



# The CO<sub>2</sub> sink of China as seen from the atmosphere

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and many data providers

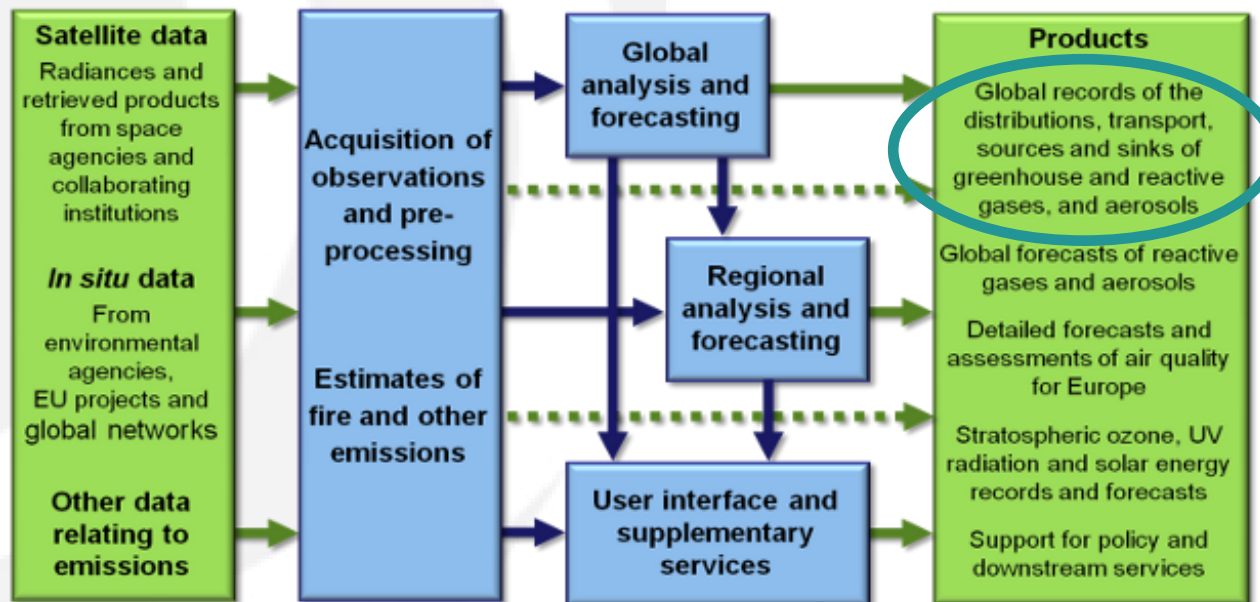


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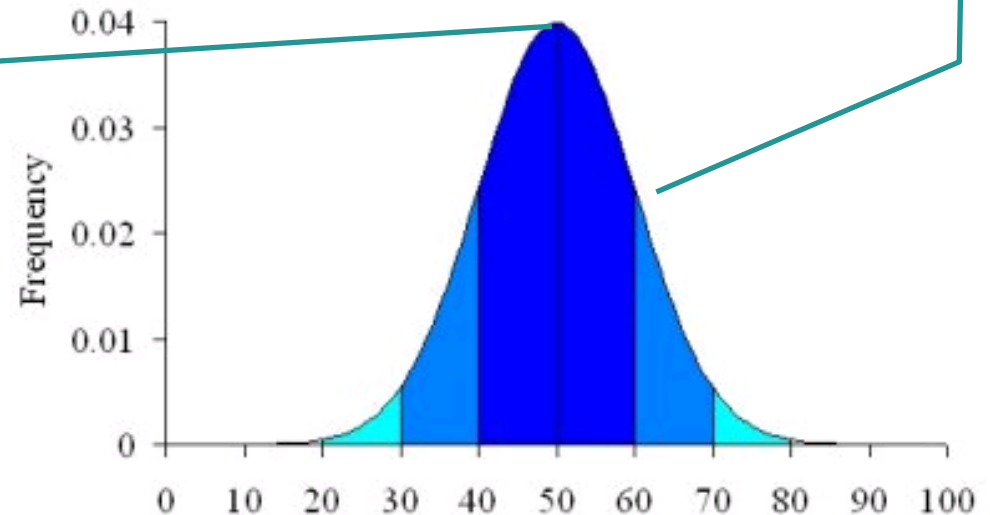
- MACC is the current pre-operational Atmosphere Service of the European Earth observation programme (coord. European Comm.).
  - 36 main contributors, lead by ECMWF
  - <http://copernicus-atmosphere.eu/>
- MACC routinely provides data records on **atmospheric composition** for **recent years**, data for monitoring **present** conditions and forecasts of the distribution of key constituents for a **few days ahead**.



