United States Environmental Protection Agency

High Resolution WRF-CMAQ modeling during LISTOS

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Long Island Sound Tropospheric Ozone Study (LISTOS)

LISTOS was a multi-agency collaborative field campaign organized by the Northeast States for Coordinated Air Use Management (NESCAUM) with the goal to improve our understanding of ozone chemistry and transport from New York City to areas downstream, especially the Long Island Sound and adjacent Connecticut coastline.

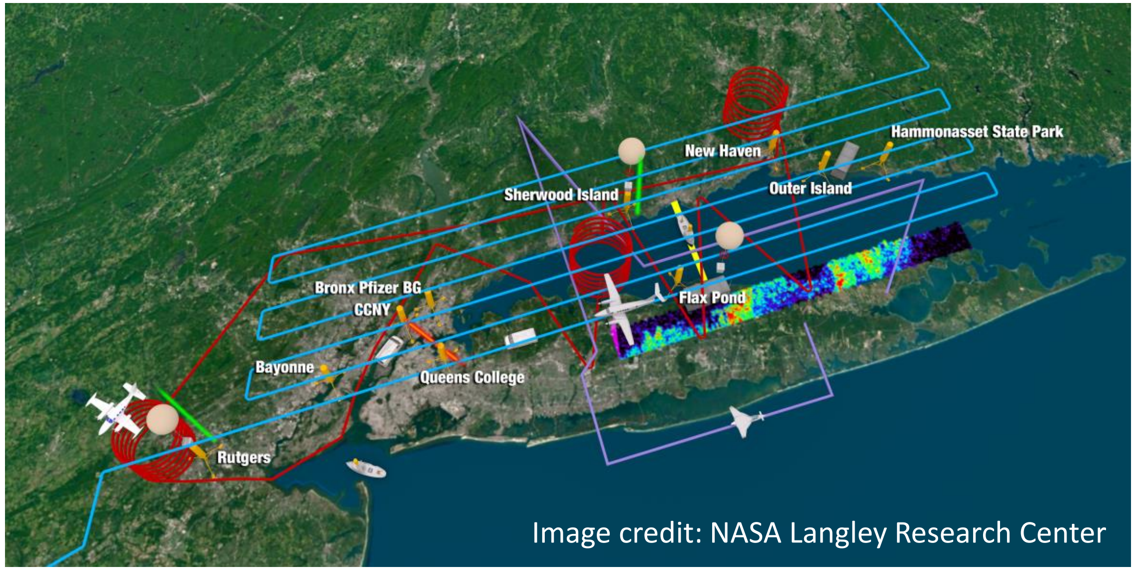


Image credit: NASA Langley Research Center

Science Questions

How well does WRF-CMAQ model represent transport features like:

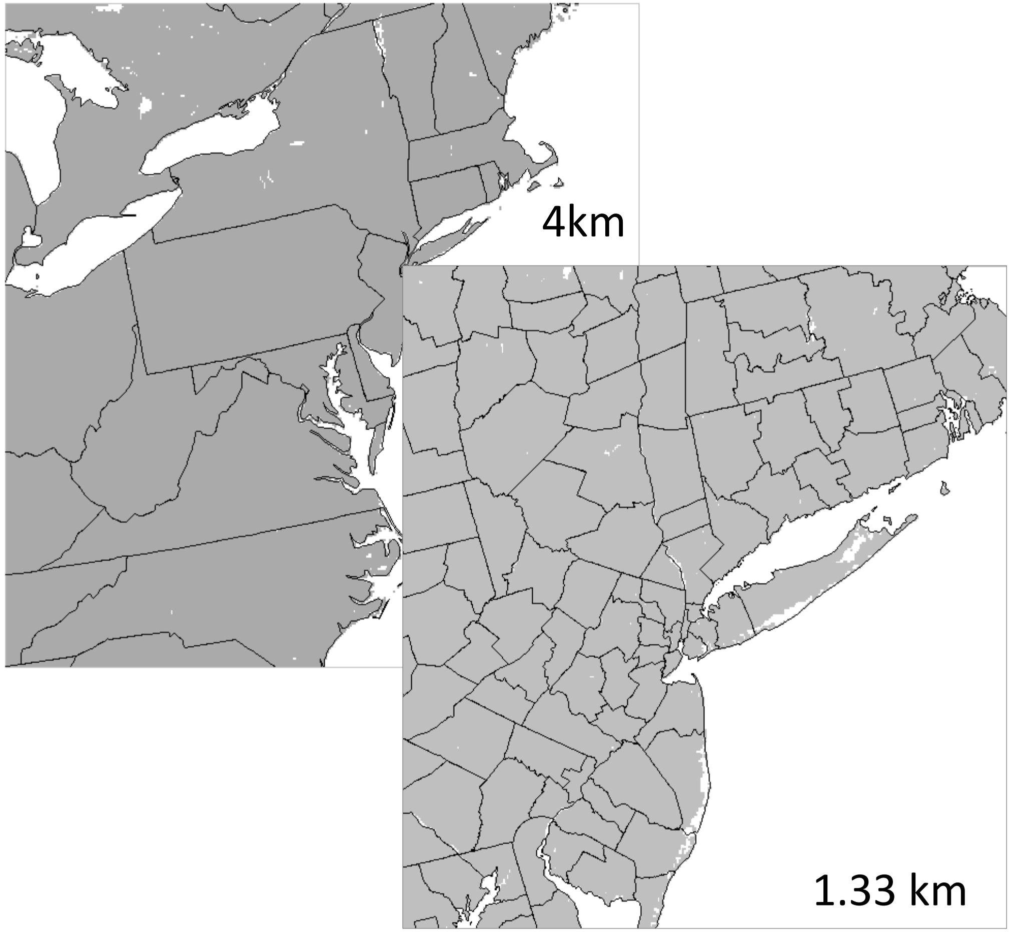
- the flow regimes that are conducive to high ozone on CT coast?
- land/sea breezes along the CT and Long Island coastlines?
- low level jets (LLJs)?

and their impacts to pollutant transport and production?

Can we improve model performance with modifications to physics or data assimilation?

Modeling Approach

Model Versions	Coupled WRF-CMAQ; WRFv4.1.1, CMAQv5.3.1
Initial Conditions for 12km simulation	NAM 12km Analysis 108km Hemispheric CMAQ
Run period	12km: 2018 4km & 1.33km : May – Sept 2018.
Emissions	2016ff projected forward to 2018; 1.33km domain had additional county-specific information.



