Sensitivity of CO_2 transport to the choice of boundary layer scheme

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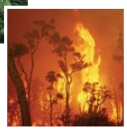
Why is CO_2 transport important?

- Comparison with atmospheric measurements of CO_2 to assess carbon fluxes from CABLE (and ocean model)
  - Diurnal Cycle
  - Seasonal Cycle
  - Interhemispheric gradient
  - Interannual variability in growth rate
- CO_2 inversions (carbon fluxes estimated by best fit to atmospheric measurements) are dependent on atmospheric transport
- CO_2 transport behaviour applicable to other trace gases
- Model evaluation
- TransCom – a number of projects to compare forward simulations or inversions of CO_2 across GCM and transport models
  - Large model dataset to compare with
  - UM model has not participated
  - Value of 'best' model (elusive anyway) vs model ensemble/range

Boundary layer options


Section 3 : Boundary Layer : Job xaln.o: "Monthly & 3-Hr Tracers (0 ppm), cp from cor219"

Choose version
- Boundary Layer not included
- <8A> MOSES-II non-local scheme for unstable boundary
- <8B> MOSES-II non-local scheme with revised diagnosis of K profile depths
- <8C> Revised treatment of entrainment fluxes plus new scalar flux-gradient option

x-gradient formulation
- Surface-driven gradient adjustment for heat only
- Generic flux-gradient relationship

- Only played with stable boundary layer options

Select type of stable boundary layer mixing scheme
- Richardson no. scheme (RiSc): Long tails
- SHARPEST function (RiSc)
- SHARPEST over sea; Long tails over land (RiSc)
- MESOSCALE model: Louis/SHARPEST blend (RiSc)
- Louis function (RiSc)
- Boundary layer depth based formulation
- SHARPEST over sea; MES tails over land (RiSc)
- Equilibrium stable boundary layer scheme

Elsewhere, N compile mode selected for all sections
- [x] Use time weights of 1 for all tracers (recommended)
- [x] Use non-gradient stress parametrization
- [x] Use shear-dominated boundary layer fix
- [ ] Reinstate code errors corrected since HadGEM1

Stable boundary layer

- Unified Model Documentation Paper 24 : The parameterization of boundary layer processes (July 2007, v 6.3)
- Boundary layer diagnosed as one of six types.
- Type I, stable boundary layer, turbulent diffusivities calculated by local scheme – first order mixing length closure

$$K_m = \mathcal{L}_m^2 \left|\frac{\partial \mathbf{u}}{\partial z}\right| f_m(Ri) \qquad \mathcal{L}_m \text{ and } \mathcal{L}_h \text{ are the neutral mixing lengths.}$$

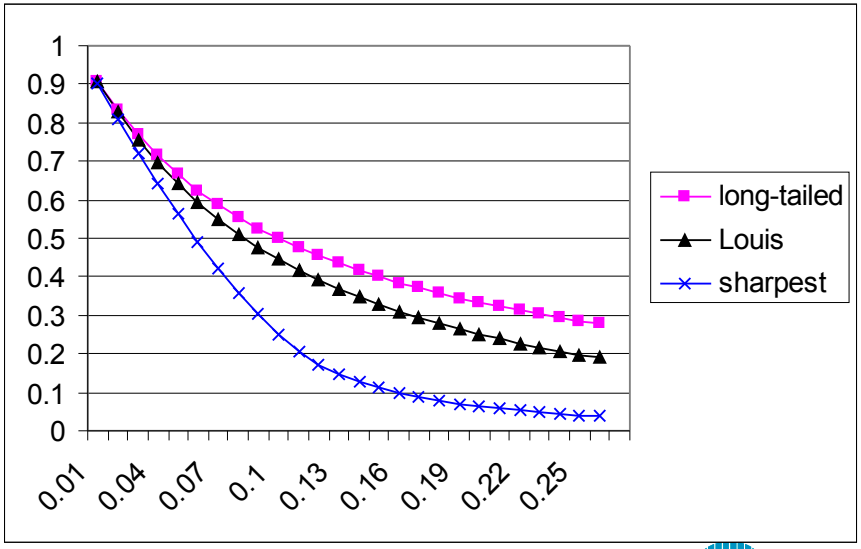
$$K_h = \mathcal{L}_h \mathcal{L}_m \left|\frac{\partial \mathbf{u}}{\partial z}\right| f_h(Ri)$$

