A Satellite Constrained Meteorological Modeling Platform for LADCO States SIP Development

Jason Otkin[1], Brad Pierce, Monica Harkey, Lee Cronce, Zac Adelman, Tsengel Nergui, Gail Good, Chris Hain, Jon Case, David Henderson, Allen Lenzen, and Jim Szykman

[1]University of Wisconsin-Madison, Cooperative Institute for Meteorological Satellite Studies

Annual Project Review: 12 October 2021

Project Goals

- We will support the modeling needs of the Lake Michigan Air Directors Consortium (LADCO) through development, verification, and delivery of a satellite-constrained meteorological modeling platform that can be used for air quality assessments of ozone in the Lake Michigan region

  - Ozone non-attainment events occur periodically, especially along the Lake Michigan shoreline, so those states are required by the Clean Air Act to demonstrate strategies to mitigate these ozone exceedance events

  - Meteorological modeling is very challenging due to the influence of lake/land breeze circulations on the transport and chemistry along the Lake Michigan shoreline

  - Complex interplay between generation of pollution along southern rim of Lake Michigan and its northward advection

Project Goals

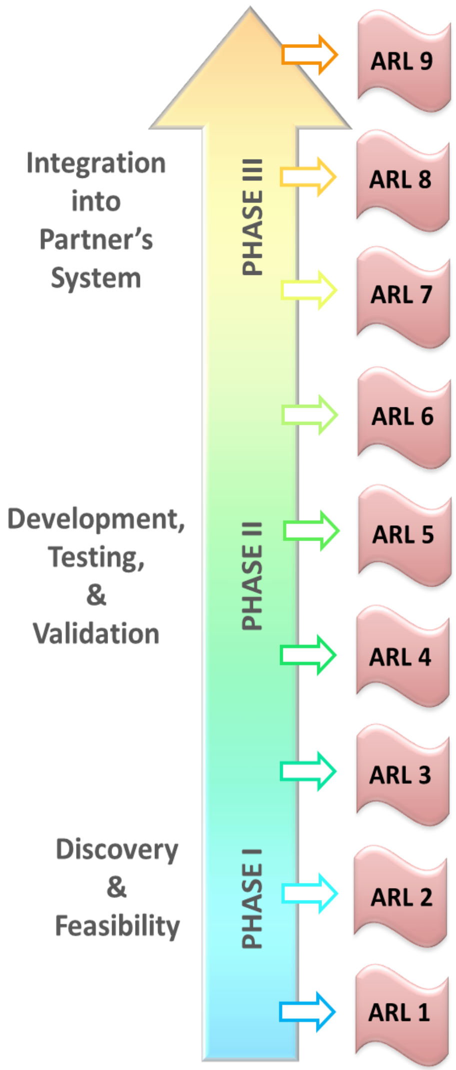
- Modeling platform is based on the WRF model, with high-resolution (4- and 1.33-km) nests covering the LADCO states
    - Sensitivity experiments will be performed to determine the optimal configuration of the modeling platform
    - Examine the impact of using different model parameterization schemes and high-resolution input datasets such as MODIS/VIIRS vegetation data, NASA LIS soil moisture and soil temperature, and GLSEA sea surface temperatures
- End goal is to deliver a well-tested modeling platform to LADCO that leverages NASA satellite observations and land surface modeling and data assimilation capabilities
    - Will enhance their ability to address requirements of air quality assessment modeling along the Lake Michigan shoreline

Milestones During the Entire Project

Project Steps by Project Year Quarter	***Year 1***				***Year 2***				***Year 3***			
	Q1	***Q2***	***Q3***	***Q4***	***Q1***	***Q2***	***Q3***	***Q4***	***Q1***	***Q2***	***Q3***	***Q4***
Generate SPoRT LIS soil moisture analyses												
Conduct WRF physics/satellite data sensitivity tests												
Generate 2017 CLAVR-x satellite cloud climatologies												
Conduct WRF/SPoRT-LIS nudging experiments												
Develop and test WRF cloud optical thickness bias correction methodology												
Develop 2017 NEI emissions surrogates												
Conduct preliminary 2017 SIP assessment modeling												
Conduct final 2017 SIP assessment modeling												
Evaluate 2017 SIP model simulations												
Generate 2016 meteorological fields												
Generate 2016 CLAVR-x satellite cloud climatologies												
Develop 2016 NEI emissions surrogates												
Generate 2016 cloud optical thickness bias corrections												
Perform 2016 SIP assessment modeling												
Evaluate 2016 SIP model simulations												
ARL Level	**3**			**4**		**5**		**6**		**7**		**8**

