

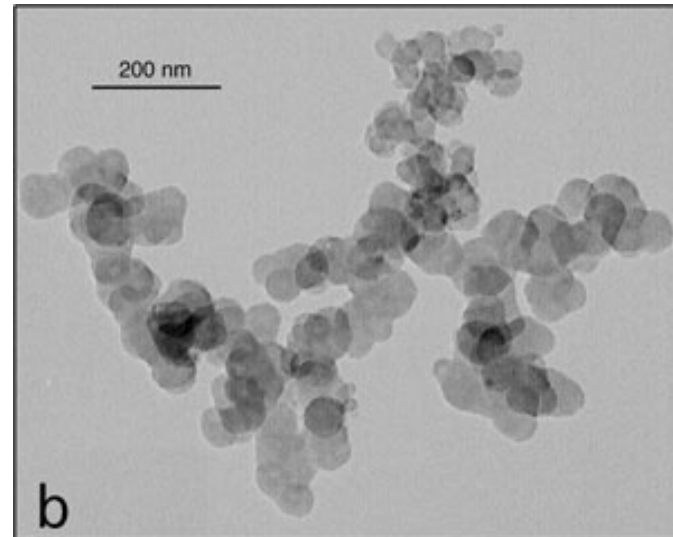
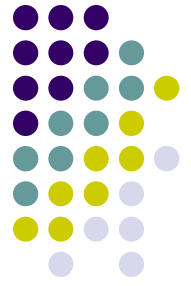
# Black carbon inventories, fluxes, and mechanisms: where are we?

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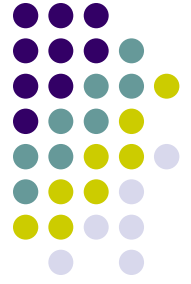
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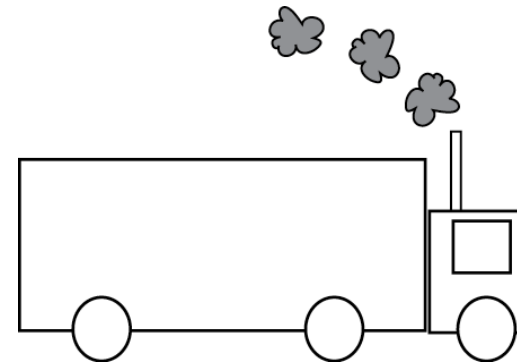
# Black carbon is charcoal and soot



# 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



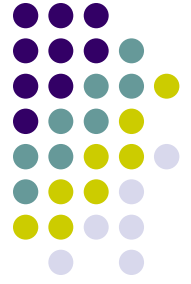
	slightly charred biomass	char	charcoal	soot	GBC
<b>formation T</b>	low	→			high
<b>size</b>	mm and larger		mm to submicron	submicron	
<b>plant structures</b>	abundant	significant presence	few	none	
<b>reactivity</b>	high	→			low
<b>initial reservoir</b>	soils		soils and atmosphere		
<b>paleotracer range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



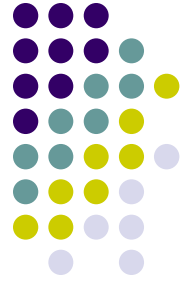
# Historic Community Questions:

- 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 CO<sub>2</sub> 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  $\tau$ ?
- 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.

