Considerations for use of Geostationary Fire Detection for Estimation of Biomass-burning Emissions

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In this Talk

- Definition of Emissions Problem
  - Refinement: “intensive” and “extensive” problems
- The “intensive” problem: fires and land cover
  - temporal issues
  - spatial issues
- Active fire data and the “extensive” problem
- Summary and Recommendations

What is the "Emissions Problem?"

- For my scientific purposes, it is this:

  "Quantifying the biosphere-to-atmosphere flux of pyrogenic emissions in a spatially and temporally explicit fashion"

- For NRL work, add "in real time"
- A specific cross-disciplinary orientation
  - Study of a surface process to solve a problem in atmospheric science.
  - not the only possible cross-disciplinary orientation

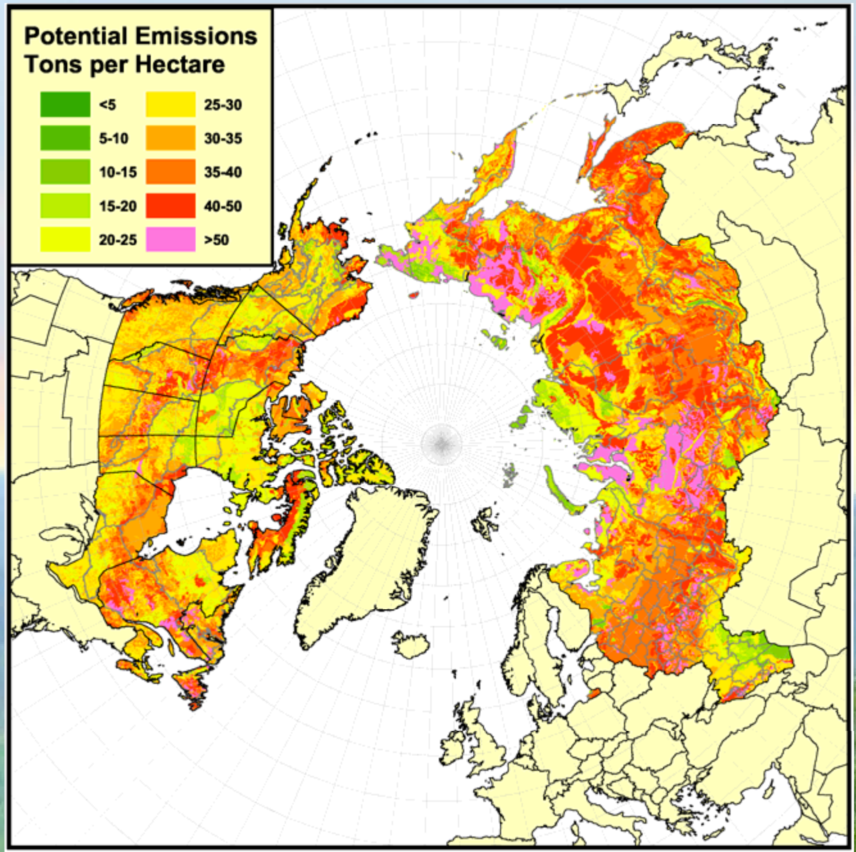
A useful conceptual breakdown of the EP

- 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)

EPint: From the field to the globe

- For the entire model domain, describe:
  1. **vegetation type**
  2. **fuel structure**
  3. **quantity of fuel**
  4. **fuel moisture**
- Field campaigns give detailed descriptions of these parameters (deep data)
- Parameters tied to basic data– whatever data covers the whole domain (wide data)
- Deep and wide data seldom a good match

