Linking dry deposition to vegetation: Implications for surface O_3

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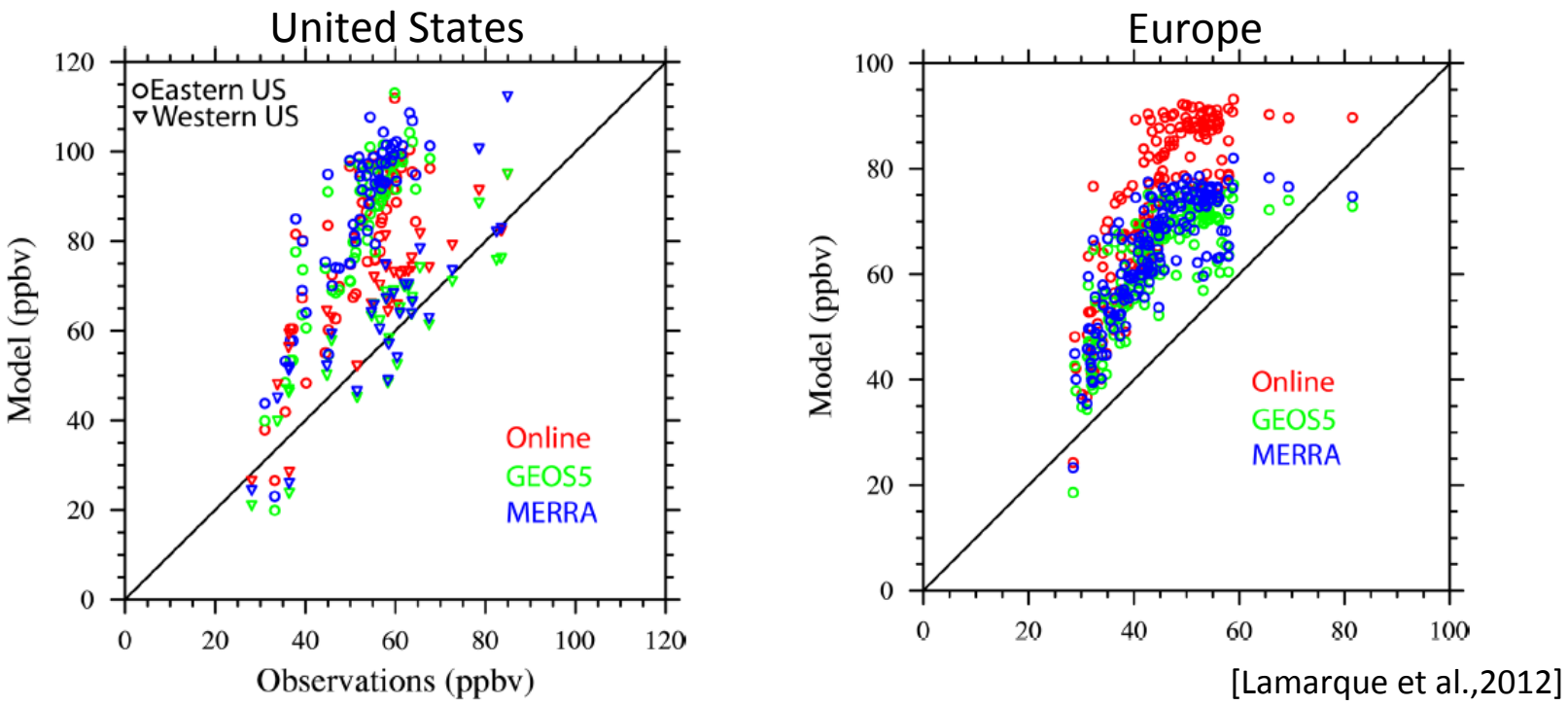
JOINT FIRE SCIENCE PROGRAM

CESM has a large positive bias in summertime surface O_3 over eastern US and Europe

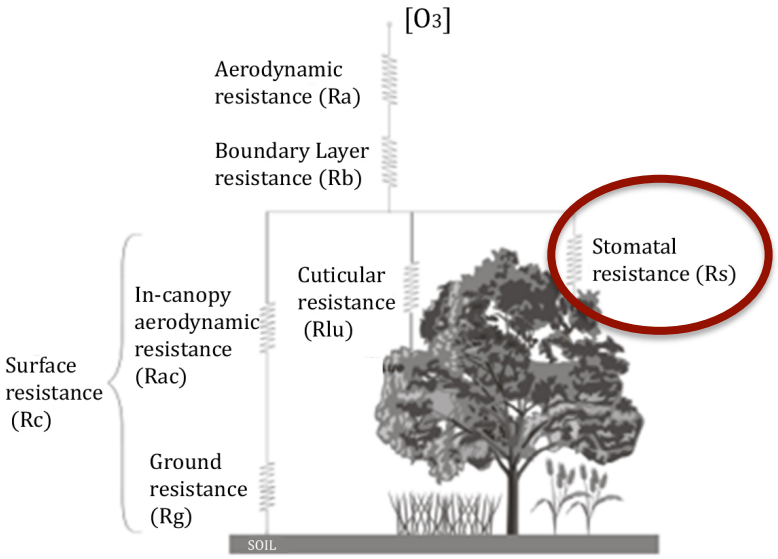


[Lamarque et al.,2012]

Summertime positive bias is a persistent, well-known issue in chemical models (e.g. Murakaki and Hess, 2006, Fiore et al 2009, Lapina et al 2014)

What is the role of dry deposition in this positive bias?

