Using the Integrated Observing System for Air Quality to Improve Our Understanding of Urban Air Pollution in New York

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TEMPO DART Team Meeting

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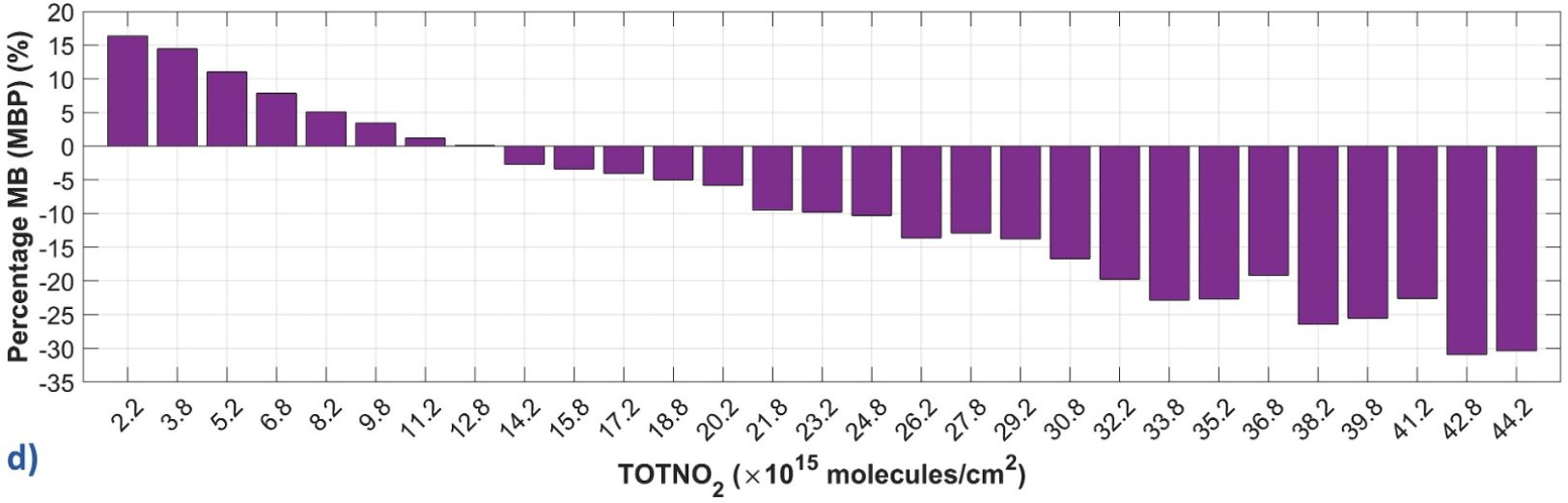
NPP
NASA Postdoctoral Program

Could Urban Parameters Reduce Low Bias?

- Satellite observations have known **low bias** in Urban regions and **high bias** in Rural regions (bias often attributed to resolution)
- Satellite Priors **don't** include urban system properties

Adapted from: Gharemanloo et al., 2025



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<u>Goal</u>: Determine the impact of urban parameterization schemes in the priors (model) of satellite retrievals to look to improve its observations in urban regions

Our Integrated Observing System for New York Air Quality

WRF | GC

Current WRF-GC Set Up			
Grid Spacing	4 km	**Radiation**	RRTMG (4)
Initial/Boundary Conditions	EPA NEI 2023 - CRACMMv2 (every hour)	**Surface layer**	Monin-Obukhov (2)
Domain Nesting	One-way	**Land surface**	Unified NOAH (2)
Output temporal resolution	1 hour	**Urban surface**	BEP+BEM (3)
Number of vertical levels	45	**Planetary boundary layer**	Boulac (8)
Microphysics	Morrison double-moment (10)	**Cumulus**	New Tiedtke (16)

- **NYC-METS + Other**: Stationary In situ
- **NASA STAQS**: Aircraft Remote Sensing (GCAS)
- **NOAA AEROMMA**: Aircraft In situ
- **TEMPO**: First observations in August 2023