When Ri>0

$$f_m = \frac{1}{1 + g_0 Ri} \qquad \text{Long-tailed}$$

$$f_m = \frac{1}{(1 + 5Ri)^2} \qquad \text{Louis}$$

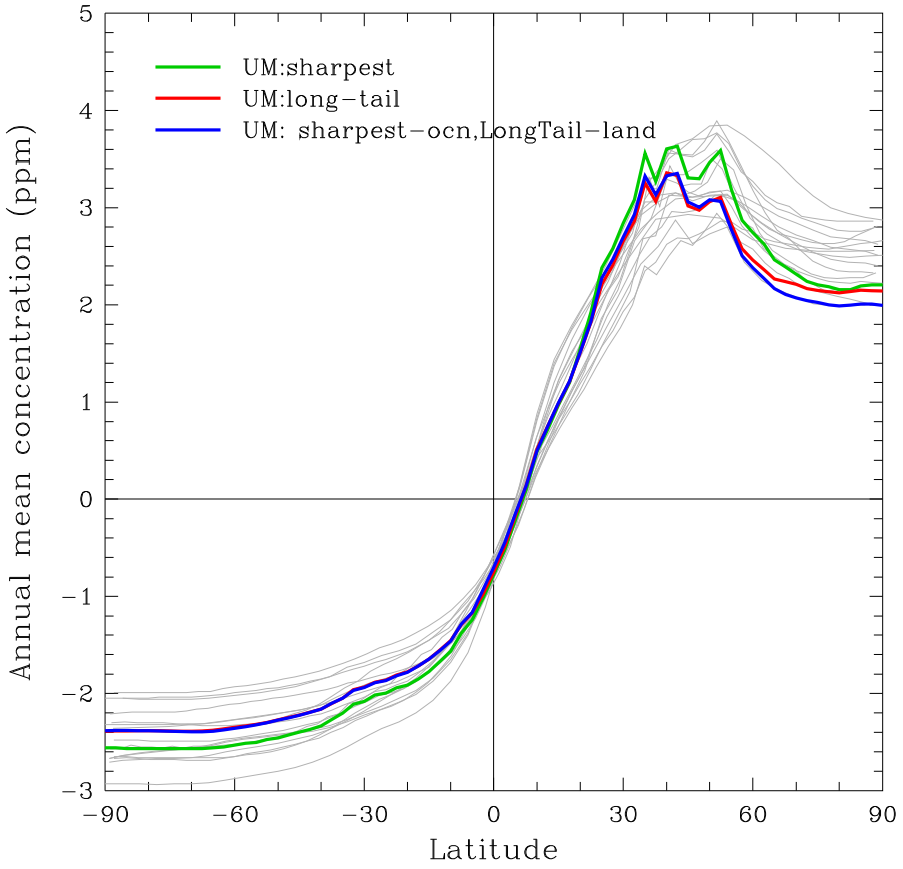
$$f_m = \begin{cases} (1 - 5Ri)^2 & \text{for } 0 < Ri < 0.1 \\ (20Ri)^{-2} & \text{for } Ri > 0.1 \end{cases} \qquad \text{Sharpest}$$

