EARTH & ENVIRONMENTAL SCIENCES

BERKELEY LAB
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Wildfire modeling with E3SM and machine learning techniques

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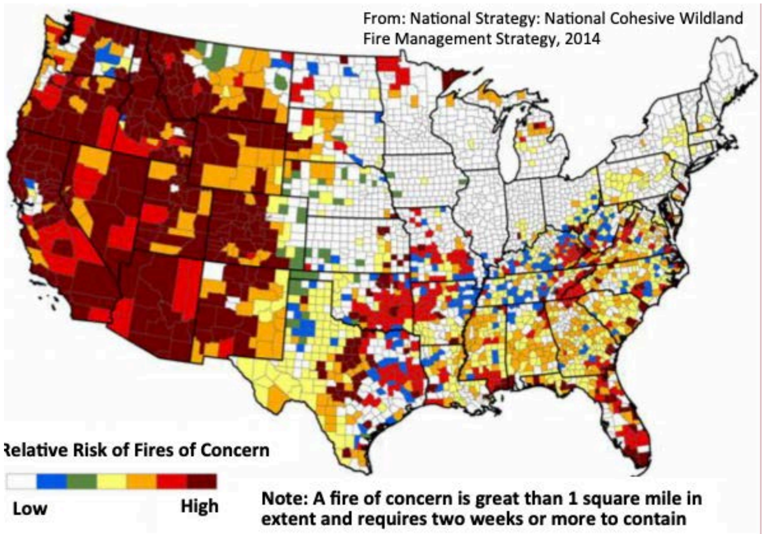
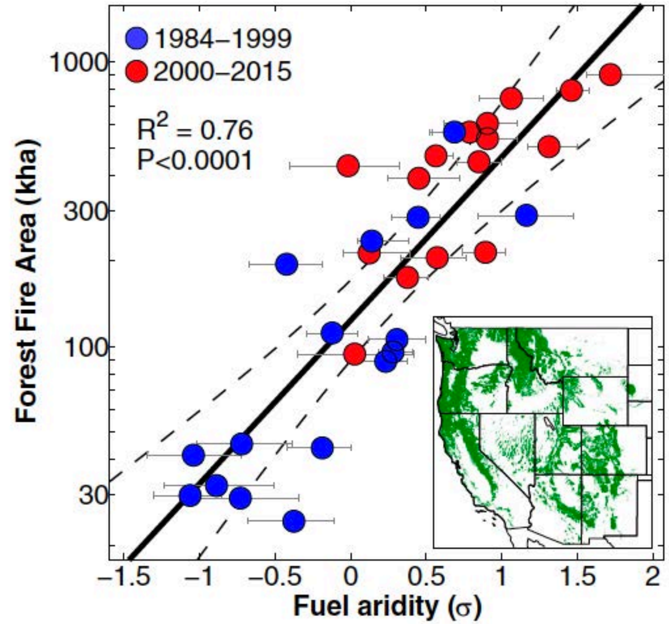


