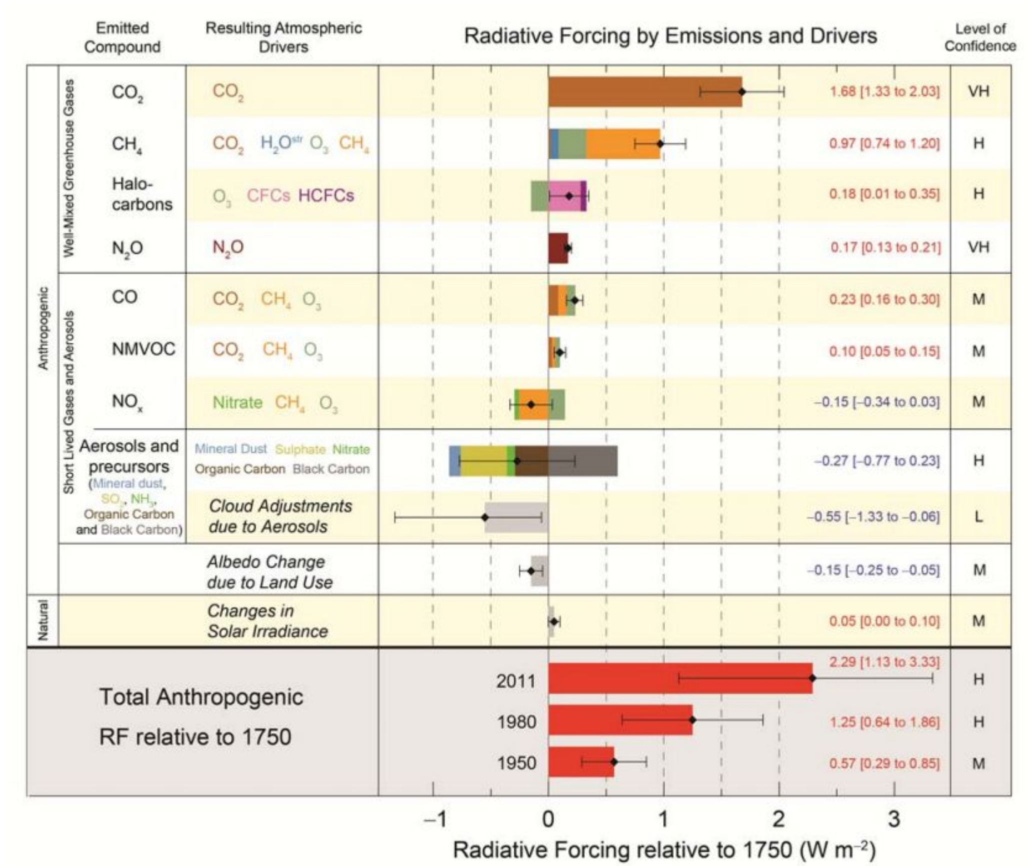
Observing the changing atmosphere from the ground : requirements for global networks for short-lived atmospheric species

Paolo Laj

Anthropogenic Forcing on Climate IPCC 2013

“the largest uncertainty to estimates and interpretations of the Earth’s changing energy budget”



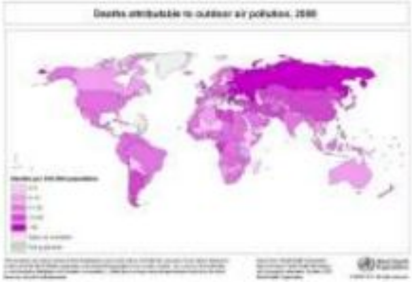
2.83 [2.26 to 3.40] W m^{-2}
(*high to very high confidence*)
Low regional variability

–0.9 [–1.9 to −0.1] W m^{-2}
(*medium to low confidence)*
High regional variability

Deadly Particles ….in the World

Ambient air pollution (AAP)

3.7 million deaths/vr*



Household air pollution (HAP)

4.3 million deaths/yr*

(*WHO, 2014)

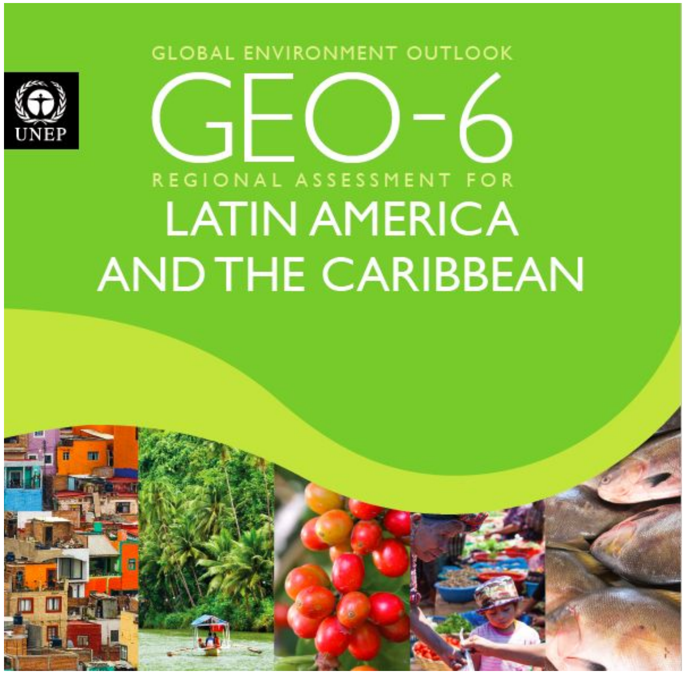
World Health Organization

Deadly Particles ….in LAC

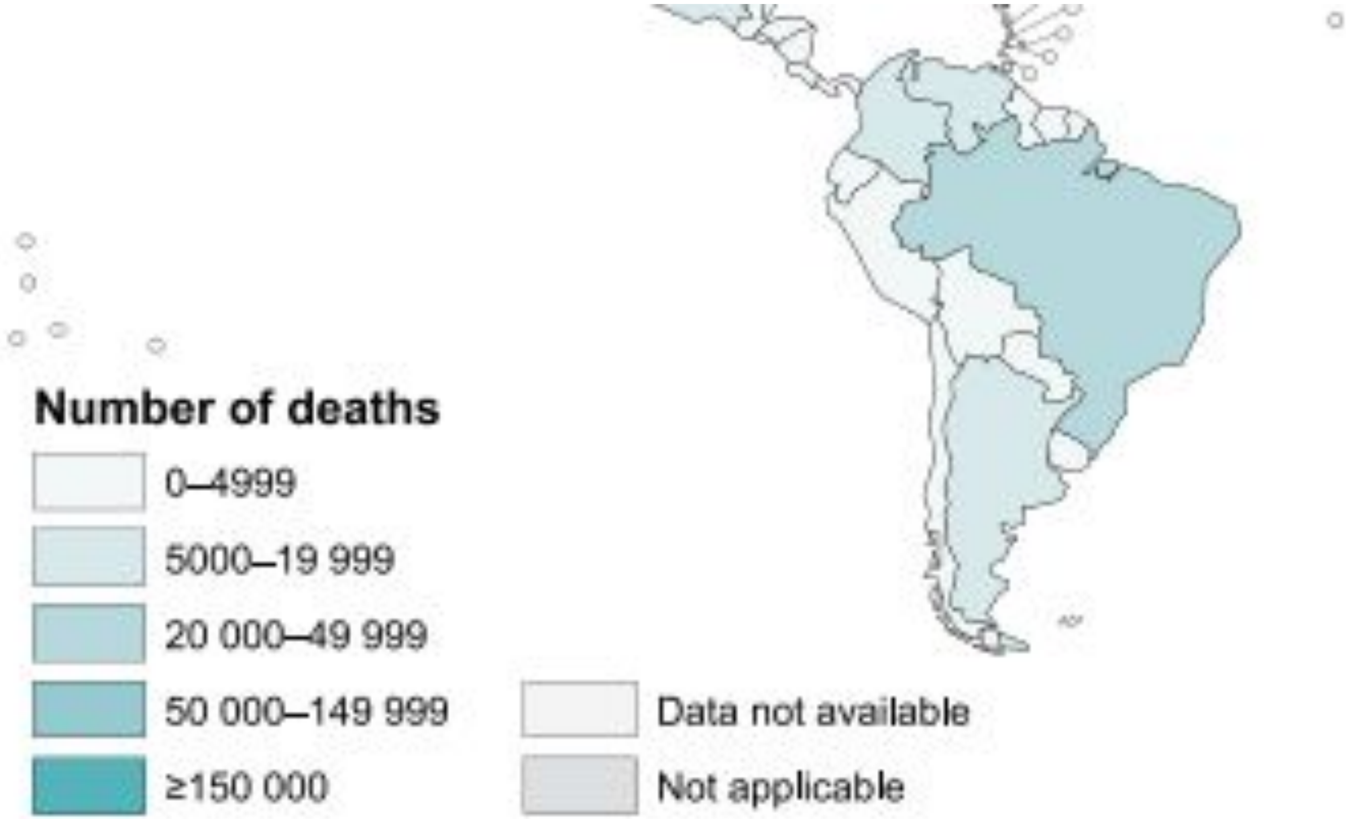
Air quality in cities has declined, and in most cities where data are available, the concentrations of particulate matter and ozone are above the WHO guidelines.

More than 100 million people in the region live in areas susceptible to air pollution.

