EARTH & ENVIRONMENTAL SCIENCES

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Surrogate modeling for E3SM wildfire activity with deep neural network

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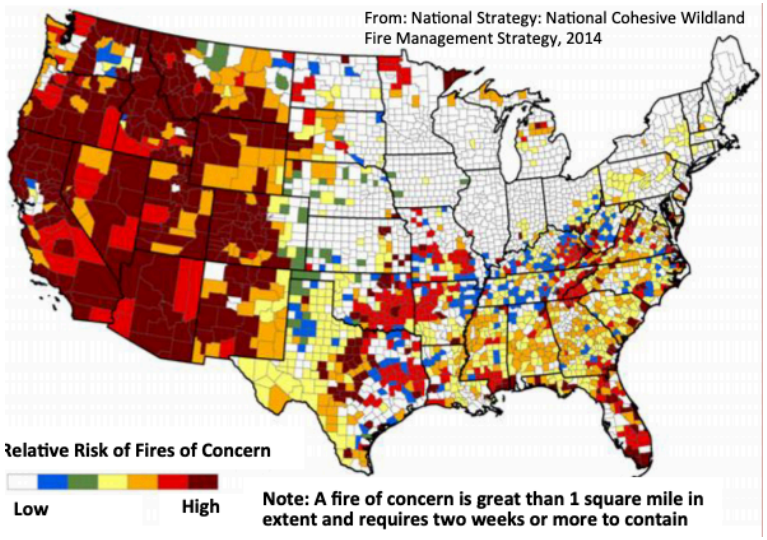
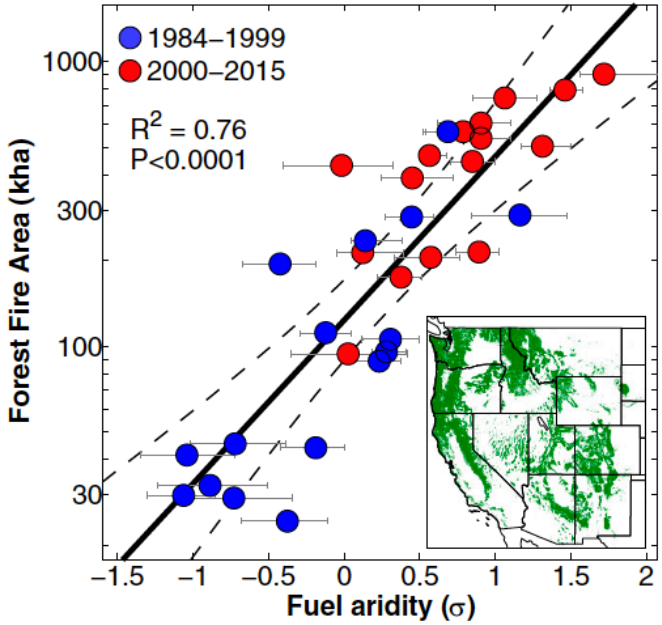


