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ARTICLES

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Read here: https://rdcu.be/b3FE6

Vegetation feedbacks during drought exacerbate ozone air pollution extremes in Europe

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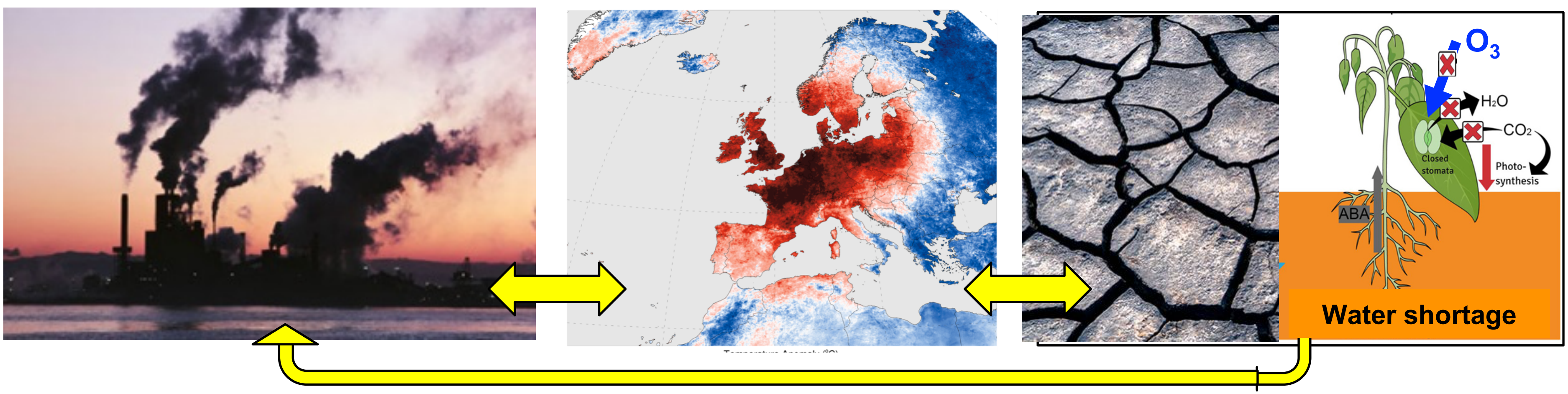
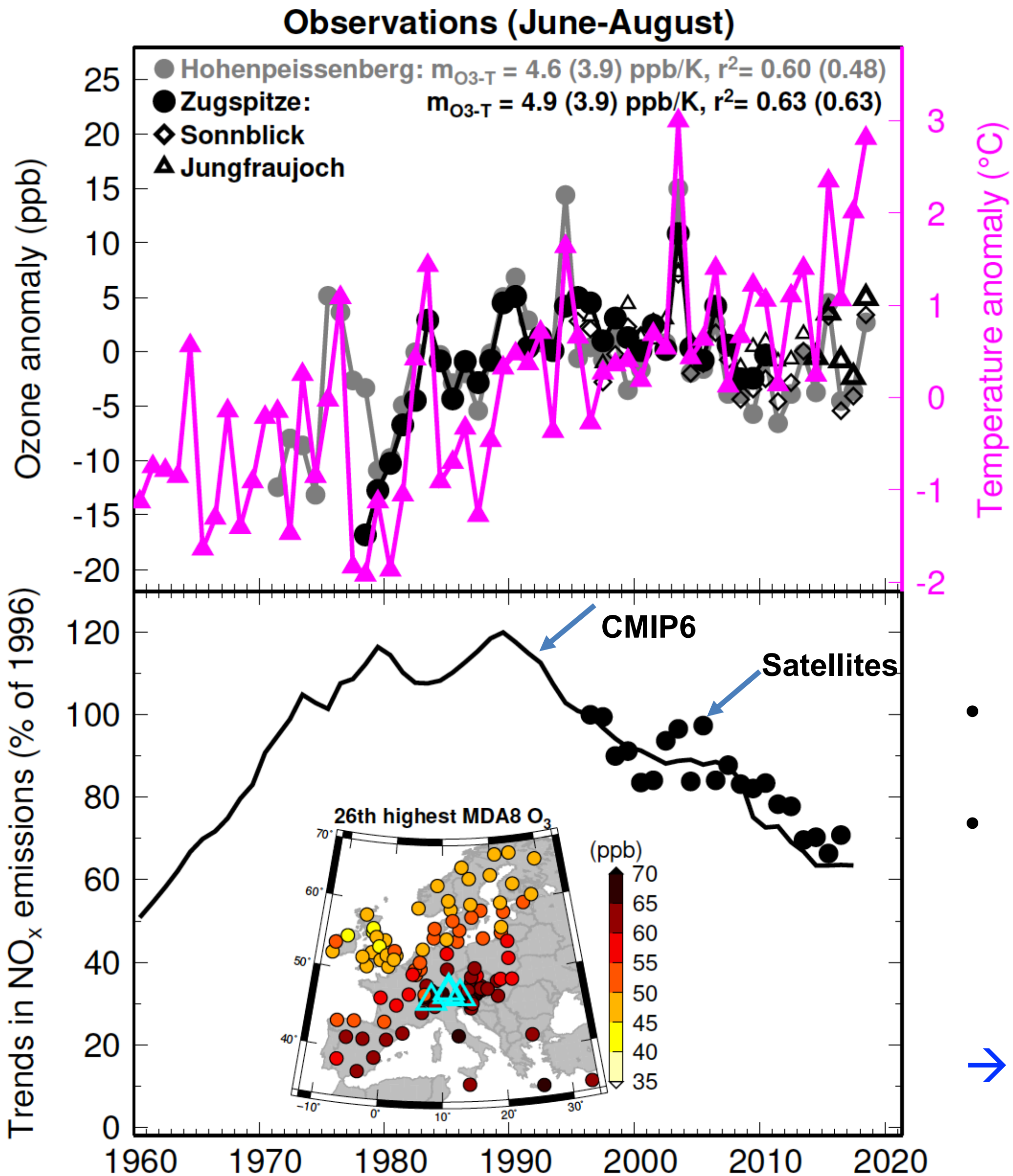
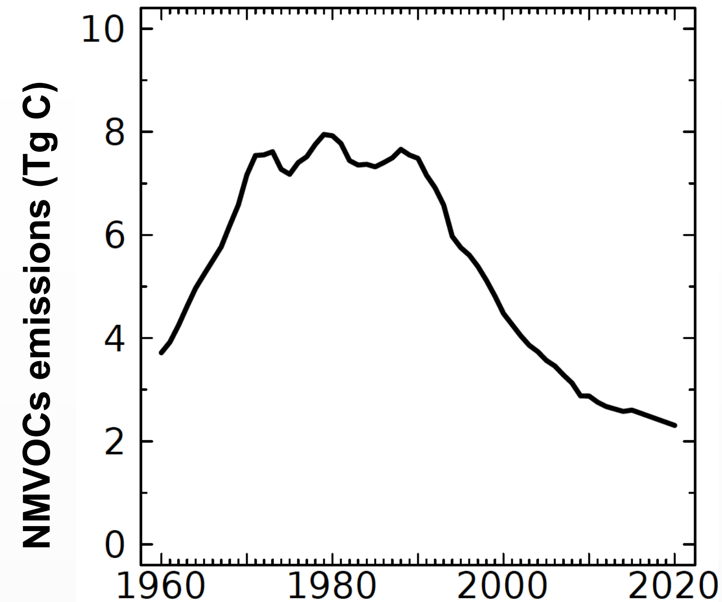


Contact: Meiyun.Lin@noaa.gov; Princeton University and NOAA GFDL

Why is ozone pollution persisting in Europe despite stringent controls on regional precursor emissions?



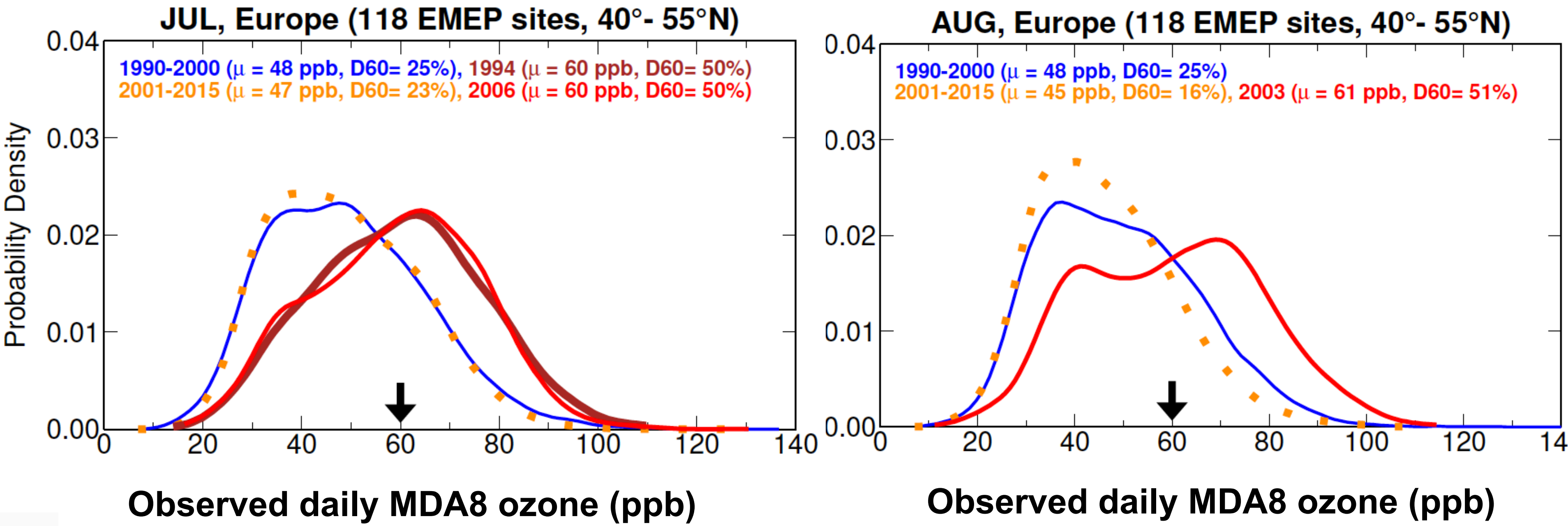


- Observed O_3 increases with rising surface air temperature
- Long-standing model challenges in representing the European O_3 trends [e.g., Lelieveld2000; Fusco2003; Lamarque2010; Koumoutsaris2012; Parrish2014]

