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"Ozone in Rural Areas of the United States":

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Recent trends, future projections

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IN THE CITY OF NEW YORK

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Symposium in celebration of Jennifer Logan
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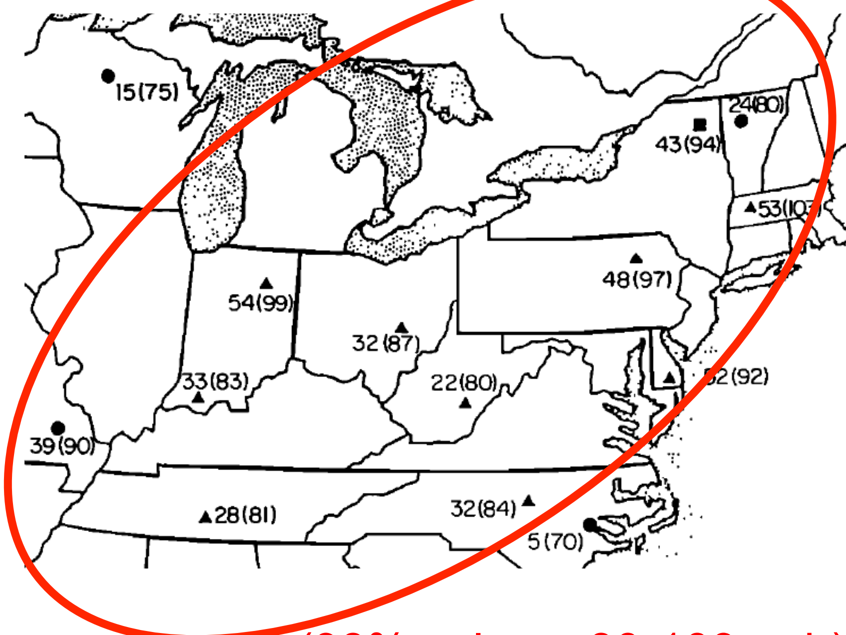
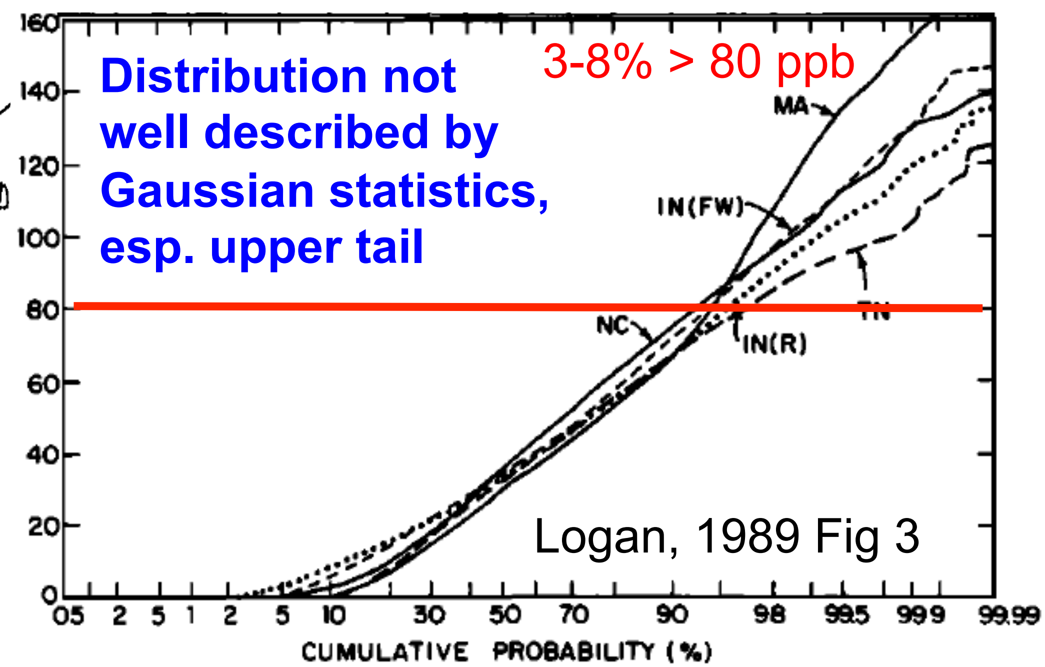
Logan, 1989: expresses urgent need for routine measurements at rural sites in the Eastern USA

