Towards Understanding What Conditions Facilitate Satellite-based AOD-PM Estimations

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HAQAST2
February 27-28, 2017

Study area - Israel


ISRAEL and...
The United States
Maps drawn to same scale.
Israel shown in blue.


ISRAEL and...
California
Maps drawn to same scale.
Israel shown in blue.

Acknowledgments

NASA Postdoctoral Program, Administered by USRA

Robert Chatfield Anthony Strawa Robert Esswein	NASA Ames Research Center
Alexei Lyapustin Yujie Wang	NASA, GFSC
David Broday Yuval Ayala Cohen	Technion – Israel Institute of Technology
Itai Kloog	Ben Gurion University, Israel

Outline

- Background and summary of published work
- The contribution of AOD to PM prediction models
- Future work

This is the first study, to our knowledge, that quantitatively presents the AOD spatiotemporal contribution to the MEM which has been found to be < 2% in different regions.

Why estimate air pollution? What do satellites tell us?

- Fine particulate matter ($PM_{2.5}$) has a large and growing literature of associations with adverse health effects
- Measurements of $PM_{2.5}$ for epidemiological studies are often based on assigning exposures based on a sparse network of ground monitors
- Satellite measures, collected daily with fine resolution, can help reconstruct the spatial and temporal exposure patterns in $PM_{2.5}$

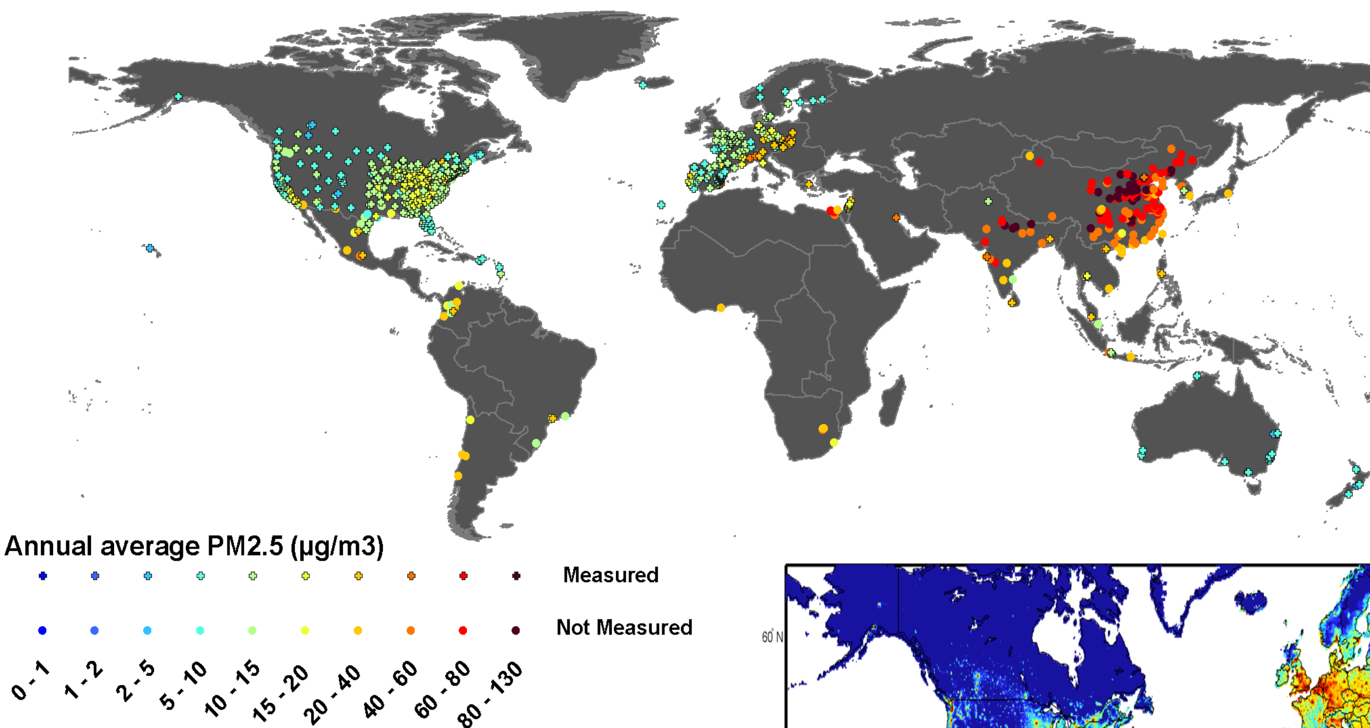
The Highest Quality of Data Rests on a Tripod

