Development of a global atmospheric transport model and its application for carbon cycle studies

Yosuke Niwa

Geochemical Research Department

Meteorological Research Institute

Summary

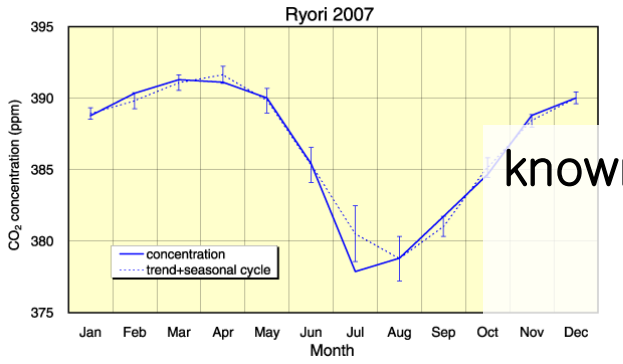
- A sophisticated transport model is needed for an accurate inversion.
- Transport model based on AGCM (NICAM-TM) has been developed.
- The model has good performances for radon, SF_6, and CO_2!

Outline

1. Introduction
2. Development of a transport model
3. Evaluation of model transport processes using ^{222}Rn and SF_6
4. Transport and inverse simulations of CO_2
5. Comparison with CONTRAIL

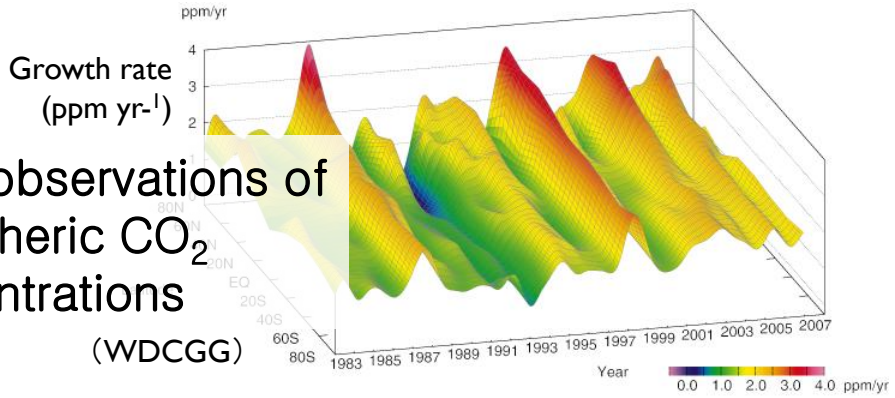
Variations of CO_2

Seasonal variation



(JMA)

Interannual variation



(WDCGG)

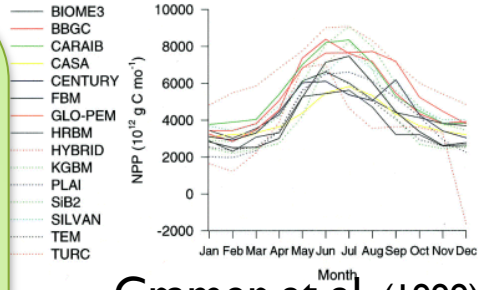
known from observations of atmospheric CO_2 concentrations

We do NOT know well…

Variation of surface CO_2 flux

Biospheric respiration/photosynthesis
El Nino/La Nina
Biomass burning
Volcano
Land use change
Rapid increasing fossil fuel combustion
Ocean circulation

Modeled NEP

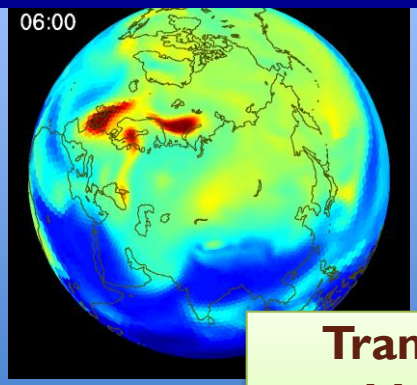


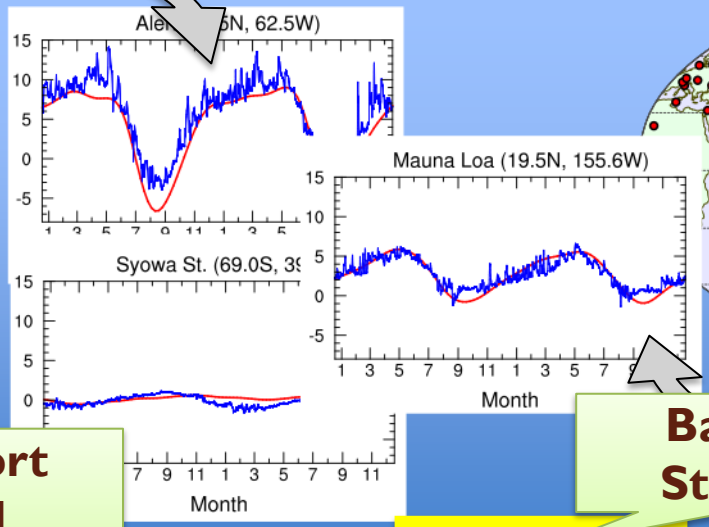
Cramer et al. (1999)

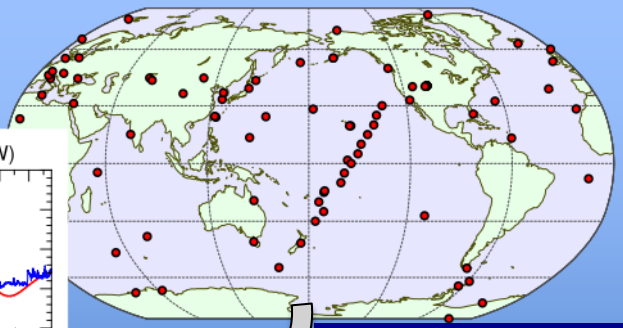
large uncertainties
less observations
much complicated

Synthesis Inversion (Enting, 2002)

Model Simulation







Observation

Transport Model

Bayesian Statistics

Atmosphere

Forward

Inverse

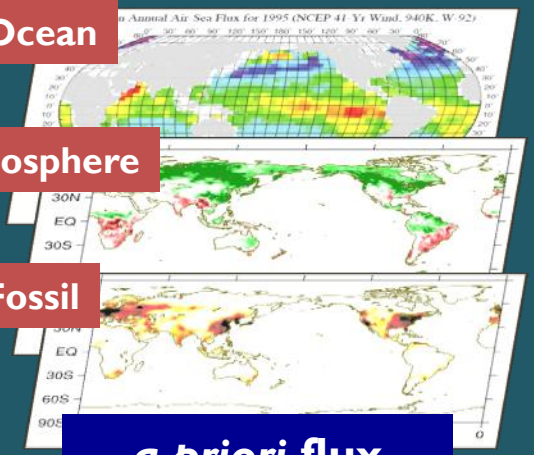
Surface Flux

Factor

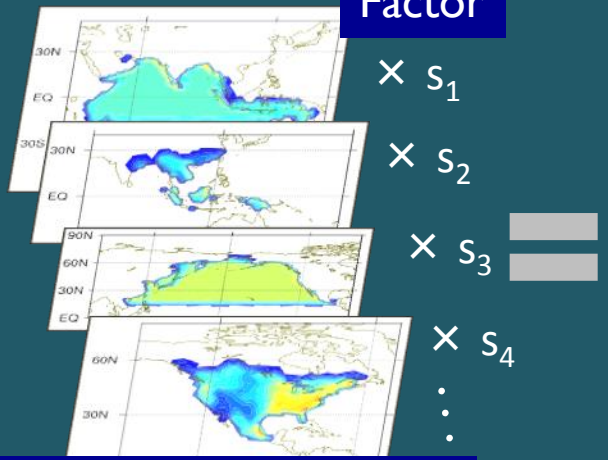
Ocean

Biosphere

Fossil



a priori flux (climatological)