# MACC hybrid approach for CO<sub>2</sub> inversion

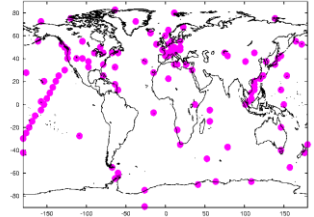
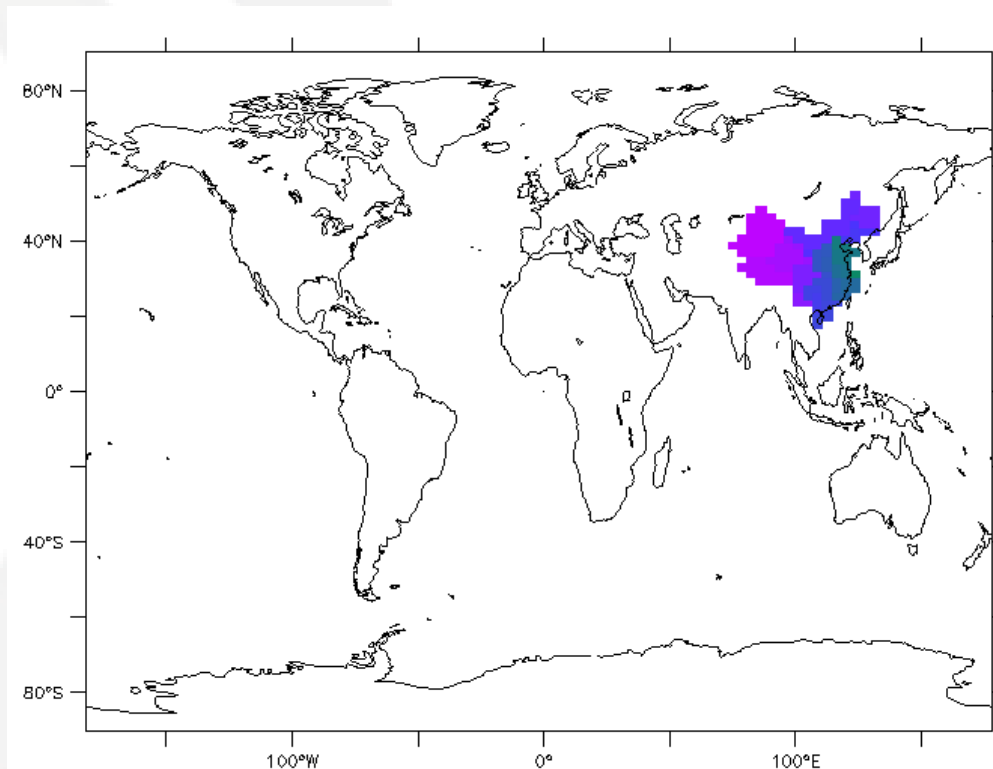
- Developed and operated by LSCE
- Variational approach for “high”-resolution information
  - Weekly day/night grid point fluxes (3.75×1.9 deg<sup>2</sup> global)
  - Heavily parallelized (patent submitted)
- Ensemble approach for coarse resolution information
  - Mean variance of the flux errors over long periods of time
  - Naturally //

$$p(\mathbf{x}|\mathbf{y}) = \frac{p(\mathbf{x}) \cdot p(\mathbf{y}|\mathbf{x})}{p(\mathbf{y})}$$



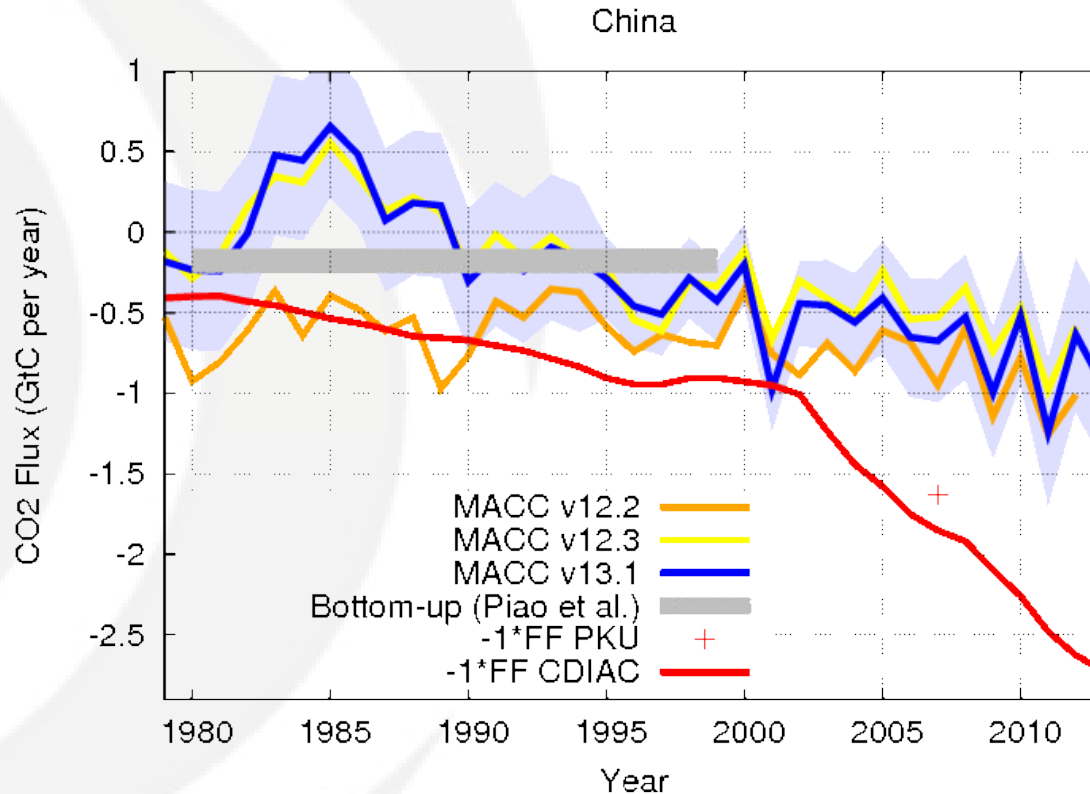
# Inversion over 1979-2013

- [CO<sub>2</sub>] from 136 surface stations.
  - NOAA, WDCGG, RAMCES databases.
- China = 145 grid points of LMDZ 96×96 horizontal grid.



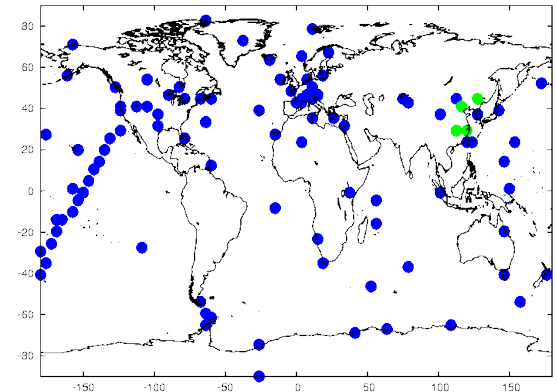
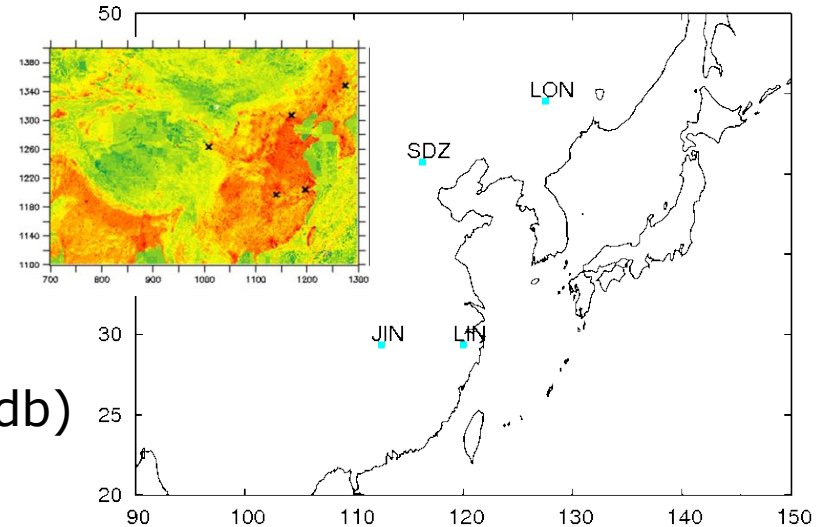
# Inversion over 1979-2013

