A joint initiative of

ccmi
chemistry-climate model initiative

AeroCom

# AerChemMIP

Main contributors (so far)
Olivier Boucher (France)
William Collins (UK)
Veronika Eyring (Germany)
Jean-François Lamarque (USA)
Michaela Hegglin (UK)
Gunnar Myhre (Norway)
Michael Prather (USA)
Michael Schulz (Norway)
Drew Shindell (USA)
Steve Smith (USA)

# Motivation for having AerChemMIP

- Address shortcomings of CMIP5 with respect to documenting composition changes (mostly aerosols and ozone)
- Define combined metrics and diagnostics for composition evaluation
- Identify science questions of relevance to CMIP6 and define the associated simulations
- Single entity to interact with other CMIP6 contributors, including emissions and forcing estimates.
- Chemistry and aerosol model components are tightly linked in many climate models

# Shortcomings in CMIP5 in relation to SLCFs

- ✓ Scenarios (RCPs) are too similar in their projected emissions of short-lived climate forcers (aerosols and tropospheric ozone)
- ✓ No straightforward way of identifying the costs/benefits of air quality measures (including health impacts)
- ✓ No detailed analysis/evaluation of composition from CMIP5 models (output data mostly unavailable)
- ✓ No CMIP5-integrated calculation of radiative forcings from aerosols or homogeneous diagnostics wrt to aerosols and chemical composition
- ✓ Attribution to aerosol effects difficult
- ✓ Limited study of chemistry-climate interactions

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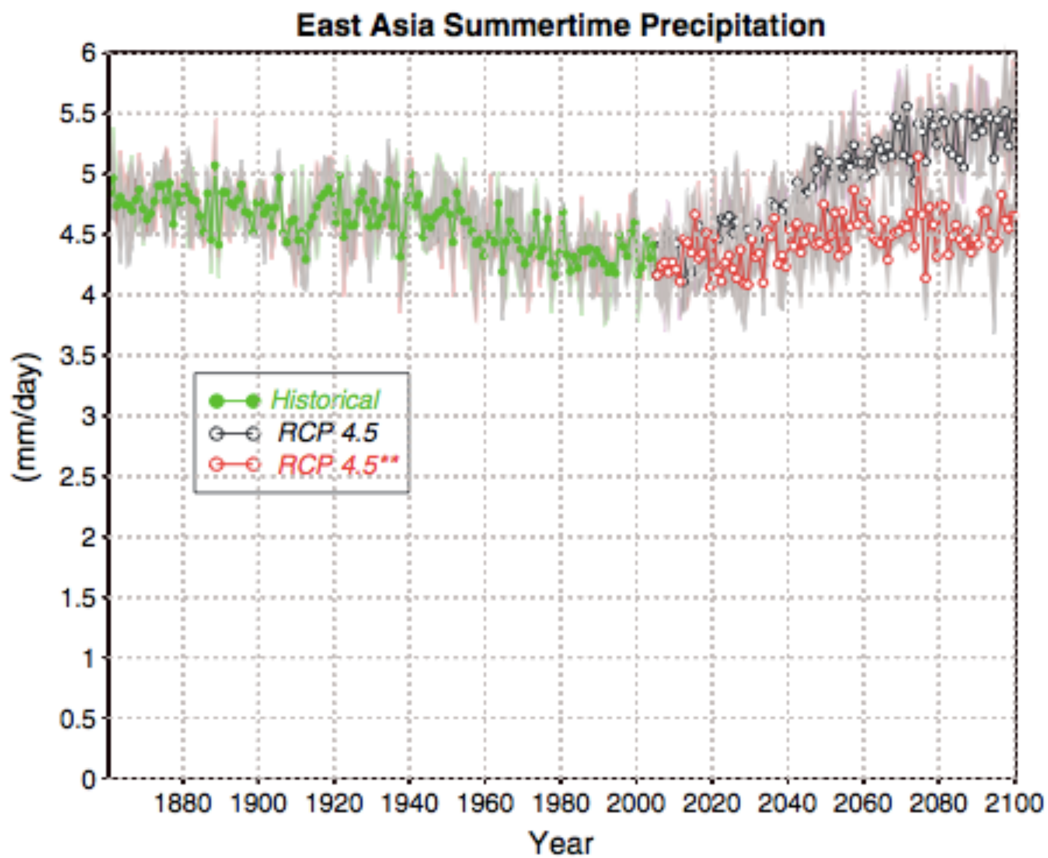
- ✓ No CM … cings from aeroso … osols and chemic…
- ✓ Attribu…
- ✓ Limite…




Levy et al., JGR, 2013

# AerChemMIP in support of CMIP6

- Interest in having scenarios to look at impacts of SLCFs. (i.e. differential scenario pairs)
- Define other scenarios of interest, e.g. Natural gas/methane for power generation?
- Understand trends in composition
- Role of natural aerosols, aerosol-chemistry coupling, other feedbacks
  (Organic Aerosols, Fires, Dust & Seasalt, OH, Radiation, Dynamics)
- Usage of observational constraints to bracket projections (current processes)
- Stratospheric impacts on climate (strat-trop coupled system)
- Identify relationship between regional forcing and climate response
- Documentation of composition, forcings and feedbacks in CMIP6
- Provide link to detailed modeling in CCMI & AeroCom
- Propose aerosol and ozone climatology fields for high resolution climate modeling
- Environmental surface (ozone, PM , nitrogen/sulfur deposition) impacts (diagnostics/evaluation) connection with scenarios (population, landuse,...)

