Process-based emission inventories from the past to the future

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March 21, 2014

Biased toward: energy-related emissions, aerosols, climate, global

Outline

1. Process-based vs sectoral
2. Comments on the past and future
3. What to do with observations
4. Climate-relevant questions

1. Process-Based Emissions

Two ways of estimating emissions

Process-based

Based on physical understanding of the underlying technologies and processes

Never fully realized!
Always some parameterization

Sector-based

Based on applying broad emission coefficients to large groups of sources ("sectors")

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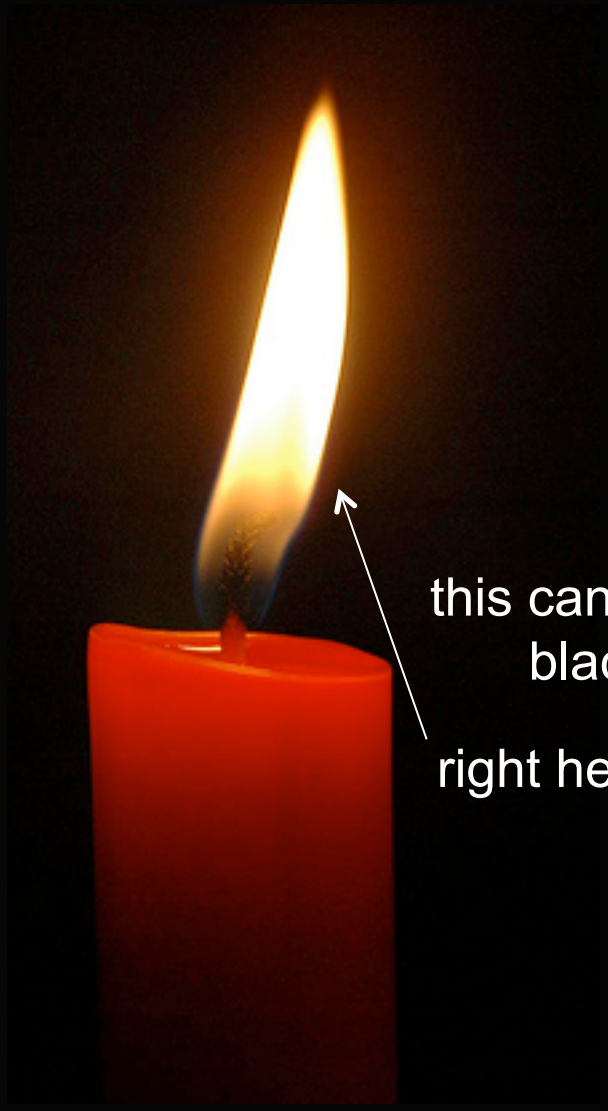
Measurement-based

Use measured emissions from individual facilities

Possible for large facilities & places with stringent environmental regulation

Example



this candle is making
black carbon

right here

this one is making “organic”
carbon…
no flame, no game!

Pros and cons

Process-based	Sector-based
Reflect physical reality Includes "how-to" levers; demonstrate effect of individual actions	Fewer data needs Capture broad trends and economy-wide policies
Data-intense Difficult to validate each component	Big assumptions about emission trends without ability to investigate mechanism

Need for community data

Individual efforts can contribute:

- Emission factors: vetted with primary data sources; compared in different regions
- Emitter features that matter: e.g. vehicle age distributions
- Activity data that are not widely available

Quality control & data provenance are of paramount importance!

Need for community guidance

Especially beyond U.S./Europe

- Guidance on when emission factors are appropriate
- Guidance on transparency, data sources, and quality
- Identification of critical inventory needs

