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Aerosol retrieval using satellite data

Application to anthropogenic pollution sources

Gerrit de Leeuw[1,2]

With contributions from the Helsinki team:

FMI[1]: Pekka Kolmonen, Edith Rodriguez, Giulia Saponaro, Larisa Sogacheva, Timo H. Virtanen

UHEL[2]: Anu-Maija Sundström, Anna Nikandrova, Ksenia Atlaskina

1. FMI, Climate Change Unit, Helsinki, Finland
2 Dept. of Physics, Univ. of Helsinki, Finland

PRESCRIBE workshop, Bremen, 15-16 May 2013

Outline & Introduction

- **Introduction: aerosol retrieval and algorithm development**
- **Aerosol-cci**
- **Applications**
  - Remote areas: ’natural’ background and transport
    - Boreal
    - Arctic (with LinLu Mei, Yong Xue and Univ. Bremen)
  - Anthropogenic influences
  - Direct radiative effects (ADRE)
  - Aerosol-cloud interactions

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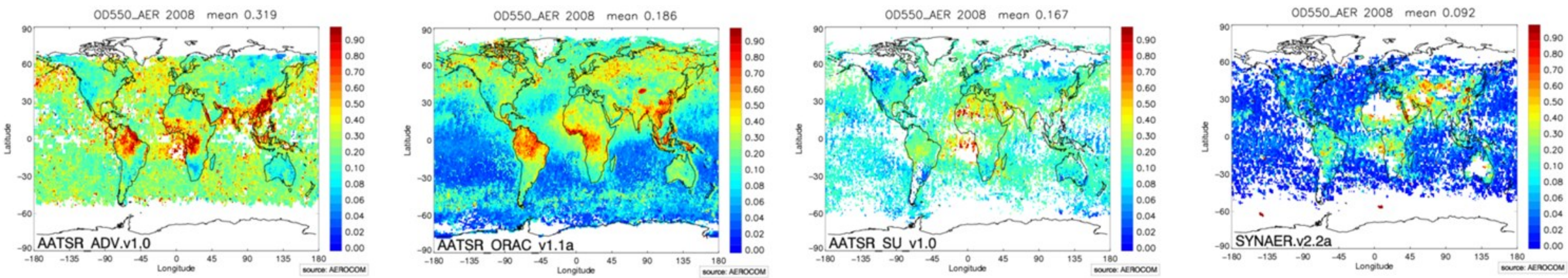
Outline & Introduction

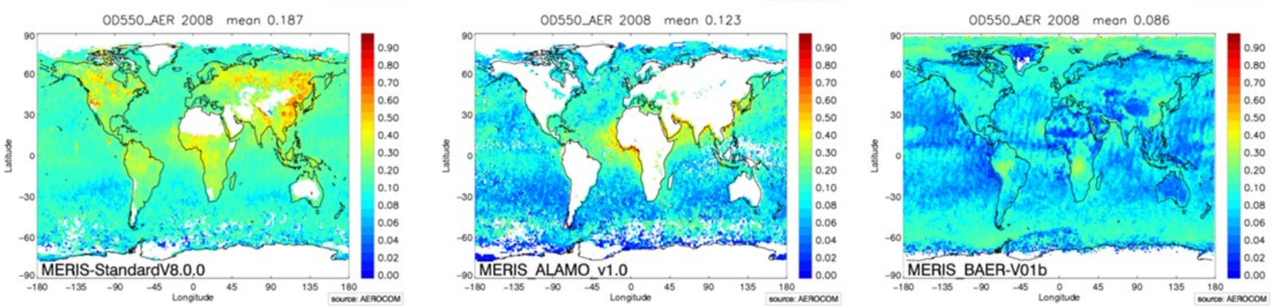
- **Focus on work in Helsinki: FMI and Univ of Helsinki**
- **Algorithm development:**
  - AATSR dual view algorithm for application over land (**ADV**)
  - AATSR single view algorithm for application over ocean (**ASV**)
  - Cooperative effort as part of the **ESA Aerosol-cci** project with European (+ US and other) experts
  - **Significant improvements**, closing gap with US satellites
- **Applications in ESA, EU, and national projects**

AEROSOL-CCI

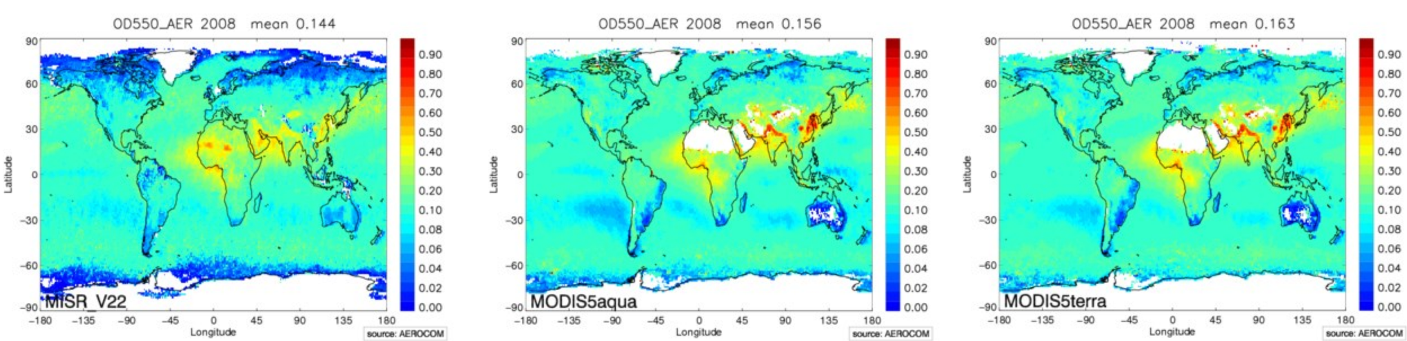
- **Cooperation of European teams on aerosol retrieval from satellite data, lead by Germany and Finland**

Aerosol-cci: baseline and reference algorithms



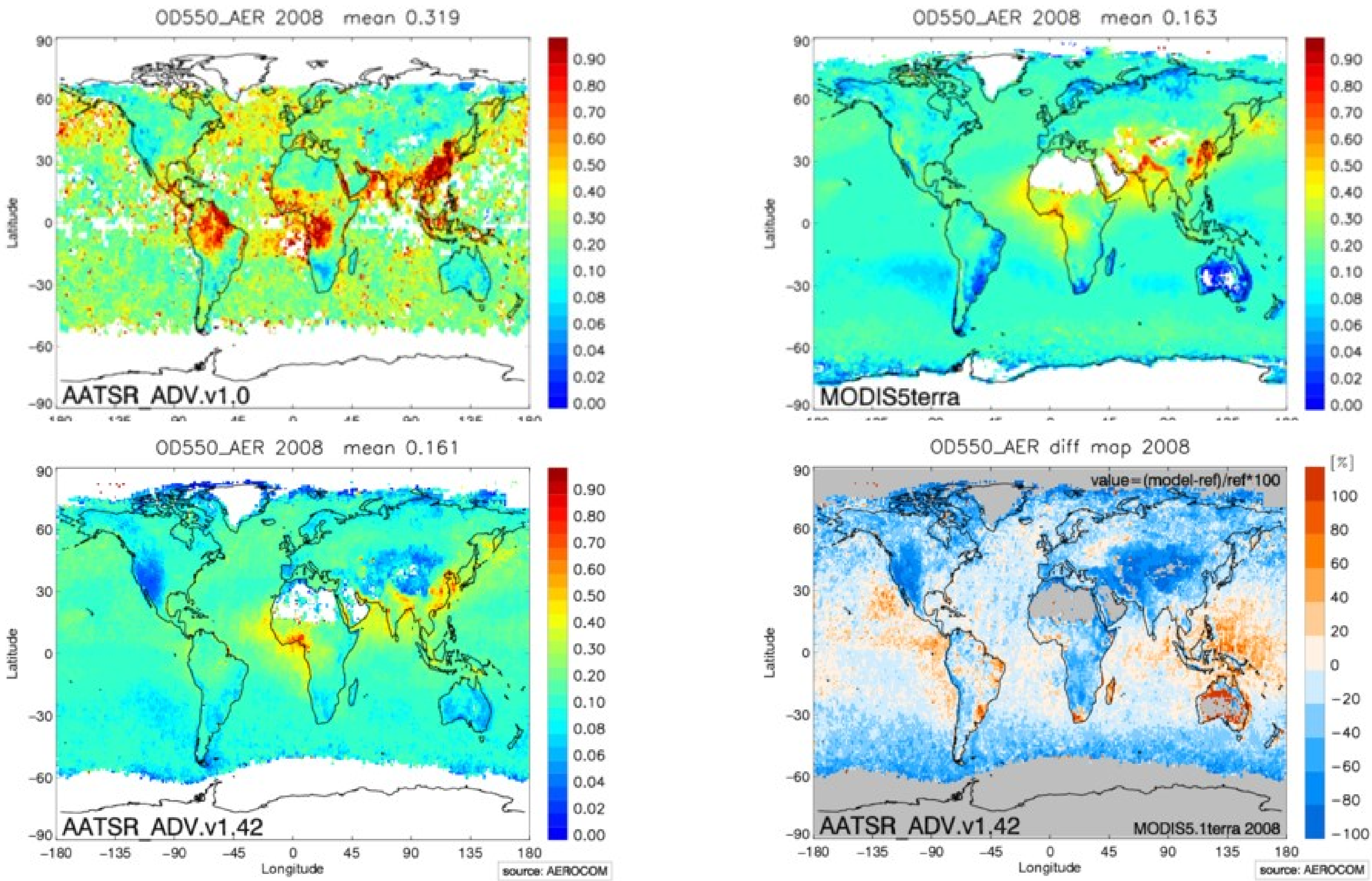


Baseline Algorithms



Reference Algorithms

Aerosol-cci: algorithm improvement: ADV/ASV



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AEROSOL-CCI

- **Cooperation of European teams on aerosol retrieval from satellite data, lead by Germany and Finland**
- **Discussions with Experts from USA and Asia (workshops)**
  - Large improvement of European algorithms providing results similar to MODIS and MISR;
  - For example, using all data points from ADV:

Level 3 daily by AEROCOM	AOD550		All No common filter	
	ADV	MOD-T	MISR	
N	5192	22665	5276	
NMB	-13%	15%	-2%	
Rms	0.13	0.15	0.13	
Correlation	0.82	0.82	0.81	
Rank	1			

