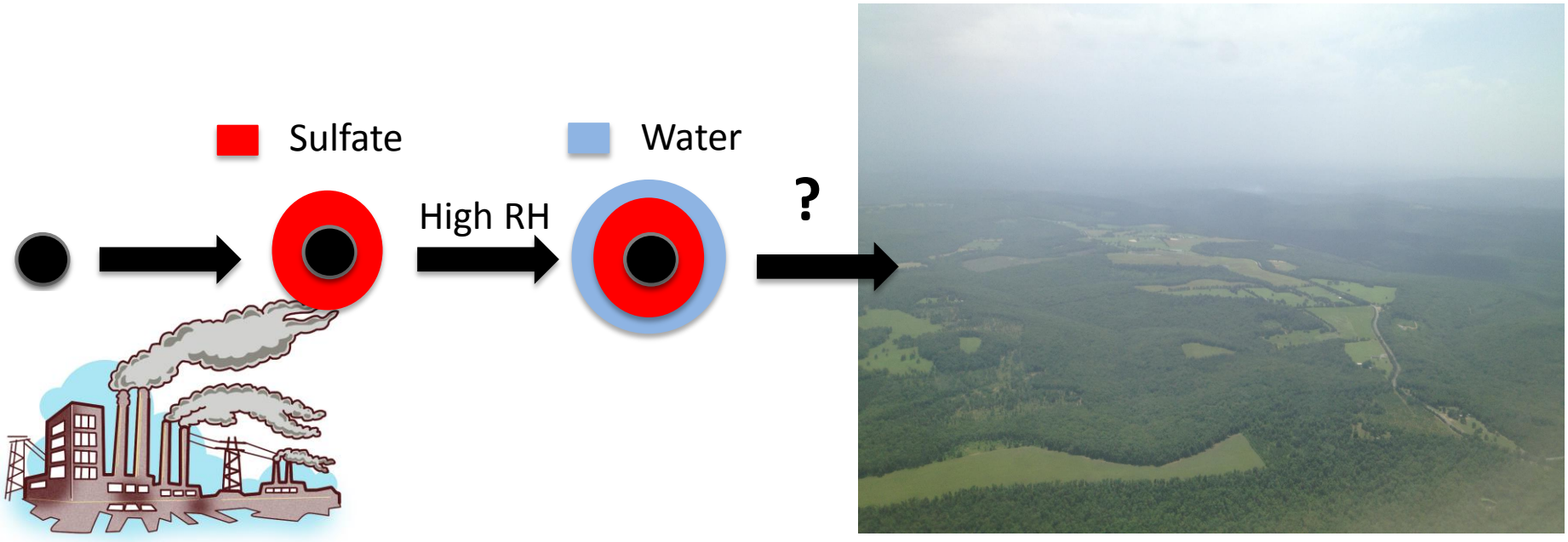
Aging of black carbon (BC) in power plant plumes during SENEX



Southeastern U.S.

Milos Z. Markovic[1, 2], A. E. Perring[1, 2], J. P. Schwarz[1, 2], R. S. Gao[1], L. A. Watts[1, 2], J. S. Holloway[1, 2], I. B. Pollack[1, 2], T. B. Ryerson[1], C. A. Brock[1], N. L. Wagner[1,2], J. Liao[1, 2], A. Welti[3], A. M. Middlebrook[1] , M. Trainer[1], and D. W. Fahey[1, 2]

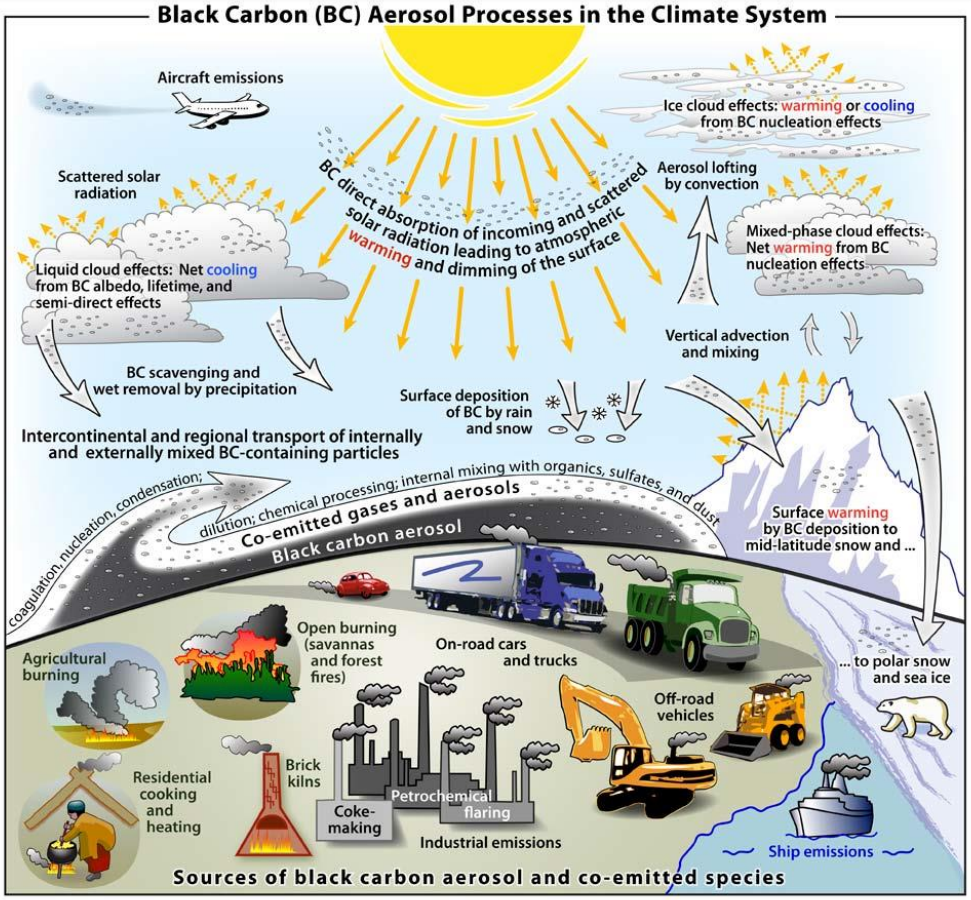
[1]Earth System Research Laboratory, Chemical Sciences Division, NOAA, Boulder, Colorado, USA