Linking the dry deposition velocity code to vegetation



Parameterization based on Wesely, (1989) multiple resistance approach

Calculation takes place in CLM for each PFT, and the weighted-mean velocity is then transferred to CAM-Chem

Standard Scheme

$$Rs = r_s \left\{1 + \frac{1}{[200(G+0.1)]^2}\right\} \left\{\frac{400}{Ts(40-Ts)}\right\} \frac{D_{H_2O}}{D_x}$$

[Wesely, 1989]

LAI-Coupled Scheme

$$\frac{1}{r_s} = m\frac{A}{c_s}\frac{e_s}{e_i}P_{atm} + b$$

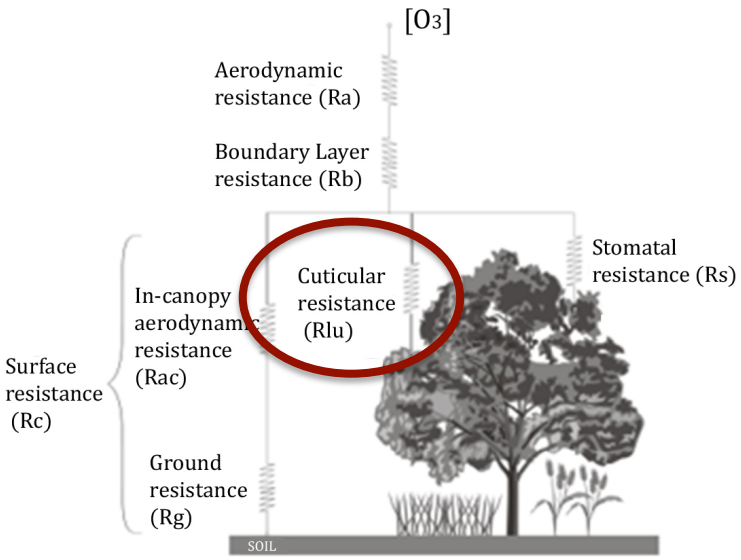
for sunlit (rs^{sun}) and shaded leaves (rs^{sha})

Scaled to the bulk canopy

$$Rs = \frac{f_{sun} \times r_s^{sun}}{LAI} + \frac{(1-f_{sun}) \times r_s^{sha}}{LAI}$$

[Collatz et al., 1991; Sellers et al, 1996]

Linking the dry deposition velocity code to vegetation



Parameterization based on Wesely, (1989) multiple resistance approach

Calculation takes place in CLM for each PFT, and the weighted-mean velocity is then transferred to CAM-Chem

Standard Scheme

$$Rlu = \frac{r_{lu}}{10^{-5}H + f_o}$$

[Wesely, 1989]