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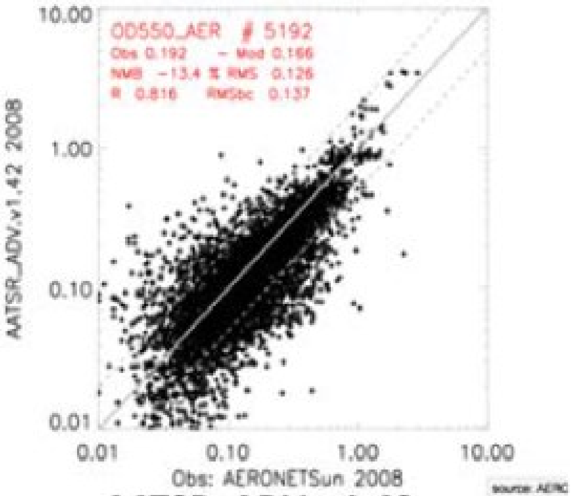
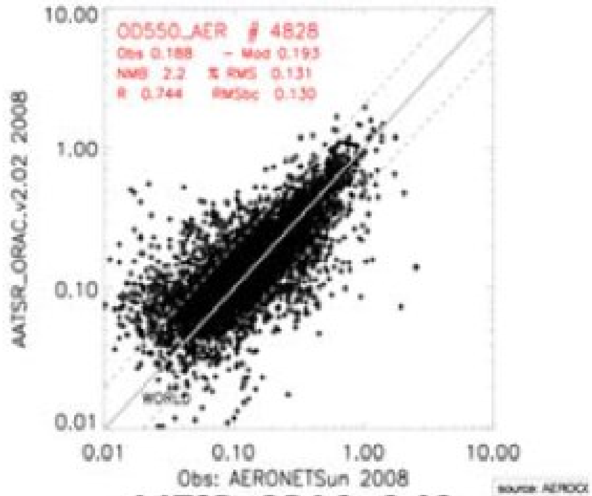
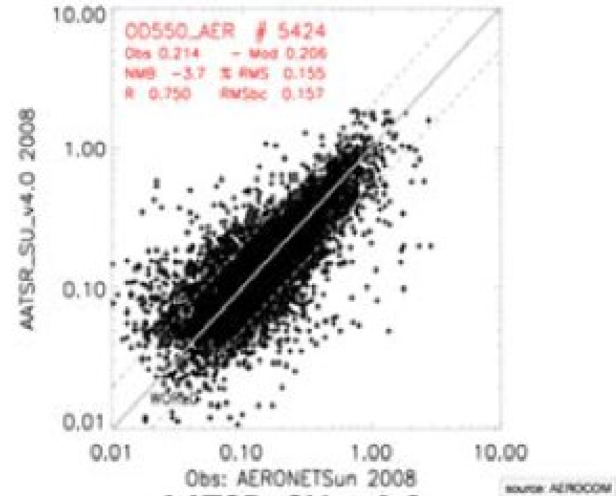
Lv3: AATSRLand No filter



AATSR_ADV.v.1.42

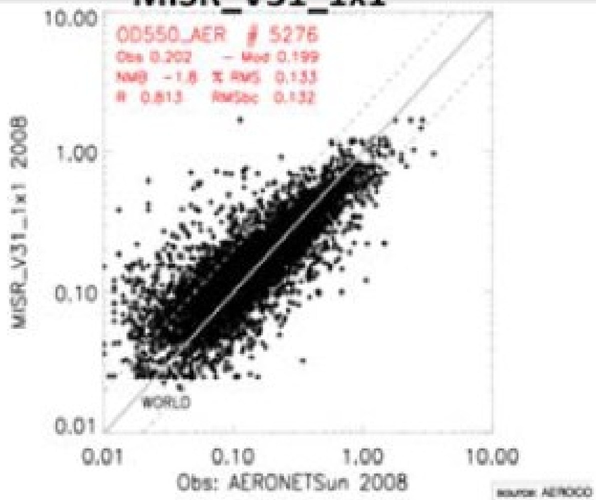


AATSR_ORAC.v2.02

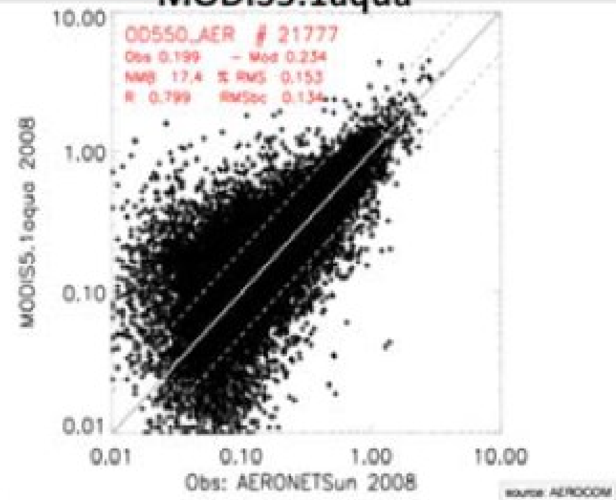


AATSR_SU_v4.0

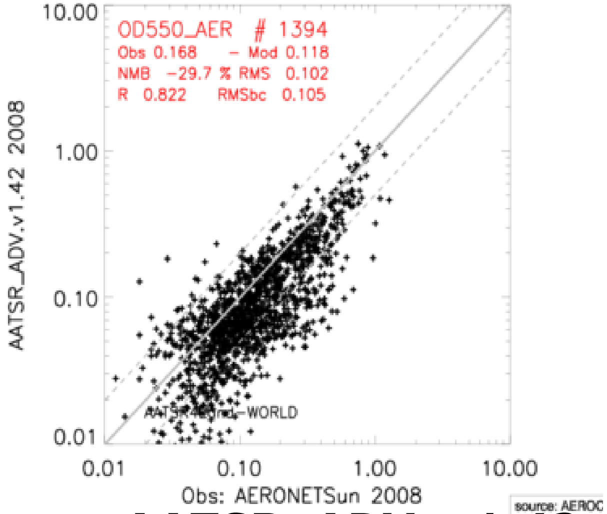
MISR_V31_1x1



MODIS5.1aqua



L3: AATSR4Land
Common point filter



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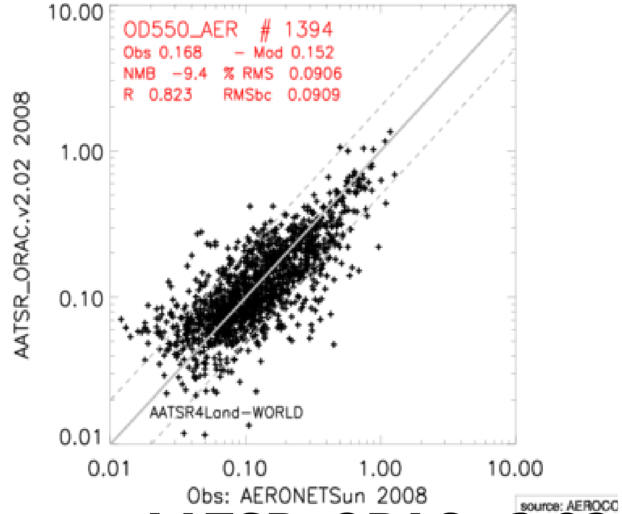
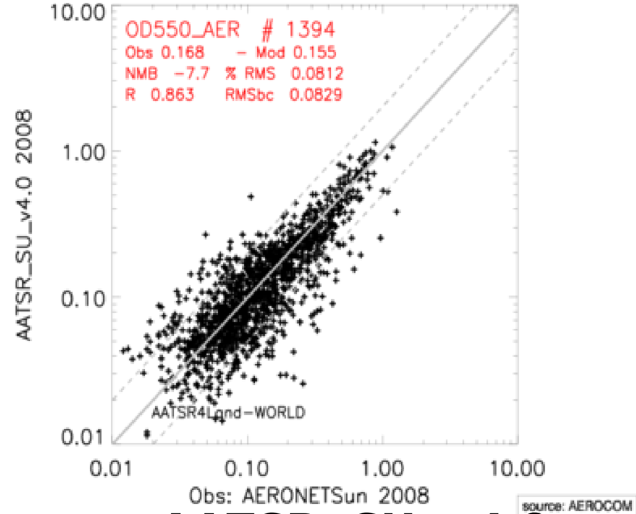
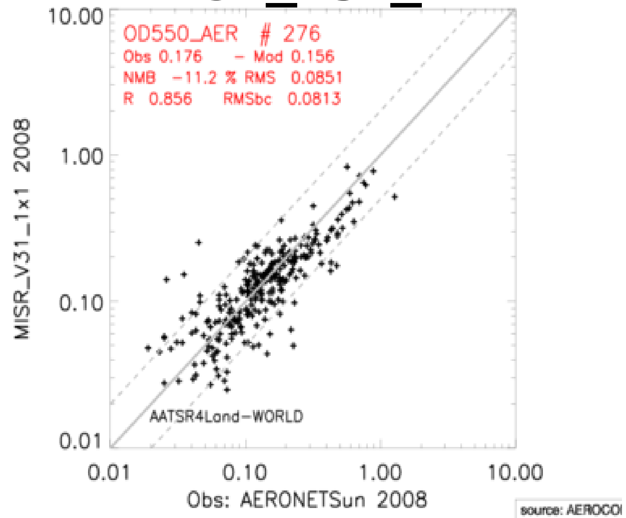


AATSR_ORAC.v2.02

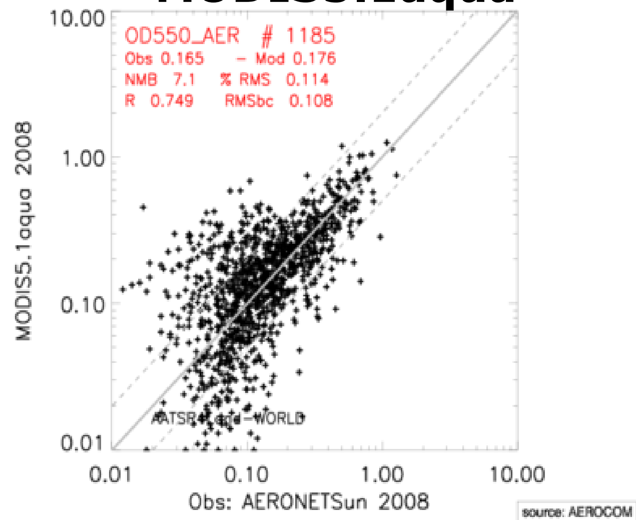


AATSR_SU_v4.0

MISR_V31_1x1



MODIS5.1aqua



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Lv3: AATSRLand Regions

No filter

Ranking:

Filter	ADV	ORAC	SU 3.1	SU4.0
China	1	4	2	3
India	3	2	1	4
East asia	1	4	2	3
Europe	1	3	4	2
Samerica	2	3	4	1
Nafrica	2	3	1	4
Namerica	1	4	3	2
DJF	1	2	4	3
MAM	2	4	1	3
JJA	1	3	2	4
SON	4	2	2	1

Average: 1,75 3 2,625 2,5

Common point filter

Ranking:

Filter	ADV	ORAC	SU 3.1	SU4.0
China	3	2	1	4
India	3	2	1	4
East asia	3	2	1	4
Europe	2	4	3	1
Samerica	3	2	4	1
Nafrica	3	4	2	1
Namerica	2	4	3	1
DJF	2	3	4	1
MAM	3	4	1	2
JJA	1	4	2	3
SON	4	2	3	1

Average: 2,5 3,375 2,75 1,375

Average excluding china, India and east asia due to low number of measurements

Lv3: AATSR4Land
Common point filter

Model name	NumObs #	R-CORR	RMS	NMB %	RMSbc
AATSR_ADV.v1.42	1394	0,822	0,102	-29,7	0,105
AATSR_ORAC.v2.02	1394	0,823	0,091	-9,4	0,091
AATSR_SU_v4.0	1394	0,863	0,081	-7,7	0,083
MISR_V31_1x1	276	0,856	0,085	-11,2	0,081
MODIS5.1aqua	1185	0,749	0,114	7,1	0,108
MODIS5.1terra	1285	0,744	0,114	1,5	0,113

- **AATSR: in general high correlation, low RMS**
- **SU v4.0 has highest R, lowest RMS, better than all reference data sets**
- **All AATSR retrievals outperform MODIS5.1**

