Why do emissions estimates differ, and what can we learn from the differences?

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Lots of Emissions Products – A Good Thing!

- No List Appears Here
  - Because I forgot about your product
- Temporal Resolutions: Monthly to Hourly
- Spatial Resolutions: 1 degree to 1 kilometer
- Global, Regional, and a few National
- Many cover the MODIS era, some cover farther
  - I am skeptical of products covering pre-satellite eras
  - Like any product, only as good as the data available to validate

Diversity of Intent

- Emissions estimates have diverse origins and purposes, e.g.
  - Balancing the ecosystem carbon budget
  - Simulation of downwind atmospheric composition
  - Testing hypotheses around, e.g. weather-climate interaction
- The purpose of an emissions product drives its architecture, and therefore its appropriateness for a given experiment

End Introduction

Begin Middle Section

FLAMBE / Fire Science Results

The Intent of FLAMBÉ

- Estimation of downwind aerosol loading
- Globally consistent
- Suitable for real-time use
- Robust multi-sensor approach
- Flexible spatial and temporal resolution
  - Preserve all spatial information from fire obs

Foci of FLAMBE development

"If we can capture the spatial+temporal patterns of emissions, we can invert for the source magnitudes." To that end:

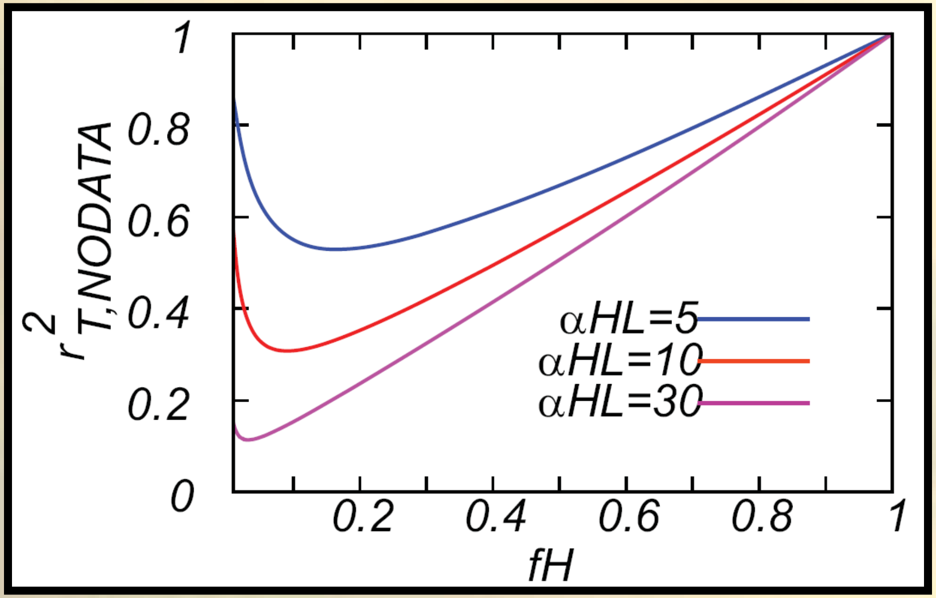
1. Coverage correction / Data Fusion
2. Detection efficiency models
   - based on well-known effects
   - view geometry, vegetation type, surface T
   - effects must be quantified, weighted, integrated
3. Fuels information

A useful conceptual breakdown of the EP

- EP*ext* (the "extensive" problem): location, timing and "magnitude" of fire activity
- EP*int* (the "intensive" problem): fuel consumption and partitioning of smoke (emission factors)
- Emissions = EP*ext*EP*int* $\left(E = \sum^{EPext} EPint(X,Y,T) \right)$
  - In the traditional formulation, this is

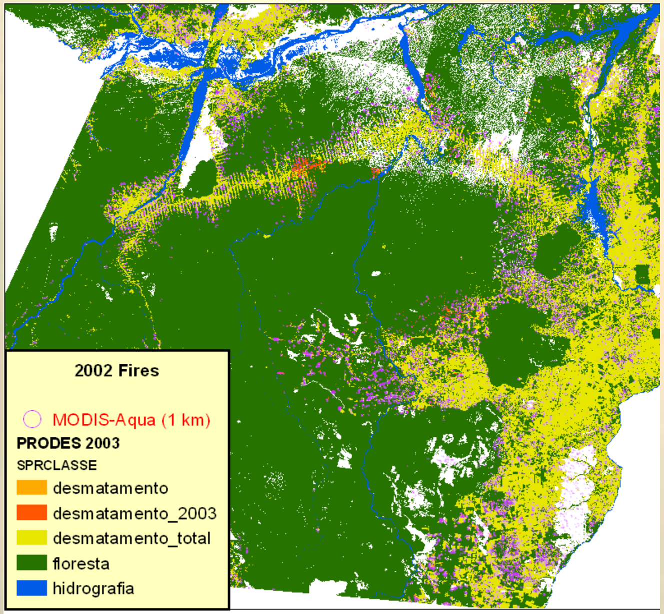
    $(m^2 \text{ fire})\cdot(\text{kg C } m^{-2})\cdot(\text{kg } \textit{species} \text{ (kg C)}^{-1})$
- Details of this breakdown are data-dependent
  - For instance, subpixel fire characterization falls on either side (or both sides)

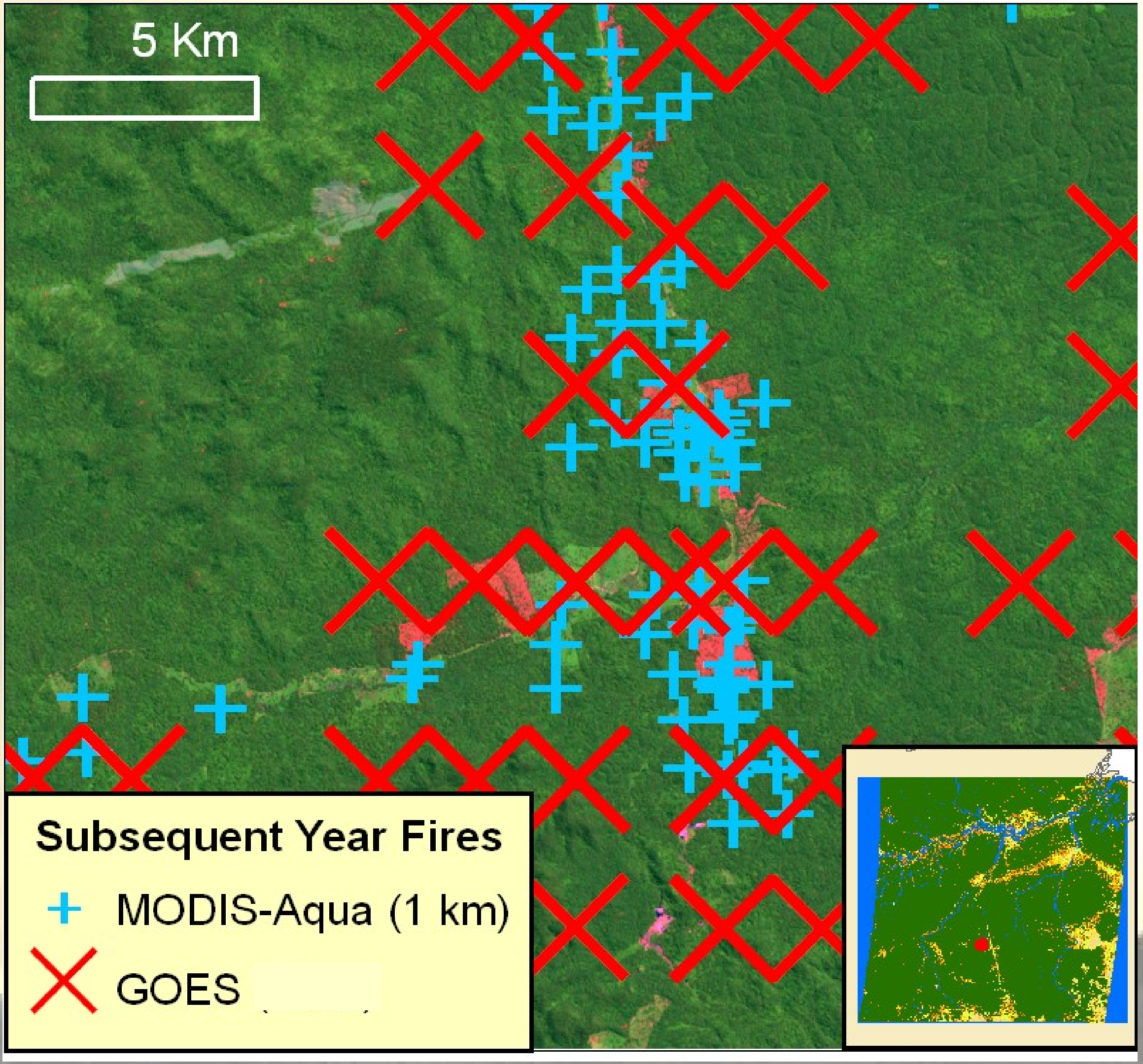
“Intensive” Properties and Pattern: Impact of fuel stratification