→ **Unknown climate penalty feedback mechanism?**

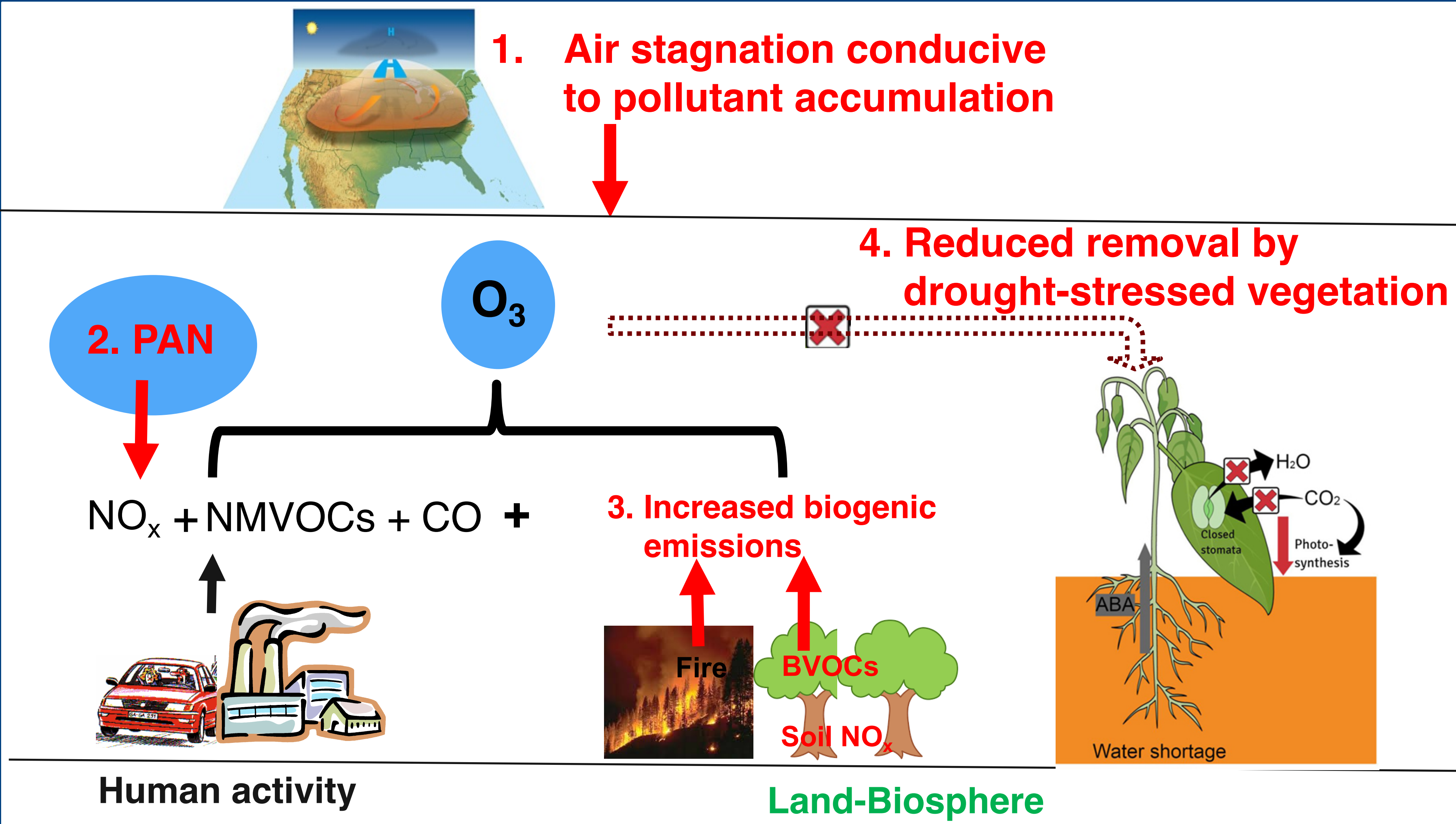
Lin M. et al. (Nature Climate Change, 2020)

Changes in surface ozone distribution in Europe



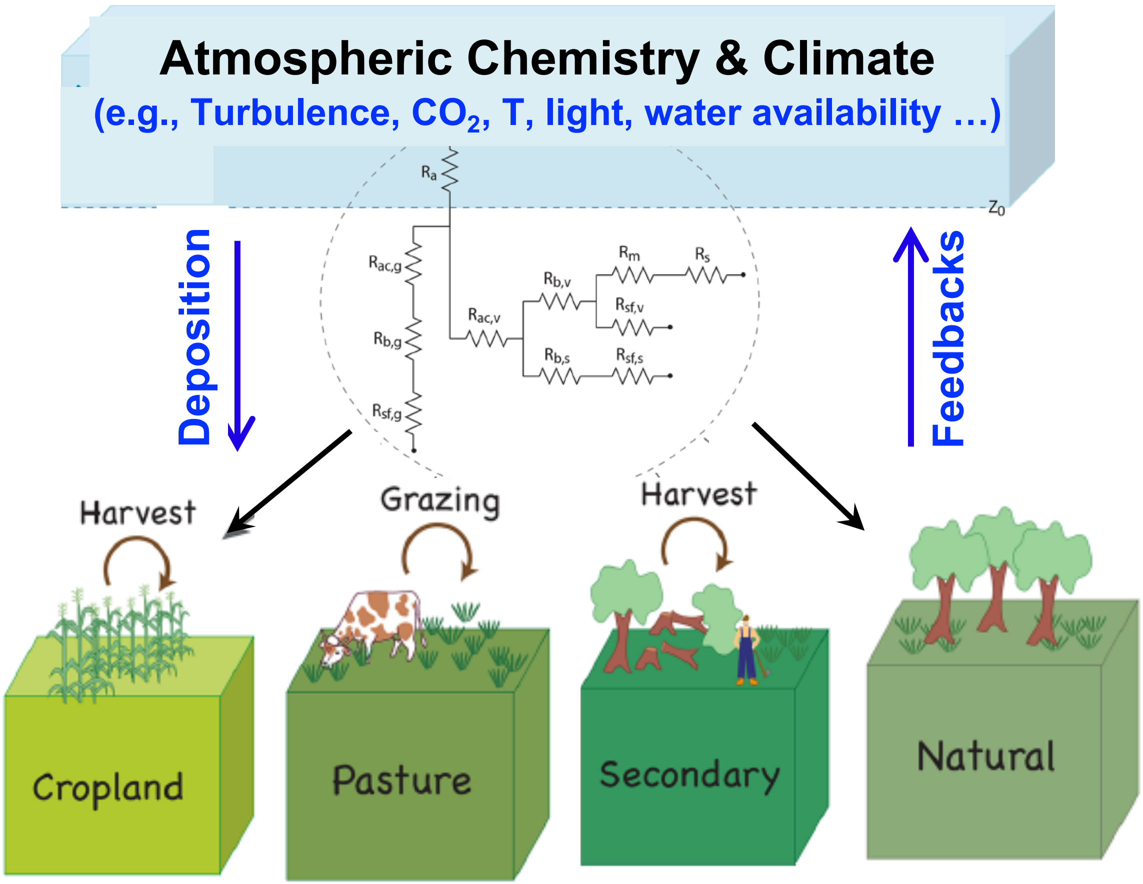
- Little change btw **1990-2000** and **2001-2015** despite precursor emission controls
- Substantial upward shifts during the historic heatwaves and drought of July 1994, August 2003, and July 2006, with events above the EU target (D60) double to triple the long-term average exceedances

How does ozone air quality respond to hot and dry spells?