…some groups are starting to re-invent wheels

2. PAST & FUTURE

The evolution of combustion

Physical result

Coal Wood Liquid



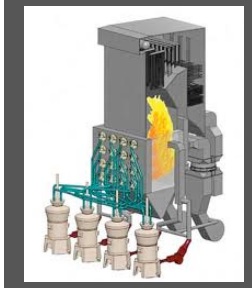
Largely uncontrolled

Lots of BC
Even more OC
Lots of VOC



Loosely managed
turbulence, time in exhaust

BC remains
OC + VOCs
burned out



Fuel-air managed
for solid fuel, by better fuel prep

Hot!
More NOx

Trajectory of anthropogenic aerosol emissions

…that is, not open biomass burning…

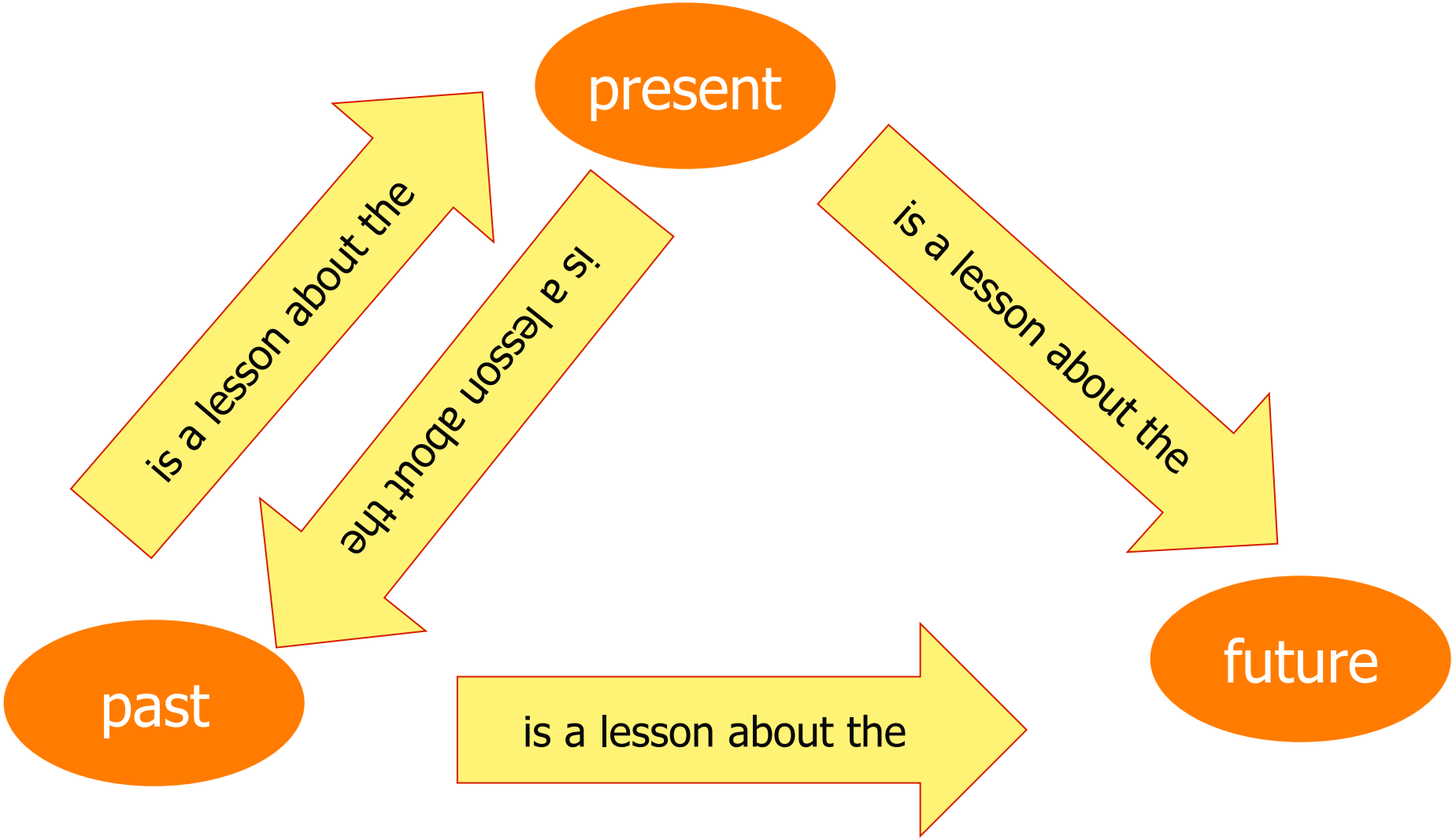
Fire well-managed
High activity
End-of-pipe controls

