



Air Quality Evaluation System: Central México Case Study

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Outline

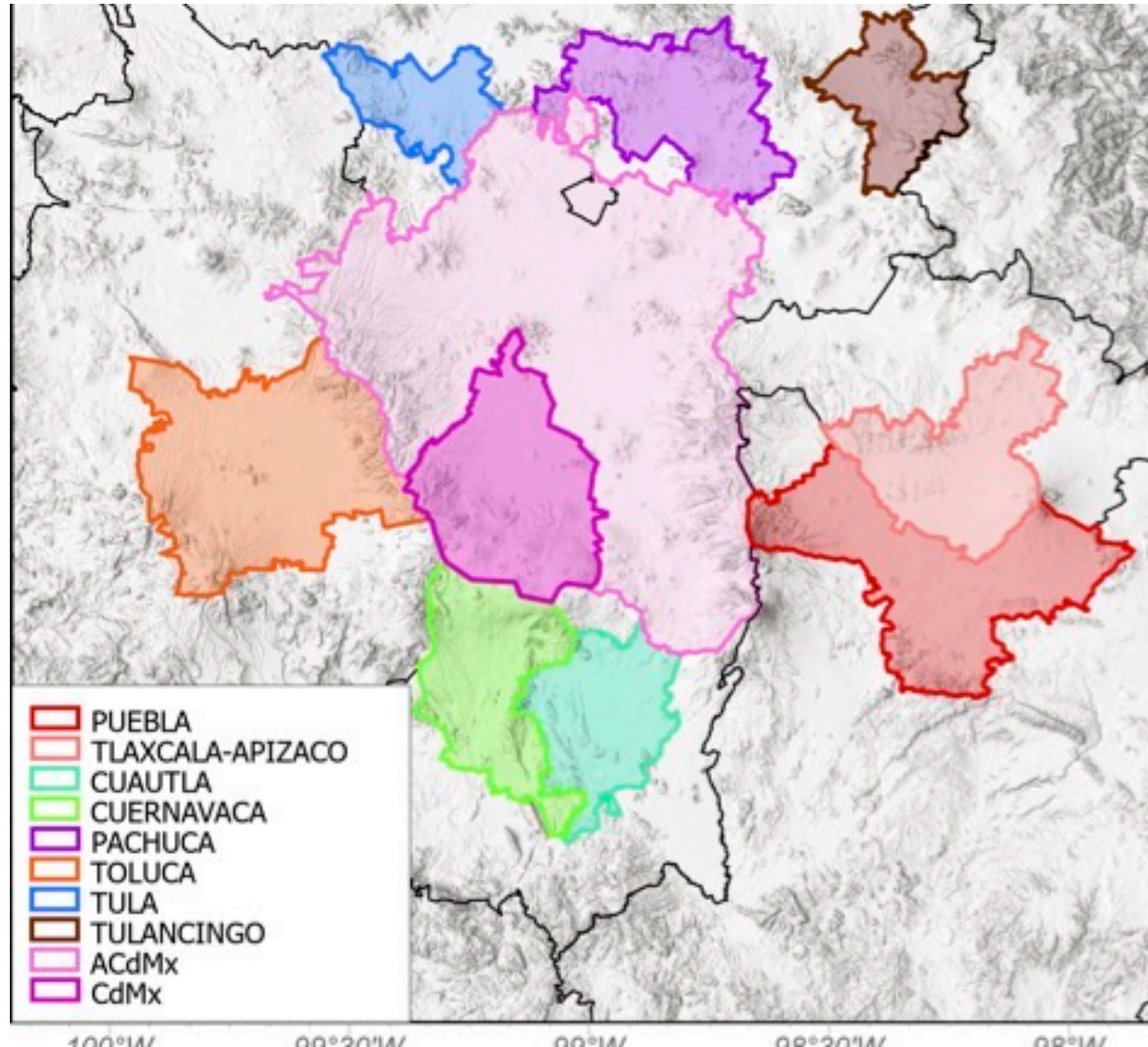
- Introduction
- Methods
- Results
- Application
- Conclusions

Introduction

- In order for an air quality model to better emulate and represent the atmospheric pollution in a region, its performance has to be evaluated
 - identify uncertainties
 - reproduce ambient observations
- An air quality forecast system has been implemented
- The region encompasses a megalopolis that includes 5 states surrounding the Mexico Megacity. Central Mexico