- **MACC v12.2**: first version with new LMDZ resolution (39×96×96), but still “old” physical package (Tiedtke 1989, Louis 1979, Laval et al. 1981).
- **MACC v12.3**: same with bugfix in MLO data selection.
- **MACC v13.1**: *idem* with extension to 2013 and more iterations.



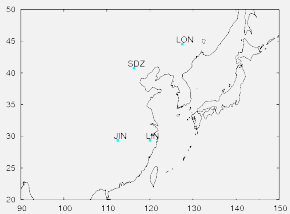
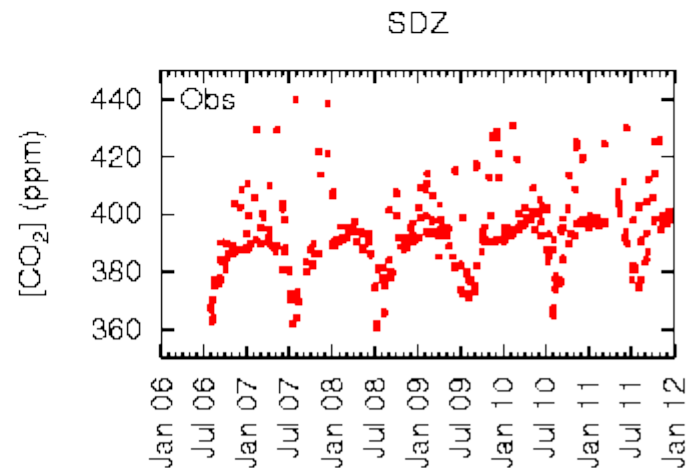
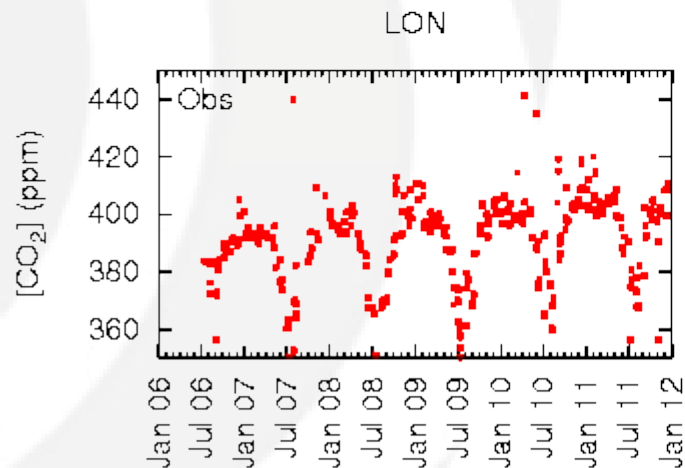
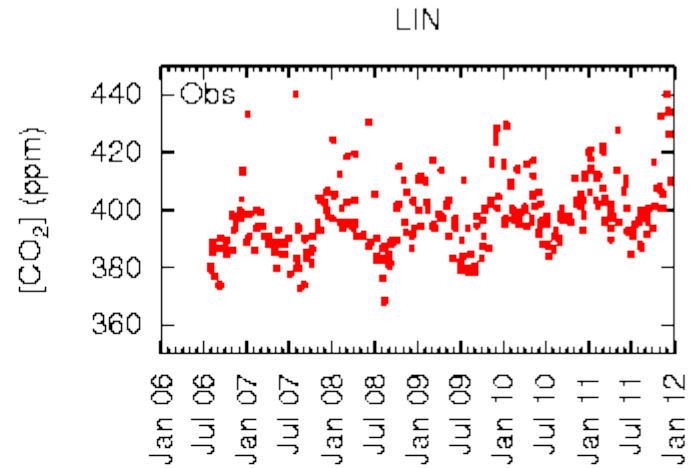
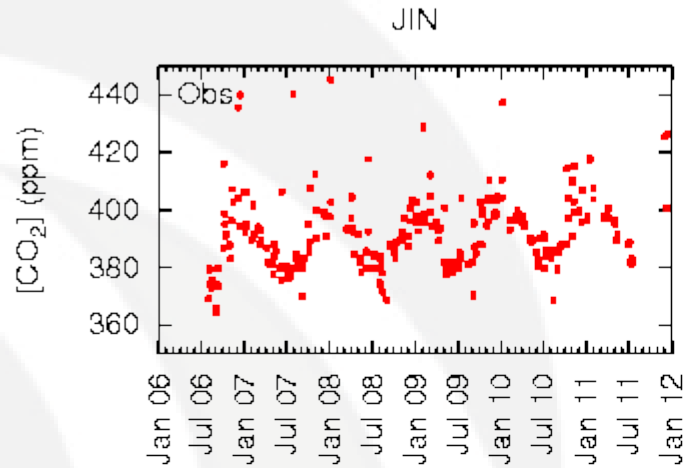
# New sites from CMA

- Longfengshan
  - height = 330.5 masl
- Jinsha
  - height = 750 masl
  - (LMDZ level 5)
- Shangdianzi (also now in NOAA db)
  - height = 293.3 masl
- Linan
  - height = 138.6 masl
- Waliguan (already in NOAA db, 1990-)
  - height = 3816 masl
  - (LMDZ level 5)

