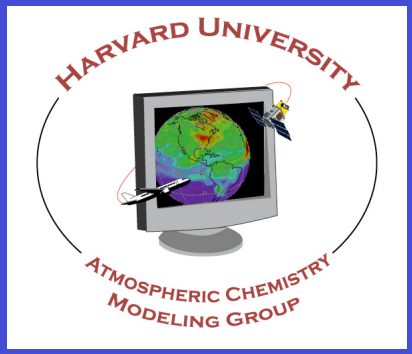
USING SATELLITES TO BETTER UNDERSTAND THE POLICY-RELEVANT BACKGROUND OF SURFACE OZONE

Daniel J. Jacob, Lin Zhang, Dylan B. Millet, Paul I. Palmer (now at Leeds),
Tzung-May Fu, Solene Turquety (now at CNES), Monika Kopacz

Supported by NASA



with Kelly V. Chance and Thomas Kurosu (Harvard/SAO)
and the TES, OMI, MOPITT Science Teams

EPA POLICY-RELEVANT BACKGROUND (PRB): ozone that would be present in surface air in absence of North American anthropogenic emissions.

Important for:

- setting the NAAQS - incremental risk from ozone above background;
- assessing intercontinental pollution influence

PROCESSES DETERMINING PRB OZONE AND RELEVANT SATELLITE OBSERVATIONS

Ozone profiles (HRDLS)

tropopause

Strat-trop exchange

Nitric acid (TES),
NO_2 (GOME, SCIA, OMI)

Lightning

Free tropospheric ozone (GOME)

Ozone-CO correlations (TES)

Intercontinental ozone pollution

Continental boundary layer

Hotspots, scars (MODIS, MISR)
CO (MOPITT, AIRS, TES)

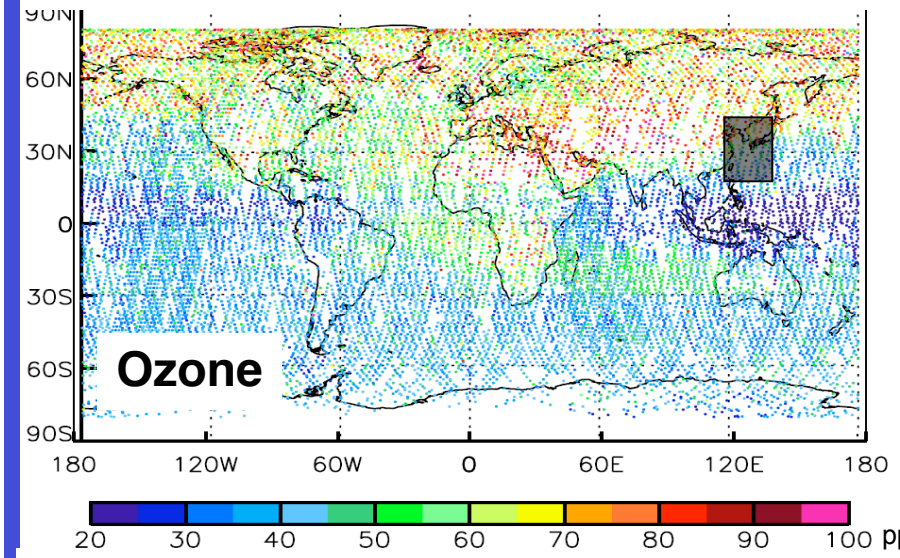
Formaldehyde and NO_2 columns (GOME, SCIA, OMI)

