GLOBAL CHANGES IN THE DIURNAL CYCLE OF SURFACE OZONE OVER FOUR DECADES

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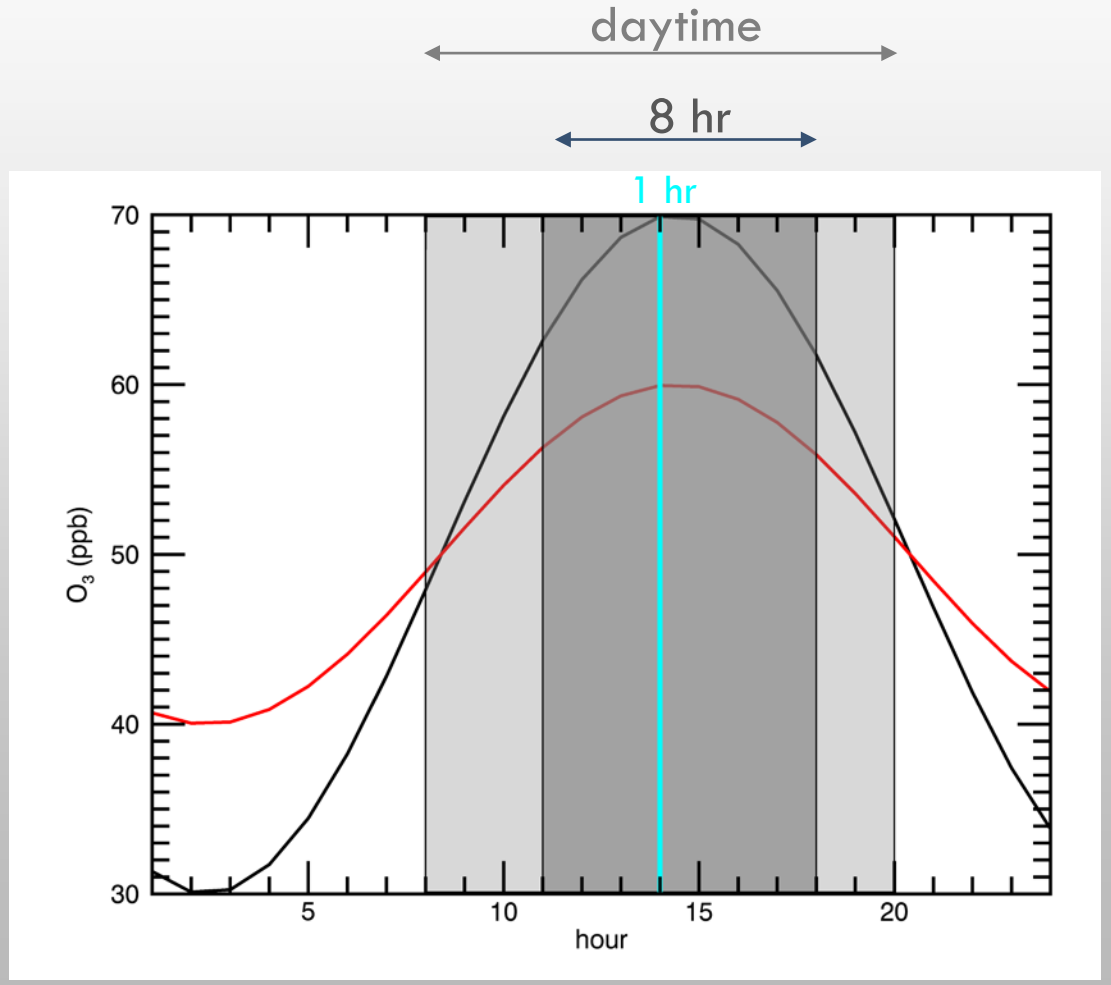
MOTIVATION