- We have completed some of our Year 2 tasks, and are making good progress on the remaining tasks

Project Application Readiness Level



- Start-of-Project ARL = #3 *(01 October 2018)*
- Goal ARL = #8
- Current ARL = #7 *(01 October 2021)*

At the start of this project, each of the components that we were planning to use to enhance the accuracy of the LADCO meteorological modeling platform had been tested and validated independently. This allowed us to place the initial readiness level at ARL-3.

The project readiness level is currently ARL-7 because collaborators at LADCO have successfully used the satellite-constrained modeling platform during their State Implementation Plan (SIP) modeling efforts in recent months. It is also based on our continued progress running CMAQ model simulations and assessing their accuracy.

Project Challenges and Risks

Rank	Type*	Risk	Mitigation Action
1	Techni cal	Proposed satellite-constrained modeling system is not more accurate than baseline configuration	We view this as a low-level risk because of the large number of potential optimizations (high-resolution soil moisture, vegetation, and sea surface temperature datasets; new model physics) that we will explore during this project. Sensitivity tests will allow us to robustly determine if any one of these potential changes leads to a poorer result, and if it does, it will not be included in the final version of the modeling system delivered to the end users.
2	Manag ement	Lack of engagement from the end of users	We also view this as a low-level risk because both end-user organizations (LADCO and Wisconsin DNR) have participated in the monthly and quarterly telecons.
3	Sched ule Risk	Delays performing/ evaluating model simulations	Researchers at the Wisconsin DNR are tasked with performing full-year model simulations during Years 2 and 3 of the project. It is possible that delays could occur due to lack of personnel or computing resources. This risk was mitigated by requesting (and receiving) an account on the NESDIS/STAR/SSEC S4 supercomputer to complete the simulations.

