A Comparison of Modeled Meteorology Patterns in a Coastal Area during Low Ozone Periods

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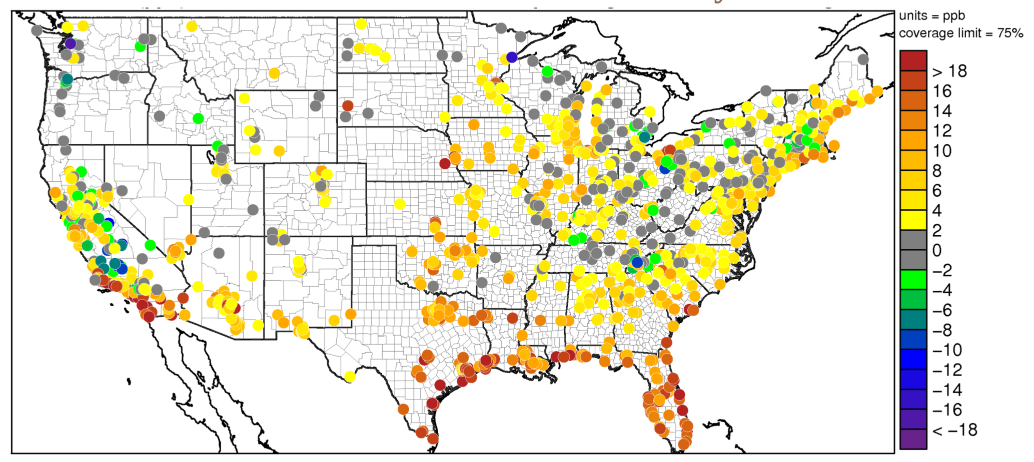
Motivation

Past studies have documented the tendency for regional photochemical models to over-predict ozone (O_3) concentrations along the Gulf of Mexico coast in the US (Yarwood et al., 2012; Environ, 2012; Simon et al., 2012, Smith et al., 2013). It has been suggested that this over-prediction is, at least in part, due to missing/under-estimated marine O_3 loss mechanisms in the model including: underestimate of O_3 deposition velocity over sea-water and O_3 destruction by halogen chemistry .

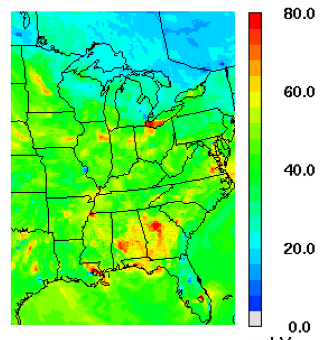
New analysis of a 2007 CMAQ model simulation support these conclusions

1. Ozone bias is larger along the Gulf of Mexico coast than for most other areas of the country

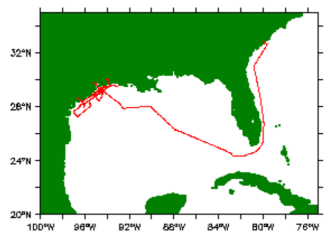


Mean Bias in MDA8 O_3 from 2007 CMAQv5.01 Simulation: Jun-Aug

2. Measurements of O_3 concentrations over the Gulf of Mexico are generally lower than modeled concentrations



CMAQ O_3: Jul 1 2007 (ppb)



Ship track of Ron H. Brown in 2006

- The Ron H. Brown was in the open gulf of Mexico for ~4 days during the 2006 TEXAQS II field study (Helmig et al., 2012)
- Measured O_3 ranged from 0-35 ppb
- Median O_3 was ~26 ppb
- Modeled O_3 over the Gulf of Mexico (2007) was generally closer to 40 ppb

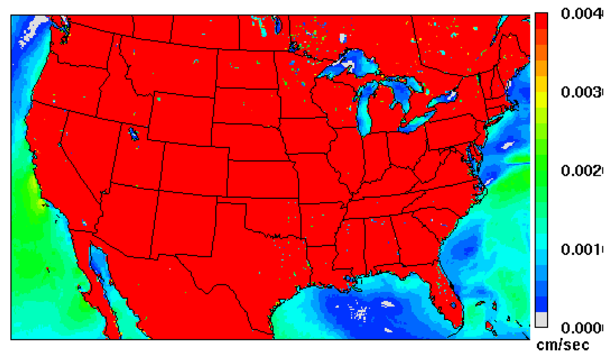
3. Measurements of O_3 deposition velocity over the Gulf of Mexico are about an order of magnitude larger than modeled deposition velocities

