MODELING STUDY OF SEASONAL AND INTERANNUAL VARIATION OF TRANS-BOUNDARY AIR POLLUTANTS IN EAST ASIA

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Contents

Seasonal and interannual variation of trans-boundary pollutions based on the CMAQ V.4.4

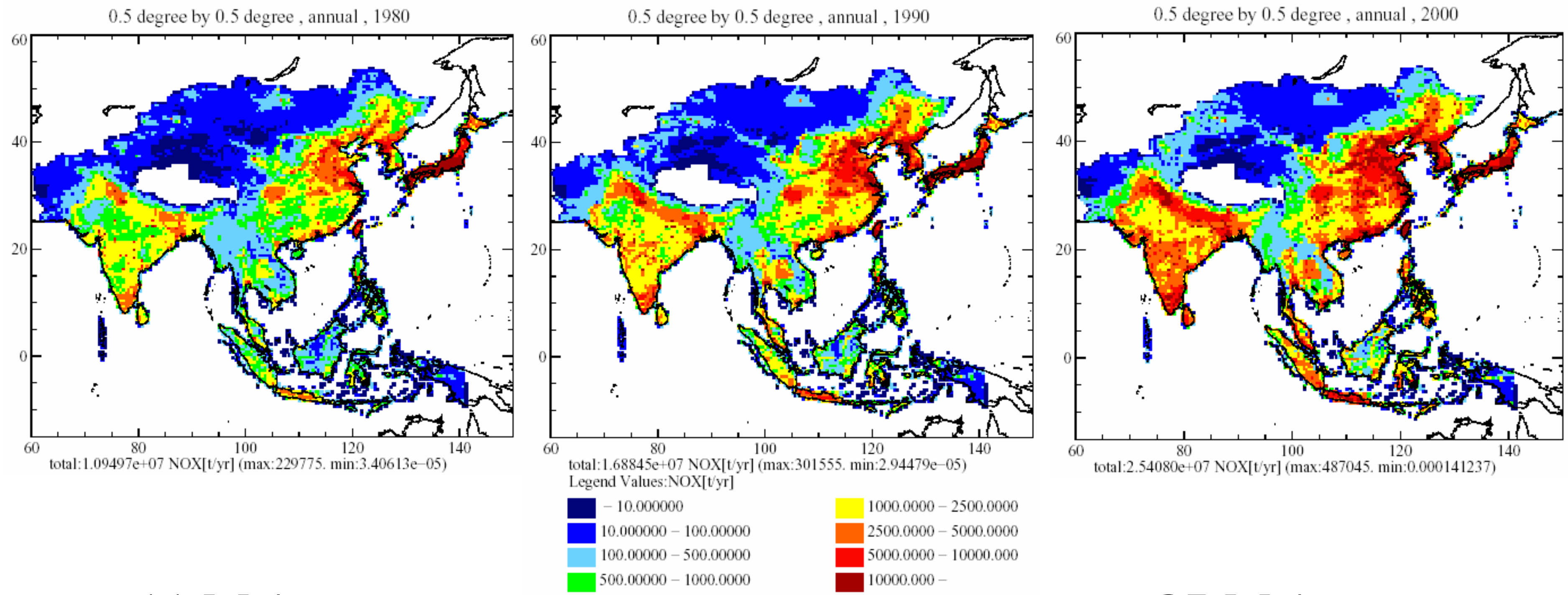
In total, 10 years CMAQ simulation was analyzed (for 1985, 1995, 1998-2004 and 2020).

Examination of historical and future prediction of Asian pollutions

Photo from summer break (2005 Aug.)

Trends of NOx emission in Asia
(Ohara et al.2005)

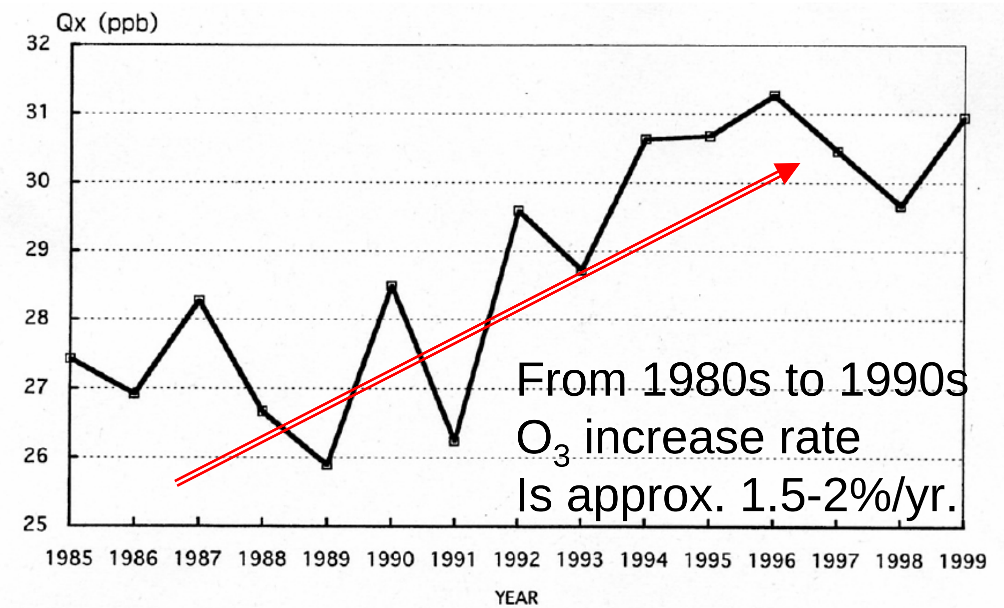
1980 | 1990 | 2000



11 Mt/year (1.0) | 17 Mt/year (1.5) | 25 Mt/year (2.3)

In 2020, NOx emission in China becomes 45% increase from 2000(FRCGC estimate).

Trend of background O_3 in Japan by Ohara et al. (2003)



NO_2 + hv + HC → O_3 → HNO_3, H_2SO_4 → Aerosol formation

Emission changes
Annual variation of meteorology (e.g., Asian monsoon has a week correlation with ENSO)

Concentration variations are combination of these factors

	Obs	CTM Mdl
Emis.	○ increase	△ Expensive
Meteorology (wind, cloud, rain)	○	○
Inflow B.C. (BCON)	○	× difficult

RAMS/CMAQ long-term simulation outline

Chemistry : SAPRC-99

Gas, Aqua, Aerosl rections

Gas : NO_y, SO_2 , O_3 , CO , OH , HO_2 ,
NMHC etc

Aqua : SO_2, HNO_3, N_2O_5, NH_3, SO_4^{2-},
NH_4^+, NO_3^- etc

Aerosols : SO_4^{2-}, NH_4^+, NO_3^-

Domain: 6400km×5600km
(78×68 grids)

Horizontal : 80km×80km

Vertical : 14layer (RAMS=23 layer)
up to 23km

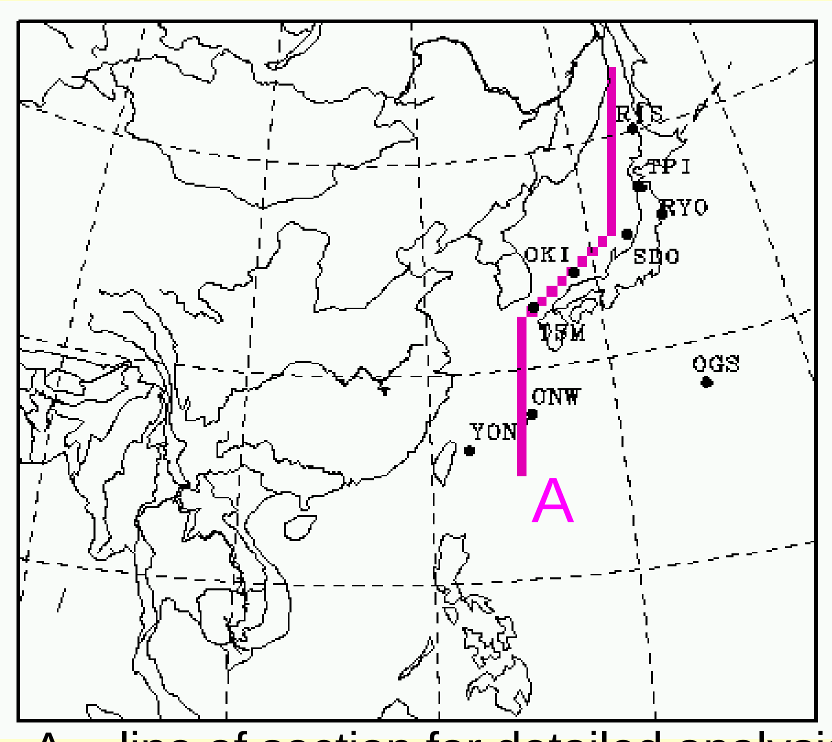
<u>Model simulation</u>

Past: 1985, 1995

Recent: 1998-2004 (fixed emis.)
to see the inter-annual variation

Future: 2021 (with CCSR/NIES
AGCM IPCC output)

