Characterizing continental-scale tropospheric mean OH trends in CESM2-WACCM6 climate model

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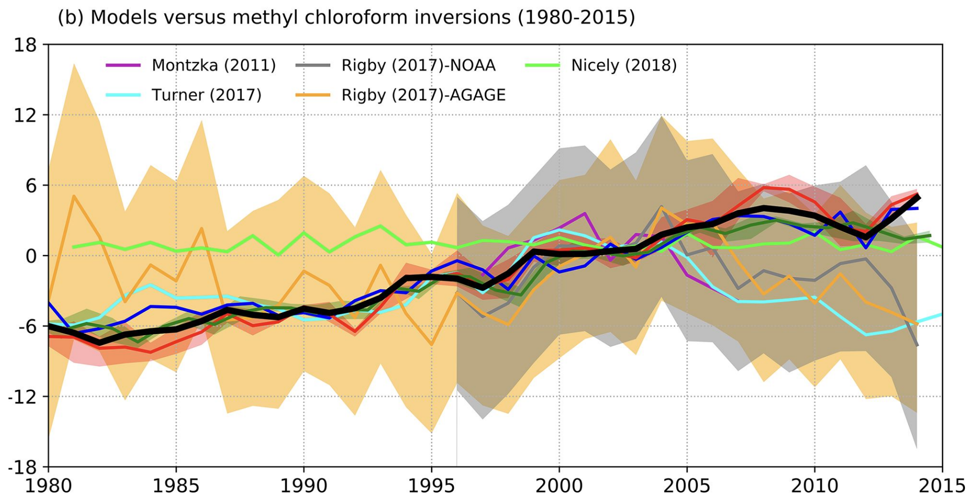
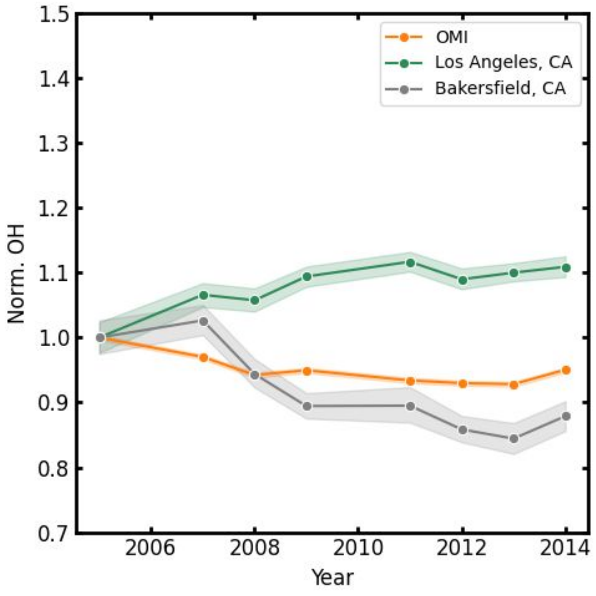
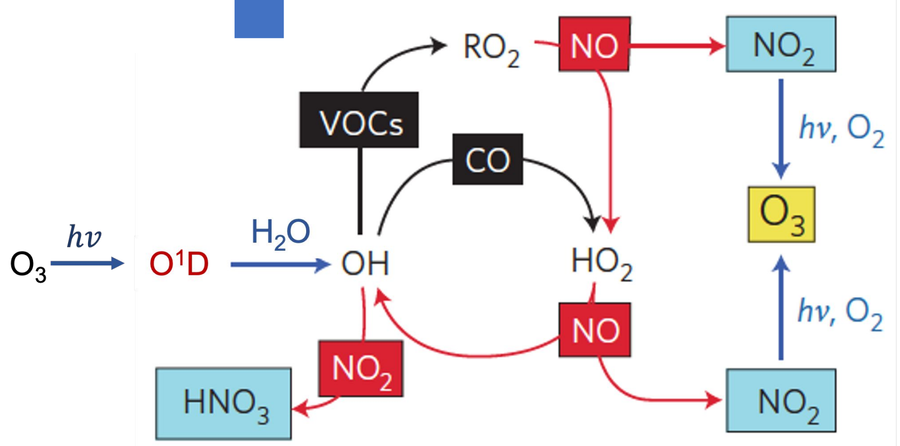
Understanding OH trends at various spatial scales