New York

7/26/23	7/28/23	8/5/23	8/9/23	8/16/23
AEROMMA STAQS	AEROMMA STAQS	STAQS TEMPO	AEROMMA STAQS TEMPO	AEROMMA TEMPO

Model Set Up to ***Now*** Include Urban Representation

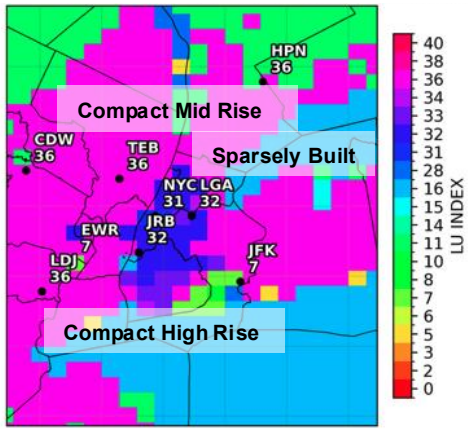
- Use **WRF-GC** and turn on an **urban parameterization scheme**: Building Energy Parameterization (BEP) + Building Energy Model (BEM)
- BEP+BEM Modifies: Land Use Types, Vertical Discretization, Turbulence and Drag, Heat and Radiation
- Urban Fraction Update from W2W: High-Resolution Dataset of Global Urban Fraction for Mesoscale Urban Modelling (Pratiman and Matthias, 2022)

