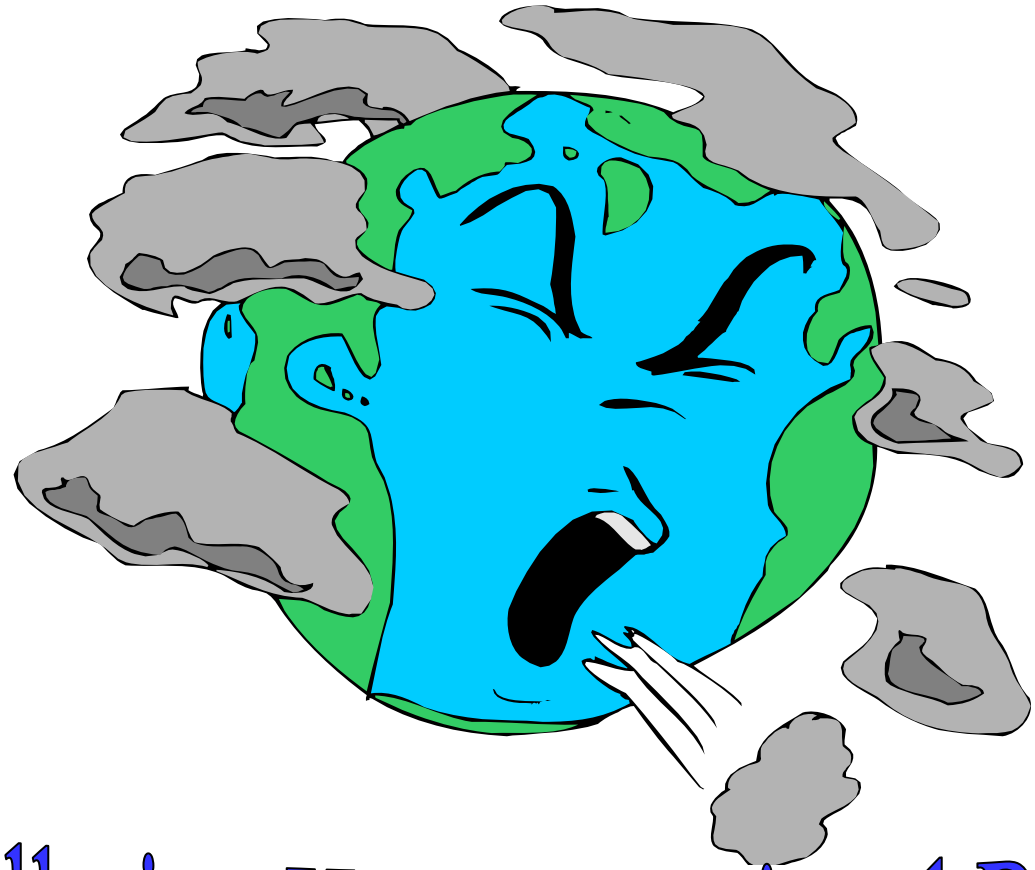
CMAS Conference Session 3:
International Modeling Applications



Air Pollution Has No National Boundaries

Air Pollution Control in 21st Century

Act Locally

Think Globally

City /Town

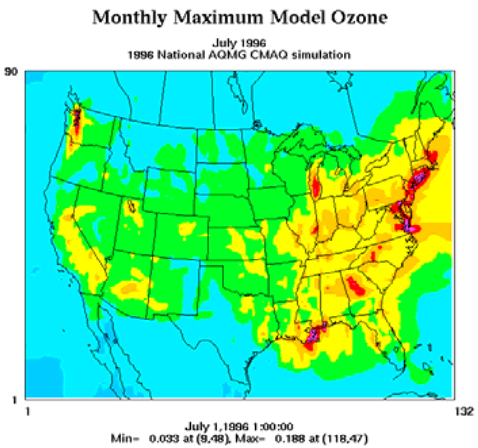
County

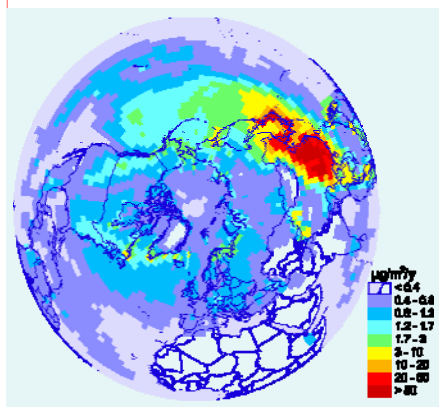
State/ Multi-Counties

Nation/ Multi-State

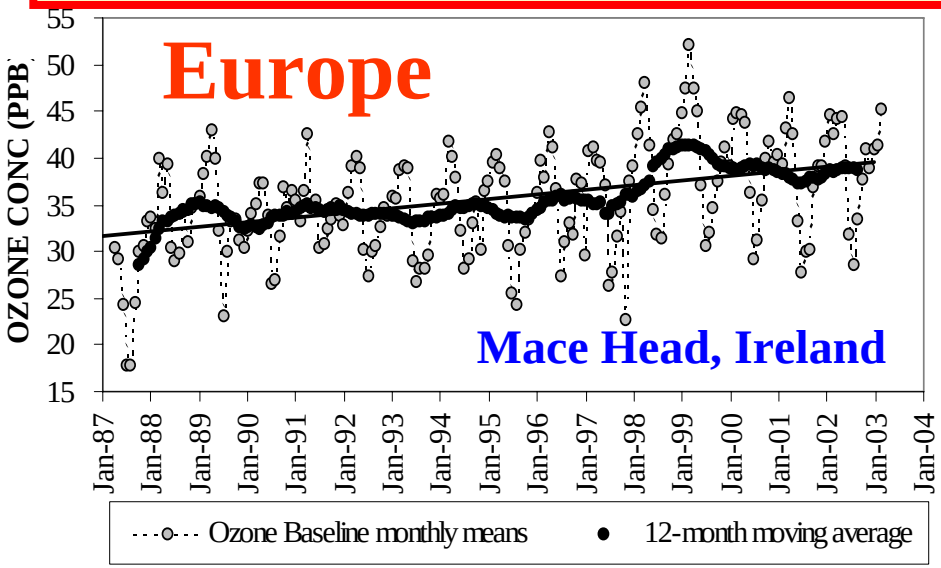
International

1920 1950 1970 1980 1990 2000

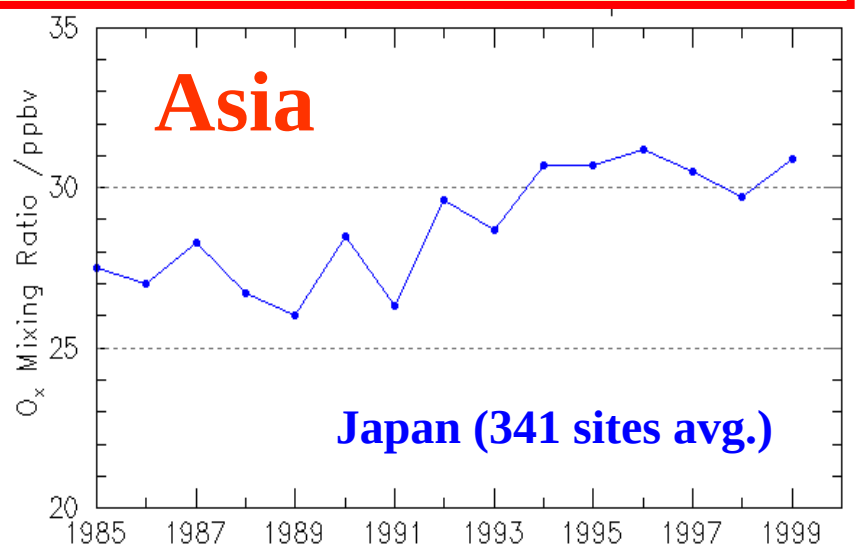




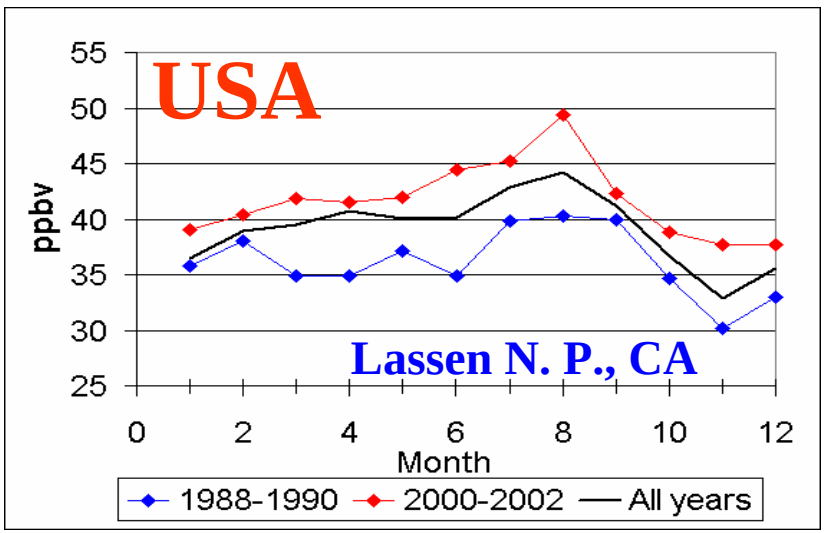
Hemispheric Background O3 Levels Are Rising



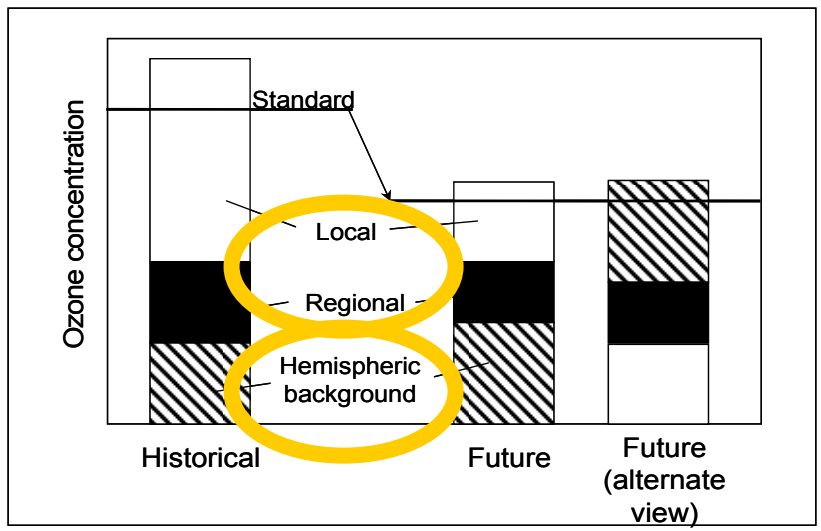
(Dick Derwent, ICAP workshop, 2004)



(Oliver Wild, ICAP workshop, 2004)

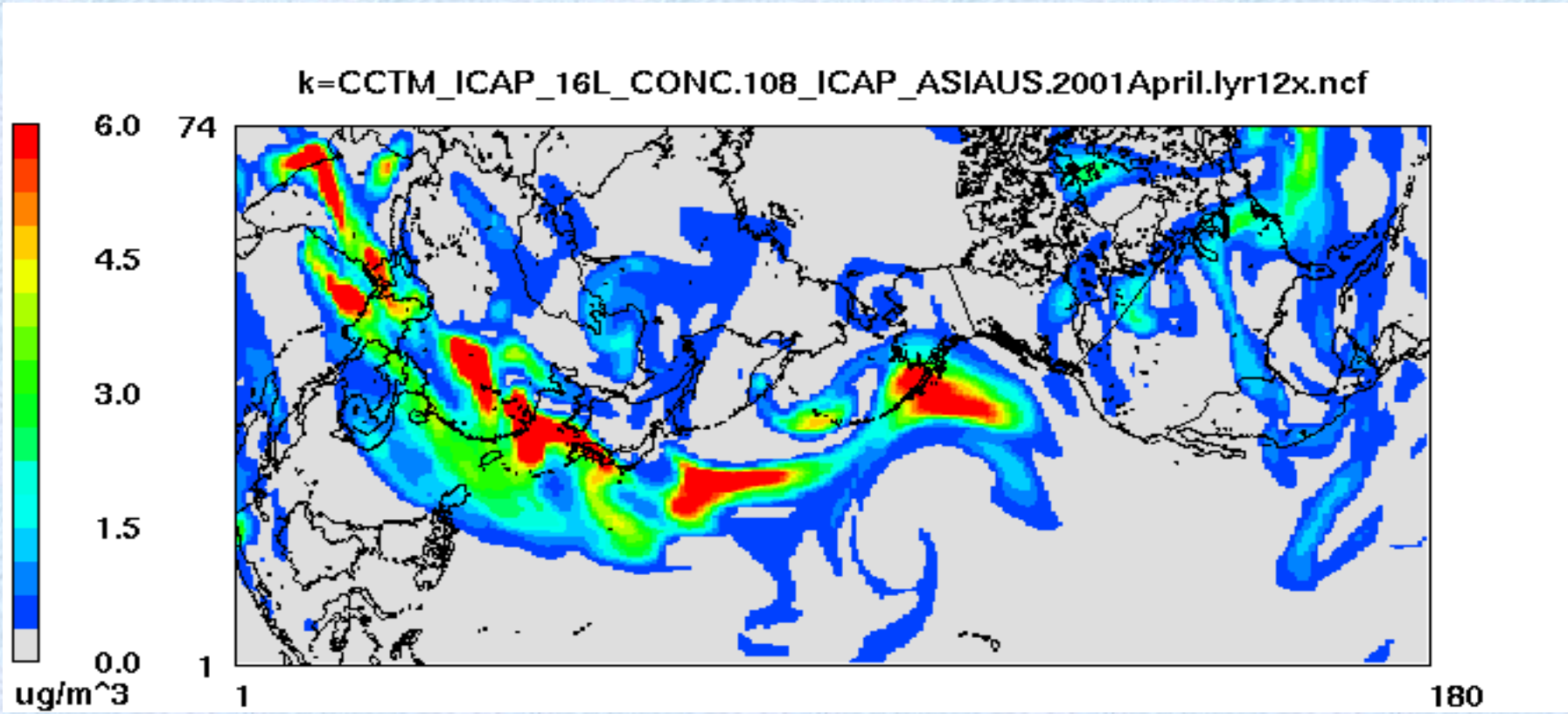


(Dan Jaffe, ICAP workshop, 2004)



(Terry Keating, ICAP workshop, 2004)

Trans-Pacific Transport of Air Pollutants and its impact over North America



Carey Jang, Air Quality Modeling Group

USEPA/OAQPS/EMAD

2005 CMAS Conference, Chapel Hill, NC, 9/27/2005

OUTLINE

- *Overview of USEPA's Intercontinental Transport and Climatic Effects of Air Pollutants (ICAP) Project: Phase 1 – 3 (2002 – 2006)*
- *Trans-Pacific Modeling*
  - **Modeling of PM & O_3 Transport (Annual 2001)**
  - **Sensitivity Analysis: Impact of Asian man-made emissions on North America**
  - **Future emission scenarios: 2030 IPCC A1B & B1**
- *Trans-Atlantic Modeling (Preliminary results)*
  - **Modeling of PM & O_3 Transport and Sensitivity Analysis of impact of North America man-made emissions**

ICAP Project Team

- **EPA/OAQPS & ORD:** Project Lead, Regional AQ Modeling (Jang, Doll, Phillips, Evarts, Bachmann, Keating, Gilliland, etc.)
- **UNC-Chapel Hill:** Regional Met. & Emission Modeling (Carolina Environmental Program, Hanna, Vukovich, Xiu, Adelman, etc.)
- **Harvard Univ.:** Global Chemistry/Transport Modeling (Jacob)

Phase 1

- **Stanford Univ.:** Global Climate/Chemistry Modeling (Jacobson)
- **DOE/Argonne Lab:** Global/Regional Emission Inventory (Streets)
- **NCSU:** Regional Modeling & Analysis (Xie, Zhang, Wang)

- **Univ. of Tennessee:** Global/Regional model Nesting & Emissions (Fu)
- **Univ. of Iowa:** Emission Inventories/Processing (Woo)
- **Univ. of Houston:** Global & Regional Model Nesting (Byun)

Phase 2

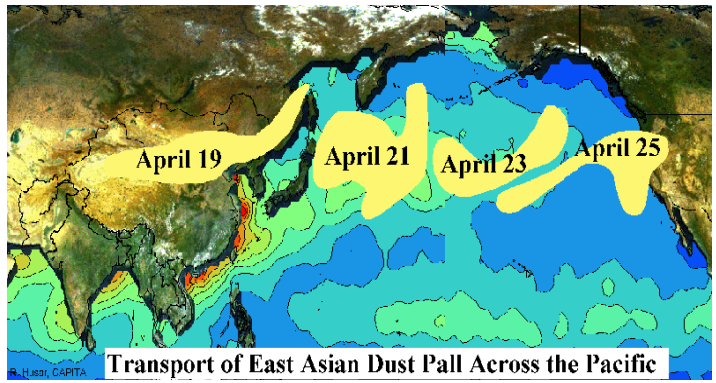
- **Research Triangle Institute (RTI):** Phase-3 PI & China project (Zerbonia)
- **NASA/Univ. of Maryland:** Model Evaluation against Satellite obs. (Chu)
- **Lamar Univ.:** Mercury Modeling (Lin)