Stevenson et al., 2020

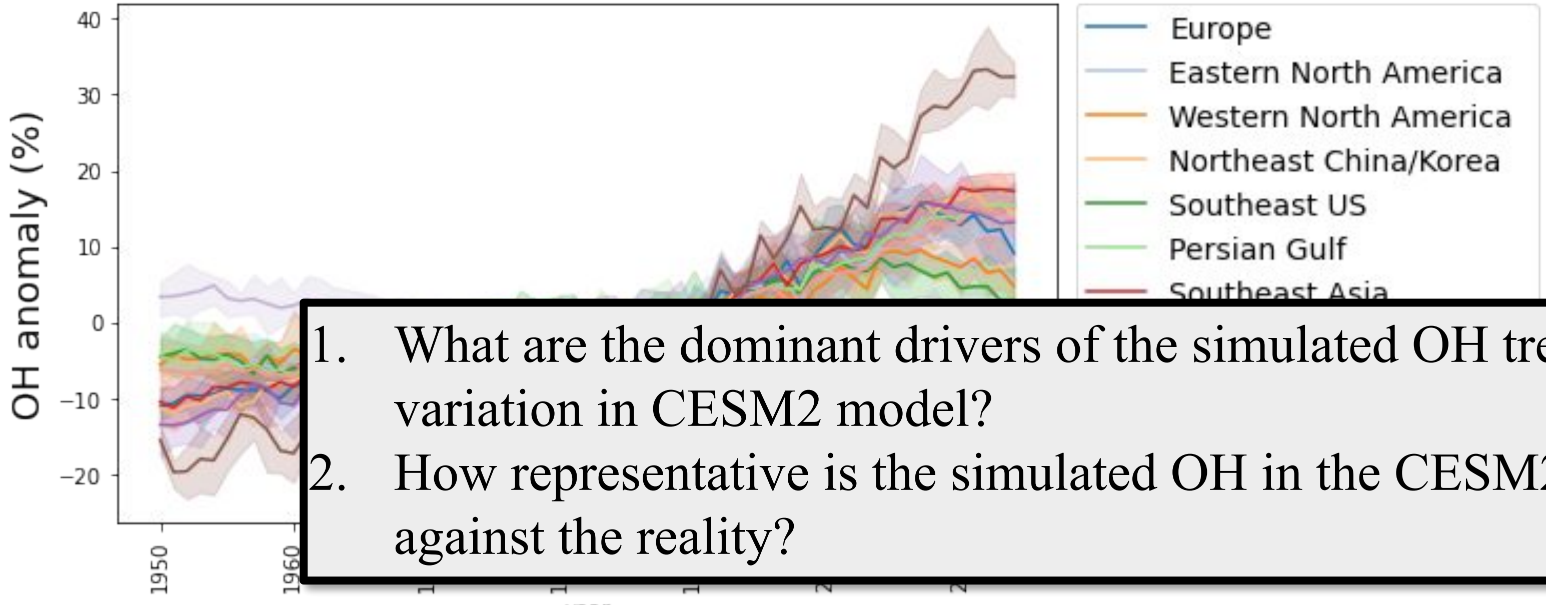


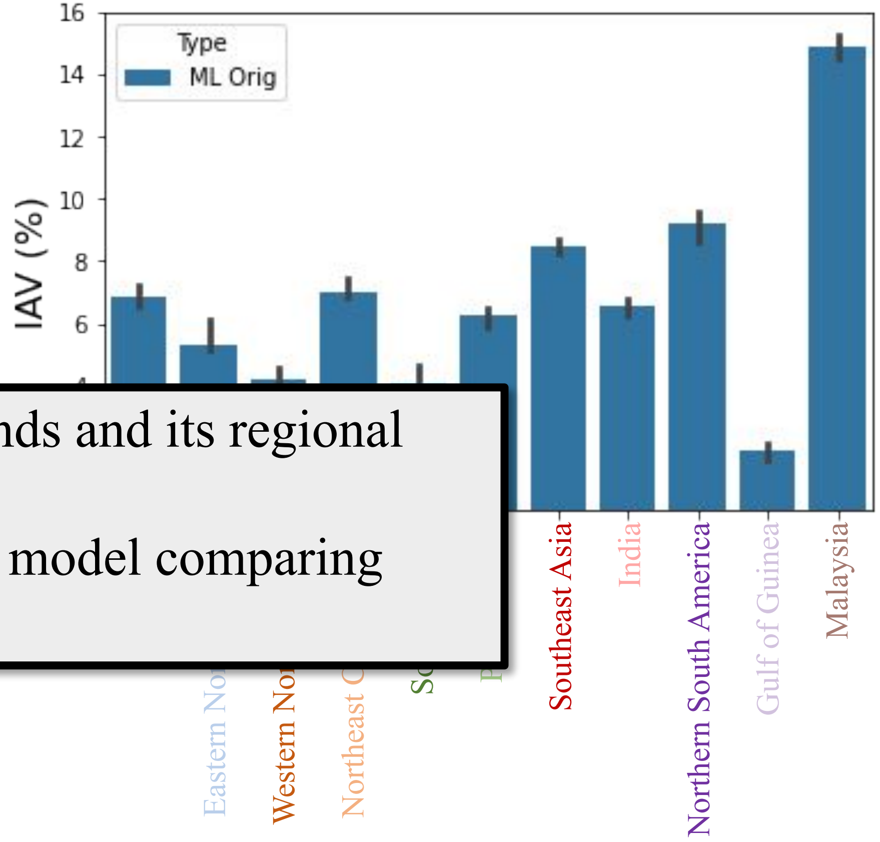
Zhu et al., 2022



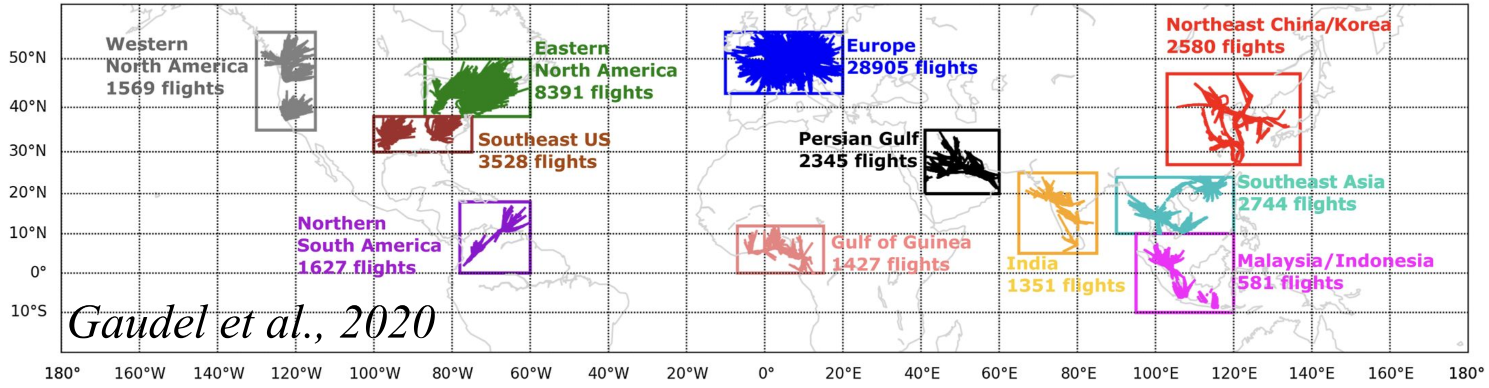
Rohrer et al., 2012

Characterize OH trends in CESM2-WACCM6 climate model





1. What are the dominant drivers of the simulated OH trends and its regional variation in CESM2 model?
2. How representative is the simulated OH in the CESM2 model comparing against the reality?



Gaudel et al., 2020

12-member chemistry-climate initial-condition ensemble simulations for 1950-2014 generated with the CESM2-WACCM6.

OH: Mass weighted trop. mean OH
OH trends: OH anomaly relative to the historical mean OH
IAV: interannual variability

Utilize ML model to explain the OH trend characteristics in CESM2-WACCM6 model

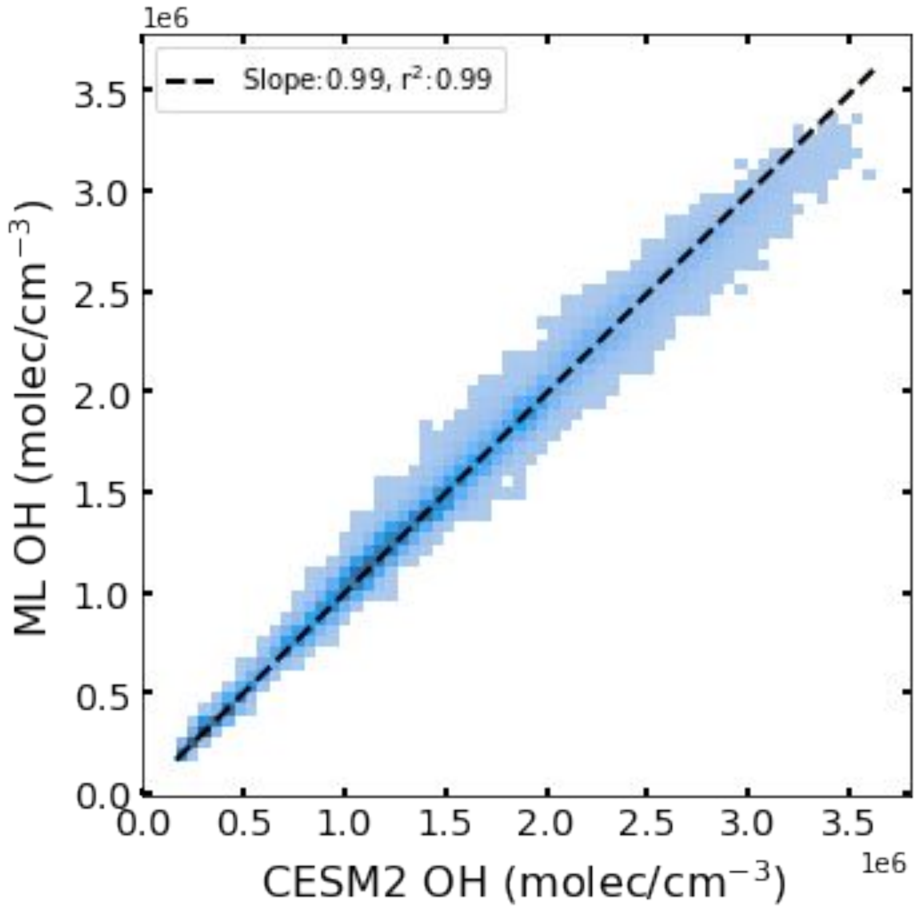
ML model: Gradient boosted tree model (xgboost)

Target:
Monthly mass weighted tropospheric mean OH

Training: grid cells covering 11 regions, monthly average, one ensemble member (wa6_ic1.005)

Test: remaining 11 ensemble members.

Input feature:
Meteorological: Q, T, lightning flash, cloud cover,
Radiation: JO1D,
Chemical: O_3, CO, NO_2 trop, CH_2O trop (adjusted by const monthly averaging kernel from OMI QA4ECV retrievals)