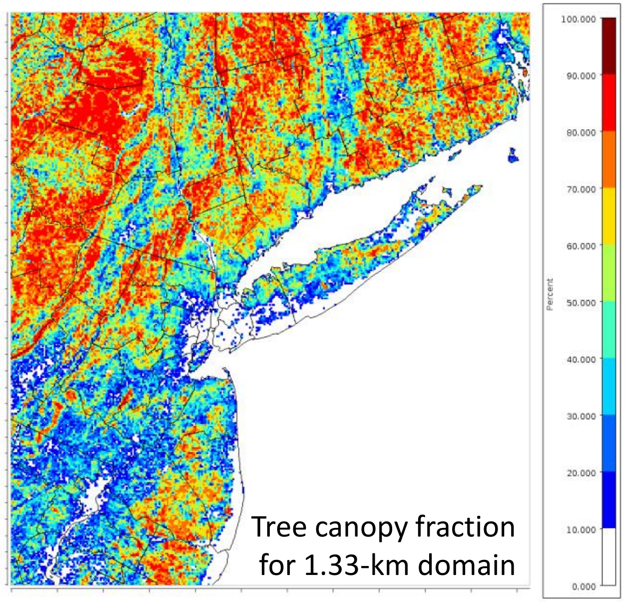
Modeling Approach

Updates to meteorological modeling:

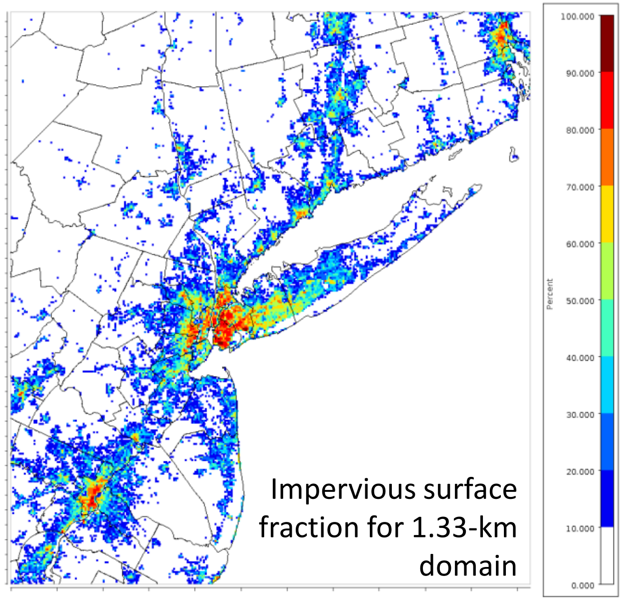
- Updated sea surface temperature using high resolution surface data: GHRSST (1 km).
- Surface data assimilation using UnRestricted Mesoscale Analysis (URMA) (2 km) through PX LSM soil moisture and temperature nudging
- Updated land-use, tree canopy and imperviousness information using 2016 NLCD-MODIS data

Key aspects of emissions

- Onroad mobile sources – Run MOVES with county specific updated VMT, age distribution, temporal profile from 2017 (adjust for day of week for 2018)
- Marine – hourly GPS ship data from 2017 (adjust for day of week for 2018)

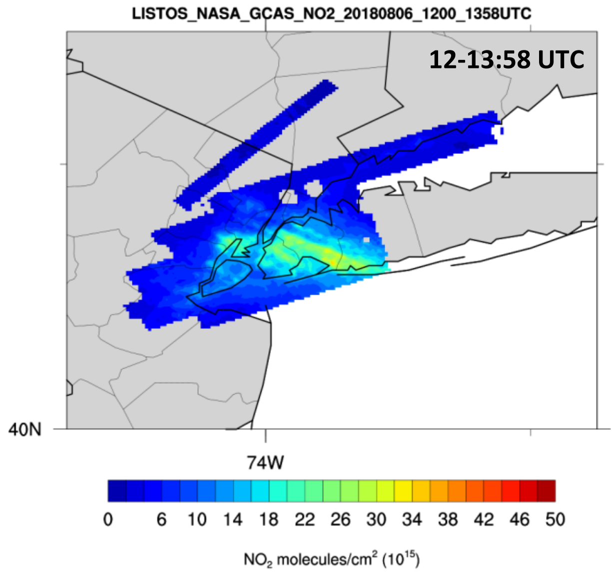


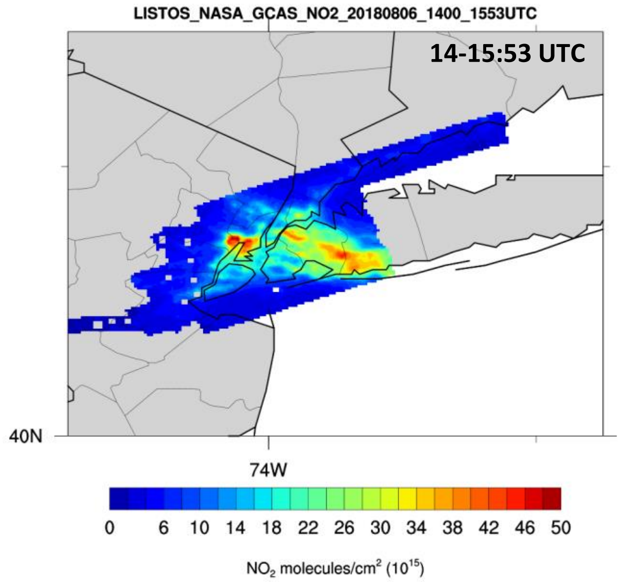
Tree canopy fraction for 1.33-km domain



Impervious surface fraction for 1.33-km domain

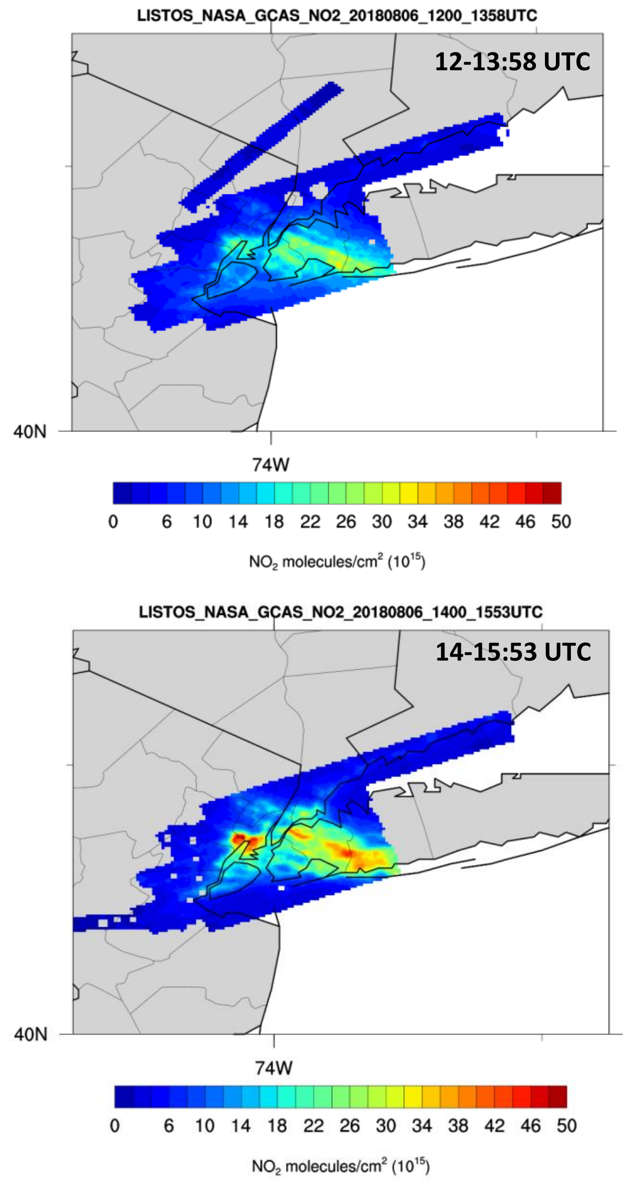
GCAS captures NO_2 sources and their transport in the early morning of August 6, 2018