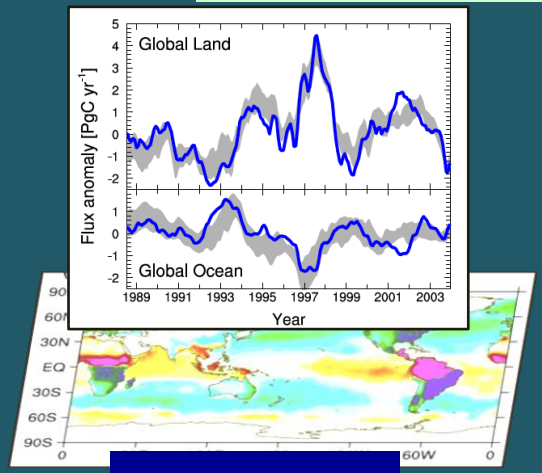
$\times s_1$

$\times s_2$

$\times s_3$

$\times s_4$

regional flux (monthly)



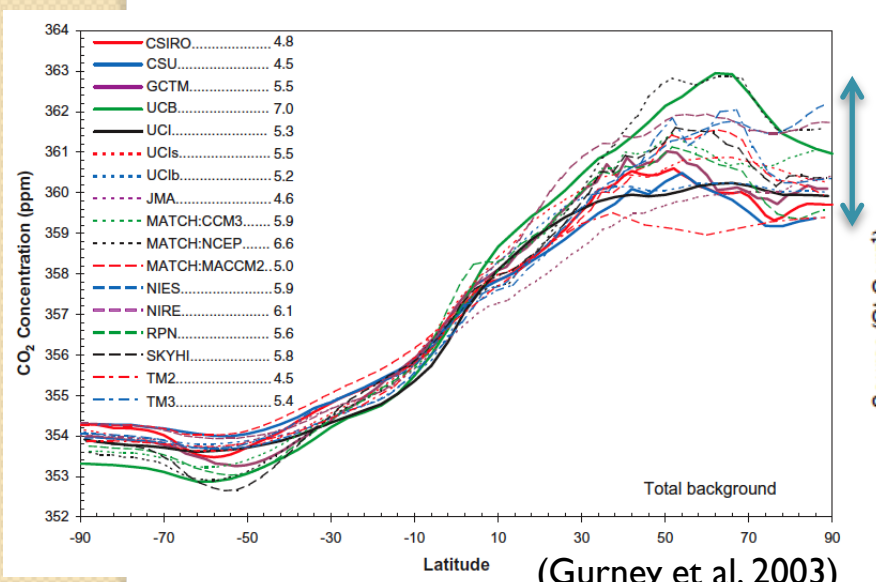
analyzed flux

Uncertainties in Inversion Fluxes

Errors come from

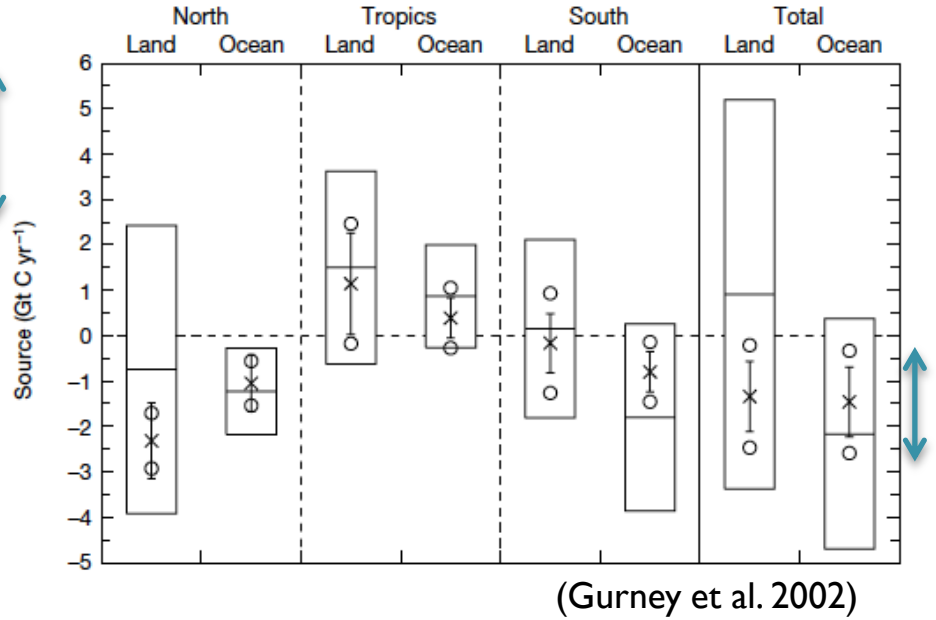
- **Transport Model…**
  - The Atmospheric Tracer Transport Model Intercomparison Project (TransCom)
    - Multi-model experiments for CO_2 transport and inversion

Transport (zonal CO_2 concentrations)



(Gurney et al. 2003)

Inversion (regional fluxes)



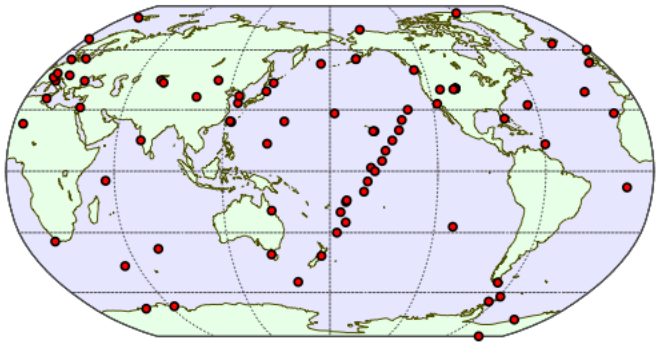
(Gurney et al. 2002)

