Air quality and chemistry

Presented by
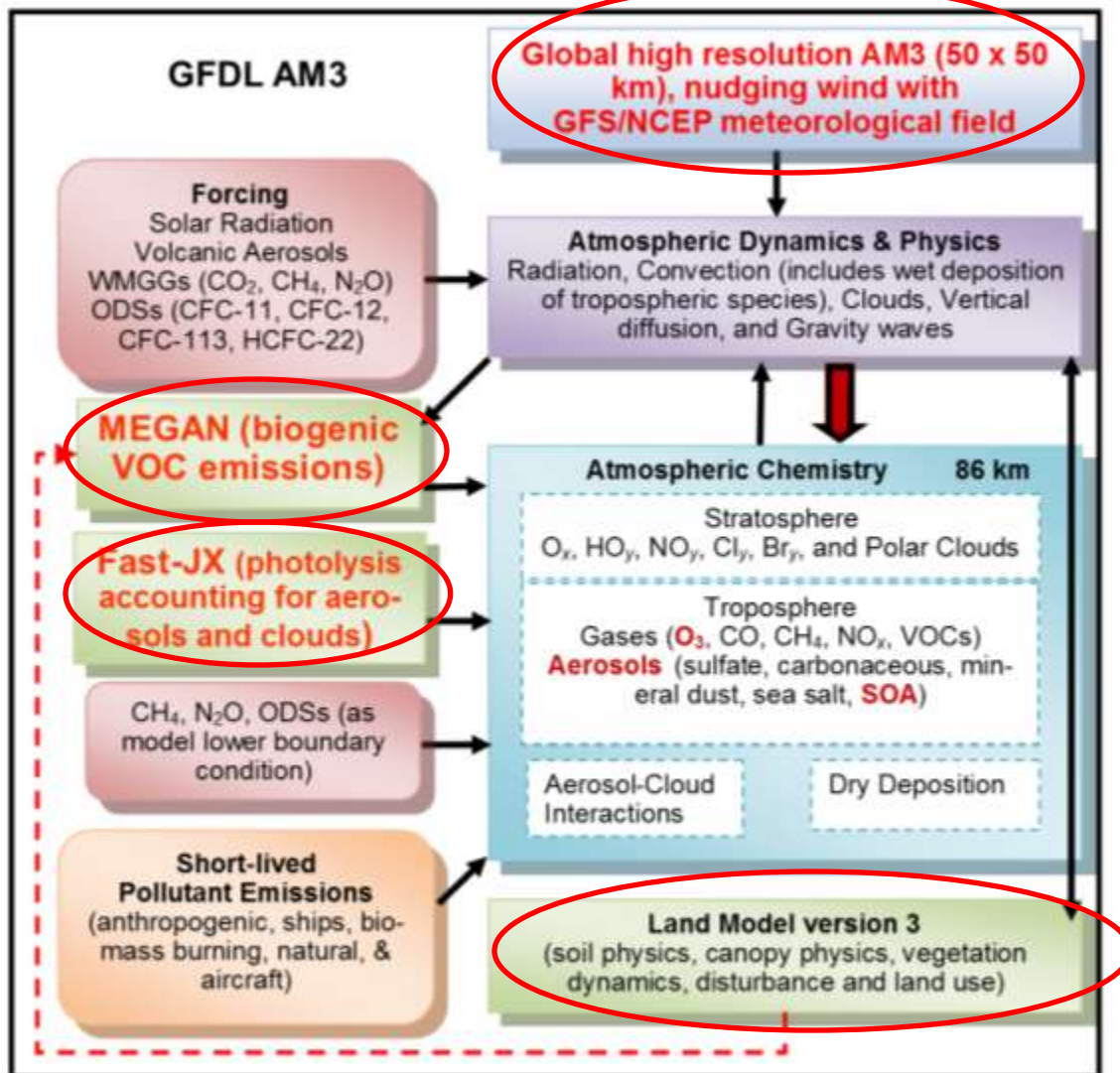
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Geophysical Fluid Dynamics Laboratory Review

