Sensitivity of ozone dry deposition to ecosystem-atmosphere interactions: A critical appraisal of observations and simulations

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How do plants deal with dry days?

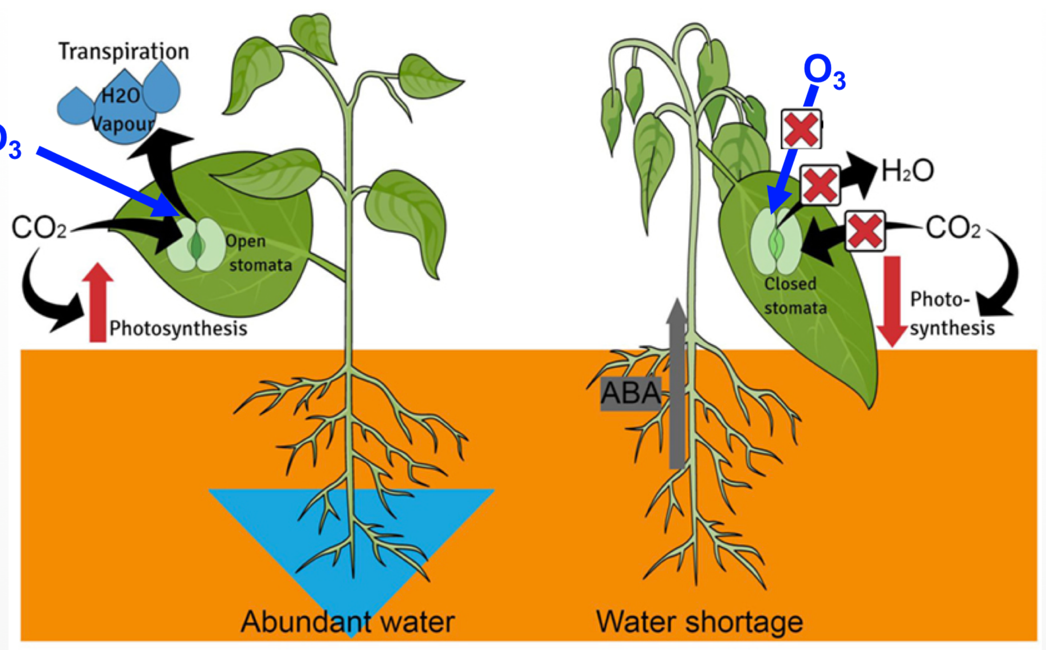
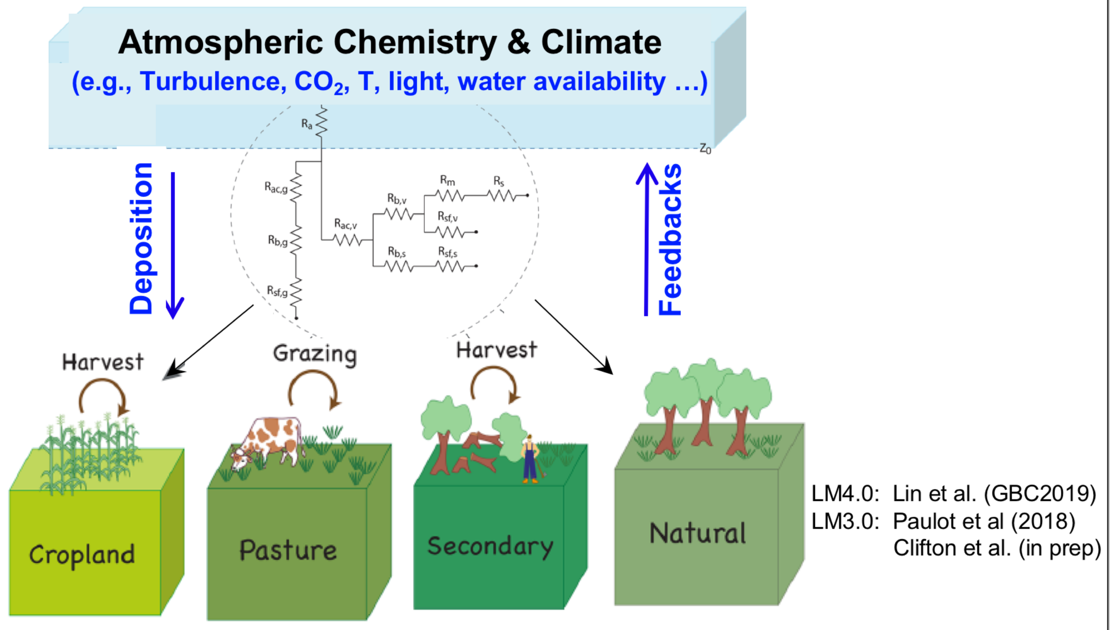


Figure modified from https://kids.frontiersin.org/article/10.3389/frym.2017.00058

Limitations in prior models:

- The widely-used Wesely scheme does not account for stomatal closure under soil drying.
- The Jarvis (1976) type empirical function assumes that environmental variables act independently to determine stomatal activity.