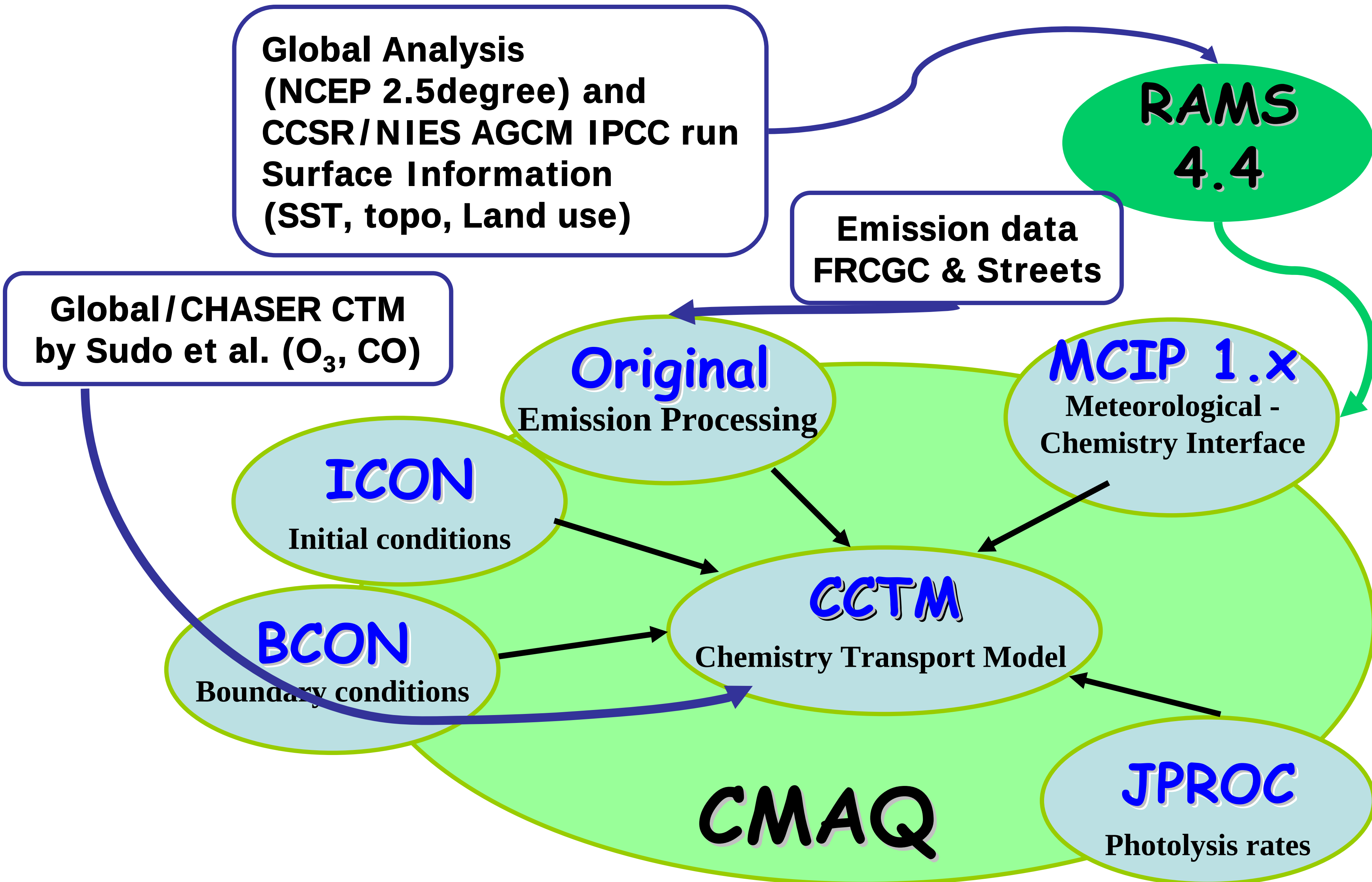
In total 10 years simulations



A = line of section for detailed analysis

CMAQ model domain

Framework of Emission/RAMS/CMAQ 4.4



NO2 from GOME/SCIAMACHY vs. CMAQ results for 2004

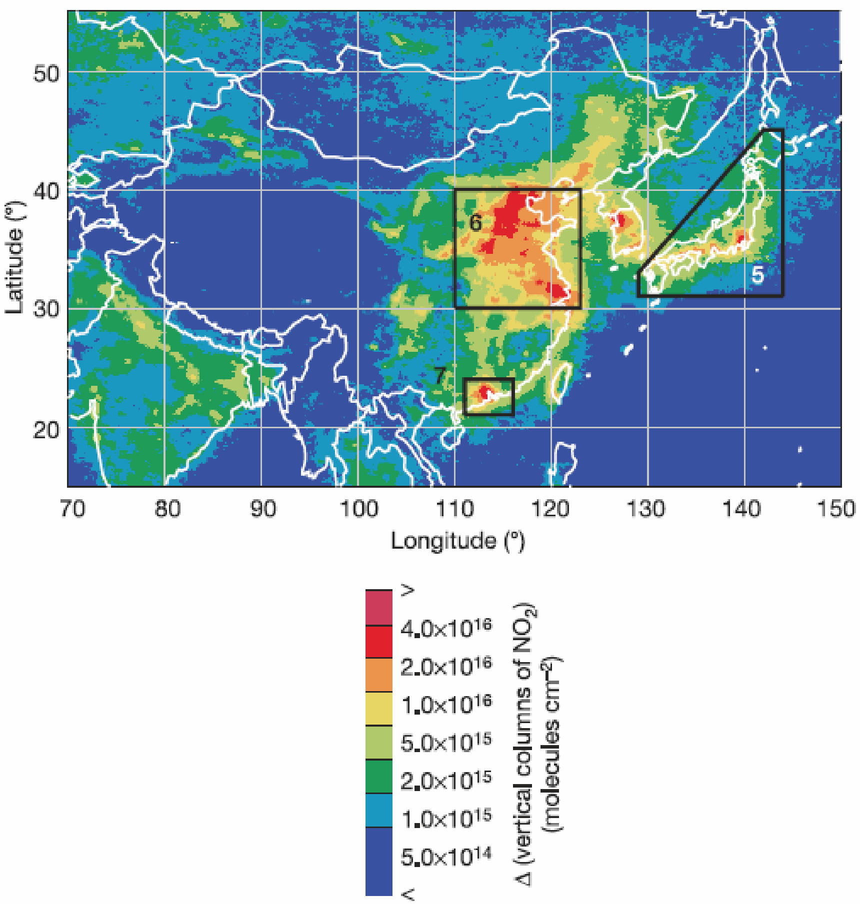
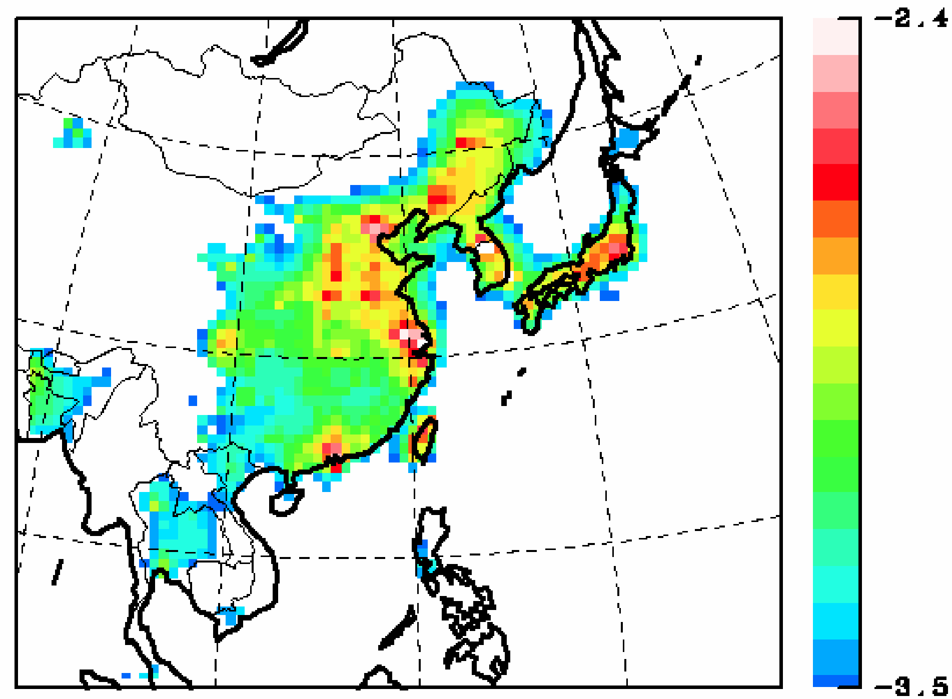


Figure 2 | SCIAMACHY tropospheric NO_2 vertical columns averaged between December 2003 and November 2004 for selected industrial regions. SCIAMACHY measurements are taken close to 10.00 a.m. LT. A nonlinear colour scale has been used because of the large range of NO_2 vertical columns. The numbered rectangles indicate the regions used in Fig. 3.

Richter et al. (Nature, 2005)

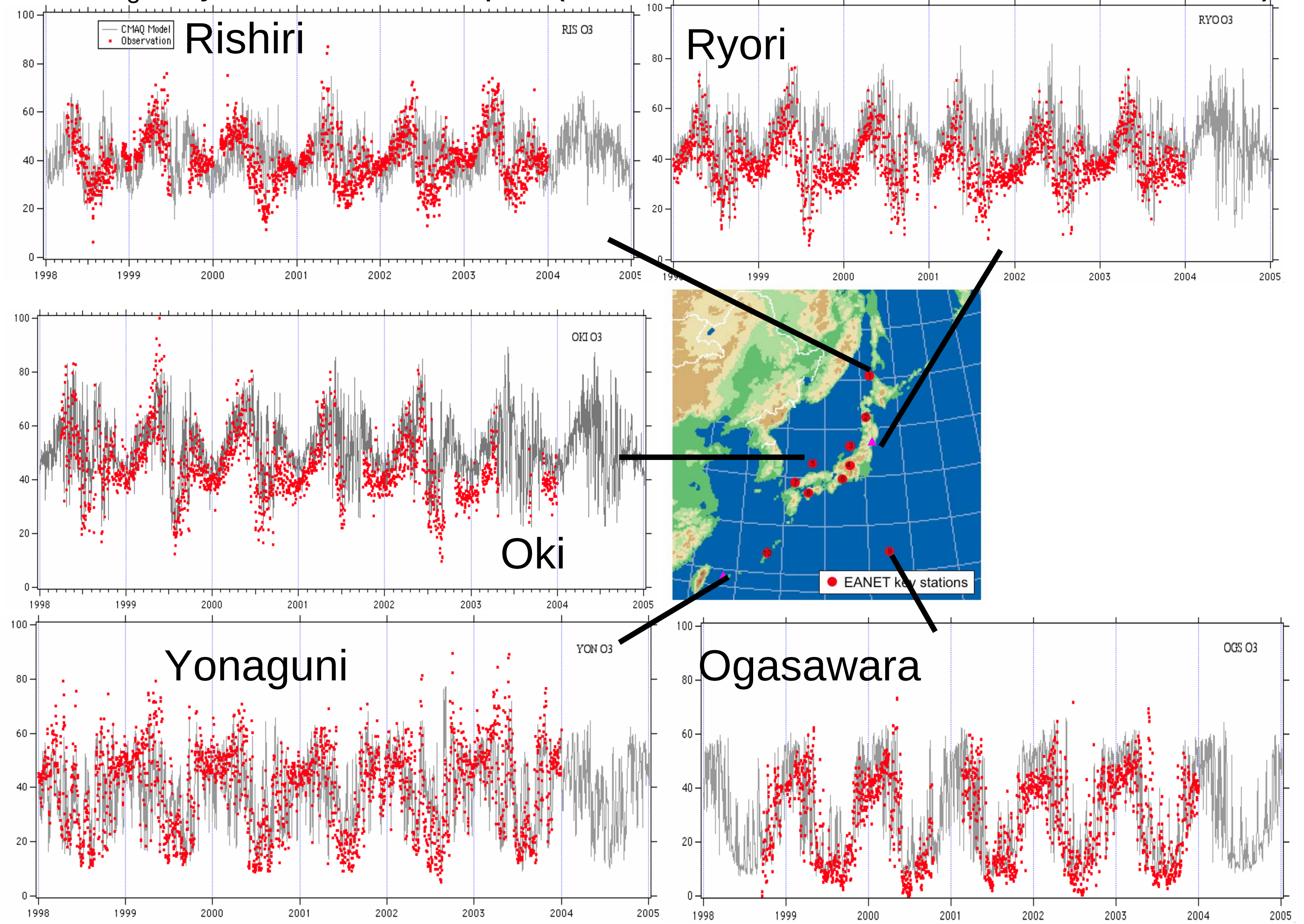


CMAQ NO_2 concentration below z<1000m for year 2004. Color in log scale.

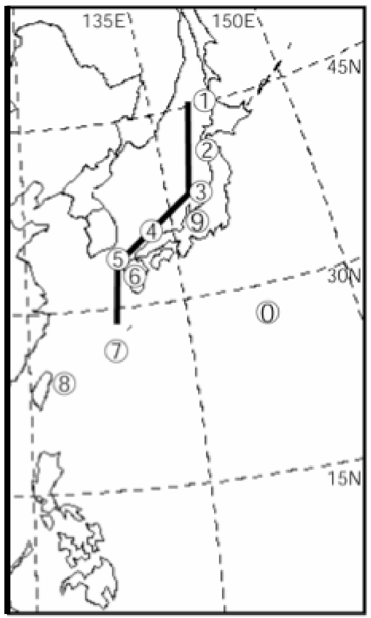
CMAQ application
- recent years -

- Model validations
- seasonal characteristics

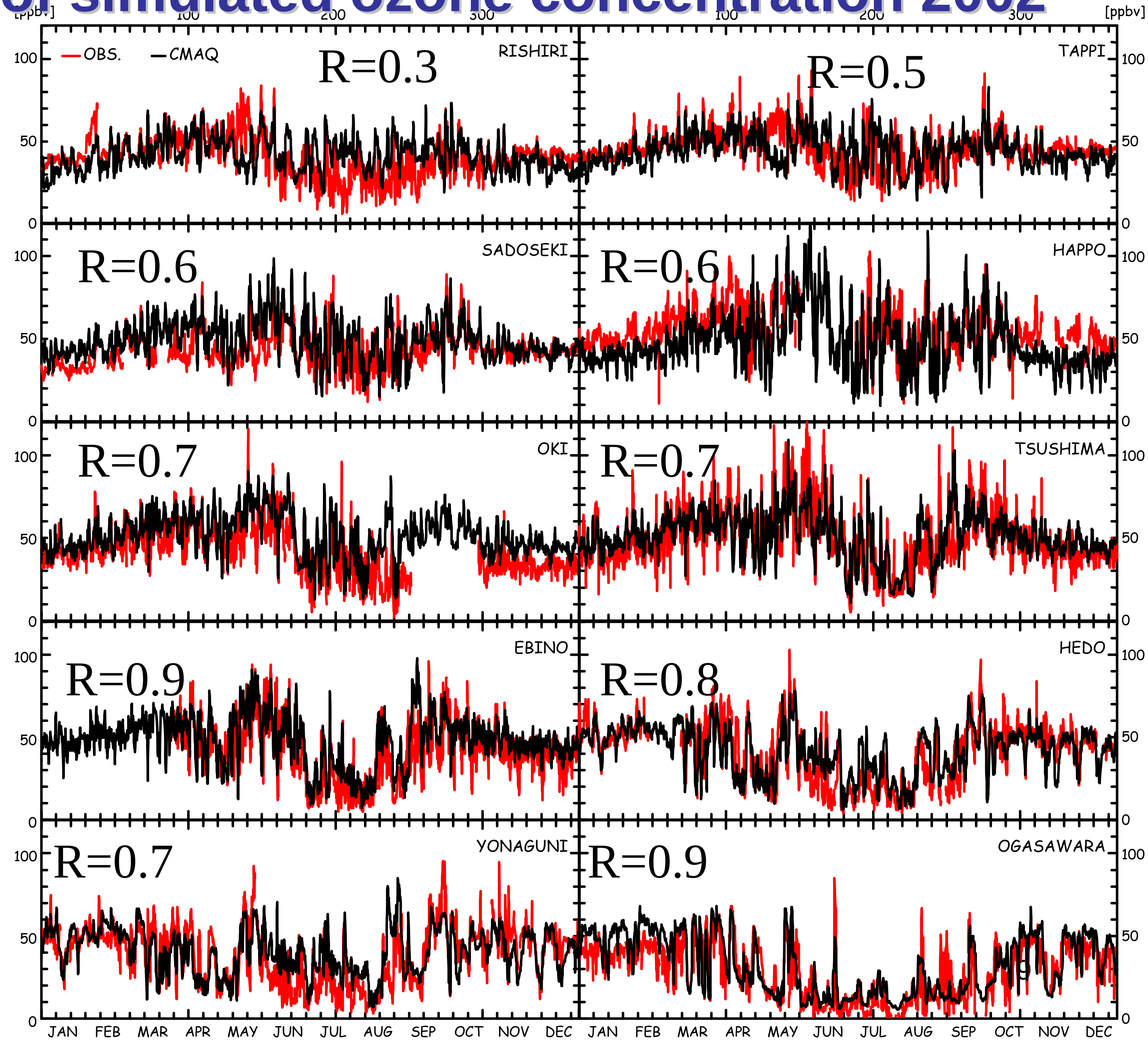
O_3 : 7 years time series plot (EANET and WMO/WDCGG, JMA 2005)