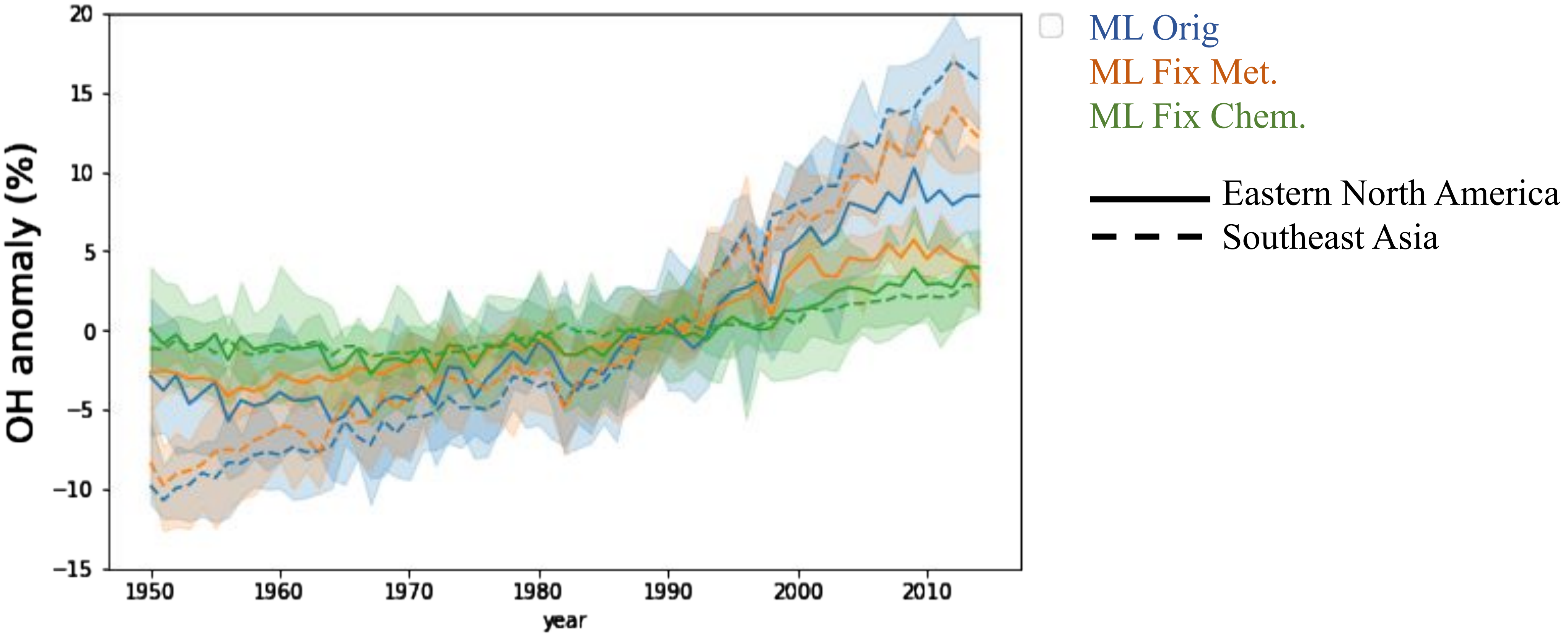
Relative RMSE: 5.2%

Utilize ML to interpret the OH trends in CESM2 model

Fix scenario: remove the interannual variability for each region

Meteorological driver fix scenario: fix T, Q, lightning, cloud cover to their regional means (ML Fix Met.)

Chemical driver fix scenario: fix O3, CO NO2 trop and CH2O trop to their regional means (ML Fix Chem.)



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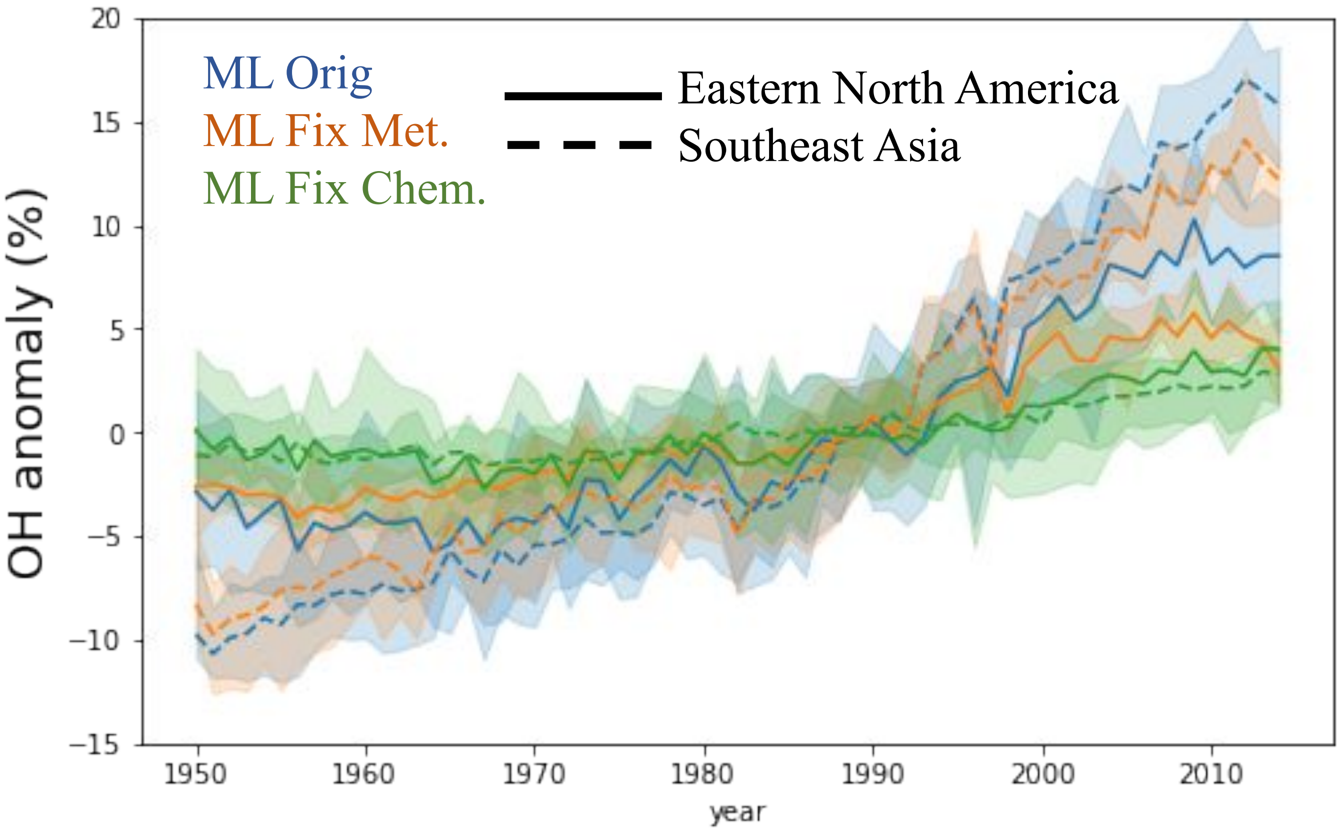