Fuel distilled
High emissions
Moderate activity
Transportation→ BC, OC

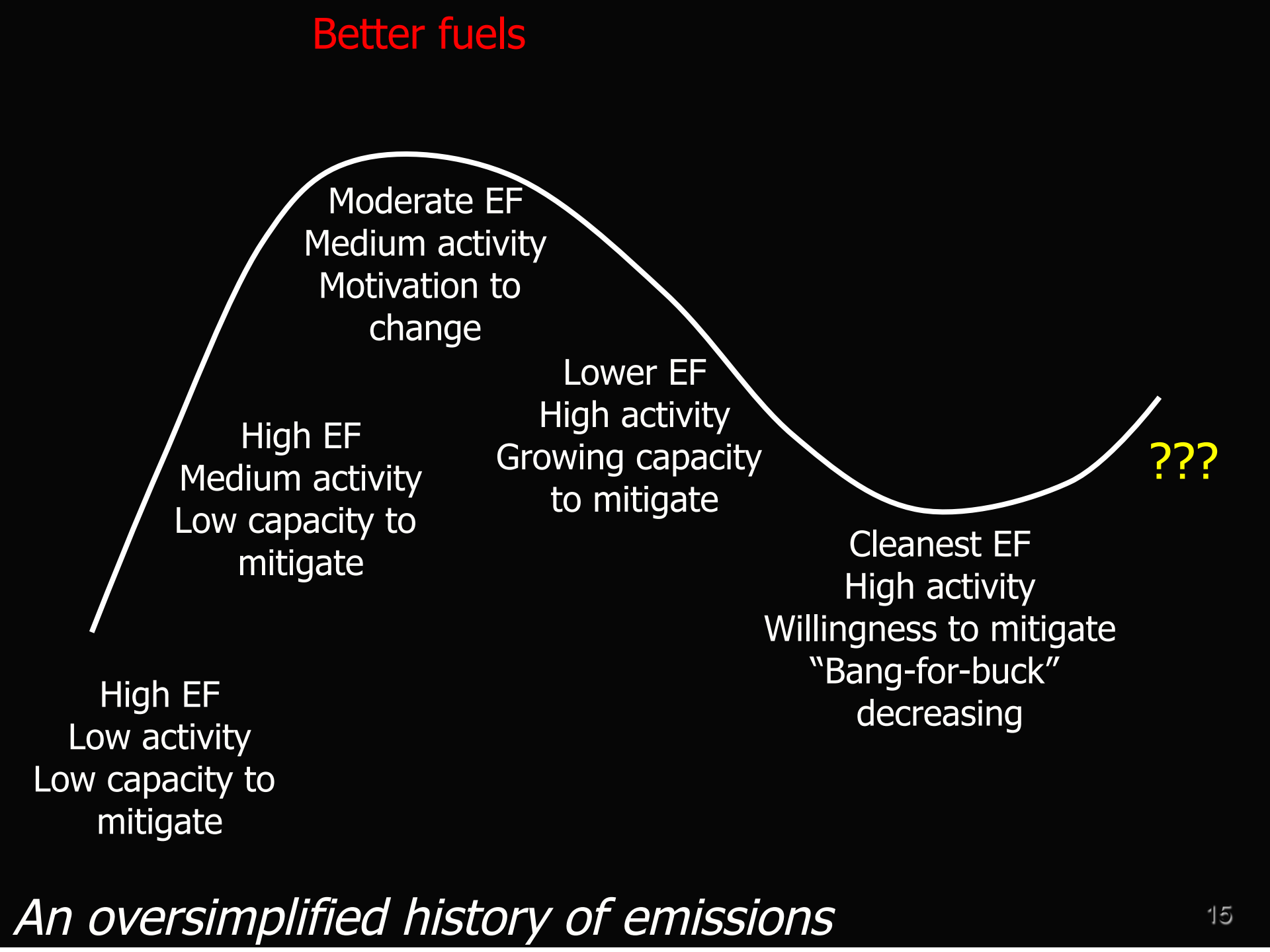
Fire manipulated
Moderate activity
Coal → SO_2, BC, OC, ash