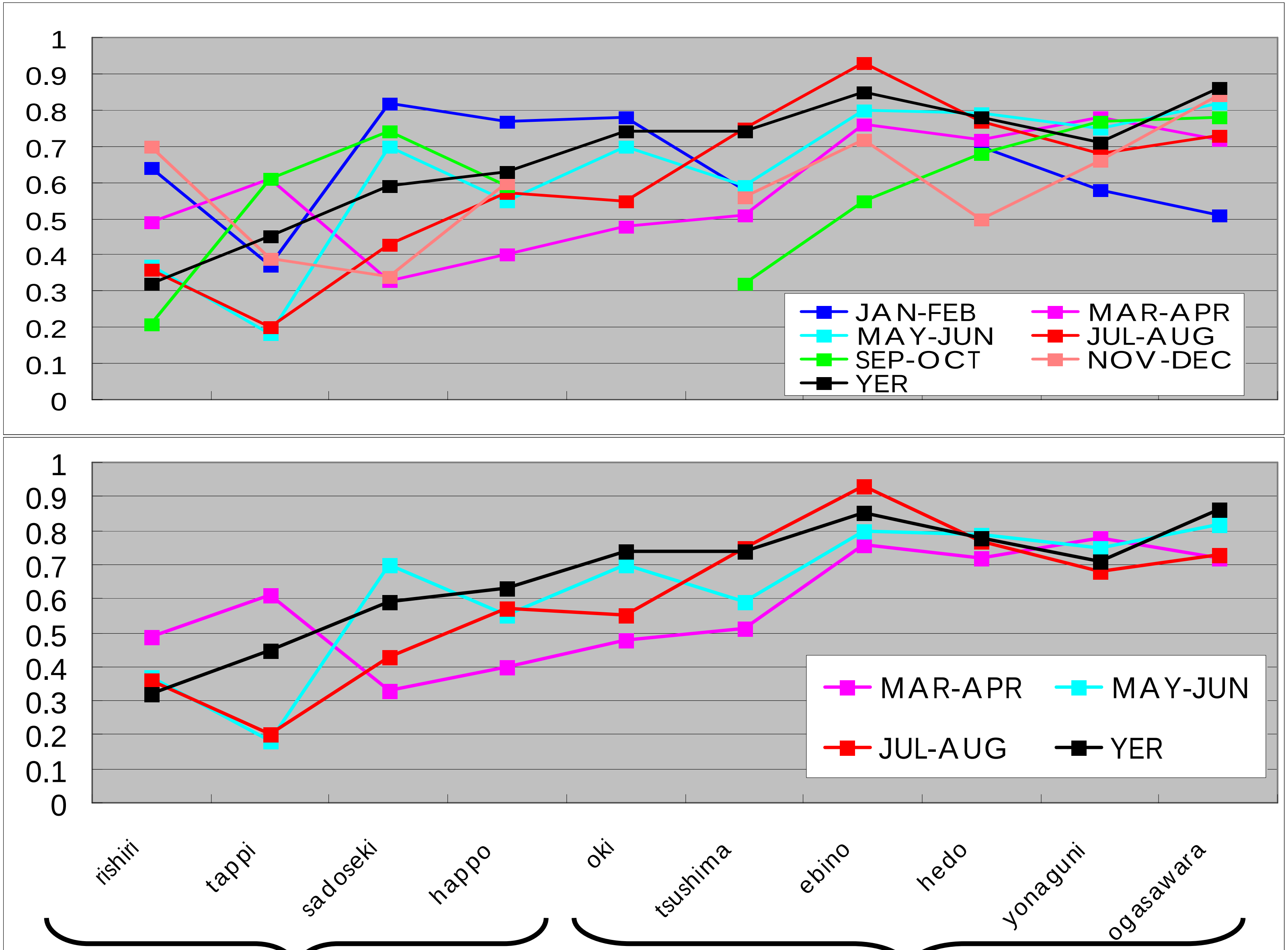
Validation of simulated ozone concentration 2002



① Rishiri
② Tappi
③ Sadoseki
④ Oki
⑤ Tsushima
⑥ Ebino
⑦ Hedo
⑧ Yonaguni
⑨ Happo
⓪ Ogasawara



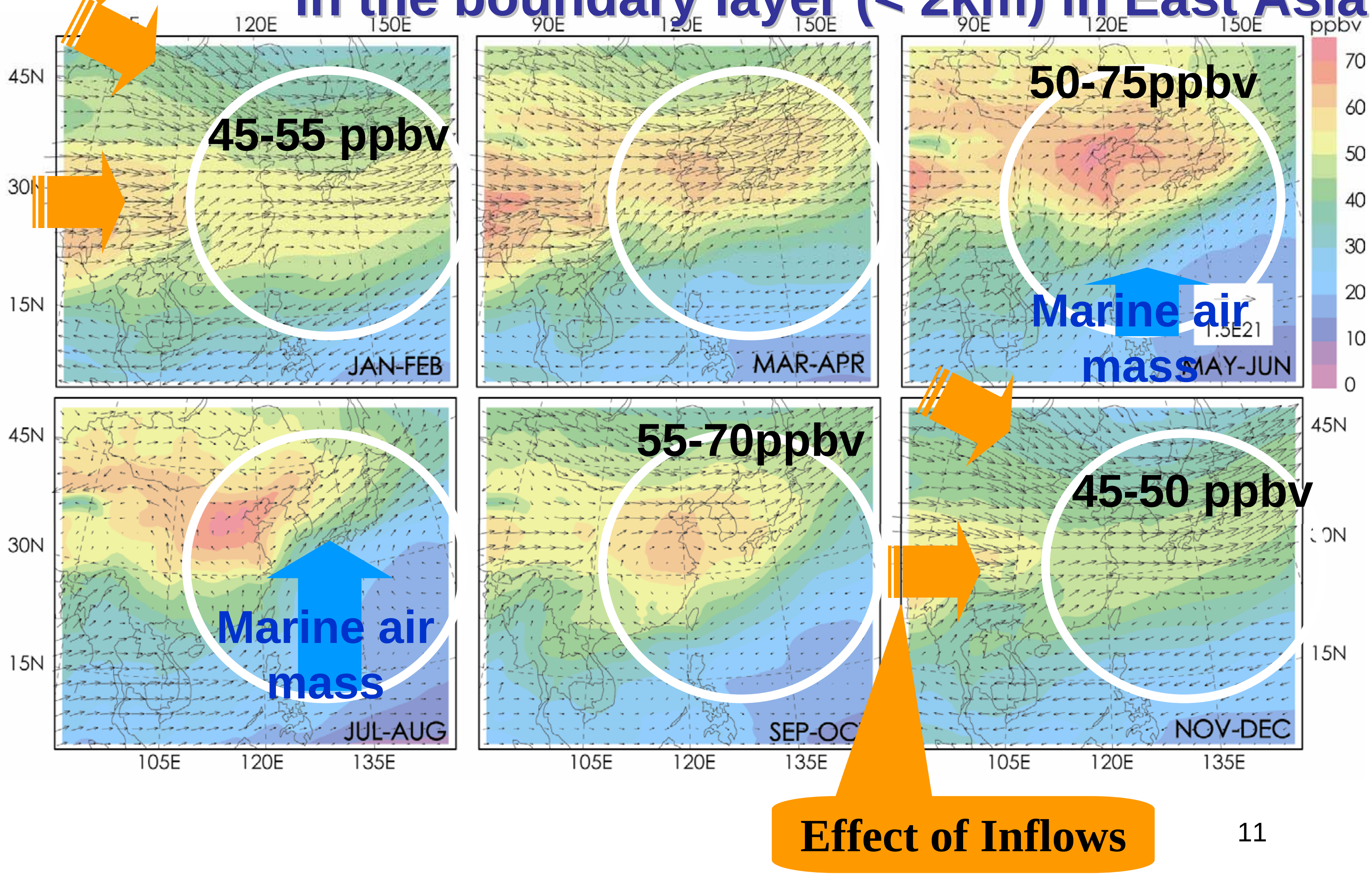
Monthly correlation of O_3 (obs vs CMAQ)



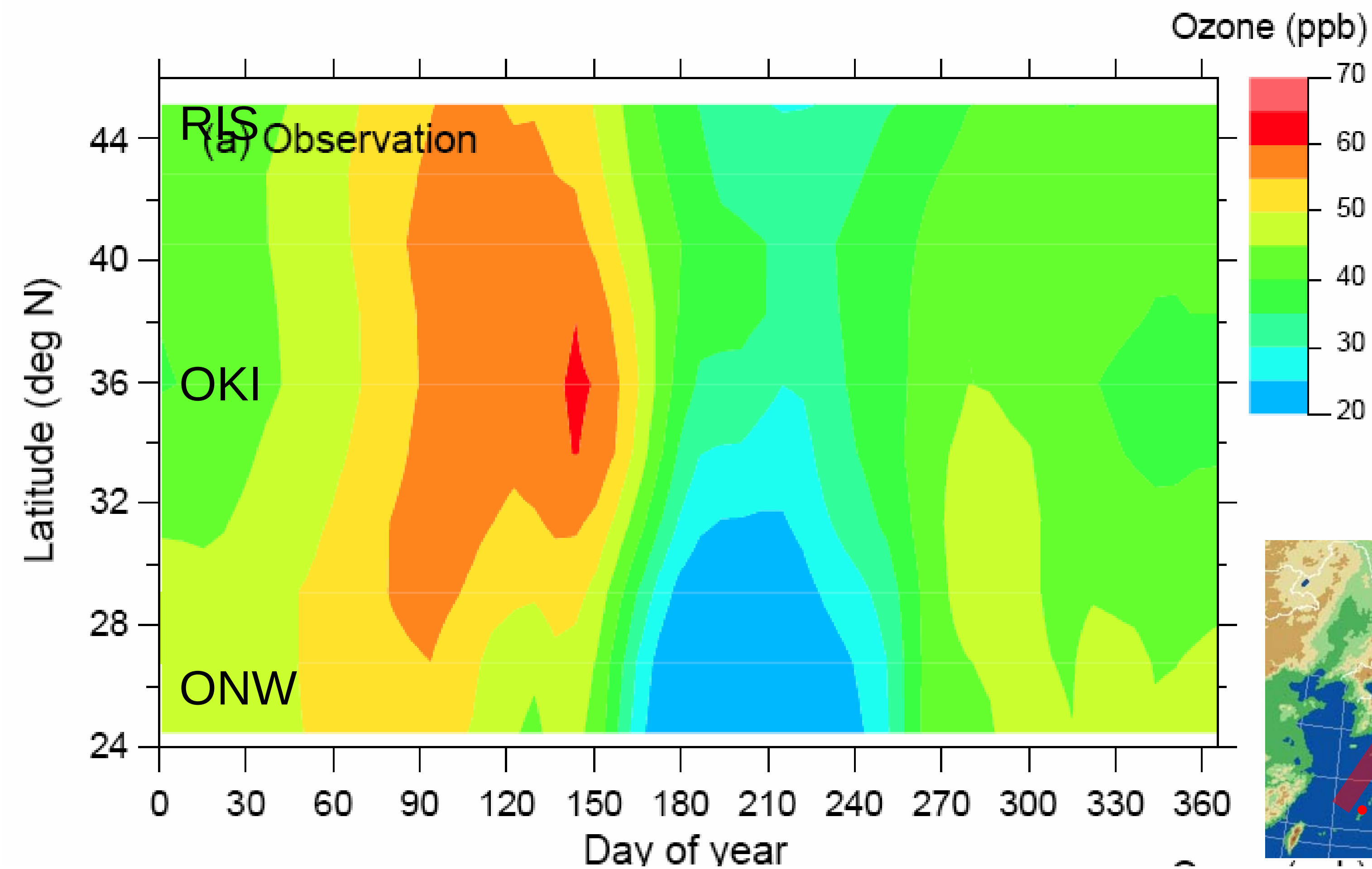
Northern Japan

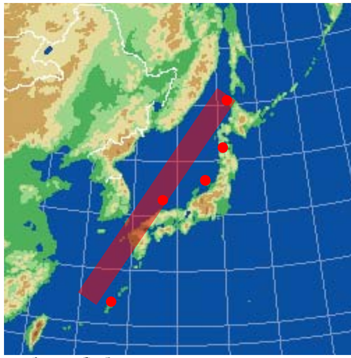
Southern Japan better correlation.

