Evaluation of WRF precipitation simulations for storm Ida over NYC Using NY/NJ Mesonet

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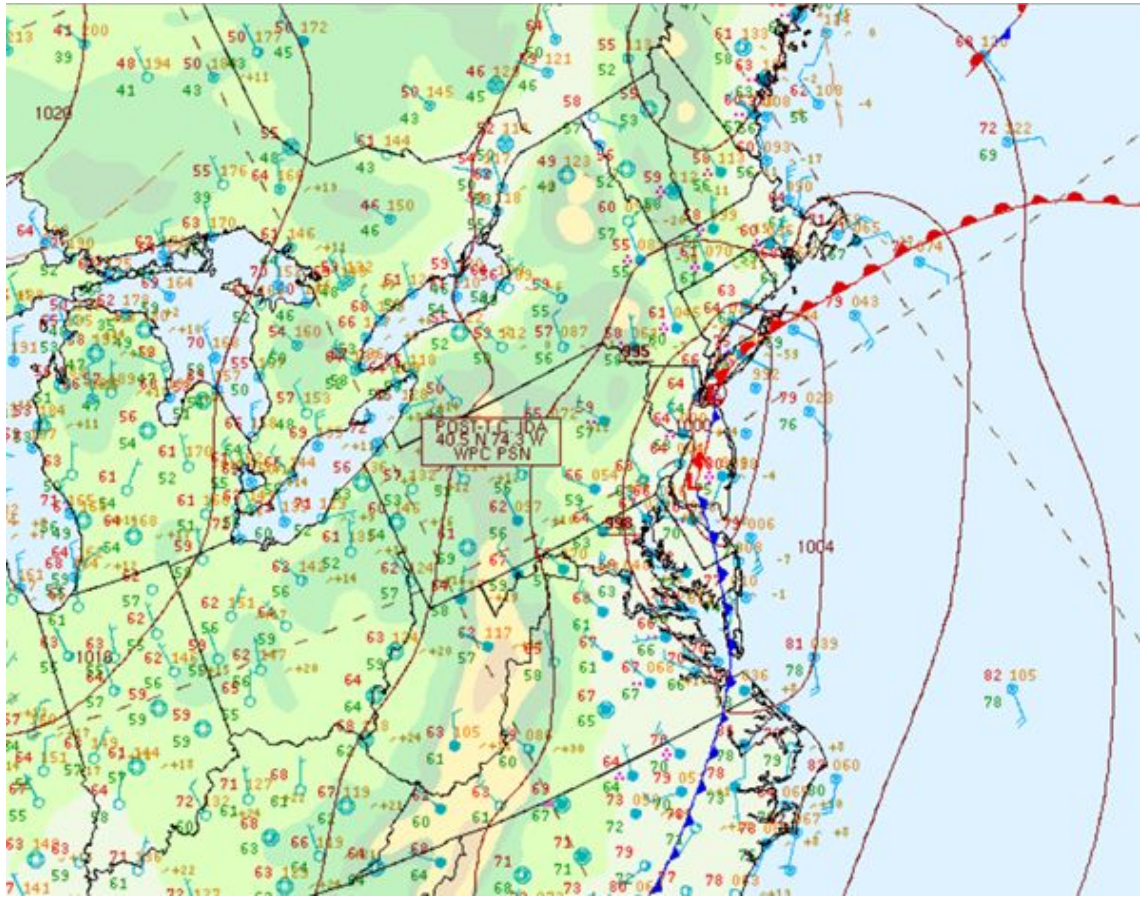
Introduction

New York Metropolitan Area (NYMA) is one of the most populated and globally diverse cities, and one of the most influential American metropolis in the country

- The NYMA is affected by high-latitude and tropical systems, and in some cases a combination of both.
- Although global and regional models allow the identification of general patterns, for local weather forecast are less accurate.
- A need for high resolution precipitation data to force block-scale hydrological models.
- In this study, WRF model was used for dynamic downscaling of precipitation in urban environment.