Fire Unmanaged
Low Activity
Wood → few impurities
Mainly OC + BC

From a process-based perspective…



An oversimplified history of emissions



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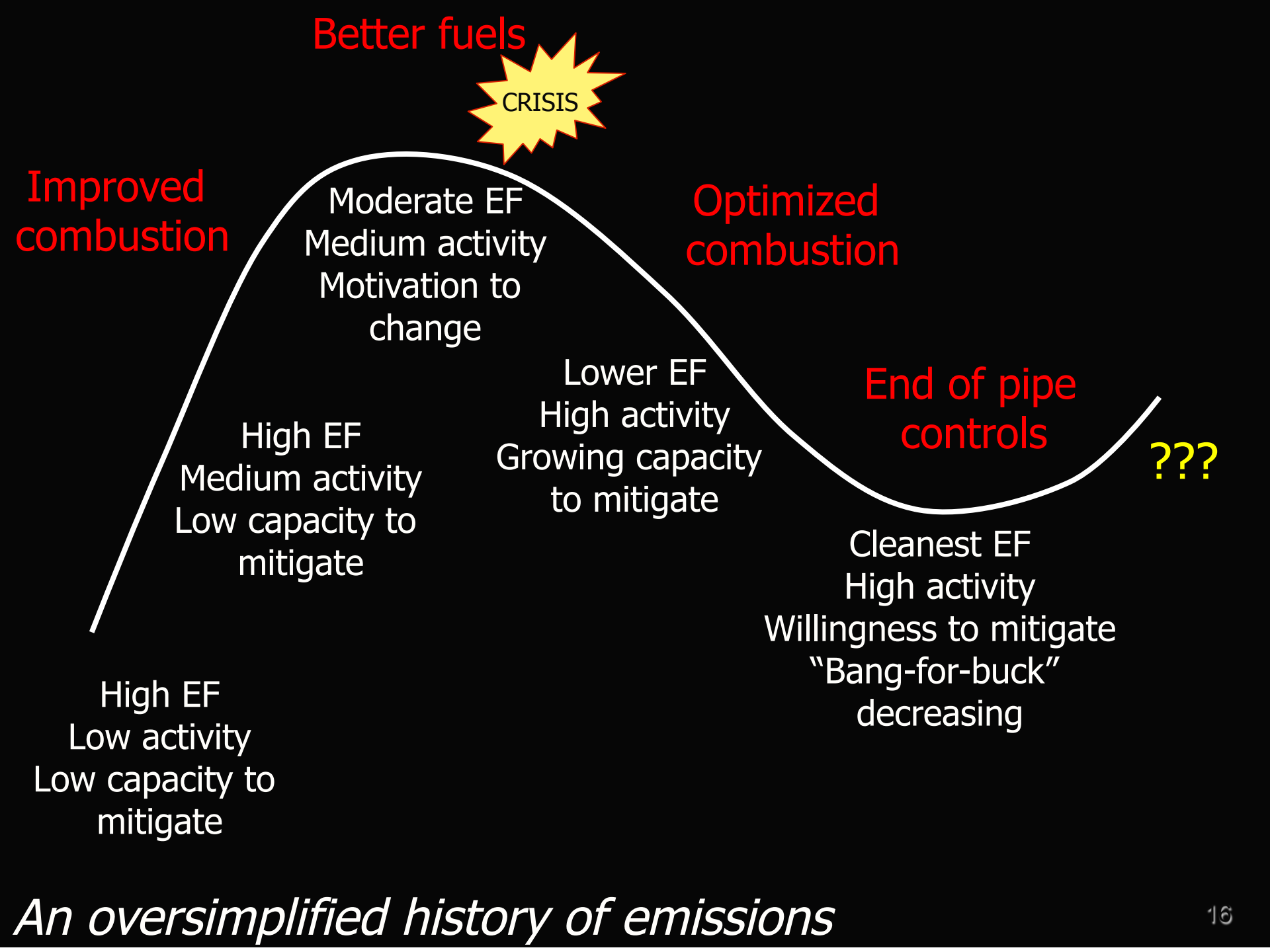


