A History of Aerosols in the Western Arctic during Recent Centuries

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- Spatial arrays of new generation ice core records can elucidate changes in aerosol concentrations, sources, & transport pathways to the Arctic.
- Very significant human impact on Arctic aerosol concentrations, biogeochemistry, & radiative forcing for at least 150 years.

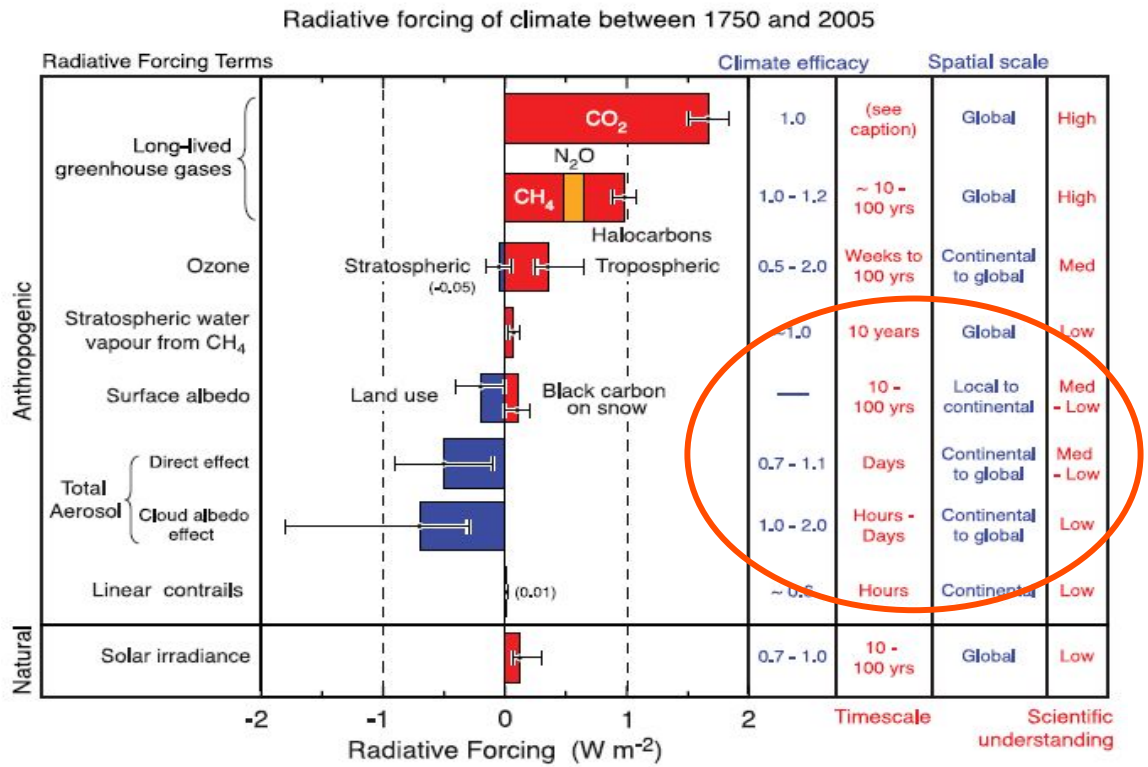
Outline

- Motivation for ice core aerosol research and ice core arrays
- DRI's unique ice core analytical system
- Recent results from the western Arctic
- Implications and future directions

Motivation

Climate forcing

Attribution of radiative forcing of climate (1750 – 2005)



IPCC, 2007

Why arrays of ice core aerosol records?

- Most Arctic aerosols from outside sources
- Aerosols are short-lived (days to weeks)
- High temporal and spatial variability
- Transport processes may dominate

Overarching questions

- How have aerosols varied in the past?

