Institute for Climate & Atmospheric Science
SCHOOL OF EARTH AND ENVIRONMENT
UNIVERSITY OF LEEDS

The Global Aerosol Synthesis and Science Project

GASSP
The Global Aerosol Synthesis & Science Project

Ken Carslaw

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NERC – Science of the Environment
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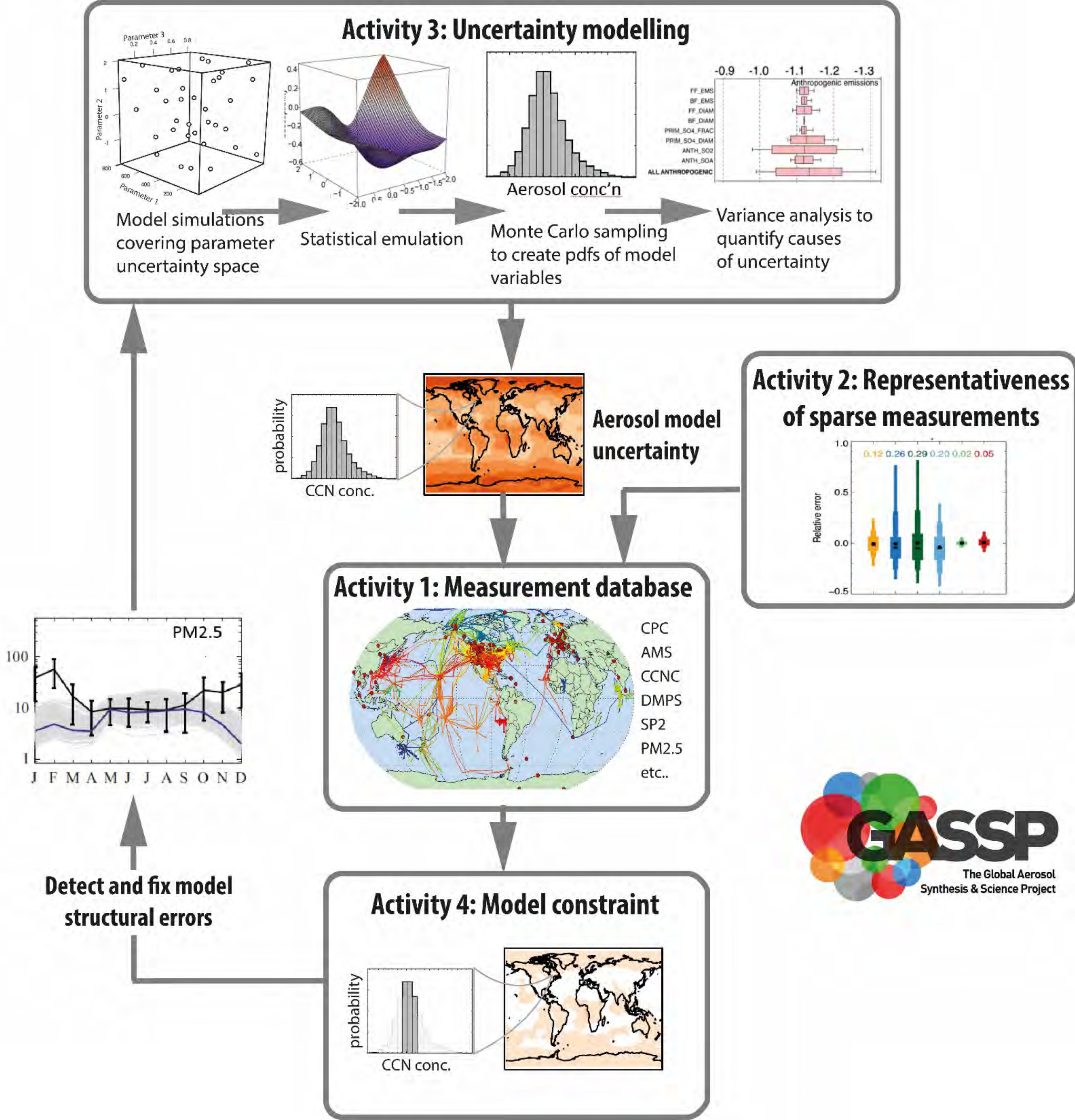
archer
Met Office
European Commission

Aims of GASSP

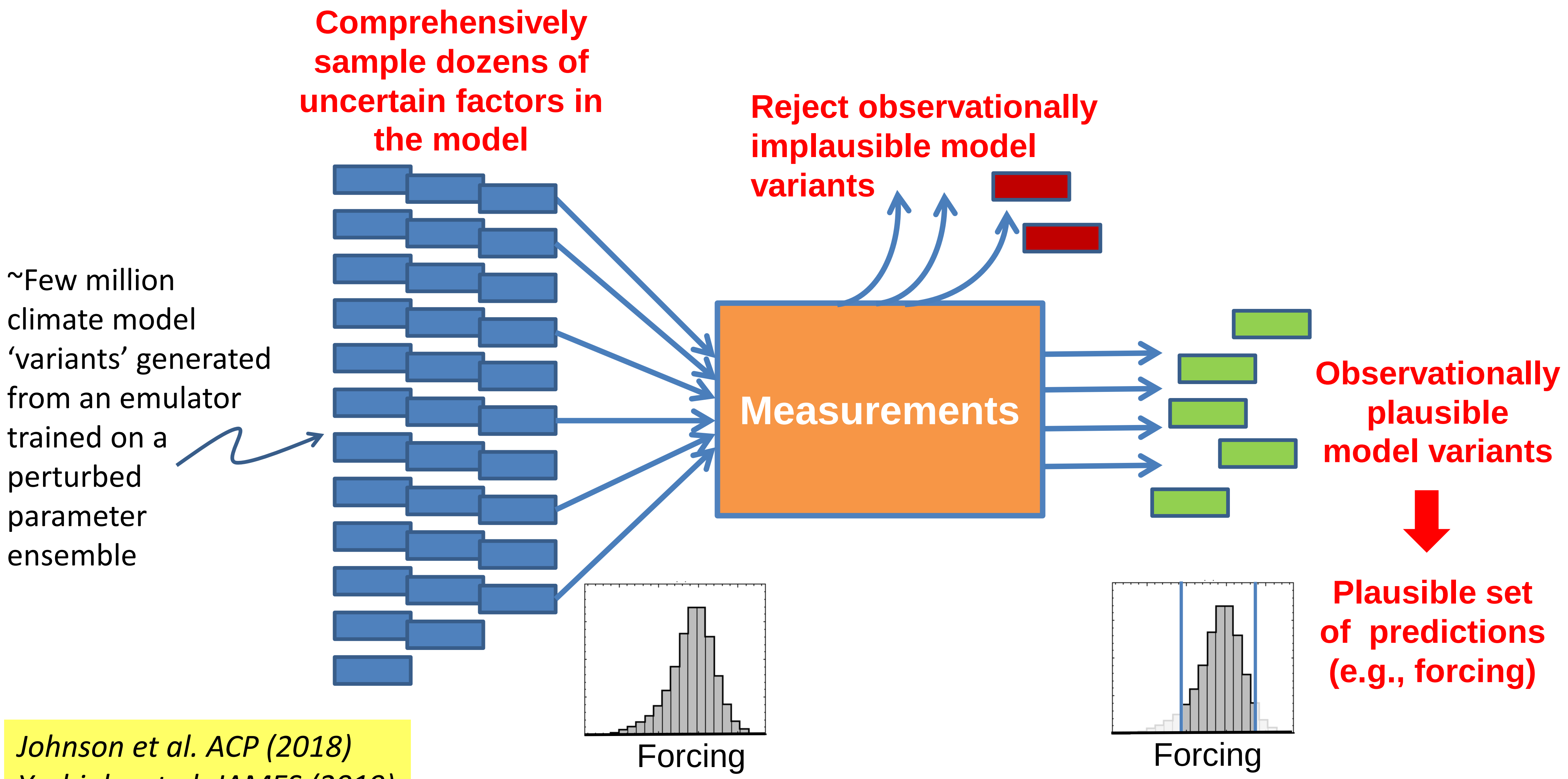
Reduce uncertainty in global model simulations of aerosol properties and radiative forcing

Use the powerful combination of extensive model data and a synthesis of measurements

Reddington et al. The Global Aerosol Synthesis and Science Project: Observations and modelling to reduce uncertainty, BAMS, *in review*



Robust model uncertainty reduction



Johnson et al. ACP (2018)
Yoshioka et al. JAMES (2019)