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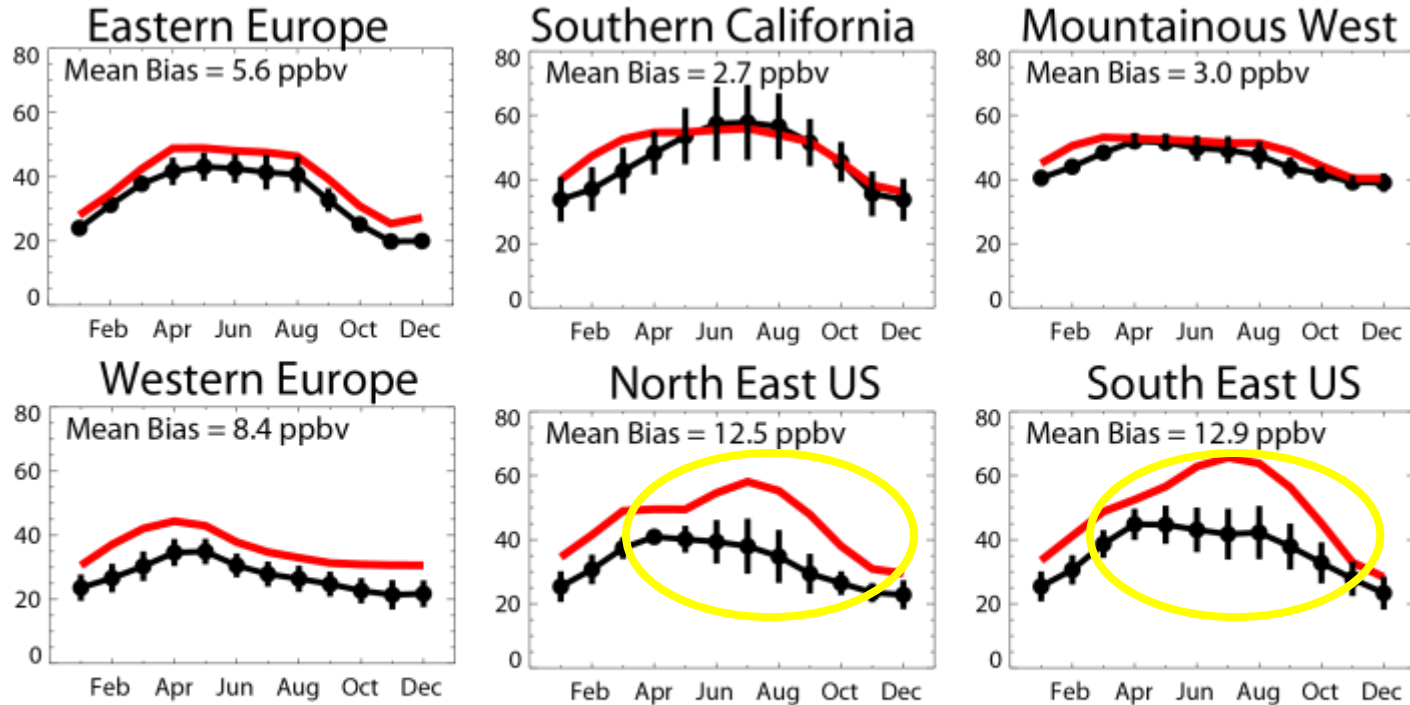
Recent chemistry developments in GFDL AM3 model

GFDL AM3

Forcing
Solar Radiation
Volcanic Aerosols
WMGGs (CO_2, CH_4, N_2O)
ODSs (CFC-11, CFC-12, CFC-113, HCFC-22)

Global high resolution AM3 (50 x 50 km), nudging wind with GFS/NCEP meteorological field

MEGAN (biogenic VOC emissions)

Fast-JX (photolysis accounting for aerosols and clouds)

CH_4, N_2O, ODSs (as model lower boundary condition)

Short-lived Pollutant Emissions (anthropogenic, ships, biomass burning, natural, & aircraft)

Atmospheric Dynamics & Physics
Radiation, Convection (includes wet deposition of tropospheric species), Clouds, Vertical diffusion, and Gravity waves

Atmospheric Chemistry   86 km
Stratosphere
O_x, HO_y, NO_y, Cl_y, Br_y, and Polar Clouds
Troposphere
Gases (O_3, CO, CH_4, NO_x, VOCs)
Aerosols (sulfate, carbonaceous, mineral dust, sea salt, SOA)
Aerosol-Cloud Interactions   Dry Deposition

Land Model version 3 (soil physics, canopy physics, vegetation dynamics, disturbance and land use)

New features implemented in GFDL AM3 :
- High resolution with nudging wind (50 x 50 km).
- MEGAN (state-of-science process-based biogenic emission inventory)
  - to be coupled with the land model (LM3/4) for future prediction.
- Fast-JX
  - Account for the effect of aerosol scattering and absorption on photochemistry