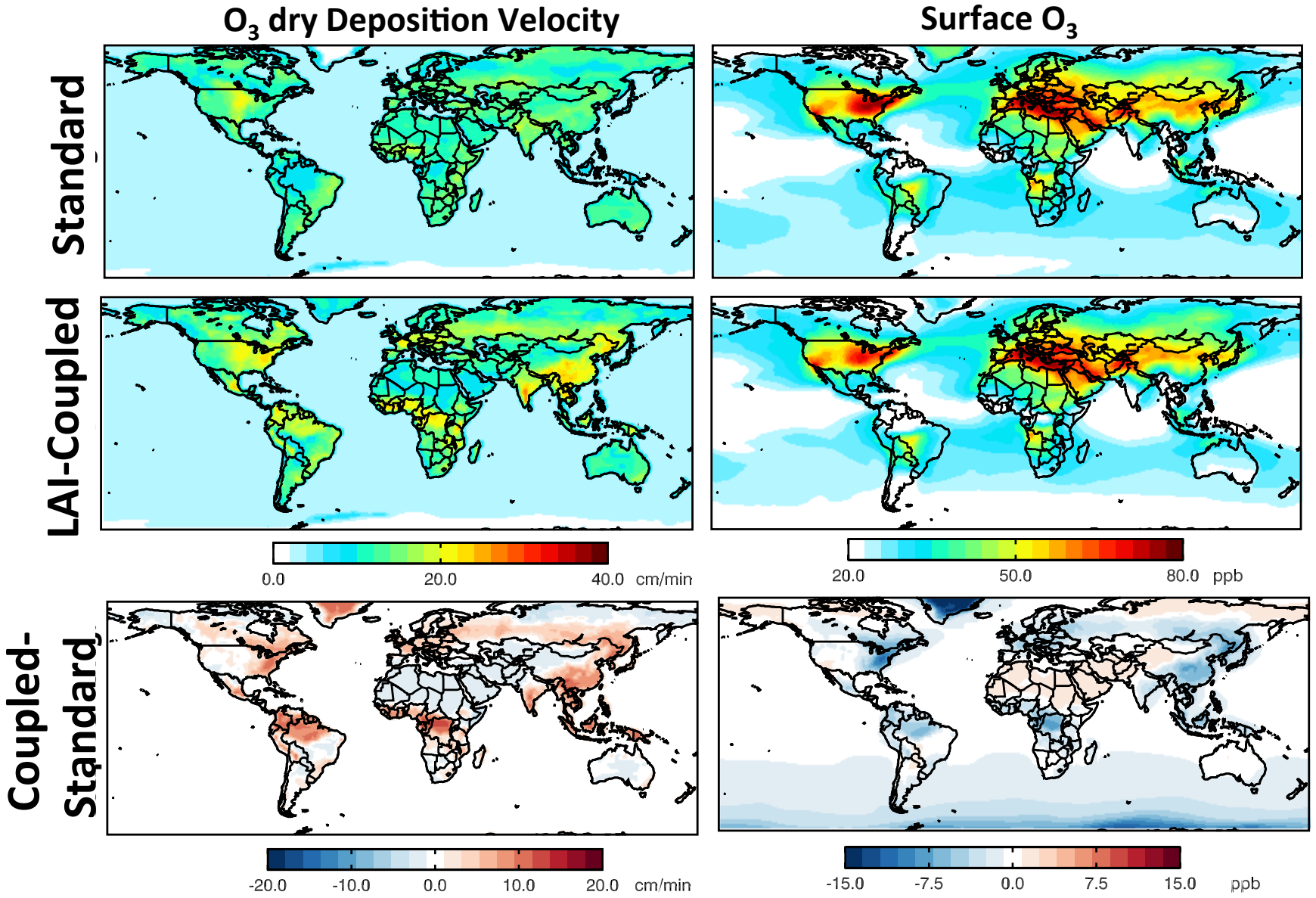
LAI-Coupled Scheme

$$Rlu = \frac{r_{lu}}{LAI \times (10^{-5}H + f_o)}$$

Scaled to the bulk canopy

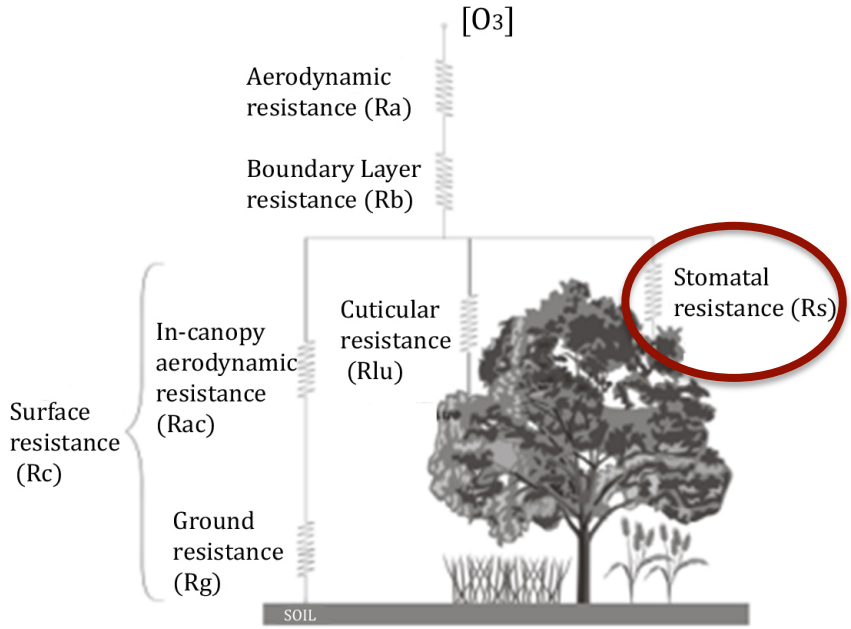
[Baldocchi et al., 1987; Gao and Wesely, 1995]

Significant changes in dry deposition velocity and surface O_3 when the scheme is coupled to LAI

