IGARSS 2020 - 2020 IEEE International Geoscience and Remote Sensing Symposium | 978-1-7281-6374-1/20/$31.00 ©2020 IEEE | DOI: 10.1109/IGARSS39084.2020.9323391

COMMUNITY REORGANIZATION RESPONSE TO CLIMATE CHANGE: SPECIES INTERACTIONS, STATE-SPACE MODELING AND FOOD WEBS

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ABSTRACT

Based on the data collected on the taxonomically diverse communities monitored in NEON (National Ecological Observatory Network), BBS (Breeding Bird Survey) and FIA (Forest Inventory & Analysis), we have forecasted community change and reorganization resulting from climate change across the coterminous USA. Predictive sensitivity analysis under climate change anticipates community reorganization and the habitats that will be most critical for new species assemblages. Our new semi-automated platform (pbgjam.org) enables revised forecasts as updated climate, remote sensing and biodiversity data come available. Our future work will build upon this modeling and platform by developing a dynamic, bio-physical framework to quantify the environment-species interactions that structure ecological communities and determine how they respond to environmental change.

Index Terms— Biodiversity, Remote Sensing, Climate change, Joint species modeling

1. INTRODUCTION AND METHODS

We have integrated key remote sensing variables with continental scale ecological data to provide broadly accessible ecological forecasts to a user community of ecologists and managers. To determine which species and communities are most vulnerable to climate change and to forecast responses of the entire communities, we have designed and implemented a forecasting framework and software that synthesizes National Ecological Observatory Network (NEON), Breeding Bird Survey (BBS), and Forest Inventory Analysis (FIA) data and related physical and biological data with remotely sensed information. Addressing the deficiencies inherent in single-species distribution models, we have developed a generative model of community response to climate change that accurately predicts distribution and abundance of each species jointly as well as their organization in communities [1]. Joint analysis has allows substantial improvement in community predictions by synthesizing directly with biodiversity abundance data such ecosystem properties as canopy density and structure, productivity, surface heat exchange, fragmentation and disturbance.

Satellite imagery characterizes habitat with temporal, spatial, multispectral detail that goes well beyond that available from interpolated climate data and land cover/use maps. We have tested our model for different communities with a range of remotely sensed products including, MODIS Vegetation Indices, Continuous Land Surface Temperature, Evapotranspiration, TRMM Precipitation, and SMOS Soil Moisture as well as soils and topography. We also developed models based on geospatial predictors to model current and projected future climates that included land cover, elevation, soils and climate data. Unique predictors were selected for each species group based on model performance.

As part of this analysis, we have extended the predictive modeling to explore fine scale ecosystem attributes from data currently being acquired for NEON sites by the airborne observation platform (AOP) which include waveform and discrete lidar and hyperspectral information from JPL's airborne imaging spectrometer [2]. We have determined fine scale ecosystem attributes are represented at the regional scale with Landsat and MODIS products.

2. RESULTS

We have successfully linked broad biodiversity data networks (i.e. NEON, FIA, BBS) to the rich time series of regional NASA and other geospatial products to improve predictions and understanding of spatial-temporal distributions of ecological communities. Our developed tool enables selection and retrieval of key remotely-sensed products (e.g. MODIS, TRMM, SMOS) via Python-Google Earth Engine, selection of publicly available biodiversity data (e.g. from NEON) or user upload, parameterization of the model and display and download of model output. We have produced models for the present, for two climate scenarios (CMIP5, RCP 4.8 and 8.5), and for two time periods (2040-2069, 2070 – 2099). The tool enables non-modelers and modelers alike to interact with the spatial and temporal predictions as well as with detailed model output of communities and individual species of trees, small mammals, breeding birds and carabids (Fig 1a-c).

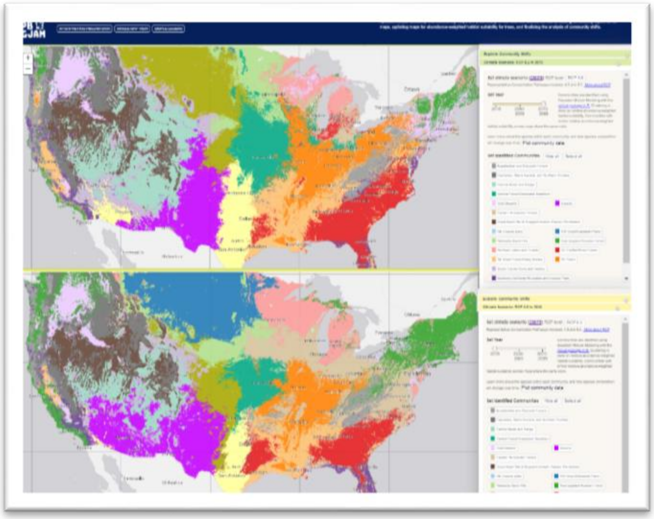

Fig. 1a. Mapping shifts in community habitat suitability.