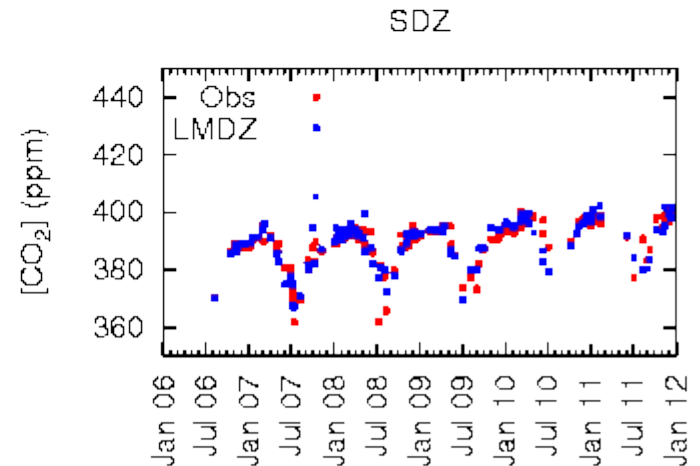
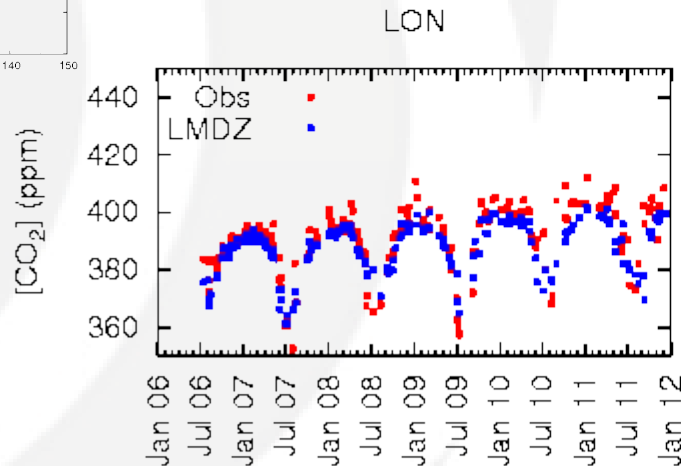
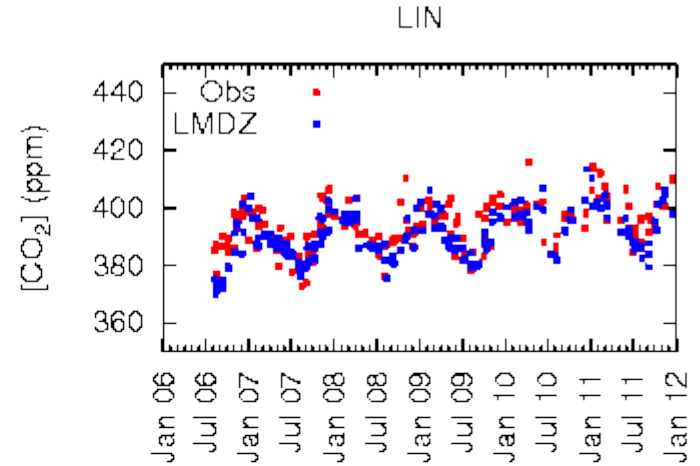
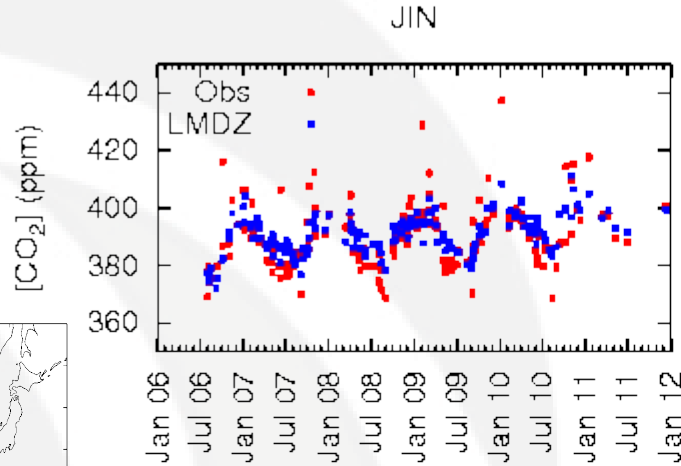
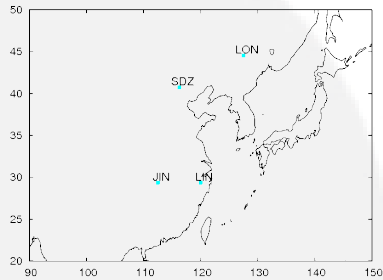


- Data provided for 2006-2011, 2-3pm LT, fossil fuel plumes and other issues flagged out (~1/3).