Evaluation of surface ozone in GFDL AM3 model

Eastern Europe — Mean Bias = 5.6 ppbv
Southern California — Mean Bias = 2.7 ppbv
Mountainous West — Mean Bias = 3.0 ppbv
Western Europe — Mean Bias = 8.4 ppbv
North East US — Mean Bias = 12.5 ppbv
South East US — Mean Bias = 12.9 ppbv

Surface observations (Regional Mean)
AM3 simulation (1981-2000)

- AM3 can well reproduce the magnitude and seasonality of surface ozone.
- However, AM3 over predicts summer surface ozone in Eastern US by 20-30 ppbv.
- **This is a long-standing problem for most global models (Fiore et al., 2009).**

Impact of heterogeneous processes (uptake of trace gases by aerosols)

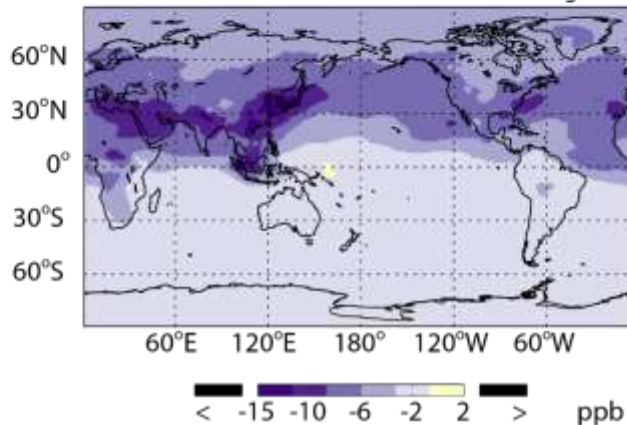AM3 (aerosol uptake on) – AM3 (aerosol uptake off)

HO_2, N_2O_5, NO_3, NO_2

Aerosol
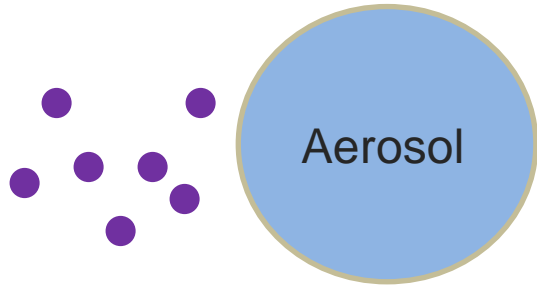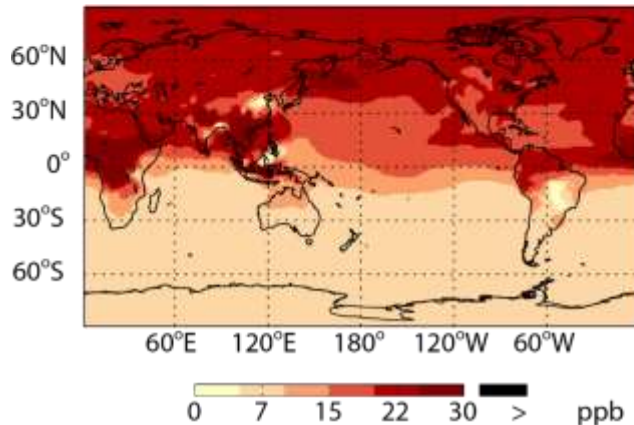
Relative difference in OH
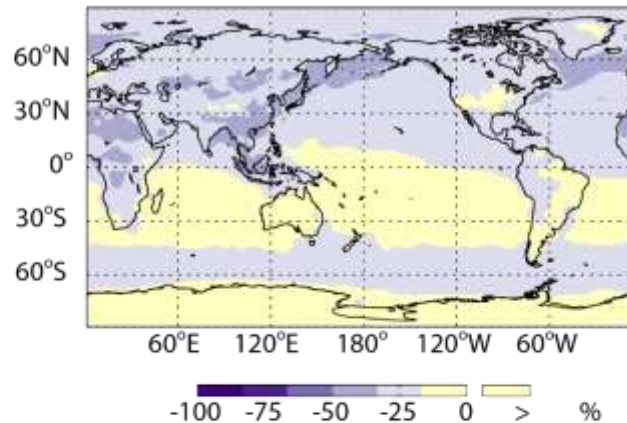
Significant improvement on model CO, mainly over NH (Shindell et al., 2006, JGR).

Significant improvement on model ozone and OH.