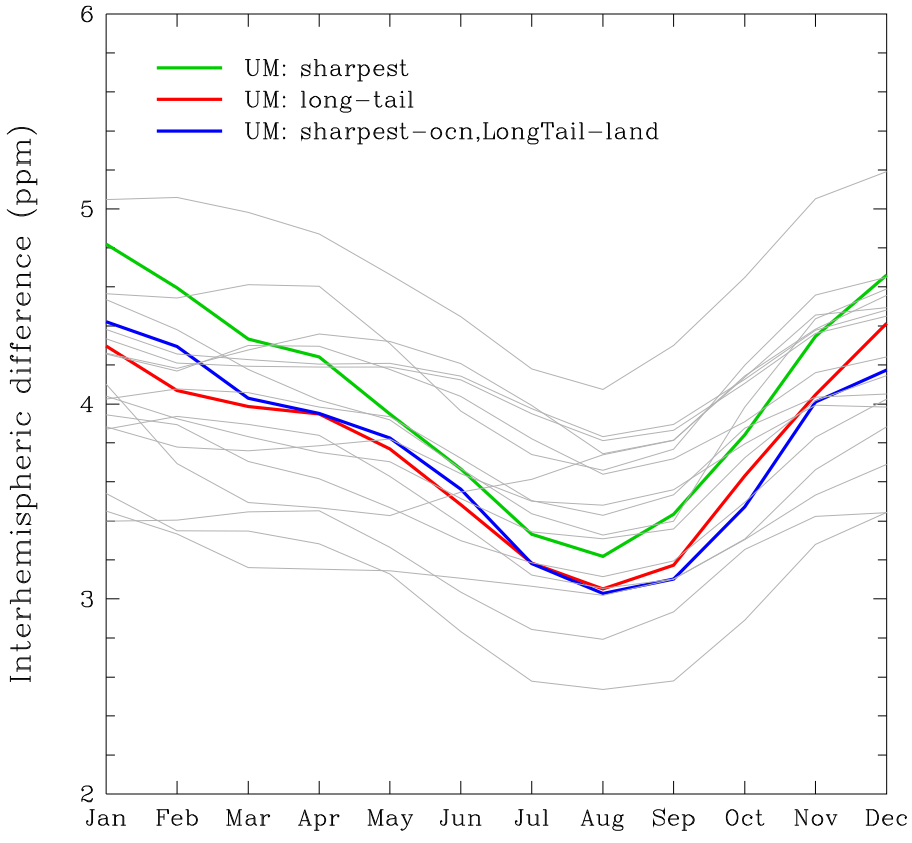


TransCom

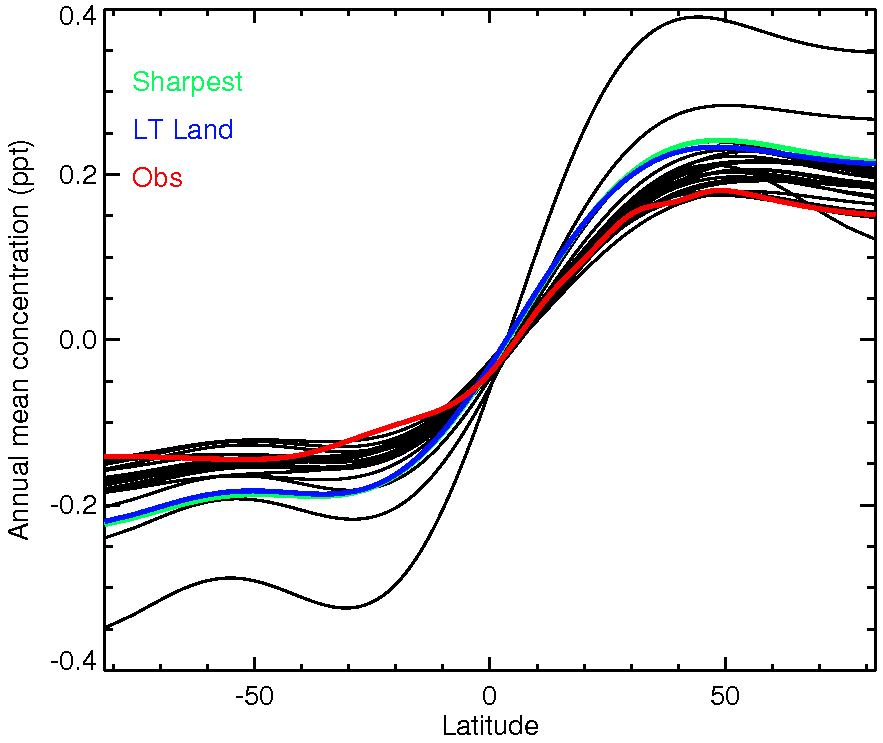
- Prescribed surface fluxes
  - CO_2: biosphere (monthly mean or diurnally varying), fossil, ocean
  - SF_6
  - Radon (not run yet)
- Regrid from 1^ox1^o or 0.5^ox0.5^o to model resolution (for UM N48, 3.75^ox2.5^o)
- 3-4 year simulations, 2 year spin-up
- TransCom-3 experiment (mostly inversions) – full model grids submitted
- TransCom-continuous experiment (synoptic/diurnal focus) – site/grid-cell samples submitted, models used/nudged to analyses (e.g. NCEP) for 2002 and 2003. Provides 'best' comparison with observations.
- UM run for 3 or 4 years from January 1991 AMIP initial condition – can only look at mean synoptic/diurnal behaviour not specific events