Interactive drydep scheme in GFDL models

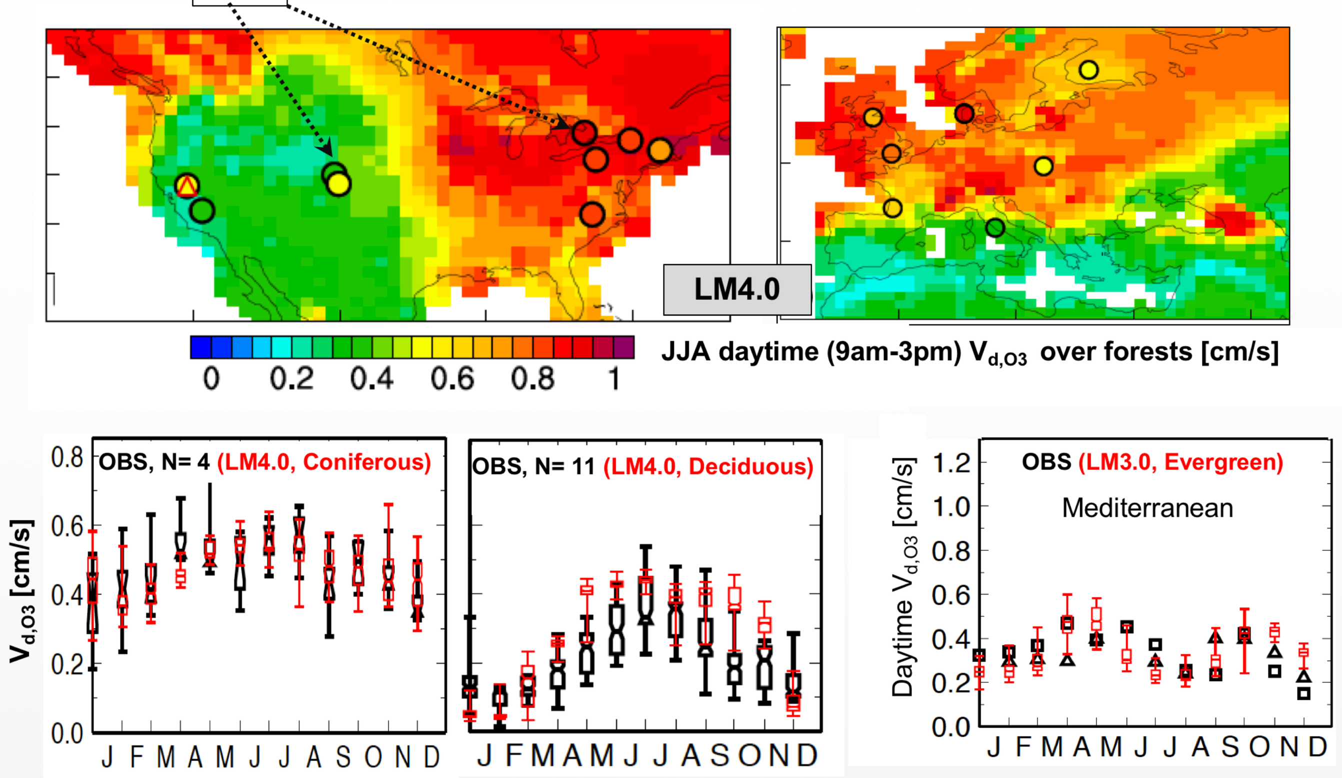


- Incorporated into GFDL's dynamic vegetation land models (LM3.0/LM4.0)
- Responding mechanistically to plant physiology, soil water availability (U_{max}/U_d), canopy air vapor pressure deficit (D_s), and atmospheric CO_2 concentration (C_i).

$$\bar{g}_s = max\left(\frac{m\bar{A}_n}{(C_i-\Gamma_*)(1+D_s/D_0)}, g_{s,min}\right) \qquad \bar{\bar{g_s}} = \psi_w \psi_i \bar{g_s}$$

