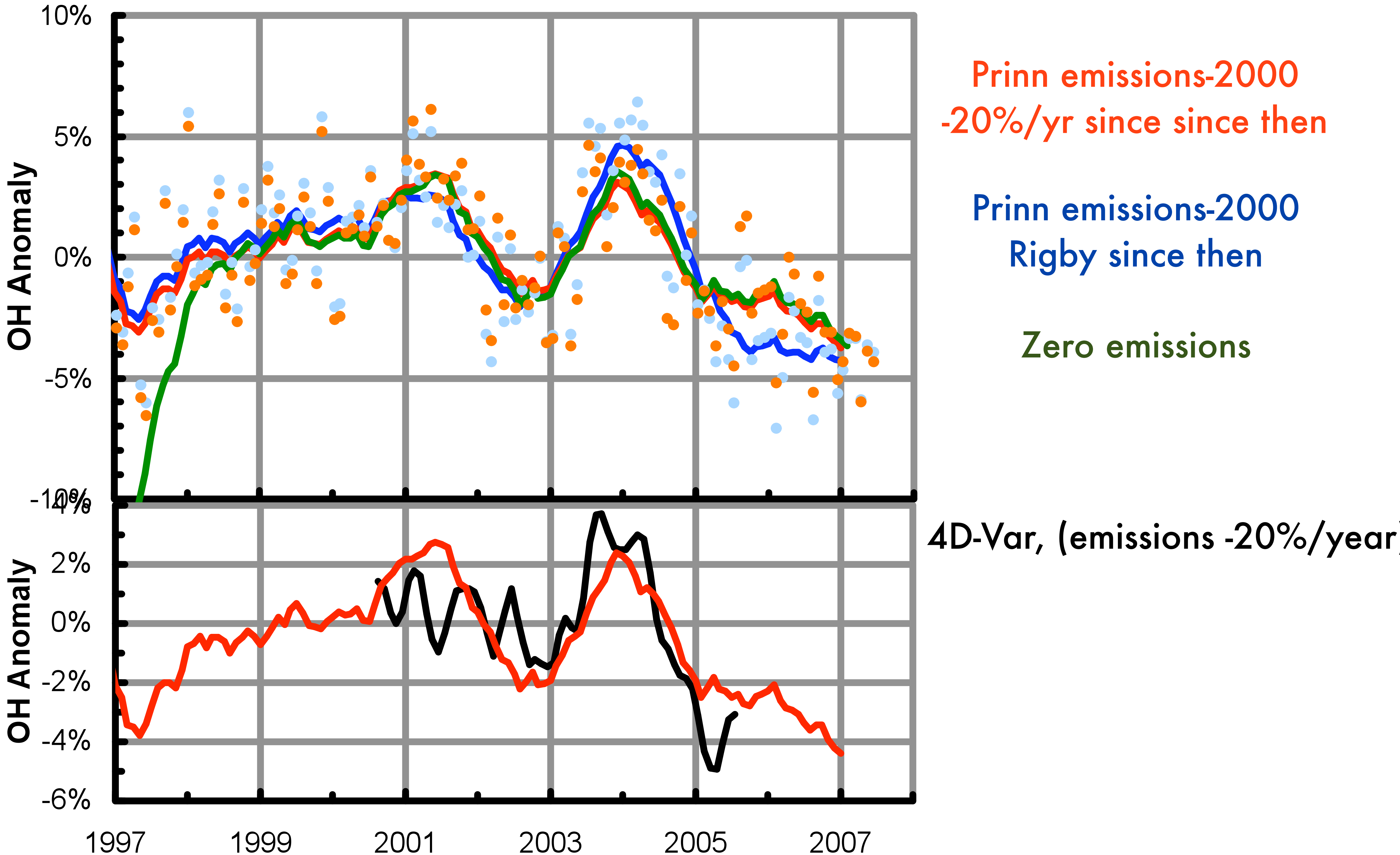
OH derived from MCF

An update: TM meeting dec. 2009, Wageningen

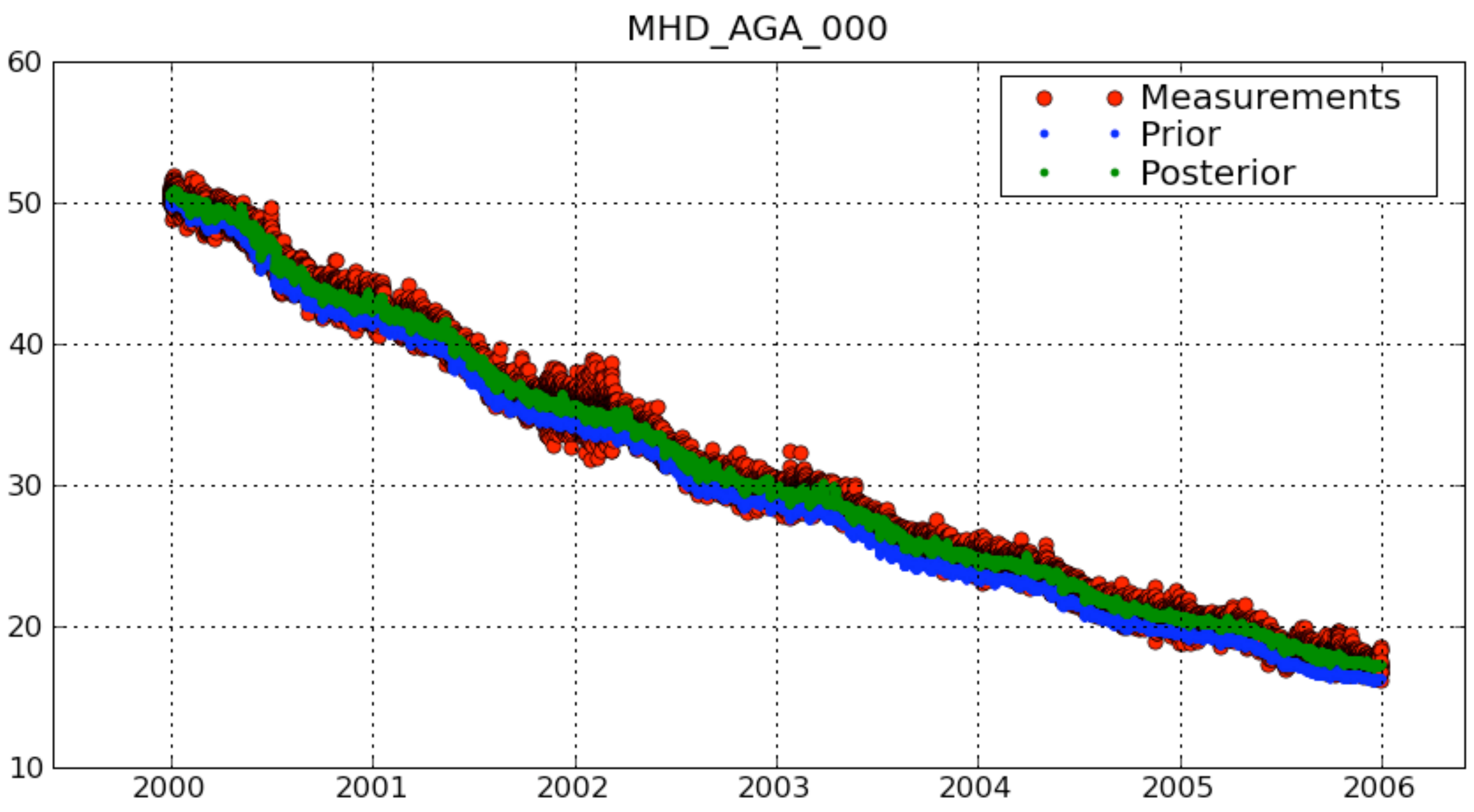
Idea

- Methyl Chloroform (MCF) sources dropped due to Montreal..
- Budget MCF now dominated by OH-depletion
- Good test for OH-fields in global models (since 1998)