# Removing the data filter

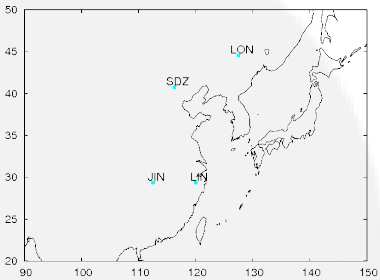
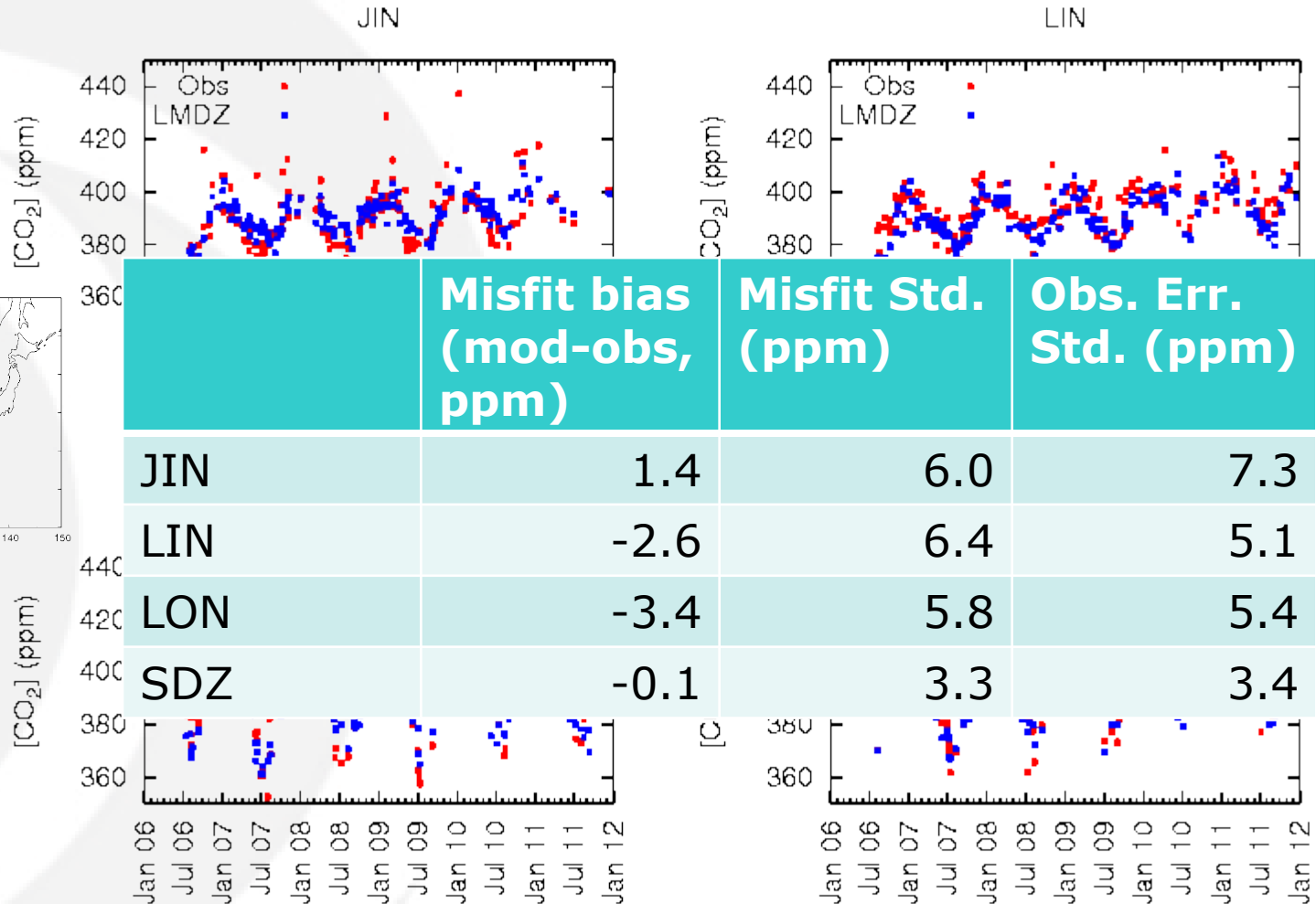