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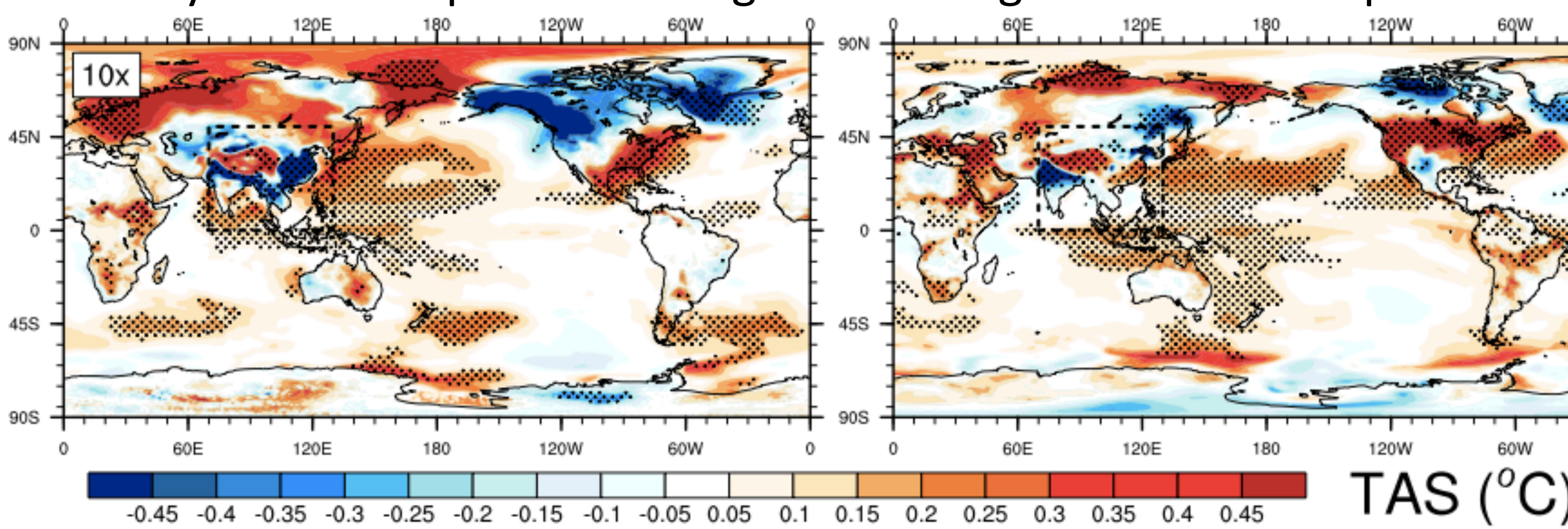

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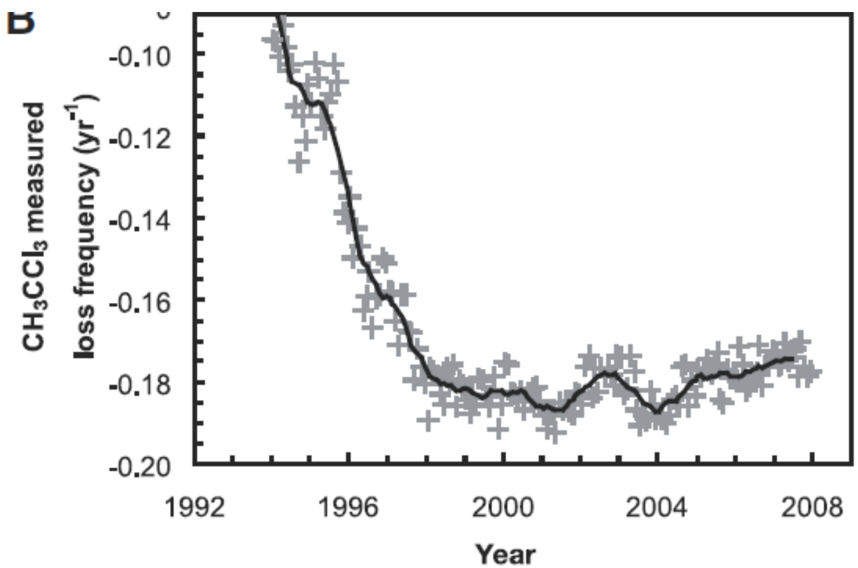
# AerChemMIP:

## Model sensitivity to OH (oxidative capacity)

## Measurements of OH var and sensitivity

**Small Interannual Variability of Global Atmospheric Hydroxyl**

S. A. Montzka,[1]* M. Krol,[2,3] E. Dlugokencky,[1] B. Hall,[1] P. Jöckel,[4]† J. Lelieveld[4,5]




C. D. Holmes et al.: Future methane,

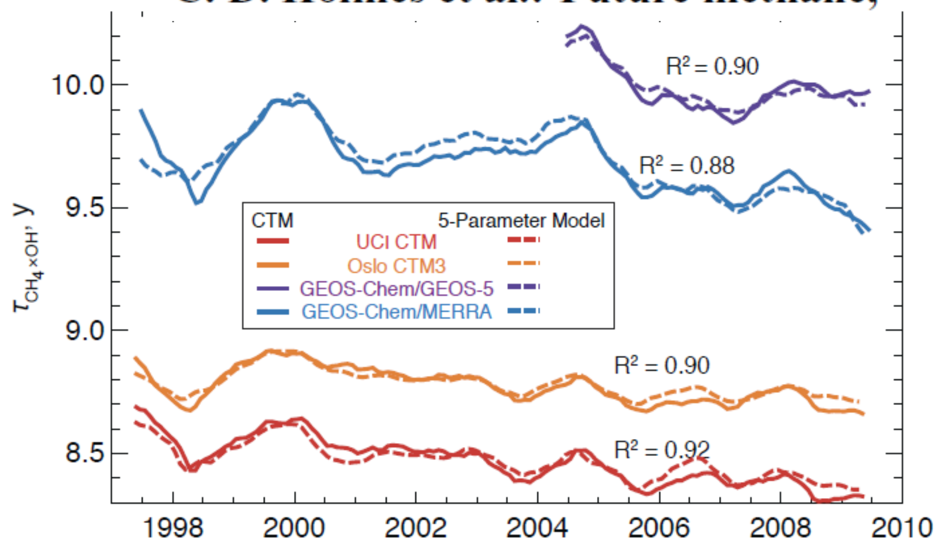



**Fig. 1.** Methane lifetime due to oxidation by tropospheric OH ($\tau_{CH_4\times OH}$) simulated by each CTM (solid lines) and reconstructed from the 5-parameter model (dashed lines). The parameters are air temperature, water vapor, ozone column, lightning $NO_X$ emission, and biomass burning emission. Parameter values for each CTM are