Accomplishments During Last 12 Months

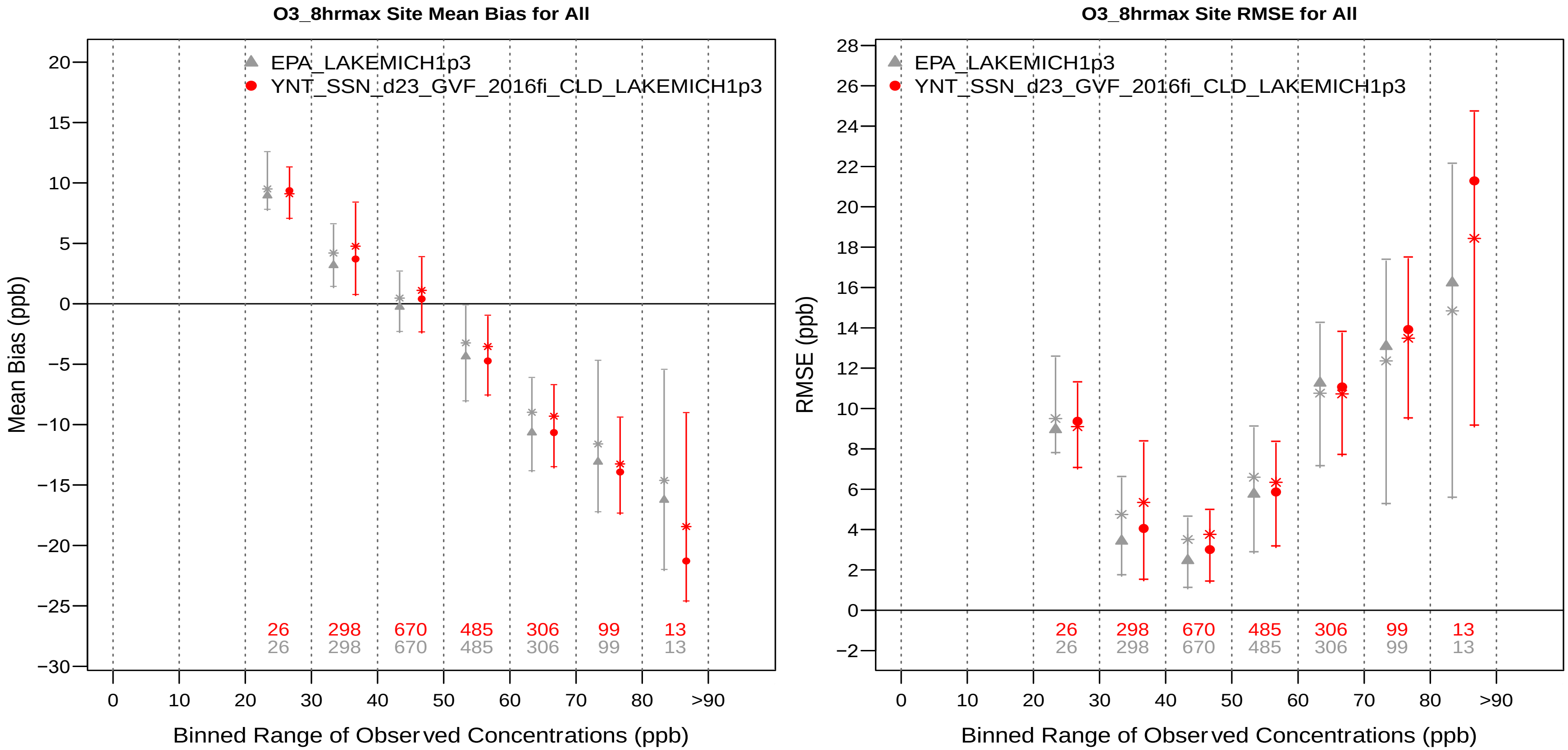
1) Performed an extensive suite of CMAQ model simulations to assess the impact of the satellite-constrained meteorological modeling platform on air quality model forecasts during the LMOS 2017 field campaign

2) Examined the accuracy of the near-surface atmospheric and chemistry fields during these simulations

3) Developed a prototype VIIRS day-night band differencing technique that is used to generate a surrogate for high-resolution surface emissions

4) Ran CAMx model simulations at LADCO to support ozone and haze SIP assessment modeling efforts.