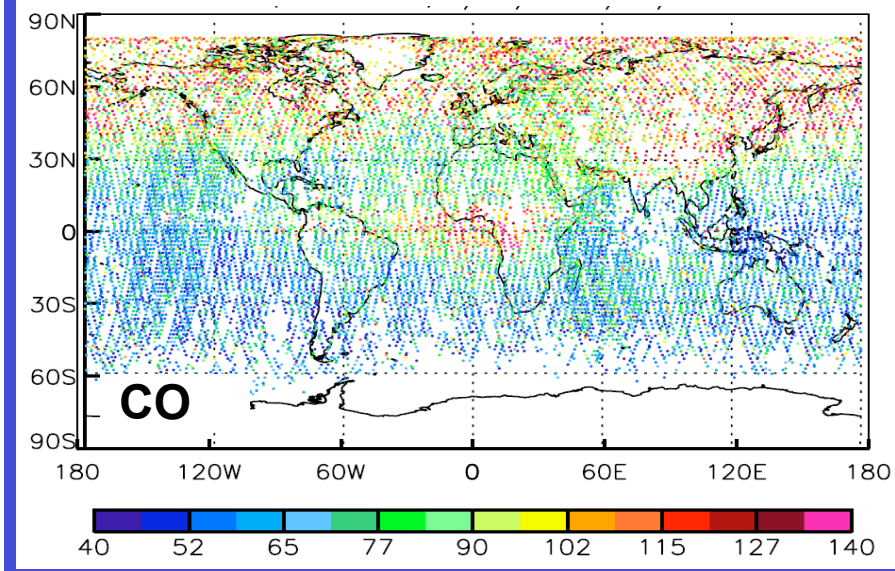
Biogenic VOCs and NO_x

Fires

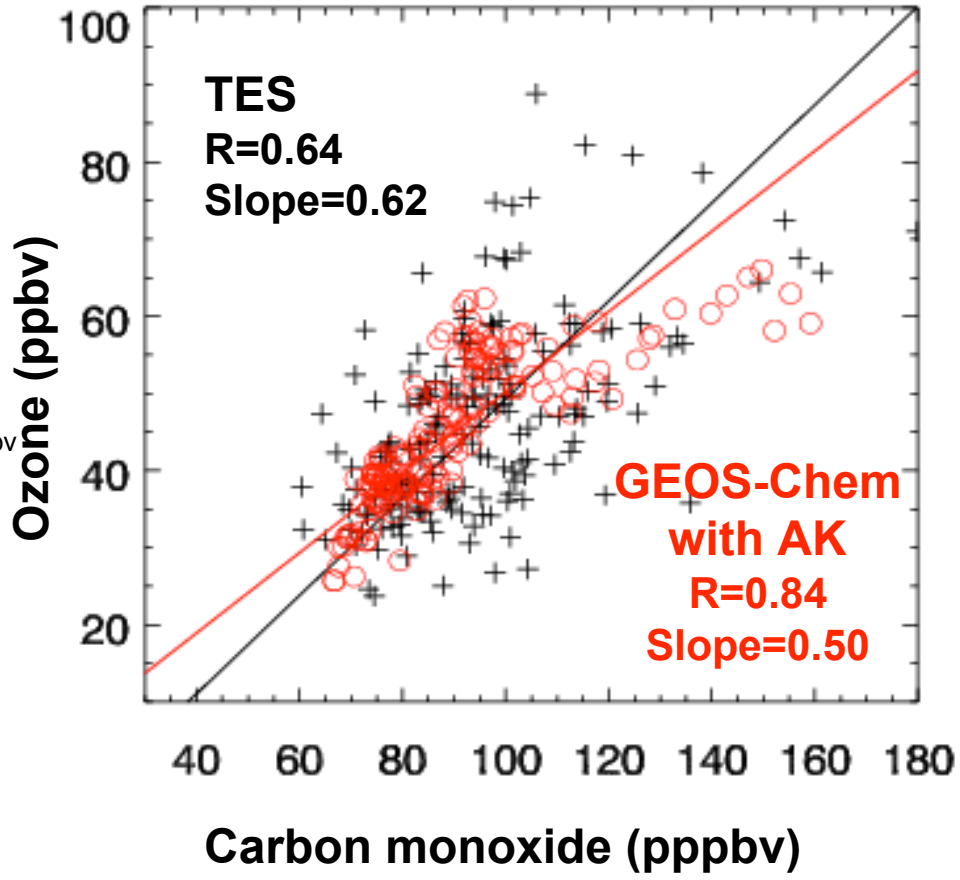
USING TES OZONE-CO DATA TO OBSERVE INTERCONTINENTAL OZONE POLLUTION

602 hPa TES observations, July 2005





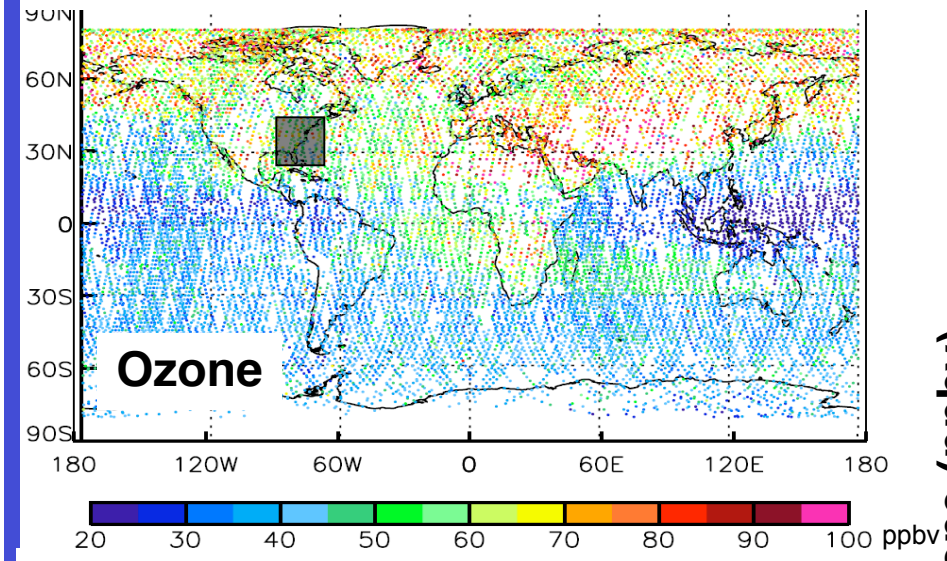
Ozone-CO relationship downwind of Asia

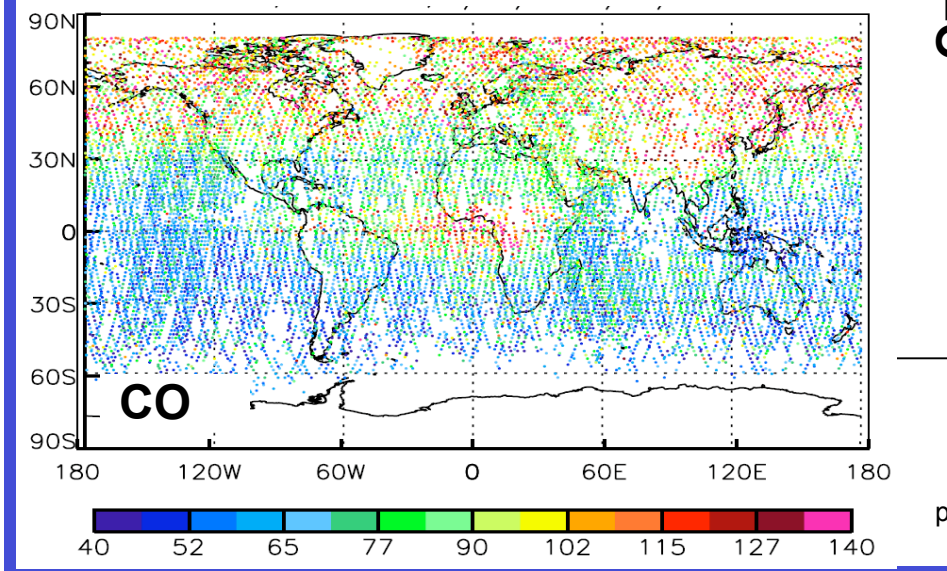


Lin Zhang, Harvard

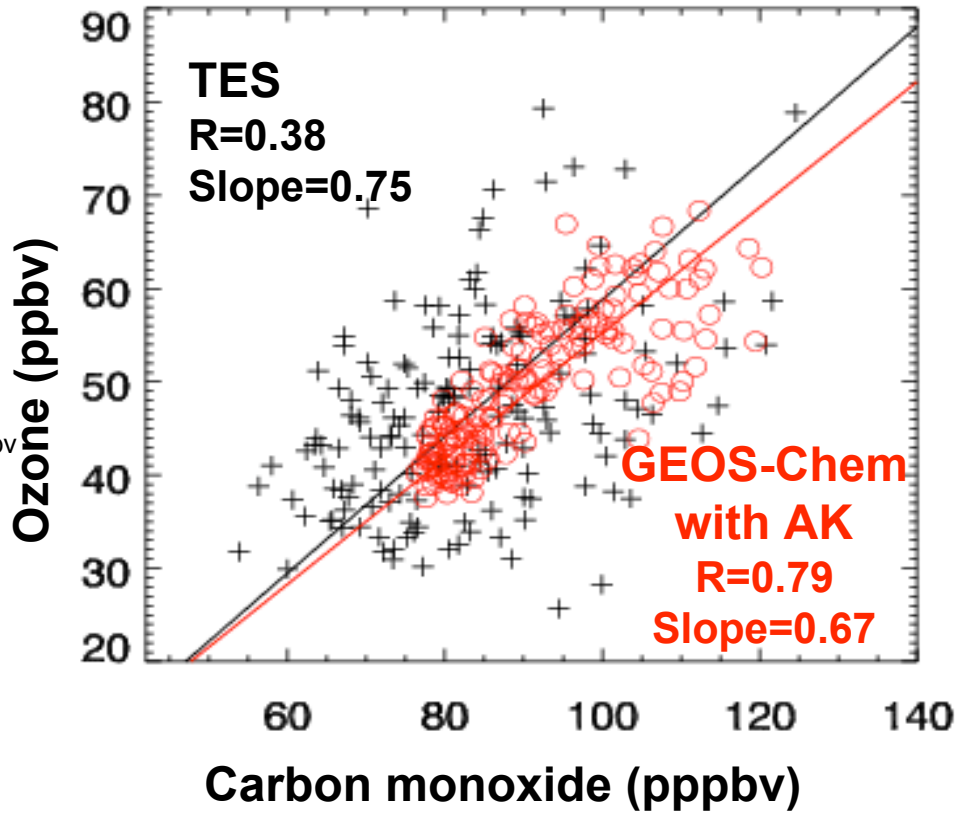
USING TES OZONE-CO DATA TO OBSERVE INTERCONTINENTAL OZONE POLLUTION

618 hPa TES observations, July 2005





Ozone-CO relationship downwind of eastern N. America

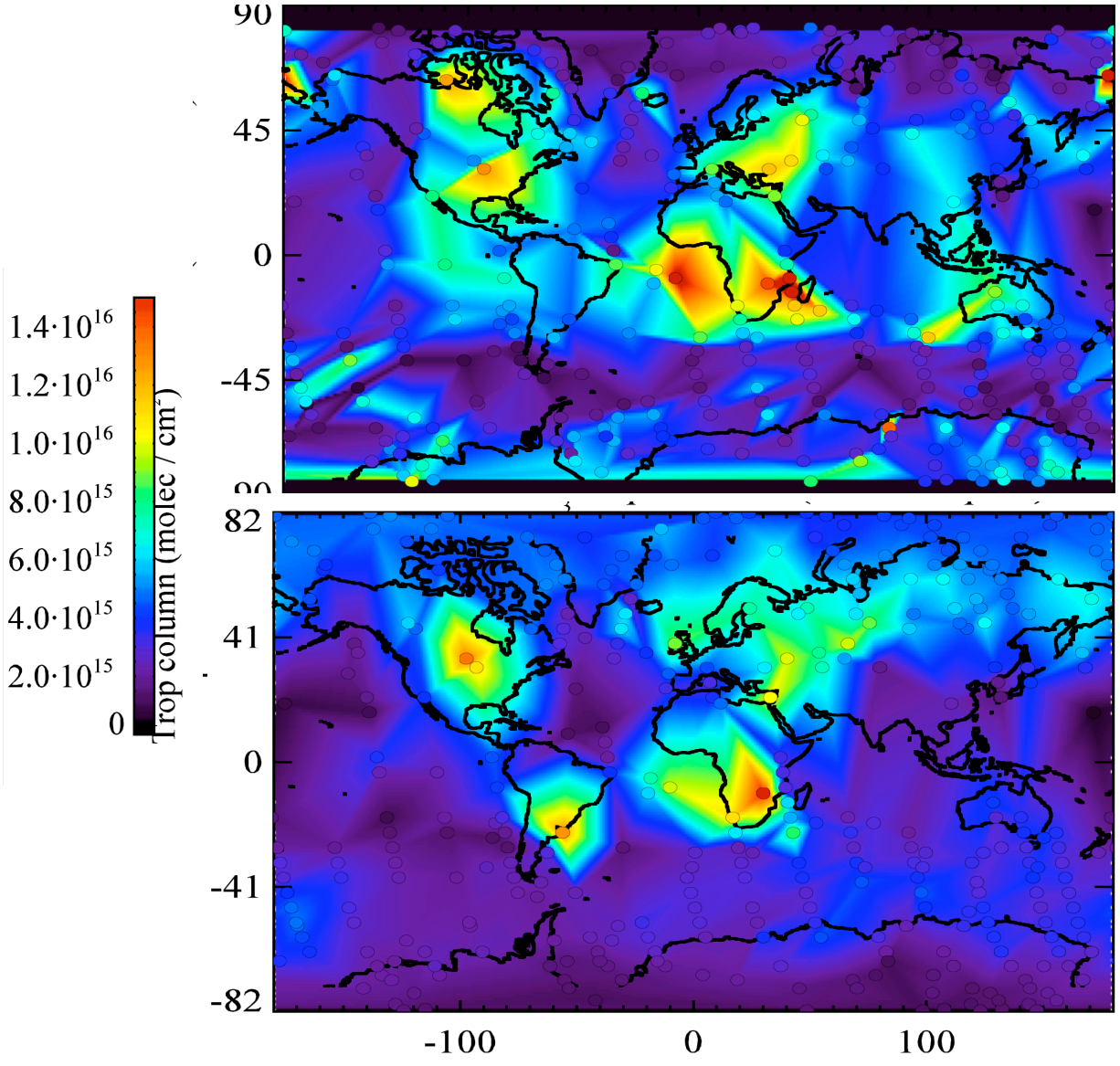


TES rertrieval noise $\hat{x} = x_a + A(x - x_a) + G\,\varepsilon$ weakens the correlation

Lin Zhang, Harvard

TES OBSERVATION OF UPPER TROPOSPHERIC HNO_3

tests lightning and other high-altitude sources of NO_x



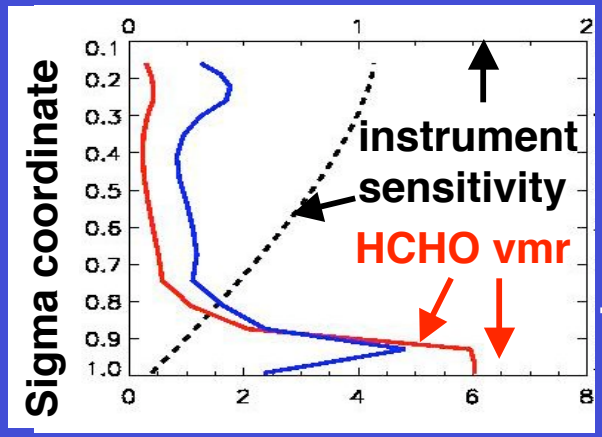
Sept 20-21 2004 TES data: hot spots over N. America, Europe, and Africa (lightning, fuel combustion, biomass burning)

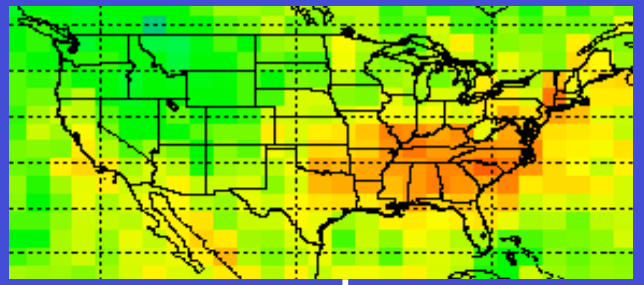
GEOS-Chem model

Susan S. Kulawik, JPL

INVERTING HCHO COLUMN DATA FOR ISOPRENE EMISSION

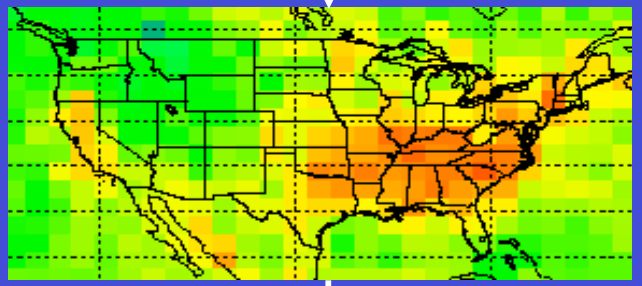
Palmer et al. [2001, 2003]





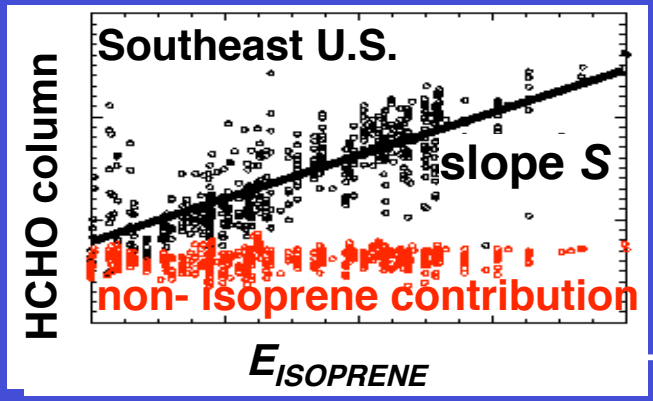
GOME slant columns (July 96)

Air Mass Factor



GOME vertical columns (July 96)

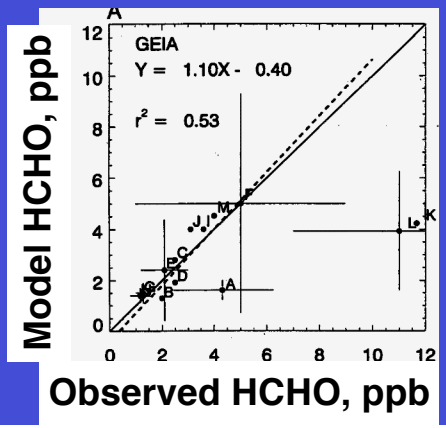
with GEIA isoprene emission inventory



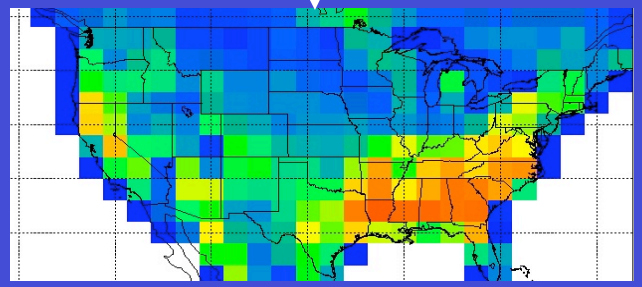
$E_{ISOPRENE} = (1/S)\Delta\,\Omega_{HCHO}$

GEOS-Chem CTM

with GOME isoprene emission inventory



validation With HCHO surface air observations

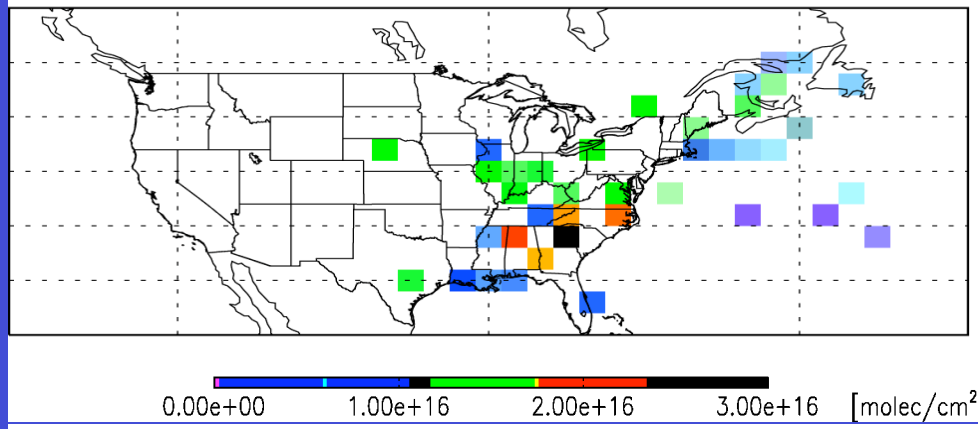


GOME isoprene emission inventory

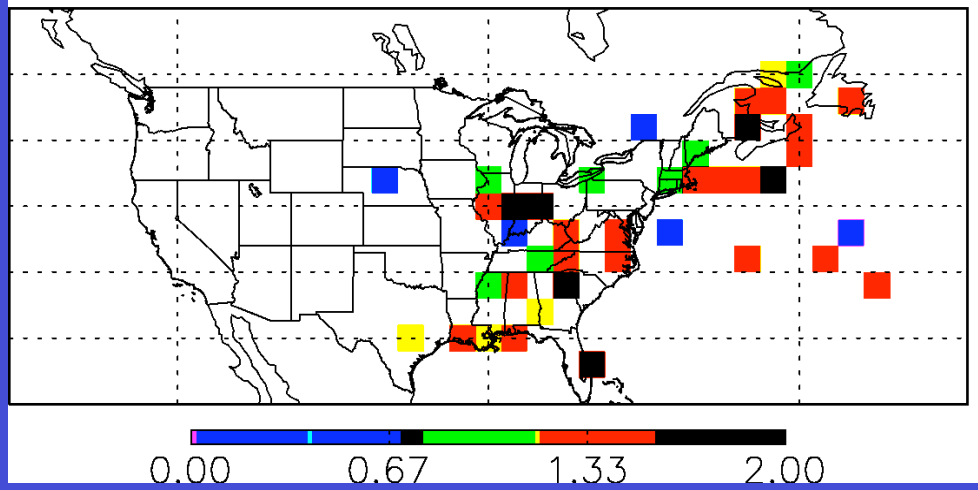
TEST AMF CALCULATION AND HCHO SOURCE ATTRIBUTION