[2]Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, Colorado, USA

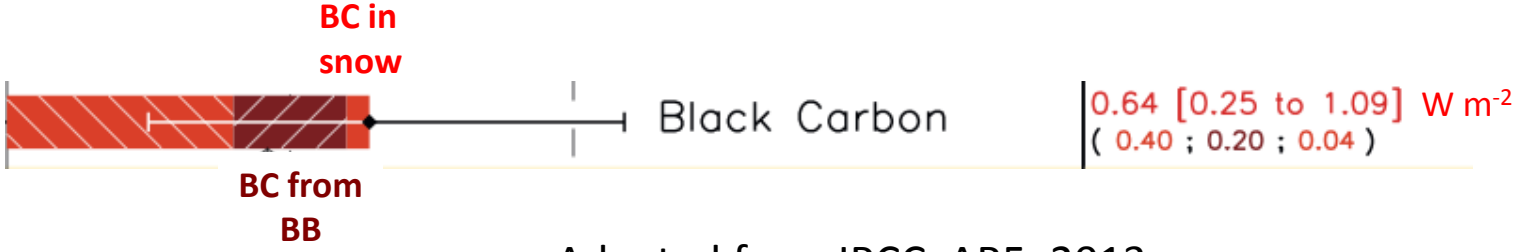
[3]Eidgenössische Technische Hochschule Zürich (ETH), Institute for Atmospheric and Climate Science, Zurich, Switzerland

INTRO - Black Carbon (BC)

- Emitted by **incomplete combustion** of fossil and bio fuel and biomass burning
- One of **most powerful** anthropogenic **climate forcers**
- BC lifetime and climate effects depend on its **size and mixing state (e.g. coating)**



Bond, T. C. *et al.*, JGR, 2013



Adapted from IPCC, AR5, 2013

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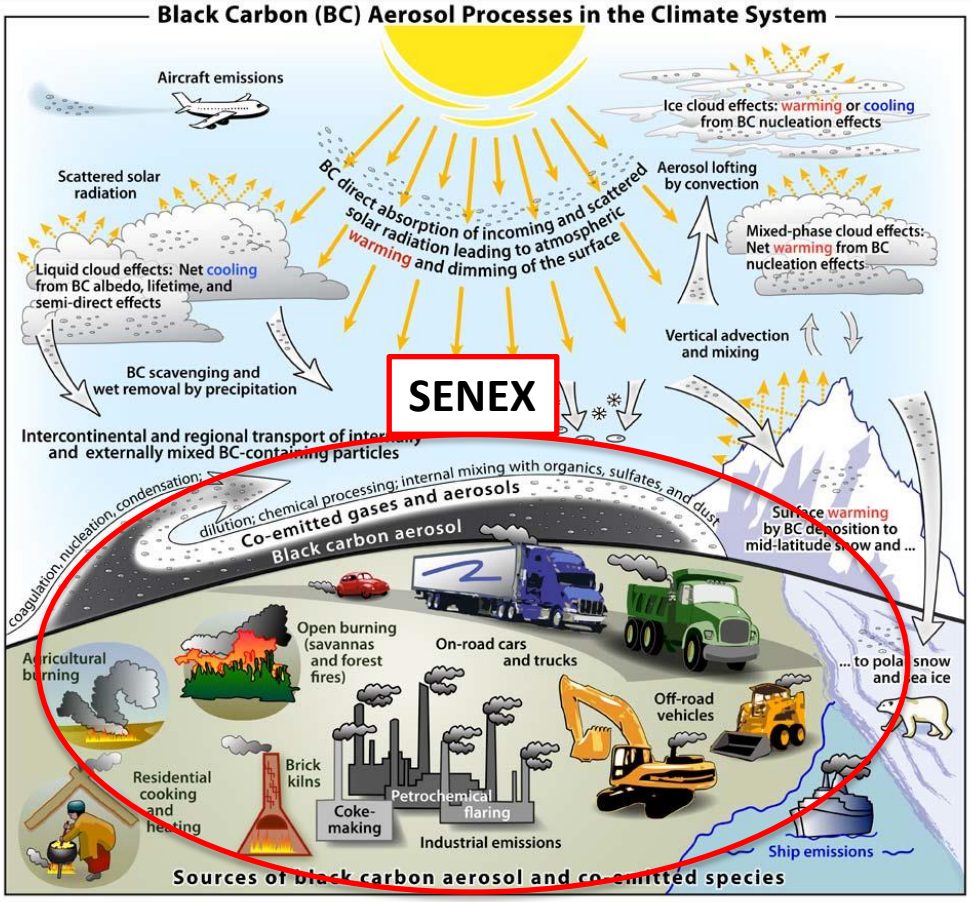
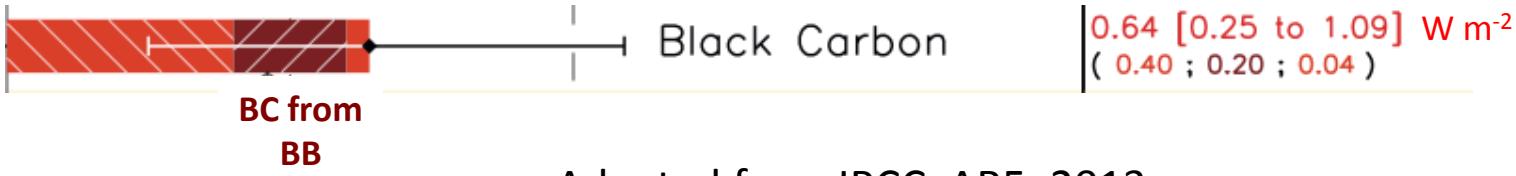


Bond, T. C. *et al.*, JGR, 2013



Adapted from IPCC, AR5, 2013

INTRO - NOAA Single Particle Soot Photometer (SP2)

- Onboard **NOAA P-3** aircraft

- Measurements of **BC mass in single particles** by laser incandescence independent of mixing state and morphology (**~90 – 550 nm**)

- Measurements of **optical size** of BC-containing particles (**~200 – 400 nm**)