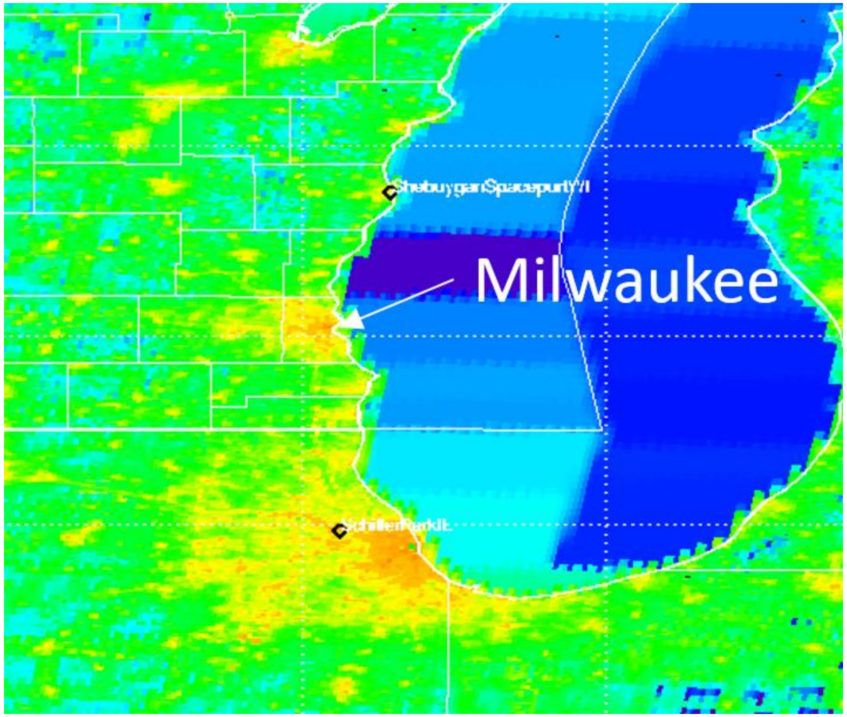
CMAQ Model Verification



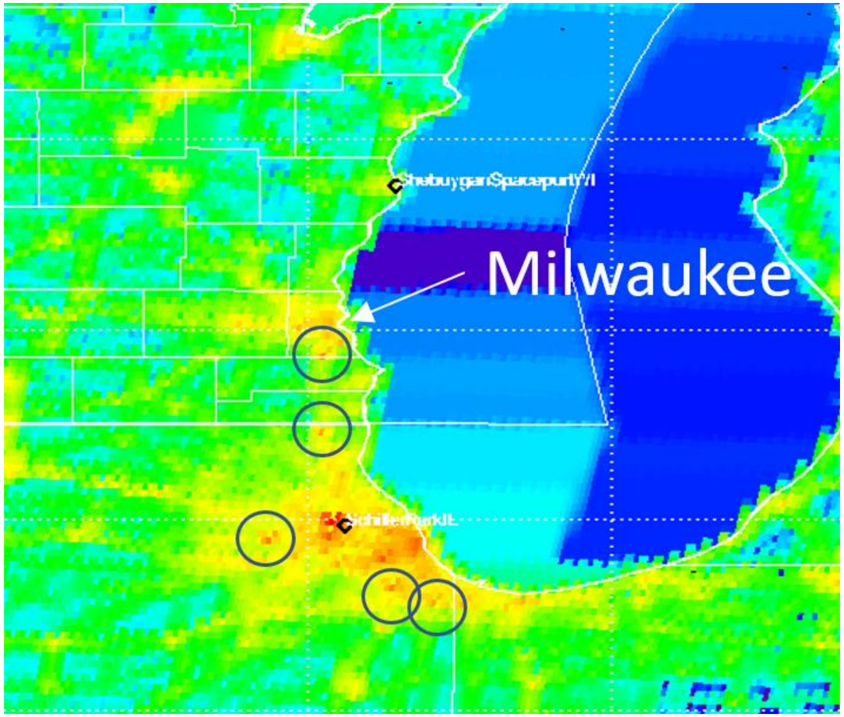
- "EPA" is baseline and "YNT" is the optimized configuration
- Binned box and whisker plots for 8-h ozone maximum concentration at AQS sites on the 1.3-km resolution domain from 22 May – 22 June 2017 (LMOS field campaign time period)
- Both configurations have high (low) bias for lower (higher) ozone concentrations
- Errors are smaller in most bins when using the EPA configuration
- This result is opposite of what we found in our analysis of the meteorological fields