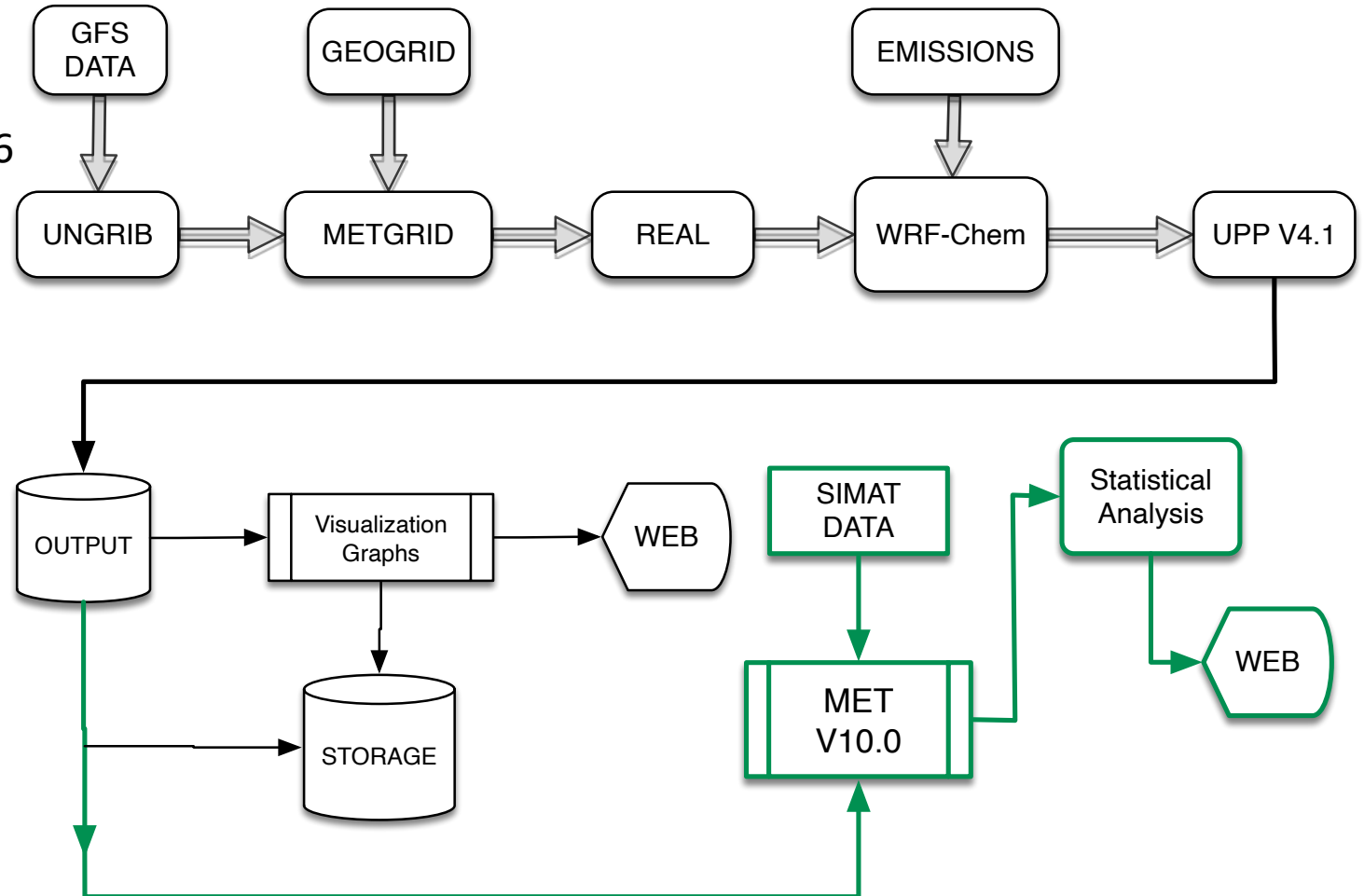
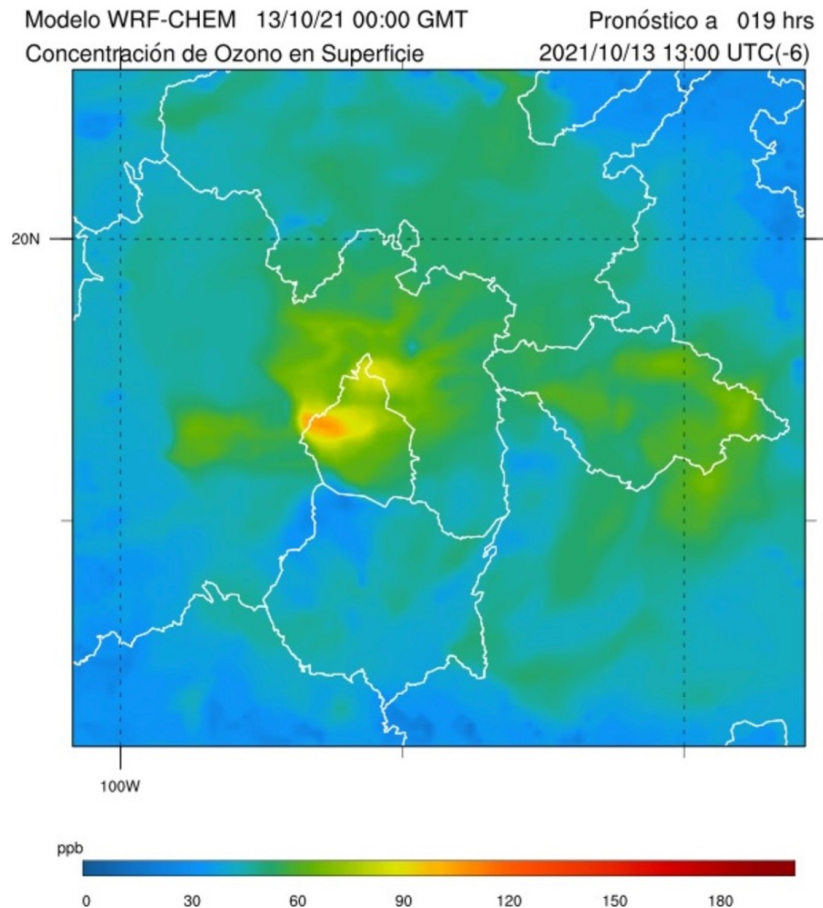
Domain Area

- Population in the area around 33 M
- 5 M of vehicles
- Complex topography
- High altitude (2240 masl)
- Measure network in center



Forecast System

- WRF-chem v 4.0
- Mexico National Emissions Inventory 2016
- Domain 90x90 with grid cell of 3x3 km



<http://grupo-ioa.atmosfera.unam.mx/pronosticos/index.php/wrf-chem/cdmx/ozono>

Evaluation Purposes: key questions

- In what monitoring stations does the model have the best performance?
- Are there meteorological regimes in which the forecasts are better or worse?
- Do the weather natural variability of the forecasts is correctly capture ?
- How is the best way to present the results to the users?