Base: 1 Urban Class

Urban: 11 Urban Classes

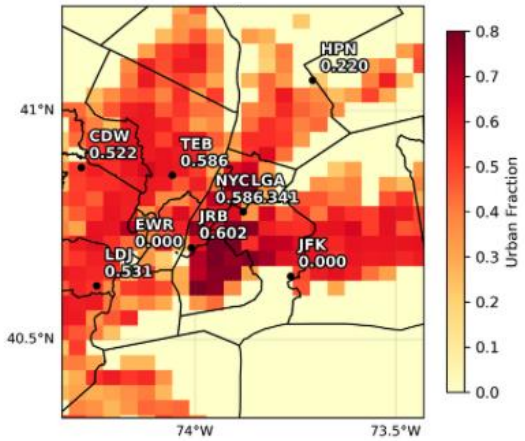
Land Class

Inclusion of Urban Land Classes

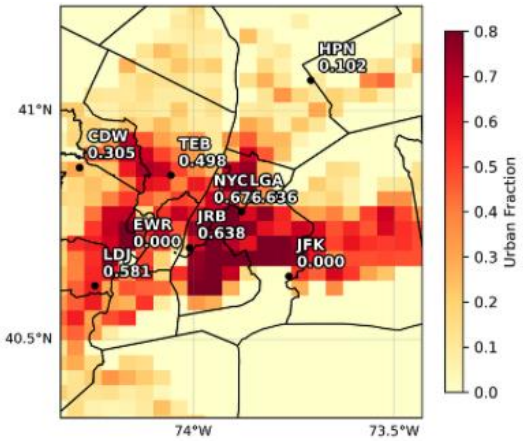


Urban Fraction

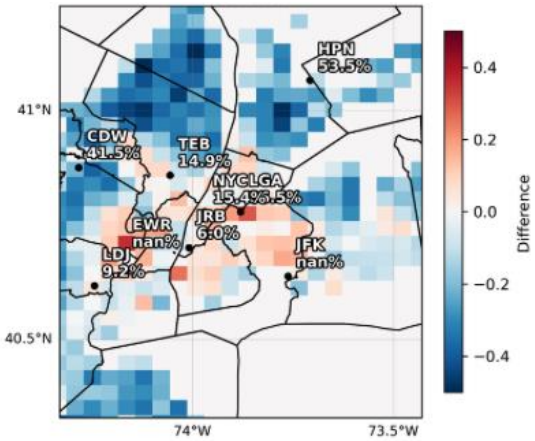
W2W



Satellite Derived Updated



Difference

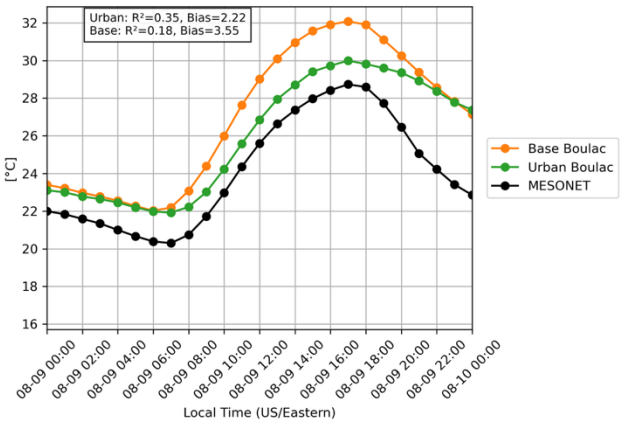
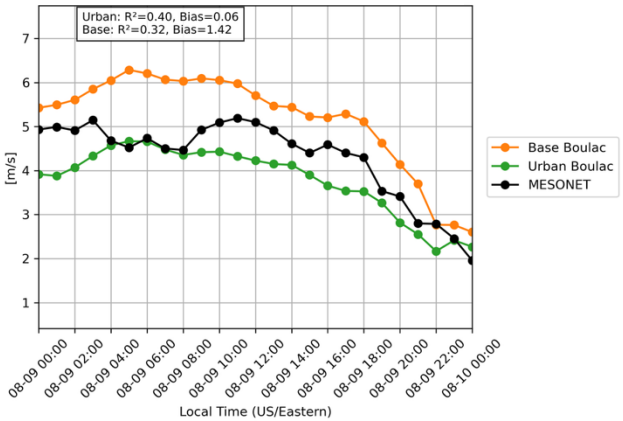
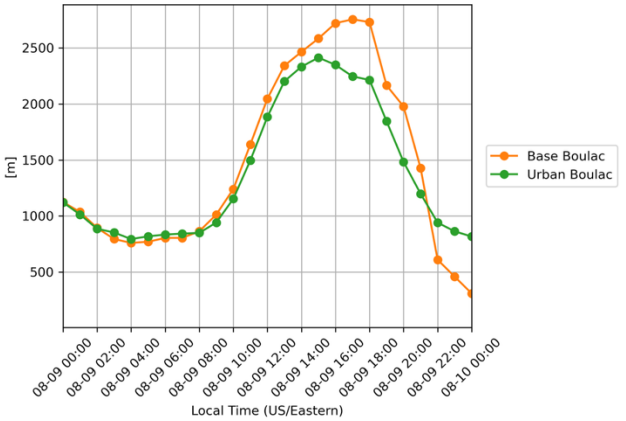
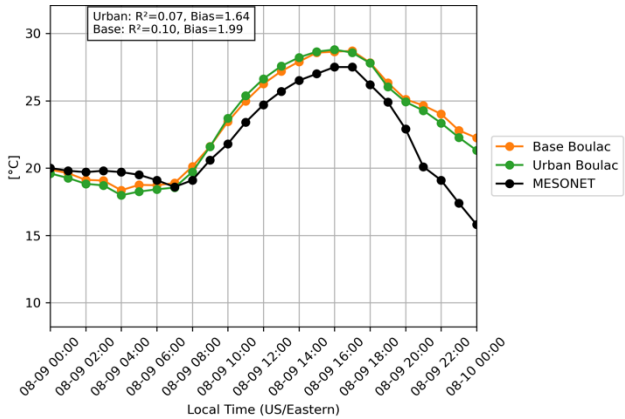
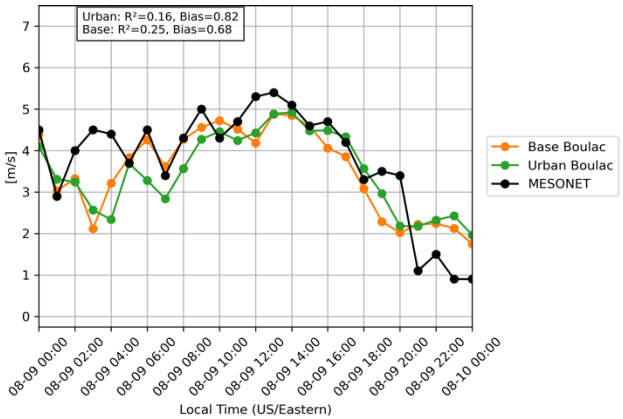
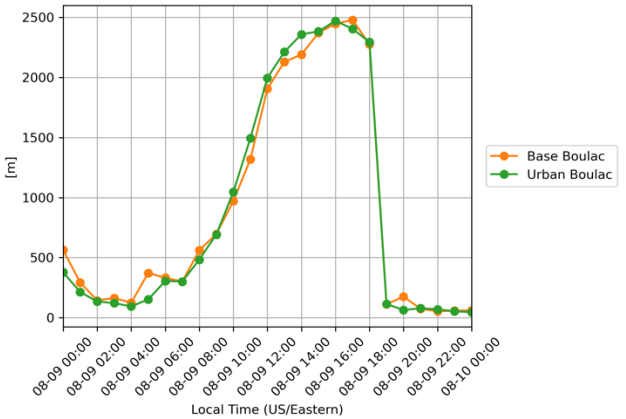