Using VIIRS Day-Night Band Reflectances for Emissions

VIIRS DNB Downscaled NO2

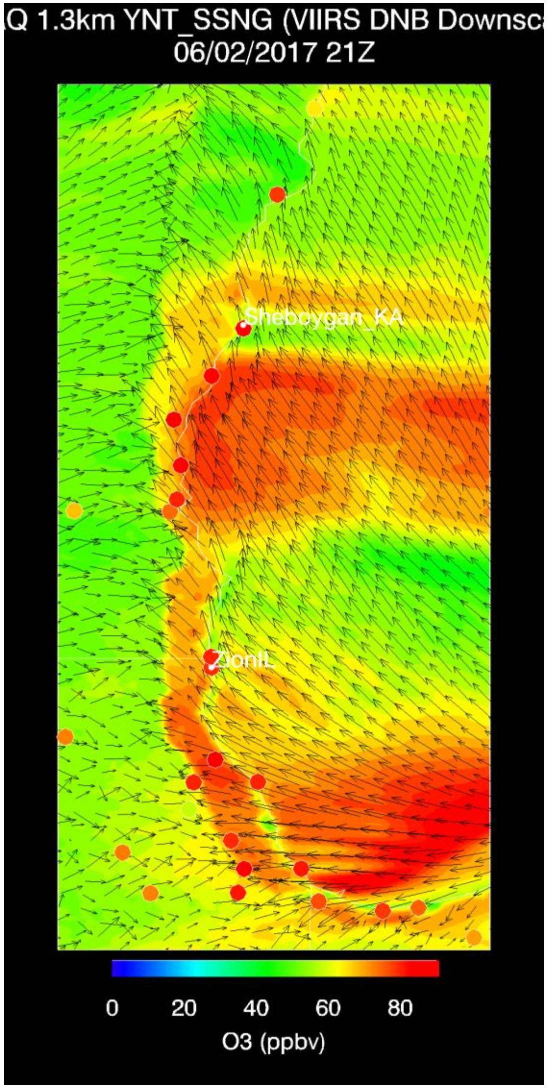


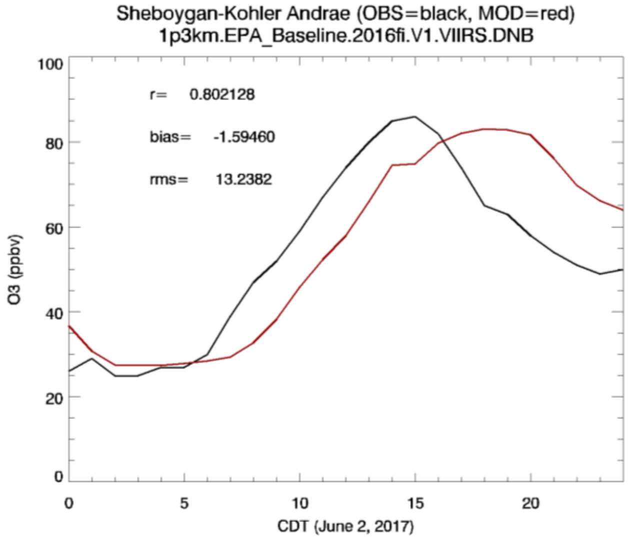
NO2 Interpolated from 2016 Emissions

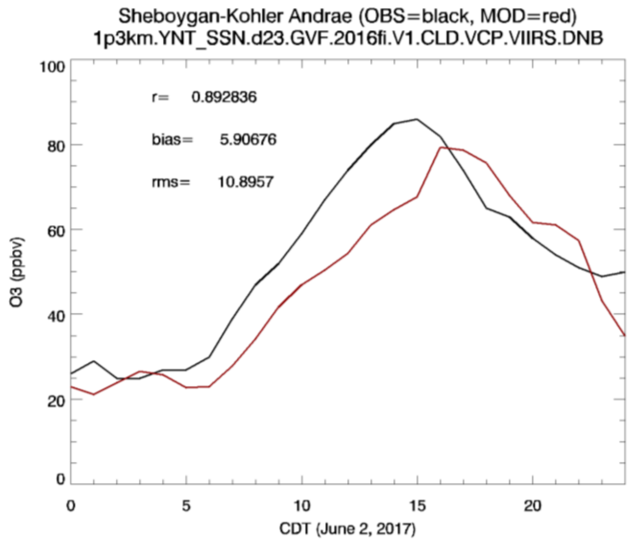


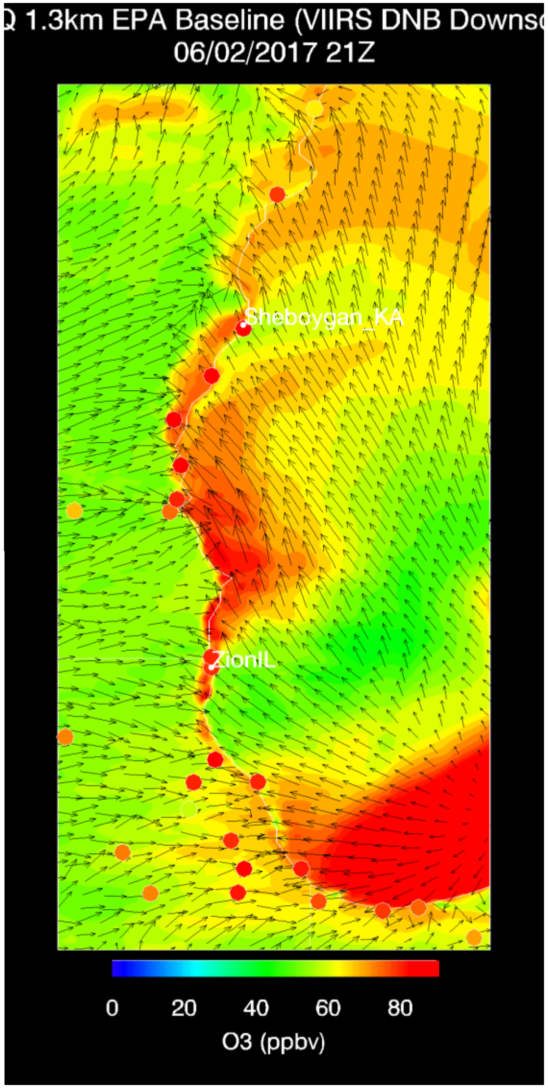
- Goal is to downscale area emissions from the 4-km domain to the 1.3-km domain using light sources in the VIIRS Day-Night band reflectances;
- Downscaling leads to spatially refined emissions along major traffic arteries and lower peak emissions in the Chicago and Milwaukee metropolitan areas
- Several NO2 area sources in the 4-km data that are not captured in the downscaled data (circles) because they are not associated with major light source
- Could be alleviated by combining the downscaling and interpolation approaches

Performance on a High Ozone Day









- Ozone simulation is more accurate at Sheboygan when using the optimized configuration

2016 and 2017 SIP Assessment Activities at LADCO

- LADCO collaborators used the modeling platform developed during this project for ozone SIP development efforts

- Ported WRF and CAMx to Amazon Web Services (AWS)

- WRF modeling platform used to estimate meteorology-dependent emissions such as biogenices and on-road mobile sources

- They showed that the optimized WRF model configuration more accurately simulates ozone season meteorology than did the national EPA simulations

- Also showed that the 4- and 1.33-km domains added value through improved representation of meteorology fields important for ozone

- Their work is an excellent demonstration of the value added by the satellite-constrained WRF modeling system developed during this project

Plans for Next Year

- Focus will be on manuscript preparation

    - Plan to write two papers describing the meteorology and chemistry results

- Continue to hold regular meetings with our project partners and contribute to their ongoing modeling efforts

Key Statements from Stakeholders

LADCO