In 2016 an estimated 93,000 people died prematurely in the region from exposure to fine particulate matter (PM2.5)



Deadly Particles ….in LAC



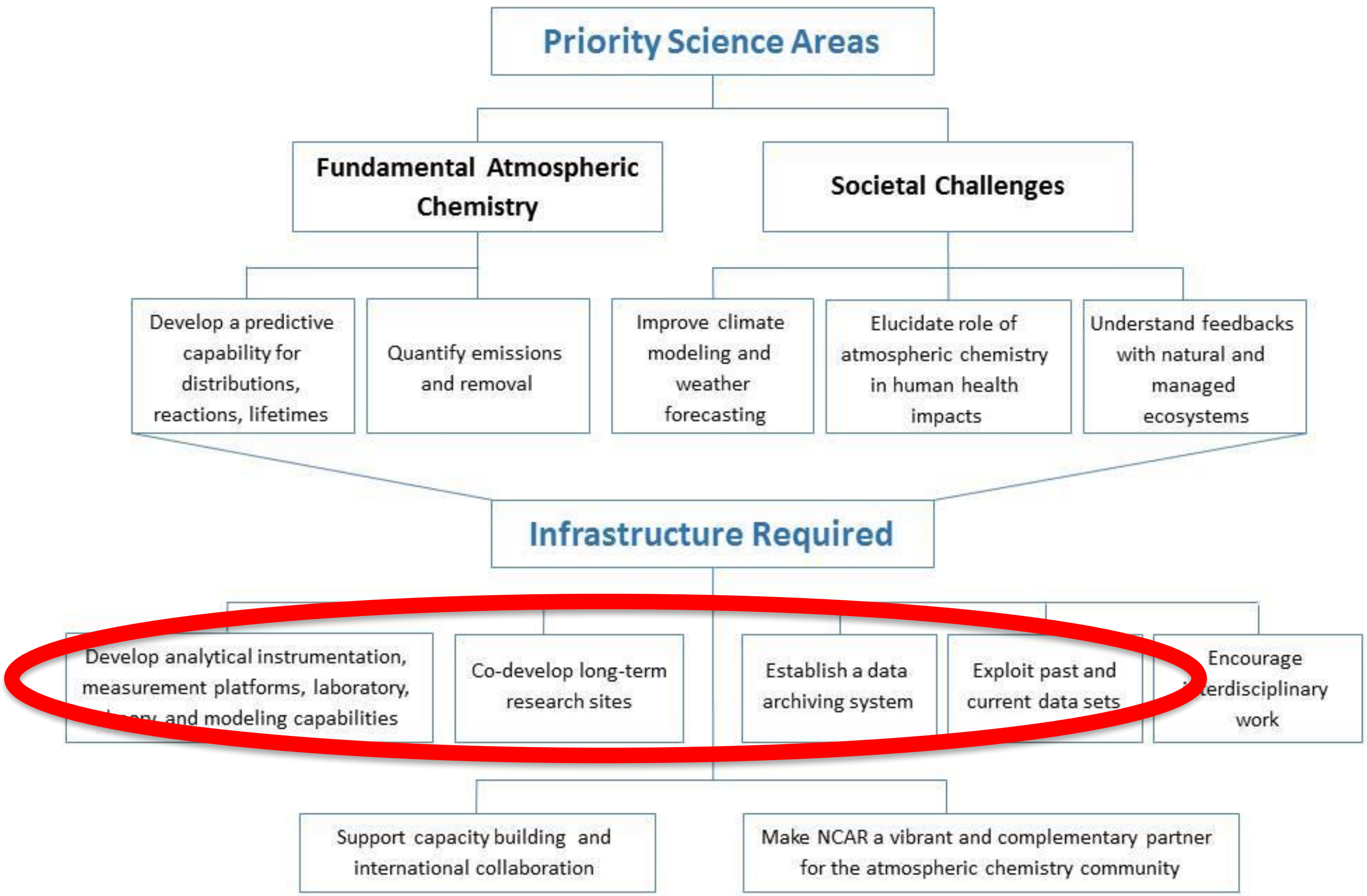
Reducing uncertainty

The uncertainty in assessing aerosol impacts on Climate and Health must be much reduced to efficiently advise on most suited policies

Reducing uncertainty will require.

- improving quality and coverage of observations from ground to space (not only PM) to constrain models
- Need good understanding of processes to simulate transport/transformation and sinks
- Need reliable climate chemistry models to evaluate scenarios
- Need reliable emission inventories to feed the models

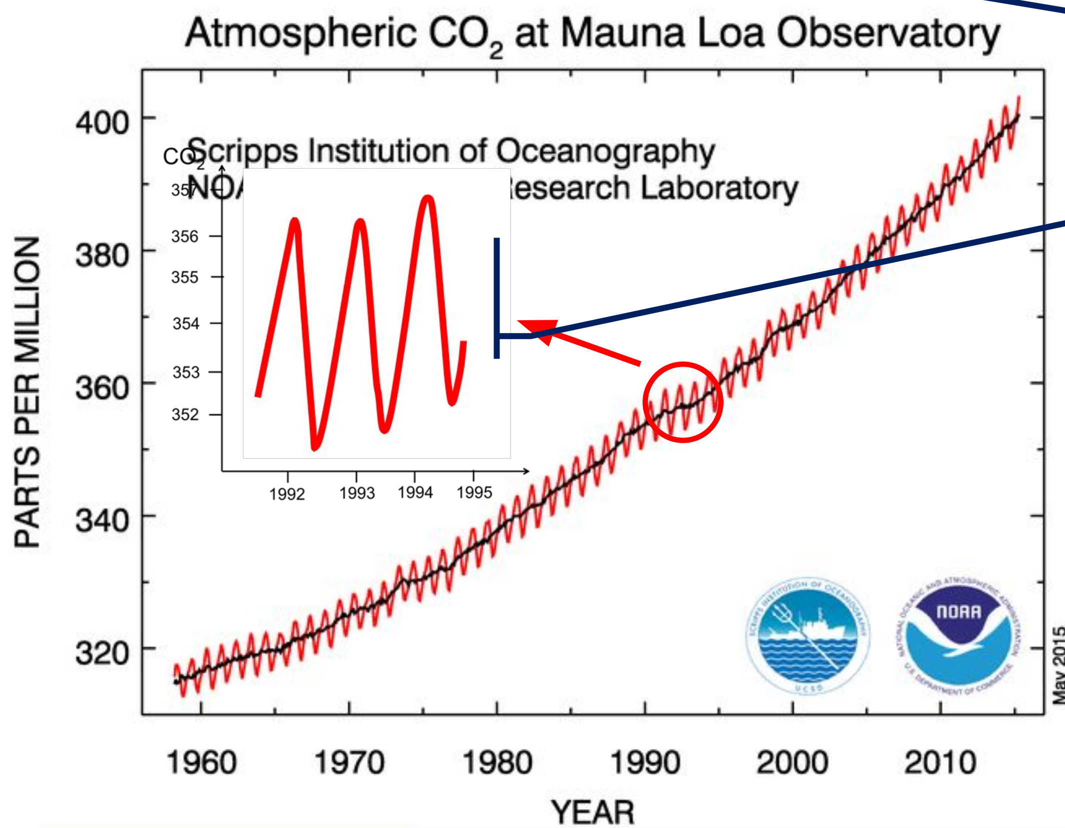
Reducing uncertainty



The observing system

	Near-Surface	Airborne	AERONET	GALION	Satellite
Length of dataset	Long-term ☺	Short-term ⊗	Long-term ☺	Long-term ☺	Long-term ☺
Temporal continuity	Continuous ☺	Variable ⊗	Intermittent ⊗	Intermittent ⊗	Intermittent ⊗
Geographical Coverage	Medium Sparse ☺	Sparse ⊗	Medium Sparse ☺	Sparse ☺	Global ☺
Vertical Resolution	Surface ⊗	Vertically resolved ☺	Column only ⊗	Vertically resolved ☺	Column (mostly) ⊗ ☺
Aerosol properties	Complete RFE suite; @ controlled RH ☺	Various ⊗ ☺	Direct and derived suite @high loading @ ambient RH ☺	Direct and derived suite @ ambient RH ☺	Mostly Derived ⊗ ☺

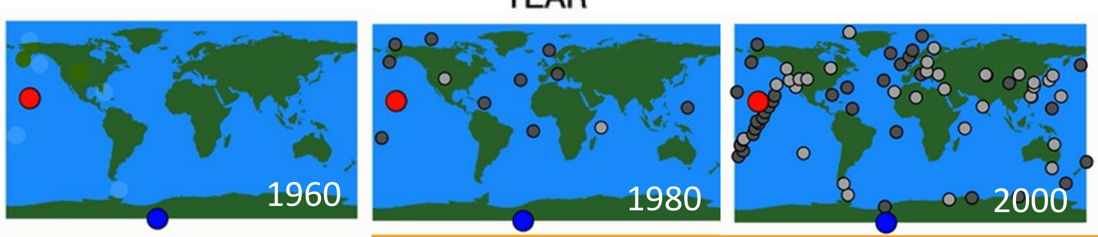
The example from CO2 observations

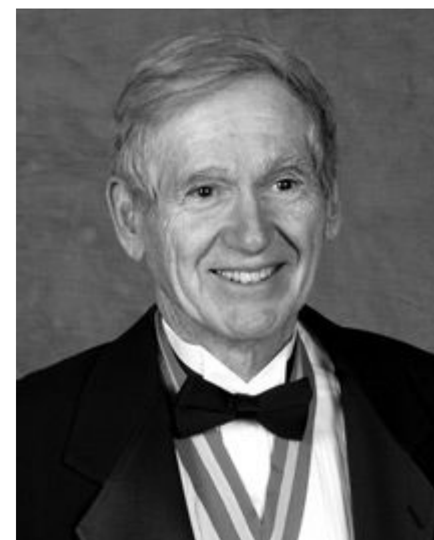


Long term record (50 years)