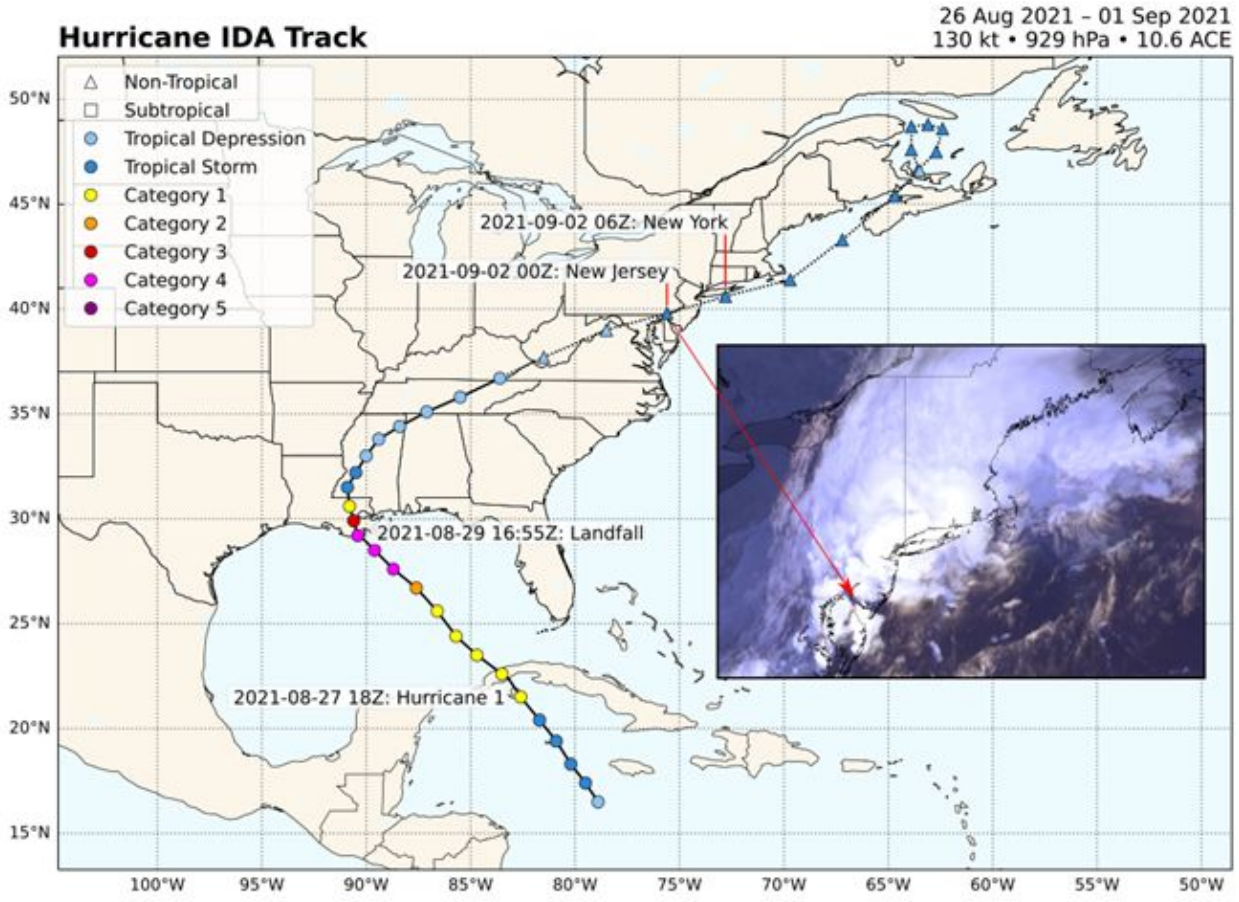


Surface analysis 03Z Thu Sep 2 2021
Image source: WPC Surface Archive Page

Study case

In the Northeastern United States, tropical cyclones are one of the main causes of extreme flood events.

- On August 29 17 UTC, the storm impacted the coasts of Louisiana as Hurricane category 4.
- Even though Hurricane Ida became much weaker as it moved inland, its impacts were far from over. The hurricane remnants, in combination with a surface front and upper air trough, led to unprecedented catastrophic tornadoes and flooding in the Northeast on September 1st.
- The transition from tropical to extratropical is the main feature that favors intense precipitation, and this is what happened with Ida during its track on September 1-2, 2021.

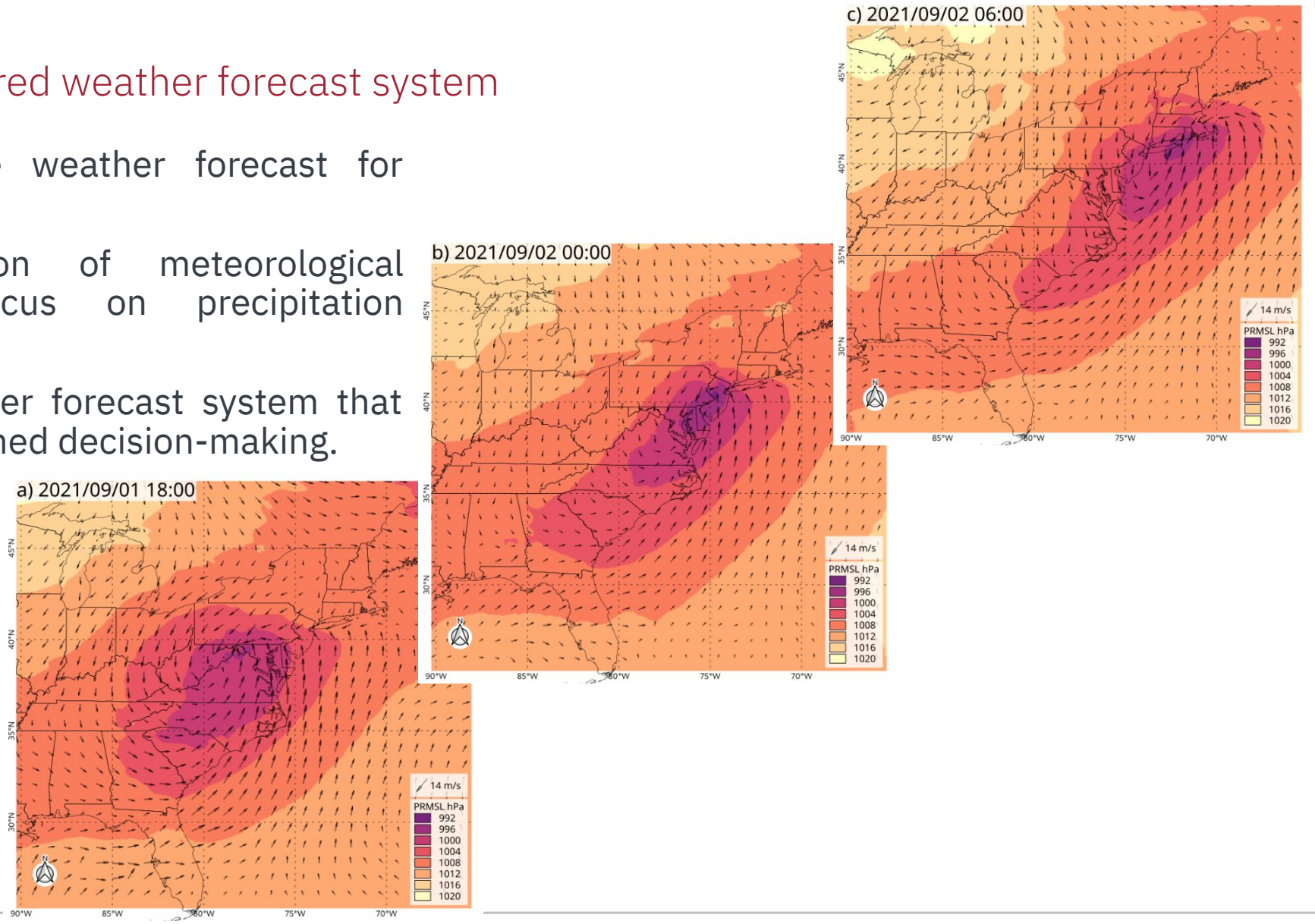


Ida's track using HURDAT data, showing important dates in its track, as well as a satellite image in an hour close to the highest precipitation in NYMA