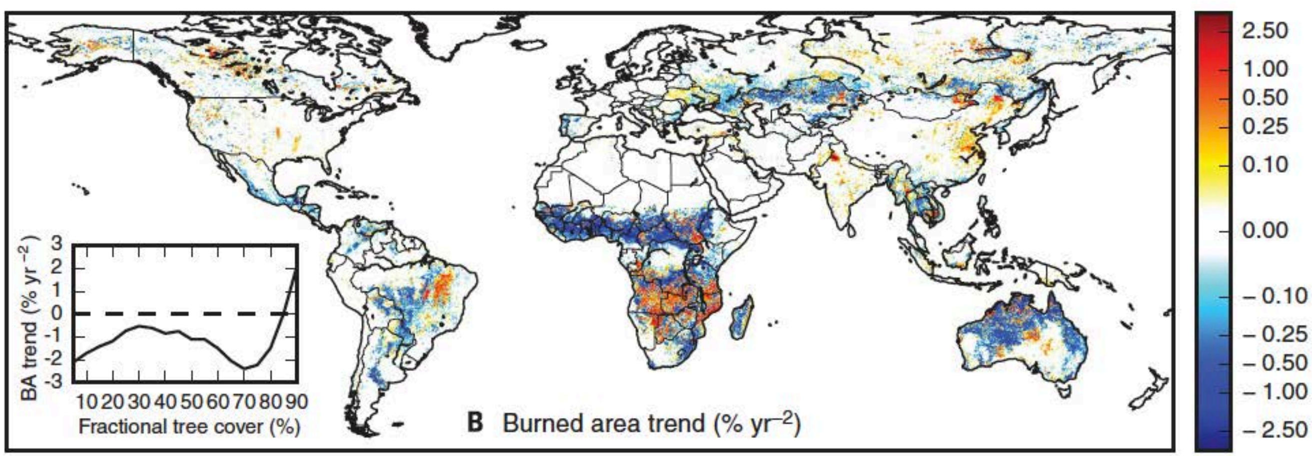
NOAA



Abatzoglou 2016

Drier climate

Higher fire risk



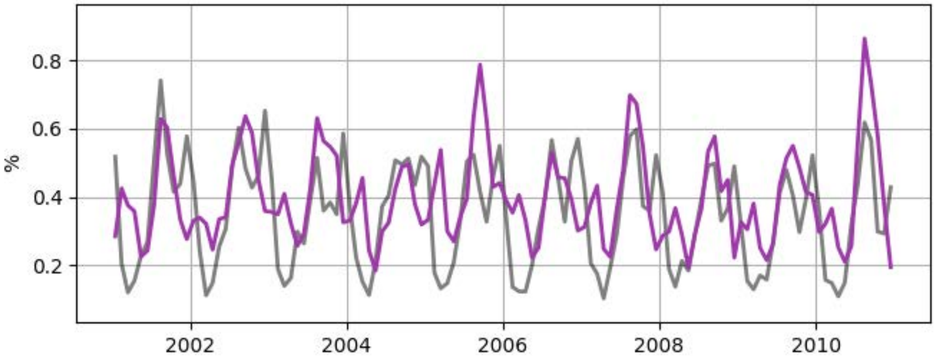
Denser population

Lower burn area

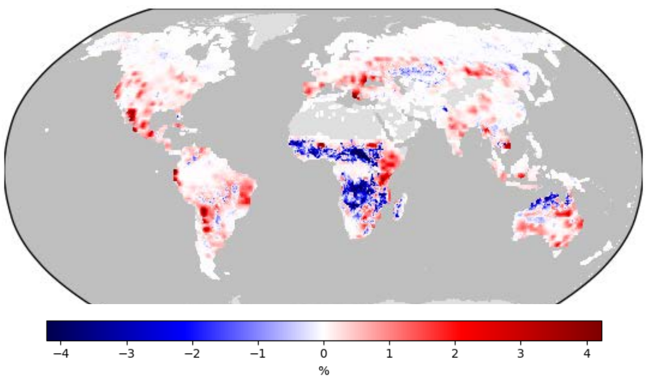
Andela 2017

Science Questions

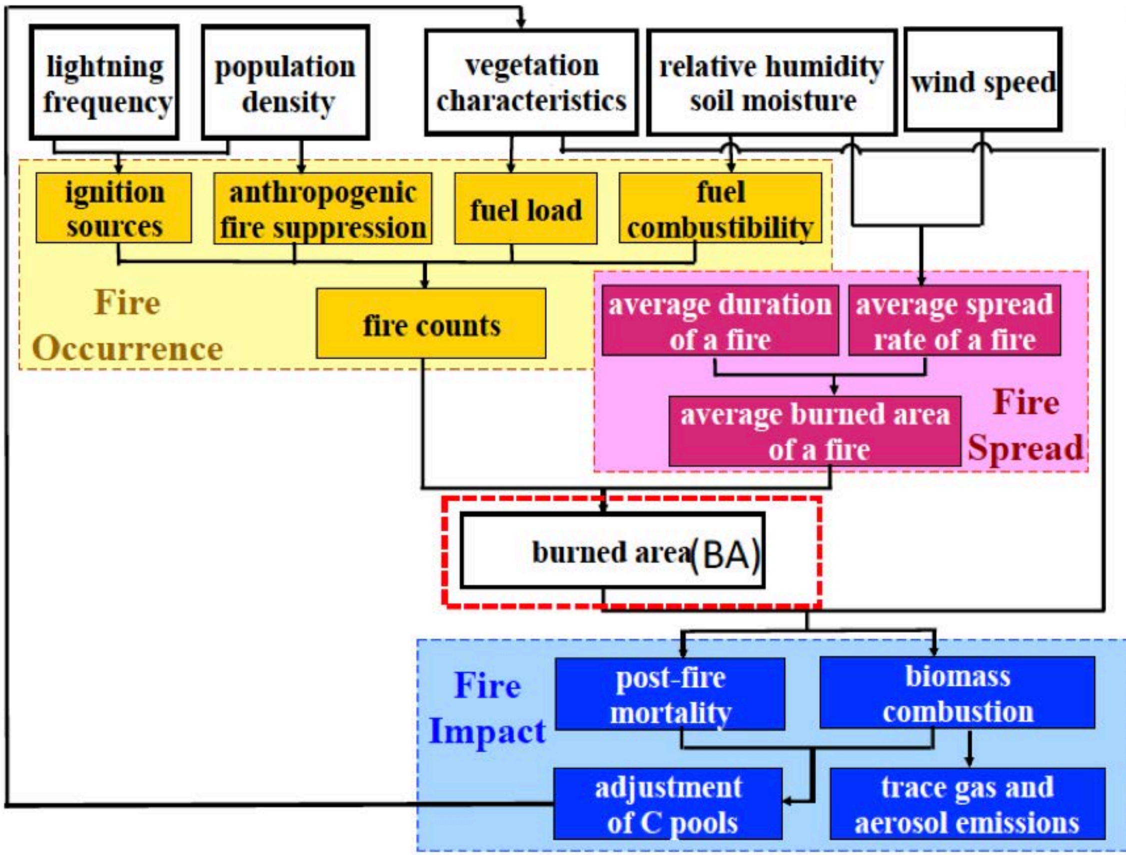
- How accurate is the current E3SM fire model in simulating burn area?
- How could machine learning help fire model parametrization?

