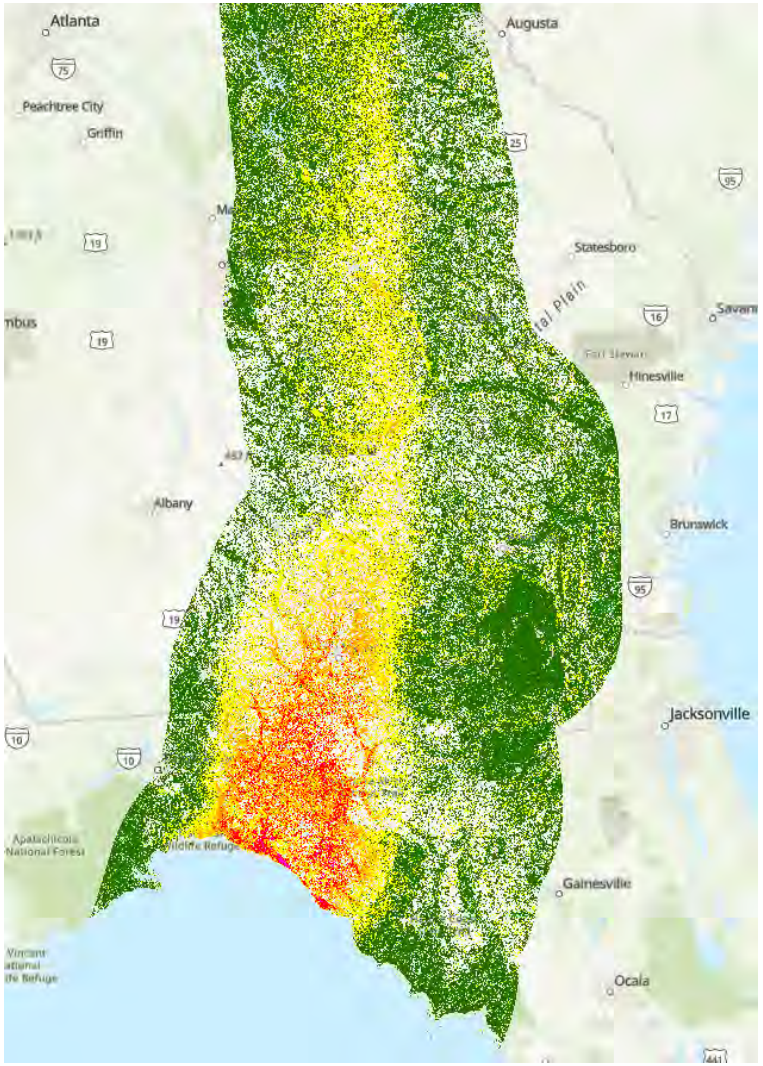
Hurricane Helene

ForestGALES Result



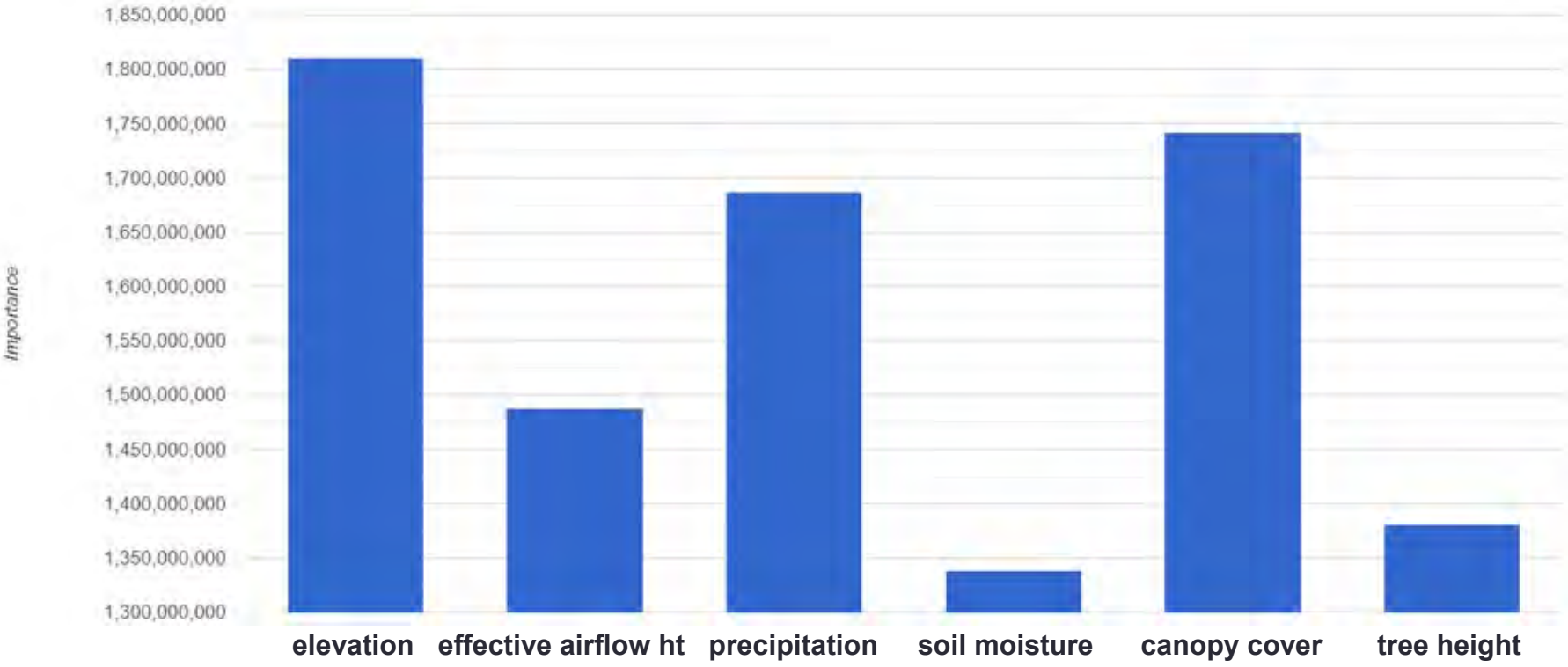
Hurricane Helene

ForestGALES 4-Class Classification



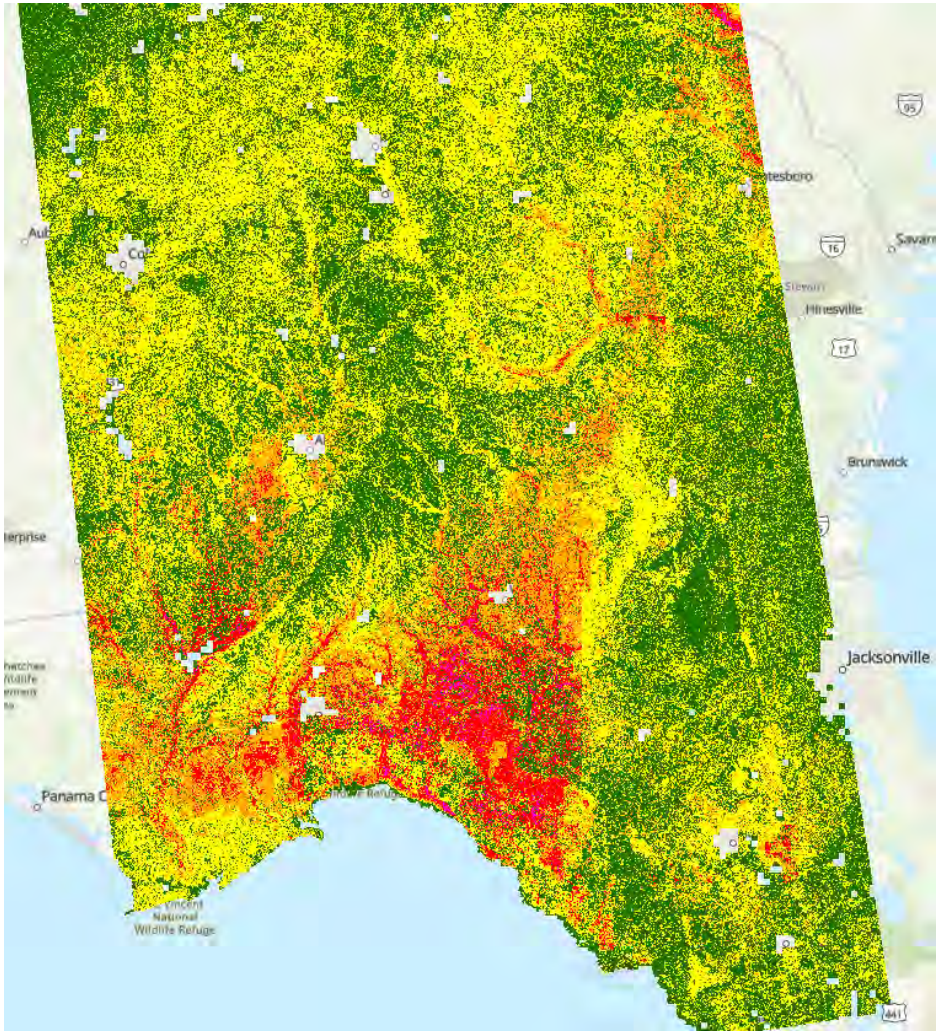
Hurricane Helene

Random Forest Model Variable Importance



Hurricane Helene

Random Forest 4-Class Classification



Hurricane Helene

Questions / Comments?

Acknowledgements:
Scott Goodrick
Ian Housman
Jonathon Case
Christopher Hain
Robert Vaughan
Bonnie Stine
Brad Quayle
Renee Jacokes
Brenna Schwert
Timothy Love
Haans Fisk