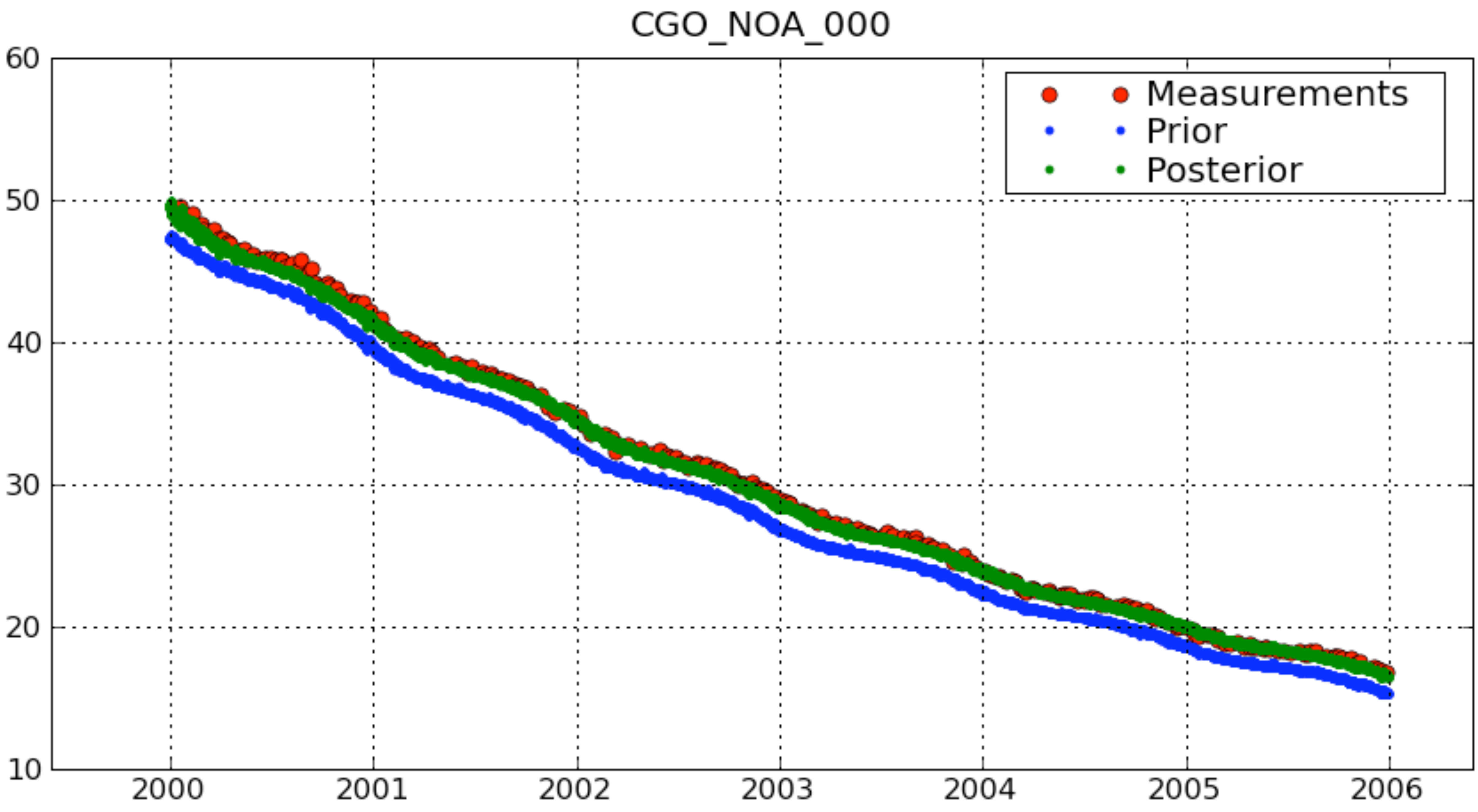


Courtesy: Steve Montzka
(NOAA/ESRL)