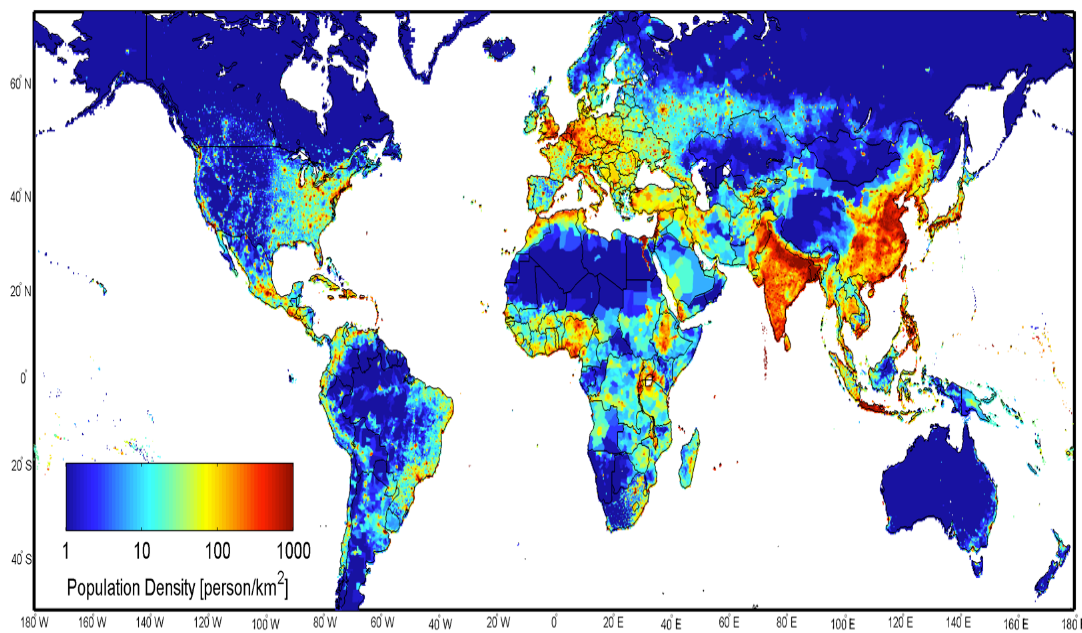
Satellite Data

Ground Measurements
and In-Situ Data

Models

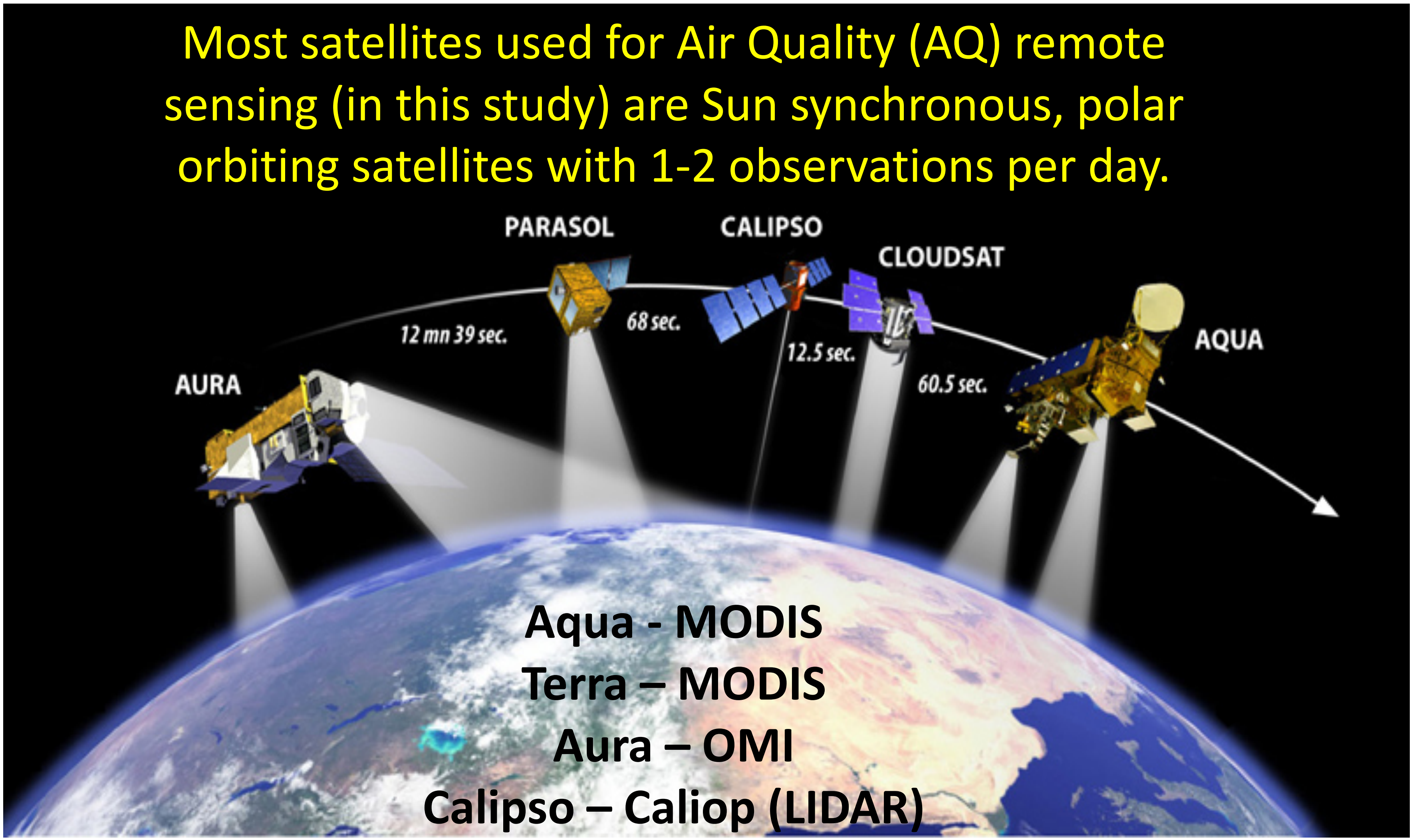
Global Status of PM2.5 Monitoring Networks