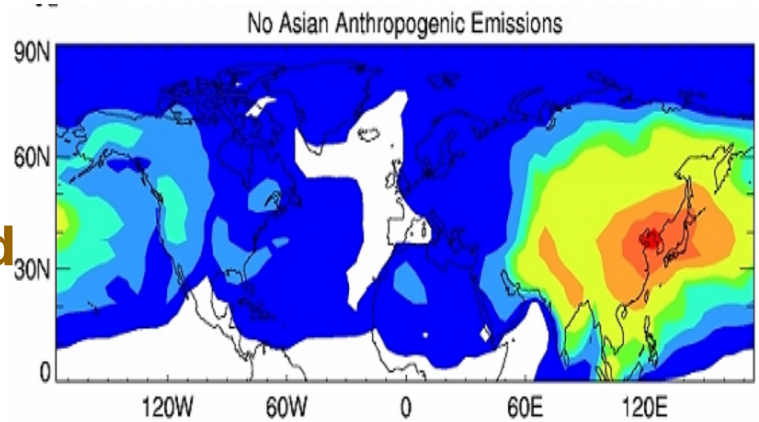
Phase 3

Intercontinental Transport of Pollutants

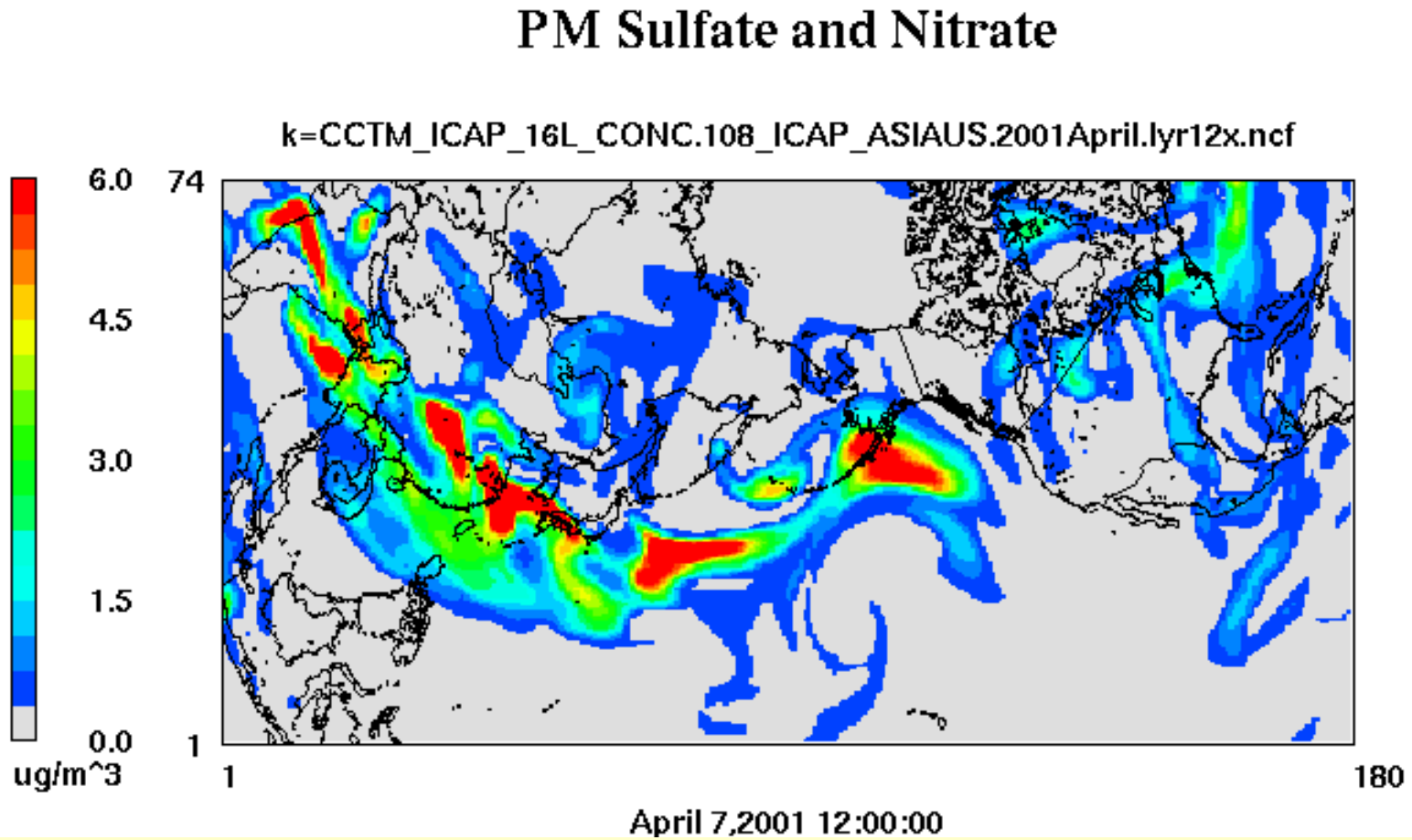
Impacts on U.S. air quality

- Growing evidence of intercontinental transport of O_3, PM, Hg & POPs based on observational and modeling studies (Jacob/GRL/1999, Fiore/JGR/2002, Jaffe/AE/2002, Jacob/RPO/2003);
- Potential impacts on U.S. background AQ burdens and associated NAAQS (e.g., 8-hr ozone, PM2.5, etc.)
- Importance of impacts will increase in the future due to rapid growth in Asian emissions (Streets/AE/2001&2003)





Intercontinental Transport & Climatic Effects of Air Pollutants (ICAP): USEPA's International modeling effort



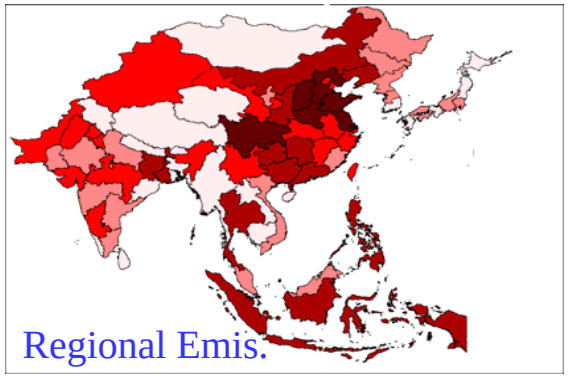
Models-3/CMAQ "Trans-Pacific" modeling of O_3, PM, and Hg

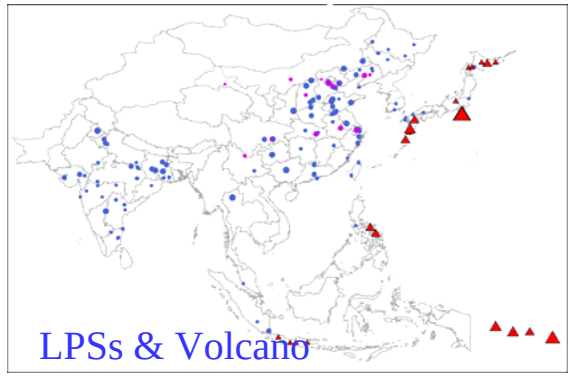
ICAP Modeling

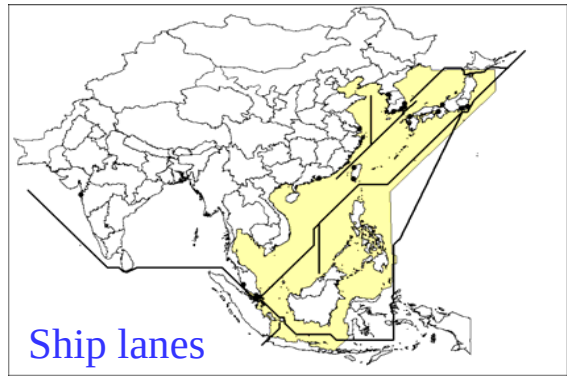
- **Modeling Tool**
  - USEPA's Models-3/CMAQ system
  - 108-km grid resolution, 16 vertical layers
  - Nested within a global model (GEOS-CHEM)
- **Emissions (North America)**
  - U.S.:
    - National Emissions Inventory (1999) Projected to Year 2001 & Biogenic EI System (BEIS-3)
  - Canada:
    - 1995 EI & BEIS-3
  - Mexico:
    - 1999 Big Bend Regional Aerosol and Visibility Observational Study (BRAVO) & BEIS-3

Asian Emissions Data (TRACE-P & ACE/Asia)

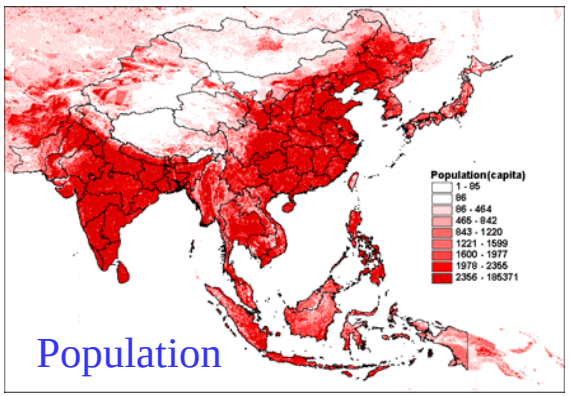
Energy/ Emission

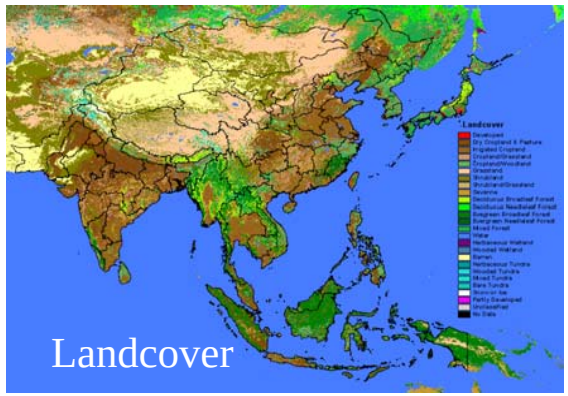


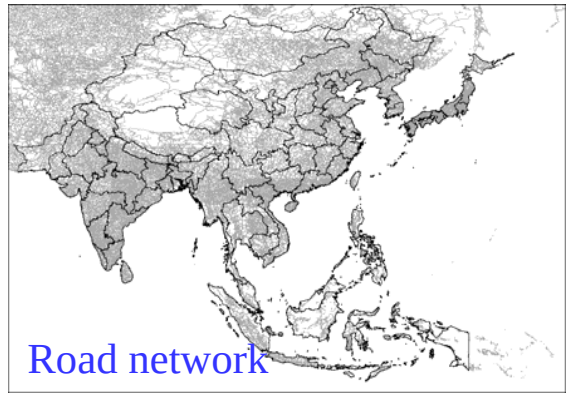




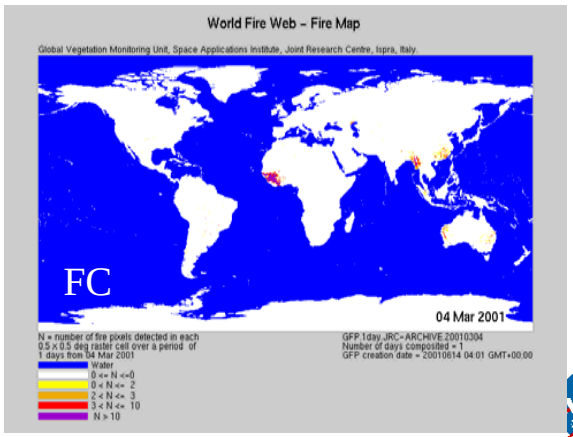
GIS

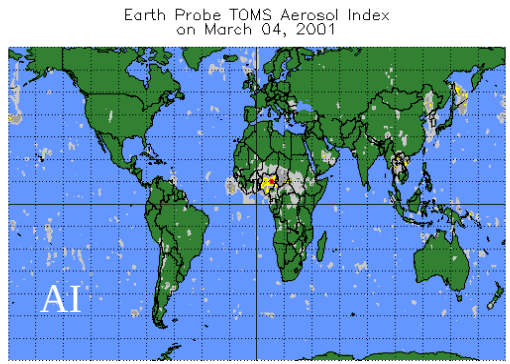


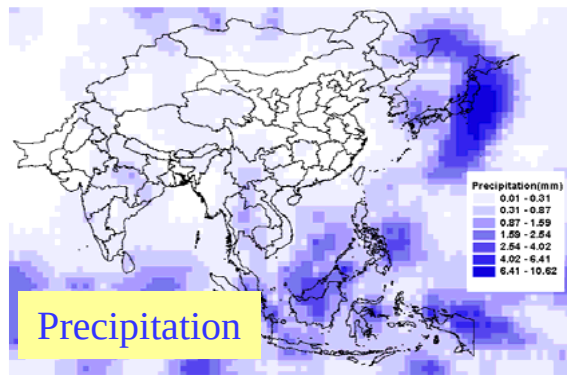




Remote Sensing /etc.