High precision measurements

Adequate station density





Charles D. Keeling
1928-2005

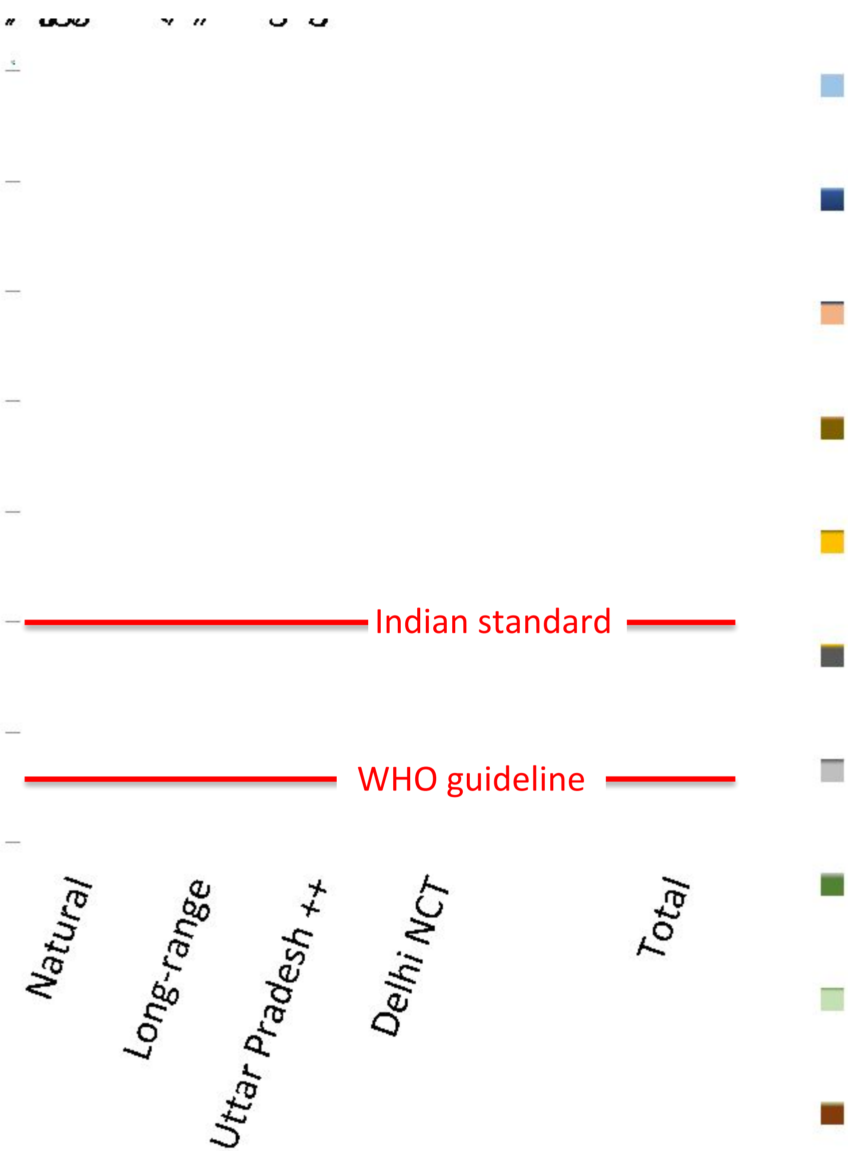
Short-Lived species Observations

Provide information that are relevant for climate (representative of large areas)

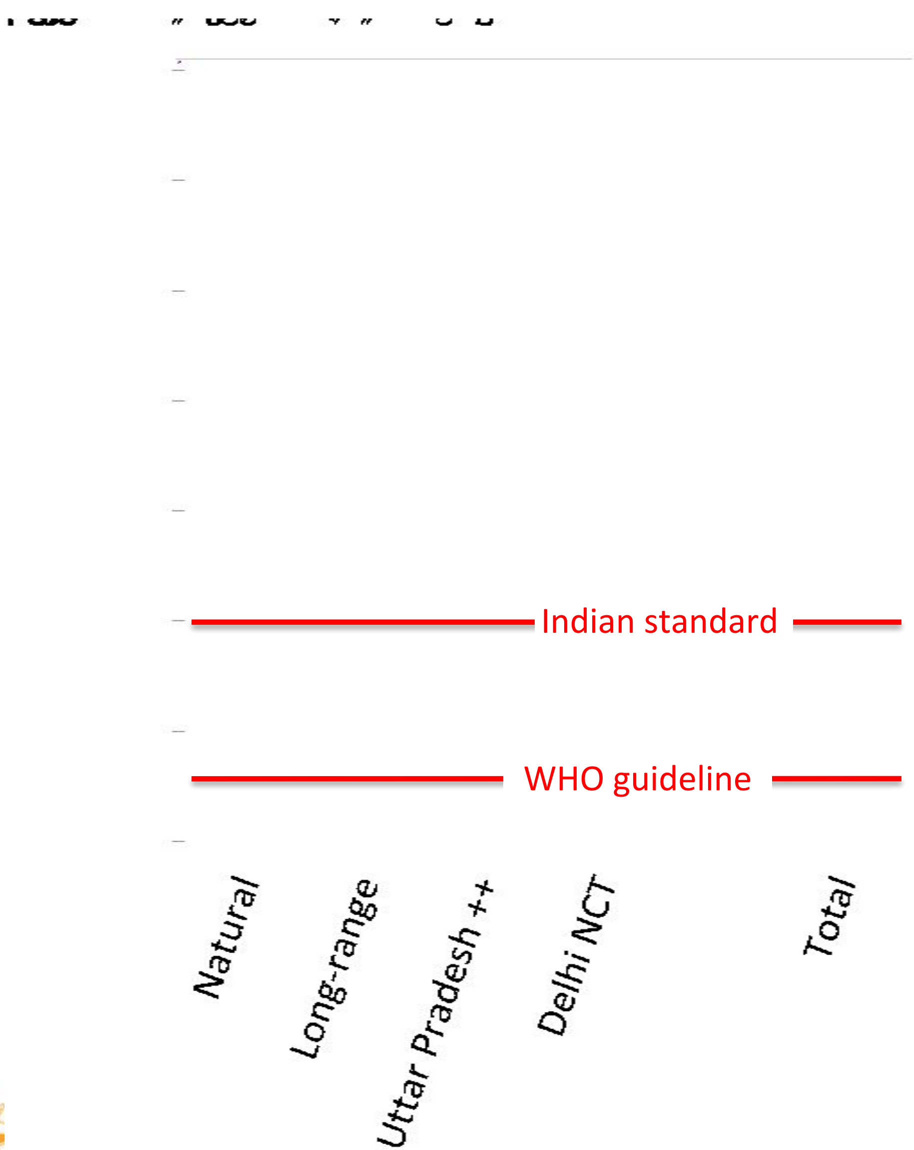
AND

Provide information that are relevant for Air Quality (representative of what population is exposed to)

Observing system for short-lived atmospheric species



Observing system for short-lived atmospheric species



On average, more than half of PM levels in New Dehli is not produced by the city itself (IAASA)

Knowledge of natural background, long-range transport (International and National contribution) a requirement

This is the case for most cities in the World, including LAC

Ideal Atmospheric Network for addressing AQ and Climate issues

Global Stations located in natural Environments :

→ instrumented for AQ and Climate measurements in 4-D
→ providing natural and Regional background
→ no need for high density of stations

Air Quality local stations

→ instrumented for AQ policies at least
→ Providing the urban and peri-urban information
→ need for higher density in relation to population

An observation system for aerosol/climate research

- Measuring the proper variables (including semantics)
- Defining Standard Operating Procedures
- Controlling implementation of SOPs and Quality
- Ensuring Traçability of data and data quality
- Ensuring conservation/curation of data
- Maintaining and Developing the observation network
- Making use of information