- Simple model: fires are either “high-emission” or “low-emission”
  - *fH* (x-axis) is “high fraction”
  - α*HL* is ratio of “high” to “low”
    - Think forest vs. grassland
- Results (colored lines)
  - Equivalent to the “scaled fire counts” approach
  - Correlation is OK for more homogeneous fires
  - **Importance of classification information is greatest when “high” and “low” fires contribute equally to total domain emissions**
- Now, let’s look at some real-world errors

Spatial Resolution Issues

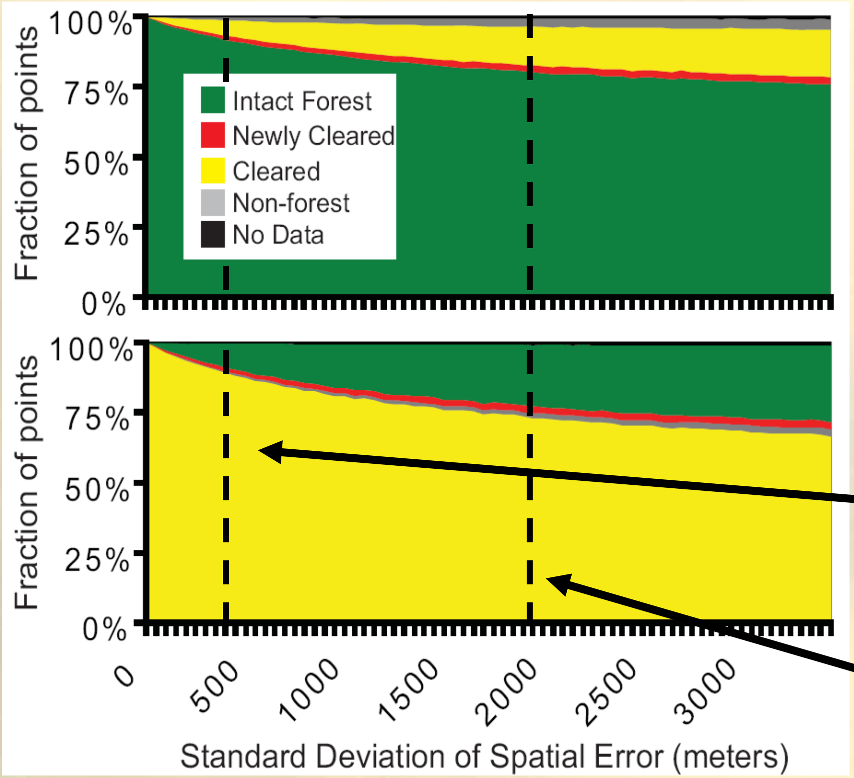




Above: PRODES 2003 deforestation map, 2002 MODIS-Aqua fires (purple)

- **fires are where human activity is**
- **Both new clearing (orange) and older clearing (yellow)**
- **Distinguishing forest clearing from agricultural fires is crucial**
- **At 1500m or 500m, location information is insufficient to characterize forest/non-forest**
- **Right: Landsat 742 + fires**

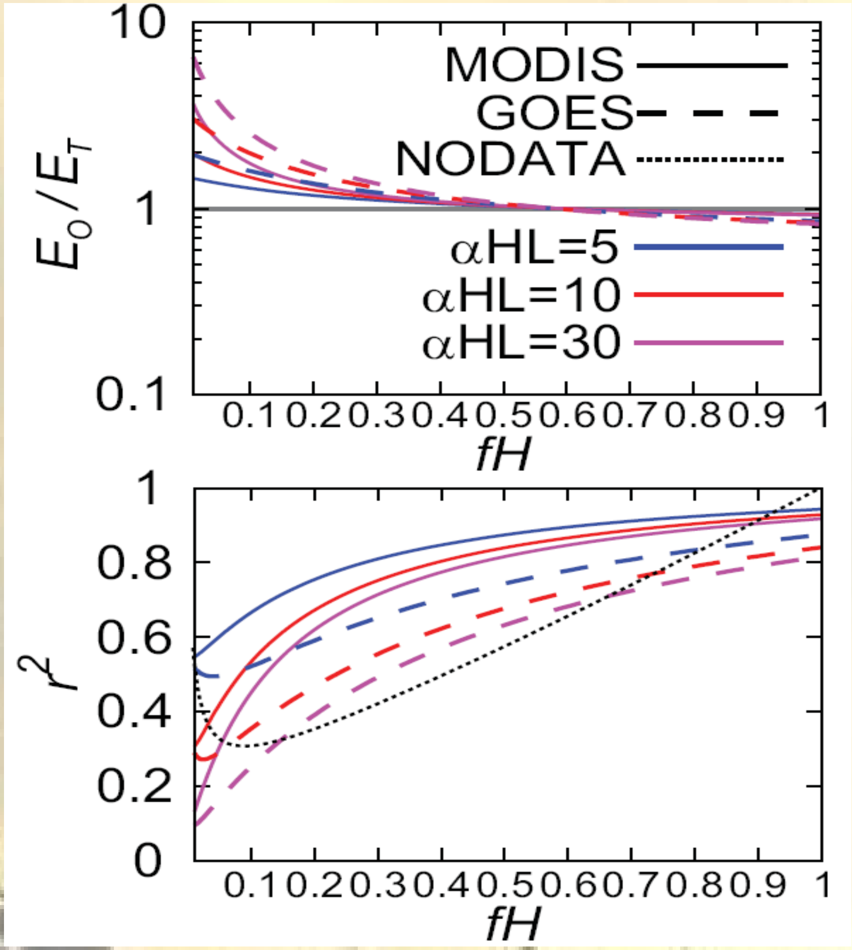
Quantifying this spatial error



Hyer and Reid, GRL 2009

- We used a Monte Carlo analysis of spatial degradation of locations on a 60-m land cover map
- Results
  - MODIS (88% same):
    - εHL = 0.08
    - εLH = 0.12
  - GOES (74% same):
    - εHL = 0.18
    - εLH = 0.25