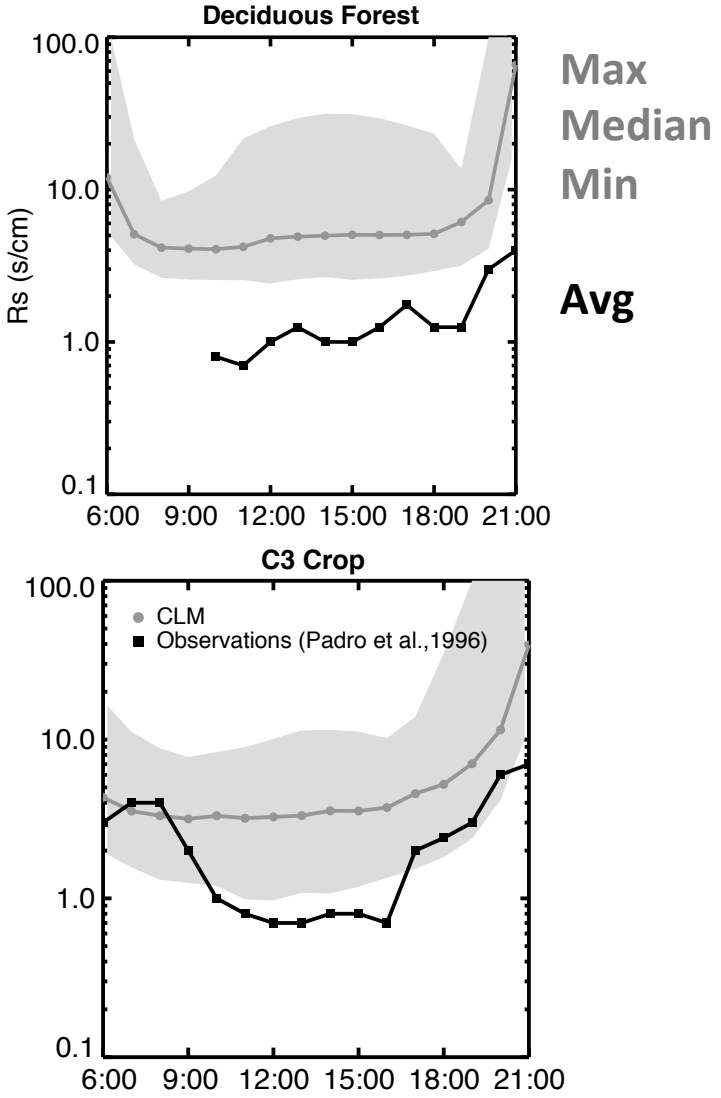


[Val Martin et al., in preparation,2014a]

The dry deposition schemes substantially overestimates daytime stomatal resistance