Objectives

Develop a region tailored weather forecast system

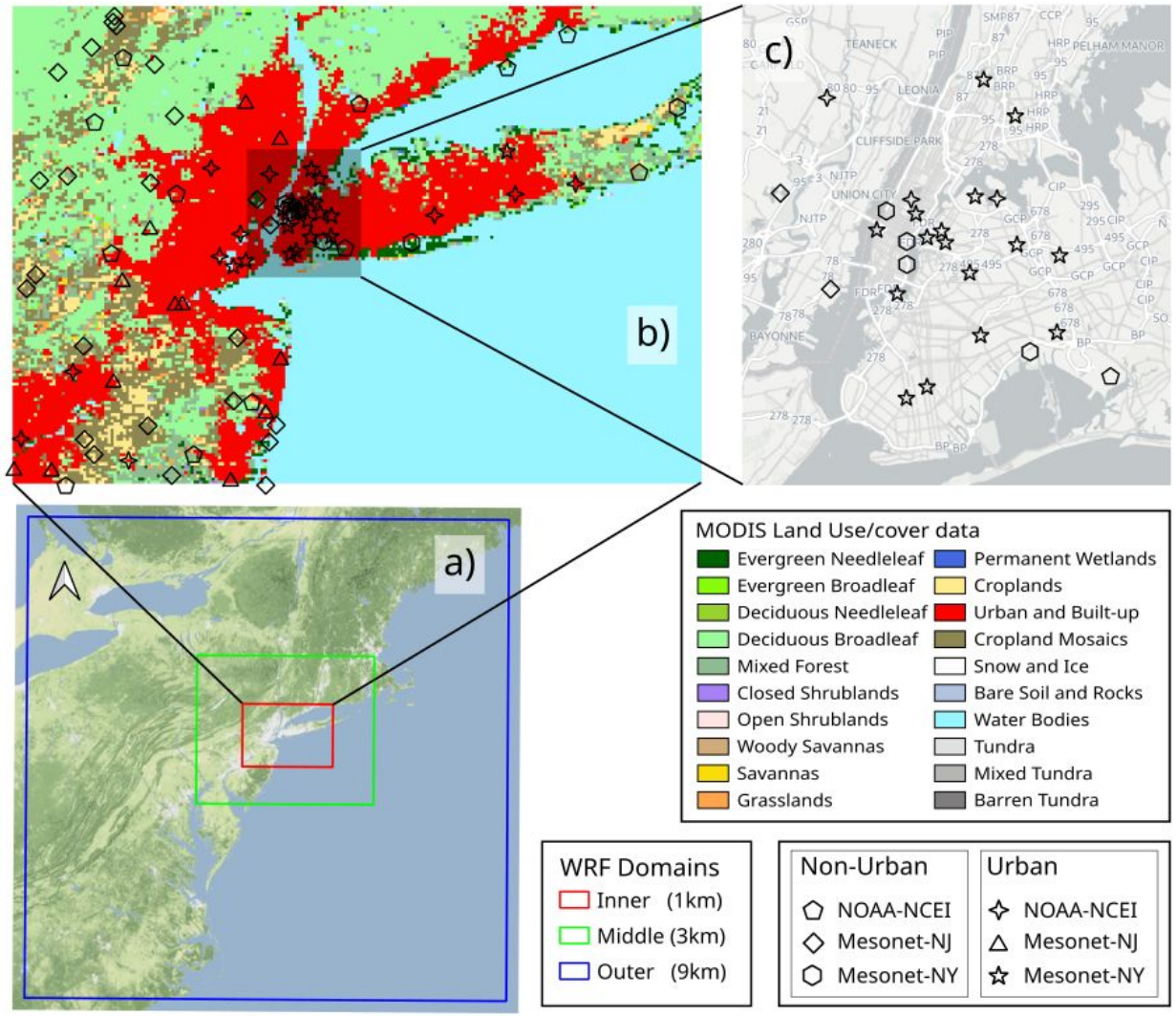
- Improve local scale weather forecast for NYMA.
- Get high resolution of meteorological variables, with focus on precipitation estimation.
- An automated weather forecast system that can be used for informed decision-making.



Study area and data

A perspective of our area of interest

- Three-tiered nested domain approach with resolutions of 9 km, 3 km, and 1km.
- ERA5 Reanalysis data used to generate different simulation scenarios and perform sensitivity analysis.
- GFS forecast data used to test the performance of the "best schemes combination".
- Weather stations from NCEI-NOAA, Mesonet-NY (MNY) and Mesonet-NJ (MNJ) for point-based evaluation.
- MRMS data for the same period for grid-based comparison of accumulated precipitation.



Methodology

A perspective of our area of interest

- ERA5-reanalysis data was considered as initial conditions to run WRF (V4.4.2) model, for the period from Aug 31 to Sep 2, 2021 (Hurricane Ida). WRF default configuration was modified with eight different schemes combination to identify the best.
- Results from the ten scenarios were evaluated using weather stations and MRMS observations.
- Urban and natural environment sites were considered to evaluate the performance of each scenarios as function of the landscape.
- Accumulated rainfall were calculated from WRF simulations and MRMS data, in the period Sep 1st to 2nd , for spatial assessment.