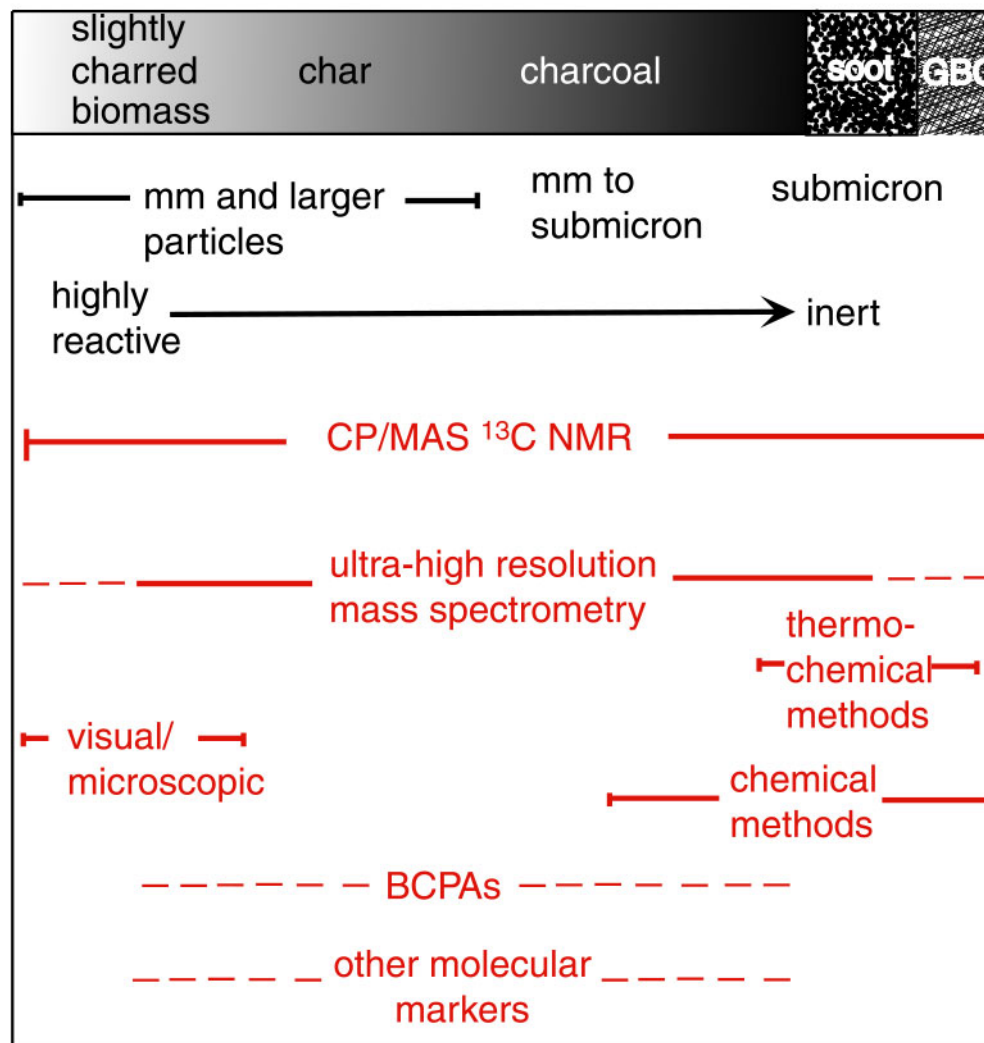


## **Comparison of quantification methods to measure fire-derived (black/elemental) carbon in soils and sediments using reference materials from soil, water, sediment and the atmosphere**