GASSP aerosol database

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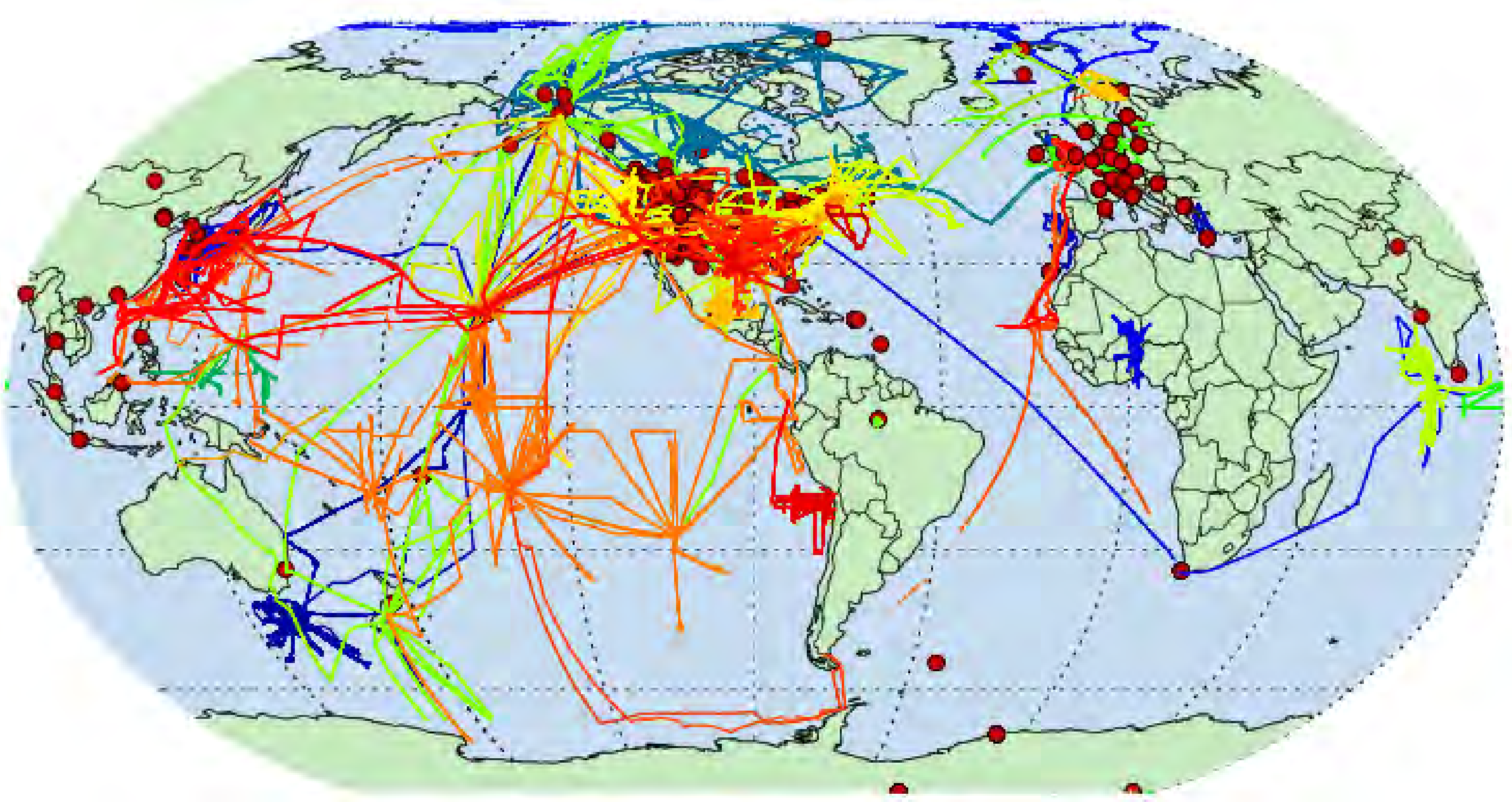

ICARTT NEAQS-ITCT2004
MAGE 92
MAMM
MIRAGE
NAURU99
NEAQS2002
NEAQS2004
OP3
PASE
PEM Tropics A
PEM Tropics B
PEM West A
PEM West B
Polarstern Cruise 1 ANT-XXVII/4
Polarstern Cruise 2 ANT-XXVIII/1
Polarstern Cruise 3 ANT-XXVIII/5
RHaMBLe
RITS 93
RITS 94
RONOCO
SEAC4RS
Southern Oxidants Study
TexAQS2000
TexAQS/GoMACCS
TEXAQS - GoMACCS 2006
TexAQS
TexAQS2006
TexAQS2006
TRACE-P
TROMPEX
VOCALS
VOCALS-REx
VOCALS-REx
WACS2012
WACS2014

ACCACIA
ACCACIA
ACE1
ACE2
ACEASIA
ACEASIA / ACE-Asia
AEGEAN GAME
AEROSOLS99 INDOEX
A-FORCE
AMMA
AOE-96
AOE-2001
APPRAISE
ARCPAC2008
ARCTAS
BORTAS
CALNEX
CAST
COPE
DC3
DISCOVER-AQ
DYNAMO
EM25
EUCAARI-LONGREX
GOAmazon
HIPPO
ICEALOT
INDOEX
INTEX-A / INTEX-NA
INTEX-B
INTEX-B
ITCT2002

- 1995-2014
- Harmonised ~55,000 hours of aircraft and ship data
- 350 ground stations from 15 networks/databases.
- Focus on **Size distributions, N, PM2.5, CCN, BC, composition**

Reddington et al., The Global Aerosol Synthesis and Science Project: Observations and modelling to reduce uncertainty, BAMS, 2017