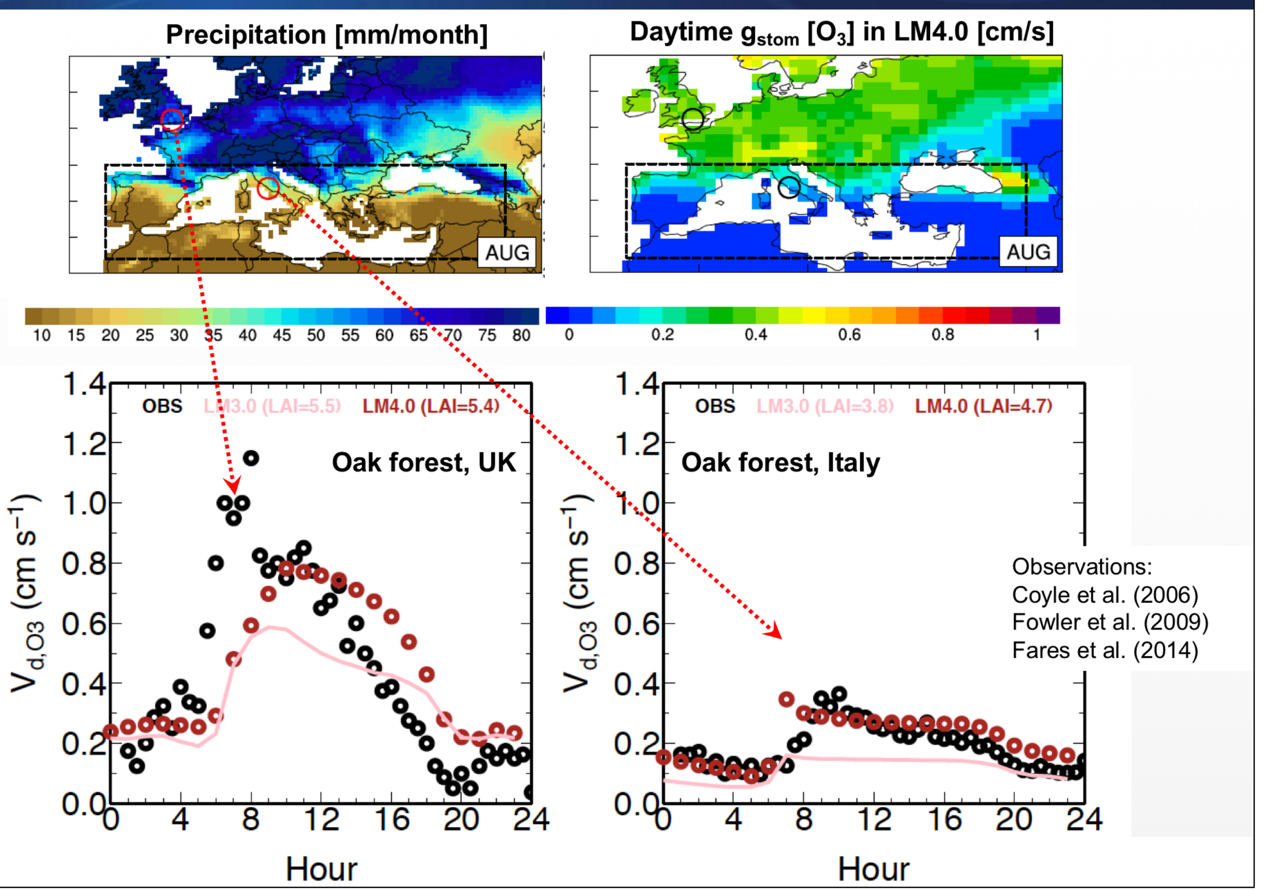
$$\psi_w = min(U_{max}/U_d, 1)$$

Seasonal climatology

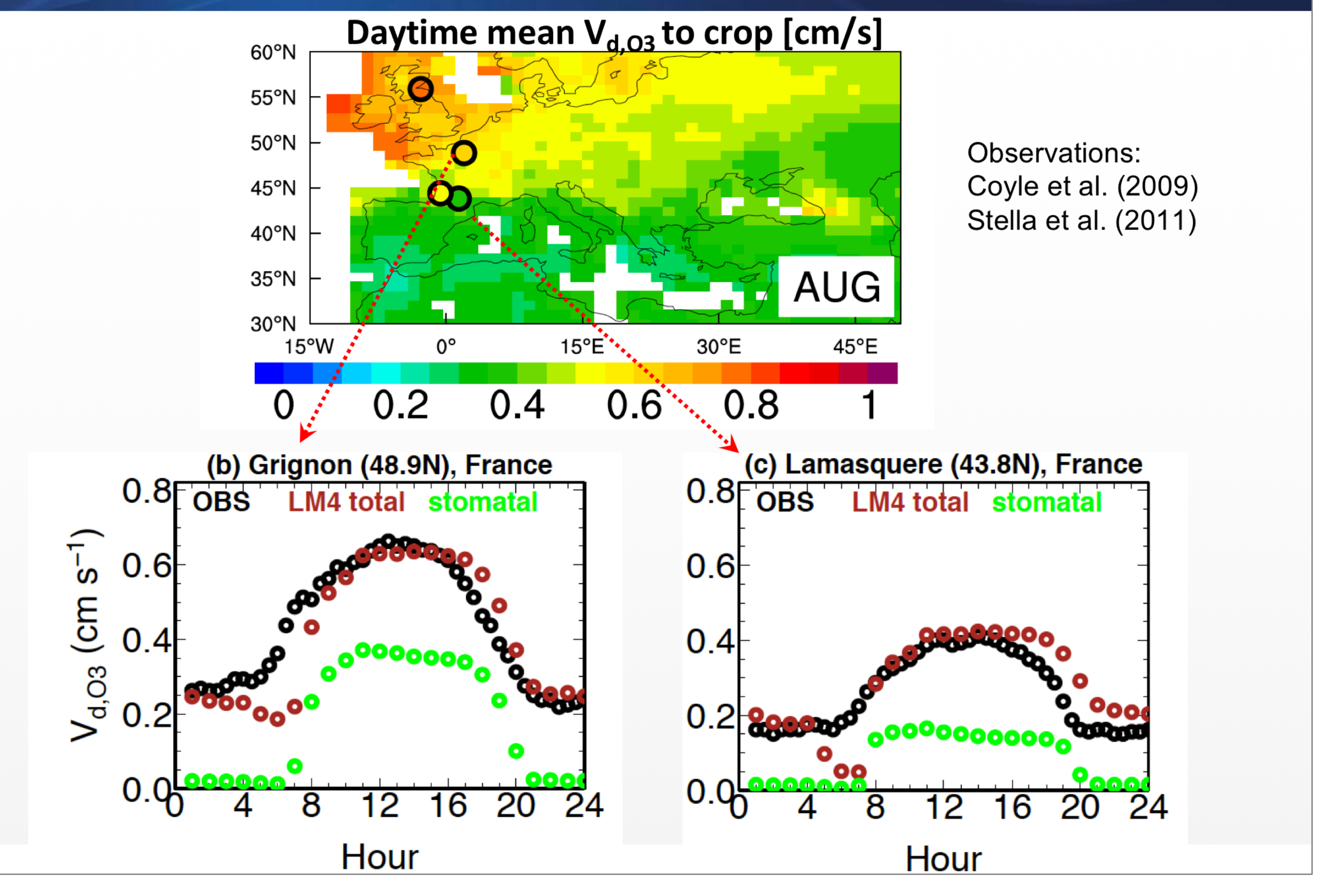


- Observations at 41 locations from 26 literature sources published during 1990-2018.