Method

Identification of the:

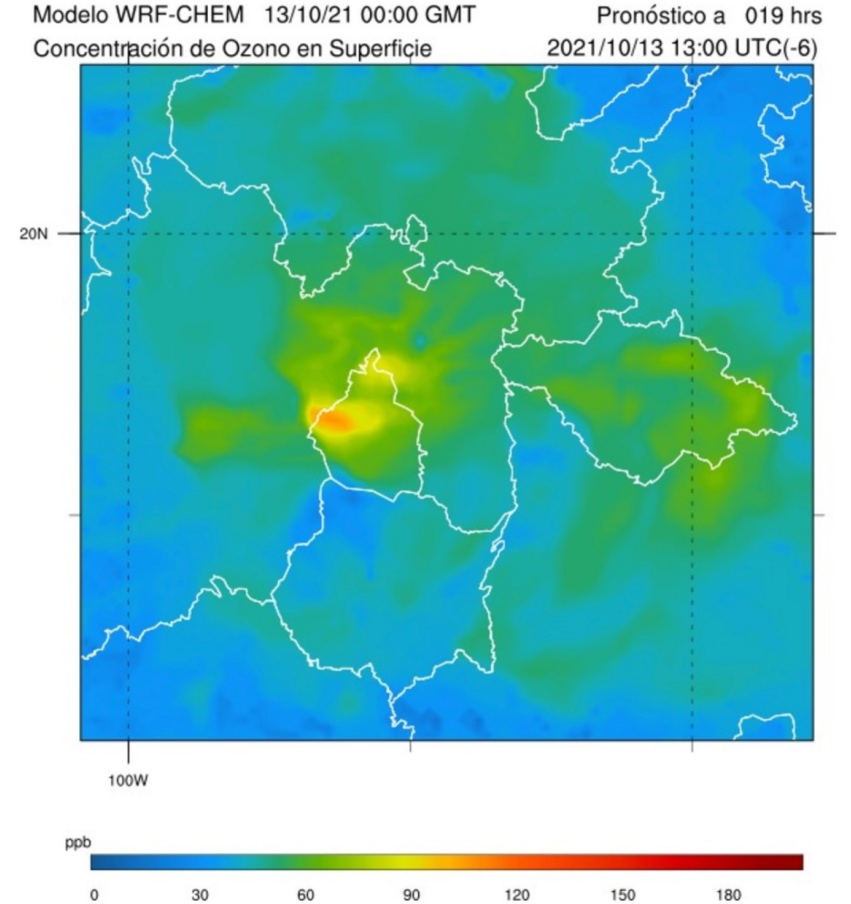
1. Evaluation Purposes
2. Forecast and observation characteristics
3. Selection of observations with representativeness and quality
4. Matching process between forecast and observations
5. Evaluation methods selection
6. Interpretation and analysis

Evaluation Purposes

- Monitoring performance
- Identifying and correcting model flaws
- Forecast improvement
- Information for decision support system.
- Support the users to interpret forecasts

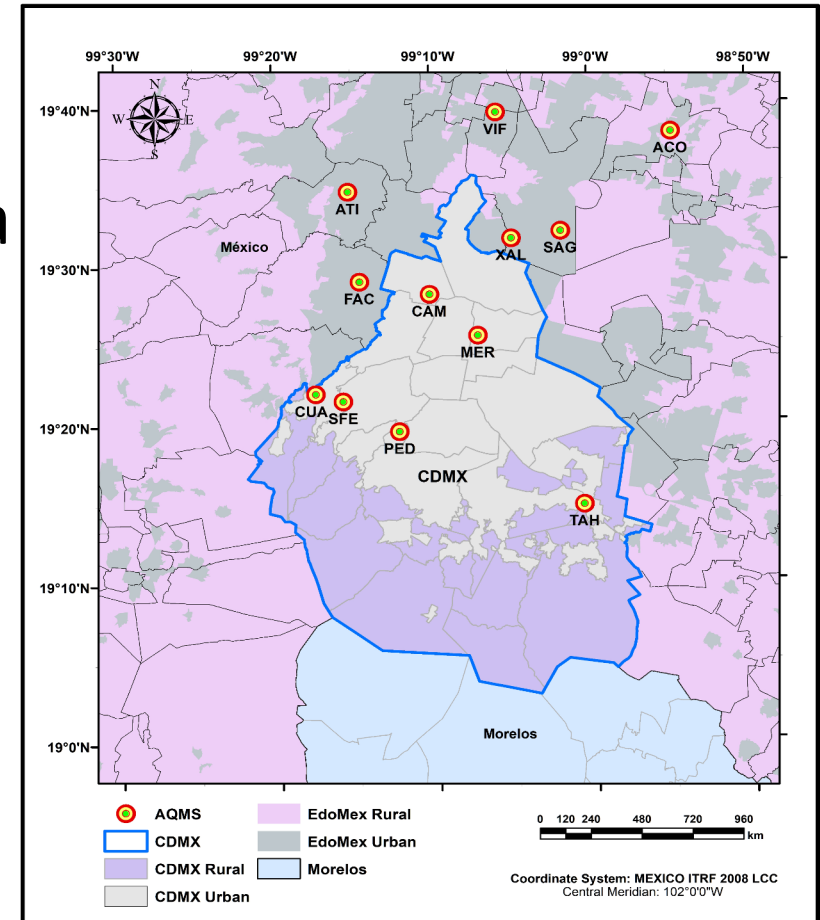
Forecast characteristics

- Hourly 3D pollutant concentrations
 - CO, NO, SO₂, PM_{2.5}, O₃
- Hourly 3D meteorological variables
 - T2m, U, V, Windir, RH, Atmospheric Pressure
- Central México 3x3 km grid 105 x 90