Test how different urban representation modifies simulated NO_2 using **WRF-GC with BEP+BEM**

Temperature and Wind Speeds Decrease in Urban

- Temperature and Wind Speeds **decrease** in Urban compared to Base in Urban Land Use Class grid cells
- Agreement increases with MESONET sites in Urban for Urban Land Use Class grid cells

8/9/23

	Temperature	Wind Speed	PBLH
Urban Land Use Class Grid Cells			
Rural (Shrubland) Land Use Class Grid Cells			

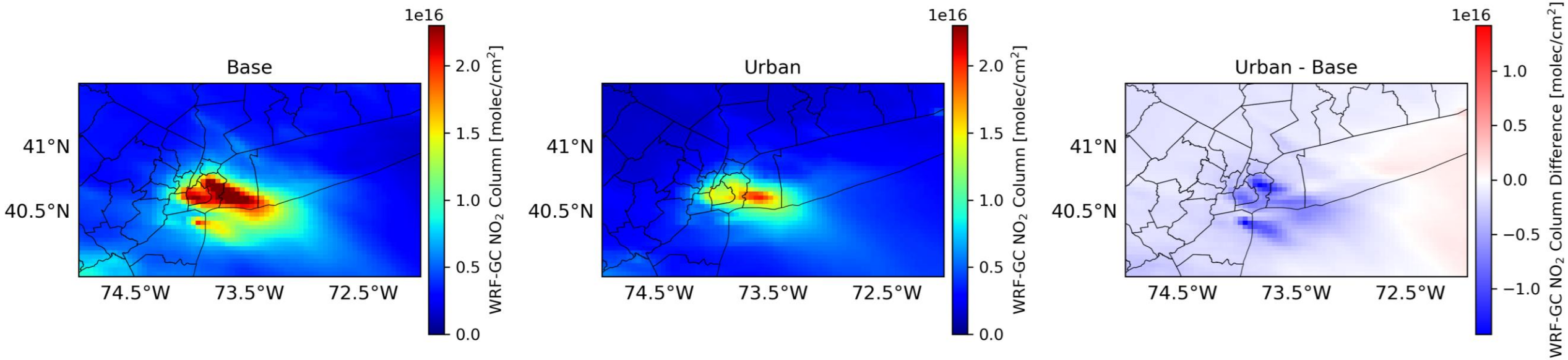
Urban vs Base

Temperature ↓ Wind Speed ↓ PBLH ↕

Urban Plume Become More Concentrated due to Reduced Wind Speeds

- BEP+BEM Changes: momentum, drag, turbulence structure
- Buildings Add Drag: Wind speed ↓ Transport ↓
- Urban plume: (1) **remains closer to source**, (2) **less diffuse appearance**

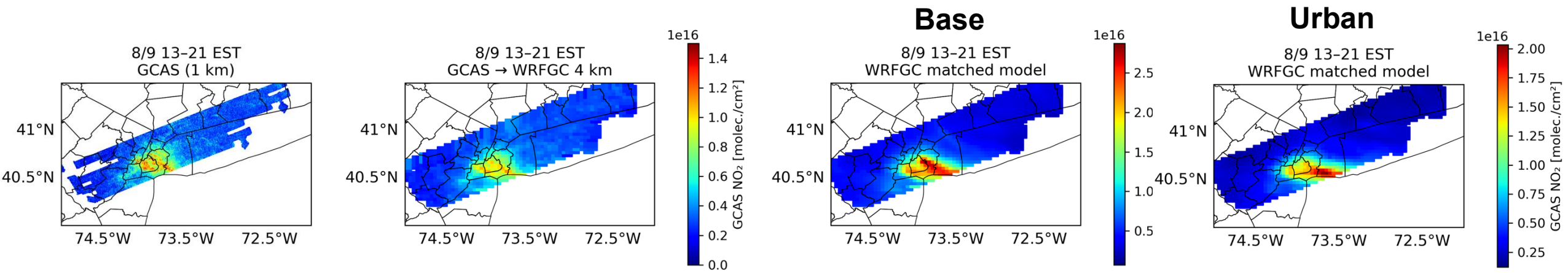
8/9/23: WRF-GC Column Averages during time period of GCAS Observations