- Process-oriented model evaluation, e.g. drought stress (Lin et al., GBC2019)

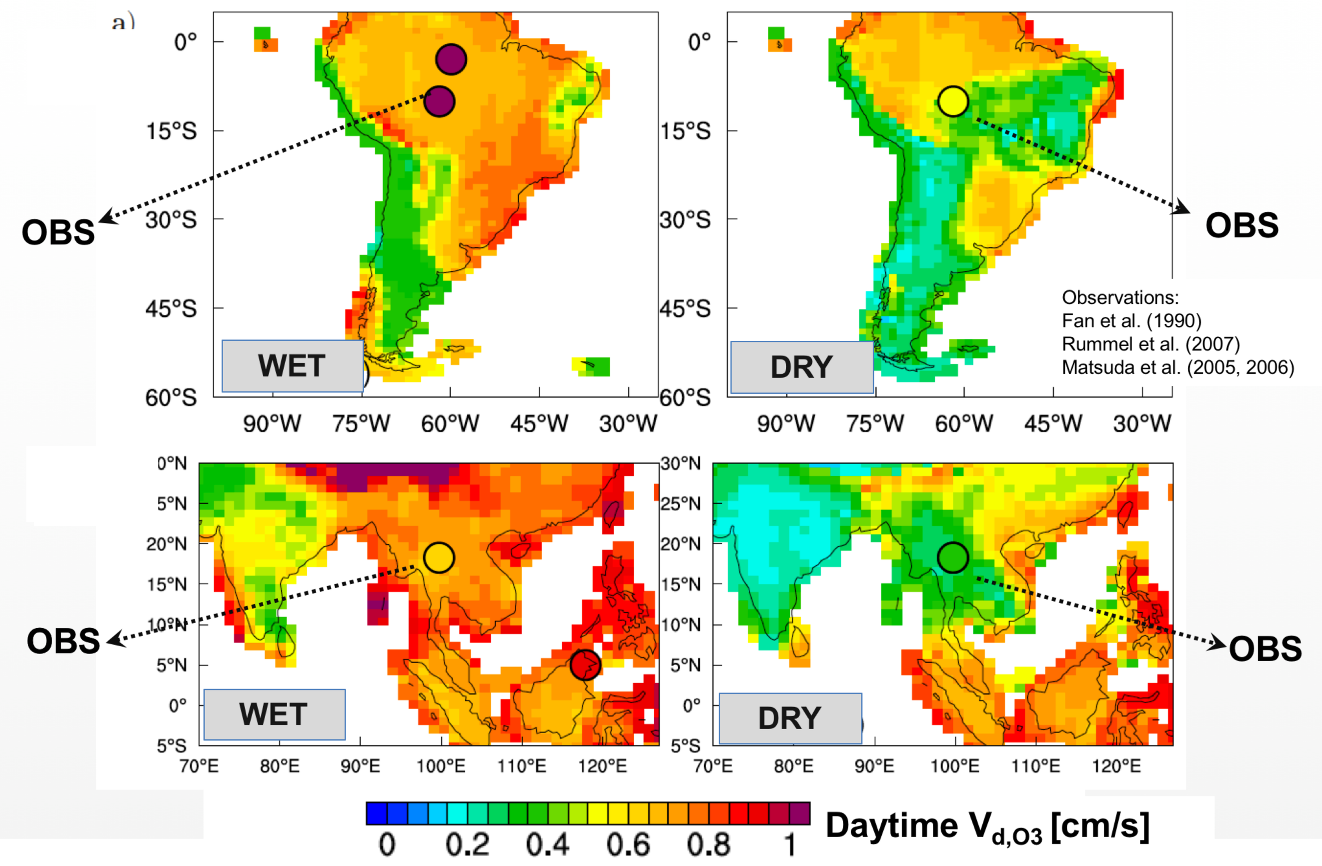
Reduced O_3 removal in Mediterranean dry summer