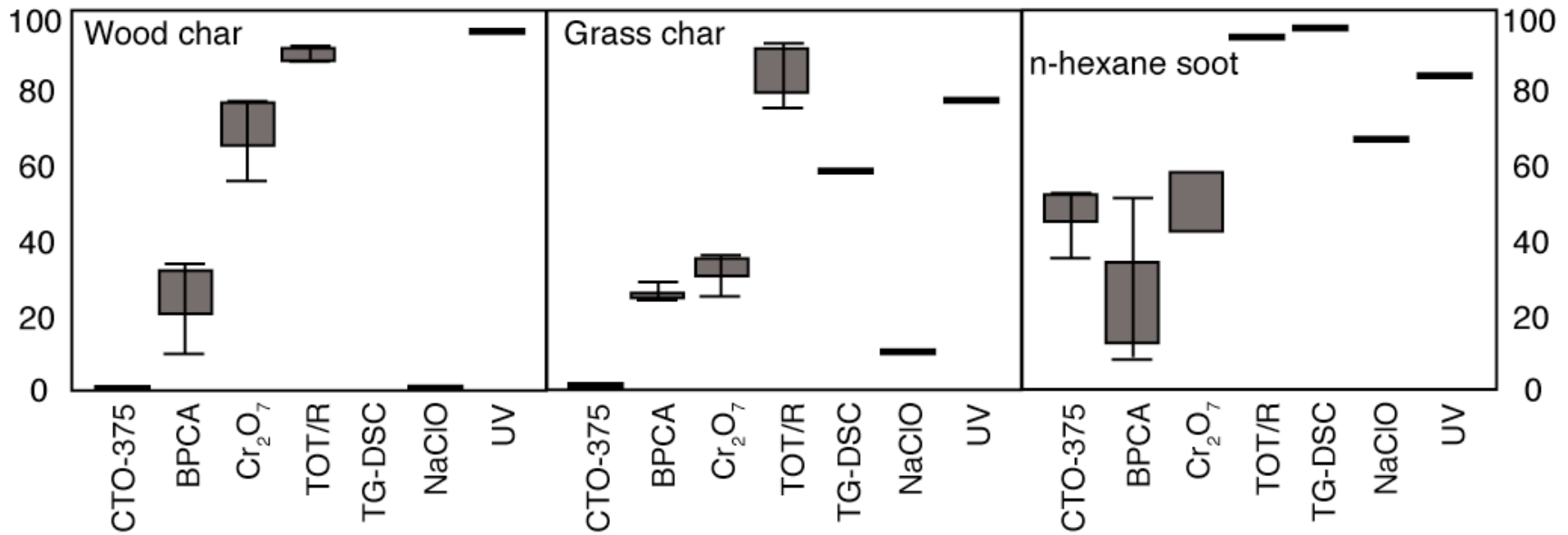
Karen Hammes,<sup>1</sup> Michael W. I. Schmidt,<sup>1</sup> Ronald J. Smernik,<sup>2</sup> Lloyd A. Currie,<sup>3,4</sup> William P. Ball,<sup>5</sup> Thanh H. Nguyen,<sup>5,6</sup> Patrick Louchouart,<sup>7,8</sup> Stephane Houel,<sup>7</sup> Örjan Gustafsson,<sup>9</sup> Marie Elmquist,<sup>9</sup> Gerard Cornelissen,<sup>9</sup> Jan O. Skjemstad,<sup>10</sup> Caroline A. Masiello,<sup>11</sup> Jianzhong Song,<sup>12</sup> Ping'an Peng,<sup>12</sup> Siddhartha Mitra,<sup>13</sup> Joshua C. Dunn,<sup>13</sup> Patrick G. Hatcher,<sup>14</sup> William C. Hockaday,<sup>14</sup> Dwight M. Smith,<sup>15</sup> Christoph Hartkopf-Fröder,<sup>16</sup> Axel Böhmer,<sup>16</sup> Burkhard Lüer,<sup>16</sup> Barry J. Huebert,<sup>17</sup> Wulf Amelung,<sup>18</sup> Sonja Brodowski,<sup>18</sup> Lin Huang,<sup>19</sup> Wendy Zhang,<sup>19</sup> Philip M. Gschwend,<sup>20</sup> D. Xanat Flores-Cervantes,<sup>20</sup> Claude Largeau,<sup>21</sup> Jean-Noël Rouzaud,<sup>21</sup> Cornelia Rumpel,<sup>22</sup> Georg Guggenberger,<sup>23</sup> Klaus Kaiser,<sup>23</sup> Andrei Rodionov,<sup>23</sup> Francisco J. Gonzalez-Vila,<sup>24</sup> José A. Gonzalez-Perez,<sup>24</sup> José M. de la Rosa,<sup>24</sup> David A. C. Manning,<sup>25</sup> Elisa López-Capél,<sup>25</sup> and Luyi Ding<sup>26</sup>