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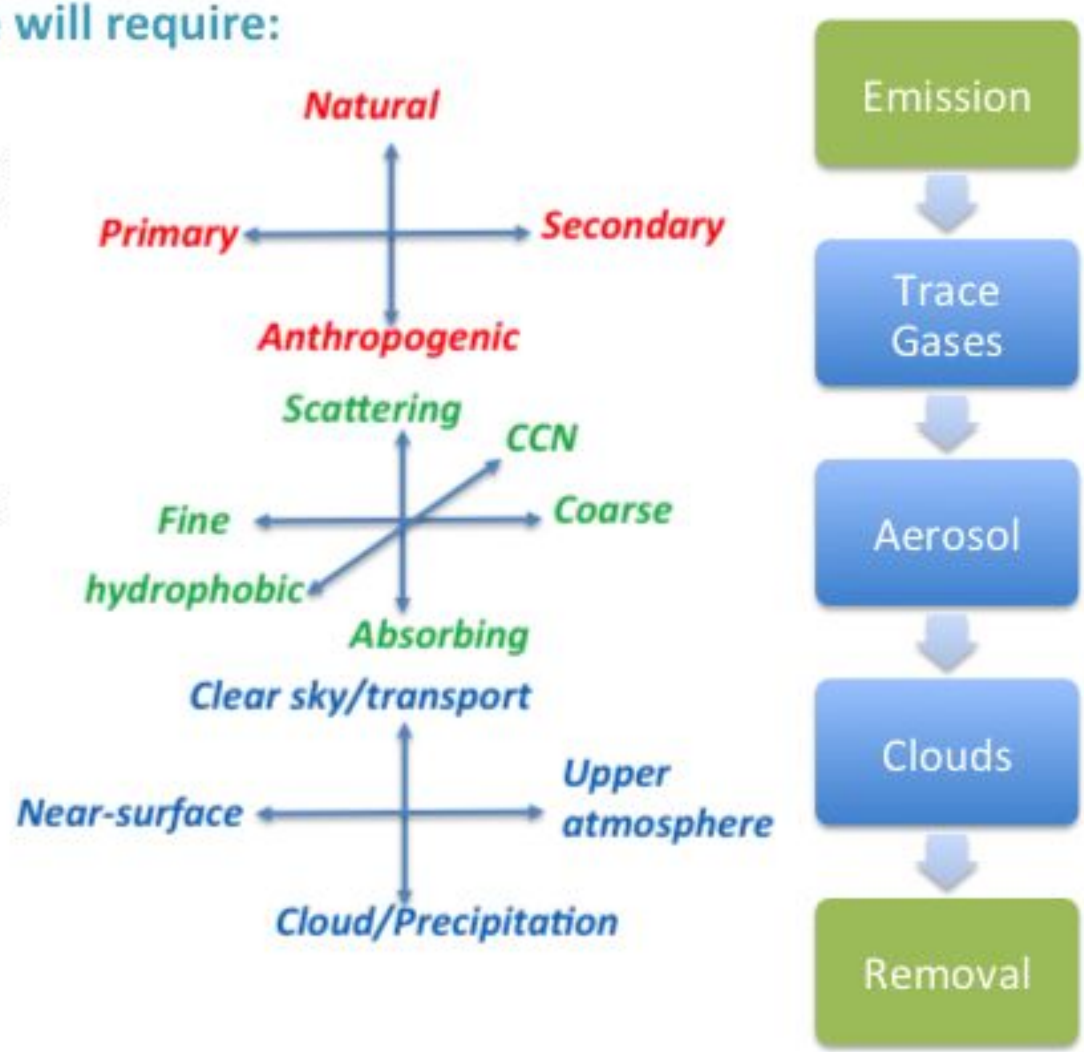
Requirements for observations of Aerosol Properties

Overcoming current knowledge will require:

- Improved knowledge of emissior intensities and source attributior
- Improved capacity for characterizing intrinsic propertie of Aerosol and Clouds
- Improved capacity for a 4D approach of multi-component interactions



Measurements for controling AQ standards are needed but not sufficient

Near-surface observations of Aerosol Properties

AQ

C

Column and Profile:	
	aerosol optical depth (various wavelengths)
	vertical profile of aerosol backscattering coefficient
	vertical profile of aerosol extinction coefficient
Optical Properties:	
	light scattering coefficient (various wavelengths)
	light hemispheric backscattering coefficient (various wavelengths)
	light absorption coefficient (various wavelengths)
Physical Properties:	
	particle number concentration (size-integrated)
	particle number size distribution
	particle mass concentration (two size fractions)
	cloud condensation nuclei number concentration (at various super-saturations)
Chemical Properties:	
	mass concentration of major chemical components (two size fractions)

It does not mean the others are useless !!

World Meteorological Organization

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QA/QC definitions

- **Quality Assurance (QA)**

Procedures, documentation, and audits used to achieve defined objectives.

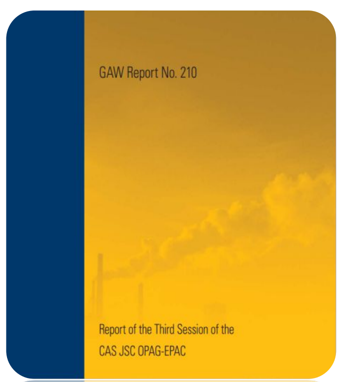
- **Quality Control (QC)**

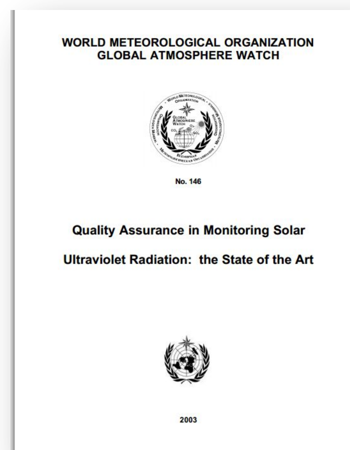
Data collected and analyzed to estimate bias and variability of measurements.

Analyze QC data to achieve QA.

Data quality

- Essential to have **harmonized measurements** to be able to do comparison over time and space
- Standard operation procedures and reference methods developed
- Regular field and laboratory inter comparison





ISO International Organization for Standardization

http://www.wmo.int/pages/prog/arep/gaw/gaw-reports.html

Establishing Standard Operating Procedures for Aerosol properties

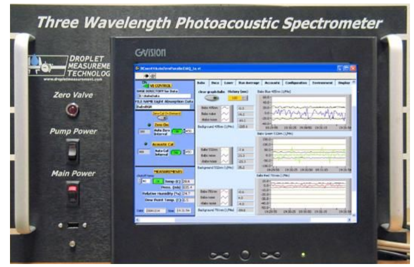
Variable	Recommended Instrument	Unit / time integration	Reference SOP
Sampling	Whole Air / PM10, PM2,5	Not applicable	GAW report # 153
light scattering coefficient	Multi-wavelenght nephelometer	M^{-1} / 1 hour	GAW report #200
light absorption coefficient	Multi-wavelenght aethalometer or single-wavelength Multi-angle Aerosol Absorption Photometer	M^{-1} / 1 hour	GAW report #200
particle number concentration	Particle counter CPC	cm^{-3}/ 1 hour	Wiedensohler et al., Atmos. Meas. Tech., 5, 657-685, 2012,
particle number size distribution (Coarse / small fractions)	Scanning Mobility Particle Counter Optical particle counter (OPC)	dN/dlogD /1h	Wiedensohler et al., Atmos. Meas. Tech., 5, 657-685, 2012, In preparation
Chemical composition (EC/OC)	-Off-line : filter based on PM10 and PM2,5 + thermo-optical instrument	µg m-3 / 12h to 48h depending on sites, 1 time a week	Cavalli et al., Atmos. Meas. Tech., 3, 79-89, 2010,
Chemical composition (inorganic ions)	-Off-line : filter based on PM10 and PM2,5 + ion chromatography - On-line: aerosol mass spectrometry (non-refractory submicron aerosols, including major inorganic ions and organic matter)	µg m^{-3} / 12h to 48h, 1 time a week µg m^{-3} / 1h	GAW report 153 and EMEP/CCC-Report 1/95 (2001) In preparation (ACTRIS protocol)

nate · Water

BC-like Measurements from commercial instrumentation

Incandescence SP2

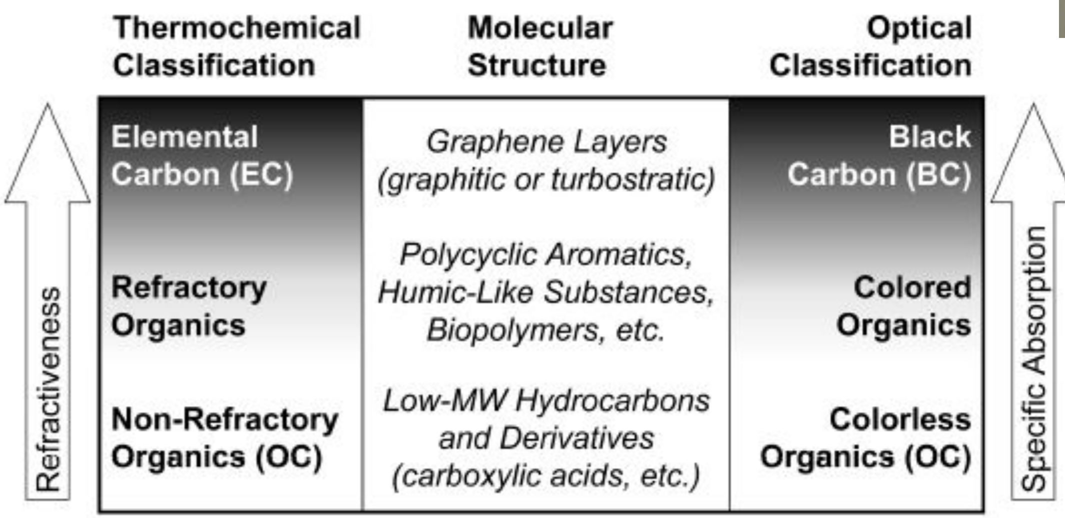
Photo-acoustic PASS



PSAP

SUNSET

DRI



AETHALOMETER

MAAP

Direct measurement of EC but difference between SUNSET and DRI protocols

required corrections to derive light-absorption coefficient

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Ensuring Traceability of data and data quality

All networks are facing big data challenges :

- Internationalisation
- Growing data
- Increasing computational needs

And practical problems

- Where to store the data?
- How to find it?
- How to make the most of it?

middle age | 19th century | 20th century | 21st century

What is Traceability ?