SURE and NAPBN sites Apr-Sep 1979
days with O_3 (8am-8pm) > 80 ppb



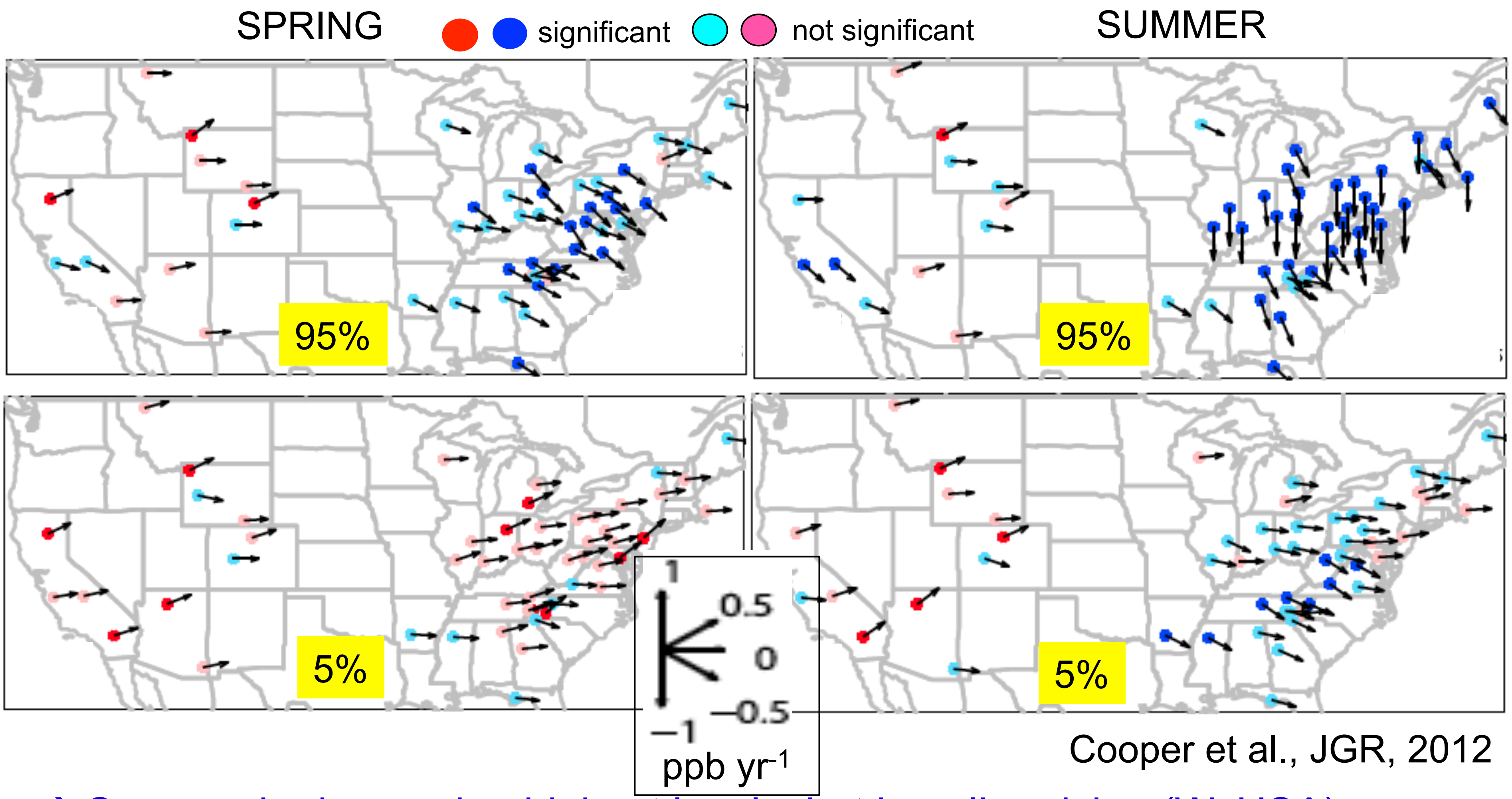
(98% values: 80-103 ppb)

April-Sept 1978-9 O_3 cumulative probability distribution
0000-2300 LT (ppb) at SURE sites



U.S. EPA CASTNet has now measured rural O_3 for over two decades
→ How has the O_3 distribution, including extreme events, changed?
→ What might the future hold?

Trends in seasonal daytime (11am-4pm) average ozone at rural U.S. monitoring sites (CASTNet): 1990 to 2010