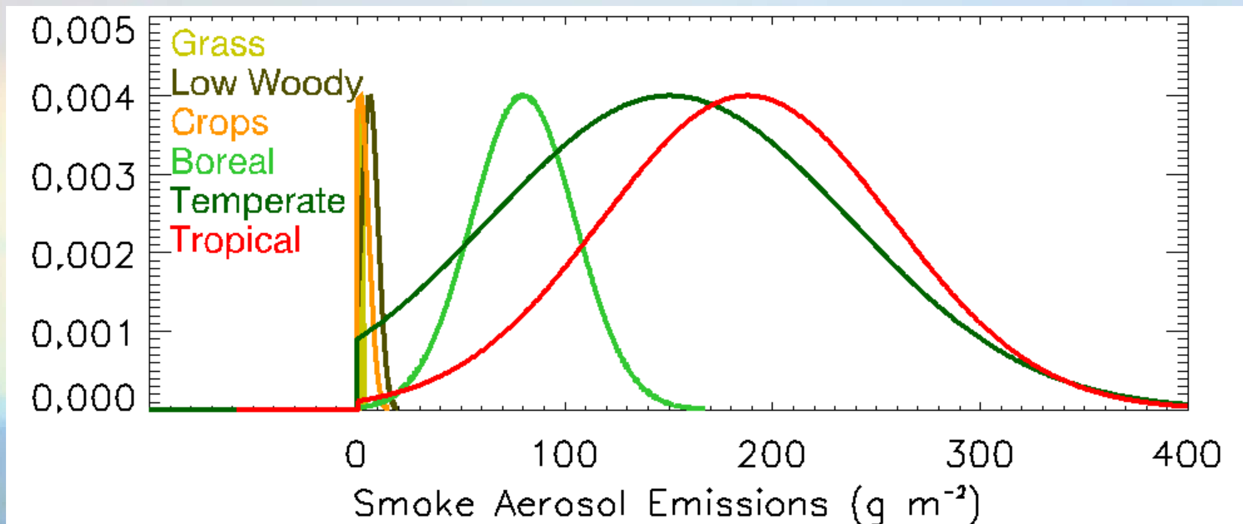


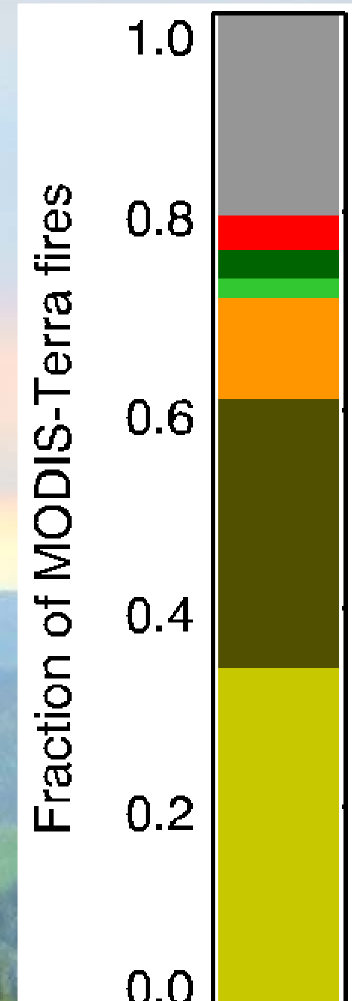
Land Cover and EP*int* 1

- LC →Directly to:
  - – vegetation type
    - …if the LC data are accurate
    - …and the legend is germane
  - – fuel structure
    - not enough information
    - land use history matters, for instance
- LC →Indirectly to: fuel loading
- LC does not relate to: fuel moisture

Land Cover and EP*int* 2

•**Distribution of intensive properties by LC type, from field campaign data, compiled by *Reid et al. (ACP, 2005)***





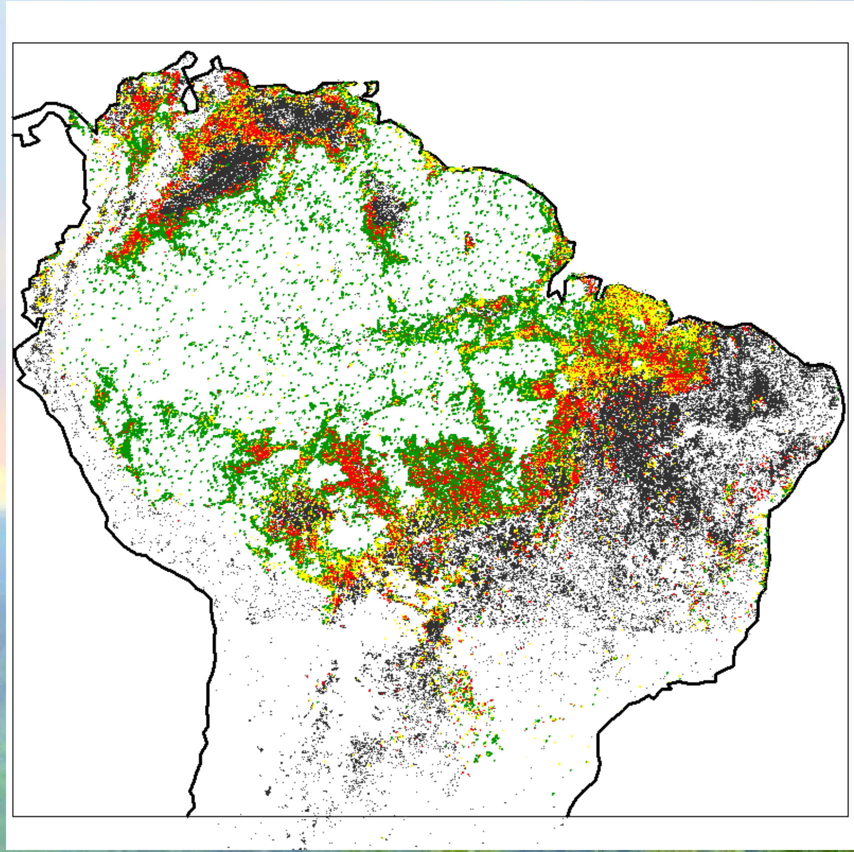
- For intensive properties:
  1. Forest vs. non-forest
  2. Variation within forest
  3. Everything else
- For EP*ext*, all classes matter

How well can we do forest/non-forest?