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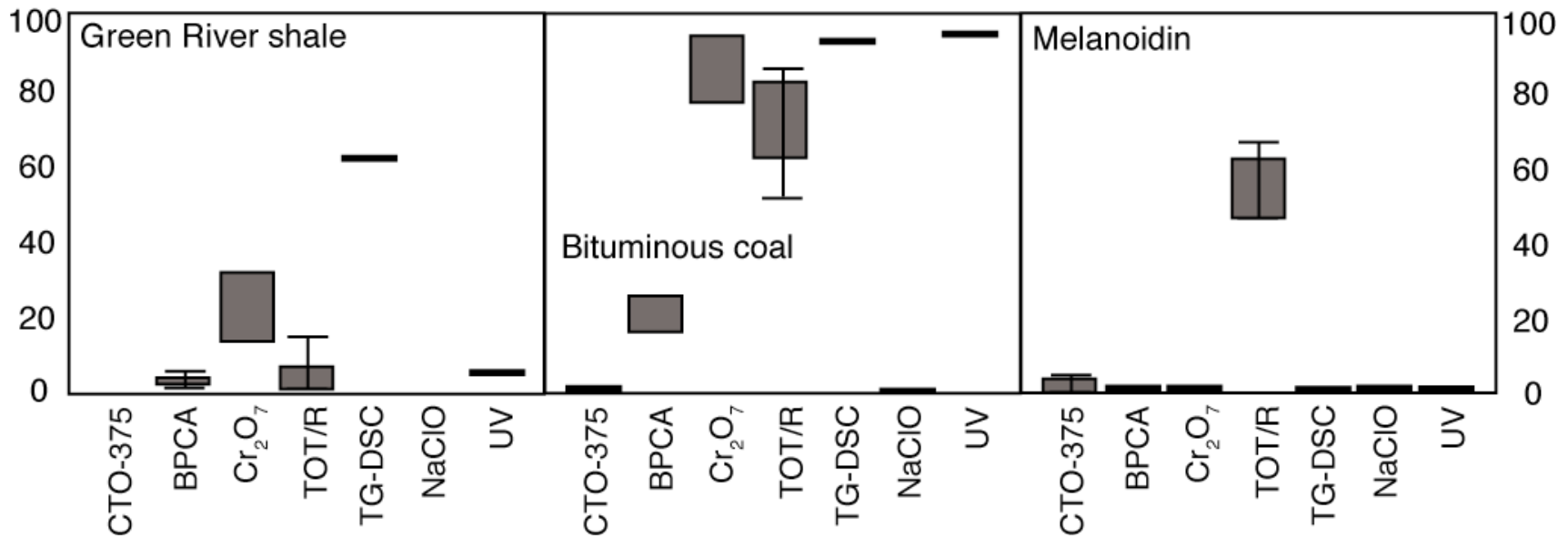
# Pre-Hammes et al., 2007: Methods uncertainty and conflict



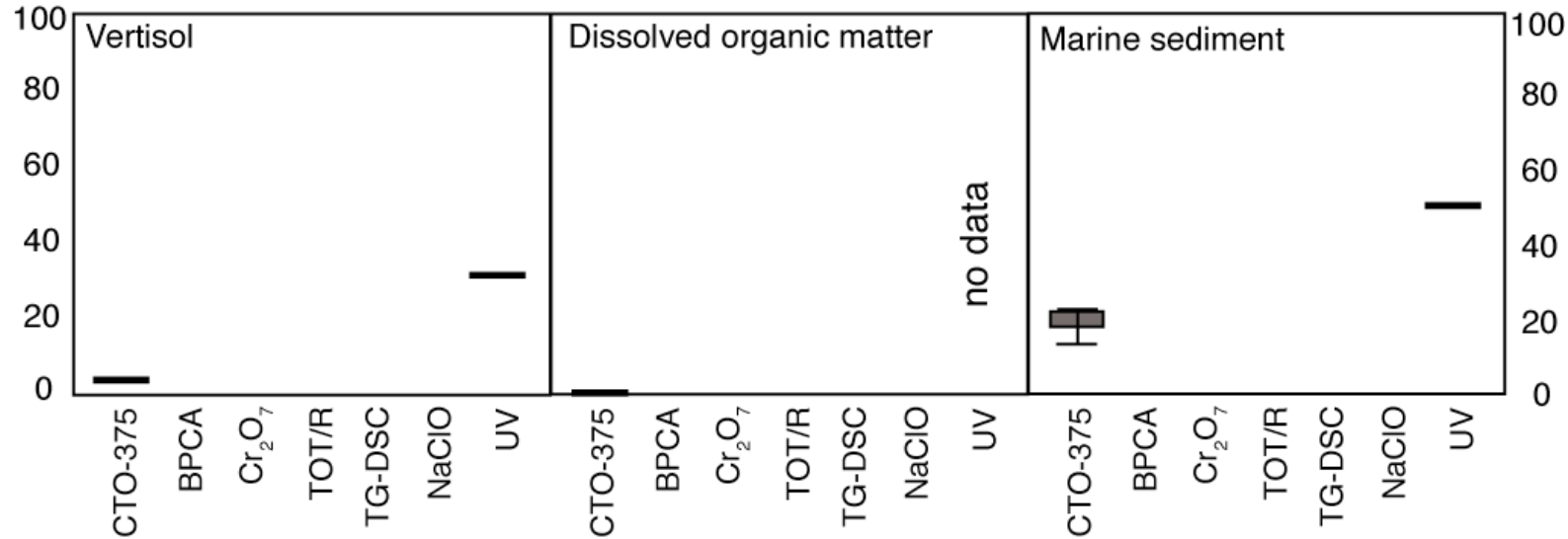
# Hammes et al., 2007: what methods detect black carbon?