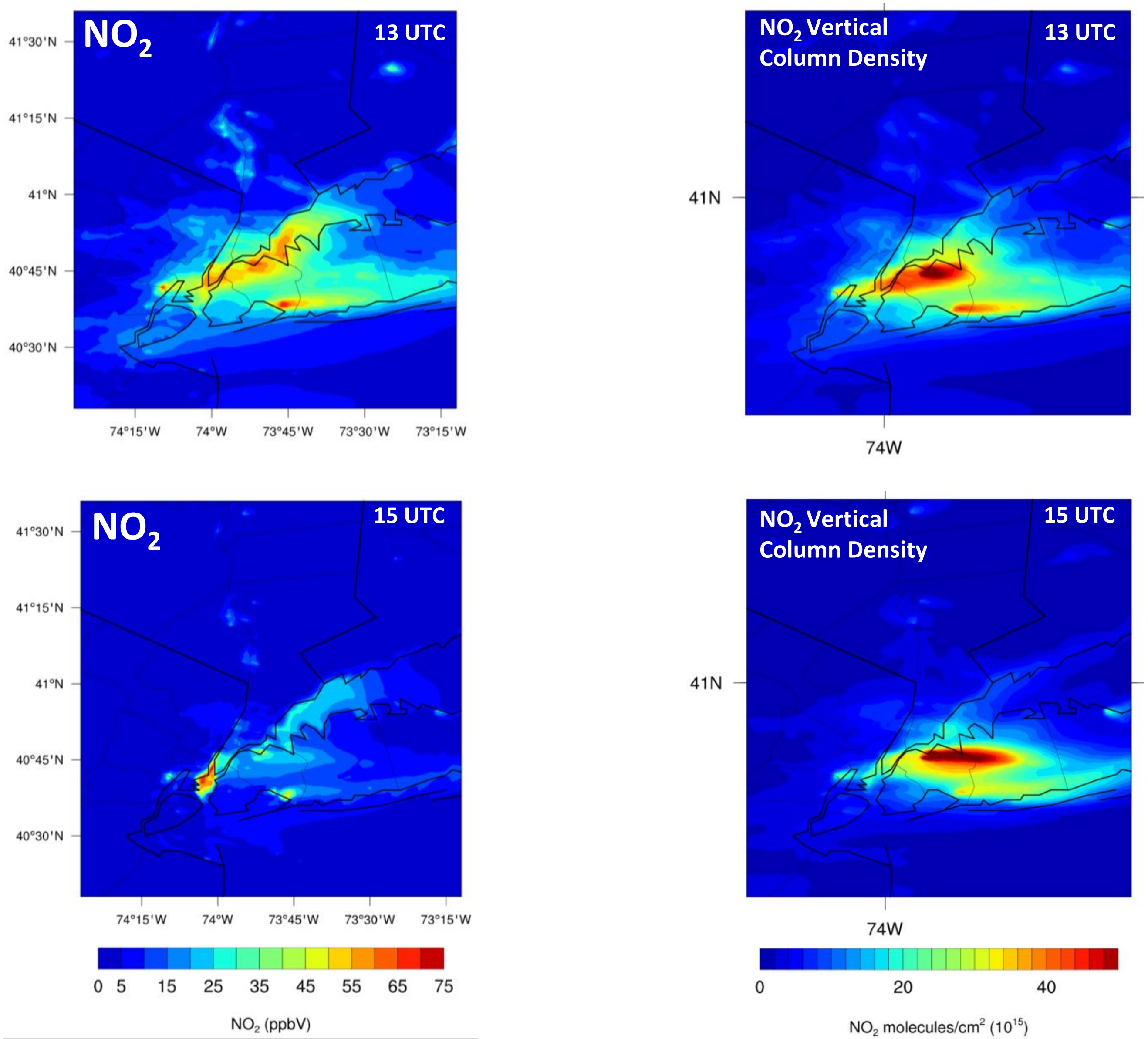




GCAS captures NO_2 sources and their transport in the early morning of August 6, 2018

Our 1.33km simulations replicates some of these sources **at the surface** but simulates different transport and timing regimes along the columns.





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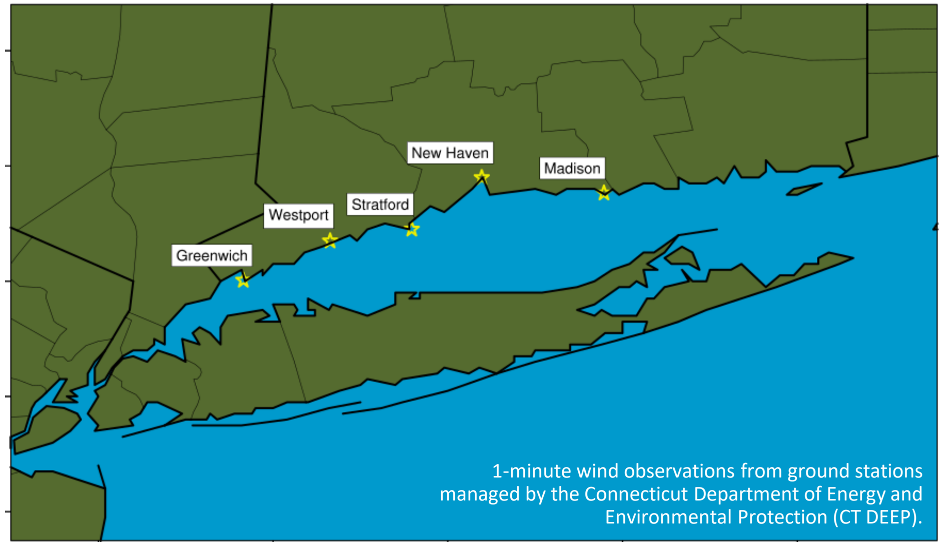
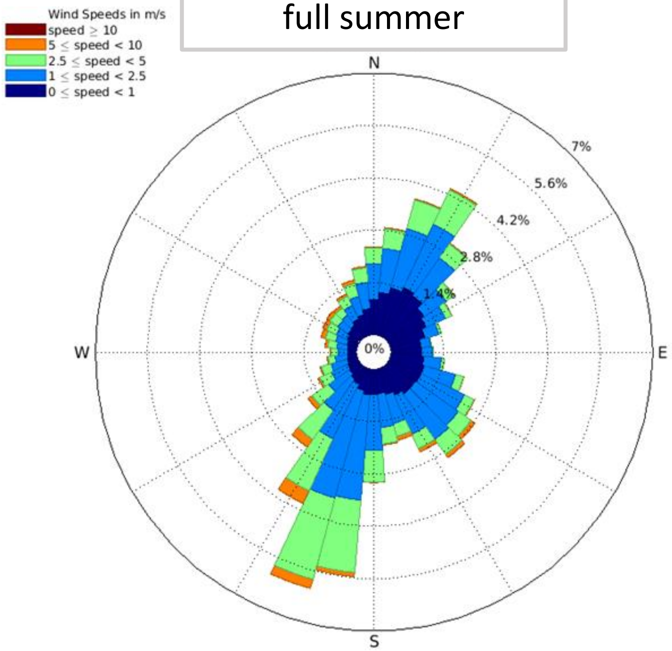
Surface-level wind flow