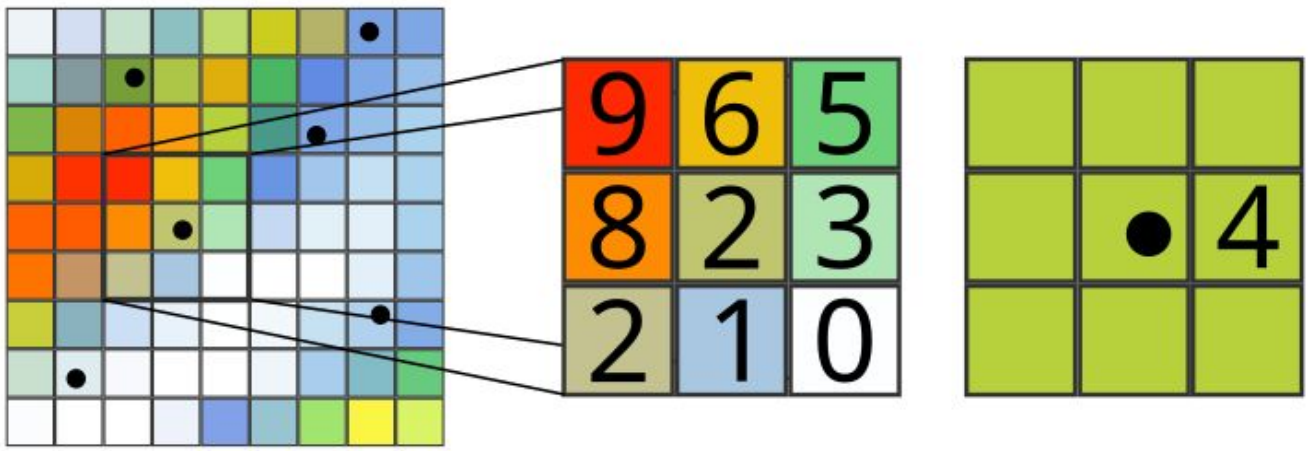
Physics	Schemes combinations									
	SDF	S01	S02	S03	S04	S05	S06	S07	S08	S09
mp_physics	3	8	2	2	2	2	2	2	6	8
ra_lw_physics	1	4	1	1	1	1	1	1	1	1
ra_sw_physics	1	2	1	1	1	1	1	1	1	1
sf_sfclay_physics	1	2	2	0	0	0	0	0	0	0
sf_surface_physics	2	4	4	4	4	4	4	4	4	4
bl_pbl_physics	1	5	8	8	8	8	8	8	8	8
cu_physics	1	0	1	1	2	93	3	0	93	93
sf_urban_physics	0	0	1	2	2	2	2	2	2	2

Name	Physics option
Microphysics	2:Lin, 3:WSM 3-class, 6:WSM, 6-class, 8:Thompson
Longwave radiation	1:Rapid Radiative Transfer Model (RRTM), 4:RRTM for GCMs
Shortwave radiation	1:Dudhia, 2:Goddard
Surface layer scheme	1:Monin-Obukhov, 2:Monin-Obukhov Janjic
Land Surface Model	2:Unified Noah land-surface, 4:Noah Land Surface
Planetary Boundary L	1:YSU, 5:MYNN 2.5 level TKE, 8:Bougeault
Cumulus	1:Kain-Fritsch, 2:Betts-Miller, 3:Grell-Freitas, 93:Grell-Devenyi
Urban Physics	1: Single-layer (UCM), 2: Multi-layer (BEP)

Evaluation

It is considered to evaluate the results using ten different metrics

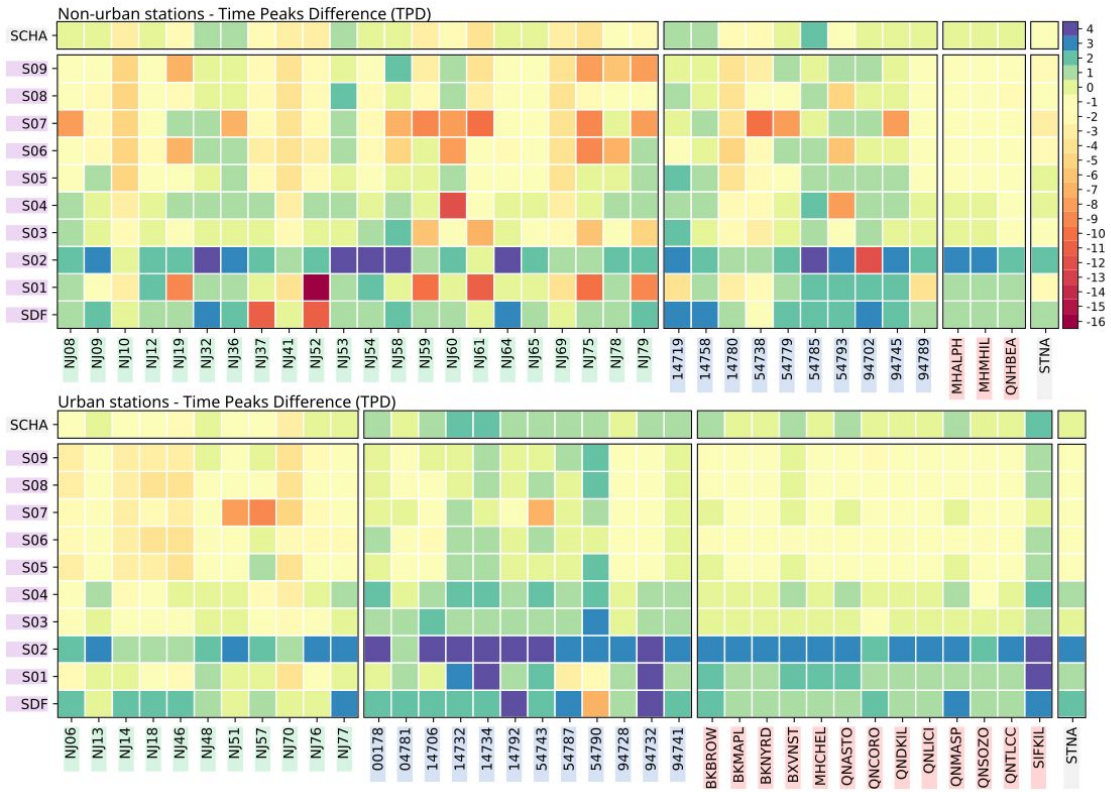
- Multiple metrics were computed for the time series in order to determine which combination of schemes produced the best results.
- Some of the metrics are, Difference between time peak, difference between magnitude peak, Percent Bias, among others.