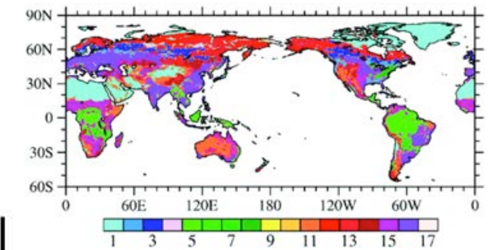


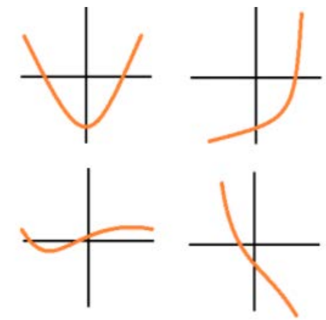
BIAS



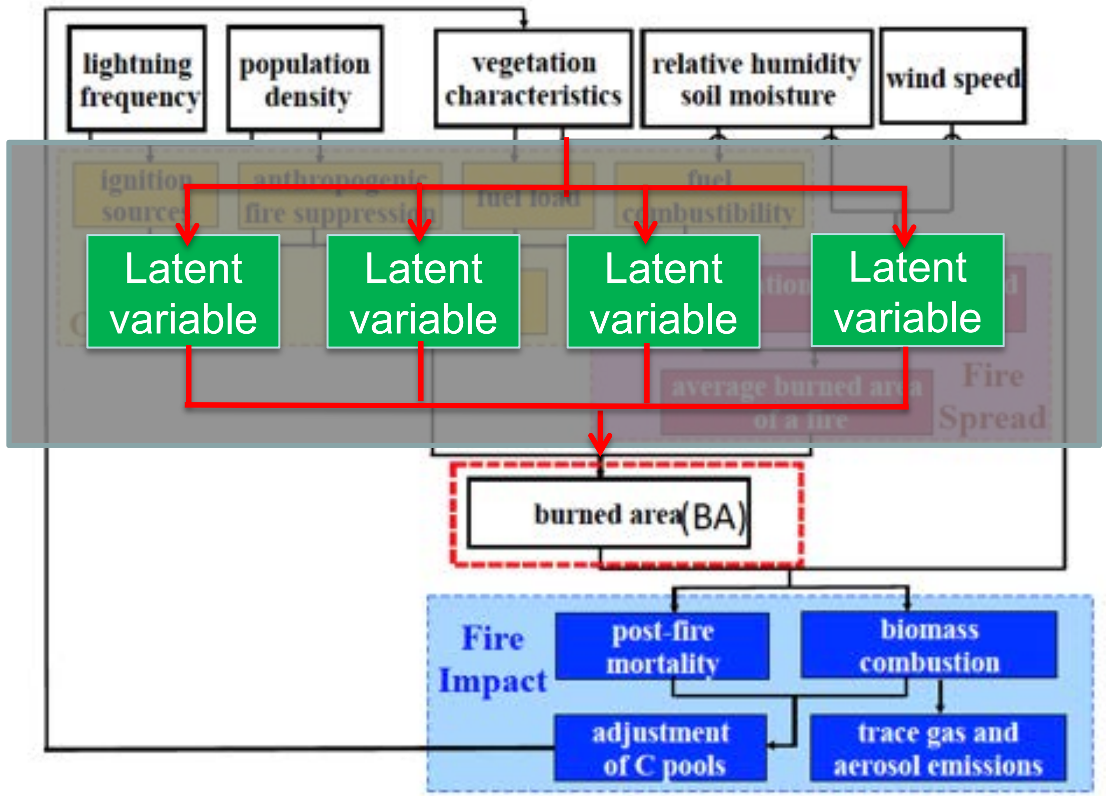
E3SM fire model



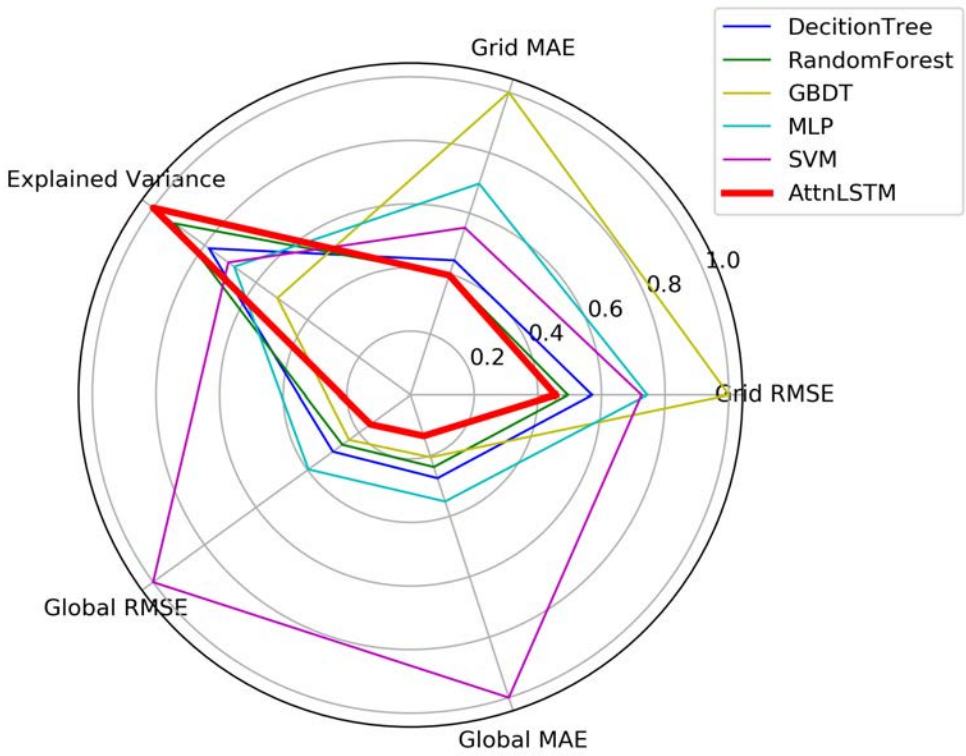


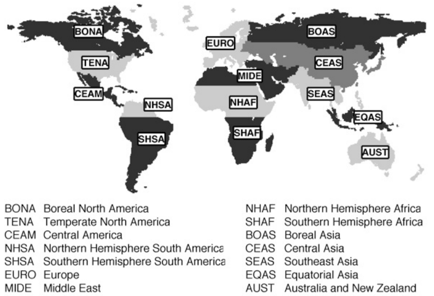


Development of a Machine Learning Fire Model in E3SM



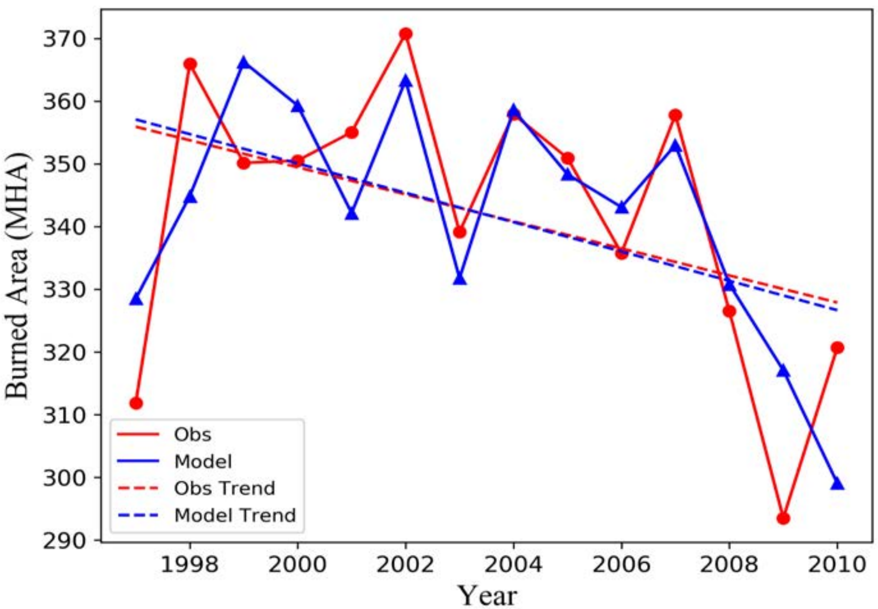
BONA Boreal North America
TENA Temperate North America
CEAM Central America
NHSA Northern Hemisphere South America
SHSA Southern Hemisphere South America
EURO Europe
MIDE Middle East
NHAF Northern Hemisphere Africa
SHAF Southern Hemisphere Africa
BOAS Boreal Asia
CEAS Central Asia
SEAS Southeast Asia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