NOAA P-3 integration, Tampa, FL

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- **BC data products:**

✓ **mass mixing ratio, ng kg^{-1} (archived)**

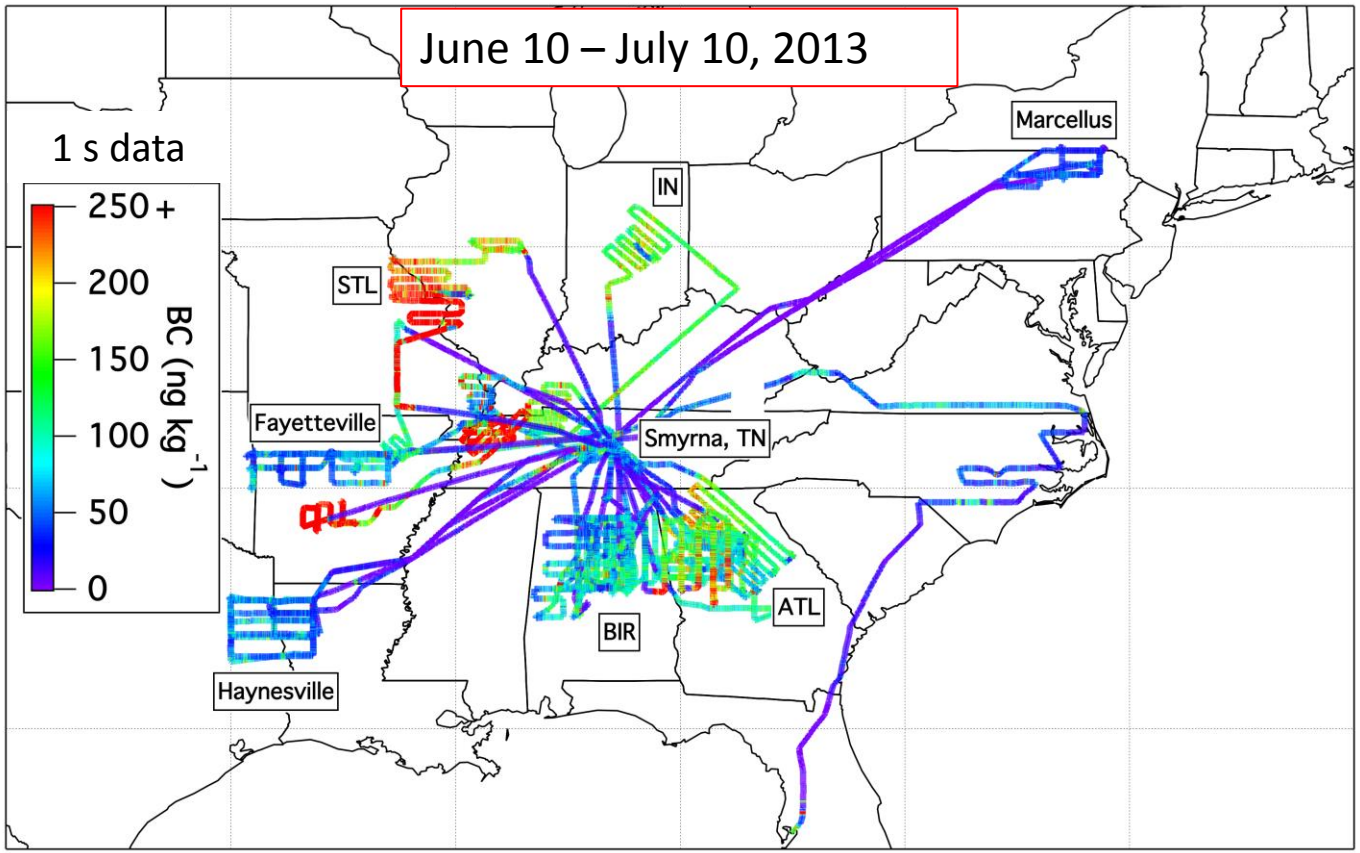
✓ **STD & AMB mass loadings, µg m^{-3} (archived)**