GASSP level 2 coverage

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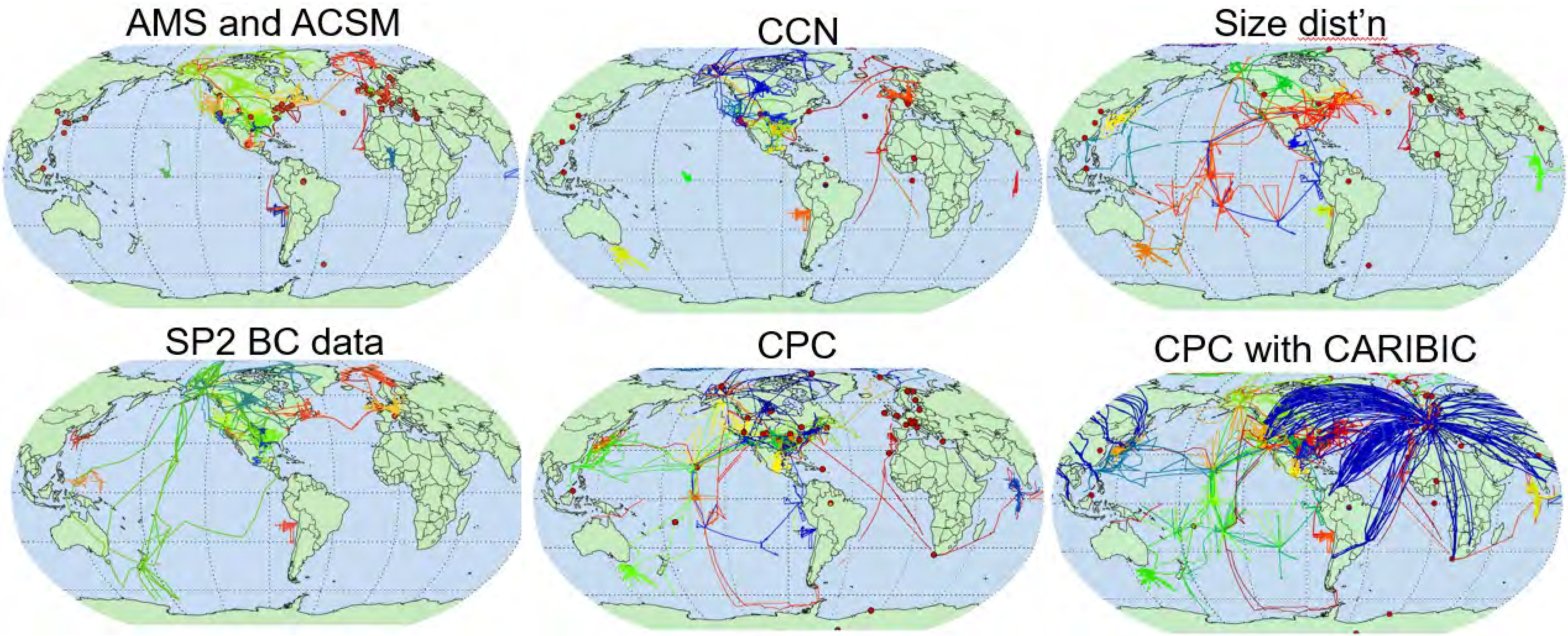
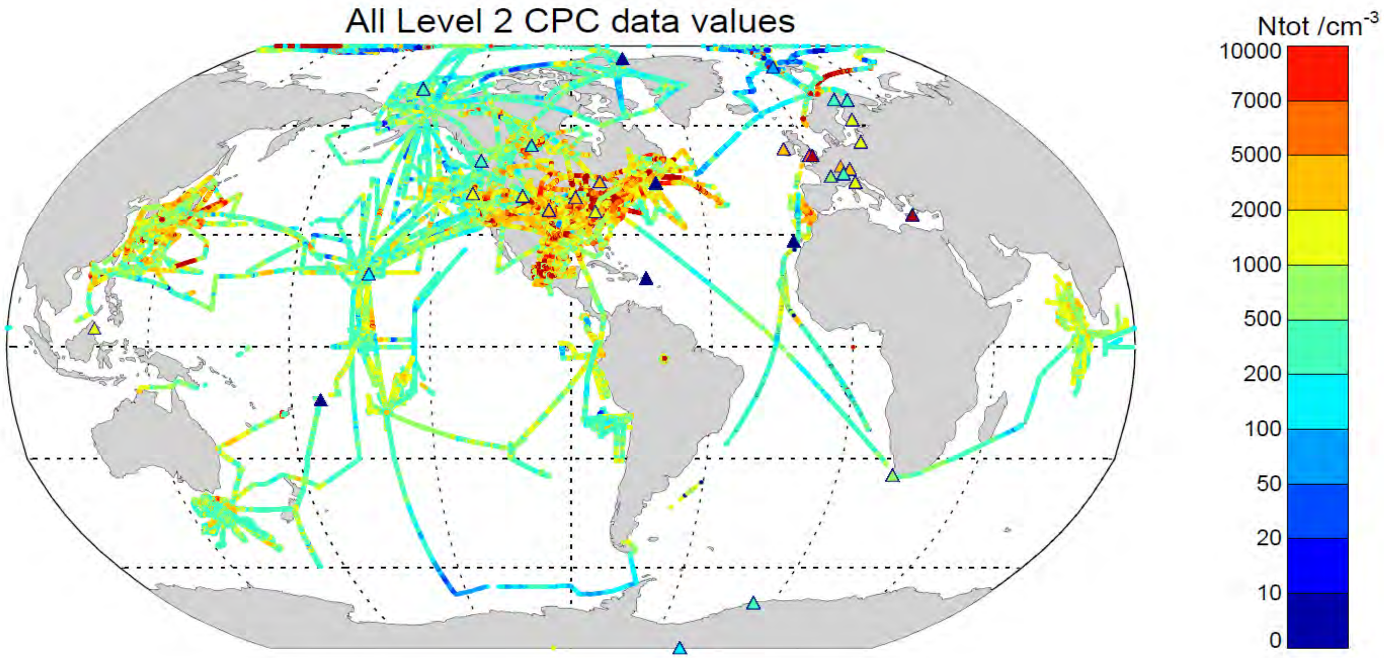
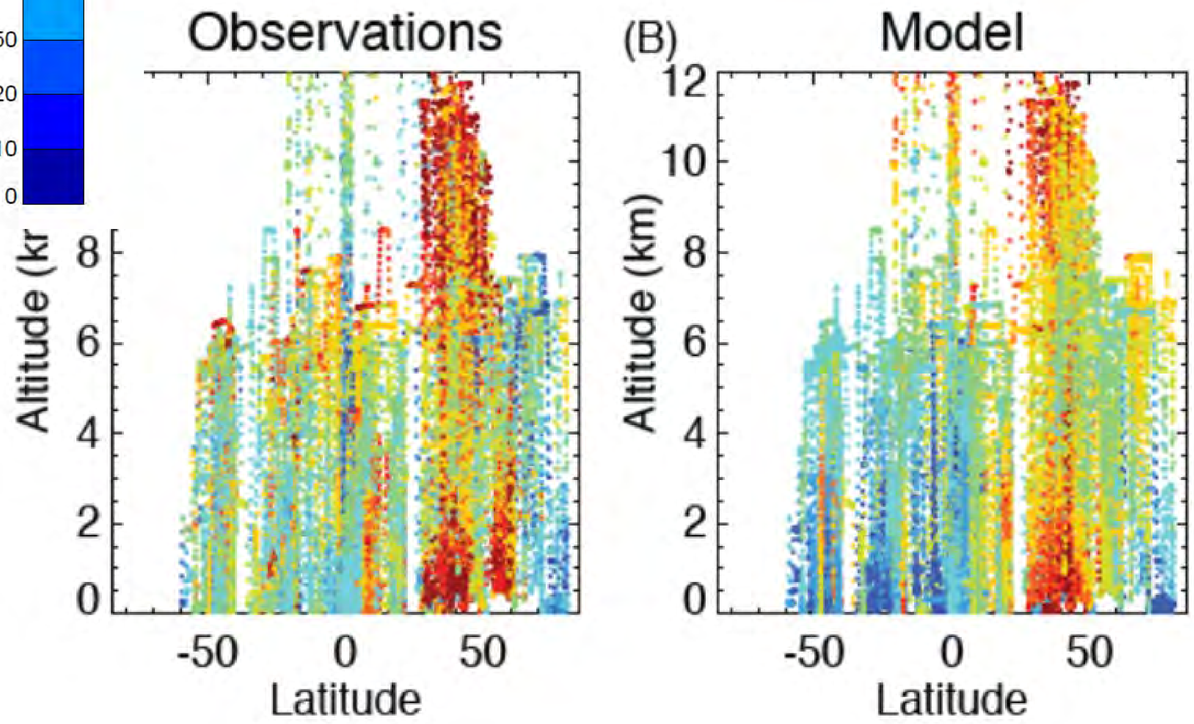


GASSP CPC data



Dunne et al., Global atmospheric particle formation from CERN CLOUD measurements, *Science* (2016)



Reduction in forcing uncertainty

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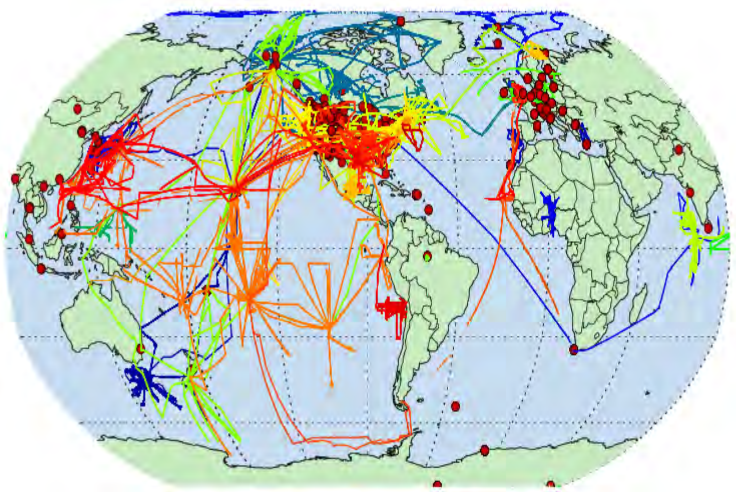
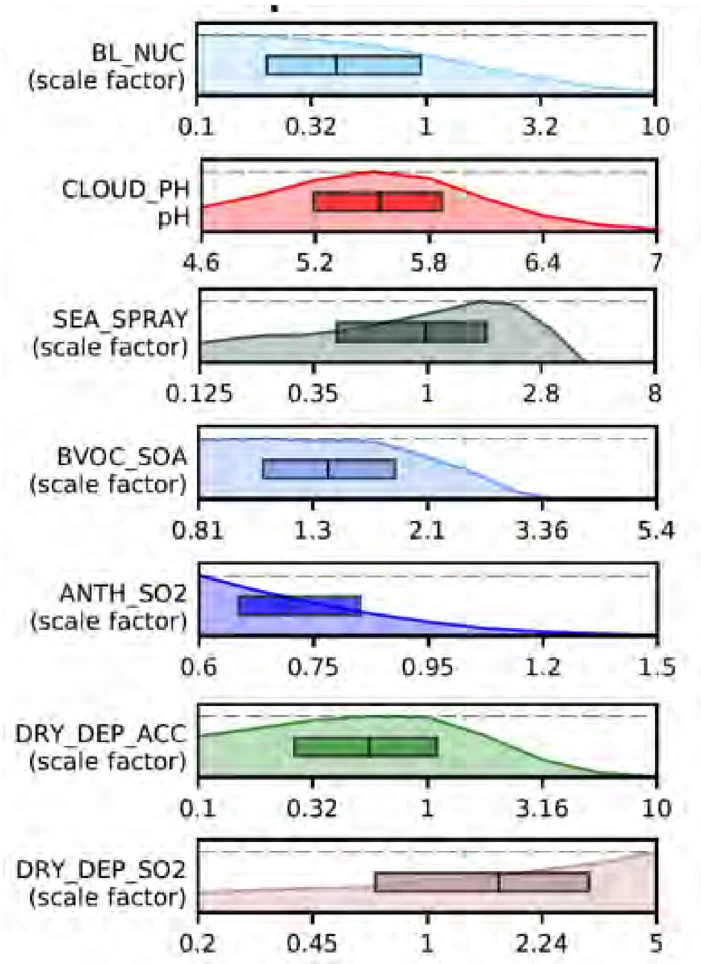
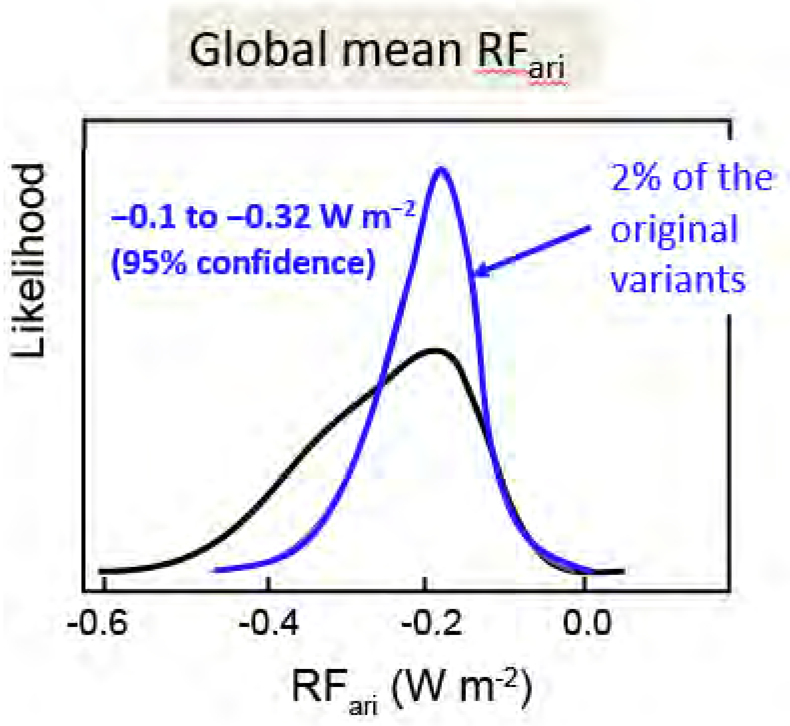
Observations → Constrained model parameters → Constrained Forcing