Seasonal variation of ozone distribution in the boundary layer (< 2km) in East Asia



Observed Latitudinal O_3 gradient and seasonal variations



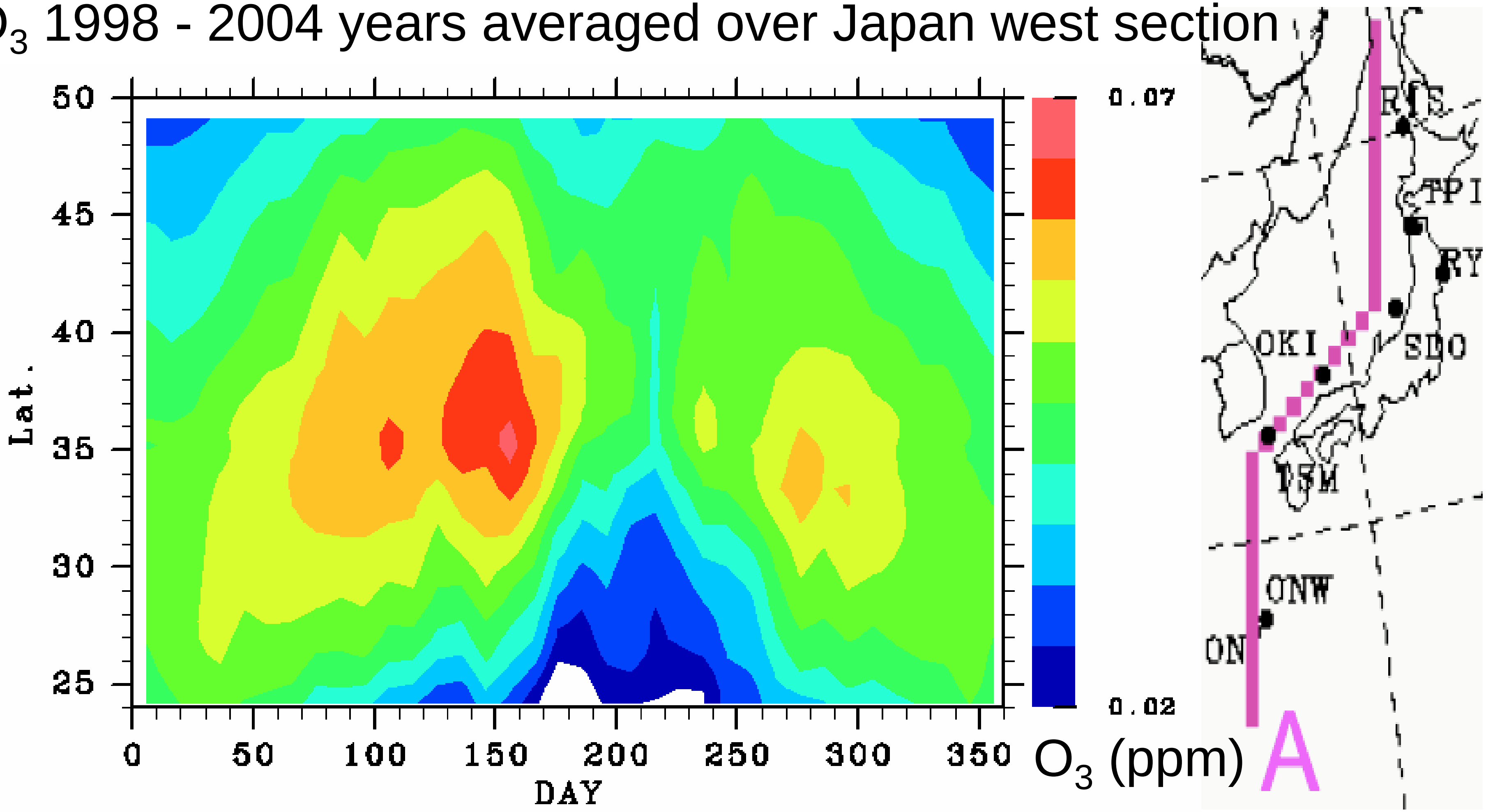


- Seasonal change both in concentration and variation range. We can see the latitudinal differences.
- Spring maximum Okinawa=March Oki=May

from NIES Tanimoto et al. (2005, GRL accepted)

CMAQ/FRCGC 2000 emission run

O_3 1998 - 2004 years averaged over Japan west section



Spring max. around 33-40 N, and second max in autumn.

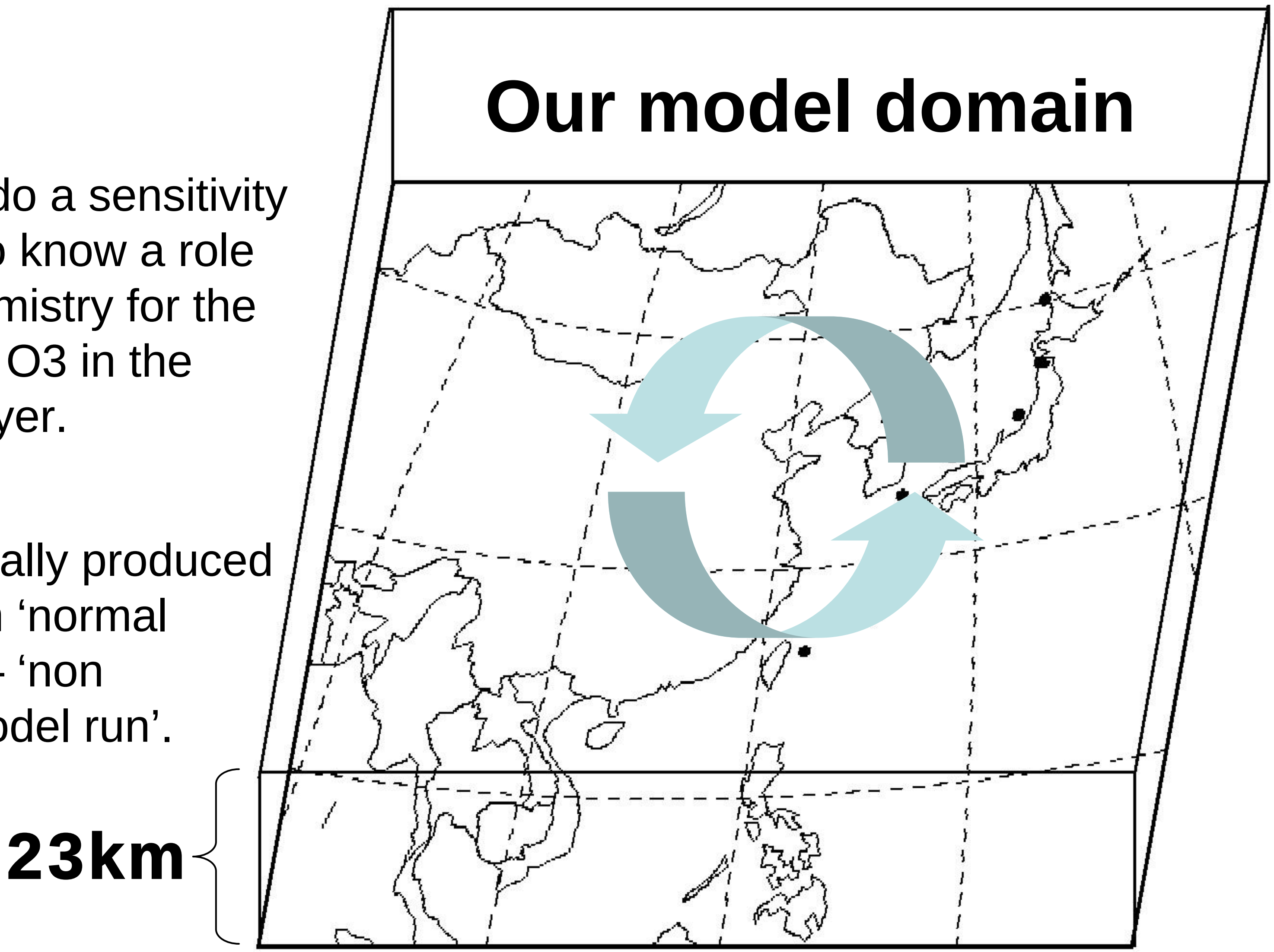
Jun-Aug. large variation in low latitude due the interaction of continental and maritime air mass

Chemical Reaction Contributions

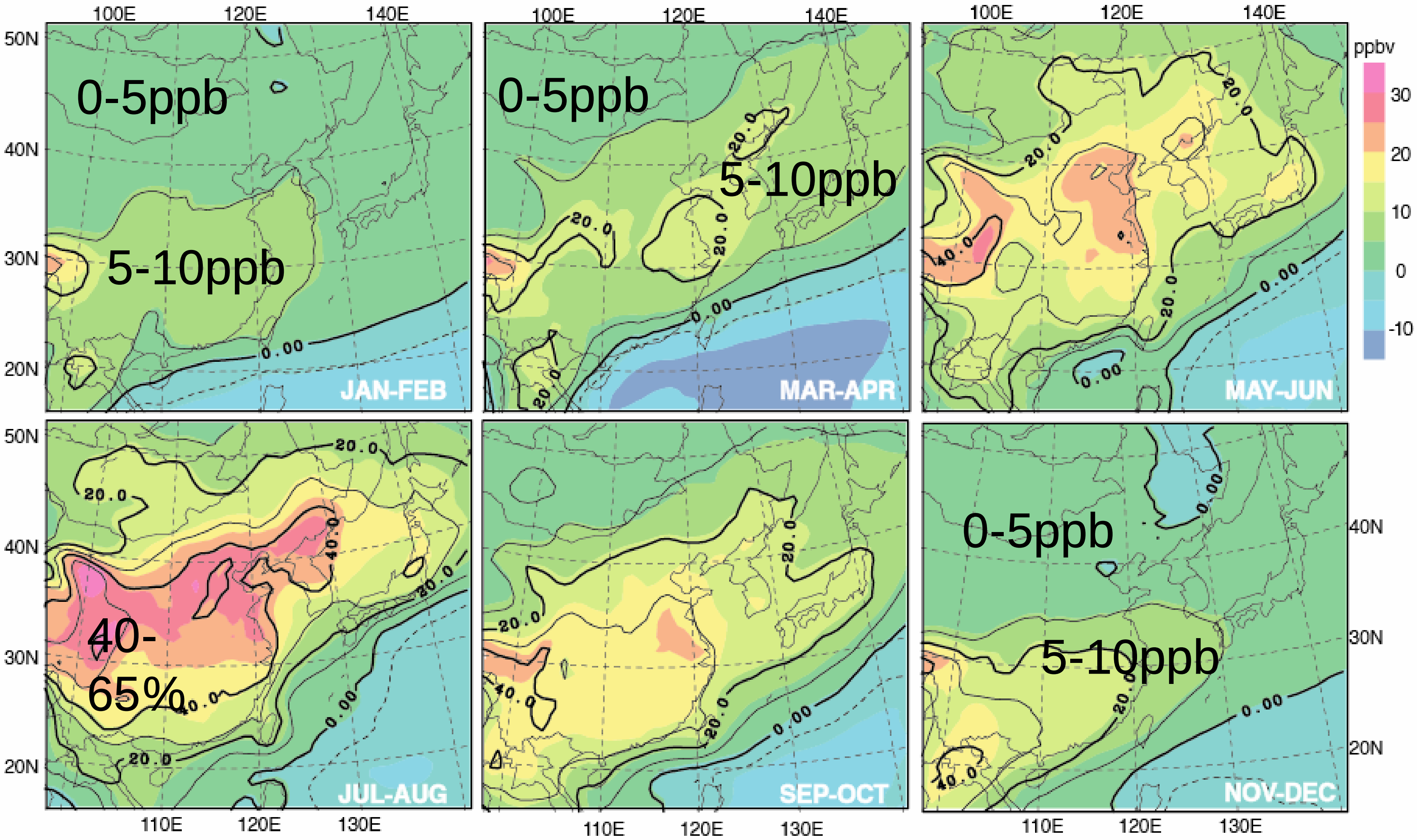
Results of sensitivity run: CNTL - NO_CHEM

We tried to do a sensitivity model run to know a role of photochemistry for the formation of O3 in the boundary layer.

