Biomass Burning Studies for SEAC$^4$RS

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Fires in Western and Eastern USA
During July and August, Peak Wildfires are over western USA
Most large fires are located in western U.S.

All years (2008-2012) saw large fires during August in ID, northern CA, and/or northern NV

Large fires generally not present in SE US during Aug-Sep

Western Fire burn acreage peaks in August

Ford and Heald, BAMS, 2003
Extended Outlook (July – September)

- Above average temperatures forecast for most of western U.S.
- Parts of California are already in severe drought
- Below average precip forecast for Northwest and New Mexico
  - Good chance of fires in both locations
Fires in the Western US

- Larger wildfires
- Smoke lofted into free troposphere where it can travel far
- More readily apparent from satellite
- Drier atmospheric conditions
Possible location of larger fires that can be reached from Palmdale, Houston, Kansas

- Large Scale Transport Typically across Northern USA. Need to head north
Fires in the SE US

- Fewer and smaller fires from prescribed burns
- Smoke generally stays within PBL and mixes with other emissions
- Not as readily apparent from satellite
- More moisture and clouds

- SW Louisiana and Everglades are candidate locations for larger fires (Yokelson has contacts)
Nature of Fine Scale Fire Activity and Smoke in the SEUS
SE US Fire Boundary Layer Haze Sept 26 2012, can study haze transport or interactions with other targets
Smoke Variability and Findings from DC3
Vertical Variability of Smoke Properties

- Brief encounters during DC3 mission revealed vertical variability of smoke properties
- DIAL/HSRL and PALMS data show variability and mix of dust and smoke
- Was this typical? What are reasons for variability?

*preliminary data*

PALMS group: Karl Froyd, Jin Liao
Preliminary DC3 Smoke Related Findings

- Biomass Burning was dominant in free troposphere mainly between 2-6 km, also at higher altitudes
- BB plumes contained dust
- Lower particle size growth factors and reduced scattering at higher RH...maybe due to restructuring or shrinking of smoke particles
- Possible size dependent wet removal of BC in upper troposphere
- Little change in aerosol properties in cloud base and detrained layers?

- Additional targeted studies during SEAC4RS with the same payload can pursue these studies
Potential Smoke Transformation Studies for SEAC4RS
Biomass Burning Aerosol Optical Properties – Motivation for Transformation Studies (Lack et al.)

Most recent data from FRESH BB plume:
- Shows non-BC absorption ($E_{\text{Abs}} > 1$) linked to mass of organic aerosol ($m_{\text{PM-NR}}$).
- Non-BC optics linked to internal mixing of BC and organic aerosol, and brown carbon.

Next step in understanding the chemistry and optics of BB aerosol is to measure these relationships as the plume ages. Single survey of many BB plumes NOT a priority.

1. Sampling of fresh (~ 10 miles downwind) BB aerosol as a benchmark.
2. Sampling of plume as it ages over multiple days.
Biomass Burning Aerosol Transformation Study (Brock, Lack, Murphy, Schwarz)

Science goals: BC transformations from fresh (~1 hr) to >1 day downwind.

Instruments: HD-SP2 (BC+coatings, water uptake), photoacoustic (absorption, with & without coatings)

Supporting: cavity ringdown extinction, size dist, AMS organic mass, PALMS BB particle comp

Considerations:

- Using sat imagery to identify plume, plan initial flight track.
- A strong, well defined plume is necessary, both for flight planning/adjustments and instrument sensitivity downwind.
- May require ½ a flight or more, depending on transit time. Aug-Sept fires may be in northern US.
- Maximize downwind range, increased sampling of background and plume for older dilute stage
- Target typical low-middle tropospheric plumes, not pyro-cumulus.
- 2 good cases would fulfill goals.
The DC8 has a payload with a combination of capabilities not present on previous BB missions like ARCTAS:

- Photoacoustic and SP2 together to measure BC
- Matched photoacoustic and cavity ringdown for 3-wavelength single scattering albedo
- Thermo-denuded photoacoustic, cavity ring down and SP2 for coatings
- Humidified SP2 and humidified cavity ringdown for complementary views of water uptake
- PALMS for dust content of BB plumes. PALMS also will constrain what is mixing into the plume.
- AMS for aging of organics
- Gas phase tracers for combustion measures (such as CO to CO2 ratio)
- Acetonitrile measured as biomass burning tracer
- Scanning flow CCN instrument to study changes in CCN as smoke ages
- f(RH) and g(RH) measured to determine water uptake