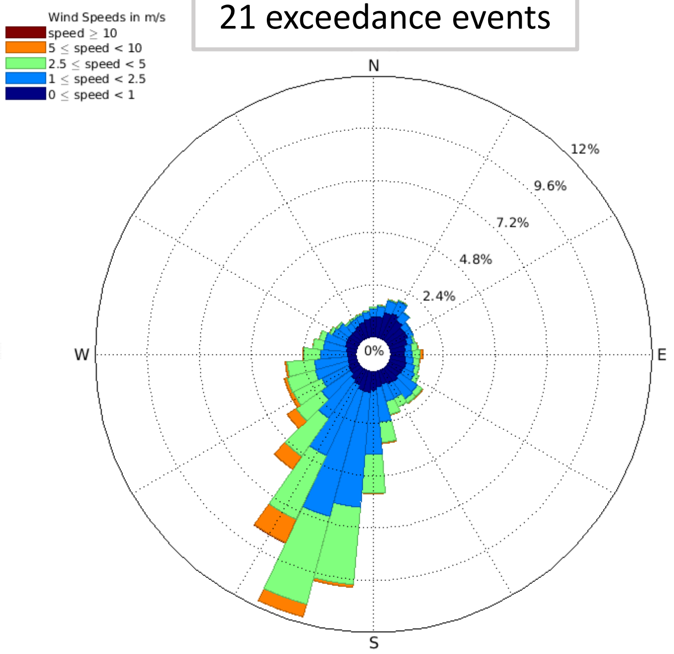
- Summer-long flow is predominantly SSW, with NE and SE activity.
- Measurements during the 21 exceedance events show predominant SSW flow.
- Model captures general character of observed flow, but overestimates wind speeds and flow variance.



