

AQRP Monthly Technical Report

PROJECT TITLE	Improving WRF representation of coastal, marine, and residual boundary layers and quantifying the effects on ozone prediction	PROJECT #	24-021
PROJECT PARTICIPANTS	Yuxuan Wang, James Flynn	DATE SUBMITTED	04/10/2025
REPORTING PERIOD	From: 03/01/2025 To: 03/31/2025	REPORT #	7

A Financial Status Report (FSR) and Invoice will be submitted separately from each of the Project Participants reflecting charges for this Reporting Period. I understand that the FSR and Invoice are due to the AQRP by the 15th of the month following the reporting period shown above.

Detailed Accomplishments by Task for reporting period

Task 4:

- Submitted Task 4 Report on March 17.
- Identified additional perturbation schemes.
- Performed simulations and conducted analysis for additional schemes.

Task 5:

- Calculated the Residual layer height.
- Working on Task 5 report.

Preliminary Analysis

A. Additional Schemes

We conducted additional sensitivity simulations to test and identify the best-performing schemes and their possible combinations to improve planetary boundary layer height (PBLH) over the Bay and the Gulf. We activated a 1-D ocean mixed layer model in the WRF. This scheme is expected to improve the PBLH over water by improving the simulation of the diurnal variation of sea surface temperature (SST) and the exchange of heat and moisture between the upper ocean and the atmosphere. Further, the 1-D ocean mixed layer model is combined with one of our previously selected best schemes (PBLH12) to see their combined effects on PBLH. A summary of additional simulations is shown in **Table 1**.

Table 1 Summary of WRF simulation cases and adopted schemes

Simulation ID	Perturbations
PBL_base	None
PBLH12	New Simplified Arakawa-Schubert (NSAS) cumulus scheme
PBLH22	1-D ocean mixed layer model
PBLH23	PBLH12 + PBLH22

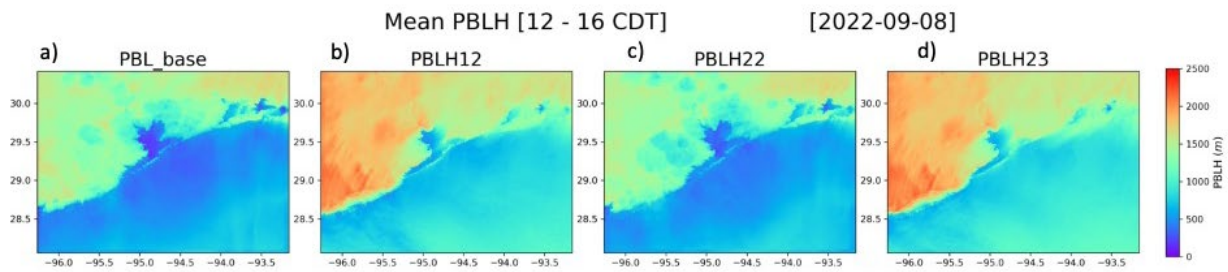


Figure 1 Spatial distribution of the afternoon (12:00 -16:00 CDT) mean PBLH from a) PBL_base, b) PBLH12, c) PBLH22, and d) PBLH23 runs over the study area for Sep 08, 2022.

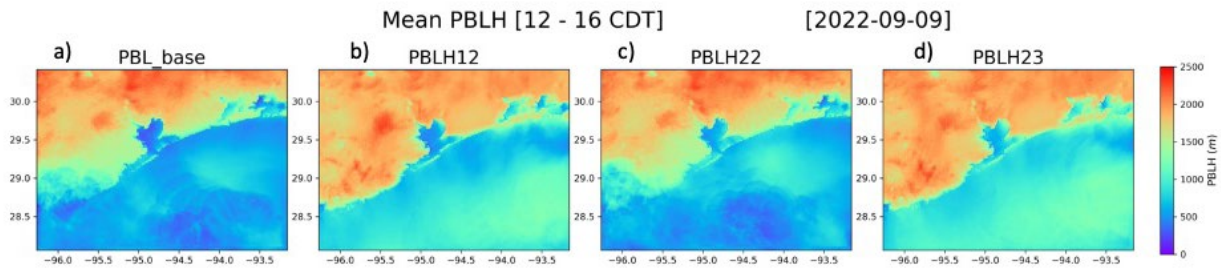


Figure 2 Spatial distribution of the afternoon (12:00 -16:00 CDT) mean PBLH from a) PBL_base, b) PBLH12, c) PBLH22, and d) PBLH23 runs over the study area for Sep 09, 2022.

The spatial distribution of the afternoon (12:00 -16:00 CDT) mean PBLH from different runs for Sep 08 and Sep 09, 2022, are shown in Figure 1 and Figure 2, respectively. The afternoon mean PBLH over the Gulf and the Bay increases by adopting a 1-D ocean mixed layer model (Figure 1c) compared to the base run (Figure 1a) for Sep 08, 2022. We also conducted the combined run (PBLH23) between PBLH12 and PBLH22 (1-D ocean mixed layer model). When we compare the

spatial distribution of the PBLH from PBLH12 (Figure 1b) and PBLH23 (Figure 1d), we see the combined results produced even higher PBLH over the water during the afternoon.