Evaluation metrics

Metrics results

It is considered to evaluate the results using ten different metrics



Evaluation

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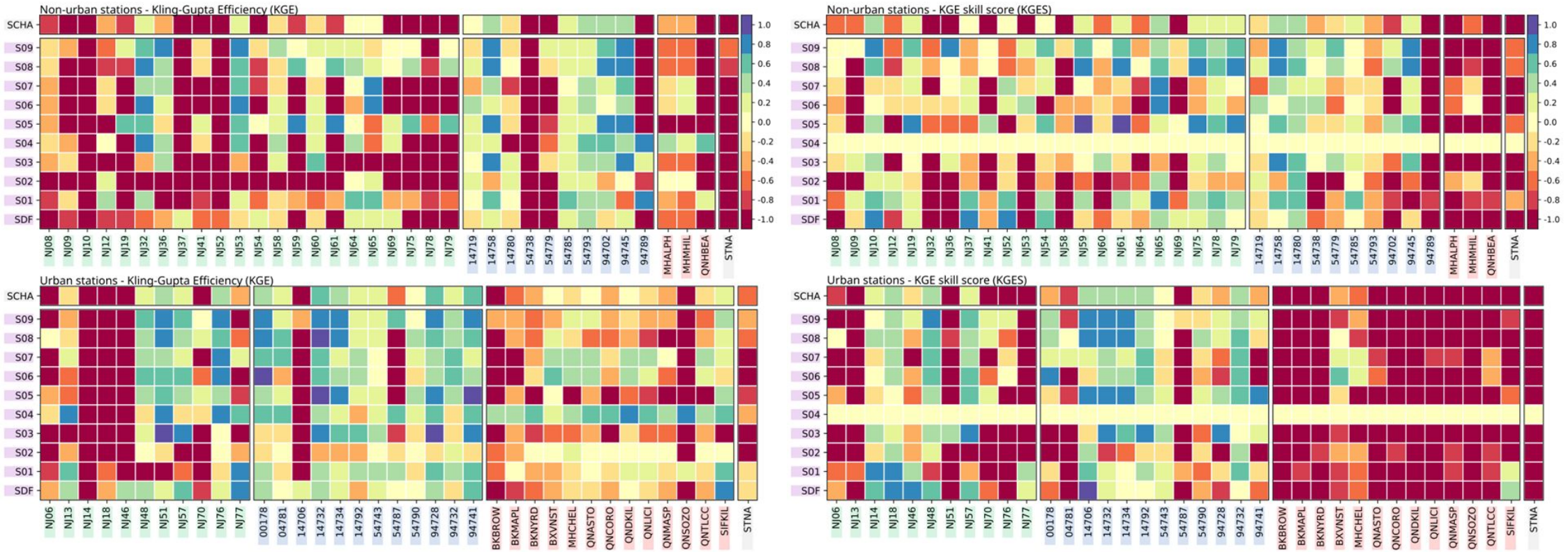
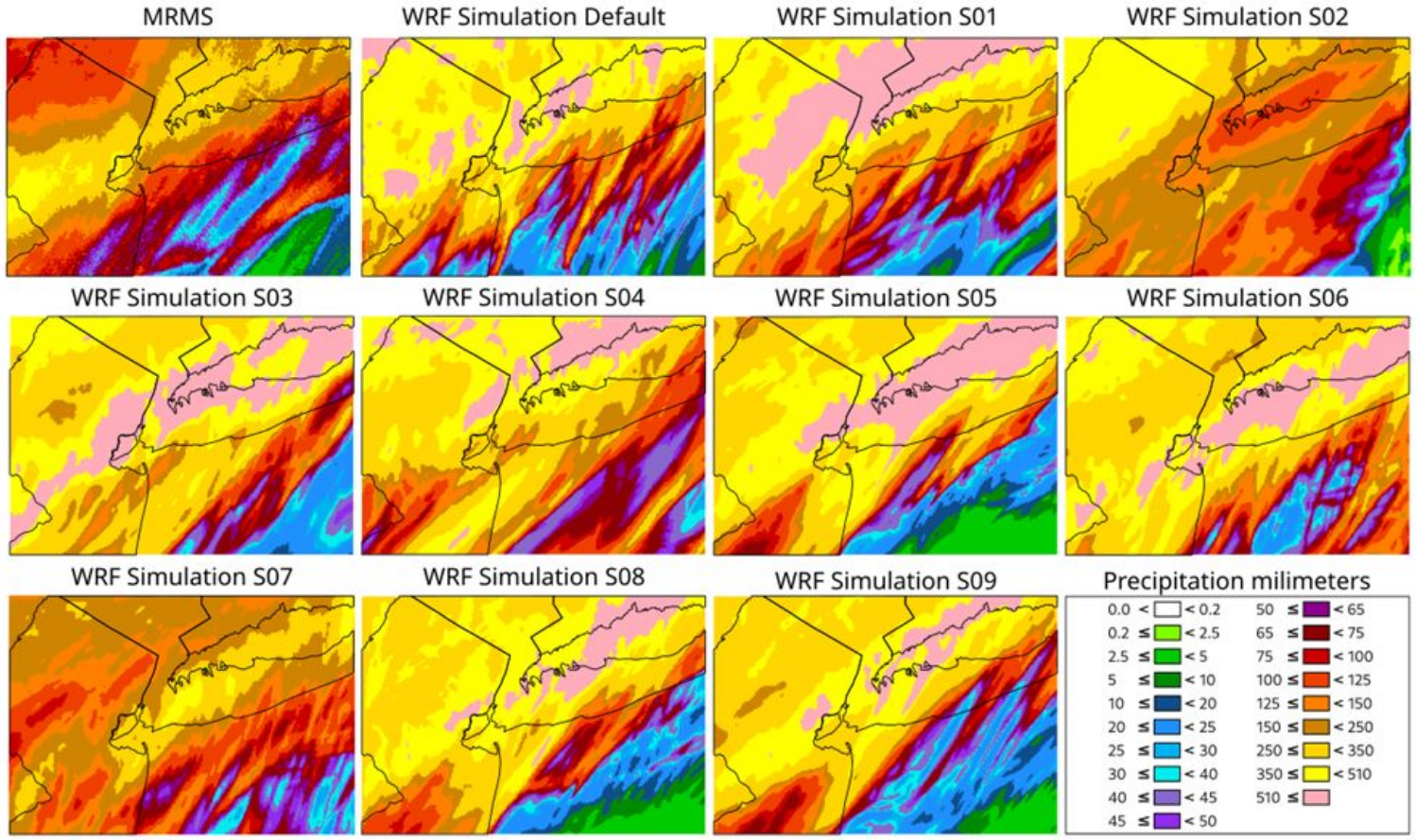