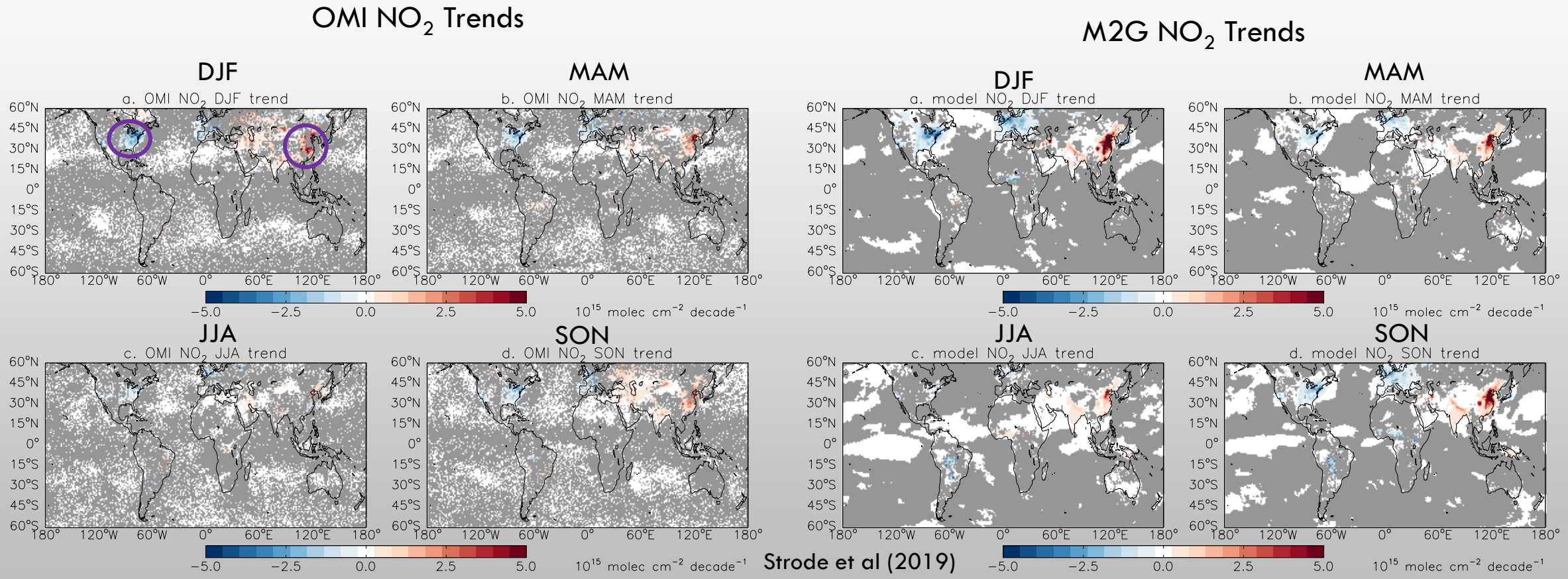
- Many different surface ozone metrics related to health & vegetation:
  - 1-hr max, max 8-hr avg, daytime avg
- Trends differ depending on the choice of metric in part because they are sensitive to the diurnal cycle, which changes over time
  - NO_x increases ozone production and night/winter ozone titration
  - OMI overpass is close to ozone peak
- MERRA-2 GMI (M2G) simulation can reveal changes in the diurnal cycle where observations are too sparse



MERRA2-GMI SIMULATION

- Global atmospheric chemistry simulation for 1980-2016
- GEOS model with the Global Modeling Initiative (GMI) chemistry mechanism
  - Represents O_3-NO_x-VOC chemistry with >100 reactions
- Meteorology is "replayed" to the MERRA2 reanalysis
- C180 (50km) horizontal resolution, 72 vertical levels covering both the stratosphere and troposphere
- Time-dependent anthropogenic and biomass burning emissions
  - NOx emission trend is positive over Asia, negative over eastern USA and Europe