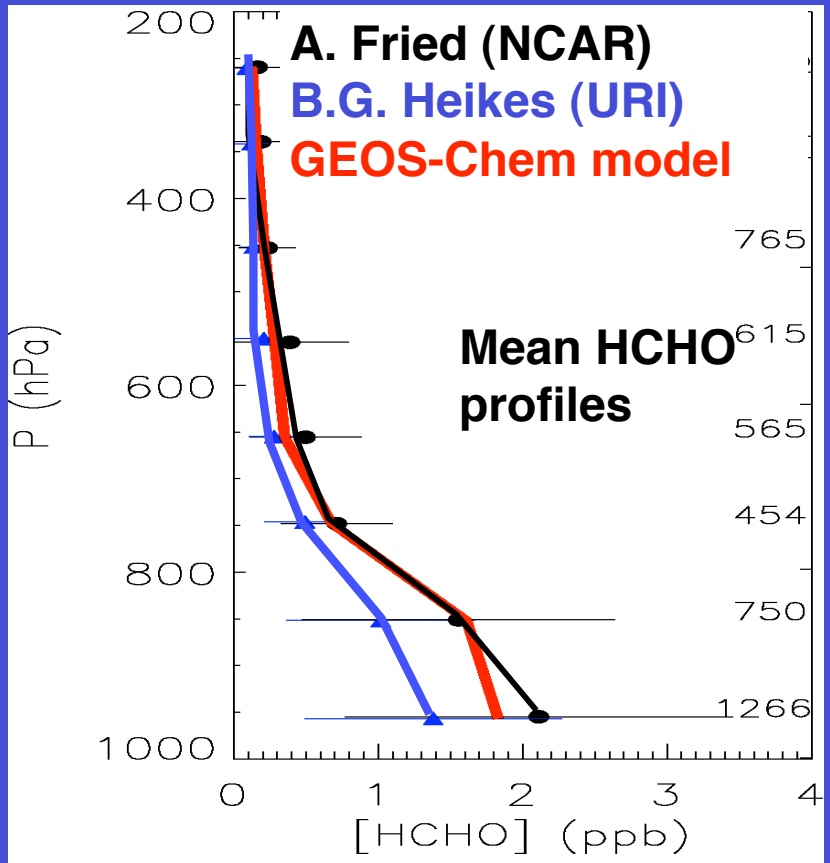
Aircraft 0-10 km HCHO profiles over N. America in INTEX-A (summer 2004)

Observed HCHO columns (A. Fried)



Observed AMF





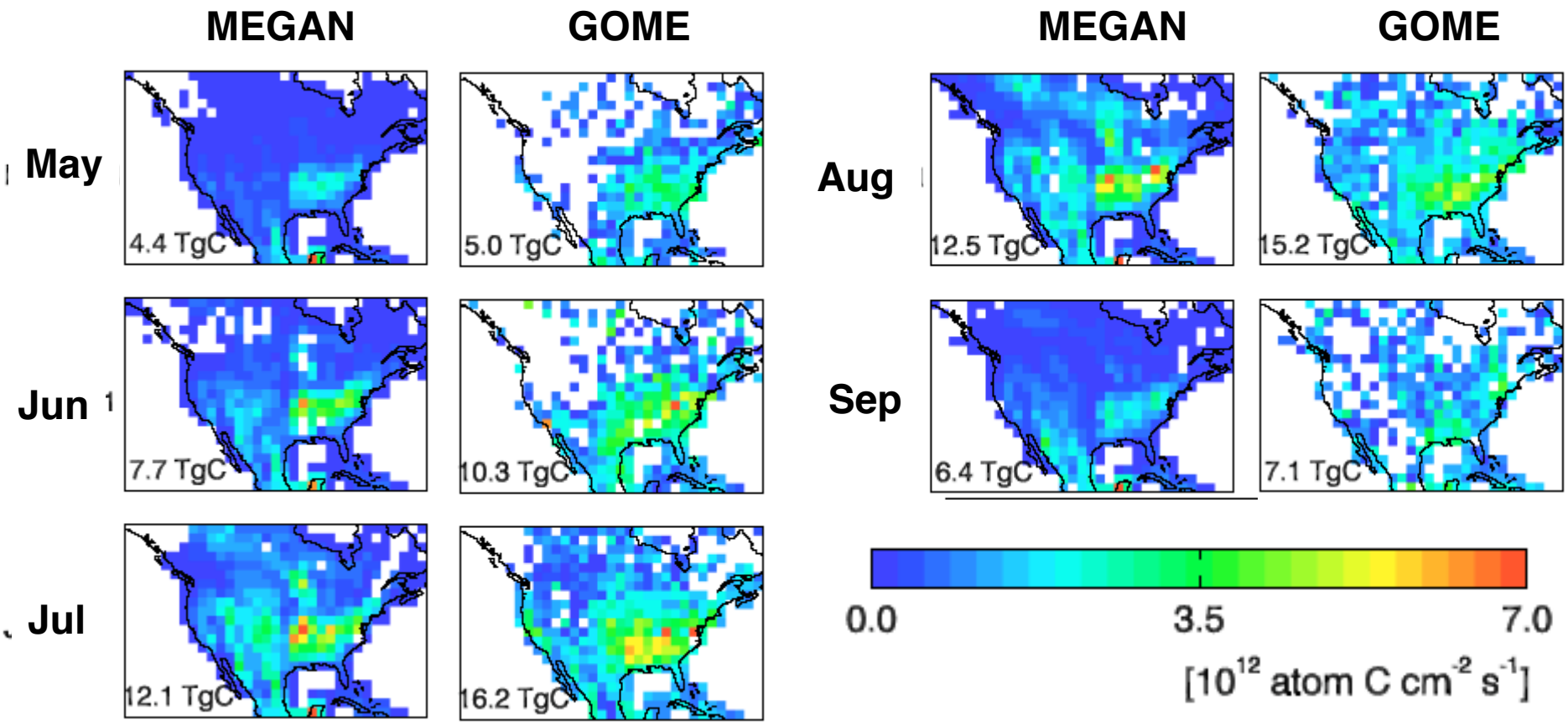
$$\frac{AMF_{model}}{AMF_{observed}} = 0.91 \pm 0.24$$

- Isoprene drives HCHO column variability; molar yield of 1.6 ± 0.5
- Clouds are the principal source of AMF error (30% for cloud cover of 40%)
- Overall 40% error on inferred isoprene emission

Millet et al. [2006]

GOME vs. MEGAN ISOPRENE EMISSION INVENTORIES (2001)

MEGAN: new emission inventory for biogenic VOCs [Guenther et al., 2006]

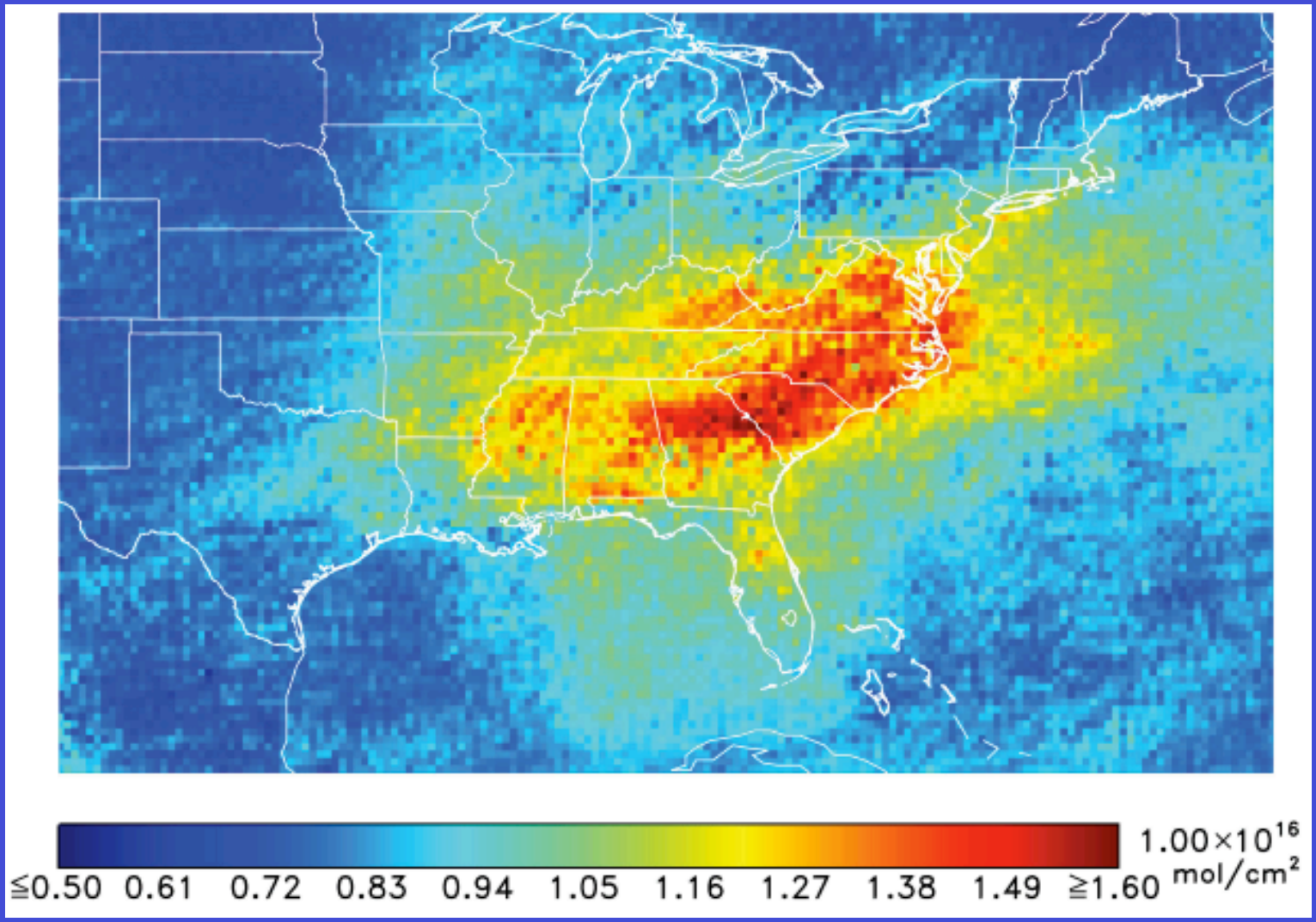


- Good accord for seasonal variation, regional distribution of emissions;
- GOME 10-30% higher than MEGAN depending on month, differences in hot spot locations

Palmer et al. [2006]