Accumulated rainfall

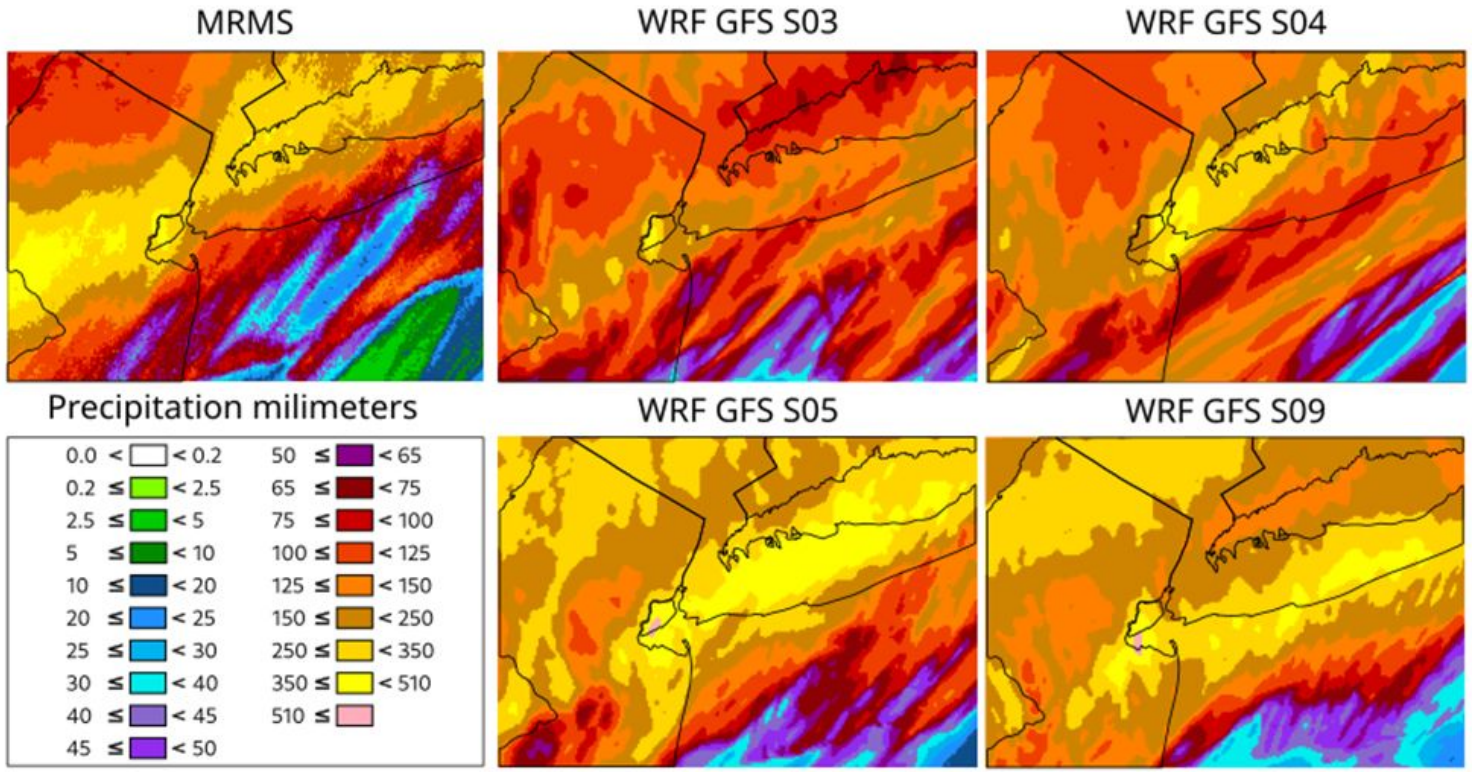
Comparison between of MRMS and each Scenarios based on ERA5



comparing outputs	SSIM
MRMS vs Default	0.777
MRMS vs S01	0.805
MRMS vs S02	0.800
MRMS vs S03	0.781
MRMS vs S04	0.774
MRMS vs S05	0.791
MRMS vs S06	0.771
MRMS vs S07	0.805
MRMS vs S08	0.788
MRMS vs S09	0.805

Accumulated rainfall

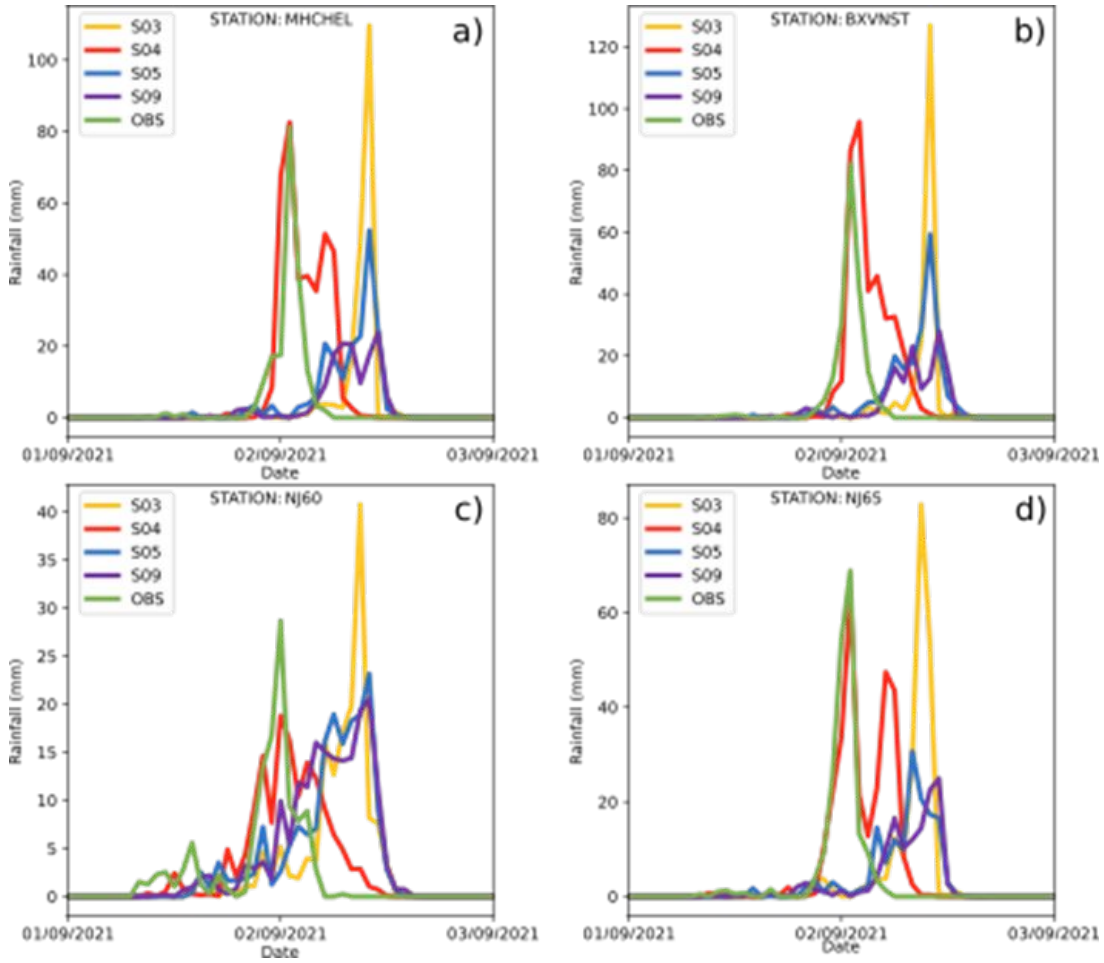
Comparison of the best-found scheme between MRMS and GFS



