

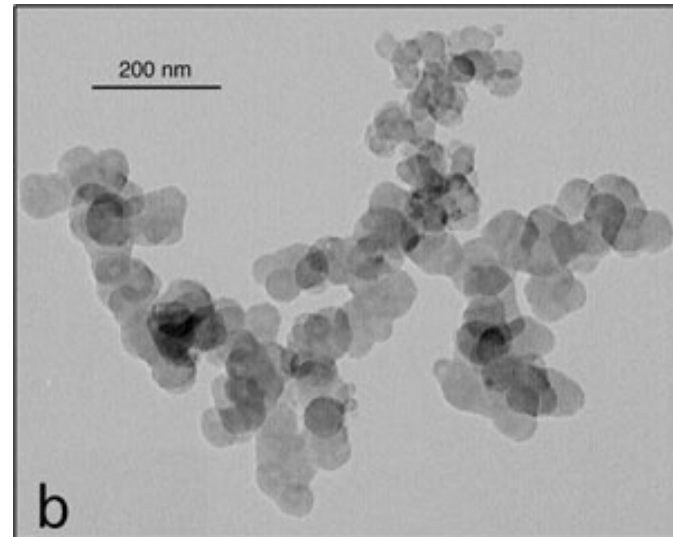
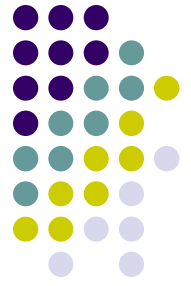
Black carbon inventories, fluxes, and mechanisms: where are we?

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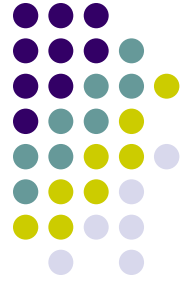


RICE

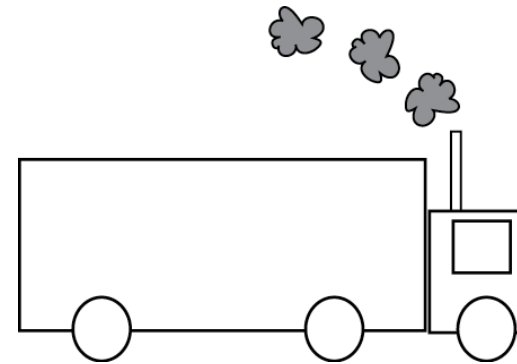
Black carbon is charcoal and soot



Black carbon is produced from incomplete combustion and pyrolysis



0.05-0.27 Gt C/yr



0.012-0.024 Gt C/yr

1 Gigaton = 10^9 tons

BC is a continuum of combustion/pyrolysis byproducts



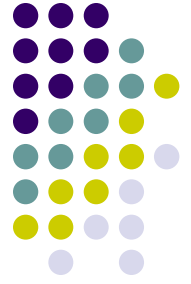
	slightly charred biomass	char	charcoal	soot	GBC
formation T	low → high				
size	mm and larger		mm to submicron	submicron	
plant structures	abundant	significant presence	few	none	
reactivity	high → low				
initial reservoir	soils		soils and atmosphere		
paleotracer range	short (meters)	short (m to km)	short (m to km)	long (up to 1000s of km)	



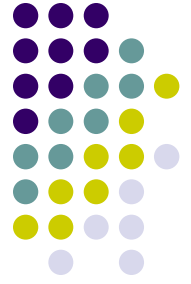
Historic Community Questions:

- Is BC a major carbon cycle sink?
 - **Answer:** yes, but when produced in biomass burning, the net result is a short-term C cycle source.
 - **Next:** can we make a BC sink with limited CO₂ emissions?
- Is BC refractory?
 - **Answer:** yes.
 - **Next:** Is the residence time of BC 500 years or 10,000 years? How do environmental parameters alter BC τ ?
- Is BC present in the ____ carbon pool?
 - **Answer:** yes, it's in all of them.
 - **Next:** how much? What are its biogeochemical roles?