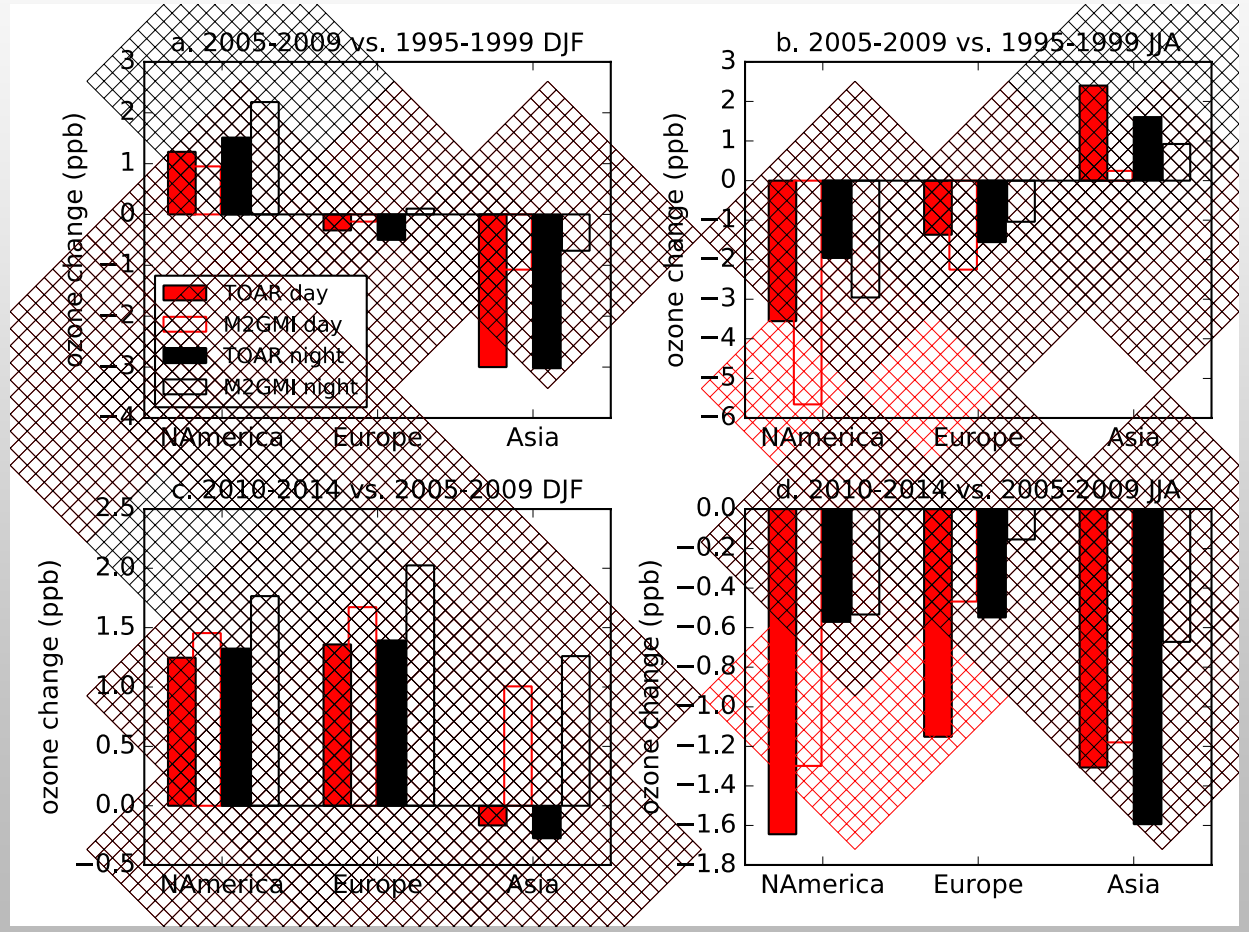
NO_X CHANGES IN OMI AND M2G



Strode et al (2019)

- M2G simulation captures the negative trend over eastern U.S. and positive trend over east Asia seen in OMI, as well as the stronger magnitude in winter vs. summer

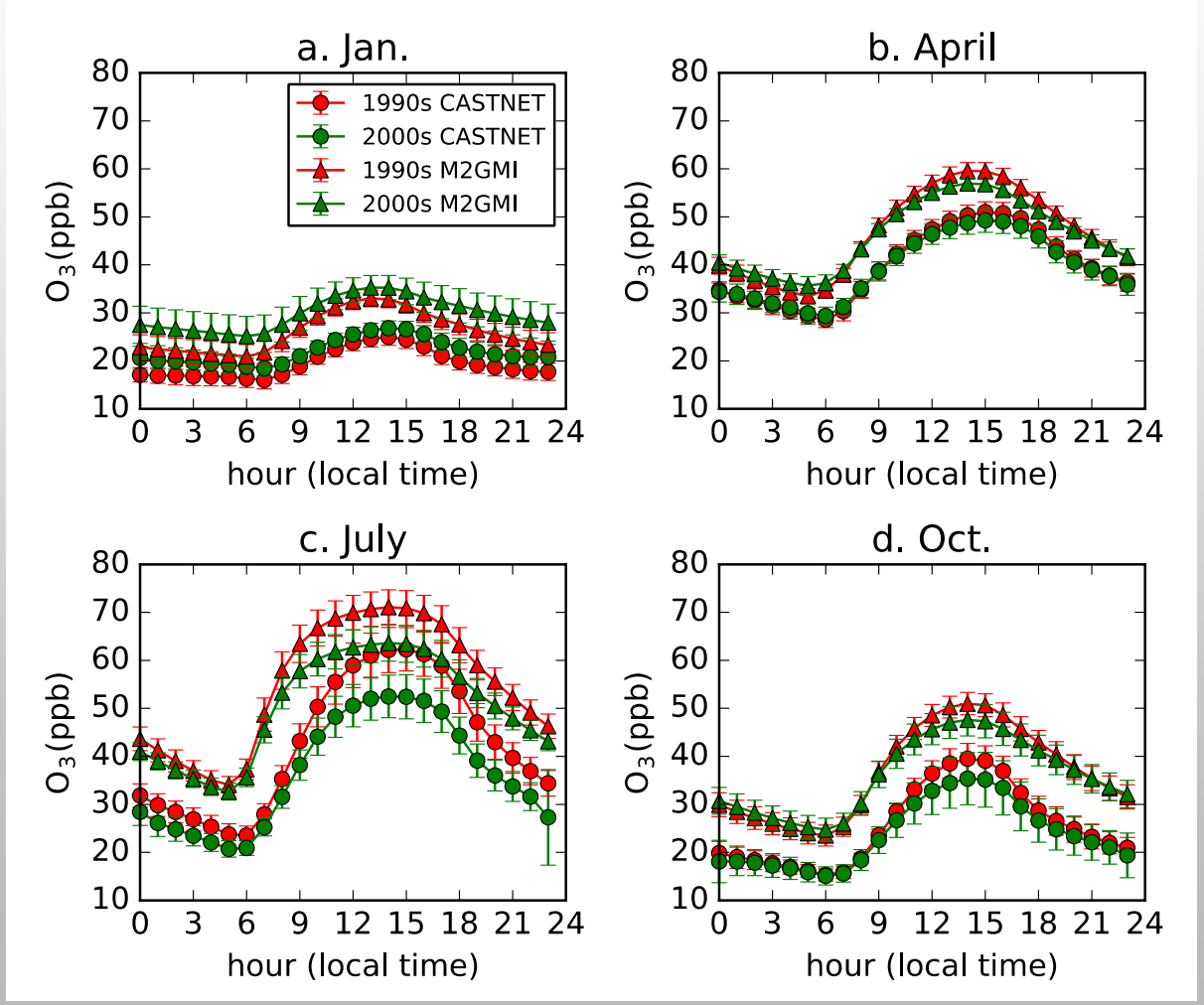
EVALUATION OF SURFACE O_3 CHANGES IN M2G WITH TOAR DATA