Brauer M, Ammann M, Burnett R et al.
GBD 2010 Outdoor Air Pollution Expert Group

Air Quality Satellite Platforms



atrain.nasa.gov

Research around the world

Author	Sensor	Date	Region	Number of Ground Monitors	$PM_{2.5}/PM_{10}$	Linear Regression	R
Wang[154]	MODIS (Terra)	2002	Alabama	7	$PM_{2.5}$ (24 hr)[a]	$77.0\tau - 0.23$	0.67
	MODIS (Aqua)	2002	Alabama	7	$PM_{2.5}$ (24 hr)[a]	$68.6\tau + 1.93$	0.76
	Average	2002	Alabama	7	$PM_{2.5}$ (24 hr)[a]	$72.3\tau + 0.85$	0.98
Chu[153]	MODIS	August–October 2000	Italy	1	PM_{10}	$54.7\tau + 8.0$	0.82
Engel-Cox[161]	MODIS	April–September 2002	United States	1338	$PM_{2.5}$	$22.6\tau + 6.4$	0.4
					$PM_{2.5}$ (24 hr)	$18.7\tau + 7.5$	0.43
Liu[208]	MISR	2003	St. Louis	22	$PM_{2.5}$	NA	0.8
Engel-Cox[163]	MODIS	July 1 to August 30, 2004	Baltimore	4	$PM_{2.5}$	$31.1\tau + 5.2$	0.65
					$PM_{2.5}$ (<PBL)	$48.5\tau + 6.2$	0.65
					$PM_{2.5}$ (24 hr)	$25.3\tau + 11.1$	0.57
					$PM_{2.5}$ (24 hr < PBL)	$64.8\tau + 1.76$	0.76
Liu[169]	MISR	2001	Eastern United States	346	$PM_{2.5}$		–
Al-Saadi[164]	MODIS	Review	United States		$PM_{2.5}$	62.0τ	NA
Gupta[171]	MODIS	2002 and July–November 2003	Global cities	26	PM_{10}[a]	$141.0\ \tau$	0.96
Koelemeijer[152]	MODIS	2003	Europe	88 ($PM_{2.5}$)	$PM_{2.5}$[a]	NA	0.63
					PM_{10}[a]	$214.0\tau - 42.3$	0.58
Kacenelenbogen[118]	POLDER	April–October 2003	France	28	$PM_{2.5}$	$26.6\tau + 13.2$	0.7
Gupta[173]	MODIS	February 2000 to December 2005	Southeastern United States	38	$PM_{2.5}$	$29.4\tau + 8.8$	0.62
					$PM_{2.5}$ (24 hr)	$27.5\tau + 15.8$	0.52
Hutchison[158]	MODIS	August–November 2003 and 2004	Texas	28	$PM_{2.5}$ (August)[a]	$68.8\tau - 39.9$	0.47
					$PM_{2.5}$ (September)[a]	$59.7\tau - 17.2$	0.98
Paciorek[177]	GOES-12	2004	United States	Not given	$PM_{2.5}$ (24 hr)	NA	0.5
					$PM_{2.5}$ (yearly)	NA	0.75
An[179]	MODIS	April 3–7, 2005	Beijing	6	PM_{10}[a]	$21.7\tau + 6.1$	0.92
					$PM_{2.5}$[a]	$31.1\tau + 5.1$	0.92
Schaap[180]	MODIS	August 2006 to May 2007	Cabauw, Netherlands	1	$PM_{2.5}$	$120\tau + 5.1$	0.72

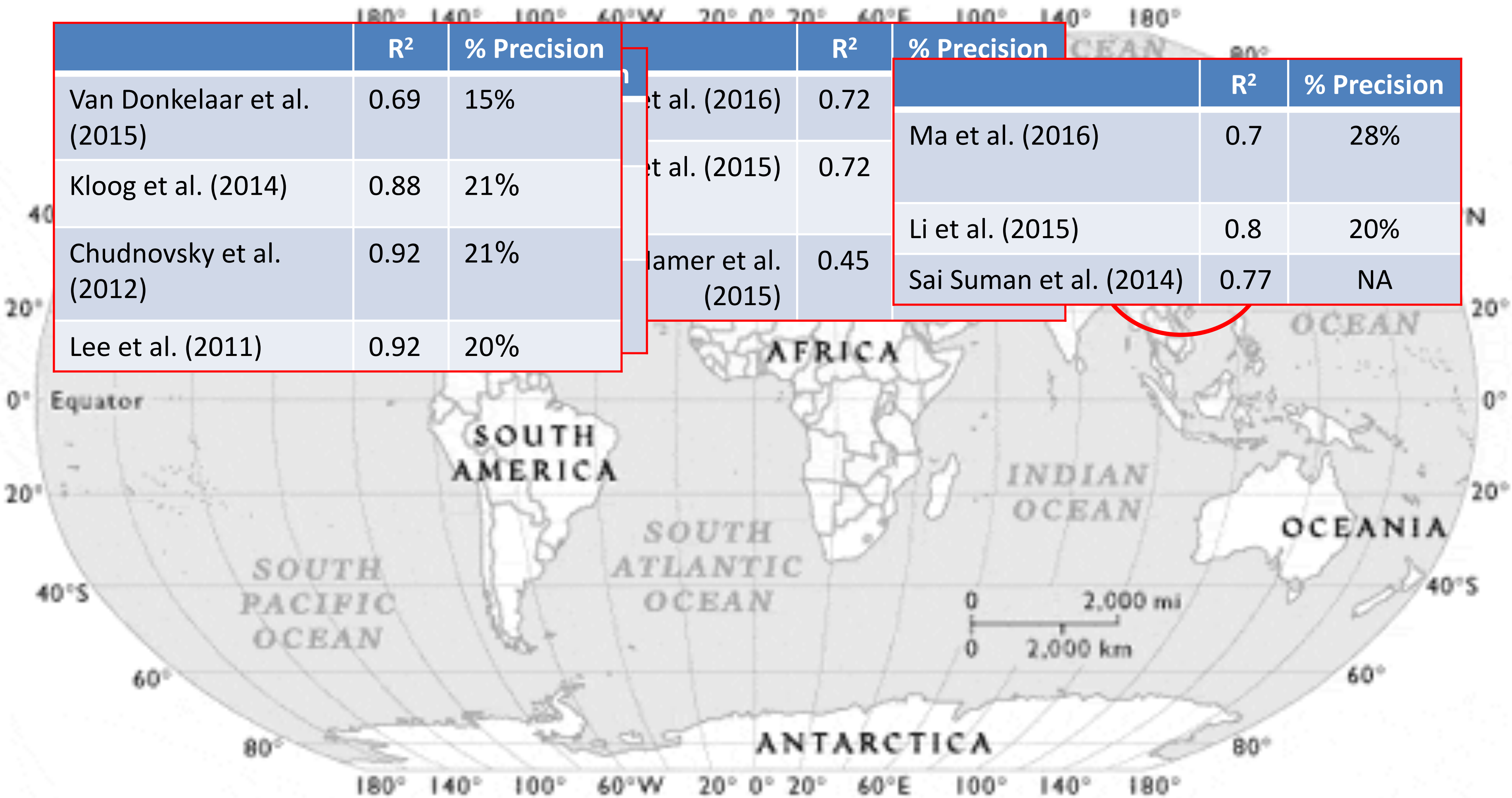
(Hoff & Christopher. AWMA. 2009)