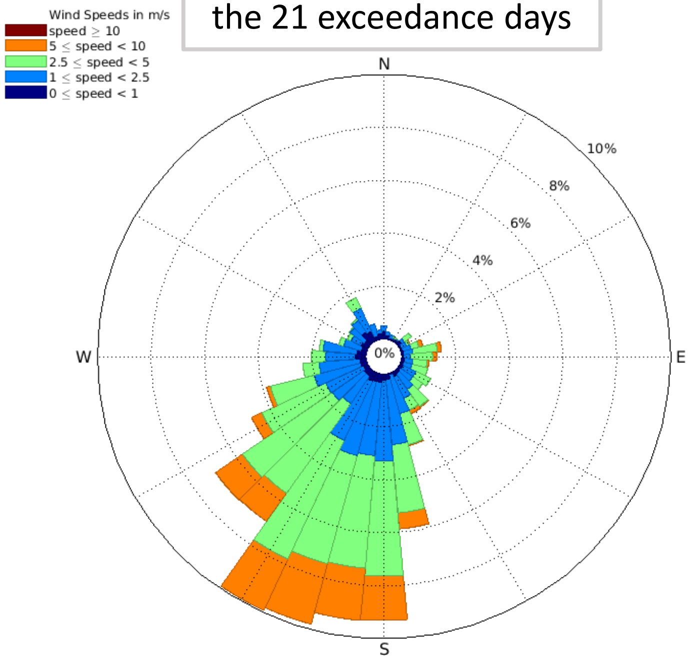
Observations from the full summer



Observations from the 21 exceedance events

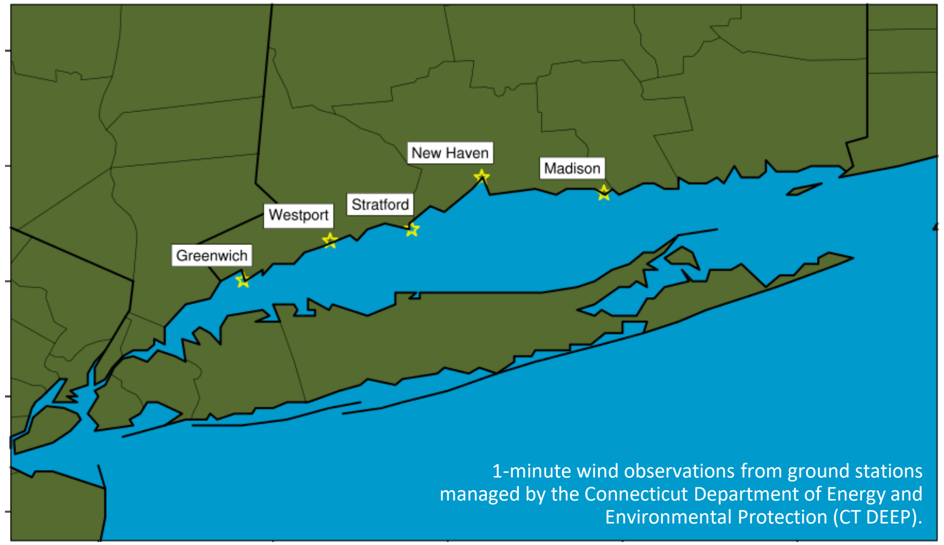


Modeled winds during the 21 exceedance days



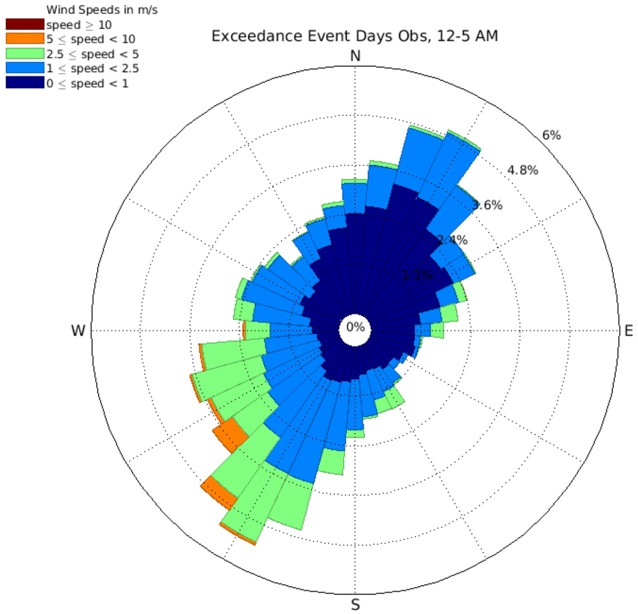
Surface-level wind flow

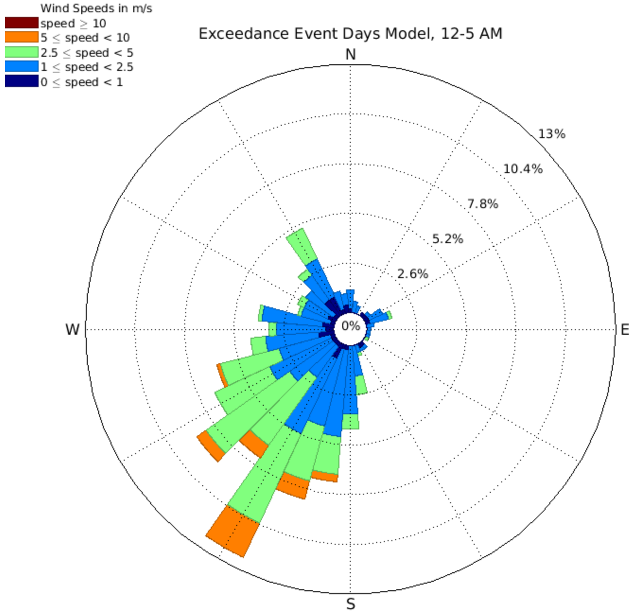
- Summer-long flow is predominantly SSW, with NE and SE activity.
- Measurements during the 21 exceedance events show predominant SSW flow.
- Model captures general character of observed flow, but overestimates wind speeds and flow variance.
- Model does not capture NNE land-breeze-like wind shift between 12 AM – 5 AM.

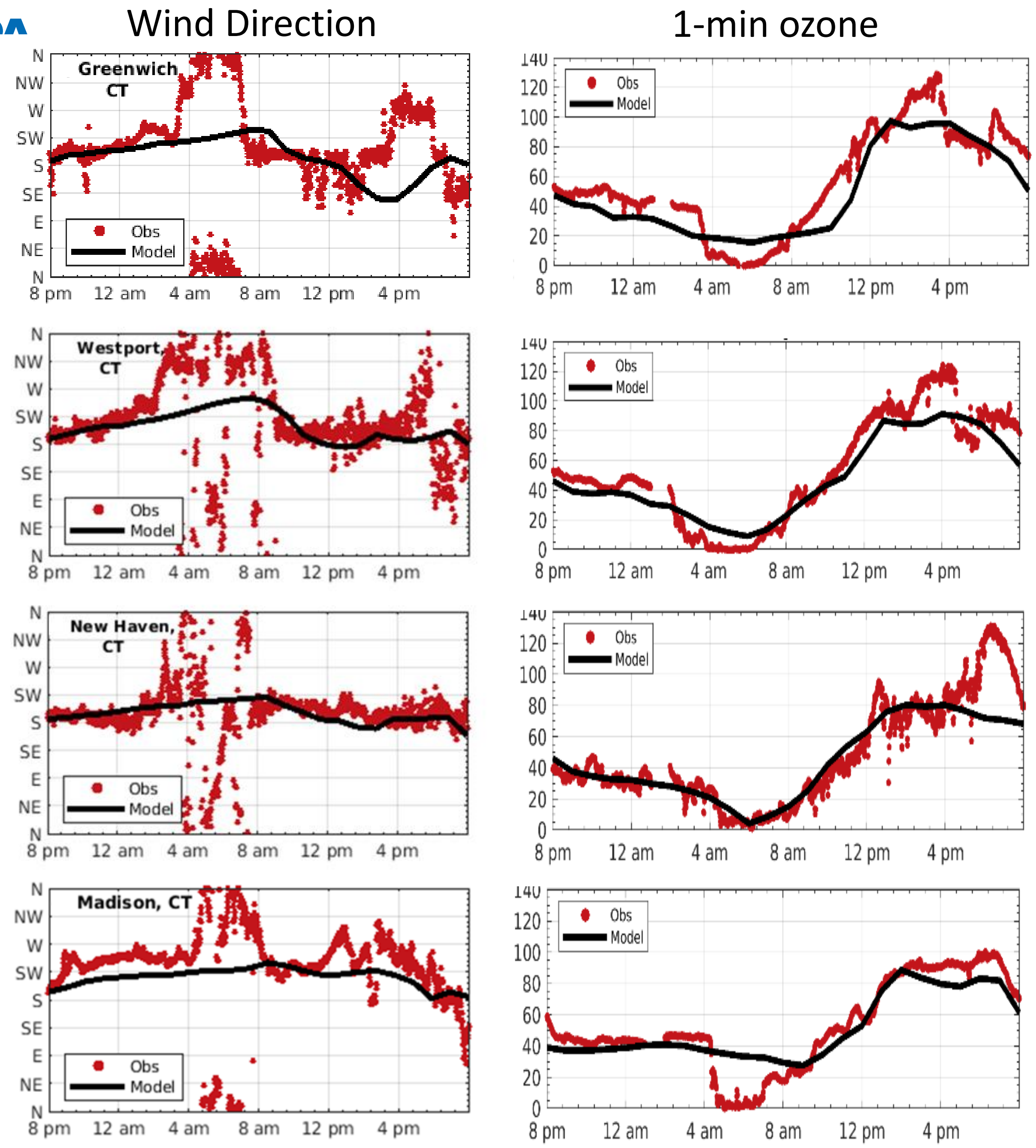


1-minute wind observations from ground stations managed by the Connecticut Department of Energy and Environmental Protection (CT DEEP).

12 AM – 5 AM Exceedance Event Observations versus Model







Surface-level wind flow along the CT coast on July 10

Model does not simulate overnight land breeze processes along coastal CT stations.

Subsequently, residual ozone from the previous day was not fully cleared out.

At Greenwich: a delay in onset of on-shore breeze coincides with a delay in ozone production, which suggests importance of flow to adequate simulation of ozone.

At Madison: onset of ozone production preceded SW flow shift, suggesting localized production.

Model misses max. ozone concentrations at all stations.

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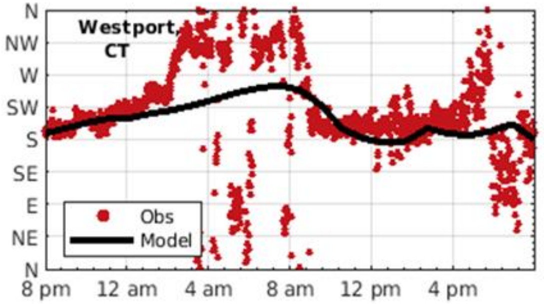
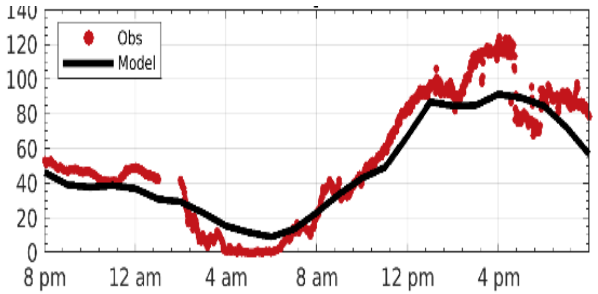
Surface-level wind flow along the CT coast on July 10

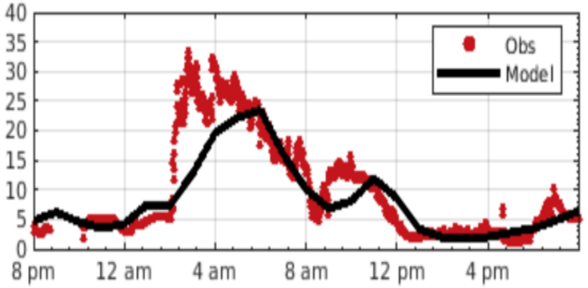
Wind Direction



1-min ozone



NO_2



Breeze-ozone-NO_2 relationships recreated by the model.