Daytime simulated versus observed Rs

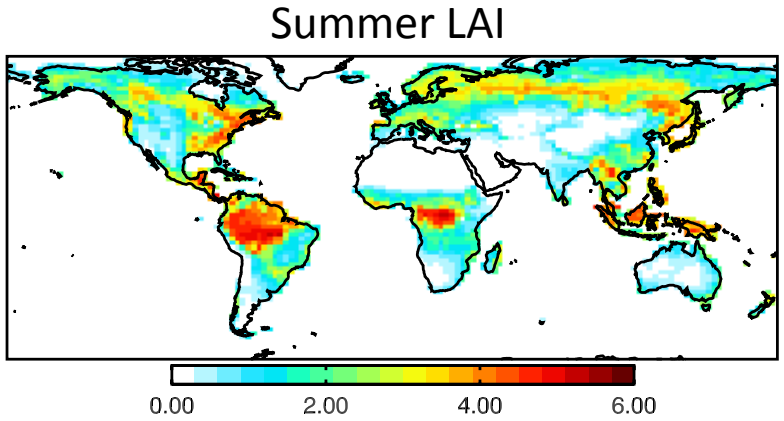


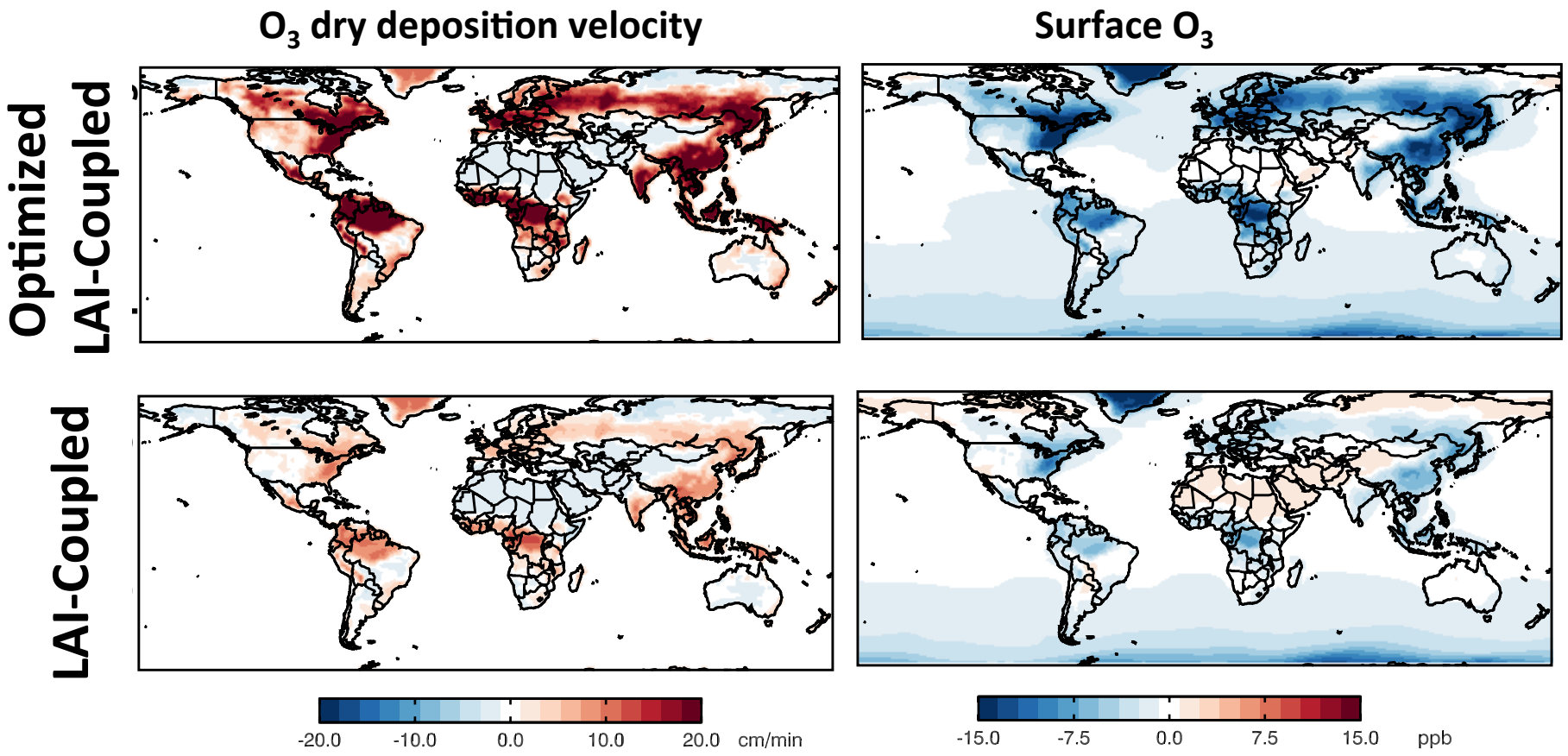
Rs is overestimated by a factor of ~5

We optimized the "LAI-coupled scheme" by applying a factor of 0.2 to Rs

[Val Martin et al., in preparation,2014a]