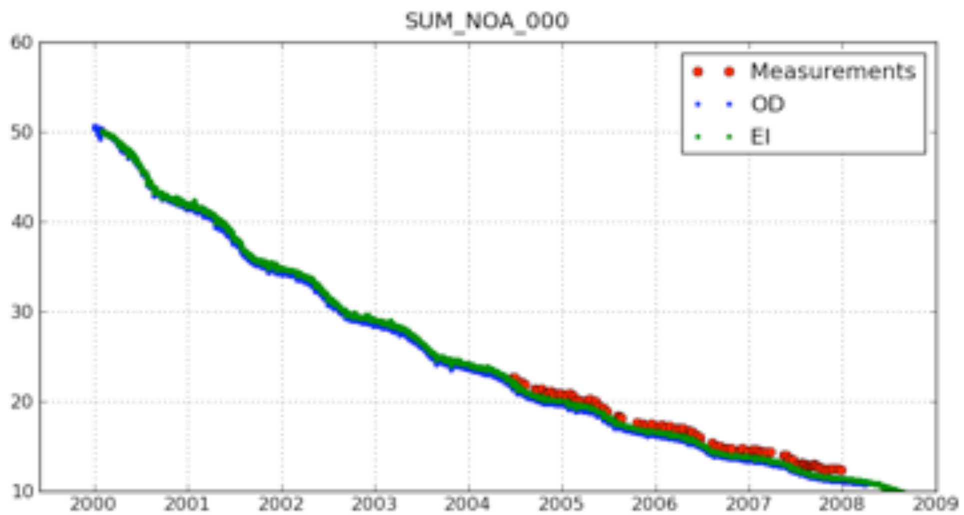
OH optimization

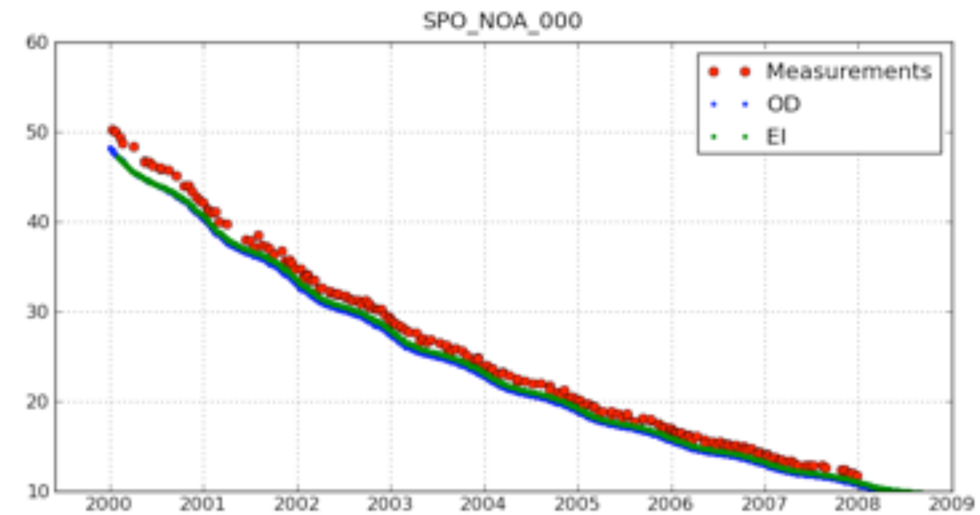


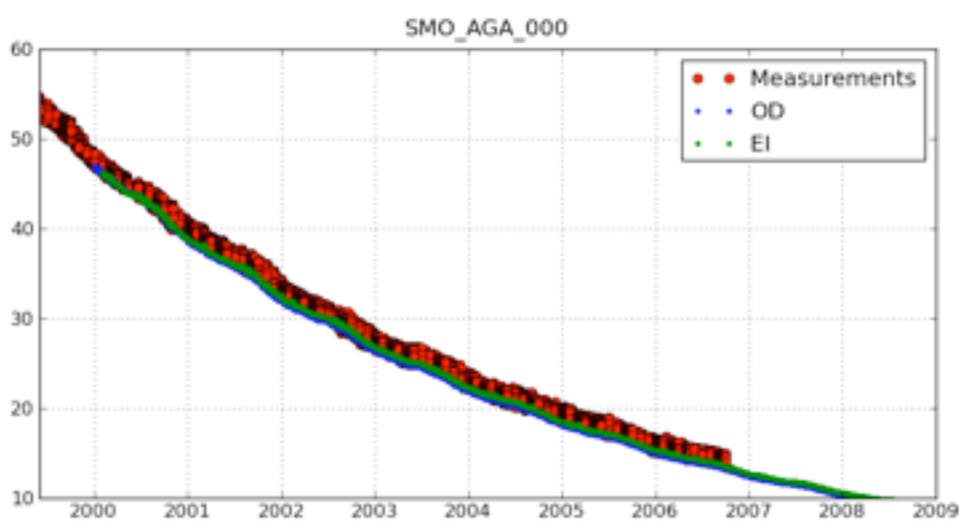
OH optimization

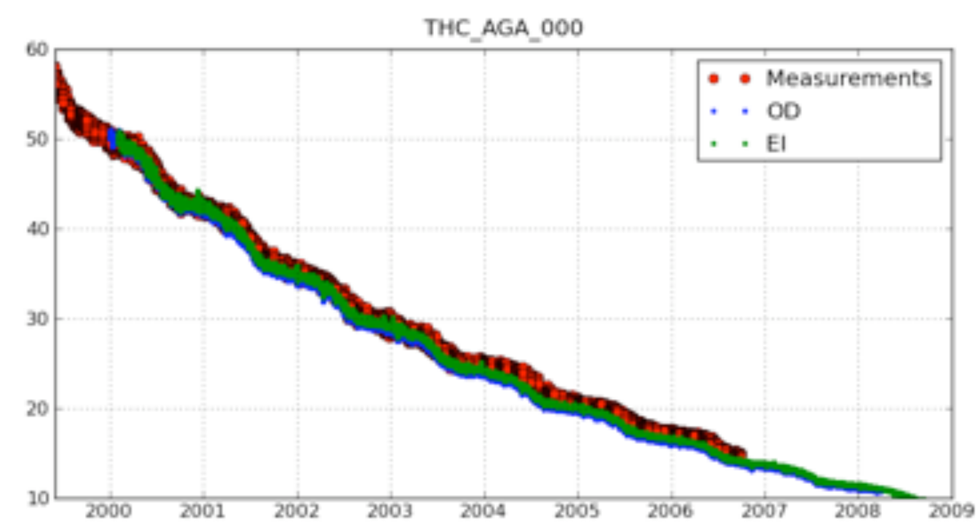


OH-Spivakovsky, scaled by 0.92
OD = operational data, EI = Era Interim









Interim conclusions

- OH pretty stable in 2000-2006
- Year-to-year variations ≈2%
- Settings 4DVAR OH optimization crucial (noisy results)
- Doubts about correct implementation (convergence problems)