# Posterior misfit to CMA





# Posterior misfit to CMA



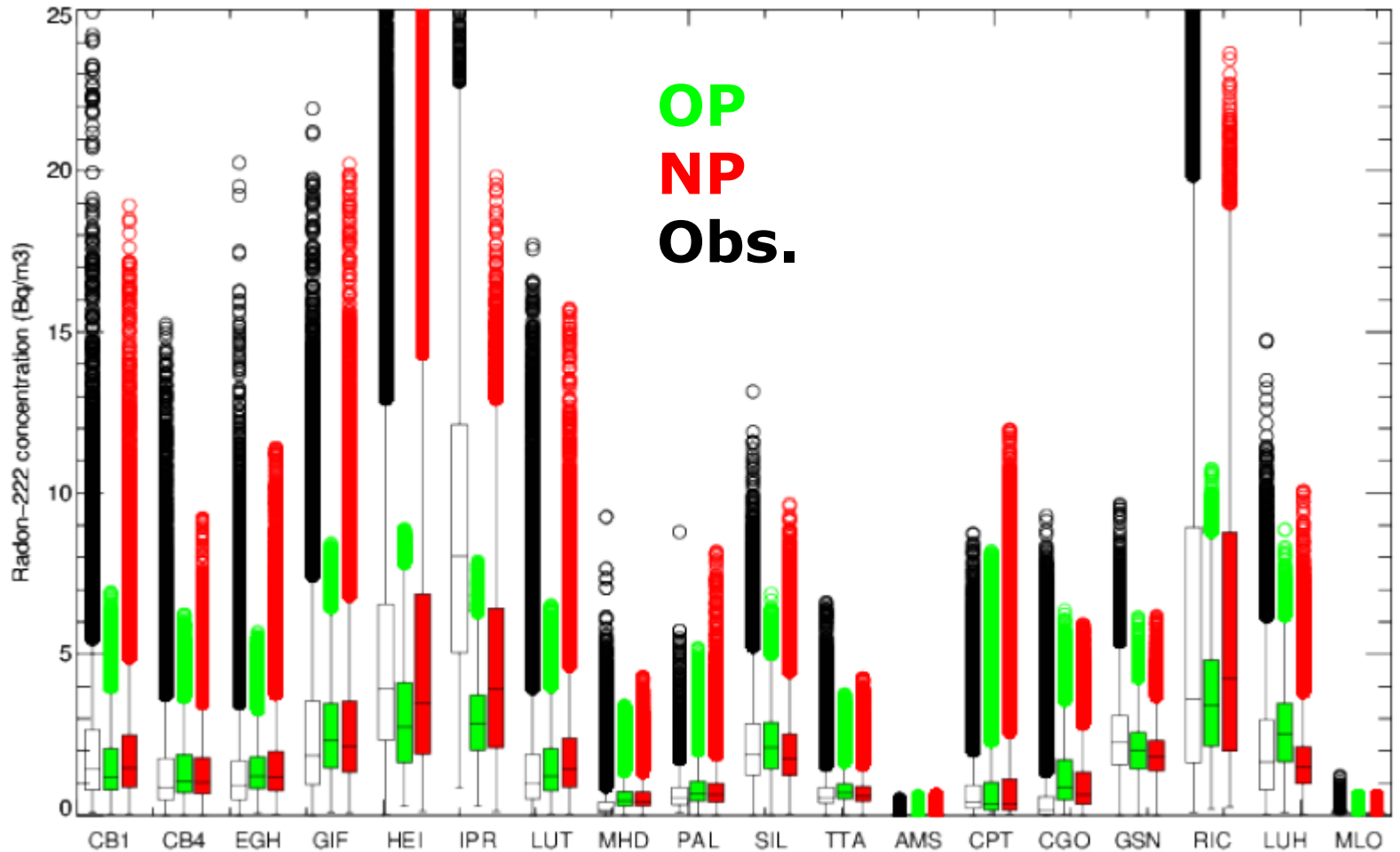
# New LMDZ physical package

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- OP:
  - Deep convection according to Tiedtke (1989).
  - Local closure of Louis (1979) in the surface layer.
  - Vertical diffusion scheme (Laval et al., 1981) in the boundary layer.
- NP:
  - Deep convection according to Emanuel (1991).
  - Thermal plume model of Hourdin et al. (2002, revised by Rio and Hourdin, 2008) combined with the Yamada (1983) diffusion scheme to represent local and non-local transport within the convective boundary layer in a unified way.
  - Much heavier computational burden for tracer transport (mass flux files volume  $\times 10$ , computing time  $\times 2-3$ ).



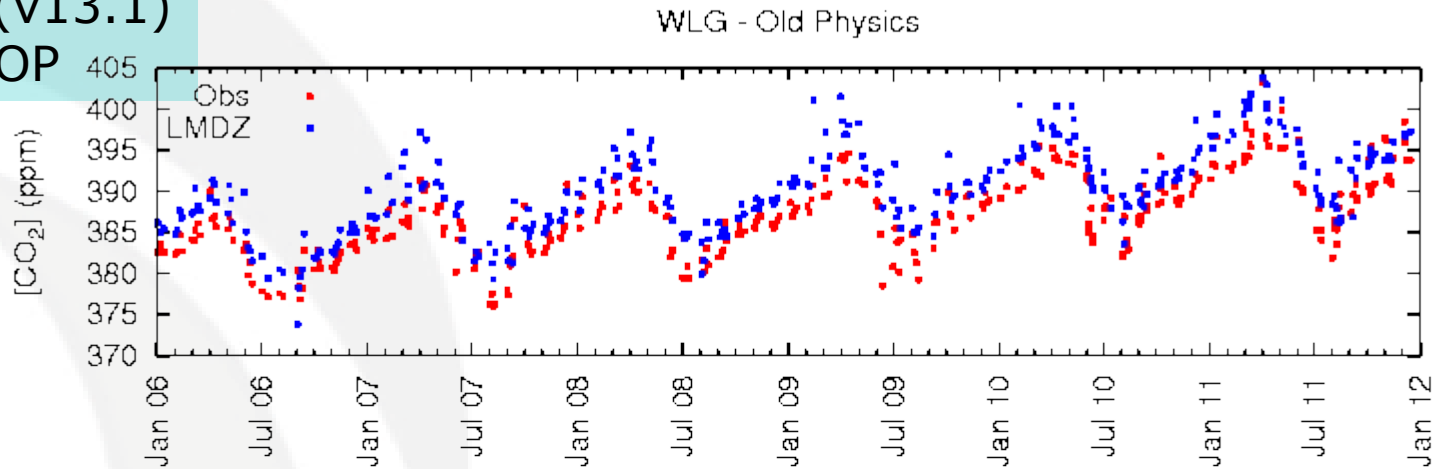
# New LMDZ physical package



# Posterior misfit to WLG

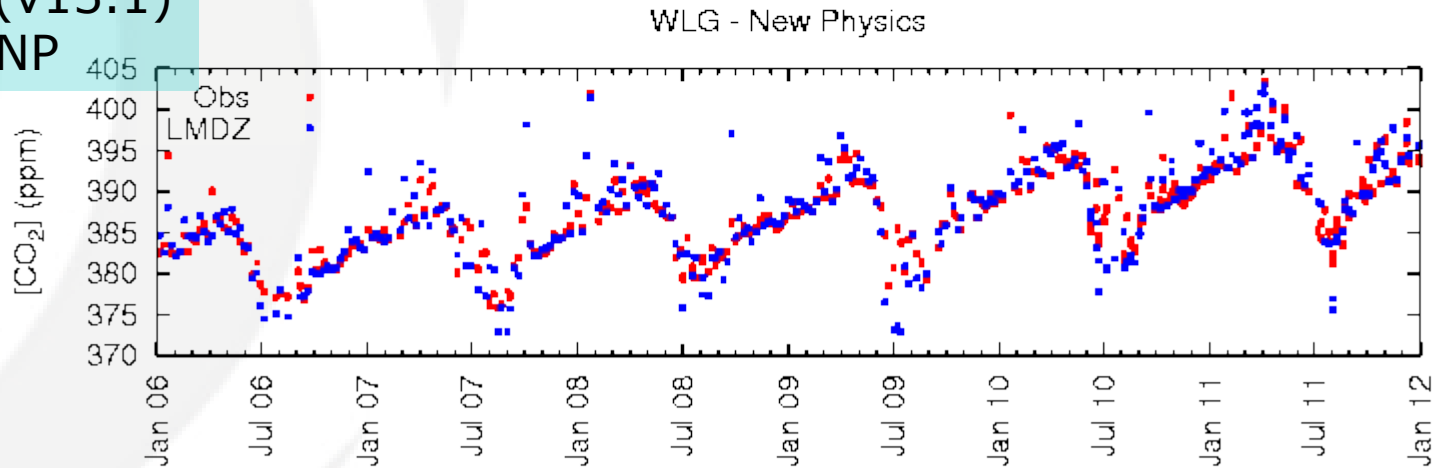
Inversion = OP (v13.1)