- The impacts of drought-stressed vegetation are poorly understood
- The widely used Wesely deposition scheme does not account for these factors

Interactive dry deposition scheme in GFDL models

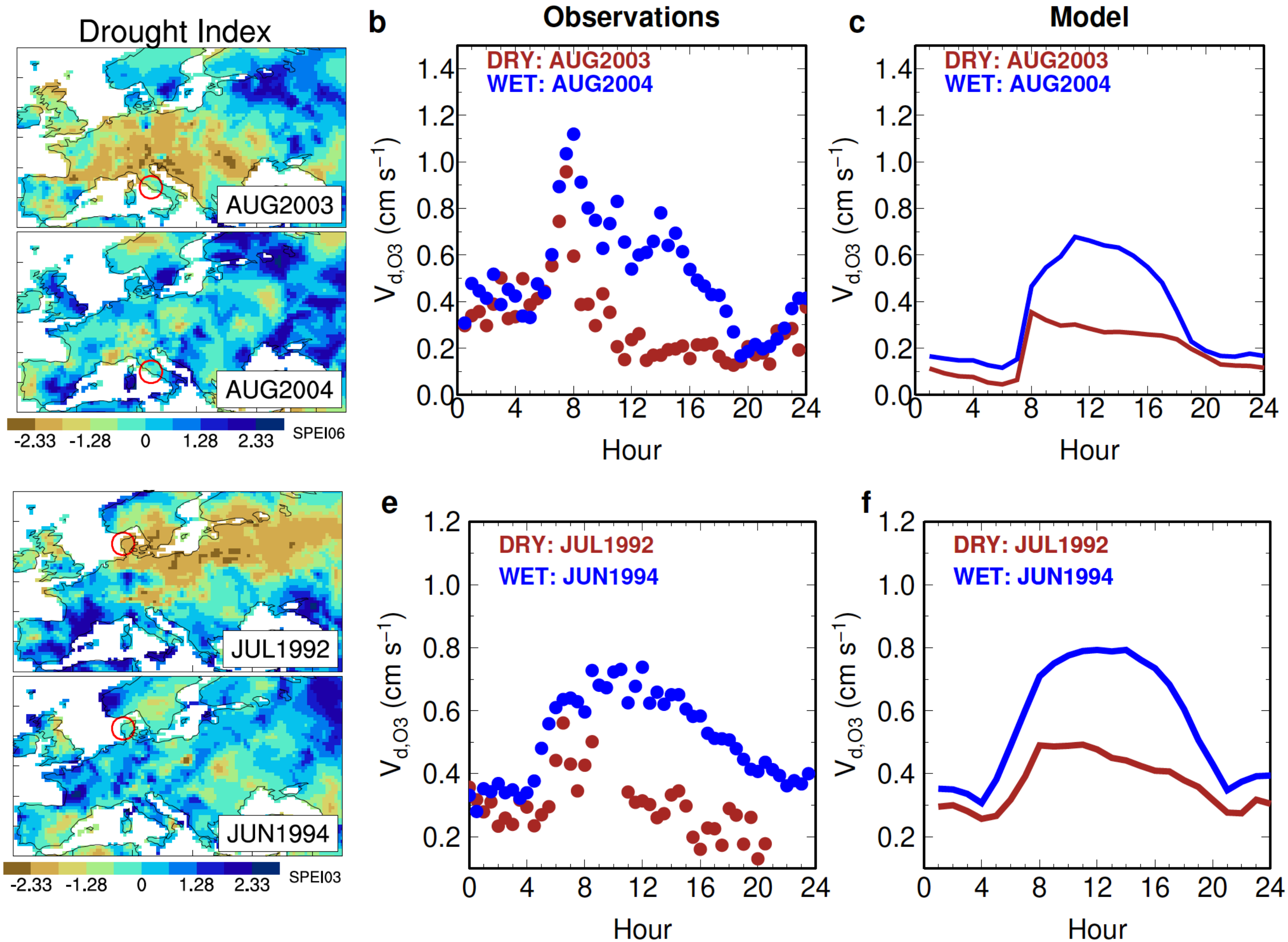


- **Incorporated into GFDL's dynamic vegetation land models** [Shevliakova et al., 2009; Paulot et al., 2018]
- **Stomatal deposition responds mechanistically to photosynthesis (A_n), soil water availability (φ_w), vapor pressure deficit (D_s), and atmos. CO_2 concentration (C_i).**

$$R_{stom} = \frac{\sqrt{\frac{M(O_3)}{M(H_2O)}}}{g_s(H_2O)} \qquad g_s(H_2O) = max\left(\frac{m\bar{A}_n}{(C_i - \Gamma_*)(1 + D_s/D_0)}, g_{s,min}\right) \cdot \psi_i \cdot \psi_w \cdot LAI$$

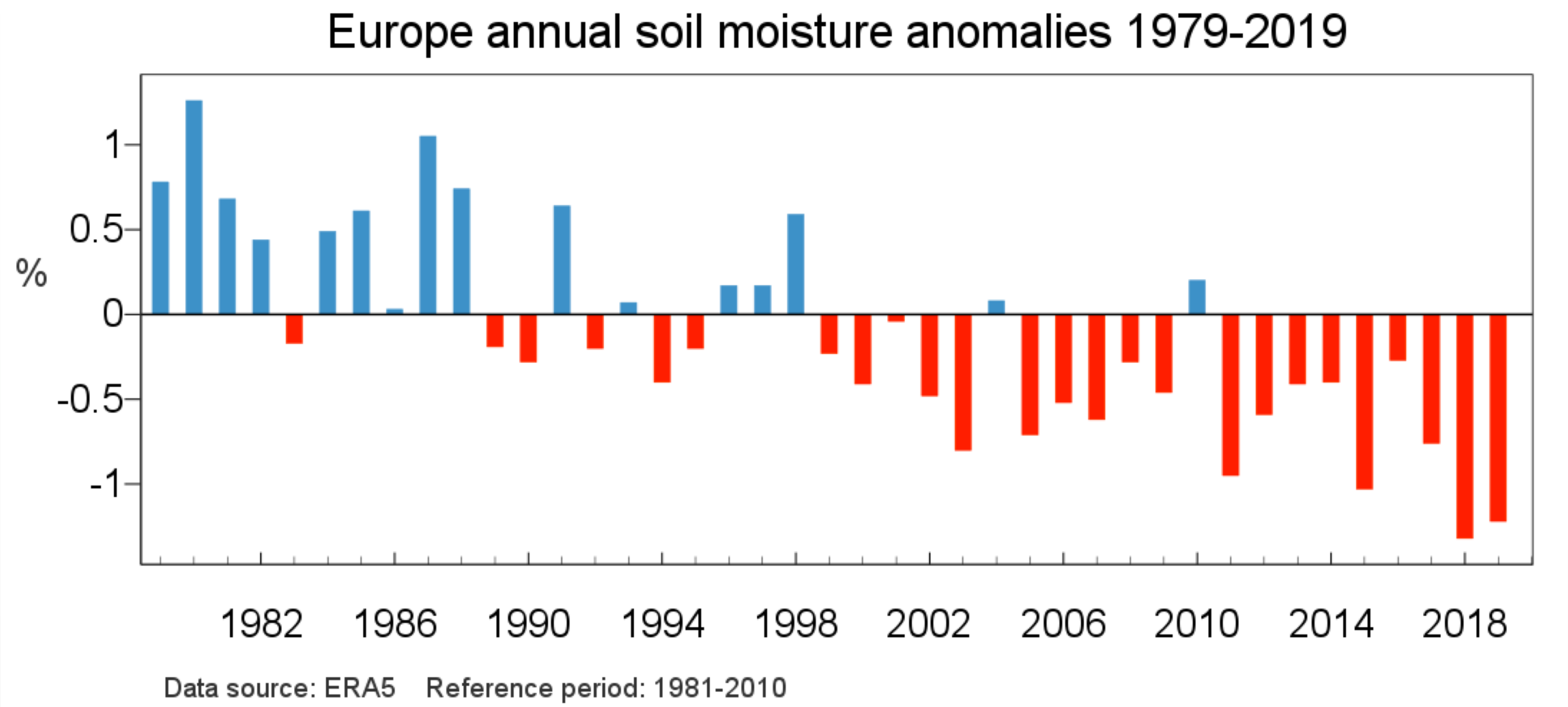
Read Lin M. et al. (Global Biogeochemical Cycles, 2019) for more model details