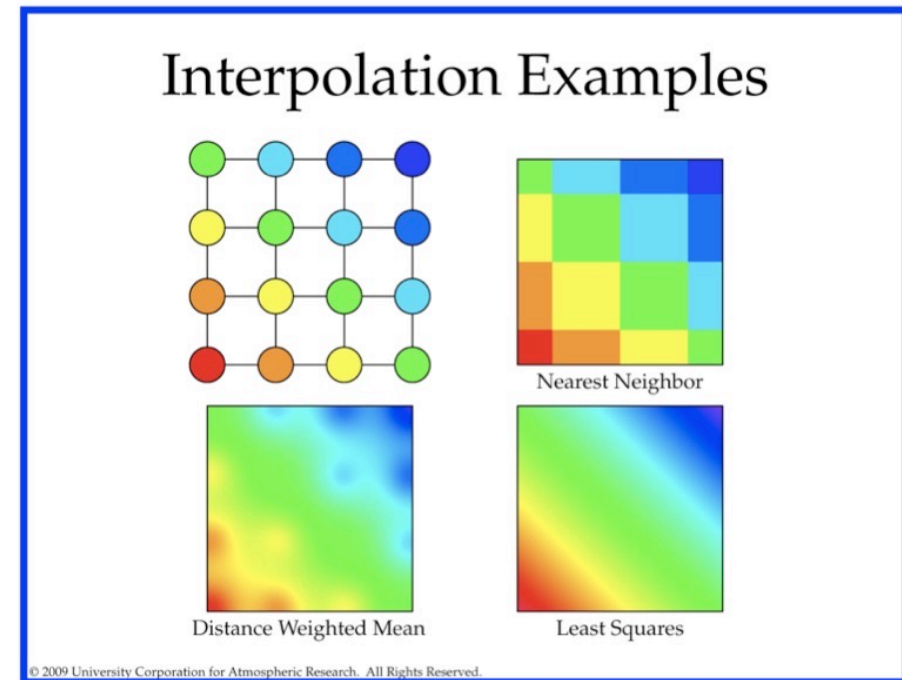
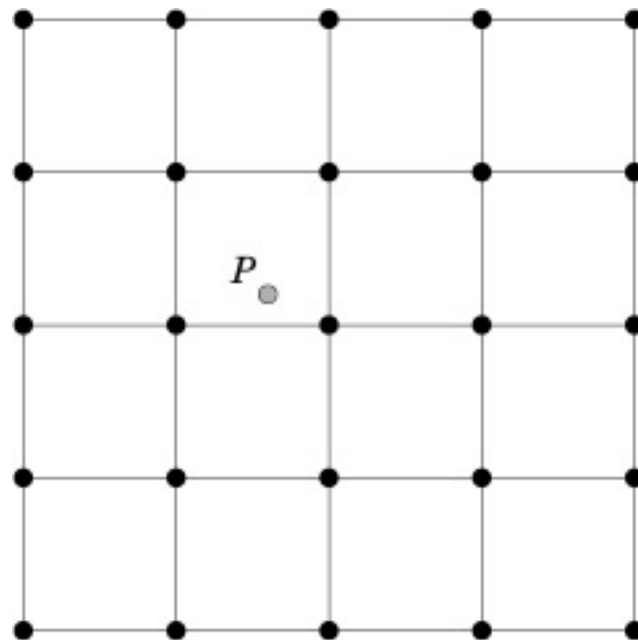
Observations Characteristics

- Hourly data in 32 stations pollutants (CO, O₃, NO₂, NO, SO₂, PM_{2.5}) and meteorological data (temp, W Dir, W Speed, HR)
- Has a QA/QC
- Availability real time, monthly and annual databases.
- Ensuring that forecasts and observations are on the same spatial and temporal scales.



Matching process

- Point-to-point matching pairs measuring site in a 3x3 forecast grid.
- Bilinear interpolation



Source: MET User's Guide (Point-Stat tool)

Evaluation Methods

- Continuous statistics MSE, ME, Pearson, RMSE
- Verification measures for categorical (dichotomous) variables
 - i.e. Ozone above 95 ppb)

Using Model Evaluation Tools (METv10.0) for computing the statistics. Visualization with R-open air, Metviewer