Similar results are seen for Sep 09, 2022, with increased PBLH with the PBLH22 run (Figure 2c) compared to the base run (Figure 2a). The combined run (PBLH23) increases PBLH over the water (Figure 2d) compared with all other perturbation runs.

B. Residual Layer:

We calculated the residual layer (RL) height using the potential temperature gradient, which is thermodynamically defined as the rate of change in potential temperature (θ) with height (z). The RL top was identified as the height where the sharpest increase in the potential temperature gradient occurred, typically above $3\text{ }^{\circ}\text{C}/\text{km}$, marking the transition from the weakly stratified residual layer to the capping inversion. We then compared the calculated RL height with ceilometer-observed PBL heights at La Porte. Figure 3 compares the observed PBLH, the model-predicted PBLH, and the thermodynamically diagnosed RL height for Sep 24, 2021, across four model configurations: PBL_base, PBLH5, PBLH12, and PBLH14. In each panel, the background shading shows the modeled vertical gradient of potential temperature ($\partial\theta/\partial z$), which helps identify key atmospheric layers. On this day, the ceilometer data clearly shows the presence of a nocturnal residual layer, which is not captured by the Base model, as it only simulates a shallow stable boundary layer at night. However, the perturbed simulations (PBLH5, PBLH12, and PBLH14) show a better agreement with the observed residual layer.

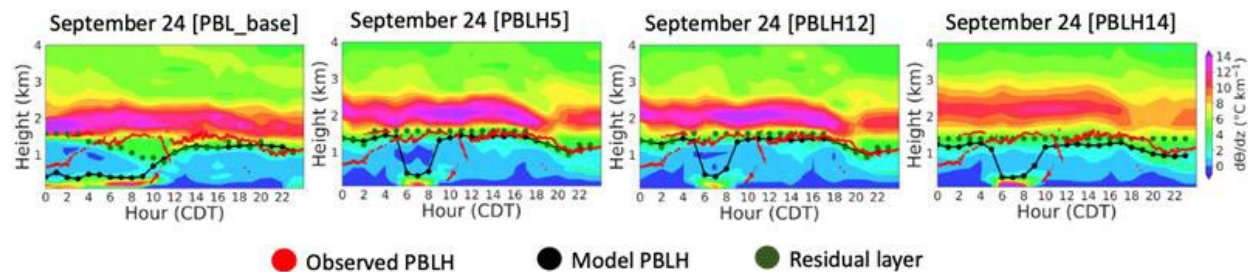


Figure 3 Observed and modeled planetary boundary layer height (PBLH), along with the calculated residual layer heights for Sep 24, 2021, at La Porte. The panels show results from four model configurations: PBL_base, PBLH5, PBLH12, and PBLH14. The background shading represents the modeled vertical gradient of potential temperature ($\partial\theta/\partial z$). Red dots indicate ceilometer-observed PBLH, black lines show model-predicted PBLH and green markers represent the diagnosed residual layer top based on potential temperature gradient analysis.

Detailed analysis of the residual layer will be described in the Task 5 Report, which is due April 15, 2025.

Data Collected

None

Identify Any Problems or Issues Encountered and Proposed Solutions or Adjustments

None

Goals and Anticipated Issues for the Succeeding Reporting Period

Goals: Continue with Task 5. Submit Task 5 Report

Anticipated Issues: None.

Detailed Analysis of the Progress of the Task Order to Date

None

Do you have any publications related to this project currently under development? If so, please provide a working title, and the journals you plan to submit to.

Yes No

Do you have any publications related to this project currently under review by a journal? If so, what is the working title and the journal name? Have you sent a copy of the article to your AQRP Project Manager and your TCEQ Liaison?

Yes No

Do you have any bibliographic publications (ie: publications that cite the project) related to this project that have been published? If so, please list the reference information. List all items for the lifetime of the project.

Yes No

Do you have any presentations related to this project currently under development? If so, please provide working title, and the conference you plan to present it (this does not include presentations for the AQRP Workshop).

Yes No

Do you have any presentations related to this project that have been published? If so, please list reference information. List all items for the lifetime of the project.

Yes No

Have any personnel changes occurred that were not listed in the original proposal? If so, please include a detailed description of the personnel change(s) below.

Yes No

Are any delays expected in the progress of the research? If so, please include a detailed description of the potential delay below.

Yes No

Describe any possible concerns/issues (technical or non-technical) that AQRP should be made aware of.

**Are you anticipating using all the available funds allocated to this project by the end date?
If not, why and approximately what is the amount to be returned?**

Yes **No**

Submitted to AQRP by
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