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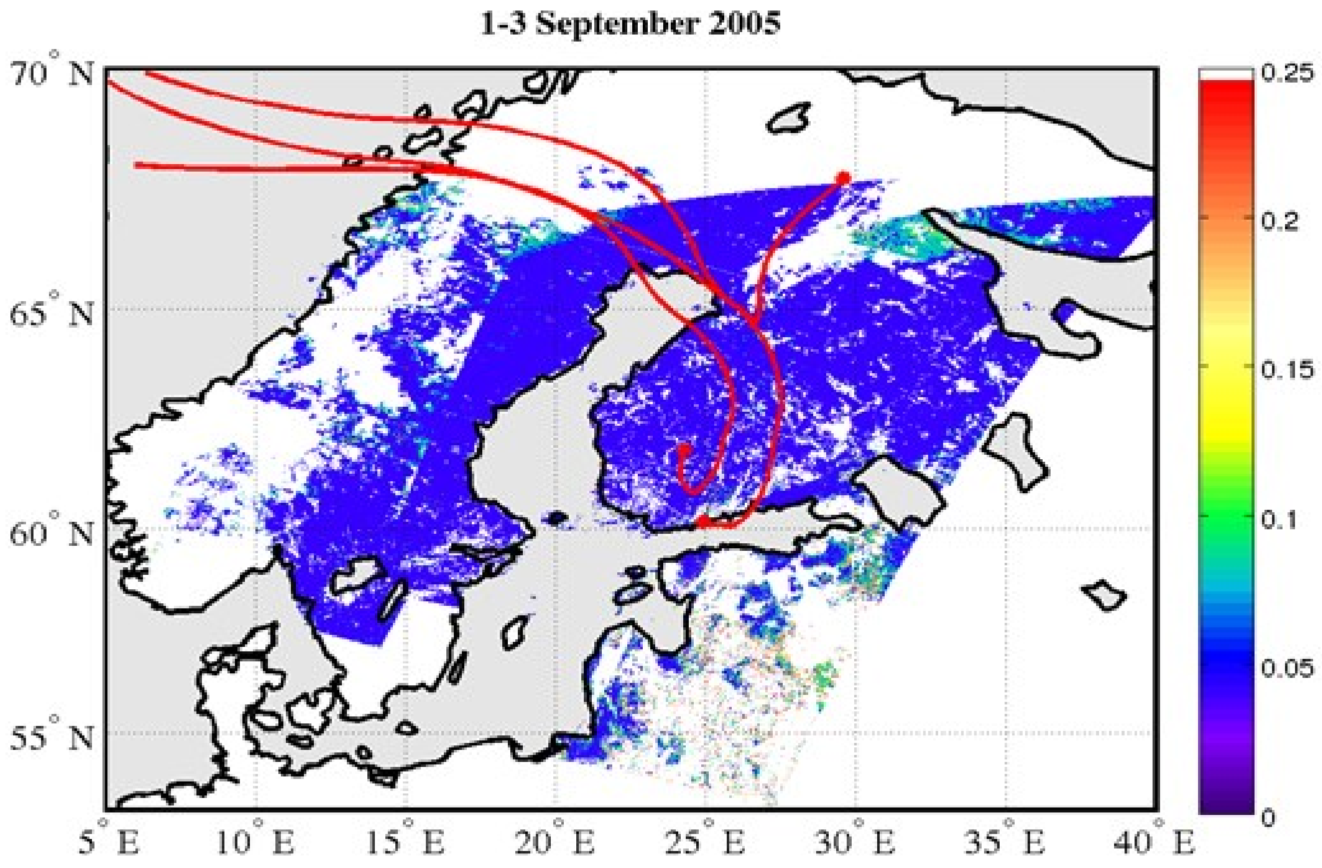
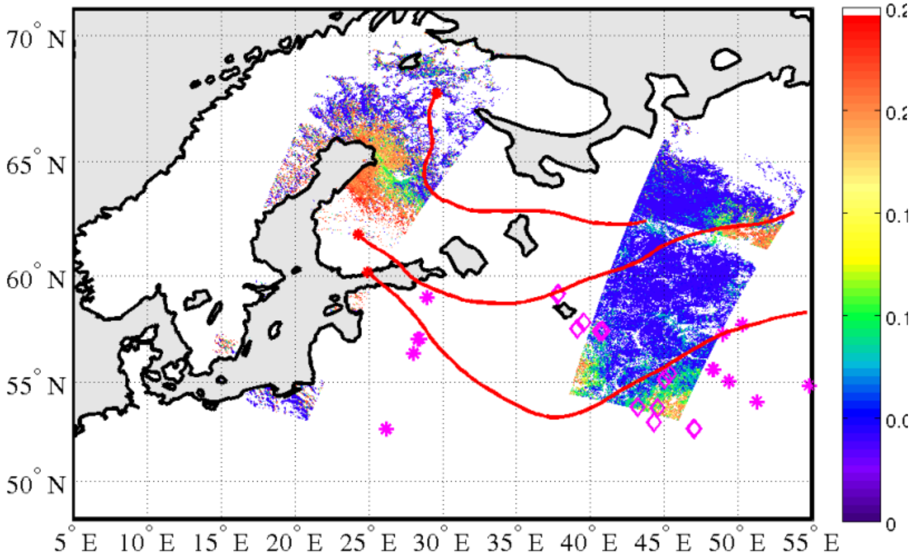
AOD over Northern Europe: Example of a natural clean background

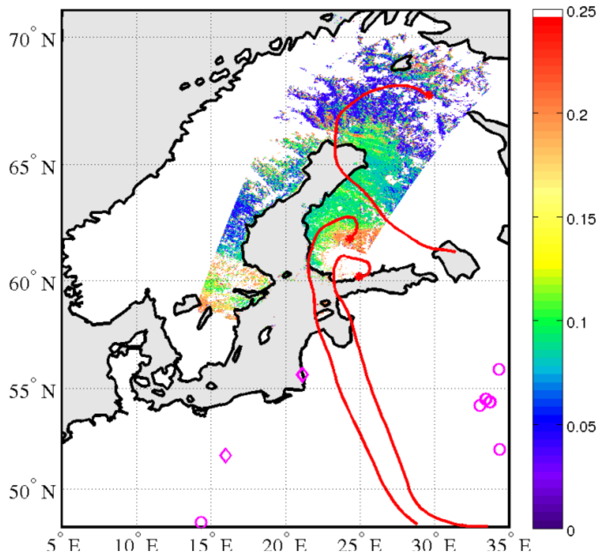


Case studies: transport to Finland

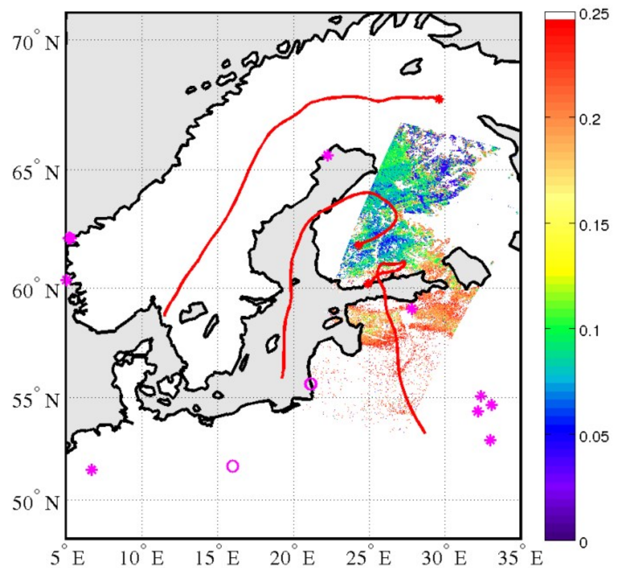
02-05-2006



05-05-2006



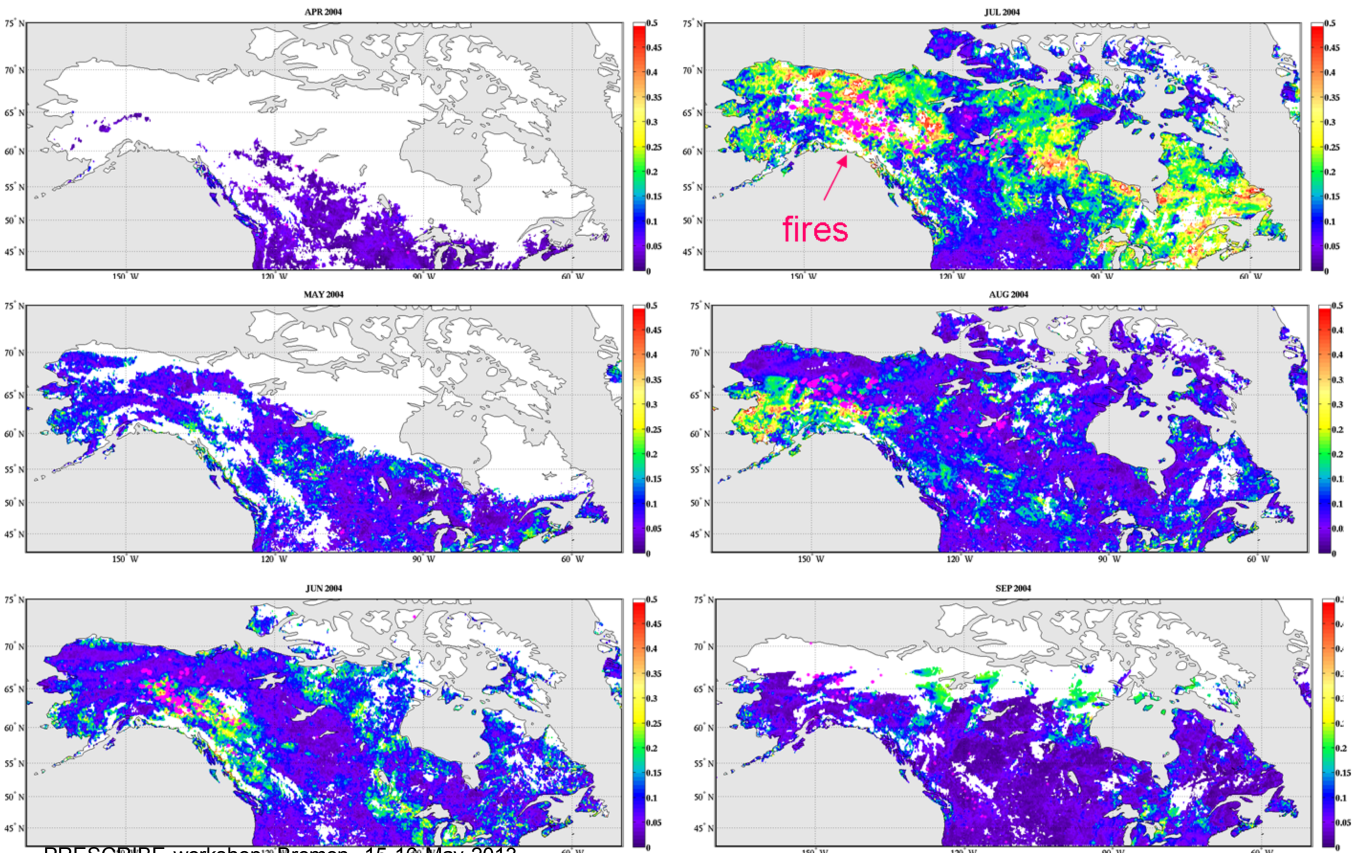
06-05-2006

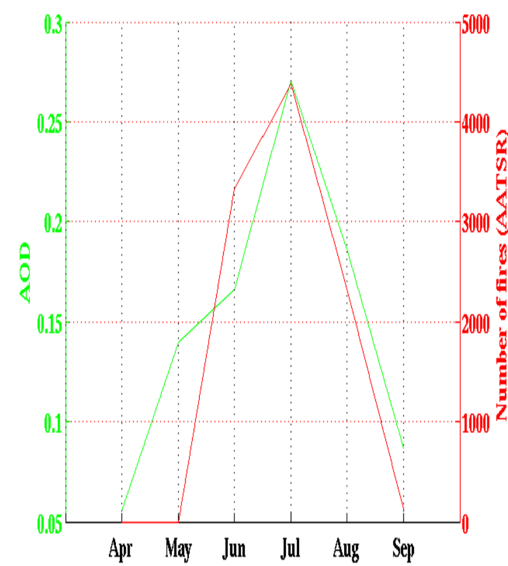


Q: How to explain AOD seasonal/interannual variation ?