✓ **coating state and thickness**

NOAA P-3 integration, Tampa, FL

Schwarz, J. P. *et al.*, GRL, 2008; Gao, R.S. *et al.*, AS&T, 2007

RESULTS – SENEX BC OVERVIEW



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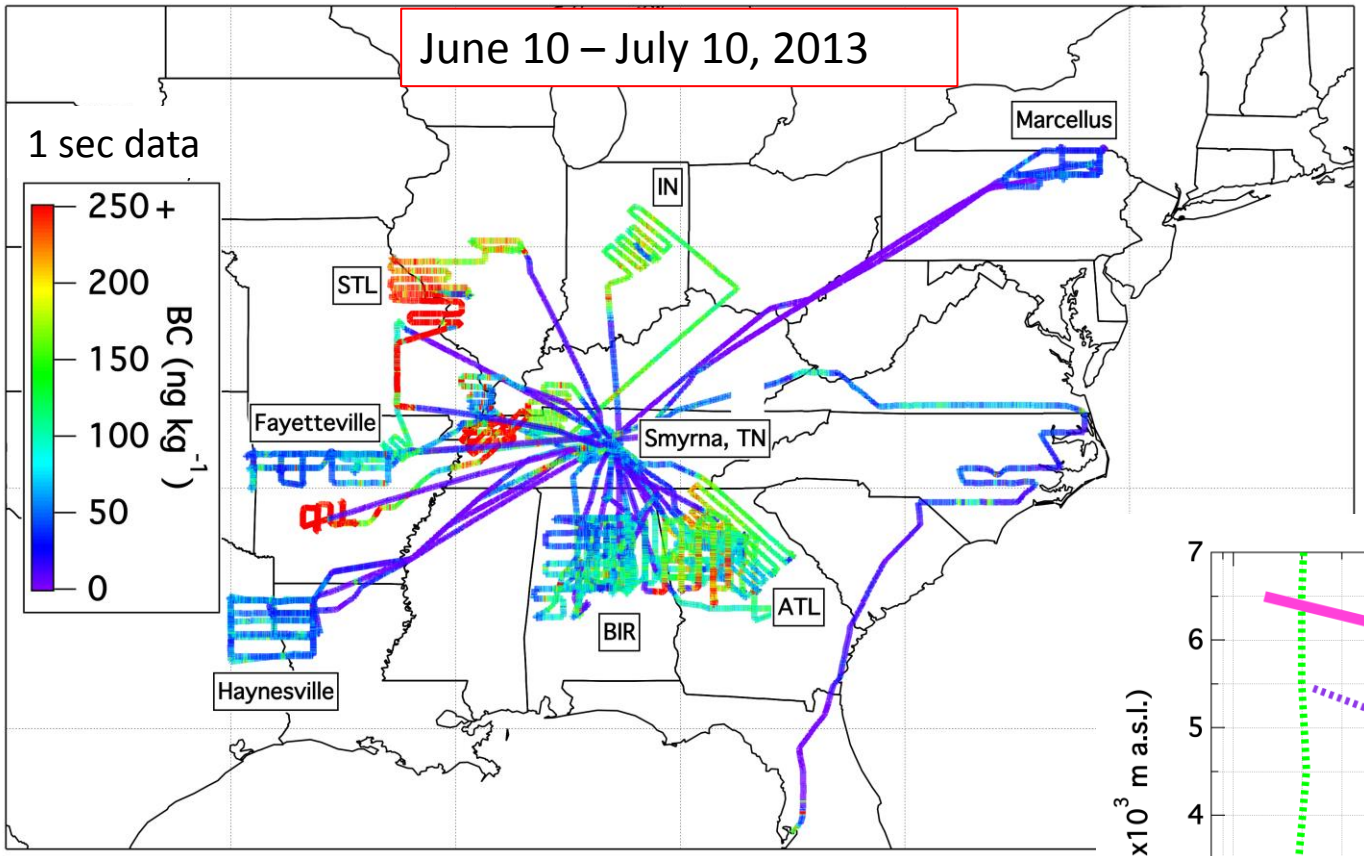
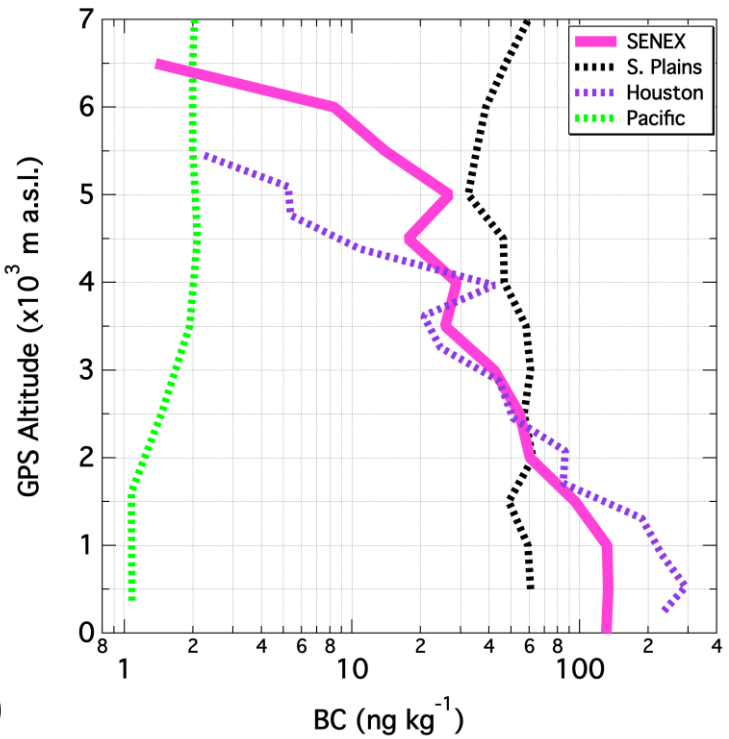
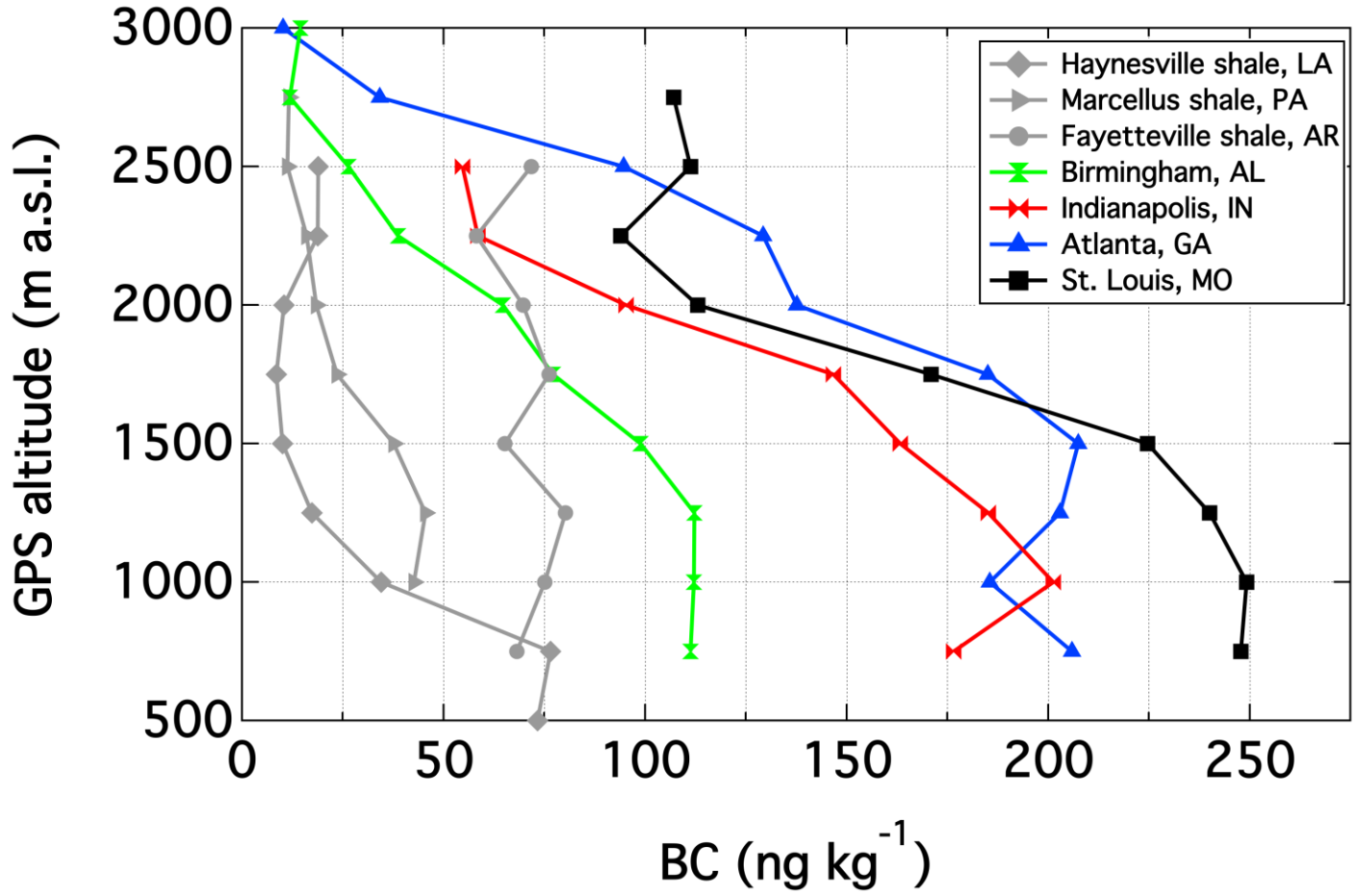




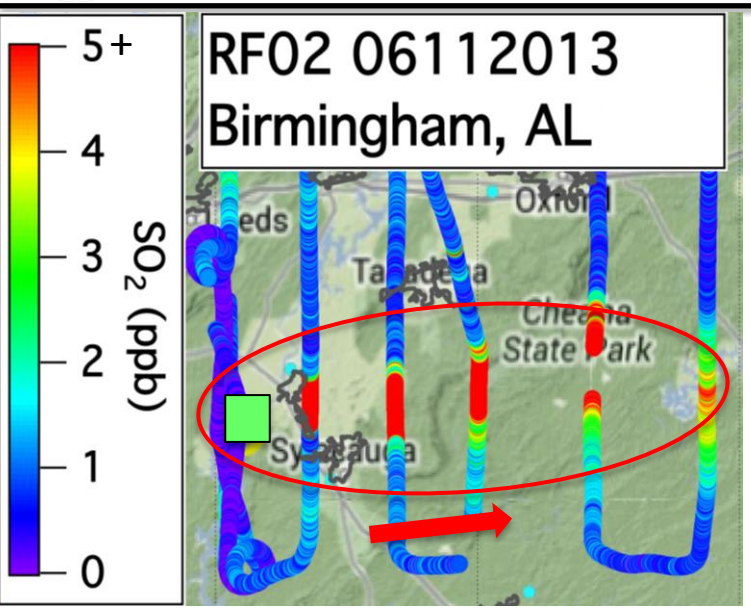
Spackman, J. R. *et al.*, GRL, 2008; Schwarz, J. P. *et al.*, GRL, 2010