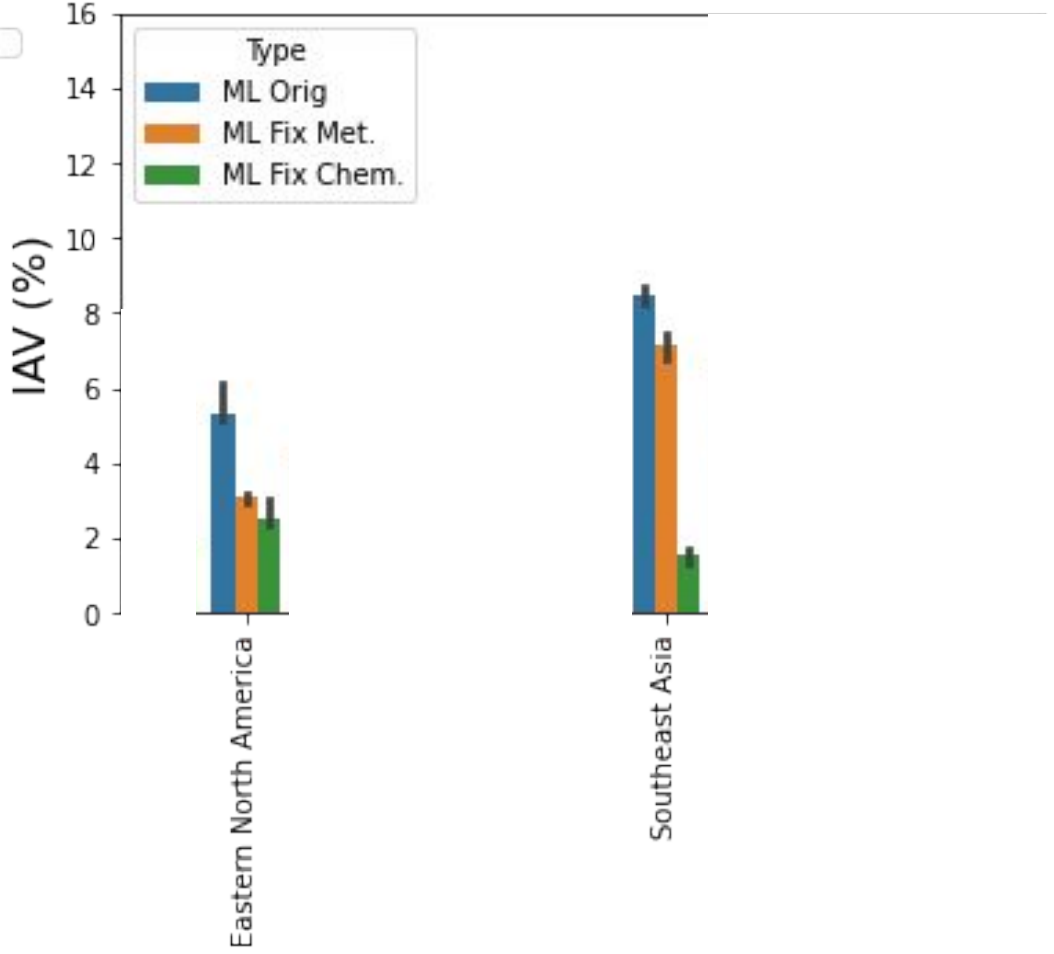

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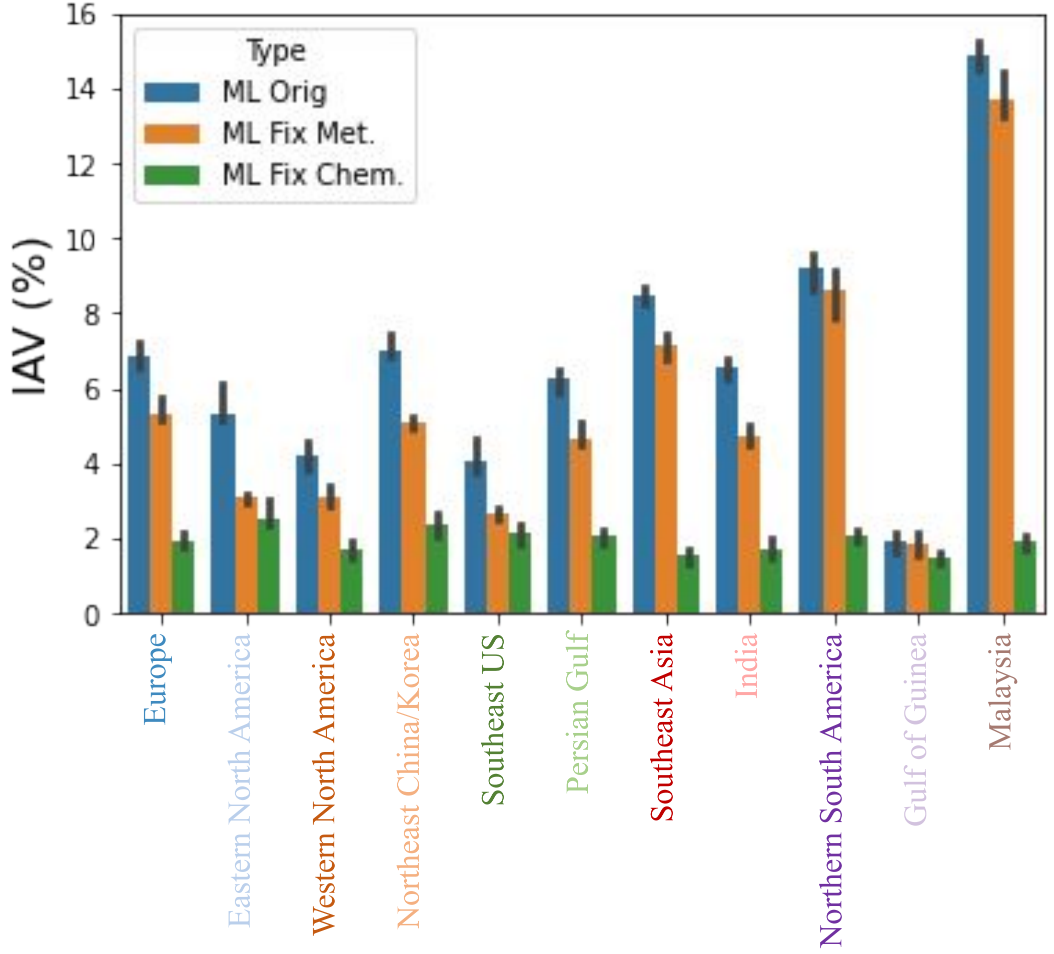
Chemical driver fix scenario: fix O3, CO NO2 trop and CH2O trop to their regional means (ML Fix Chem.)

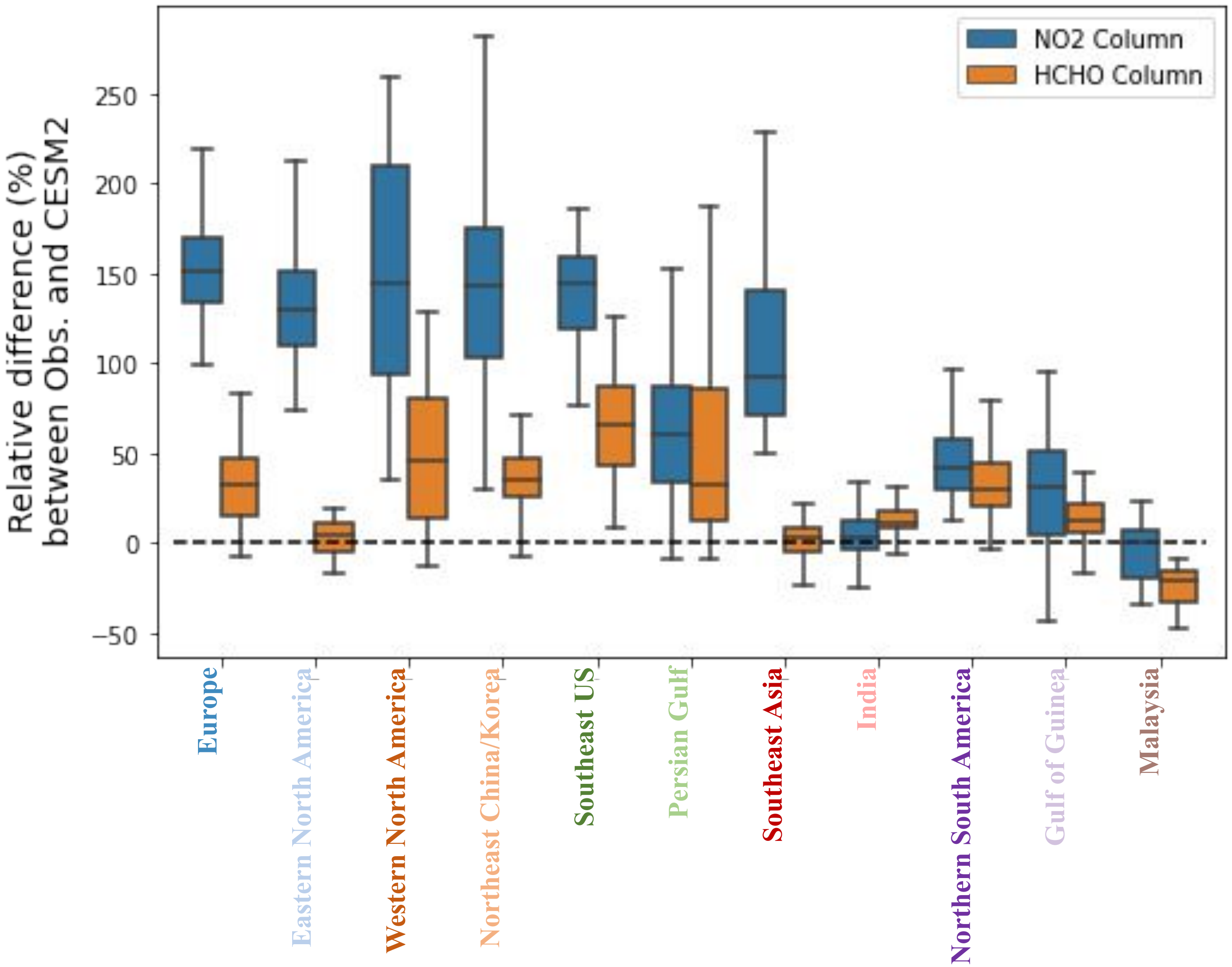
- The pattern of OH trends in tropical regions such as Malaysia, are dominated by chemical drivers.
- OH trends in northern mid-latitudes, such as Eastern North America and Northeastern China, are determined by both meteorological and chemical drivers.
- The interannual variability of chemical drivers dominates the **regional variation** of OH trends.



Evaluate the chemical drivers by comparing against observation

NO_2 trop. column and CH_2O trop. column can be obtained from satellite measurements.

We compare the OMI retrievals of NO2 column and HCHO column against CESM2 simulations between 2004 and 2014 after the adjustment of averaging kernel.