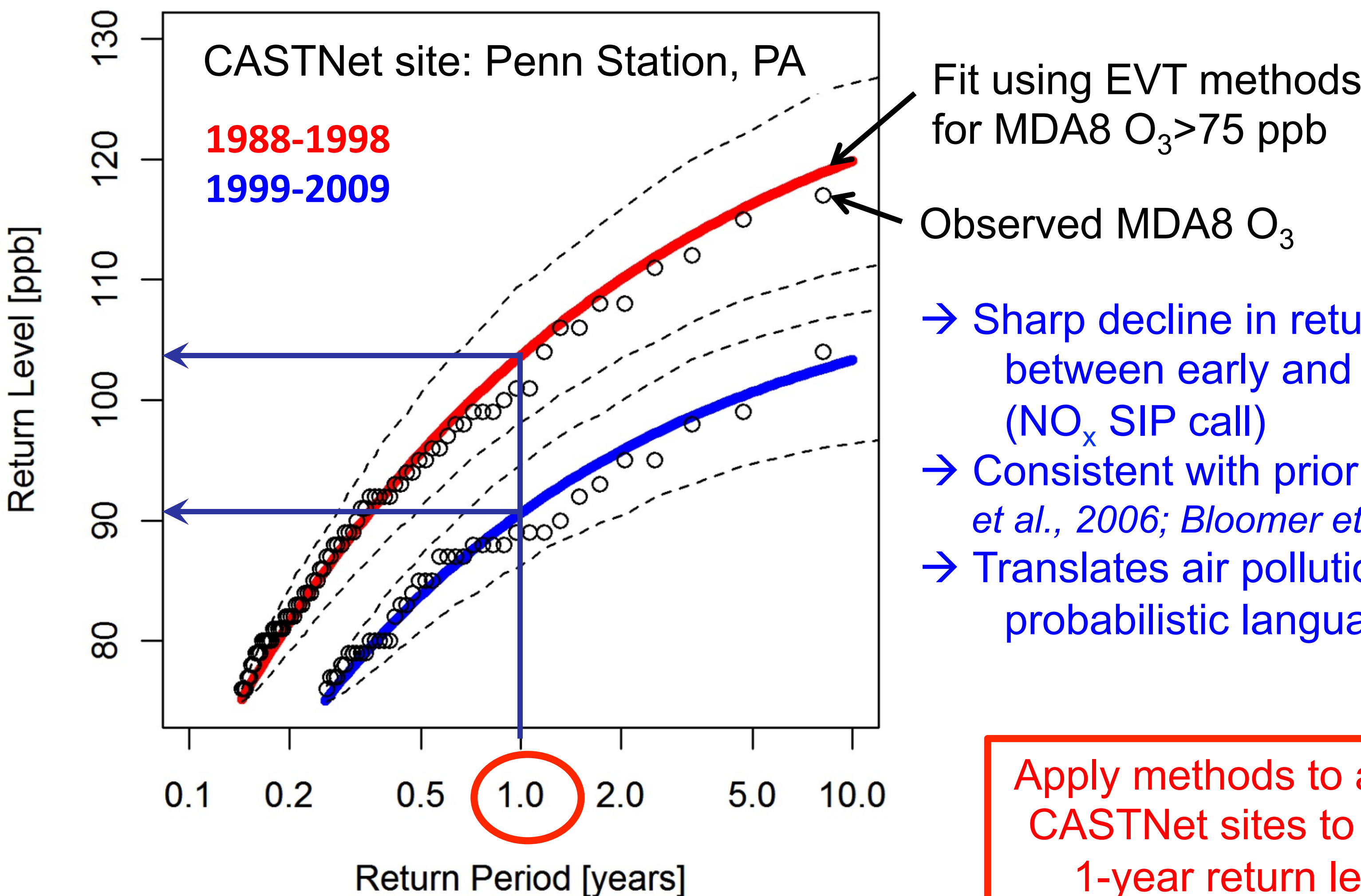
Cooper et al., JGR, 2012

→ Success in decreasing highest levels, but baseline rising (W. USA)

→ Decreases in EUS attributed in observations and models to NO_x emission controls in late 1990s, early 2000s [e.g., Frost et al., 2006; Hudman et al., 2007; van der A. et al., 2008; Stavrakou et al., 2008; Bloomer et al., 2009, 2010; Fang et al., 2010]

Extreme value theory statistical methods enable derivation of "return levels" for JJA MDA8 O_3 within a given time window

Return level = value (*level*) that occurs or is exceeded within a given time *(period)*



Rieder et al., ERL 2013

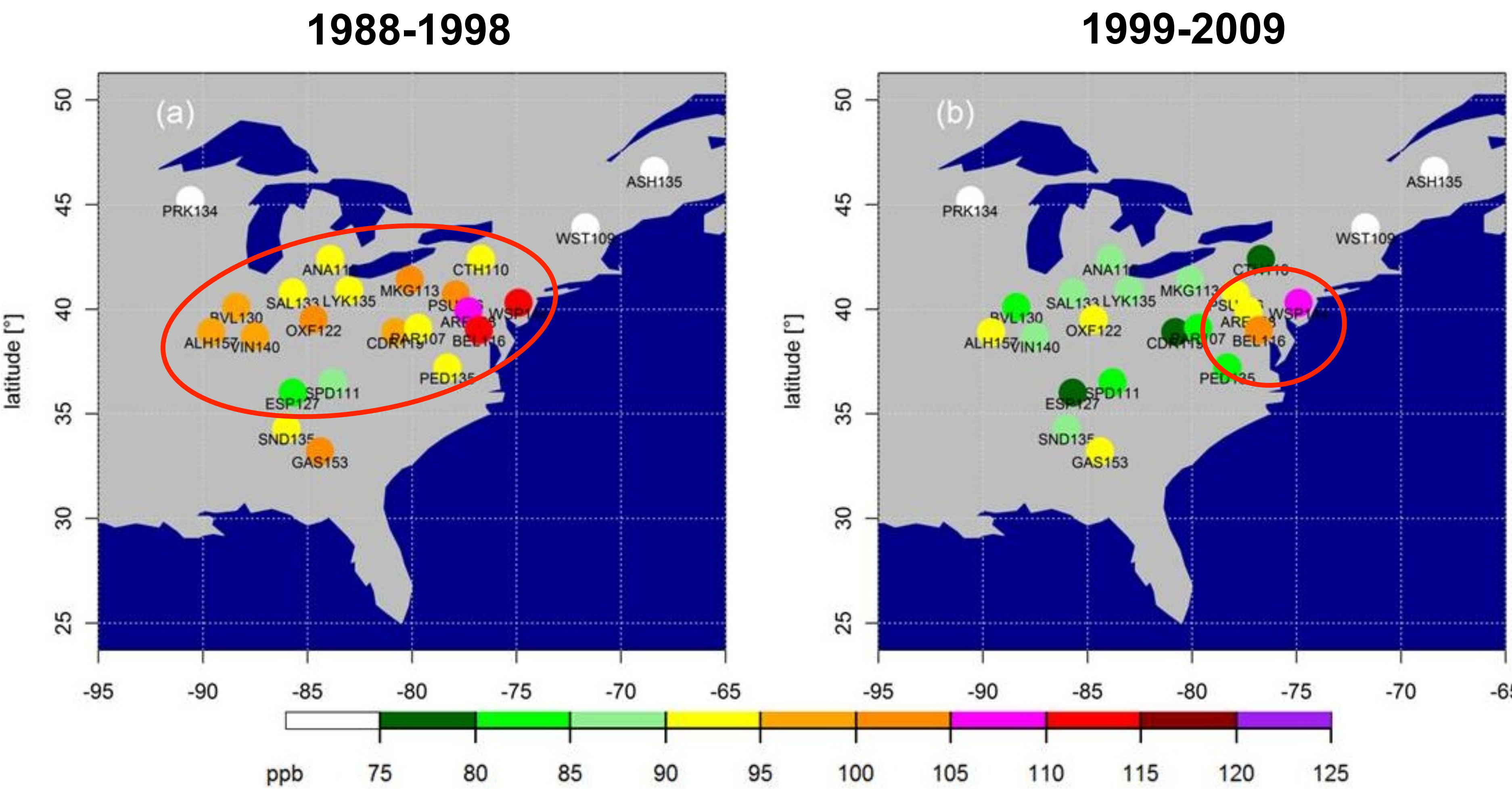
→ Sharp decline in return levels between early and later periods (NO_x SIP call)

→ Consistent with prior work [*e.g., Frost et al., 2006; Bloomer et al., 2009, 2010*]

→ Translates air pollution changes into probabilistic language

Apply methods to all EUS CASTNet sites to derive 1-year return levels

One-year return levels for JJA MDA8 O_3 over EUS decrease following NO_x emission controls



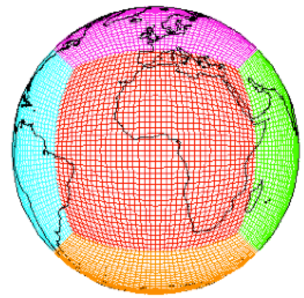
→ 1-yr return level decreases by 2-16 ppb
→ 1-year levels remain above the NAAQS threshold (75 ppb)

Rieder et al., ERL 2013

How will NE US surface O_3 distributions evolve with future changes in emissions and climate?