Put Spatial Error into Simple Model



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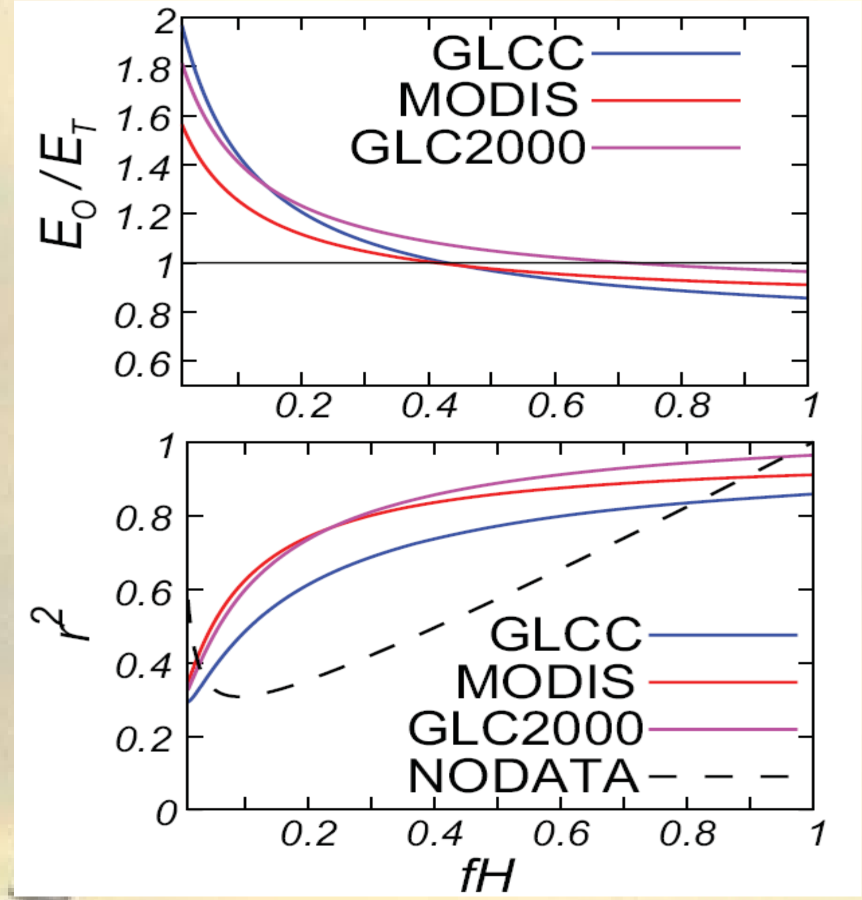
- Results:
  - Spatial uncertainty of hot spots reduces the benefit of LC data in heterogeneous environments
  - Spatial pattern of landscape + spatial uncertainty of location = too much “forest” burning = positive bias in emissions
  - For Amazon basin, bias estimated at
    - MODIS: +3% to +19%
    - GOES: +6% to +39%
  - Correlation of spatial pattern limited by location uncertainty