~9000 grid-point measurements:

- AOD
- $PM_{2.5}$
- $N_{>50nm}$
- $N_{>3nm}$
- Sulphate
- OC





Johnson et al. (ACP, 2020)

Reduction in forcing uncertainty

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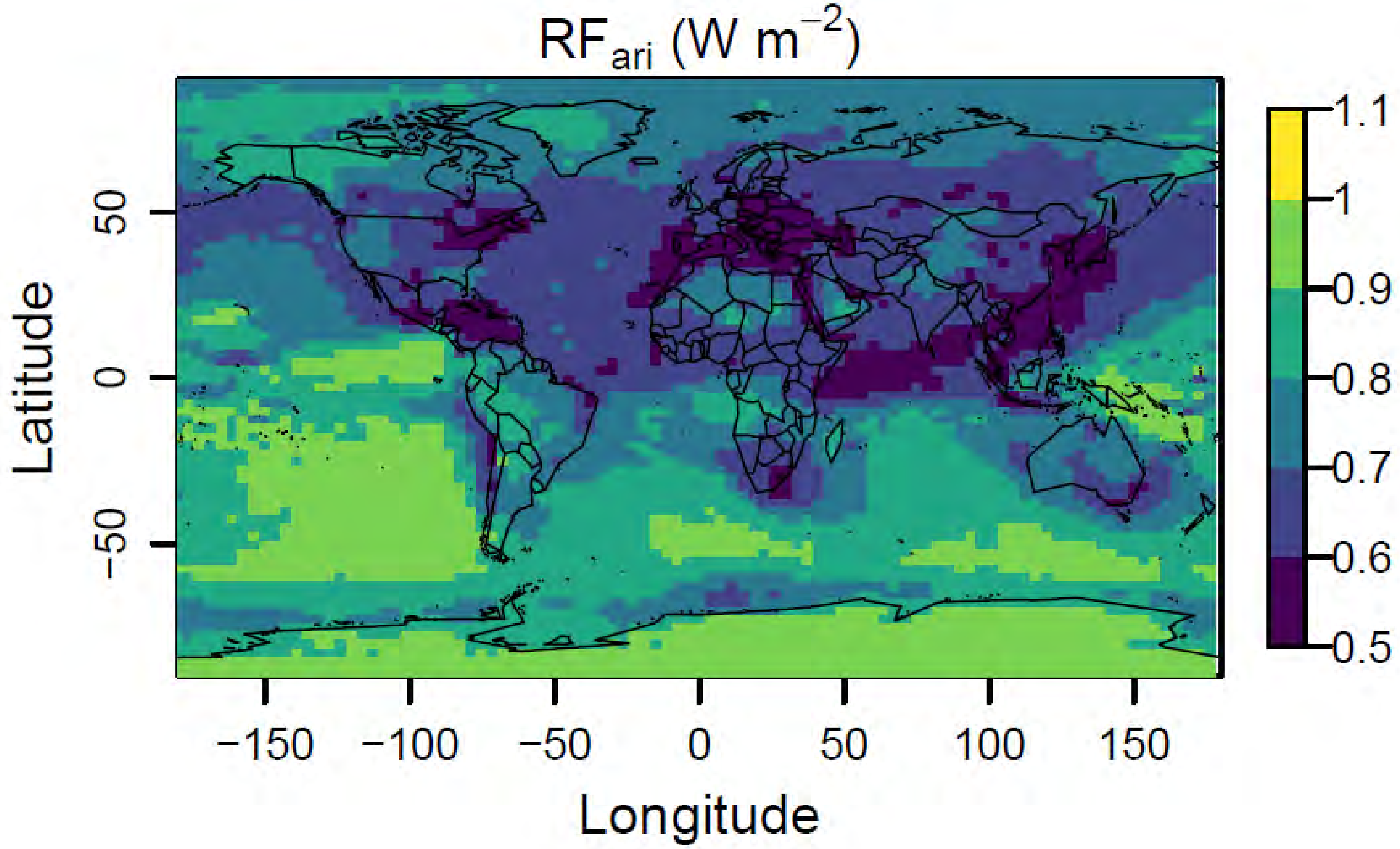
Global RF_{ari} standard deviation reduced by 34%
Local reductions up to 50%



$$\frac{\sigma_{constrained}}{\sigma_{unconstrained}}$$

What have we learned?

- Diversity of measurement types (variables) is very useful for model constraint
  - But it comes with challenges of data harmonisation
- In situ datasets are not created with large-scale automated model constraint in mind
- Measurement *representativeness errors* are a major limiting factor in constraint
- We need measurements from *characteristic aerosol environments*
  - There is a lot of ‘over-sampling’
  - We can (to some extent) define these environments

Dataset issues

Dataset heterogeneity

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In situ measurement datasets are set up for case studies, not large-scale model evaluation and constraint

Variable	#Files	#Instruments	#Variable names
CCN	18,400	4	111
Number	153,615	27	236
BC	916	4	18
PM	716	21	9
Composition	15,948	8	23
Size distribution	879	11	2

Example *Number* names

N4
CNsubten
N10
d_9p0um_particles
N3_4
N4_20
N14_NONVOL
N8TO40
N13_volatile
pa12_p14conc
pd_0p24um_particles
N150
ScNcSTP
CNcold_3760
Cnvolatile
N20_150
… Etc
… Etc.

Variable **NUM**
Variable attributes **diam_upper, diam_lower**

Other dataset problems

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Web interfaces	Manual download of sites / variables / years separately
File formats	~20 different formats: Txt, excel, csv and netCDF etc. One file per variable per day -> many variables and multiple years per file
Environmental data	T, p, location etc often in separate file with different time base
Essential data	Missing STP, cut-off sizes, wet/dry conditions, radius/diameter, $\log_{10}$ or $\log_e$
Contextual information	E.g. a plume-hunting flights not flagged
Time axis	Inconsistent. We use Unix Epoch (1 Jan 1970)
Units	Very heterogeneous (nm, e-9 m, nanometer, nanometre etc.)
Attribution	Inconsistent info on how to use/cite data