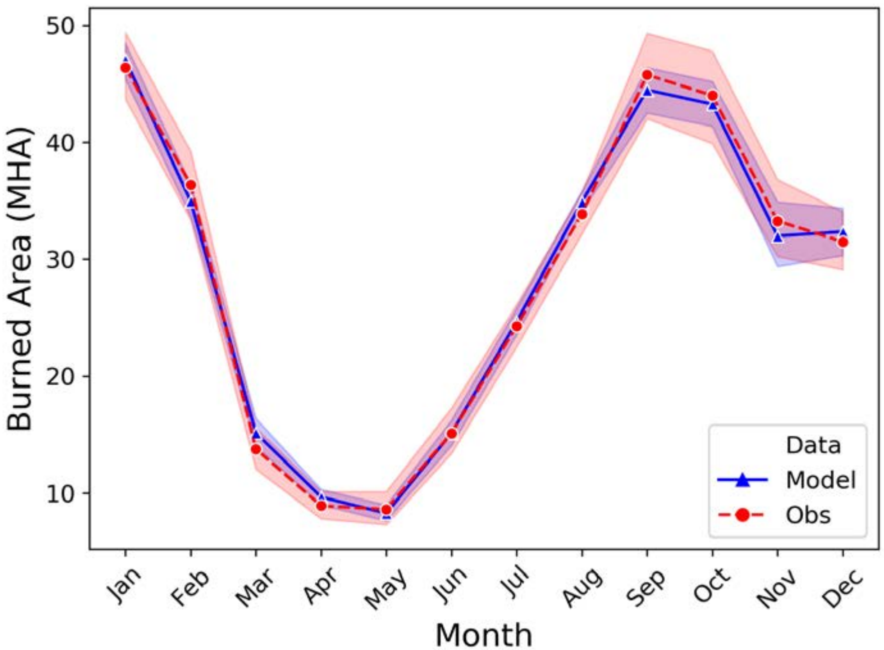




Model	Grid RMSE	Grid MAE	Global RMSE	Global MAE	Global Explained Variance
DecitionTree	0.064337	0.00897	27.282946	24.113867	0.618629
RandomForest	0.055752	0.008004	23.945963	20.859749	0.724087
GBDT	0.112835	0.020174	21.605206	18.018206	0.408553
MLP	0.083888	0.014080	35.889773	30.894498	0.541029
SVM	0.081880	0.011141	90.508528	87.970343	0.55925
AttnLSTM	0.051353	0.007965	14.100684	11.831382	0.790124

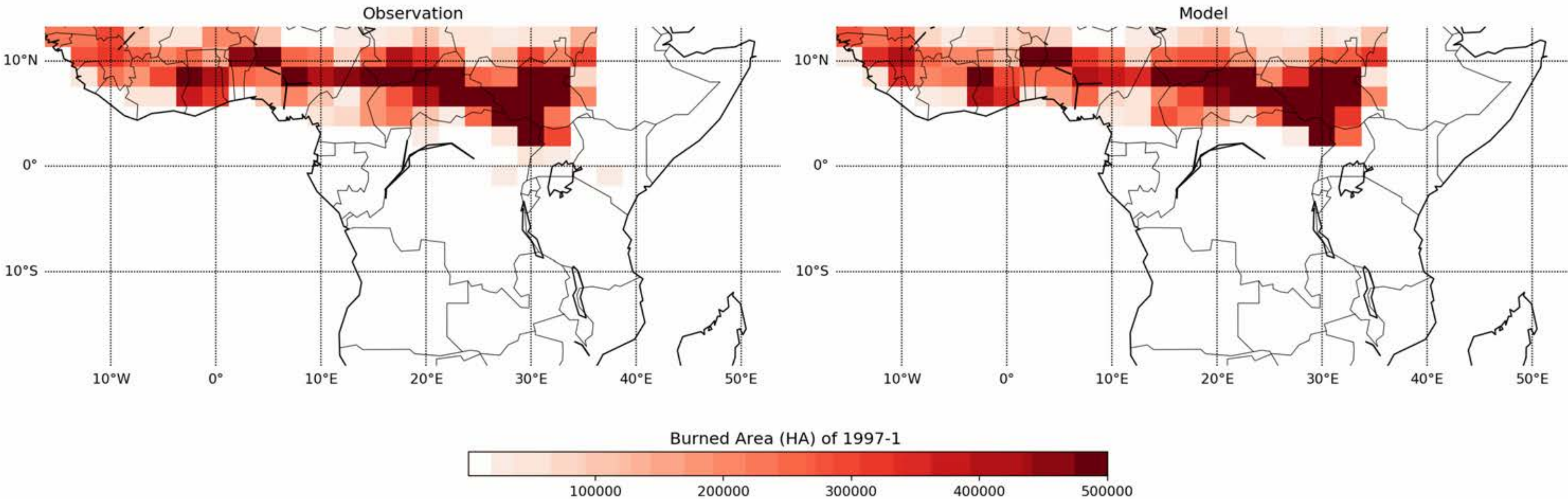
Development of a Machine Learning Fire Model in E3SM