Posterior run = OP

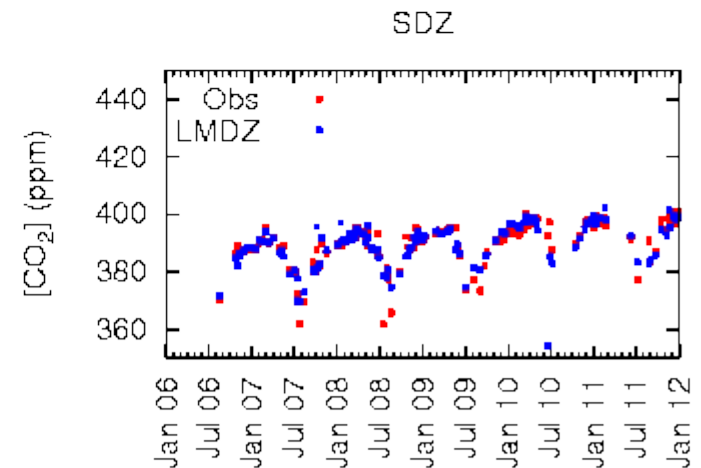
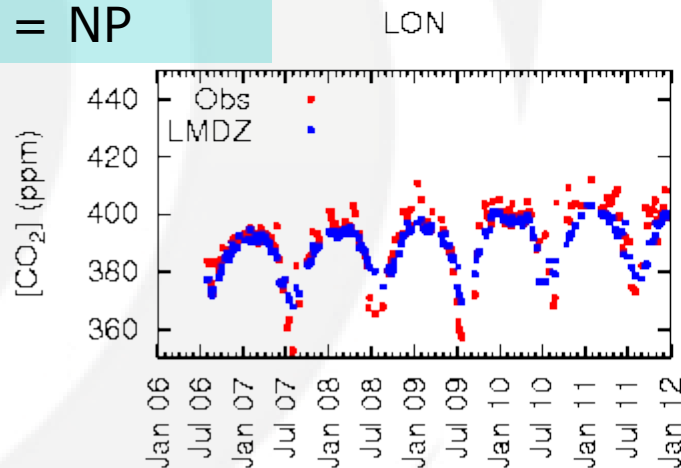
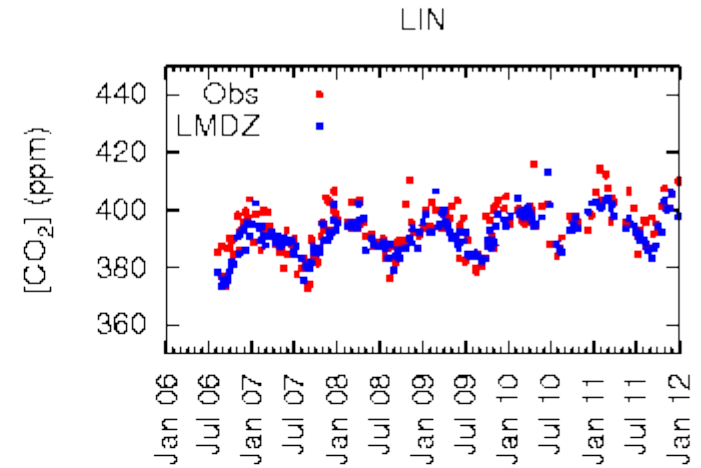
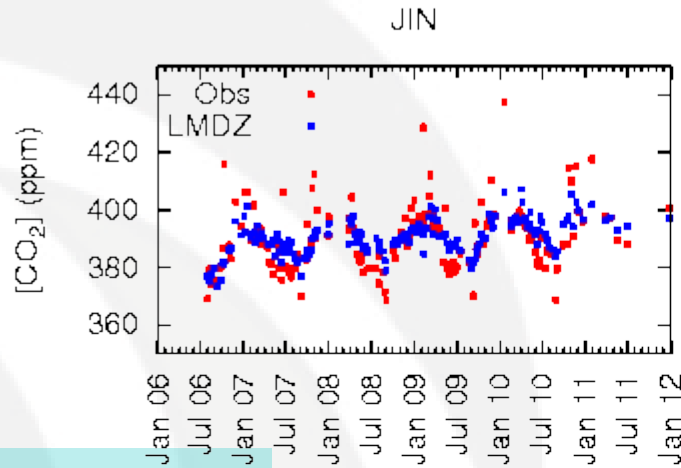


Inversion = OP (v13.1)