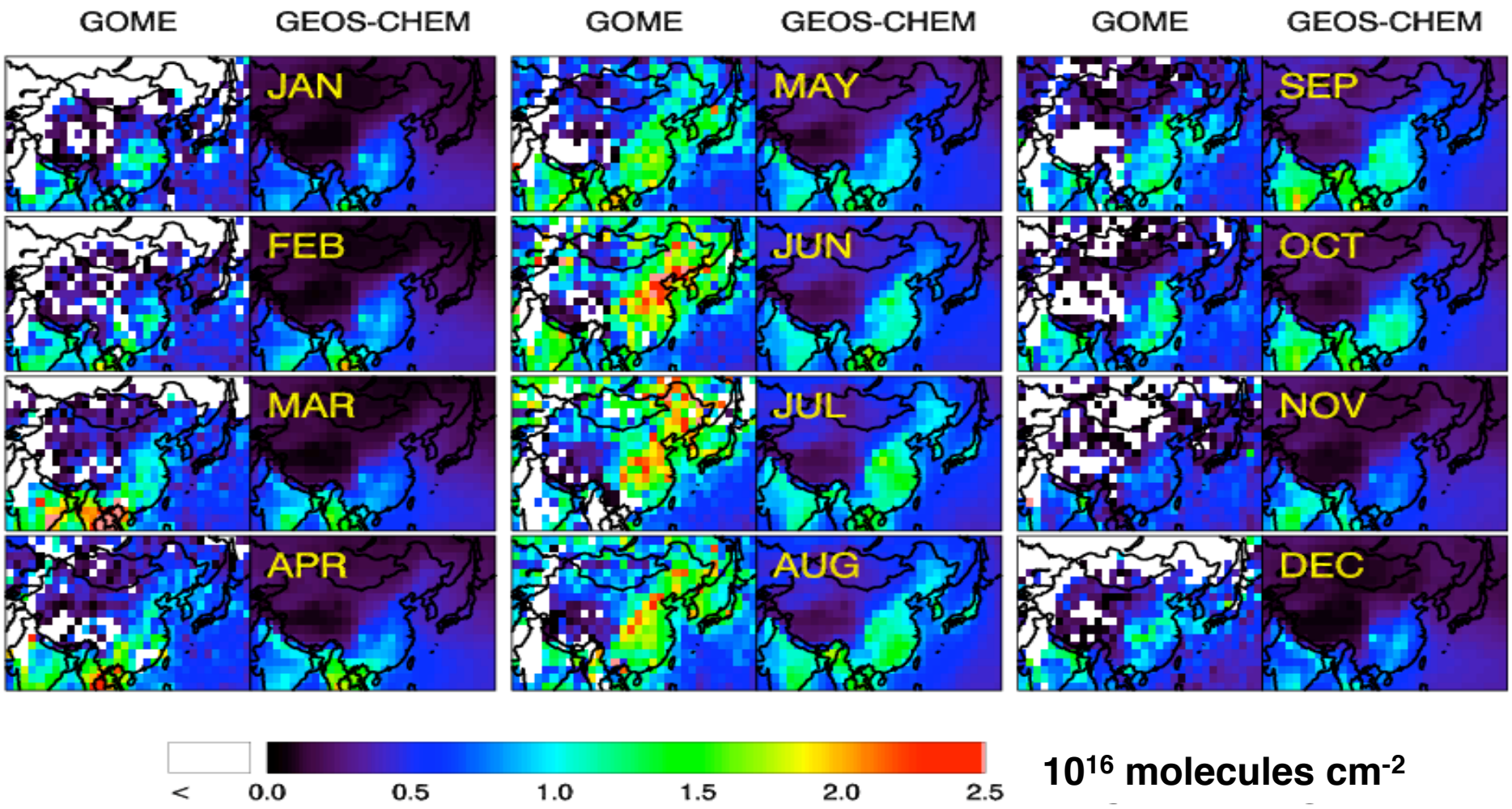
PRELIMINARY HCHO COLUMN DATA FROM OMI (Jul. 2005)

consistent with GOME maximum over southeast Atlantic states



Thomas Kurosu and Kelly V. Chance (Harvard/SAO)

GOME HCHO COLUMNS OVER EAST ASIA (1996-2001)



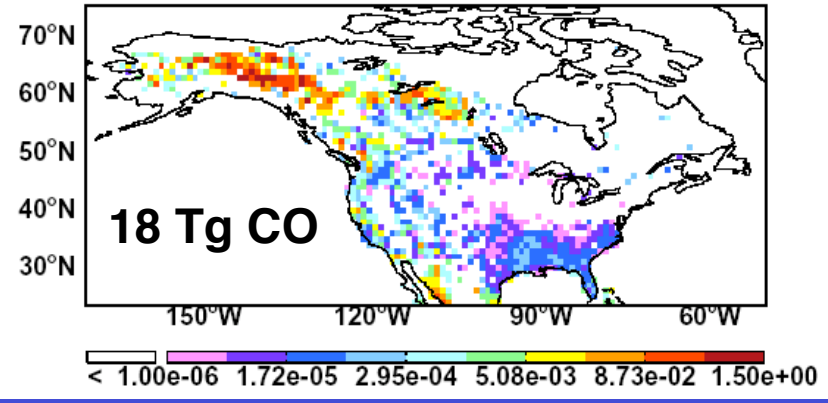
- Winter data imply vehicular VOC emissions 3x Streets et al. [2003] inventory
- Large, previously recognized agricultural burning source in E. China in Jun-Jul
- Biogenic emissions 3x higher than MEGAN

Tzung-May Fu , Harvard

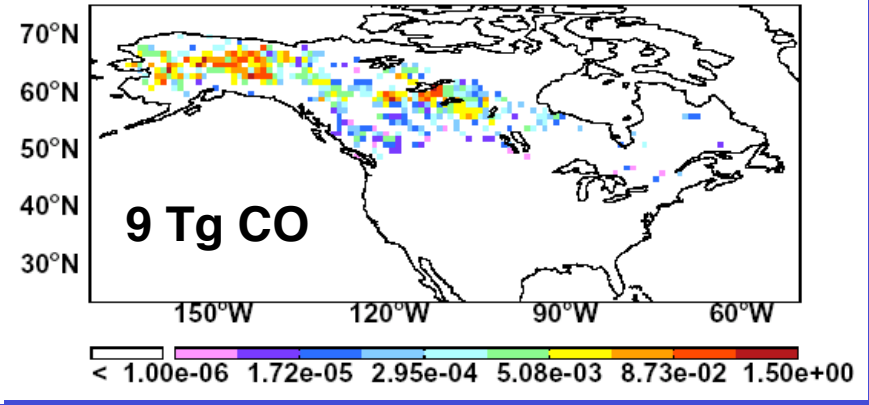
USING MODIS TO MAP FIRES AND MOPITT CO TO OBSERVE EMISSIONS

Bottom-up emission inventory (Tg CO) for North American fires in Jul-Aug 2004

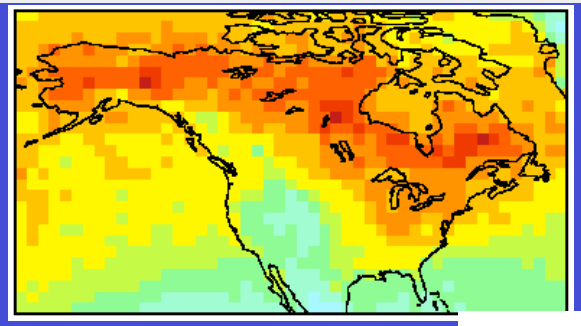
From above-ground vegetation



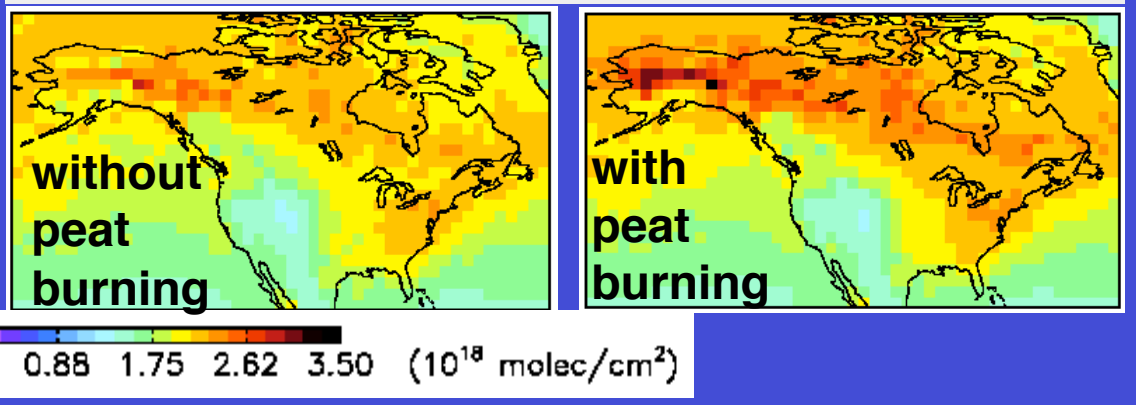
From peat



MOPITT CO Summer 2004



GEOS-Chem CO x MOPITT AK

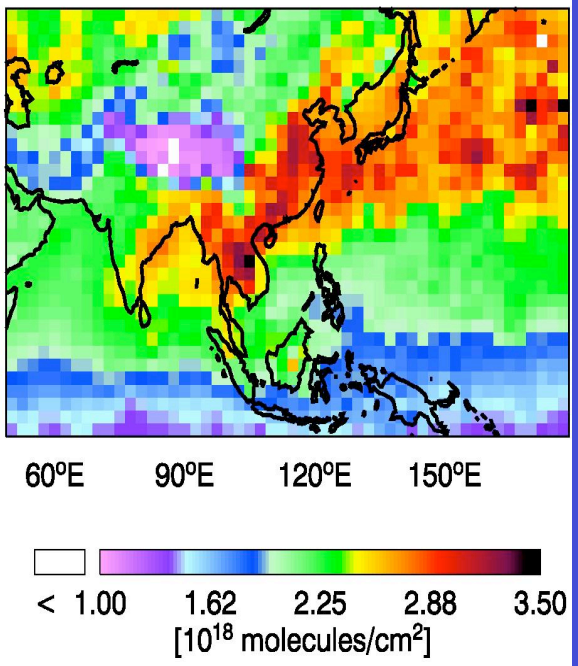


MOPITT data support large peat burning source, pyro-convective injection to upper troposphere

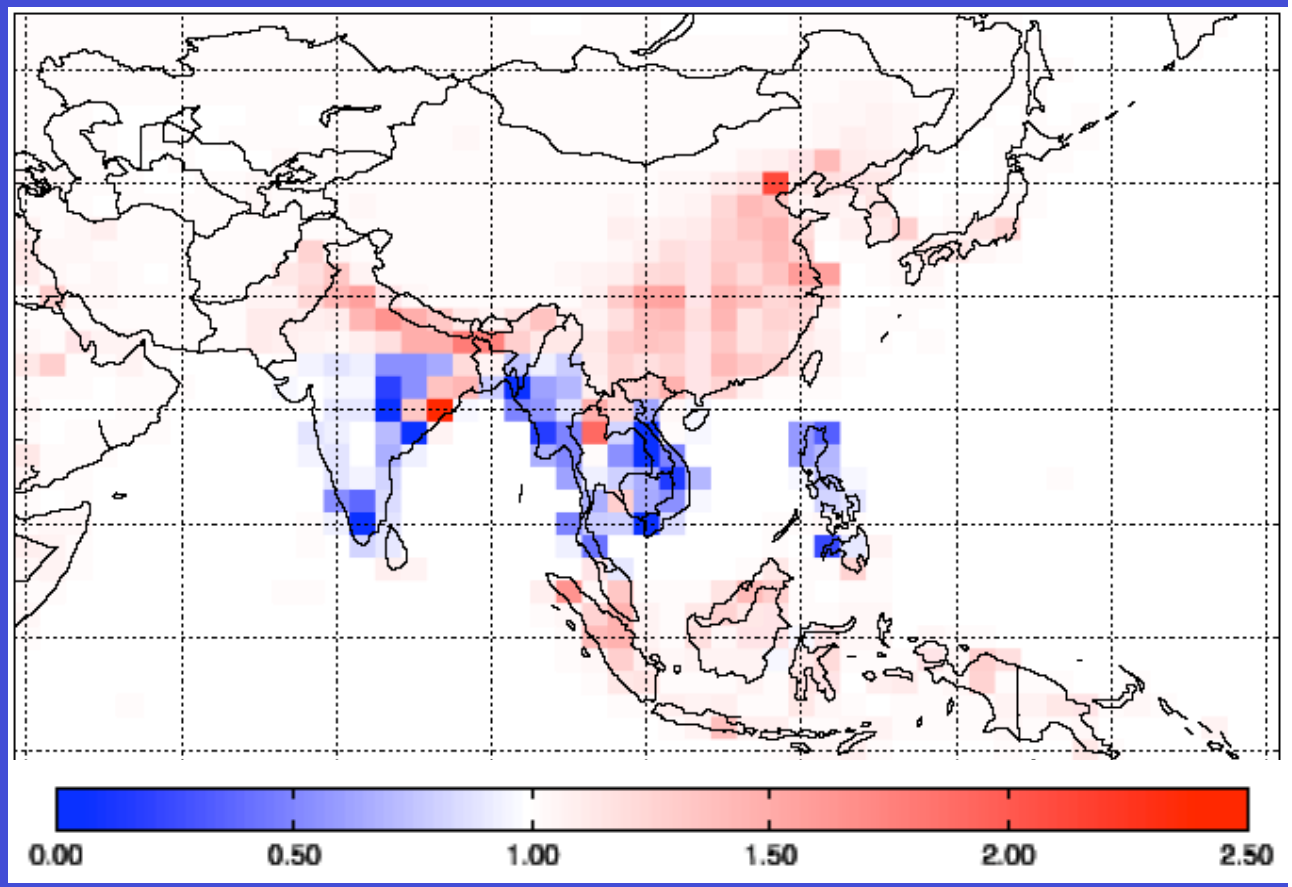
Solene Turquety, Harvard/CNES

USING ADJOINTS OF GLOBAL MODELS TO INVERT FOR EMISSIONS WITH HIGH RESOLUTION

MOPITT daily CO columns (TRACE-P, Mar-Apr 2001)