Model errors have large impacts on estimated fluxes

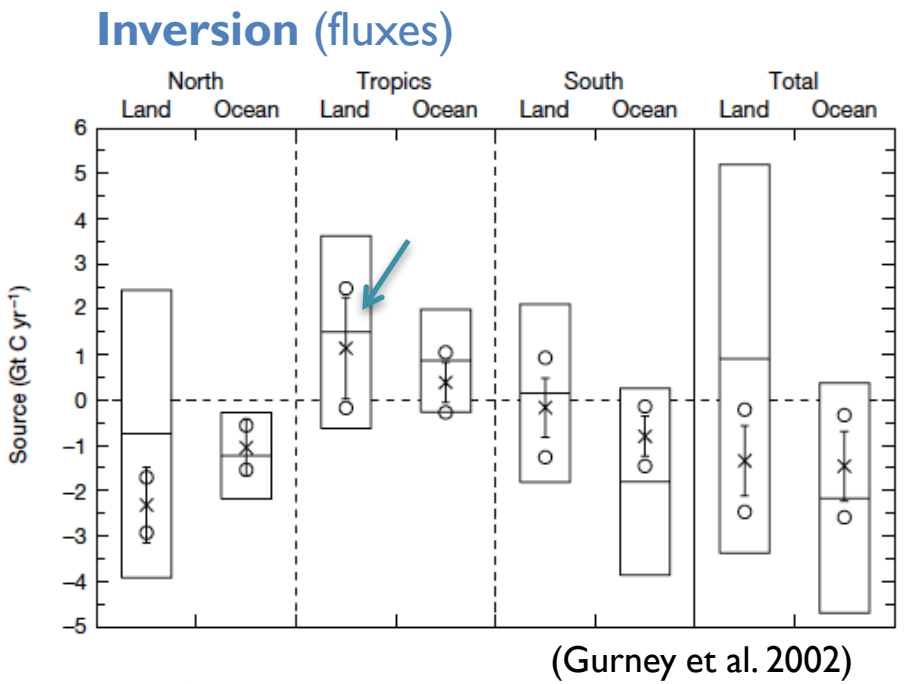
Uncertainties in Inversion Fluxes

…and errors also come from

- **Lack of observation…**



Recently measurement network is rapidly increasing!



(Gurney et al. 2002)

aircraft, satellite and continental site measurements…

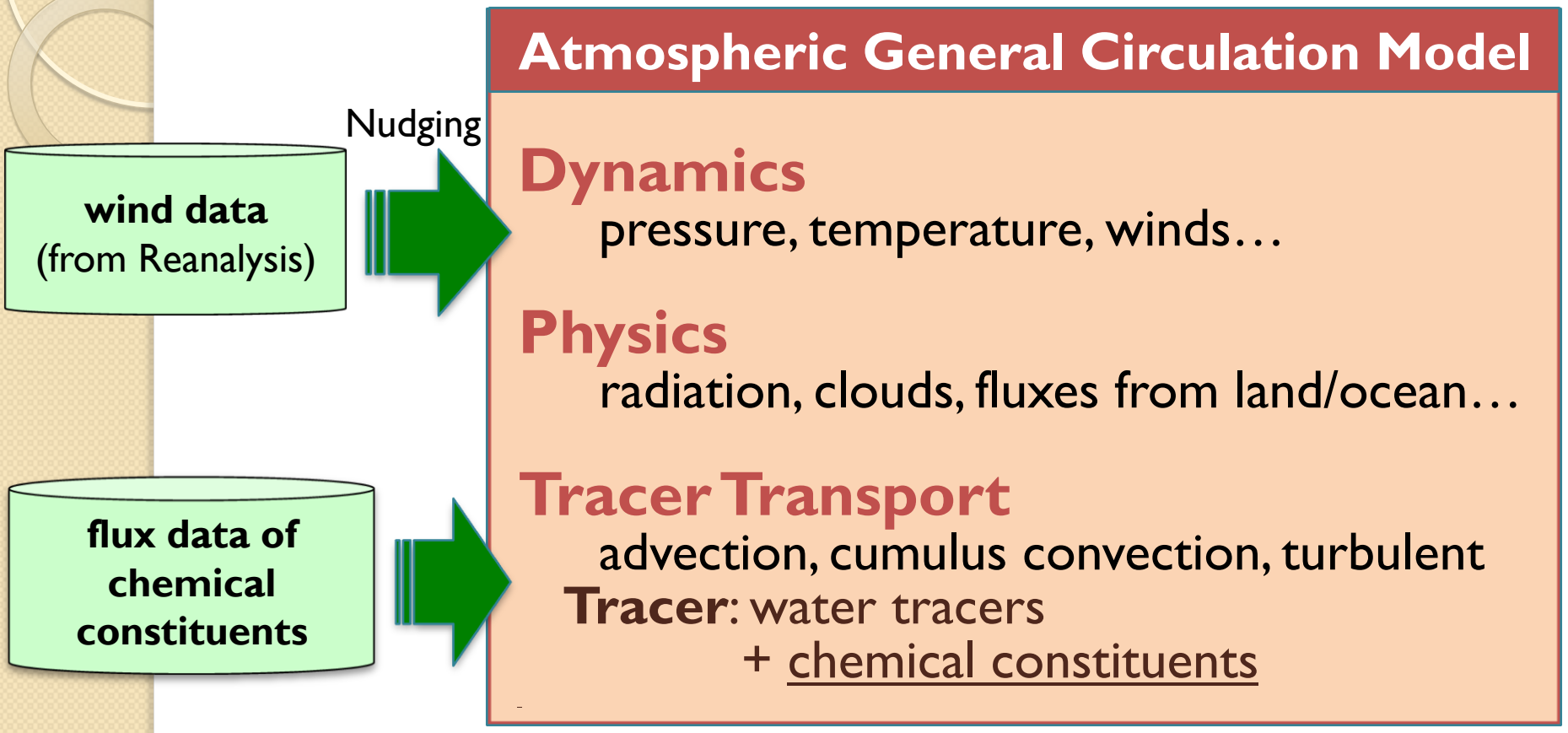
CONTRAIL

GOSAT

High-frequency… monitoring small scale variability

We need a transport model sophisticated enough to treat those observations in inversion!

Three-dimensional Transport Model Based on AGCM

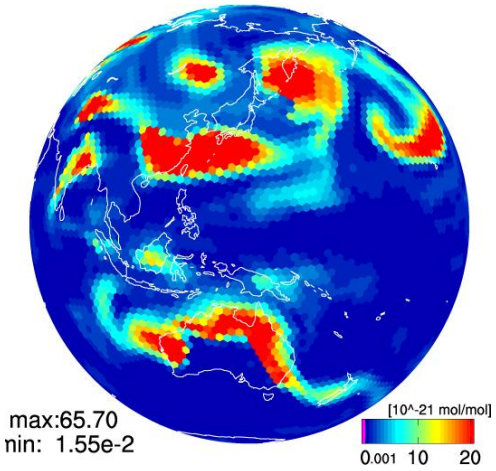


We developed NICAM-based Transport Model (NICAM-TM) in cooperation with the University of Tokyo (UT) and Japan Agency for Marine-earth Sciences and Technology (JAMSTEC).