Observed and modeled reductions in O_3 removal by forests during drought

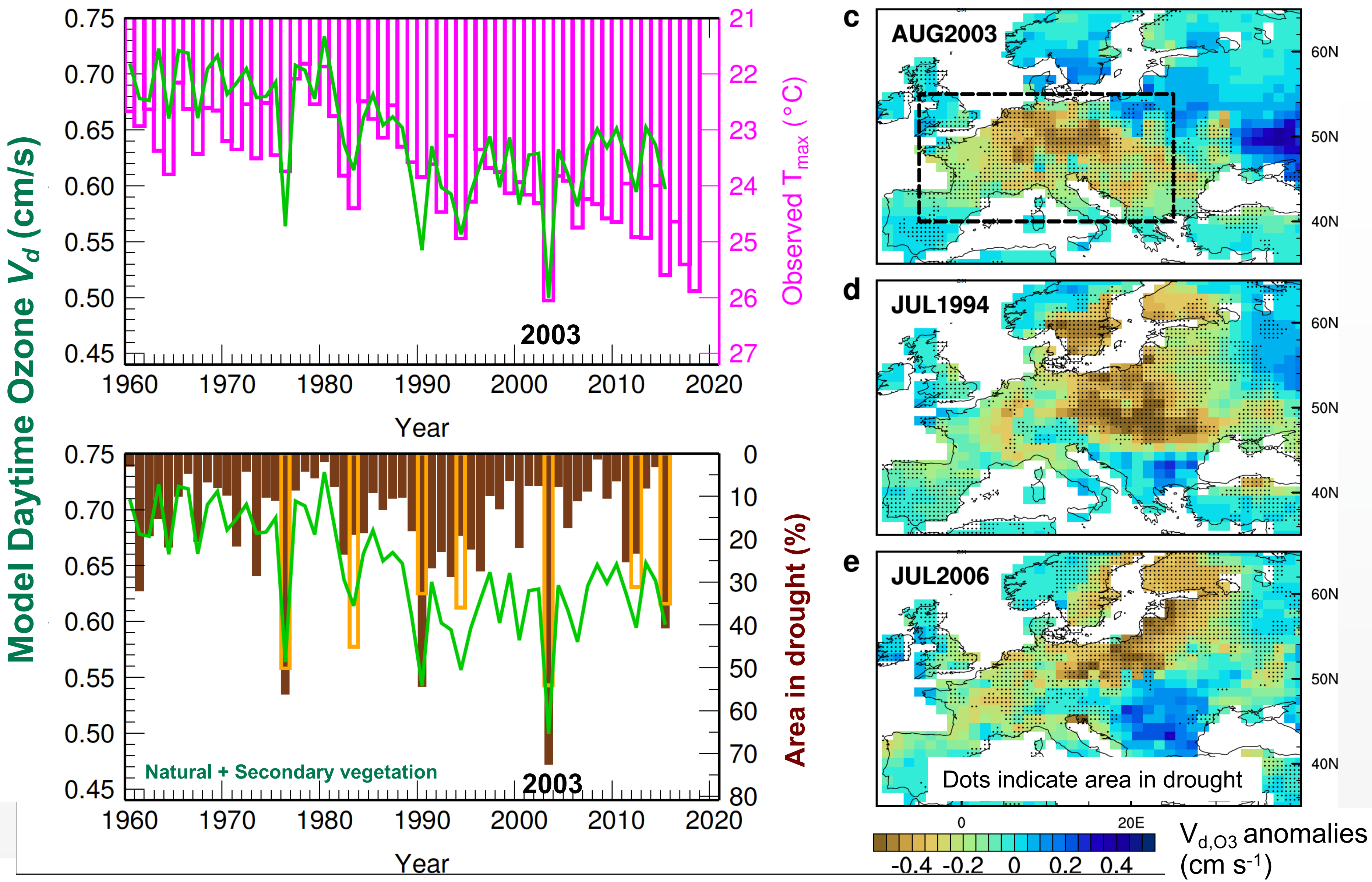


Lin M. et al. (Nature Climate Change, 2020)

Soil drying in Europe over the last four decades

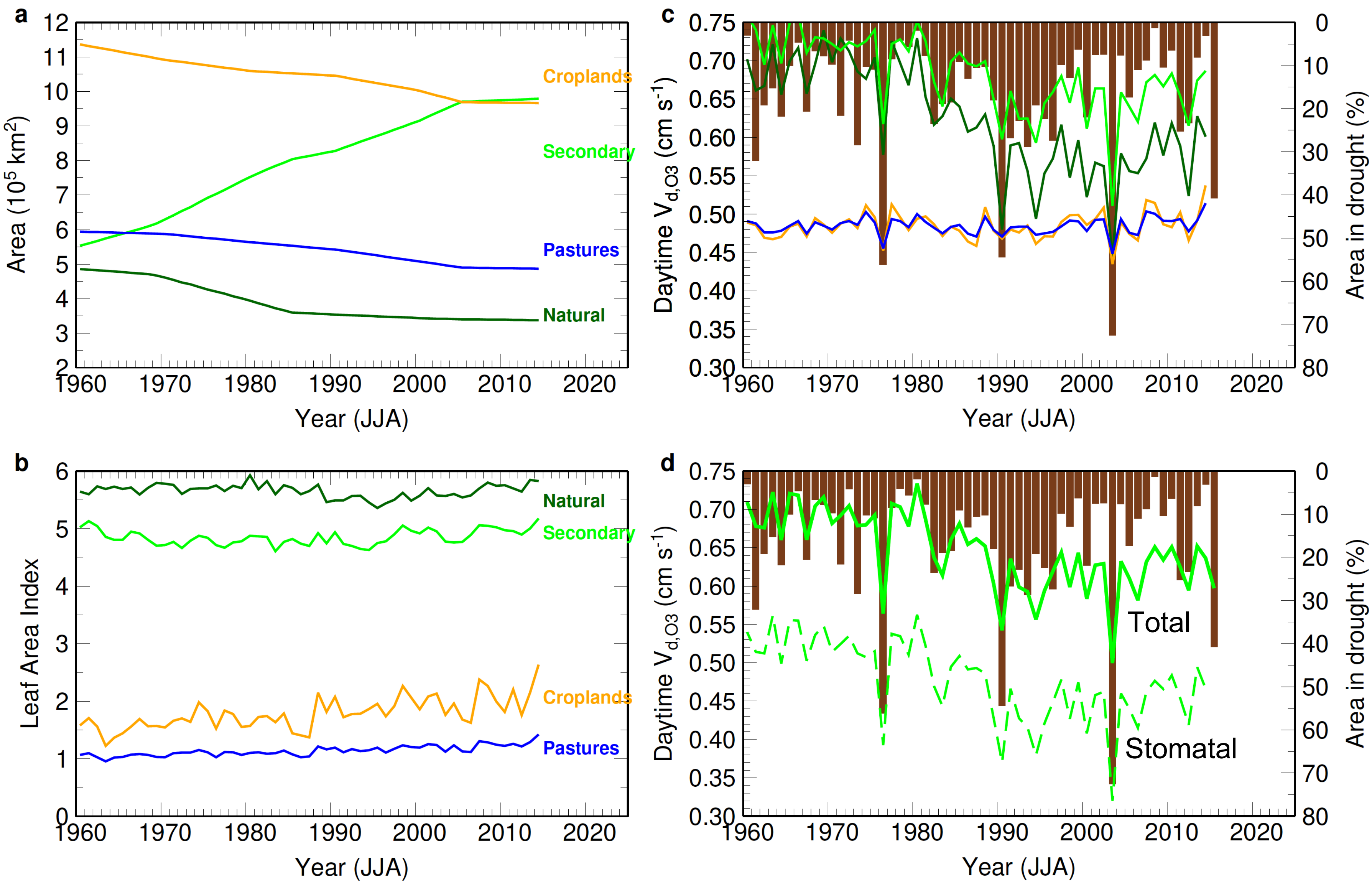


Declining ozone removal by drought-stressed vegetation over the last four decades



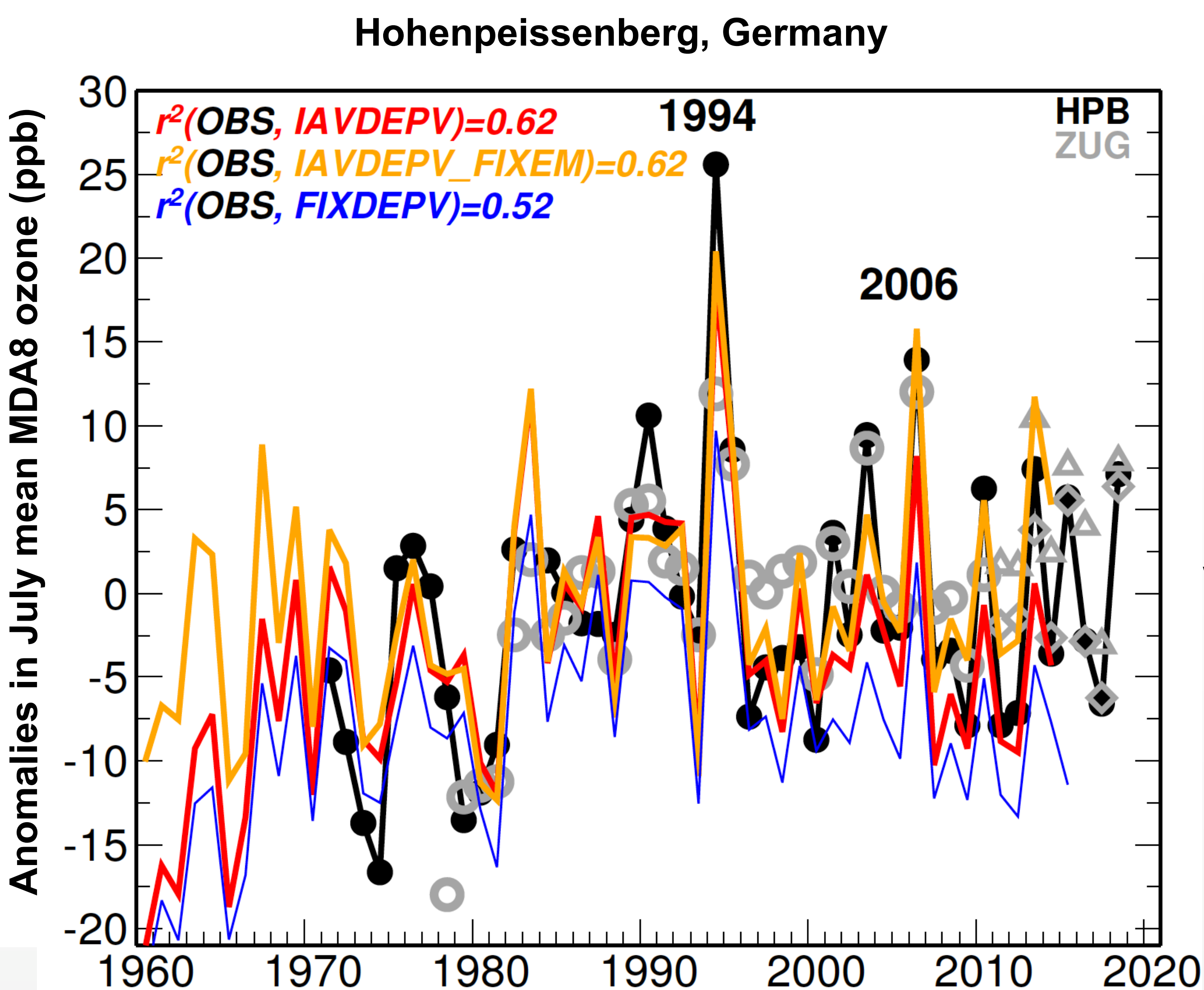
Lin M. et al. (Nature Climate Change, 2020)