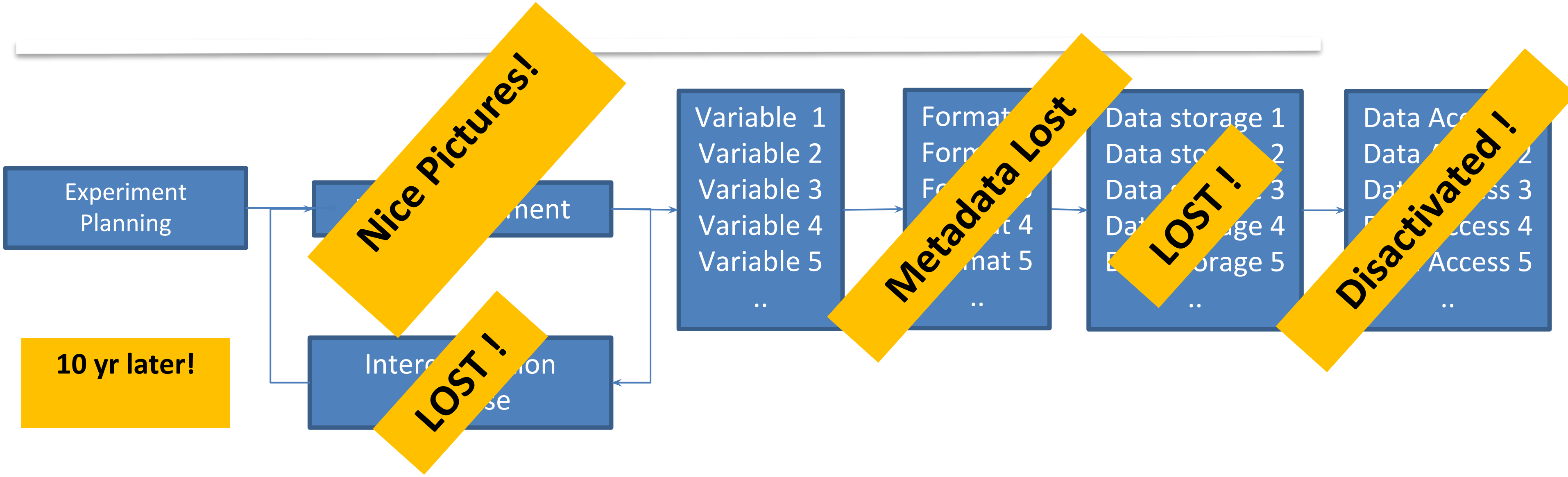
- Whole chain of data acquisition / processing / QA can be traced back to the time of measurement.
- Allows to reprocess the data.
- Separates DA / processing / QA chain into well defined steps, great tool for finding the cause of failing intercomparison.
- Data is documented also for a user in 15 years from now.
- Higher level frameworks are moving to requiring this feature.

The Big Data revolution .

How to make sure your data will be available to you (and others) 20 years from now ….

(and don’t behave like I (We) did….)

Where are the data from my Post-Doc years?

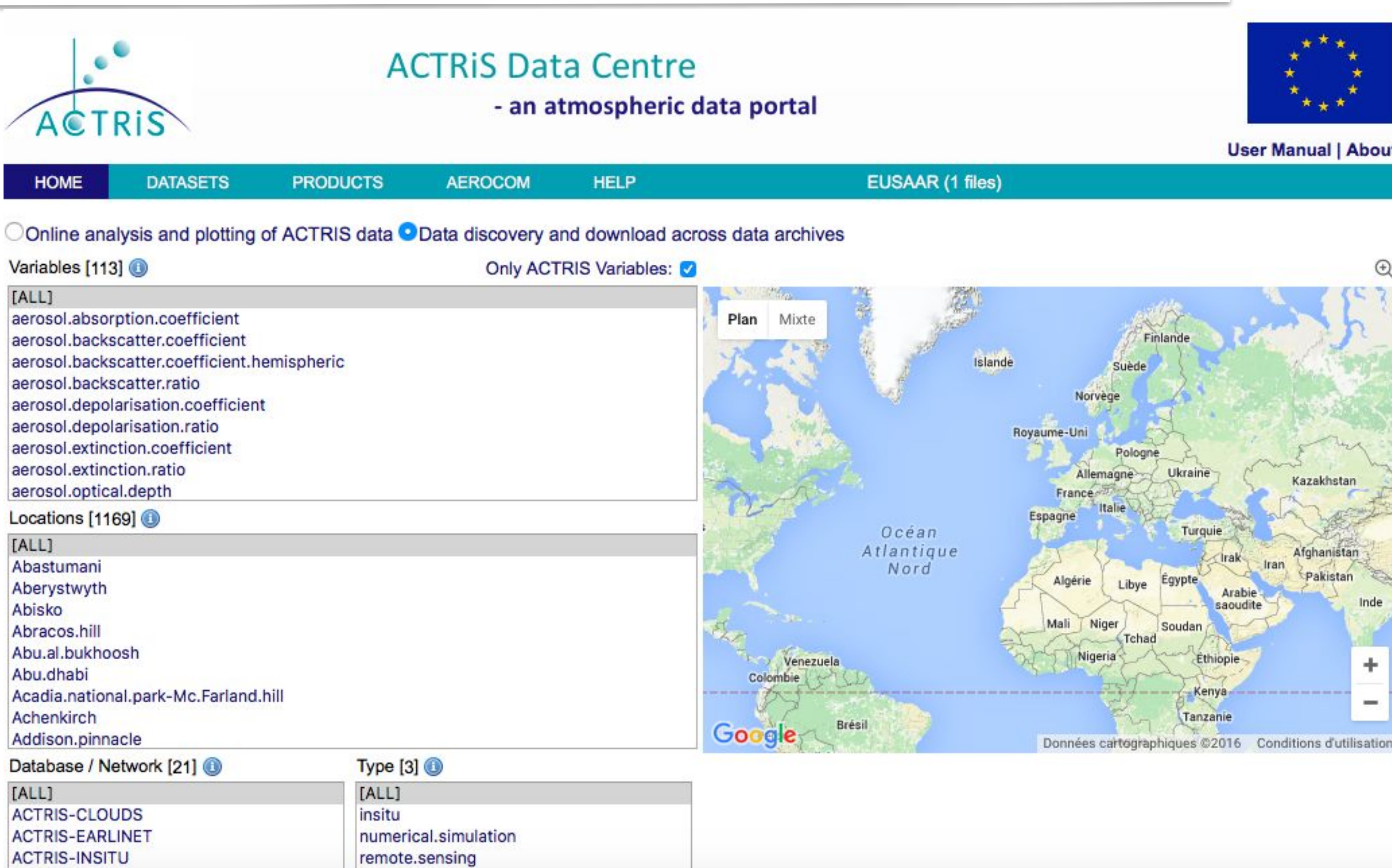


Information from the 80s is almost totally lost –

We have lost the 90s as well –

Deriving trends for aerosol species requires >10yr continuous data –

ACTRIS Data Center= World Data Center for Aerosol and Trace Gases = EBAS



Data is open access

Then your data will be available to everyone

- Do you agree ?

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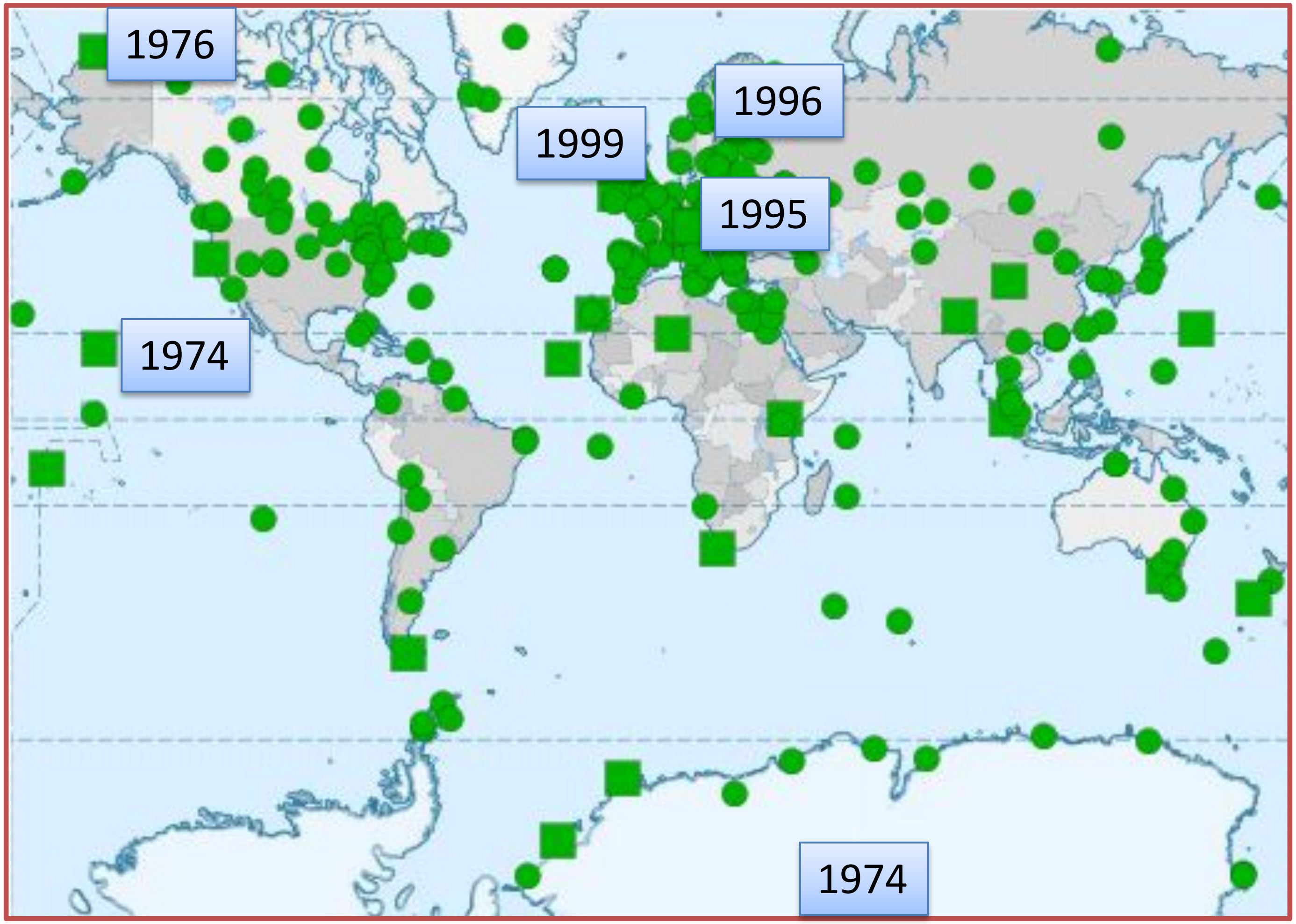
The World Aerosol observation network in 2017