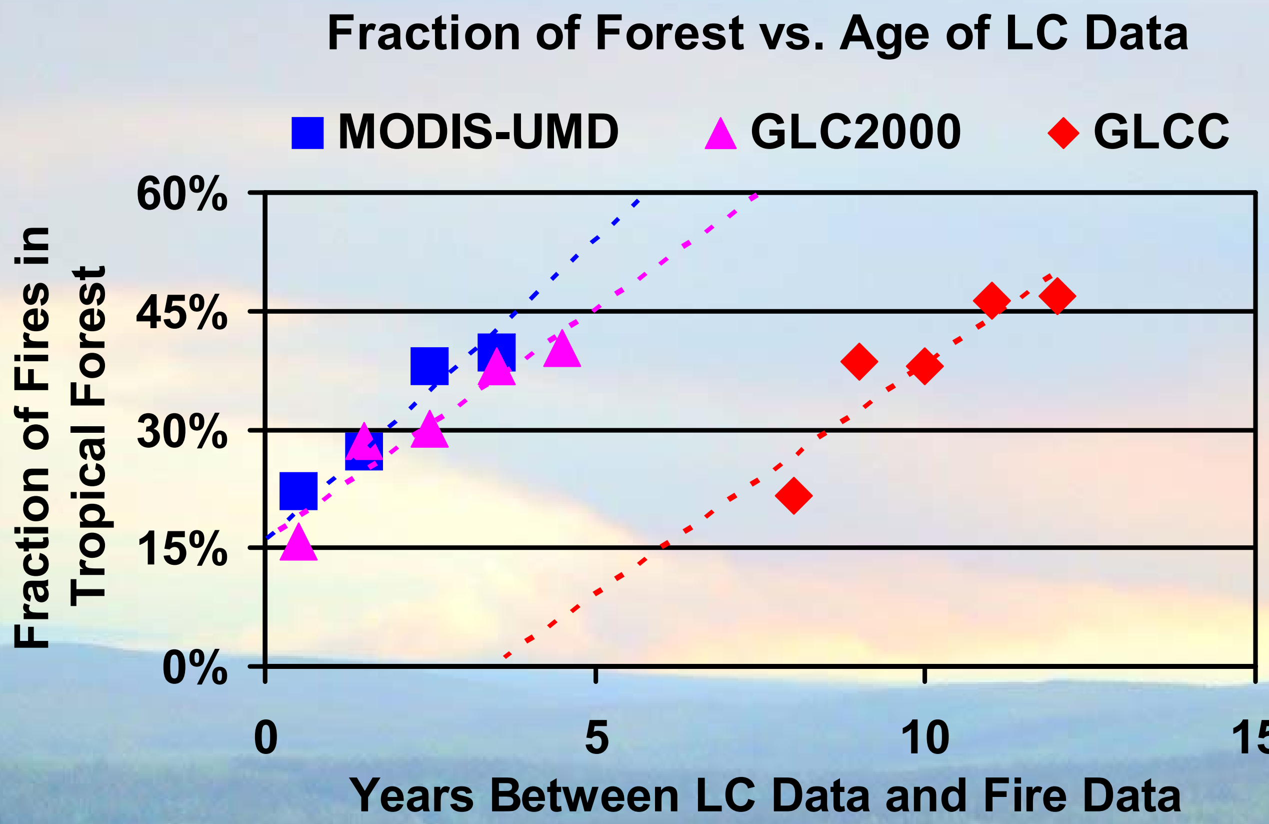
- GLCC: 63% user accuracy for forest/nonforest (*Scepan, PERS*, 1999, IGBP legend)
- MODIS: 89% user accuracy for forest/nonforest (v003 validation, IGBP legend)
- GLC2000: Legend does not split closed vs. open canopy
  - "Forest" classes include woodlands
  - Woodlands ≠ Forest for EP*int*
- *MODIS numbers look good, but...*

Fire brings out the worst in LC products

- Right: 2001 fires from GOES-12 WF_ABBA, comparing GLCC (1992-1993) to MODIS (2001) land cover:
  - green=forest/forest (27%)
  - yellow=forest/woodland (7%)
  - red=forest/grassland (14%)
- Bulk accuracies of LC products are ++ optimistic for fires