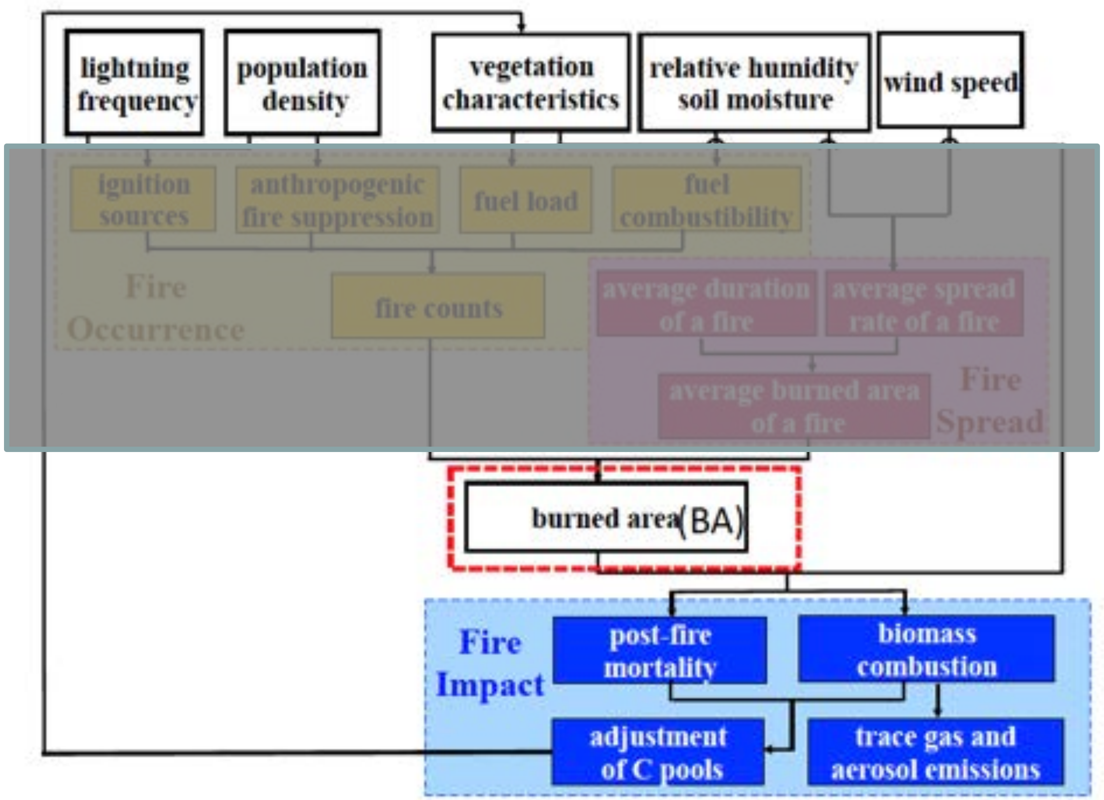


Critical fire zone

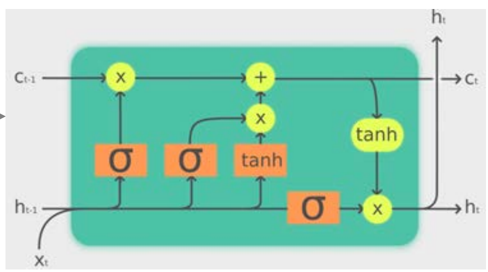
BONA	Boreal North America	NHAF	Northern Hemisphere Africa
TENA	Temperate North America	SHAF	Southern Hemisphere Africa
CEAM	Central America	BOAS	Boreal Asia
NHSA	Northern Hemisphere South America	CEAS	Central Asia
SHSA	Southern Hemisphere South America	SEAS	Southeast Asia
EURO	Europe	EQAS	Equatorial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