Tool: GFDL CM3 chemistry-climate model

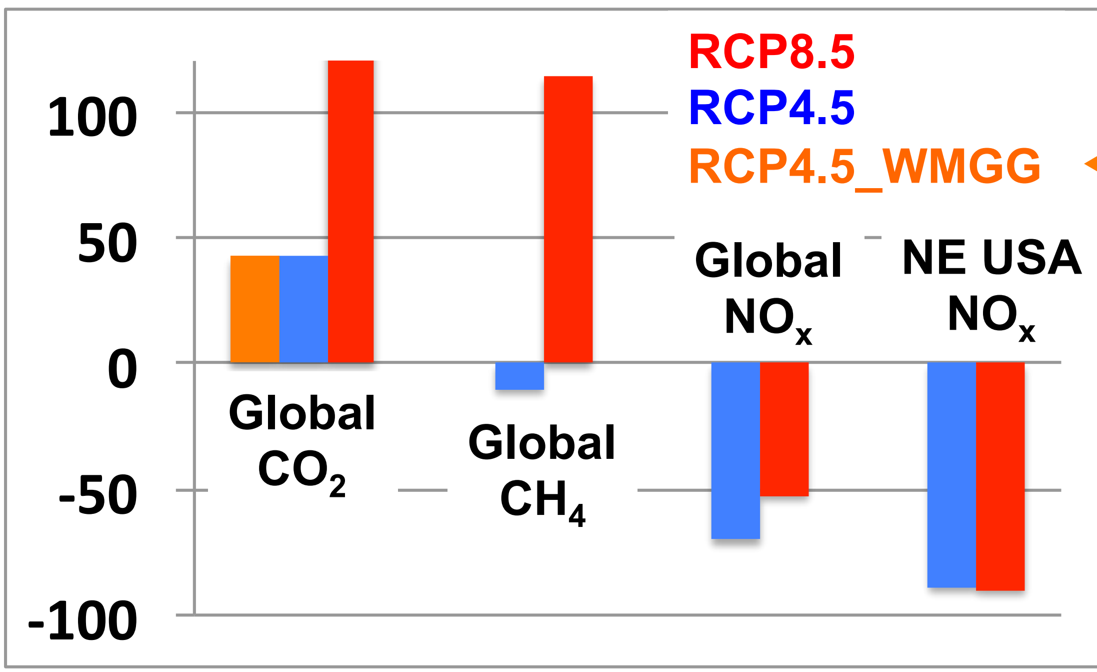
- ~2°x2°; 48 levels
- Over 6000 years of climate simulations that include chemistry (air quality)
- Options for nudging to re-analysis + global high-res ~50km[2] [*Lin et al., JGR, 2012ab*]



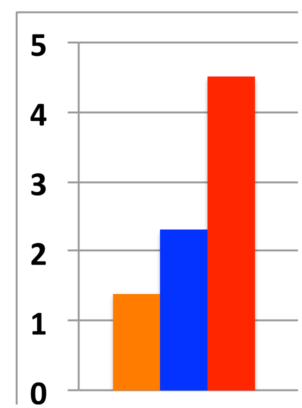
Donner et al., J. Climate, 2011;
Golaz et al., J. Climate, 2011;
John et al., ACP, 2012
Turner et al., ACP, 2012
Naik et al., submitted
Horowitz et al., in prep

Climate / Emission Scenarios: Representative Concentration Pathways (RCPs)