The ‘chemically produced O3’ got from ‘normal model run’ – ‘non chemical model run’.



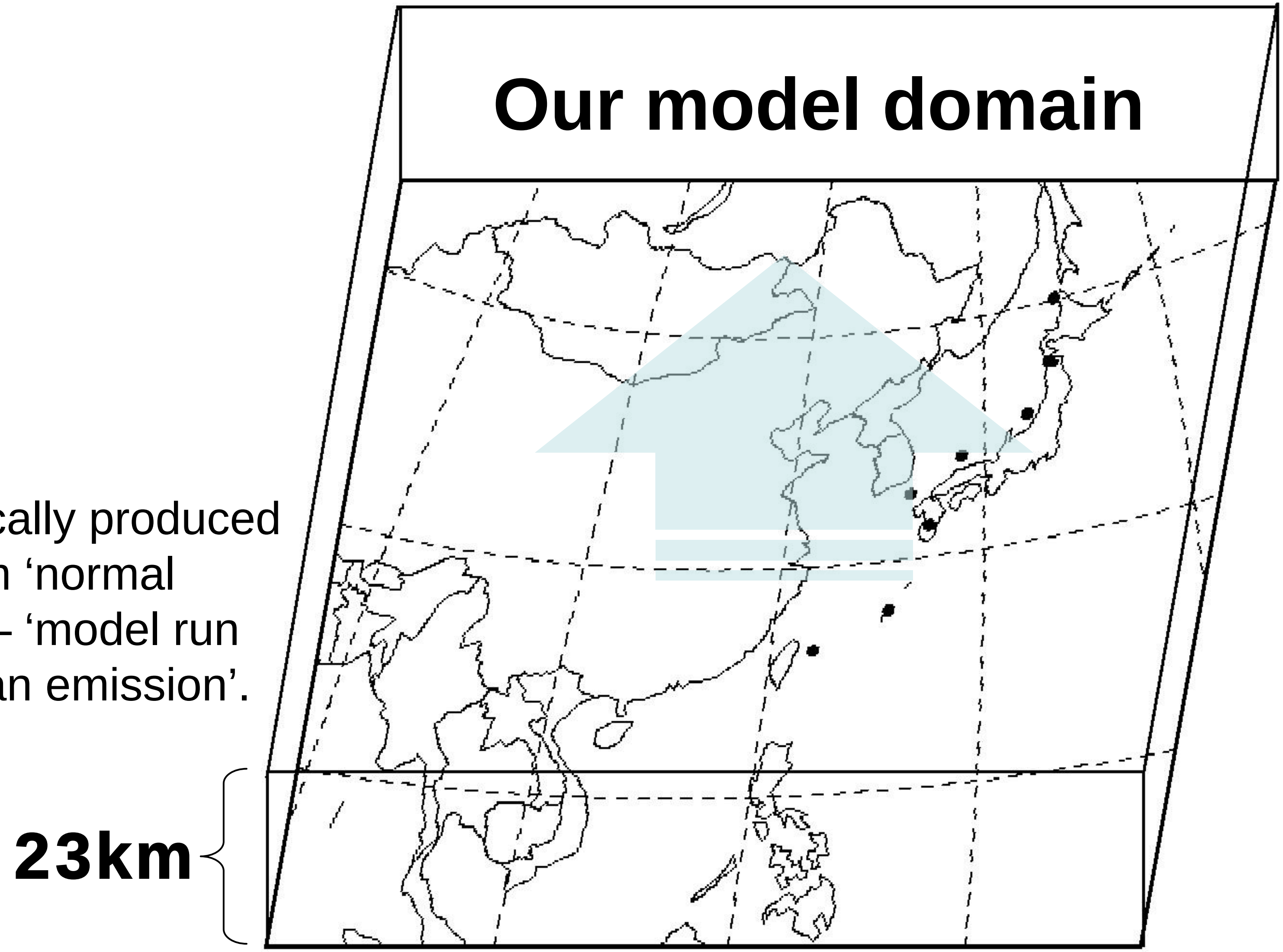
Results of sensitivity run: CNTL - NO_CHEM



Colors: chemically produced O3 Contours: chemical contribution to O3 concentration

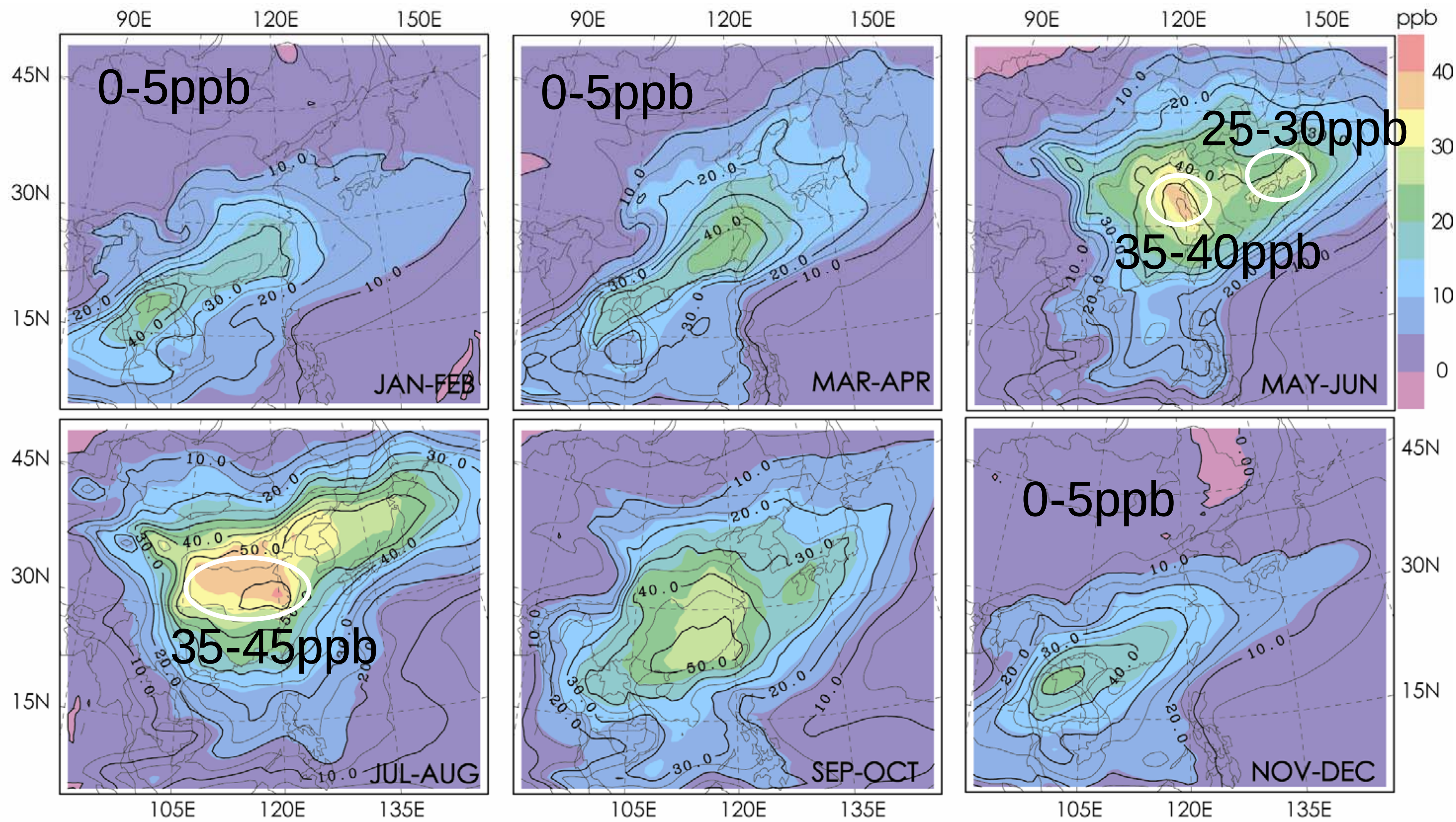
Asian Emission Contributions

Results of sensitivity run: CNTL - NO_ASIAN_EMISSION



The 'chemically produced O3' got from 'normal model run' – 'model run without Asian emission'.

O_3 production from Asian



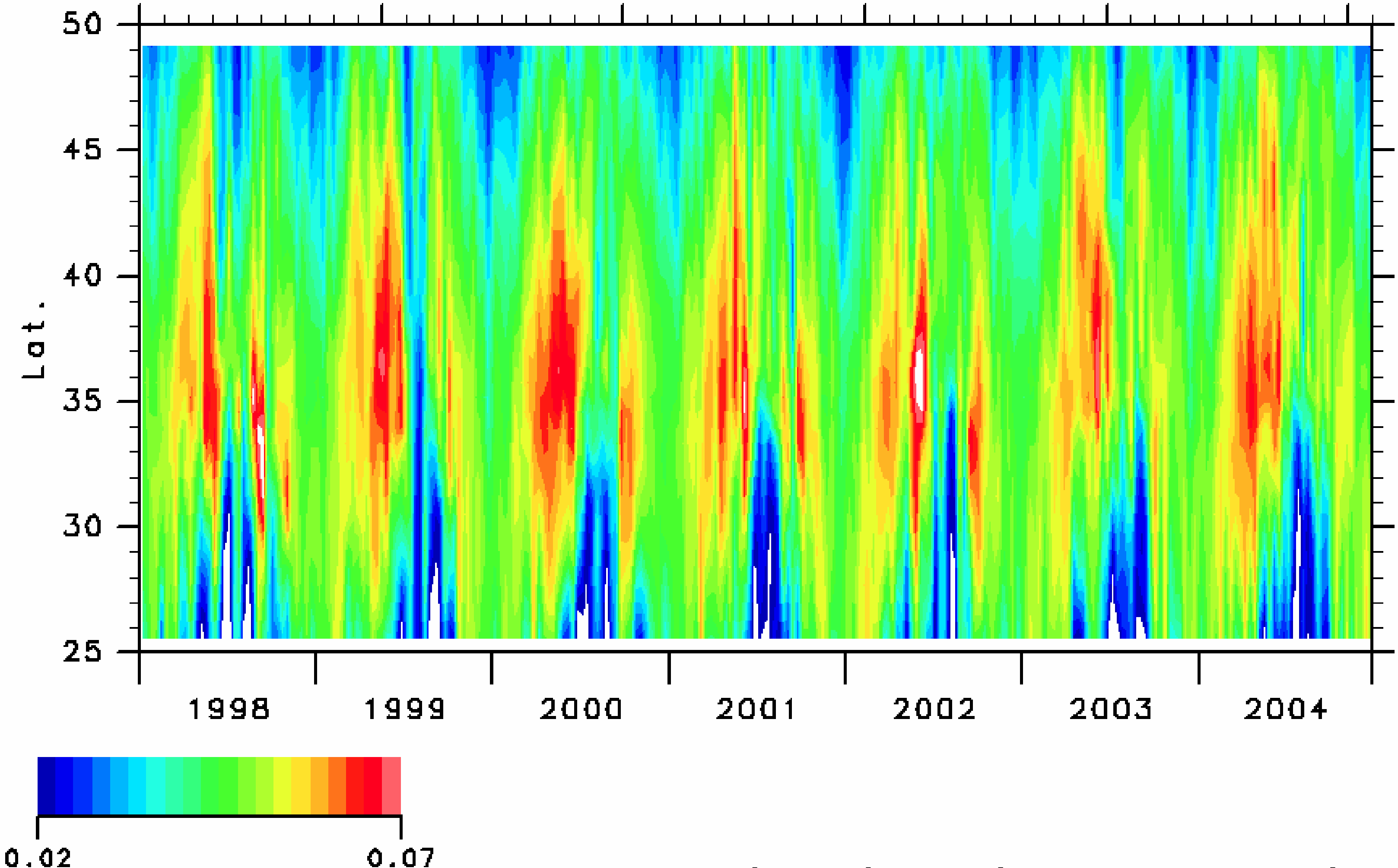
Colors: produced O3 from Asian emission Contours: Asian emission contribution to O3 concentration