A: fire frequency is one of the factors

2004, monthly (April-September) variation





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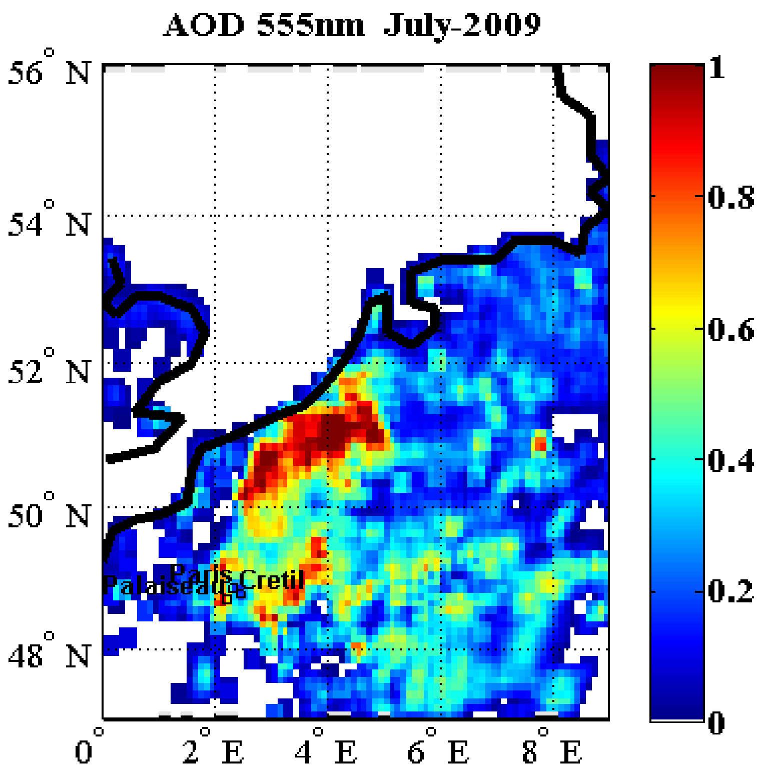
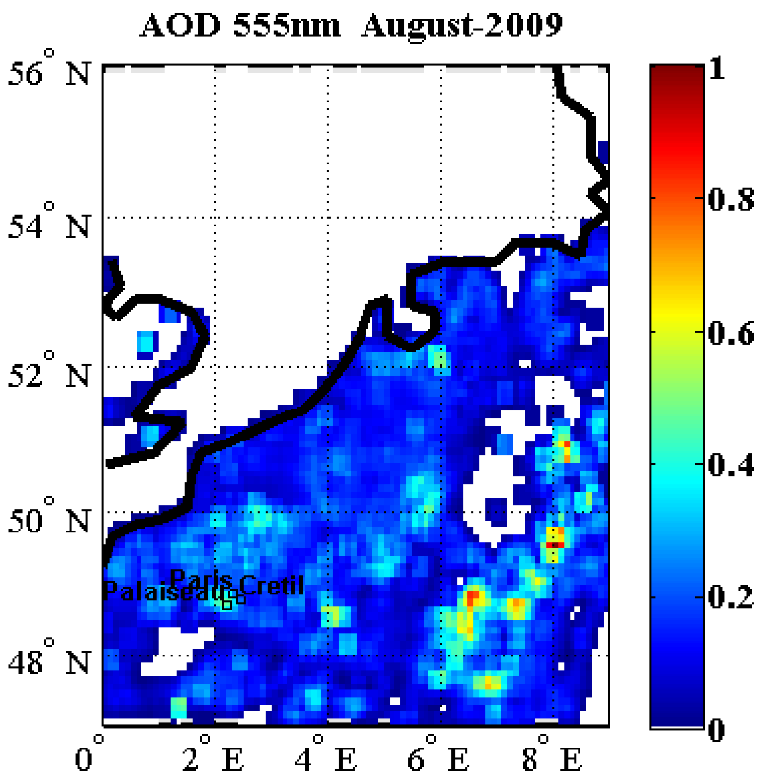
Megacities: Paris





Paris clearly visible when regional pollution levels are low / moderate; when pollution levels are elevated the *relative* effect is smaller

Edith Rodriguez

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Paris

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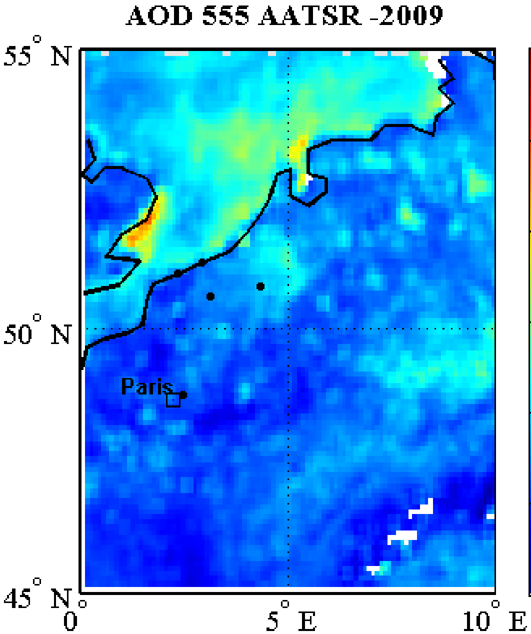
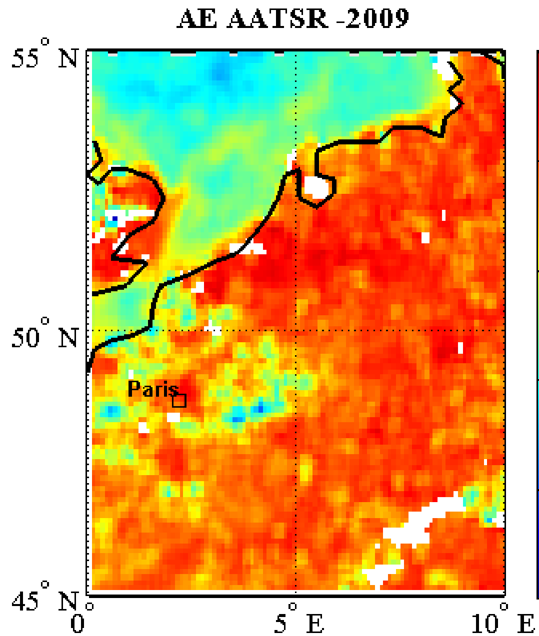
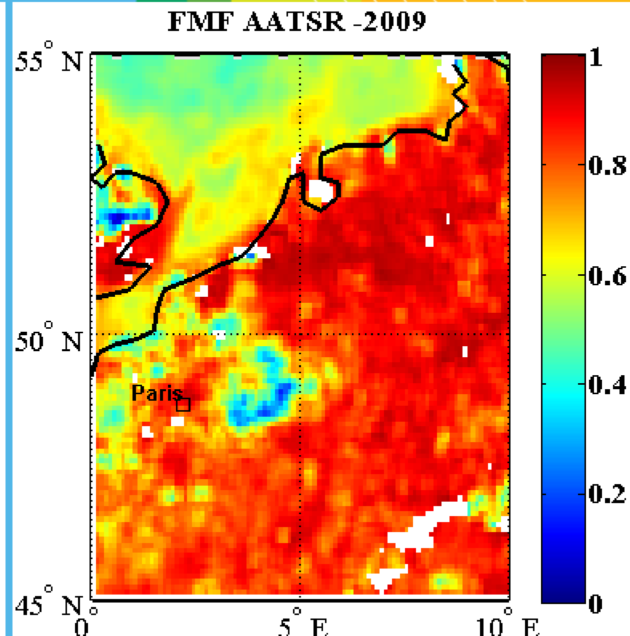
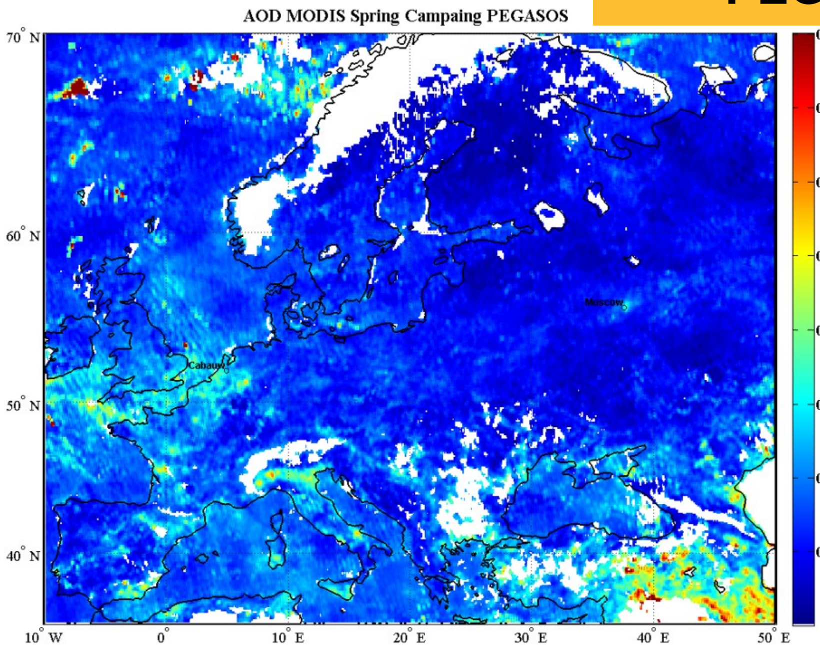