RESULTS – BC Vertical Profiles

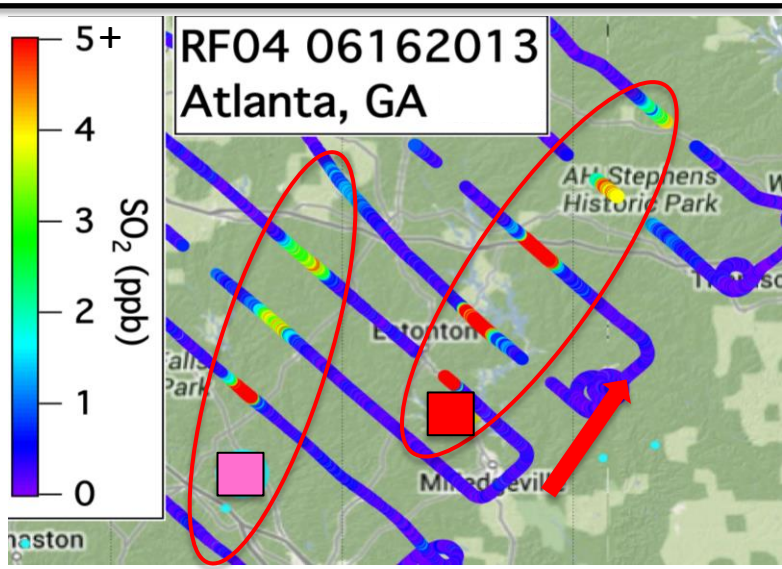


- **Shale** exploration regions are **not** a significant **source of BC**
- Larger **urban** and **industrial** centers are **larger sources of BC**
- **Analysis of BC from BB coming soon**