New questions



- Understand the role of BC (and fire) in natural ecosystems:
 - Impact of soil BC on ecosystem structure, pedogenesis;
 - Feedbacks between burning and soil processes;
 - Role of BC in marine/aquatic systems;
 - N cycle and BC.
- Develop techniques to sustainably use BC to mitigate GHG emissions:
 - Chemical, physical, microbial characterizations of natural vs produced chars.
- Needed for both:
 - Better budgets;
 - Mechanisms.



Outline

- New methods intercomparison work makes possible next steps in BC budgets and methods;
- Budget next steps;
- Mechanism next steps.

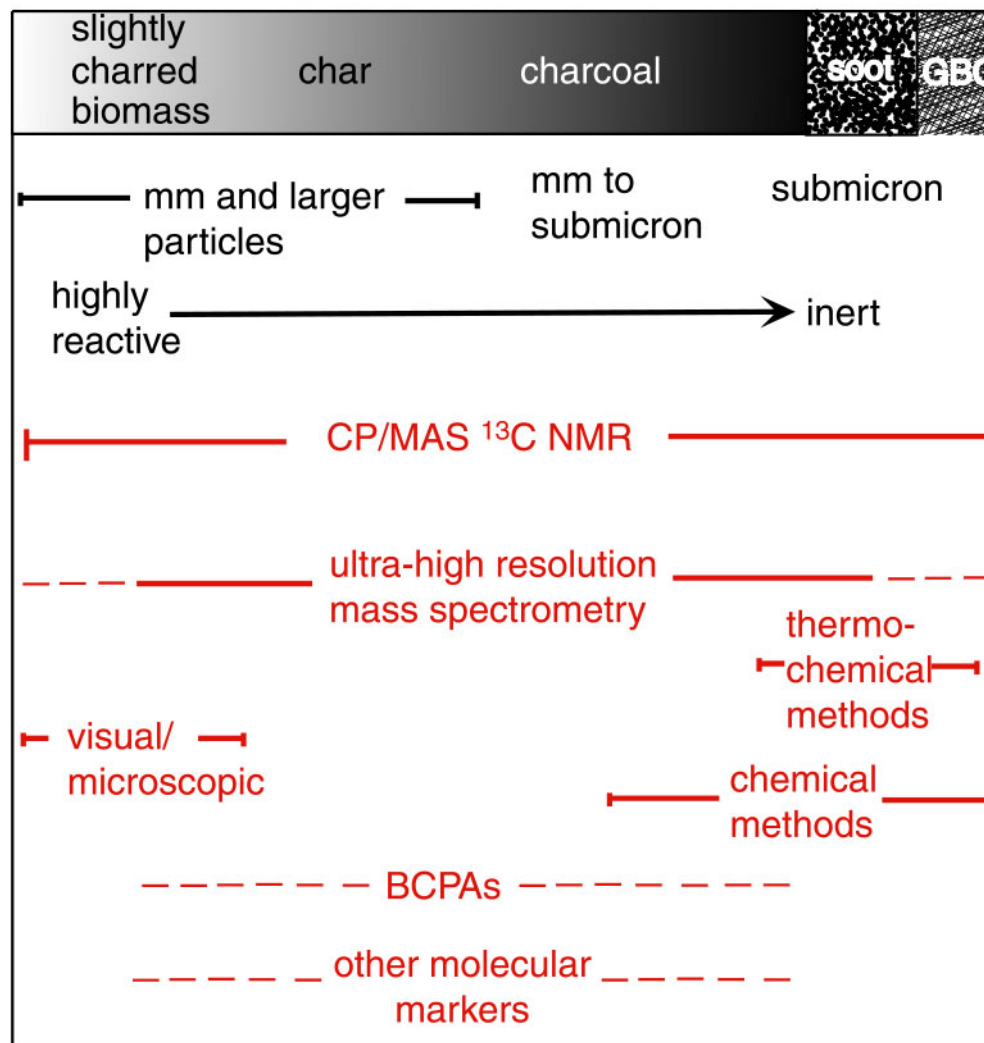


Comparison of quantification methods to measure fire-derived (black/elemental) carbon in soils and sediments using reference materials from soil, water, sediment and the atmosphere