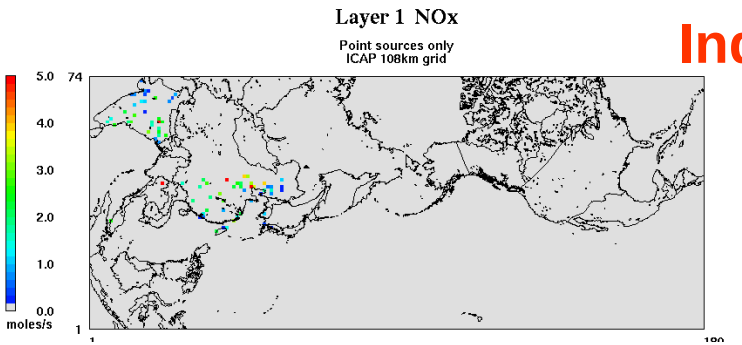




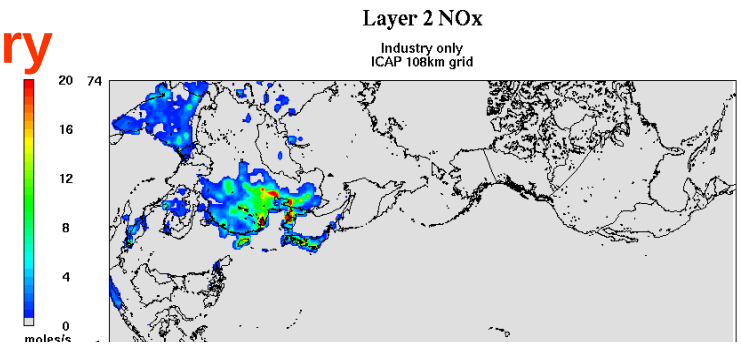


Courtesy of Dr. Jung-Hun Woo, Univ. of Iowa

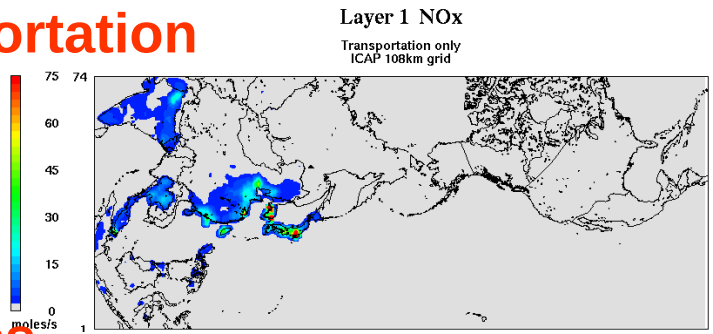
Large Utility



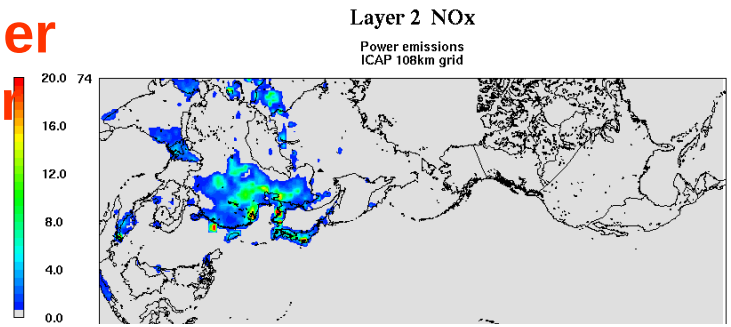
Industry



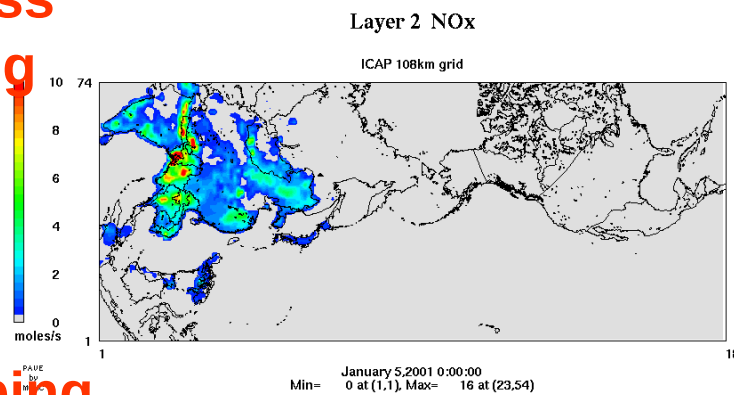
Transportation



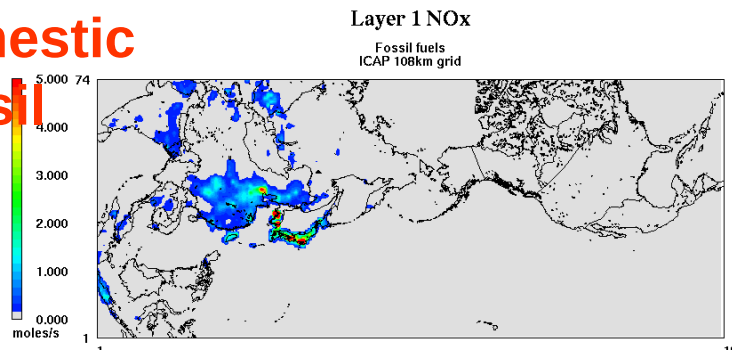
Smaller Power



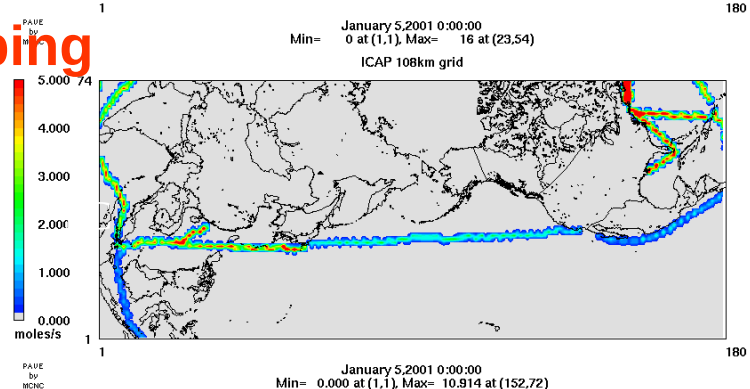
Biomass Burning



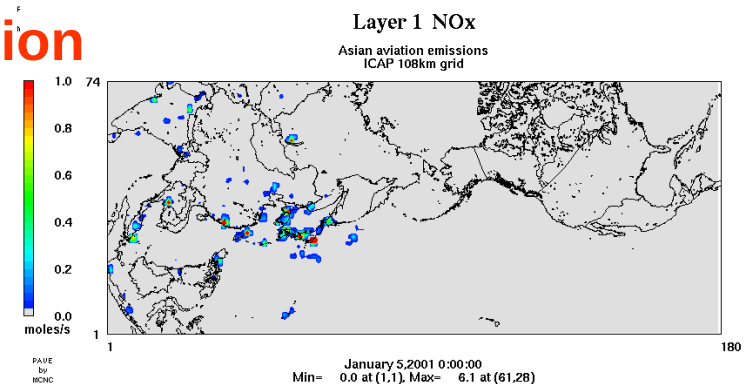
Domestic Fossil Fuel



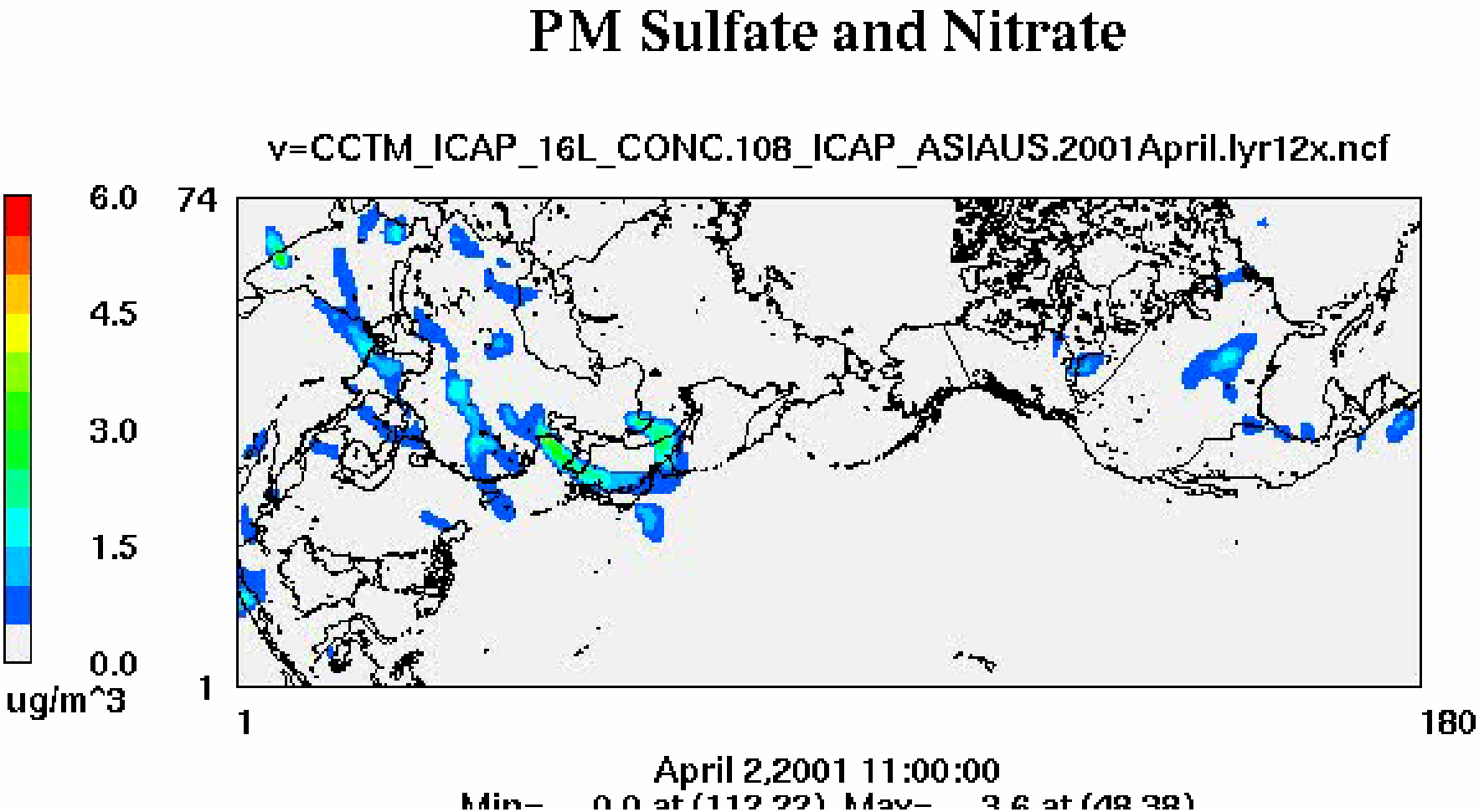
Shipping



Aviation



ICAP Trans-Pacific Modeling Domain

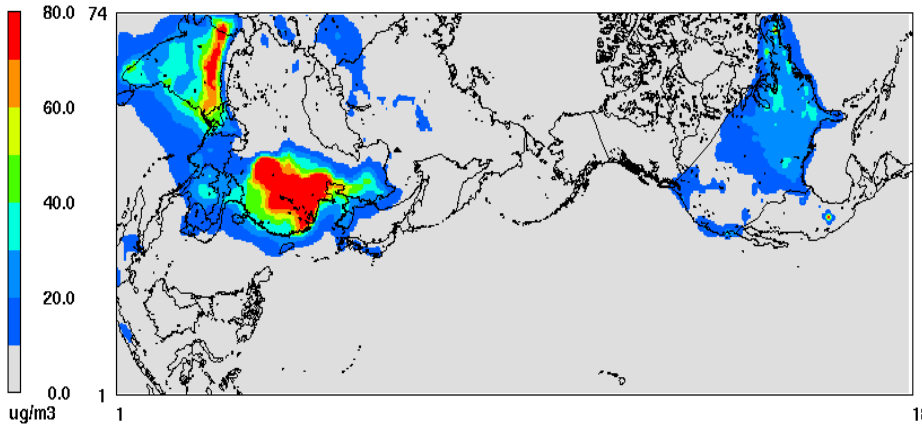


Trans-Pacific Transport of Air Pollutants: PM

PM 2.5 (monthly average, 2001)

80

January



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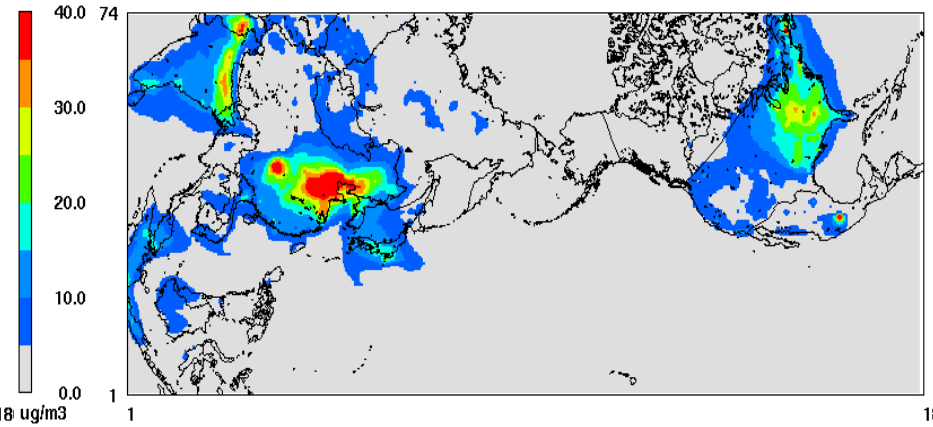
July



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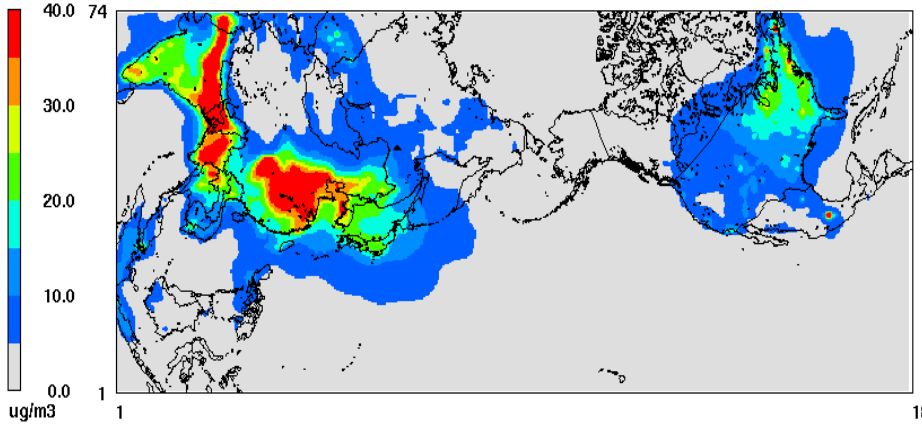
April

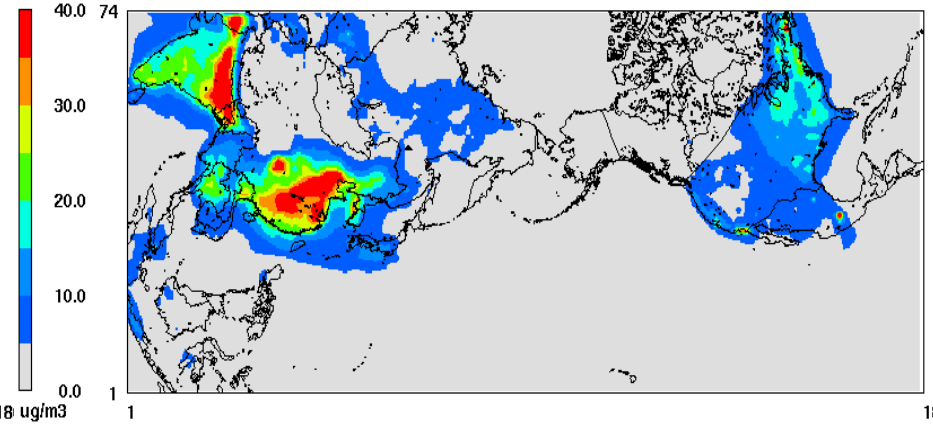


ug/m3

April 1,2001 1:00:00
Min= 0.2 at (30,1), Max= 64.9 at (150,71)

40

October

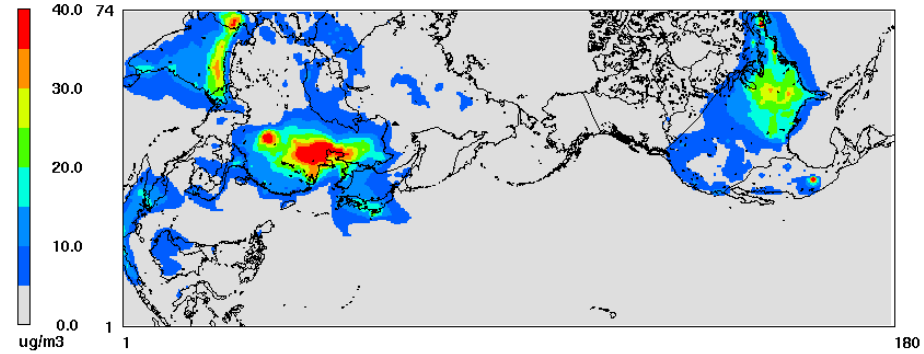


ug/m3

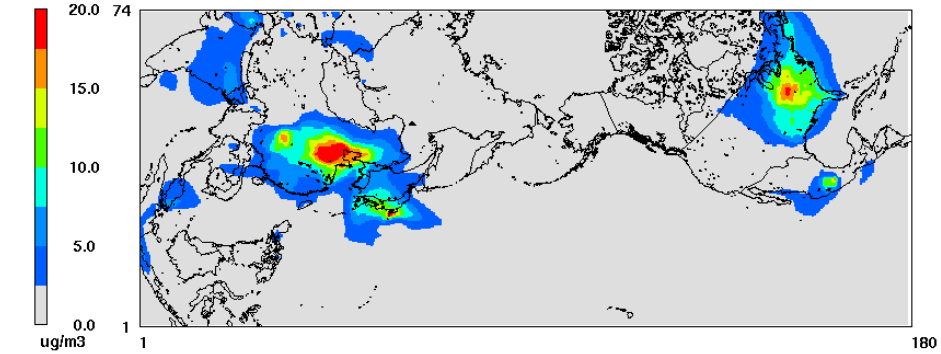
October 1,2001 1:00:00
Min= 0.1 at (37,2), Max= 63.4 at (25,72)

PM 2.5 & Species (July average, 2001)