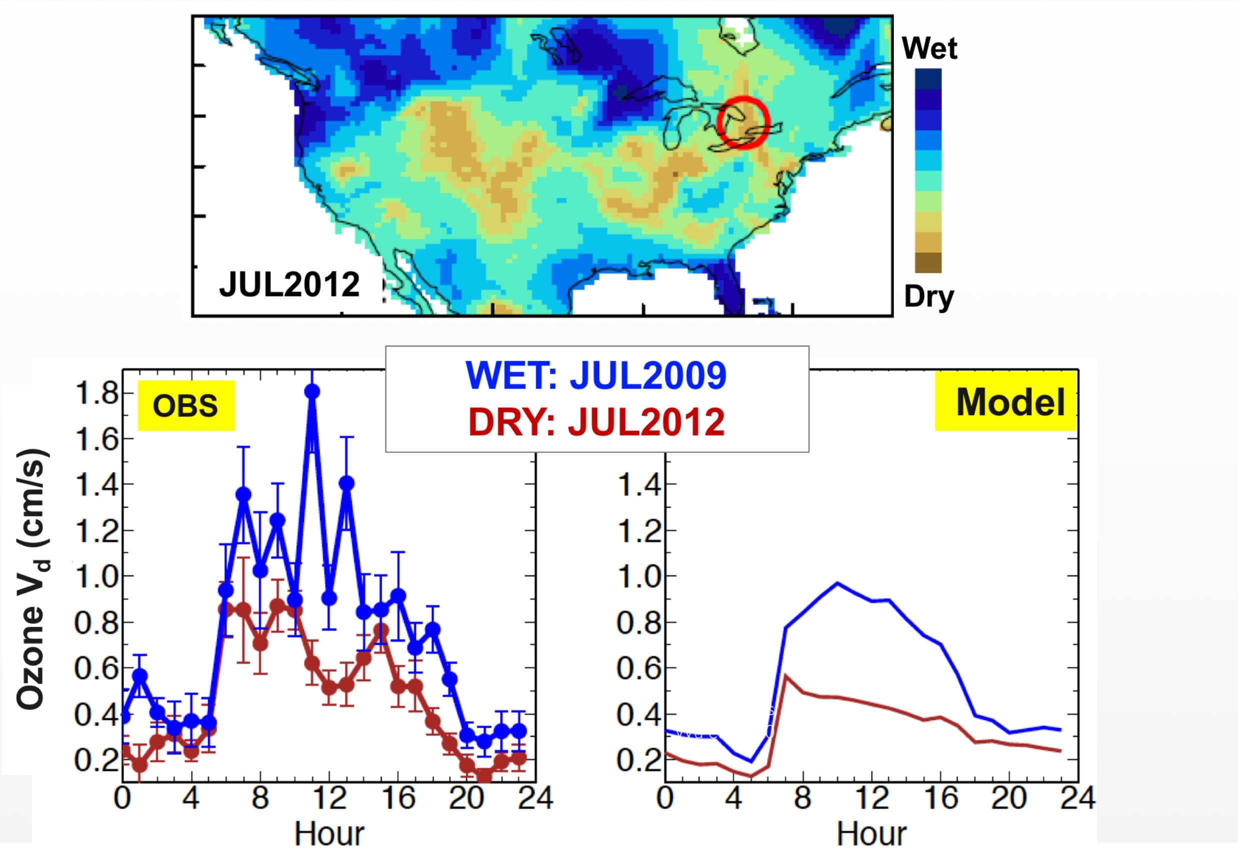
Reduced O_3 removal in Mediterranean dry summer