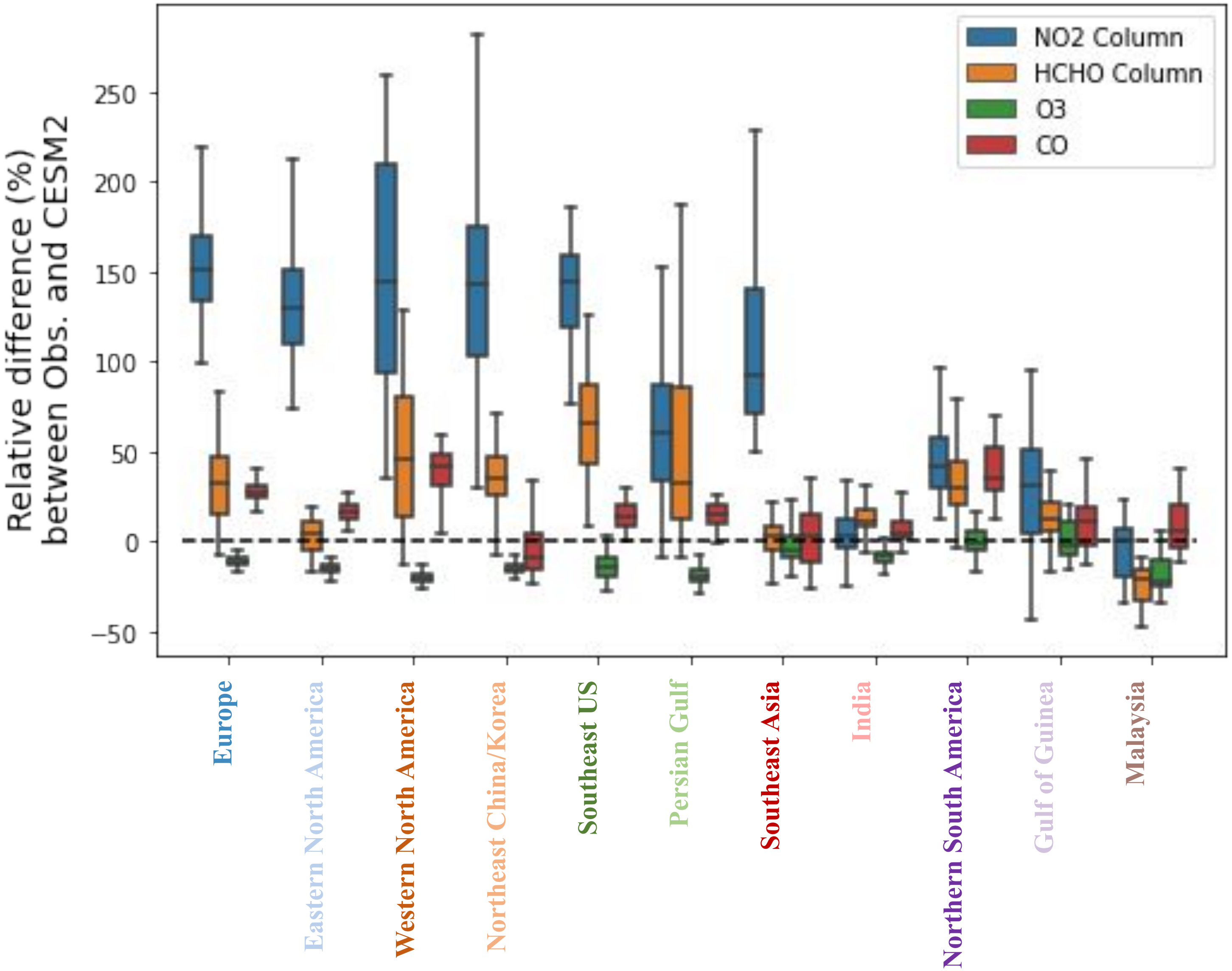
KNMI OMI Ozone Monitoring Instrument NASA

Evaluate the chemical drivers by comparing against observation

CO and O_3 can be obtained from IAGOS aircraft measurements.

We compare the airborne observed O_3 between 1995 and 2014, and airborne observed CO between 1997 and 2014 against CESM2 simulations.

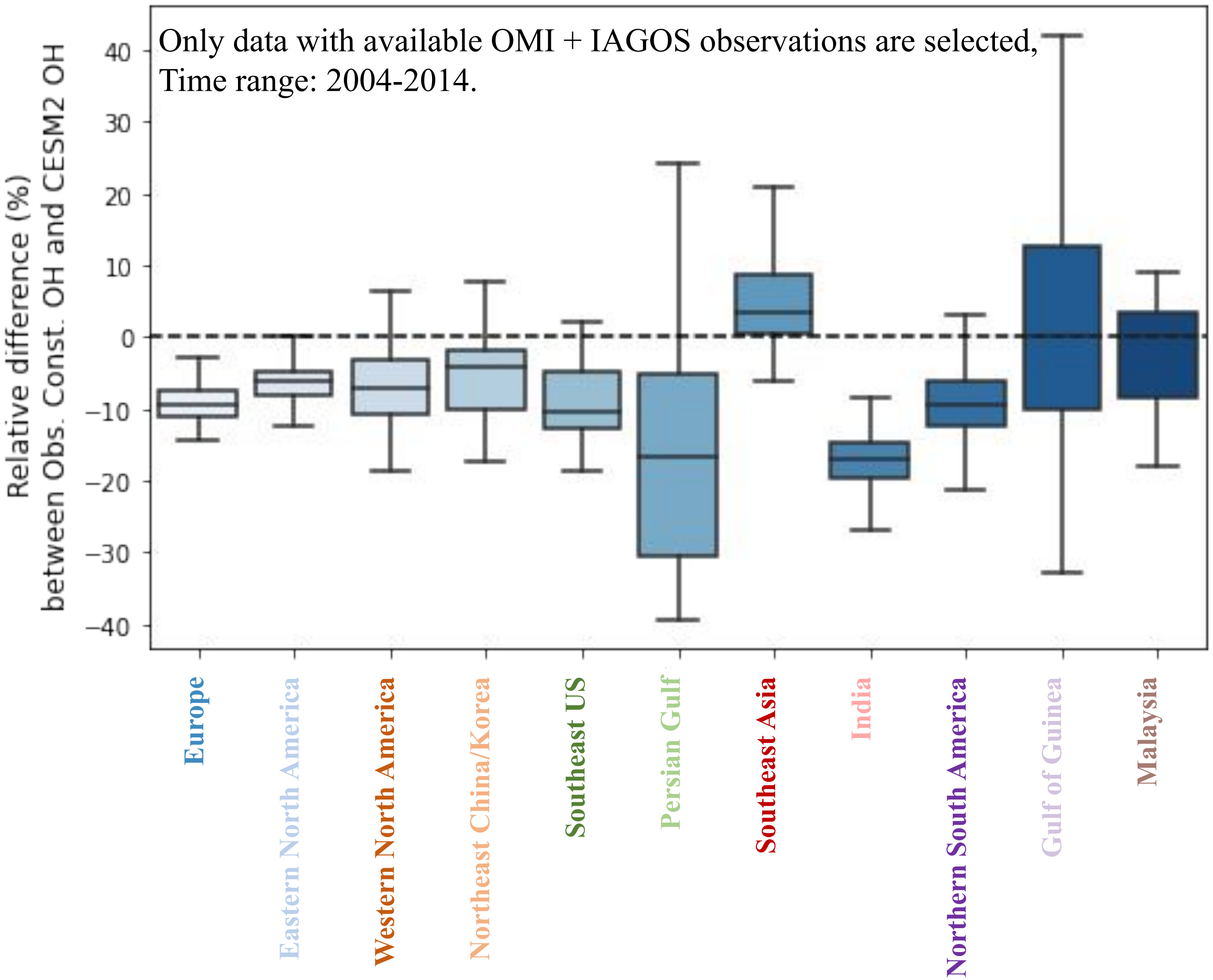
IAGOS
IN-SERVICE AIRCRAFT FOR A GLOBAL OBSERVING SYSTEM



Utilize observations to constrain chemical driver and investigate its influence on OH in each regions

Observation constrained OH predictions:
ML predictions using meteorological drivers from CESM2 + chemical drivers from OMI and IAGOS observations.

- Replacing chemical drivers from CESM2 with observations, the ML predicted OH is lower than CESM2 simulated OH in most regions.
- In Northern mid-latitudes, India and Northern South America, the observation constrained OH is on average 5-20% lower than CESM2.
- Only in Southeast Asia, ML OH prediction constrained by observations is higher than CESM2.



Conclusion

- We utilize an existing 12-member initial-condition ensemble of the CESM2-WACCM6 chemistry-climate coupled model, spanning the years 1950 to 2014, to characterize the spatial and decadal variation of OH.

- We show a substantial spatial variation of historical trends of tropospheric column OH, ranging from a 60% increase over Malaysia to a 5% reduction over the Gulf of Guinea.

- Using ML, we identify the dominant drivers contributing to the variation in the OH trends. The interannual variability of chemical drivers dominates the regional variation of OH trends.

- We compare the difference of chemical drivers between observations and CESM2. The ML predicted OH constrained by observations are 5-20% lower than CESM2 simulations in most of study regions.

Future work

- We will look into the contribution of individual drivers (both met. and chem.) to OH trends in each region.

- We will combine the ML predictions with chemical processes to understand the OH trend sensitivity to meteorological drivers in regions such as Eastern North America and Northeastern China.

- We will investigate the OH trends constrained by the observations.