# AerChemMIP:
## Model surface O3 extremes.
## Will they change with climate?

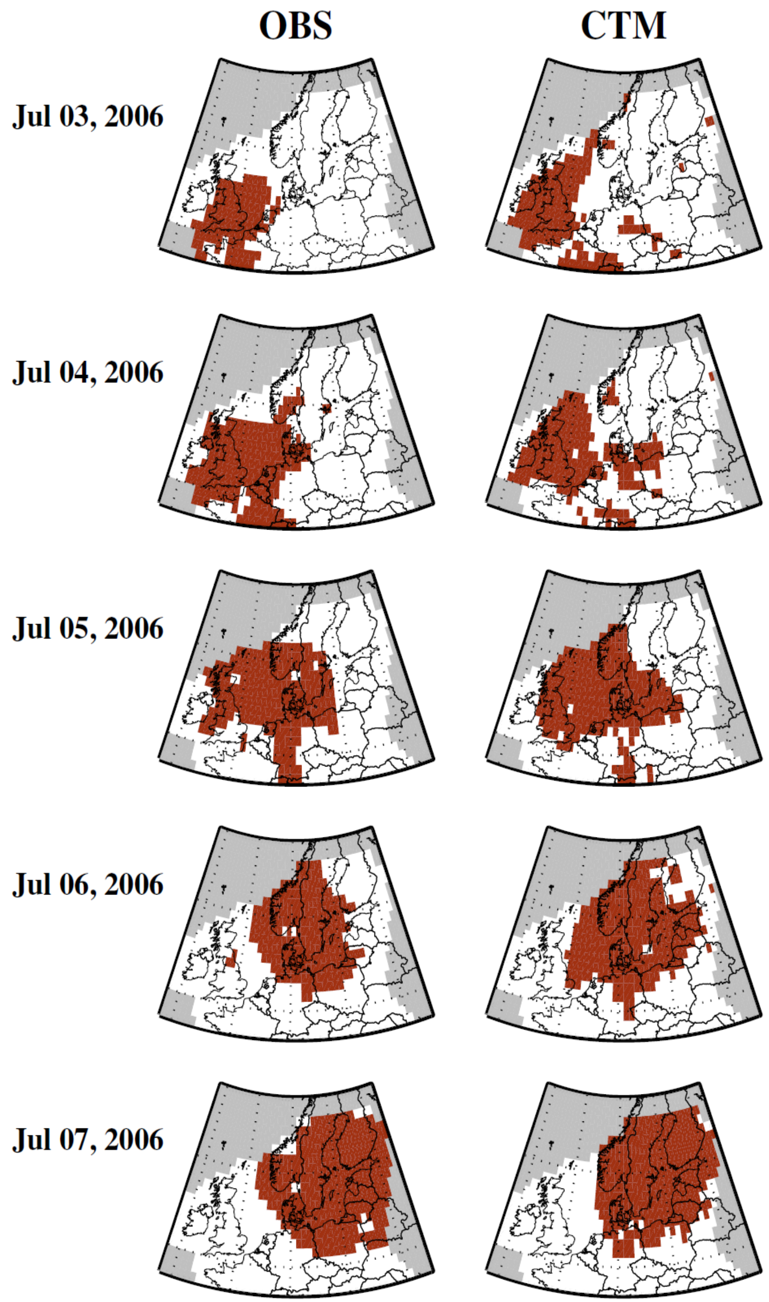
## Measurements of surface AQ over US

Air Quality Extreme (AQX) events ***[red 1x1 cells]***, when identified as 97%ile form mega-episodes,

=> matched by global model hindcast.

TODAY bad years have:
- (1) most AQX events
- (2) largest AQX episodes
- (3) highest mean $O_3$.

Will this get better or worse in future climate?

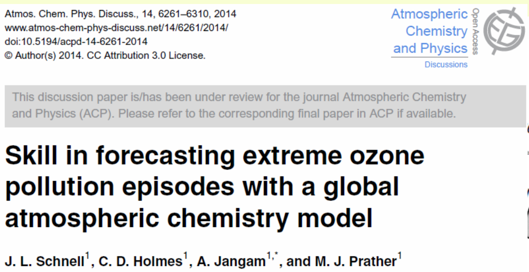



*Schnell ++, 2014 ACPD (current)*

# *ACCMIP hourly surface $O_3$ diagnostics:* *Model tests with full EU/US surface sites*

*from J. Schnell et al 2014 ACP , UC Irvine*

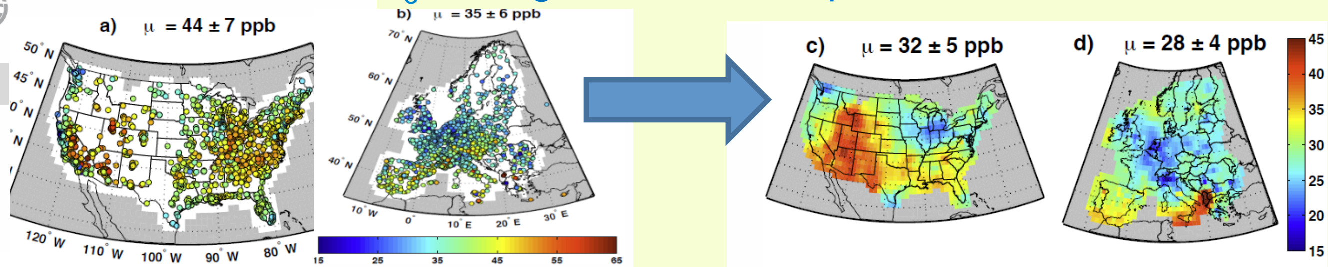
## surface AQ $O_3$ sites gridded for comparison with ACCMIPs


Atmos. Chem. Phys. Discuss., 14, 6261–6310, 2014
www.atmos-chem-phys-discuss.net/14/6261/2014/
doi:10.5194/acpd-14-6261-2014




