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Sub-kilometer mobile emissions grid and dispersion model for Medellín, Colombia

Juan J. Henao*[1,2], John F. Mejia[1], Angela M. Rendón[2] and Juan F. Salazar[2]
1. Department of Atmospheric Sciences, Desert Research Institute, Reno, Nevada.
2. GIGA, Escuela Ambiental, Facultad de Ingeniería, Universidad de Antioquia, Medellín, Colombia.
* jjose.henao@udea.edu.co

- The dispersion of traffic emissions in a highly urbanized and narrow inter-Andean valley is examined using two dispersion model types (Lagrangian and Eulerian) with a passive tracer emulating CO.
- We followed a simple top-down approach to distribute total annual emissions in space (300m) and time (hourly for each weekday) based on road network and category and vehicle counts.
- High horizontal resolution (300m) is important to represent intra-valley circulations. However, the error metrics for temperature, precipitation and wind speed are similar for the domain 5 (300 m) and domain 4 (900 m).
- The 3 PBL schemes evaluated using surface stations and a profiler show fairly similar results.
- Results show the regions of the valley where “mobile emissions” tend to accumulate.

Site description

Medellin and Metropolitan area:

- Second largest city in Colombia
- 4 million inhabitants in 1150 km²
- Steep and narrow valley
- Cases of severe air pollution exceedances (especially in march)
- 343 vehicles per 1000 inhabitants

Models Configuration

WRF-CHEM v. 3.9.1.1 (WRF)

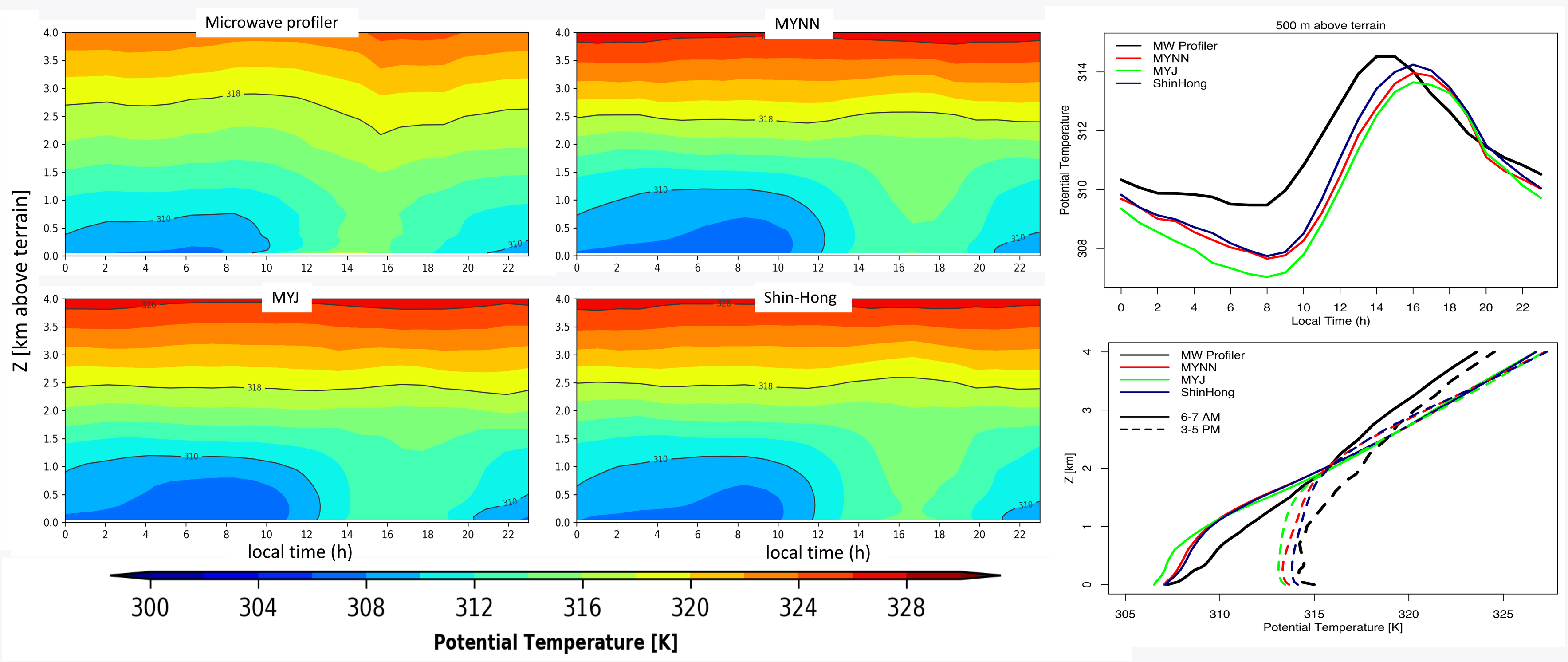
- **Period**: March 6-20 2016
- **Topo**: SRTM (D5) & USGS
- **LULC**: MODIS
- **ICBC**: CFSR
- **Domains**: 5 (one way)
- **Resolution**: 24km – 300m
- **Land Surface**: Noah-MP
- **Surface**: Jimenez revised
- **PBL**: MYJ, MYNN, ShinHong
- **MP**: Thompson
- **Cu**: Kain-Fritsch (D1-2)
- **Chem:** Passive tracer