Percentage changes from 2005 to 2100

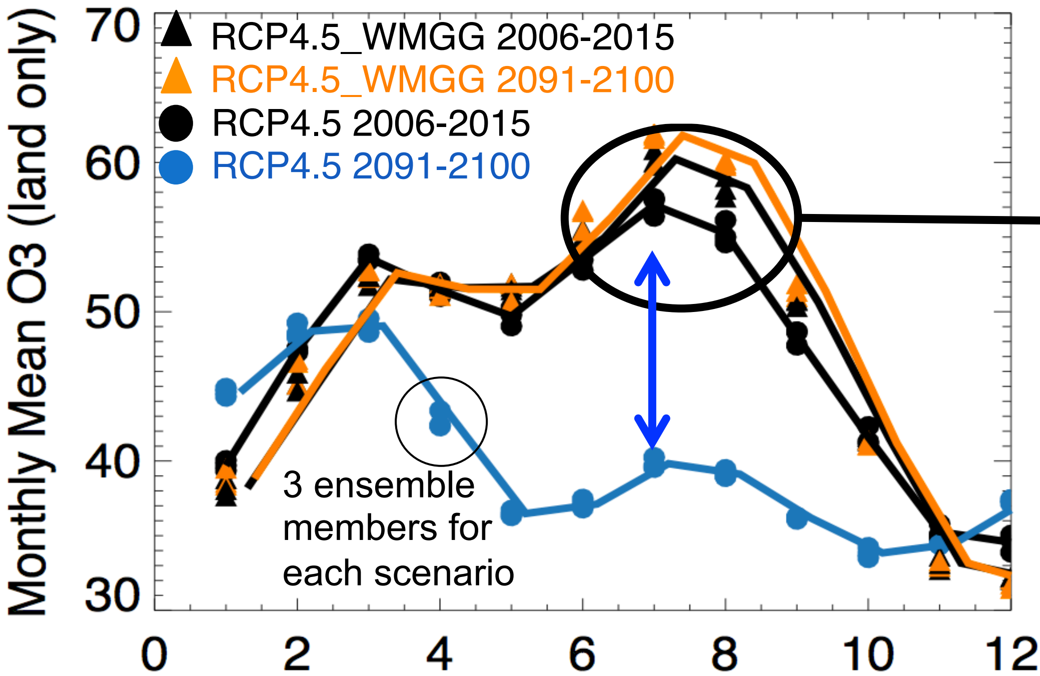


Enables separation of roles of changing climate from changing air pollutants

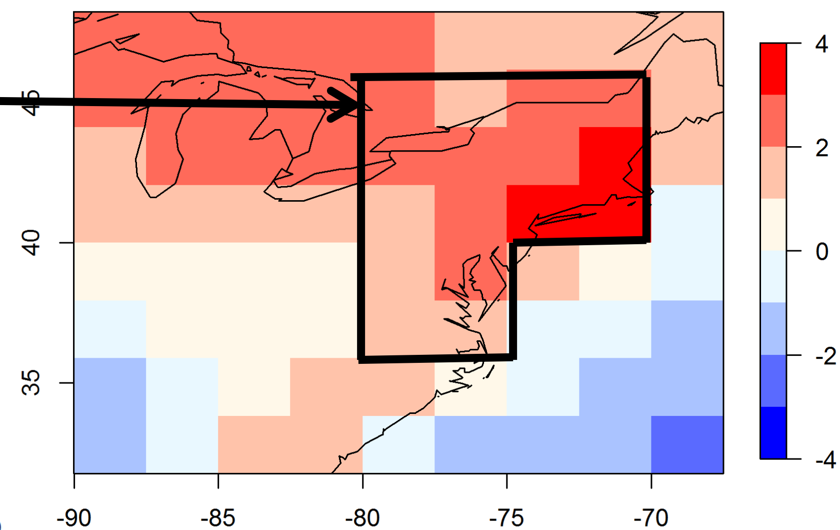


Global T (°C) (>500 hPa)

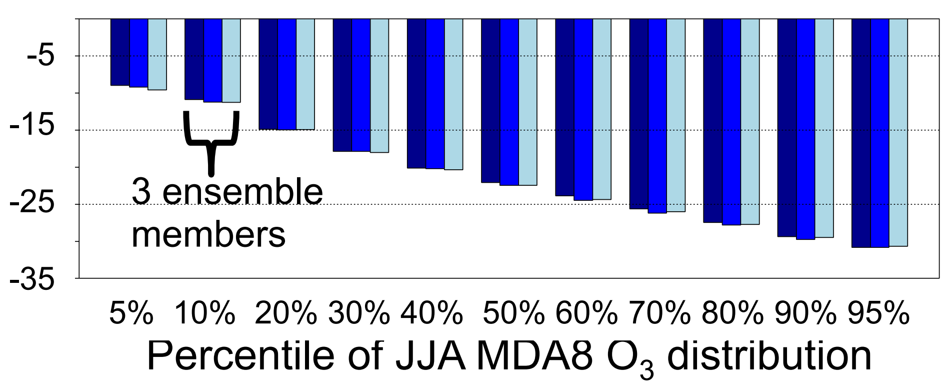
Impact of changes in climate vs. emissions on surface O_3 under moderate warming scenario over NE USA



(2091-2100) – (2006-2015) RCP4.5_WMGG 3 ens. member mean:

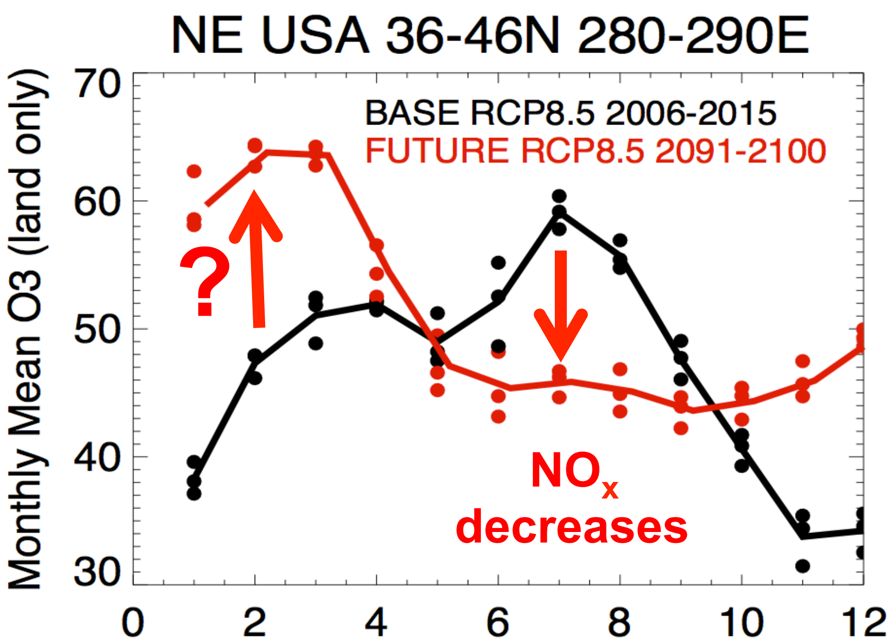


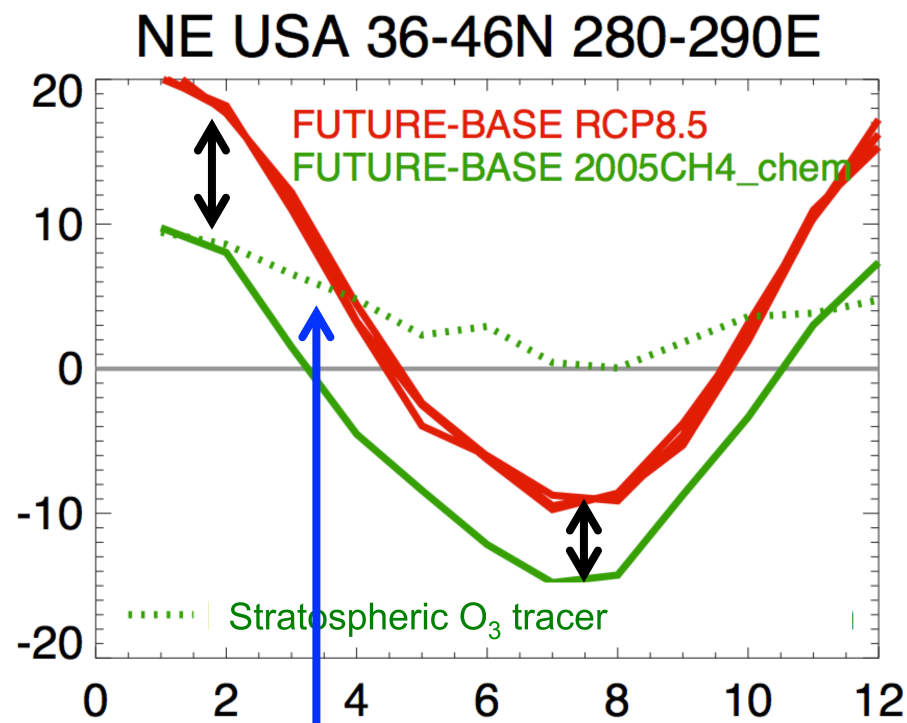
RCP4.5 O_3 change (ppb)(2091-2100)-(2006-2015)



- **Moderate climate change increases NE USA surface ozone up to 4 ppb**
- **But large regional NO_x reductions fully offset this;**
- **O_3 decreases most for polluted conditions;**
- **Seasonal cycle reverses**

NE USA: surface O_3 seasonal cycle reverses in CM3 with large regional NO_x controls in RCP8.5 (extreme warming)





→Difference between **RCP8.5** and **RCP8.5 but with CH_4 held at 2005 levels** indicates that doubling CH_4 increases surface O_3 over NE by more than 5-10 ppb;