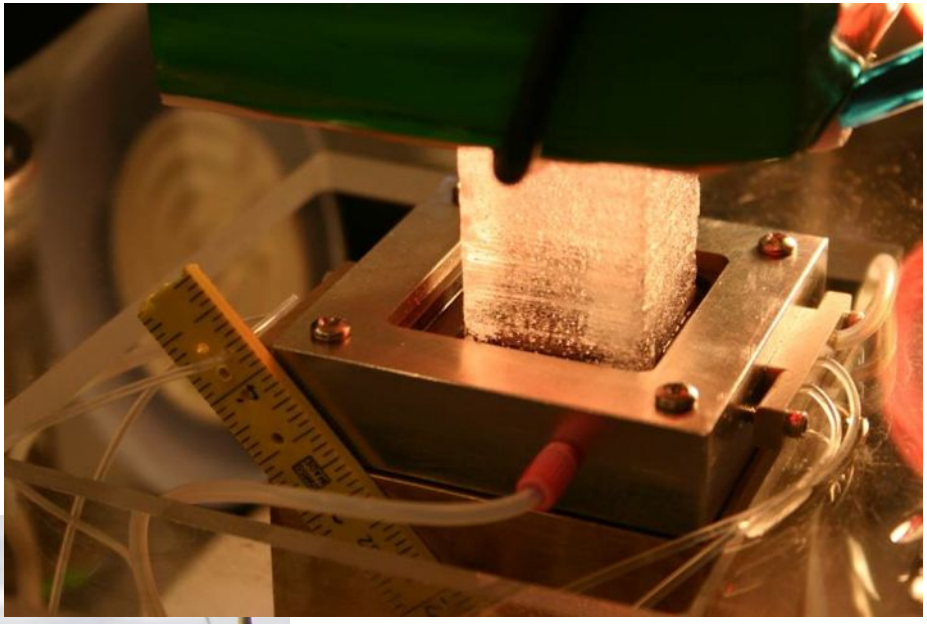
Dust, sea salt, emissions from volcanism, biomass burning, industry

- What are the sources today and in the past?
- What are the primary transport pathways?
- How have transport pathways changed in the past?
- How will Arctic aerosols (and so climate forcing) change in future?

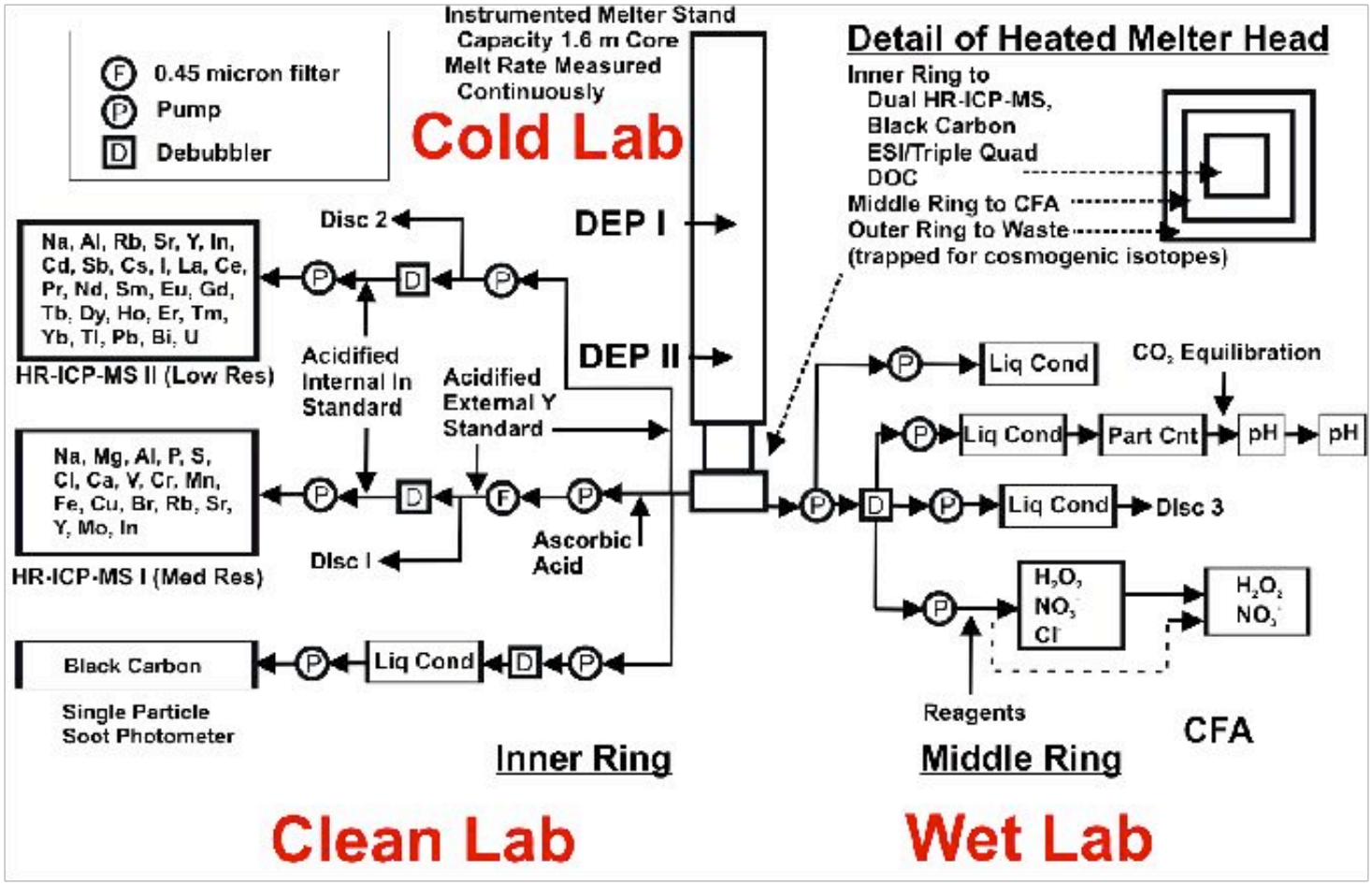
Why are ice cores records so valuable?