Table 3. Summary and Statistical Evaluation of Ozone Deposition Velocity Results, With Results for TexAQS Broken Up Into $TexAQS_{Coast}$ (Land- and Coast-Influenced Regions) and $TexAQS_{OO}$ (Open Ocean) and GOMECC Data Broken Up Into Subsets for the Gulf of Mexico (GOM) and North Atlantic Region (ATL) Measurements[a]

	Ozone v_d (cm s^{-1})							
	Mean	Median	25th%	75th%	No	Nf	T1 (h)	T2 (h)
$TexAQS_{All}$	0.22	0.056	0.024	0.19	6588	3059	1098	510
$TexAQS_{Coast}$	0.55	0.27	0.122	0.547	3521	1106	587	184
$TexAQS_{OO}$	0.036	0.034	0.009	0.065	3067	1953	511	326
STRATUS	0.0090	0.0090	0.0041	0.037	1662	1336	277	223
$GOMECC_{All}$	0.019	0.018	−0.0063	0.045	3480	1784	580	297
$GOMECC_{GOM}$	0.014	0.019	−0.014	0.043	1100	663	183	111
$GOMECC_{ATL}$	0.022	0.018	−0.0041	0.045	2380	1121	397	187
GasEx	0.010	0.0090	−0.005	0.026	4628	2745	771	458
AMMA	0.026	0.020	−0.0029	0.044	2568	1147	428	191

[a]No is the total number of 10 min flux data points, and Nf is the remaining number of data points after filtering (10 min averages). T1 is the total time of collected data; T2 is the total time of good data (left after filtering).

Table from Helmig et al. (2012)



CMAQ O_3 deposition velocity: Jul 1 2007 (cm/s)

Marine O_3 Loss Sensitivity Analysis

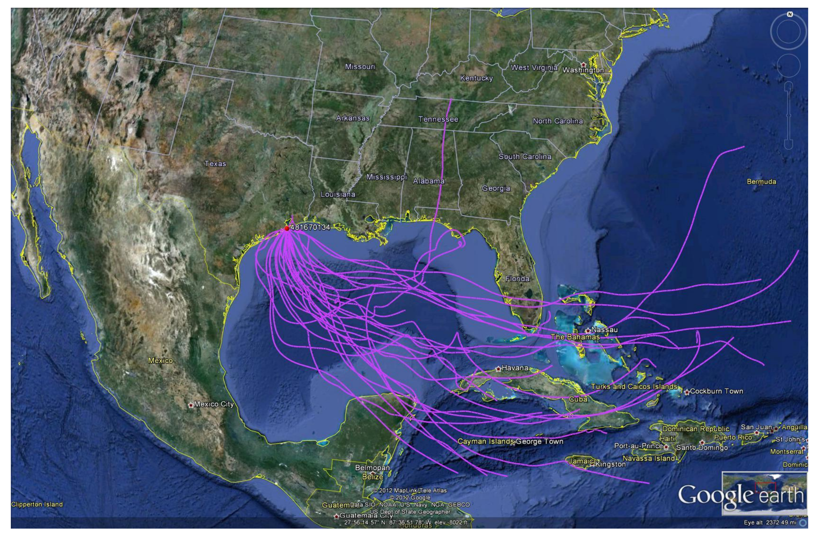
To investigate this phenomenon further, we performed a CMAQ sensitivity simulation with a first-order O_3 loss reaction over marine grid cells in the boundary layer

- July-Aug 2007
- CMAQv5.0.1, WRFv3.3
- O_3 loss rate = 2.0×10^{-6} s^{-1} (based on Read et al., 2008)
- O_3 deposition velocity over water set to 0.034 cm/sec based on Helmig et al. (2012)
- See Sarwar et al. (poster #11) for more sophisticated evaluation of marine O_3 chemistry