O_3 dry deposition velocity is very sensitive to Rs in densely vegetated regions

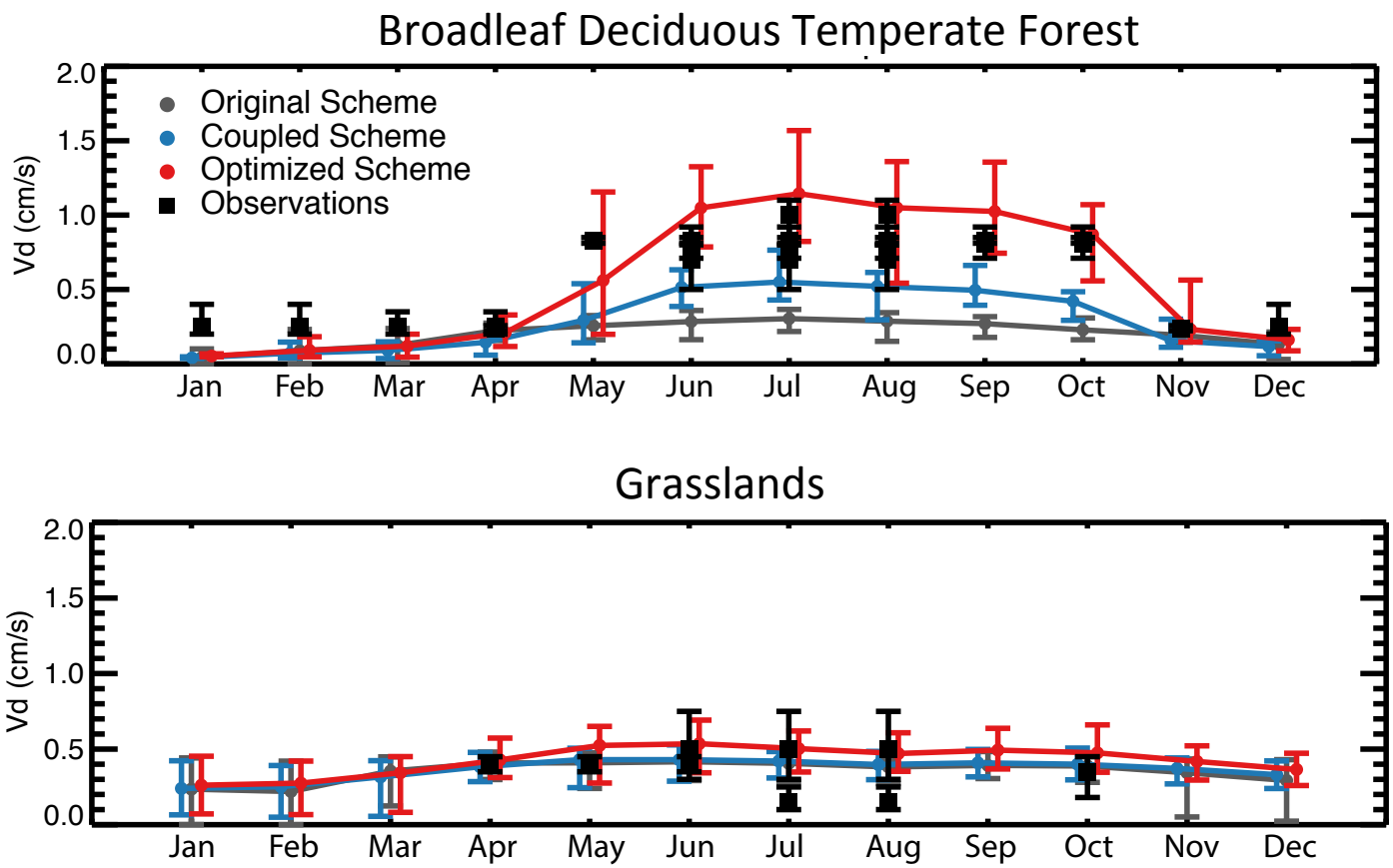


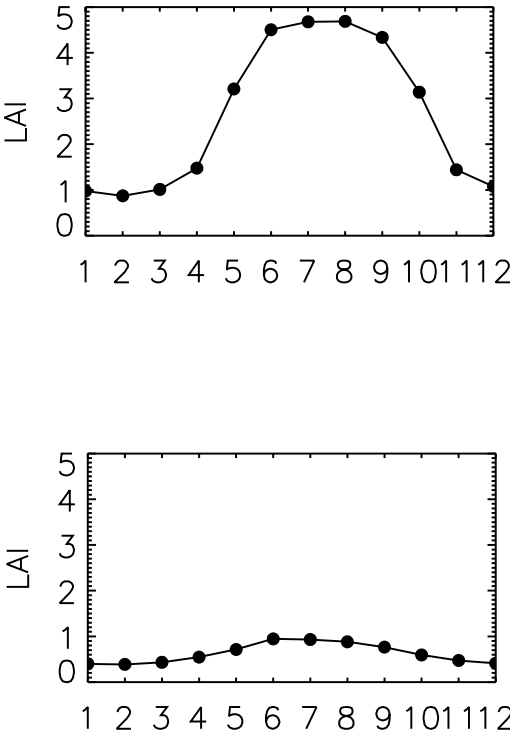


O_3 Vd is significantly improved with the LAI-dependence over densely vegetated regions

Seasonal cycle of midday (9:00-15:00) O_3 dry deposition velocity

Seasonal cycle of LAI

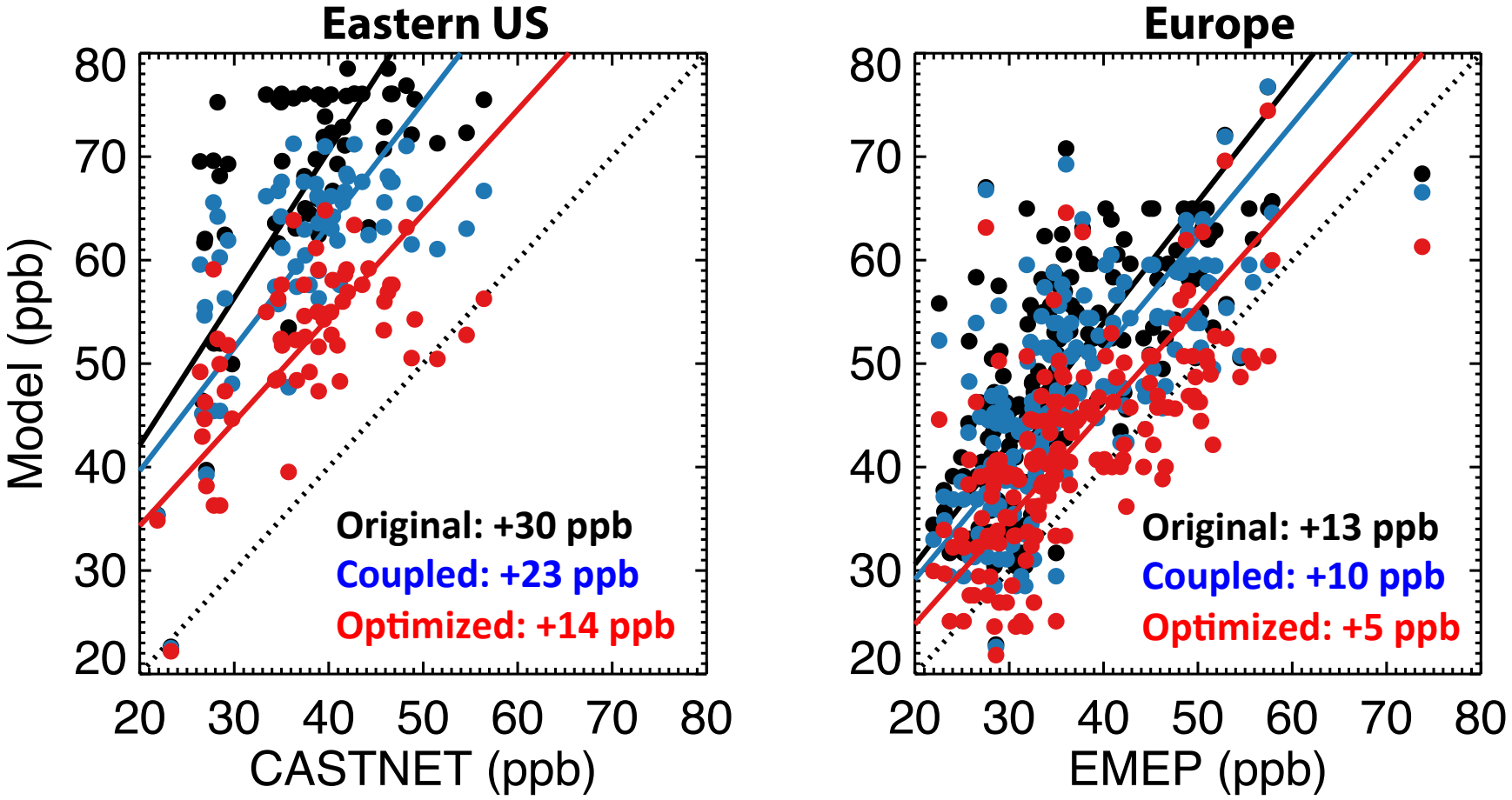




Observations from Wu et al. [2011], Padro et al. [1991, 1992, 1994], Finkelstein et al. [2000], Meyers et al. [1998] and Gao and Wesely [1995]