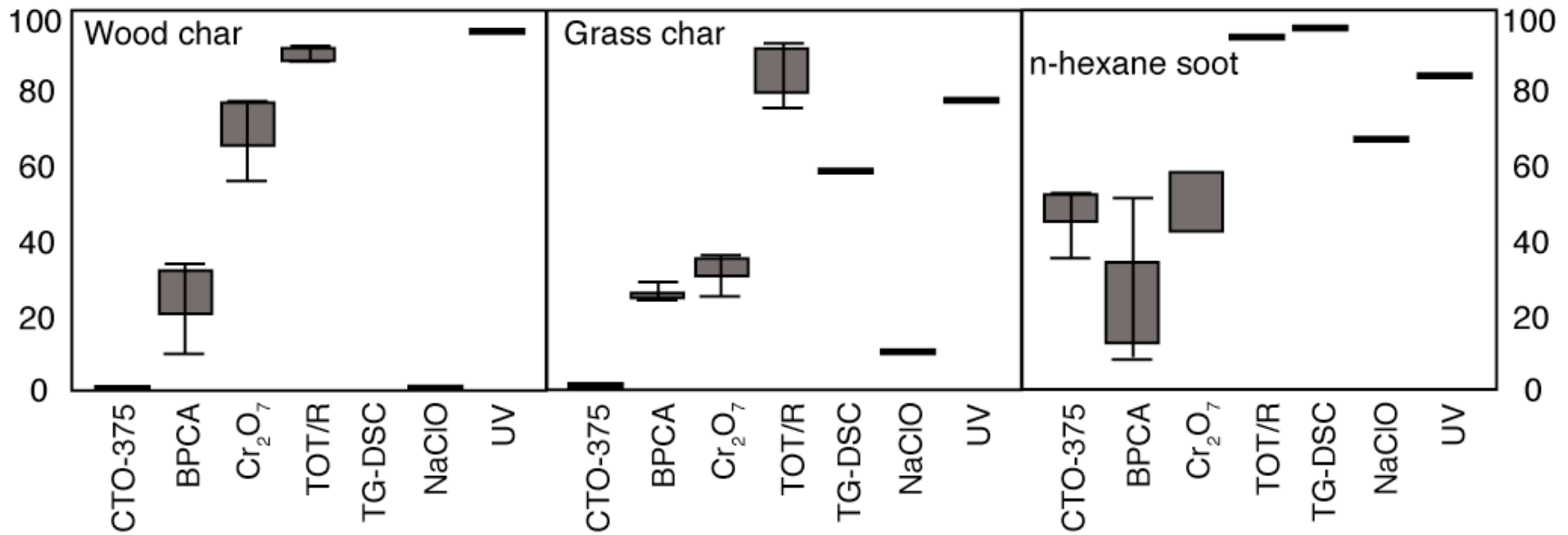
Karen Hammes,¹ Michael W. I. Schmidt,¹ Ronald J. Smernik,² Lloyd A. Currie,^{3,4} William P. Ball,⁵ Thanh H. Nguyen,^{5,6} Patrick Louchouart,^{7,8} Stephane Houel,⁷ Örjan Gustafsson,⁹ Marie Elmquist,⁹ Gerard Cornelissen,⁹ Jan O. Skjemstad,¹⁰ Caroline A. Masiello,¹¹ Jianzhong Song,¹² Ping'an Peng,¹² Siddhartha Mitra,¹³ Joshua C. Dunn,¹³ Patrick G. Hatcher,¹⁴ William C. Hockaday,¹⁴ Dwight M. Smith,¹⁵ Christoph Hartkopf-Fröder,¹⁶ Axel Böhmer,¹⁶ Burkhard Lüer,¹⁶ Barry J. Huebert,¹⁷ Wulf Amelung,¹⁸ Sonja Brodowski,¹⁸ Lin Huang,¹⁹ Wendy Zhang,¹⁹ Philip M. Gschwend,²⁰ D. Xanat Flores-Cervantes,²⁰ Claude Largeau,²¹ Jean-Noël Rouzaud,²¹ Cornelia Rumpel,²² Georg Guggenberger,²³ Klaus Kaiser,²³ Andrei Rodionov,²³ Francisco J. Gonzalez-Vila,²⁴ José A. Gonzalez-Perez,²⁴ José M. de la Rosa,²⁴ David A. C. Manning,²⁵ Elisa López-Capél,²⁵ and Luyi Ding²⁶