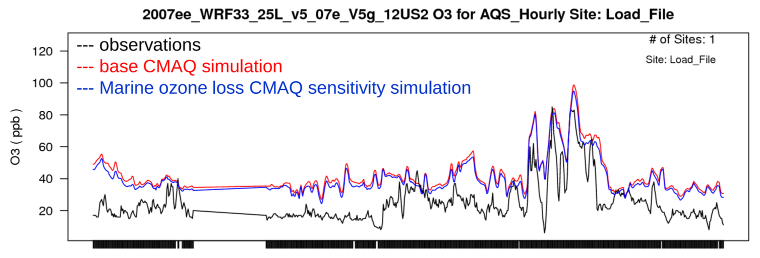
Galveston, Texas Case Study

Galveston's location as a coastal site that can be influenced by marine as well as continental and urban air masses makes it an ideal case study for further investigating the causes of coastal O_3 over-predictions

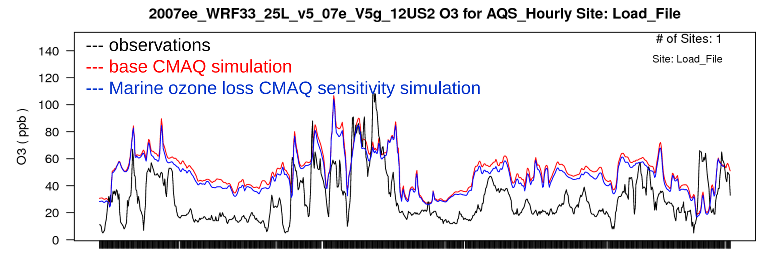
1. 120-hr back trajectories on days with the poorest model performance during the summer of 2007, suggest that O_3 over-prediction is associated with onshore flow from the Gulf of Mexico (similar to Smith et al., 2013)



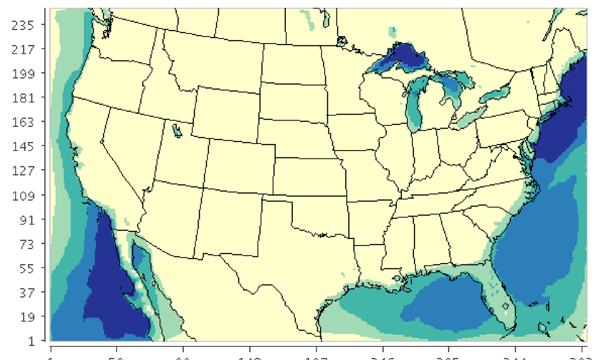
2. The largest model over-predictions occur on low O_3 days. Despite reducing O_3 concentrations over marine grid cells, the sensitivity simulation did little to improve this model over-prediction at the Galveston monitor



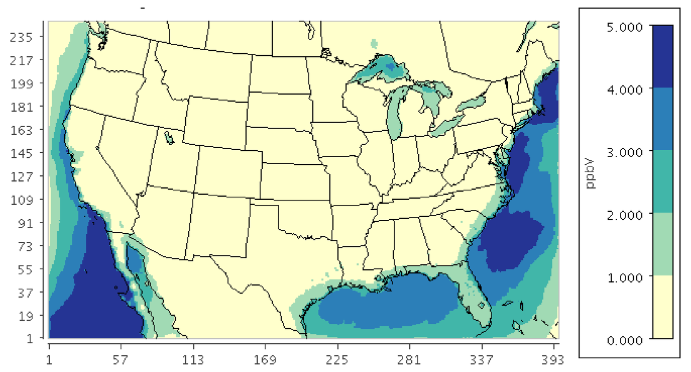
Hourly time series of observed and modeled O_3 in Galveston, TX: Jul 2007