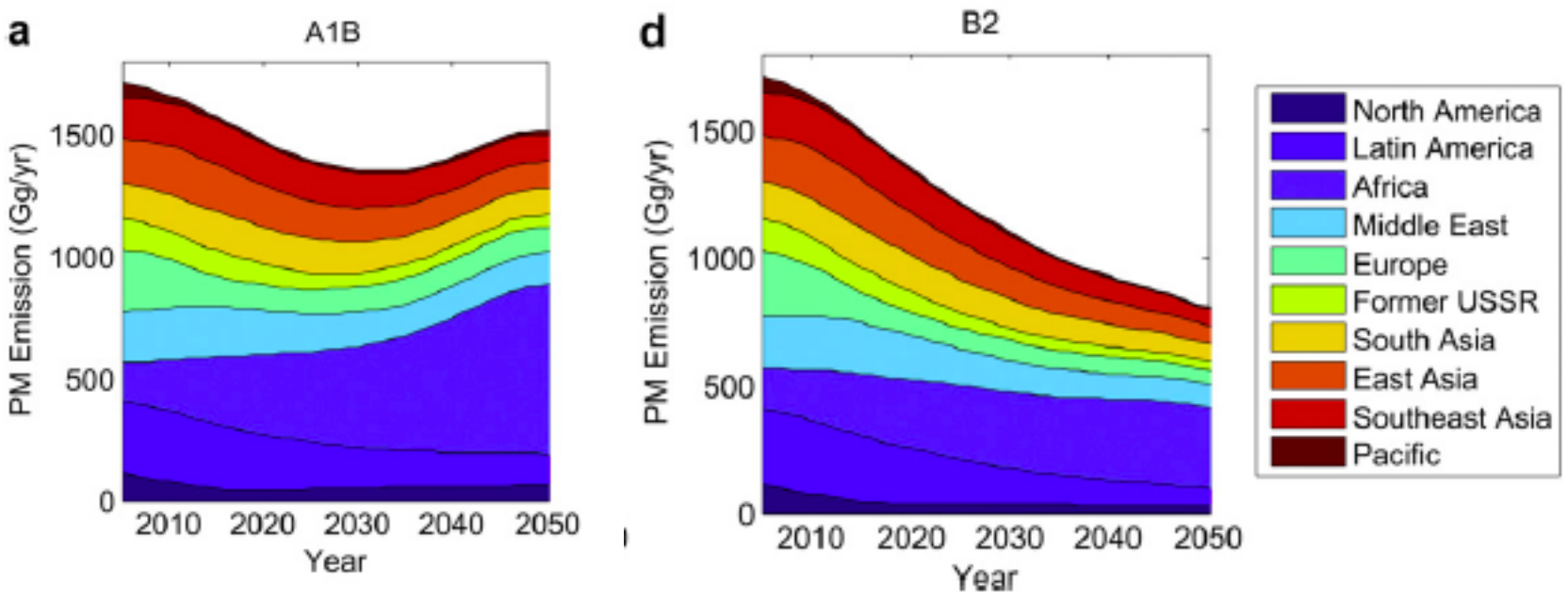
An oversimplified history of emissions

Questions about the future (mine)

- Will emissions rise again? (Minimum after the maximum)
- How strong is “leapfrogging”?
- To what extent does capital stock and infrastructure lock in emission rates?
- How does regulation effectiveness depend on national priorities and governance?