Categorical Verification and Scores

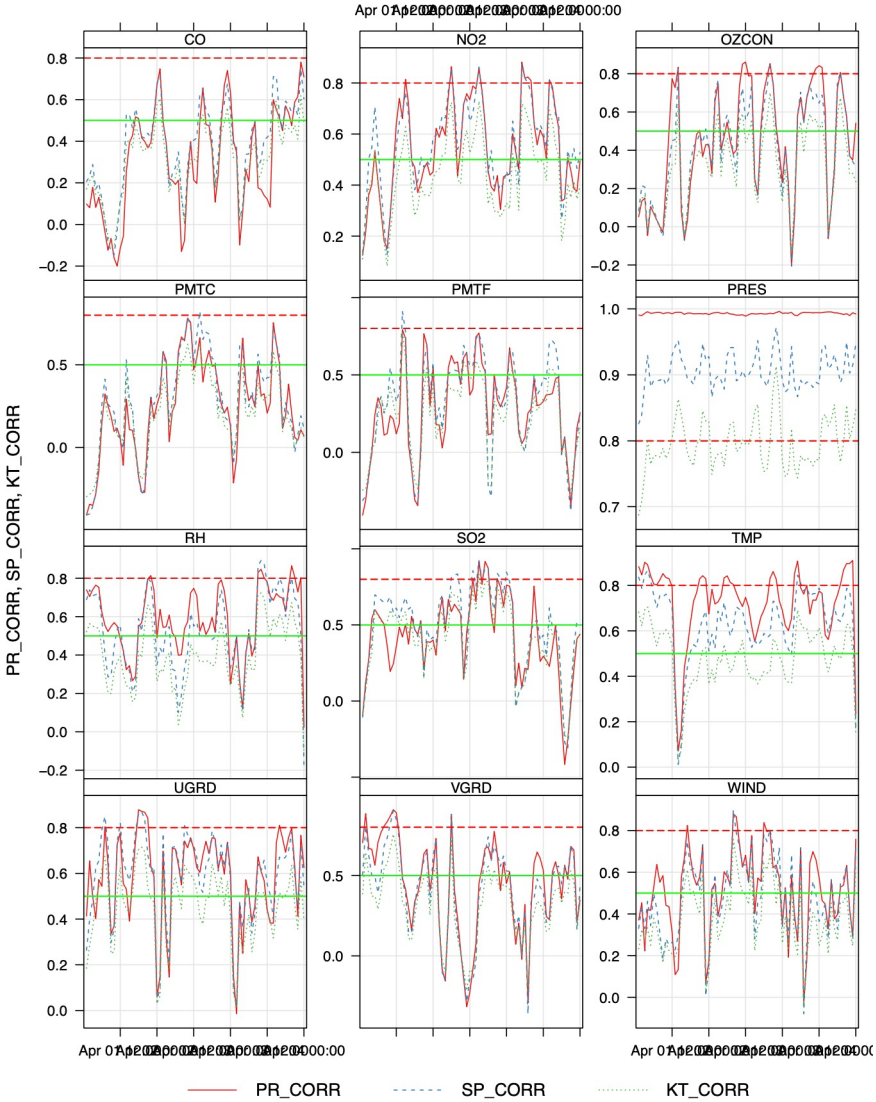
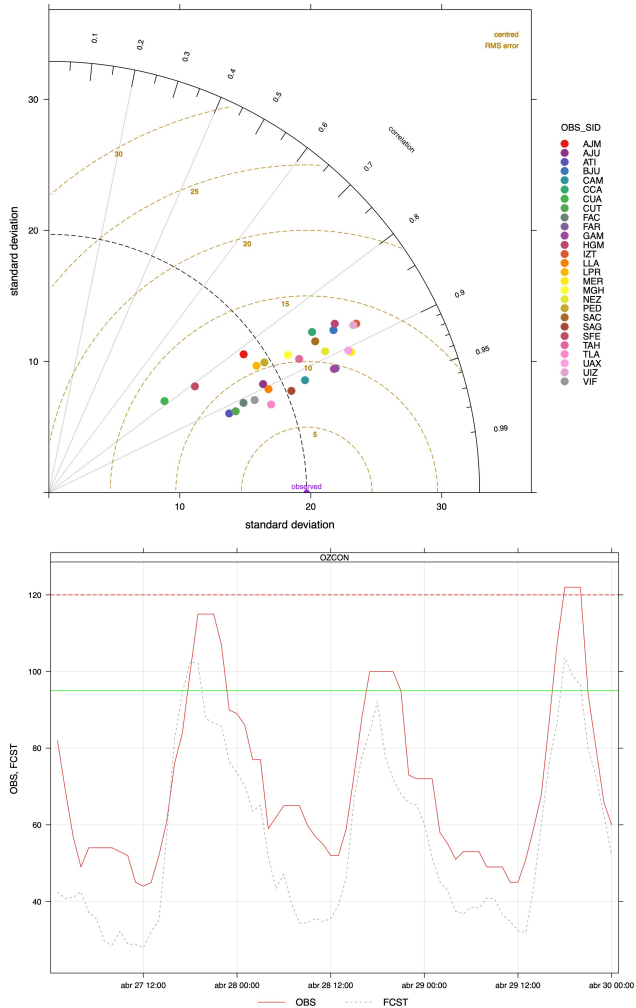
Statistics	Other names for the same statistic
Probability of Detection	Hit Rate
Probability of False Detection	False Alarm Rate (not Ratio)
Critical Success Index	Threat Score
Gilbert Skill Score	Equitable Threat Score
Hanssen and Kuipers Discriminant	True Skill Statistic, Pierce's Skill Score
Heidke Skill Score	Cohen's K
Odds Ratio Skill Score	Yule's Q
Mean Error	Magnitude Bias
Mean Error Squared (ME2)	MSE by Mean Difference
Bias Corrected MSE	MSE by Pattern Variation
MSESS	Murphy's MSESS
Pearson Correlation	Anomalous Pattern Correlation
Anomaly Correlation	Anomalous Correction
Rank Histogram	Talagrand Diagram
Reliability Diagram	Attributes Diagram
Ignorance Score	Logarithmic Scoring Rule