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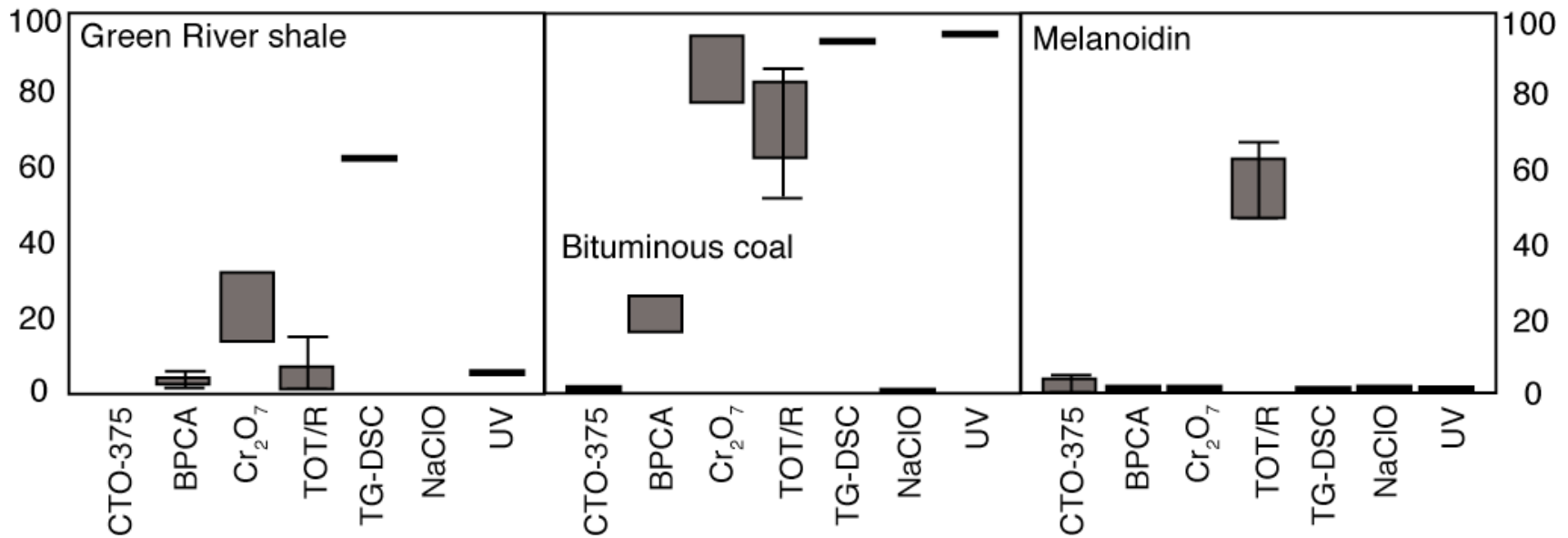
Pre-Hammes et al., 2007: Methods uncertainty and conflict