Backup

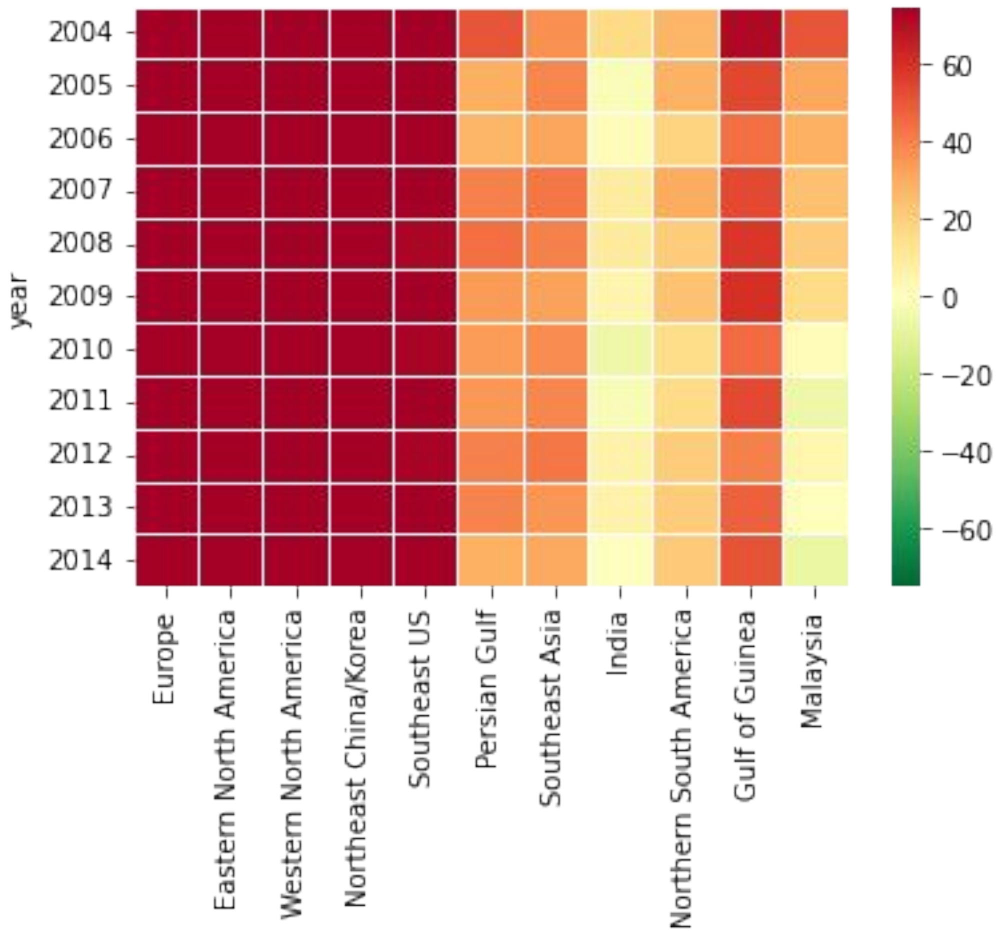
Evaluate the chemical drivers by comparing against observation

NO_2 trop. column and CH_2O trop. column can be obtained from satellite measurements.