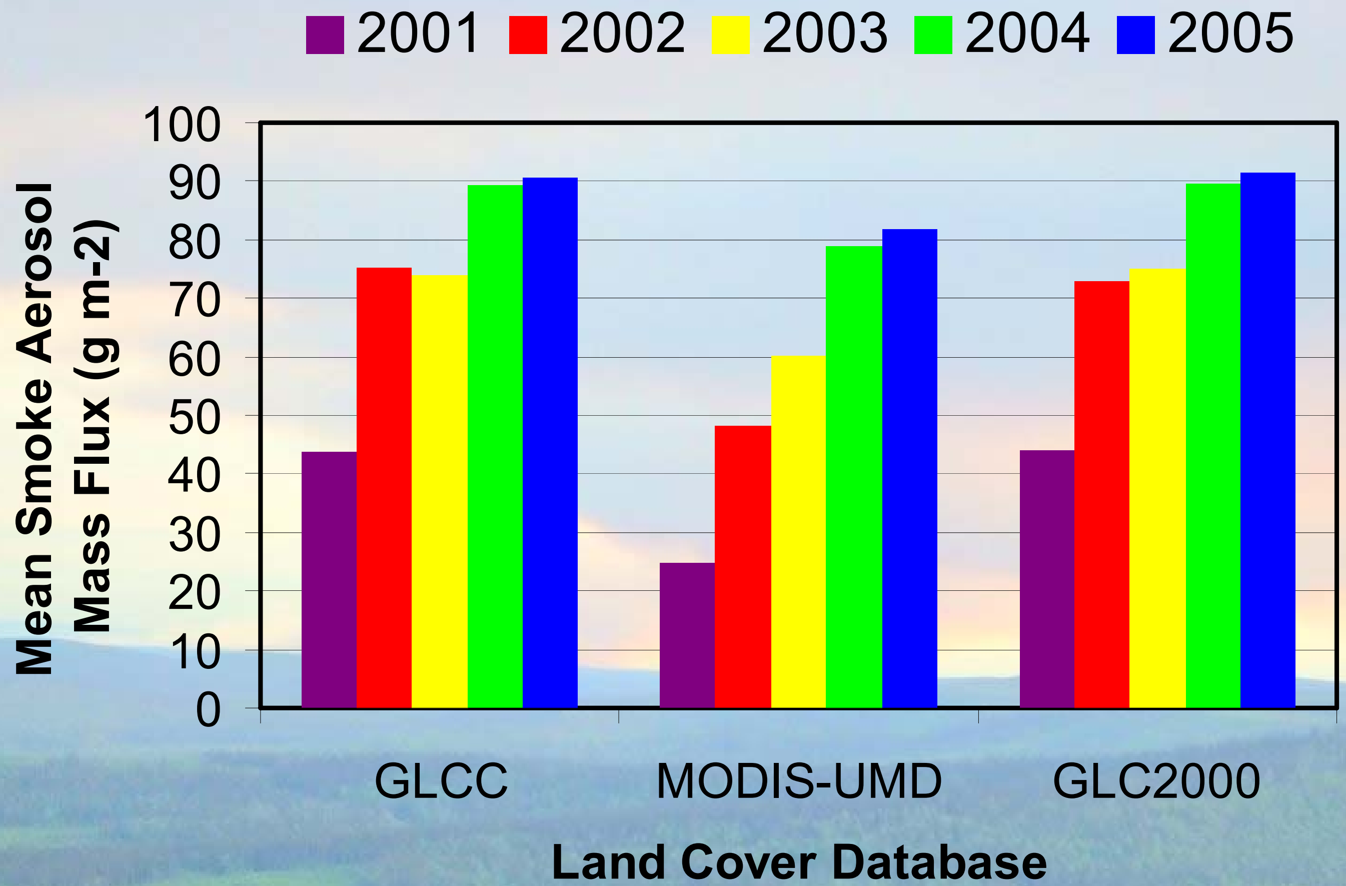


LC Products Age Badly



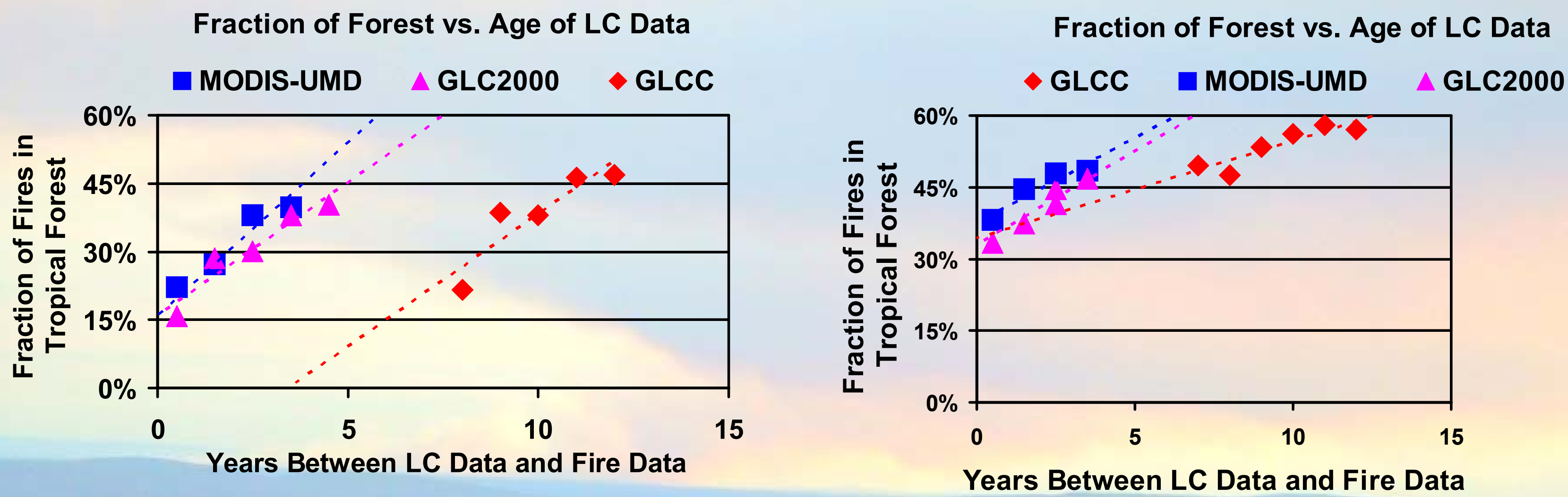
- **Based on MODIS-UMD LC classification of MODIS-Terra fire locations**
- **Fraction of fires in "Tropical Forest": 22% in 2002, 40% in 2005**