Scaling factors for *a priori CO* sources obtained with 4D-var using the GEOS-Chem model adjoint



A priori emissions from Streets et al. [2003] and Heald et al. [2003]

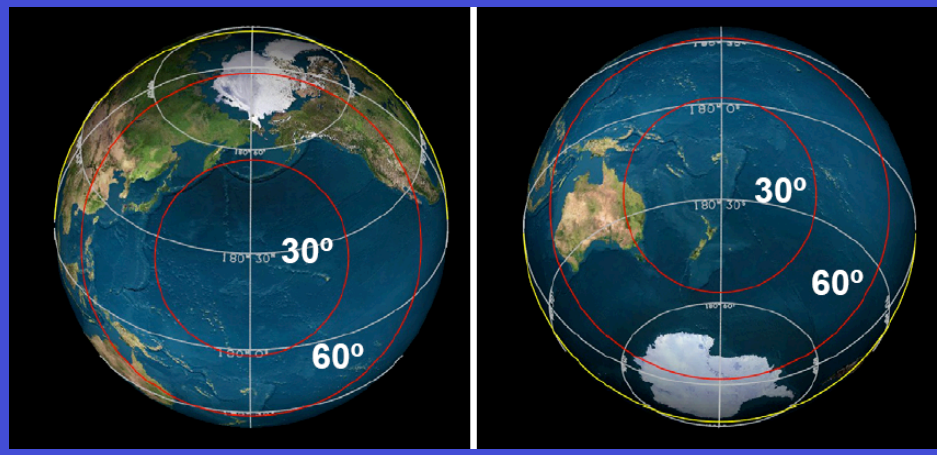
Monika Kopacz, Harvard

LOOKING TO THE FUTURE: L-1 AIR QUALITY MISSION

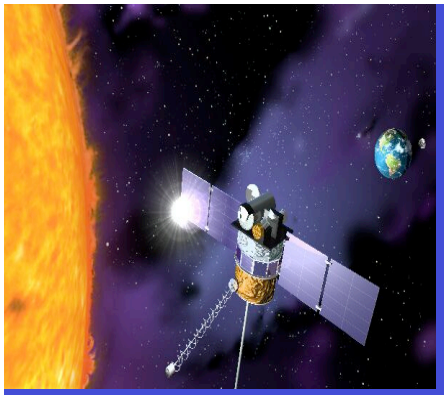
Daedalus and Janus RFI concepts

- Continuous global observation of Earth sunlit disk with 5 km nadir resolution
- UV-IR spectrometers for observation of ozone, NO_2, HCHO, CO, aerosols
- Global continuous view from L-1 critical for observation of hemispheric pollution, tropospheric background, greenhouse gases
- Bridge with interests of climate, upper atmosphere, space weather, solar physics communities

L-1 point : 1.5 million km from Earth along Earth- Sun line



NH and SH summer views from L-1: global continuous daytime coverage



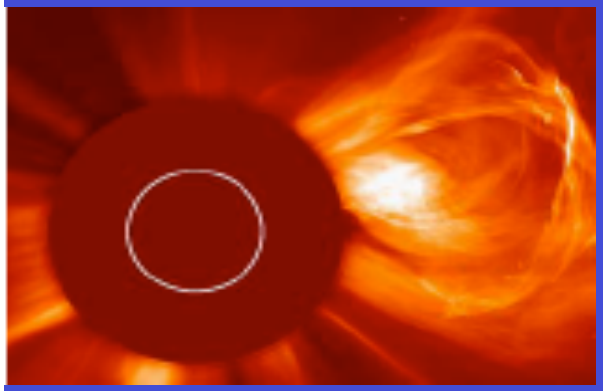
JANUS MISSION

Earth-Sun observation from L-1

Overarching theme: Sun-Earth connections

Includes continuous observation of Earth w/ 5 km nadir horizontal resolution

Sun : coronal heating, solar wind acceleration, flares and transients. CMEs, UV irradiance variability

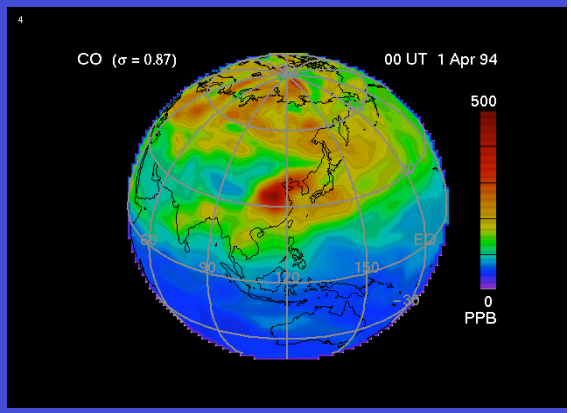


- White light coronagraph
- soft X-ray/EUV spectrometers (0.1-63 nm)

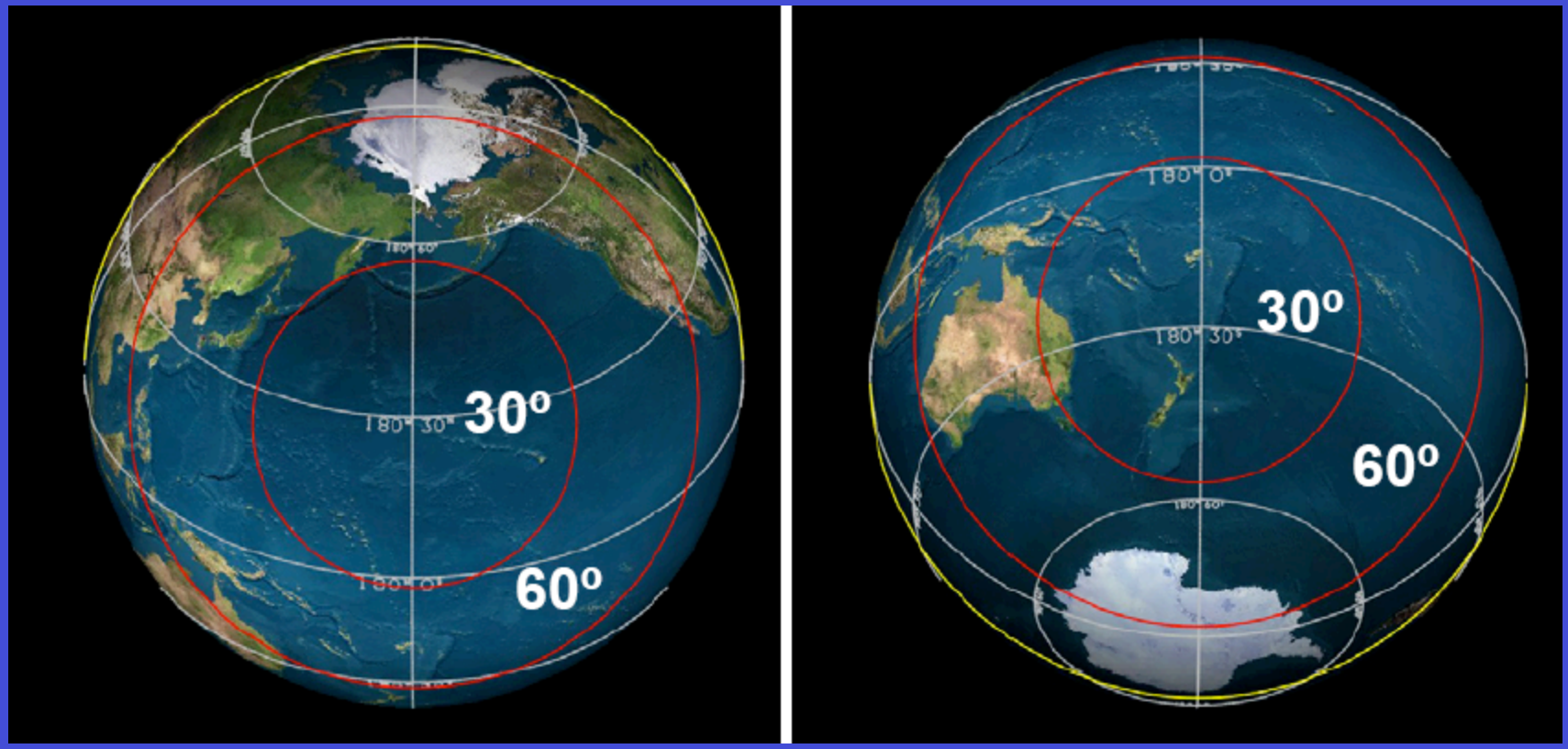
Solar wind and middle/upper atmosphere: space weather, Sun-Earth connections, upper atmosphere and stratosphere chemistry and dynamics

- EUV/MUV spectrometers (50-340 nm)
- Magnetometer
- Faraday Cup

Troposphere: sources and sinks of gases and aerosols, long-range transport of pollution

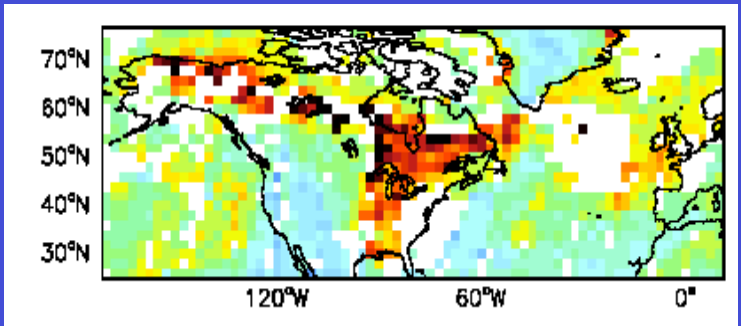


- near-UV/near-IR spectrometers, 300-2400 nm

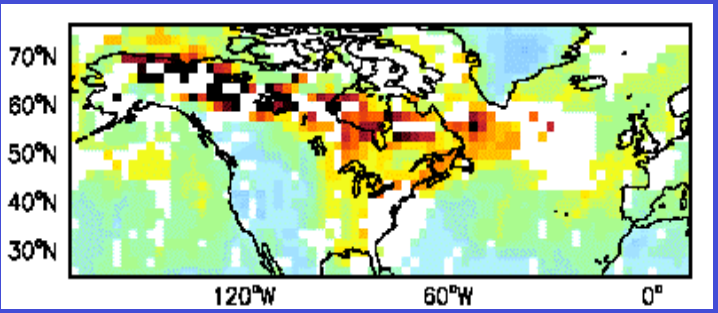

30°
60°
30°
60°

MOPITT CONSTRAINTS ON FIRE INJECTION HEIGHTS

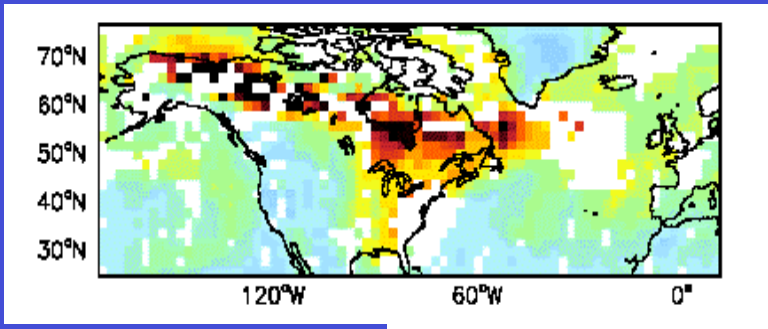
MOPITT CO column (Jul 17-19)