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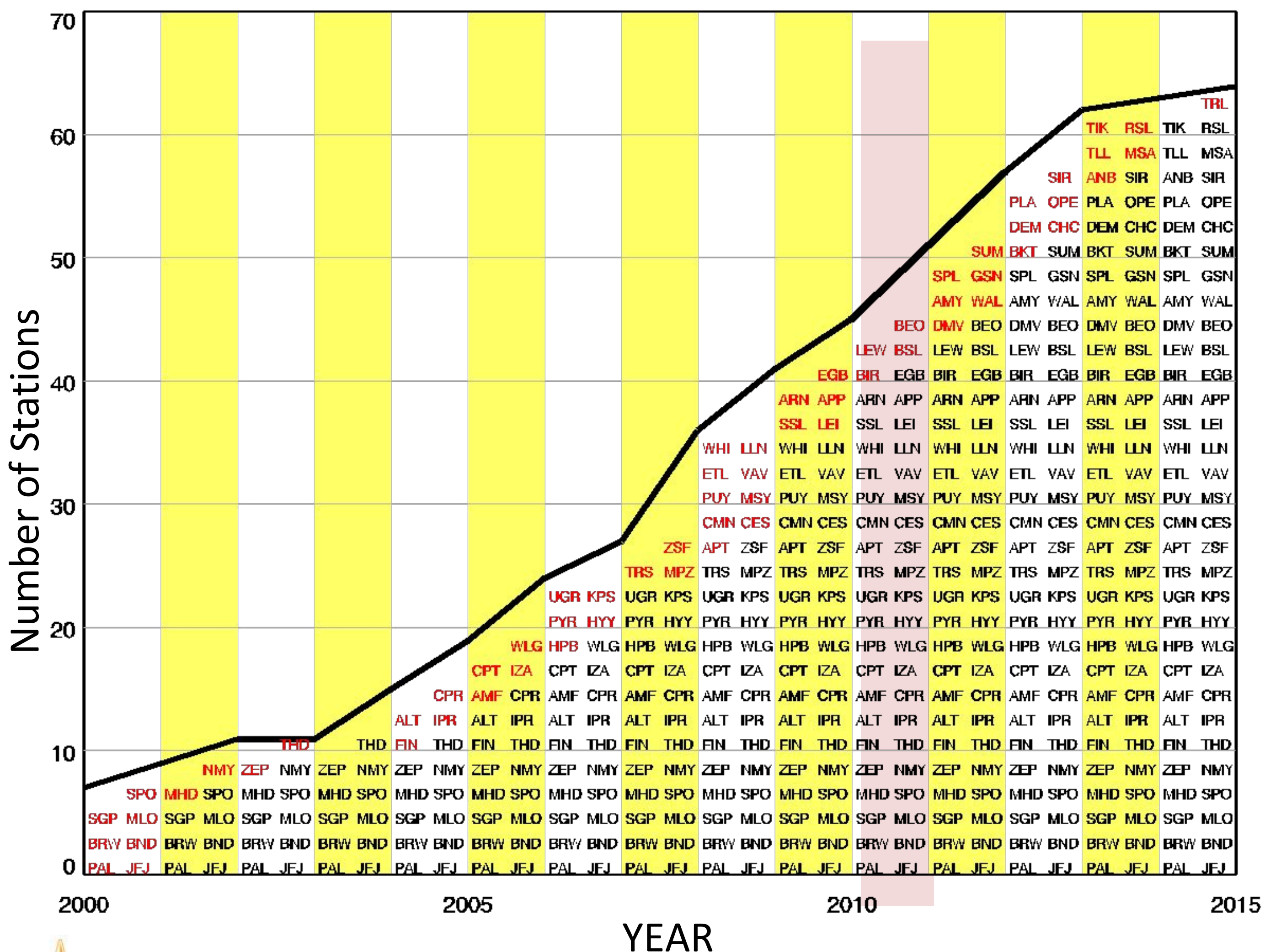


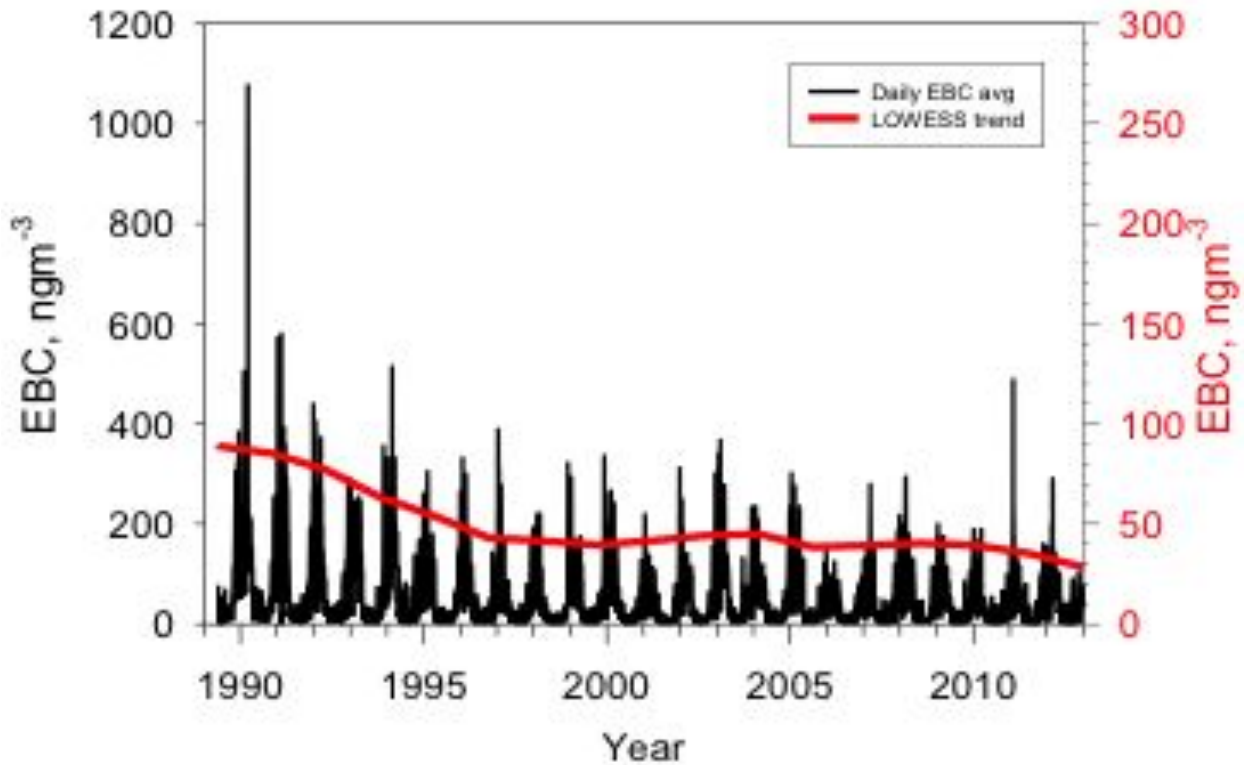
- Stations providing scatt. + Abs
- Number of stations increasing by ~5/year
- Data for more than 60 sites by 2015

Aerosol long-term trend: a limited 10-year vision

- How many years are required to derived trends ?
- Is this independent from the studied parameter ?
- How many stations can provide >10 yr measurements of aerosol properties Worlwide ?
- Negative or positive trends ?