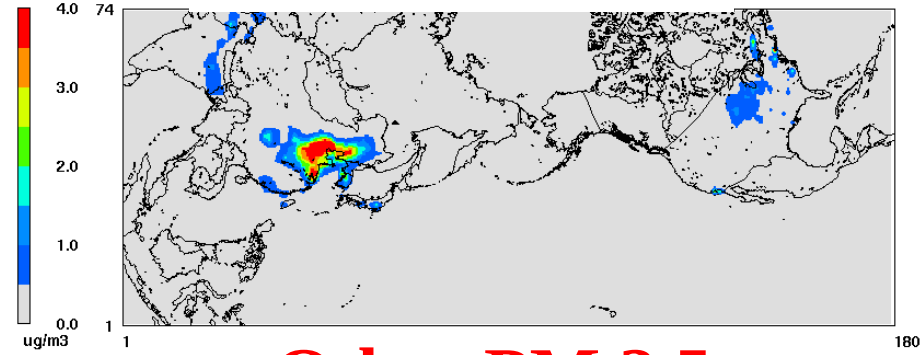
PM 2.5



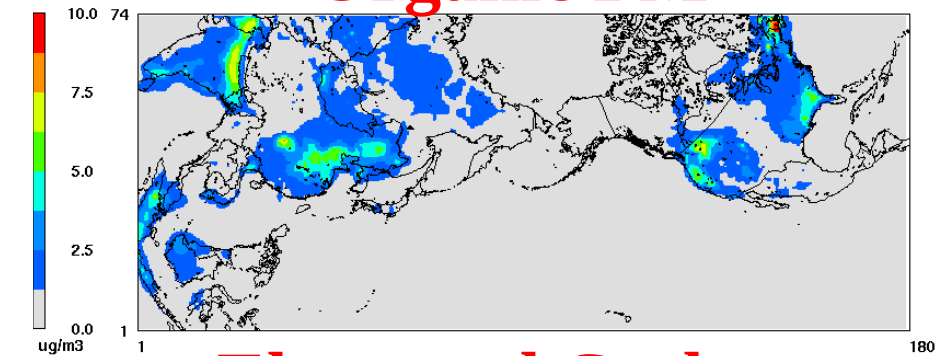
Sulfate PM



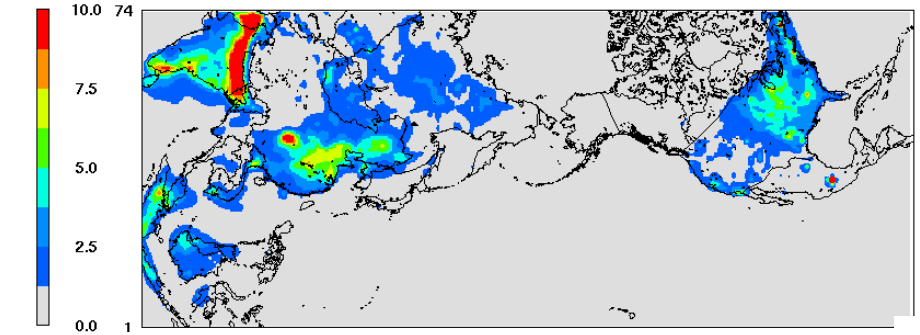
Nitrate PM



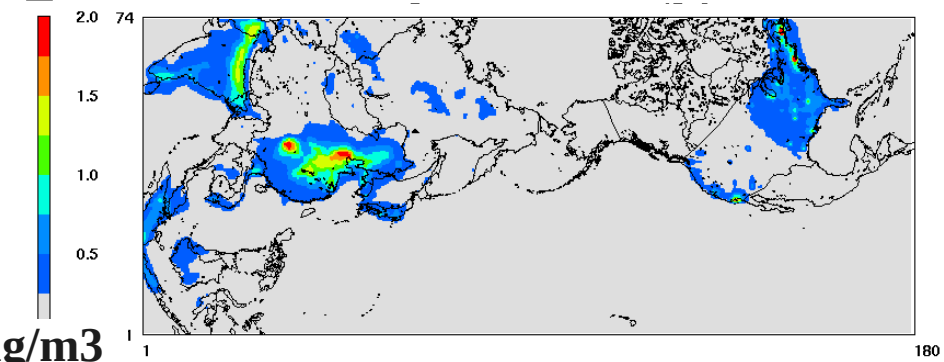
Organic PM



Other PM 2.5

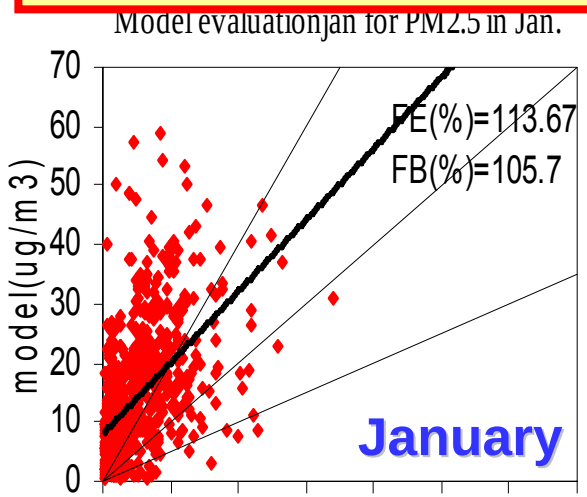


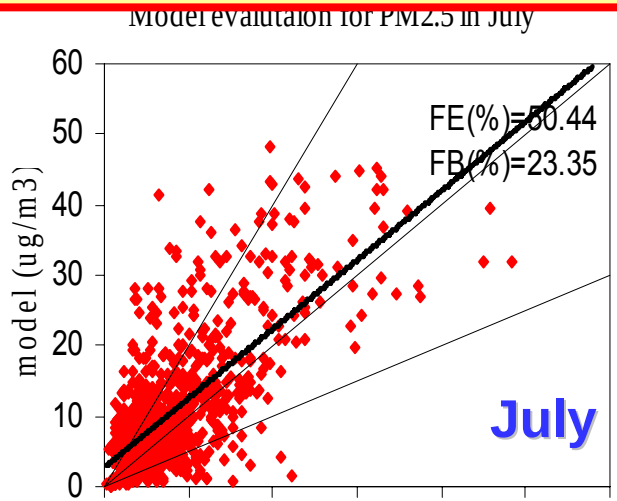
Elemental Carbon

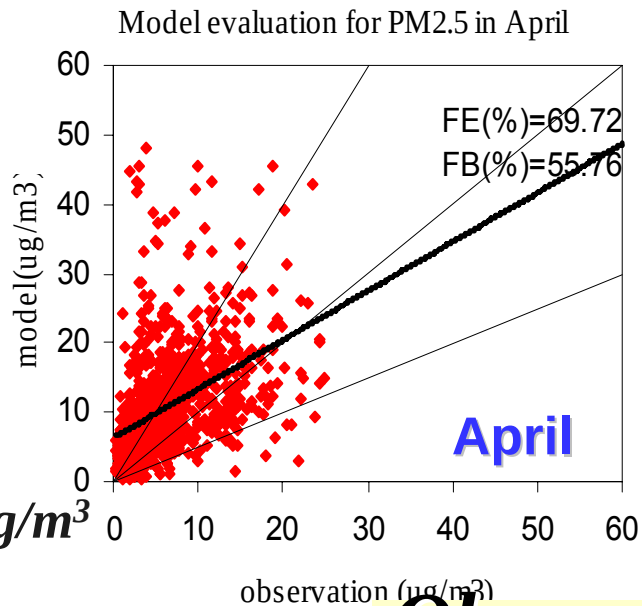


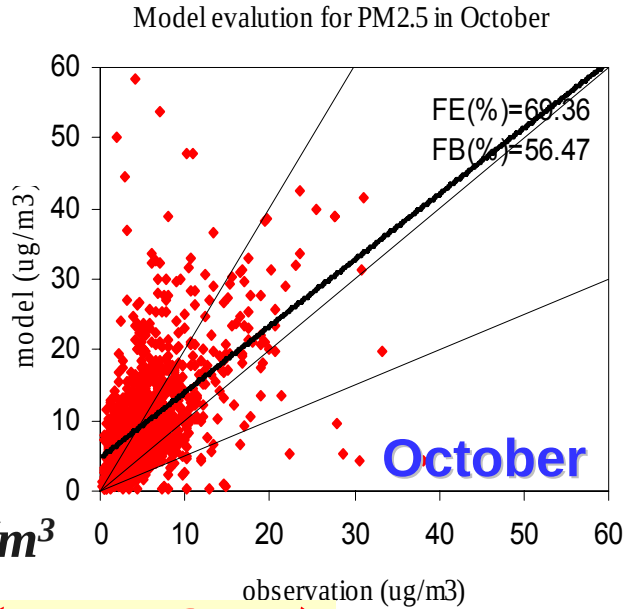
Model Evaluation (vs. U.S. ambient data)

Model







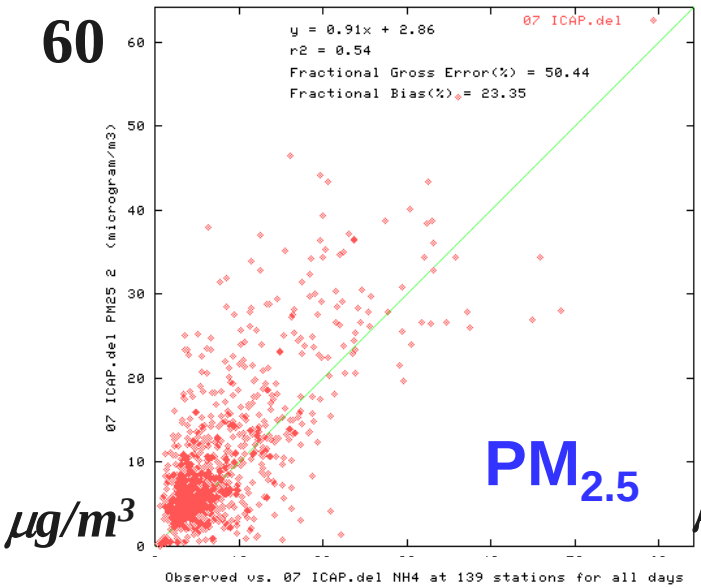


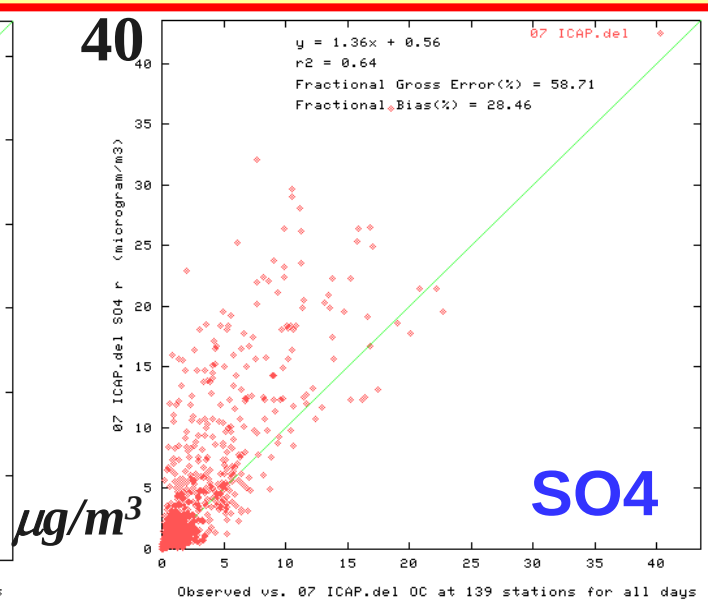
$PM_{2.5}$ 2001

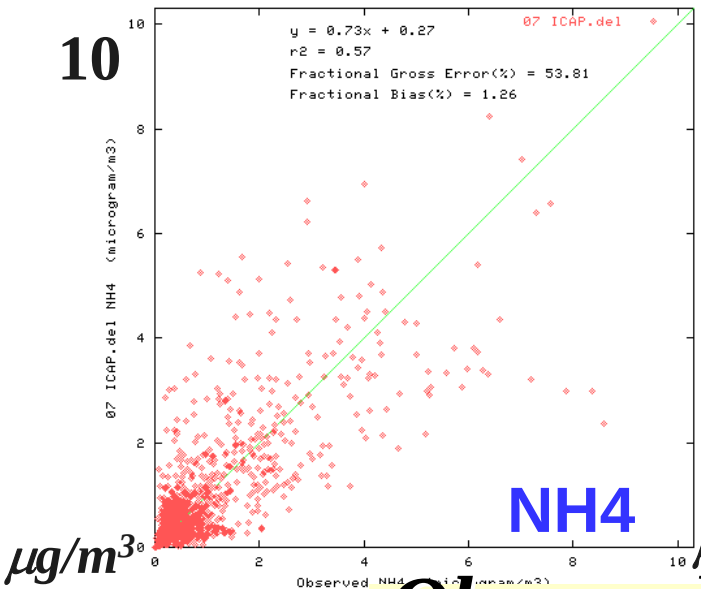
Observed (IMPROVE)

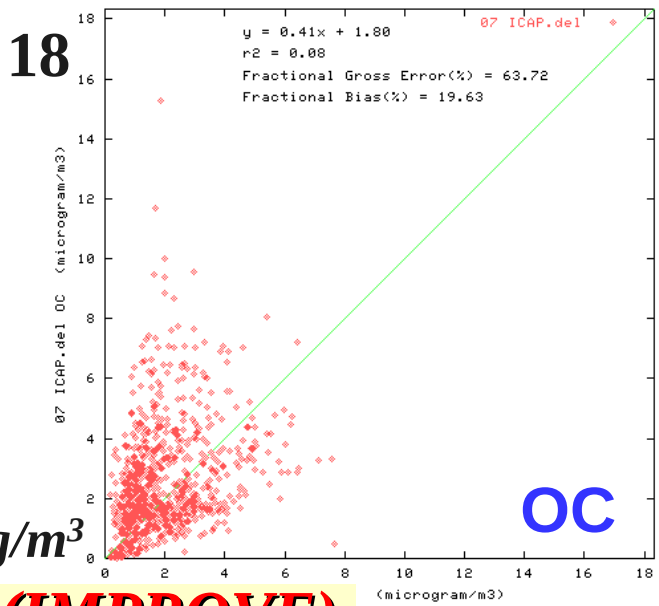
Model Evaluation (vs. U.S. ambient data)

Model









July 2001

Observed (IMPROVE)

Sensitivity Analysis:

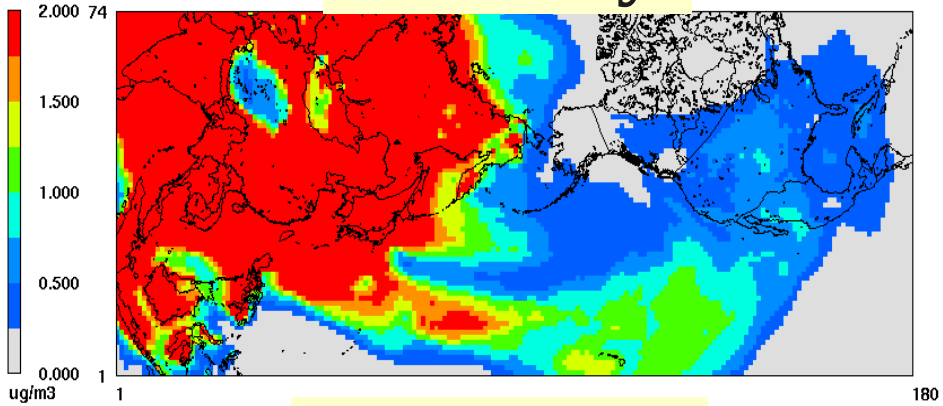
Impacts of Asian Man-Made Emissions on North America

(by removing Asian man-made emissions)

Δ PM 2.5 (Monthly Average, μg/m³)