Sample of Current Research Around the World

	R^2	% Precision
Van Donkelaar et al. (2015)	0.69	15%
Kloog et al. (2014)	0.88	21%
Chudnovsky et al. (2012)	0.92	21%
Lee et al. (2011)	0.92	20%

	R^2	% Precision
…t al. (2016)	0.72	
…t al. (2015)	0.72	
…lamer et al. (2015)	0.45	

	R^2	% Precision
Ma et al. (2016)	0.7	28%
Li et al. (2015)	0.8	20%
Sai Suman et al. (2014)	0.77	NA



AOD contribution to MEM

$$(1)\quad PM_{ij} \sim \alpha + (\alpha_j) + \varepsilon_{ij} \quad (\text{Base Model})$$

$$(2)\quad PM_{ij} \sim \alpha + (\alpha_j + \beta AOD_{ij}) + \varepsilon_{ij}$$

$$(3)\quad PM_{ij} \sim \alpha + \beta AOD_{ij} + (\alpha_j) + \varepsilon_{ij}$$

Training subset

$$\text{AOD Contribution} = \left(\text{Deviance}_{(2)\text{ or }(3)} - \text{Deviance}_{\text{base model}}\right) * 100 \Big/ \text{Deviance}_{\text{base model}}$$

Testing subset

Model fit: R^2, RMSE, % Precision

AOD contribution

	Published		Current Study		
	R^2	% Precision	R^2 MEM Base model (Linear reg.)	% Precision (mean PM [μg/m³])	**AOD Contr.**
North East USA	0.88-0.92	20%-21%	0.71 (0.25)	38% (10.4)	**2%**
SJV, CA, USA	0.66-0.77	43%-48%	0.41 (0.13)	70% (19.4)	**1.5%**
Israel	0.45-0.72	37%-52%	0.47 (0.07)	46% (16.9)	**0.35%**
Italy	0.72	30%	0.42 (0.01)	52% (22.4)	**0.64%**
France	0.64*	NA	0.52 (0.1)	44% (108.8)	**1.1%**
India	0.77	NA	0.44 (0.38)	50% (20.4)	**2.1%**

" …none of these models has been tested in developing countries…It would be appropriate to start building a simpler model…cross validate…"

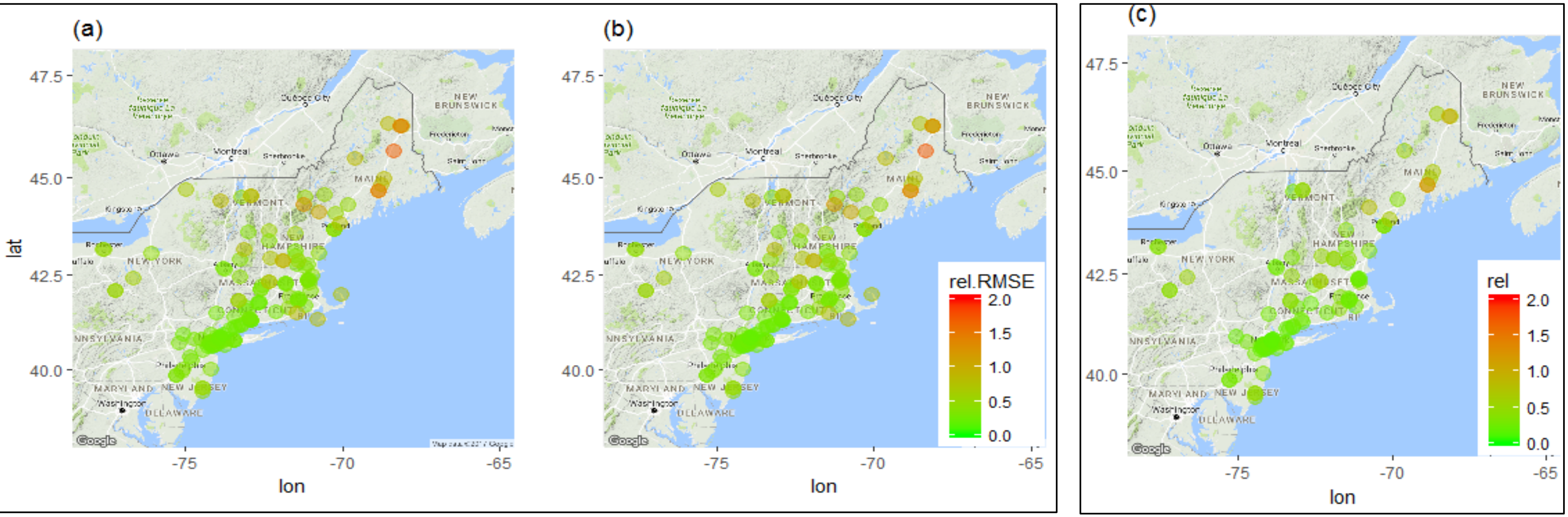
(Liu Y. 2013)