my group has (lately) focused on connecting

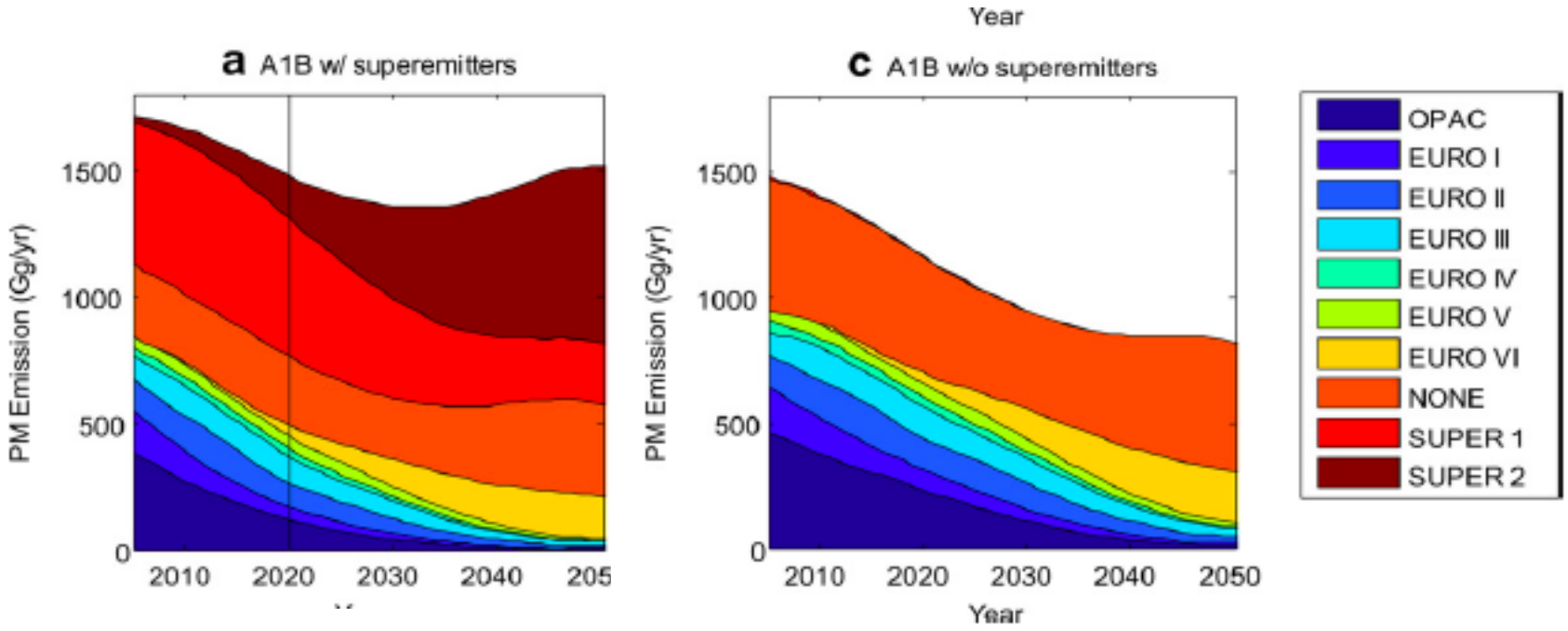
On-road vehicle emission projections



Could increase or decrease, depending on economic trajectory

Yan et al., Atmos Env, 2011

With and without "superemitters" (RED)



Soon we will see whether we CAN minimize emissions with control technology

Yan et al., Atmos Env, 2011

Ideals for emission inventories:

- Seamless from past to future *
- Consistent among relevant pollutants **
- Rapidly updatable, based on technology stock and emission drivers *
- Each data point fully traceable to original source *
  - Emission factor, hierarchical activity, extrapolation
  - Includes uncertainty
- Linked to national circumstances, e.g. infrastructure, land use, regulation **
- Quality flags, including evaluation status
- Consistent among different inventory classes (e.g. biogenic & energy-related)

in my group: * current practice; ** ongoing work

3. How I wish we could use Observations

A. Every observation comes with a label

PRODUCT OF A COMPRESSION-IGNITION ENGINE

Greg's "top-down"—
NO2 is best,
particulate matter difficult

1. Use tracer ratios, seasonality, and diurnal variability to apportion concentration totals among sectors
   - → long-term observations with *sufficient* detail
   - → ratios with CO_2 would be great
   - → done now, but not systematically
2. Investigate causes of emission discrepancy
3. Propagate these findings to other regions and sectors

GENERALIZE please

B. We solve the resolution problem

(and the transport problem, too)