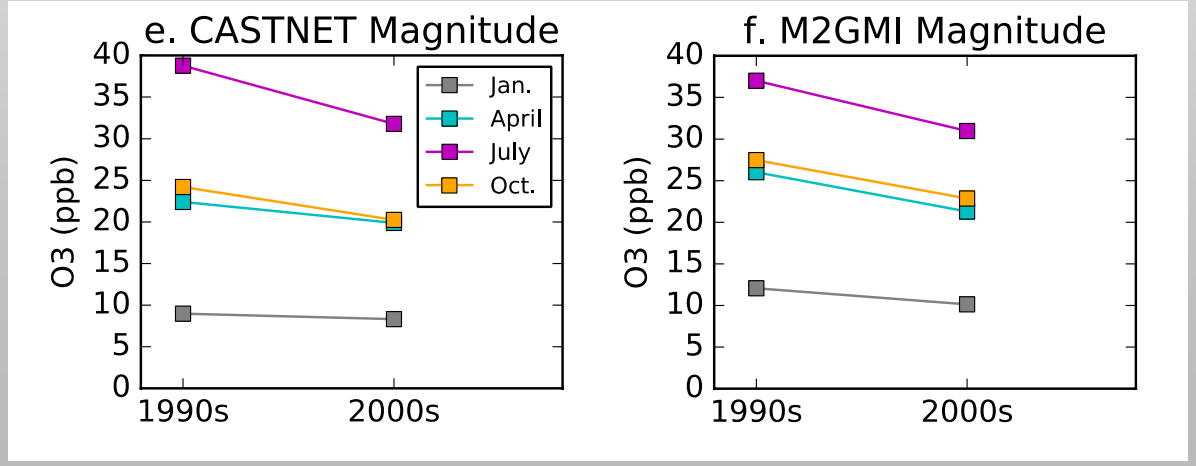
Strode et al (2019)

- TOAR provides semi-decadal averages of surface ozone
- Model reproduces sign of changes for most regions/time periods
  - Mismatch over Asia likely due to incorrect RCP emission trends
- Day vs. night differences in the magnitude of the decadal changes in summer → diurnal cycle is changing!