LC Class Error in Simple Model

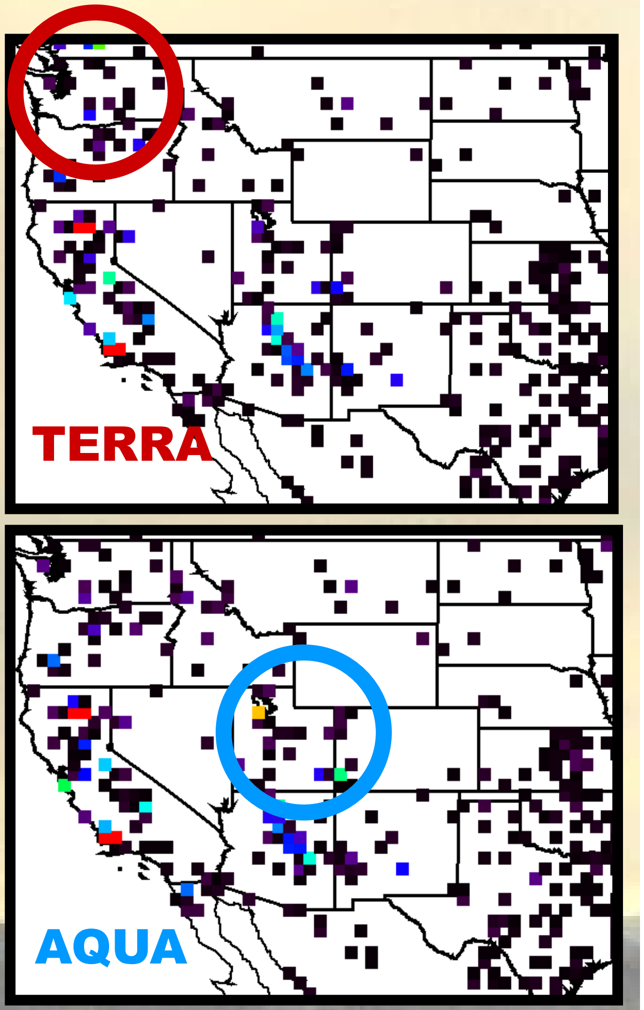


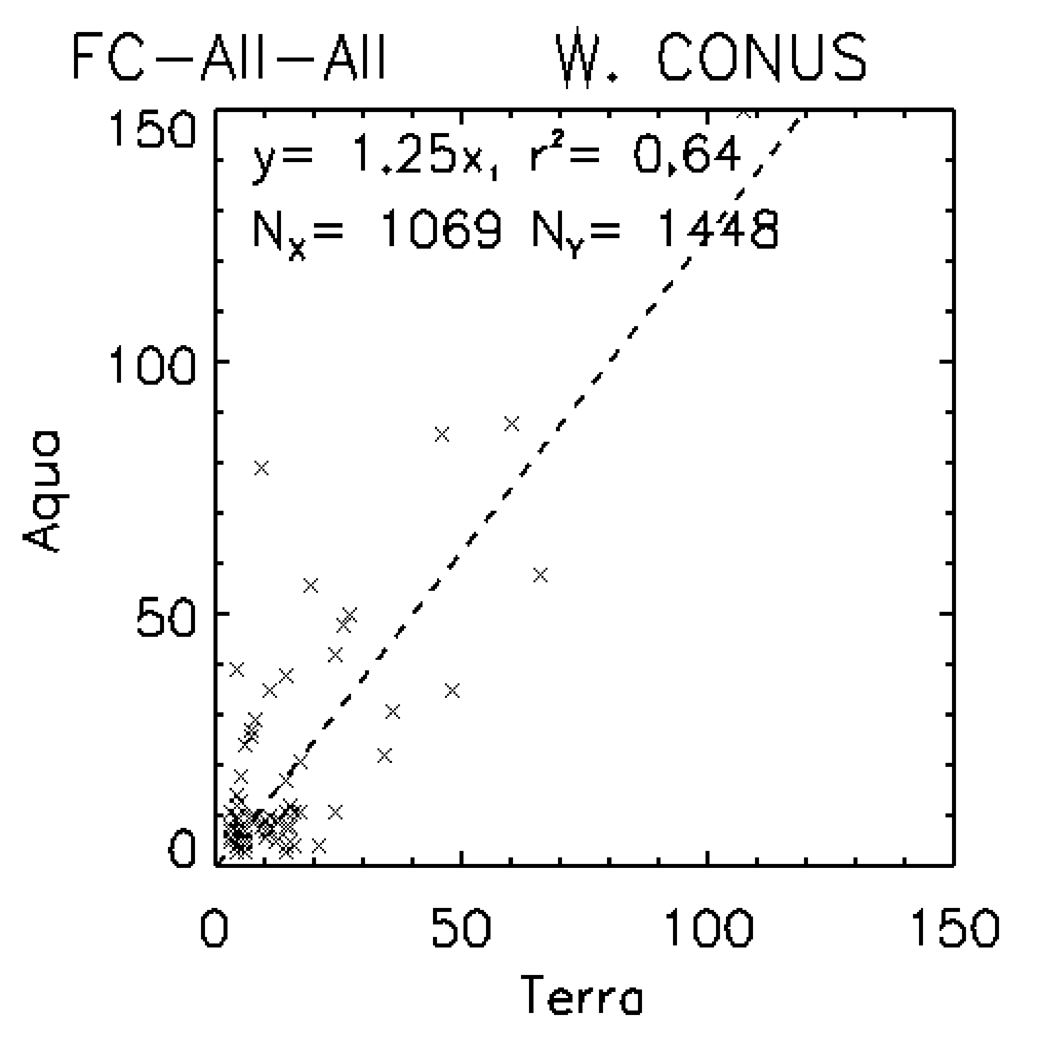
- Published error matrices for LC products
  - GLCC (Scepan IJRS 1999)
  - MODIS (Friedl, bu.edu)
  - GLC2000 (Mayaux IGRS 2006)
  - Matrices collapsed to forest/non-forest
  - Errors weighted by distribution of fire activity
- Results:
  - GRAIN O' SALT: Regional errors will not necessarily be the same as global errors
  - Land cover information adds value (improves correlation) in all scenarios
  - MODIS and GLC2000 perform better than GLCC
  - Errors for all products are potentially severe when "low-emission" fires dominate

Spatial Pattern Capture: comparison of 2 MODIS sensors

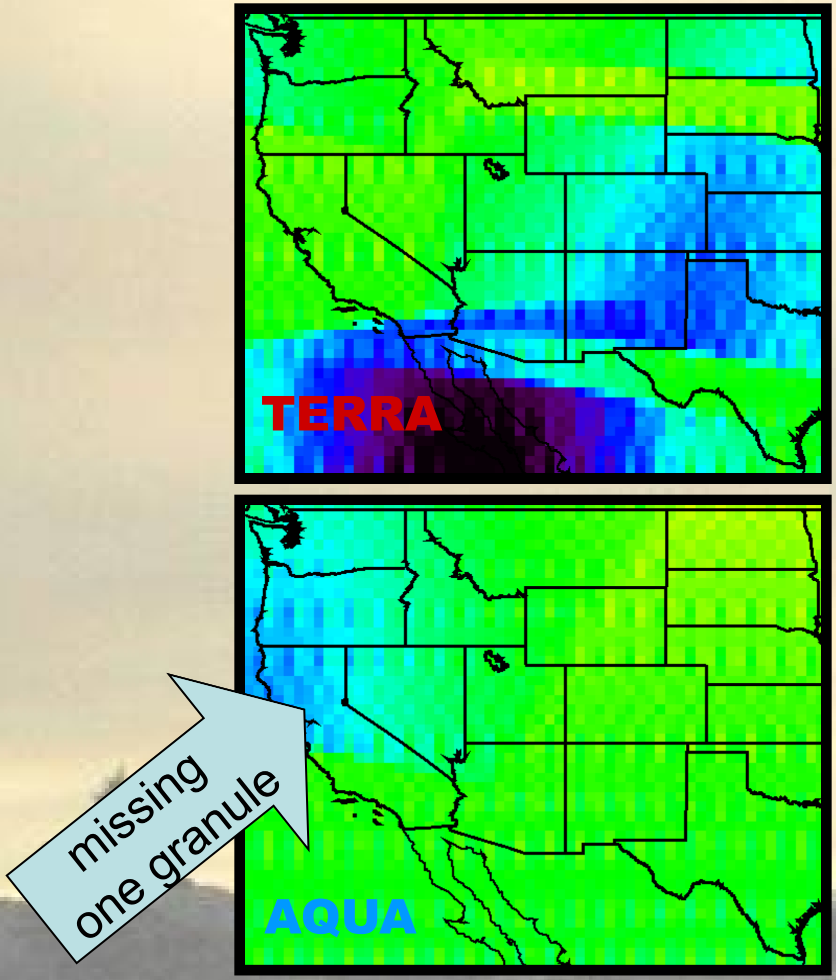
- Use 16 days of data
  - 1-16 August 2009
- Bin data into half-degree boxes
- In each box, count
  - fire pixels
  - total pixels
  - total area
  - pixel area (incl. pixel overlap)
- Compare only within regions
  - Example: Western US