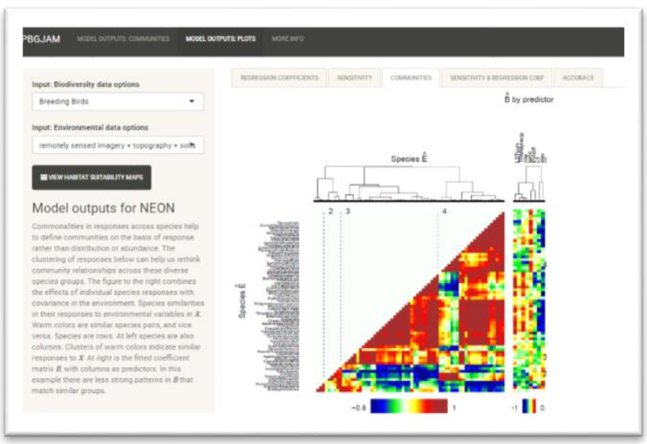

Fig.1b. Model output: Species group community clustering.

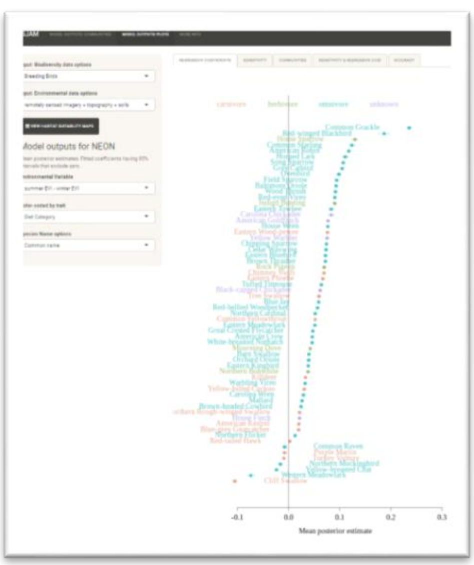

Fig 1c. Model output e.g.: regression coefficients relative to a single predictor, color-coded by trait. PBGJAM.org

3. DISCUSSION AND FUTURE WORK

Observational studies have not yet convincingly shown that climate gradients determine the non-linear and interaction responses observed across continents. The experiments that would be needed to dissect biotic versus climatic contributions to community composition may never be feasible. We hypothesized that communities that are dominated by interactions between species will respond to both fast disturbance and slow climate change in ways that are non-linear, unpredictable, and hard to attribute to any specific cause. Conversely, the non-linear and interaction patterns in species abundances that are commonly observed in nature need not signal non-linear effects of the environment. Instead, these patterns are induced by the combined interactions of species and environment.

To quantify their effects, we are developing a dynamic, bio-physical framework to quantify the environment-species interactions that structure ecological communities and determine how they respond to environmental change. We embedded species interactions with one other and environmental change within spatio-temporal (state-space) model implemented at the regional scale [3]. Analytical analysis demonstrates how non-linear species responses can be induced by species interactions, without non-linear effects of environment. Simulation studies demonstrate how effects of environment on movement and population growth combined with species interactions must each be included in the model to lead to accurate interpretation. Applications to food-web time series show contrasting contributions of species- and environment interactions that agree with intuition on where these effects should dominate [3]. We anticipate analyzing NEON biodiversity trends, and producing indices of ecosystems that characterize community and physical habitat structure, energy flow, herbivore food webs, and their vulnerability to climate change by drought stress [4].

Building upon the pbgjam.org mapping and statistical modeling interface (i.e. gjam and mastiff [5]), we will create a web visualization portal that provides display and interaction with model results as well as visualization of biodiversity trends. The three elements lead from canopy characterization to mast production by individual trees to continent al scale prediction of mast and the consumers that depend on it, jointly as a community.

4. REFERENCES

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