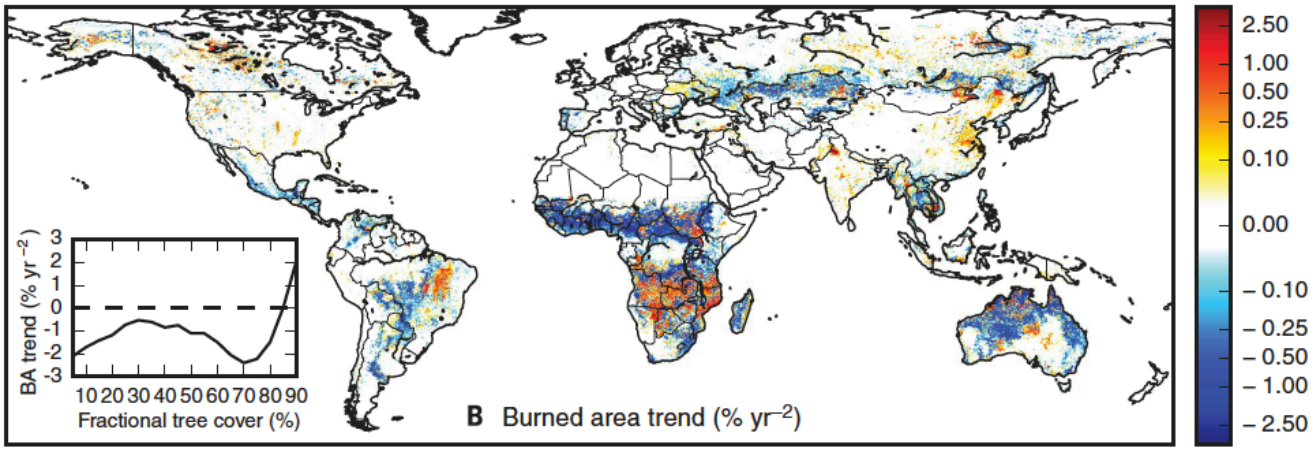
NOAA



Drier climate

Higher fire risk

Abatzoglou 2016



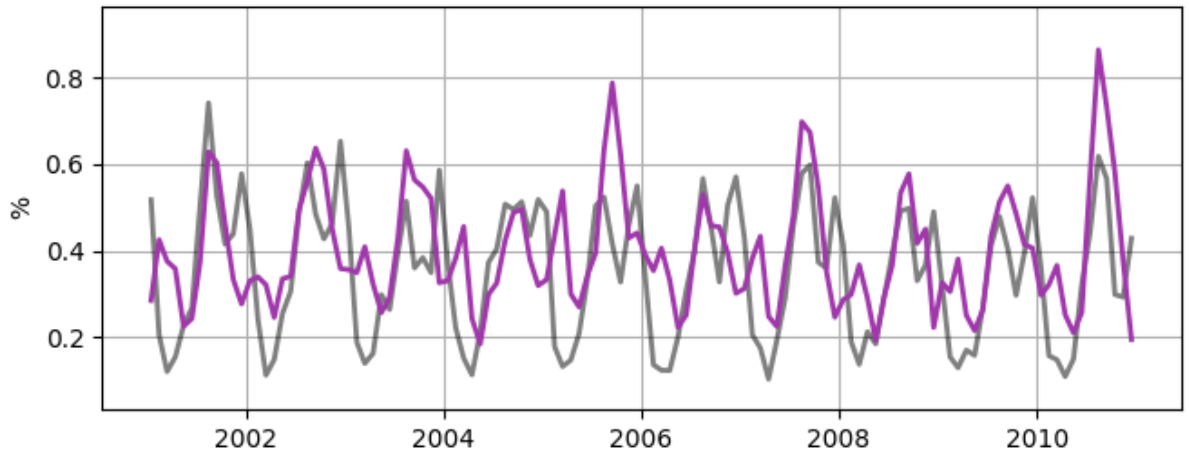
Denser population

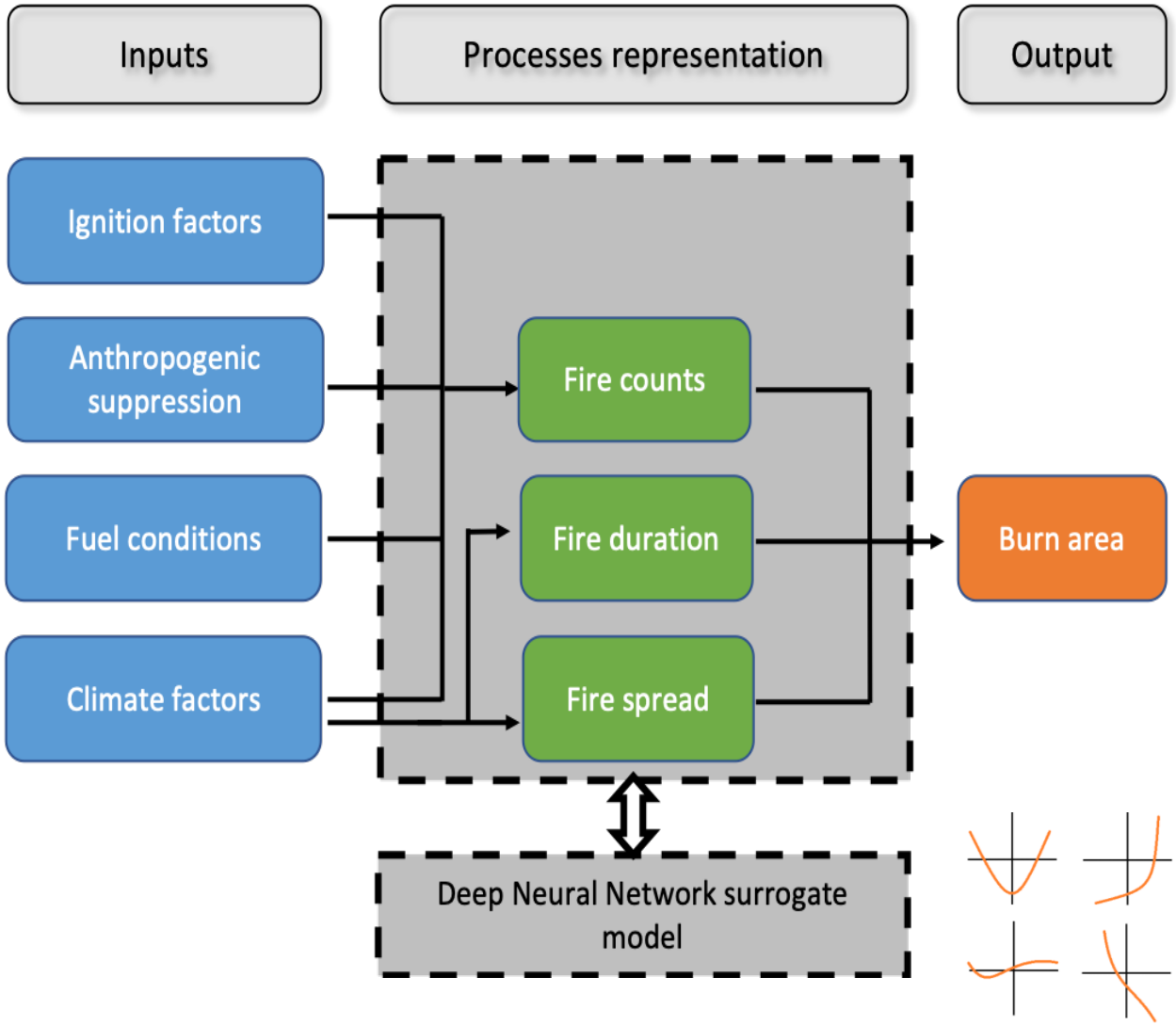
Lower burn area

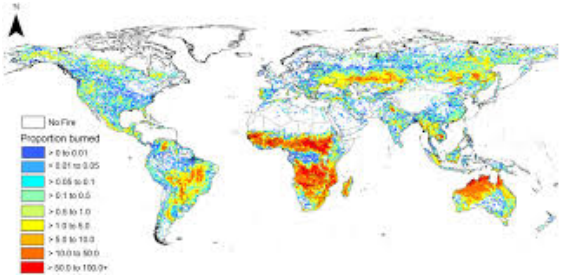
Andela 2017

Science Questions

- How accurate is the current E3SM fire model in simulating burn area?
- How could machine learning help improve fire model?