Consequence for Emissions



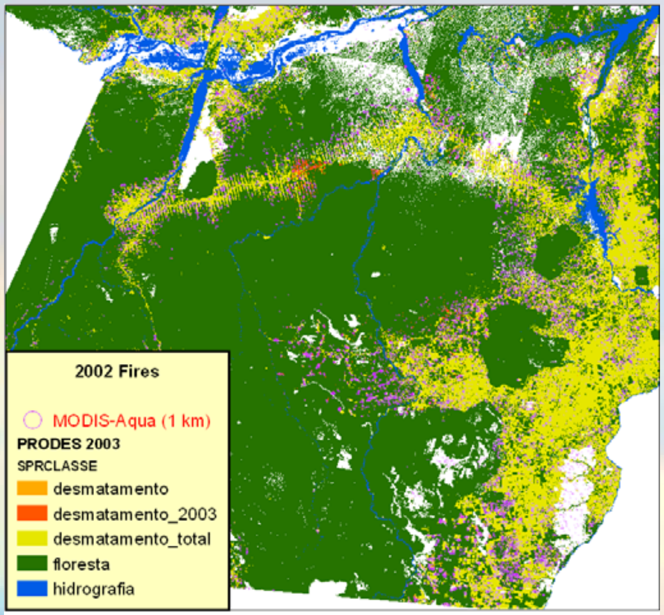
That's an 80% increase in mean smoke flux from South America, resulting from using data 4 years out of date!

Same results with GOES fires? Not quite.



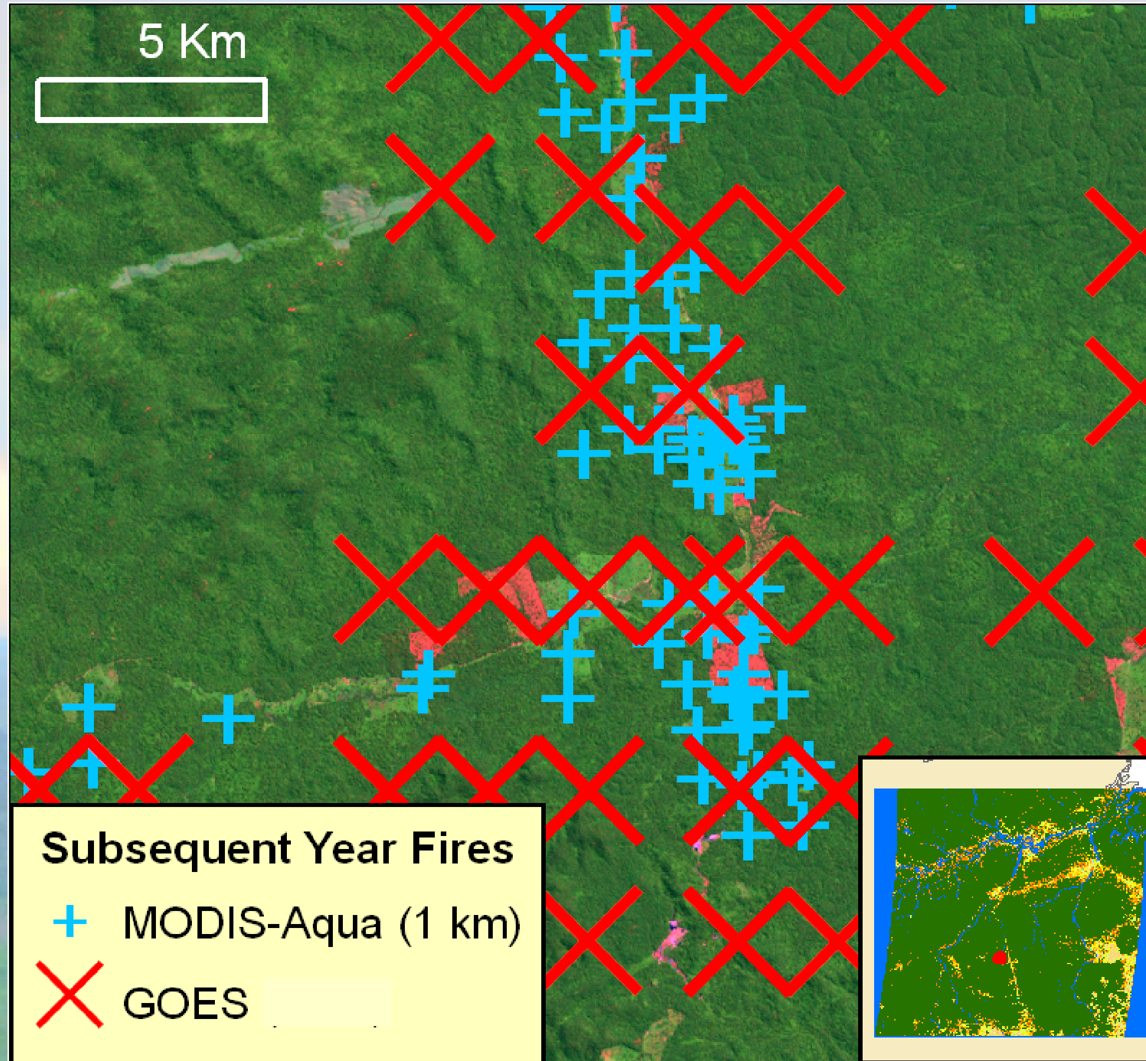
- **Left: MODIS-Terra, Right: GOES WF_ABBA (GOES-8 / GOES-12)**
- **MODIS gives lower P*forest*, and steeper slope**
- **Spatial error does not cancel out in South America**
- **Why? Heterogeneous landscapes**