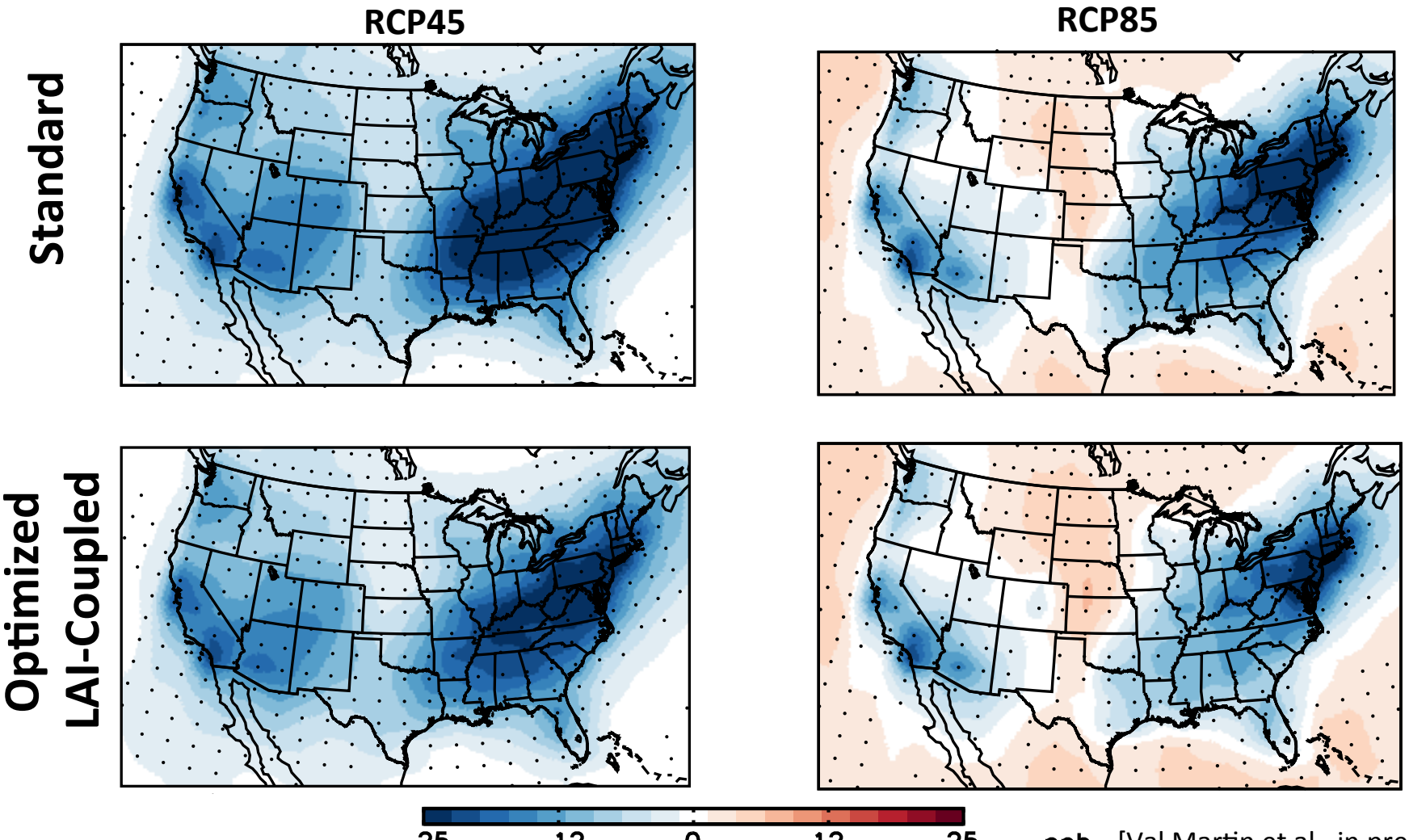
LAI-coupled simulations improve surface O_3, yet it is still overestimated

Simulated versus observed summertime surface O_3



Changes in the dry deposition scheme and implications for the RCP O_3 simulations

2050-2000 changes in summertime O_3 MDA-8 due to emissions, climate and land cover/use

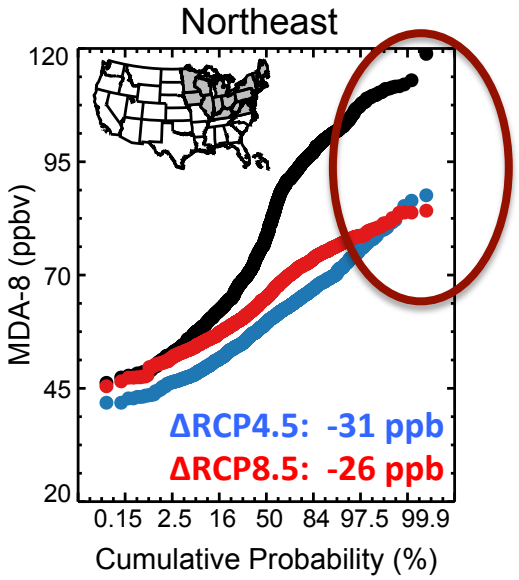


[Val Martin et al., in prep., 2014b]