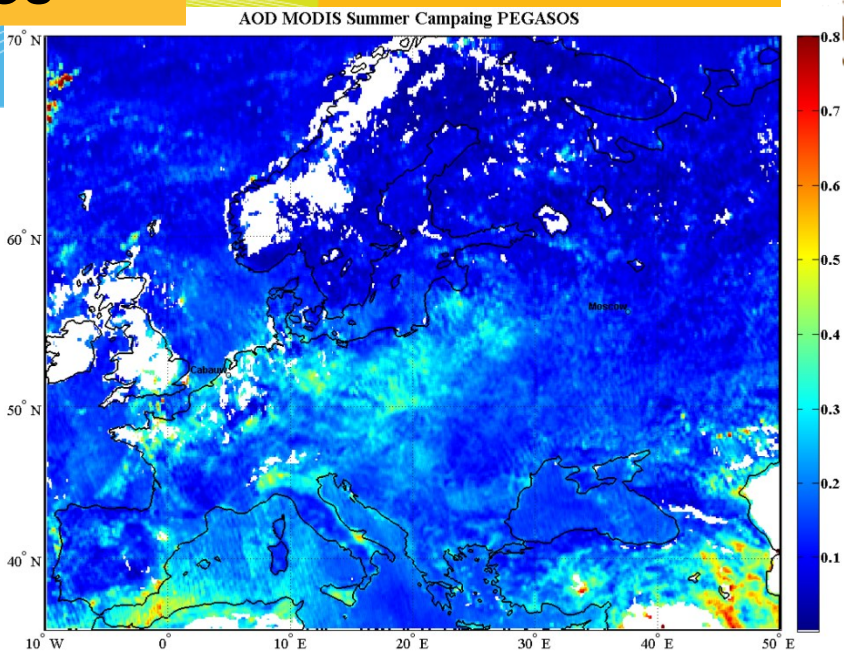


PEGASOS

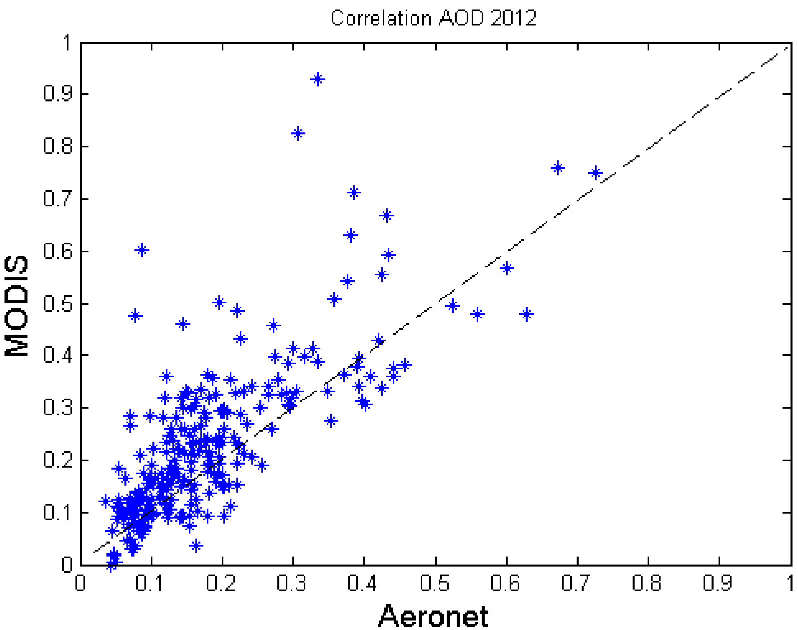


SPRING

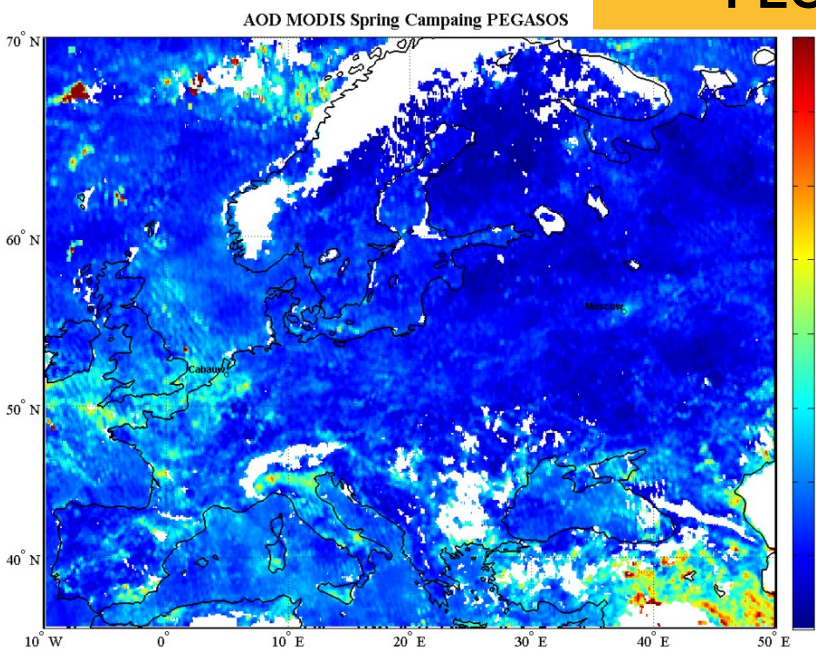
MODIS AOD



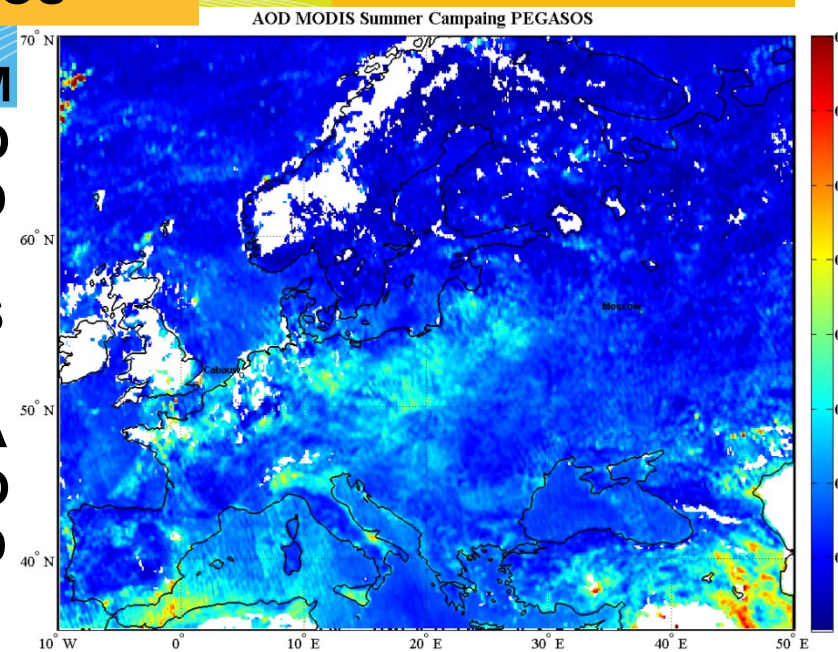
SUMMER



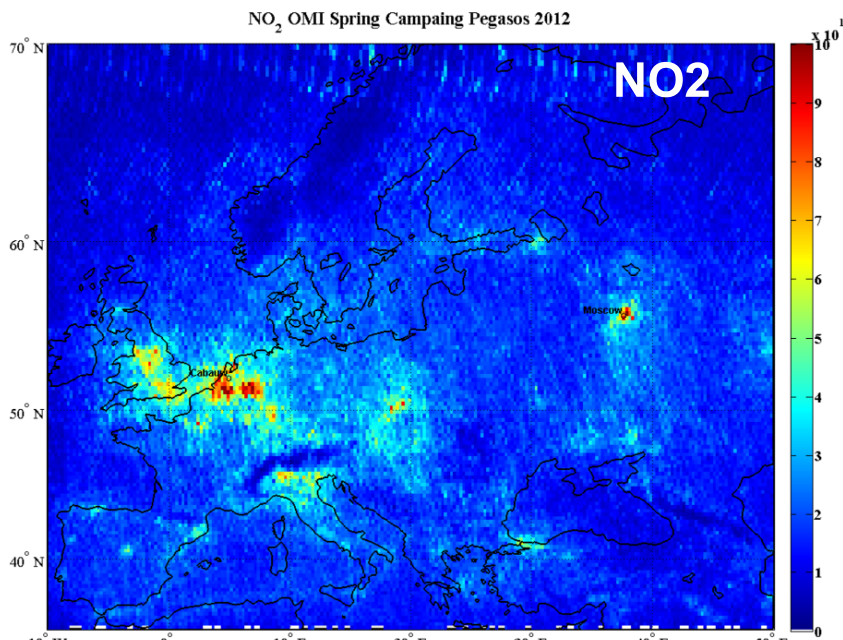
PEGASOS



MODIS AOD

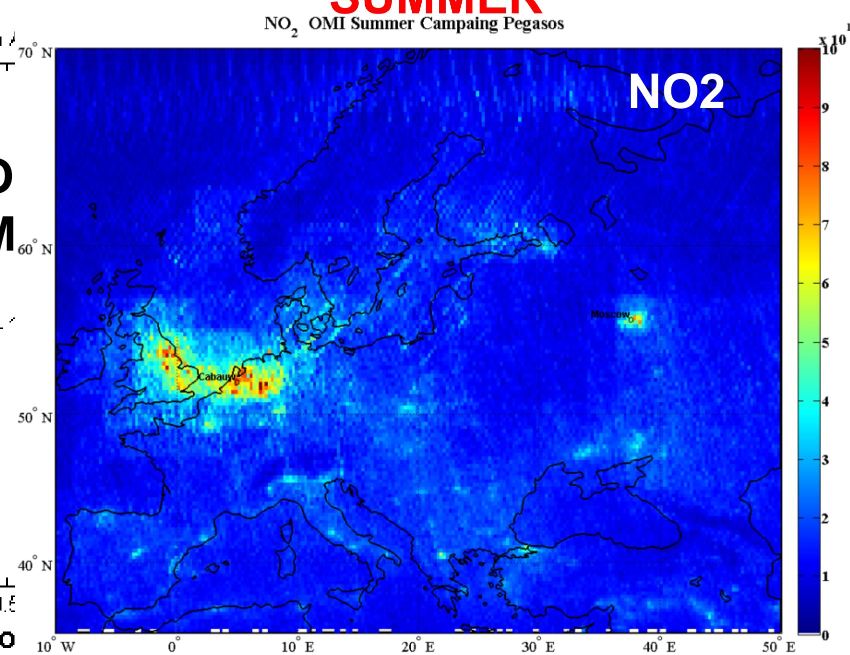


SPRING

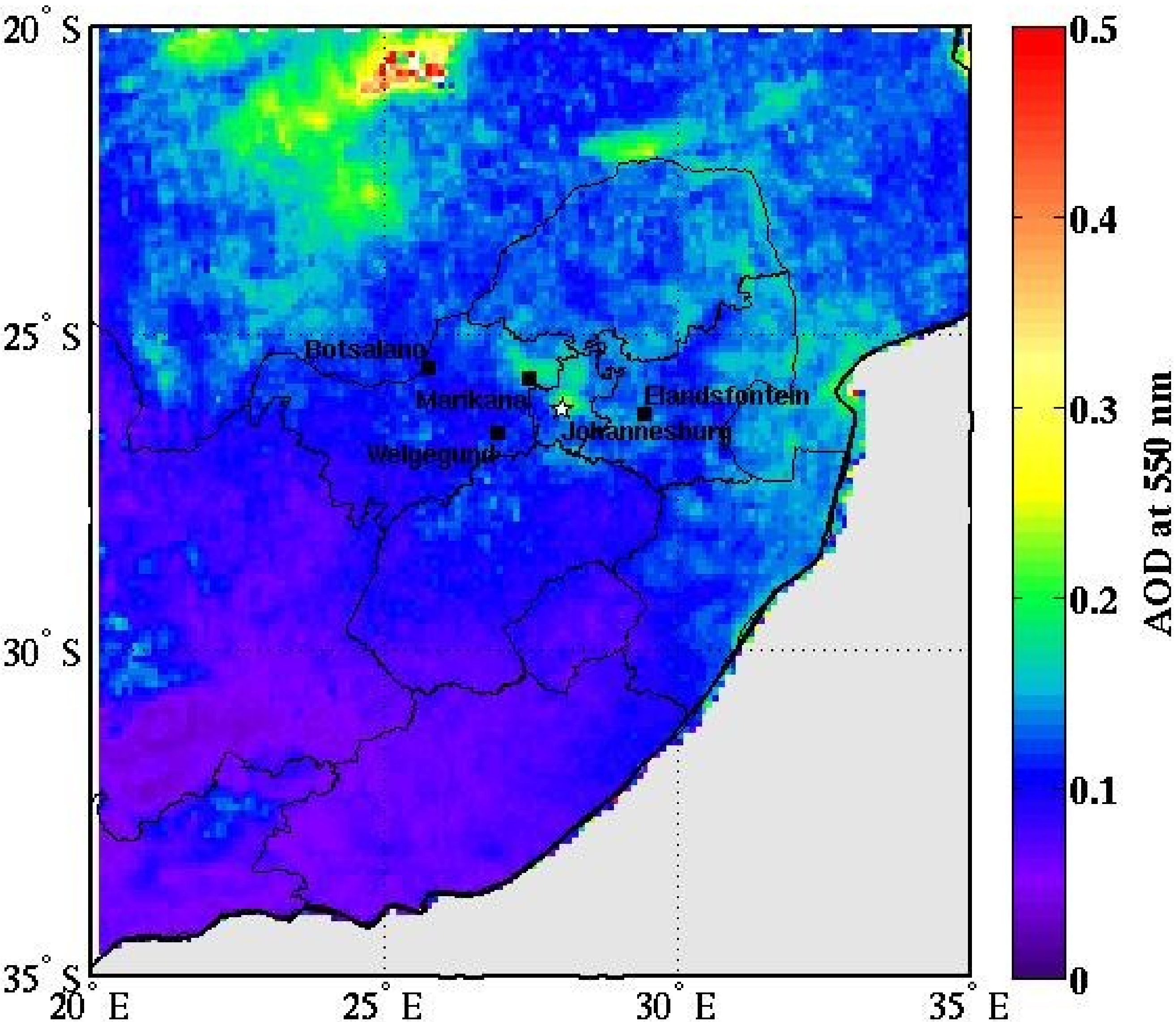


OMI

SUMMER

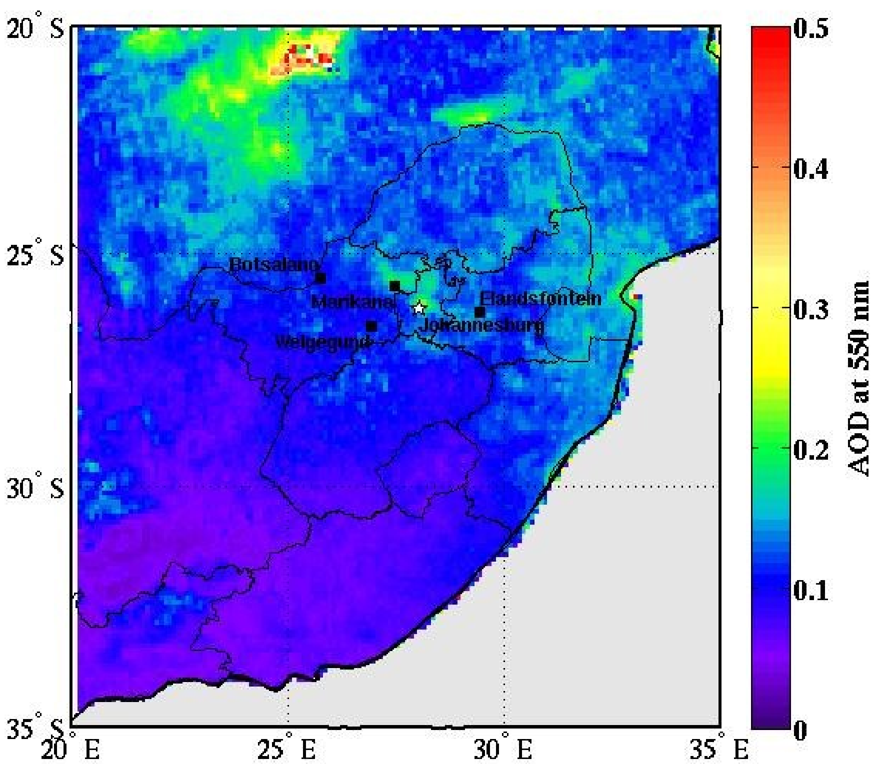


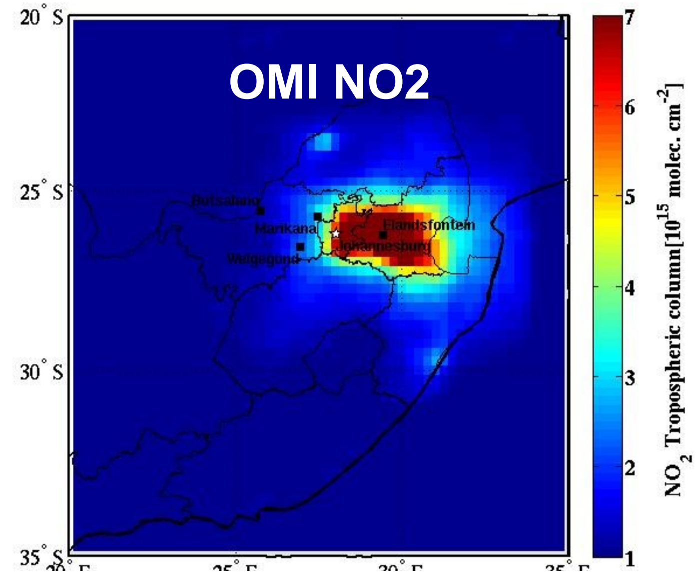
S. Africa: Highveld:
MODIS Aqua AOD at 550nm 3 years average (2007-2009)

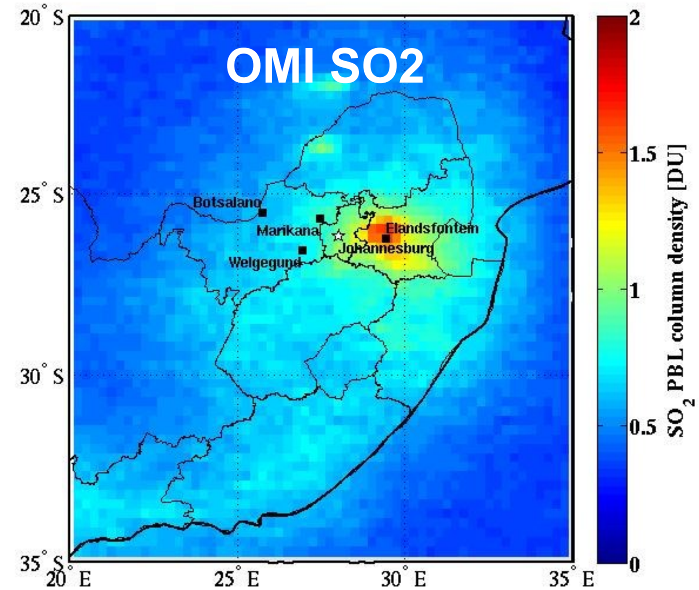


MODIS Aqua AOD at 550nm 3 years average (2007-2009), vs OMI NO2 and SO2, same period

MODIS AOD







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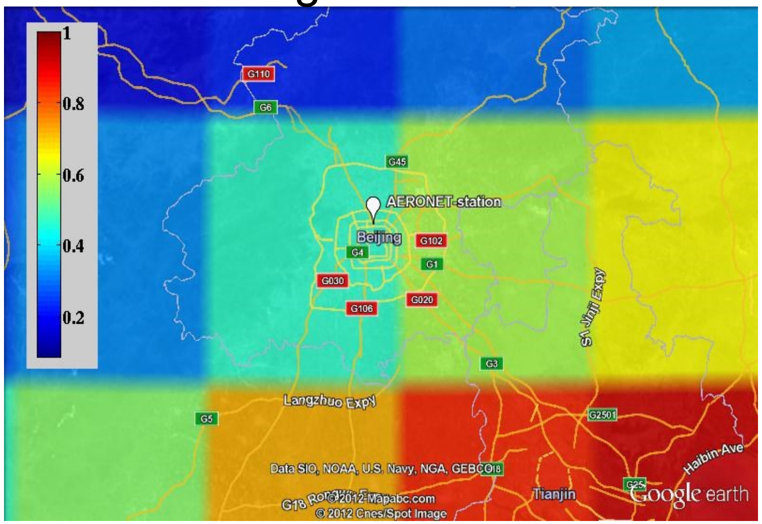
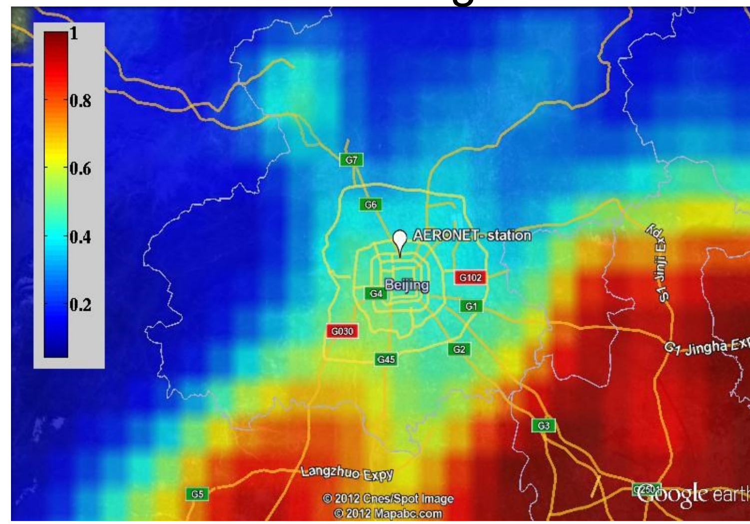
High resolution AATR retrievals over Beijing

Example of AOD at different spatial resolution over the megacity of Beijing 3.7.2008