WRF-GC Reproduces GCAS Plume Structure, with Urban Improving Column Magnitude Bias

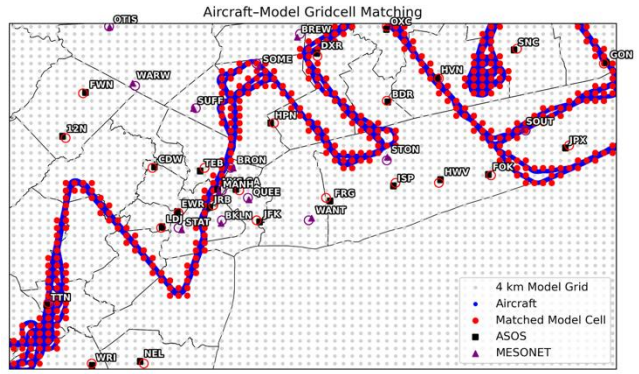
- Both Base and Urban **reproduce observed** GCAS plume structure and spatial gradients
- Base and Urban exhibit a positive NO_2 column bias relative to GCAS
- Urban reduces NO_2 column magnitude, improving quantitative agreement with GCAS while maintaining plume shape

8/9/23: GCAS and WRF-GC Column Averages during time period of GCAS Observations



NO_2 Vertical Profile Increase Aloft in Urban

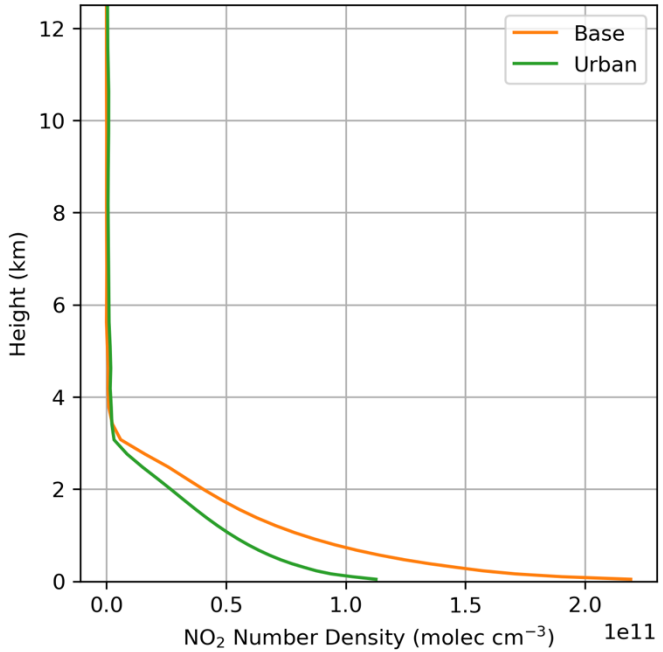
- Urban redistributes NO_2 vertically
- Urban Site: Urban sees **decreased** NO_2 at surface but **increased** NO_2 aloft
- Shape Factor changes result in ~10% increase in AMF:
  - Lower near Surface → Urban redistributes NO_2 upward relative to Base → More NO_2 aloft → Higher satellite sensitivity → Higher AMF