		Observed		
		Yes	No	Total
Forecast	Yes	Hit	False Alarm	Forecast Yes
	No	Miss	Correct Negative	Forecast No
	Total	Obs. Yes	Obs. No	Total
		Observed		
		Yes	No	Total
Forecast	Yes	a	b	a+b
	No	c	d	c+d
	Total	a+c	b+d	n

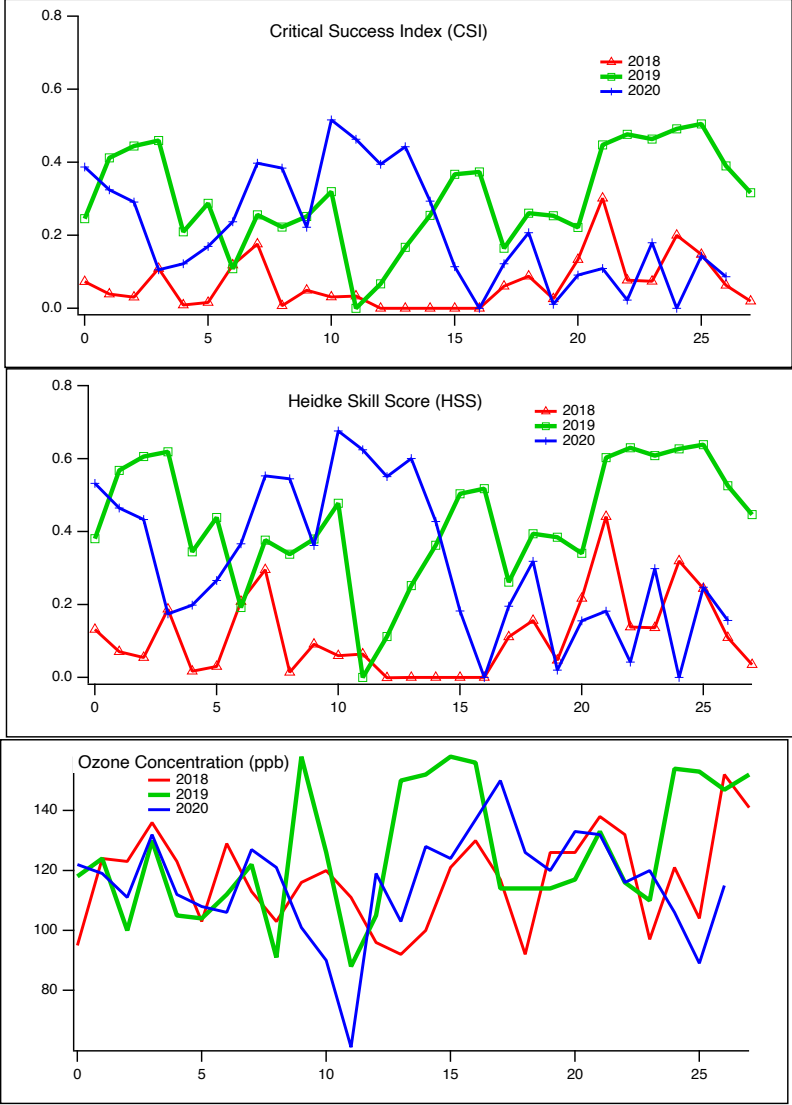
- Hit Rate (POD_y) = $a/(a+c)$
- False Alarm **Ratio** (FAR) = $b/(a+b)$
- POD_n = $d/(b+d) = (1 - \text{POFD})$
- False Alarm Rate (POFD) = $b/(b+d)$
- (Frequency) Bias (FBIAS) = $(a+b)/(a+c)$
- Threat Score or Critical Success Index = $a/(a+b+c)$

Evaluation Results

Continuos statistics



Categorical

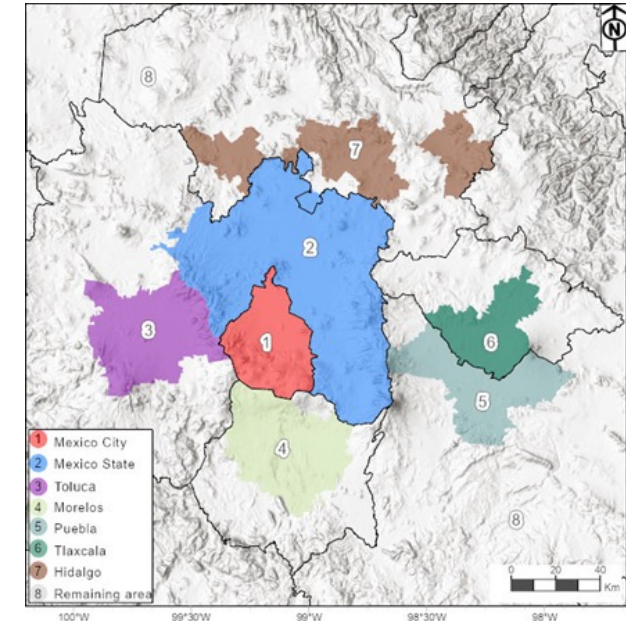


CO emissions scaling by using satellite and modeled information

- February 2011 carbon monoxide concentrations were modeled using two different inventories: 2008 and 2014 emission inventories.
- Chemistry was turned off and 9 regions were analyzed: Mexico City, Toluca, Morelos, Puebla, Hidalgo, Tlaxcala, Mexico State municipalities surrounding Mexico City, the model background concentration and the remaining region.
- Scaling factors were estimated by comparing WRF-Chem modeled data and satellite measurements from IASI (Metop-A).