Especially for "peaky" primary aerosol distributions

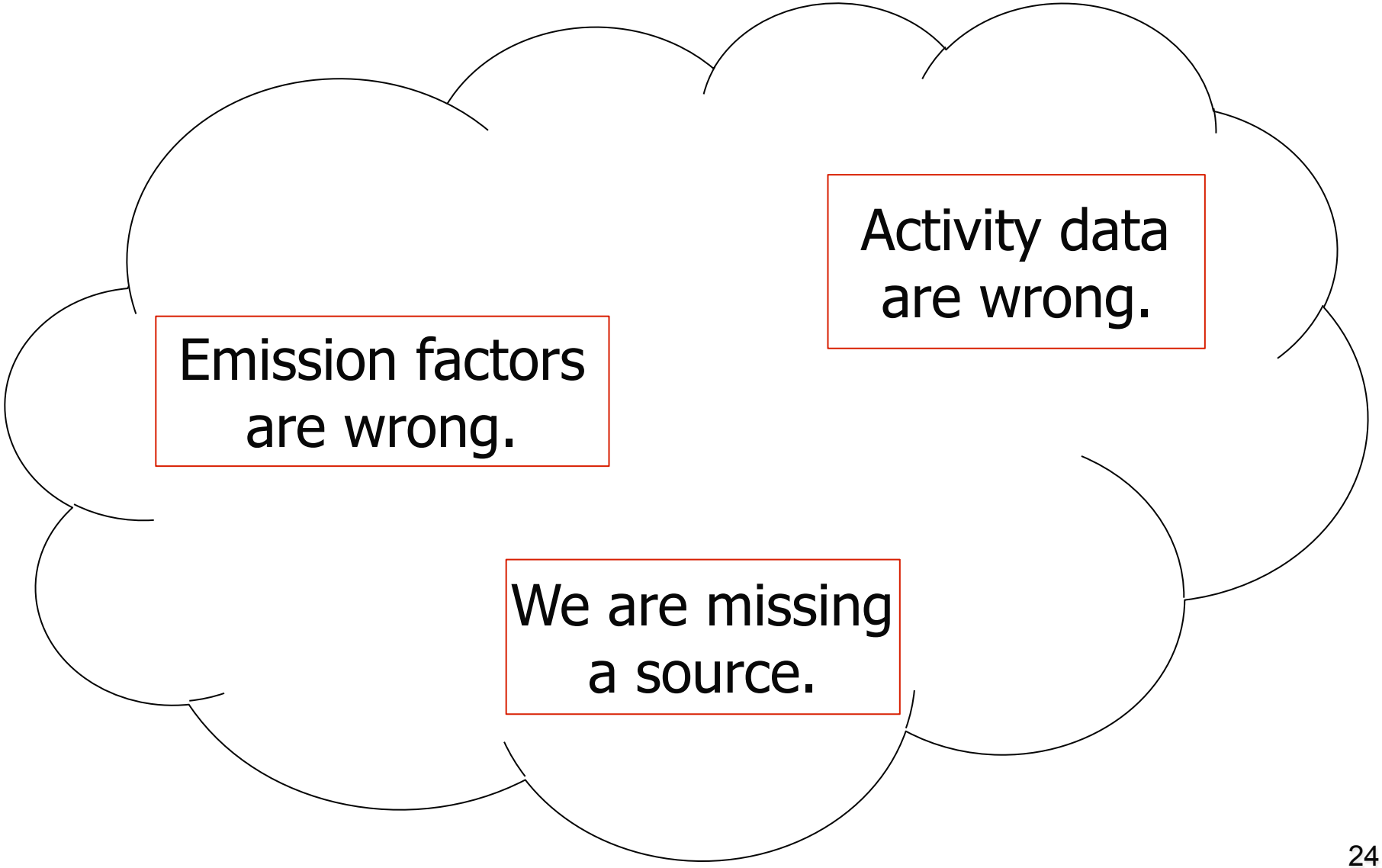
Examples:

- Point observation doesn't represent model boxes
  So tell me what it *does* represent!
- Urban-rural divide: trends & magnitudes

Need to formally and systematically disentangle these contributions

If I had that information….