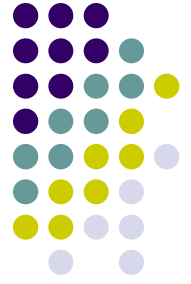
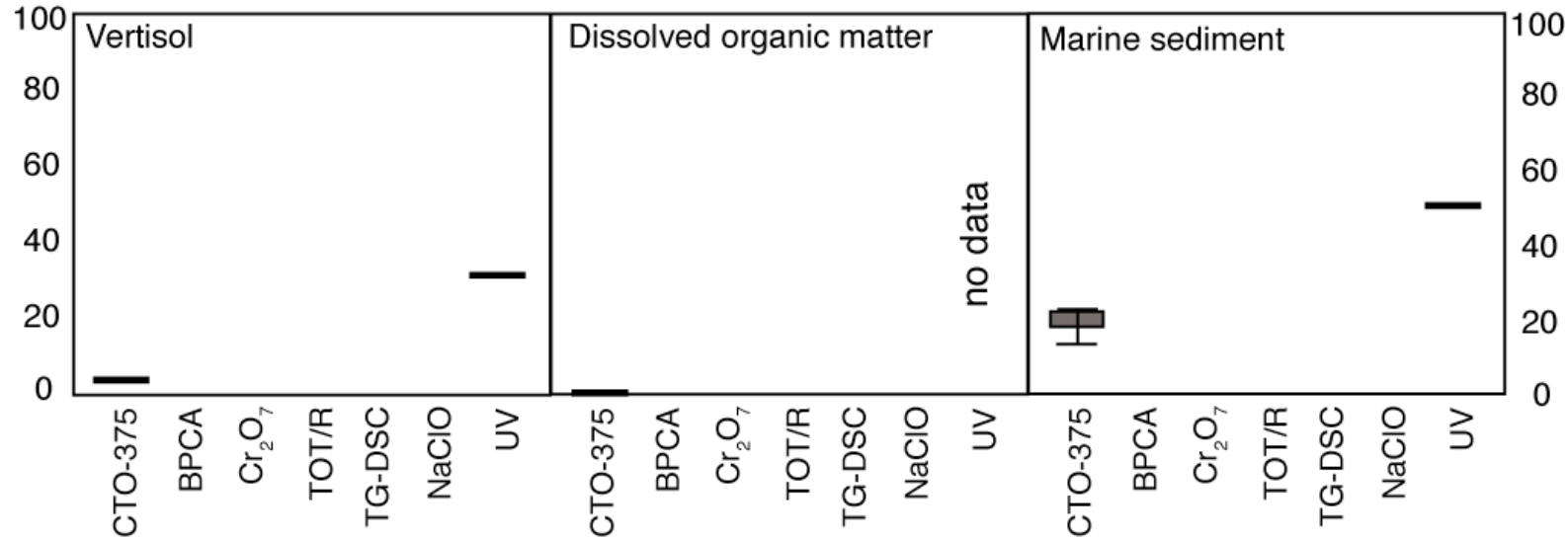
Hammes et al., 2007: what methods detect black carbon?



Hammes et al., 2007: what methods have low blanks?