Declining ozone removal due to stomatal closure under soil drying as opposed to land use changes



Lin M. et al. (Nature Climate Change, 2020)

Impacts of interactive dry deposition on surface air quality

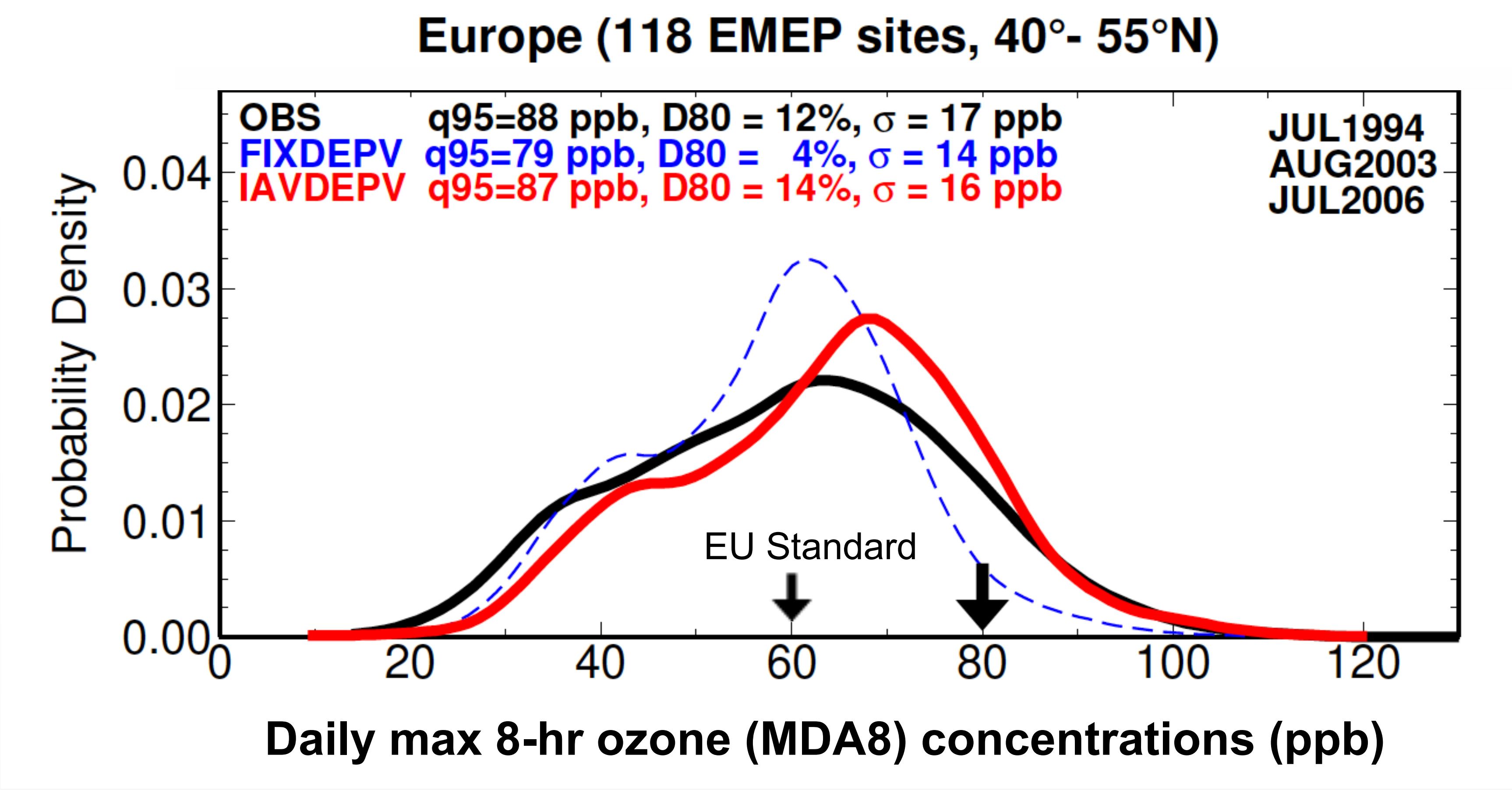


IAVDEPV_FIXEM: IAVDEPV under 1980 high emission conditions

IAVDEPV: Ozone V_d varying with climate and vegetation state

FIXDEPV: Ozone V_d held constant at 1960 levels

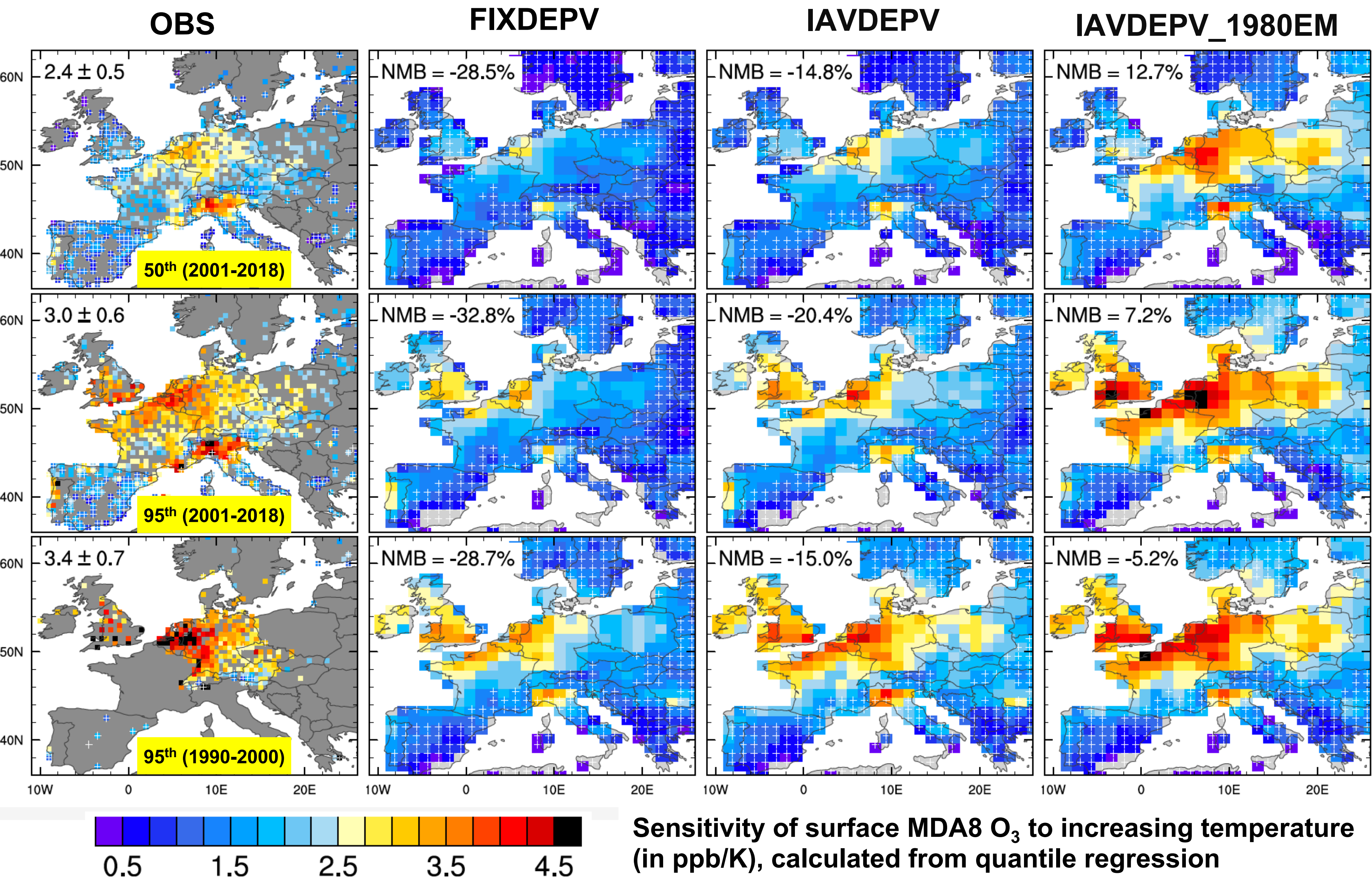
Reduced ozone removal by drought-stressed vegetation worsens the most severe ozone pollution episodes



- **Accounting for vegetation feedbacks (IAVDEPV) leads to a three-fold increase in high-O_3 events above 80 ppb (D80), in good agreements with OBS.**