- Most direct paleo-aerosol record
- Actual (not proxy) atmospheric & precipitation chemistry
- Point to regional scale information (long range transport)
- Spatial resolution (arrays)
- High temporal resolution (similar to air filters)
- New generation ice core data suitable for GCM evaluation!

High-resolution, continuous ice core measurements of aerosols



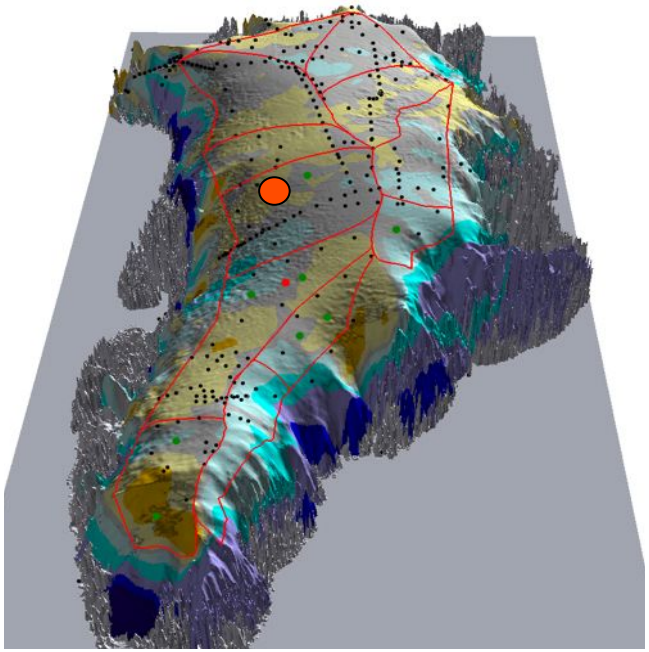
CFA-TED/BC Schematic

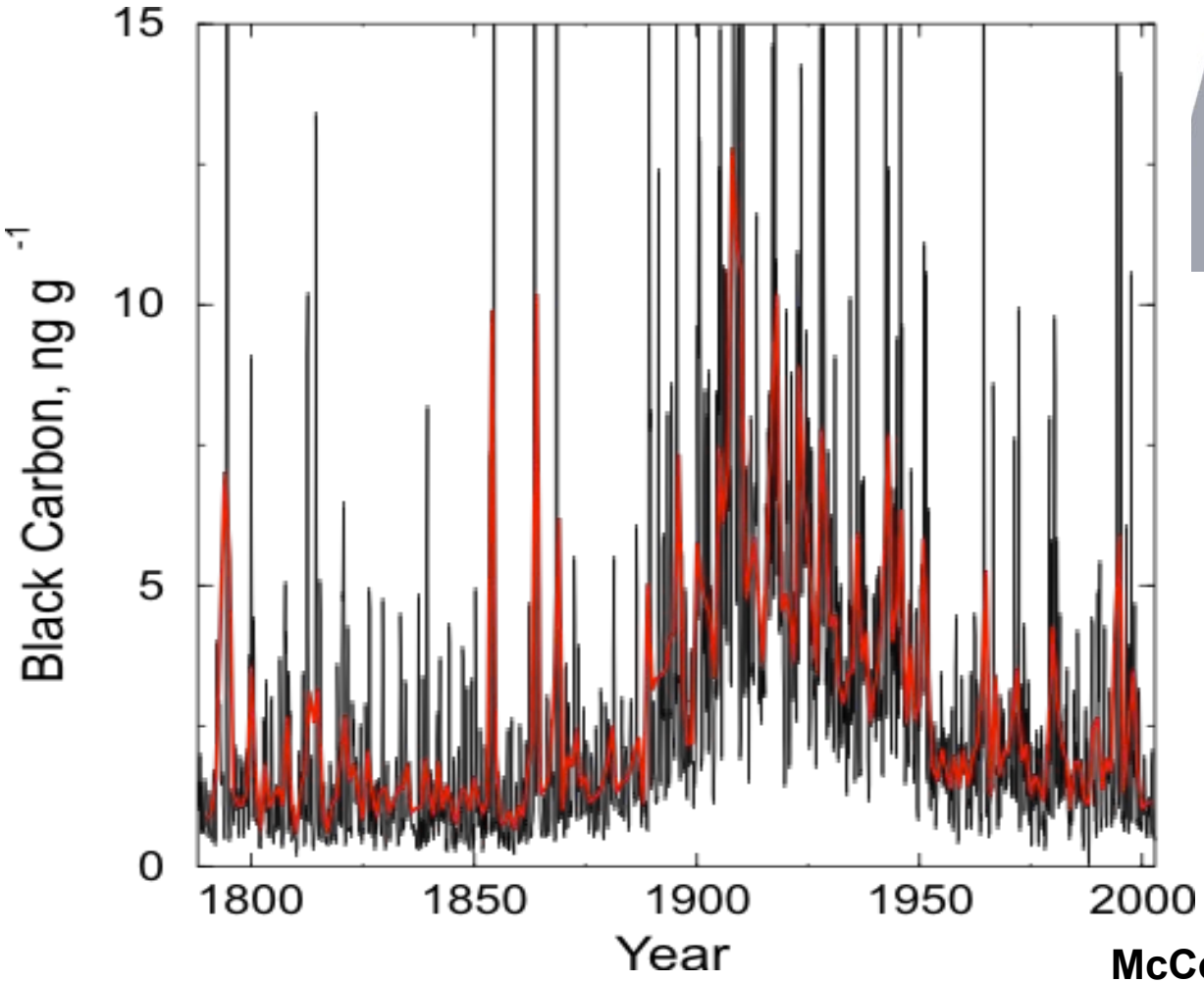


See upcoming D. Pasteris' talk on acidity

~5 sec dt ~ 5 mm dz

Black Carbon in Greenland 1788-2002





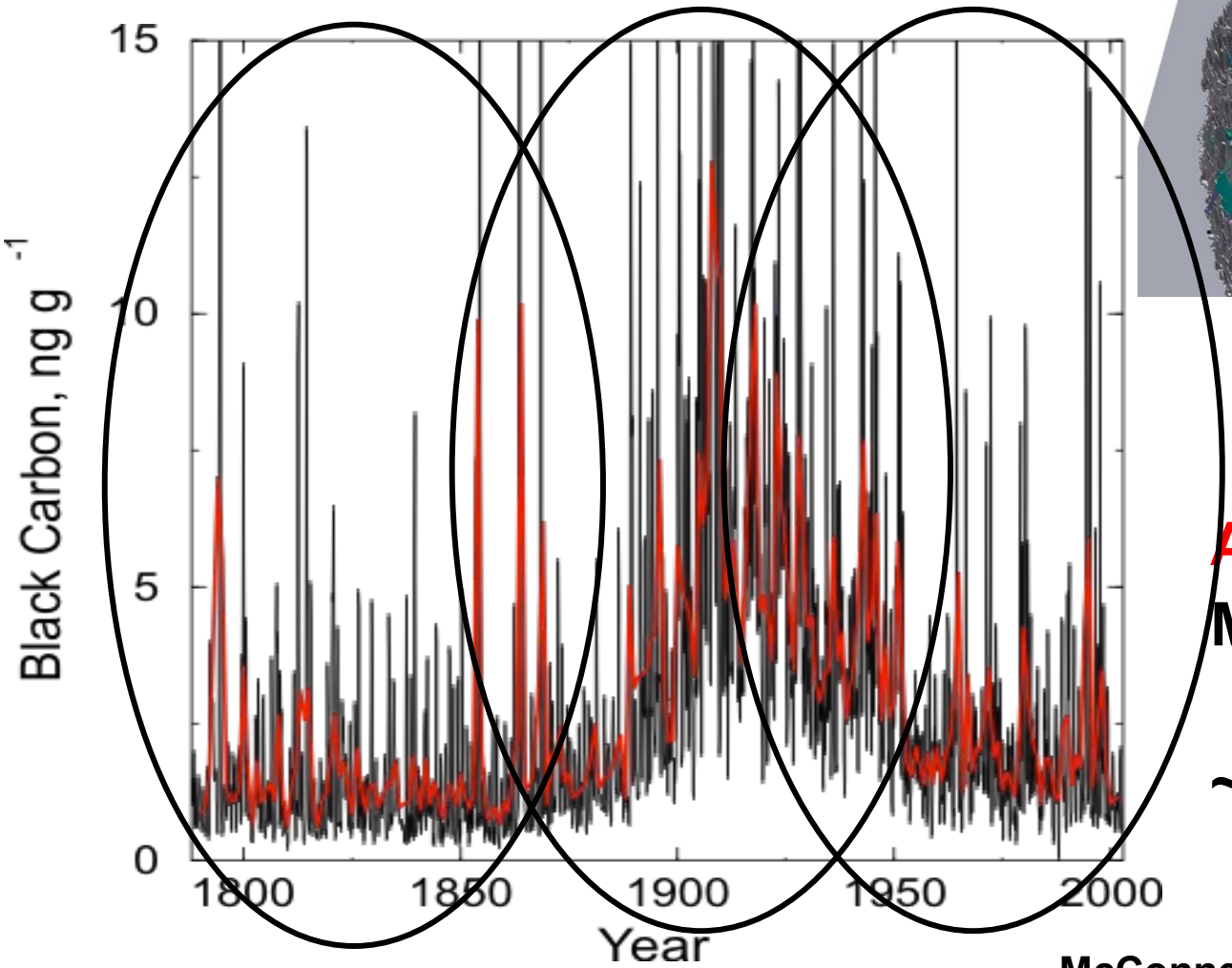