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



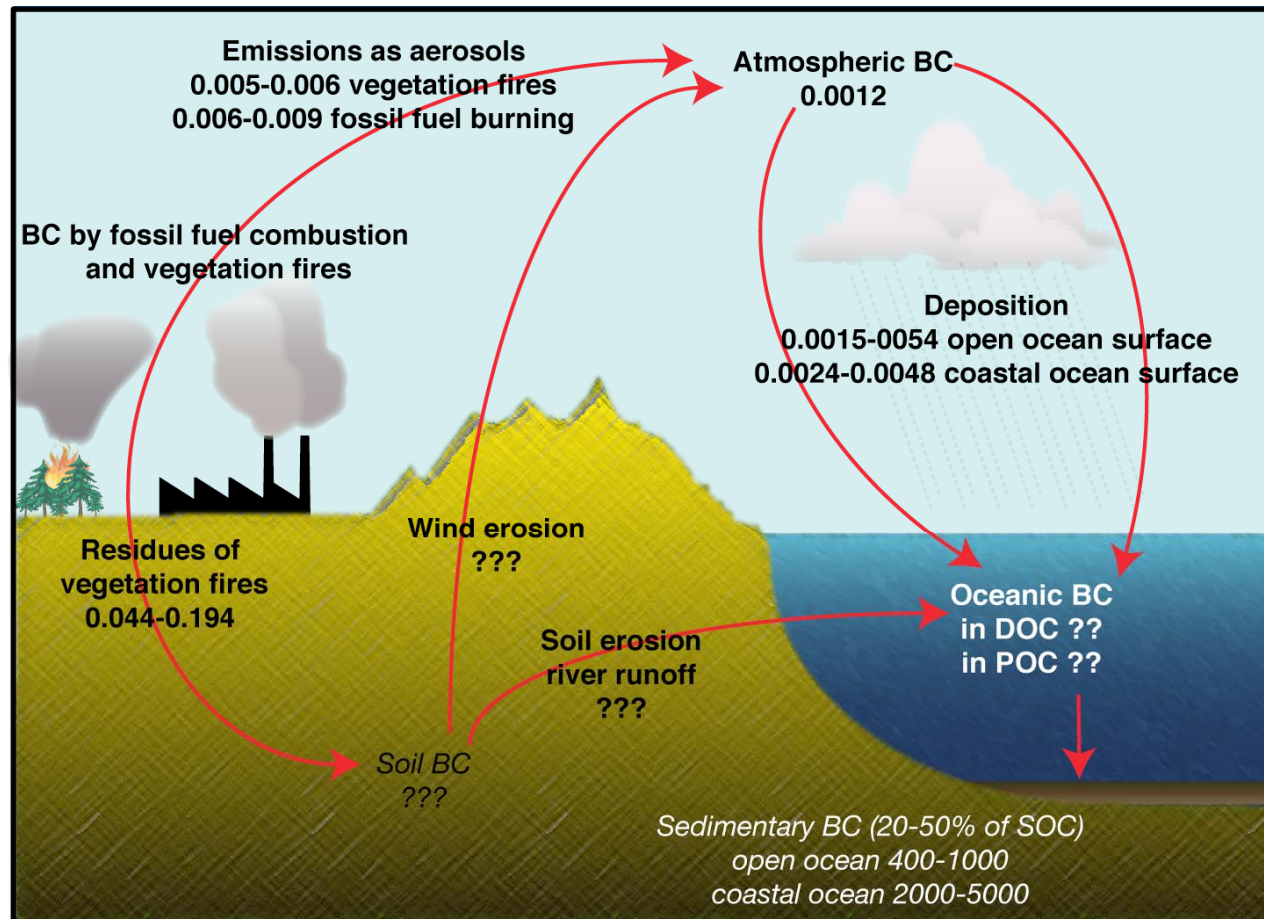
# Hammes et al. data implications



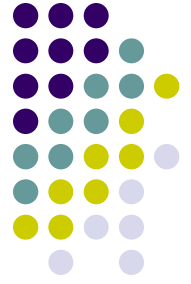
- Soot/BC total is higher in sediments than soil;
- But there's no soot in the DOM;
- Implications:
  - Exclusive aerosol transport of soot to sediments;
  - Long marine  $\tau$  for soot in DOC pool;
  - Very different terrestrial  $\tau$  for soot and charcoal.



# What is the status of the global BC budget?



Kuhlbusch, Science, 1998



# 1998 BC budget, missing items:

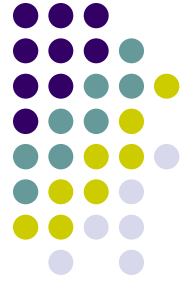
- Any estimate of inventories for:
  - Soil BC pool;
  - Marine dissolved organic carbon (DOC) and particulate organic carbon (POC) pools;
  - Terrestrial DOC pool.
- Any decomposition flux estimates;
- Any residence times (except sediments);
- Any mechanisms.



# Next method steps

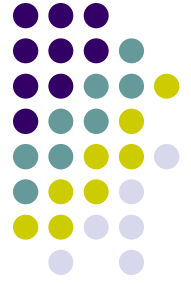
- Methods:
  - Correction factors for methods
    - E.g.  $BC_{total} = \text{char } BC_{NMR} * 0.8$ ; soot  $BC = BC_{CTO-375} * 0.5$
    - Spiked sample experiments?
- Methods aside:
  - CTO 375 values reflect soot budget only;
  - NMR, BPCA values reflect soot + charcoal
    - (with a correction factor).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

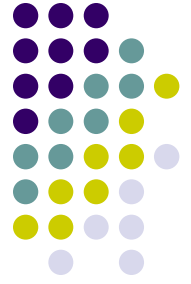


- **Loss Fluxes:**
- Fire, microbial consumption, transport between reservoirs.
  - Microbes: Baldock and Smernik (2002), Hamer et al. (2004), Bruun et al. (2008); interx: Wardle et al. (2008), Steiner (2008)
  - Fires: Czimczik et al. (2005)
  - Transport via rivers: Masiello & Druffel (2001), Mitra 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  $\tau$
  - Definitely present in soil + river DOC (Hockaday 3 pm)
  - BC in marine DOC pool? (Ziolkowski pm)