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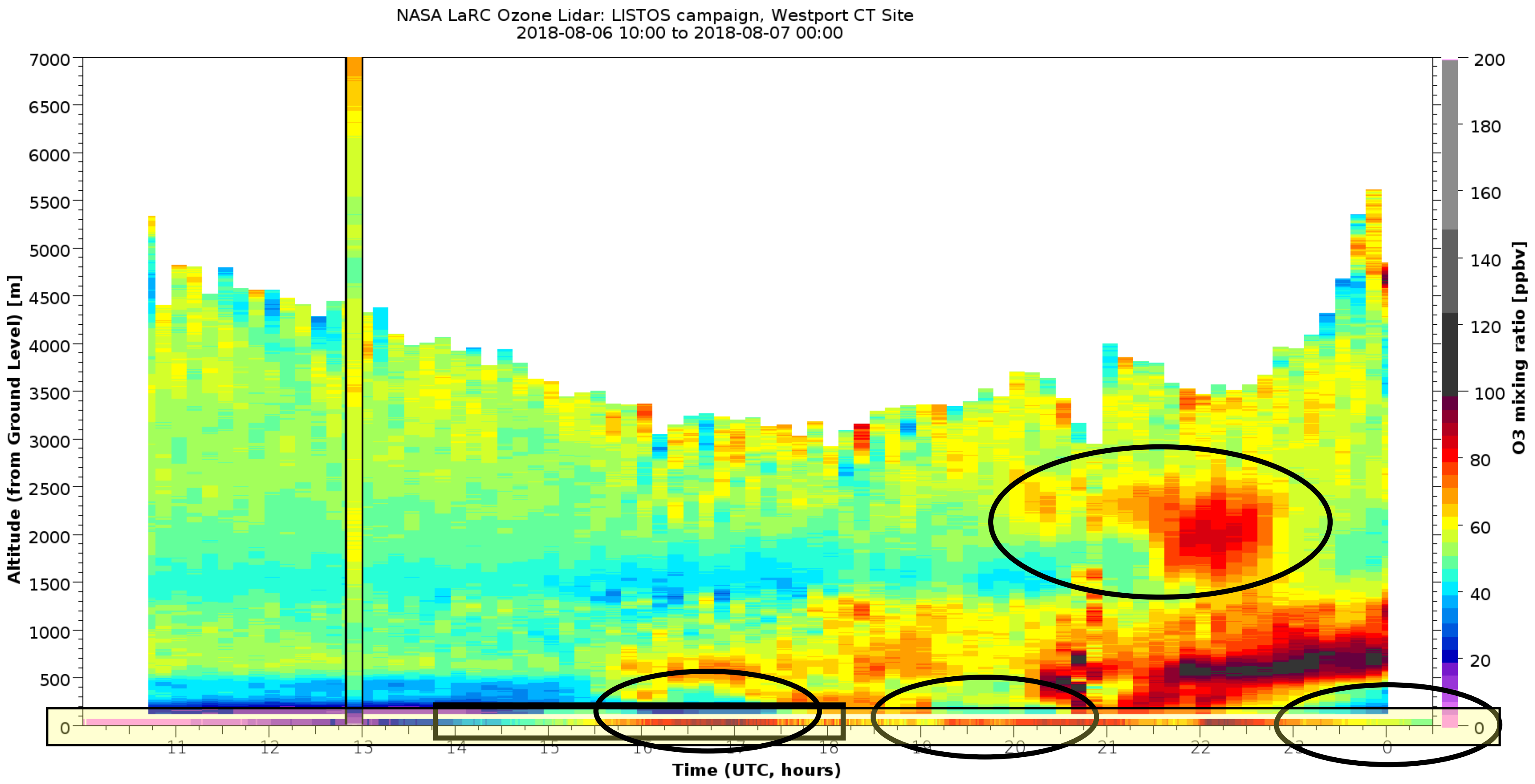
Ozone LIDAR at Westport

Potential evidence of:

1. Rapid growth within shallow surface layer
2. Localized low-level jets
3. …and a plume transporting high ozone concentrations over Westport.



Ozone LIDAR data at Westport provides us with an encompassing snapshot of processes related to ozone production and ozone exceedances along the CT coast.

Data courtesy of Tim Berkoff, NASA.