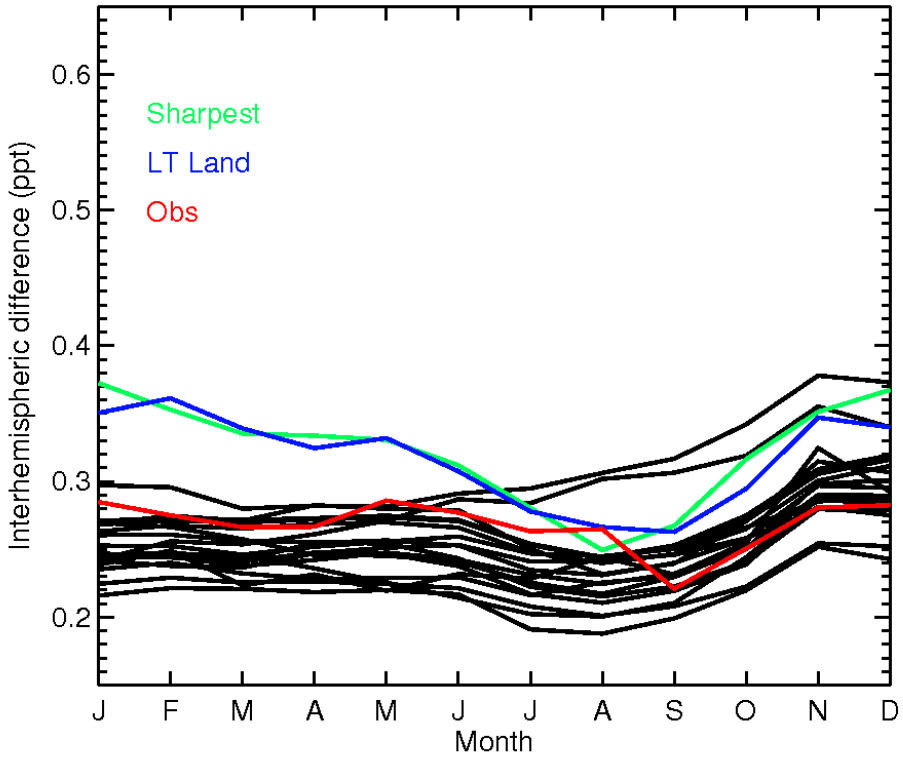
Fossil CO_2 – zonal mean and IHD





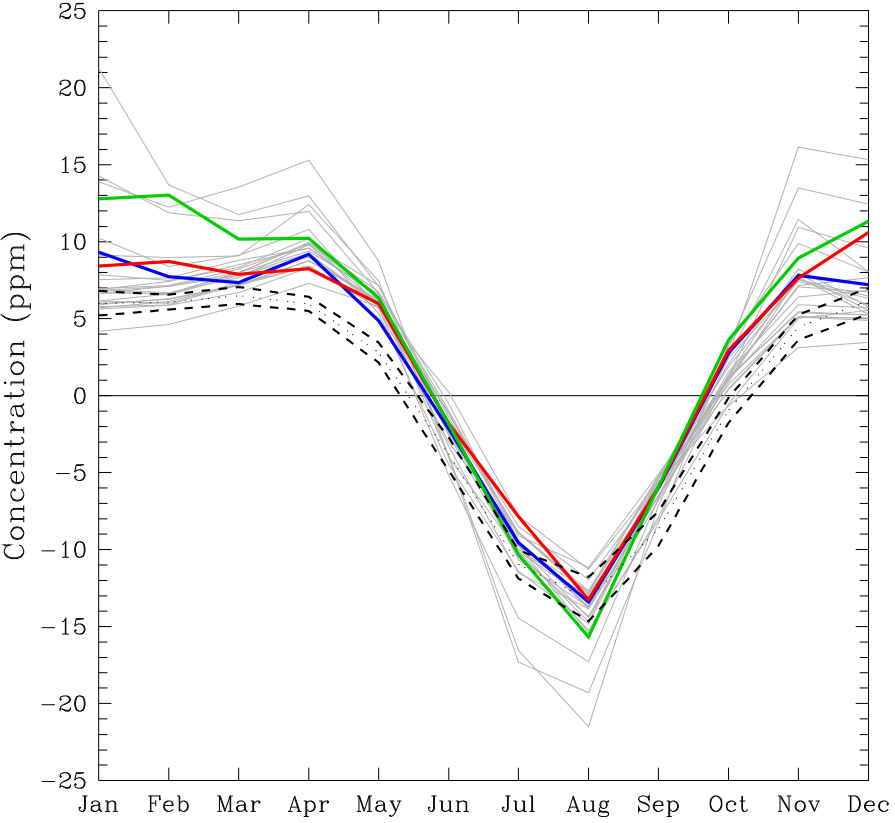
SF6


Sharpest
LT Land
Obs
Annual mean concentration (ppt)
0.4
0.2
0.0
-0.2
-0.4
-50
0
50
Latitude

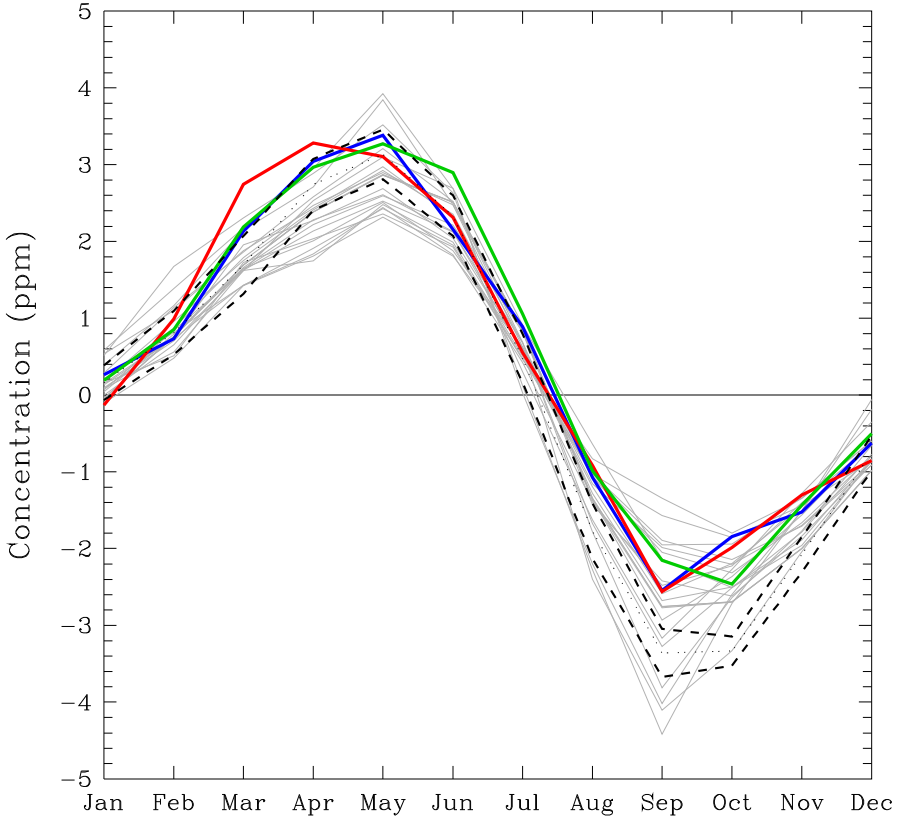

Sharpest
LT Land
Obs
Interhemispheric difference (ppt)
0.6
0.5
0.4
0.3
0.2
J
F
M
A
M
J
J
A
S
O
N
D
Month