Annual

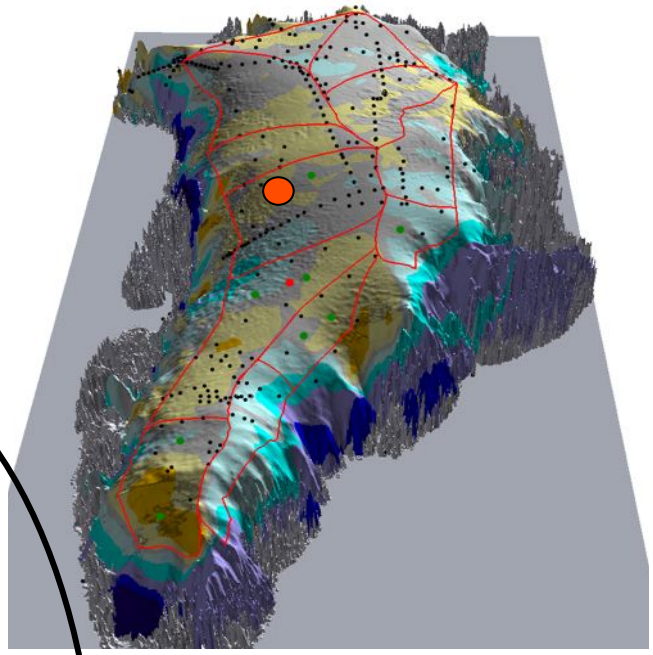
Monthly

~30 samples y^{-1}

McConnell et al., *Science,* 2007.

BC in Greenland 1788-2002





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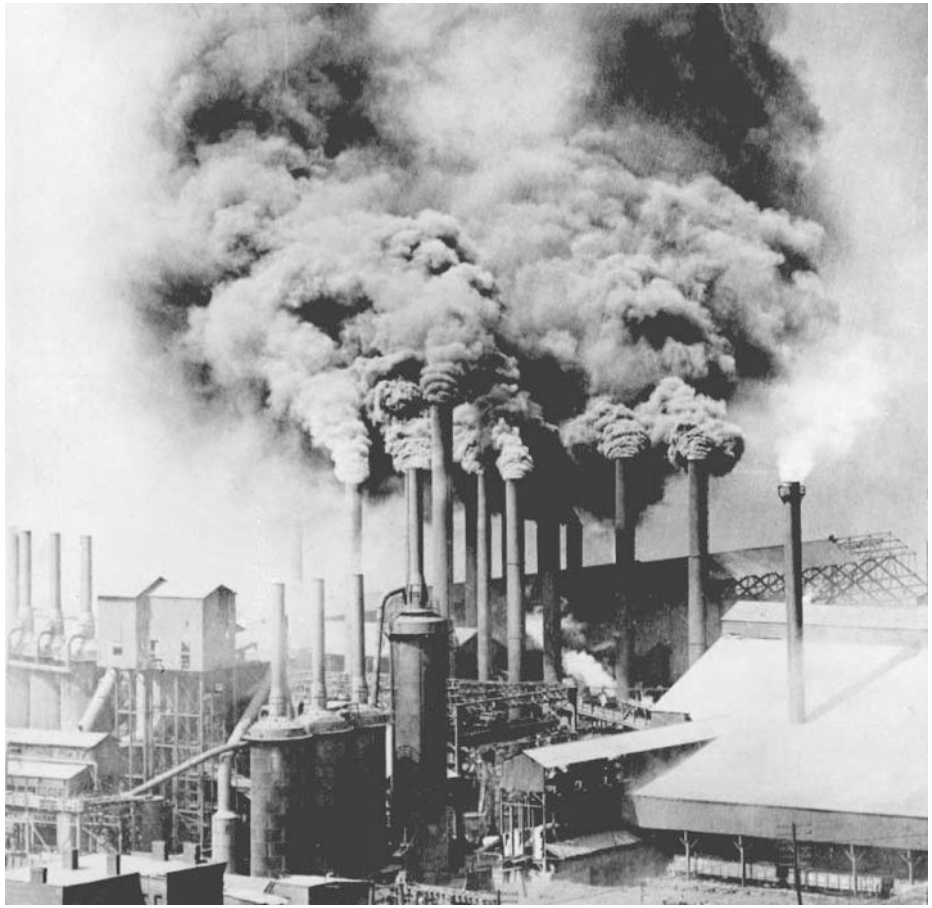
Vanillic Acid as a tracer biomass burning (conifer) emissions