EASTERN U.S. EVALUATION WITH CASTNET

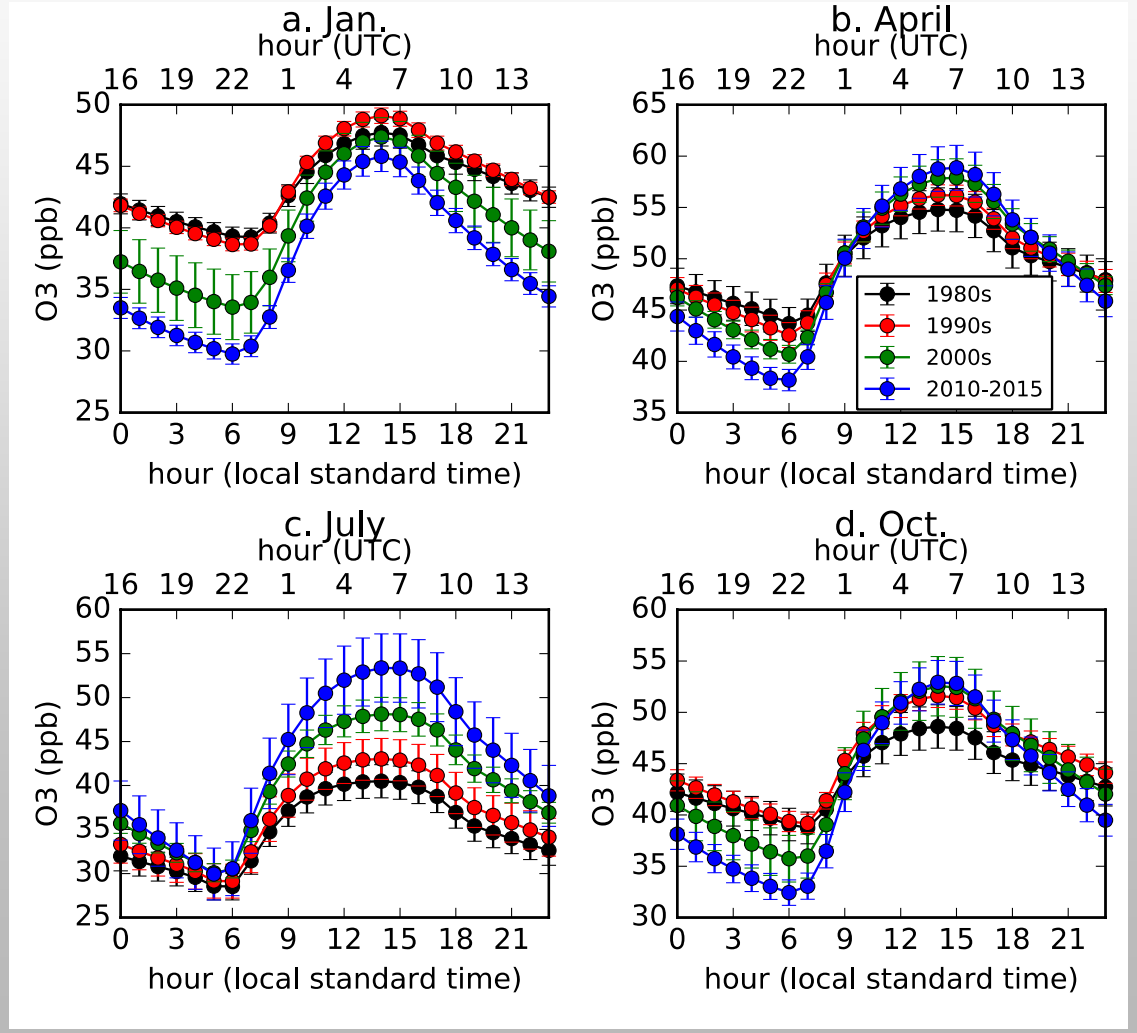


- Compare simulated diurnal cycle changes to CASTNET data
- M2G is biased high, but changes are reasonable
- Reduction in O_3 between 1990s and 2000s largest in daytime in summer

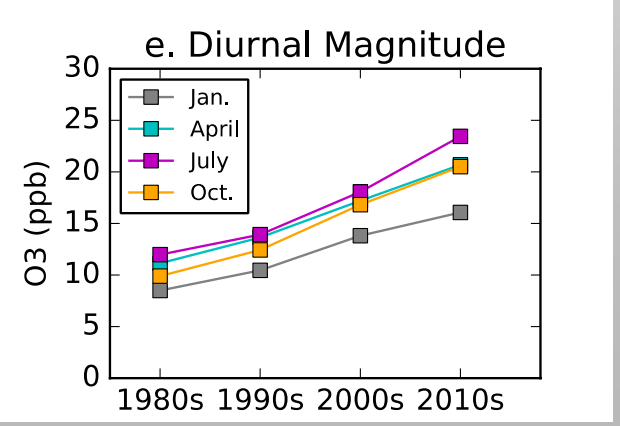


Strode et al (2019)