RESULTS – Impact of power plants on BC

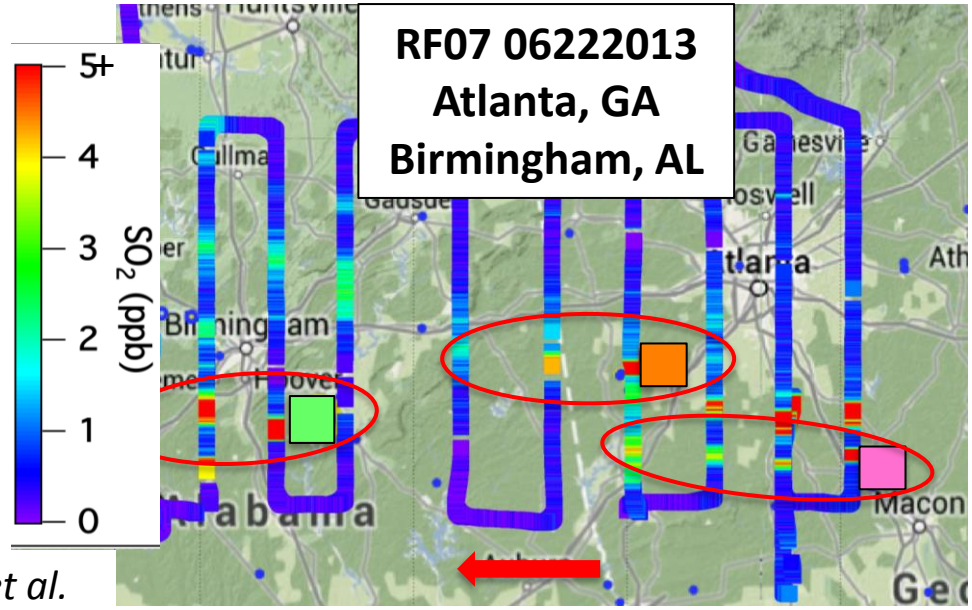


Gaston PP **COAL** 1881 MW



Scherer PP **COAL** 3405 MW

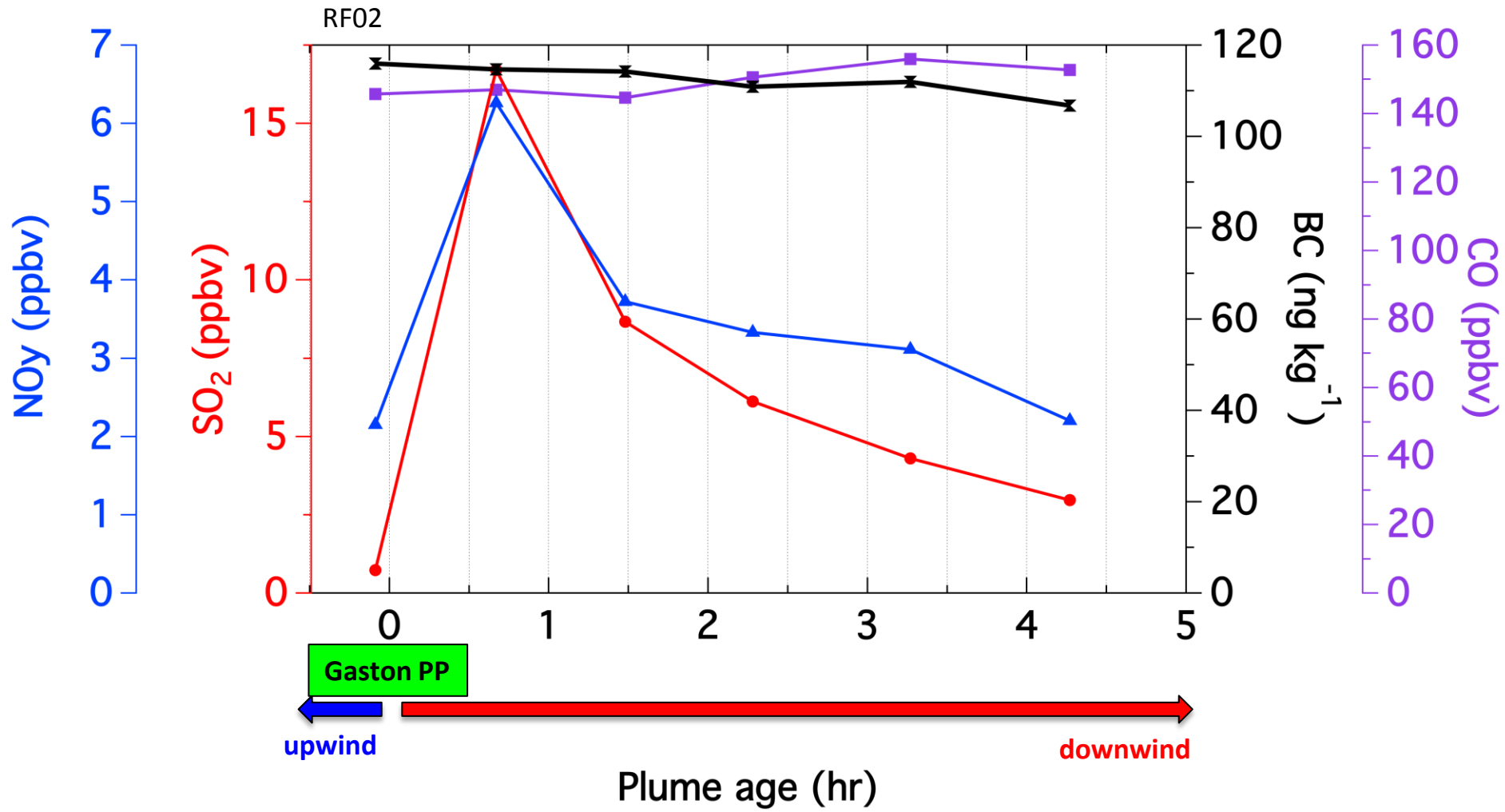
Harllee branch PP **COAL** 1607 MW



Yates PP
COAL 1250 MW

SO_2 data from J. Holloway *et al.*

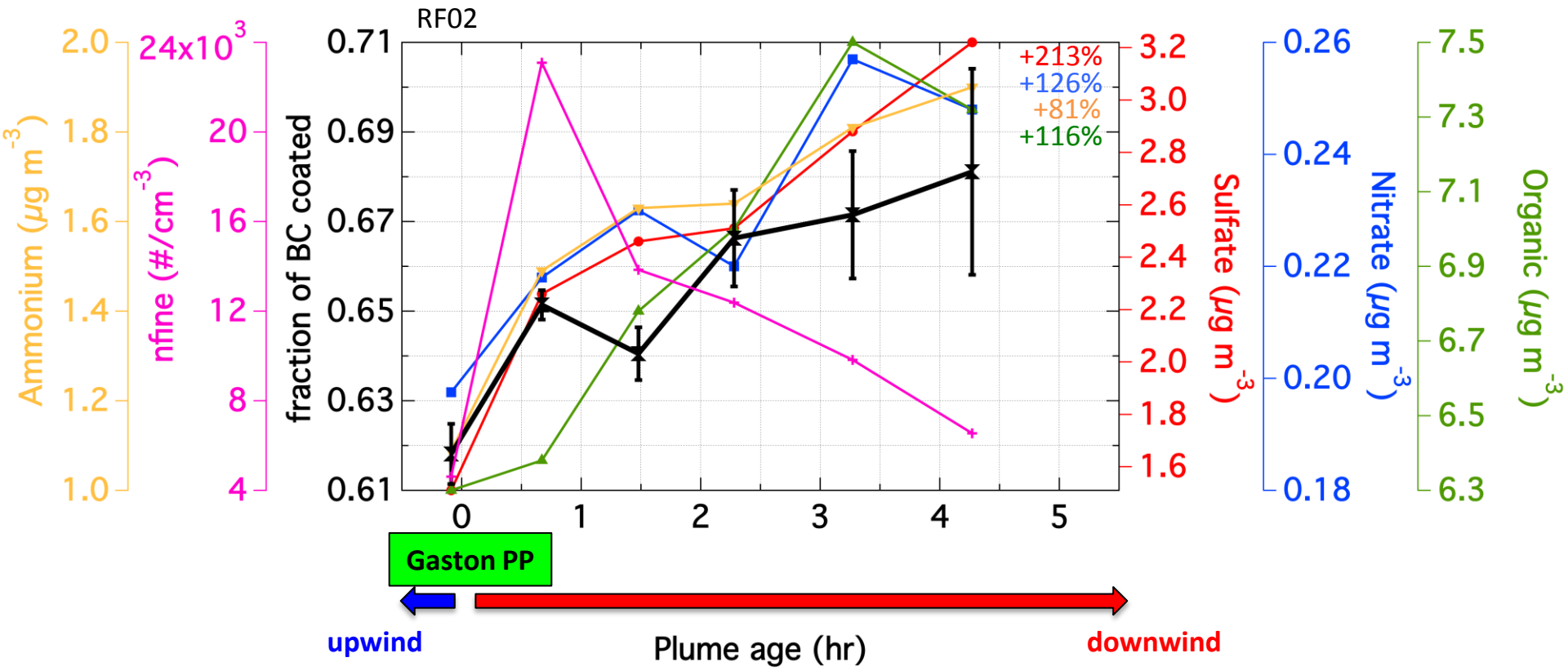
RESULTS – power plant emissions of BC



Power plants are not a significant source of BC – opportunity to perform a "lab test" in the field

NOy data from I. B. Pollack, T. B. Ryerson *et al.* ; CO and SO_2 data from J. Holloway *et al.*