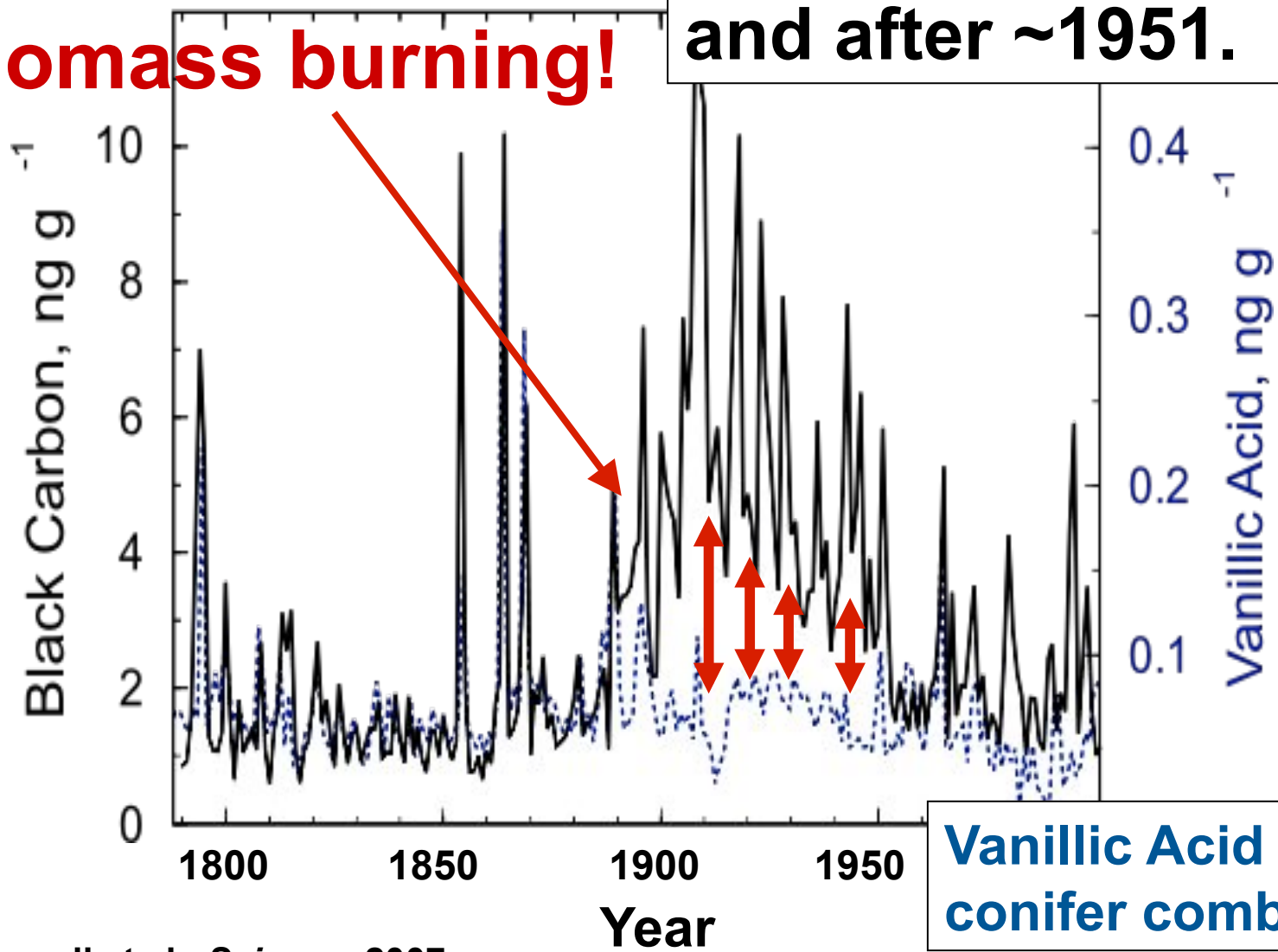
Photo courtesy of A. Stohl



Non-sea salt sulfur as a tracer of industrial emissions

Biomass burning dominated 1788~1860 and after ~1951.