Maldonado-Pacheco et al. 2020

Metropolitan areas



Scaling factors for February 2011

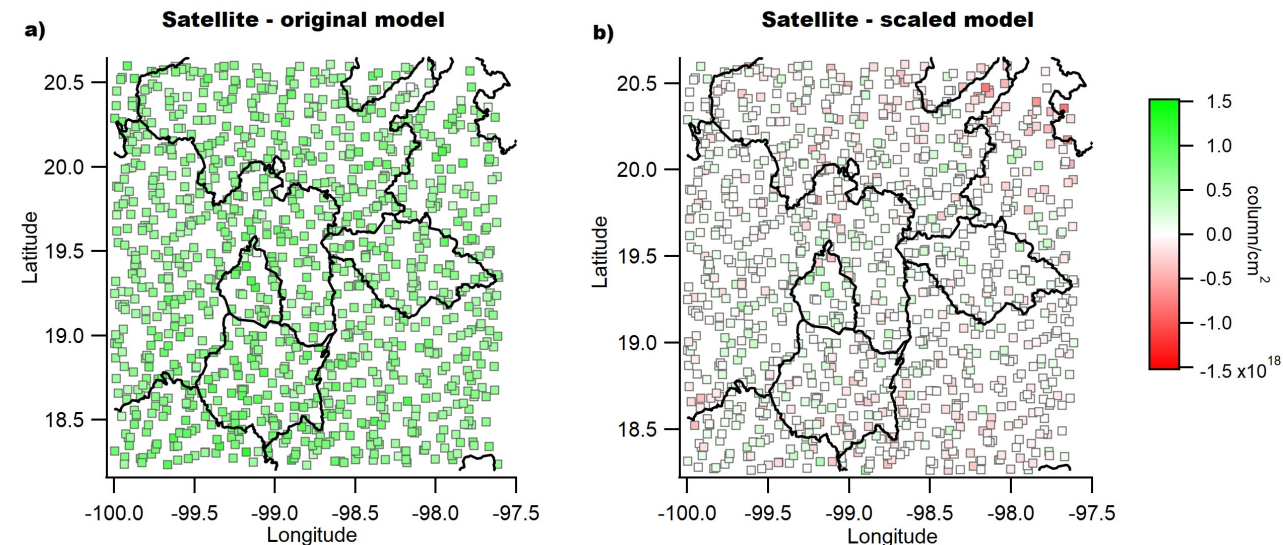
Region / input	2008 Inventory	2014 Inventory
Mexico City 1	0.49	0.80
Toluca 3	0.13	1.09
Morelos 4	0.16	0.93
Puebla 5	0.41	0.67
Hidalgo 7	3.26	1.13
Mexico State 2	0.29	1.60
Tlaxcala 6	1.15	0.66
Remaining region	0.18	0.24
Background	1.86	1.90

CO emissions scaling by using satellite and modeled information (2)