GASSP database

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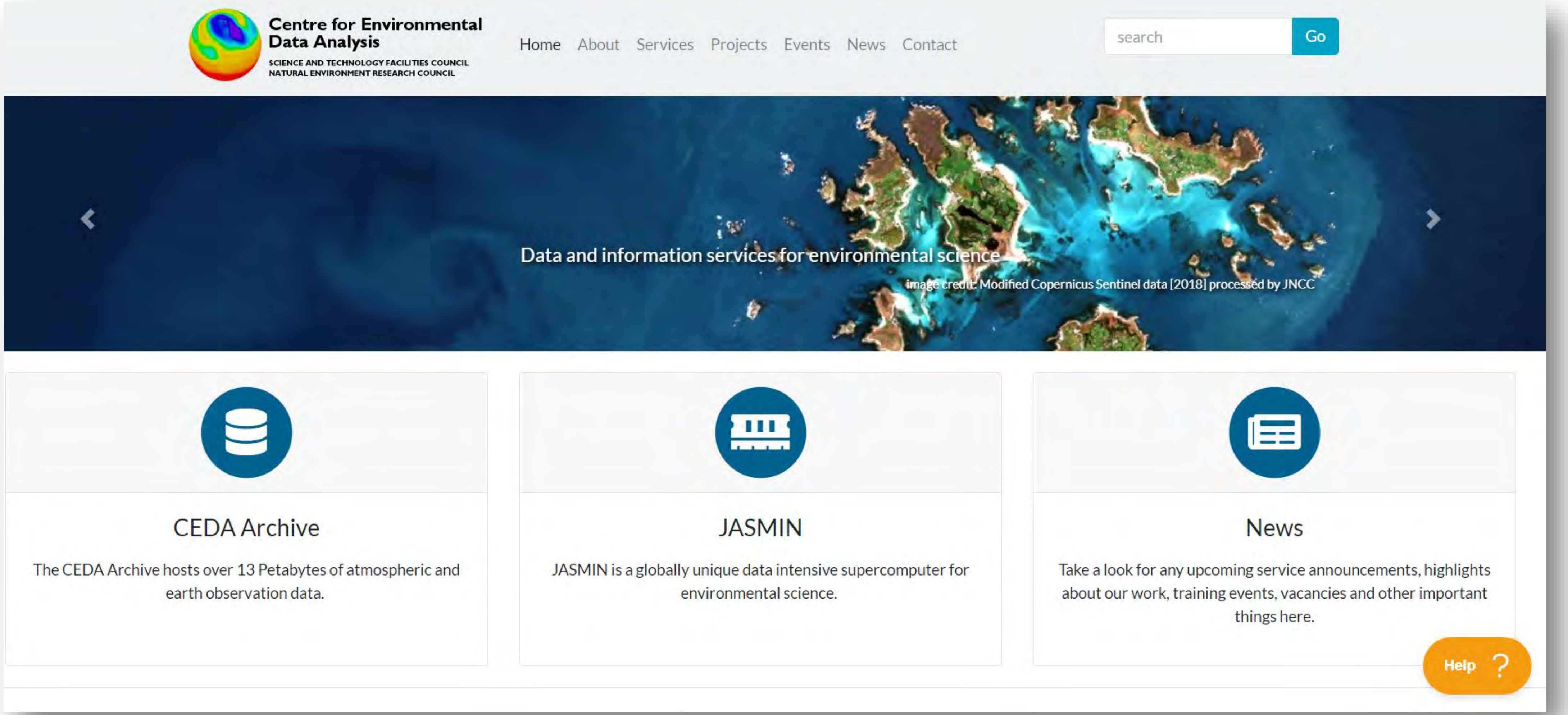
Subject to PI approval, harmonized, model-ready data will be available through CEDA in self-describing, machine-readable NetCDF format



Spatial representativeness error

Spatial representativeness errors

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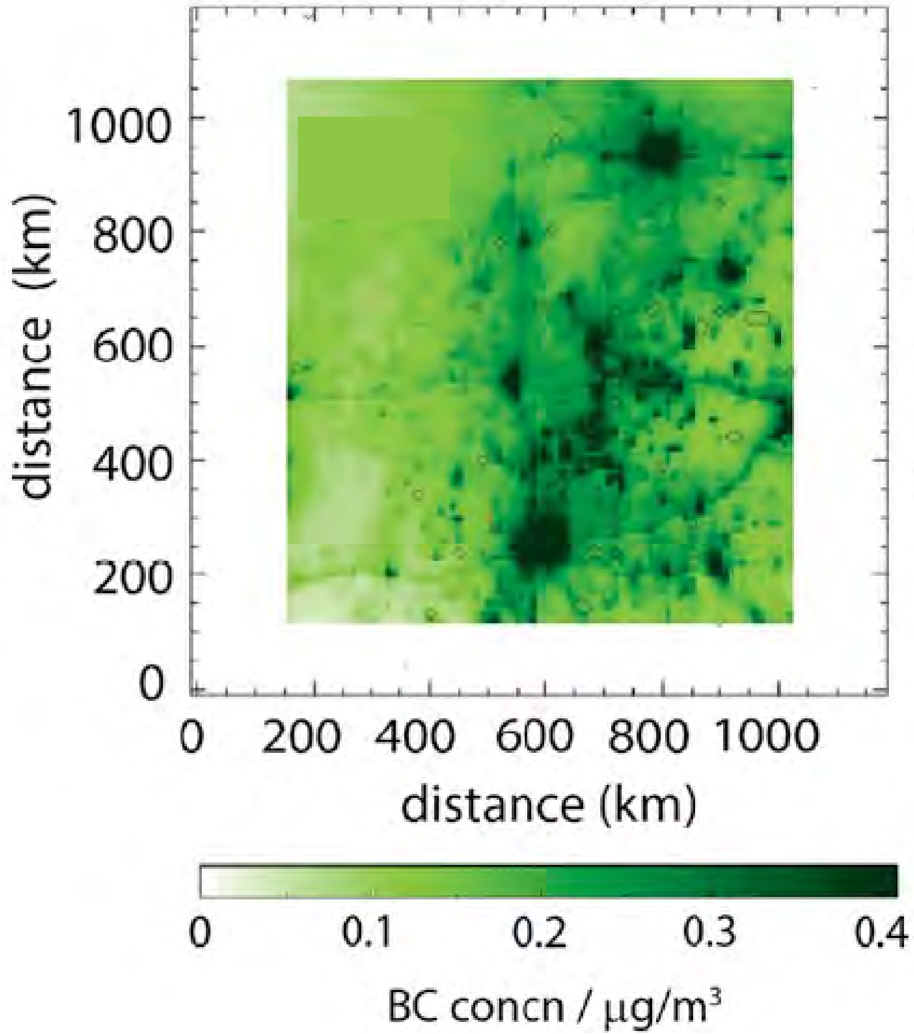
Black carbon over Oklahoma

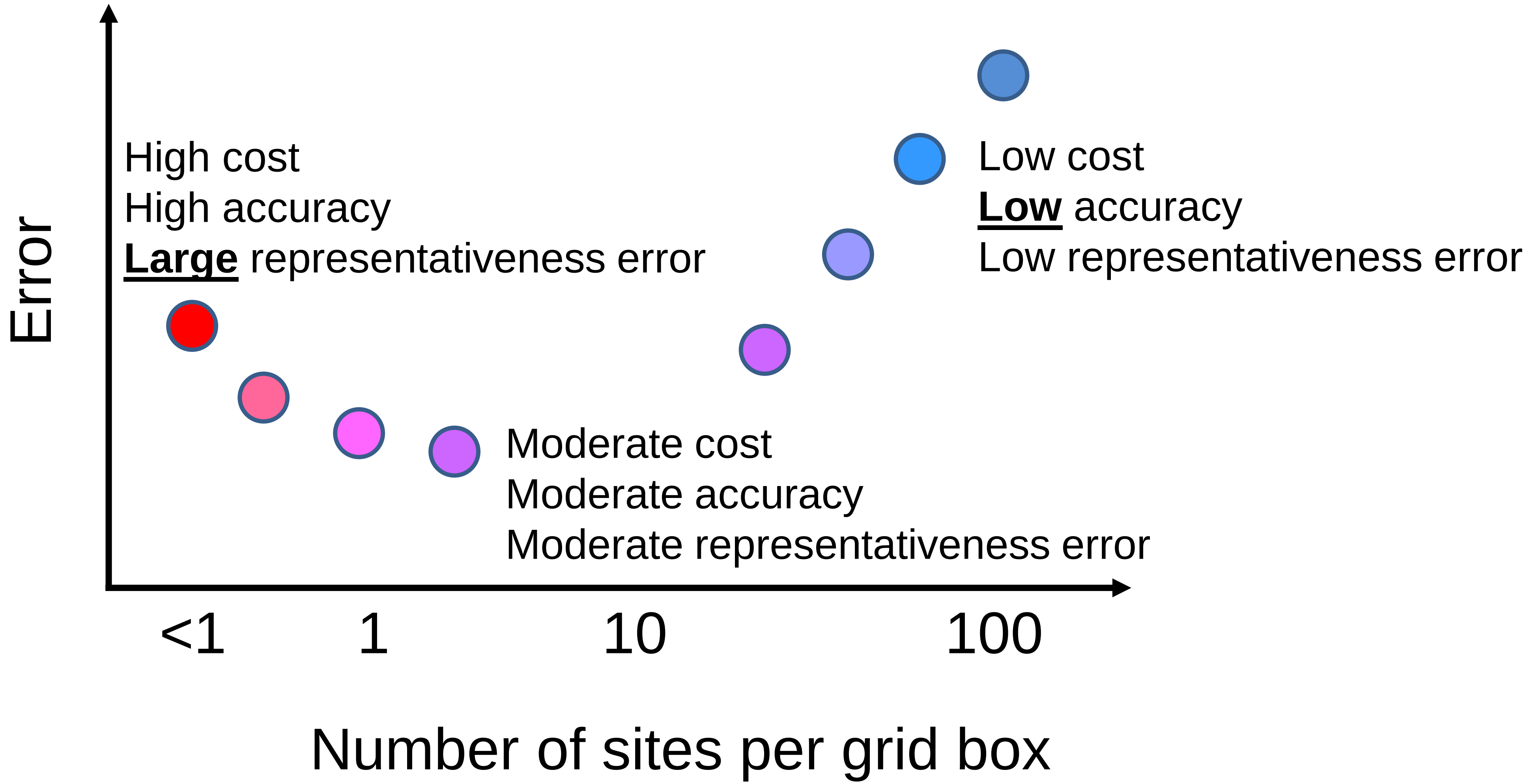


Johnson et al. ACP 2020: *"The biggest challenge (and the factor that most limits the constraint, other than model structural error) is quantification of the representativeness error associated with comparing point measurements with a global model."*