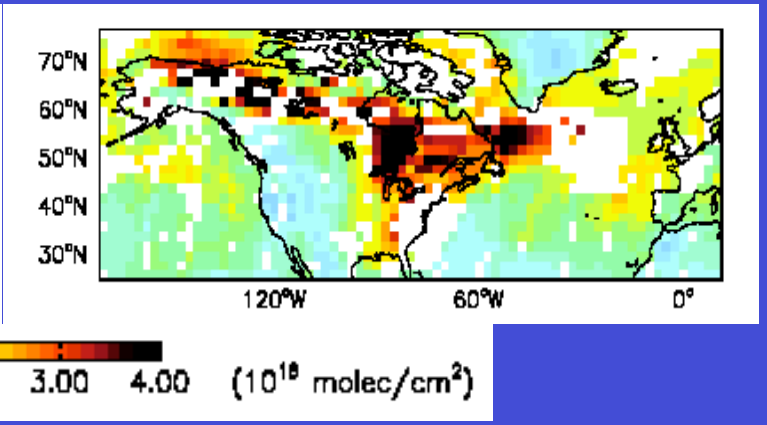
GEOS-Chem w/AK – BB 100% BL



GEOS-Chem w/AK –
BB 40% BL + 55% MT + 5% UT



GEOS-Chem w/AK –
BB 30% BL + 40% MT + 30% UT



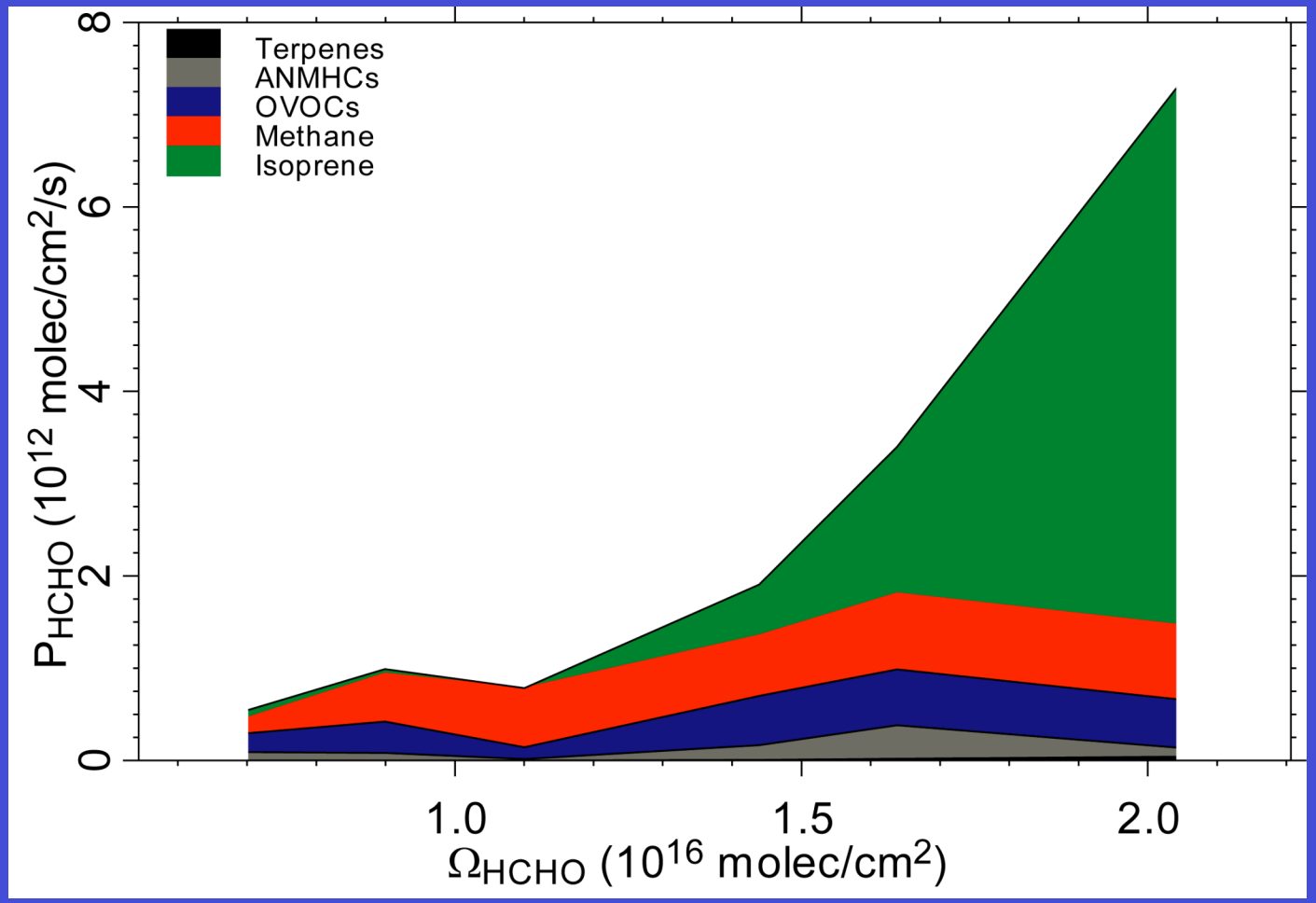
Strong day-to-day variability in injection heights

Solene Turquety, in prep.

RELATING OBSERVED HCHO COLUMNS TO PARENT VOCs

Calculate P_{HCHO} from concurrent column observations of VOCs during INTEX-A

(D. R. Blake and H.B. Singh)

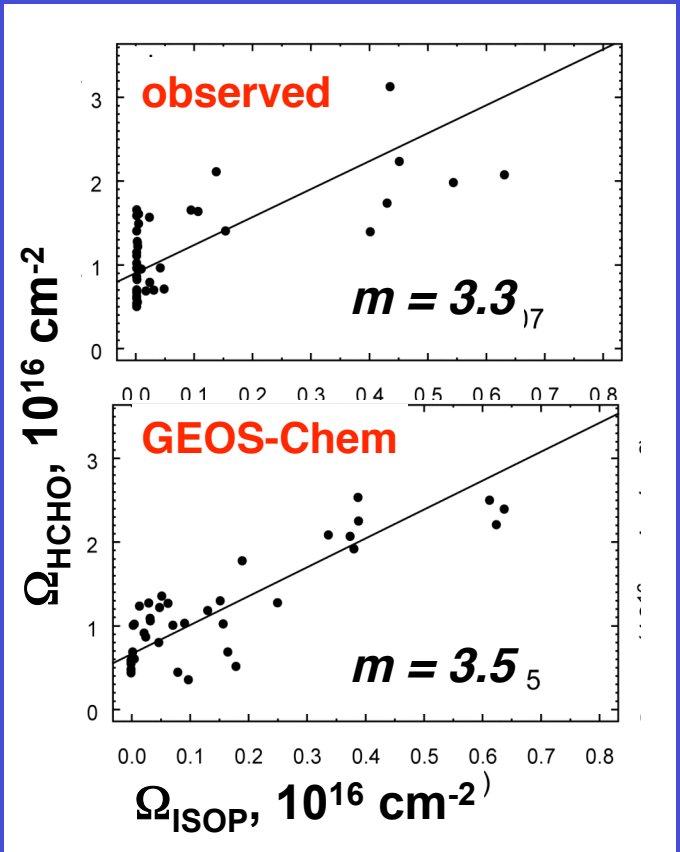


Detectable HCHO columns and variability over N. America are driven by isoprene

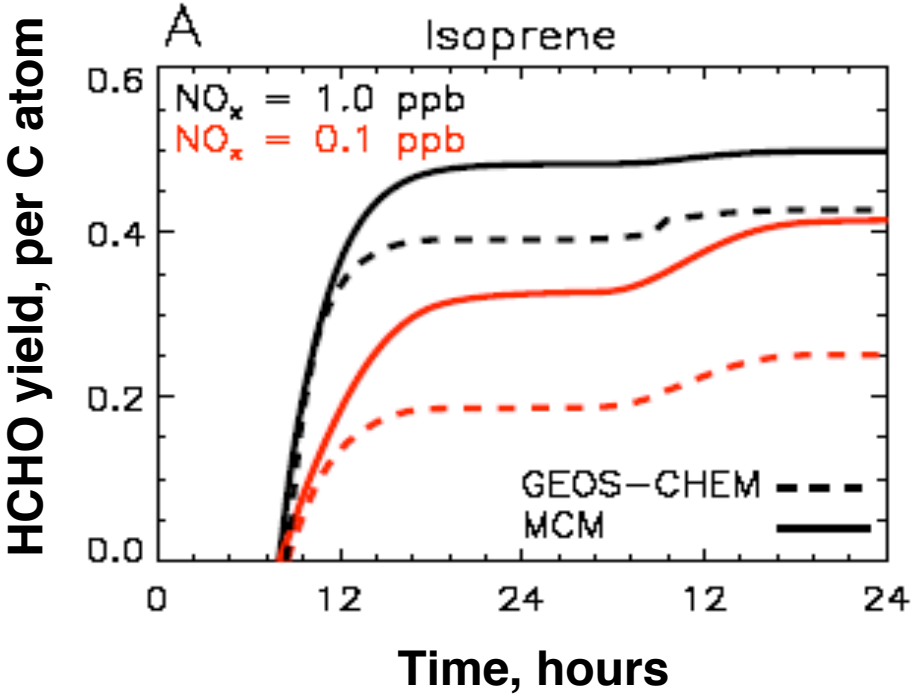
Dylan B. Millet, in prep.