Absolute difference in CO

Absolute difference in O_3

Tropospheric CH_4 lifetime increases from 8.5 to 9.6 years, in better agreement with the observational estimate-- 11.2 years (Prather et al., 2012, GRL)**!**

(Mao et al., 2013a, ACP; 2013b, GRL) 3

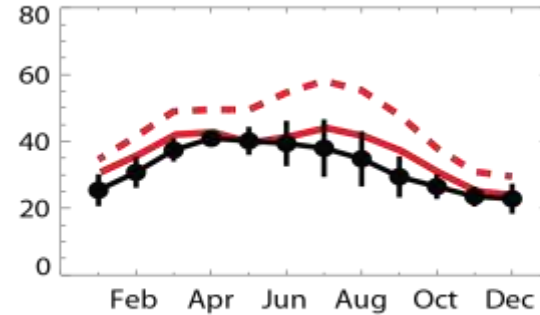# A new isoprene chemistry for global models

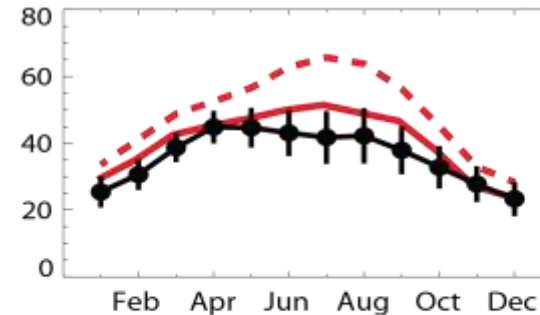**Global Emissions (Tg/yr)**
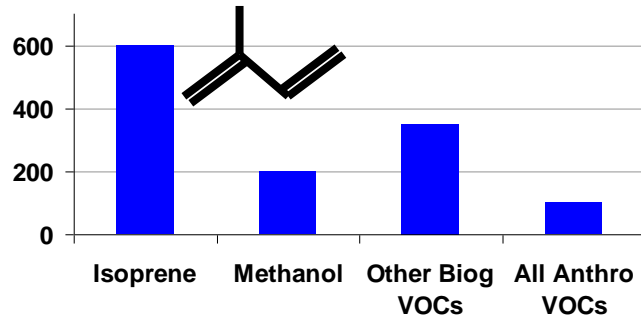
A new mechanism based on recent laboratory progress on isoprene oxidation (Mao et al., 2013)
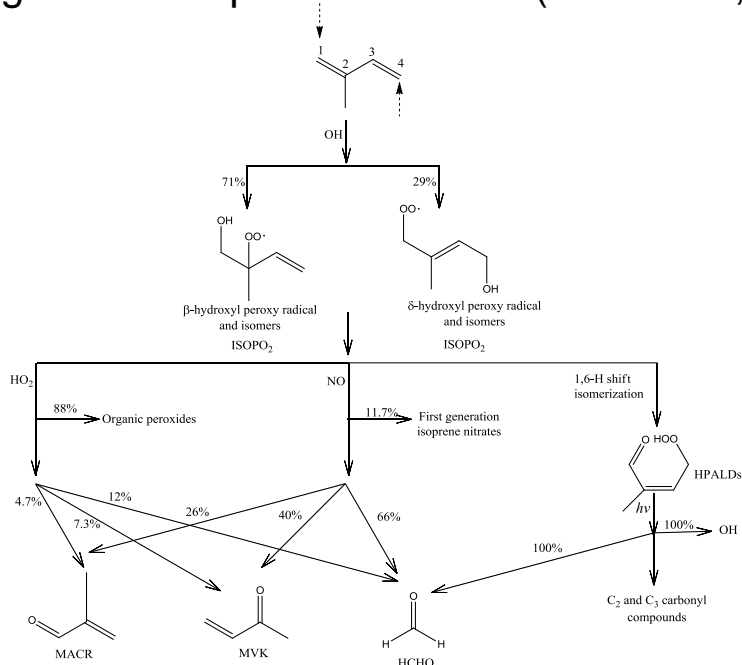
North East US surface ozone (ppbv)

South East US surface ozone (ppbv)

— Surface observations (Regional Mean)
— AM3 simulation with new chemistry
- - - AM3 simulation with old chemistry