Reddington et al., BAMS, 2017

Measurement strategy to constrain models

Find sweet spot of representativeness error and instrument error



POPSNet: A pilot network to understand representativeness error

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- Portable Optical Particle Spectrometer (POPS) designed at NOAA (Gao et al. 2016)
- 0.13 – 2.5 μm
- See Lizzy Asher's AGU poster
  https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/550294

An ARM Small Campaign

Project team:
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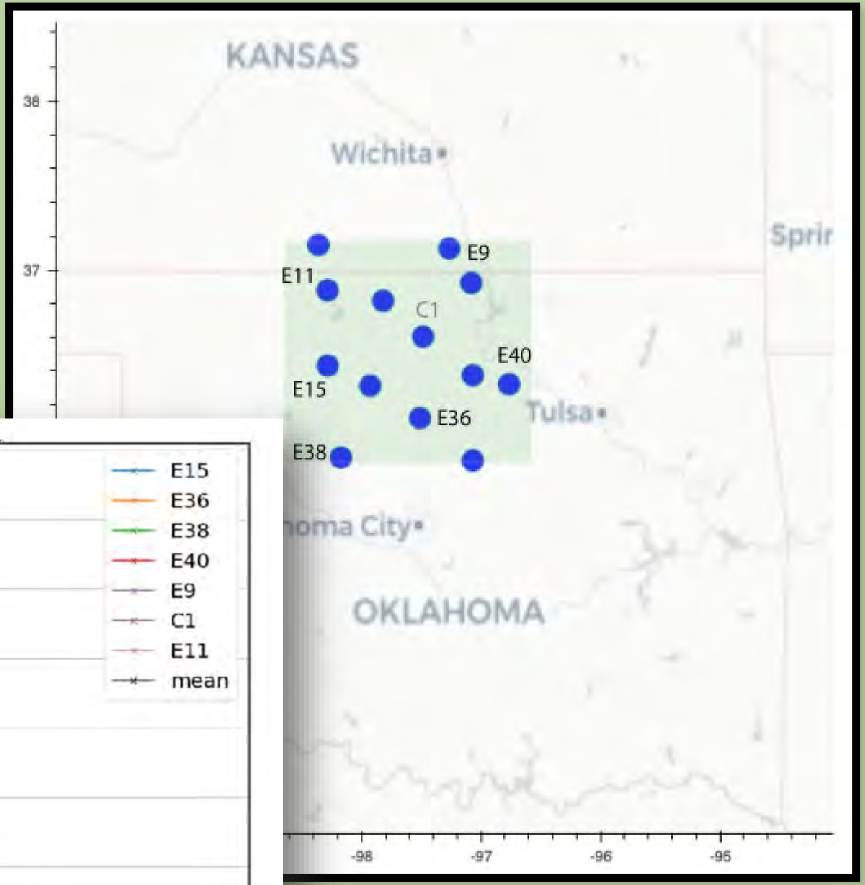
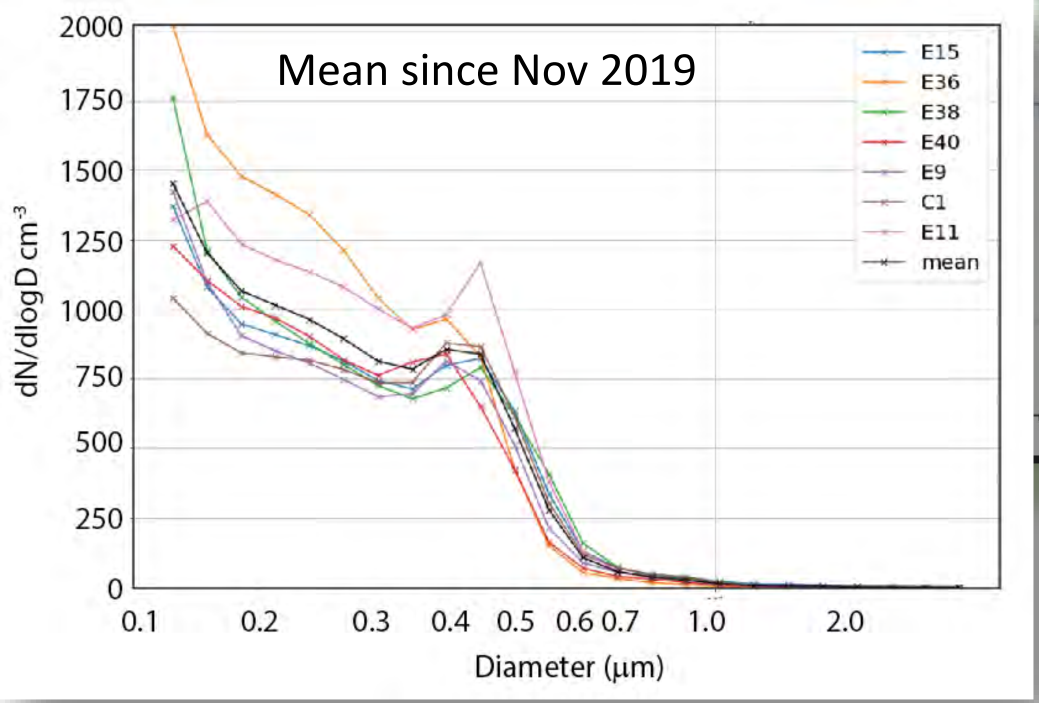
Ru-Shan Gao,
Drew Gentner