"During the third year of this project, LADCO used the tools, methods, and data developed during the previous project years to develop air pollution policy support applications. We interacted with the project team to transfer the capabilities for running and evaluating the WRF configurations developed during this project to the modeling staff at LADCO. We used the satellite-constrained WRF configuration developed during this project to produce meteorology modeling inputs for air quality State Implementation Plans (SIP) and air permitting applications for our member states. LADCO ported the WRF modeling configuration from this project to the Amazon Web Services (AWS) cloud during year 3 to enable access to more computing and data storage capacity. Access to the AWS cloud allowed LADCO to run WRF simulations on larger modeling grids, with multiple nests using a configuration that was too computationally demanding for their local computing cluster. LADCO applied the methods and data developed during years 1 and 2 for SIP modeling studies and operationalized the work from this project into their air quality planning workflows. They will continue to use the deliverables from this project for the foreseeable future as they provide decision support to their member states through meteorology and air quality modeling applications."

Wisconsin DNR

"This collaborative project continues to further refine technical modeling efforts supporting Wisconsin's state implementation plan (SIP) requirements. Ozone policy activities rely heavily on meteorological and photochemical models and these models have long-standing, well documented issues predicting ozone around Lake Michigan. These limitations are due in large part to pollutant transport along the lake-land interface, where surface temperature gradients often result in small-scale dynamical features. This project is probing how models resolve meteorology and forecast ozone concentrations by refining multiple sets of model inputs and assumptions using satellite retrievals, including both meteorological and precursor emissions data sets. Improved meteorological configurations resulting from this work are already being utilized by LADCO, while sensitivity testing of high-resolution precursor emissions data continues. The "update and evaluate" progression of this NASA-funded project will continue to lead to improved modeling outcomes for SIPs and other purposes in the future."