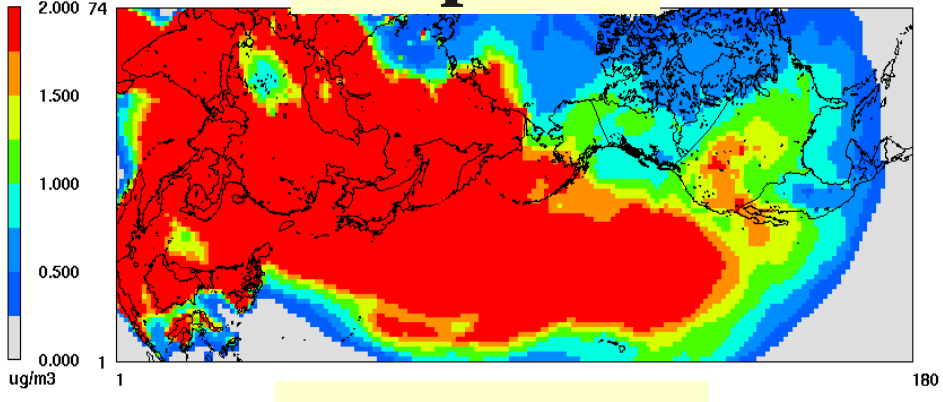
Impact from Asian Man-made Emissions

January



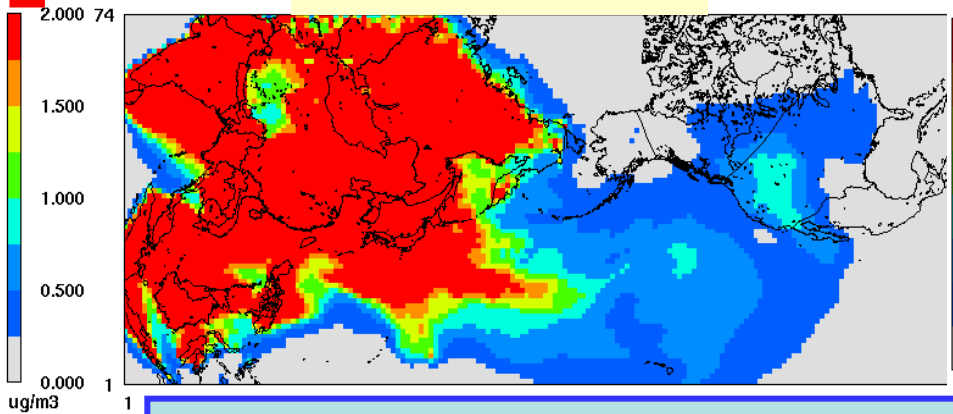
ug/m3

April



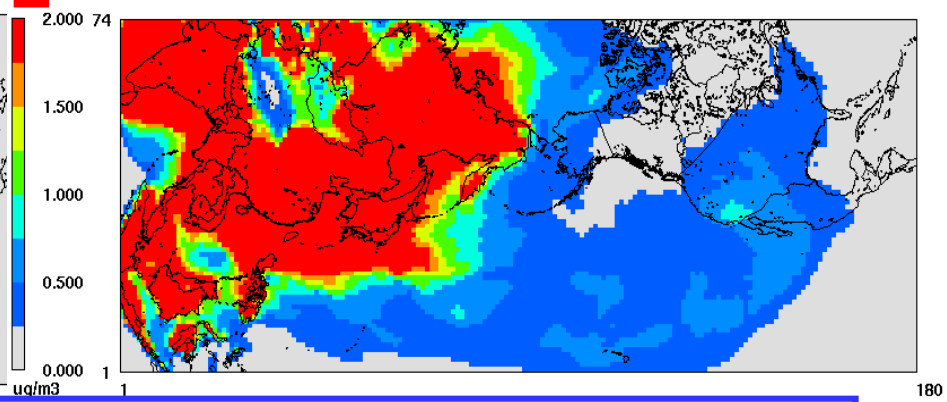
ug/m3

July



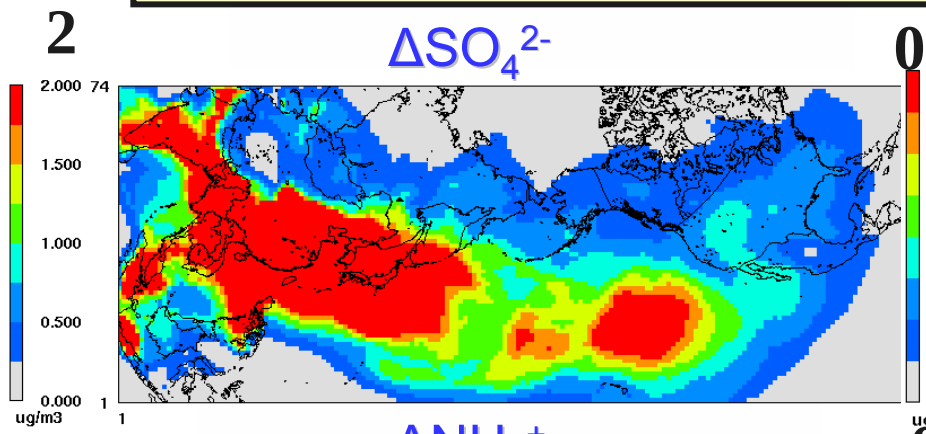
ug/m3

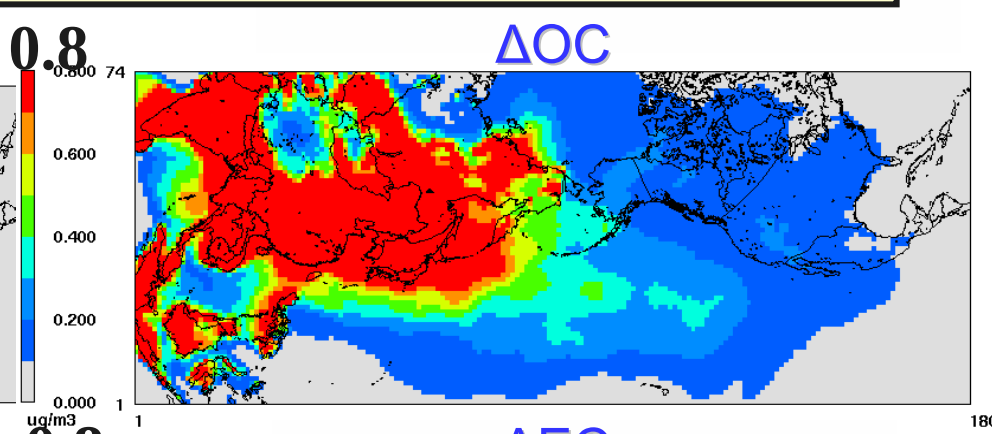
October

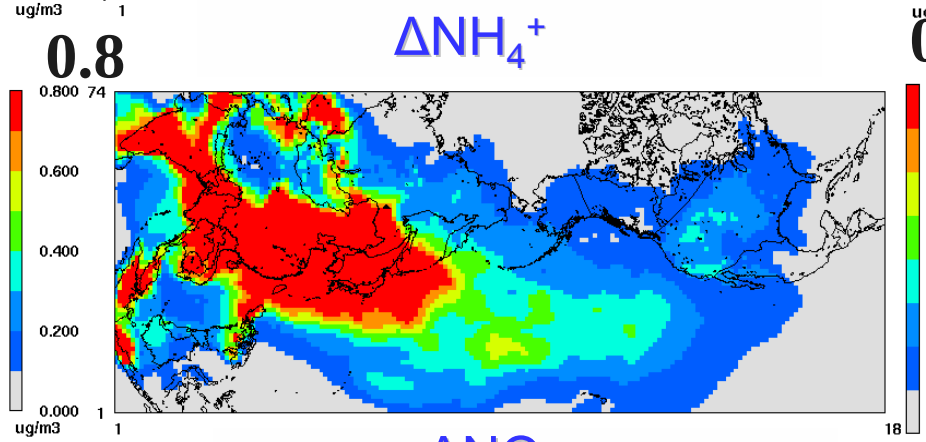


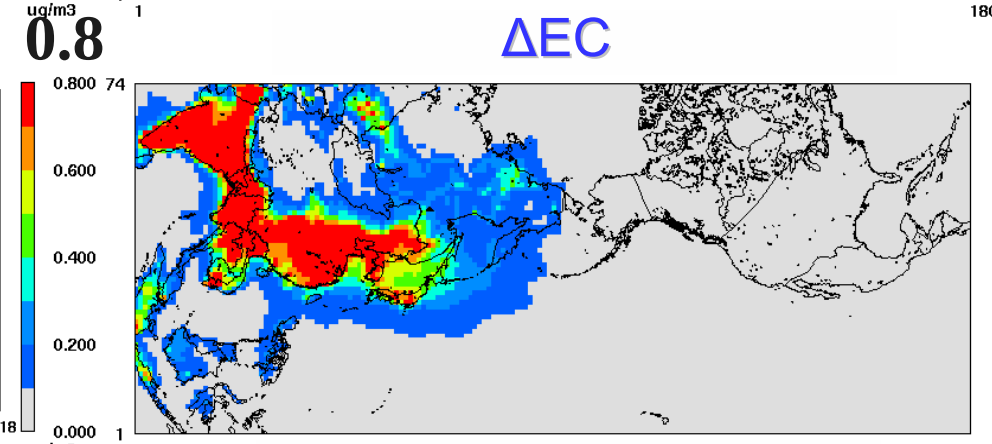
(Base case – Asian manmade emissions removed)

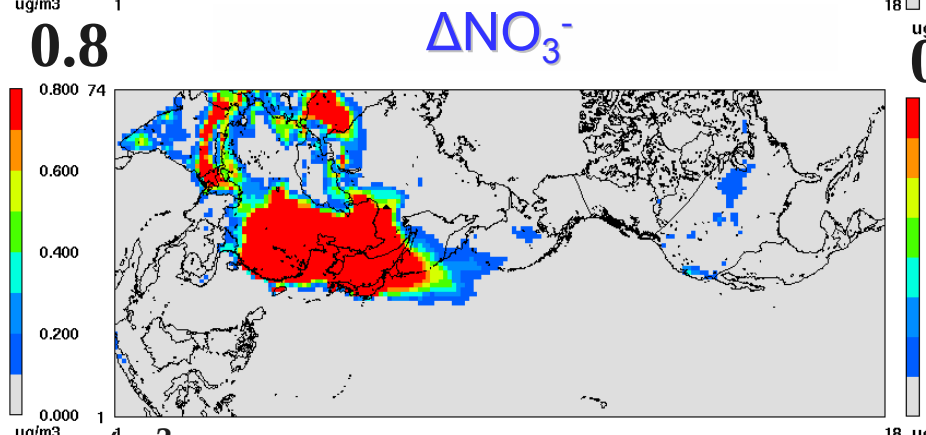
$PM_{2.5}$ Species Enhancement (April average, 2001)

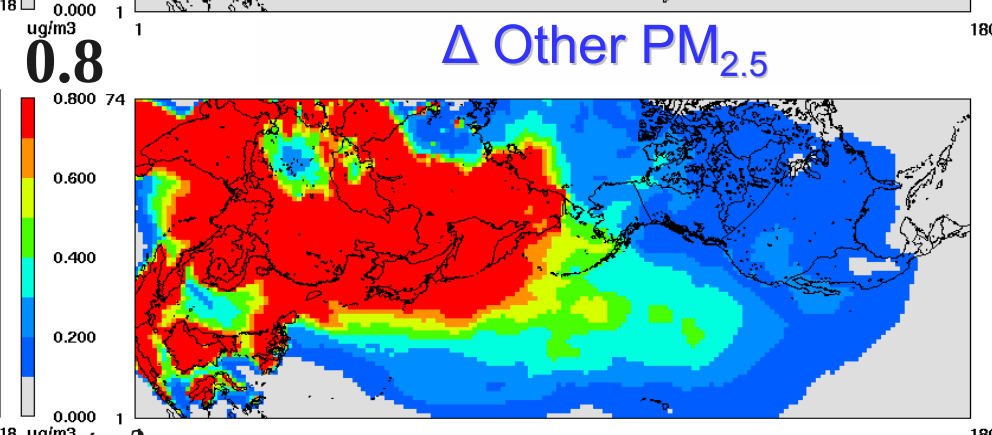


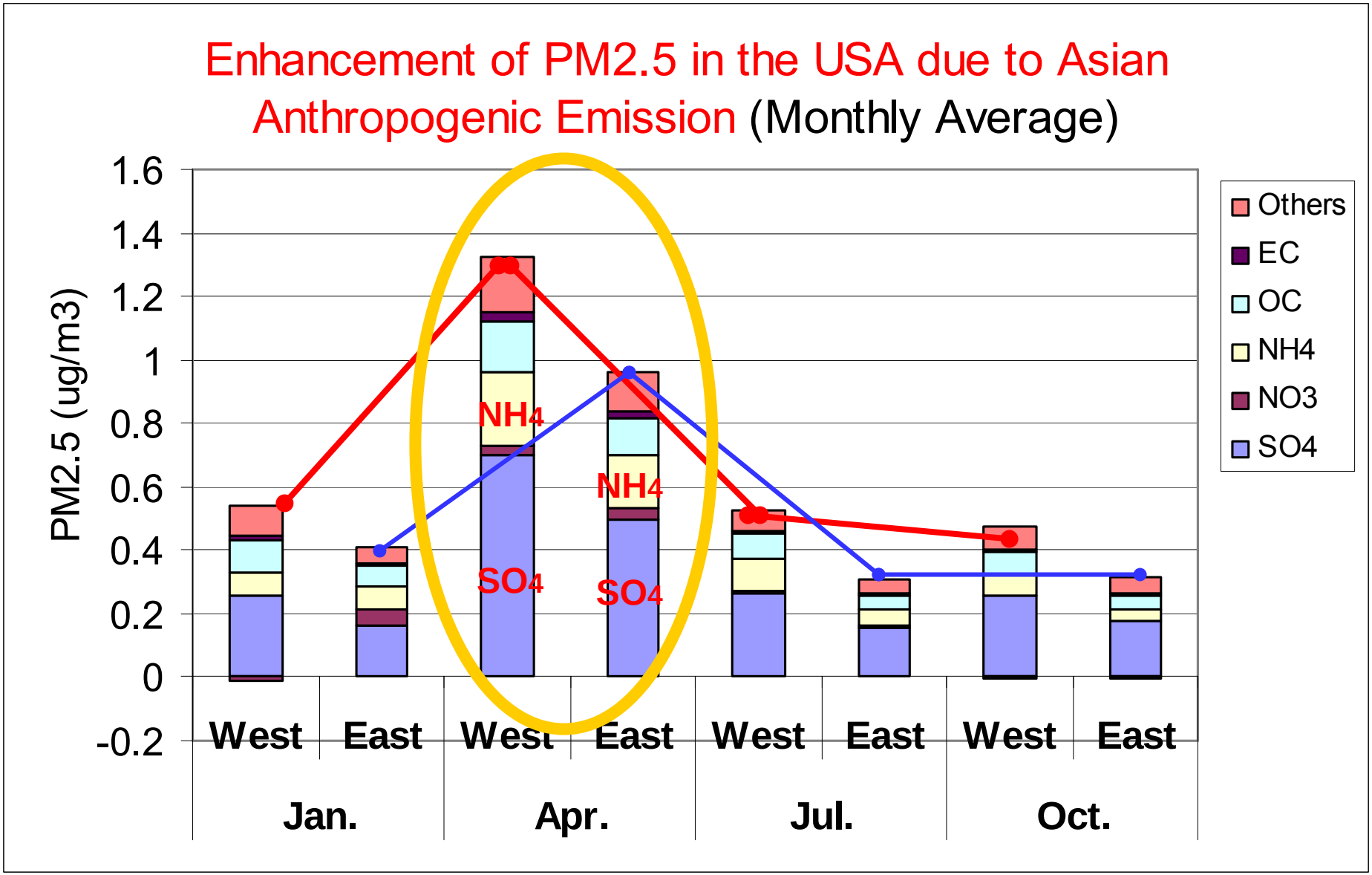






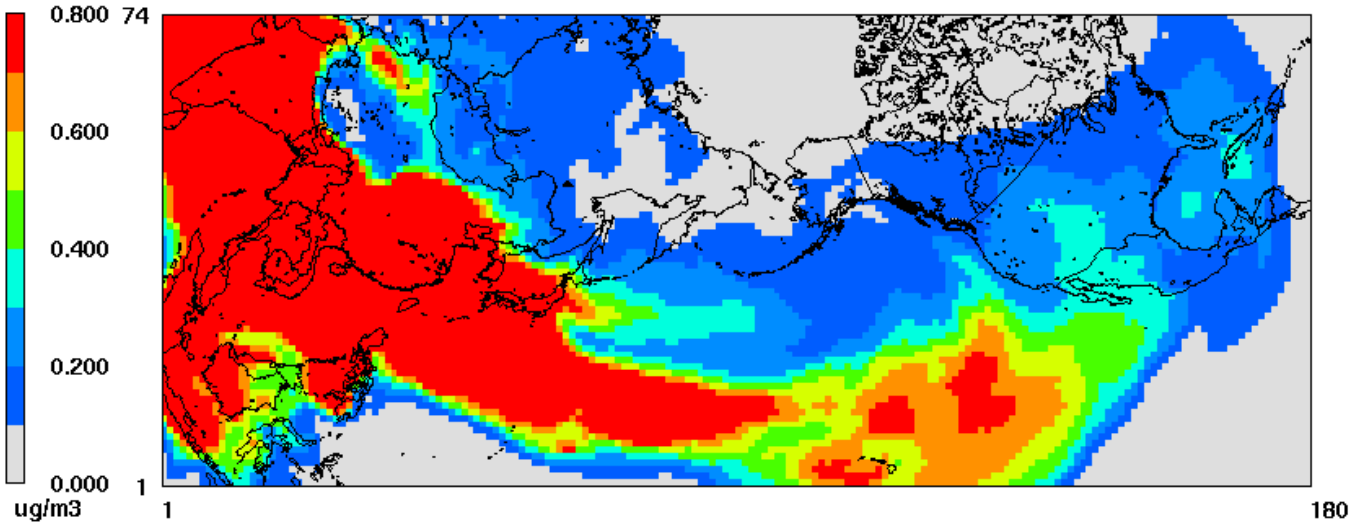




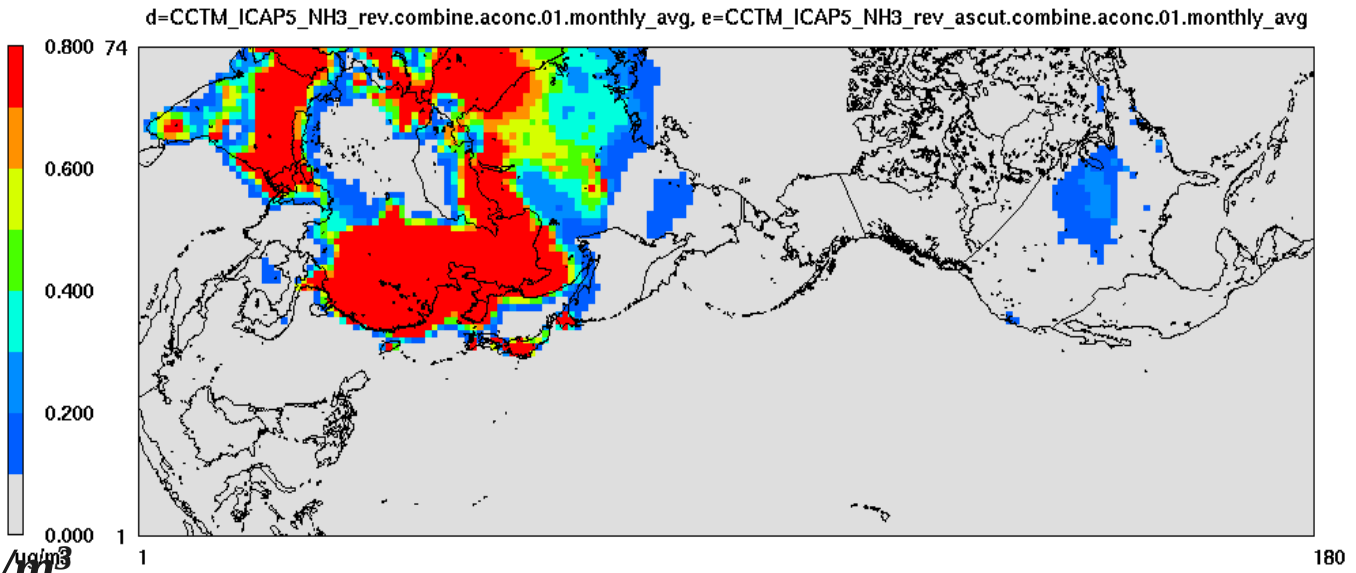

Enhancement of PM2.5 in the USA due to Asian Anthropogenic Emission (Monthly Average)
PM2.5 (ug/m3)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
NH4
SO4
NH4
SO4
Others
EC
OC
NH4
NO3
SO4
West
East
West
East
West
East
West
East
Jan.
Apr.
Jul.
Oct.