comparing outputs	SSIM
MRMS vs WRF-GFS S03	0.79
MRMS vs WRF-GFS S04	0.83
MRMS vs WRF-GFS S05	0.78
MRMS vs WRF-GFS S09	0.80

Time series comparison

In urban and non-urban stations



Conclusions

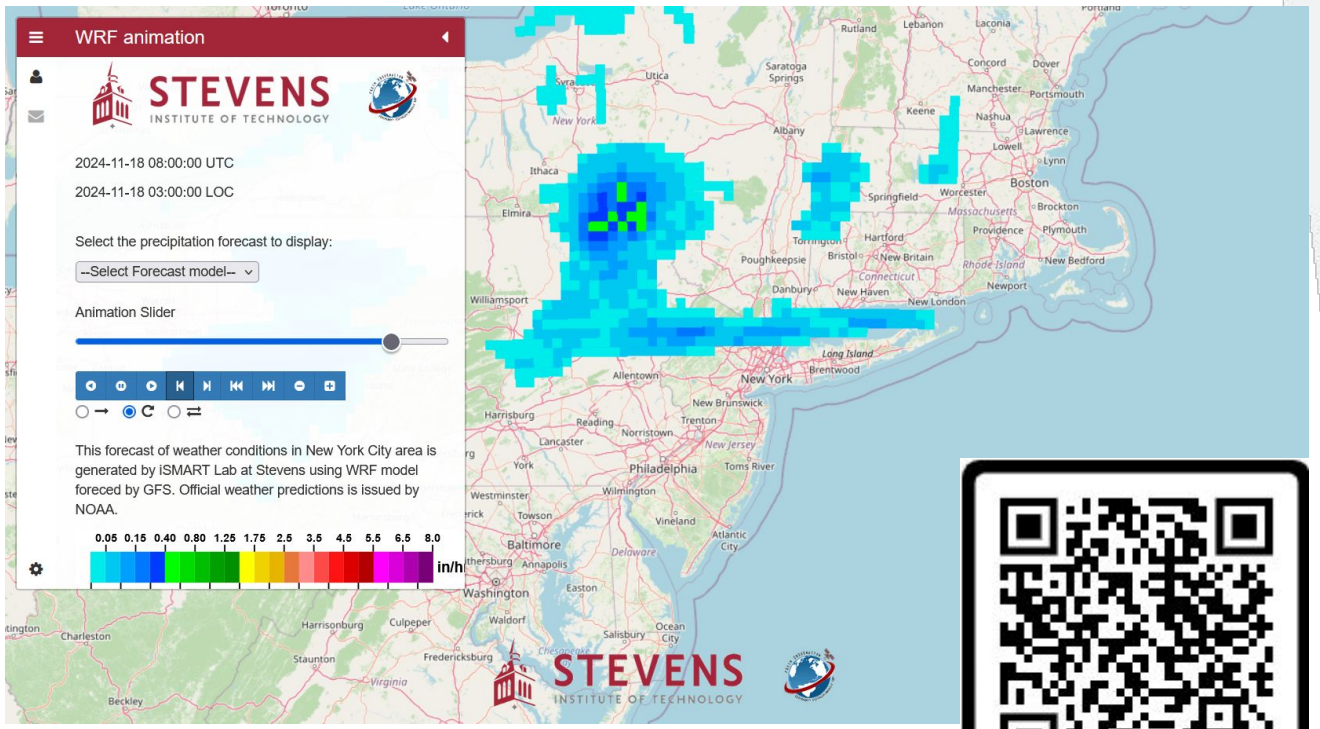
- WRF rainfall simulations showed better agreement with urban sites observations, when urban physics scheme was activated.
- Correlation results showed a good agreement with urban station from Mesonet-NY compared to Mesonet-NJ and NCEI. Similarly, for the non-urban areas, a better agreement was obtained with MNY station.
- The accumulated precipitation results showed a general tendency to overestimate MRMS observations.
- According to the different metrics evaluated in all the schemes used, in general all metrics show that S04 has better performance.

Name	Physics option
Microphysics	2:Lin
Longwave radiation	1:Rapid Radiative Transfer Model (RRTM)
Shortwave radiation	1:Dudhia
Surface layer scheme	0: Deactivated
Land Surface Model	4:Noah Land Surface
Planetary Boundary L	8:Bougeault
Cumulus	2:Betts-Miller
Urban Physics	2: Multi-layer (BEP)

Automated system

Enhanced weather forecast to support emergency management in highly populated urban areas

- Run the model once a day and get forecasts up to 120 hours with a time interval of one hour
- Three domains with spatial resolution of 9 km, 3 km and 1 km, targeting NYMA
- Data post processing to obtain derived variables, (e.g., radar reflectivity)
- Interactive web map operational daily