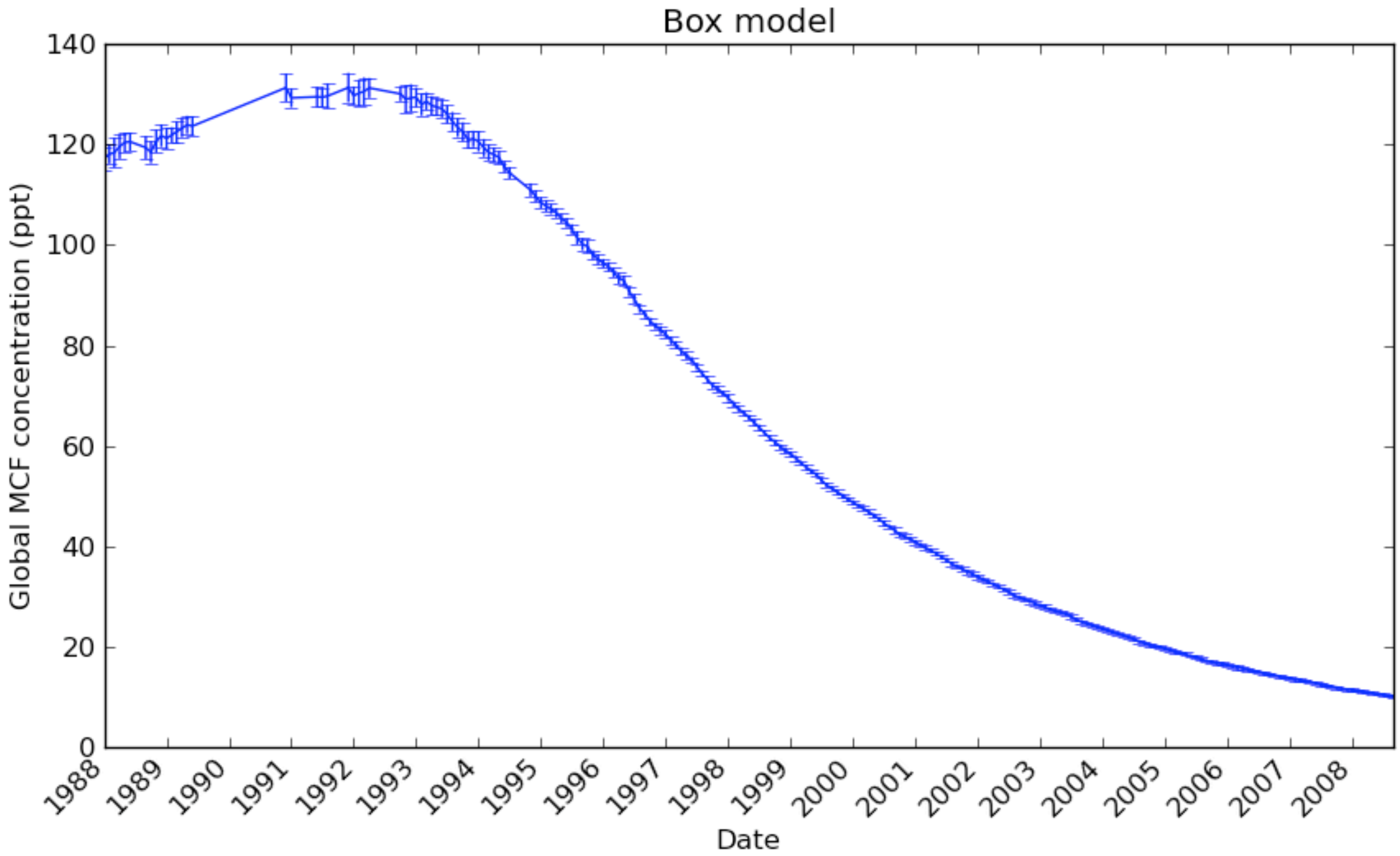
Remaining Questions

- What caused the inferred OH swings in the 1990s?
- Mean OH 1990s   vs. Mean OH 2000s?
- How to apply 4D-VAR to OH in an optimal way?
- Try 1990-2010 optimisation with ERA-interim...