Impact of Asian Man-made Emissions on Sulfate & Nitrate PM

Sulfate PM January 2001, Monthly Avg.



Nitrate PM January 2001, Monthly Avg.



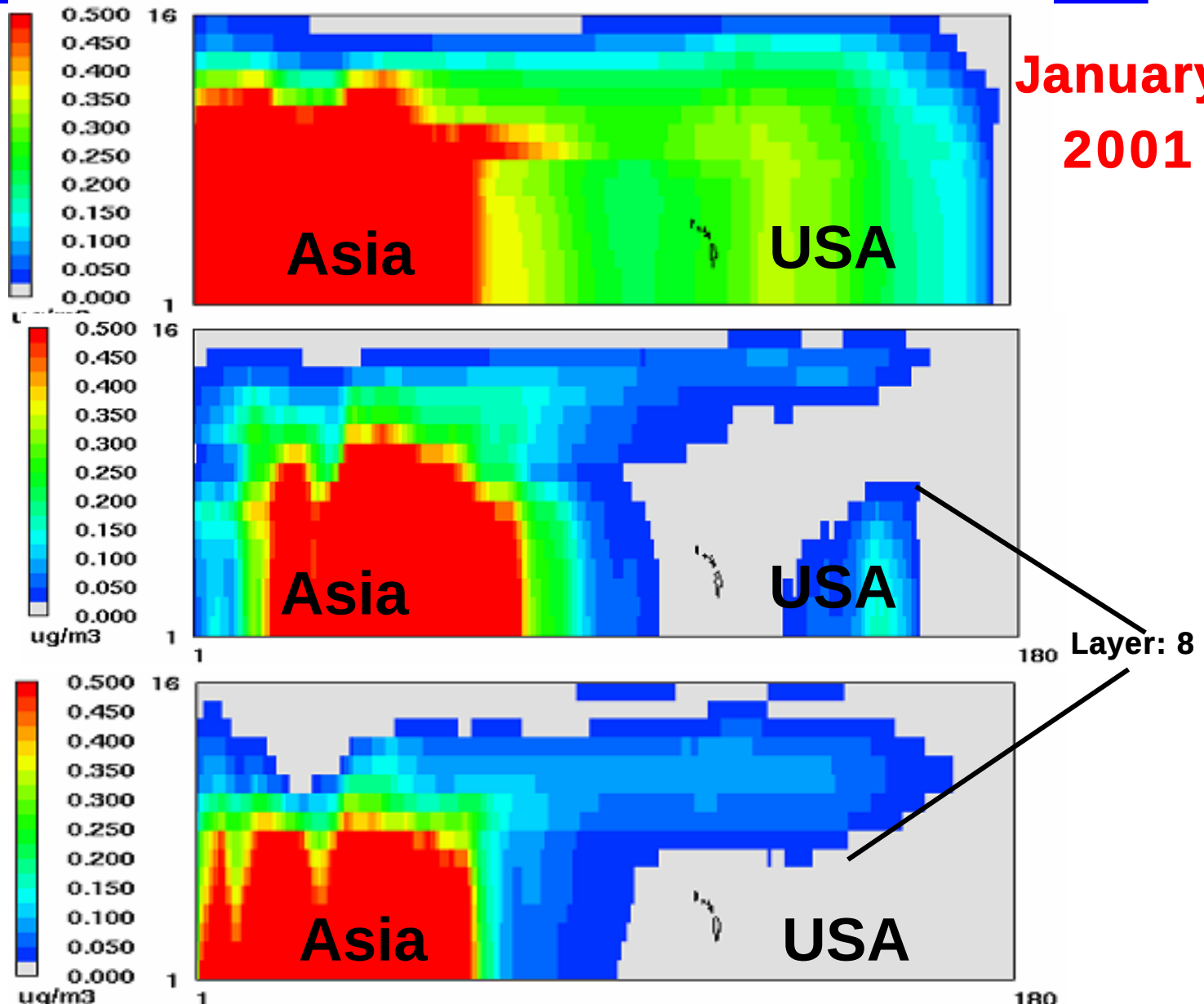
μg/m³

Impact of Asian Emissions on Sulfate & Nitrate PM
(X-Z vertical cross section)

SO_4^{2-}

NO_3^-

NO_Y



$\mu g/m^3$

Sulfate PM

Western U.S.

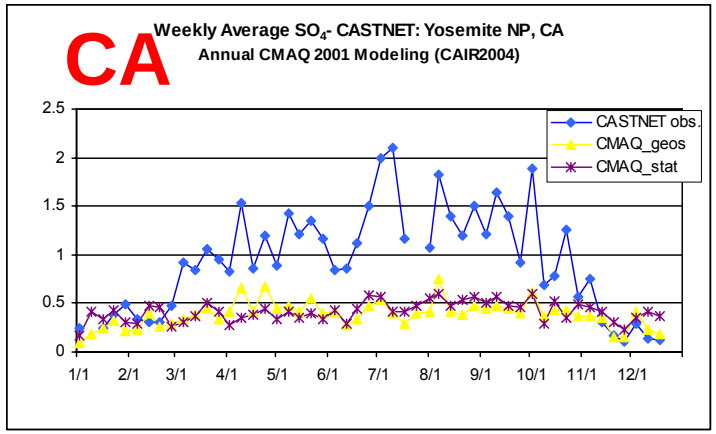
Eastern U.S.

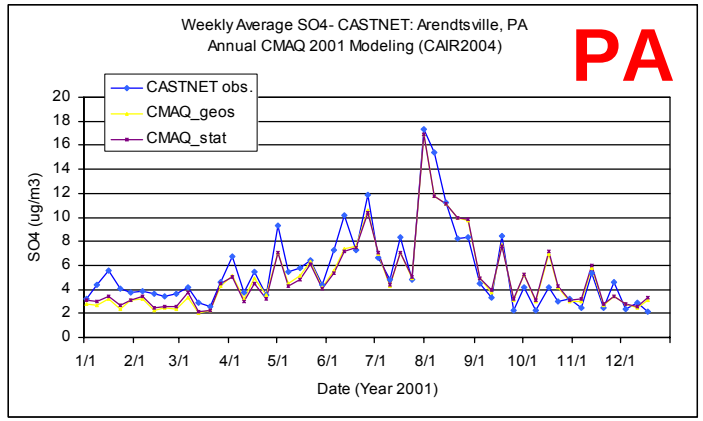
Observed (CASTnet)

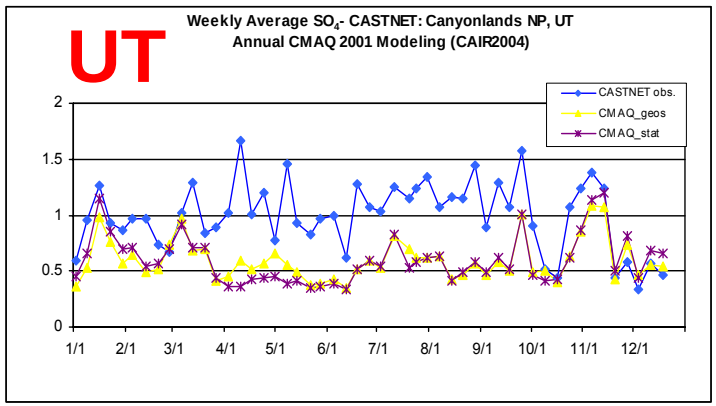
Model (GEOS-CHEM BCs)

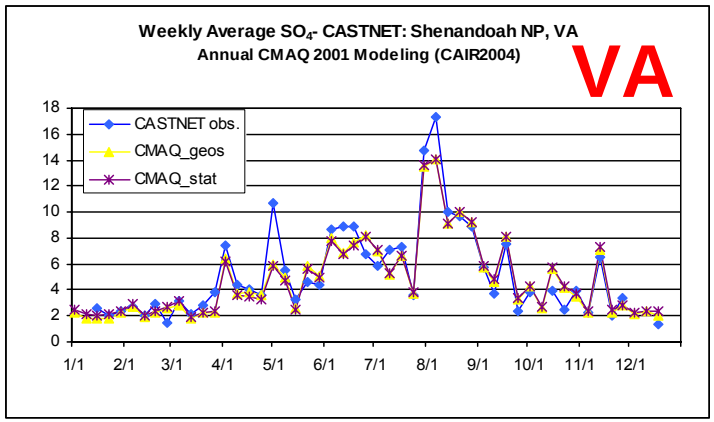
Model (Static BCs)

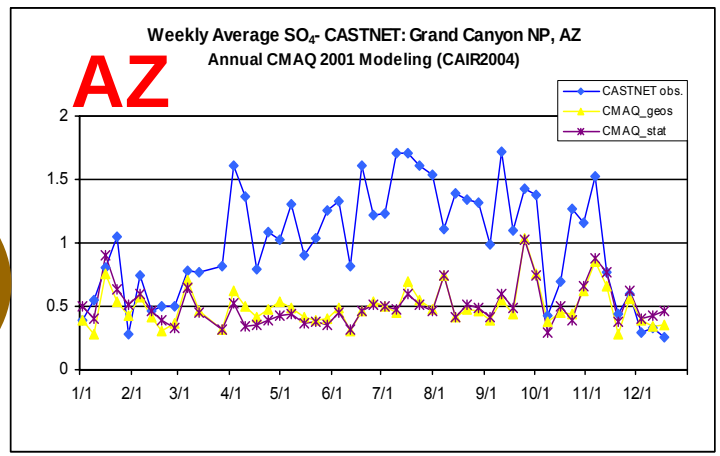
CMAQ/ Continental US Modeling

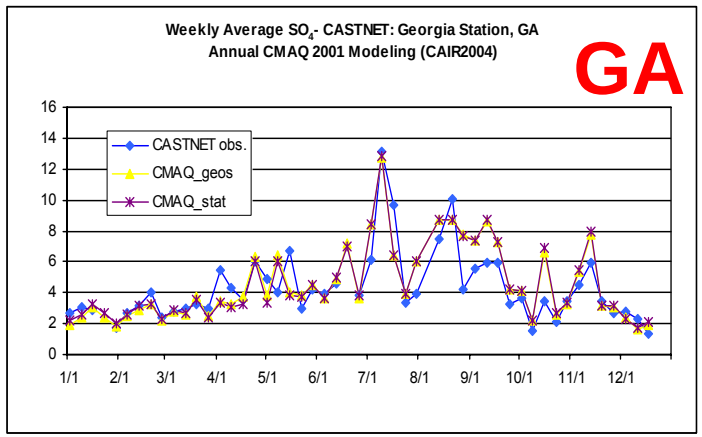












Sulfate PM

Western U.S.

Eastern U.S.

Observed (CASTnet)

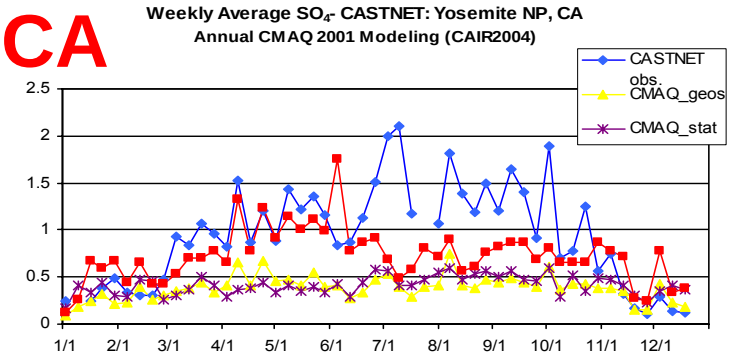
Model (ICAP BCs)

Model (GEOS-CHEM BCs)

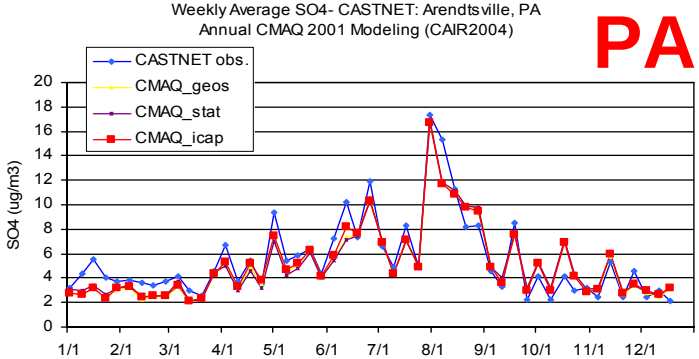
Model (Static BCs)

CMAQ / Continental US Modeling

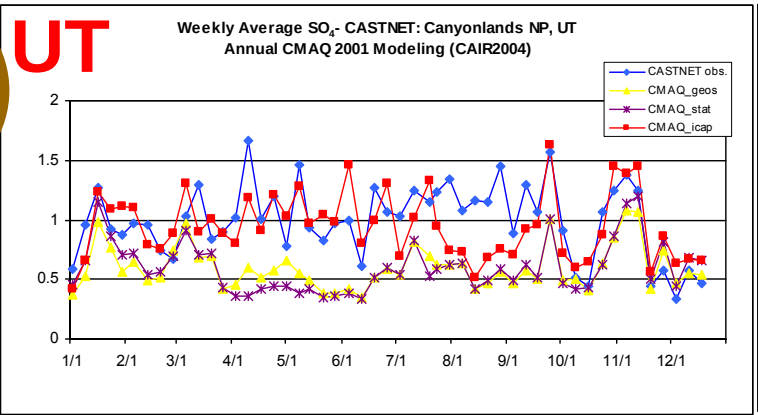
CA



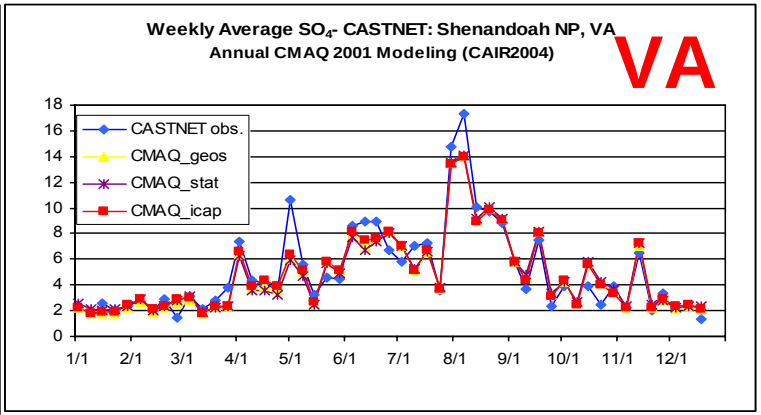
PA



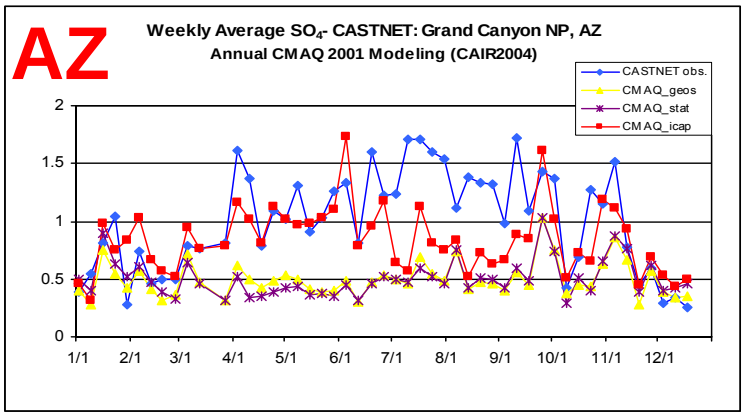
UT



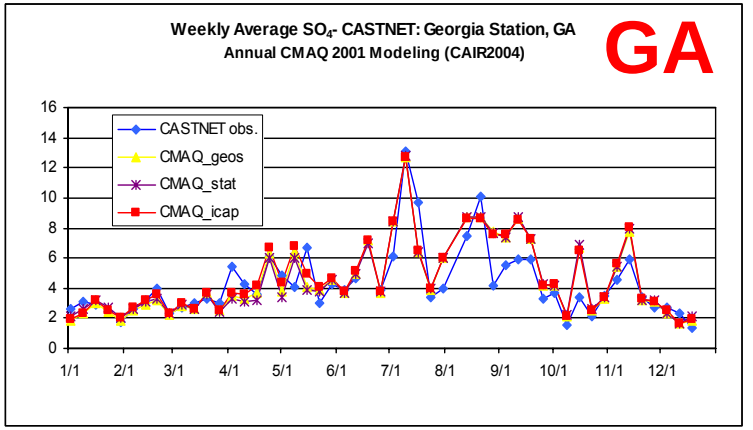
VA



AZ



GA



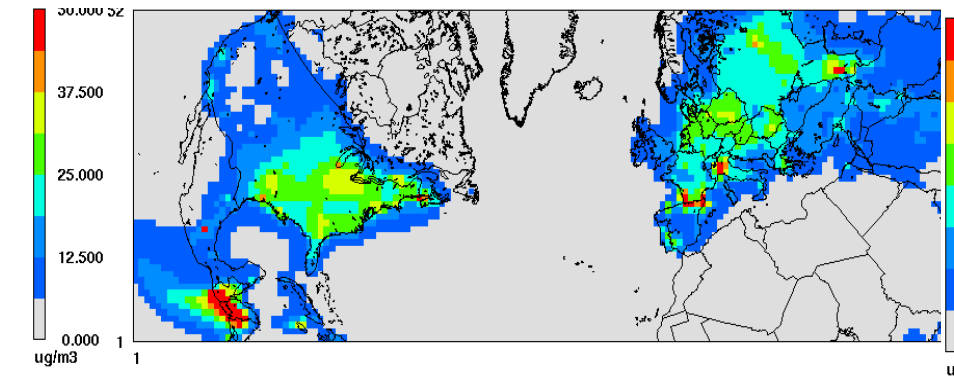
Trans-Atlantic Modeling and Sensitivity Analysis:

Impacts of North America Man-Made Emissions on Europe

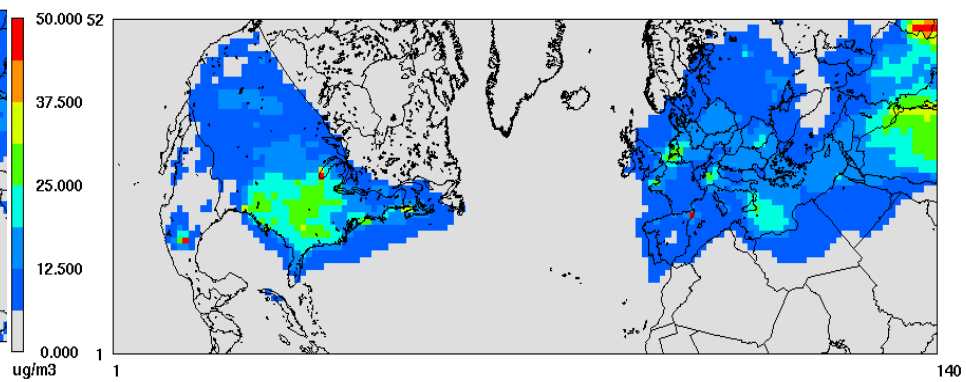
(by removing North America man-made emissions)

PM 2.5 (monthly average, 2001): Trans-Atlantic Modeling

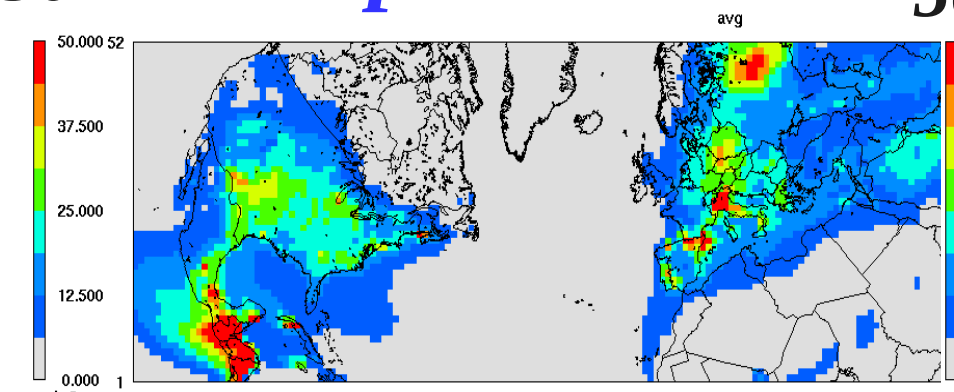
January



July



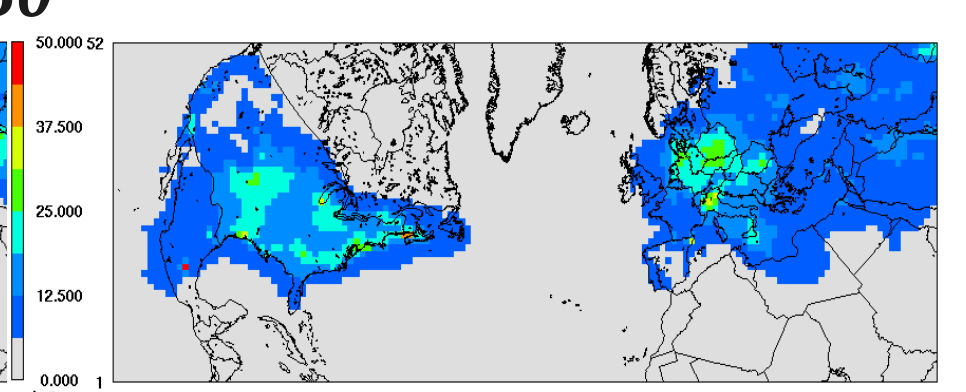
April



$\mu g/m^3$

April 1,2001 1:00:00
Min= 0.345 at (140,1), Max= 235.923 at (99,22)

October

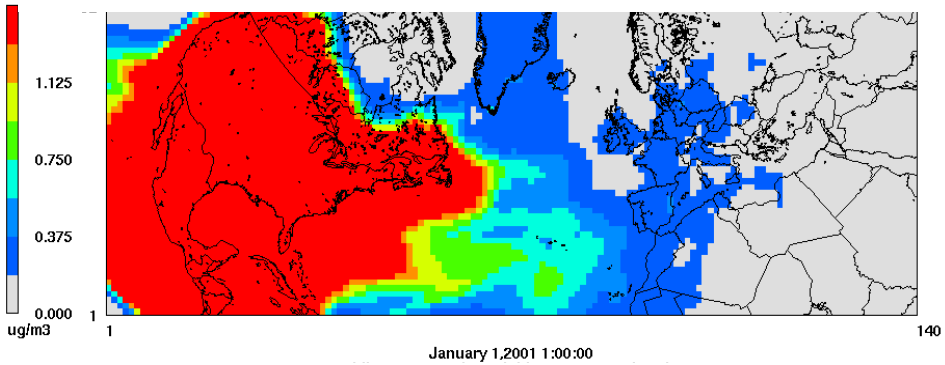


$\mu g/m^3$

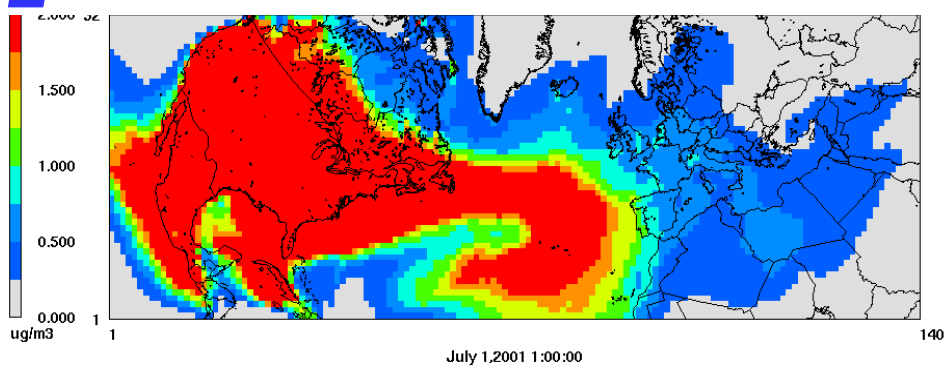
October 1,2001 1:00:00
Min= 0.257 at (53,8), Max= 55.554 at (13,18)

Δ PM 2.5 (monthly average, µg/m³)
Impact from North America Man-made Emissions

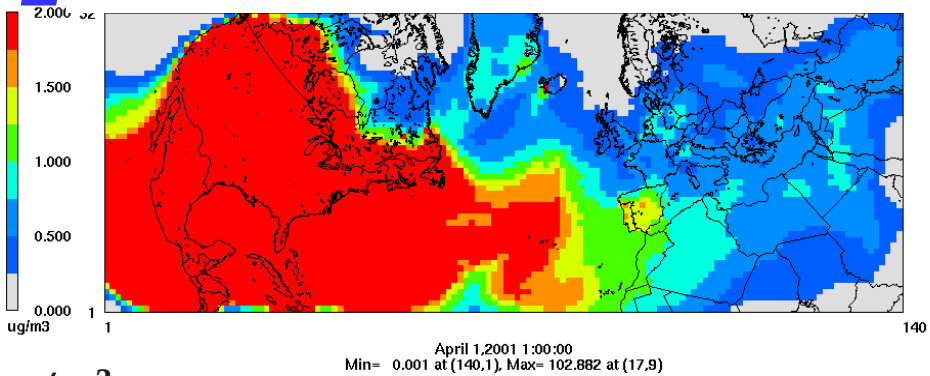
January



July

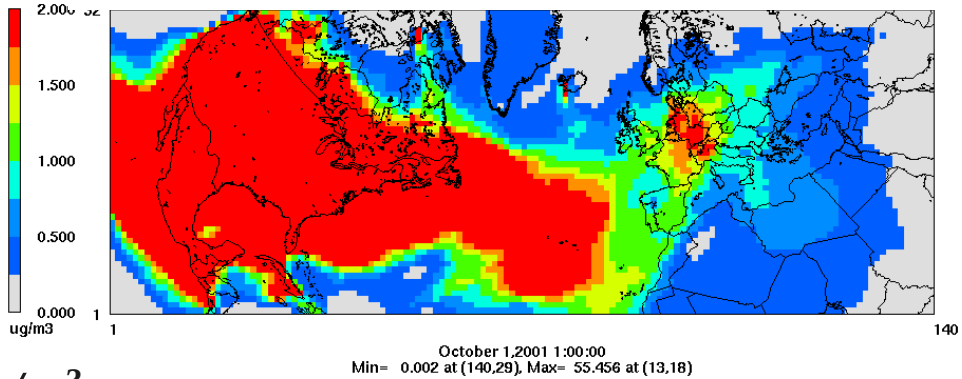


April



µg/m³

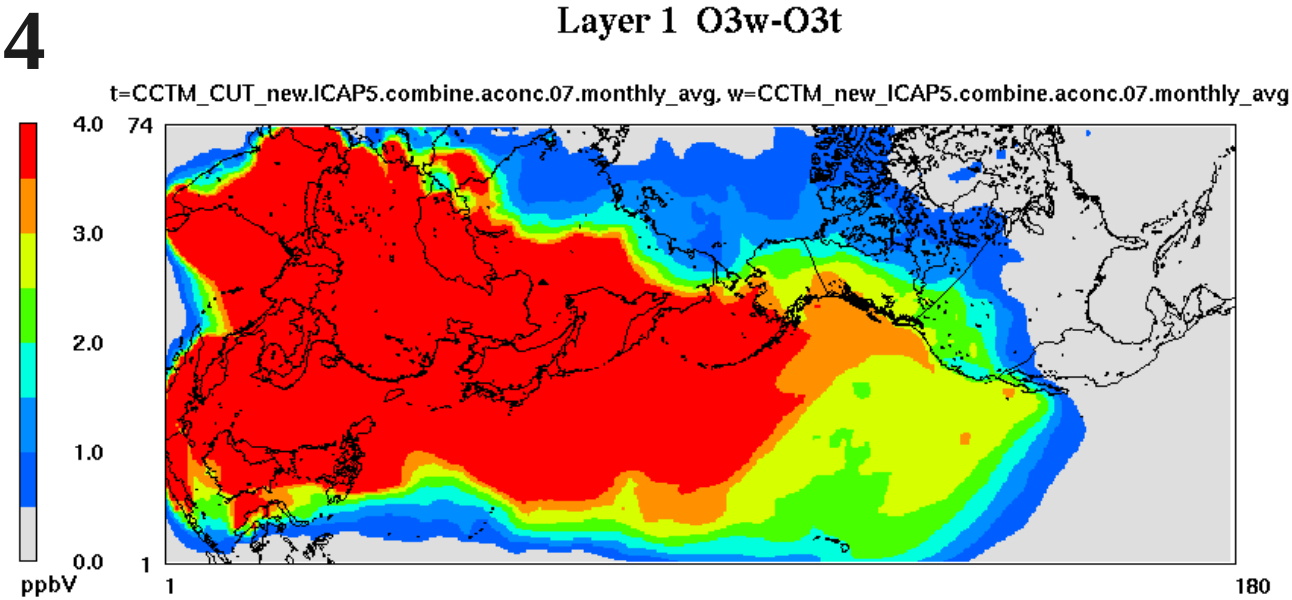
October



µg/m³

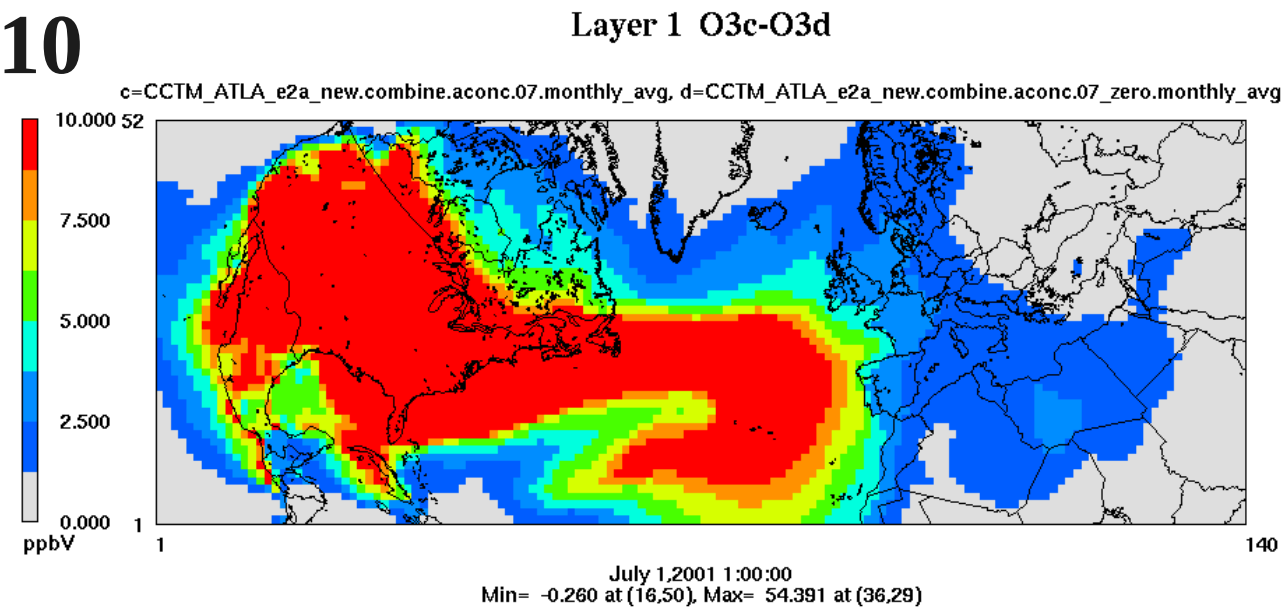
Trans-Pacific

Transport of O3 (monthly avg.): Impact of Asia Emissions



Trans-Atlantic

Transport of O3 (monthly avg.): Impact of North America Emissions

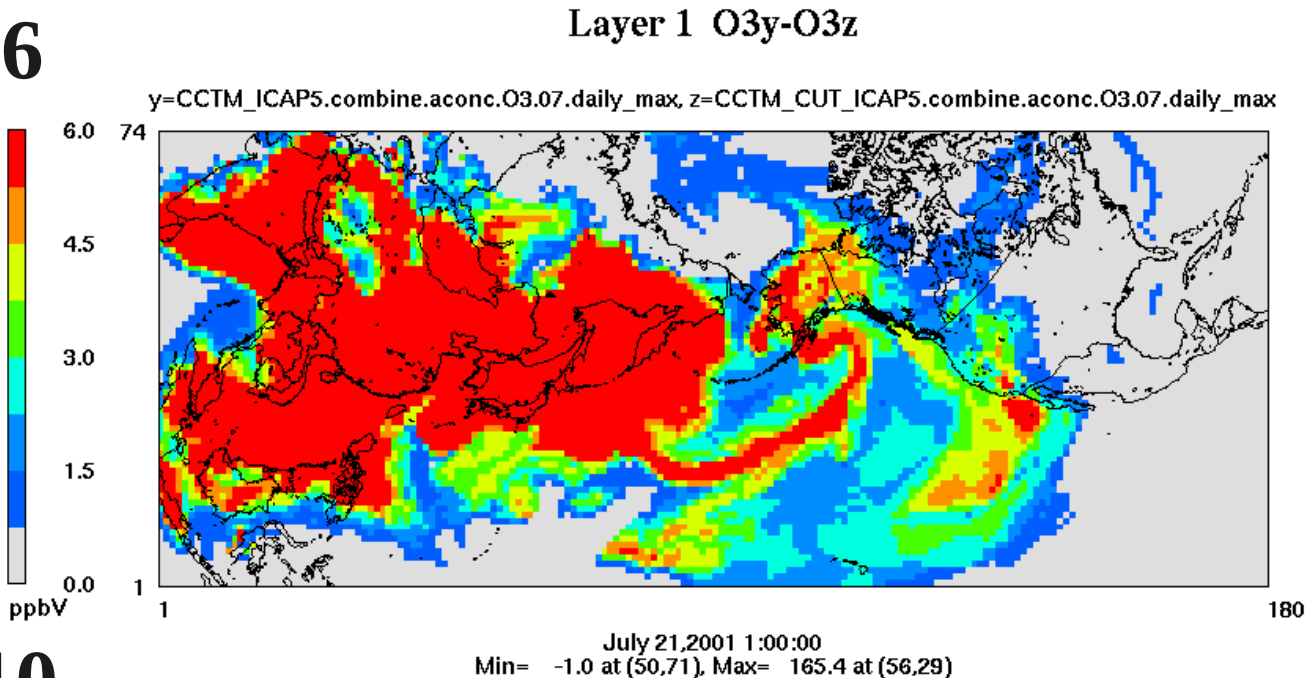


July monthly avg., 2001

Trans-Pacific

Transport of O3 (daily max):