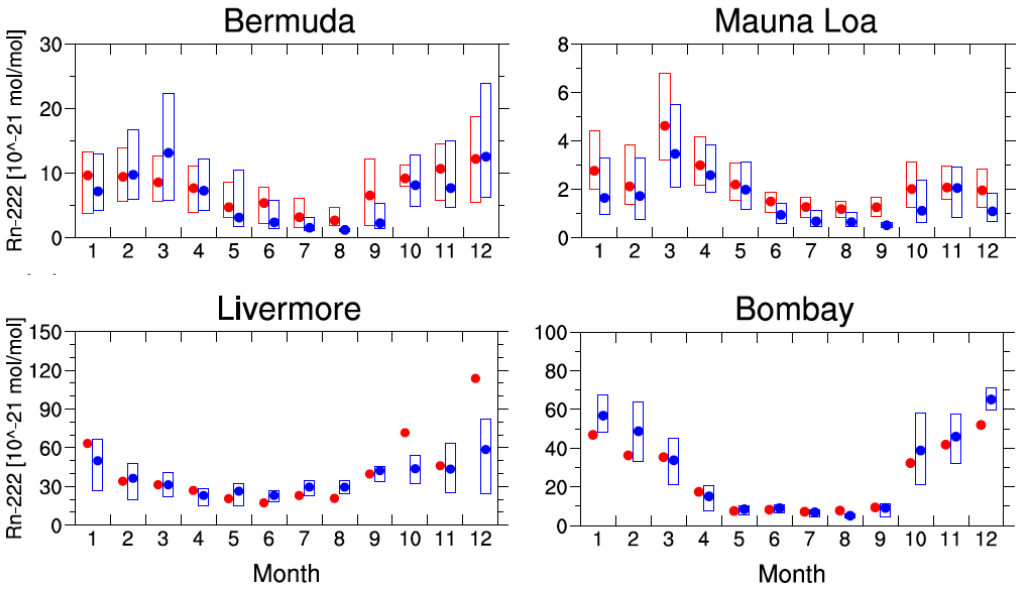
NICAM: Nonhydrostatic ICosahedral Atmosphere Model
(Tomita and Satoh, 2004; Satoh et al. 2008)

Radon-222 Transport Simulation

Evaluation for short-lived tracer transport

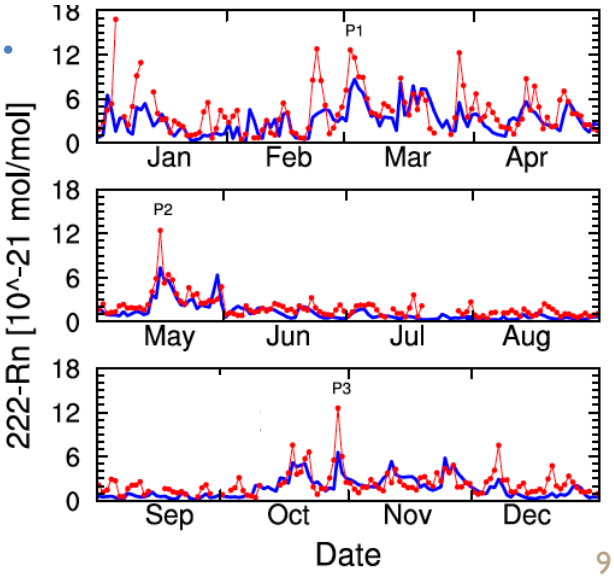


Monthly mean ^{222}Rn conc.



Blue: Model
Red: Obs.

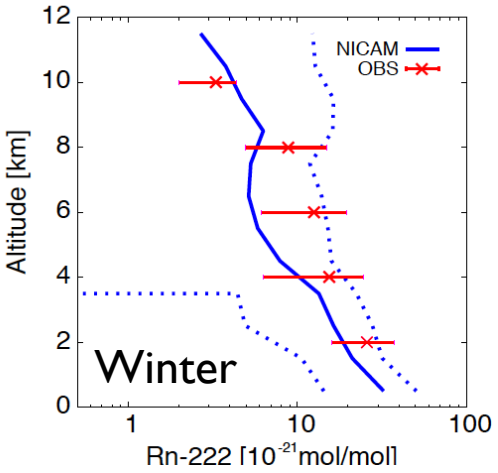
Daily ^{222}Rn conc. @ Mauna Loa

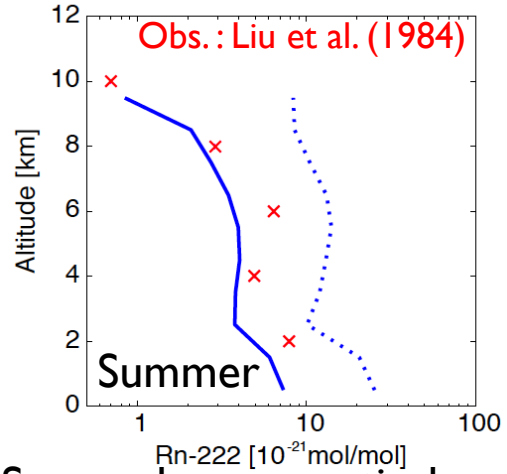


Both seasonal and synoptic variations are well captured by the model!

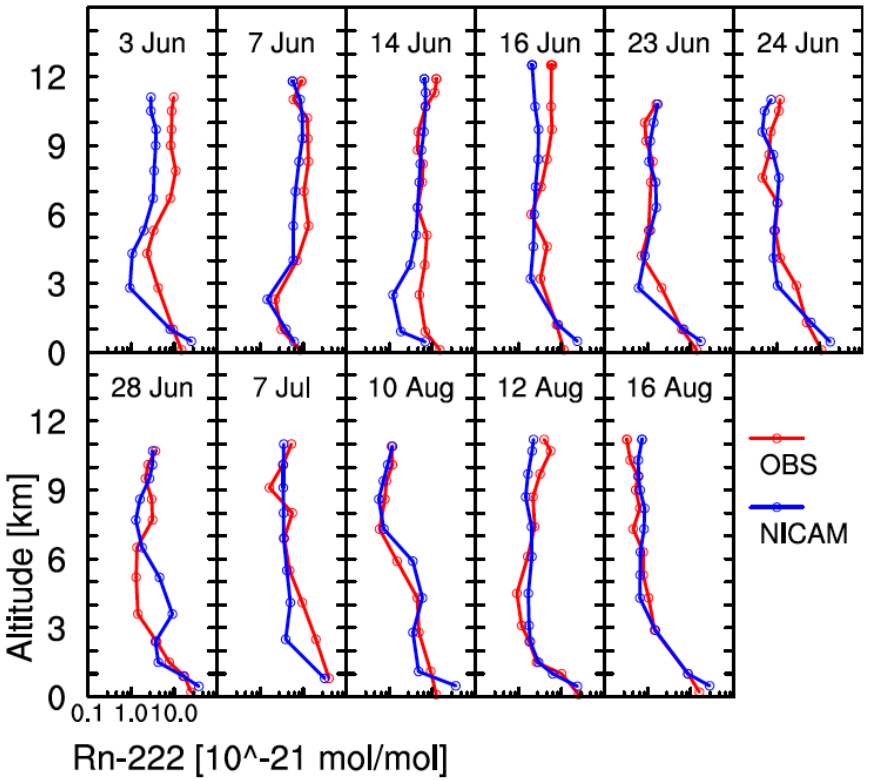
Radon-222 Transport Simulation

Blue: Model Red: Obs.