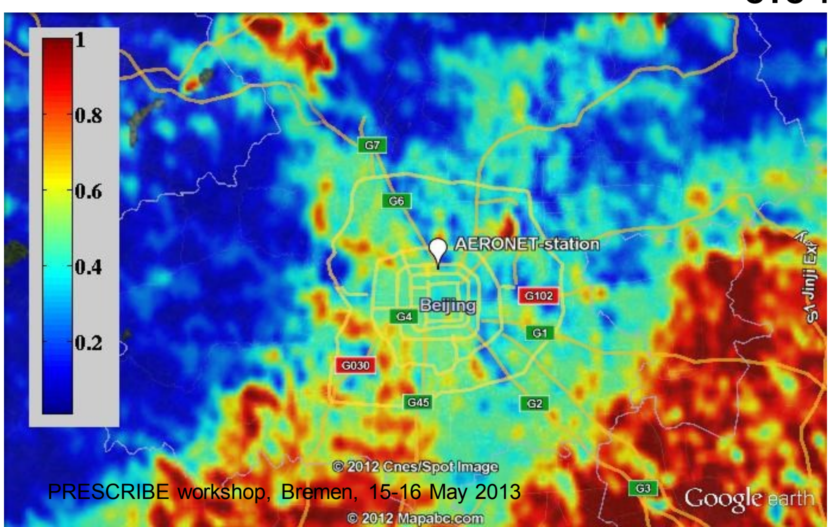
1 x 1 deg. resolution



0.1 x 0.1 deg resolution

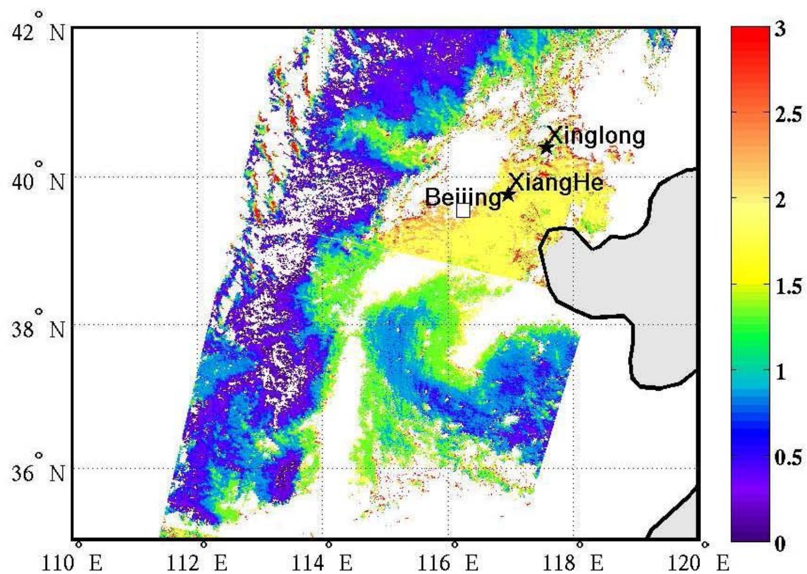


0.01x0.01 deg. resolution

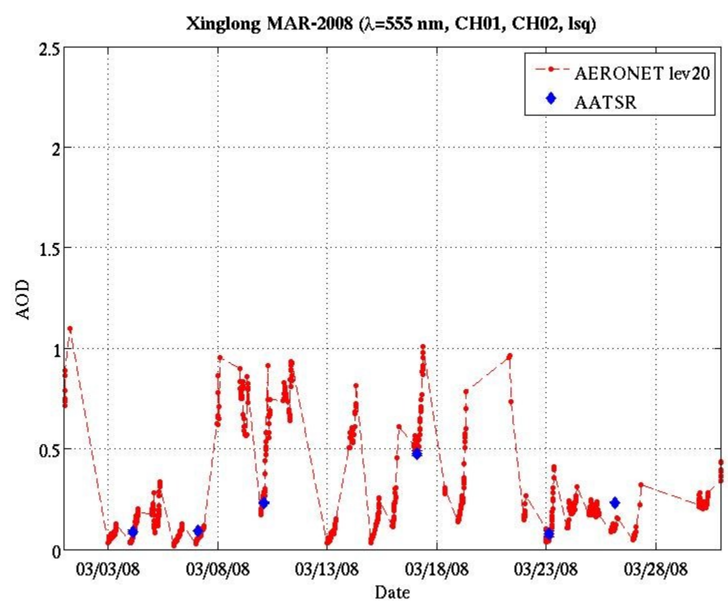


ADV Aerosol Remote Sensing Applications

Focus on China



3.0



0.55 μm; 25 July 2008

Variability (0.55 μm):
March 2008

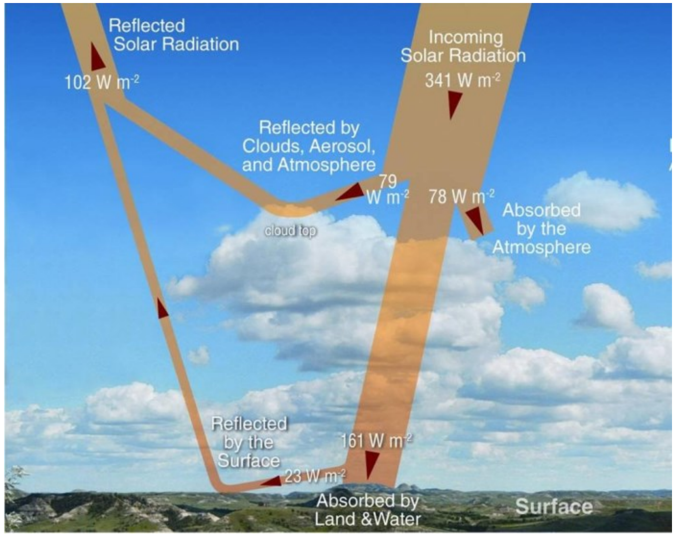
(Anu-Maija Sundström)

Aerosol Direct Radiative Effect

- **Aerosol radiative effect (ADRE) at TOA:**

$$ADRE_{TOA} = F^{\uparrow}_{TOA,no\_aer} - F^{\uparrow}_{TOA,aer}$$

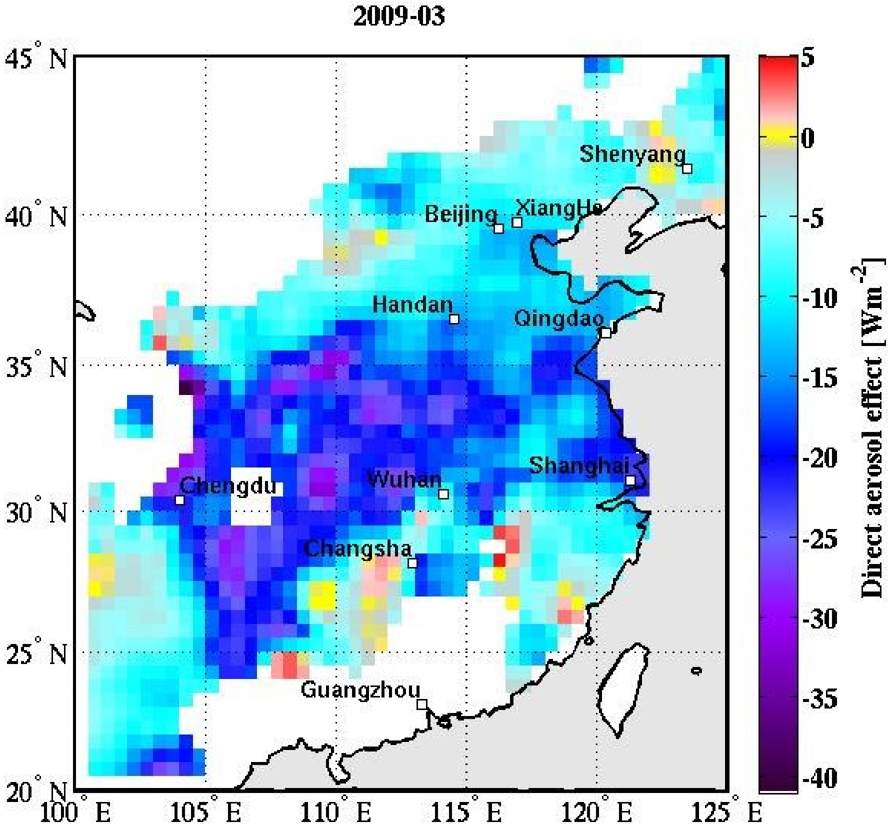
ADRE < 0, cooling
ADRE > 0, warming



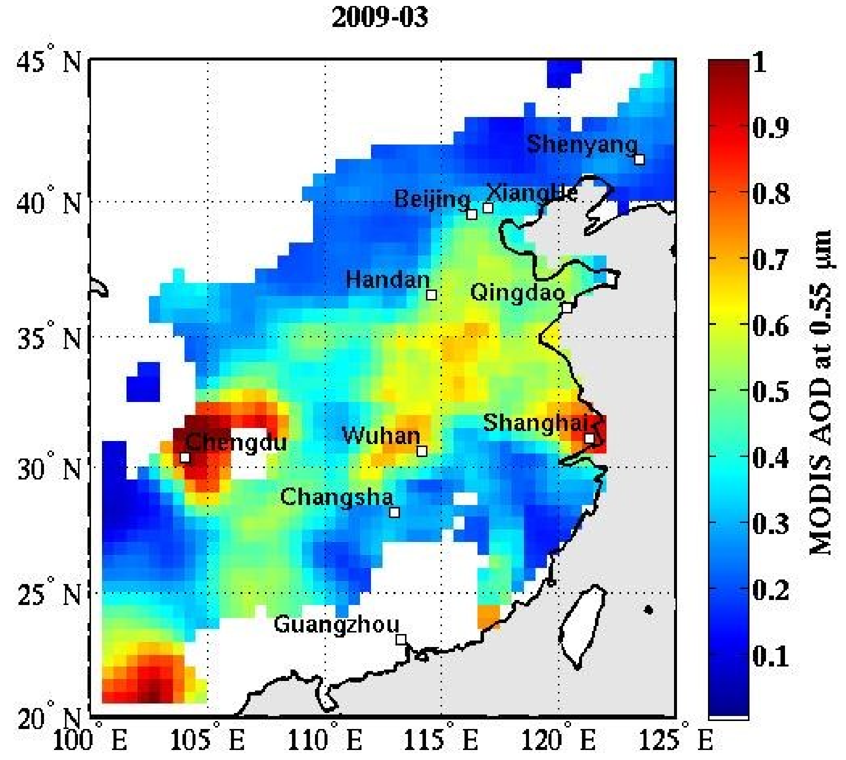
- Commonly used approaches to derive ADRE:
  - Radiative transfer models
  - Radiative transfer models coupled with remote sensing observations.
  - Remote sensing observations

Instantaneous ADRE: satellite based method
Need to evaluate essential assumptions