**Sampling Requirements:**
- Sampling of fresh to very aged plume (up to >1 day old plume).
- Level flight for 30 – 60 seconds for each sampling “leg”, depending on signal level.
- “Fresh” means less than 1 hour old, but DC8 doesn’t have to pretend to be a slurry bomber
- Excursions into background air near plume to see what is mixing in

**Higher Level Science Products:**
- Black carbon optics.
- Brown carbon optics.
- Effect of internal mixing.
- Evolution of coatings.
- Sub-saturated aerosol RH dependence.
- Most inputs for direct radiative forcing inputs (when combined with UHSAS).
- Wavelength dependent optics for comparison to remote sensing.
- Dust implications for ice nucleation.
Aerosol and Ozone Evolution Studies
Hypothesis?

- Larger increase in SOA in warm-wet case
- Decrease in OA in cool-dry environments—evaporation, but increase in light scattering due to coagulation
- But, SCAR-C showed massive SOA production in cool-dry environments. SAFARI 2000 showed SOA production, but Liousse saw evaporation

**MILAGRO: Warm-wet plume (Yokelson et al., 2009)**

**Cool-dry plume (Akagi et al., 2012)**

DeCarlo, Jimenez, Campos, data

Craven, Seinfeld, data
Variability in ozone production

- Higher rate of ozone production in warm-wet plume vs. cool-dry.
- SE USA plume showed high rate of ozone production as plume interacted with urban plume.
Increase in particle scattering with time, possibly as OA coating enhances scattering and/or increase in particle size.
Potential Coordination with Other Missions
DOE Biomass Burn Observation Project (BBOP)

- Art Sedlacek, Larry Kleinman (PIs)
- Quantify the downwind evolution of biomass burning aerosols
- Study impacts of chemical composition/particle morphology on BC radiative forcing
- Probe evolution of size distribution
- Constrain processes and parameterizations in Lagrangian model of aerosol evolution
- Incorporate evolution information into SCM for determining for unit carbon burned
- Deployment on DOE G-1 from Pasco, WA (35 hrs Aug, 15 hrs Sept)
- Flights to focus on near source properties and evolution of smoke
BBOP to study smoke microphysical properties

- Possible joint study of short (BBOP) and long (SEAC4RS) range evolution of smoke properties
- BBOP can provide detailed near source information that could help place SEAC4RS smoke observations in context

**Impacts of chemical composition/particle morphology on BC radiative forcing:**
- SP-AMS (Soot Particle Aerosol Mass Spectrometer):
  - chemical composition of non-refractory material associated with rBC
- SP2 (single particle soot photometer):
  - using lagtime methodology probe particle morphology
- Microscopy (TEM):
  - chemical composition and particle morphology

**Probe the evolution of size distribution:**
- FIMS (Fast Integrated Mobility Spectrometer):
  - Range: 30 nm - 100 nm
  - Time response: 1-Hz

TEM images of smoke aerosols from Timbavati fire, South Africa, 2000

(Li et al, 2003)
During TexAQS/GoMACCS (2006), smoke and elevated CO observed aloft over Houston from fires in northwest US.

P3 in situ and King Air remote (HSRL-2) could reveal smoke during DAQ (in September).

(McMillan et al., JGR, 2006)
Remote Sensing Retrievals
Polarimeters (RSP, AirMSPI) desire high (>0.4) AOT test cases missing from PODEX.

- Smoke over low stratus clouds is challenging for passive retrievals and induces errors in cloud retrievals. Validation data would be highly desired for testing/developing retrievals.
- Differences in particle properties between plume top and bottom might influence interpretation of polarimeter signals.
- The brighter the clouds, the greater the sensitivity to aerosol absorption.
- Prefer early morning (9-10 am) observations to obtain side scattering angles as well as rainbow to sense cloud microphysics.
CALIPSO retrieval uncertainties associated with smoke

- Accuracy of CALIPSO retrievals of AOD and extinction depend on correct assignment of lidar ratio
- Coincident CALIPSO and airborne HSRL measurements show differences in lidar ratios associated with smoke
- HSRL data show wide variety of lidar ratios associated with smoke

DIAL/HSRL data from DC3 show vertical variability of lidar ratio and depolarization associated with smoke
Flight Planning
DC8 and ER2 can follow long axis

Can also follow pseudo-Lagrangian path to facilitate sampling other targets as well

But, remember plumes are 3 dimensional objects, with differences in chemistry and particle properties between plume top and bottoms.
Must be careful in interpreting measurements...