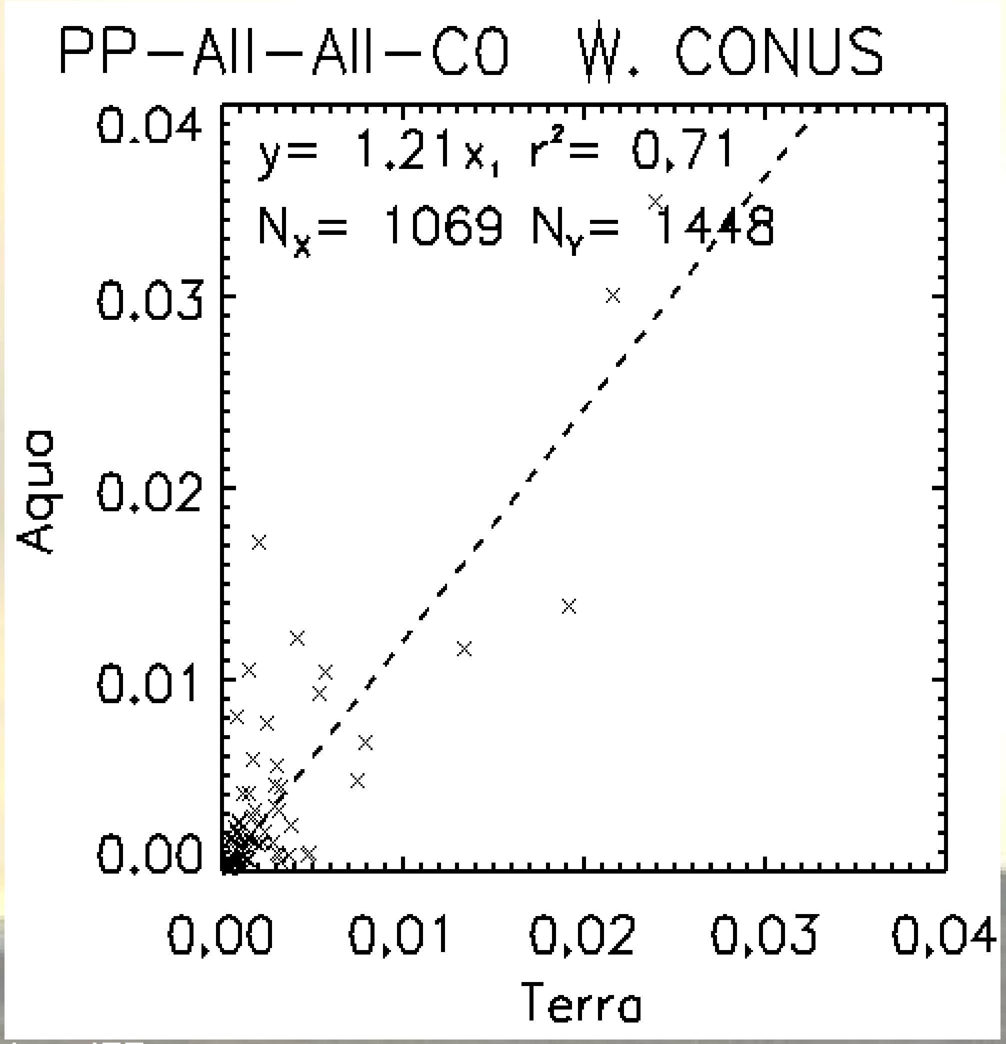
Step 1: Raw Fire Counts



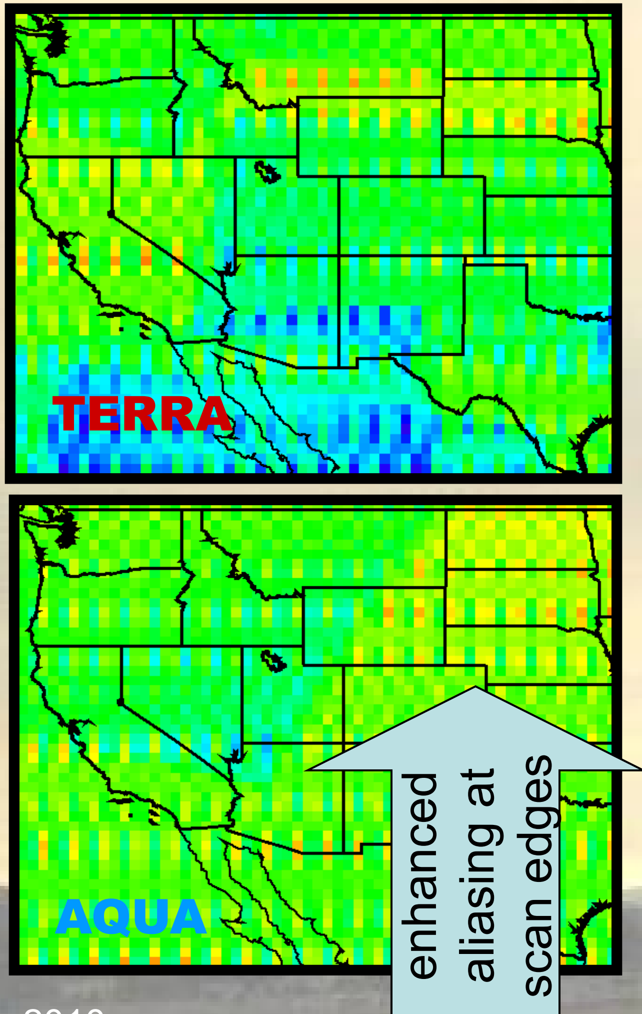


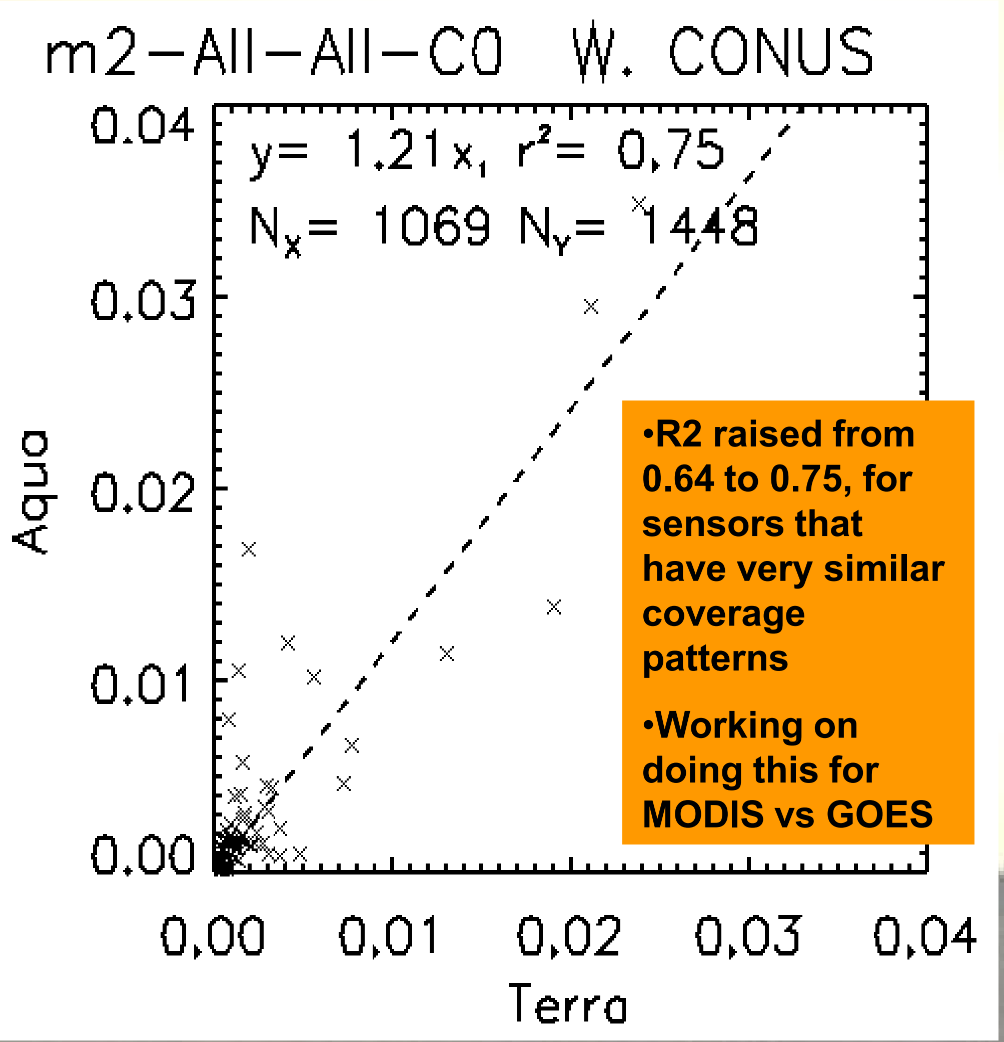
Step 2: Fire Counts per Pixel





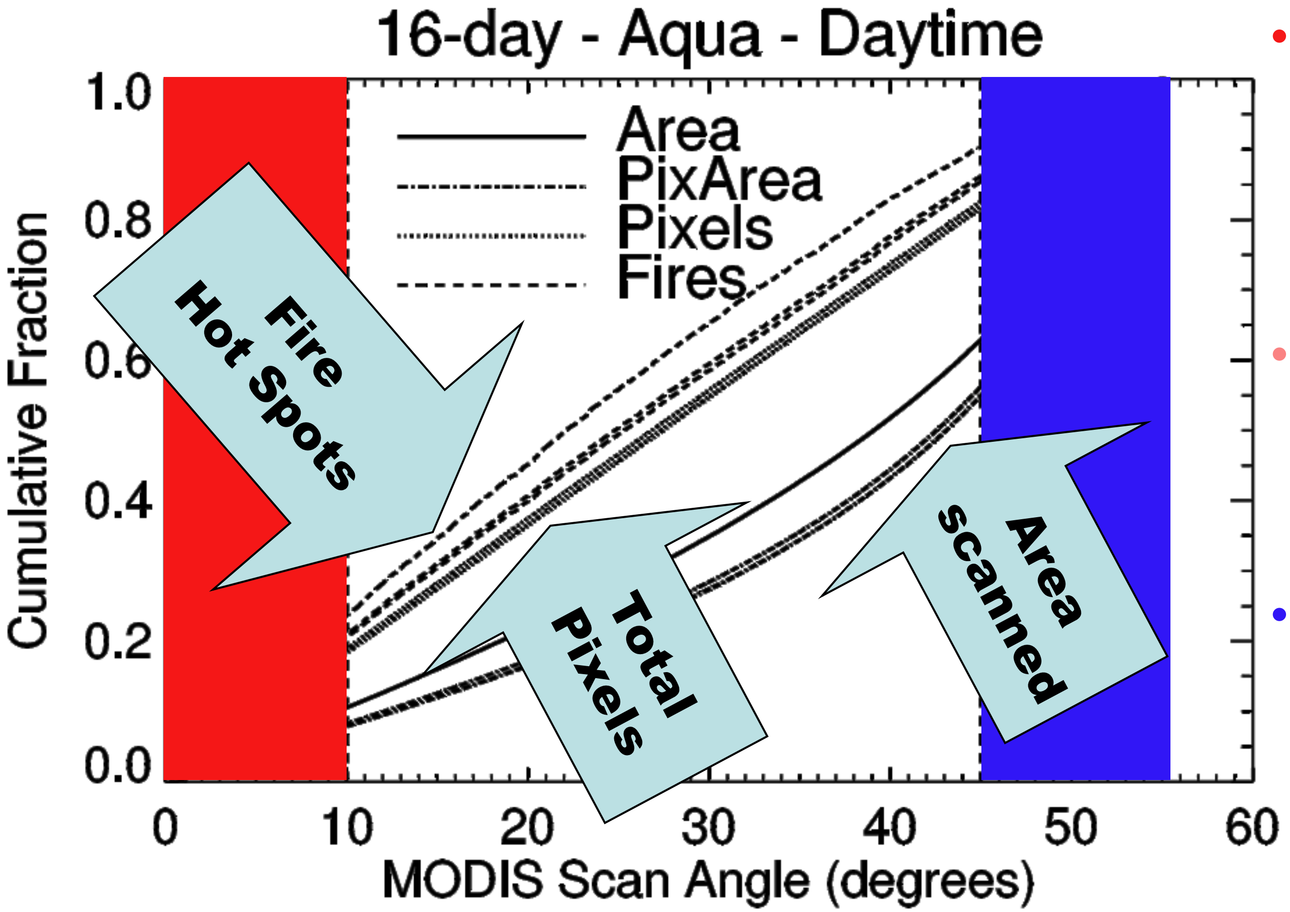
Step 3: Fire Counts per Pixel Area





- R^2 raised from 0.64 to 0.75, for sensors that have very similar coverage patterns
- Working on doing this for MODIS vs GOES

Next Q: What does MODIS detection look like across the scan?



- **Left zone = nadir**
  - **15% of MODIS pixels**
  - **8% of pixel area**
  - **~20% of fires**
- **Center = mid-scan**
  - **65% of pixels**
  - **48% of pixel area**
  - **~65% of fires**
- **Right = scan edge**
  - **20% of pixels**
  - **45% of pixel area**
  - **~15% of fires**

THESE ARE DIFFERENT SENSORS w/r/t detection

Middle Section Summary

- FLAMBE development focussed on spatial/temporal pattern of emissions
- Role of LC and LC errors
- Role of satellite/sampling coverage
- Satellite detection efficiency

End Middle Section

FLAMBE / Fire Science Results

Begin Final Section

Selection and use of emissions estimates in atmospheric simulations

How do I choose an emissions product for my experiment?

- I've got the fire data. Should I just make my own product?
  - No. Don't.
- Things to consider when researching products:
  - Scope: Need a product that covers your domain