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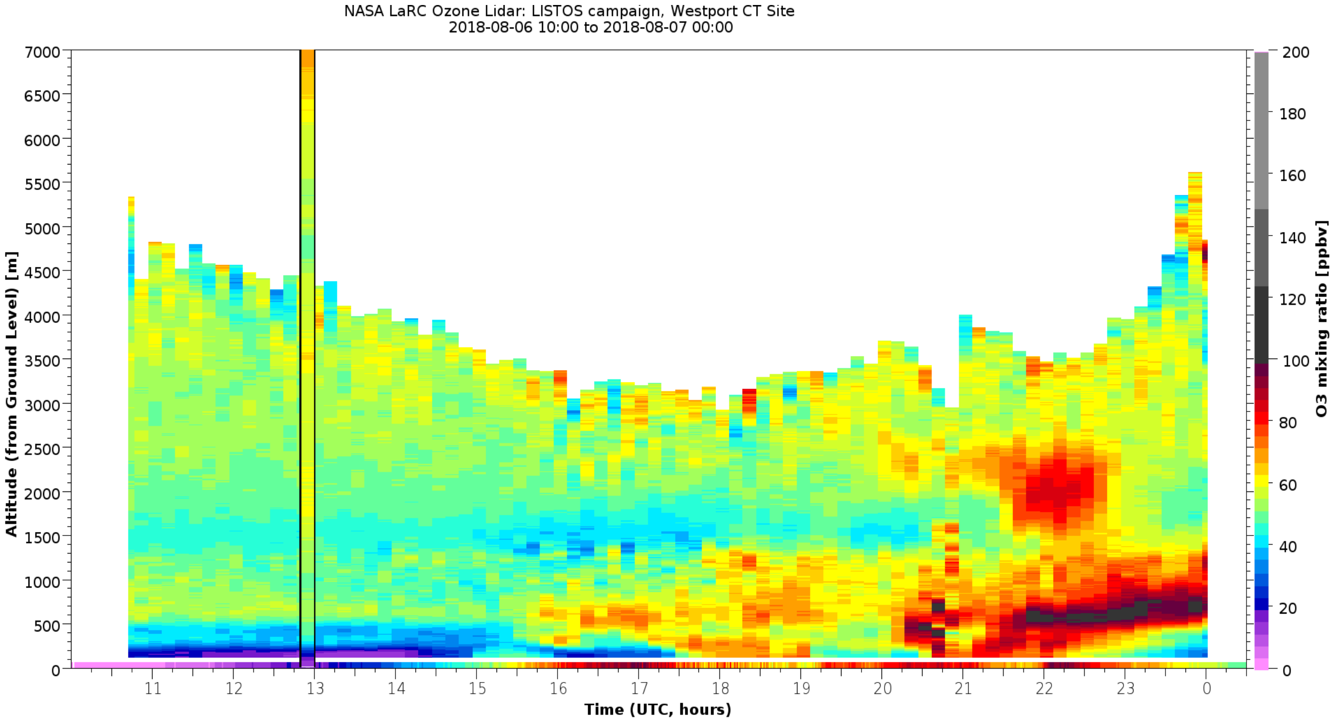
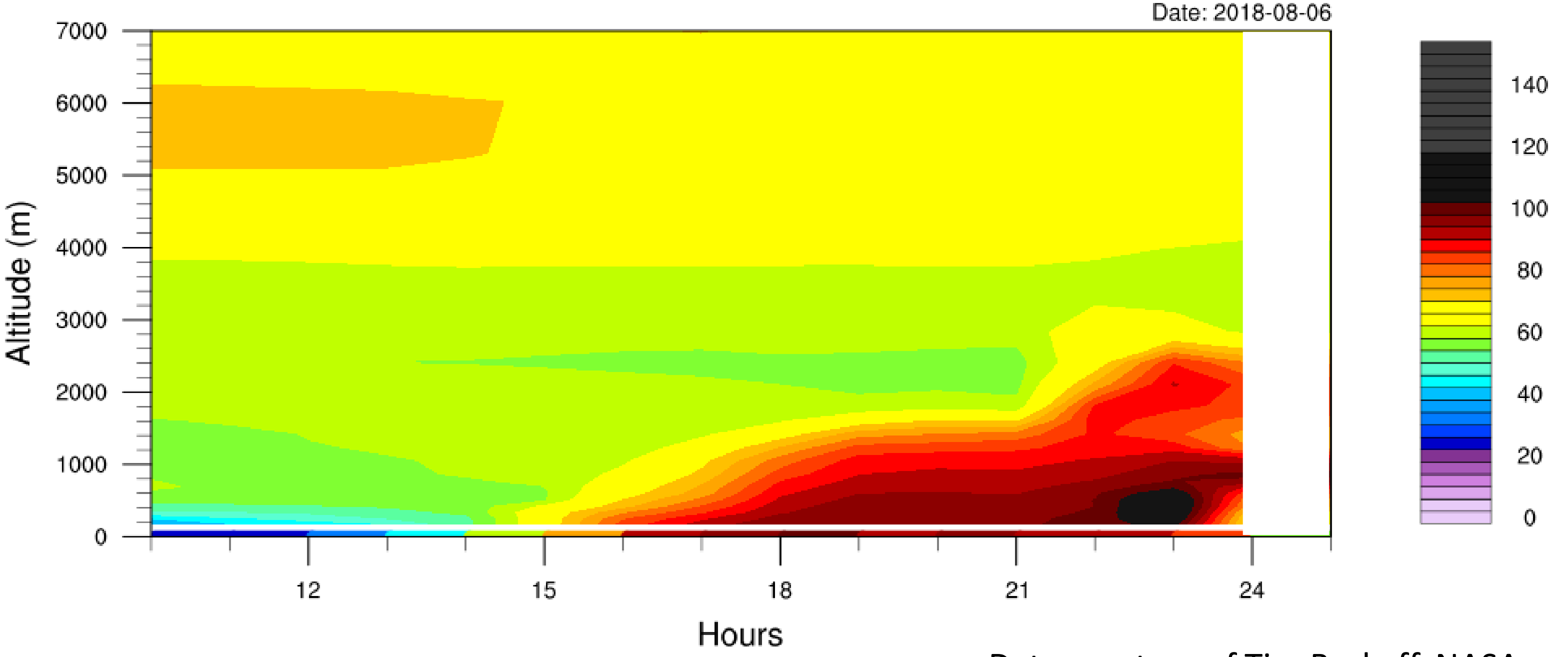
1. Rapid growth within shallow surface layer

   Model captures surface level growth, but it's very similar to behavior higher along the column.

2. Plume transporting high ozone concentrations over Westport.

   Timing of plume arrival later than observed.





** NOTE: there are discrepancies between LIDAR vertical column ozone values and those captured by the ozone sondes.

Data courtesy of Tim Berkoff, NASA.