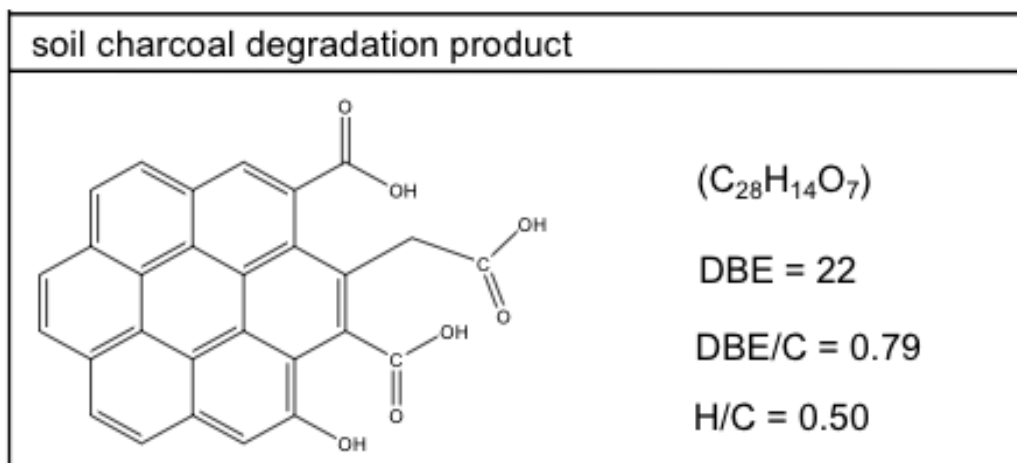
# More mechanistic information

- 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

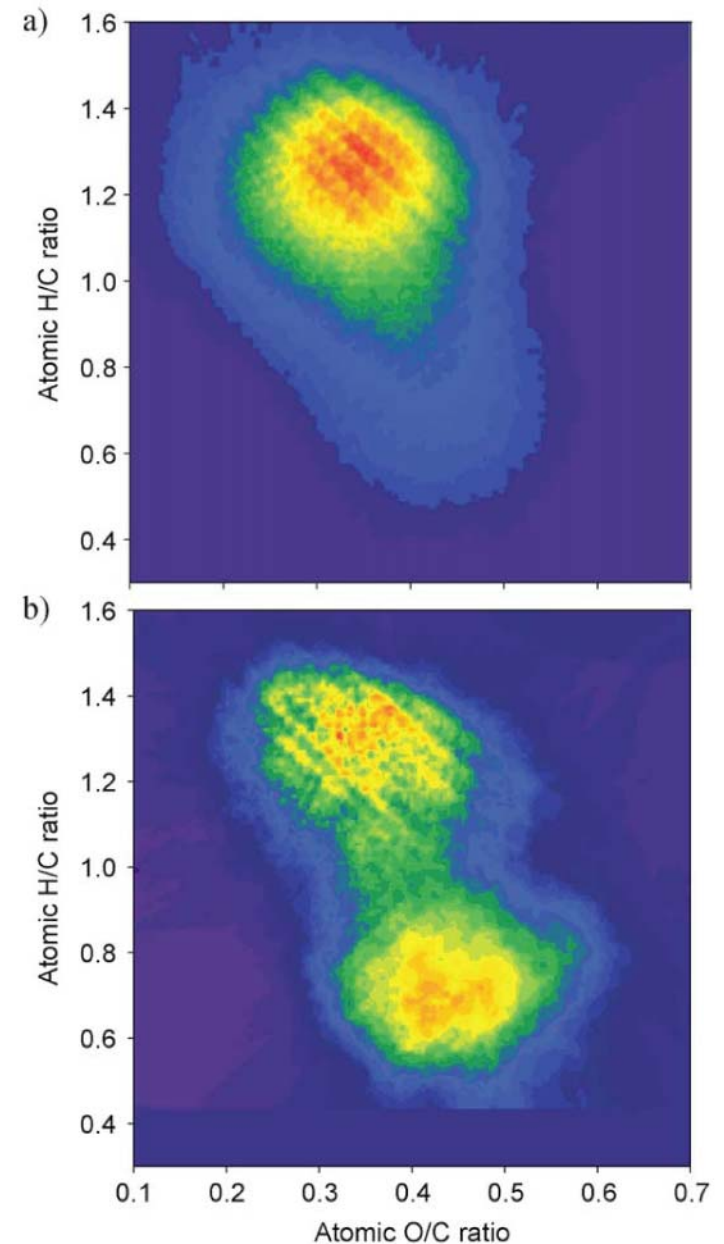


Fig. 4. The 3D van Krevelen diagrams constructed from ultra-high resolution data of (a) McDonalds branch and (b) Rio Negro DOM. Relative intensities of the signal increase in the order purple, blue, green, yellow, and red.