    - If there's a regional product you think works best, have a plan re: transboundary pollution
  - Resolution: Preferably, as good as your atmospheric model
    - Not always achievable, esp. in time domain
  - Speciation: *Andreae and Merlet GBC 2001* is still standard, but lots of new data since then
    - Check whether the product uses A&M or custom #s
    - If the product doesn't explicitly estimate your species, check for the latest #s for your region of interest
- If you're not sure if a product is appropriate for your experiment:
  - **contact the developers!**

Some Important Use Cases for BB Emissions Products

- Case 1: I am studying, for instance, nitrogen photochemistry, I just need some estimate of BB emissions
- Case 2: I am designing an experiment to examine XX aspect of fire behavior
- Case 3: I want to run products X,Y and Z through my model so I can tell everyone which is the best

Case 1: Not Everything is About BB

- Subcase 1A: Using a BB tracer to de-select obs. with heavy BB contributions
- Subcase 1B: Investigating a chemical-physical process, want “correct BB contribution”
  - I like the approach of *Fisher et al. ACP 2010*:
    - Use CO observations for gross correction
    - Use “tuned” emissions for process study

Case 2: BB studies

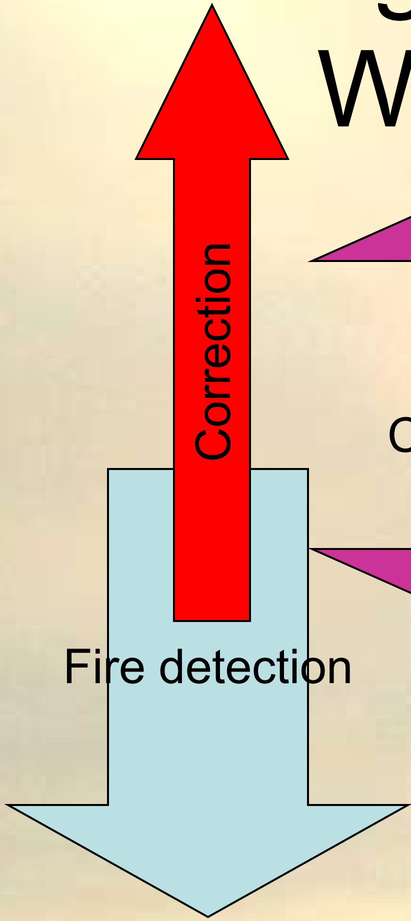
Consider: Could this experiment be improved with a customized version of the emissions product?