**Skill in forecasting extreme ozone pollution episodes with a global atmospheric chemistry model**

J. L. Schnell[1], C. D. Holmes[1], A. Jangam[1,*], and M. J. Prather[1]

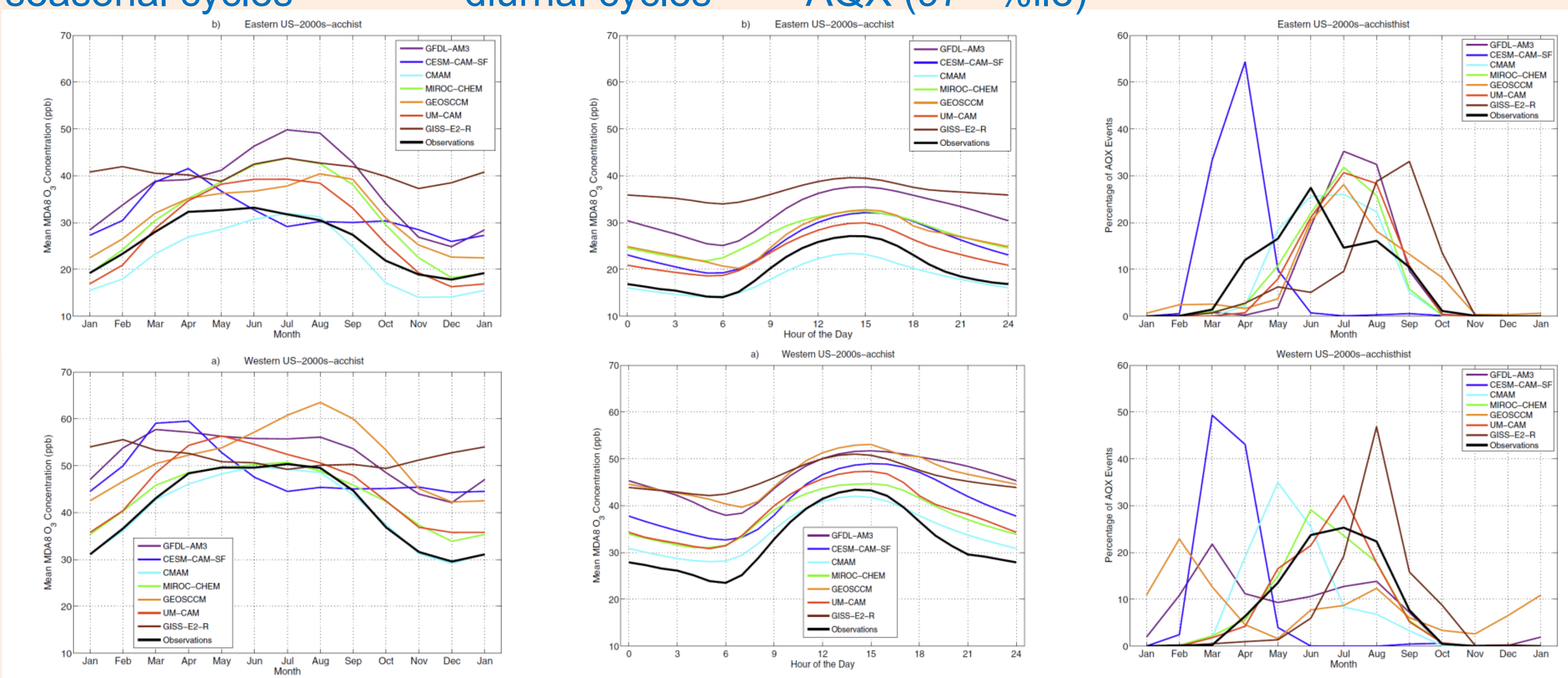



## Test 2000s decade of ACCMIP for:

seasonal cycles | diurnal cycles | AQX (97$^{th}$ %ile)

eastern US

western US



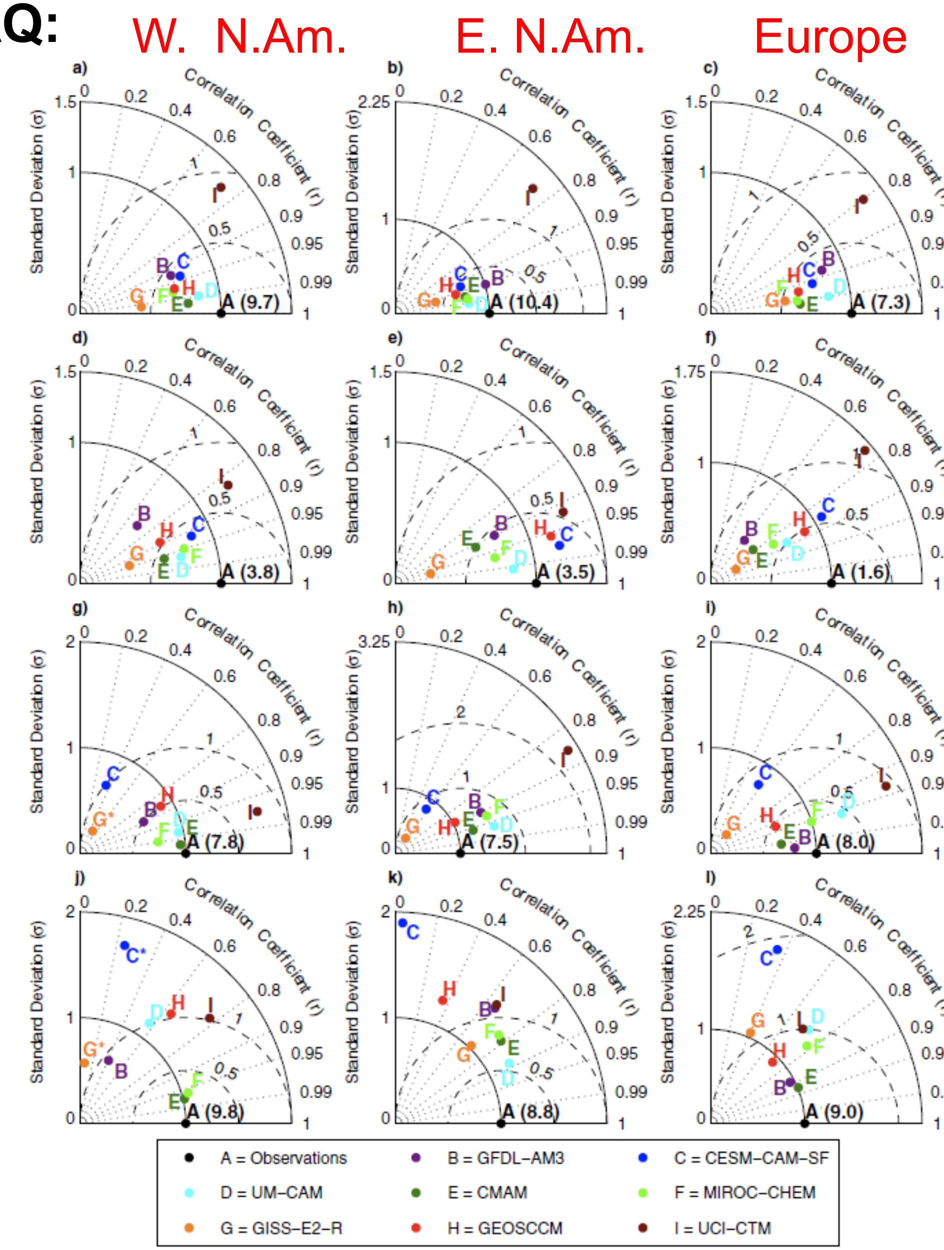
# Taylor diagrams for surface AQ:

Summer (JJA) diurnal cycle

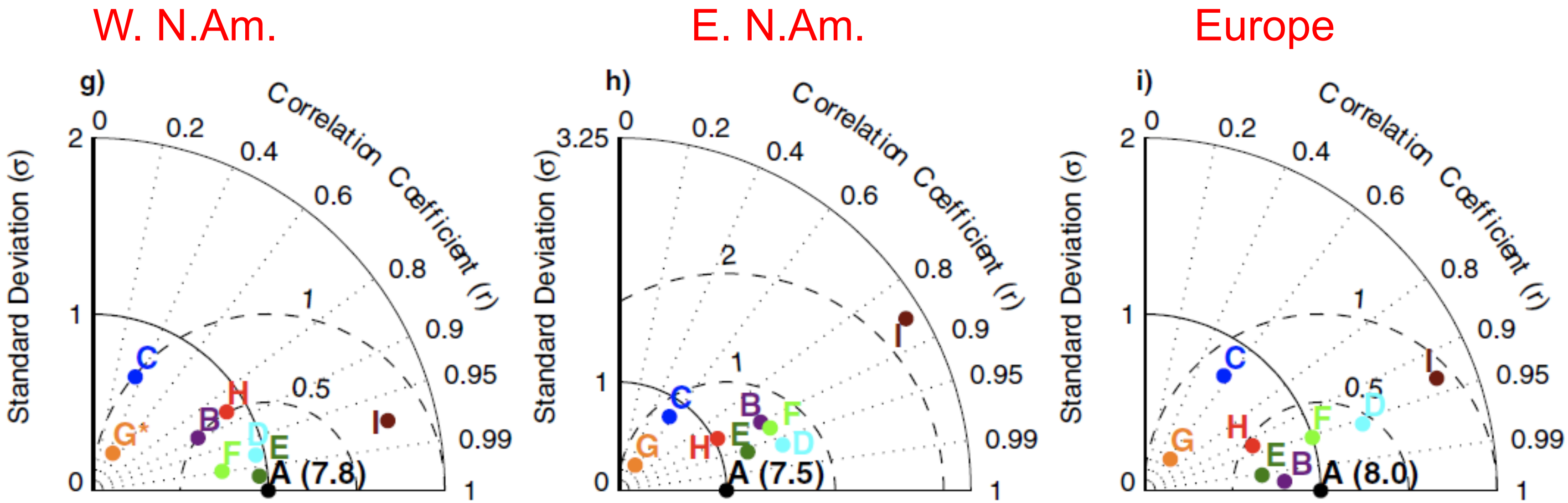
Winter (DJF) dirunal cycle

Seasonal cycle

AQ extreme events /month



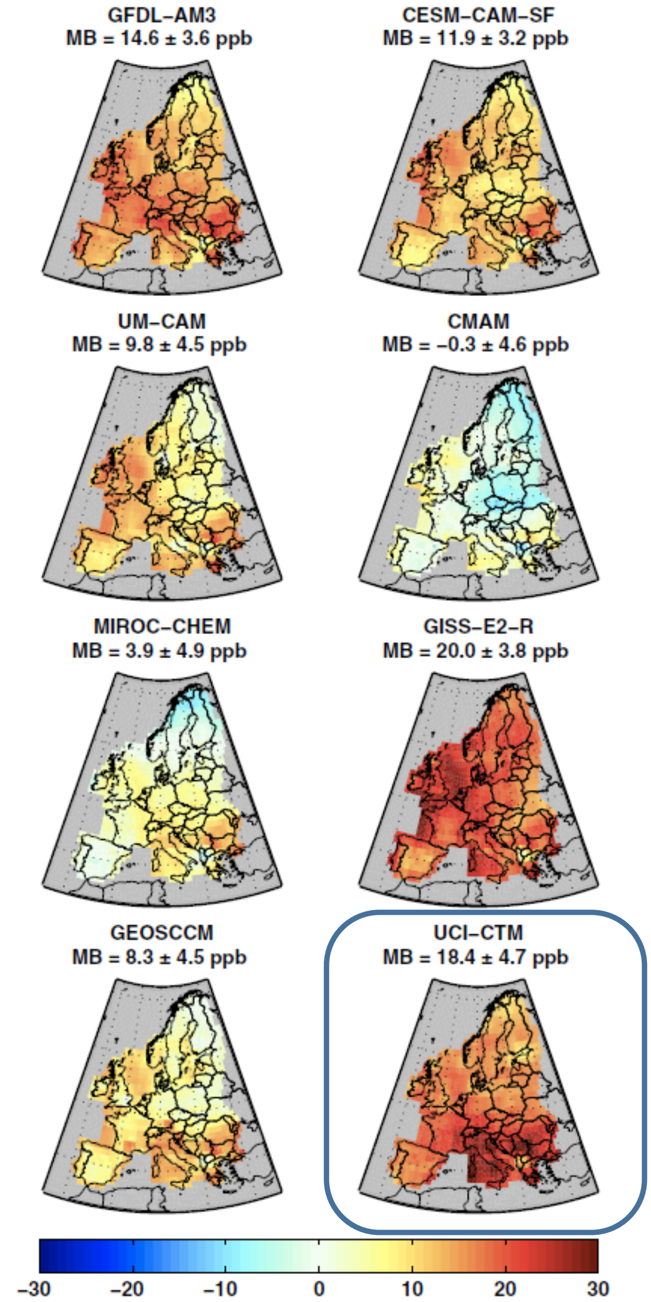
Seasonal Cycle



ACCMIP model biases:

EU summer (JJA) $50^{th}$ %ile

UCI CTM treated here as 'climate' model, but as a hindcast,
it can look different !