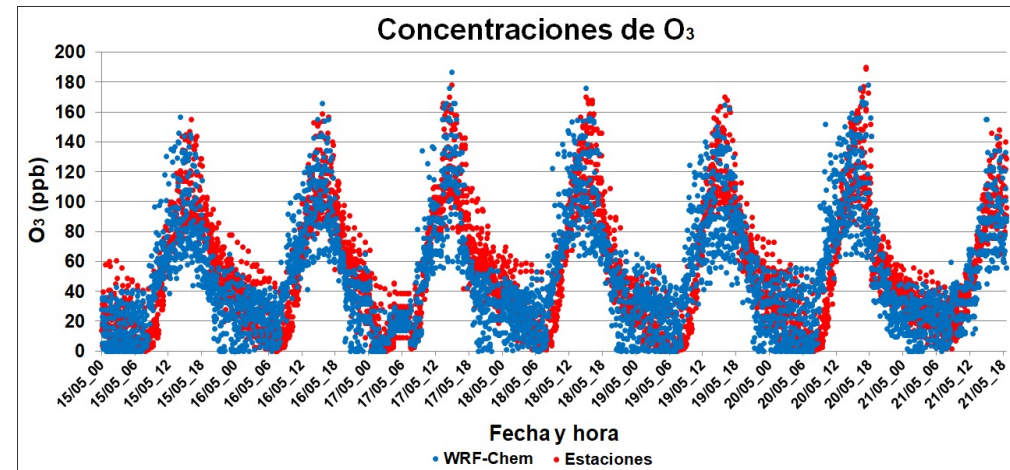
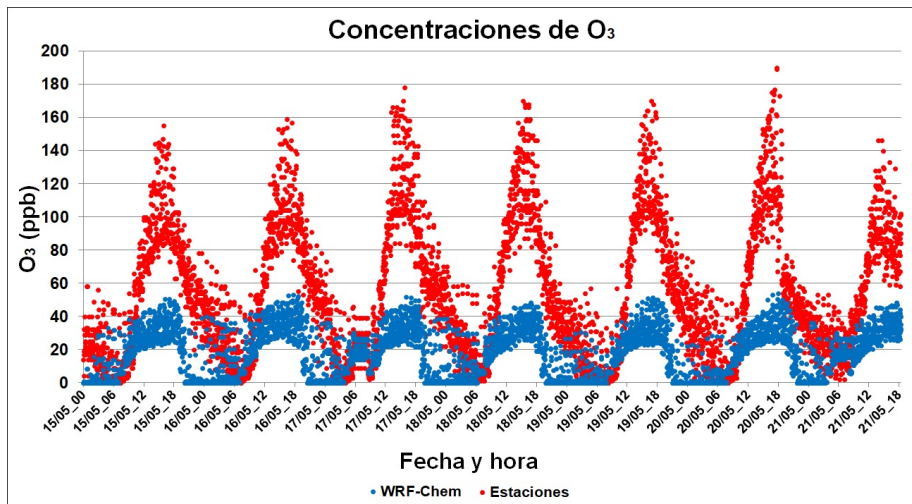
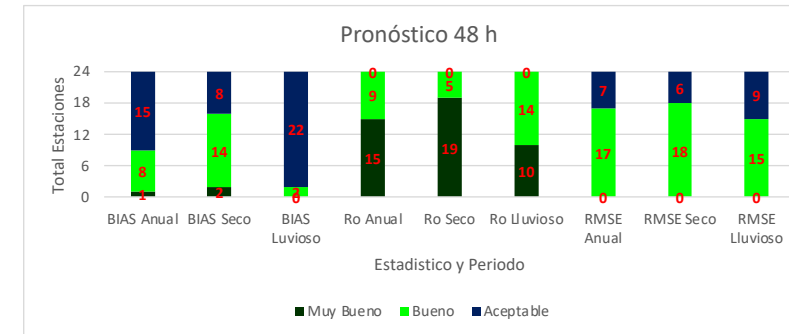
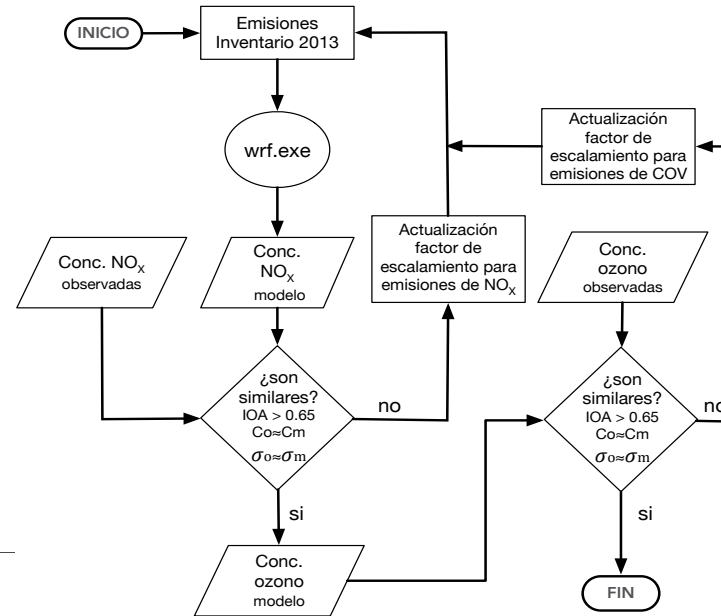
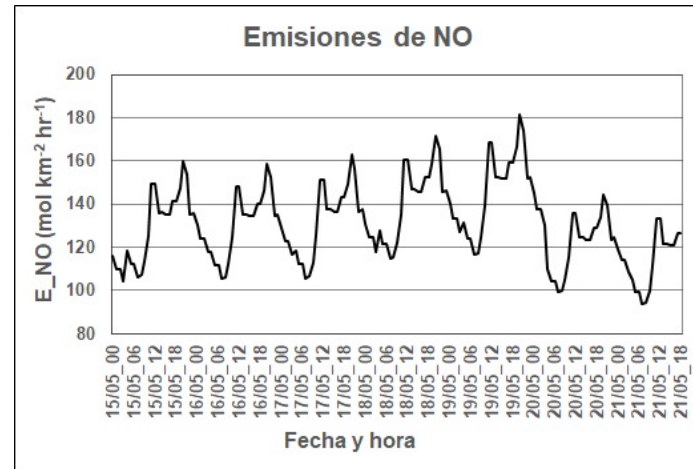
- Scaled CO emissions converged for both emission inventories in most regions. This indicates a good agreement.
- Differences between satellite and modeled total columns are reduced when the scaled emission inventories are used.
- These results show that this methodology could be used to scale carbon monoxide emissions. More research is needed.

Total scaled emissions in Mg/year

Region	2008	2014	Ratio (2014/2008)
Mexico City	560	530	0.93
Toluca	170	210	1.2
Morelos	70	90	1.22
Puebla	190	180	0.94
Hidalgo	230	30	0.13
Mexico State	470	500	1.06
Tlaxcala	90	100	1.12
Remaining Area	280	220	0.8
Average	2,060	1,860	0.93



Emissions Inventory for AirQuality Forecast



Future work

- Characterization of the uncertainty in the observations
- Identification of different verification attributes in order to provide answers to specific questions
- Selection of measures and graphics that appropriately measure and represent the attributes of interest
- Identification of a standard for a reference skill level comparison (e.g., persistence)
- Select appropriate methods to present/display verification results

Conclusions

- A system for air quality forecast was implemented by using available tools that facilitate the comparison process with a consistent set of metrics. A comparison between different years and measurement stations can be performed in order to evaluate the performance of the forecast during ozone seasons.
- Verification can support emissions inventory evaluation and improvement.

Acknowledgments

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- SIMAT for provide an Air quality and Meteorological measurements data by web page.

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