Predicting Fire Emissions for S2S Forecasts Using the UFS-Aerosols Model

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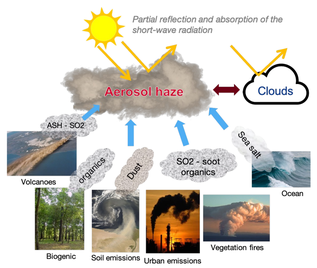
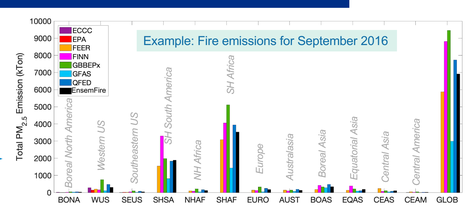
1. Motivation



- Aerosols play an important role in the Earth system. Particles can interact with solar radiation and cloud formation
- Biomass burning emits around 2000 Tg of particles every year into the atmosphere
- **How will fires (and their emissions) evolve in the upcoming days and weeks?**
- Using real-time fire emissions with a "persistence" approach for prediction is suitable for short-term forecasts but not for subseasonal-to-seasonal (S2S) predictions.
- This is particularly important for S2S forecasts where all the Earth system components are considered and alter the forecasts

2. Ensemble Fire Emissions

PROBLEM:
Significant discrepancies exist among different fire emission inventories, leading to high uncertainties and biases in models when relying on a single inventory, including GBBEPx used in UFS forecasts



EnsemFire: Ensemble emissions

- Based on 7 biomass burning inventories to mitigate inventories' discrepancies: ECCC, EPA, FEER, FINN, GBBEPx, GFAS and QFED
- Forecasted emissions:

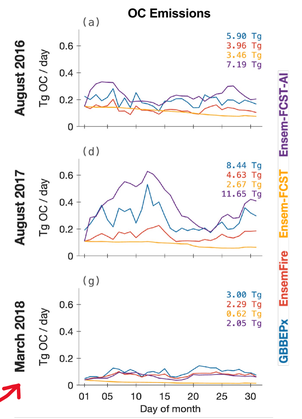
Ensem-FCST

- Based on climatological data and current day fire emissions
- Projection up to 45 days

Ensem-FCST-AI

- LightGBM ML model trained on data from previous years
- Predicts FRP evolution

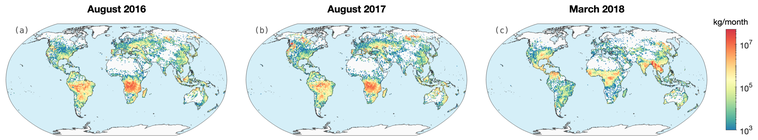
Comparing EnsemFire products to GBBEPx



Modeling setup:
Run UFS-Aerosols (S2SWA) for 3 periods using GBBEPx and EnsemFire products

2. Ensemble Fire Emissions (cont'd)

EnsemFire total OC (kg) emissions per study period



- Intense fire activity in Southern Africa and South America, which is typical for this time of the year
- Fires occurring in the US Pacific Northwest and Siberia
- Multiple regions with small agricultural fires (Southeast US, Eastern Europe, East China)

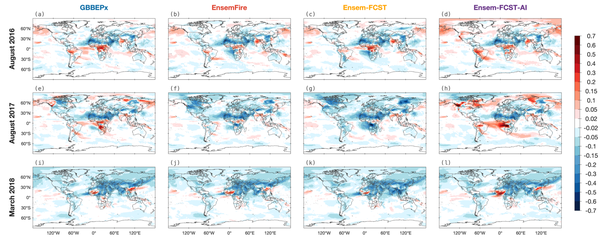
- Fire season in Southern Africa and South America is slightly less active than previous year
- Strong and record-breaking wildfire activity in Canada and Siberia
- Small agricultural fires in same regions from previous year

- At this time of the year, fire activity is typical in Southeast Asia, Sub-Saharan Africa and Central America, although their emissions are much smaller than in Southern Africa and South America in August

3. Modeling Results

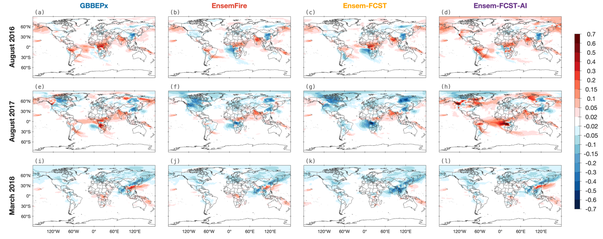
Total AOD 550 nm bias with respect to MERRA-2