Biosphere – seasonal cycle

Fraserdale, Canada



Mauna Loa, Hawaii



Green: sharpest

Red: Long-tails

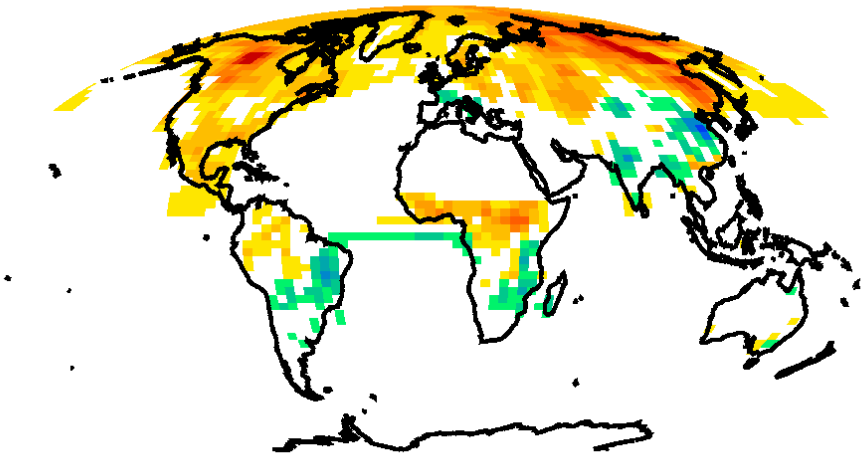
Blue: sharpest ocean, long-tails land

Black, dashed: Observed

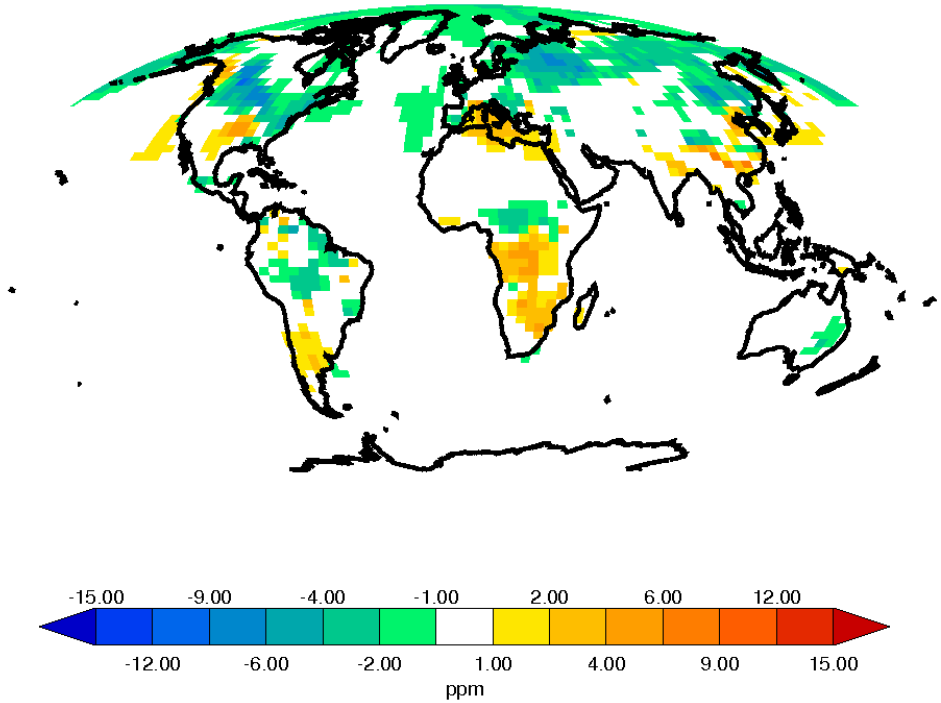
Biosphere CO_2 Monthly Mean Differences