Not from biomass burning!

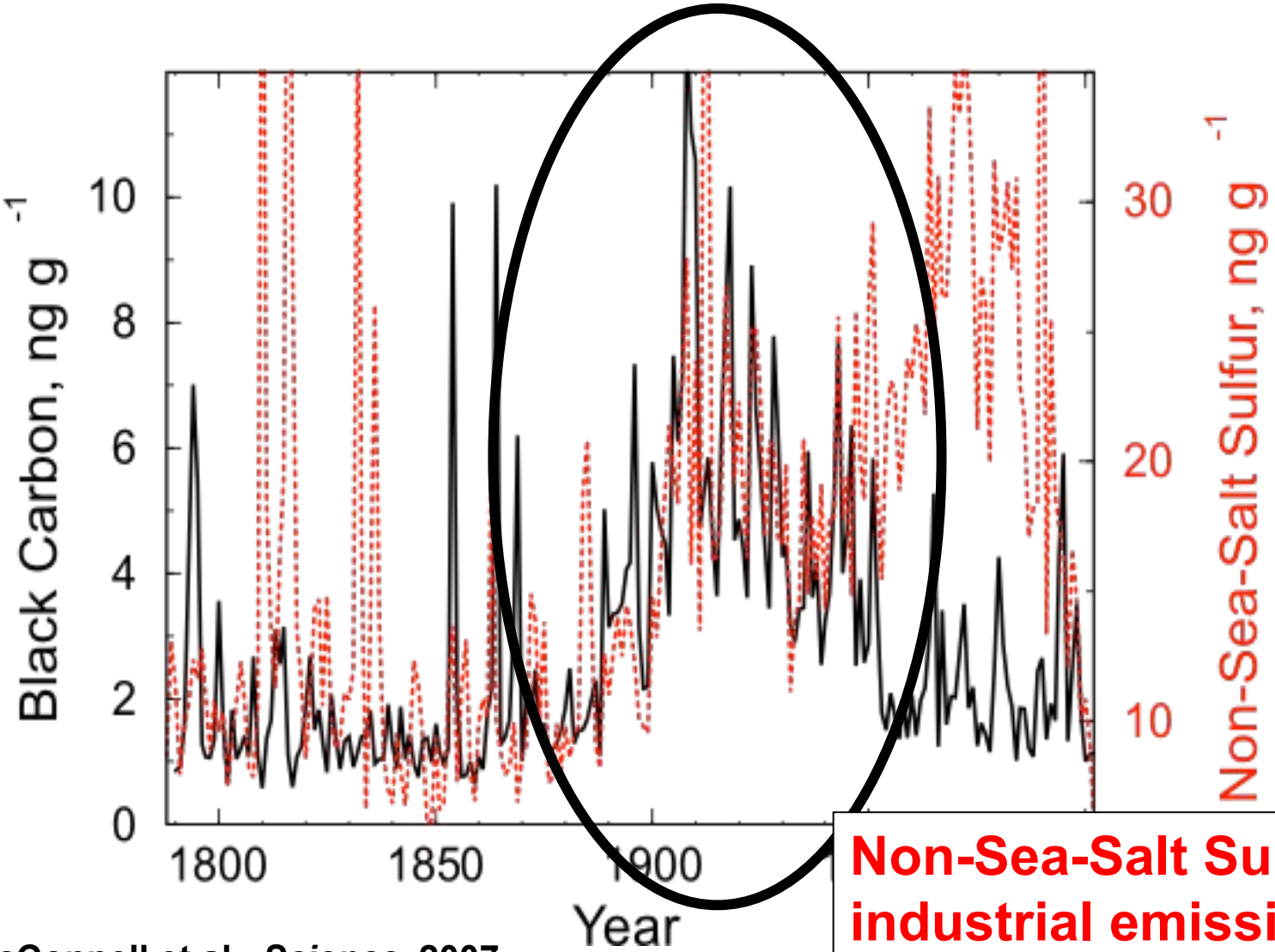


Vanillic Acid from conifer combustion

McConnell et al., *Science,* 2007.

Annual: 0.67 ($p < 0.0001$)
Winter: 0.74 ($p < 0.0001$)
Summer: 0.59 ($p < 0.0001$)

Coal burning dominated ~1850 to 1951



Non-Sea-Salt Sulfur from industrial emissions

McConnell et al., *Science,* 2007.