Spatial Resolution Issues

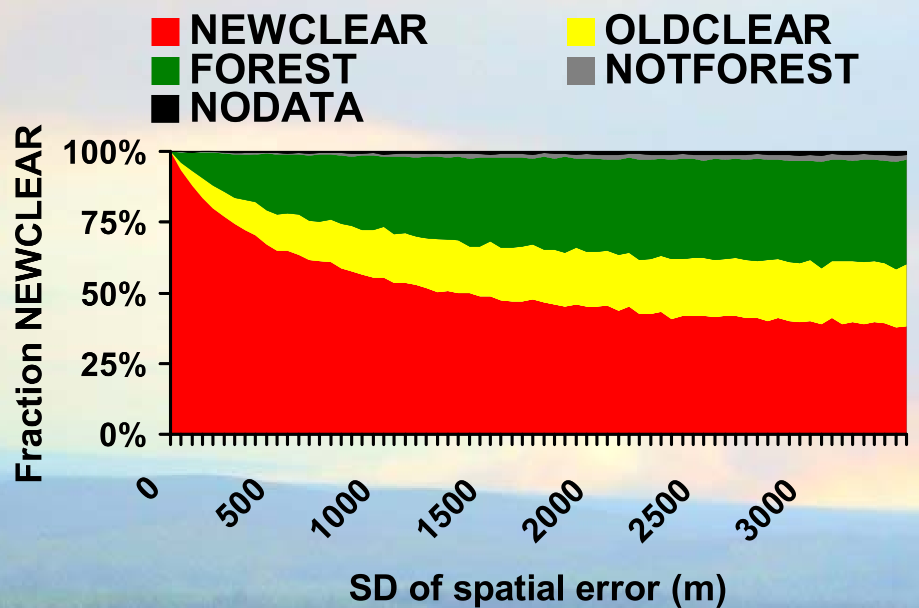


Above: PRODES 2003 deforestation map, 2002 MODIS-Aqua fires (purple)

- **can't show GOES, too many fires**
- **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**



How much information is lost to spatial error?



PRODES classification of pixels after application of spatial error to random sample of locations in PRODES "Newly Cleared Forest" from 2003.

- This chart is just a hint
- We need a comprehensive model of spatial errors:
  - PSF/MTF
  - Geo-referencing
  - View geometry dependence

Can we get information for EP*int* in other ways?

- FRE-based methods: EP*int* in a single step, using fire energetics to scale for fuel consumption + fuel moisture
  - Fuel structure (canopy) dependence remains
- "Persistence" (temporal filtering) methods
  - Work ongoing at NASA/UMD (Giglio/Morton/Shroeder)
  - Effectiveness depends on detection efficiency
  - Problematic in real-time
- LC needed to stratify detection efficiency
  - This is part of EP*ext*

Geostationary Fire Data for EP*int*

1. Location info connects fires to intensive surface properties– **spatial error must be accurately and comprehensively described**

1b. Native resolution causes LC error in fragmented landscapes

- ***even if geolocation is perfect***

2. Fire data only as good as underlying LC data– ***we need systematically updated global LC***

3. LC alone does not complete **EP*int***
   - Fuel loading, fuel moisture also needed
   - FRE approach has potential, but still needs LC data