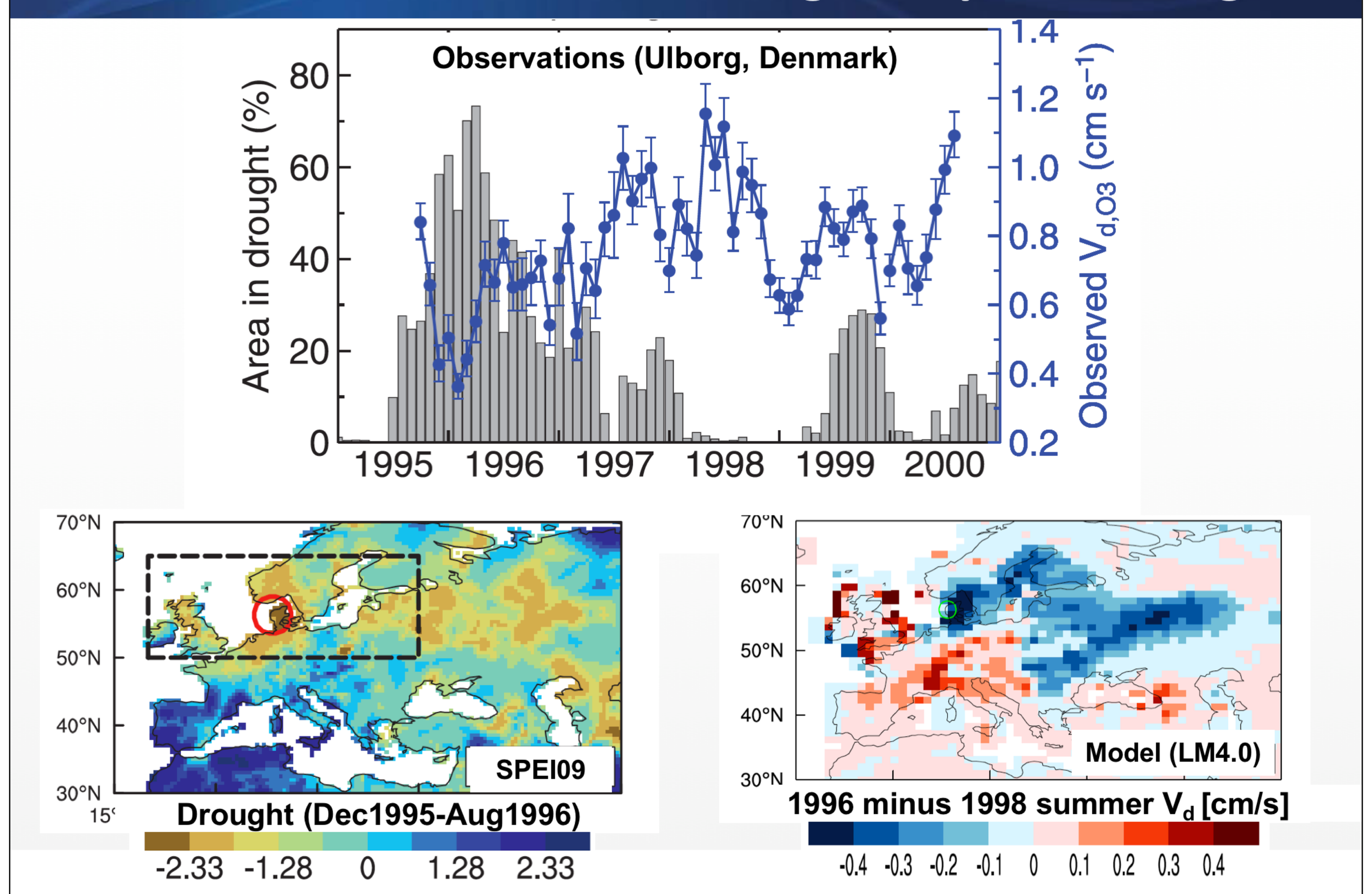
Tropical forests during wet vs. dry season