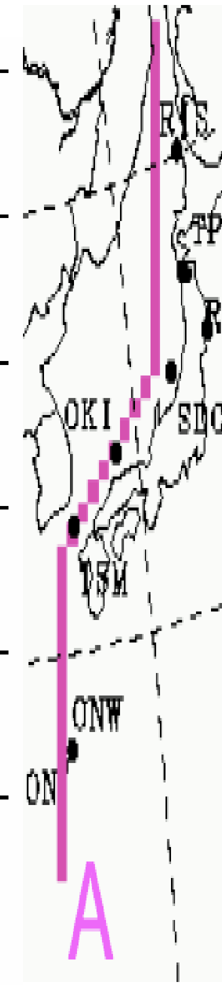
Inter-annual variations

1998 - 2004 with fixed emission (2000 base)

CMAQ/FRCGC 2000 emission run

O_3 1998 - 2004 years along the Japan west section

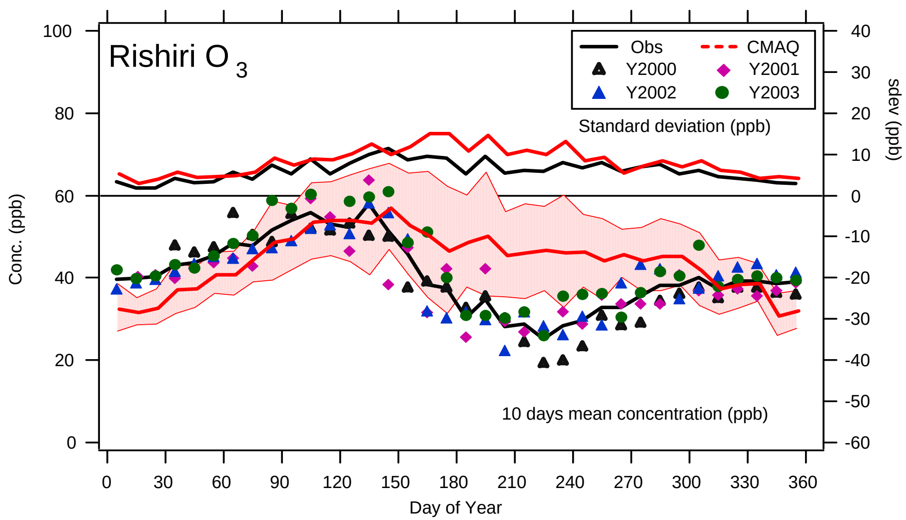


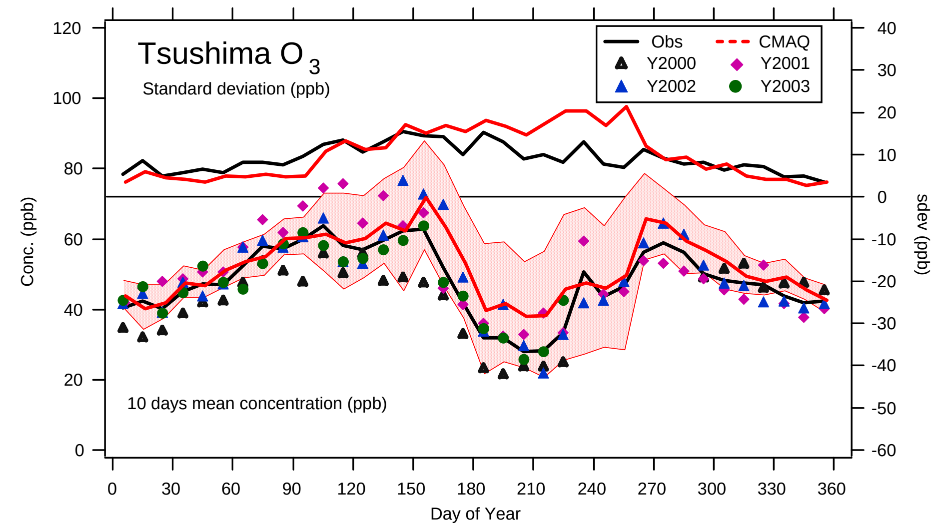


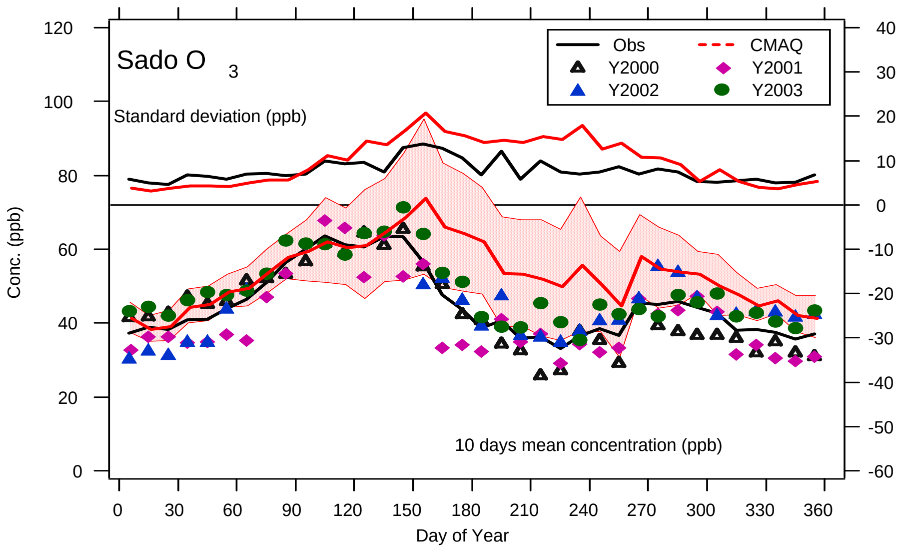
O_3 (ppm) 10 days averaged

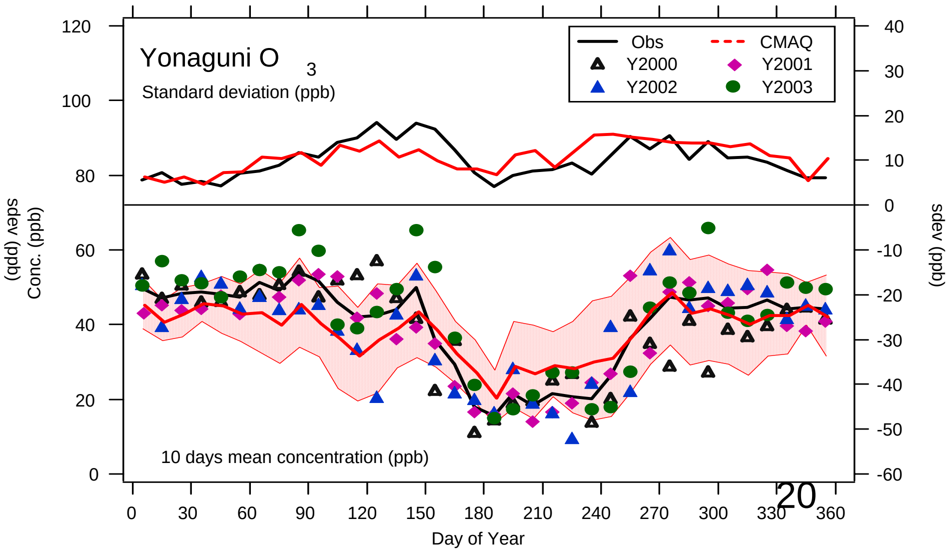
Observed O_3 variation (10days mean and standard dev.) for 2000-2003 (model results are also analyzed same way and shown by red line and tone)

Observed variation is within the model variation !