Box model

- monthly GAGE-AGAGE data
- construct a global average mixing ratio
  - 30N-90N: California + Ireland (25%)
  - 0-30N: Barbados (25%)
  - 0-30S: Samoa (25%)
  - 90S-30S: Tasmania (25%)

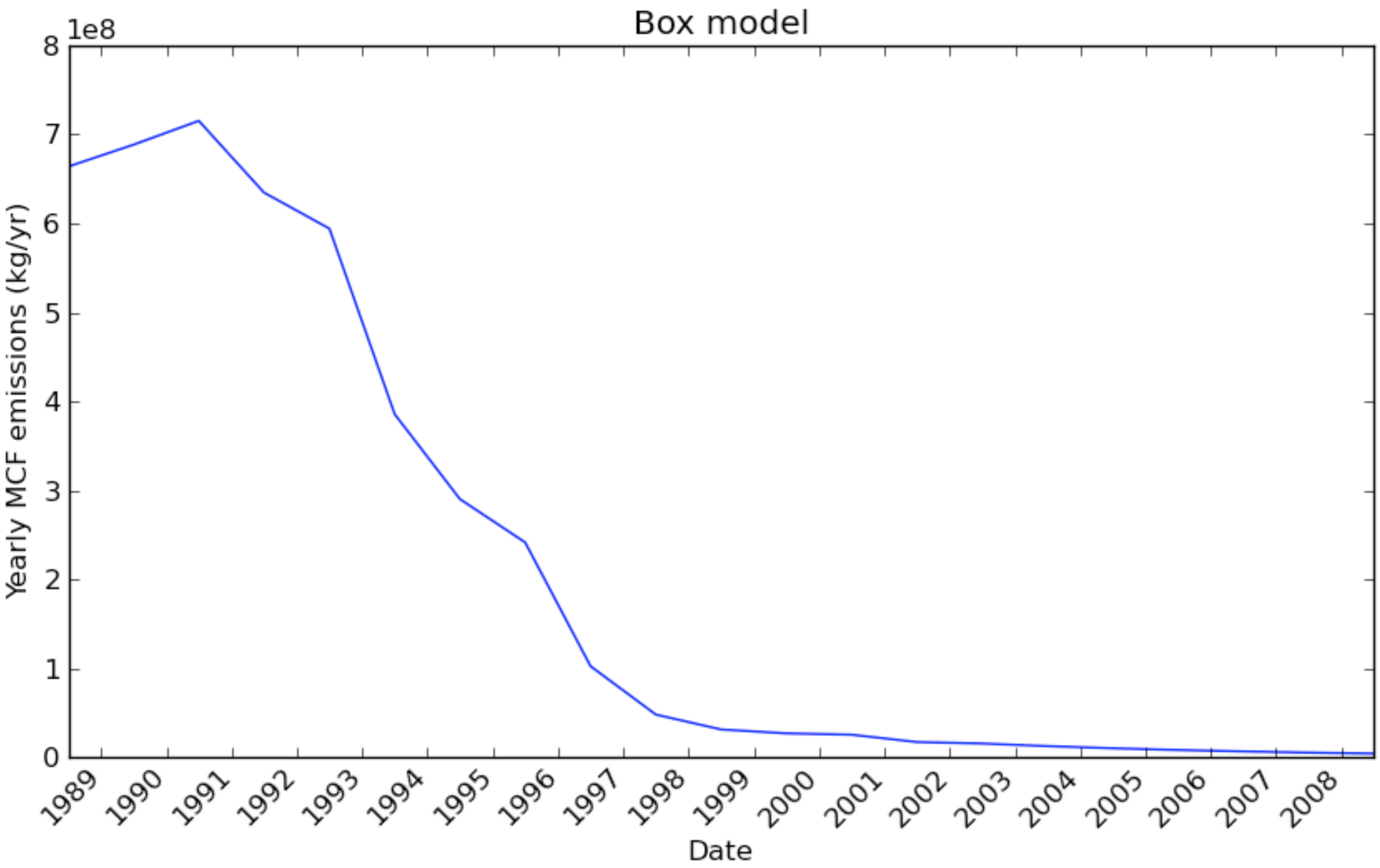
Global MCF concentration



Simplest model