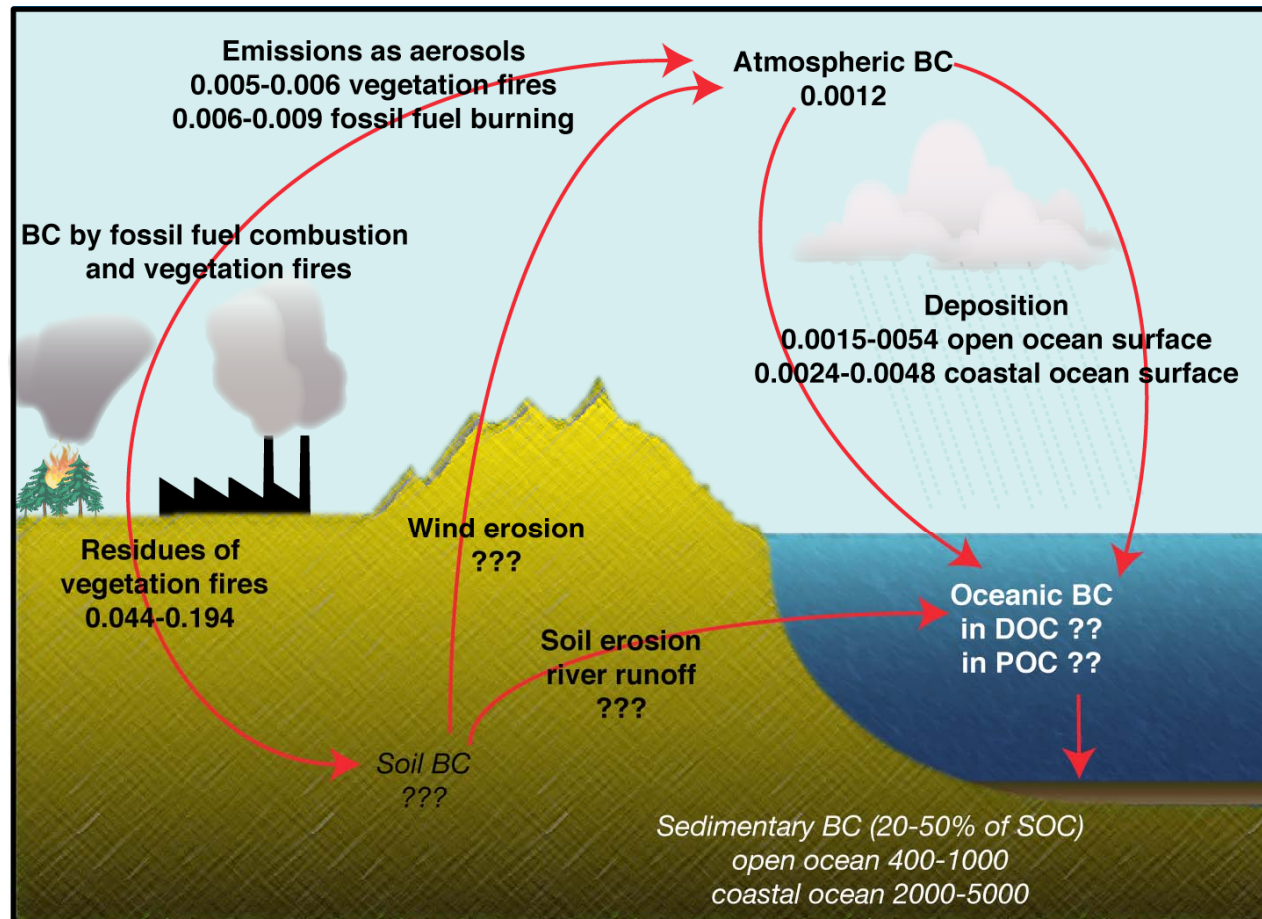
Hammes et al. data implications



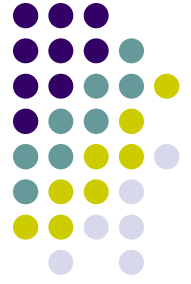
- Soot/BC total is higher in sediments than soil;
- But there's no soot in the DOM;
- Implications:
 - Exclusive aerosol transport of soot to sediments;
 - Long marine τ for soot in DOC pool;
 - Very different terrestrial τ for soot and charcoal.



What is the status of the global BC budget?



Kuhlbusch, Science, 1998



1998 BC budget, missing items:

- Any estimate of inventories for:
 - Soil BC pool;
 - Marine dissolved organic carbon (DOC) and particulate organic carbon (POC) pools;
 - Terrestrial DOC pool.
- Any decomposition flux estimates;
- Any residence times (except sediments);
- Any mechanisms.