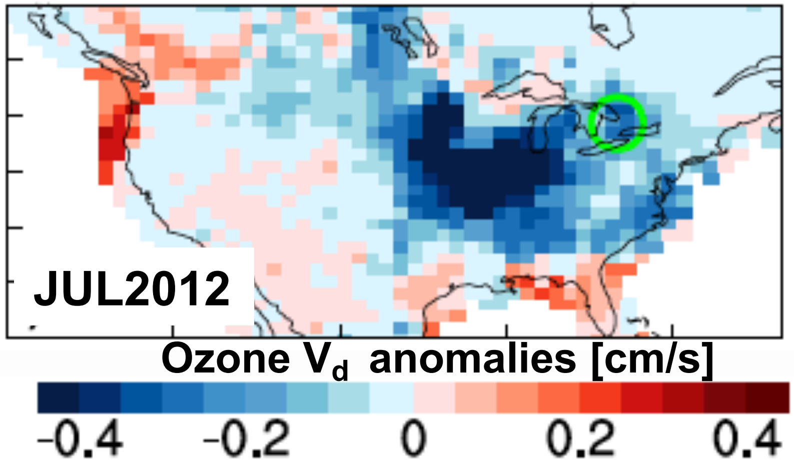
Lin M. et al. (Nature Climate Change, 2020)

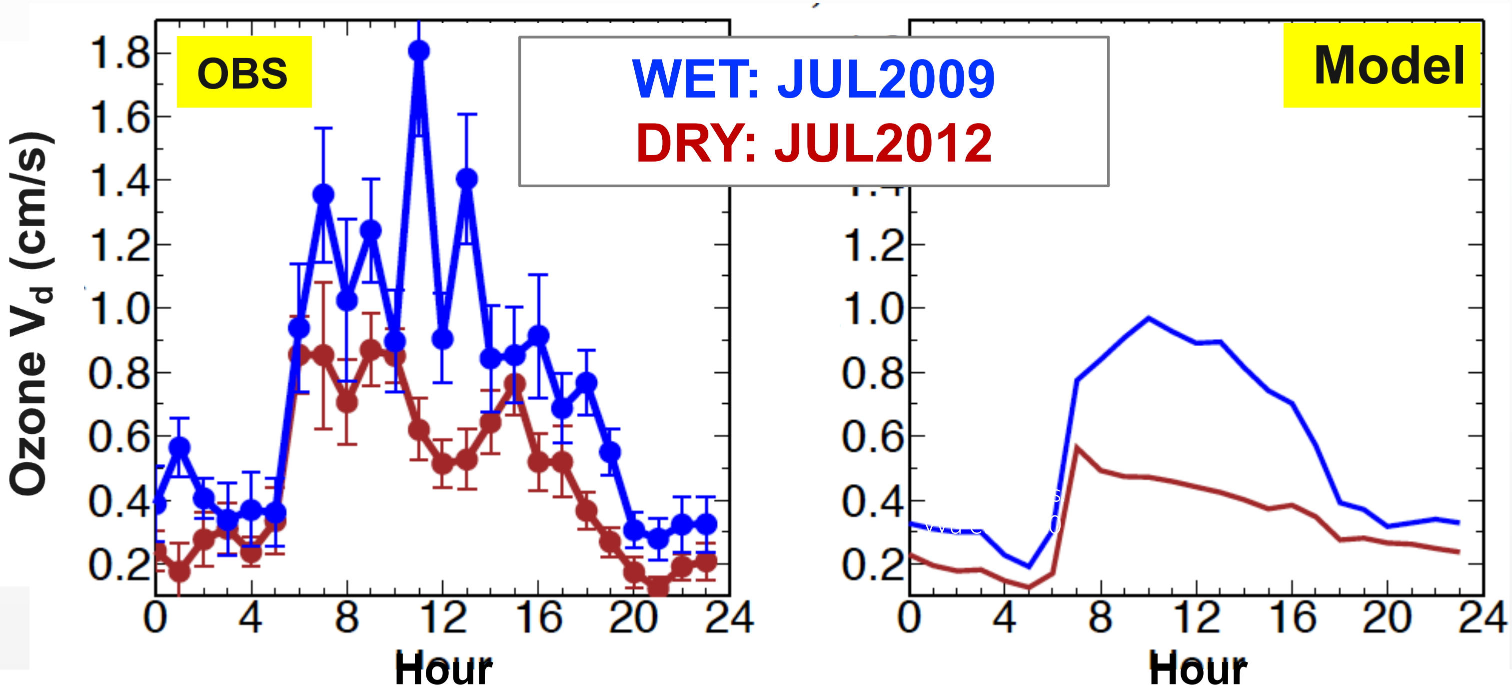
Vegetation feedbacks exacerbate climate penalty on ozone extremes



Sensitivity of surface MDA8 O_3 to increasing temperature (in ppb/K), calculated from quantile regression

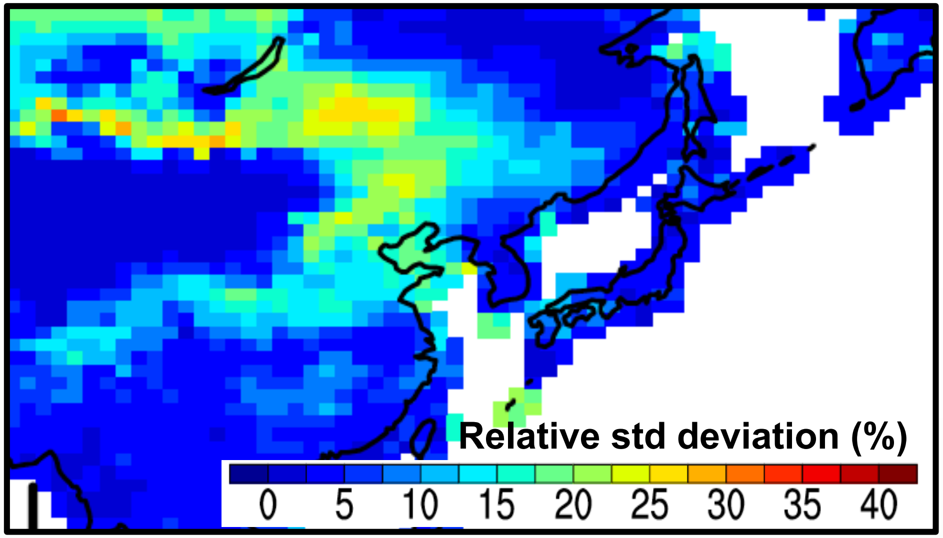
Marked reductions in O_3 removal by vegetation during N. America's historic heatwave/drought of 2012



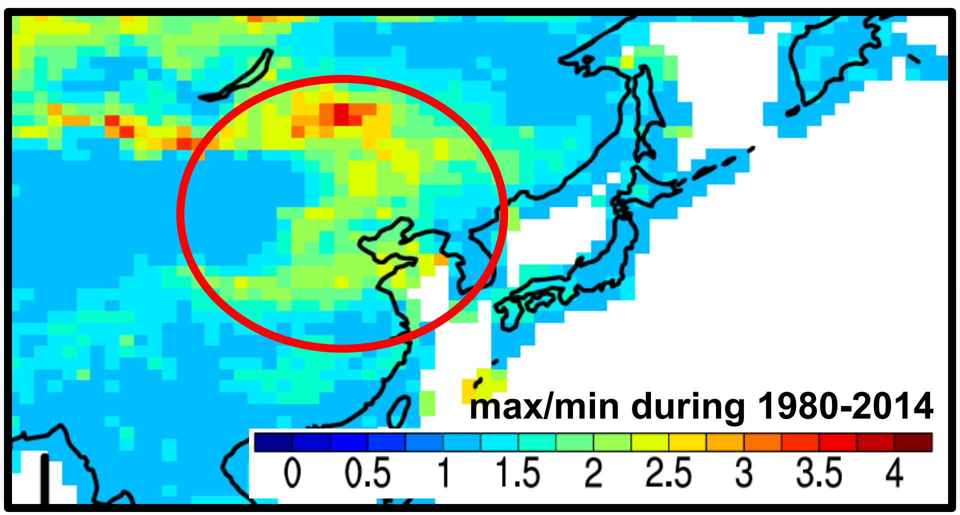


Read Lin M. et al. (Global Biogeochemical Cycles, 2019) for more details

Large interannual variability of ozone V_d in the semi-arid, highly polluted central eastern China

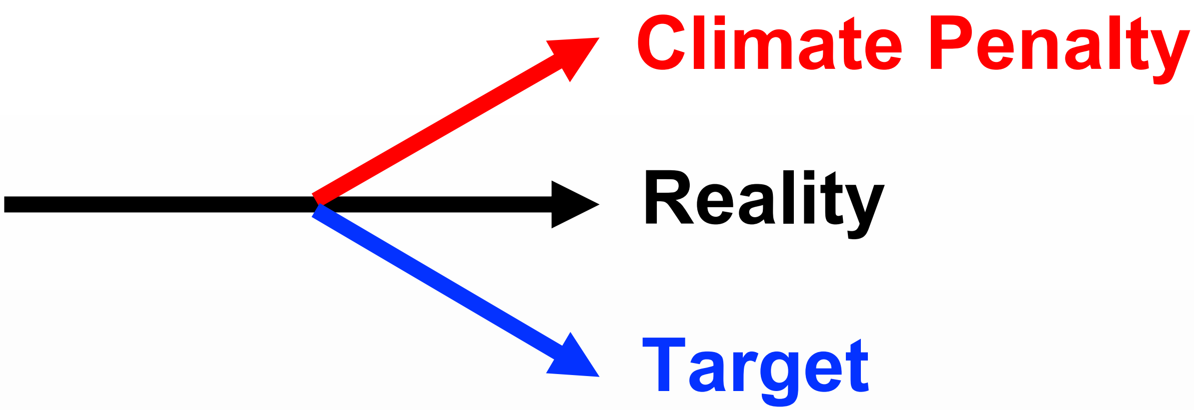


Interannual variability of June-August daytime mean ozone V_d over natural and secondary vegetation in GFDL LM4.0 over the last 35 years (1980-2014) expressed as the relative standard deviation (top) and the ratios of maximum and minimum values (bottom)