BC First Conclusions

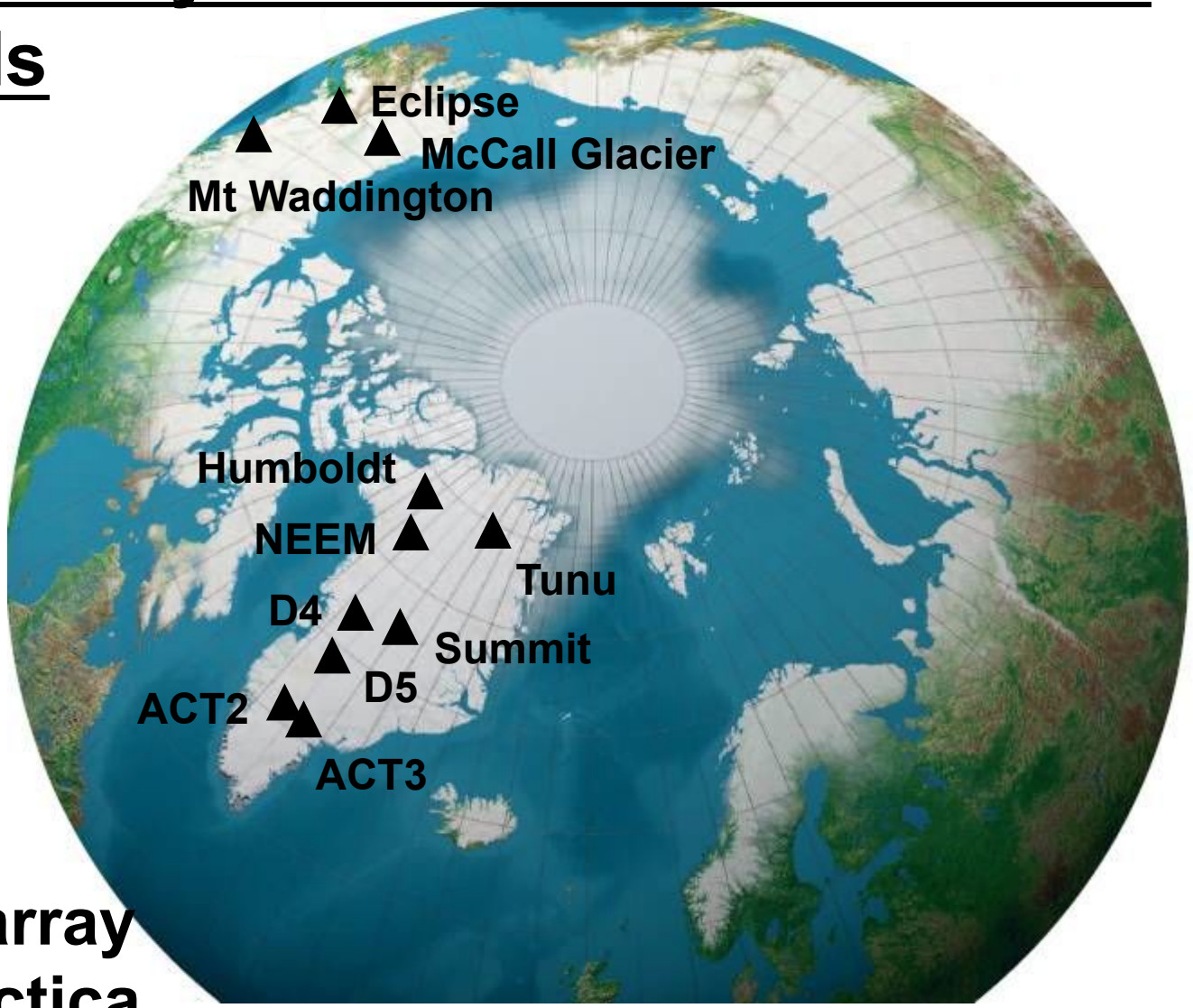
- BC comes from boreal forest fires & industrial emissions
- Pre-Industrial and for all summers: Primary source is burning in conifer-rich boreal forest
- From ~1850 to 1951, N American (Shindell et al., 2009) industrial emissions resulted ~2 to ~4 fold increase (~10 fold in winter (five years from 1906 to 1910))
- BC drop in ~1951 linked to change in fuel type (Bond et al., 2007), burning technology improvements & possibly fire supression
- Coal-dominated era anomalous during past millennium
- What is the impact on radiative forcing (SNICAR)?

Photo courtesy of B. Stocks

Implications

- Ice cores document large historical changes in Arctic aerosol concentrations & fluxes from industrialization
- 20th century levels in most aerosols are anomalous
- Widely space records show significant differences but also surprising similarities
- Modeling, emissions estimates, & tracers suggest mid-latitude sources and significant impacts on radiative forcing

A western Arctic array of multi-century, subannually resolved ice core aerosol records



And a similar array in Antarctica

Thanks!