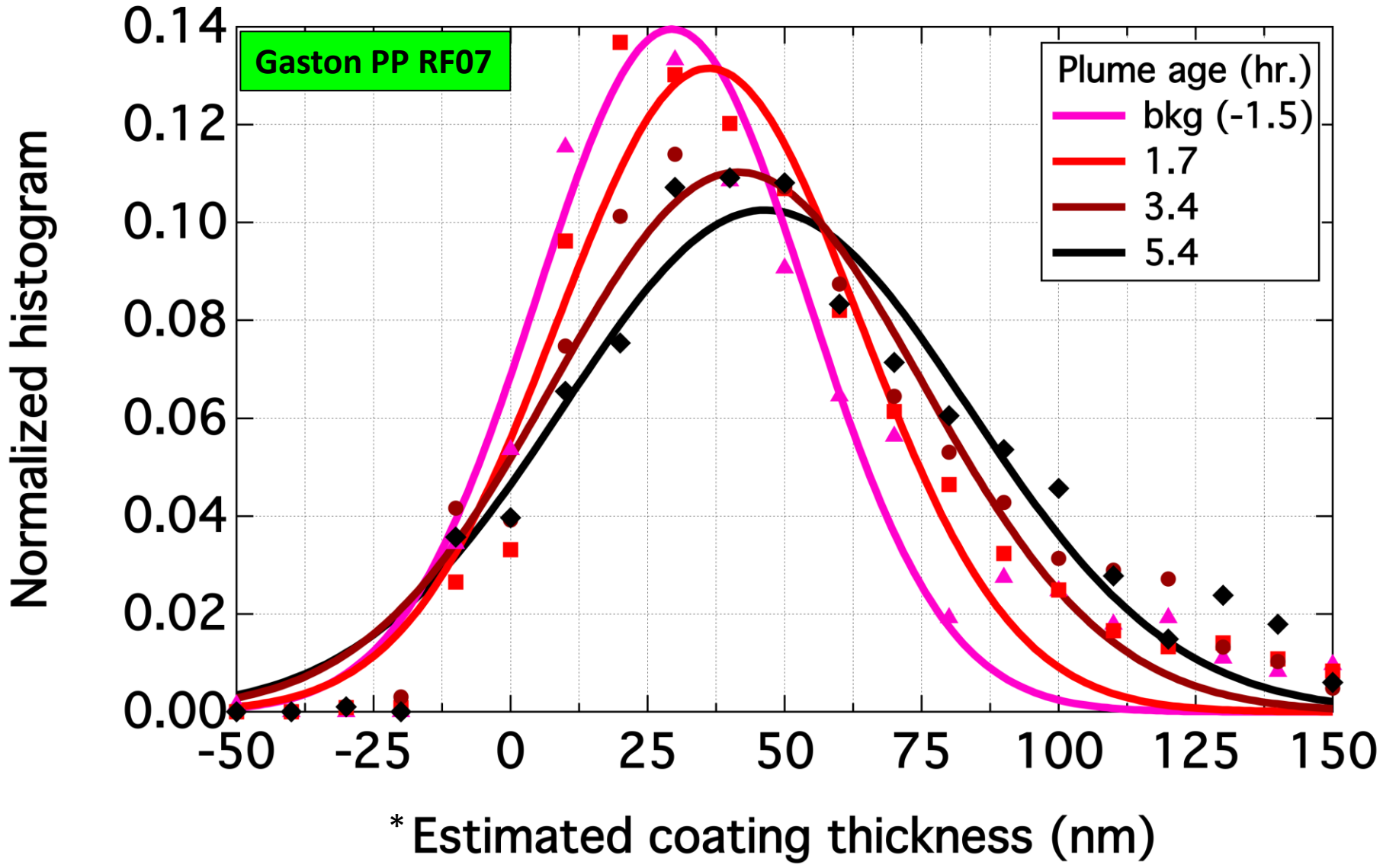
RESULTS – power plant AGING of BC



The fraction of BC particles that can be identified as coated increases in power plant plumes by sulfate condensation/coagulation and subsequent chemistry

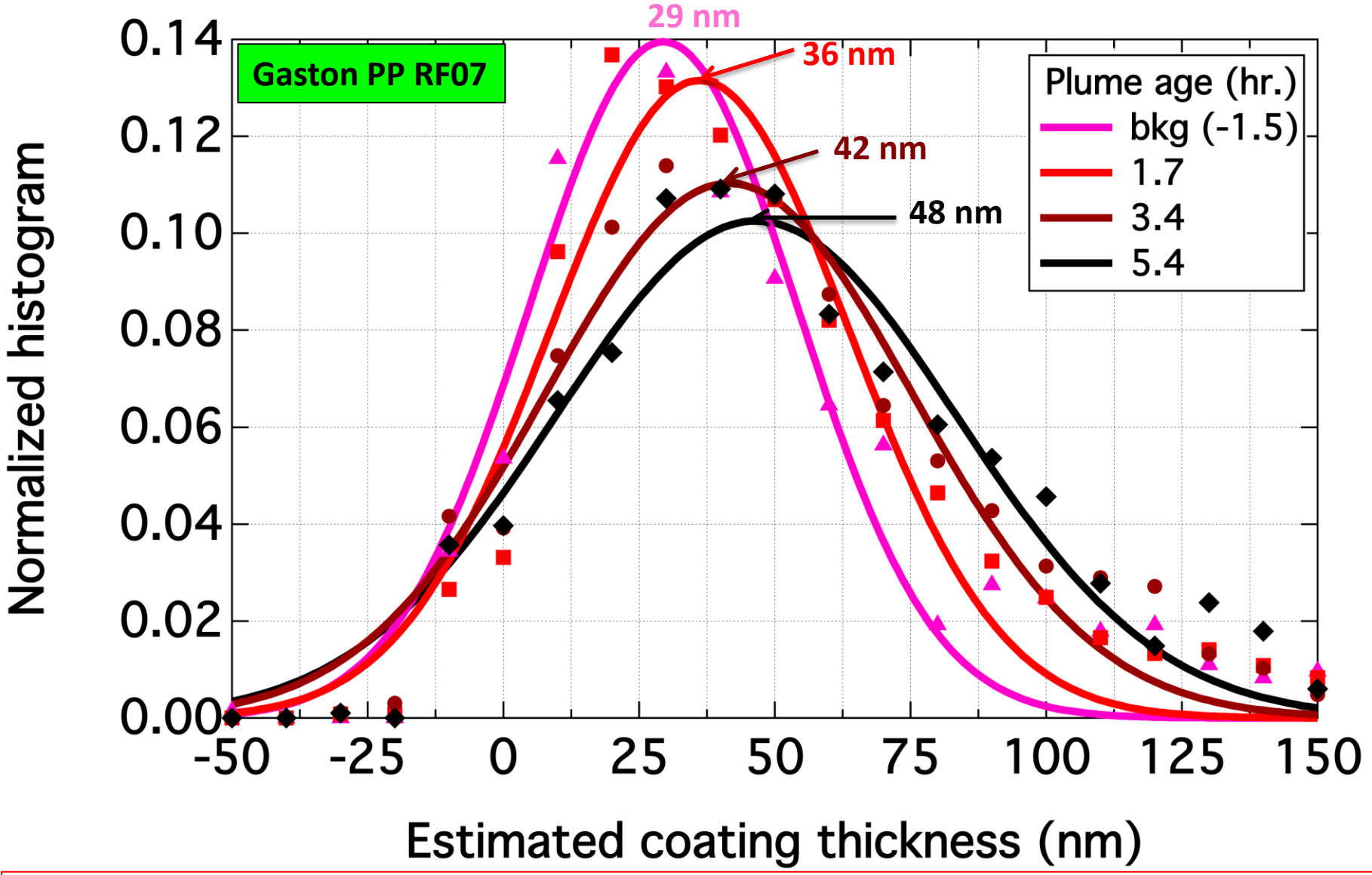
NMASS data from C. A. Brock, N. L. Wagner *et al.* ; AMS data from J. Liao, A. M. Middlebrook *et al.*