Next method steps

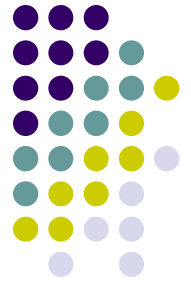
- Methods:
 - Correction factors for methods
 - E.g. $BC_{total} = \text{char } BC_{NMR} * 0.8$; soot $BC = BC_{CTO-375} * 0.5$
 - Spiked sample experiments?
- Methods aside:
 - CTO 375 values reflect soot budget only;
 - NMR, BPCA values reflect soot + charcoal
 - (with a correction factor).
 - Can we combine them to get distinct pools?

What can we say about fluxes and pools 10 years later?

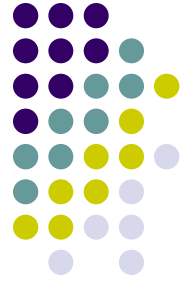


- **Production Fluxes:**
- Forbes et al. (2006) reassessed fluxes:
 - compendium of fire studies;
 - Data normalization to BC per carbon consumed by fire (BC/CC);
 - No new production rates, though.
- Missing from existing production literature:
 - Any data on BC production rates from temperate N American ecosystems.

What can we say about fluxes and pools 10 years later?

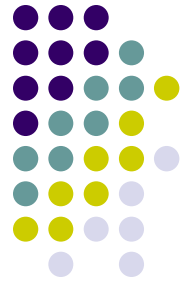


- **Loss Fluxes:**
- Fire, microbial consumption, transport between reservoirs.
 - Microbes: Baldock and Smernik (2002), Hamer et al. (2004), Bruun et al. (2008); interx: Wardle et al. (2008), Steiner (2008)
 - Fires: Czimczik et al. (2005)
 - Transport via rivers: Masiello & Druffel (2001), Mitra et al. (2002), Hockaday et al. (2007), Kim et al. (2004) Hunsinger et al. (2008)...



Pools in the BC budget

- Vast literature of BC soil data. How to assemble?
 - Soil type? Ecosystem? Biome?
 - “As much as 30% of OC in some soils!”
- BC in DOC:
 - 1998: only by inference, long τ
 - Definitely present in soil + river DOC (Hockaday 3 pm)
 - BC in marine DOC pool? (Ziolkowski pm)



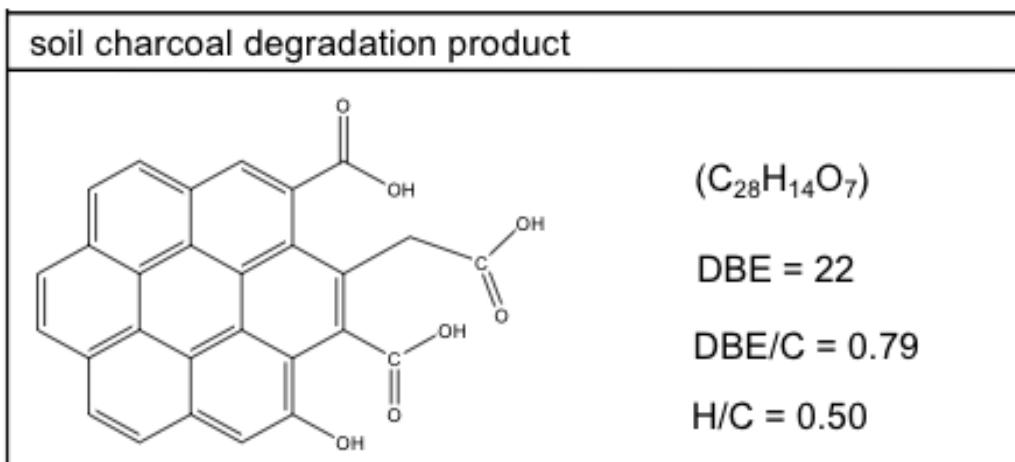
More mechanistic information

- BC and N cycle, natural and amended, terrestrial and marine.
- BC and soil physical properties
 - Density, strength, shrink-swell, hydraulic conductivity
- Mechanisms of decomposition: big picture assessment
- BC and pedogenesis