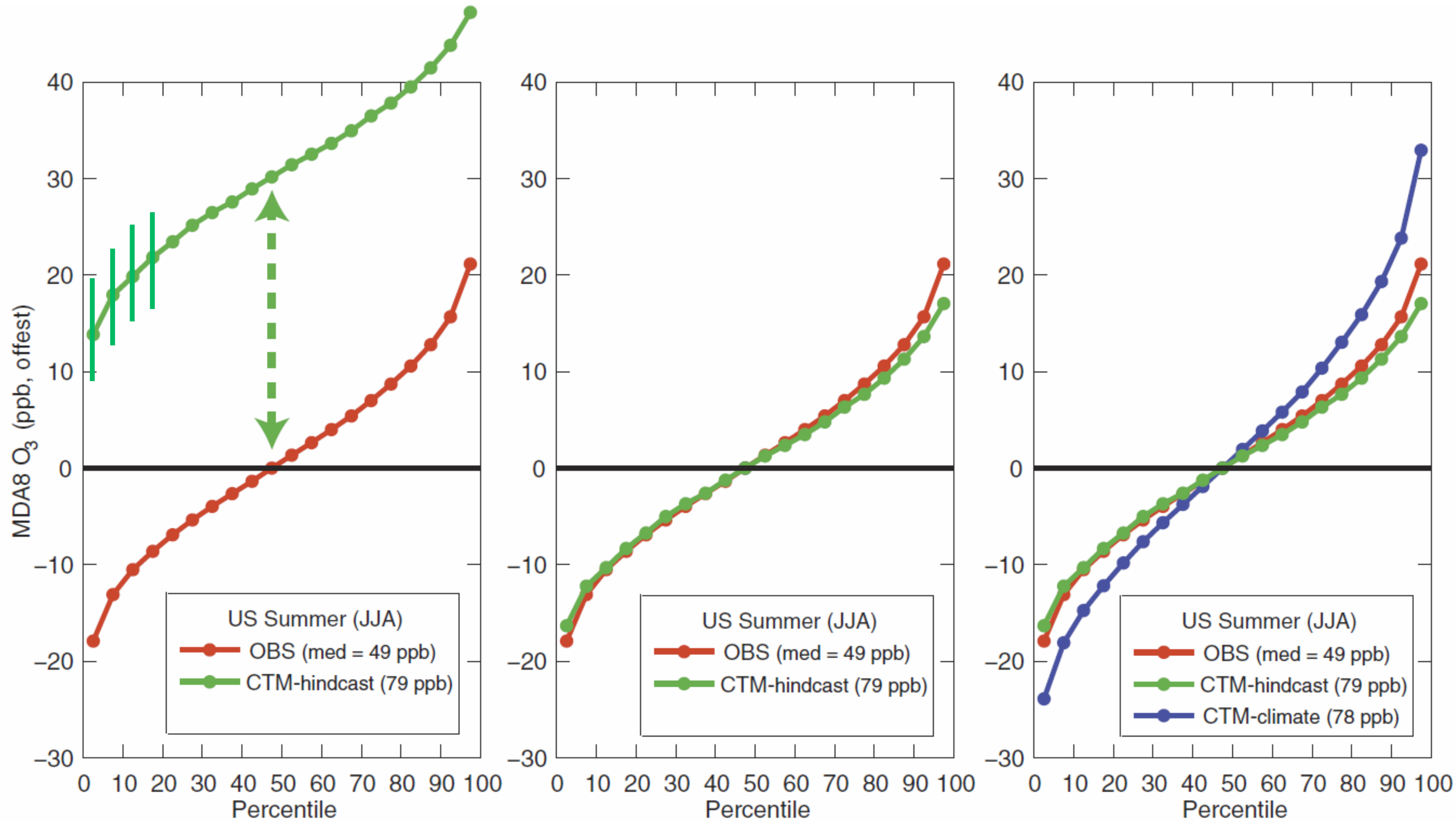


Cumulative probability distribution of $O_3$ (MDA8, ppb) for the US in Summer (JJA)

**Observations binned** at every 5th percentile

**CTM-hindcast binned for exact-day** matches w/observations (**concurrent**)

**CTM-climate binned independently** of the observations



# Historic Data For Anthropogenic Emissions

STEVEN J. SMITH
Joint Global Change Research Institute

Department of Atmospheric and Oceanic Science
University of Maryland
College Park, MD

AGCI

August, 2014

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

UNIVERSITY OF MARYLAND

# Historical Emissions for CMIP6

**The community (funders + scientists) needs to make a choice**

- Are MIPs idealized exercises to compare models?
  - If so, then any "reasonable" emissions can be used for the models since the key goal is to have the same inputs for all models
- However, if the model results are meant to be compared to observations, then emissions should:
  - Be a "best estimate" of actual emissions, 2) have consistent trends over time
  - Contain uncertainty estimates (otherwise, how doyou compare with observational data?)
- If the model results are meant to be have some policy relevance for atmospheric chemistry
  - Then emissions should be based on country inventory data where those are judged (by the scientific community) to be adequate

**This can be done, but it requires a dedicated effort.**

- For CMIP5, we got lucky. By coincidence, several individuals were able to devote quite a lot of time, building off of current projects, to put together a historical dataset. That won't happen this time.

# What is “Plan B”

**What can be done without a dedicated historical emissions effort for anthropogenic emissions in general**

1) Use gridded RCP from 1850-2000 with EDGAR-HTAP 2000-2005 and EDGAR-HTAP v2 (2008, 2010) gridded emissions.
   - Grids not consistent over time.
   - Not most recent years.
   - Country level, emissions should be somewhat, consistent.
   - No seasonality.
2) Use EDGAR v4.3 (1970-2010) + RCP before 1970
   - Annual resolution from 1970 - 2010
   - Won’t contain the most recent years.
   - Consistent from 1970, but break to 1960.
   - Not consistent with country inventories (or RCP). Large differences with literature “best estimate” are possible.
   - No seasonality.