I would fix the inventory throughout the past and future



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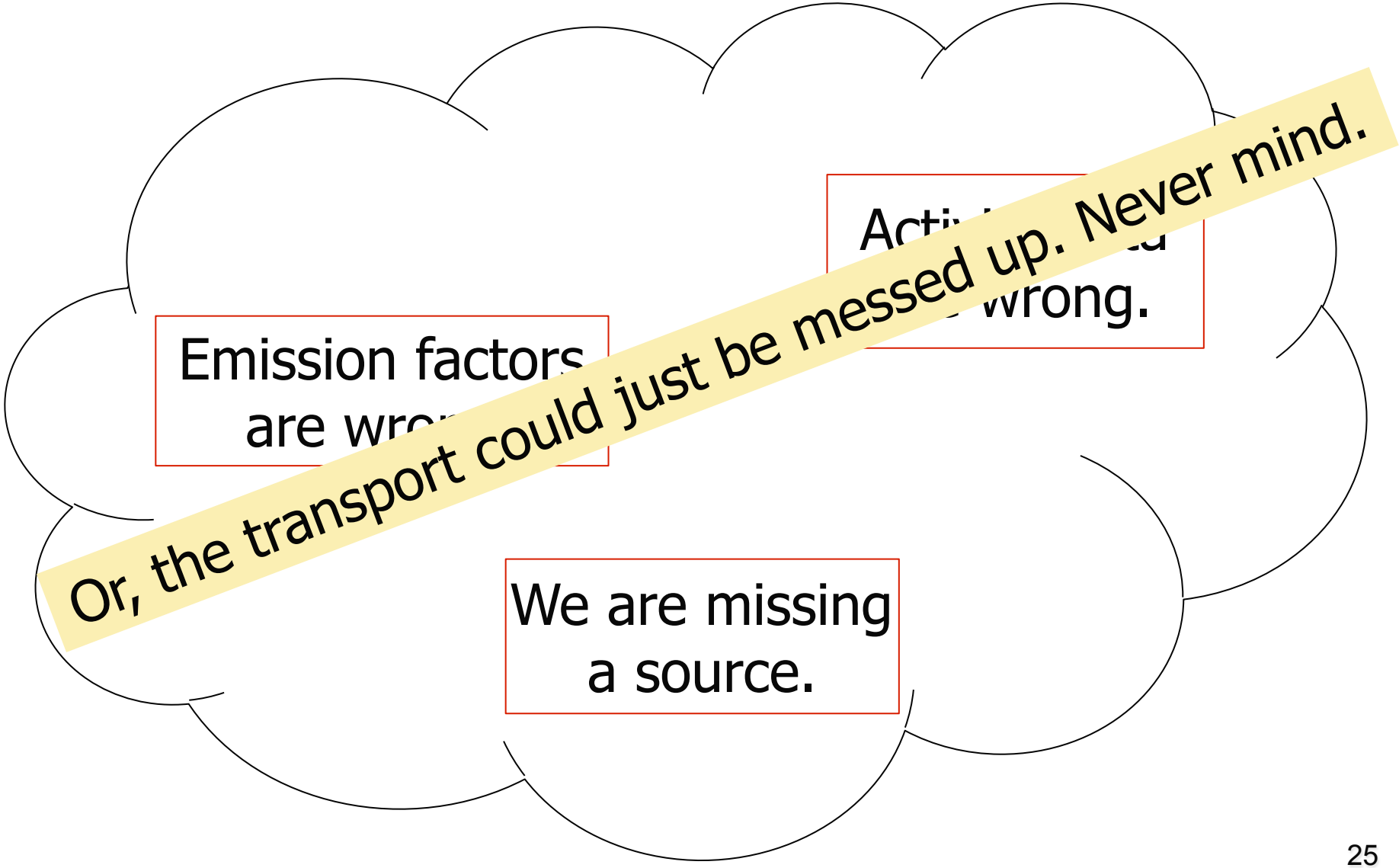

4. Climate Questions

especially about aerosols

“How far back should we go?”

Answer: For what?

- Farther back = More uncertain (no activity records) and less constrained (no observations)
- Is an uncertain reference year useful in understanding climate forcing?

Also: How far forward should we go?

The aerosol-cloud connection

Cloud-related forcing may be larger than direct forcing, and will (probably) die away more slowly

- Need properties of aerosols relevant to clouds
  - Size– definitely; composition— possibly
- Need observations & constraints of cloud-relevant properties (if not cloud effects themselves)
  - And these must tie back to emissions

Summary

Needs:

- Community development of *lacking* (not repeated) data, and quality control
- Formalisms for learning from the past and understanding future
- Formalisms for assessing emissions vs observations given transport constraints
- Emission inventories for climate purposes, considering all limitations