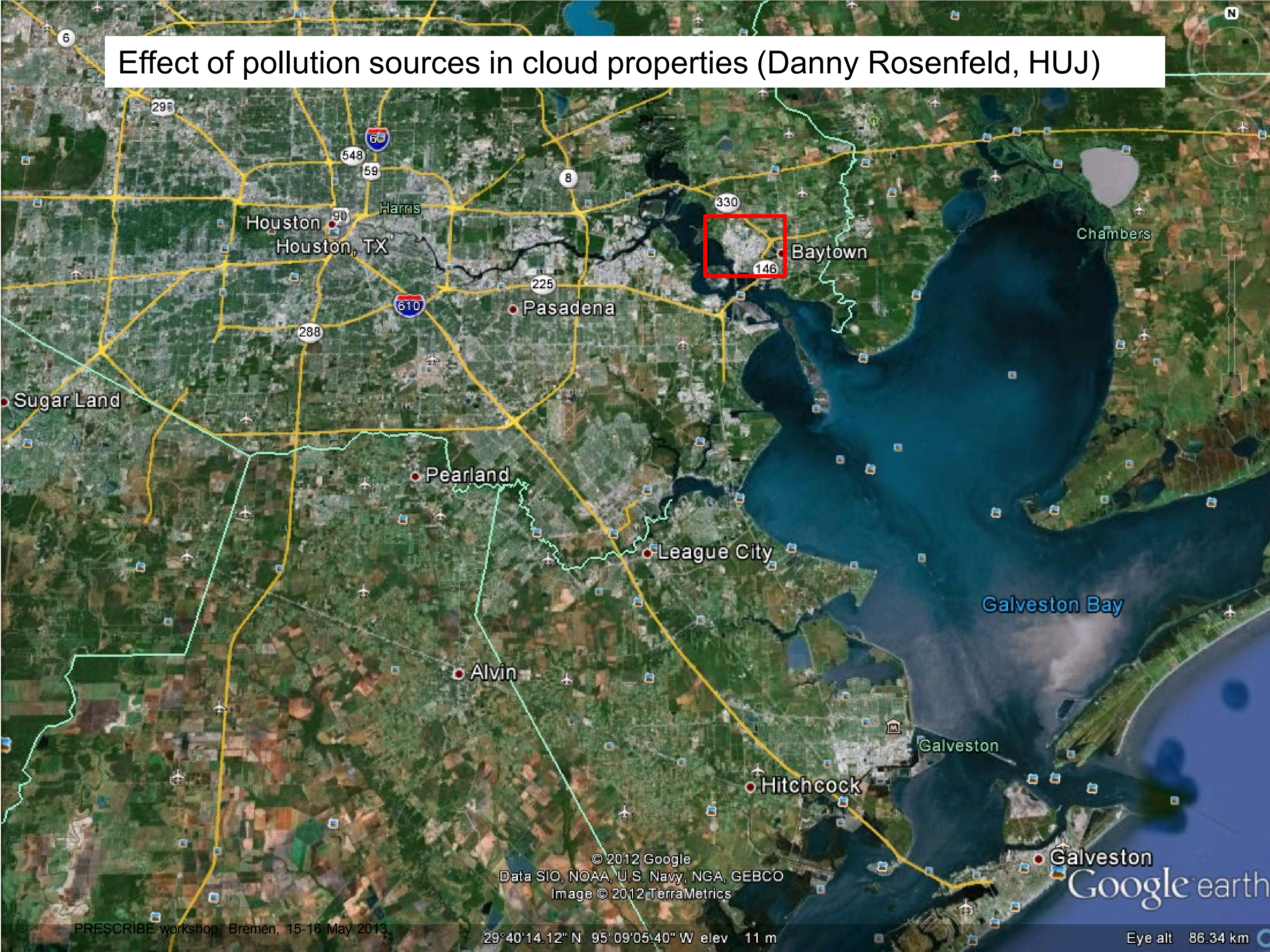
ADRE



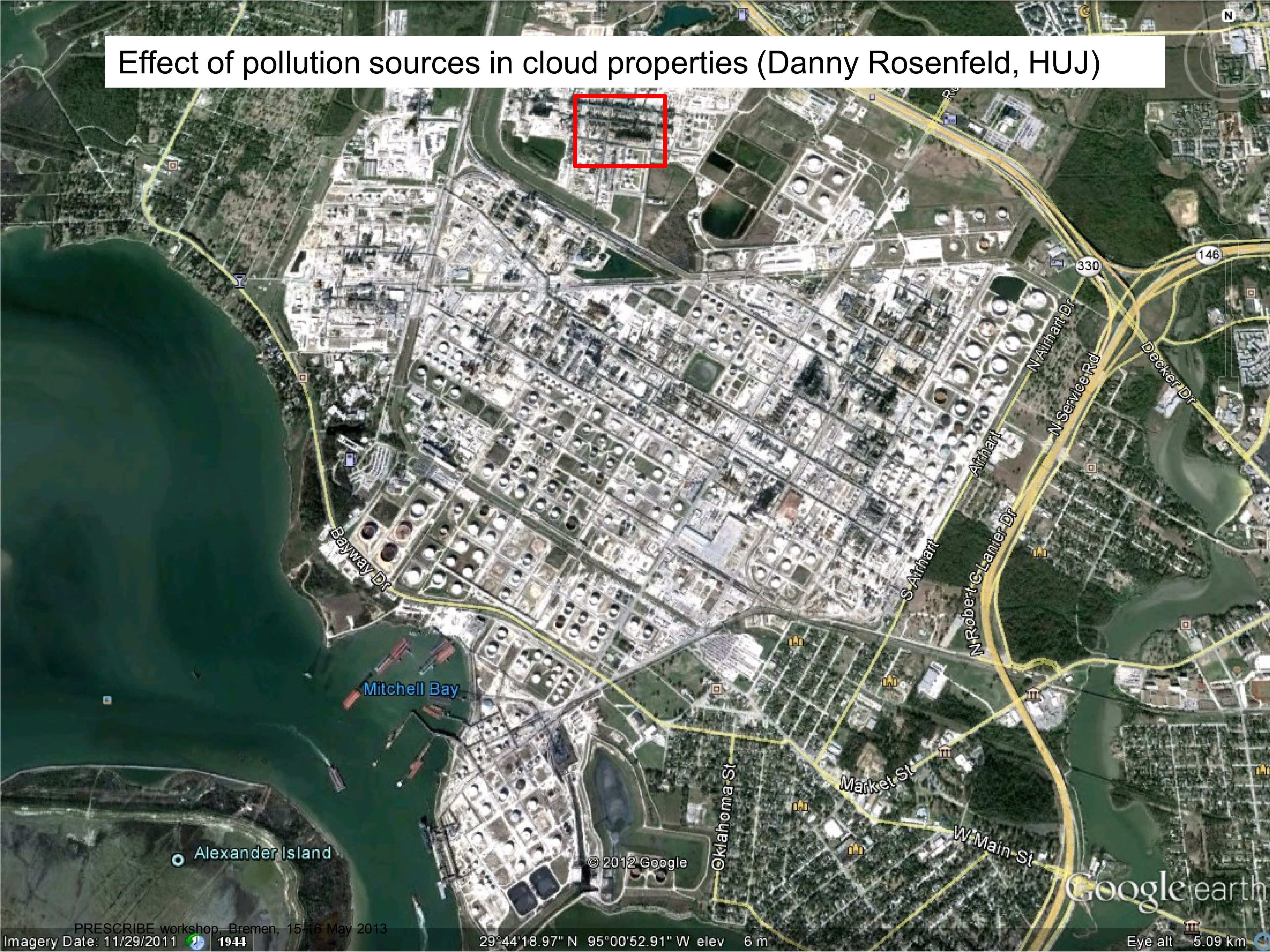
MODIS AOD



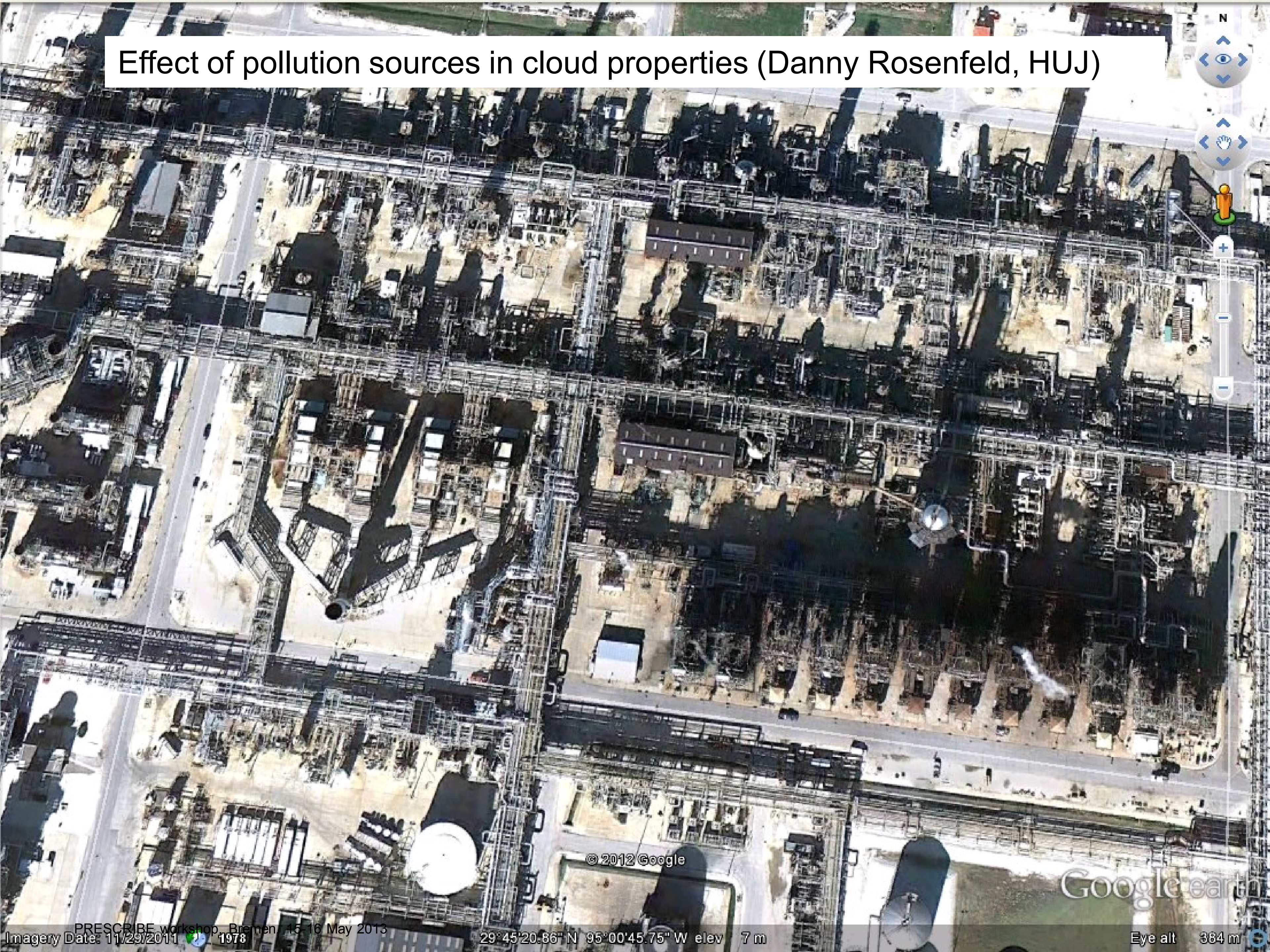
Effect of pollution sources in cloud properties (Danny Rosenfeld, HUJ)

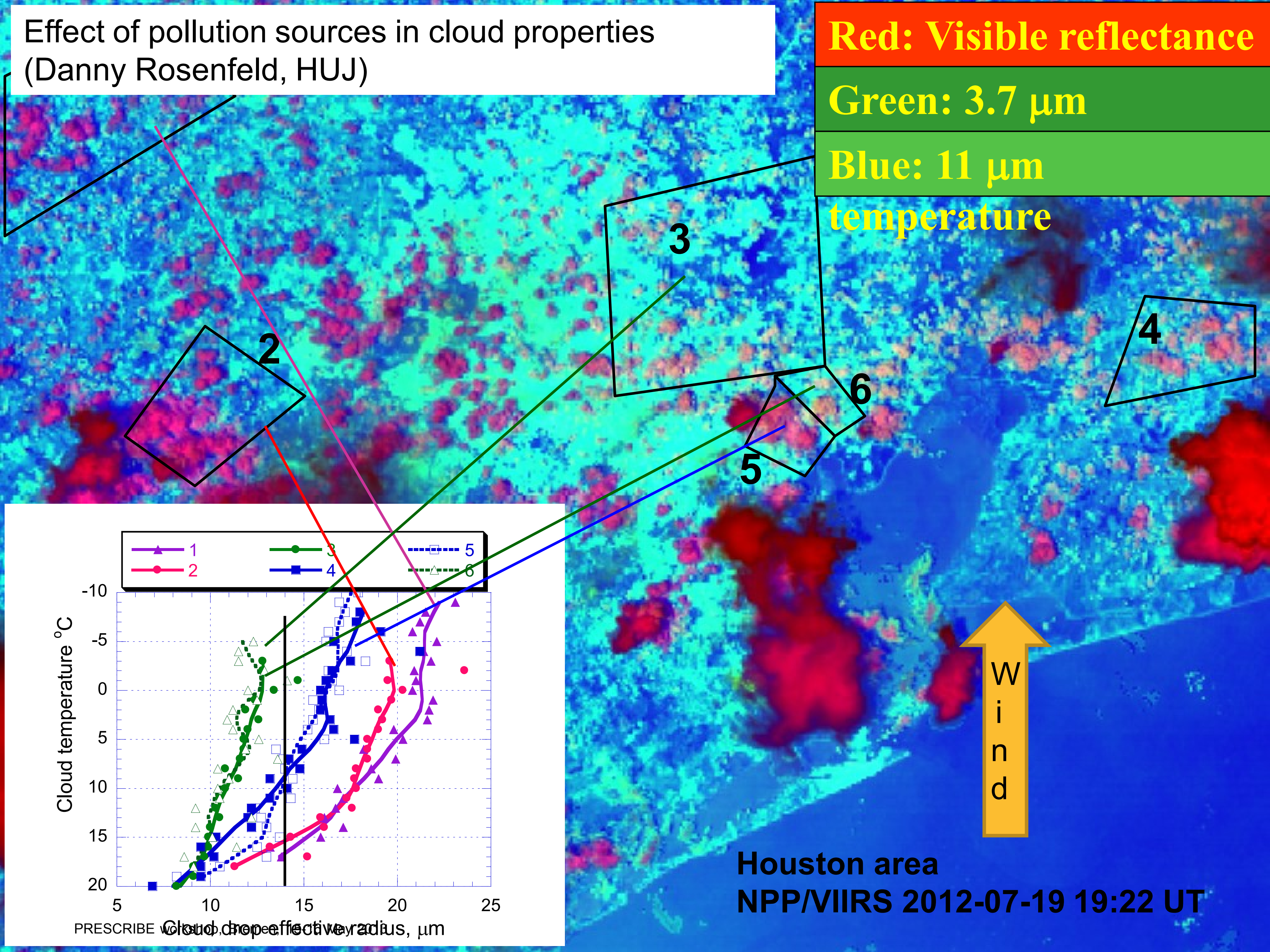


Effect of pollution sources in cloud properties (Danny Rosenfeld, HUJ)



Effect of pollution sources in cloud properties (Danny Rosenfeld, HUJ)




Effect of pollution sources in cloud properties
(Danny Rosenfeld, HUJ)
Red: Visible reflectance
Green: 3.7 µm
Blue: 11 µm temperature
1
2
3
4
5
6
Cloud temperature °C
-10
-5
0
5
10
15
20
5
10
15
20
25
Cloud drop effective radius, µm
W i n d
Houston area
NPP/VIIRS 2012-07-19 19:22 UT

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Conclusions

- **All European algorithms participating in Aerosol-cci have been significantly improved**
- **AATSR algorithms provide statistically similar results**
- **AATSR AOD statistics similar to MODIS and MISR products**
- **PARASOL over ocean superior**
- **Long time series will be produced from AATSR**
- **Applications to areas varying from clean (Eurasia, Arctic) to strong anthropogenic influences (Europe, China, other continents; forest fires)**
- **Measurement-based aerosol direct radiative effects**
- **Aerosol-cloud interaction studies**