The Extensive Component EP*ext*

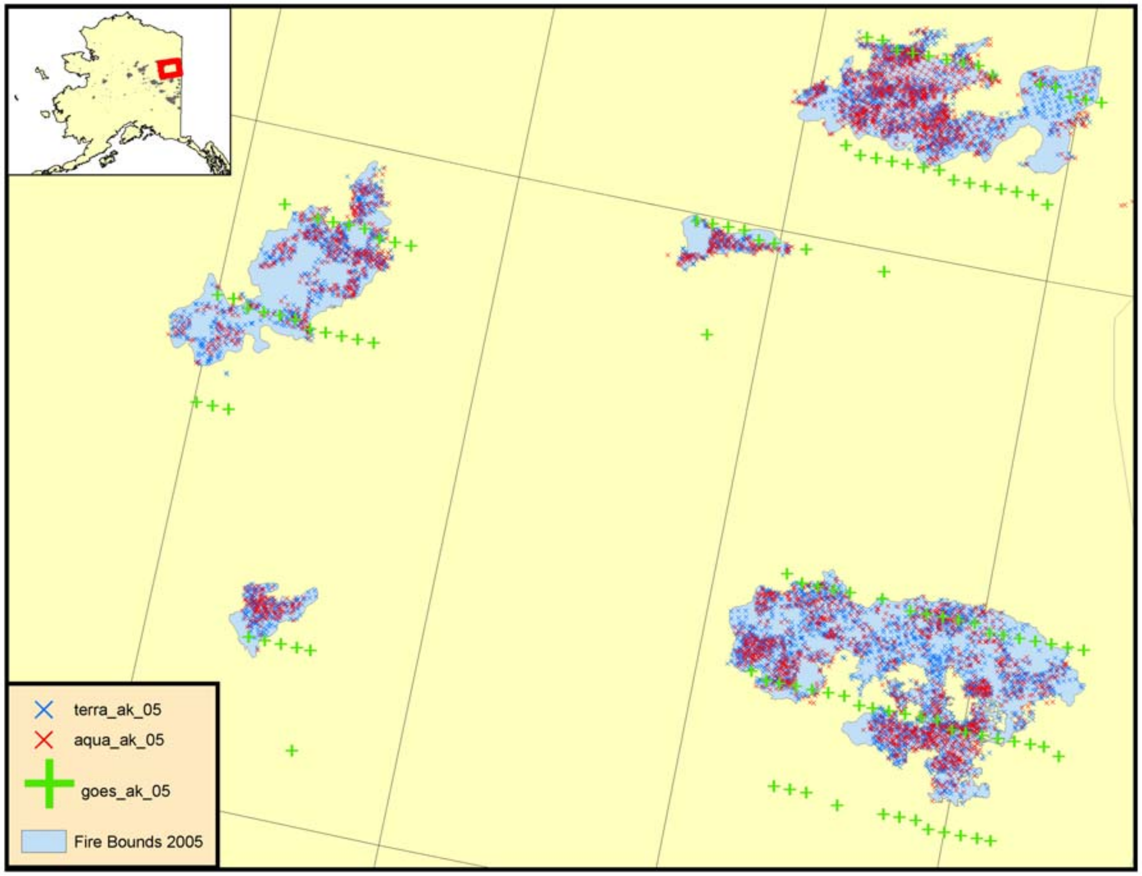
- In *post-facto* models, this is “area burned”
- In an “ideal” real-time scenario:
  - active fires for ignition detection
  - slope-scale model of fire spread
    - topography
    - fuels
    - weather
- With “real-world” data, this is a non-starter
  - location information insufficient AND/OR
  - coverage insufficient AND
  - weather model resolution insufficient

Use of Active Fire Data for EP*ext*

1. Traditional: detections per burned area
   - calibrate with RS/aerial burn scar data
   - Stratify calibration by:
     - **Land Cover**
     - **View Geometry**
     - **Region**
   - subpixel characterization as modifier
2. FRE: Emissions per detection
   - calibrate with inverse modeling
   - Stratify calibration by Land Cover / Fuel Structure

- Both require parameterization of fire persistence
  - Even 15 minute coverage is not “continuous”
  - Coverage must be considered