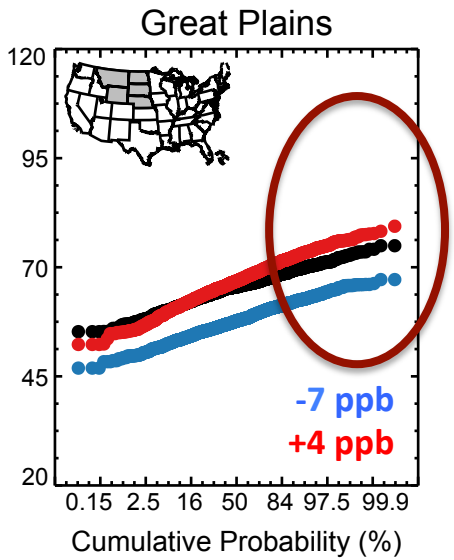
The standard dry deposition code may overestimate changes in O_3 in some US regions

Regional summertime O_3 MDA-8 probability distributions

Standard

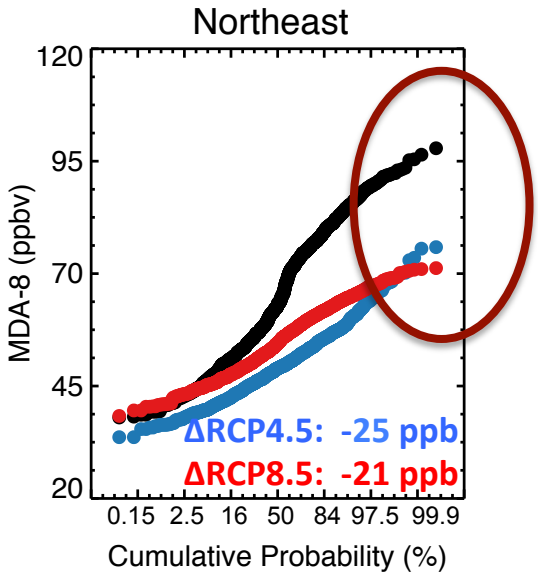


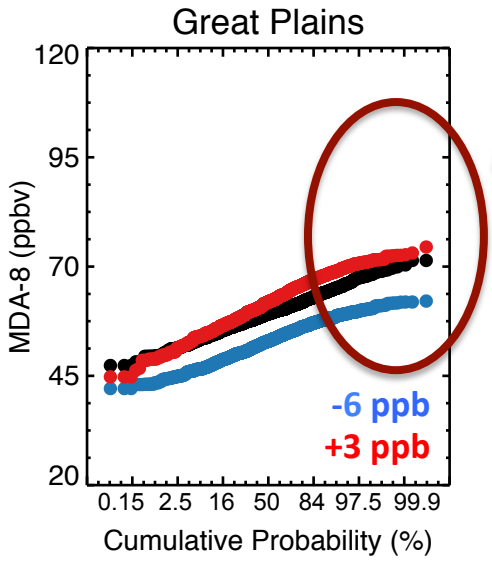
20% larger decreases in 2050-2000 during most polluted days



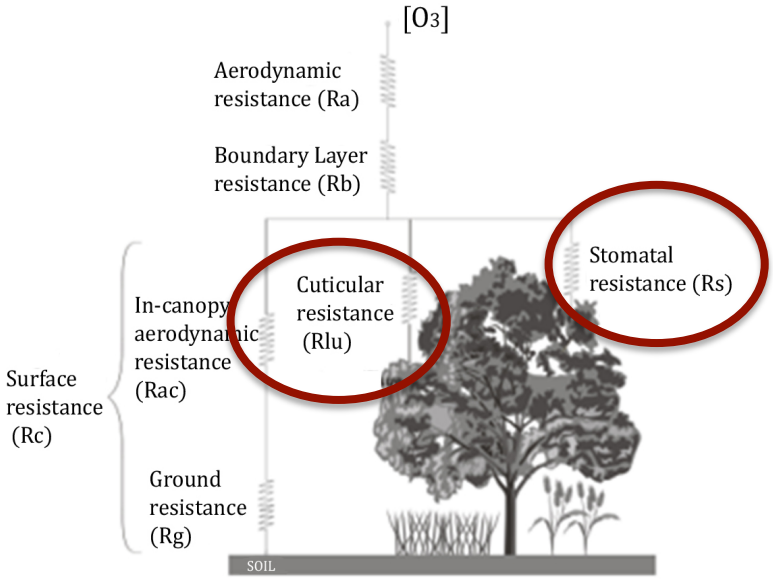
Little difference

Optimized LAI-Coupled





Wrapping-up….



The LAI-coupled and Optimized dry deposition codes are available for CESM1.1.1 and CESM1.2.0

Coupling the dry deposition to vegetation improves significantly surface O_3 over densely vegetated regions

The effect of changes in the dry deposition code in other species and above 900 hPa is negligible

Further work is needed to understand the causes in the Rs bias and implications to the hydrological and carbon cycles