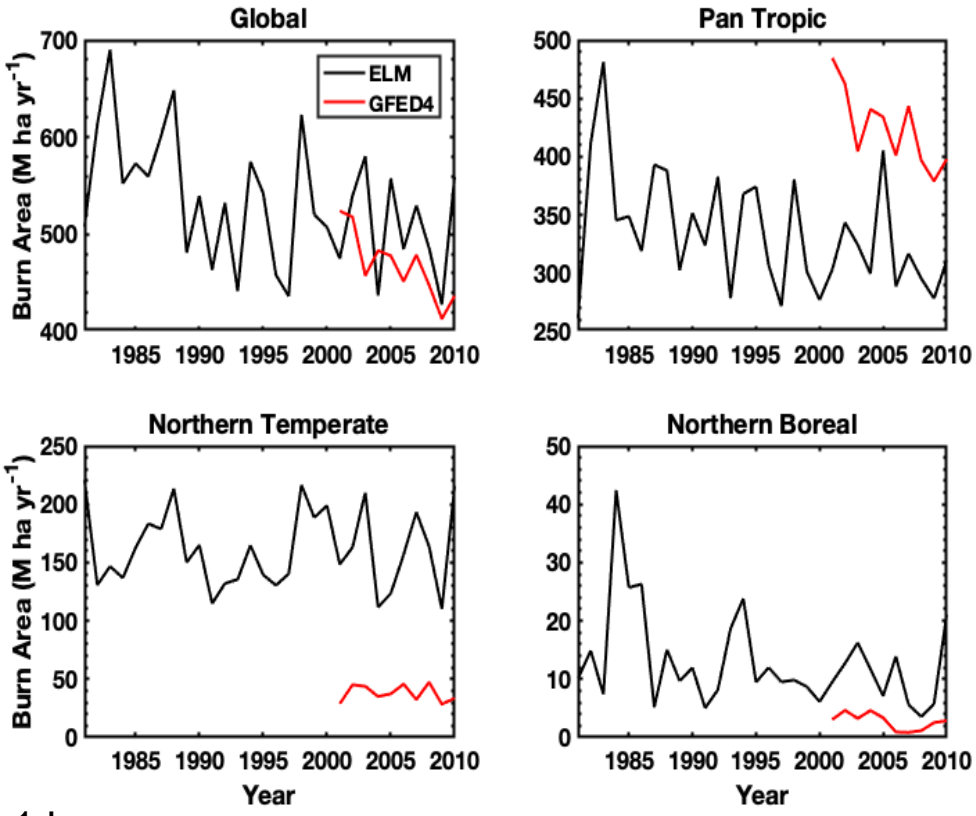



Inputs
Processes representation
Output
Ignition factors
Anthropogenic suppression
Fuel conditions
Climate factors
Fire counts
Fire duration
Fire spread
Burn area
Deep Neural Network surrogate model



Development of a Machine Learning Fire Model in E3SM

1



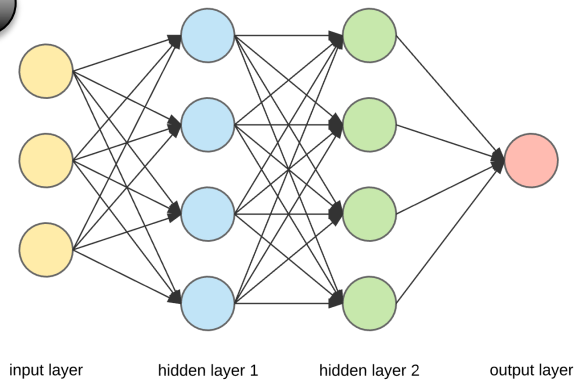
- ~ 500 Mha yr-1 burn area
- Declining trend of burn area
- Underestimate tropical fire burn area
- Overestimate temperate and boreal fire burn area

Development of a Machine Learning Fire Model in E3SM

2

BONA	Boreal North America	NHAF	Northern Hemisphere Africa
TENA	Temperate North America	SHAF	Southern Hemisphere Africa
CEAM	Central America	BOAS	Boreal Asia
NHSA	Northern Hemisphere South America	CEAS	Central Asia
SHSA	Southern Hemisphere South America	SEAS	Southeast Asia
EURO	Europe	EQAS	Equatorial Asia
MIDE	Middle East	AUST	Australia and New Zealand

3



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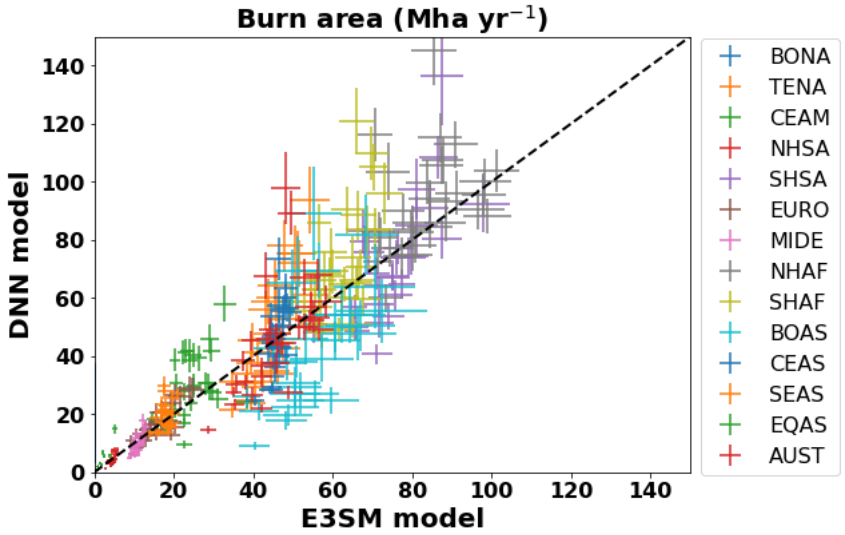