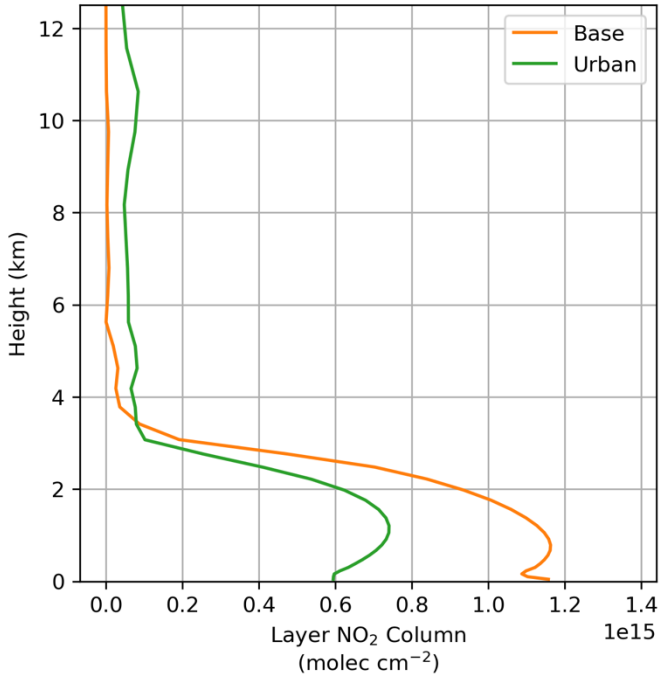
8/9/23

Urban Grid Cell: QUEENS

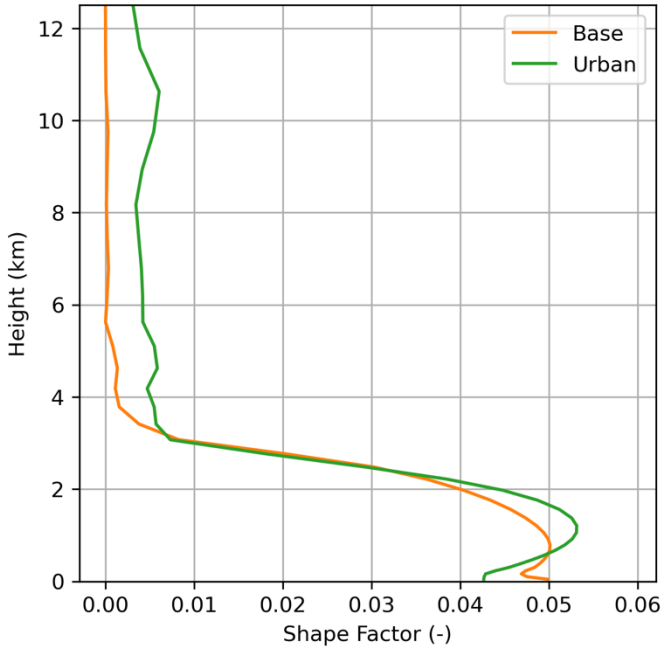
NO_2 Number Density



NO_2 Partial Column



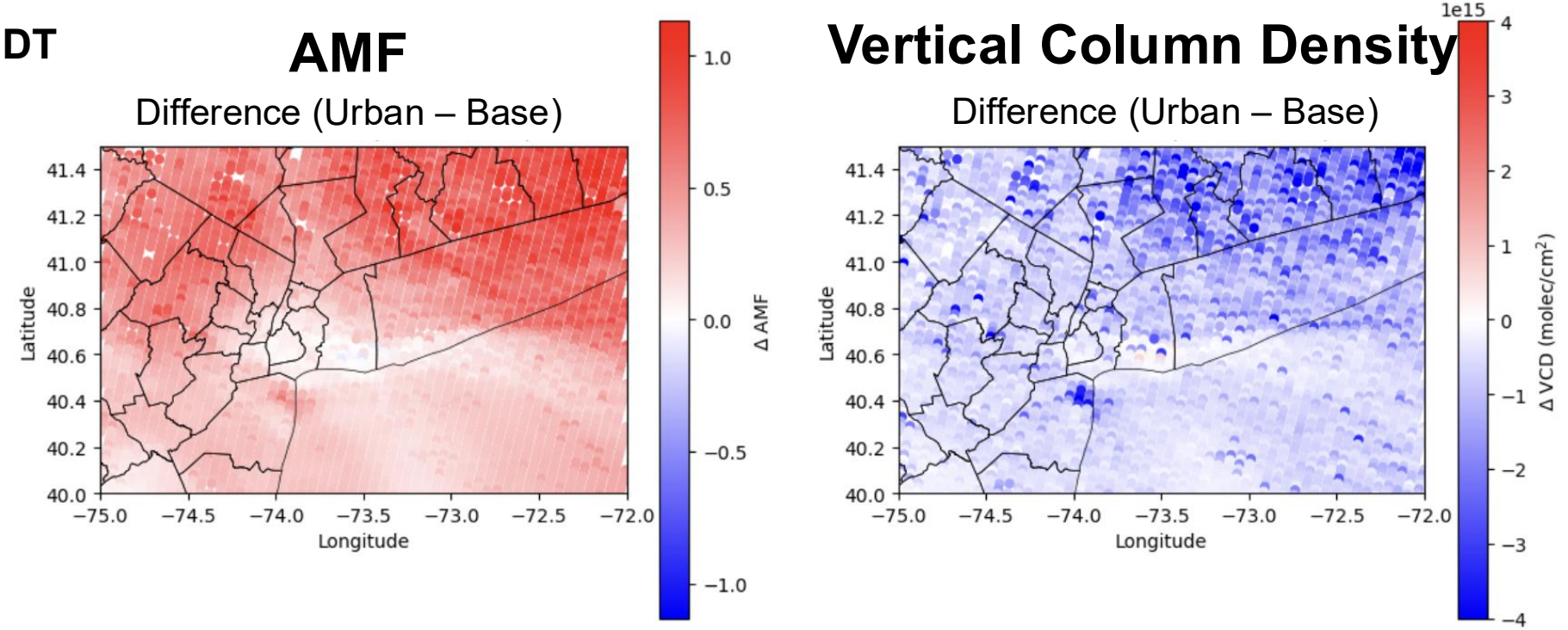
NO_2 Shape Factor



Urban AMF Increases compared to Base Model

- WRF-GC calculated AMF with TEMPO V04 Scattering Weights
- AMF in Urban **increases** compared to the Base, but little changes in urban areas (so far…)
- Vertical Column Density decreases ~ 0 – 4e15 (in this hour…)

8/9/23: 6pm EDT



Current Findings

- WRF-GC Urban plumes become more concentrated due to reduced wind speed
- ***In this case***: WRF-GC Urban AMFs increase which can lead to decreased columns in urban regions