4 DECADES OF SIMULATED CHANGES: EASTERN CHINA

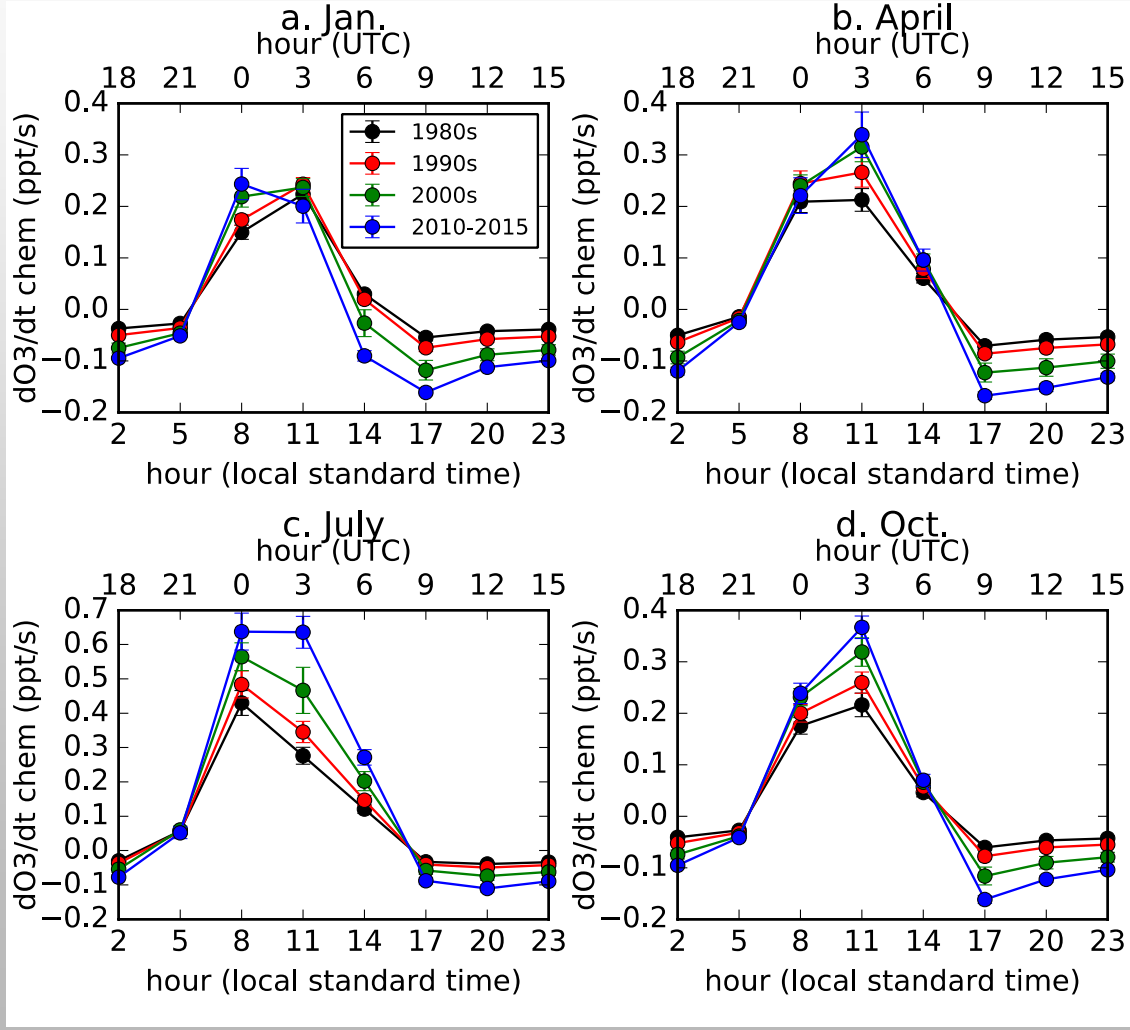


- Lack of long-term observations, so M2G provides new information on how the diurnal cycle is changing over China
- Magnitude of the diurnal cycle increasing, opposite to the situation in the U.S.
- Consistent with higher NO_x



Strode et al (2019)