Lagrangian model (Lag)

- Langevin equation: advection by mean wind and sub-grid turbulent fluctuations
- Mean wind component (15 min WRF output)
- Turbulence diffusion is a function of WRF-TKE and a random Normal stochastic component with mean zero and standard deviation Δt = 30sec
- 10^8 particles per day

WRF Model Performance

Potential temperature vertical structure using a microwave radiometer



(surface met stations from SIATA)

TEMP

PBL	Domain	RMSE	BIAS	MAE	COR	pVal
Shin-Hong	D04	1.469	-0.901	1.234	0.934	1.13e-146
	D05	1.309	-0.593	1.045	0.935	1.34e-147
MYJ	D04	1.884	-1.537	1.659	0.941	3.57e-154
	D05	1.72	-1.337	1.498	0.943	2.61e-156
MYNN	D04	1.809	-1.211	1.444	0.919	7.23e-133
	D05	1.608	-0.876	1.231	0.919	3.35e-132

PREC

PBL	Domain	RMSE	BIAS	MAE	COR	pVal
Shin-Hong	D04	3.605	-2.102	2.609	0.089	0.762
	D05	3.715	-2.203	2.879	-0.048	0.87
MYJ	D04	3.723	-2.661	2.843	0.239	0.411
	D05	3.728	-2.583	2.853	0.204	0.484
MYNN	D04	3.887	-1.675	2.99	0.09	0.759
	D05	3.728	-1.74	2.892	0.09	0.76

WIND

PBL	Domain	RMSE	BIAS	MAE	COR	pVal
Shin-Hong	D04	1.73	1.345	1.428	0.491	3.75e-21
	D05	1.811	1.454	1.501	0.508	1.06e-22
MYJ	D04	1.857	1.48	1.537	0.63	2.03e-37
	D05	1.966	1.606	1.643	0.651	1.36e-40
MYNN	D04	1.672	1.289	1.387	0.498	8.25e-22
	D05	1.741	1.376	1.463	0.517	1.37e-23

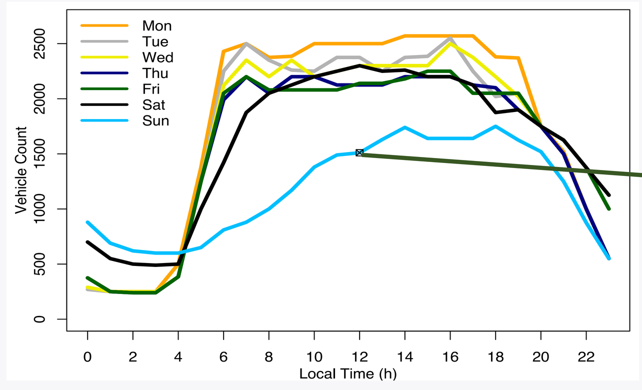
- Model is slightly colder than surface met stations. The vertical structure shows colder (warmer) model temperatures below (above) 2km.
- Model precipitation in D4-5 has less rainfall compared to surface stations.
- Model overestimates wind speed compared to surface stations.
- Similar error metrics for D5 vs D4 and the three PBL’s. There is added value in the resolved local circulation and better representation of valley topography in D5.