Pearson correlation p= 0.91
Coefficient of determination R^2= 0.79
MAE: 8 Mha yr-1 averaged over 14 GFED regions

Development of a Machine Learning Fire Model in E3SM

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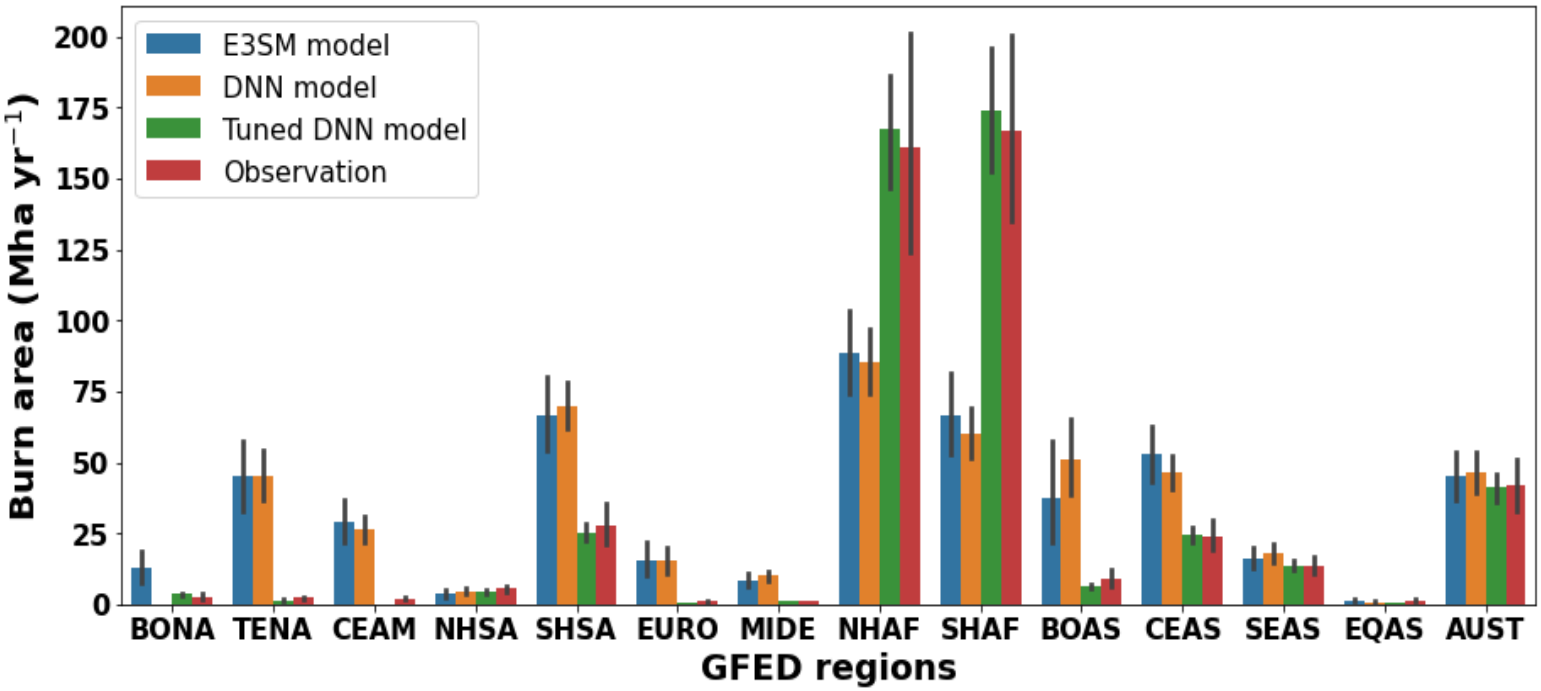

- Fine tune surrogate model with GFED burn area observations 2001-2010
- MAE reduction ~ 90%
- Parameterization time ~ minutes (compared with traditional parameterization ~ days-months)