CHANGES IN CHEMISTRY: EASTERN CHINA



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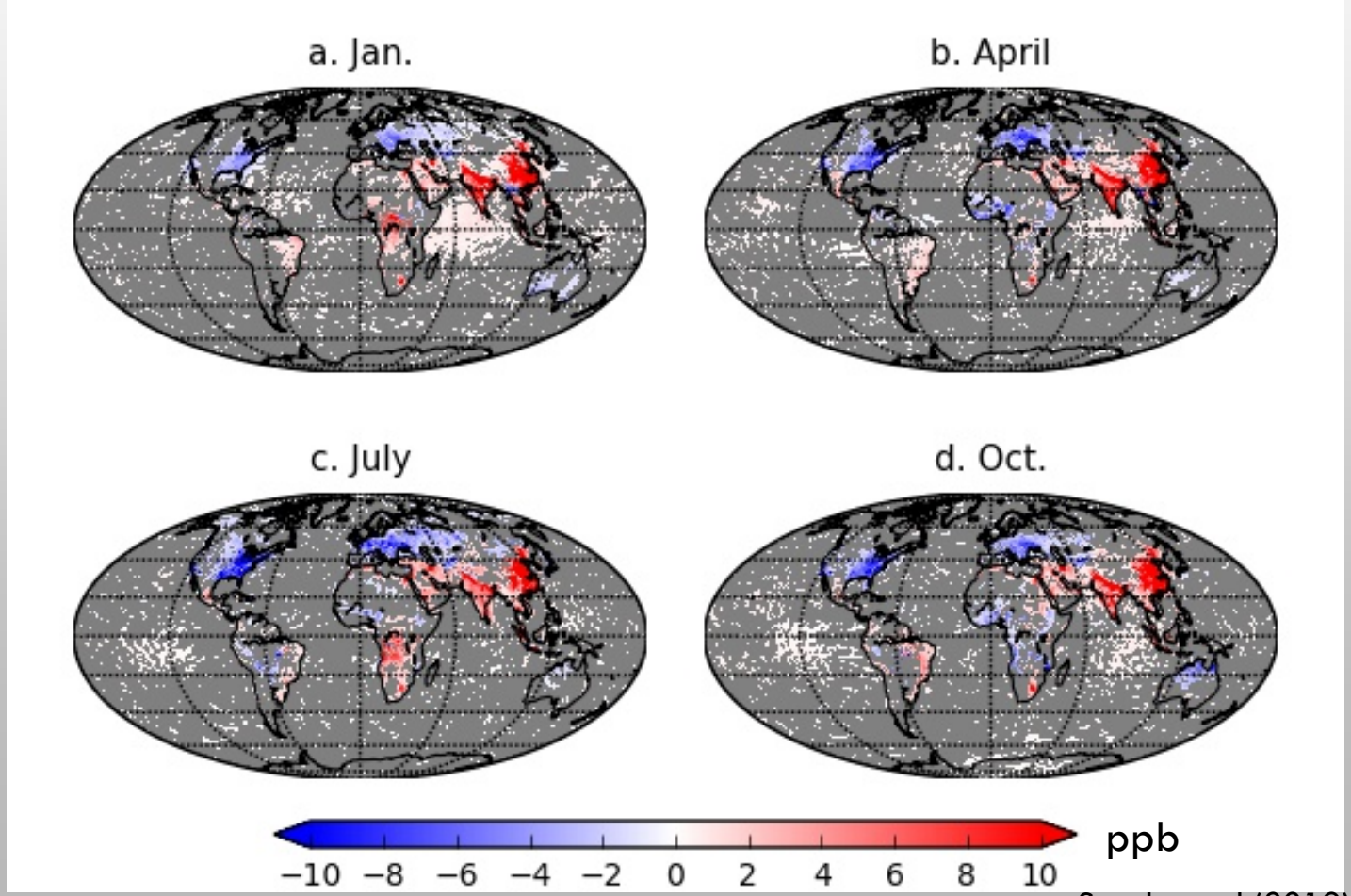
- Chemical tendency from the model: production – loss - deposition
- Choose pressure level one above the surface to remove effect of deposition
- Higher ozone production in the morning increases daytime peak
- Greater ozone loss in evening/night lowers nighttime ozone

GLOBAL VIEW: MAGNITUDE OF THE DIURNAL CYCLE

- M2G gives a global picture of where there may be significant changes in the diurnal cycle of surface ozone
- M2G suggests increases over Africa and India