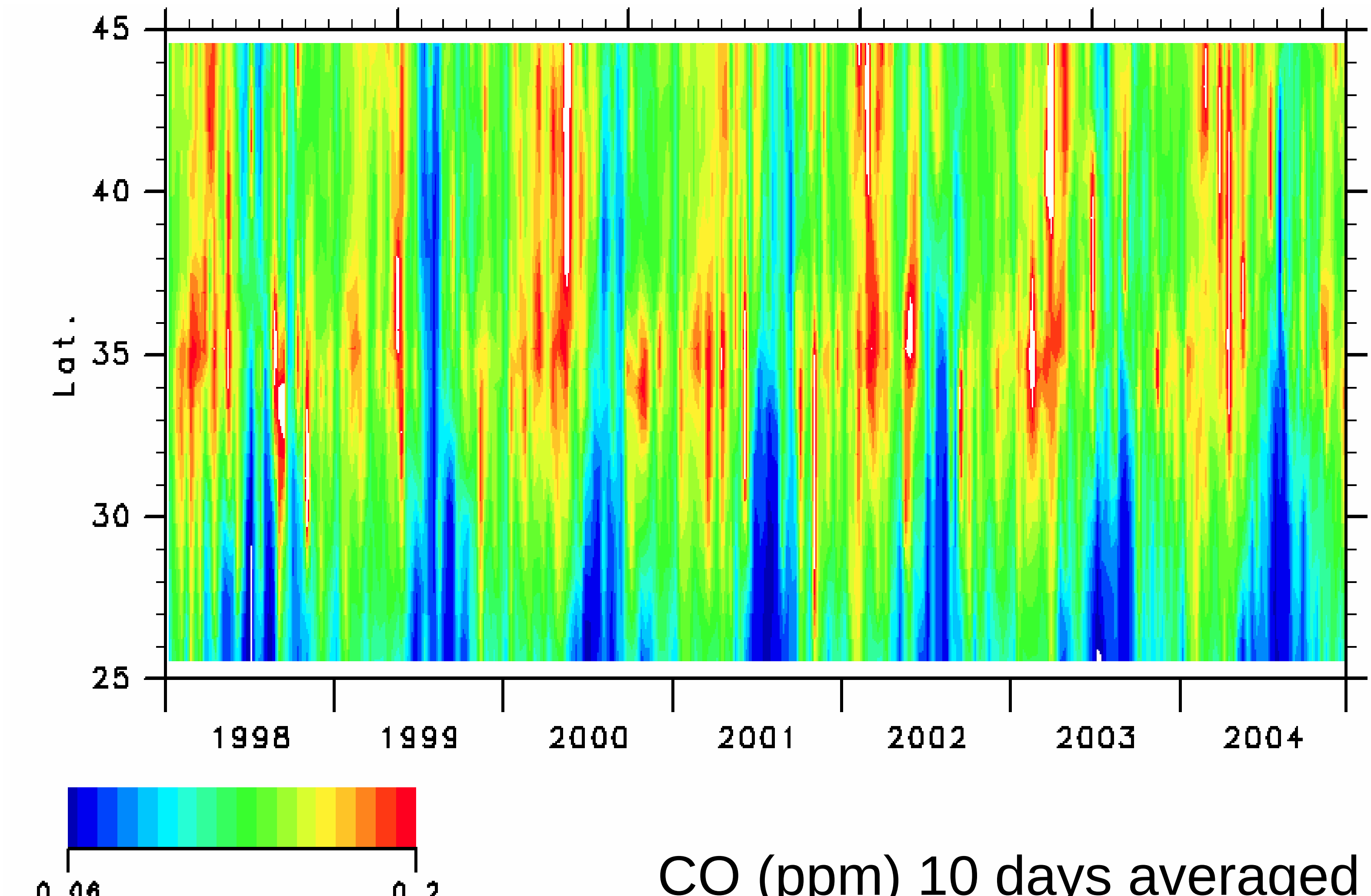




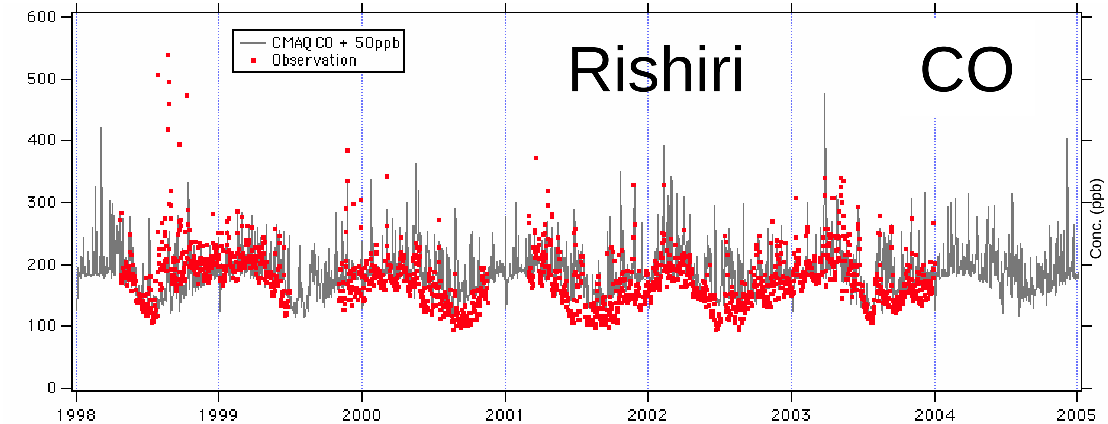


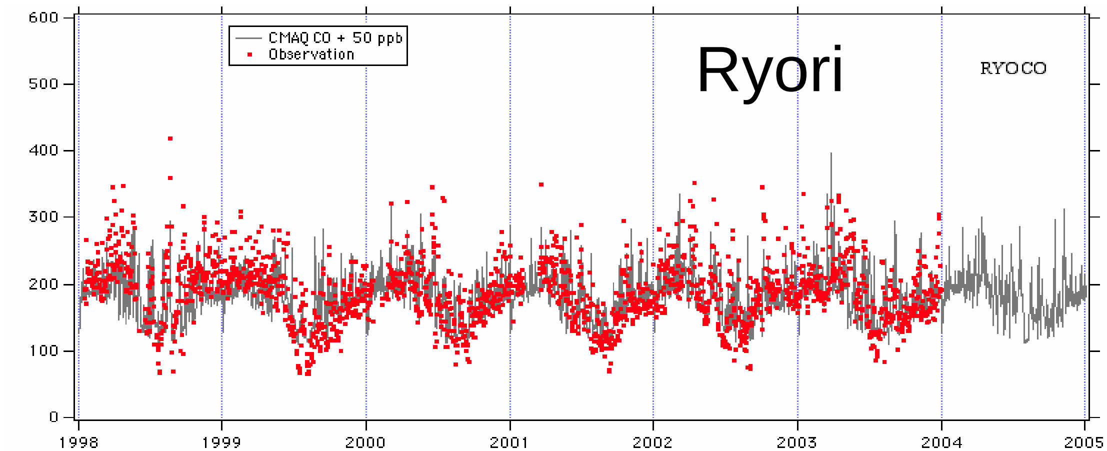
CMAQ/FRCGC 2000 emission run

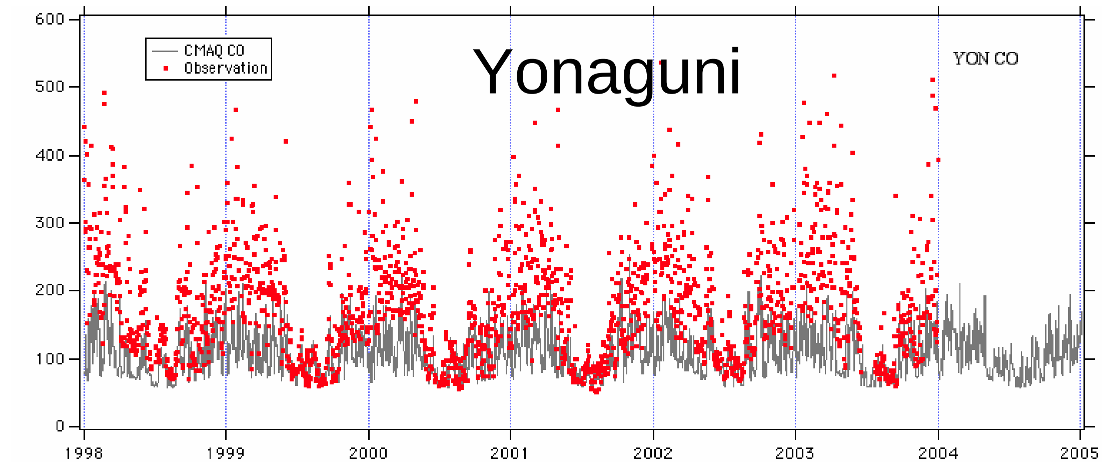
CO 1998 - 2004 years along the Japan west section

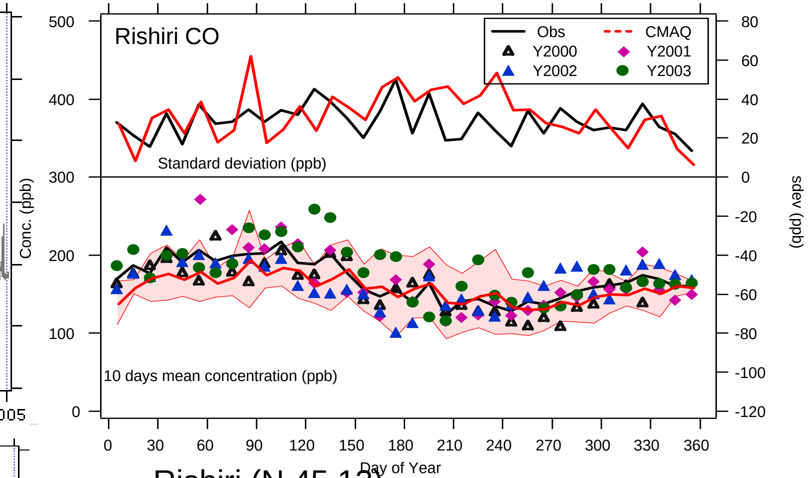


CO (ppm) 10 days averaged

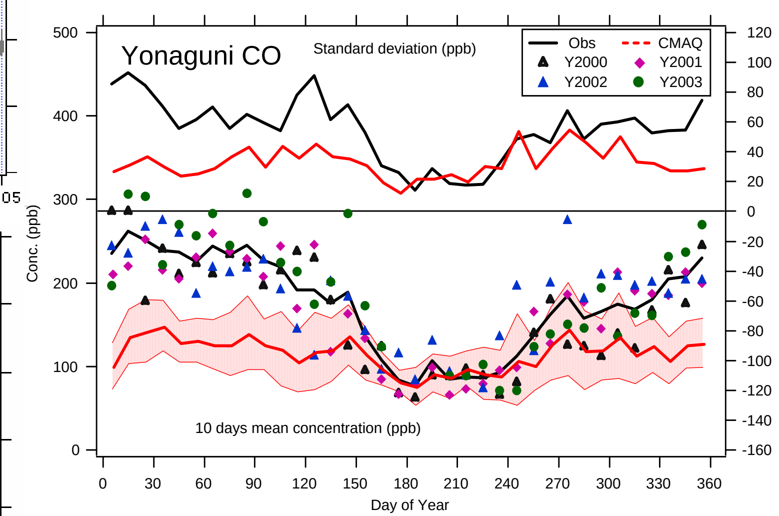






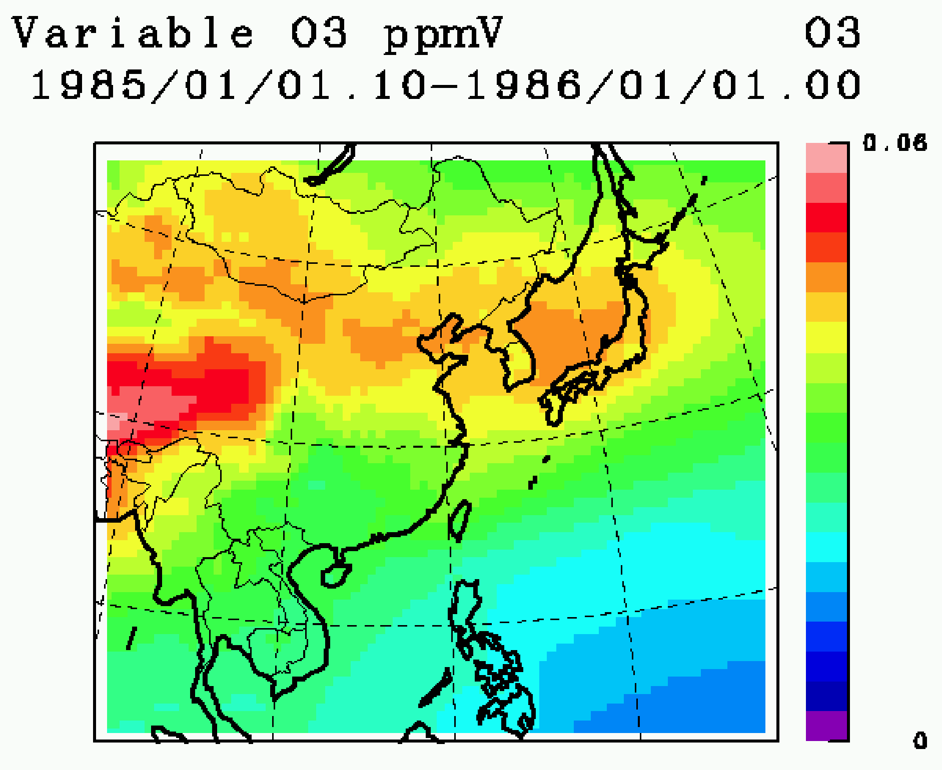


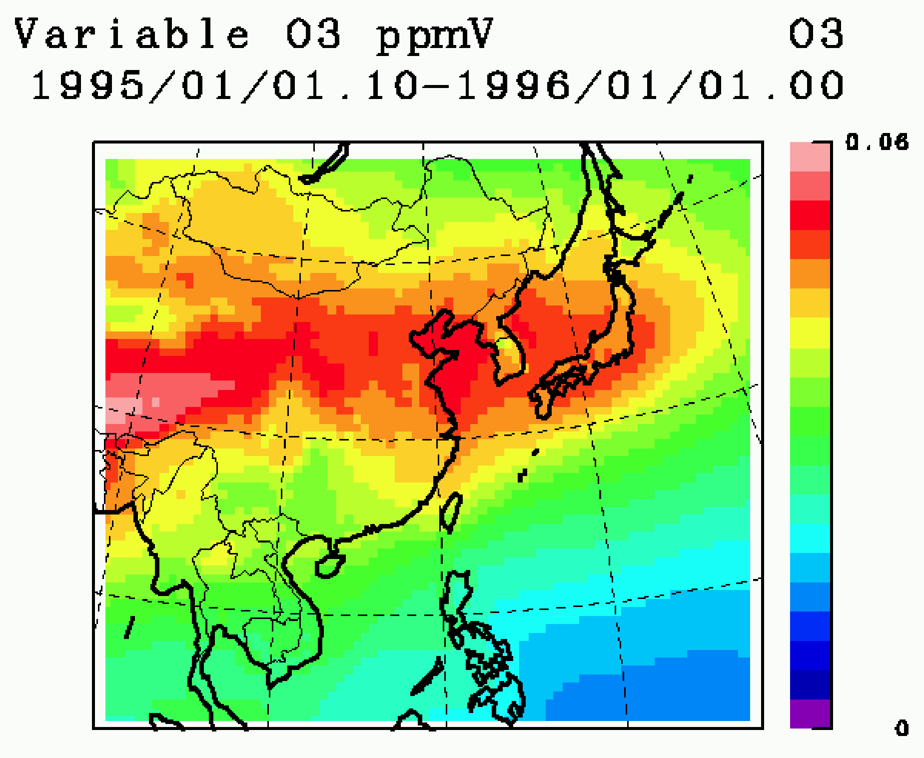
Rishiri (N 45.13)
Model captured the observed seasonal variation very well.
Observed 10days averaged is almost within the ±σ variation of model.