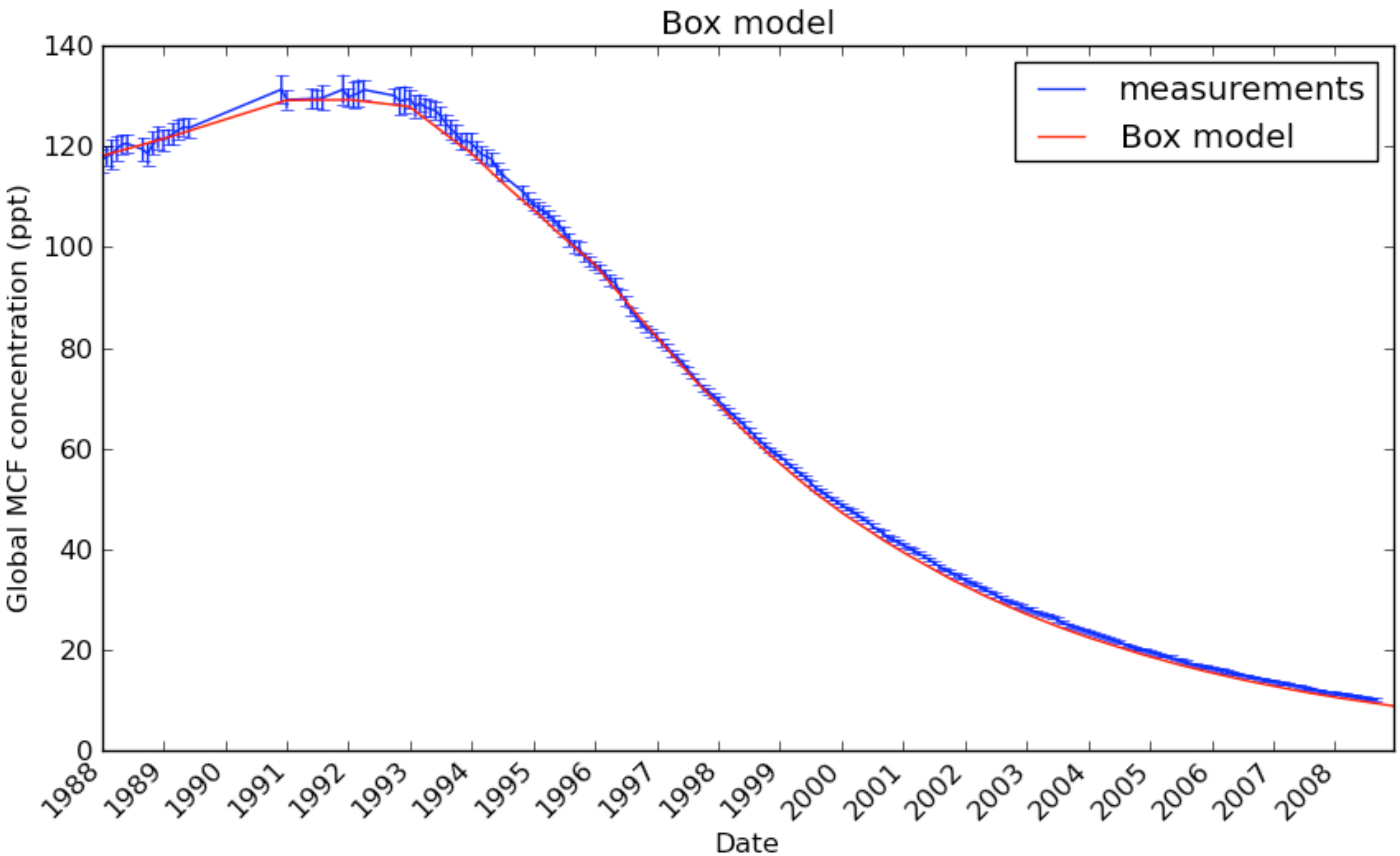
- Global emissions
- Loss by OH
- Loss in the stratosphere
- Loss by ocean uptake
- $dMCF/dt = E_t - MCF^*(k\ OH + k_s + k_o)$

Emissions



Box model
1e8
8
7
6
5
4
3
2
1
0
Yearly MCF emissions (kg/yr)
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Date