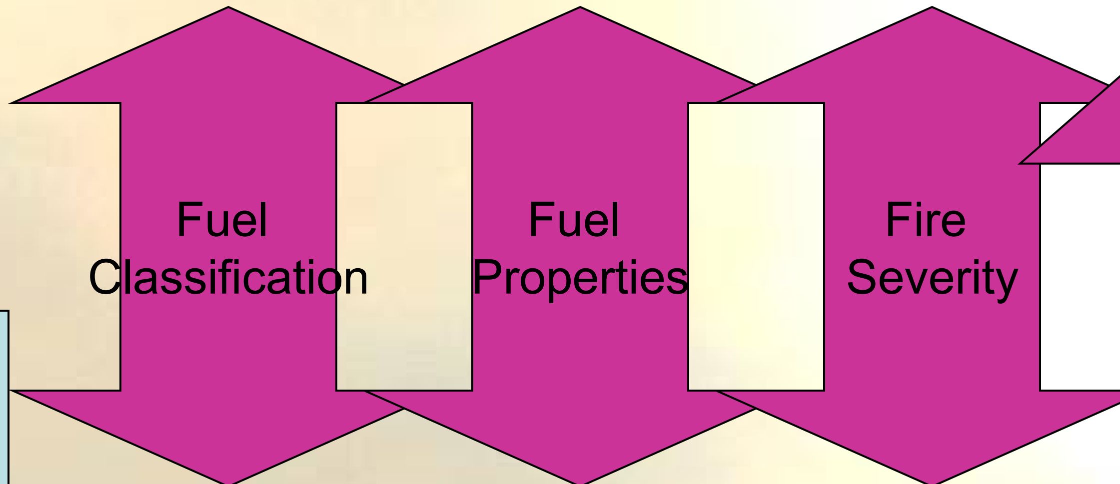
- 1) You may need to isolate XX fires
  - For instance:
    - Agricultural fires
    - Fires larger/smaller than X
  - Metadata in publicly downloadable products can do some splits
- 2) You may need a product customized in some specific way:
  - Tracers for pollution from specific regions;
  - Modified timing to simulate smoldering combustion;
- 3) You may want to evaluate a specific improvement to an emissions estimate:
  - Injection height
  - Fire-weather interactions
- In every case, you'll have better results if you ***talk to the developer***
  - Splits you need may be easy for the developer, hard for you
  - Developer can ensure that splits are consistent with model construction
    - E.g. if product uses land cover A for fuels estimation, don't use land cover B to isolate forest burning
- Work with emissions product developers to design experiments– everyone wins!

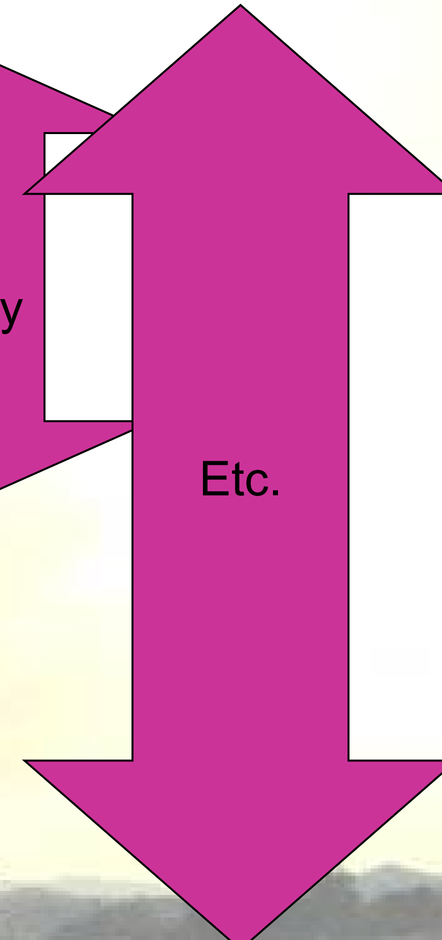
Case 3: BB Product Comparison

- Comparison of emissions estimates is worthwhile
- You will always learn more than you planned on
- Bear in mind:
  - Too High / Too Low is not very useful by itself
  - There's more to atmospheric simulation than source terms
  - What you find depends on where you look

Too High / Too Low Won't Get Us Where We Need to Go



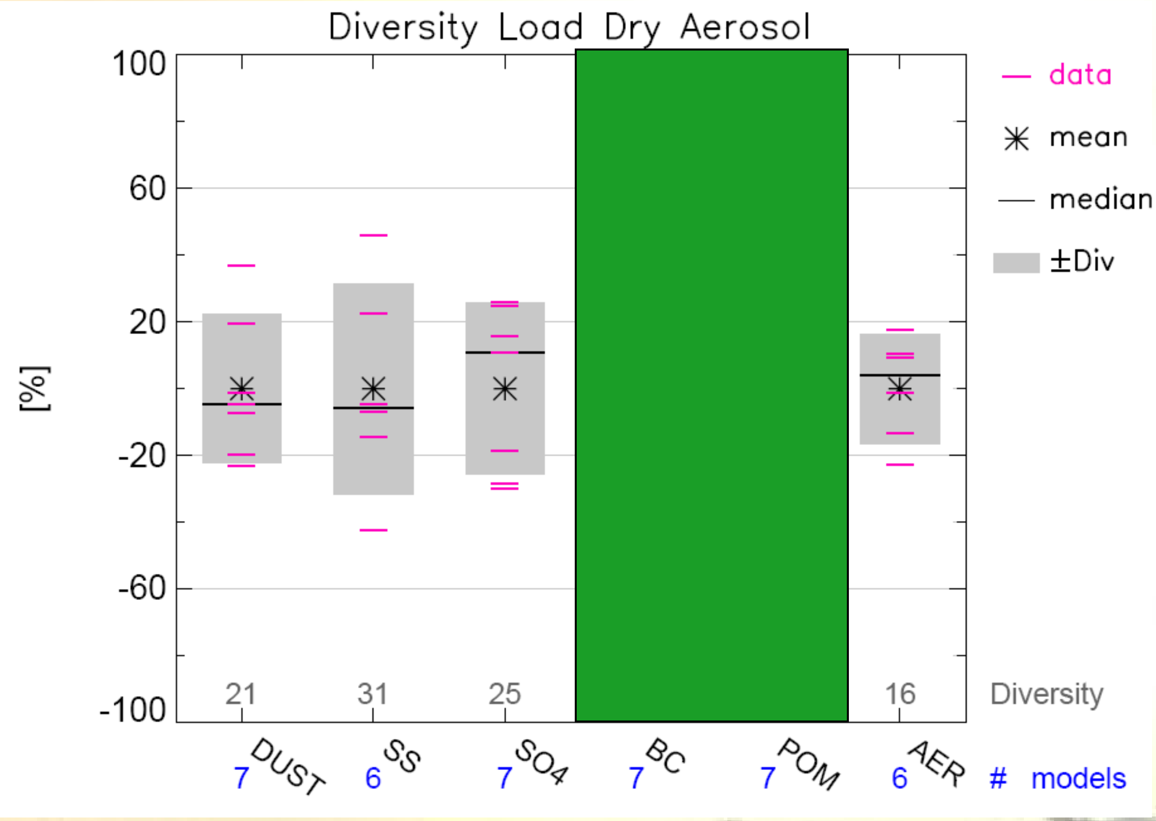




- It is necessary, and useful, to report bias vs. obs and attempt to attribute
- But with so many reasons a source could be too high/ too low, it's not sufficient
- **We need sensitivity tests to move forward**