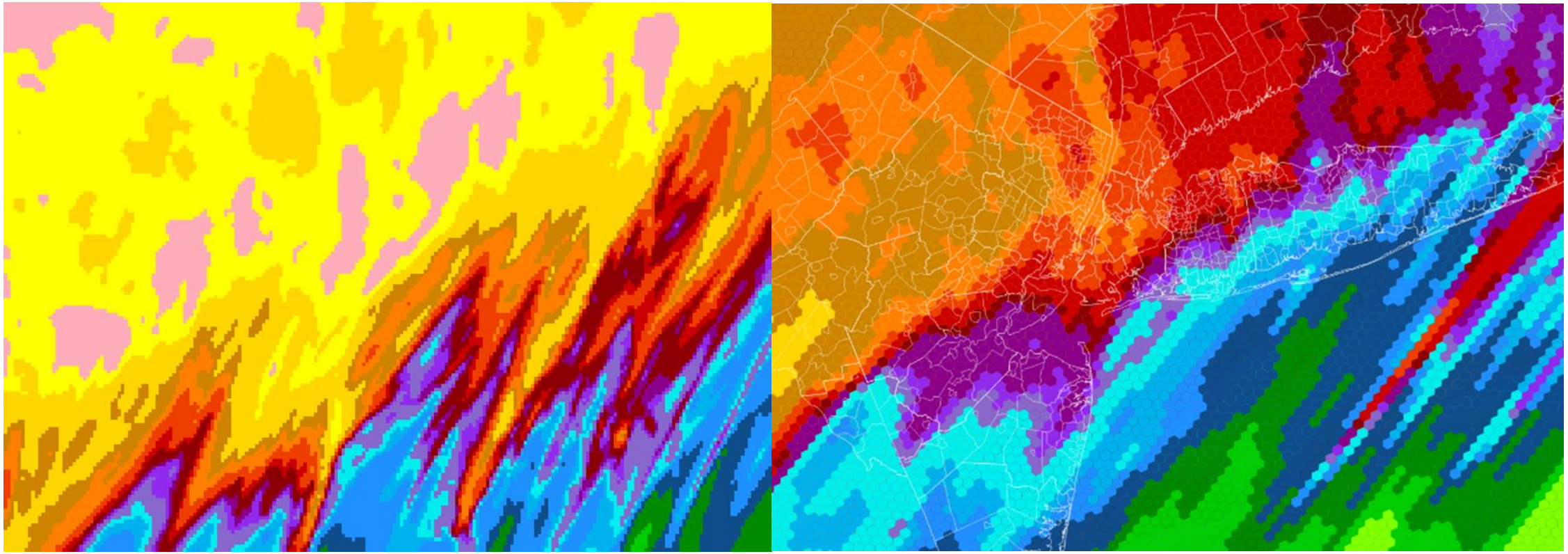


SCAN ME

https://jhbravo.gitlab.io/ismart/index_wrf_dev_gee.html

Next steps

Use the next generation of models with unstructured meshes: MPAS

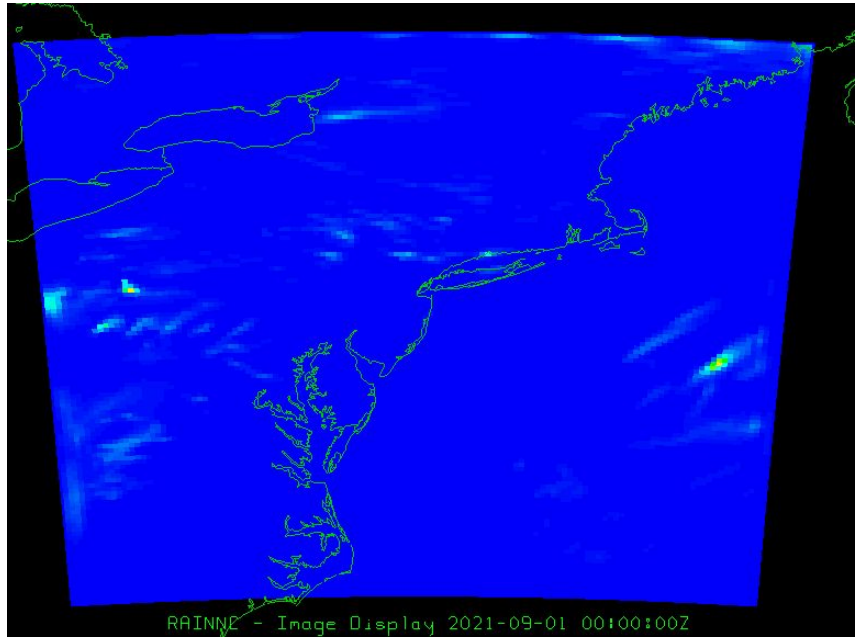


Next steps

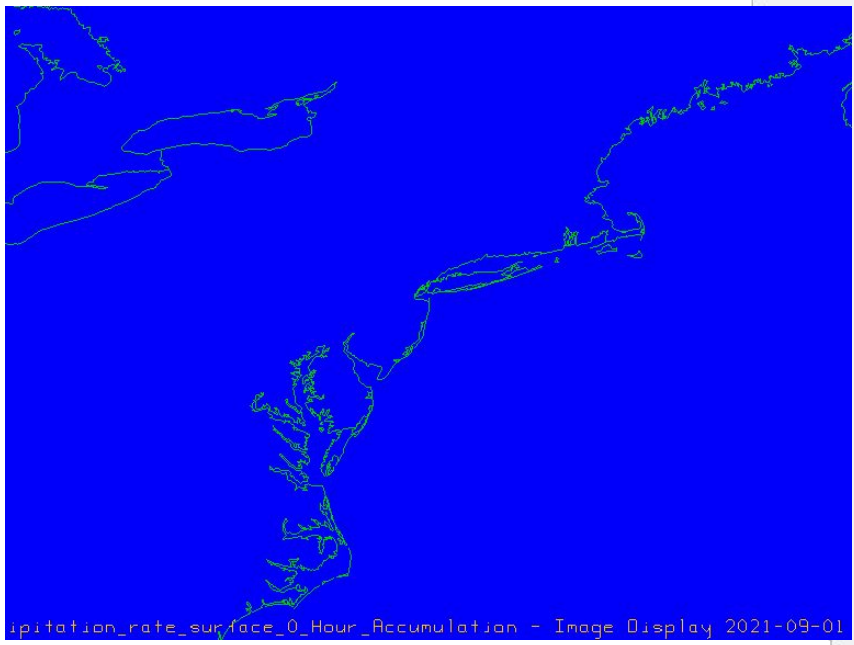
The use of the AI models for weather prediction

GFS

WRF



Fourcasnet



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THANK YOU

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