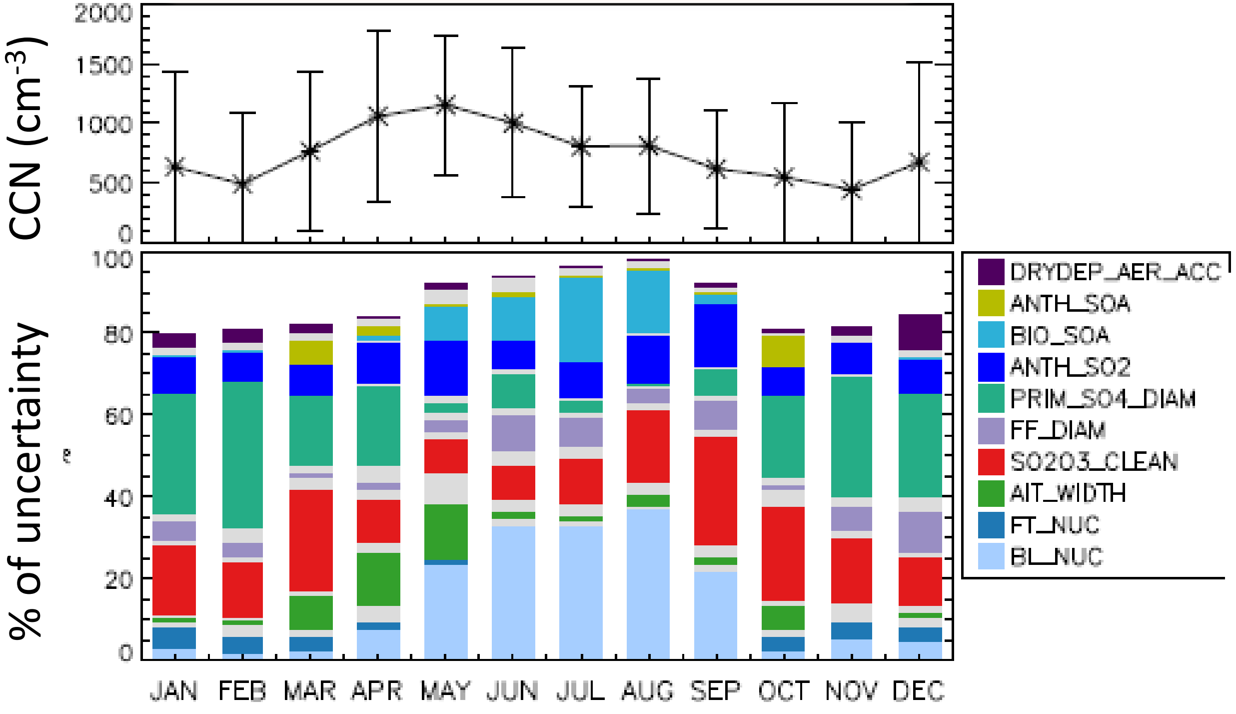


What / where to measure

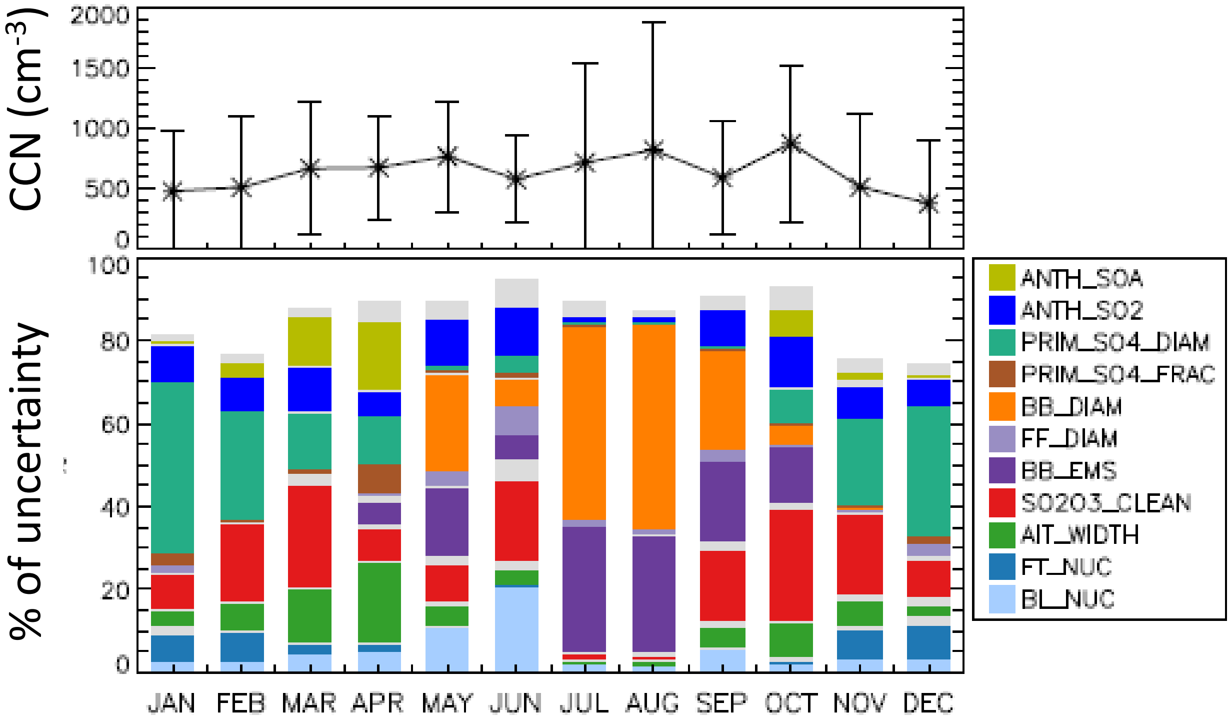
Causes of model uncertainty

Rather than clean/polluted or land/marine, we can define regions according to *model uncertainties that can be reduced*

CCN uncertainty at Hyytiala



CCN uncertainty at Tomsk



Lee et al., The magnitude and causes of uncertainty in global model simulations of cloud condensation nuclei, ACP, 2013

Model uncertainty clusters

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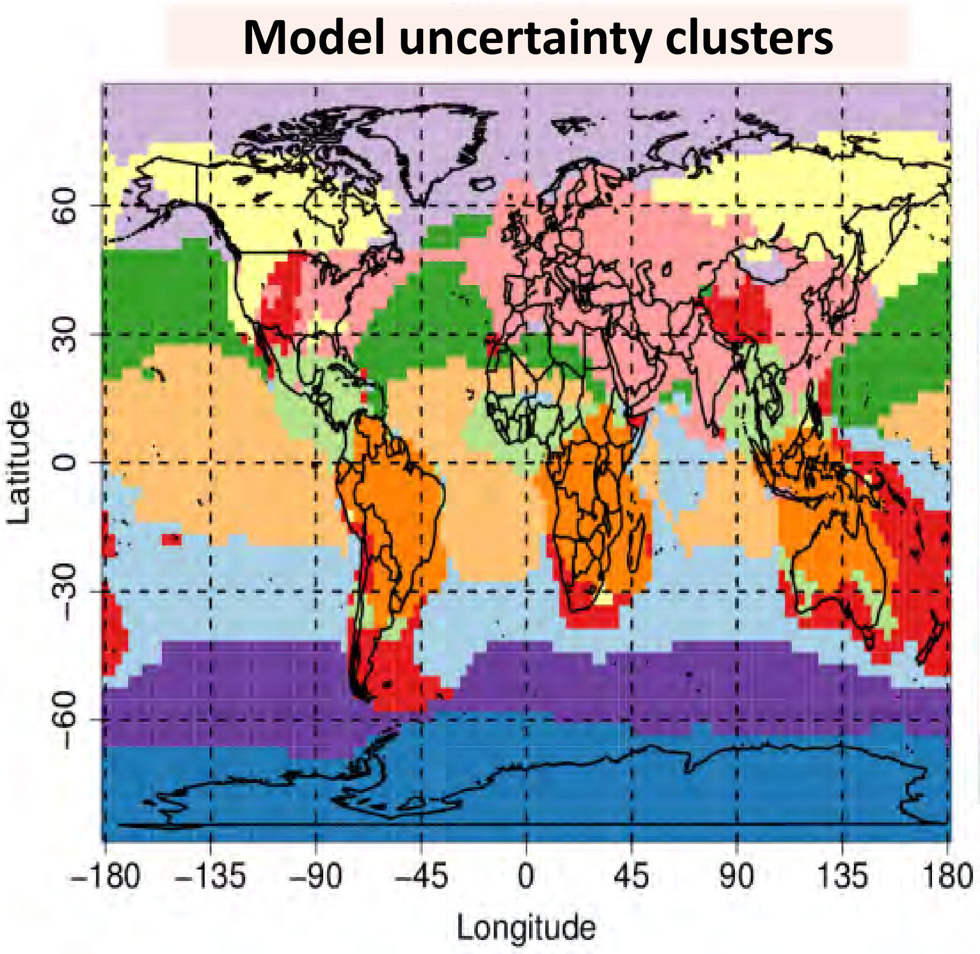

Lee et al., On the relationship between aerosol model uncertainty and radiative forcing uncertainty, PNAS, 2016

Summary

1. GASSP database of aerosol microphysical and chemical properties harmonized and made machine-readable ~200,000 data files
2. Used successfully to constrain global aerosol model uncertainty
3. “Mass use” of in situ datasets presents huge challenges because of dataset heterogeneity and lack of inter-operability
4. Model-measurement representativeness errors are possibly more important than instrument error – a measurement strategy to reduce this error would be valuable
5. Model sensitivity analysis can provide a guide to “what to measure where”