Ozone bias is significantly reduced from 13 ppbv to 3 ppbv for SE US, due to both heterogeneous processes and updated isoprene chemistry.
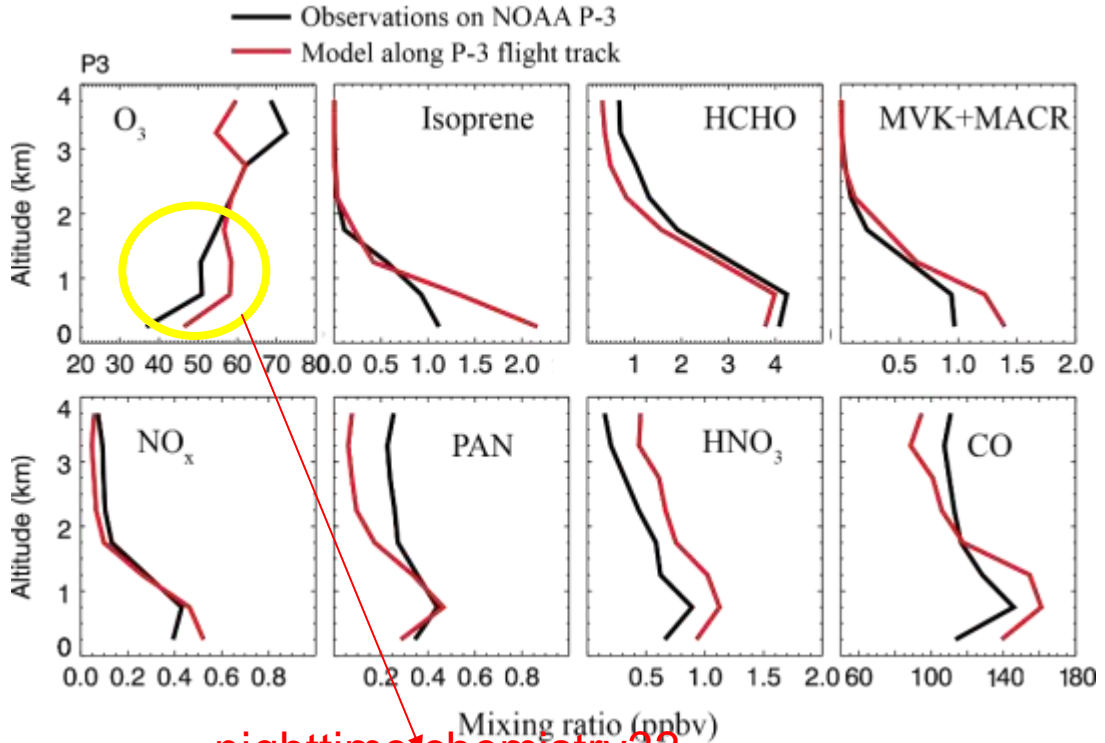
Cross-lab collaboration: SENEX and GFDL AM3

- Southeast Nexus (SENEX) field campaign - NOAA aircraft study over the Southeast U.S. to study the interaction between anthropogenic and biogenic emissions.
  - organized by NOAA Earth System Research Laboratory)
- Global high resolution AM3 (50 x 50 km)
  - nudging with GFS wind; new chemical mechanism; MEGAN biogenic emission.
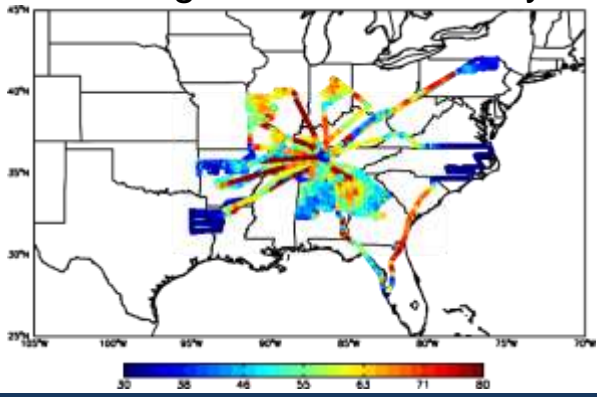
June 3rd to July 10th (2013)