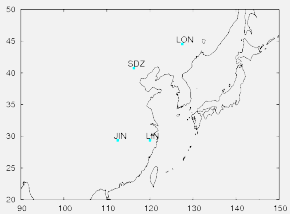
Posterior run = NP



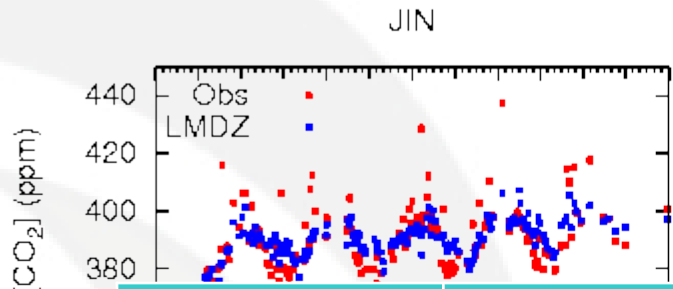
# Posterior misfit to CMA



Inversion = OP (v13.1)  
Posterior run = NP



# Posterior misfit to CMA

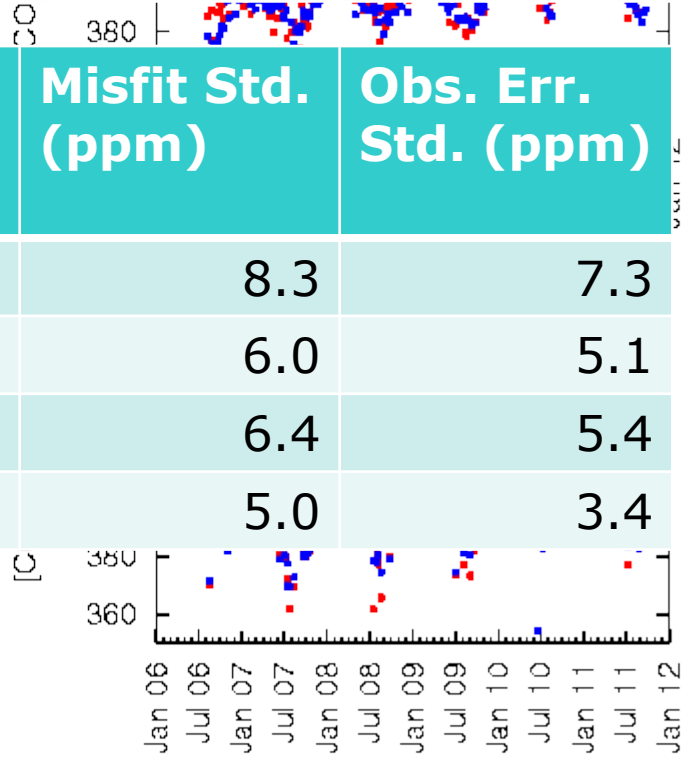
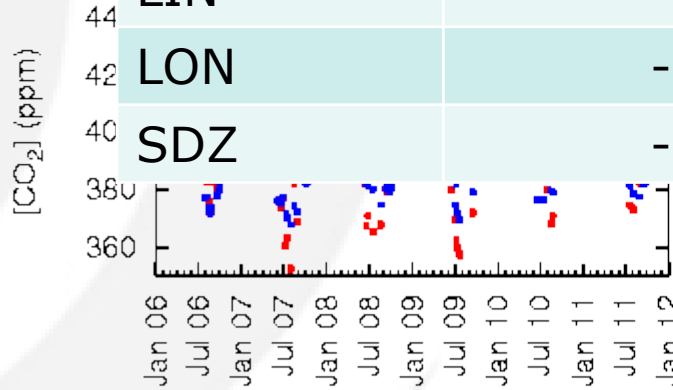
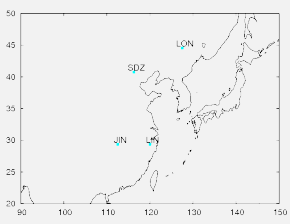


JIN	1.4	6.0	7.3
LIN	-2.6	6.4	5.1
LON	-3.4	5.8	5.4
SDZ	-0.1	3.3	3.4

	Misfit bias (mod-obs, ppm)	Misfit Std. (ppm)	Obs. Err. Std. (ppm)
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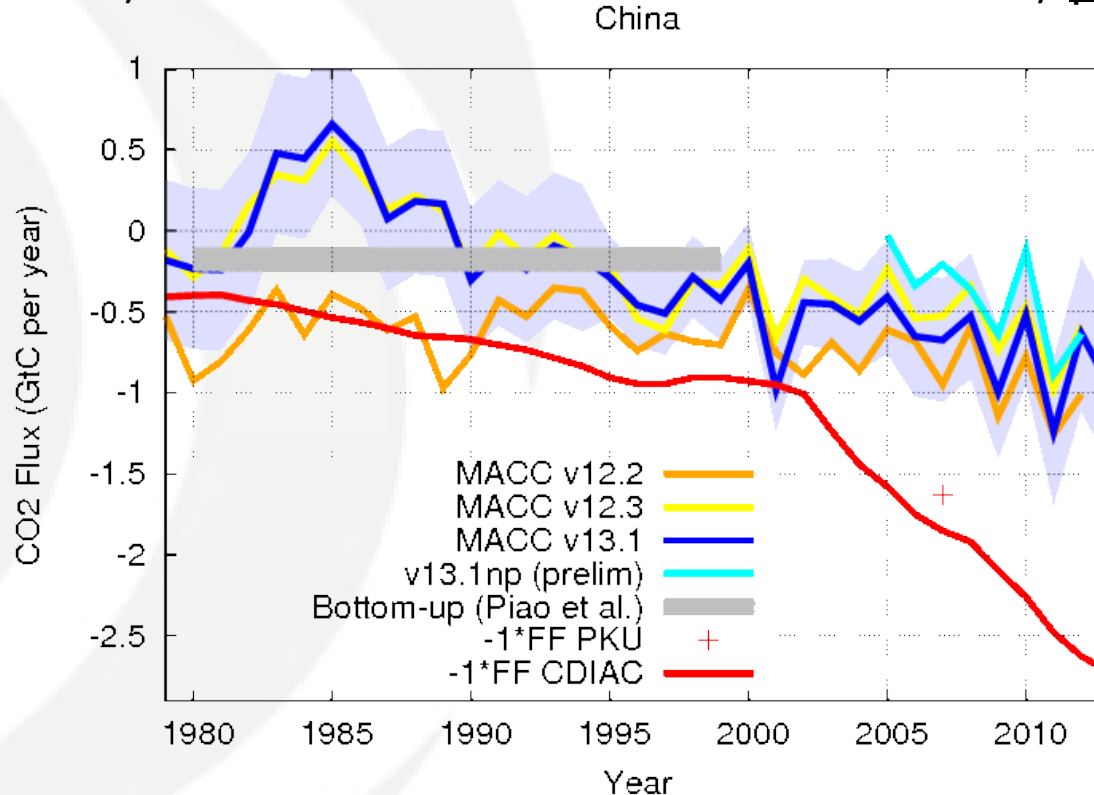
JIN	0.1	8.3	7.3
LIN	-2.2	6.0	5.1
LON	-2.4	6.4	5.4
SDZ	-0.1	5.0	3.4

Inversion = OP (v  
 Posterior run = NF



# Inversion over 1979-2013

- **MACC v12.2**: first version with new LMDZ resolution, still OP.
- **MACC v12.3**: same with bugfix in MLO data selection.
- **MACC v13.1**: same with extension to 2013.
- **13.1np**: same, restricted to 2005-2012 and with NP, preliminary.



# Conclusions

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- MACC inversion suggests a large and increasing carbon sink in China (>1GtC in 2011), ...
- ... or overestimated fossil fuel emissions in standard inventories (local trend following ff growth is suspicious).
- Only the net flux seems reliable. Robust result wrt change in transport model, to the addition of new CMA stations in the inversion, and to a change in the spatial ff emission pattern.
- New CMA stations are well modelled by LMDZ (OP and NP) despite their location close to urban areas.
  - Nearly within the uncertainty assigned in the inversion,
  - But with a slightly too small seasonal cycle.
  - Modest impact expected when assimilating them.
- To be continued.





# Thank you

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LSCE