Monthly mean $V_{d,O3}$ for the highest years is two to three times that of the lowest, with significant implications for ozone air pollution extremes in this region

TAKE-HOME MESSAGES



- **Accounting for land-biosphere feedbacks during drought is central to determining extreme pollution events in Europe and other midlatitude populated regions.**

- **The ozone climate penalty may be significantly larger than estimated by current generation CCMs since these models typically do not include the drought-vegetation feedbacks.**

- **As hot and dry summers are expected to increase over the coming decades, effective emissions policies must consider the drought-vegetation feedbacks**

For more information, please read the papers:

Lin, M. et al. (2020): ***Vegetation feedbacks during drought exacerbate ozone air pollution extremes in Europe***. Nature Climate Change, DOI:10.1038/s41558-020-0743-y (PDF)

Lin, M. et al. (2019): ***Sensitivity of ozone dry deposition to ecosystem-atmosphere interactions: A critical appraisal of observations and simulations.*** *Global Biogeochemical Cycles*, **33(10)**, 1264-1288, DOI:10.1029/2018GB006157 (PDF)

Lin, M. *et al.* (2017): ***U.S. surface ozone trends and extremes from 1980 to 2014: Quantifying the roles of rising Asian emissions, domestic controls, wildfires, and climate,*** *Atmospheric Chemistry and Physics, 17,* 2943–2970, *doi:* 10.5194/acp-17-2943-2017 (PDF)

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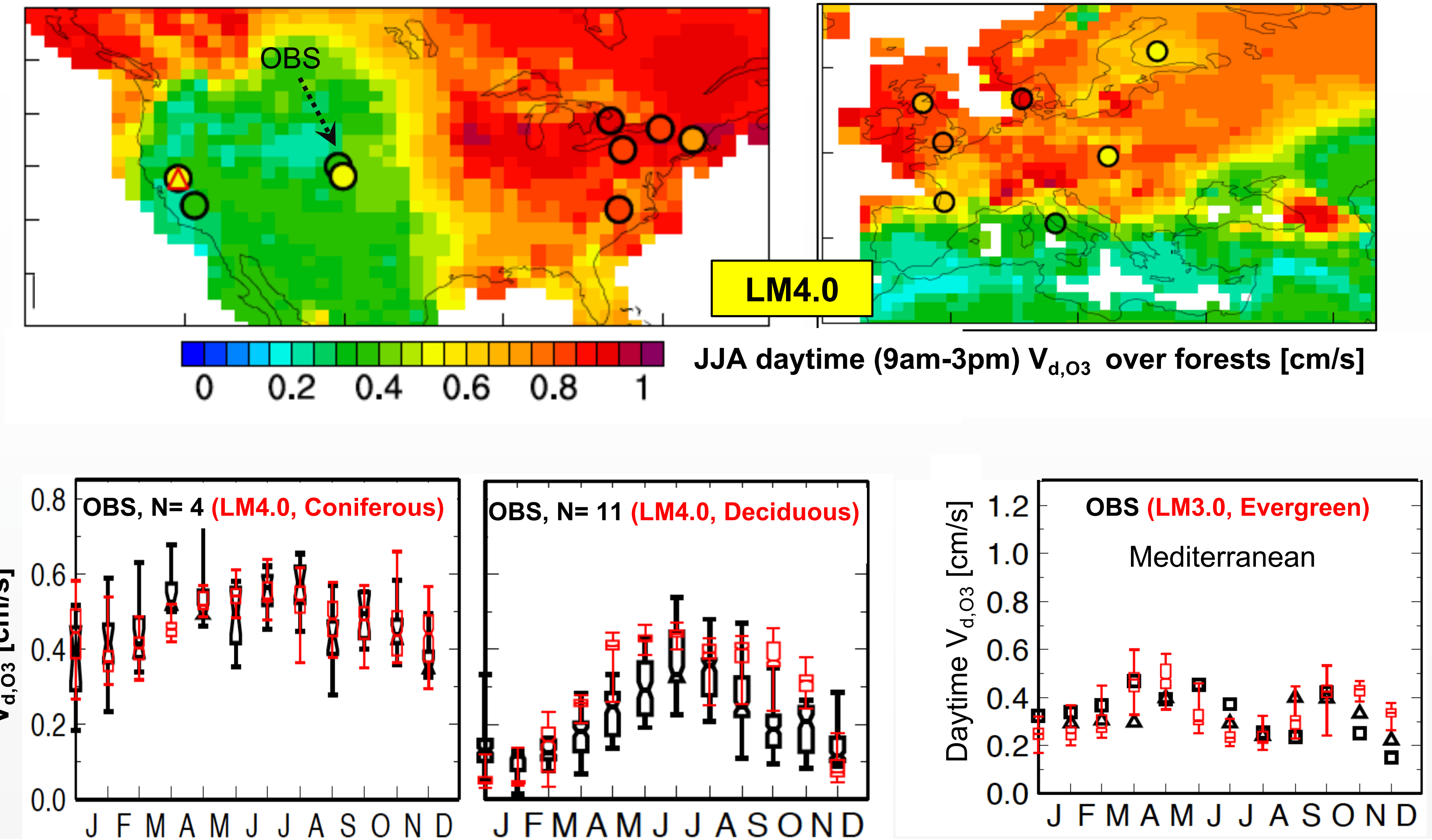
Observations and multi-decadal model simulations used in these studies are fully available upon request to Meiyun.Lin@noaa.gov

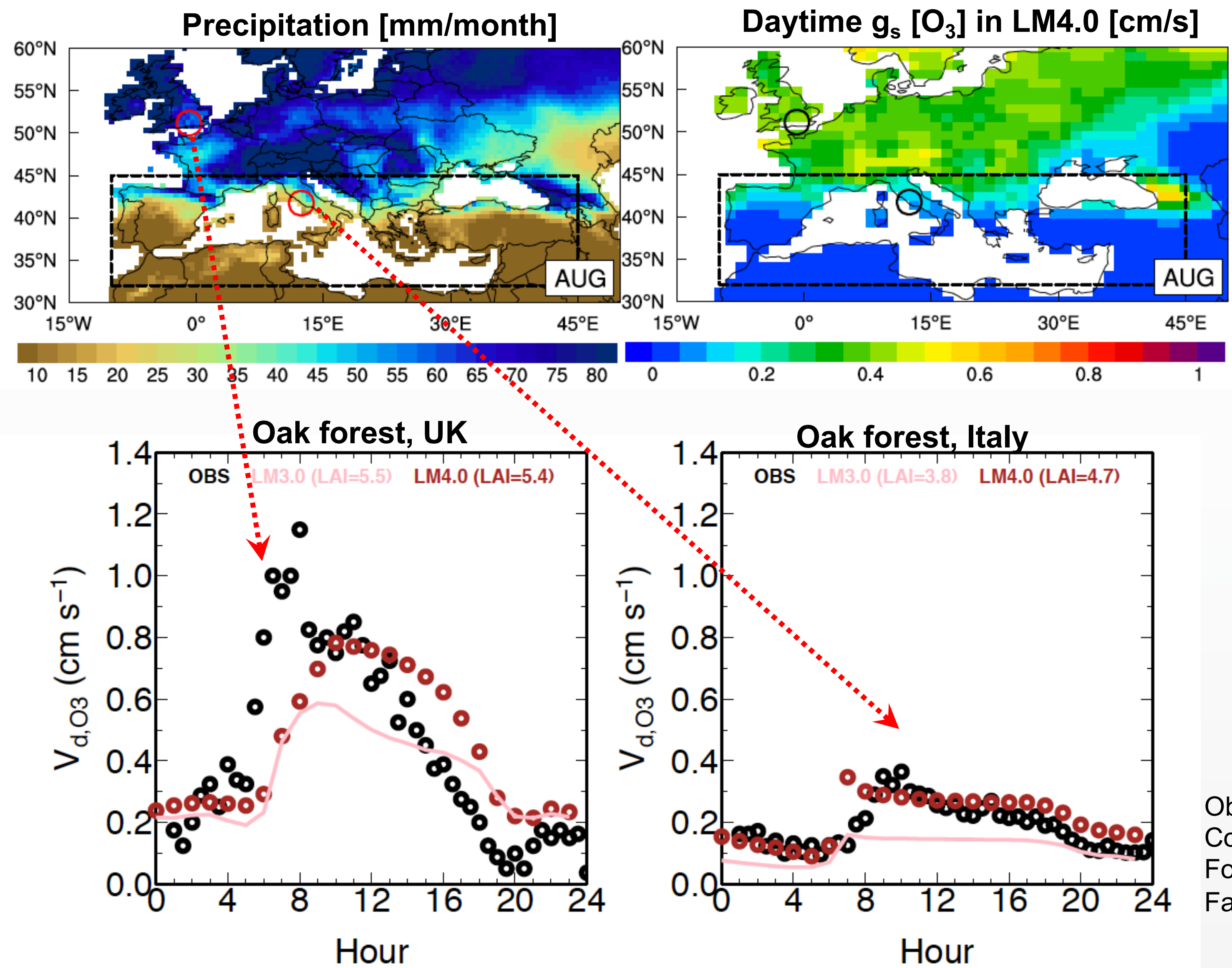
Bonus slides for model evaluation

Observed versus modelled ozone dry deposition velocities ($V_{d,O3}$)