*In preparation

AOD Spatial Contribution

Date only

Date , AOD



Date +AOD+Met

Specific spatiotemporal conditions count

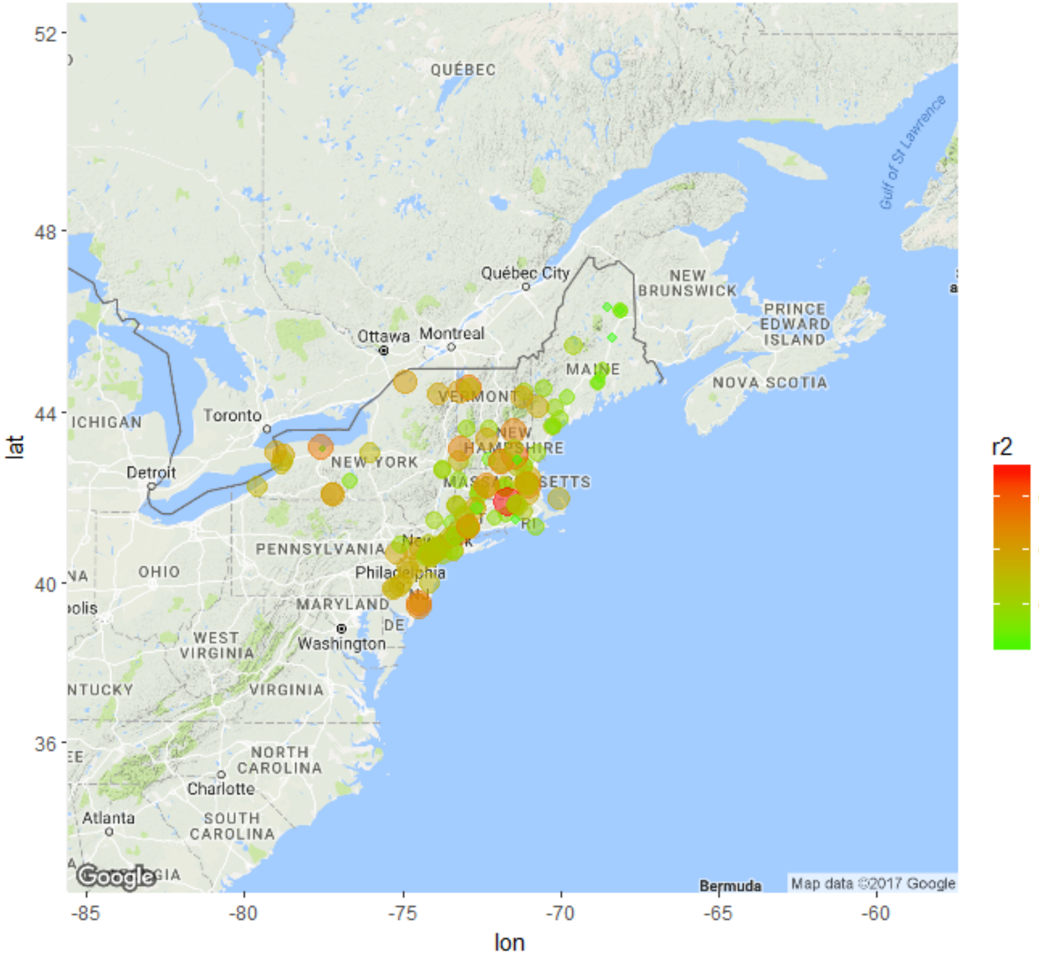
•Van Donkelaar 2011	Biomass burning event
•Chatfield 2017* and Chu 2015	Discover-AQ results
•Kim 2016	Localized empirical model

What are the Environmental-Physical conditions that facilitate a certain accuracy level of AOD-PM association **?**

*In preparation

Linear regression – PM~AOD
NE USA, 2000-2013.