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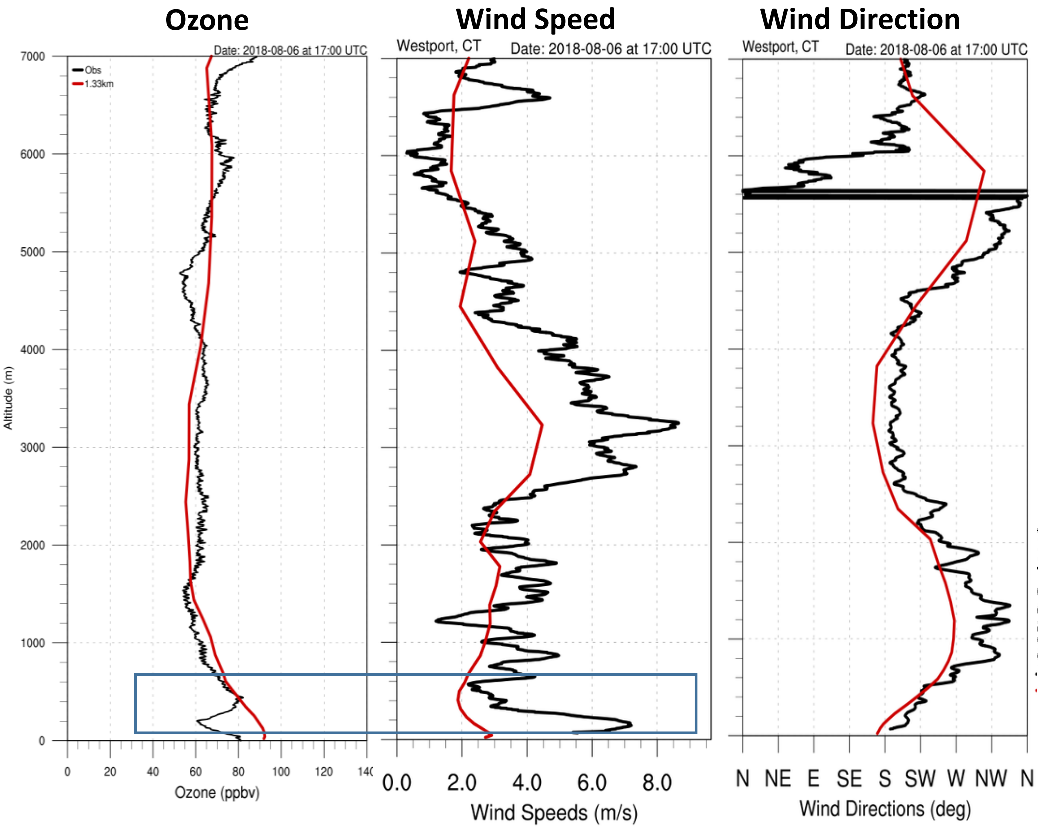
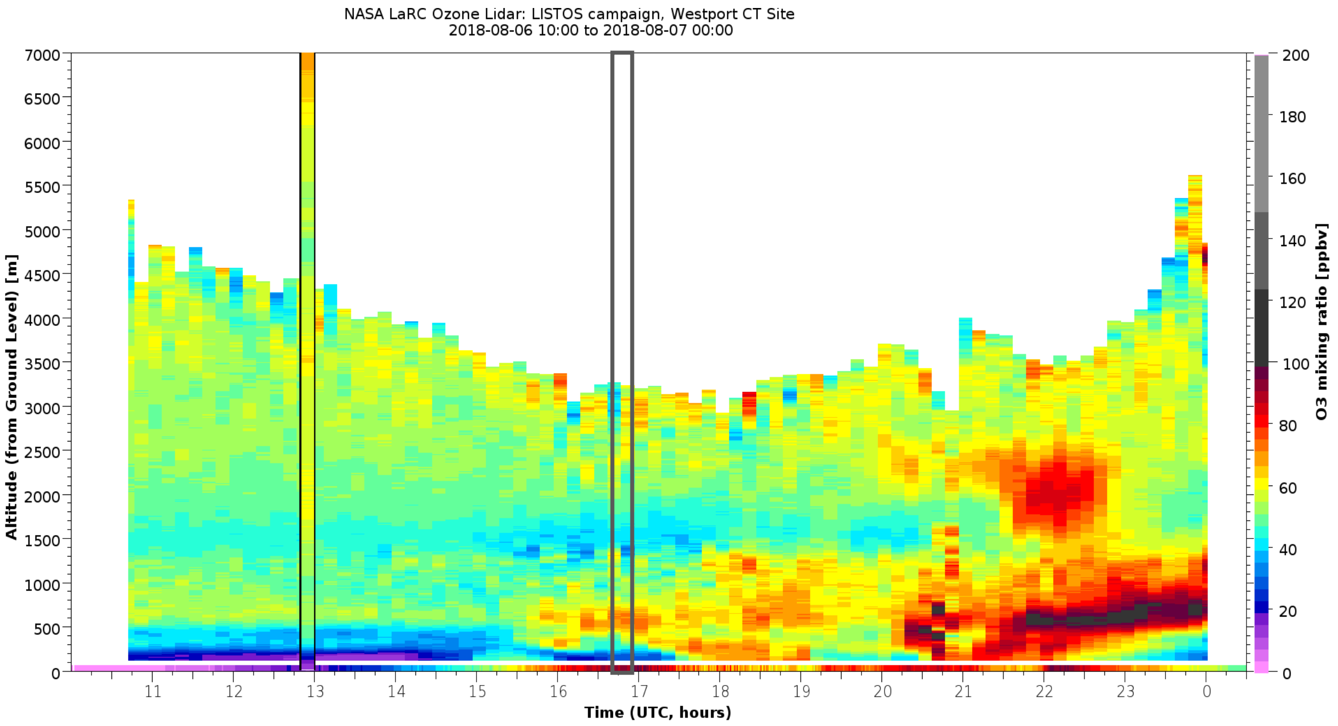
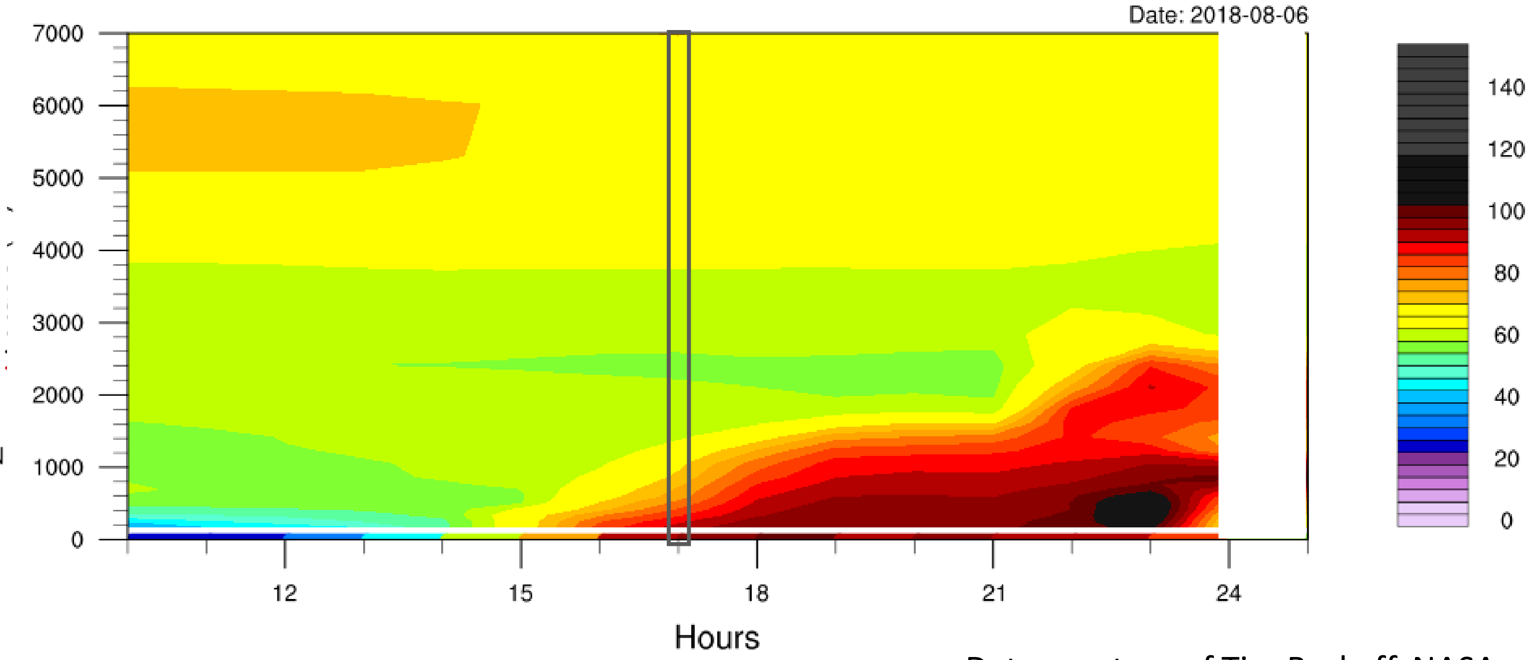
3. Potential evidence of localized low-level jets







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Data courtesy of Tim Berkoff, NASA.

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To summarize

- The model captured prevailing wind flows and general high ozone concentrations over the region but struggled to adequately represent sea and land breezes and low-level jets, even at 1.33km grid lengths.

- Evidence that transport issues are both local and regional.

- There is evidence of this impacting the representation of NO_2 and ozone.