- *Observations are compiled at 41 locations from 26 literature sources published during 1990-2018.*

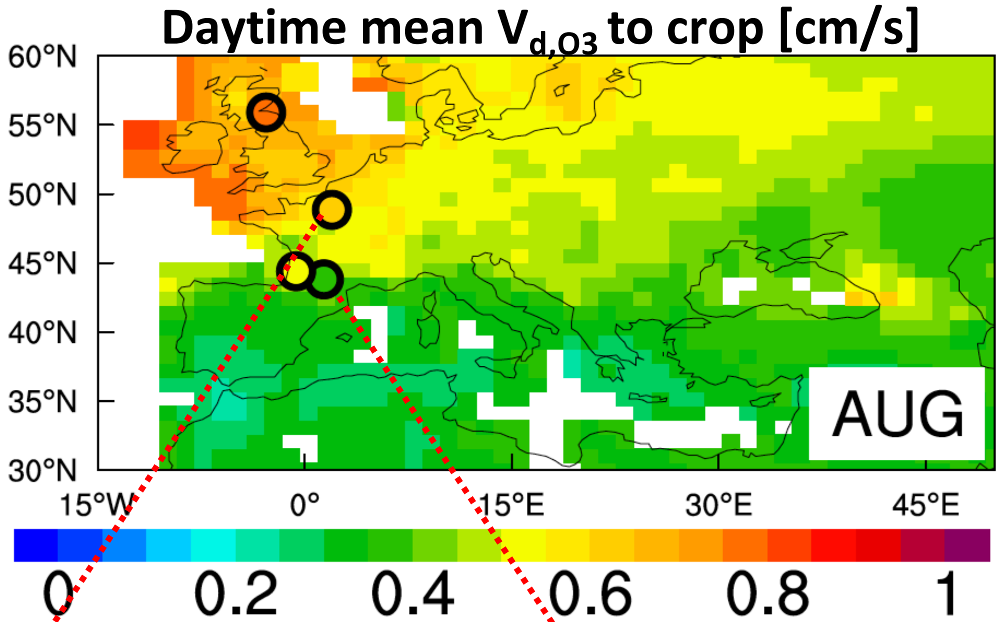
Reduced O_3 deposition over forests in Mediterranean summer climate

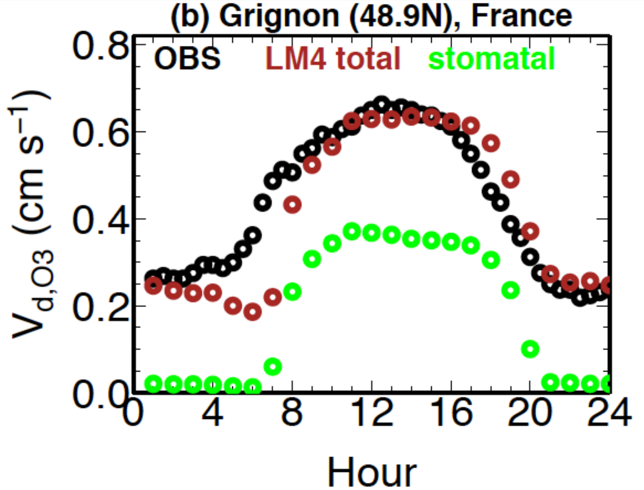


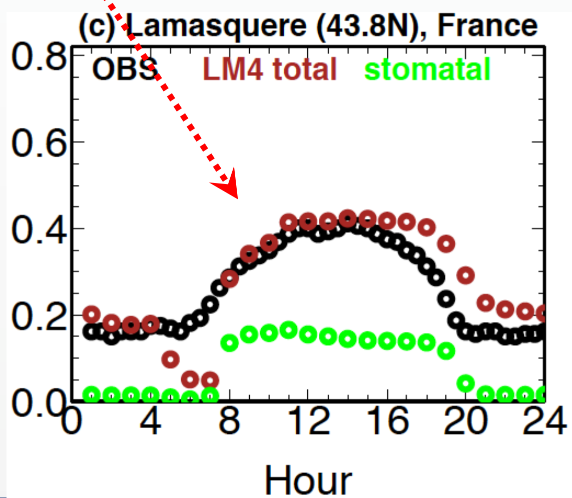
Observations:
Coyle et al. (2006)
Fowler et al. (2009)
Fares et al. (2014)

Lin M. et al. (Global Biogeochemical Cycles, 2019)

Reduced O_3 deposition over crops in Mediterranean summer climate



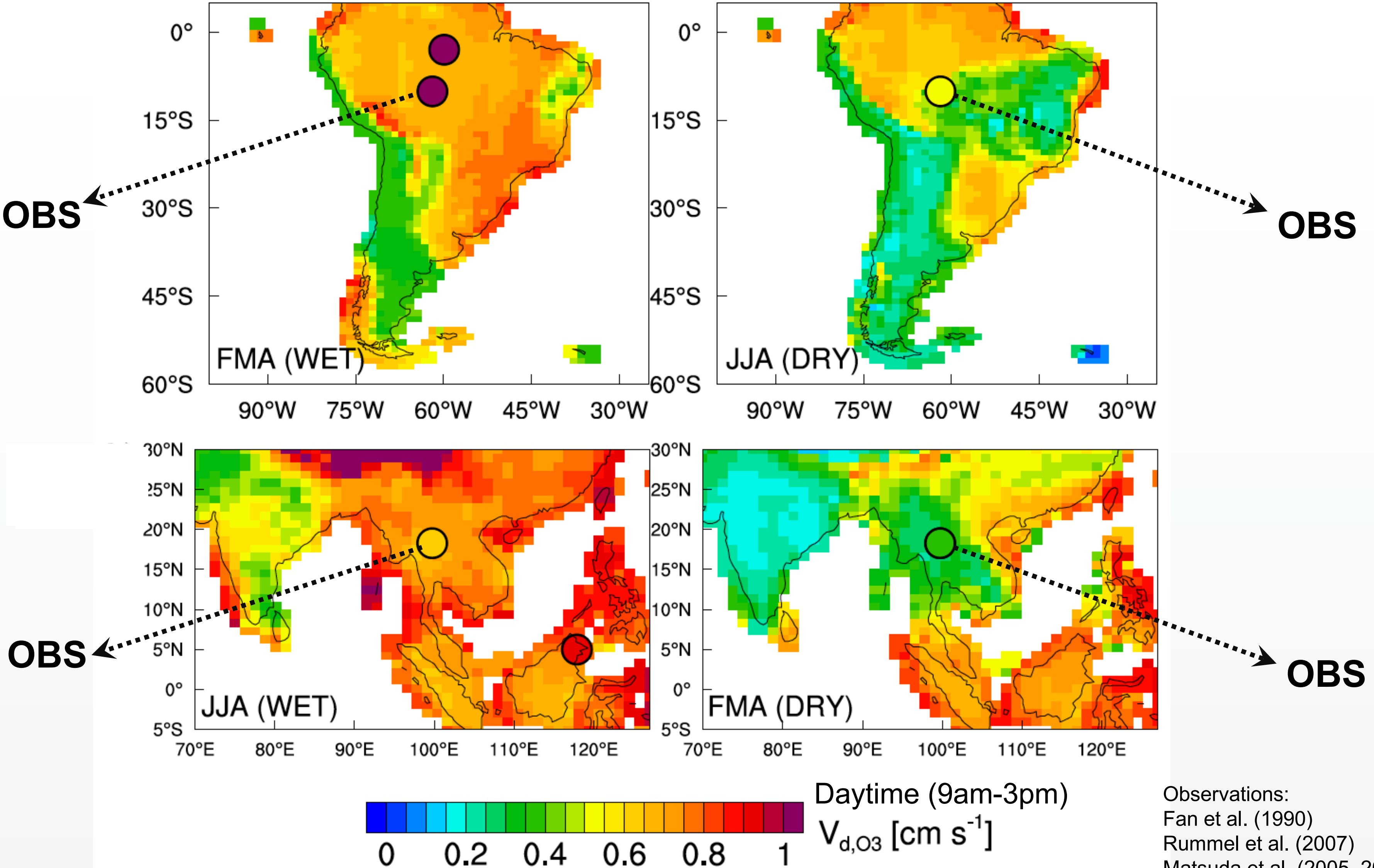




Observations:
Coyle et al. (2009)
Stella et al. (2011)

Lin M. et al. (Global Biogeochemical Cycles, 2019)

Ozone deposition over tropical forests during wet vs. dry season



Observations:
Fan et al. (1990)
Rummel et al. (2007)
Matsuda et al. (2005, 2006)

Lin M. et al. (Global Biogeochemical Cycles, 2019)