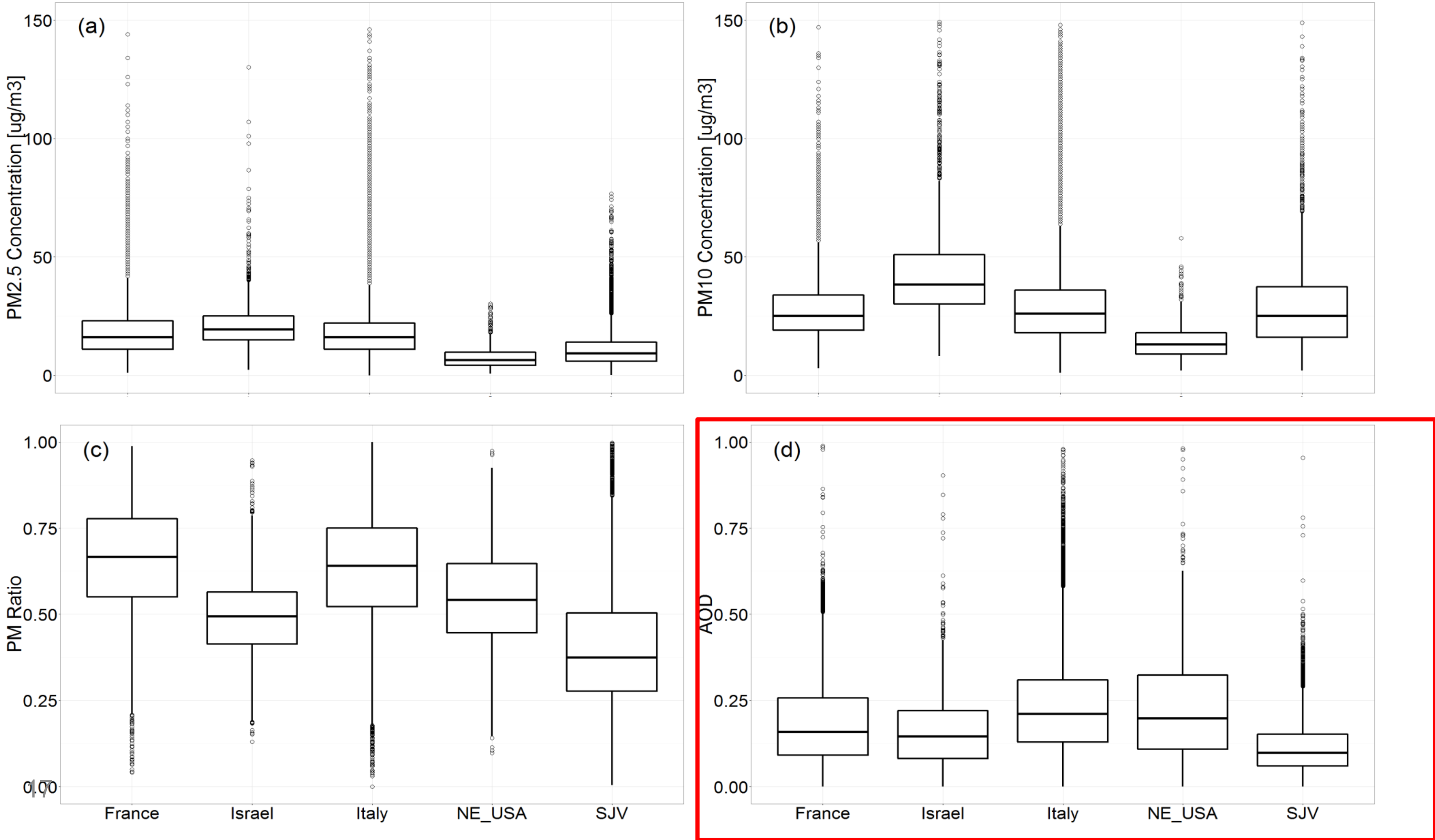
Only Stations with R^2>0.5



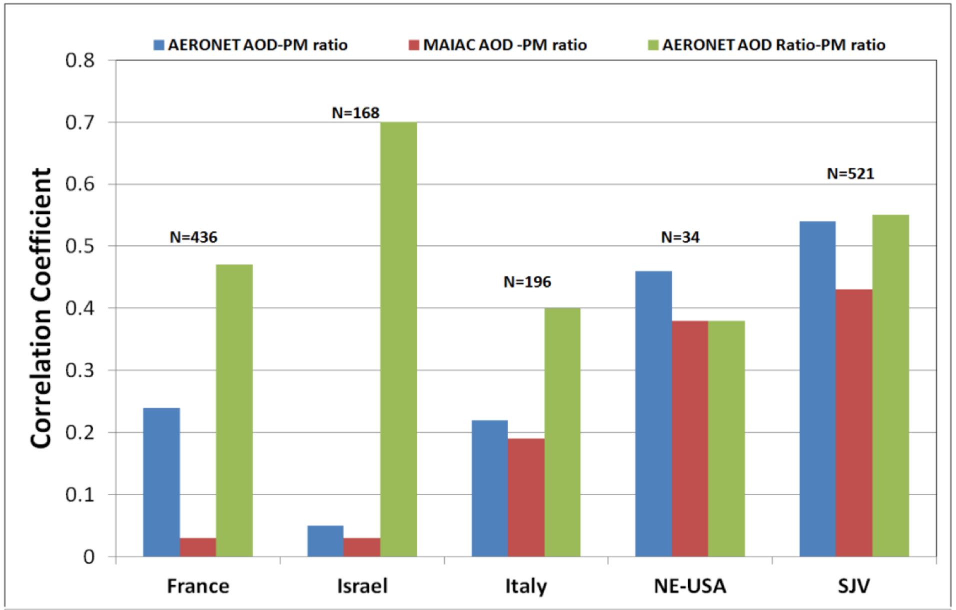
All stations

AOD sensitivity to PM Ratio

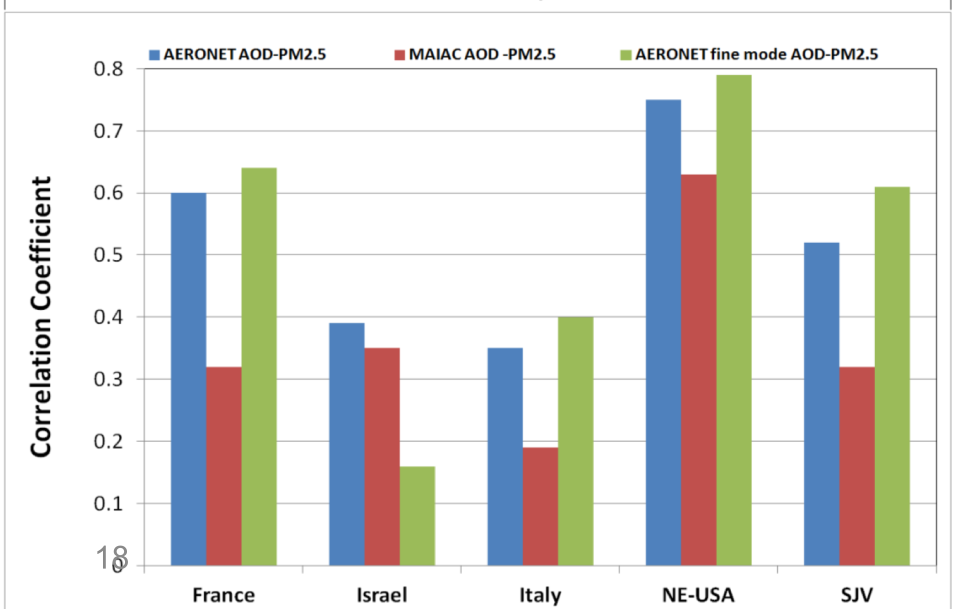
$$\boxed{\frac{PM_{2.5}}{PM_{10}} = \frac{PM_{2.5}}{(PM_{2.5} + PM_{2.5-10})}}$$



AOD sensitivity to PM ratio



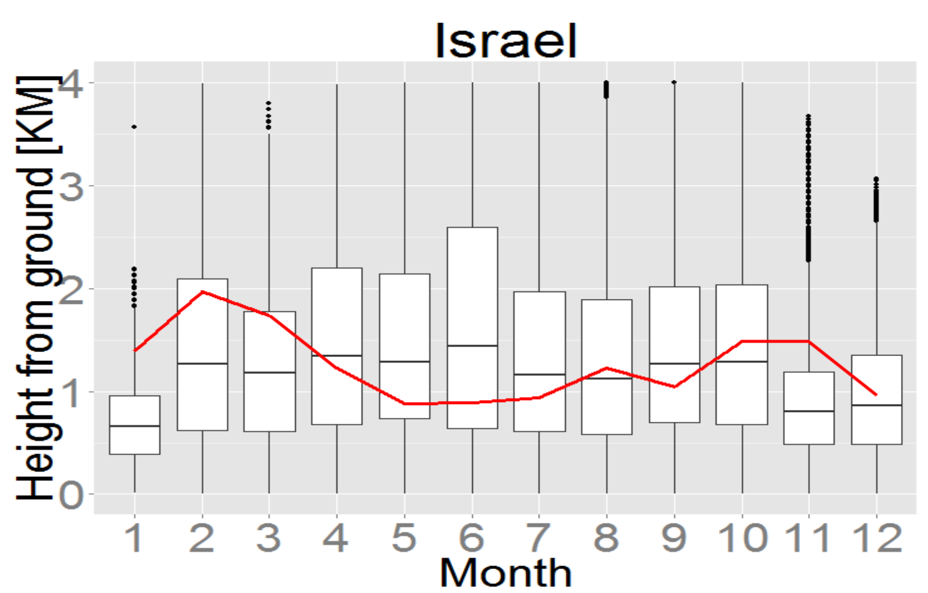
Comparison between AERONET and MAIAC AOD variables to the PM ratio