Seasonal mean vertical profiles over continents



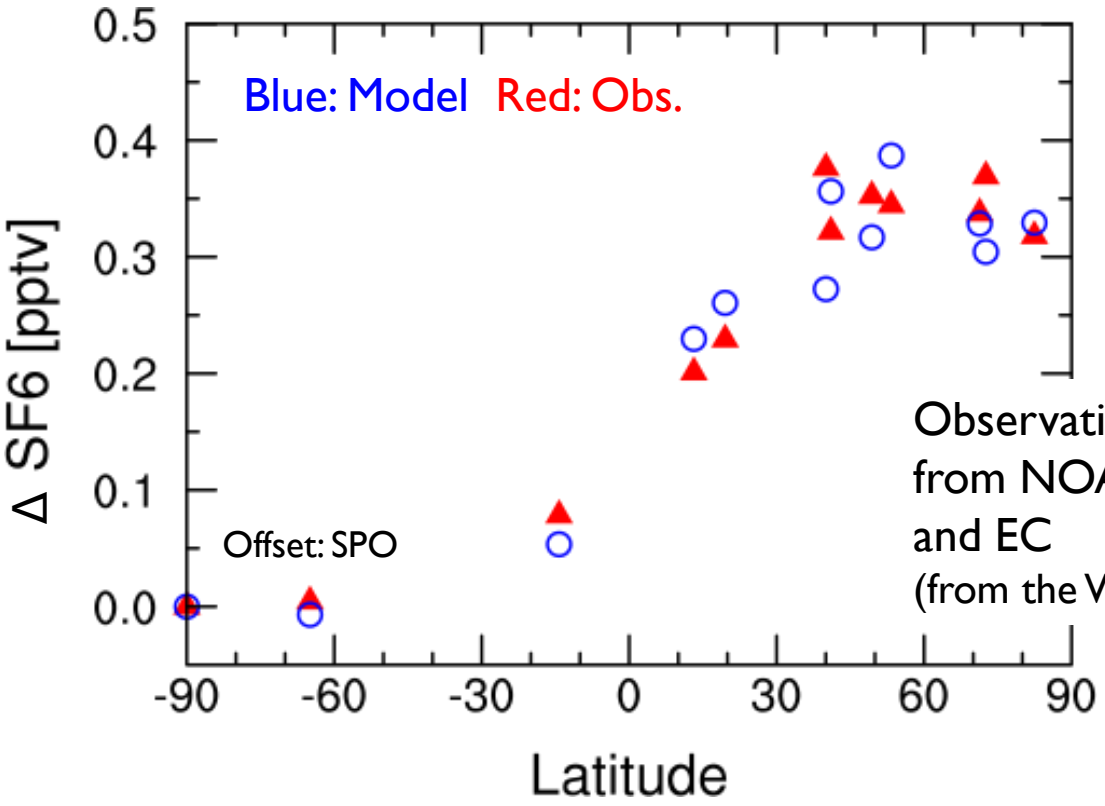
Obs. Kritz et al. (1998)

Vertical profiles over west coast area of North America

Good indication of well-simulated vertical transport!

Consistent Latitudinal Gradient of SF_6

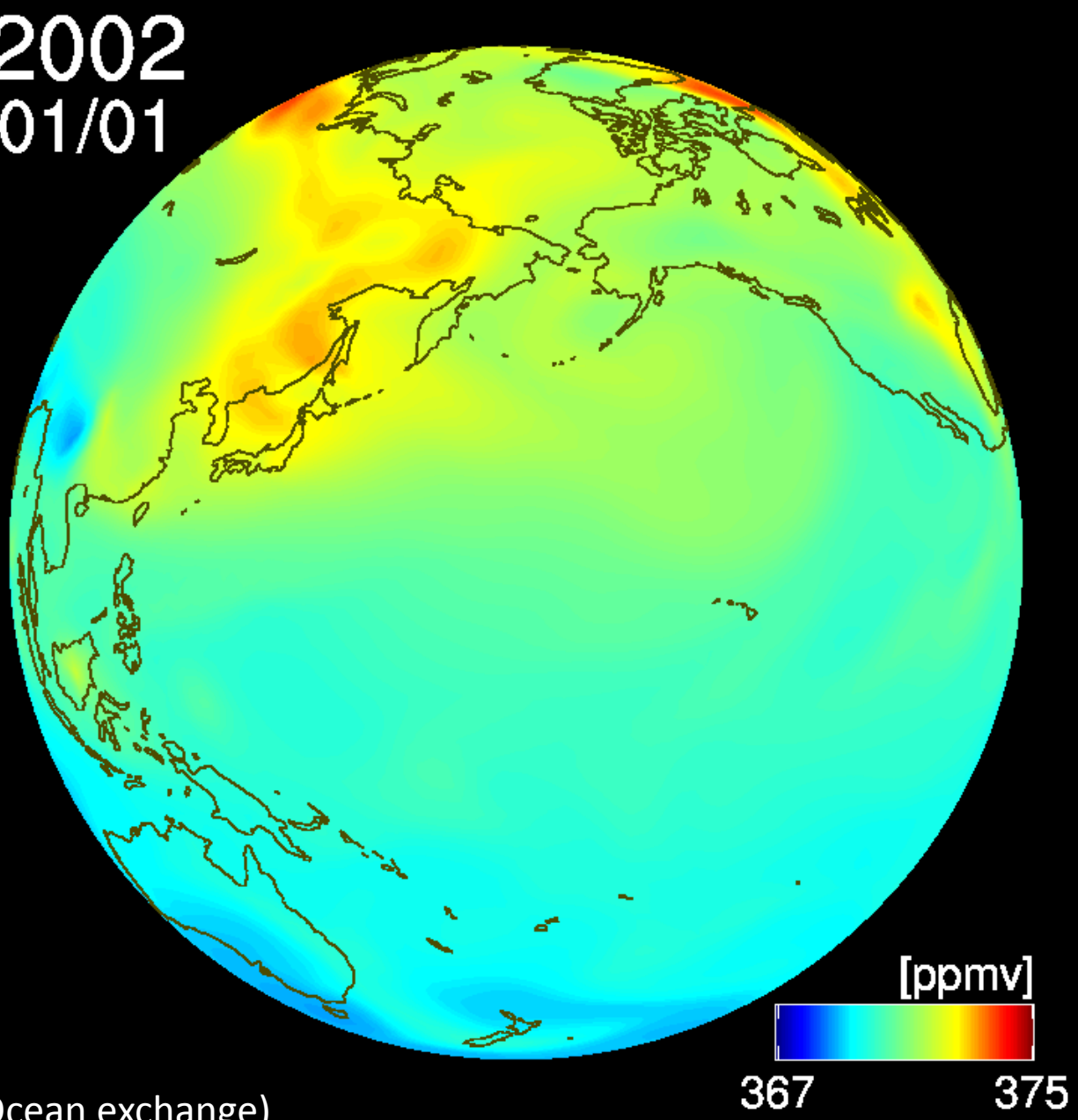
Latitudinal gradient of annual mean SF_6 concentration near the surface