- Mixed results in the 3 periods on the performance of EnsemFire and its forecasted products
- We noticed a systematic underestimation of dust produces negative biases in all simulations near dust sources
- Similar results are observed against CAMS reanalysis (not shown)



Fire AOD 550 nm ($OC + BC + SO_4$) bias with respect to MERRA-2

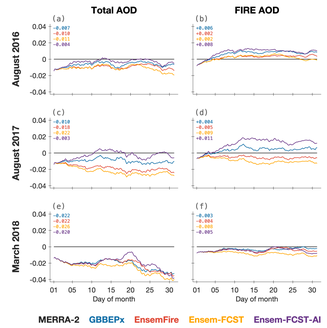
- By isolating fire aerosol effects, we get a clearer and fairer evaluation
- In 2016 and 2018, EnsemFire produces better results than GBBEPx, but the opposite is true in 2017, because EnsemFire emissions are much lower than GBBEPx for this period (2017)
- Ensem-FCST tends to extinguish the fires in time, resulting in underestimations



- Ensem-FCST-AI produces higher emissions than the other products, thus, producing overestimations. This is something that we are currently investigating and tunning the ML to produce better results
- Note that August 2017 had massive wildfires in British Columbia, Canada, that injected smoke up to 20 km. Since UFS-Aerosols does not include a plume rise process, all the emissions are distributed within the boundary layer. This produces downwind underestimations of smoke and overrepresentation of AOD near the fire source
- The lack of a plume rise process in UFS-Aerosols makes the evaluation of the emission inventories more challenging

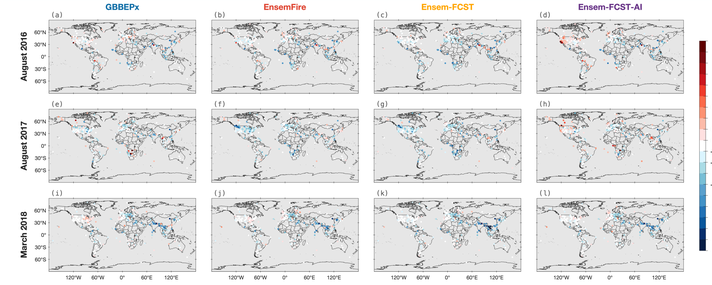
3. Modeling Results (cont'd)

Evolution of biases with respect to MERRA-2

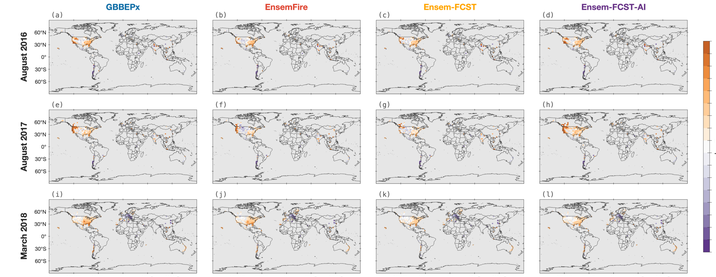


- Globally, GBBEPx and EnsemFire products underestimate total AOD, with March 2018 showing an even greater underestimation
- When considering only Fire aerosol related AOD, results vary depending on the period
- EnsemFire tends to underestimate Fire aerosol related AOD, but with mixed results depending on the period
- For example, globally, EnsemFire performs better than GBBEPx in August 2016, but this is not the case in August 2017, since EnsemFire produces significant lower emissions than GBBEPx
- Note that these are global averages, and for the case of total AOD (left column) the data has signal from the widespread underestimations of dust AOD

AOD 550 nm Bias against AERONET sites



$PM_{2.5}$ bias ($\mu g\ m^{-3}$) against OpenAQ stations



TAKE-HOME MESSAGES

- Fire emission inventories have significant discrepancies among them. EnsemFire aims to provide emissions that consider a wide range of inventories can be reduced the uncertainties and used for ML/AI training
- In operational S2S forecasts, predicting fire emissions is challenging due to their chaotic nature. The statistical method (Ensem-FCST) relies on climatology and current day fire emission to predict fire emissions in time, while Ensem-FCST-AI uses the LightGBM ML model that accounts several meteorological variables and FRP. However, none of those methods consider the ignition of new fires
- The lack of a plume rise process in UFS-Aerosols makes more challenging the evaluation of these inventories