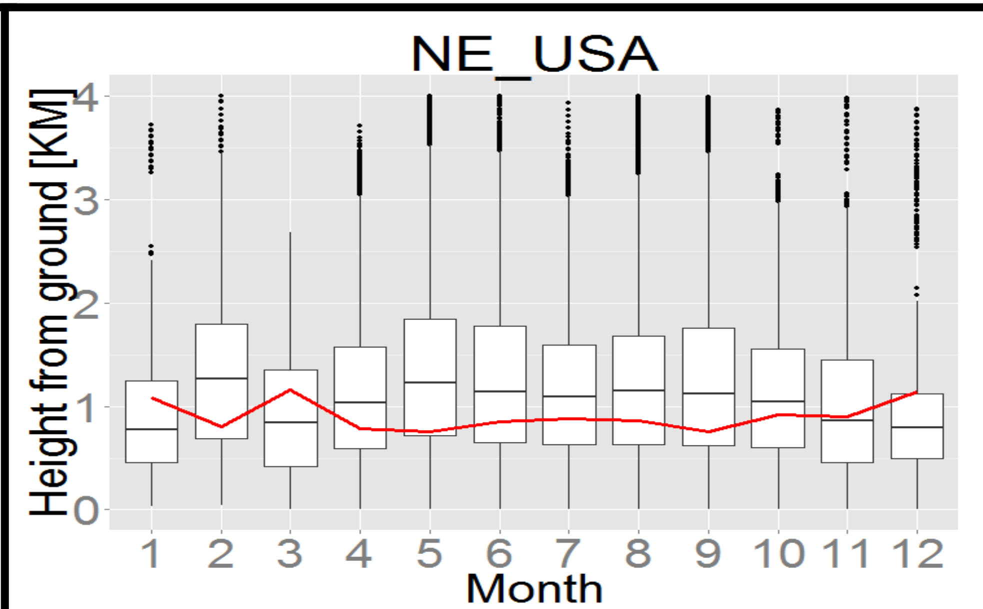


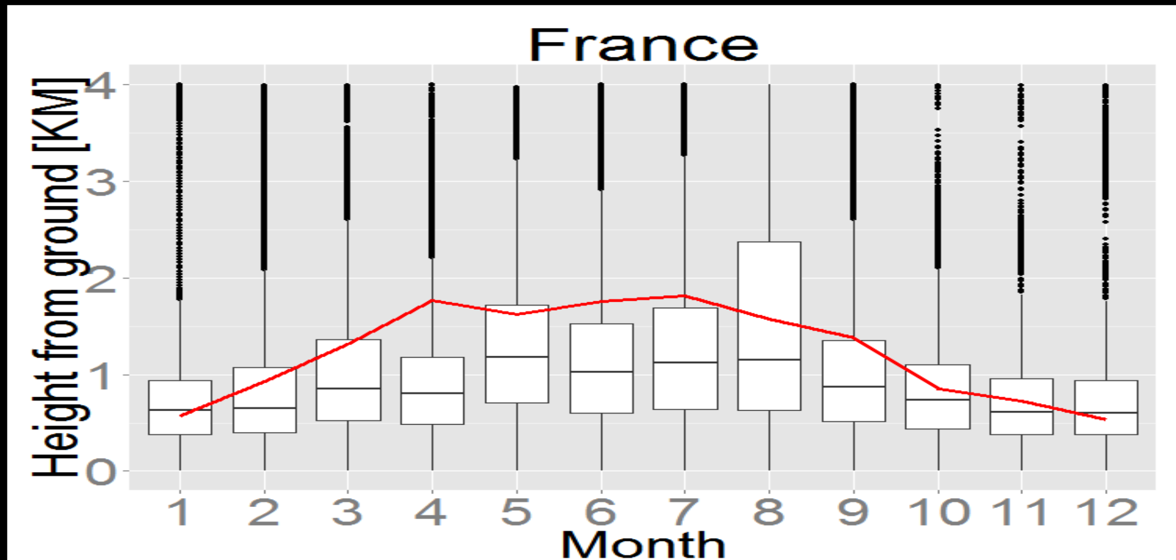
Comparison between AERONET and MAIAC AOD variables to the $PM_{2.5}$ concentrations

(Sorek-Hamer et al., 2016)