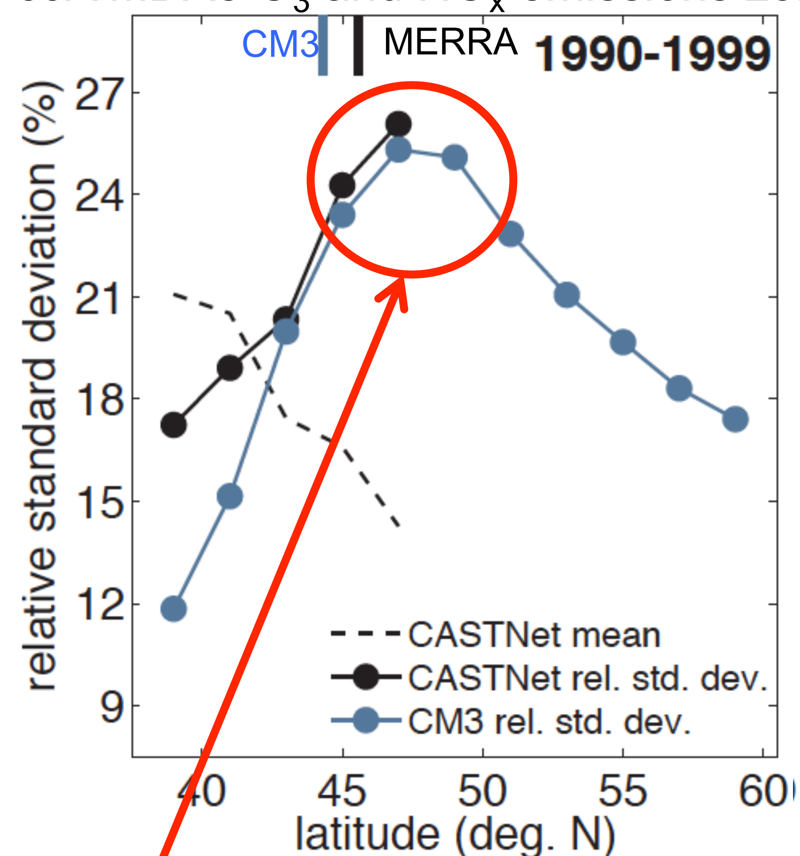
→Largest in winter

→ Tracer of strat. O_3 increases in winter-spring

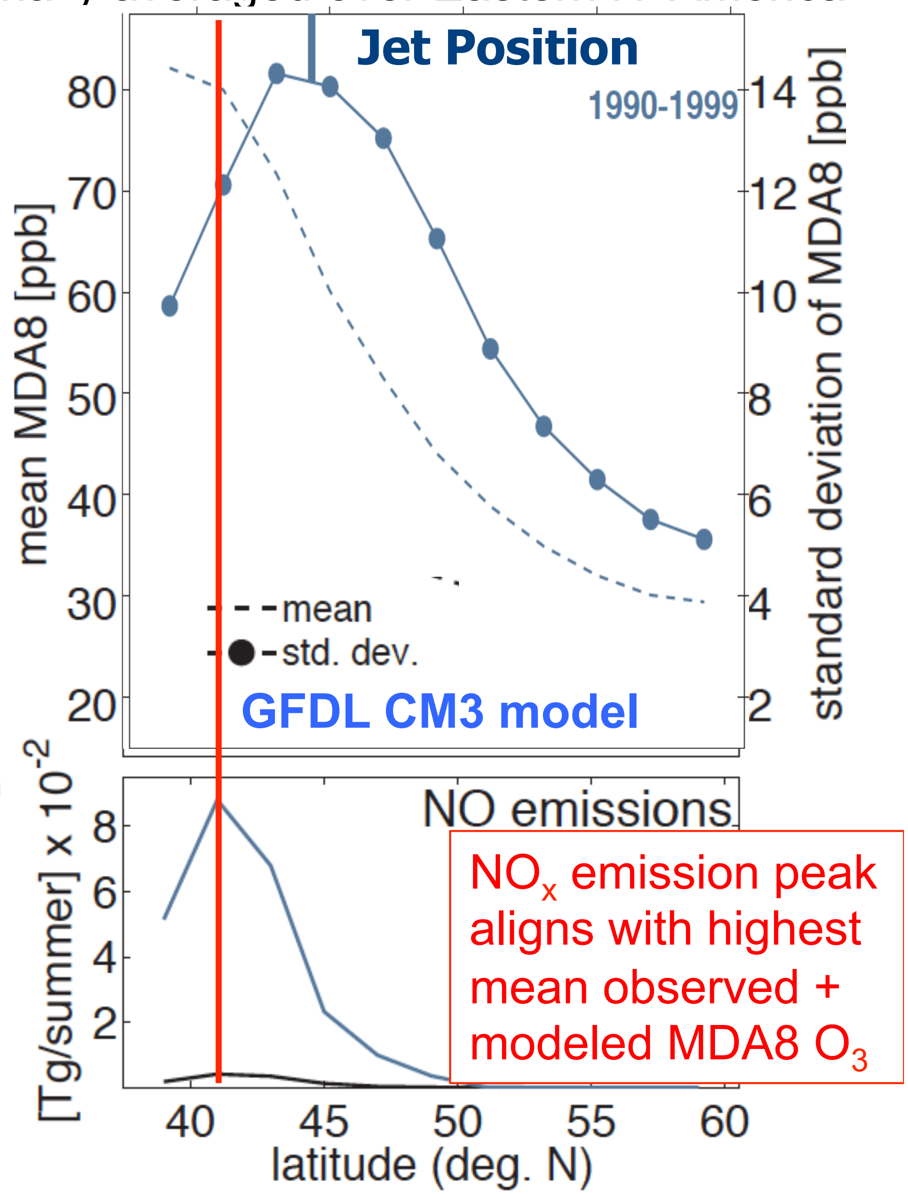
→ Recovery + climate-driven increase in STE? [*e.g.,Butchart et al.*, 2006; *Hegglin&Shepherd*, 2009; *Kawase et al.*, 2011; *Li et al.*, 2008; *Shindell et al.* 2006; *Zeng et al.*, 2010]

Summertime surface O_3 variability aligns with the 500 hPa jet over Eastern N. America