Yonaguni (N 24.47)
Model reproduces general trend but the winter and spring concentration are quite under-estimated (maybe biomass emission in the model is too low)

Photo from summer break (2005 Aug.)





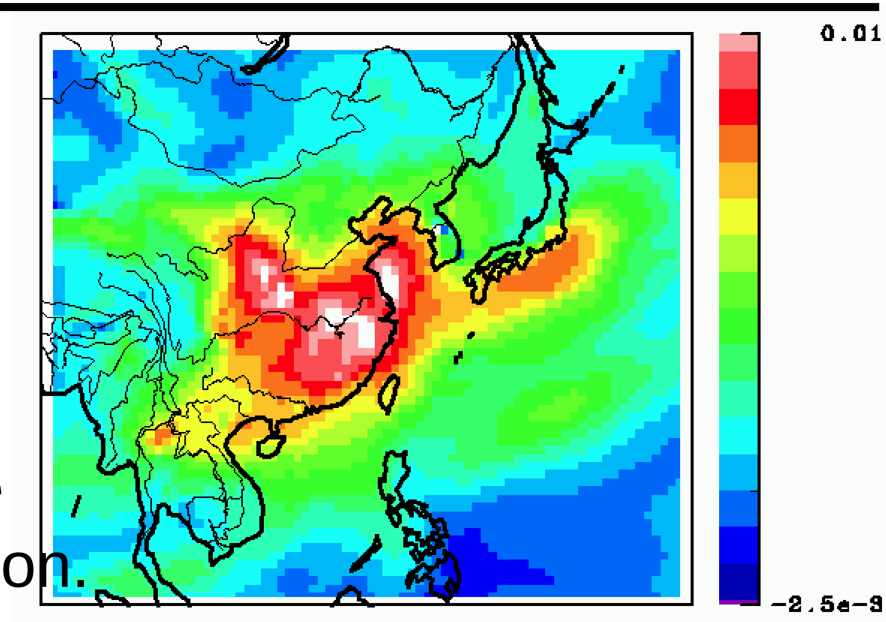
Simulated O_3 (annual av.) between 1985 and 1995.

<u>Central and South China 10ppb</u>

<u>Japan Sea side 3-4ppb</u>

<u>South of Japan 7ppb up</u>

These increase is quite reasonable compared with Japanese observation.



GOME NO_2 trend

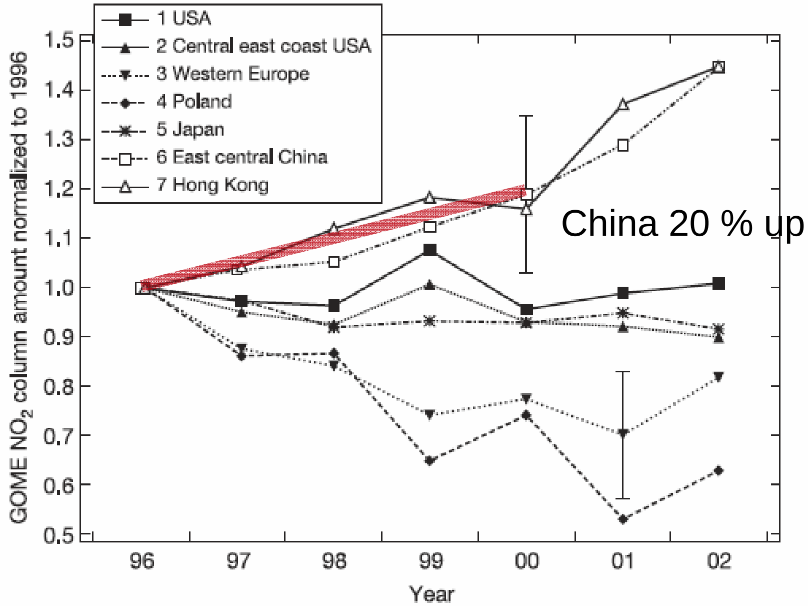
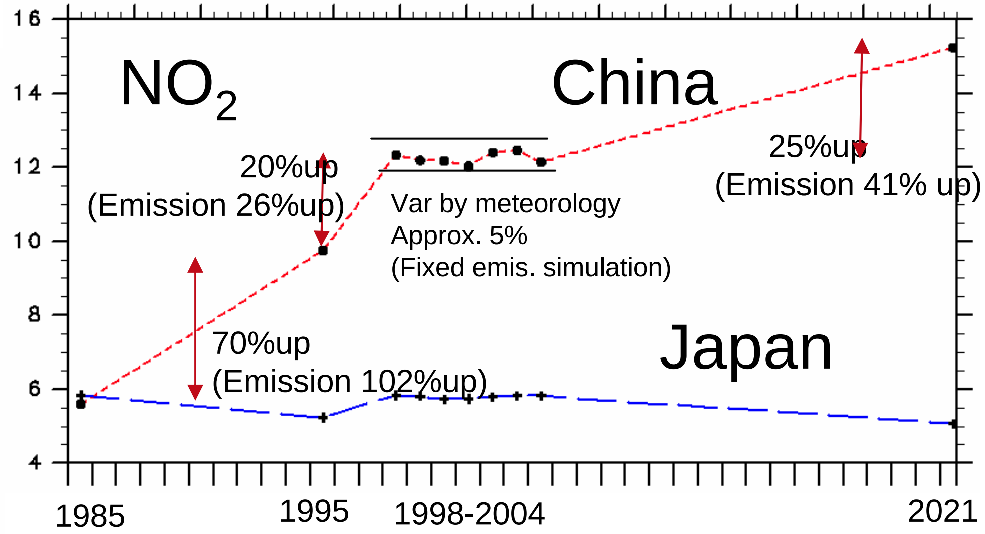
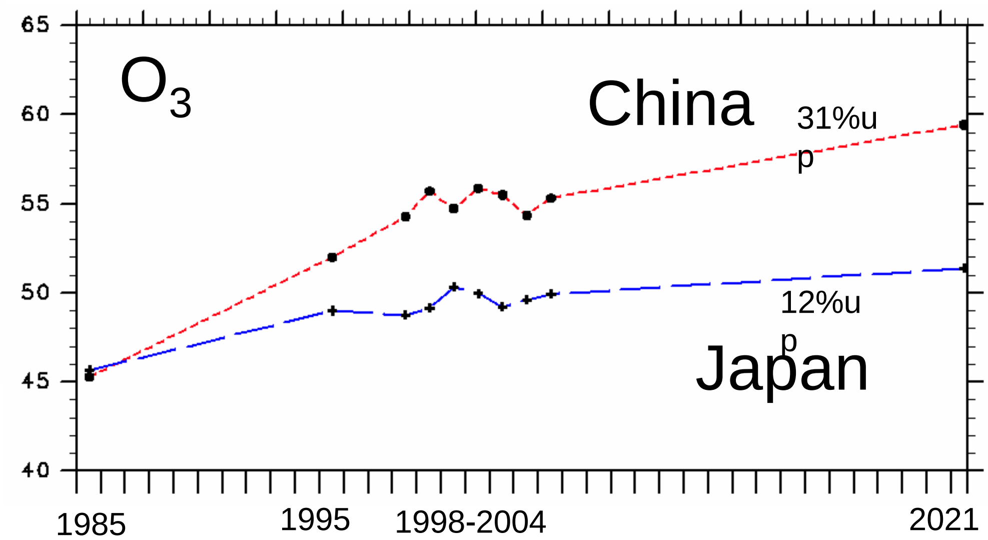


Figure 3 | The temporal evolution of tropospheric NO_2 columns from GOME for selected areas. The mean annual NO_2 column amount normalized to that in 1996 for the geographical regions USA, Central East Coast USA, Western Europe, Poland, Japan, East Central China, and Hong Kong, which are defined in Fig. 2. The error bars represent the estimated uncertainty (s.d.) for an individual year, the values over China being larger as a result of the poorer knowledge and therefore larger uncertainty of the aerosol loading and its changes.

Richter et al. (Nature, 2005 Sept.)

CMAQ NO_2 and O_3 trend for China and Japan (annual mean)

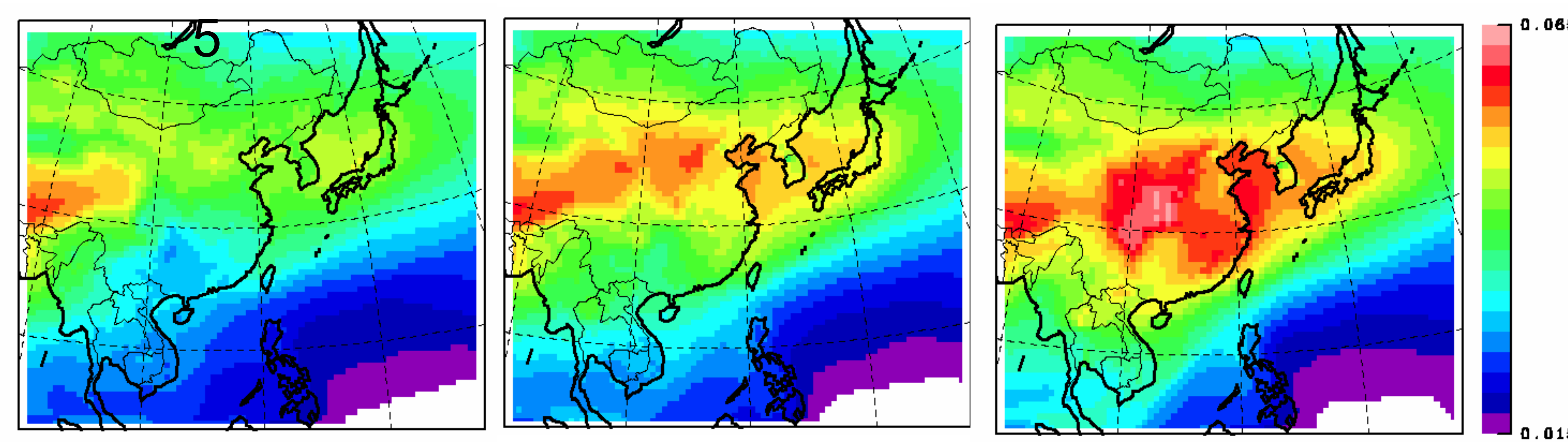




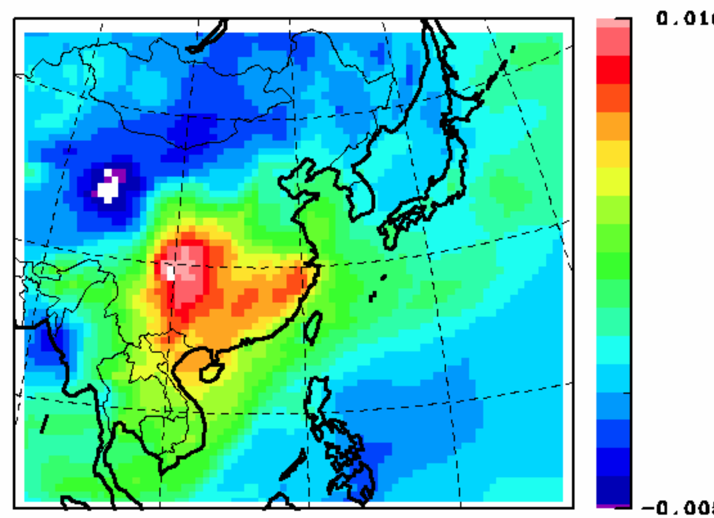
Note: BCON for 2002 is used in all case

Change of surface O_3 (annual av.)

1 9 8 5 | 2000 | 2021



2021-2000



Quite rapid increase in
Central and south China
Including the East-China Sea !!!

Concluding Remarks

1. RAMS/CMAQ 10 years simulation(1985, 1995, 1998-2004, 2021) with FRCGC & Streets emis.
2. CMAQ O_3 shows an excellent agreement with observation.
3. We can explain the recent increase of observed O_3
4. But it indicates the importance of variation of meteorological field (inter-annual variation) for concentration field.
5. Future O_3 must be an important environmental issue in Asia (NOx - Nitrate becomes more serious than sulfate)
6. We will extend the analysis of deposition field soon.

Thank you very much for your attention