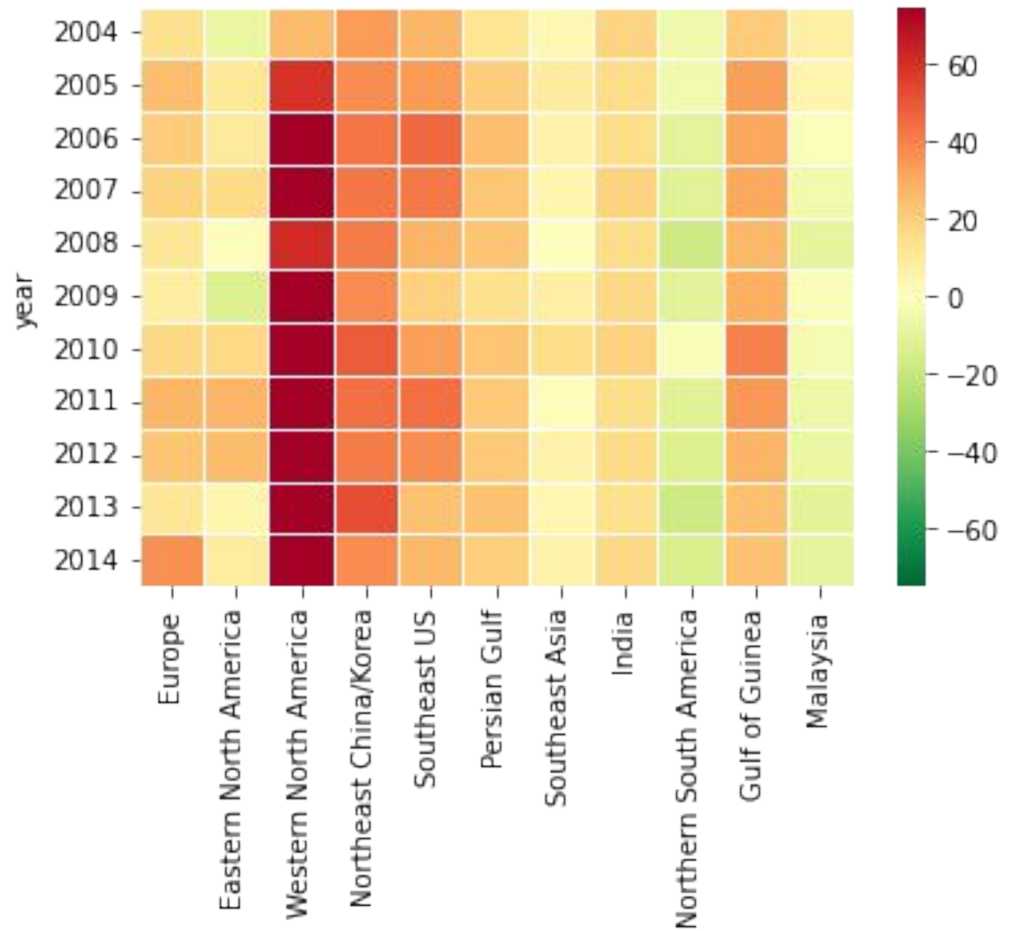
OMI
Ozone Monitoring Instrument

2004-2014

Relative difference (%) between OMI and CESM2 NO_2 column

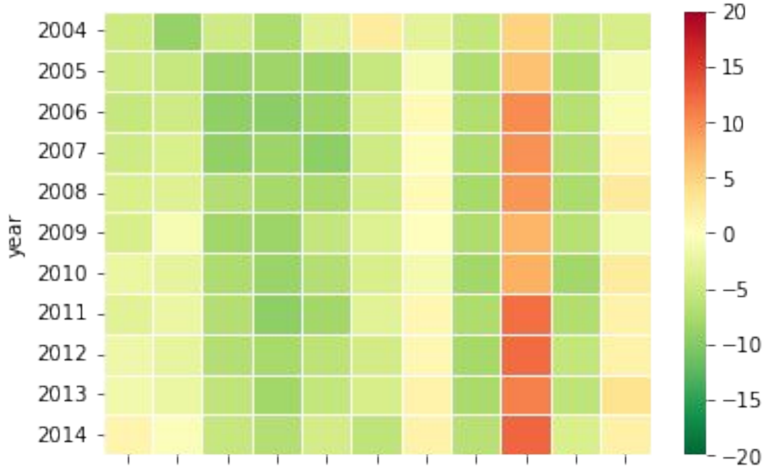


Relative difference (%) between OMI and CESM2 HCHO column

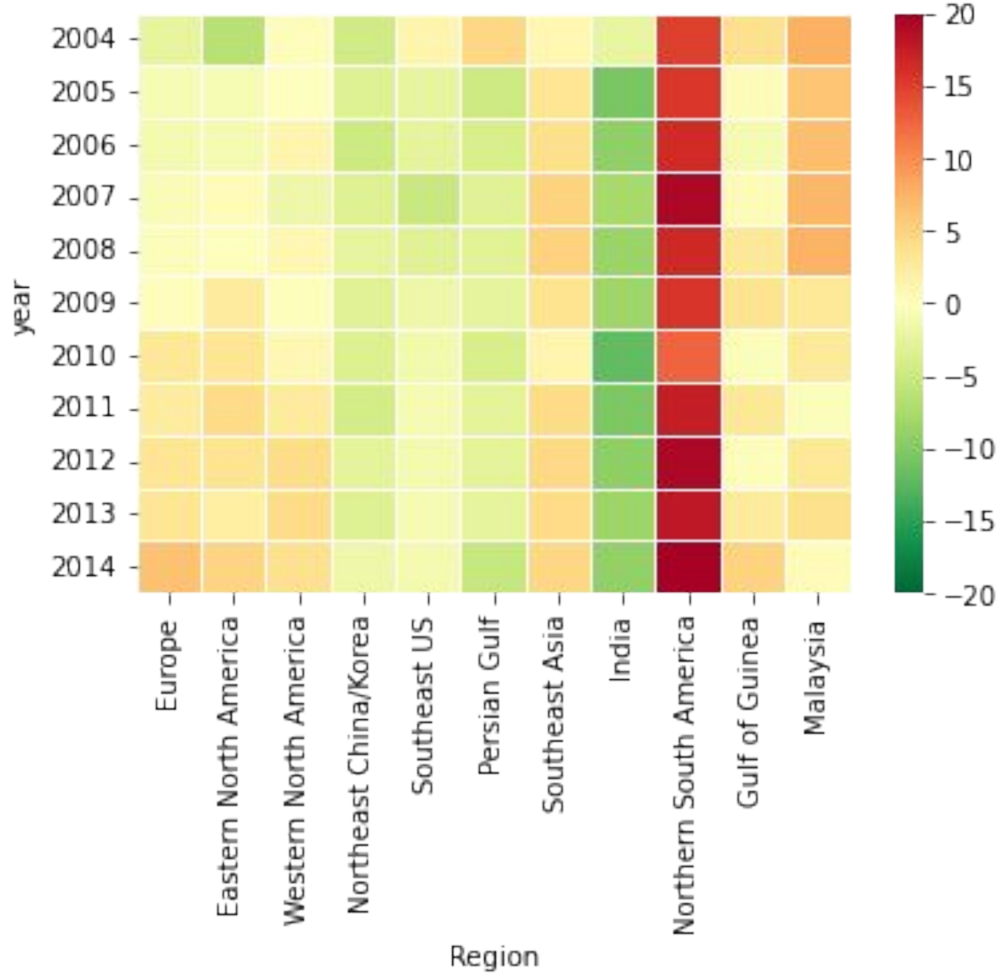


Utilize observations to constrain chemical driver and investigate its influence on OH trends

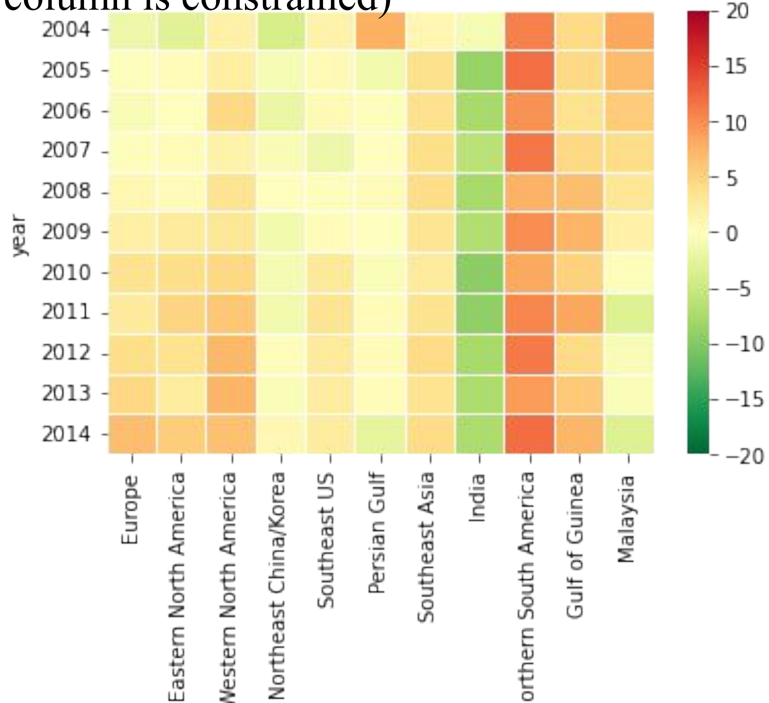
Relative difference (%) between OMI constrained OH and CESM2 OH
(only NO2 column is constrained)



Relative difference (%) between OMI constrained OH and CESM2 OH
(both NO2 column and HCHO column are constrained by OMI)



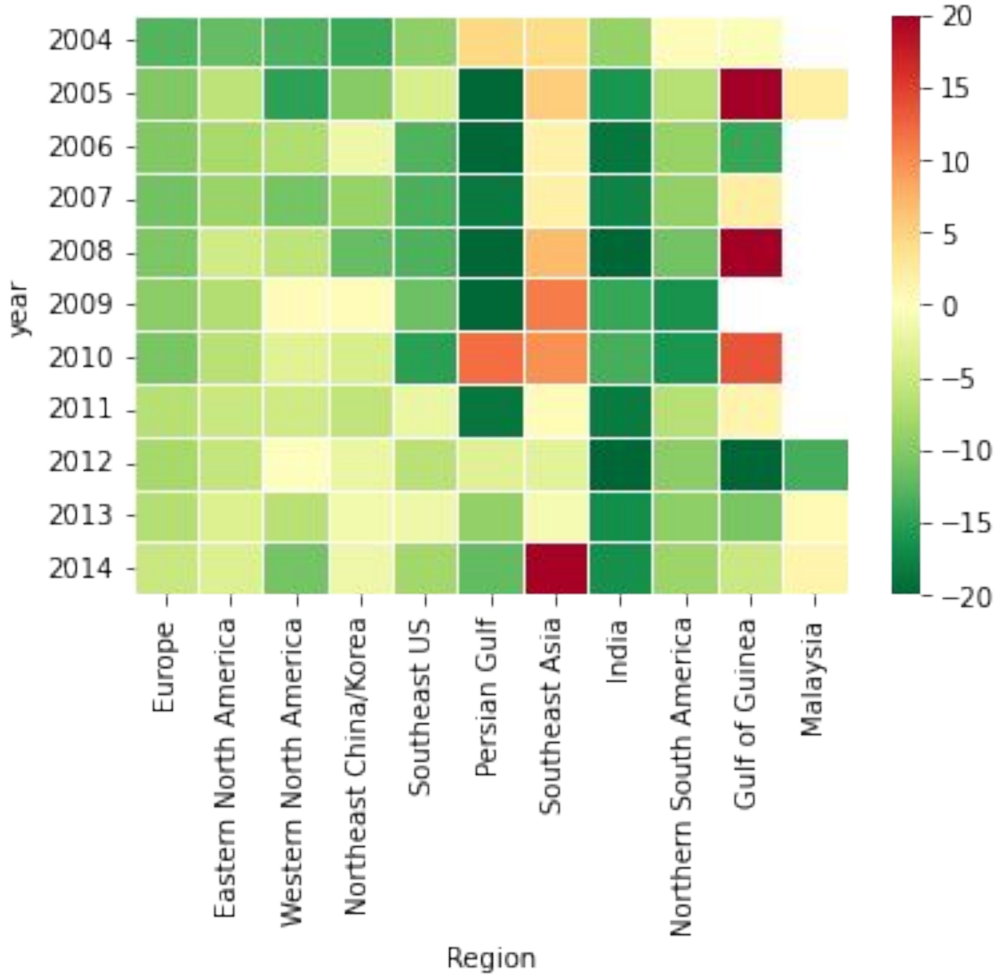
Relative difference (%) between OMI constrained OH and CESM2 OH
(only HCHO column is constrained)



Utilize observations to constrain chemical driver and investigate its influence on OH trends

Observation constrained OH predictions:
ML predictions using meteorological drivers from CESM2 + chemical drivers from OMI and IAGOS observations

Relative difference (%) between observation constrained OH and CESM2 OH



Evaluate the chemical drivers by comparing against observation

CO and O_3 can be obtained from IAGOS aircraft measurements.