Development of a Machine Learning Fire Model in E3SM

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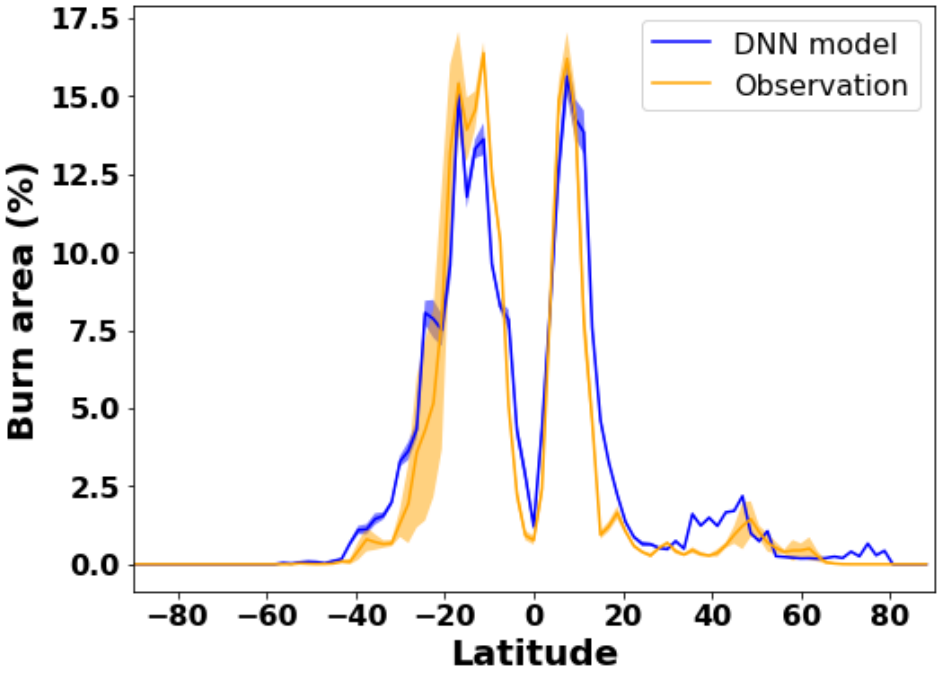


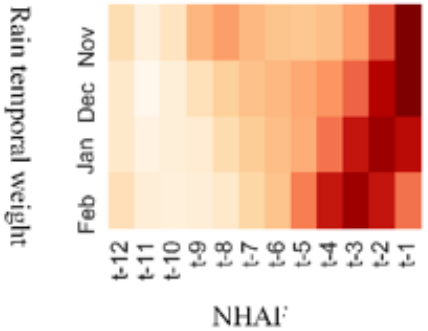
- Prognostic simulation of surrogate model during 2011-2015
- Latitudinal distribution of modelled and observed burn area
- Two peaks correspond to Southern Hemisphere Africa, and Northern Hemisphere Africa