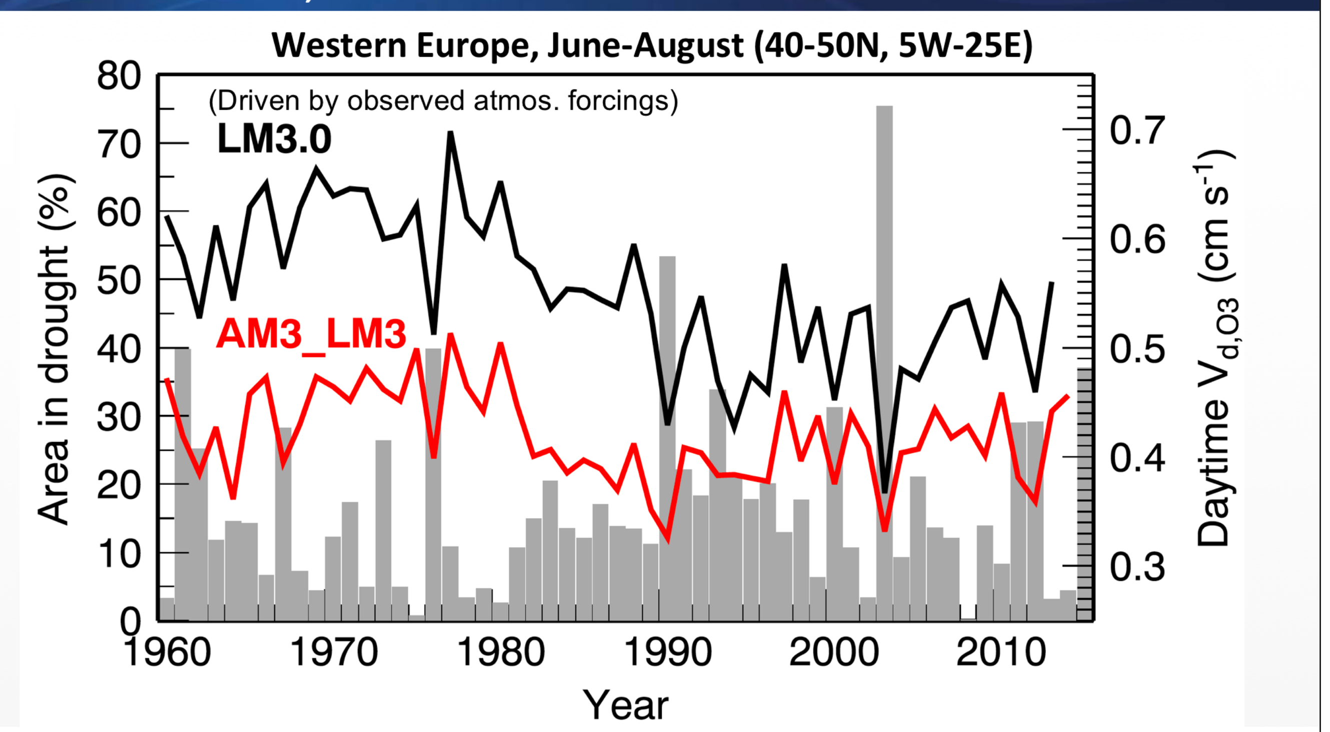
Marked reductions in $V_{d,O3}$ during U.S. droughts