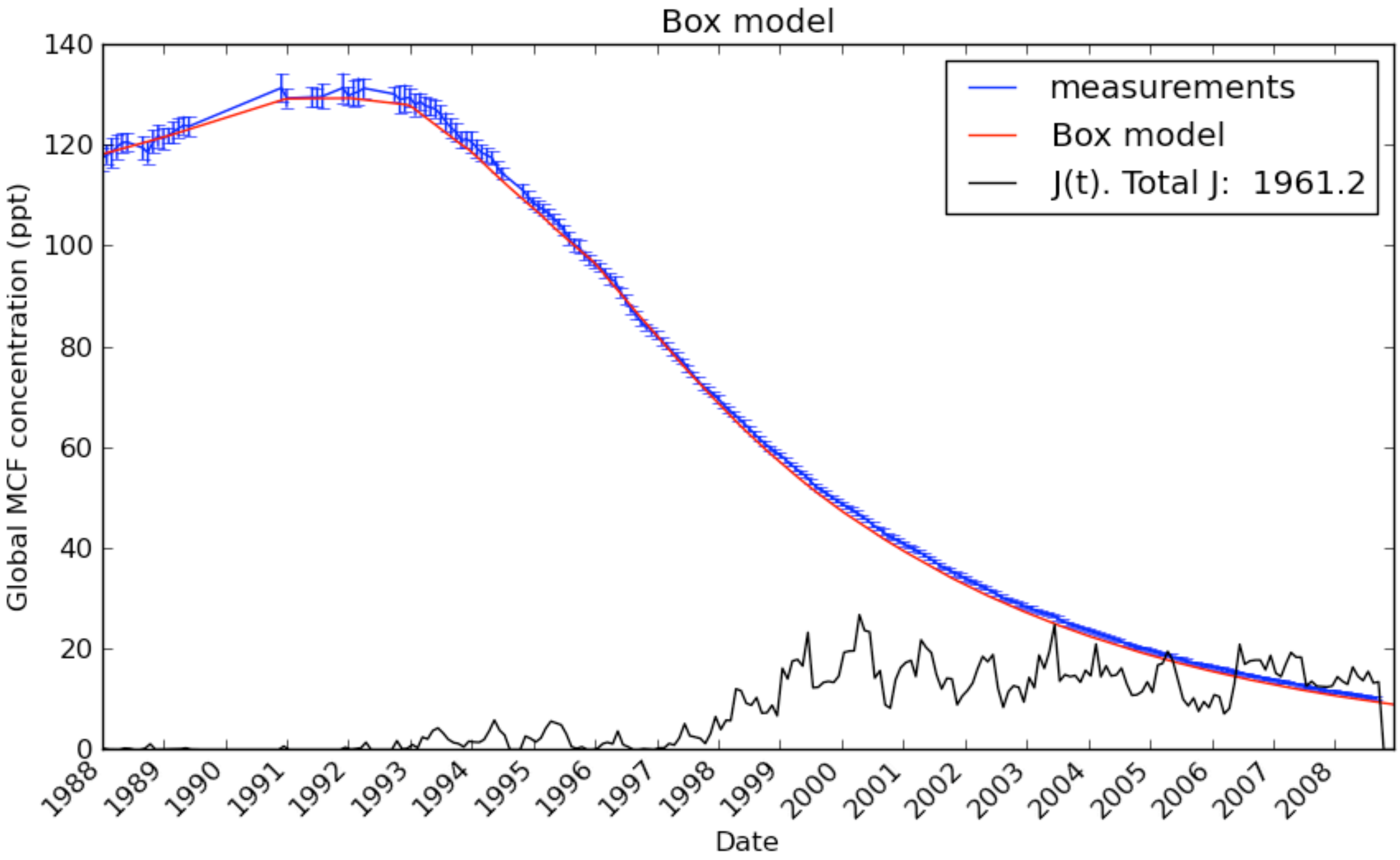
Hand-optimized model



Set-up inverse model

- Define state-vector x (initial condition, yearly emissions, yearly OH)
- Cost function $J(\mathbf{x}) = (\mathbf{y}-H(\mathbf{x}))^T \mathbf{R}^{-1} (\mathbf{y}-H(\mathbf{x}))$
- Set-up linearized ($\mathbf{H}$) and adjoint model ($\mathbf{H}^T$) to calculate $dJ_i / dx_i = \mathbf{H}^T\mathbf{R}^{-1} (\mathbf{y}-\mathbf{Hx})$
  - run adjoint model and feed in $\mathbf{R}^{-1}(y_i-\mathbf{H}x)$
- Note: H is a non-linear model when OH is in state vector $\mathbf{x}$

Time-evolution J(x)



Tangent linear model

Emission: TL model trivial

$$x = x + e$$

$$dx = dx + de$$

OH: optimise for f_{oh} makes system non-linear:

$$x = x \cdot (1 - f_{oh} l_{oh})$$

$$dx = dx \cdot (1 - f_{oh} l_{oh}) - x \cdot df_{oh} l_{oh}$$

Adjoint model emission

$$\begin{pmatrix} dx \\ de \end{pmatrix}^{n+1} = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} dx \\ de \end{pmatrix}^{n}$$

$$\begin{pmatrix} adx \\ ade \end{pmatrix}^{n} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \end{pmatrix} \begin{pmatrix} adx \\ ade \end{pmatrix}^{n+1}$$

$$adx = adx$$

$$ade = ade + adx$$

Adjoint model OH

$$\begin{pmatrix} dx \\ df_{oh} \end{pmatrix}^{n+1} = \begin{pmatrix} 1 - f_{oh} l_{oh} & -x \cdot l_{oh} \\ 0 & 1 \end{pmatrix} \begin{pmatrix} dx \\ df_{oh} \end{pmatrix}^{n}$$

$$\begin{pmatrix} adx \\ adf_{oh} \end{pmatrix}^{n} = \begin{pmatrix} 1 - f_{oh} l_{oh} & 0 \\ -x \cdot l_{oh} & 1 \end{pmatrix} \begin{pmatrix} adx \\ adf_{oh} \end{pmatrix}^{n+1}$$

$$adx = adx \cdot (1 - f_{oh} l_{oh})$$

$$adfoh = adfoh - adx \cdot x \cdot l_{oh}$$

Test: optimize OH in 2000