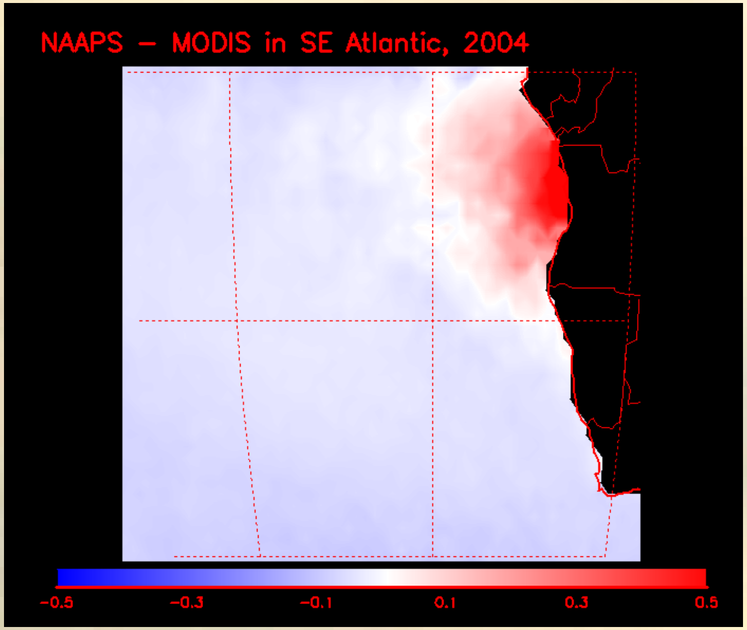
There's More To This Than Sources!

- Results from AEROCOM simulations
- Identical sources
- Identical size distributions
- Identical injection
- **Diversity in transport and sink processes**



Textor et al., AEROCOM, *ACP* 7:4489-4501, 2007

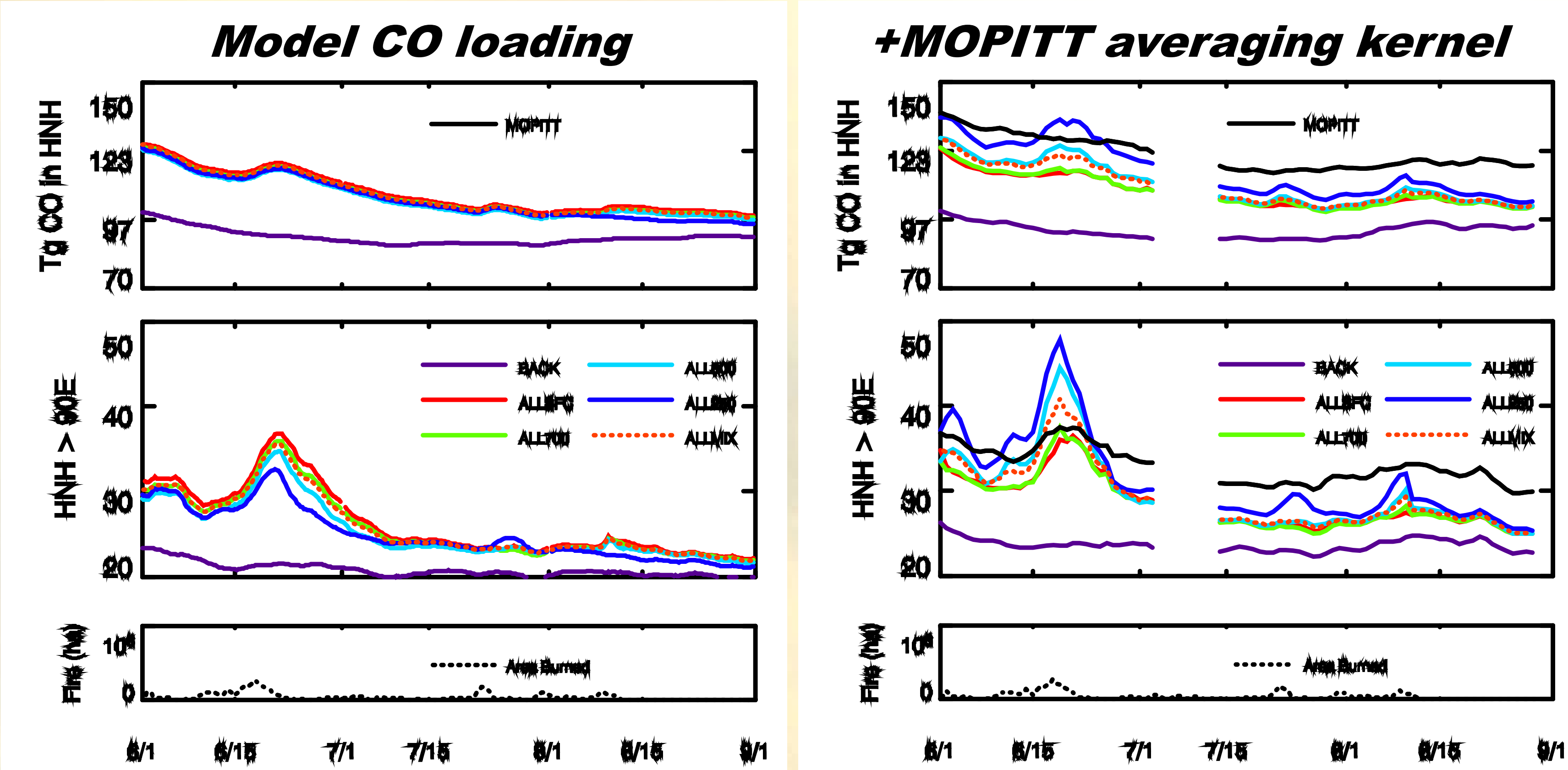
What You Find Depends on Where You Look I: Horizontal



- NAAPS (FLAMBE emissions) vs MODIS AOD, 2004 off of Southern Africa
- Positive Bias near-source
- Negative bias over open ocean
- Eulerian models have numerical diffusion

•Consider separating near-field obs. It's a good check on sink terms

What You Find Depends on Where You Look II: Vertical



Hyer et al., JGR 2007

- Consider what effect sampling is having on integrated pollutant loads
- Emission injection interacts strongly with satellite trace gas observations

Summary

- There is now a good selection of emission estimates to choose from
  - In the peer-reviewed lit.;
  - Some tested against multiple models;
- These products have diverse objectives that determine their architecture
  - And their appropriateness for your experiment
- Goals of experiment determine best use of emission estimates