Reduced ozone removal during European droughts

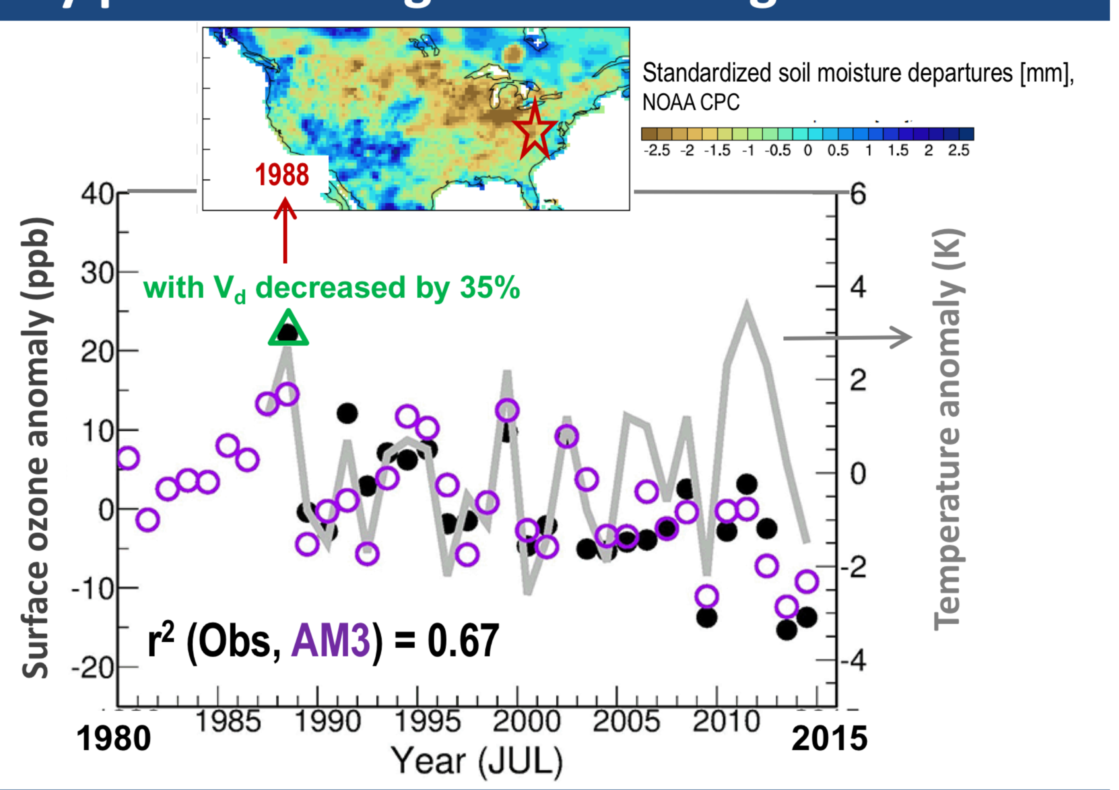


Strong $V_{d,O3}$ interannual variability in Europe



- Modulated by drought and stomatal closure
- IAV is a factor of 2 weaker in LM3 coupled with AM3, due to difficulty in representing drought extremes (e.g., 2003 event)

Ozone pollution worsens due to reduced uptakes by plants during severe drought



Lin M. et al. [Atmos. Chem. Phys., 2017]

TAKE-AWAYS & CHALLENGES

- Drought dress can cause 50-70% reductions in ozone uptakes by vegetation, affecting the observed surface ozone pollution extremes, interannual variability, and long-term trends.
- Dynamic vegetation land models with an interactive dry deposition scheme yield process insights.
- Future climate - air quality projections require improved representation of hydroclimate extremes and consideration of land-biosphere feedbacks.

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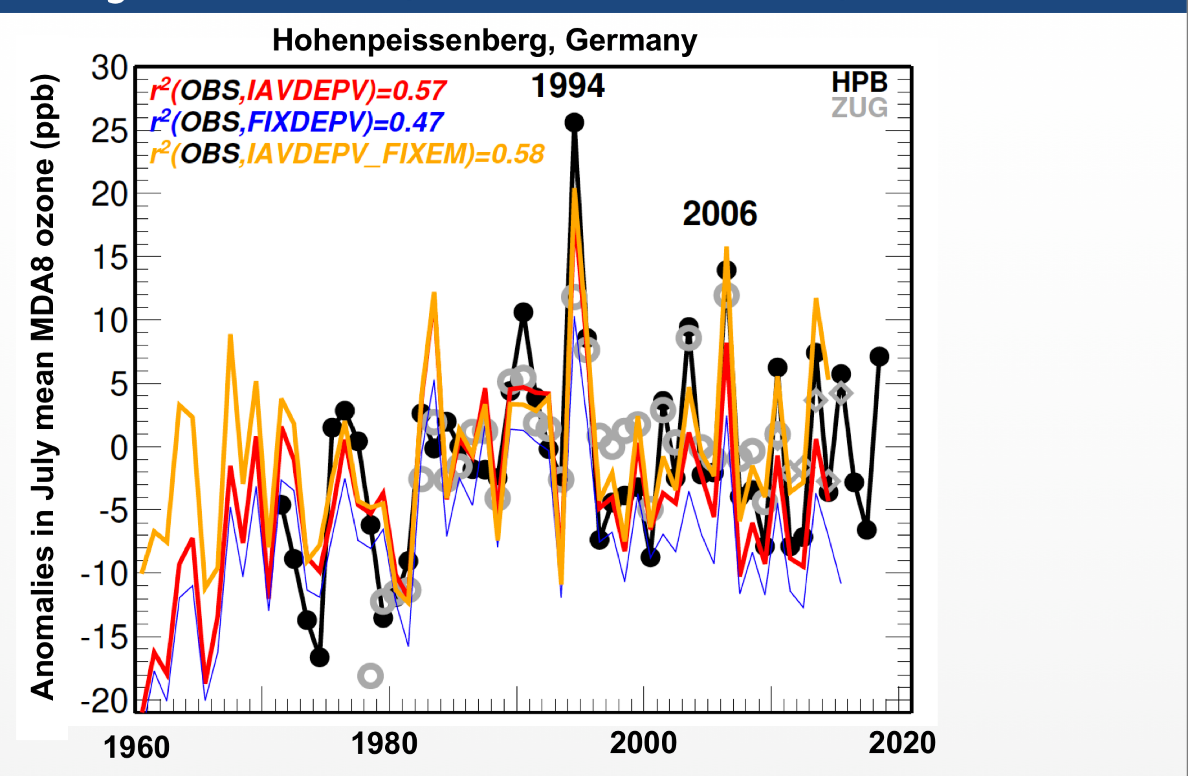
Increasing surface ozone in Europe due to reductions in O_3 removal by water-stressed plants



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