Development of a Machine Learning Fire Model in E3SM

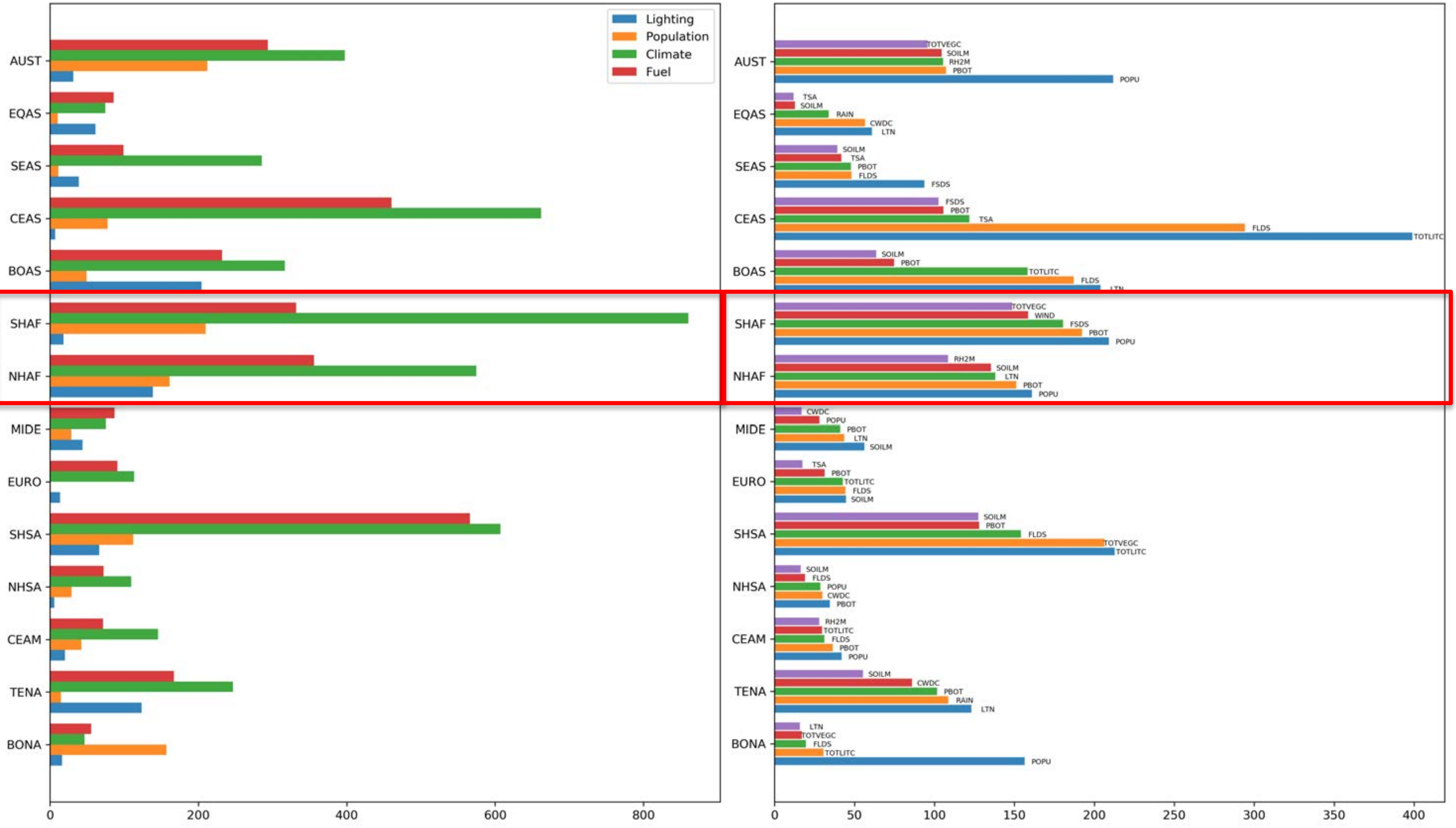


Surrogate fire model using recurrent neural network



Accuracy improvement: **50-90%**

Parameterization time save: **>99%**



Lighting
Population
Climate
Fuel
AUST
EQAS
SEAS
CEAS
BOAS
SHAF
NHAF
MIDE
EURO
SHSA
NHSA
CEAM
TENA
BONA
0
200
400
600
800
TOTVEGC SOILM RH2M PBOT POPU
TSA SOILM RAIN CWDC LTN
SOILM TSA PBOT FLDS FSDS
FSDS PBOT TSA FLDS TOTLITC
SOILM PBOT TOTLITC FLDS
TOTVEGC WIND FSDS PBOT POPU
RH2M SOILM LTN PBOT POPU
CWDC POPU PBOT LTN SOILM
TSA PBOT TOTLITC FLDS SOILM
SOILM PBOT FLDS TOTVEGC TOTLITC
SOILM FLDS POPU CWDC PBOT
RH2M TOTLITC FLDS PBOT POPU
SOILM CWDC PBOT RAIN LTN
LTN TOTVEGC FLDS TOTLITC POPU
0
50
100
150
200
250
300
350
400

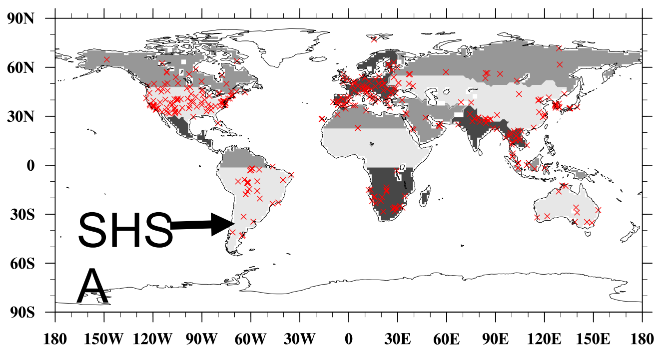
summary

- Machine Learning surrogate fire module produced high accuracy wildfire burned area
- Parameterization time could be reduced from ~weeks to ~minutes
- Powerful analytic capability with Attention mechanism

Simulation experiments

Experiment	Sources of carbonaceous aerosol and sulfate
No fire	Non-fire sources
Org. fire	Non-fire sources + fire emission from the original GFED4s data
Adj. fire	Non-fire sources + fire emission from the optimized GFED4s data