Change in Surface Ozone Diurnal Cycle Magnitude: 2006-2015 vs. 1980s



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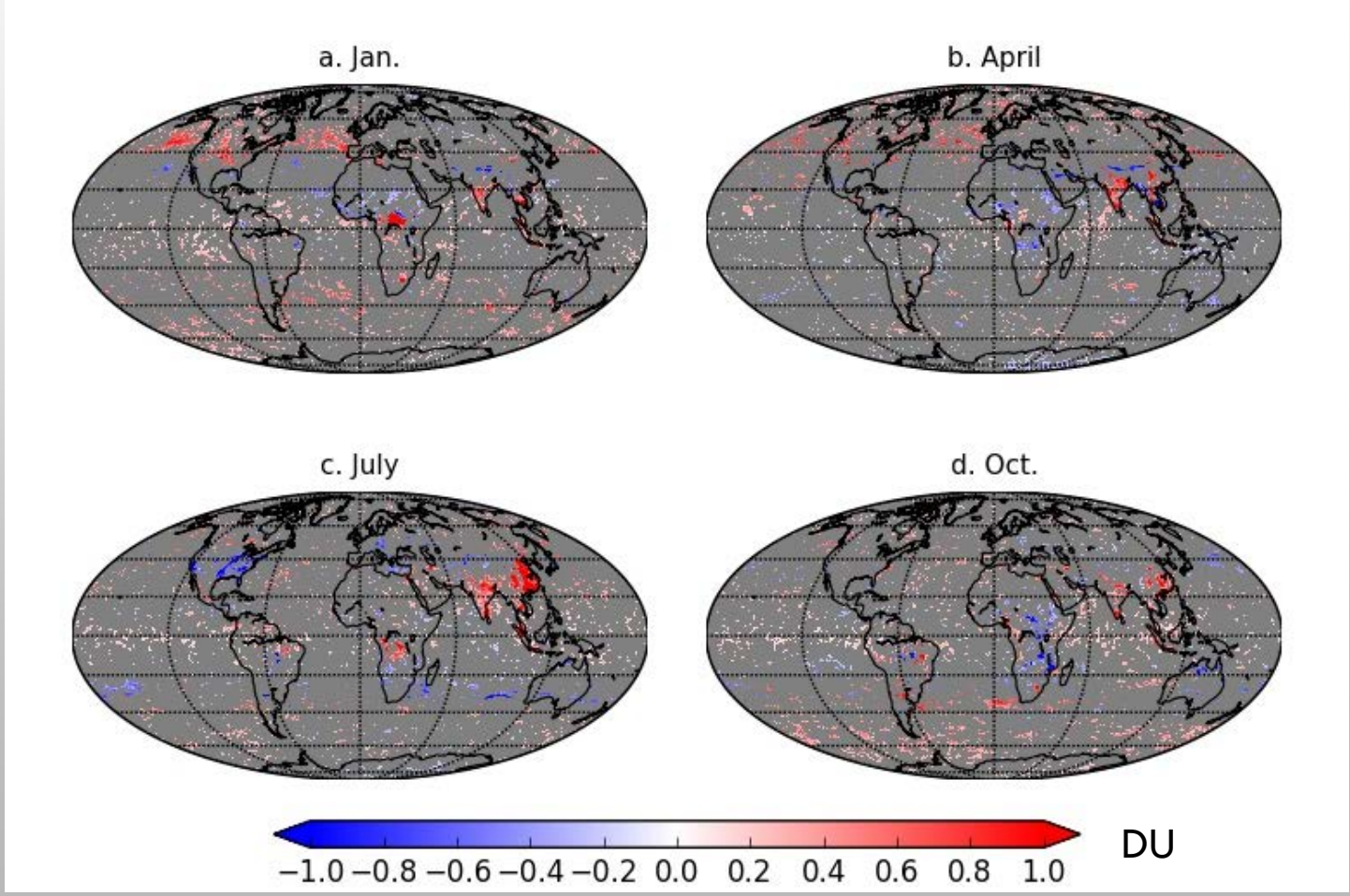
DOES THIS MATTER FOR SATELLITES?

- Is the diurnal cycle of the tropospheric column changing, or just the surface concentrations?
- Significant changes in some regions, but IAV is large
- Magnitude is non-trivial: OMI trends up to 2-3 DU/decade
- This is an upper limit since OMI lacks sensitivity at the surface, where diurnal changes are largest

Change in Tropospheric Ozone Column Diurnal Cycle Magnitude: 2006-2015 vs. 1980s



Strode et al (2019)

SUMMARY

- Changes in the diurnal cycle of surface O_3 affect trends in different O_3 metrics
- MERRA2-GMI simulation comparison to observations:
  - reproduces the NO_2 trends over the eastern U.S. and Asia observed by OMI
  - Agrees with CASTNET sites on changes in the diurnal cycle of eastern U.S. ozone, but biased high in the mean
- Simulated changes in the diurnal cycle agree with expectations from NO_x trends: increasing NO_x increases amplitude of the cycle and vice versa
- M2G shows the amplitude of the cycle is increasing over east Asia, India, and equatorial Africa: more long-term observations are needed in these regions
- Changes in the diurnal cycle of the tropospheric column are significant in a few regions, affecting how we interpret satellite-derived trends