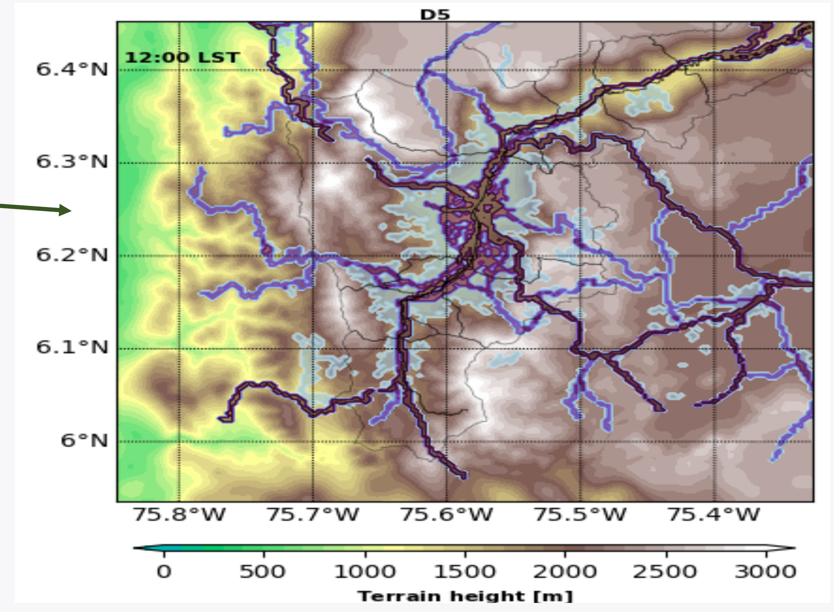
Emission Inventory

Top-down approach:

- Road network
- Road categories
- Traffic dynamics
- Total annual emissions

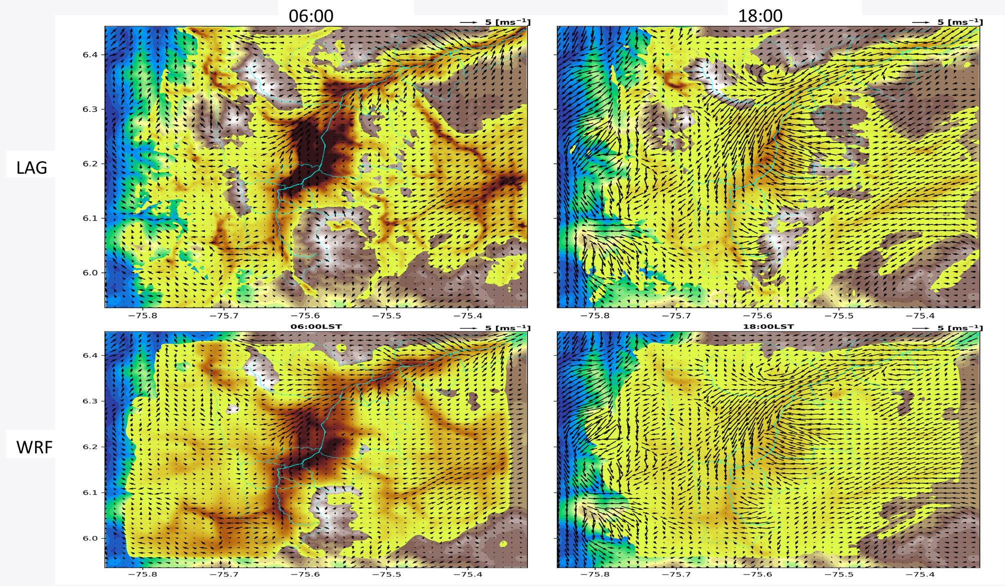
Following Saide et al. 2009, Atmos. Environ.