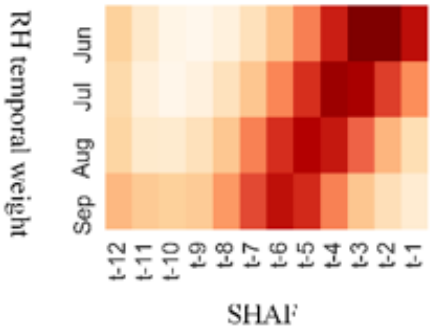
summary

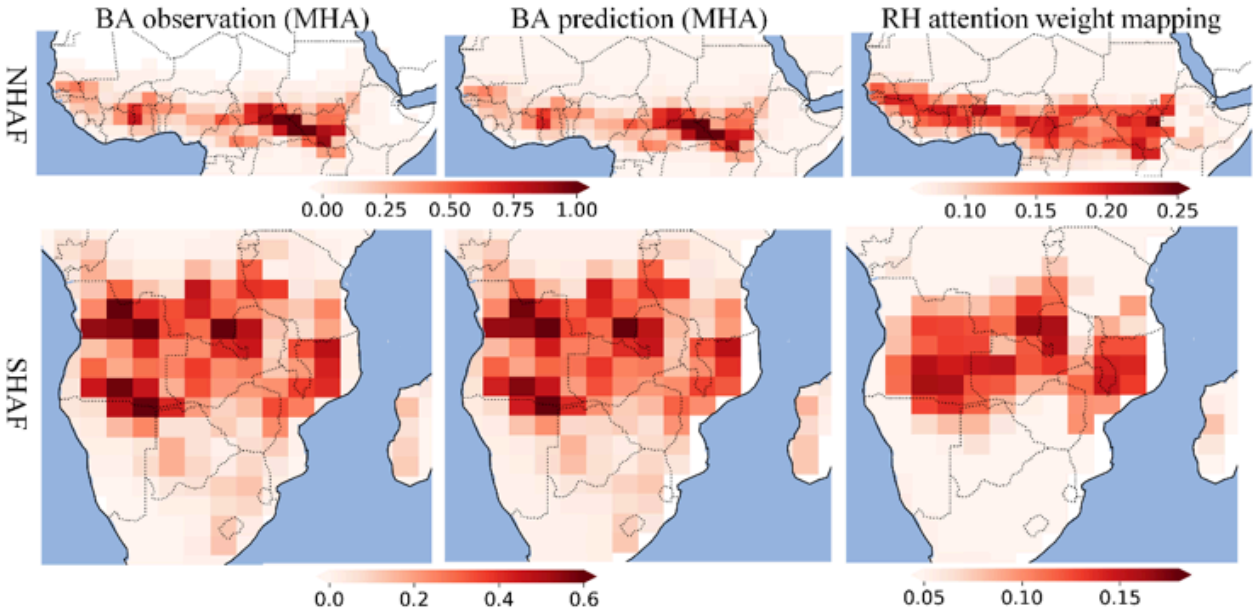
- The DNN model reproduced the original E3SM wildfire behavior with high accuracy.
- The fine-tuned DNN wildfire model was significantly improved over the 14 GFED regions.
- Fine tune cost 99% less computational time, achieved 90% higher accuracy
- The improved DNN also generalized well that it prognostically simulated 2011-2015 global burn area
- DNN model could serve as an alternative wildfire model coupled in E3SM (fast, accurate, flexible)

Ongoing & Future work

Spatial-temporal attention capability

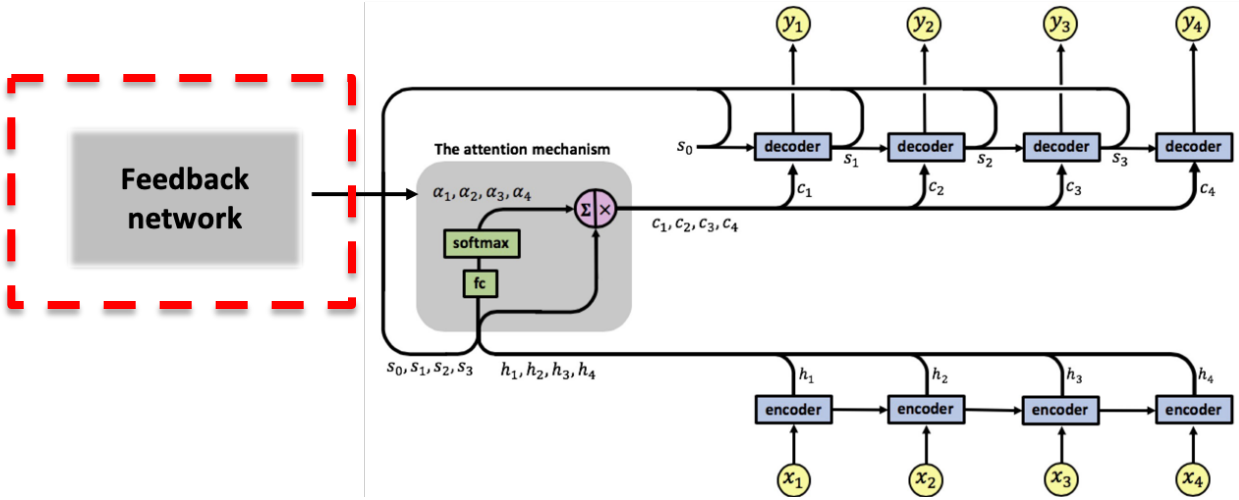






Ongoing & Future work

Physically constrained neural network



$$Loss = \frac{1}{N}\sum_{t=1}^{N}(y_t^o - y_t)^2 + \lambda \sum_{t=1}^{N}\sum_{i=1}^{M} TE\alpha^i \log\frac{TE\alpha^i}{\alpha_t^i}$$

Thanks!