Aerosol long-term trend: not an issue in the Northern hemisphere

Eq Black-Carbon Barrows: -70% since 1989



Barrows record captures the drastic emission changes from the 80‘s

Integrated studies on aerosol climatology and trends

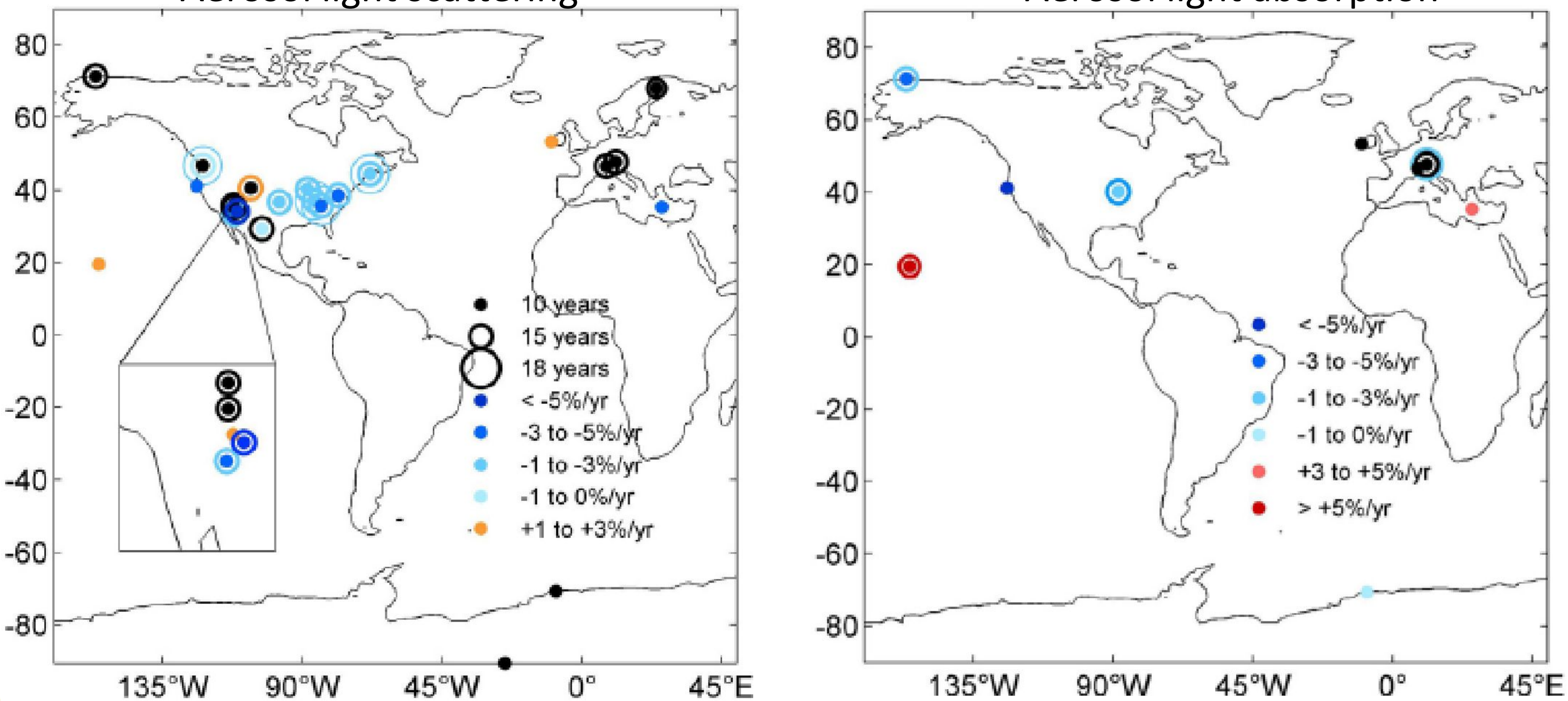
Authors	Region	Variable	Scope	# of sites
Putaud et al., 2010	Europe	PM, Number	Climatology	60
Asmi et al., 2011	Europe	Number	Climatology	24
Reddington et al, 2011	Europe	Size/ Number	Model/climatology	15
Andrews et al., 2013	World	Optical prop.	Climatology	10 (mountain)
Collaud Coen et al., 2013	World	Optical prop.	Trends	20
Asmi et al., 2013	World	Number, Size	Trends	15
Grenberg et al., 2013	Europe	Black Carbon	Climatology	6
Beddows et al., 2014	World	Size	Climatology	22
Torseth et al, 2015	Europe	Chemistry	Climatology and trends	>100 (EMEP)
Cavalli et al., 2016	Europe	Chemistry	Climatology	10
Zanatta et al., 2016	Europe	Black Carbon	Climatology	9
Schmale et al. submitted	Europe	CCN	Climatology	15
Dall'Osto et al., submitted	Europe	Size	Climatology	21
Andrew et al., in prep	World	Optical prop.	Model/obs and trends	60
Pandolfi et al., in prep	Europe	Optical prop.	Climatology and trends	35
Bressi et al., in prep	Europe	Online Chemistry	Climatology	23

Aerosol optical properties

- No significant trend for European continental sites, opposite trends for others
- Mostly decreasing trends in continental USA, increasing at Mauna Loa

Aerosol light scattering

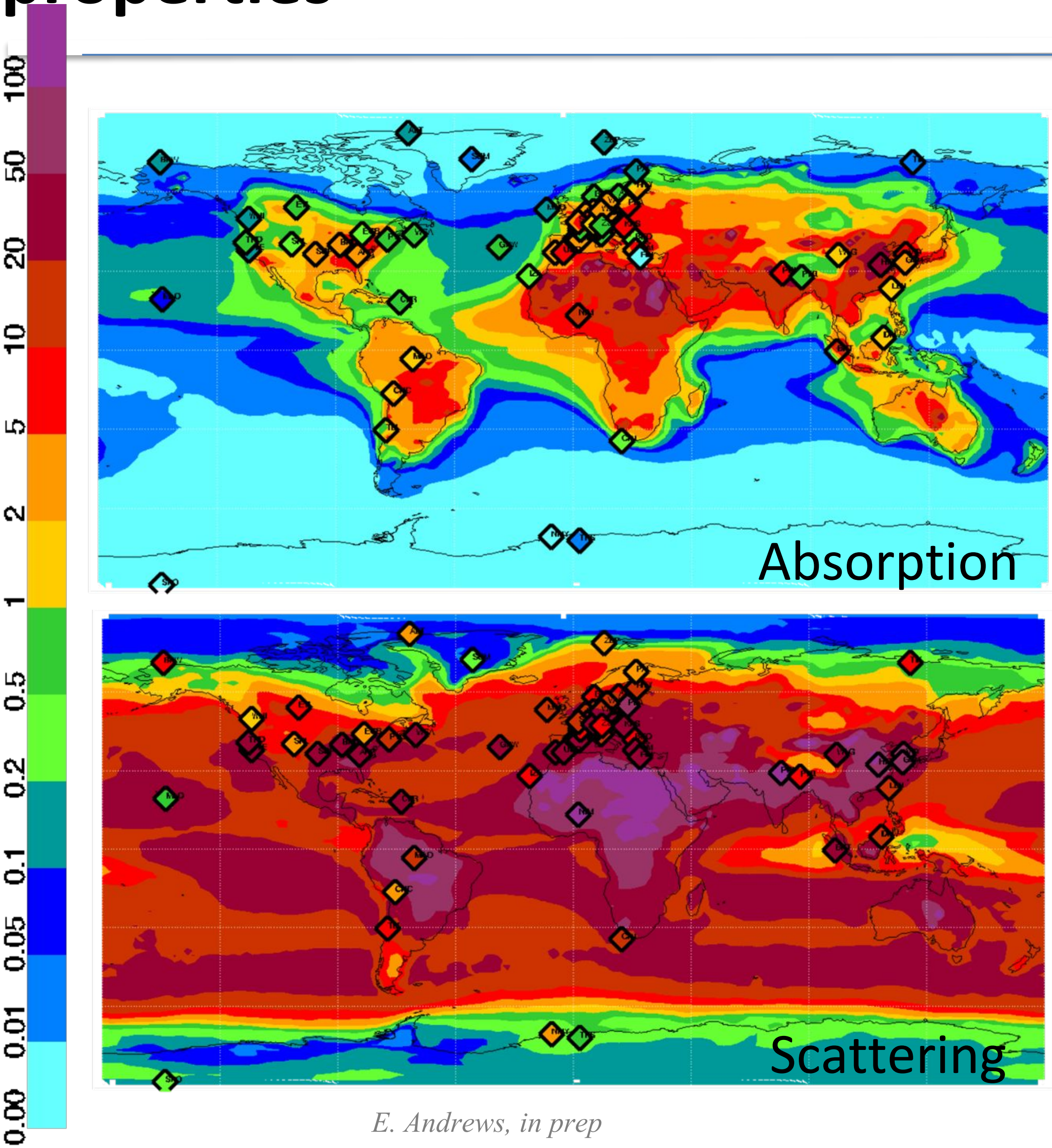
Aerosol light absorption



● No significant trend (95% confidence level)