hourly emissions for each weekday at 300m resolution

Results

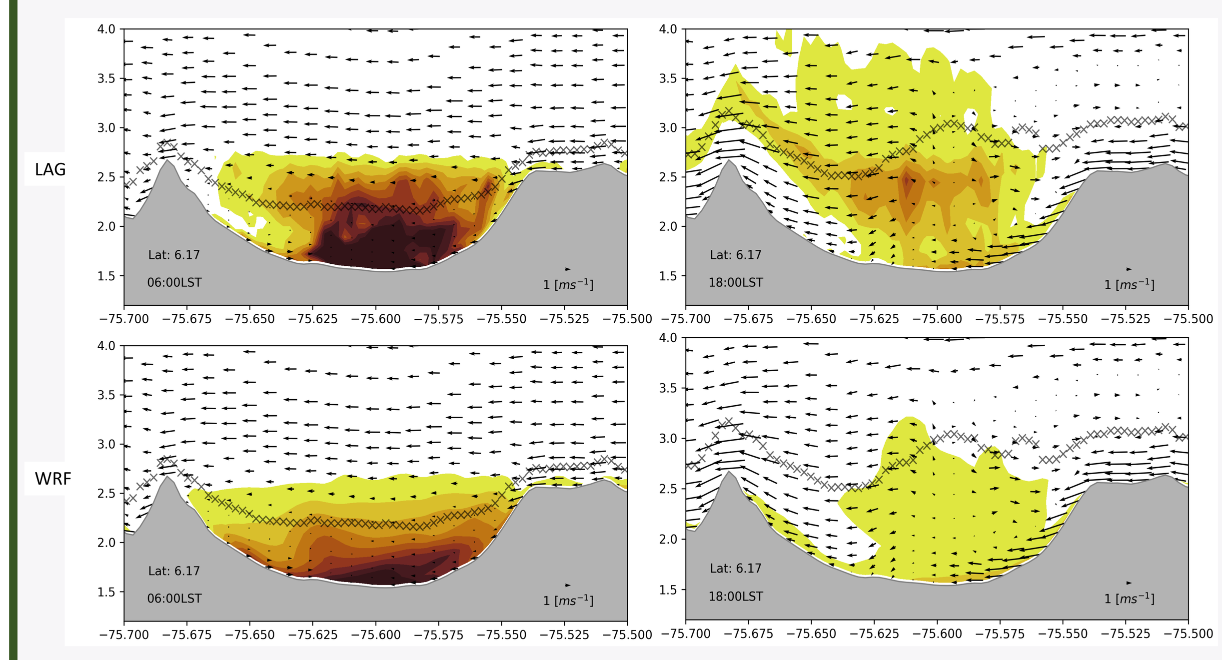


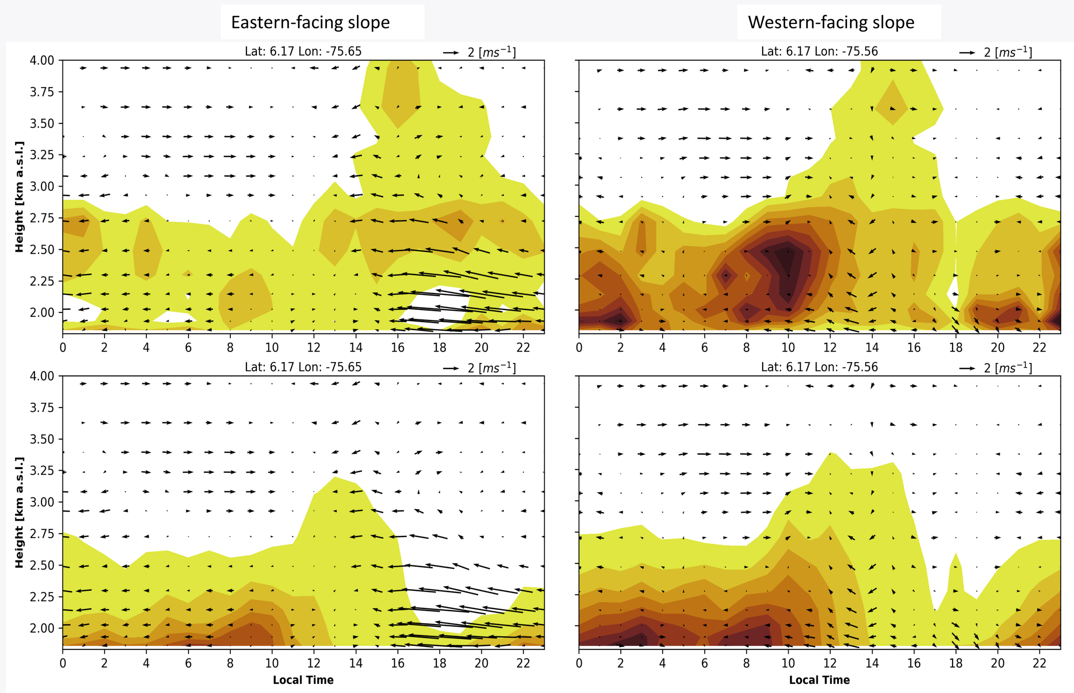
Both Lag and WRF models agree on:

- **AM**: Tracer is trapped within the valley and accumulated near sources.
- **PM**: Ventilation associated to the evolution of the local circulation (valley flows) and PBL mixing reduce the concentration of the tracer near surface.
- Asymmetries in the distribution of tracer across-valley (one slope more polluted).
- With the growth of the PBL, pollutants reaching the valley top are transported with the predominant easterly flow.

Models differ:

- Vertical distribution of the tracer, with higher dispersion in the Lag model
- Hence, significant transport occurs at higher levels in the Lag model





Concluding remarks

- Evaluated PBL schemes produced similar error statistics using surface met stations. MYNN resulted in larger nocturnal PBL heights.
- Both Lagrangian and WRF show similar dispersion of pollutants, asymmetries in the across-valley distribution, associated to the along-valley circulation and the interaction between the local and regional flow.
- Lagrangian model exhibits dispersion to higher layers, apparently associated to the stochastic turbulent diffusion.
- Reduced computational cost of the lagrangian model, in addition to particle tagging, provides potential for scenarios and sensitivity tests.

Aknowledgements

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