SENEX flight track colored by ozone

Mean vertical profiles during SENEX
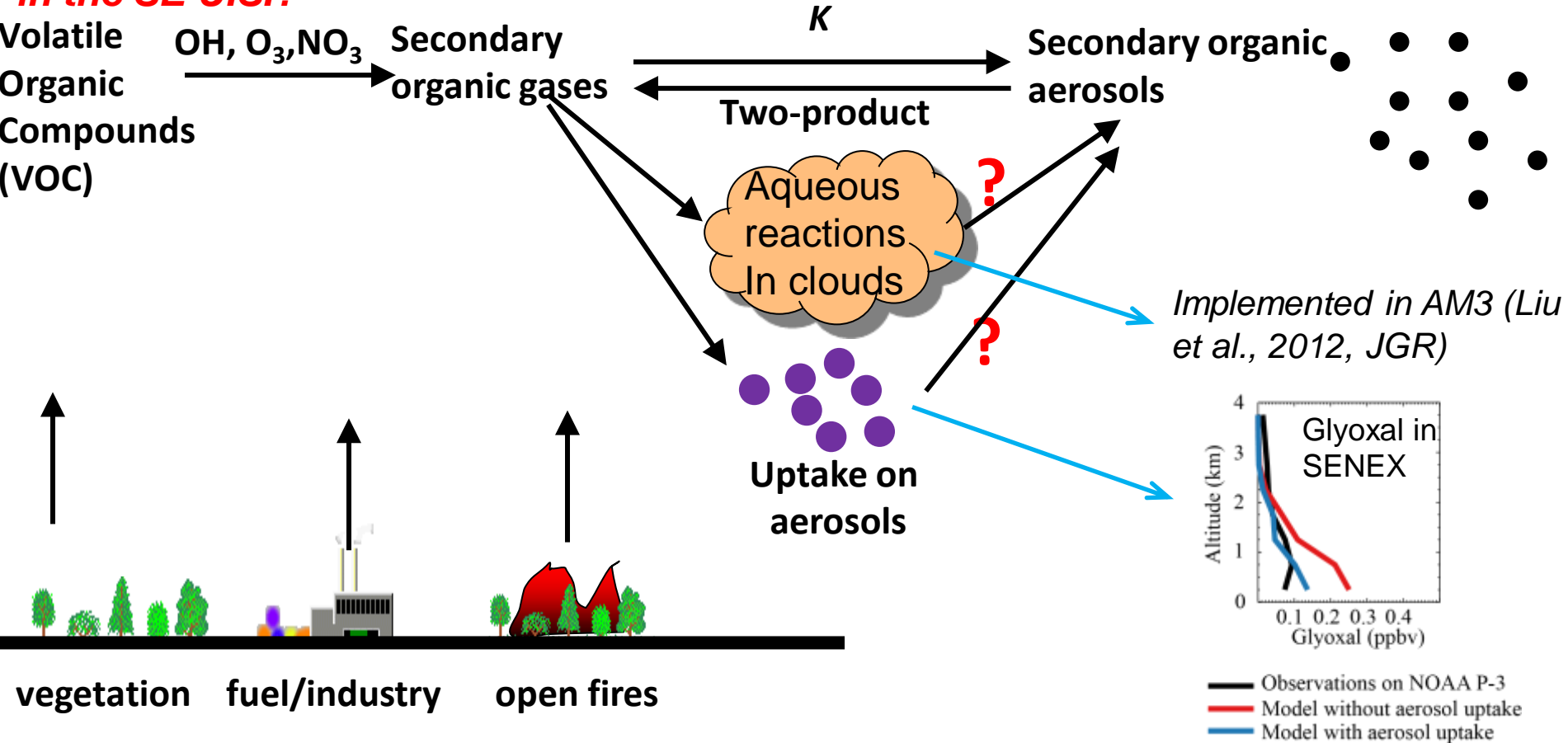
nighttime chemistry??

Future work: formation of secondary organic aerosols (SOA)

Question: What are the formation mechanisms of secondary organic aerosols in the SE U.S.?

Volatile Organic Compounds (VOC)

OH, O_3, NO_3

Secondary organic gases

K

Two-product

Secondary organic aerosols

Aqueous reactions In clouds

?

?

Uptake on aerosols

Implemented in AM3 (Liu et al., 2012, JGR)

Glyoxal in SENEX

Altitude (km)

4
3
2
1
0

0.1 0.2 0.3 0.4
Glyoxal (ppbv)

— Observations on NOAA P-3
— Model without aerosol uptake
— Model with aerosol uptake

vegetation   fuel/industry   open fires

- The "role of aerosols in regional climate" was recently identified as an important crosscutting research challenge for NOAA.

Conclusions

- We have improved the chemical mechanism in AM3 in both heterogeneous processes and isoprene oxidation mechanism.
    - This leads to significant improvement on ozone, OH, CO in AM3 (and other models too).

- We deploy a high resolution version of AM3 to the SENEX campaign, and model can well reproduce ozone and its precursors.
    - nighttime VOC oxidation may play an important role on daytime ozone.
    - Next step is to evaluate the secondary organic aerosols in GFDL AM3 with SENEX dataset.