Sharpest – LT Land

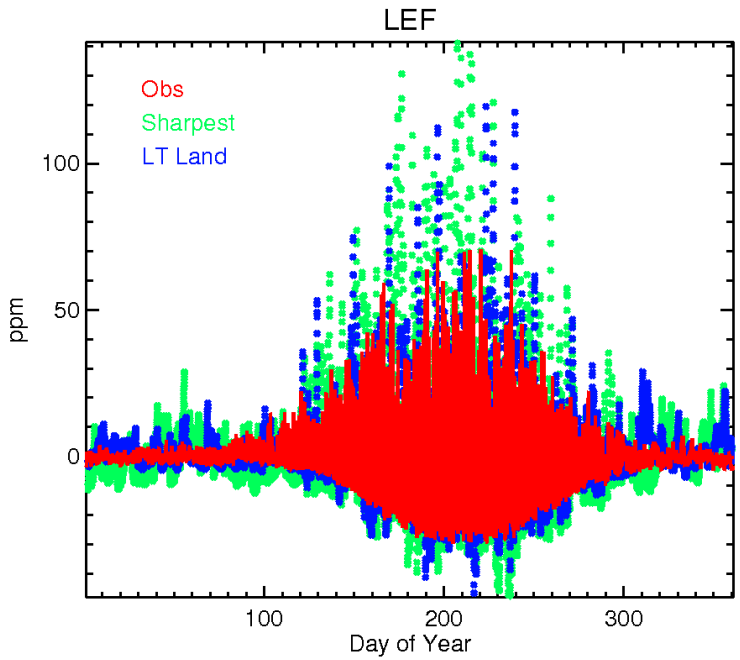
January

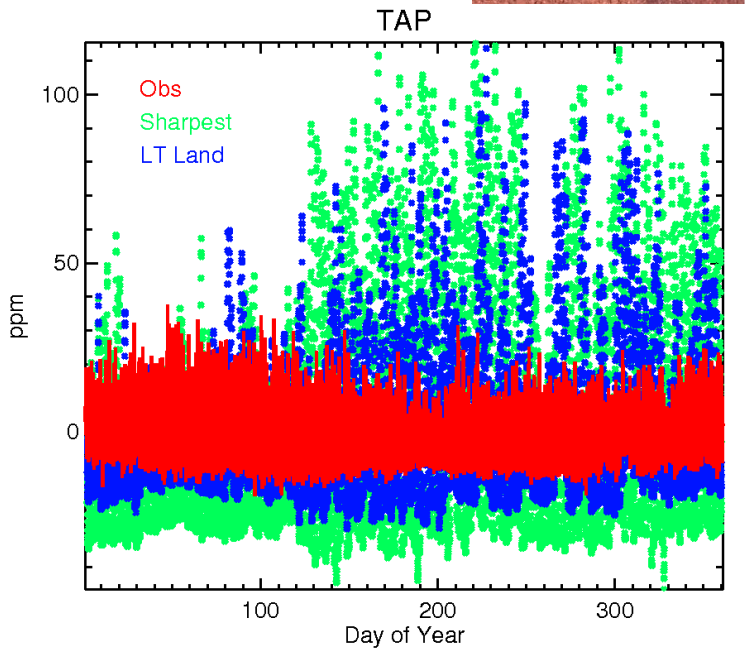


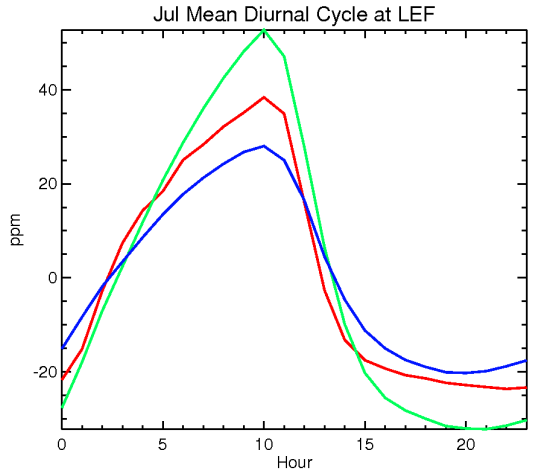
July

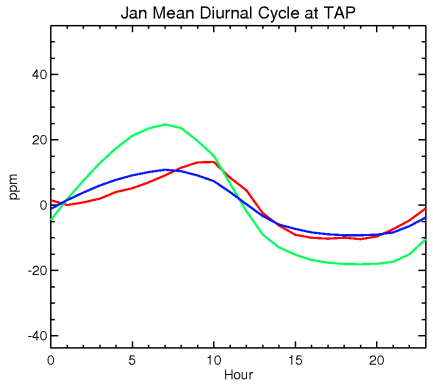


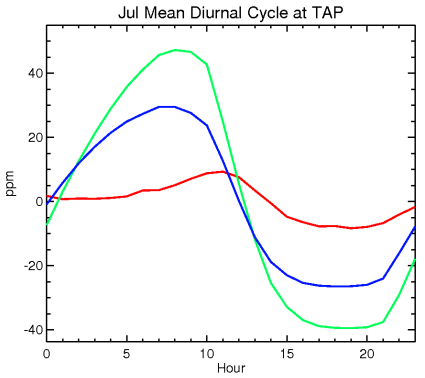