M. Collaud Coen et al., Atmos. Chem. Phys., 13, 869-894, 2013

Observations/Model comparisons Aerosol properties

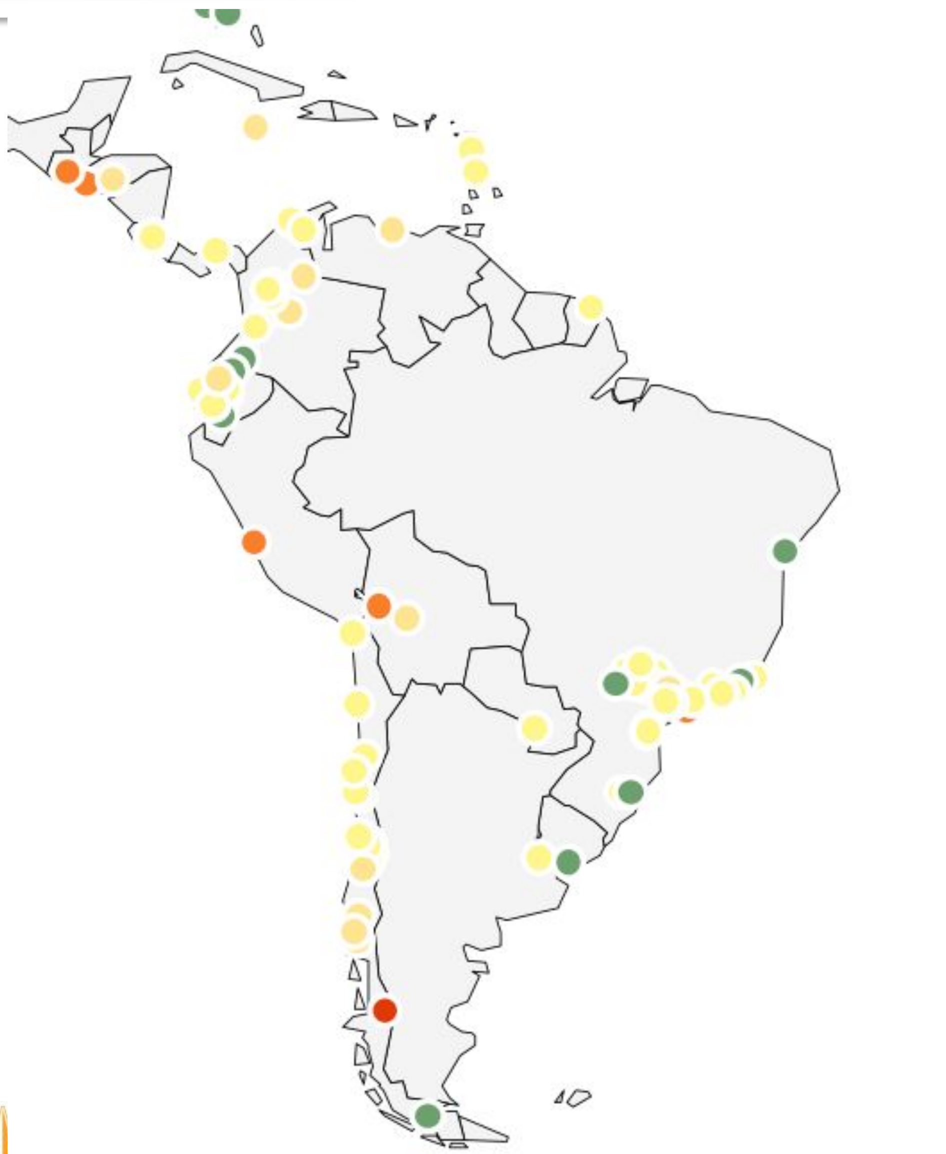


E. Andrews, in prep

- Annual pattern of absorption and scattering is similar for models and in-situ measurements
- Differences are observed for some sites

Global Aerosol observationin LAC in 2017

AQ observation network in LAC Cities



Annual mean $PM_{2.5}$ (μg/m³)

- <10
- 10–19
- 20–39
- 40–59
- 60–99
- ≥100

AQ observation network in LAC Cities

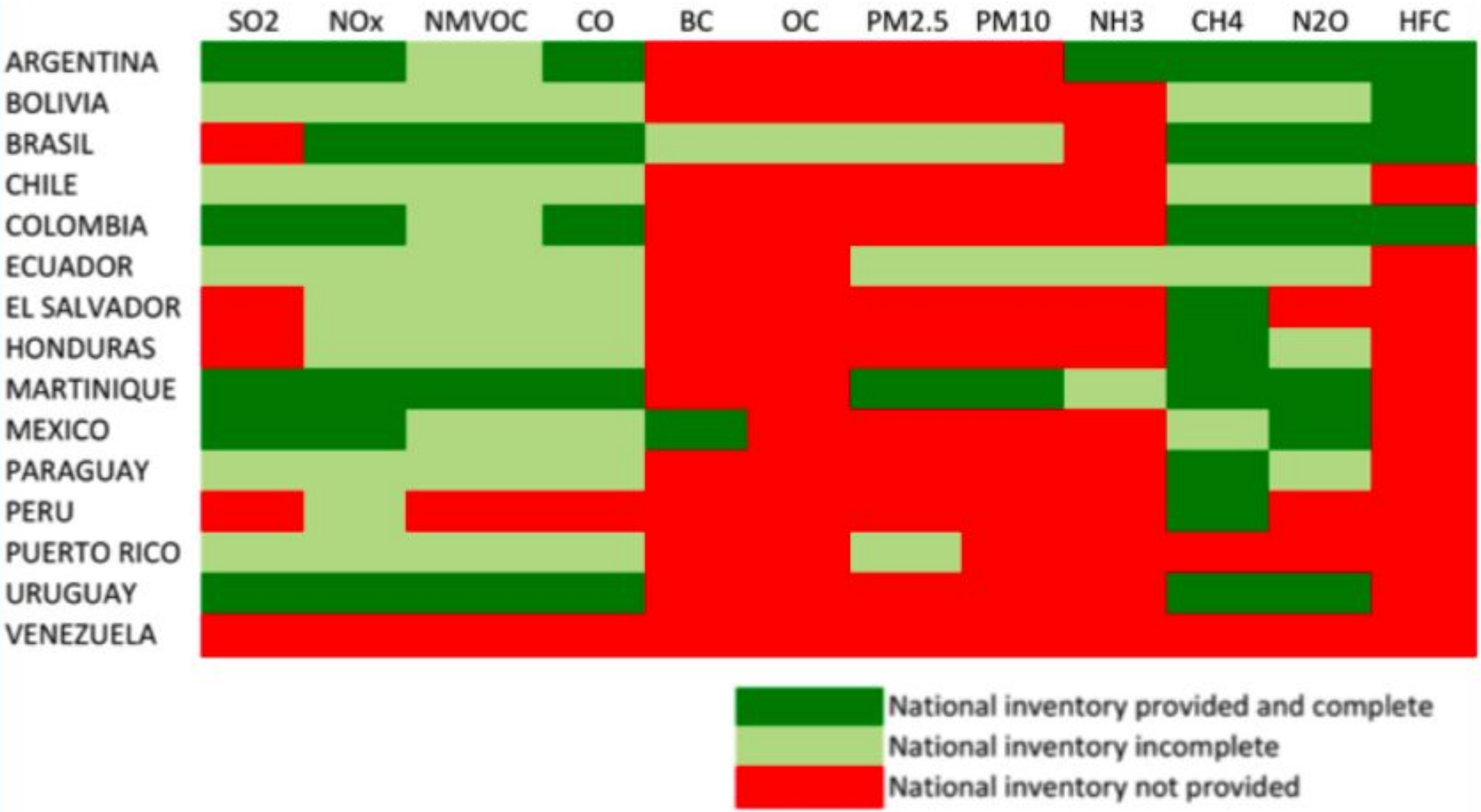
Table 2.1.1: Annual mean concentration of particulate matter of less than 10 microns of diameter (PM_{10}) [µg m⁻³] and of less than 2.5 microns ($PM_{2.5}$) in major cities in LAC countries.

Country	PM_{10}: annual mean, µg m⁻³	Year	$PM_{2.5}$: annual mean, µg m⁻³	Year	Number and type of monitoring stations
Argentina	30	2012	16	converted	3 stations, 2 stations in residential/ commercial with fixed sources and 1 in mixed zone with medium to low traffic in capital city
Bolivia	51	2010	27	converted	5 stations in 2 cities
Brazil	41	2012	22	converted	>56 stations in 40 cities
Chile	64	2011	28	2008-2012	47 stations in 24 cities
Colombia	43	2010-2012	24	converted	37 stations in 10 cities
Costa Rica	31	2011	17	converted	8 stations in 4 cities
Ecuador	38	2012	18	converted	9 cities
Guatemala	45	2012	33	2012	4 stations in capital city
Honduras	58	2013	32	2013	2 stations in capital city
Jamaica	36	2011	20	converted	12 stations, mixed, in 3 cities
Mexico	79	2011	27	2011	>24 stations in 9 cities
Paraguay			18	2010	3 stations in capital city
Peru	63	2011	38	2011	4 stations in capital metropolitan region
Uruguay	27	2012	18	2012	2 stations for PM_{10}, 1 station for $PM_{2.5}$, in capital city
Venezuela	47	2011	26	converted	Monitoring in 2 cities

Note: Annual mean PM_{10} data were estimated, when not available, on the basis of $PM_{2.5}$ using a conversion factor. As the conversion factor $PM_{2.5}/PM_{10}$ may vary according to location, the converted PM_{10} value for individual cities may deviate from the actual value (generally between 0.3 and 0.8), and should be considered as approximate only.

Source: WHO 2014c

Emission inventories knowledge in LAC



** Referring to information provided within the LAC Assessment work.*
Data for various years between 2000 and 2010

Conclusions

- Make use of existing data : there is a lot to do with that
- Contribute to network design and evolution of the observing system
- Share your data and information and make sure it will be available 20 yrs from now
- Don’t overlook at QA/QC procedures
- Be prepared to Long-term commitment
- Properly evaluate ressources
- Be prepared to the Low-Cost Sensor revolution