Observations are taken from NOAA/GMD, AGAGE and EC (from the WDCGG web site)

Indicating that inter-hemispheric transport is well simulated by NICAM-TM.
inter-hemispheric exchange time (3D) = 0.69 year

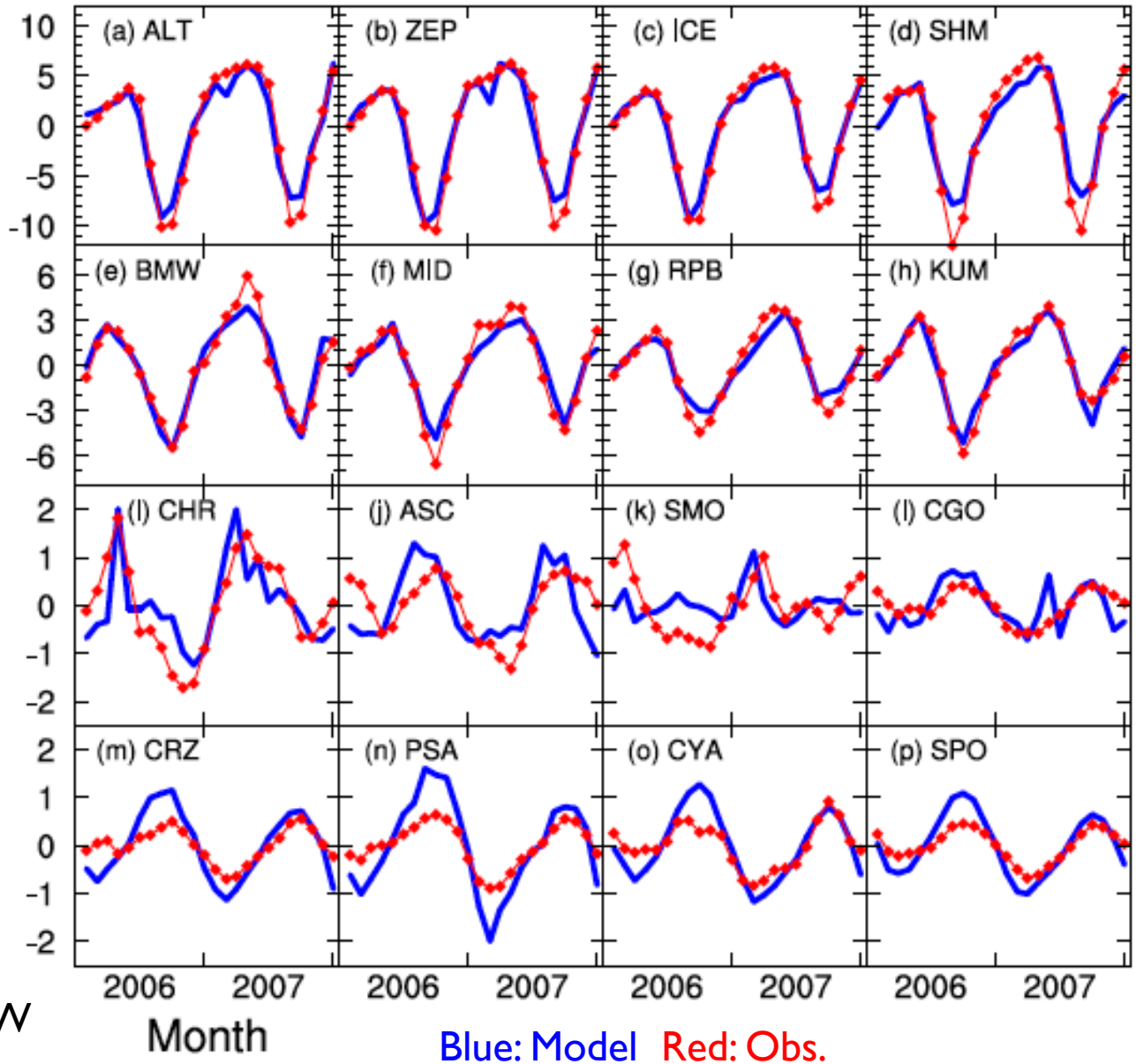
CO_2 Transport Simulation with Prescribed Fluxes



Flux Data:

CDIAC+EDGAR4 (fossil fuel)
CASA NEP (biosphere)
Takahashi Ocean (Atmosphere-Ocean exchange)

Seasonal Variations of CO_2

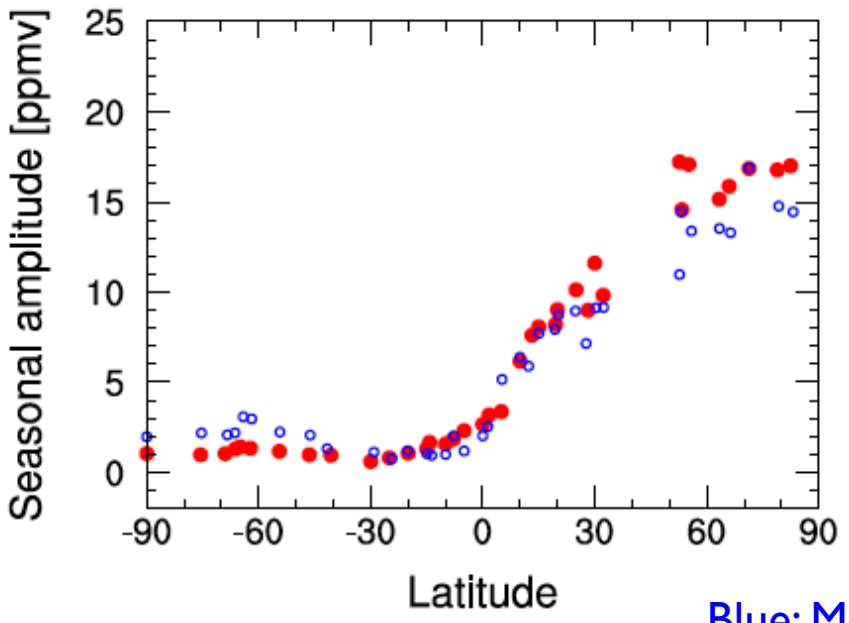


obs. from GLOBALVIEW

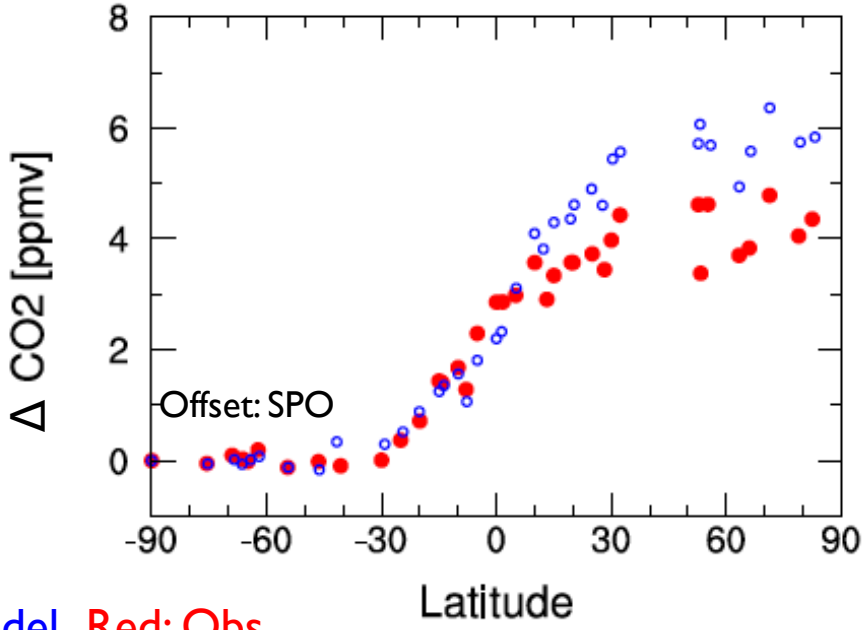
Blue: Model Red: Obs.