Biosphere CO_2 Diurnal Variability











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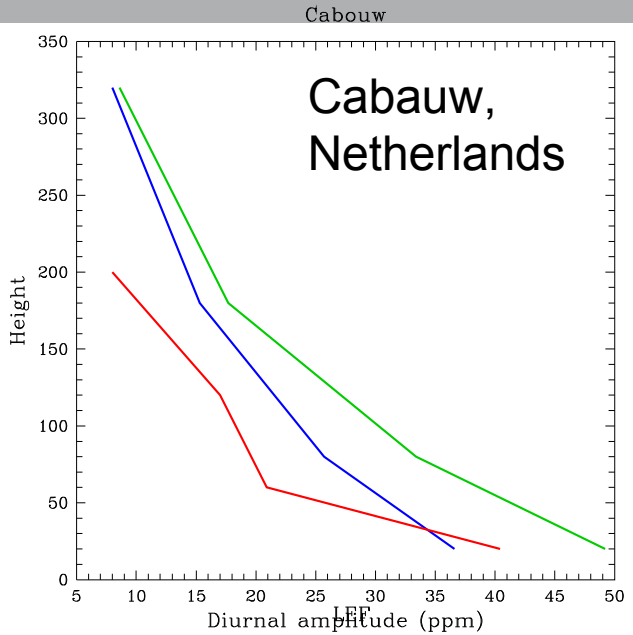
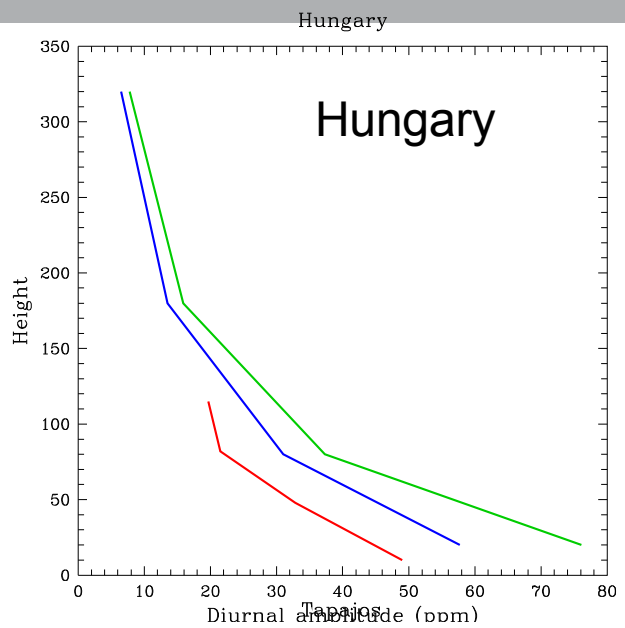
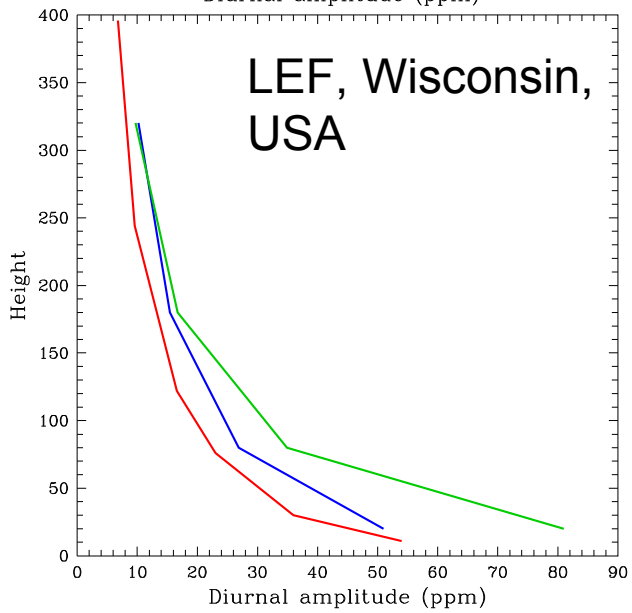
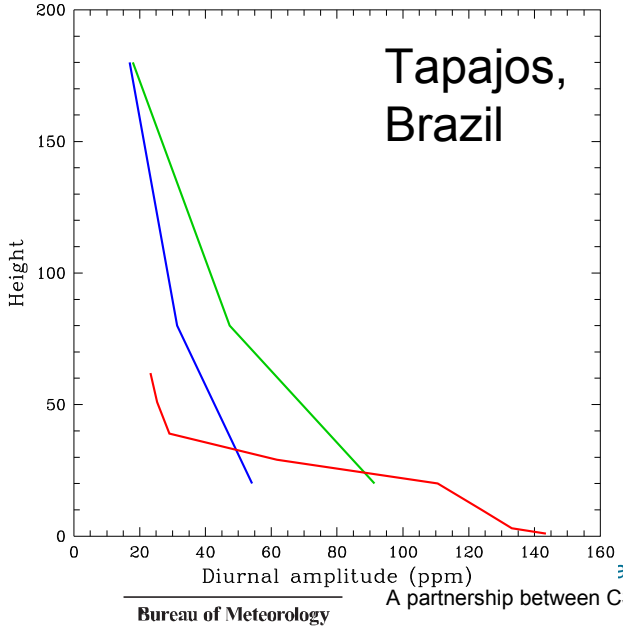
Diurnal cycle with height