RESULTS – Power Plant AGING of BC



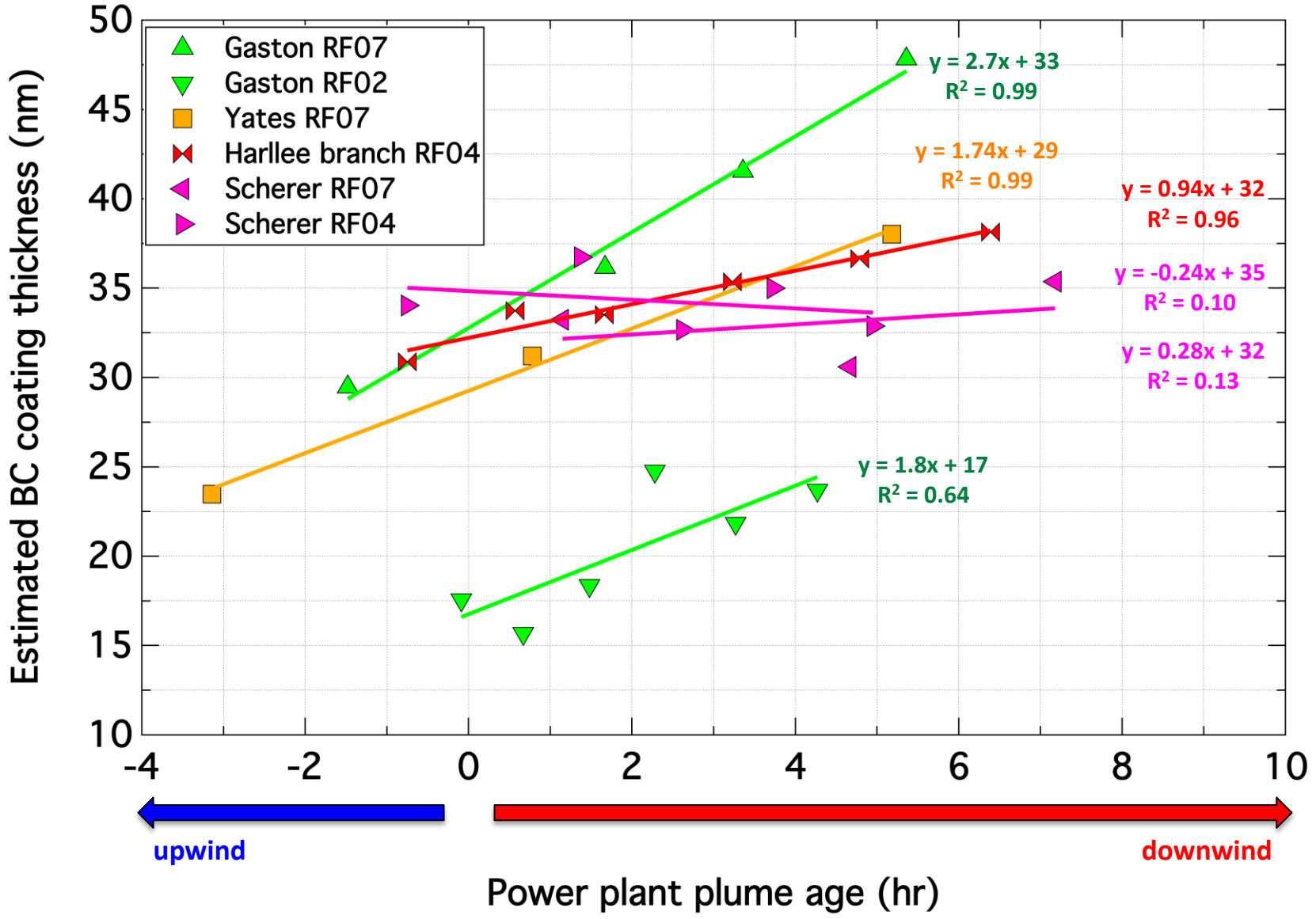
*** Approximated from scattering and BC mass measurements** (Schwarz, J. P. *et al.*, GRL, 2008; Gao, R.S. *et al.*, AS&T, 2007)

RESULTS – Power Plant AGING of BC



Distribution of **BC coating** thicknesses **increases** with **age of PP plumes**

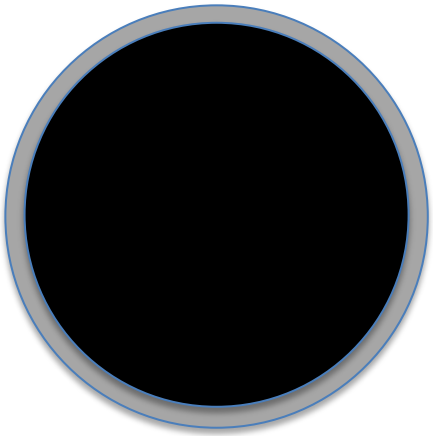
RESULTS – Power Plant AGING of BC



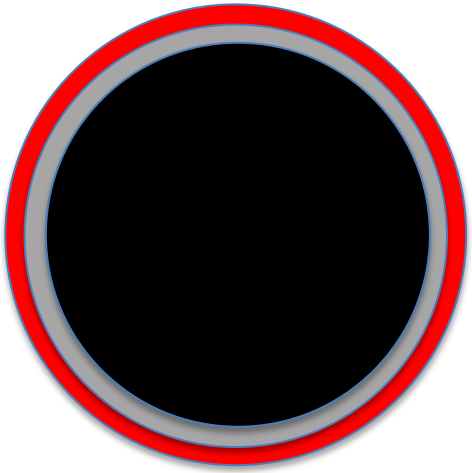
BC coating thickness **increases** with PP **plume age** in most cases

RESULTS – Power Plant AGING of BC

ave ~220 nm BC cores



220 nm core + 20 nm



220 nm core + 40 nm

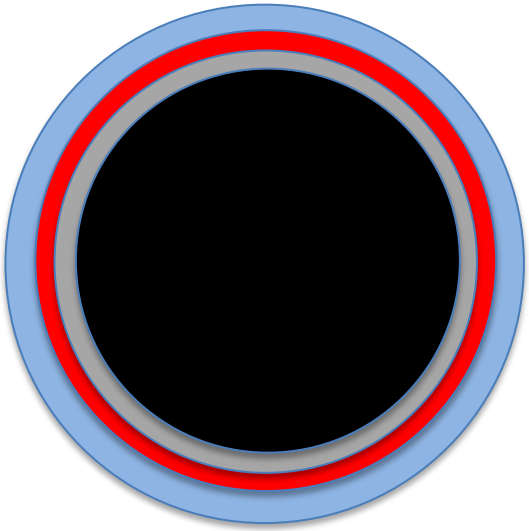
Sulfate

Water

$A_2/A_1 = 4\pi r_2^2/4\pi r_1^2 =$ **20 %** $V_2/V_1 = 4/3\pi r_2^3/4/3\pi r_1^3 =$ **30 %**

$A_3/A_1 =$ **50 %**

$V_3/V_1 =$ **80 %**



220 nm core + 70 nm

Very different lifetime and radiative properties

Bond T. *et al.*, JGR, 2006;
Stier, P. *et al.*, JGR, 2006

RESULTS – Power Plant AGING of BC

166 coal- and oil-fired PP > **25 MW**

Adapted from www.epa.gov/mats/pdfs/20111221facilitiesmap.pdf

CONCLUSIONS

- **Shale** exploration regions are **NOT a significant** source of **BC**

- **Urban/industrial areas** are **major** sources **of BC** in the **SE USA**
  - St. Louis more than Atlanta

- **Power plants** are **NOT a significant** source **of BC** in the **SE USA,** but affect BC mixing state and aging:

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- **Power plants** are **NOT a significant** source **of BC** in the **SE USA,** but affect BC mixing state and aging:

with **aging of** a **PP plume**:

Fraction of BC that can be identified as **coated increases**

Coating thickness of BC particles **increases**

…from **condensation/coagulation of sulfate** and consequent chemistry

FUTURE WORK

Investigate plumes from other power plants

Study the differences in **aging rates** between plumes as a **function of:**

- **AMS**
  composition (sulfate, nitrate etc.)
  organic factors (LV-OOA, SV-OOA, HOA)

- **NMASS**
  NON-BC fine particle number

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Examine the:

- Aerosol **EXTINCTION** measurements

- **CCN Activity** measurements

MODEL/CALCULATE PP AGING IMPACTS ON BC LIFETIME & RADIATIVE PROPERTIES

ACKNOWLEDGEMENTS

- NOAA WP-3D crew and everyone from NOAA AOC
- Smyrna municipal airport folks
- SAS-SENEX participants
- Session chairs
- You for listening !