Charcoal and pedogenesis

- high resolution mass spec (ESI FT-ICR) allows exact molecular identification of molecular BC fragments in soil (Hockaday, 3 pm)



Hockaday et al., 2007

Charcoal, pedogenesis, and rivers

- Both ecosystems burned. Why BC in only 1 river?
- Does soil type control export/storage of BC?

Kim et al., 2004

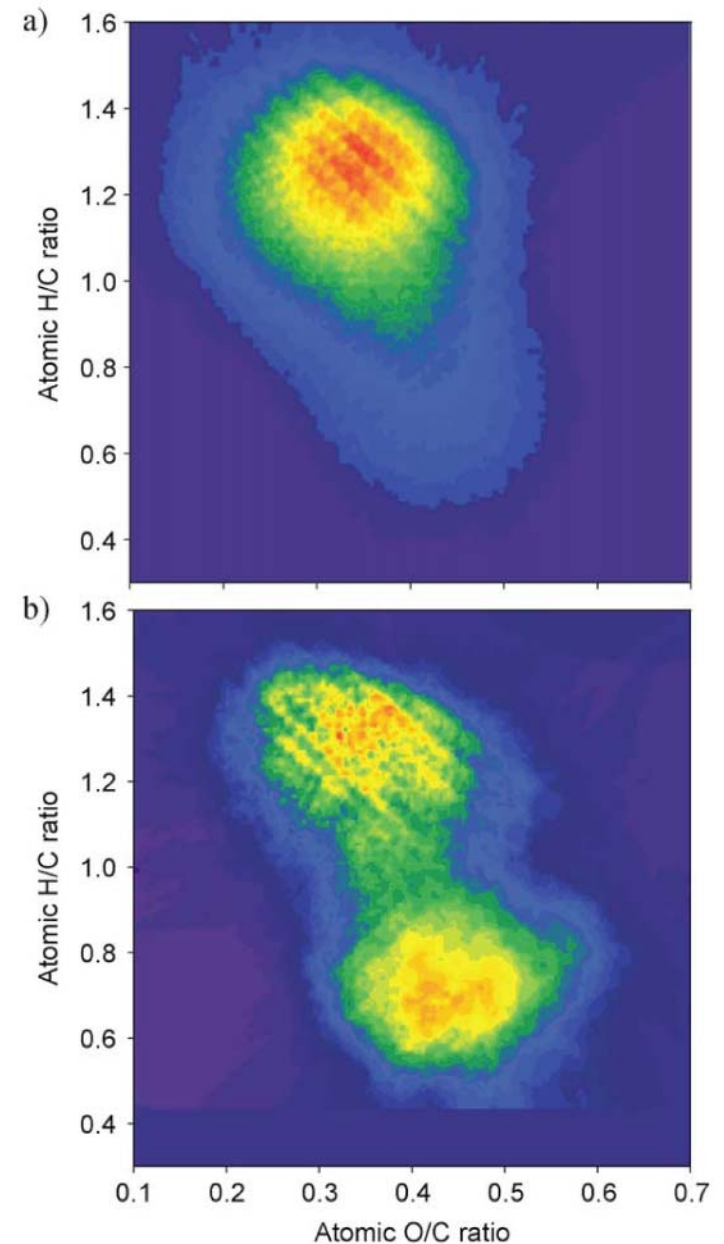


Fig. 4. The 3D van Krevelen diagrams constructed from ultra-high resolution data of (a) McDonalds branch and (b) Rio Negro DOM. Relative intensities of the signal increase in the order purple, blue, green, yellow, and red.