Hourly time series of observed and modeled O_3 in Galveston, TX : Aug 2007

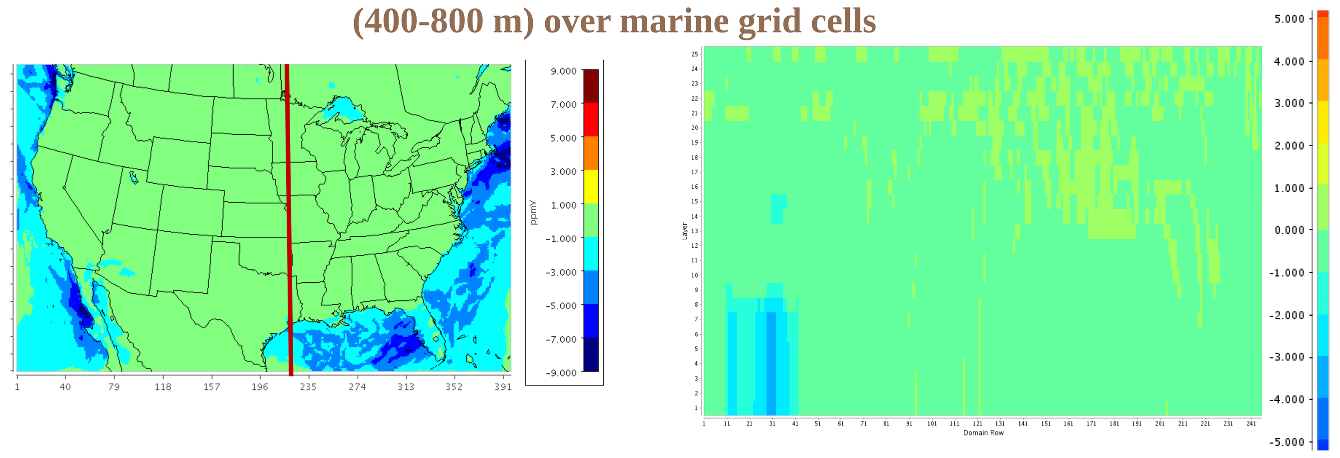


Mean decrease in hourly O_3 from the marine O_3 loss sensitivity simulation: Jul 2007



Mean decrease in hourly O_3 from the marine O_3 loss sensitivity simulation: Aug 2007

3. A vertical profile of the O_3 response to the modeling sensitivity simulation shows that O_3 reductions occur in the lowest 7-9 model layers (400-800 m) over marine grid cells



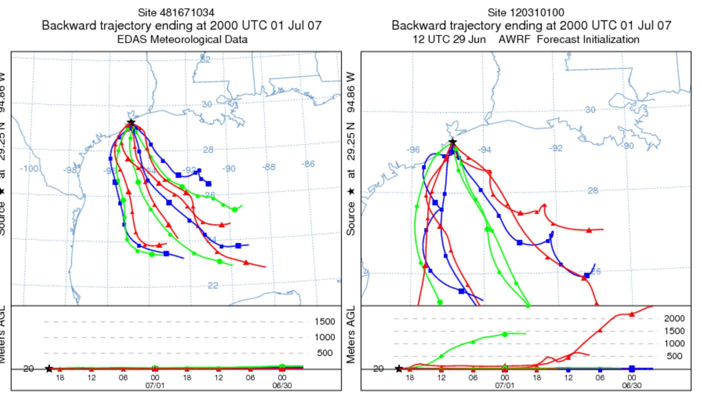
Decrease in O_3 from the marine O_3 loss sensitivity simulation: July 13, 2007 17:00 UTC in the first model layer (left) and for the vertical profile cross section for transect shown in red (right)

- *Galveston observed Jul 13 MDA8: 16.5 ppb*
- *Galveston modeled Jul 13 MDA8: 38.9 ppb*

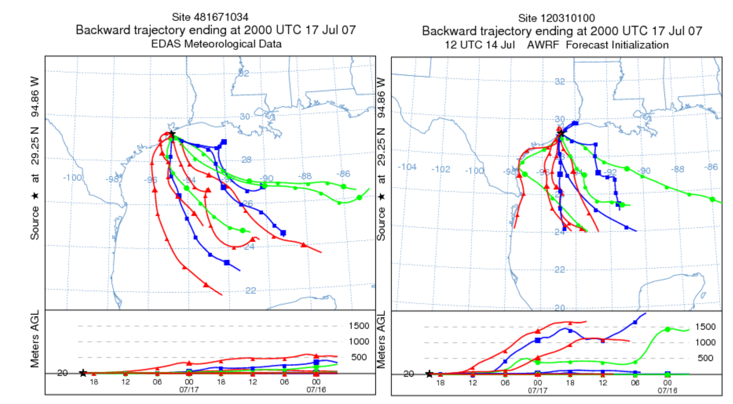
Comparison of WRF and EDAS Back Trajectories

To further investigate why the marine O_3 sensitivity simulation did not substantially lower O_3 in Galveston on low O_3 days that were predominately marine influenced, we compare HYSPLIT back trajectories from the model simulation (WRF) versus those from the Eta Data Assimilation System (EDAS) during the summer of 2007.