Optimized fire emission



$$AOD_{AERONET} = \beta AOD_{nofire}$$

$$AOD_{AERONET} = \beta AOD_{nofire}$$

$$+ \alpha AOD_{fire}$$

Region	Fire emission scalar (α)
SHSA	2.79

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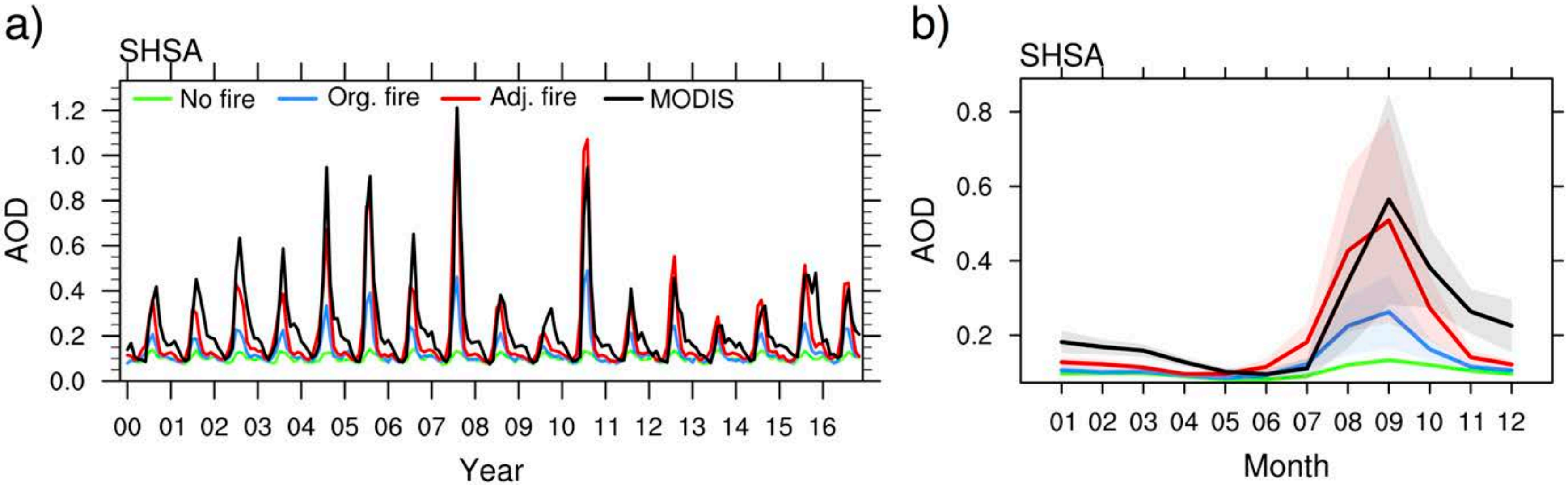
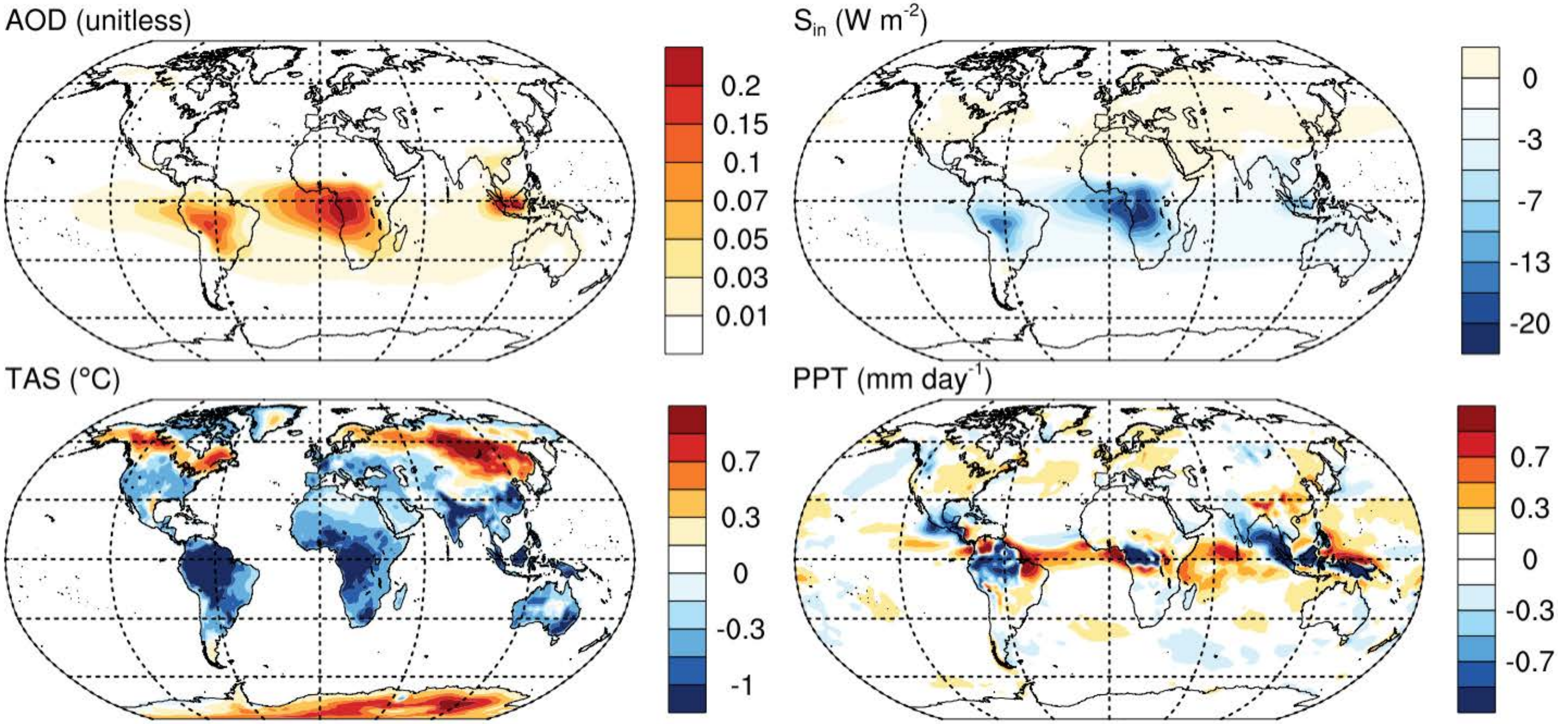
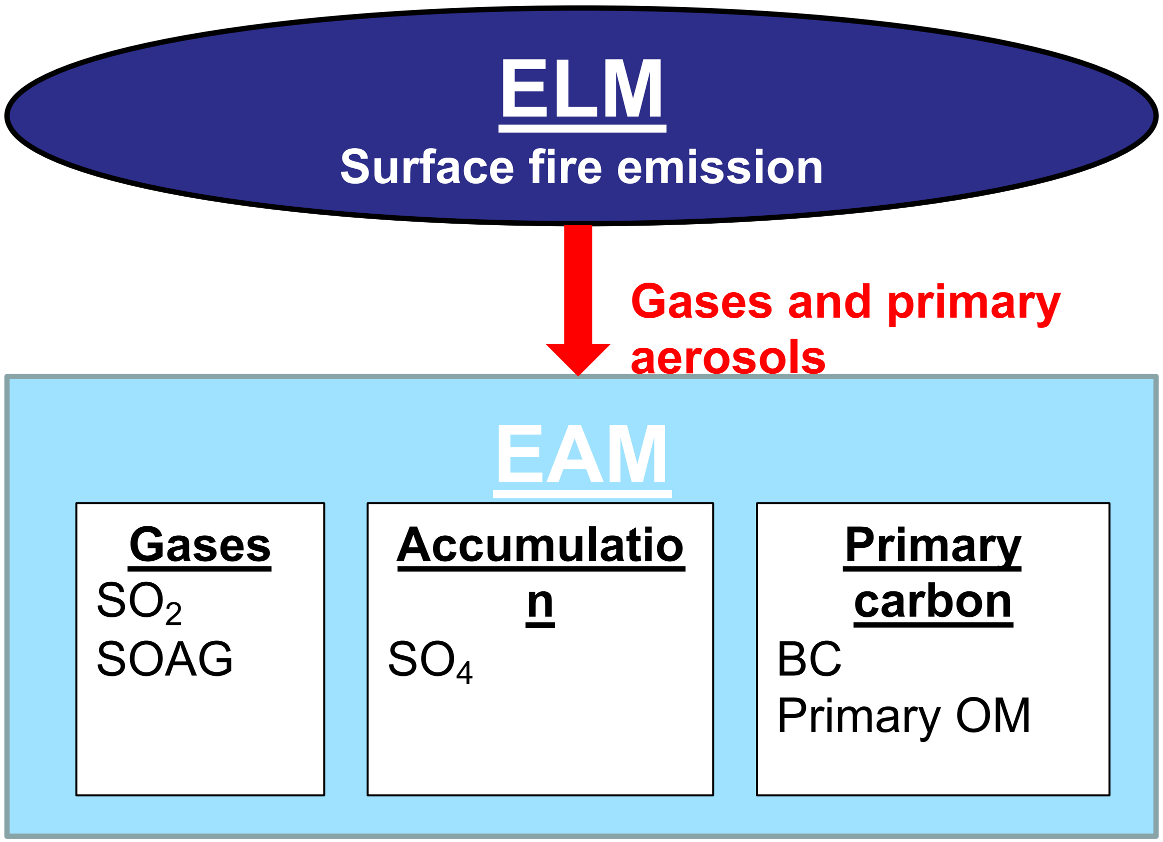
The modeled aerosol optical depth from the optimized fire emission simulation has better agreement with the MODIS AOD