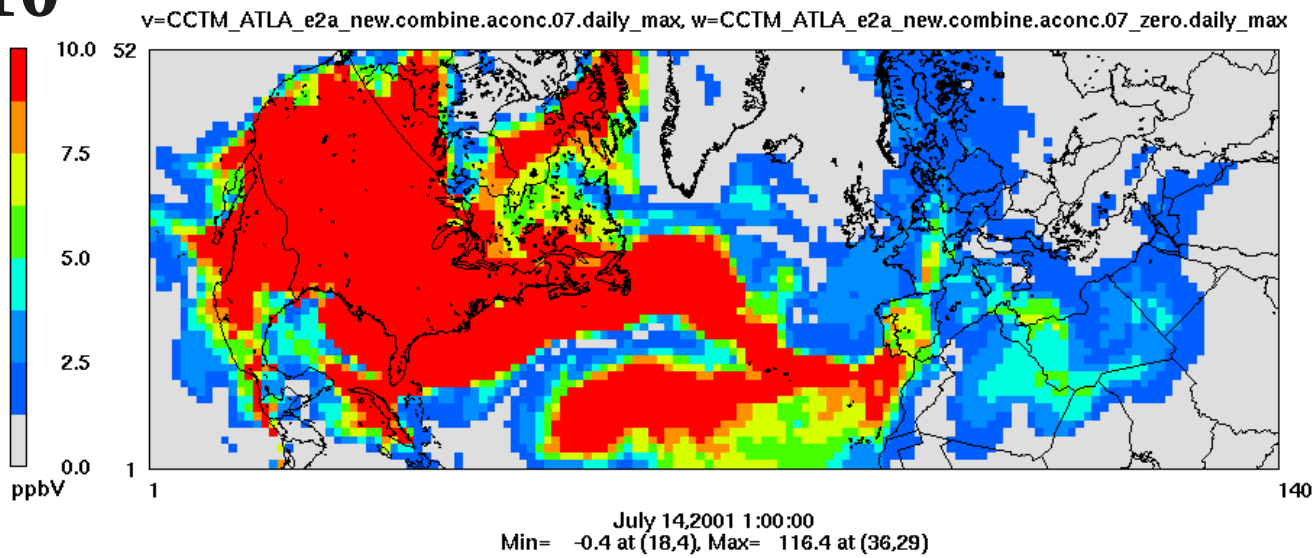
Impact of Asia Emissions



Trans-Atlantic

Transport of O3 (daily max):

Impact of North America Emissions



July daily max, 2001

Future Scenarios

1. IPCC 2030 A1B:

   Growth Scenario

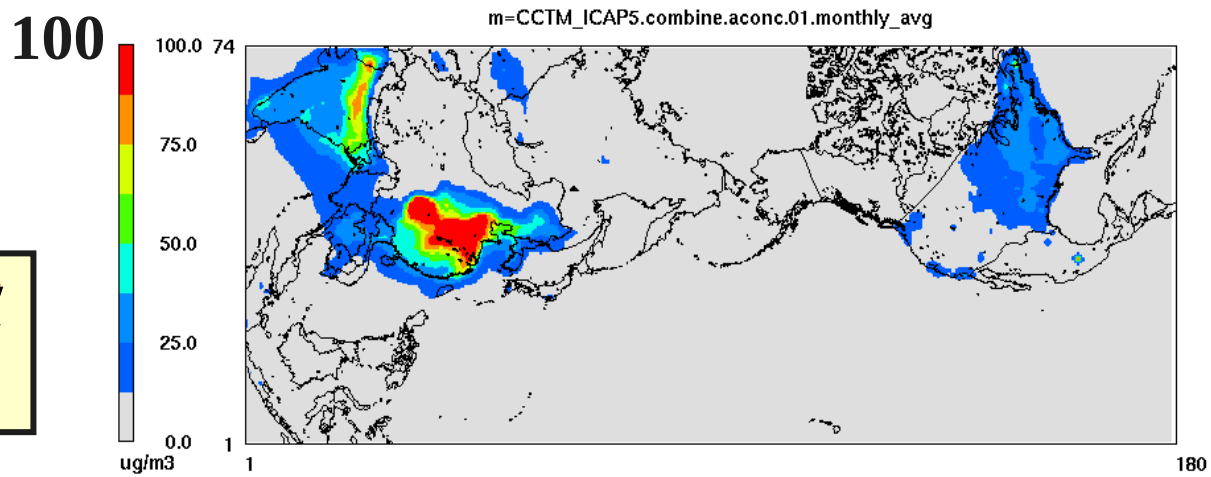
2. IPCC 2030 B1:

   Sustainable Development

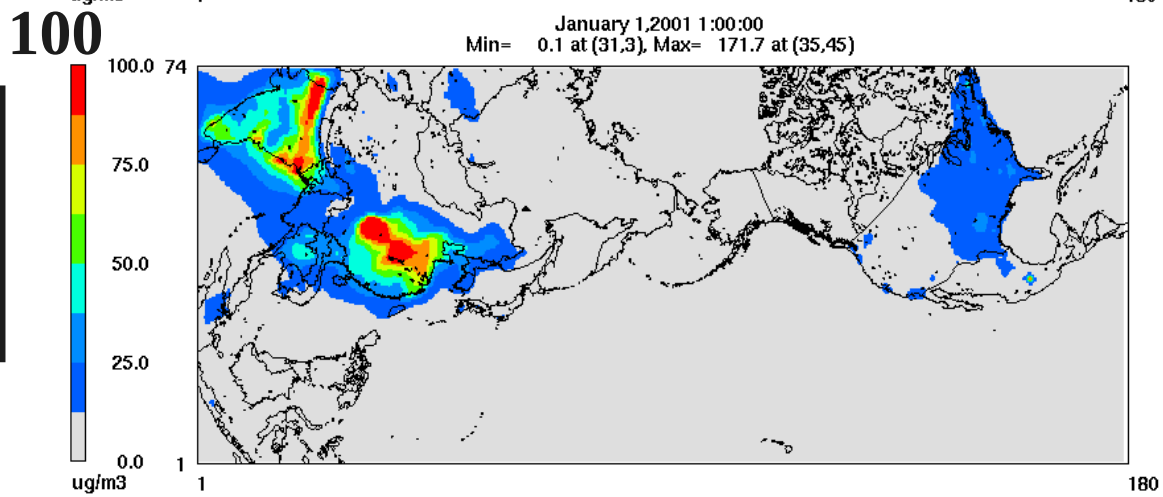
PM 2.5

(Monthly Average)

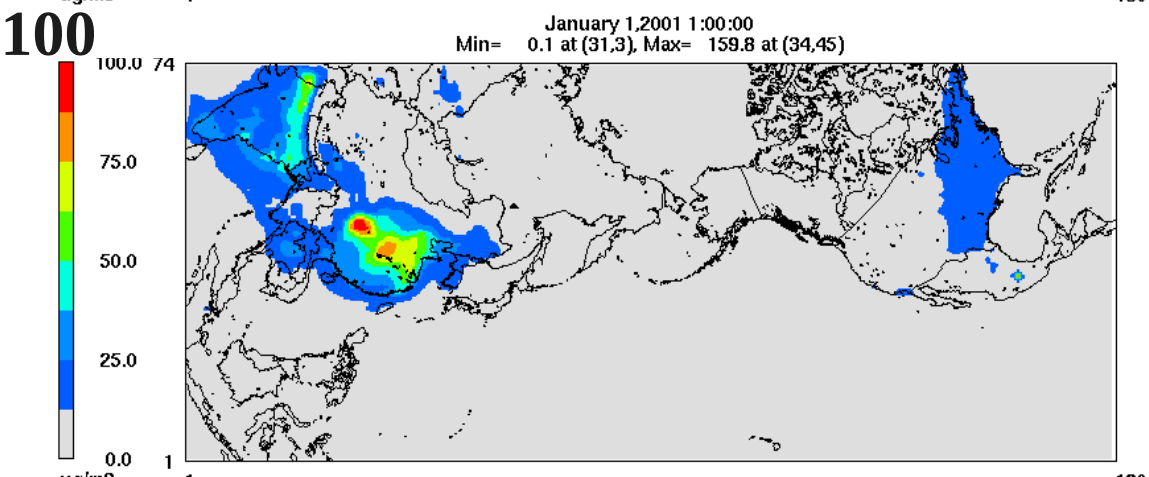
January 2001 (Base Case)



IPCC 2030 A1B (Growth Scenarios)



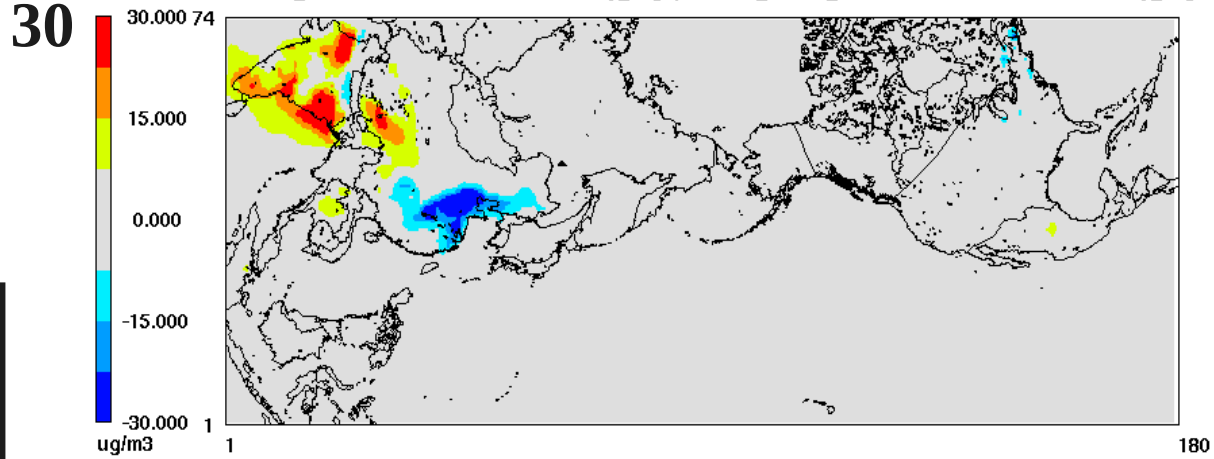
IPCC 2030 B1 (Sustainable Development)



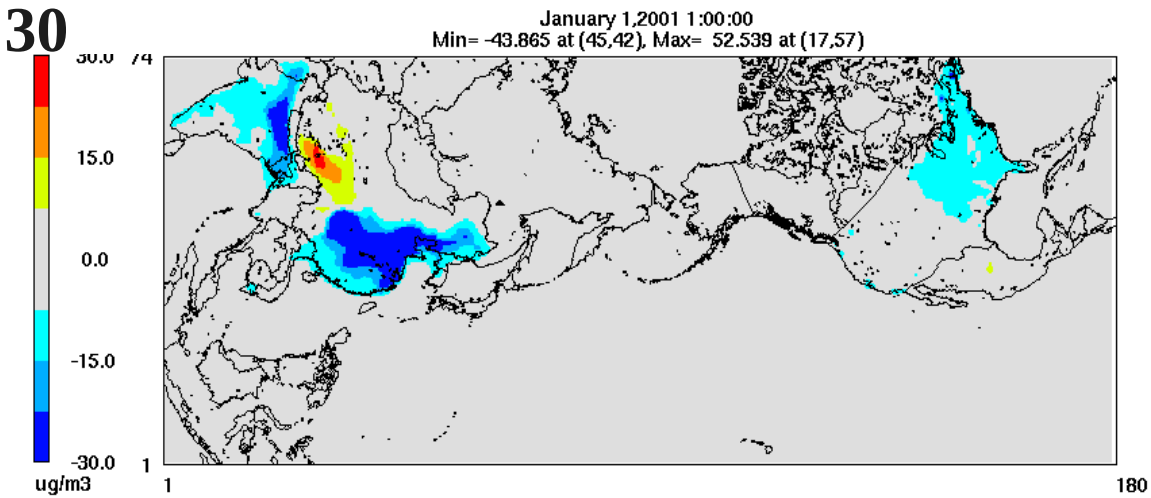
Δ PM 2.5

(Monthly Average)

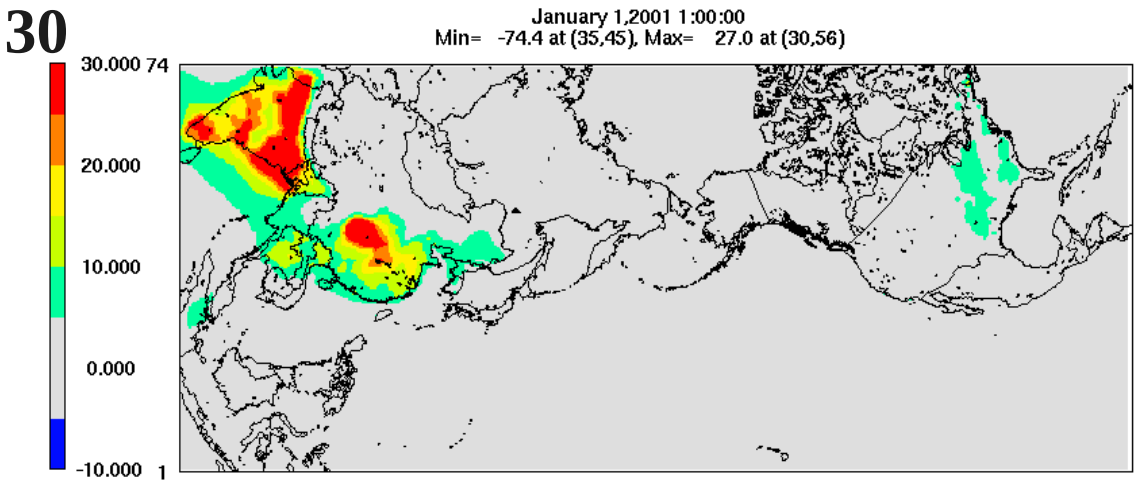
2030 A1B – Base Case



2030 B1 – Base Case



2030 A1B – 2030 B1 (Growth – Sustain)



Summary

- Intercontinental Transport of Air Pollutants (PM, O3, and Hg) can significantly impact regional air quality over the USA and other regions
- Impact of trans-Pacific transport PM & O_3 to USA is persistent thru the year; USA is also an exporter
- Max PM 2.5 impact of Asian emissions to USA occurred in the Spring (West: ~1.3 ug/m^3, East: ~0.9 ug/m^3); Also significant impact on summer O_3 (West: ~2 ppb monthly avg., up to 7 ppb daily max; East: ~0.3 ppb monthly avg.)
- Future year simulations (2030) showed that sustainable development scenarios will improve air quality in both Asia and North America