- Changes in observations along plume are due to variability in fire behavior as well as photochemistry.
- Need to look at how source changes during sampling.
- This is an even bigger challenge at looking at far field evolution over days. But for large fire complexes, much may come out in the wash.
Finding Fires
Significant Fire Forecasts

7-Day Significant Fire Forecast
(http://psgeodata.fs.fed.us/staticmap.html)

- Daily probability for occurrence of new large fires
- Daily probability for significant growth on existing fires
- Updated daily for each PSA

Fire potential is function of:
- Fuel dryness
- Burn environment factors
- Ignition triggers
- Available resources to respond
Latest Hotspots and Fire Locations

- Several sources of active fire geospatial data/mapping applications
  - Large Incident Map
  - New Large Incident Map
  - Forest Service Active Fire Mapping Program
  - USGS GeoMAC
  - InciWeb
  - GACC Fire Intelligence websites

http://www.inciweb.org/

http://www.firedetect.noaa.gov/viewer.htm
Daily IMSR details wildfire activity including:

- Fire size and 24hr change in size
- Observed fire activity
- Fuels consumed
- % containment
- Committed resources and costs to date
- New fire activity in last 24 hours
- Uncontained large fires
- Current national and GACC preparedness levels

Prepared by the National Incident Coordination Center (NICC)
Aviation Operations
Aviation Operations in Proximity to Wildfires

- Non-suppression aircraft; reconnaissance, and non-essential aircraft must be coordinate with interagency Air Operations Organization

- Contact the GACC Aircraft Dispatcher at least 24-48 hours in advance of mission in the vicinity of any wildfire
  - Contact GACC directly

- GACC Aircraft Dispatcher will assist in coordinating with other elements of the Air Operations Organization to review and approve mission, and provide necessary guidance

- Aviation operations in the area of wildfires is also dictated by vertical and lateral separation rules of Fire Traffic Areas (FTAs) and Temporary Flight Restrictions (TFRs)
Potential Fire Monitoring Plans

- **Step 1 Monitoring to locate “actual” large-scale events**
- **Step 2 Assess probable persistence of large-scale events**
  - Talk with Chuck McHugh USFS Fire Behavior Analyst (cmchugh@fs.fed.us 406-829-6953)
    a) Fire specific
      - Inciweb: fire specific outlook at bottom of public page.
      - Inciweb: Call the POC in upper right and ask for plans chief
    b) Regional specific
      - Regional weather and fire behavior outlook at www.nifc.gov
      - Under logistics > aviation http://airspacecoordination.org/coord.shtml
- **Step 3 Establish airspace POC for selected targets**
  - Regional Dispatch or Inciweb POC.
  - Ask each Regional Aviation Officer in advance how they prefer we approach it. It may differ region to region
    - (Bob used USFS aircraft/pilots in past and they handled the airspace issues.). Bob is working with Mike Hubbell on Missoula one-day visit for BBOP. Can do same for NASA pilots if we want
- **Step 4 Generate and sell a flight plan with good backup target (e.g. fracking, etc)**
- **Step 5 Execute flight plan**
- Extra Slides
Fire Traffic Area (FTA) Environment

- Fire Traffic Area (FTA) – a standardized initial attack airspace structure to enhance air traffic separation for all aircraft over wildfire incidents
  - Unique to land management agencies
  - Utilizes a 5nm radius from the incident lat/long, but could be larger or smaller
  - Vertical restrictions are typically 2500 to 3000 feet above highest point in terrain (AGL) and any incident-related aircraft, but could vary
  - Radio communication is initiated at 12nm from the incident lat/long
  - Negative Radio Contact requires holding a minimum of 7nm from the incident lat/long
- An FTA is implemented by land management agencies in coordination with the FAA
Temporary Flight Restrictions (TFR)

- Temporary Flight Restriction (TFR) – defines an area restricted to air travel due to a hazardous condition or other factor
  - Issued as a Notice to Airmen (NOTAM) by the FAA
    - http://tfr.faa.gov
  - Closes the airspace to aircraft that are not participating in fire fighting activities (with some exceptions)

- TFRs are implemented predominantly for daytime operations
  - Nighttime and early morning operations in the TFR by non-suppression aircraft are possible

- TFRs encompass FTAs
  - Can be revised daily by coordination of agency aviation managers with the FAA as incidents evolve
C. Correlation with August PDSI one year prior

D. Correlation with August PDSI, current year