Biases in Simulated CO_2

Seasonal Amplitude



Annual mean

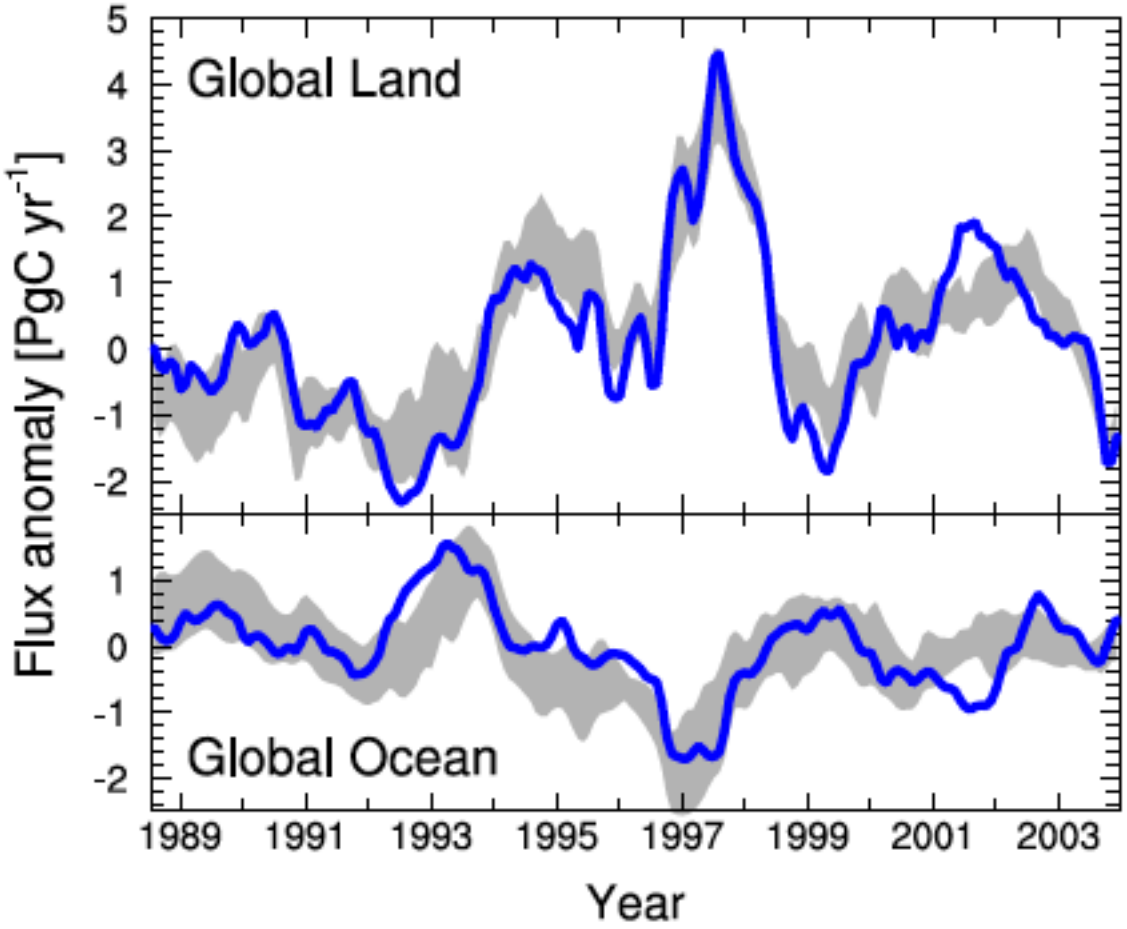


Blue: Model Red: Obs.

We can NOT produce perfect CO_2 concentrations with the prescribed fluxes… The differences from observations are good information of real CO_2 surface at the surface. DO INVERSION!

Inversion Product

Interannual variations of the global fluxes



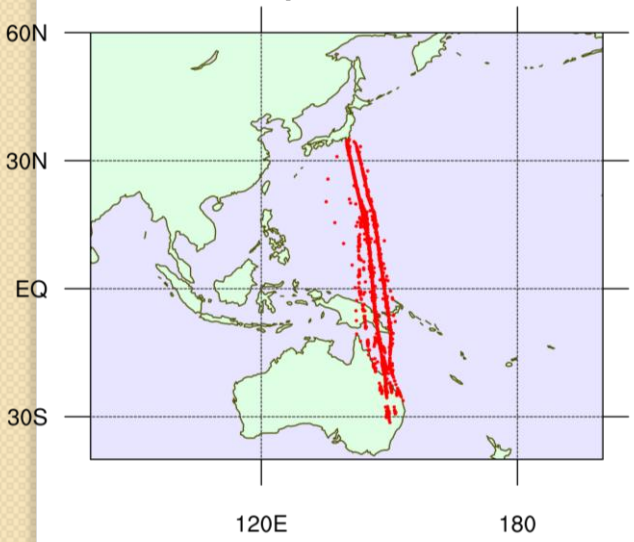
NICAM-TM
TransCom

Well consistent with the previous TransCom study
Showing some hints for mechanisms of carbon out-gassing/uptake
Correlation with ENSO, volcano eruption etc…