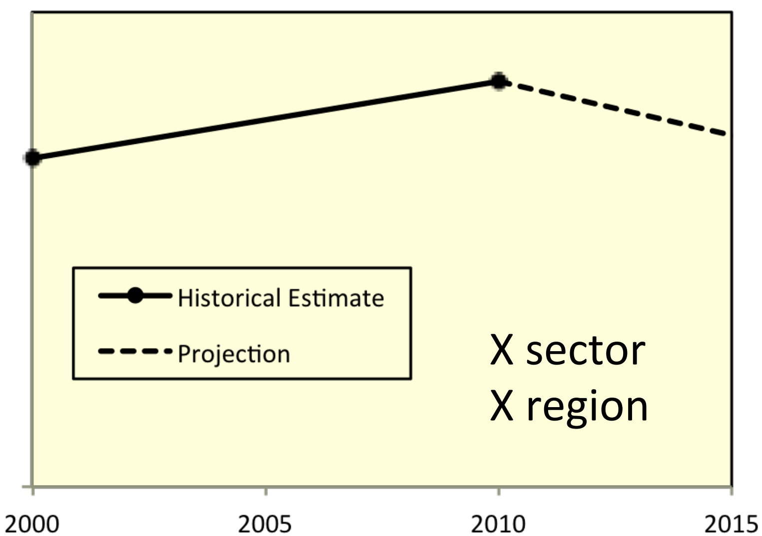
*The historical land-use community also needs guidance on what is needed, and by when.*

# A Solution: Proposed Community Emissions Data System

Timely estimates for emissions of aerosol (BC, OC) and aerosol precursor compounds ($SO_2$, $NO_x$, $NH_3$, $CH_4$, CO, NMVOC) are key inputs for aerosol research and Earth System Models

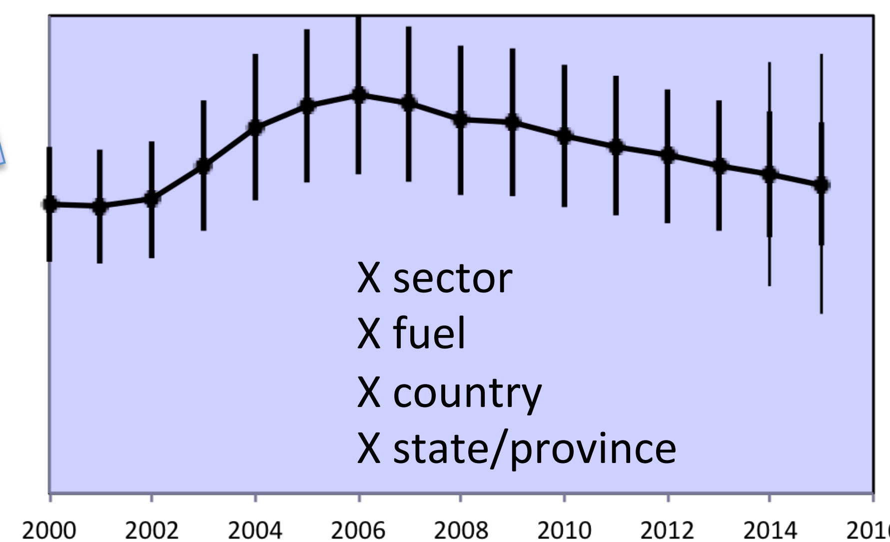
*Needed for historical and future simulations, validation/comparisons with observations, historical attribution, uncertainty quantification, IAM calibration and validation, and economic/policy analysis.*

## Instead of this




## Produce

***Uncertainty essential if extended to more recent years.***




Produced using an open-source data system to increase data transparency and facilitate research advancements.

# A Solution

**Have proposed the development of a open-source Community Emissions Data System**

- Annual estimates of all chemically reactive species and $CO_2$ over the entire industrial era (as reference). Updated every year.
- Emissions estimated at level of country, sector/sub-sector, and fuel.
  - Have proposed greater spatial detail (state/province) for large countries
- **Uncertainty estimated** at the same level (Country, fuel, sector)
- Seasonal cycle (monthly)
- Aggregate NMVOCs by sector/sub-sector
- Annual updates up to latest full calendar year.
- Gridded emissions (0.1°) w/ sub-national resolution for large countries

# Goals

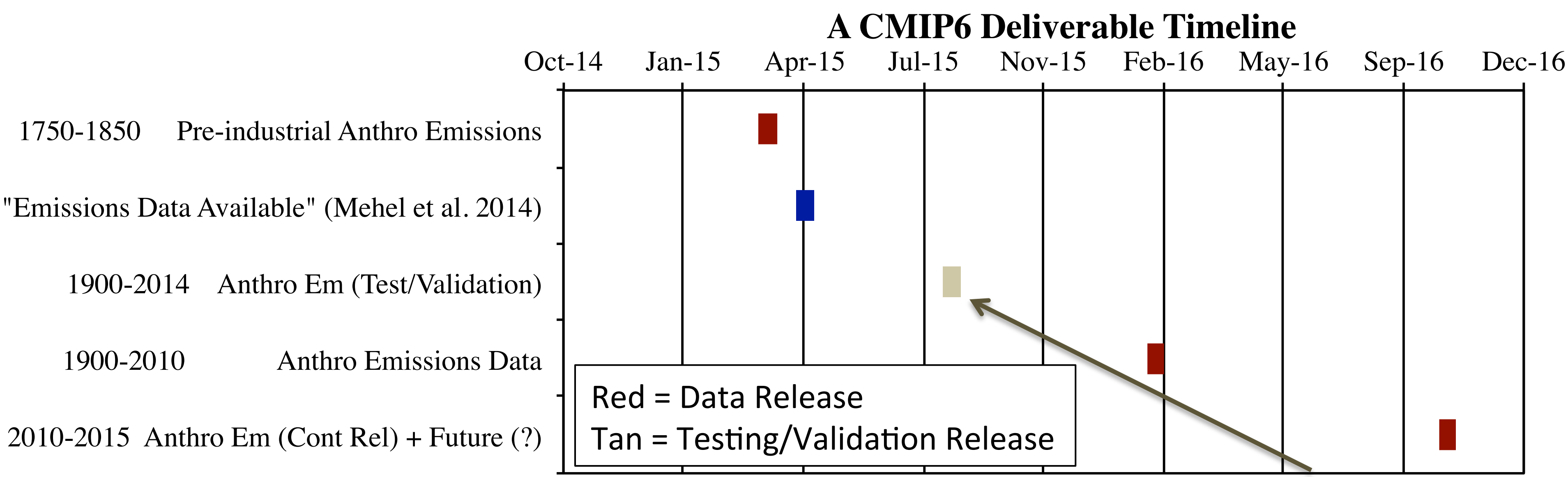
- Consistent extrapolation over time (prevent spurious discontinuities)
- Community data review: aggregate (country, sector, ...) & gridded
- Facilitate cross-country comparison (EF consistency, trends)
- Transparent emission results (assumptions -> emissions)