An example from Alaska 2005

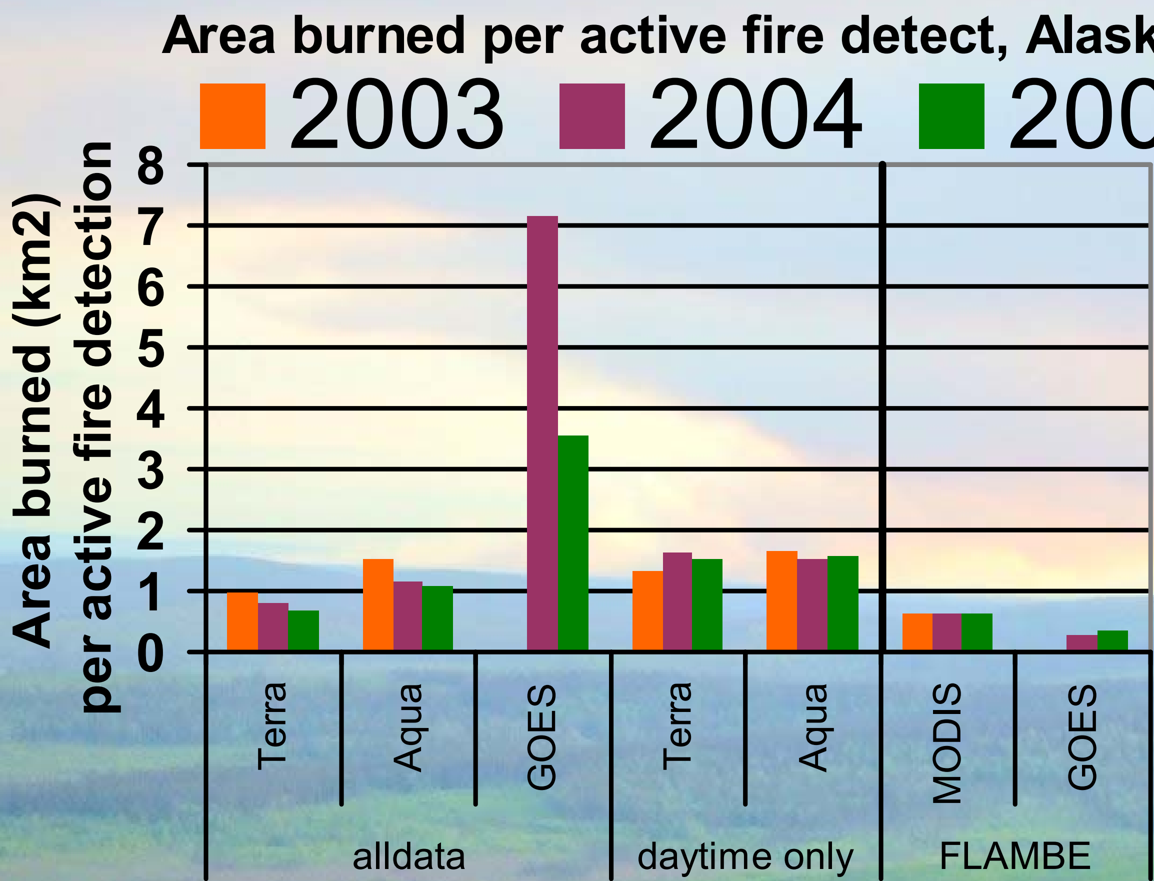


- Drawn fire boundaries are from Alaska Forest Service
- AFS: 1.84 million hectares
- Terra: 27,459 in AK
    - 88% within fire perimeter
    - 100% within 5km
- Aqua: 17,395 in AK
    - 86% within perimeter
    - 100% within 9k
- GOES: 6,167 in AK
    - 48% within perimeter
    - 100% within 18km

Some grounds for confidence that sensors are seeing the same thing, broadly.

SEE ALSO: at a finer scale, things look different (J. Hoffman poster)

Detection Efficiency AK



- This is worst-case for GOES (62-66°N)
- daytime Terra is consistent
  - **1.3-1.6 km² mapped fire per detection**
- Aqua is very consistent
  - **1.53-1.65 km²**
  - **excluding nighttime**
- MODIS burned area (MCD45) [L. Boschetti] will be very useful

Geostationary Fire Data for EP*ext*

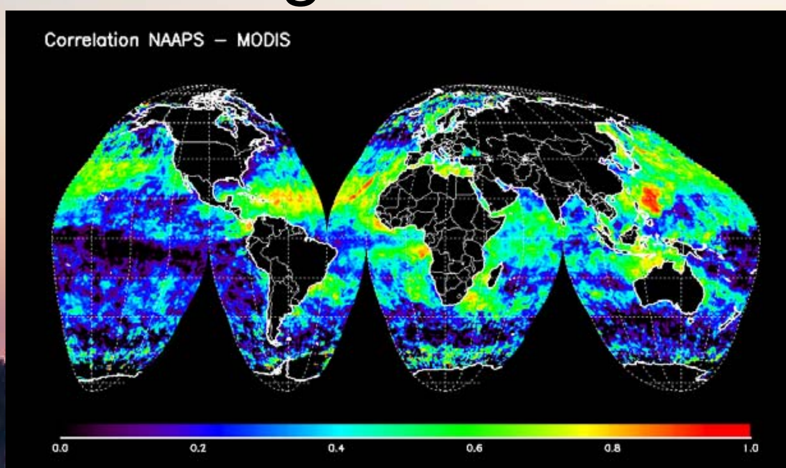
1. Detection efficiency and its enemies:
   1. Coverage (products must include scan coverage)
   2. View geometry (algorithms must be characterized)
   3. Fire size regime (cal. must be stratified by LC)
   4. Cloud cover
      - parameterized? See poster by W. Schroeder
2. Data fusion: sensor capabilities must be described both absolutely and relatively

- Global geostationary fire is coming, but geostationary and polar-orbiter data must be cross-calibrated for integration into global systems

Conclusions?

For operational use, well-characterized products are just as important as good products.

- Not all gloom…



Correlation (r) NAAPS AOT vs. MODIS AOT, 2005, 1° x 5 days

Thanks!

- Chris Schmidt & Elaine Prins
- Sponsors:
  - ONR 32
  - NASA
- Organizers! Great meeting!
- Thank you! *Auf wiedersehen!*