HCHO YIELDS FROM ISOPRENE OXIDATION

HCHO vs. isoprene columns in INTEX-A



Box model simulations: GEOS-Chem and MCM v3.1 mechanisms

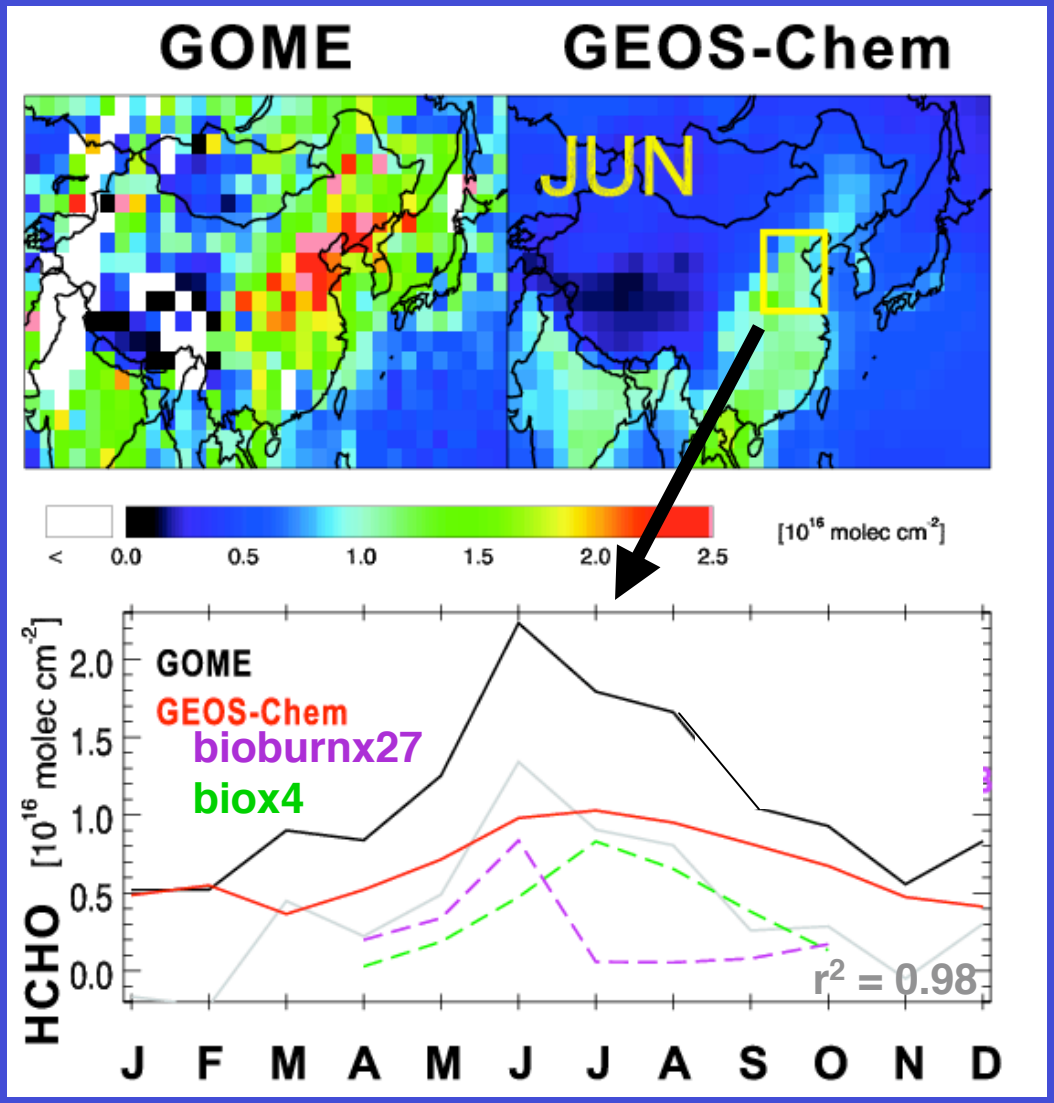


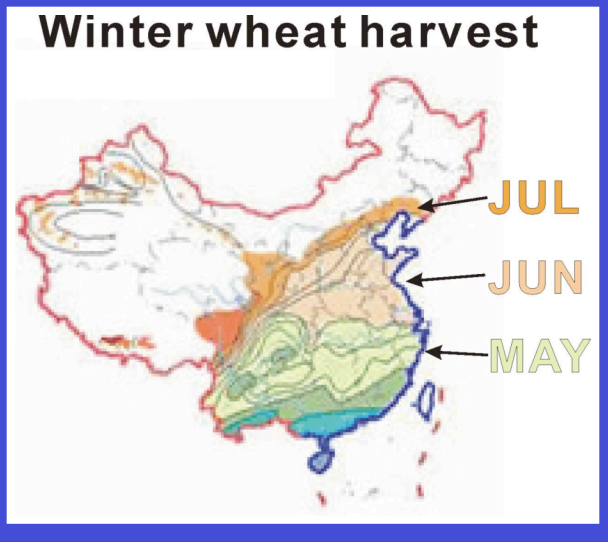
Estimate yield uncertainty of ~20%, greater in low-NO_x regime

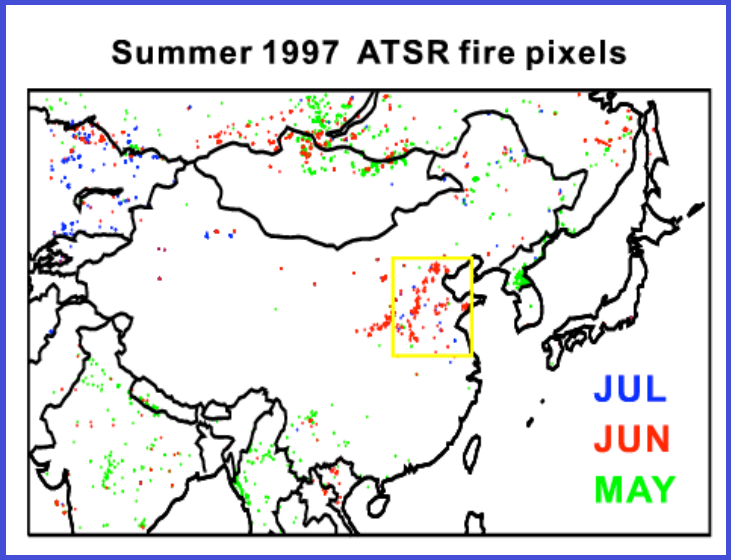
Dylan B. Millet , in prep.; Palmer et al., submitted

AGRICULTURAL BURNING IN E. CHINA PLAIN IN JUNE

Large, previously unrecognized VOC source from winter wheat harvest



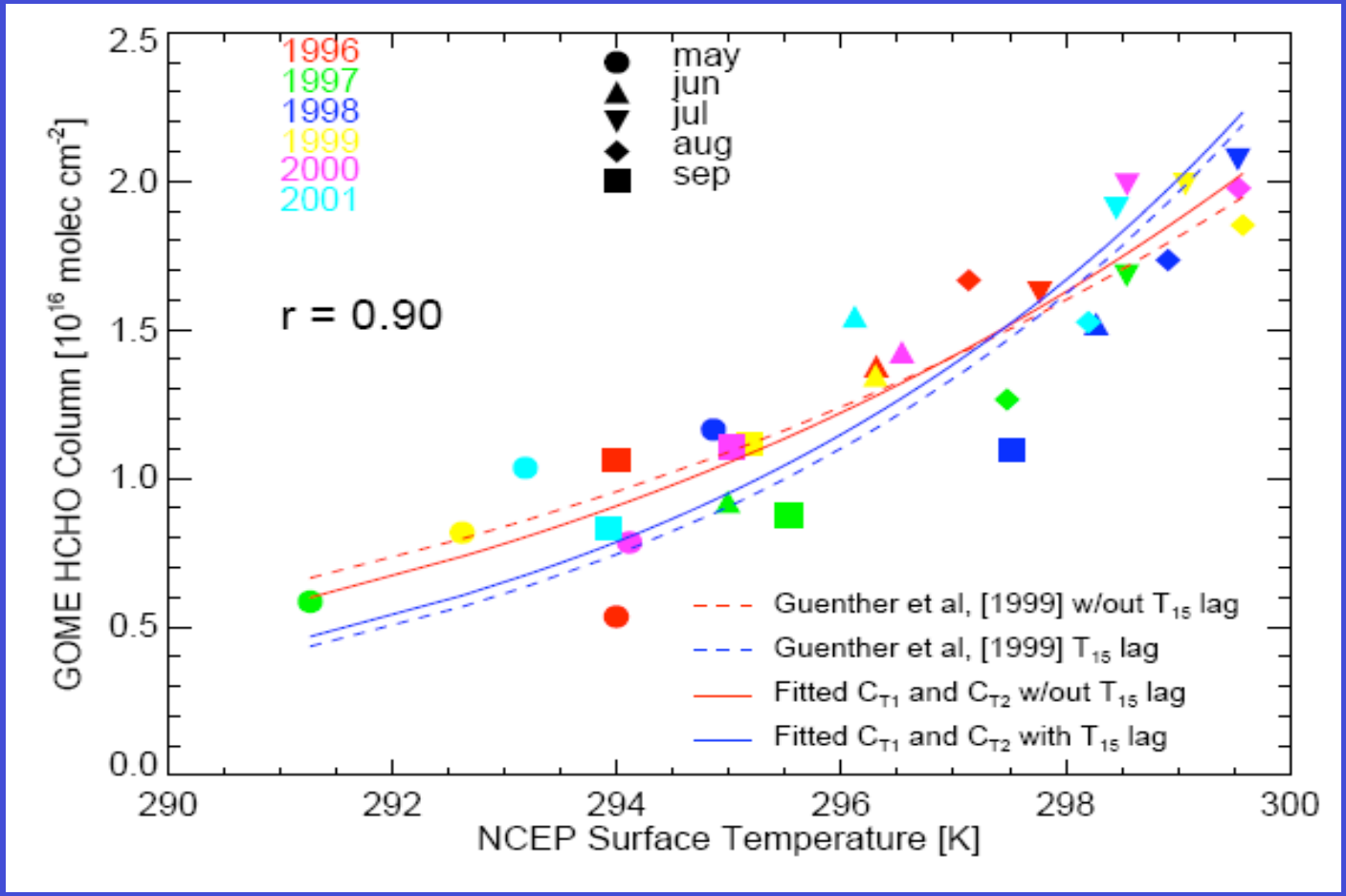




Tzung-May Fu, in prep.

WHAT DRIVES THE TEMPORAL VARIANCE OF ISOPRENE OVER SOUTHEAST U.S. DURING THE GROWING SEASON?

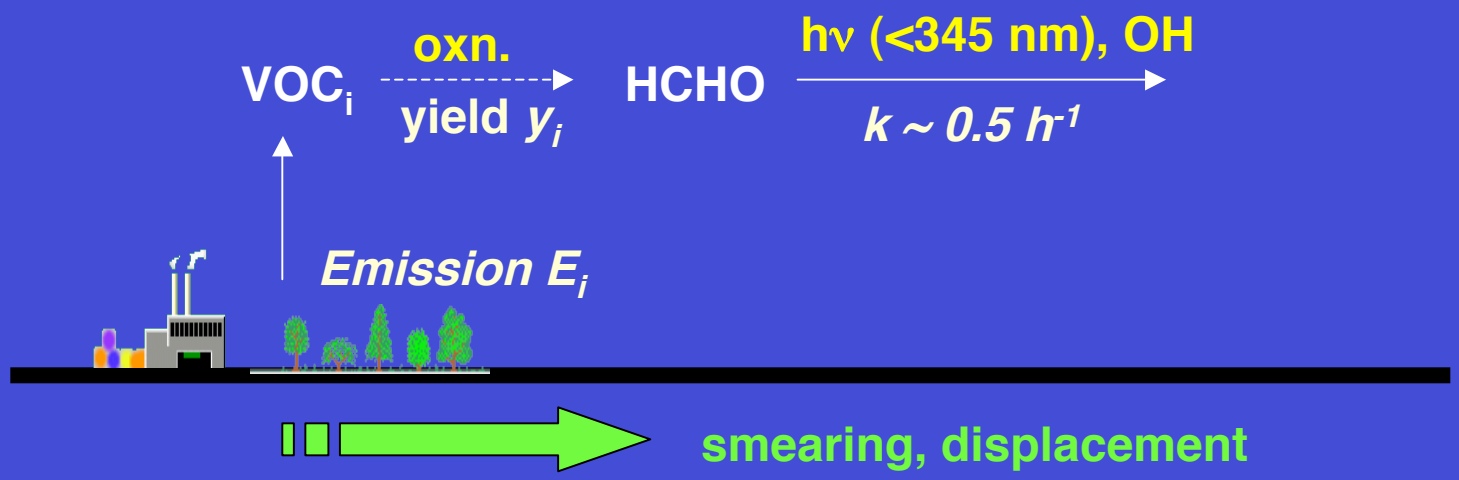
Monthly mean GOME HCHO vs. surface air temperature;
MEGAN parameterization shown as fitted curve



Temperature accounts for ~80% of the variance

Palmer et al., submitted

RELATING HCHO COLUMNS TO VOC EMISSION

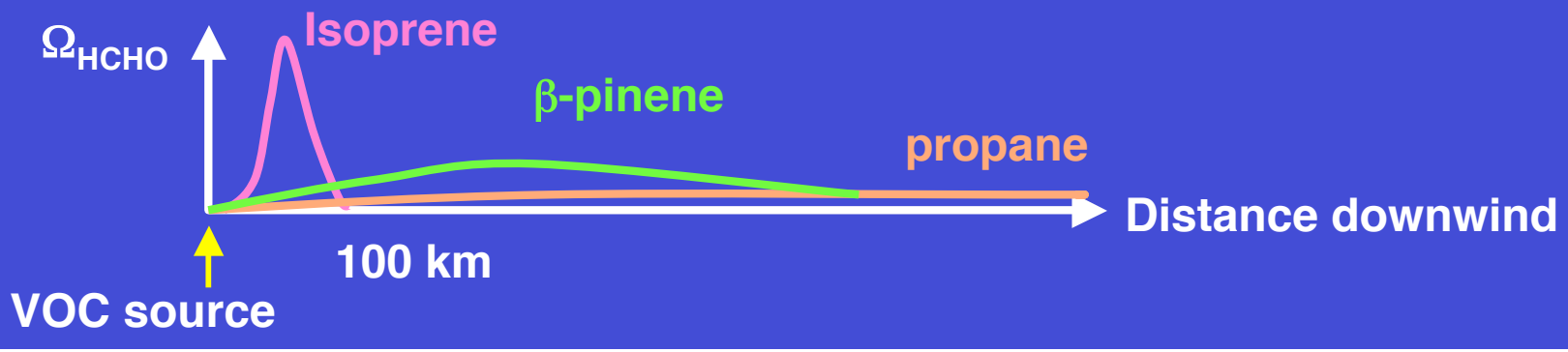


In absence of horizontal wind, mass balance for HCHO column Ω_{HCHO}:

$$\Omega_{HCHO} = \frac{\sum_i y_i E_i}{k}$$

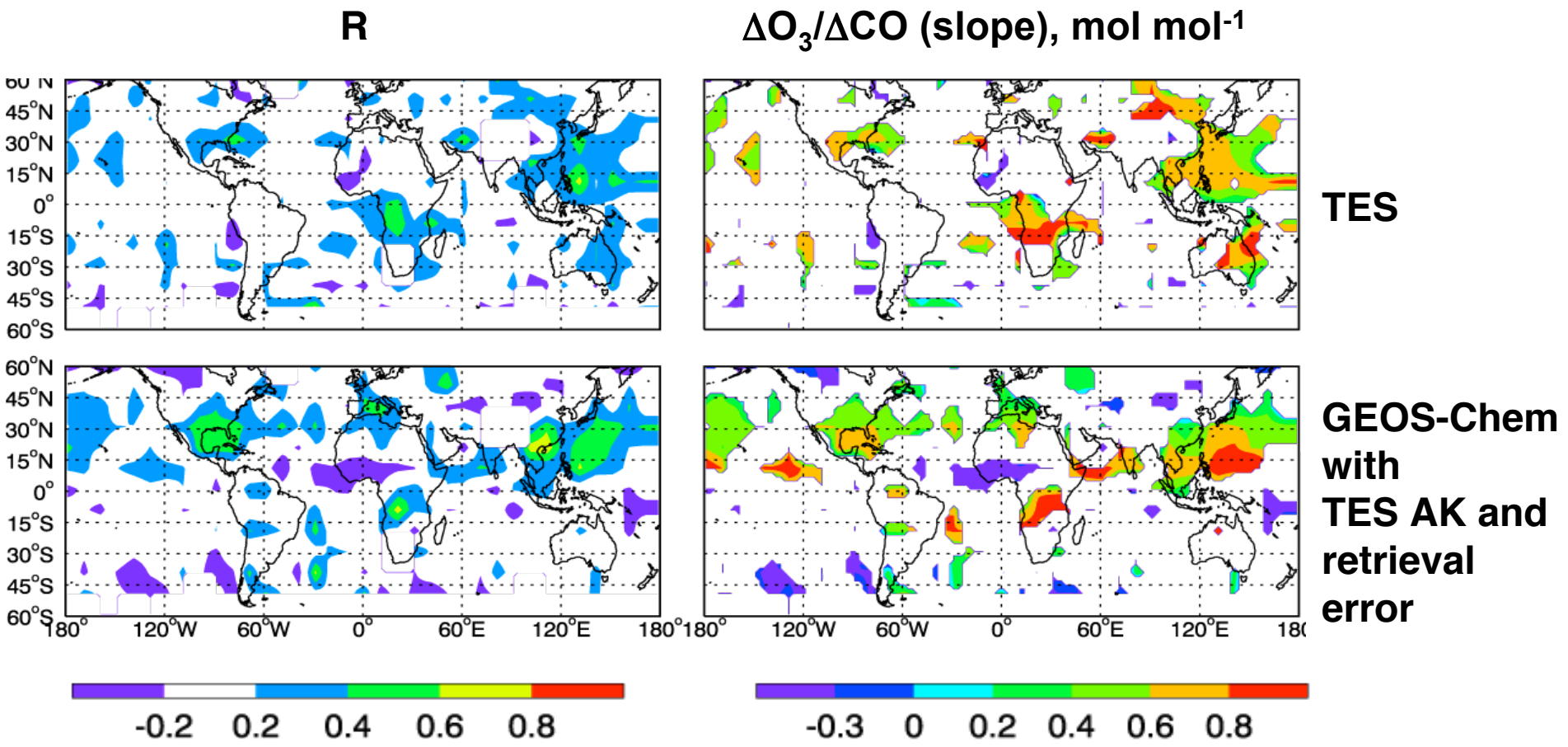
Local linear relationship between HCHO and *E*

… but wind smears this local relationship between Ω_{HCHO} and E_i depending on the lifetime of the parent VOC with respect to HCHO production:



OBSERVATION OF OZONE-CO CORRELATIONS IS SENSITIVE TO RETRIEVAL ERROR

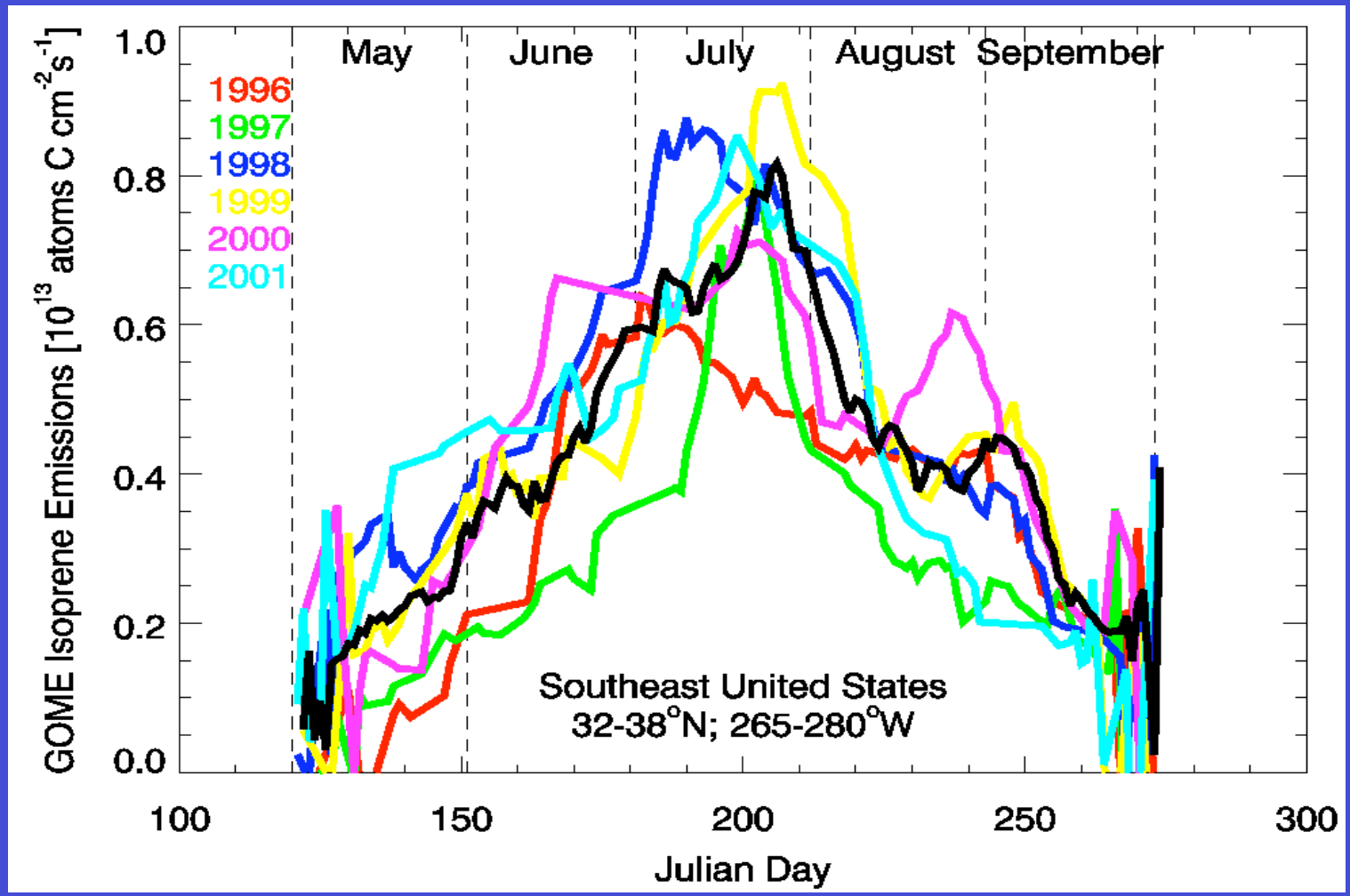
Applying TES retrieval error $\hat{x} = x_a + A(x - x_a) + G\,\varepsilon$ **to the model fields degrades correlations to values consistent with observations**

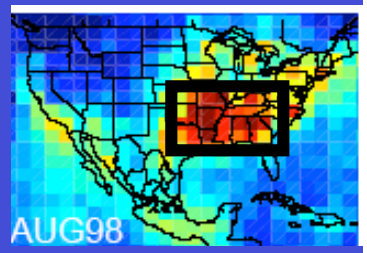


Recent optical bench warm-up has decreased retrieval error for CO

Lin Zhang, Harvard

INTERANNUAL VARIABILITY OF GOME ISOPRENE EMISSIONS OVER SOUTHEAST U.S.

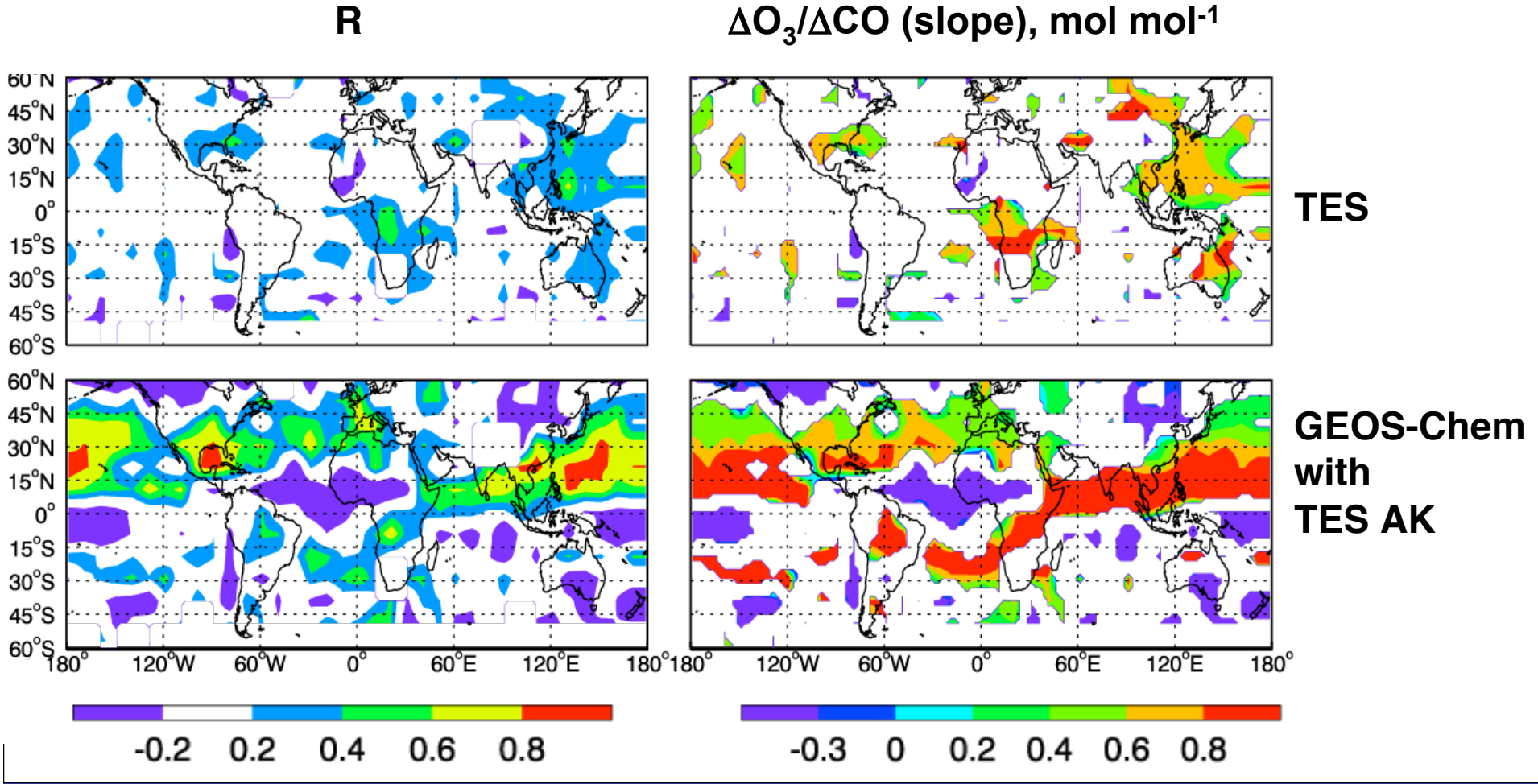




Amplitude and phase are highly reproducible; interannual variability driven by temperature

Palmer et al. [2006]

GLOBAL OZONE-CO CORRELATION OBSERVED BY TES (July 2005, 618 hPa)



Model shows stronger correlations, extending further downwind of the continents; can be explained by random retrieval error in observations

Recent warm-up of TES optical bench should help

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