# CMIP6 Timing

~~New (higher resolution & seasonal) **pre-industrial** emissions could be made available by Spring 2015, if full project starts fall 2014.~~

~~A tested, gridded data set for the **industrial era** could be made available Spring 2016.~~

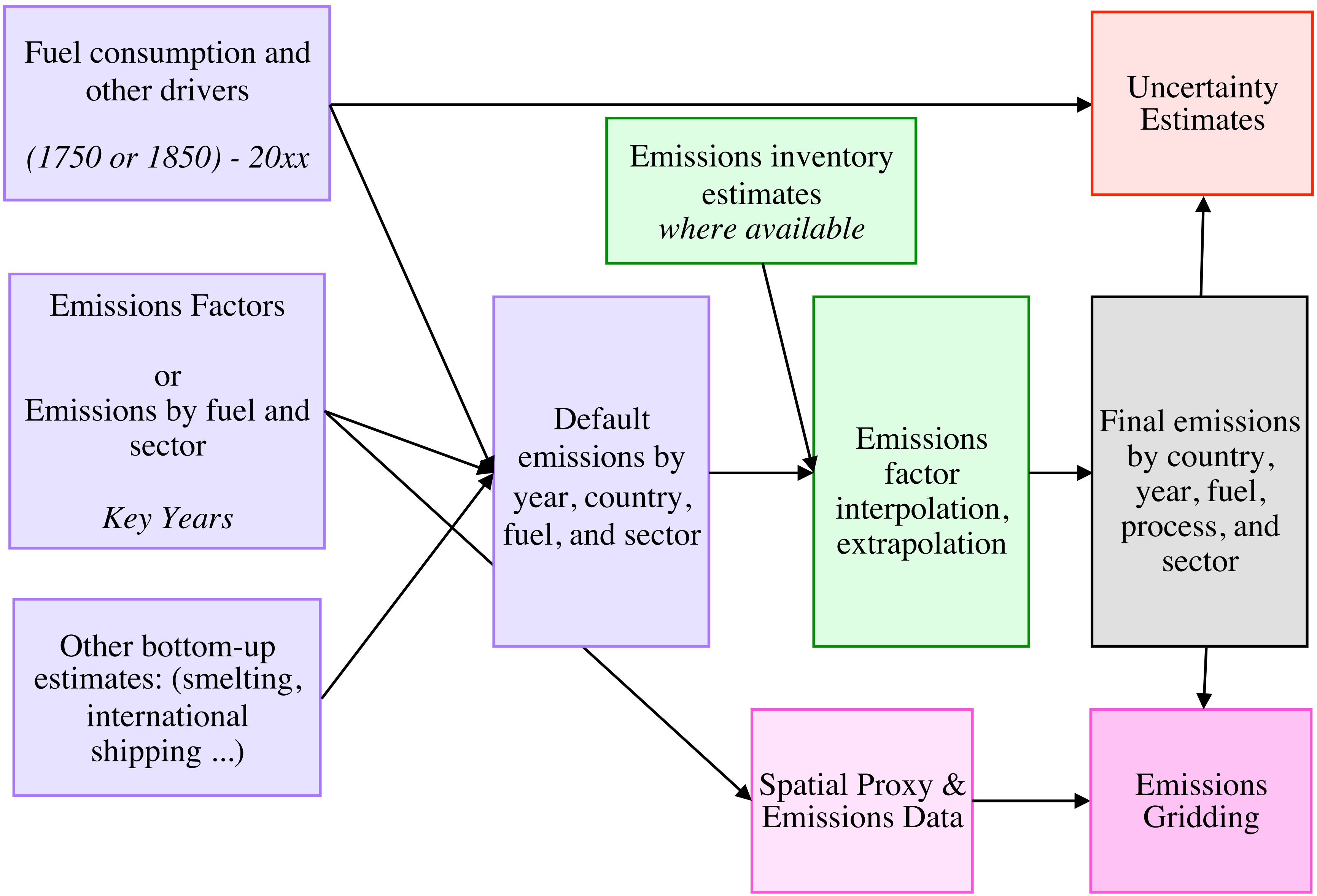
If substantial work could start relatively soon we could still get close to this timeline. Some (but not many) short-cuts may be possible.




*Have built in time for testing/validation.*

# ADDITIONAL SLIDES

# System Diagram



# Uncertainty Estimates

## Overall Approach

*All bottom-up emission uncertainty estimates contain a substantial element of expert judgment*

- Guide assumptions with literature & comparisons between inventories
- Reduce dimensionality by a "tiered" approach to group assumptions

  *Otherwise: ~10 sectors X 200+ countries X 5 fuels X ~10 emissions*

- Consider correlations across sectors and countries
- Result: consistent uncertainty across emissions and regions

## Uncertainty For Most Recent Years

***It is critical that emissions for recent years are coupled with uncertainty estimates***

- The additional uncertainty in the most recent years can be rigorously assessed by applying the extension methodologies to past data

  *Although "past uncertainty does not guarantee future uncertainty"*

# Issues II

- Emissions gridding
  - Many gridding processes rely on proprietary data that cannot be released and that would be difficult for users to obtain.
  - Goal is for the community data system would produce gridded data
  - Produce only on basis of broad sectoral grids? (e.g. RCP sectors)
  - Globally consistent proxies (e.g., EDGAR) or use regionally detailed data (e.g. most recent HTAP)
- NMVOC speciation
  - Are there specific sectors that should be explicitly detailed in order to facilitate NMVOC speciation?
  - Perhaps the greater sectoral detail of EDGAR can be used where needed for sub-sector speciation detail?
- Special sectors/sub-sectors
  - Updates to shipping and aircraft emissions? Bricks? Others?
- Coordination with Open burning emissions
  - Temporal resolution (annual?). Speciation? Other?

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