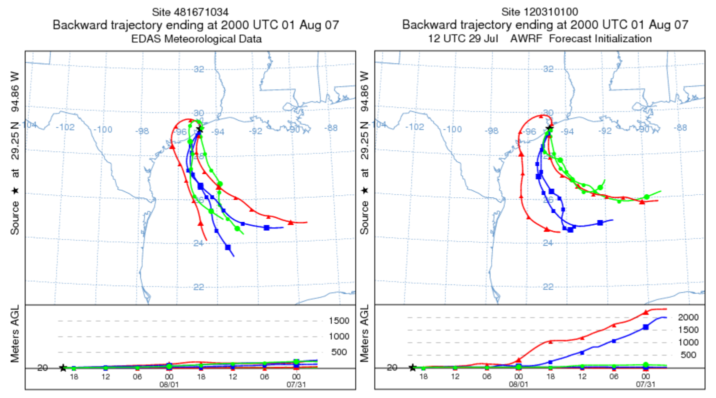
- Back trajectories were evaluated for a starting location of Galveston, Texas at a height of 20m
- All back trajectories were run for 48 hours starting 2pm local time on all days for which MDA8 O_3 was less than 35 ppb
- HYSPLIT was run using the default model vertical velocities for both WRF and EDAS



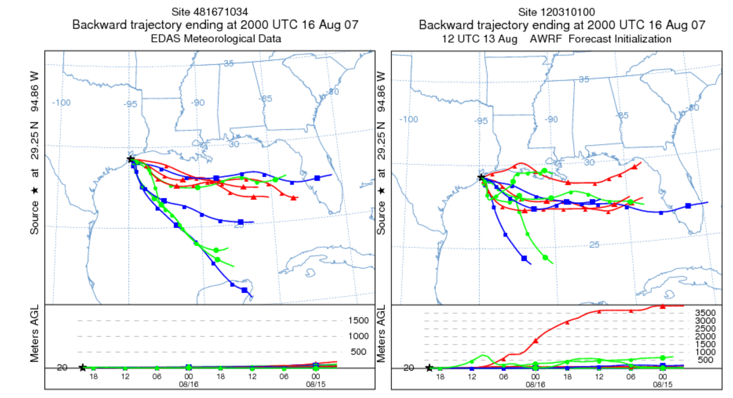
Back trajectories from EDAS (left) and WRF (right) on July 1, 2, 3, 4, 10, 11, 12 ,13, 14, 15



Back trajectories from EDAS (left) and WRF (right) on July 17, 18, 19, 20,26, 27, 28, 29, 30, 31



Back trajectories from EDAS (left) and WRF (right) on August 1, 5, 6, 7, 8, 9



Back trajectories from EDAS (left) and WRF (right) on August 16, 17, 18, 21, 22, 23, 24, 25, 29

- These plots show that both EDAS and WRF consistently predict that air originates from marine locations on low ozone days. The horizontal back trajectories cover similar horizontal extents.
- These plots also show, that on some days, WRF vertical mixing is substantially greater than EDAS vertical mixing. WRF back trajectories often reach up to 1000-1500 m while EDAS back trajectories generally stay within 500 m of the surface
- This suggests that although the marine O_3 loss sensitivity depletes O_3 in the marine boundary layer, WRF may be drawing down higher O_3 air from aloft resulting in higher surface O_3 at coastal sites
- If this is the case, then coastal O_3 concentrations will not be substantially impacted on these days unless either 1) coastal WRF treatment is modified to reduce vertical mixing or 2) marine O_3 loss were to extend above the marine boundary layer
- This analysis is not conclusive but raises questions about the combined effect of processes included in the air quality model, the meteorological model and the boundary condition representations on coastal O_3 predictions

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