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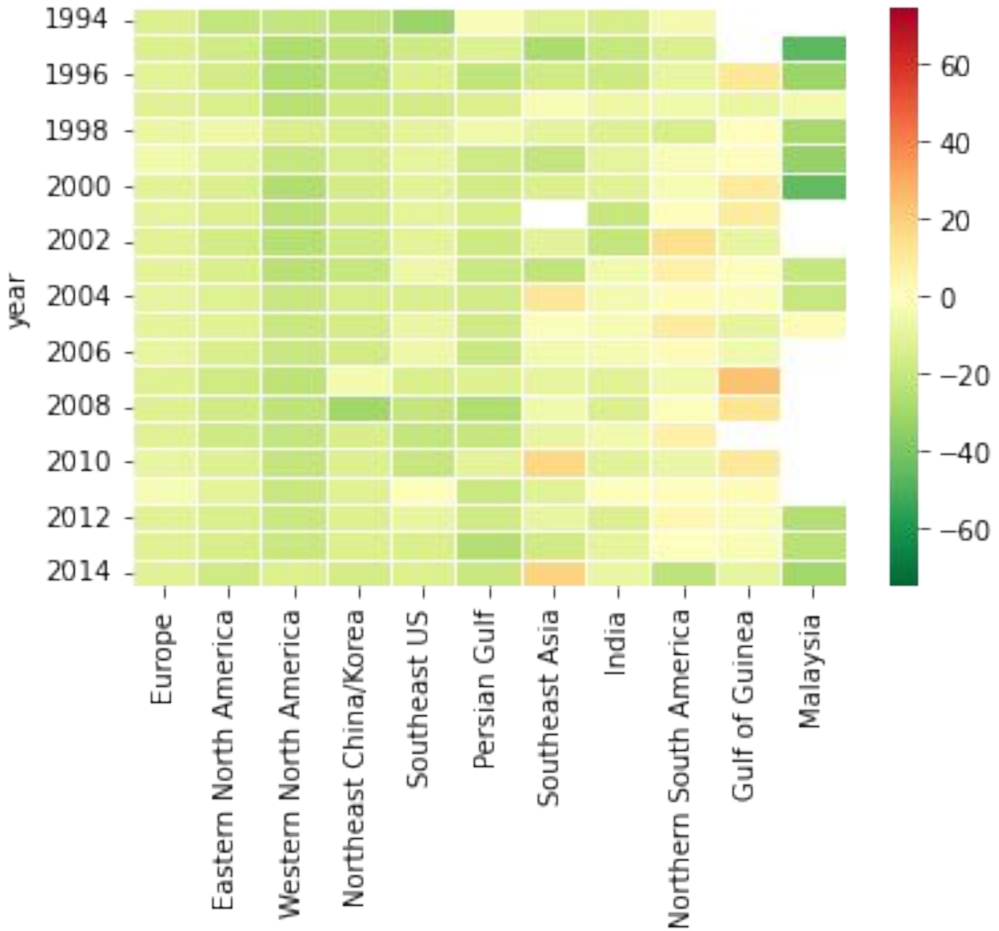
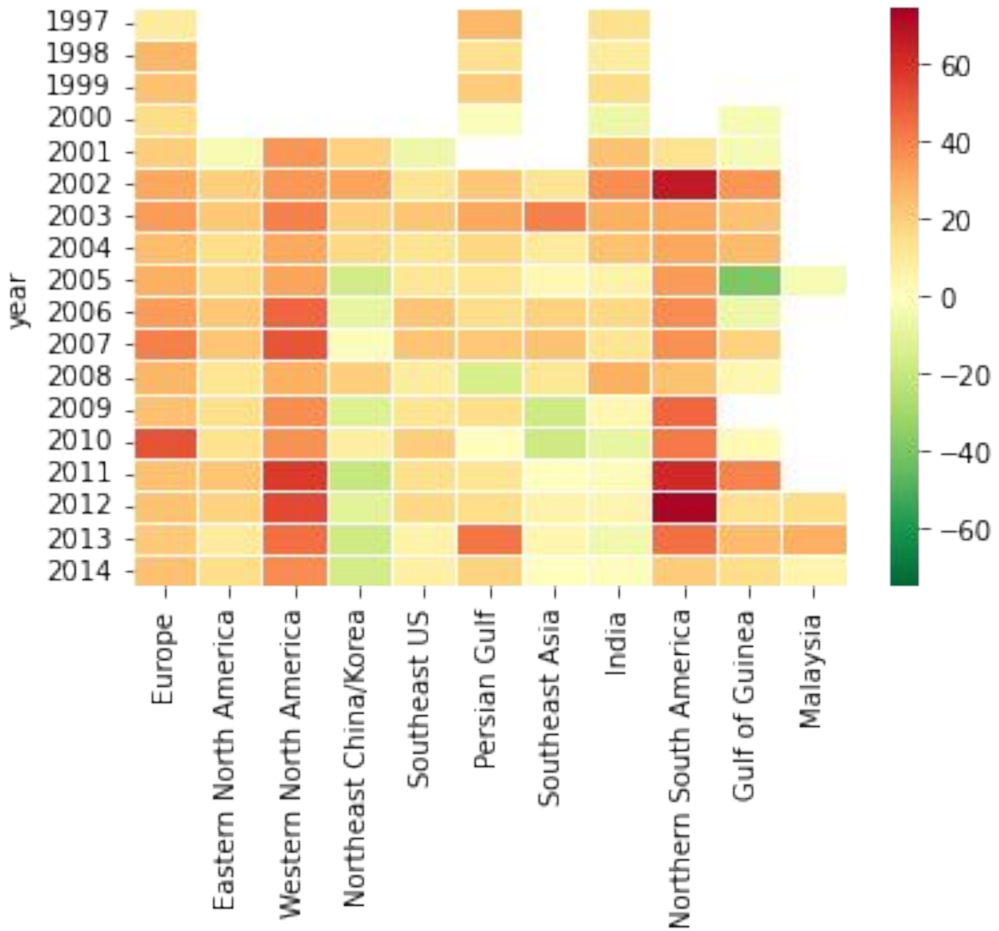
1995-2014

Relative difference (%) between IAGOS and CESM2 O3

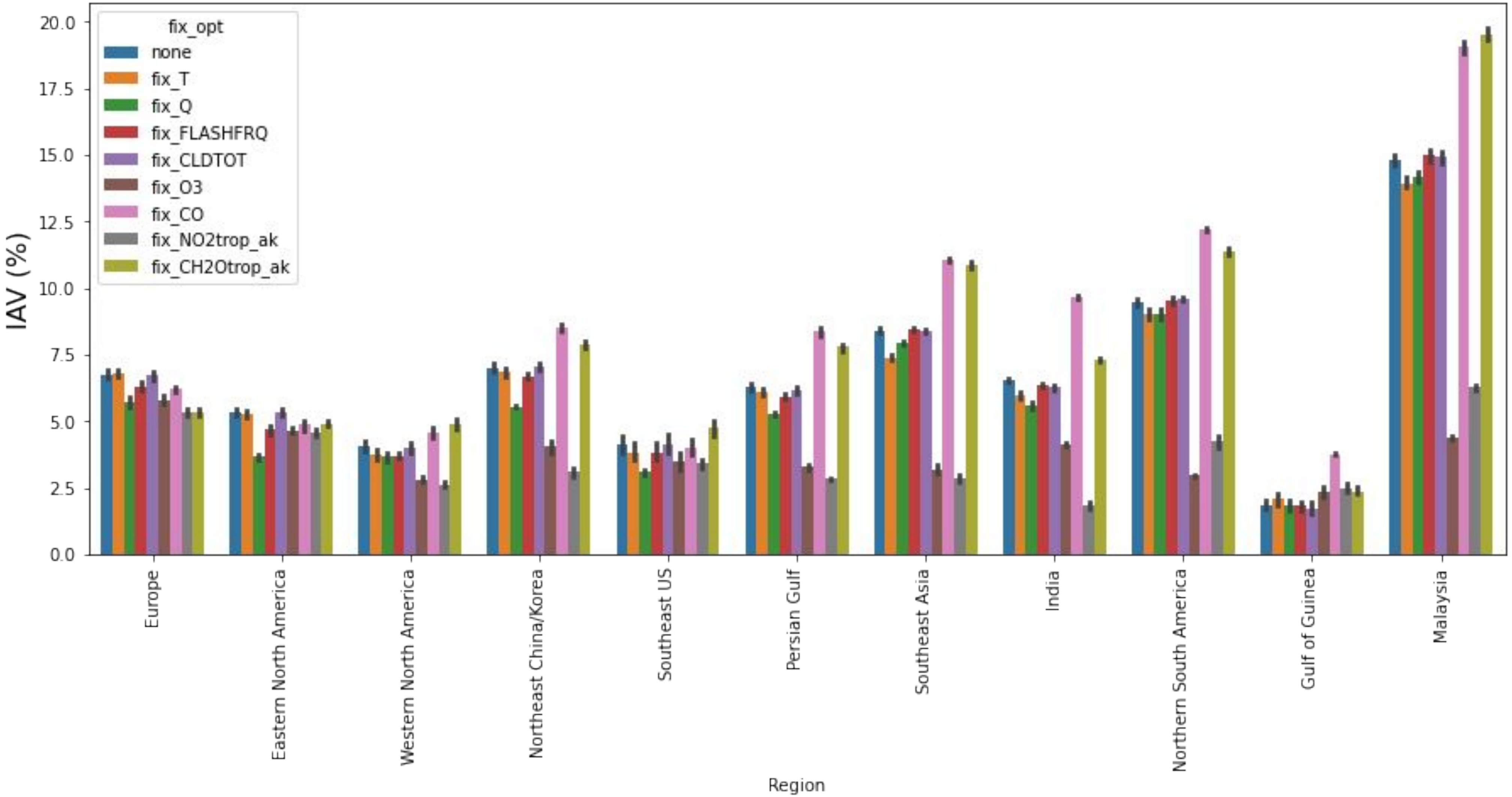


Relative difference (%) between IAGOS and CESM2 CO



Utilize ML to interpret the OH trends in CESM2 model

The contribution of each input feature to IAV of OH trends



Urban OH is the key species characterizing local air pollution events