Fire aerosols significantly impact aerosol optical depth, induce strong cooling at surface and cause changes in surface temperature and precipitation, particularly at tropics



Coupled fire emission module in E3SM

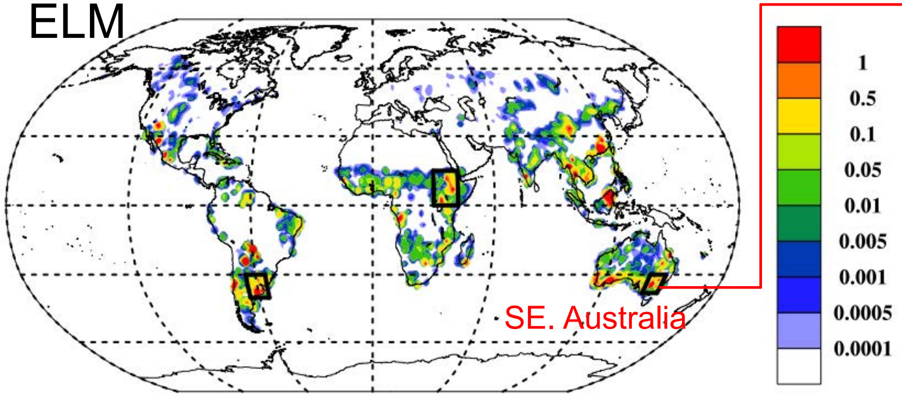


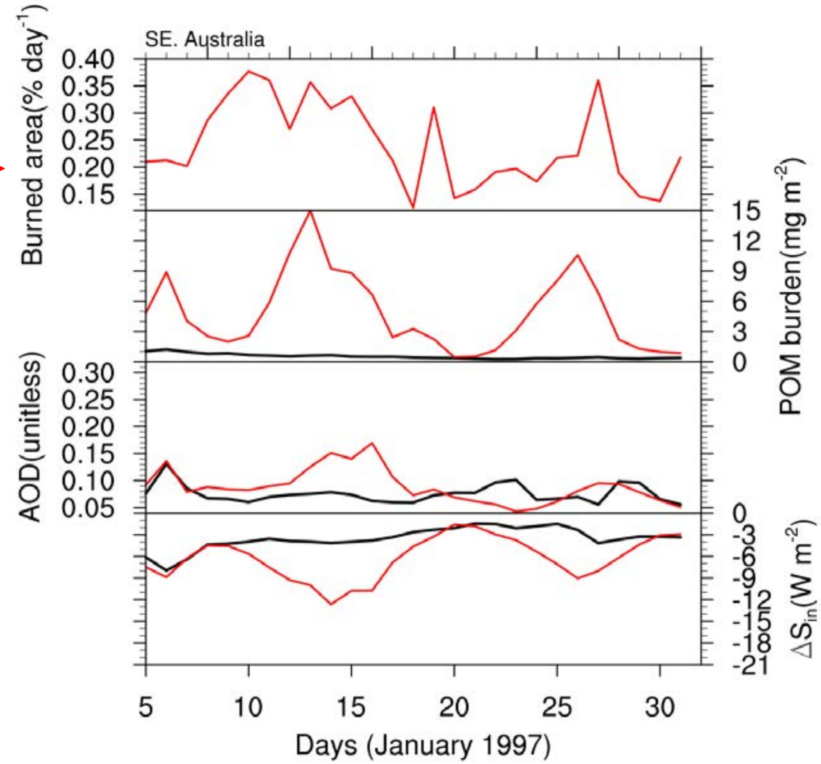
- PFT-dependent emission factor for each species
- Consideration of peat fire emission factor in the equatorial Asia
- Choice of surface or vertical fire emission in EAM

The coupled fire emission simulation

- instantaneously emits the fire-associated carbonaceous aerosols into the atmosphere
- produce a day-to-day variability of aerosol optical depth and aerosol radiative effects

POM fire emission (g m^{-2} $month^{-1}$) from ELM





summary

- Adjusted fire emissions better represent observed AOD during fire peak season in tropical fire regions.
- Fire aerosols induce the strong surface cooling through both scattering and absorption of sunlight.
- Fire-associated aerosols species are instantaneously emitted into the atmosphere.

Thanks!

Model Settings

Model	Settings
Decision Tree	*Minimum leaf sample: [3,6,9]* *Maximum depth: 150*
Random Forest	*Minimum leaf sample: [3,6,9]* *Number of trees: [20,30,40]*
Gradient Boosting Decision Tree (GBDT)	*Learning rate: 0.01* *Maximum depth: [3,4,5]* *Number of trees: 100*
MLP	*Learning rate: 0.001* *Batch size: 32* *Tow hidden layers with 10 and 5 neuro units* *Optimizer: SGD*
SVM	*Maximum iteration: 10,000* *Kernel: [‘rbf’,’linear’]*
AttnLSTM	*Learning rate: 0.001* *Batch size: 32* *Hidden dimension: 16* *Sequence length: 12* *Optimizer: SGD*