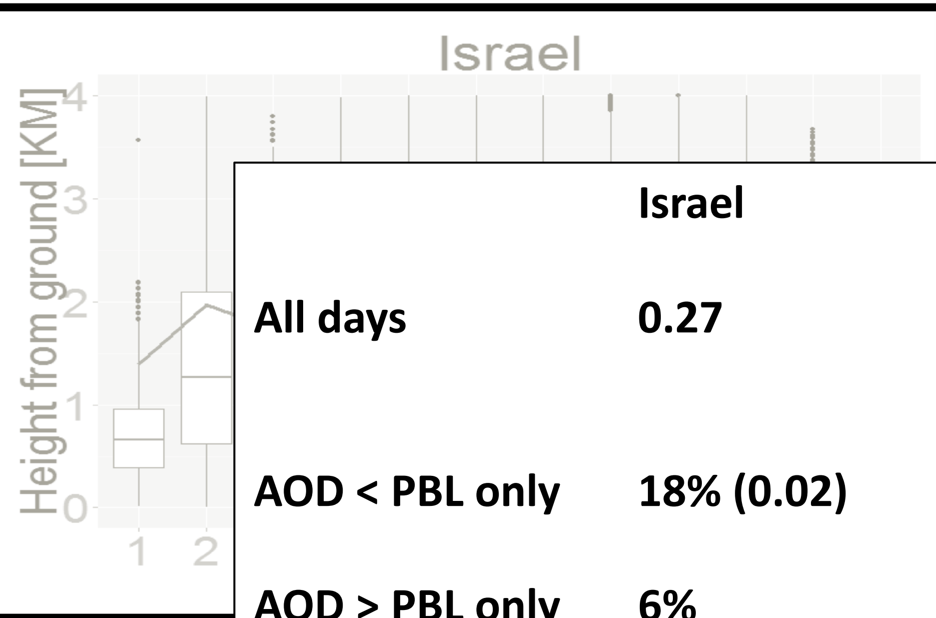
Aerosol Vertical Profile

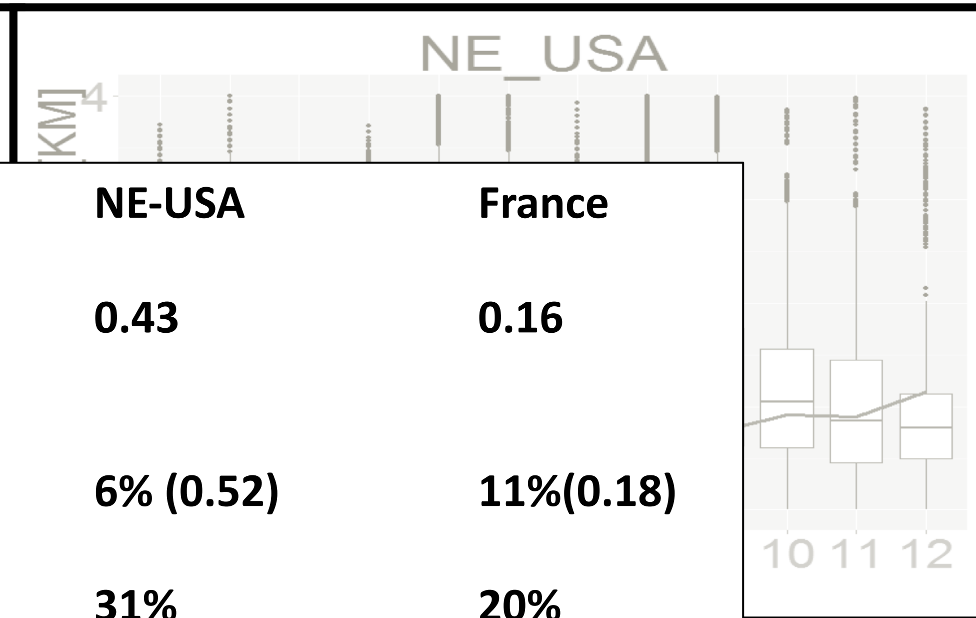




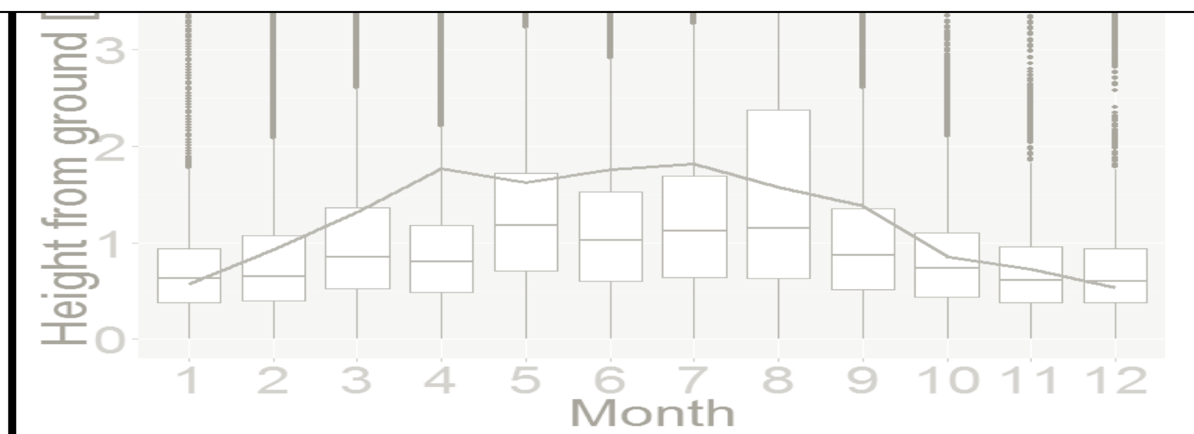


AOD-PM Fit by Vertical Subset Location





	Israel	NE-USA	France
All days	0.27	0.43	0.16
AOD < PBL only	18% (0.02)	6% (0.52)	11%(0.18)
AOD > PBL only	6%	31%	20%
AOD<PBL<AOD	76%	63%	69%



Conclusions

- ✓ The possible advantages of using satellite data are known.
- ✓ This is the first study, to our knowledge, that quantitatively presents the AOD spatiotemporal contribution in different locations which has been found to be < 2%.
- ✓ The underlying assumptions and conditions when using AOD to estimate PM concentrations should be further examined on a local spatial and temporal basis.
- ✓ Accurate understanding of these conditions will enable better utilization of satellite data to improve our knowledge on air quality, to develop localized AOD/models and expand exposure matrices for Env. health studies.
- ✓ **Next step**: Classification of daily conditions on a worldwide database (SOM)

Backup Slides

Table 3. Correlations between collocated AOD and $PM_{2.5}$ concentrations in ground stations near the CALIPSO path.

		Israel		NE_USA		France	
		R	N(no. of stations)	R	N(no. of stations)	R	N(no. of stations)
Available days with obs. From MAIAC, and PM	Multianual	0.27	58,131 (41)	0.43	49,202 (144)	0.16	10231 (195)
	Winter	0.29	9,214	0.53	13,302	0.26	2,401
	Spring	0.37	9,529	0.24	8,332	0.32	2,414
	Fall	0.17	15,198	0.15	11,856	0.05	2,236
	Summer	0.18	24,190	0.46	15,712	0.25	3,180
Days which CALIPSO detected aerosols within PBL	Multianual	-0.02	788 (5)	0.52	306 (95)	0.18	1,707 (34)
	Winter	-0.11	120	0.46	16	0.34	383
	Spring	-0.25	117	0.52	104	0.38	428
	Fall	0.1	175	-0.01	177	0.04	387
	Summer	-0.002	376	0.94	9	0.14	509