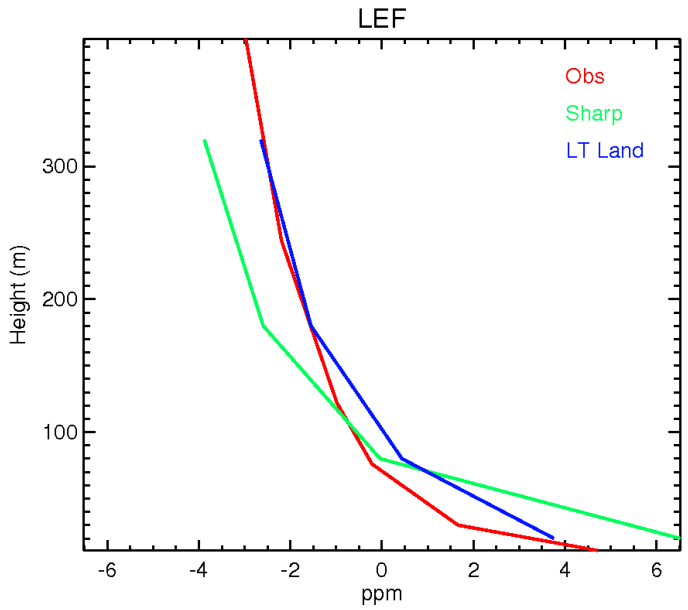
Amplitude of the summer (JJA) diurnal cycle of CO2 at four towers

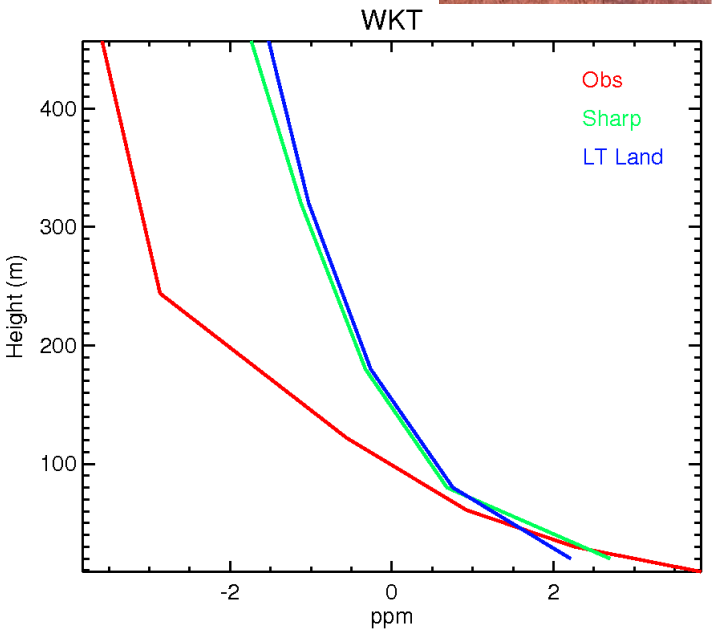
Blue: sharpest over ocean, long-tails over land

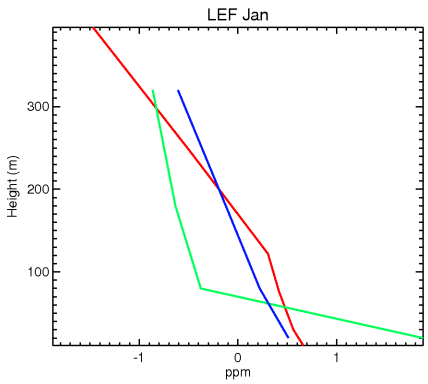
Green: sharpest

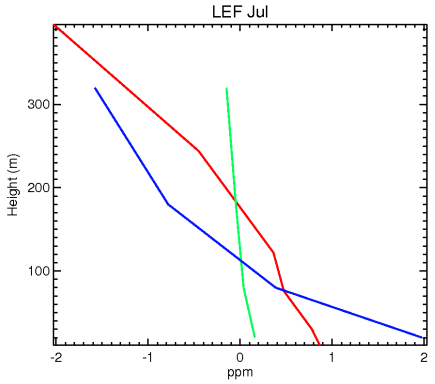
Red: observed

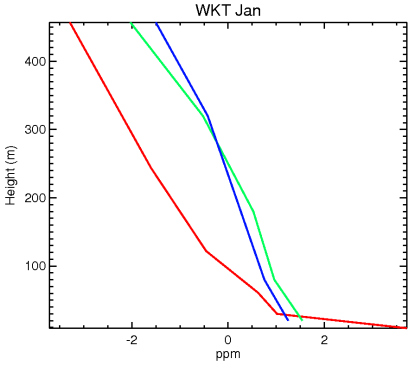
CO_2 Vertical Profiles

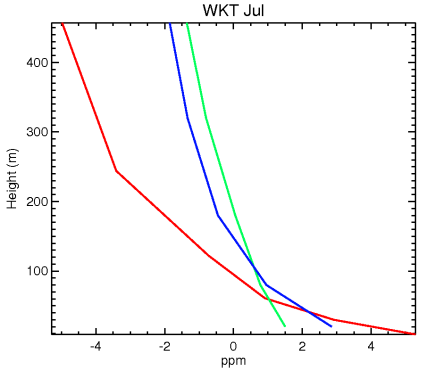












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Summary/Conclusions/Where next?

- Sharpest scheme appears less consistent with observations and other models
- Higher resolution (N96)
- Test with UM+CABLE
- Run with nudging would allow comparison with synoptic variations in CO_2 (continental sites in winter can show large differences between boundary layer schemes).
- How would AMIP run change e.g. impact on what fields, if used Sharpest-ocean, long-tails land?

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Thank you

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