  - Other days show different results and thus a more in depth analysis of all results is needed to determine overall average effect
- Other implications include column to surface ratio changes, ozone production efficiency, interpretation of aircraft vs ground data, and others…
- Further analysis will reveal the full influence of urban parameters included as a satellite prior

Inclusion of urban parameters in satellite priors can have influence on their column retrievals

Future work is needed to determine their exact effects

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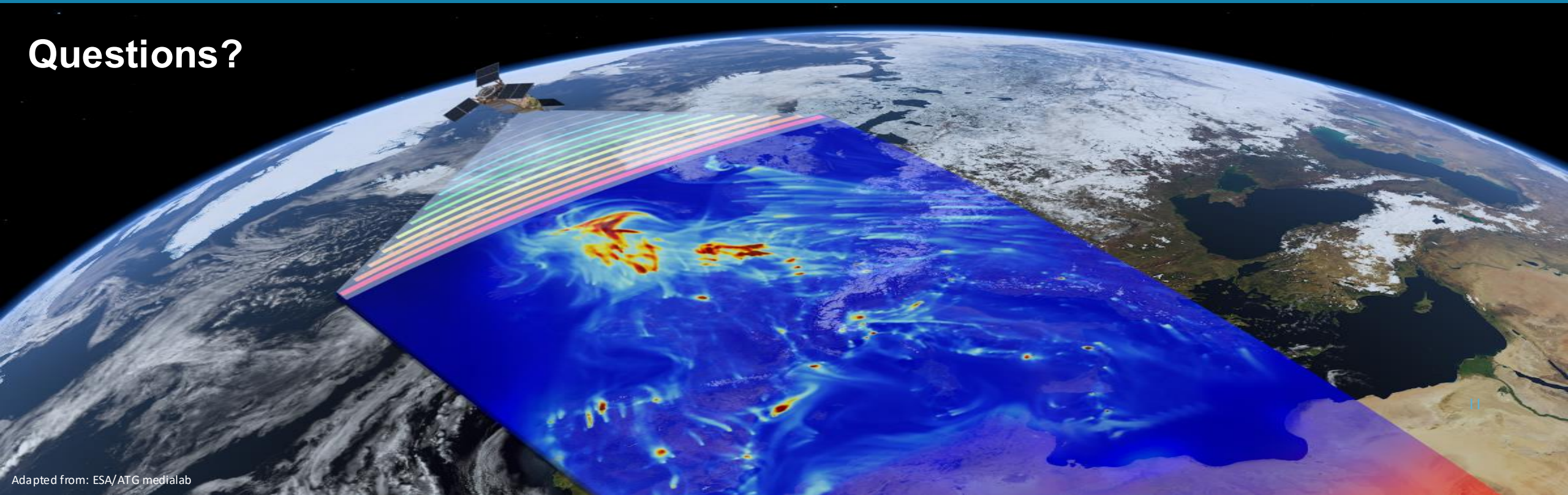
Questions?



Adapted from: ESA/ATG medialab