JJA MDA8 O_3 and NO_x emissions zonally averaged over Eastern N. America

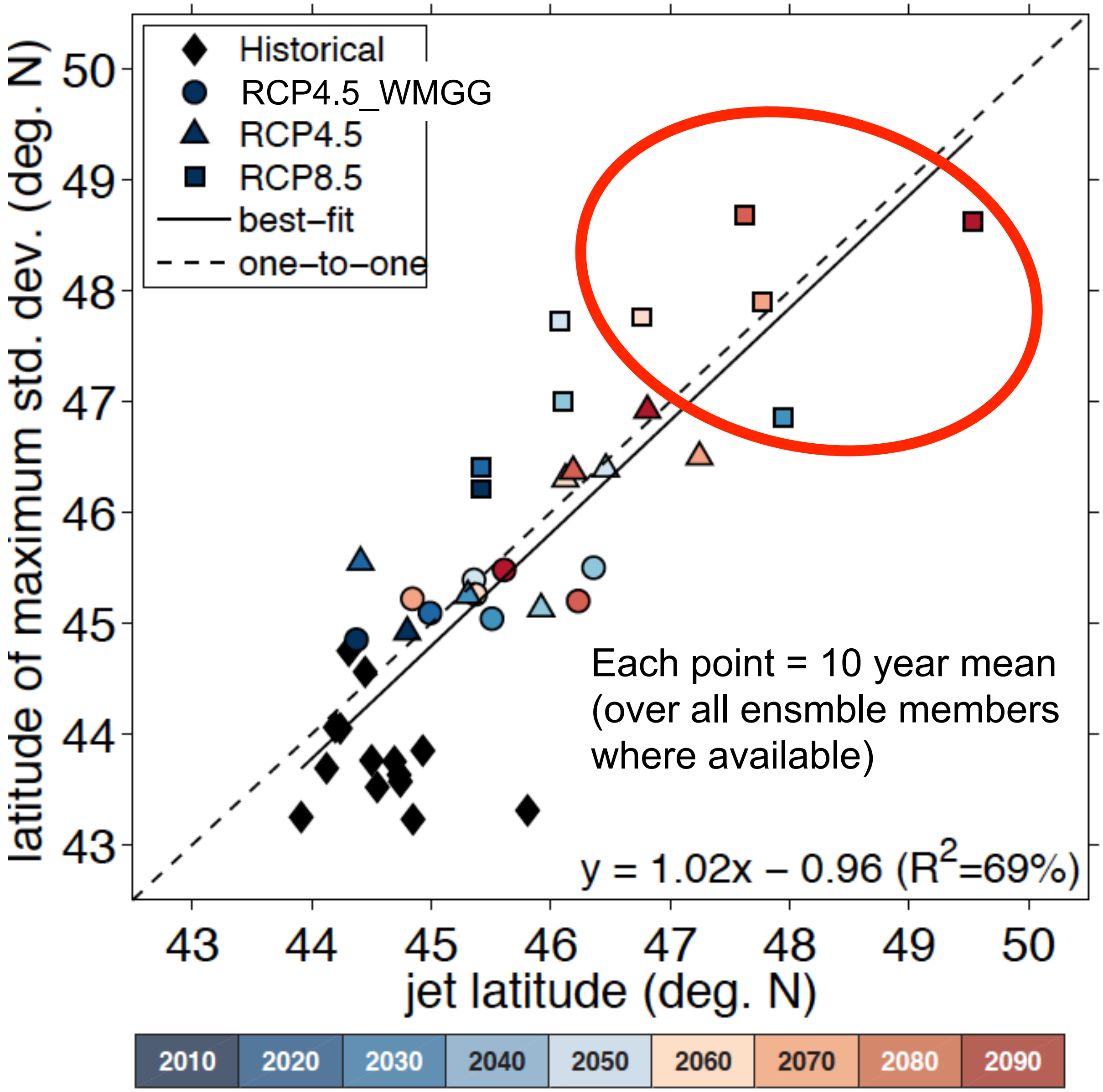


Relative standard deviation **max at the jet latitude**



Barnes & Fiore, in press, GRL

Peak latitude of summertime surface O_3 variability over Eastern N. America follows the jet as climate warms



RCP8.5: most warming, Largest jet shift

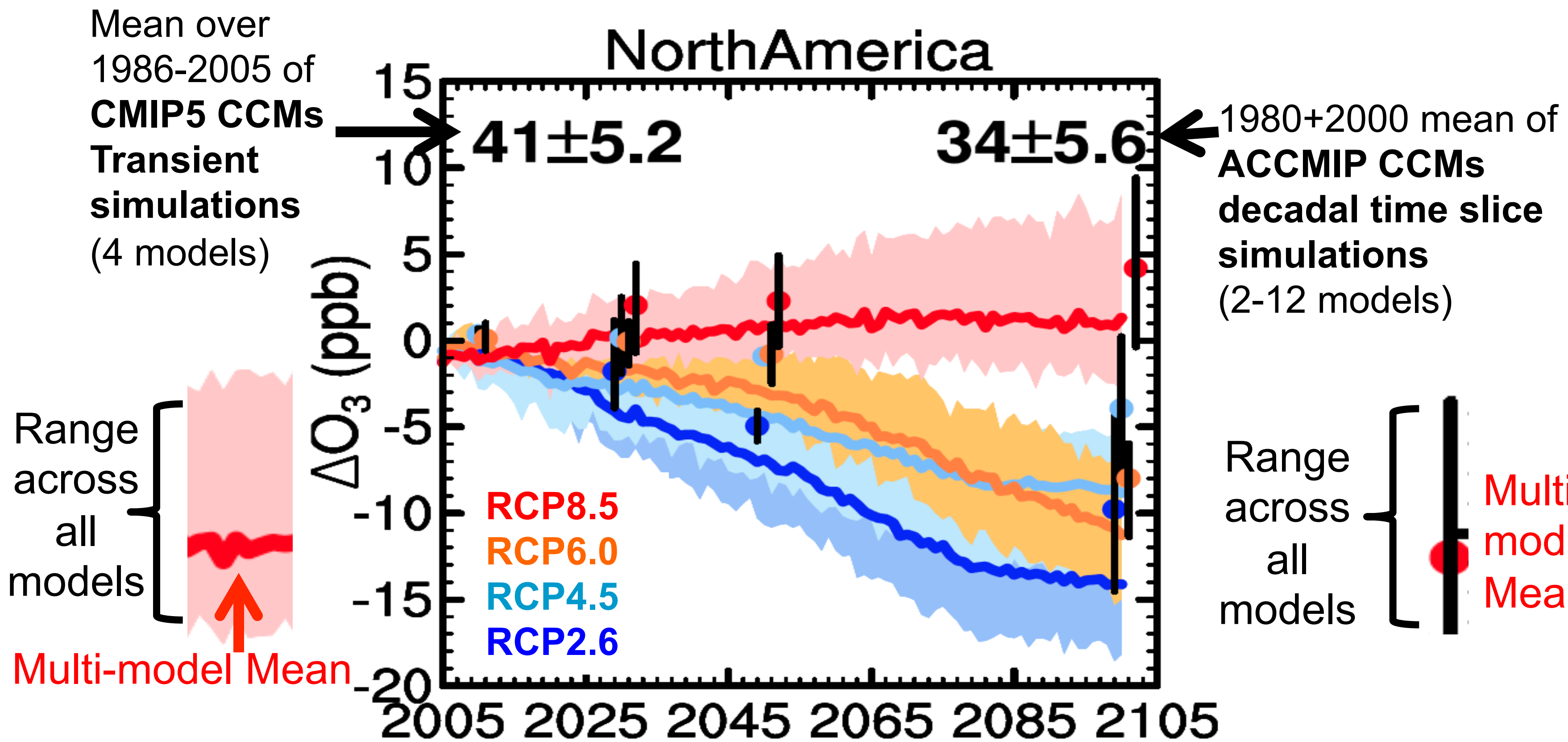
Local O_3:T relationships also follow the jet (not shown)
→ observed O_3:T may not apply if large-scale circulation shifts

Could different simulated jet positions explain cross-model disagreement in regional O_3 response to climate change?

Barnes & Fiore, GRL, in press

‘First-look’ future projections with current chemistry-climate models for North American Ozone Air Quality

Annual mean spatially averaged (land only) O_3 in surface air



V. Naik, adapted from Fiore et al., 2012

Beyond annual, continental-scale means: Shifting balance of regional and baseline O_3 changes seasonal cycles and daily distributions; Role of regional climate change?