GASSP data versus time

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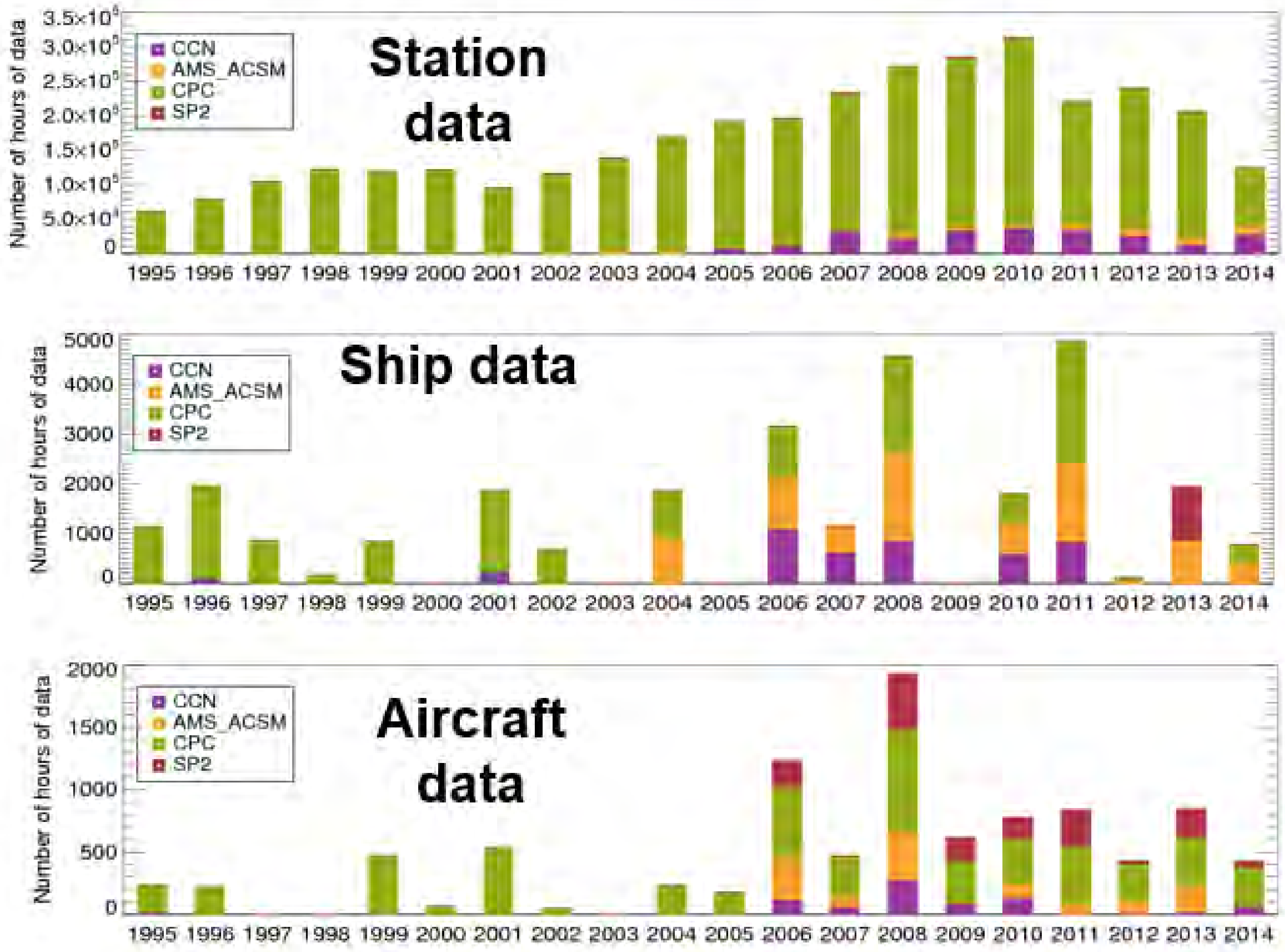

Reddington et al., BAMS, 2017

GASSP data versus latitude

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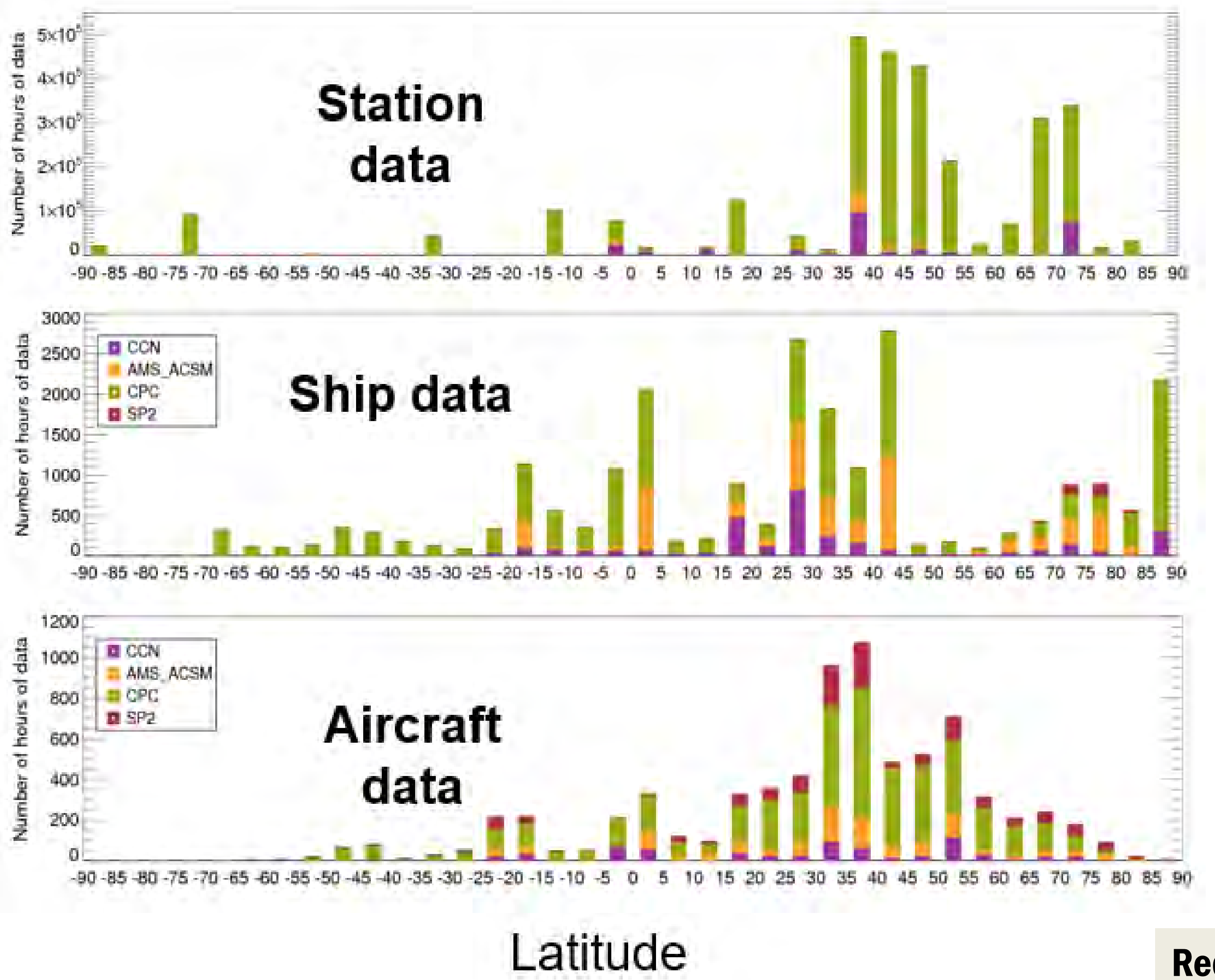

Reddington et al., BAMS, 2017

Networks used in GASSP

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Network acronym	Network name	Years	Location	Measurement
—	EBAS	1990–2014	Europe, North America, Arctic, Antarctica, Asia	N, NSD, Comp, BC, $PM_{2.5}$
ACTRIS CCN	Aerosols, Clouds, and Trace Gases Research Infrastructure CCN data	2010–14	Europe, Arctic, Brazil, South Korea	CCN
ARM	Atmospheric Radiation Measurement Program	1995–2015	Germany, United States, Brazil, Arctic, eastern Atlantic Ocean, China, India, Niger	N, NSD, CCN, Comp
AMS Global Database	Aerosol Mass Spectrometry Global Database	2000–11	Europe, North America, East Asia, South Africa, Atlantic Ocean, South America	Comp
IMPROVE	Interagency Monitoring of Protected Visual Environments	1990–2014	North America (United States)	$PM_{2.5}$
NAPS	National Air Pollution Surveillance Program	1990–2014	North America (Canada)	$PM_{2.5}$
A-PAD	Asia–Pacific Aerosol Database	2002–11	Asia	$PM_{2.5}$

Instruments used in GASSP

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Acronym	Instrument	Manufacturer	Reference(s)
CPC	Condensation particle counter	Various (mostly TSI Inc.)	—
SMPS (DMPS)	Scanning (differential) mobility particle sizer	Various [e.g., TSI Inc. (Shoreview, MN), Grimm GmbH (Ainring, Germany)]	Wiedensohler et al. 2012
DMA	Differential mobility analyzer	Various	—
APS	Aerodynamic particle sizer	TSI Inc. (Shoreview, MN)	—
UHSAS	Ultra-high-sensitivity aerosol spectrometer	Droplet Measurement Technologies	—
PCASP	Passive Cavity Aerosol Spectrometer Probe (PCASP-100X)	Droplet Measurement Technologies	—
OPC	Optical particle counter	GRIMM Aerosol Technik GmbH and Co.KG	—
CCNC	Cloud condensation nuclei counter	Droplet Measurement Technologies, University of Wyoming	Roberts and Nenes 2005; Snider et al. 2006
—	Aethalometer	Magee Scientific	Hansen and Novakov 1989
PSAP	Particle soot absorption photometer	Radiance Research	—
MAAP	Multiangle absorption photometer	Thermo Scientific	Petzold and Schönlinner 2004
OCEC	Organic carbon elemental carbon analyser	Sunset Laboratories, Desert Research Institute	Birch and Cary 1996
AMS	Aerosol mass spectrometer	Aerodyne Research	Canagaratna et al. 2007
ACSM	Aerosol chemical speciation monitor	Aerodyne Research	Ng et al. 2011
PILS	Particle into liquid sampler	Brechtel Manufacturing Inc.	Weber et al. 2001
SP2	Single particle soot photometer	Droplet Measurement Technologies	Schwarz et al. 2006
—	Gravimetric filter analysis	GENT sampling unit, IMPROVE module A with cyclone inlet, Teflon filter	Hopke et al. 1997

Learning about model structural errors