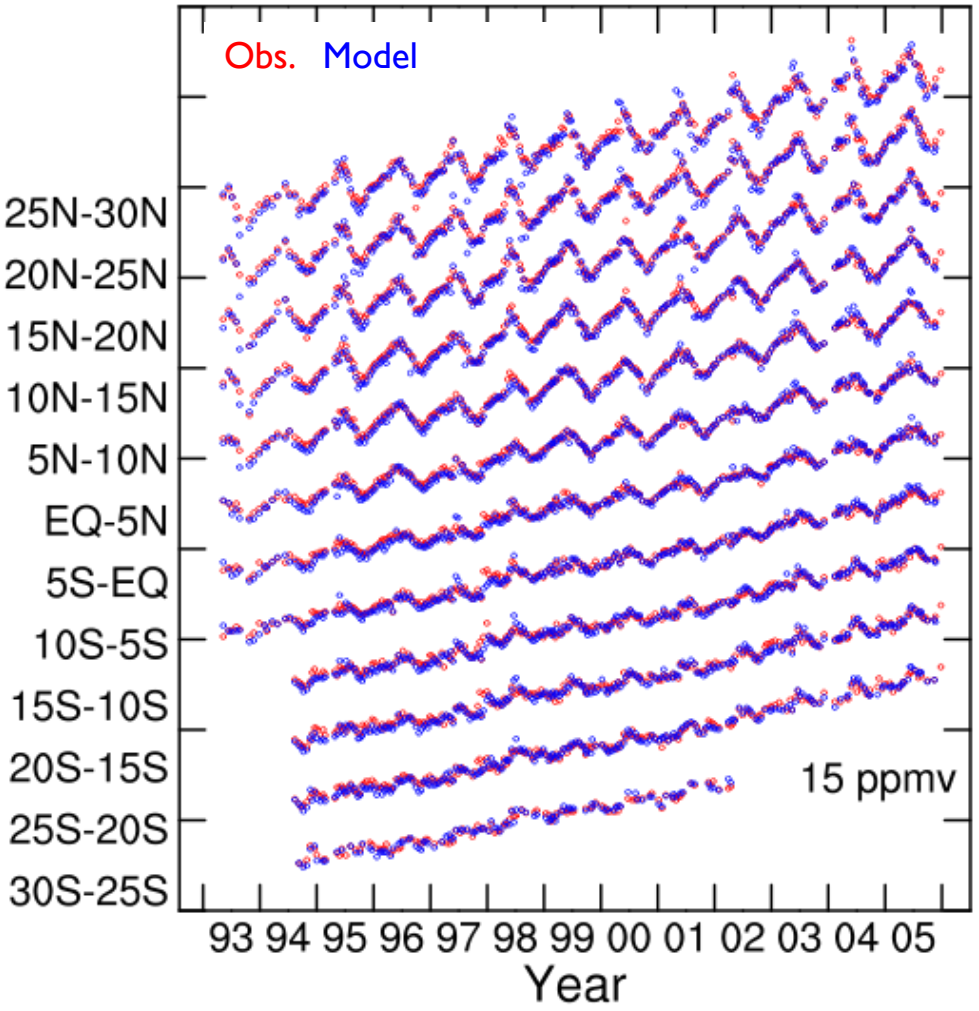
CO_2 Transport Simulation with Inversion Flux

CO_2 over the western Pacific
Comparison JAL aircraft measurements (1993~; Matsueda et al. (2002, 2008))

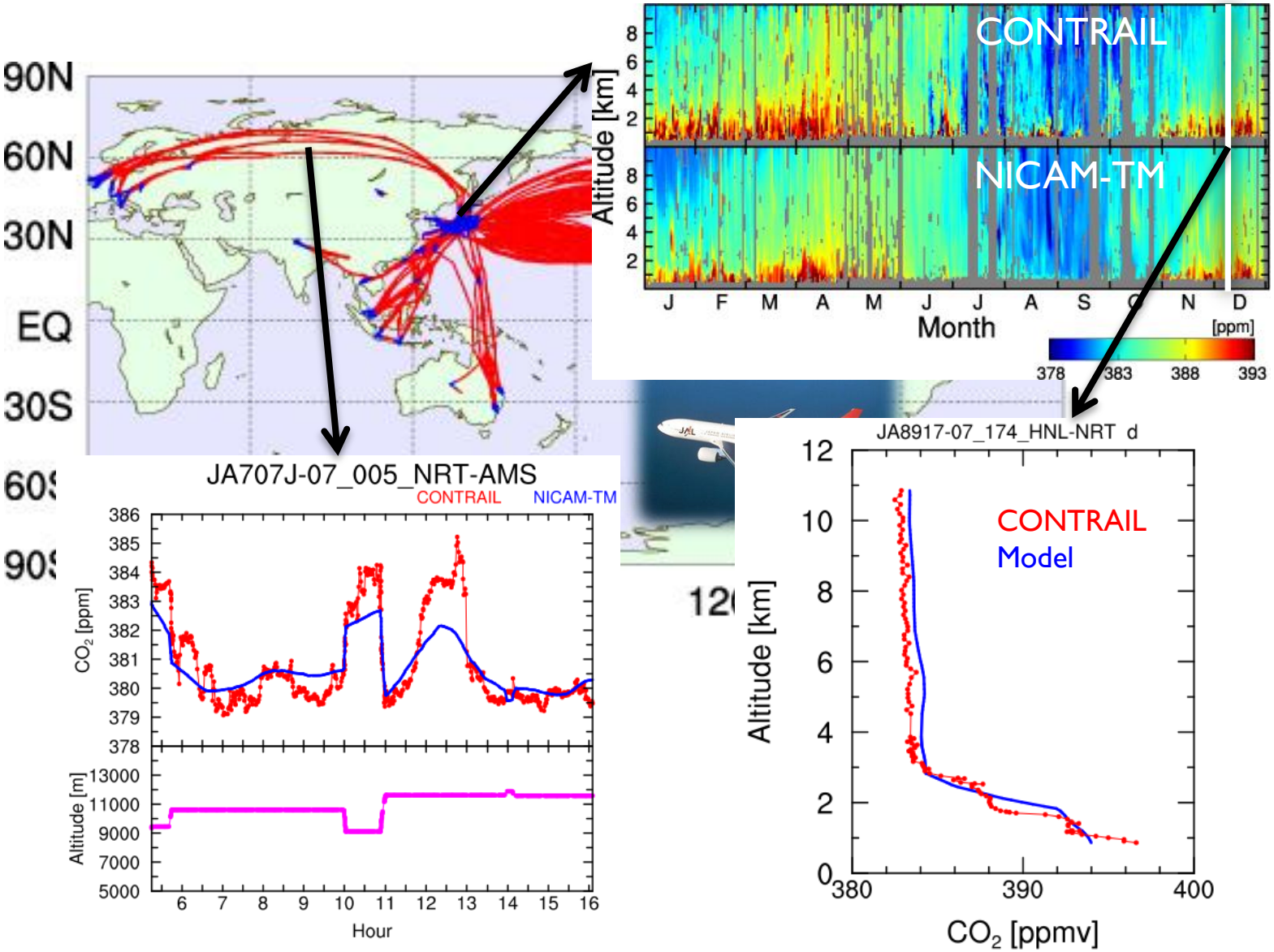
Measurement points （11 km ASL）



Both seasonal and interannual variations are consistent with the measurement data.



Comparison with the CONTRAIL Data



Participation in TransCom

We participated in new TransCom experiments using NICAM-TM

- TransCom continuous data experiment
  - R. Law et al. (2008), P. K. Patra et al. (2008)
- TransCom satelliete data experiment
  - underway
- TransCom inversions
  - underway

Summary

- A sophisticated transport model is needed for an accurate inversion.
- Transport model based on AGCM (NICAM-TM) has been developed.
- The model has good performances for radon, SF_6, and CO_2!

We, modelers, appreciate measurement people for their effort to establish and maintain measurement networks!