PyroCbs: Satellite observations of fire-induced thunderstorms

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riza_pyrocu_timelapse.mov
Outline

1. What is a pyroCb?
2. Observing fires from satellite
3. PyroCb Examples
4. Aerosol effects on clouds
*Pyro*

**Pyrocumulus** *(pyroCu)*
- condensation but no lightning, no ice

**Pyrocumulonimbus** *(pyroCb)*
- subset of pyroCu
- lightning, ice, rain, ice, tornado
- can penetrate the tropopause

*Courtesy of Mike Fromm*
Fire Observations from Satellite

GOES 3.9 micron band ideal for locating and monitoring fires

• More sensitive to subpixel heat sources than the “window” 10.7 band
Hayman Fire – largest in Colorado’s history
Modified by increasing surface temp
Modified by increasing surface temp and moisture
Western Russia Fires – July/August 2010

26 July 2010, 0800 – 2045 UTC
Western Russia Fires – July/August 2010

Meteosat-8 Rapid Scan Visible Loop – images courtesy of Zdenek Charvat, CHMI
The Chisholm (Alberta) PyroCb
28 May 2001

Fromm & Servranckx, (GRL, 2003)

See Rosenfeld et al., (ACP, 2007)
The Chisholm (Alberta) PyroCb
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See Rosenfeld et al., (ACP, 2007)

GOES-10, Visible Loop
GOES-10, 3.9 µm Loop
The Chisholm (Alberta) PyroCb
28 May 2001

GOES-10, 10.7 µm Loop
The “Day After” Chisholm Smoke Plume Northwest Territories

See Fromm et al. 2008, JGR
TOMS Aerosol Index  “Day After” Chisholm

See Fromm et al. 2008, JGR
TOMS Aerosol Index following Chisholm

See Fromm et al. 2008, JGR
Australia’s Christmas Gift to Itself

14 December 2006 pyroCb smoke plume comes back over the continent on Christmas Day, after global transport

Views from OMI, CALIPSO, and MTSAT
“I'd say something phenomenal just happened over eastern Victoria. 38°S 147°E, 06 UTC 14 Dec 2006.”
- Rick McRae, ACT Emergency Services Authority, Australia

(Near real-time email message)
The day after
Late Day Geostationary 
Vis image, 25 Dec 06 
0933 UTC

See how the smoke 
Jumps out in the low 
Sun-angle view.
Plume is above tropopause

(~3-6 hr after MTSAT & A-Train)
“The Untold Story of Pyrocumulonimbus”

• Four observations of stratospheric aerosols in the late 1980’s and early 1990’s, previously attributed to volcanic eruptions, are shown to actually originate from pyroCbs.

• One example from the summer of 1991 was attributed to the eruption of Mt. Pinatubo (Philippines)
Baie Comeaux fire and pyroCb anvil, AVHRR Imagery

19 June 1991, Quebec

TOMS AI > 3, Day by Day

AVHRR Imagery

19 June 1991, Quebec

Baie Comeaux fire and pyroCb anvil, AVHRR Imagery
There’s a story in every spike.
Fires > 200 ha, pyroCu, pyroCb, & Al Spikes, 2002
Western Canada pyroCbs – 4-5 July 1998

- Note the fires (white hot spots) in the 3.9 µm loop, and the pyroCbs which initiate over them
- These storms have significantly warmer 3.9 µm brightness temps than the surrounding convection, indicating smaller ice crystals
- In the 10.7 µm loop, notice how much longer the pyroCb anvils persist compared to the other storms’ anvils
Western Canada pyroCbs – 4-5 July 1998

- Ice effective radius retrieval loop from GOES-9
- Notice how the pyroCb anvils have significantly smaller ice crystals than the surrounding “clean” convection

Cloud Lifetimes:
Southern regular anvil: ~12 hours
Southern pyroCb anvils: ~18 hours
Northern regular anvils: ~13 hours
Northern pyroCb anvils: ~30 hours
Western Canada pyroCbs – 4-5 July 1998

GOES-9 visible loop from 4-5 July 1998
What is the effect of smoke on convective cloud microphysics?

Increase surface CCN concentration
Summary

• PyroCbs occur over large, hot wildfires, typically during the warm season

1. They can penetrate the tropopause and transport large amounts of smoke into the lower stratosphere

• These stratospheric aerosols can be tracked for days, and may effect the Earth’s radiation budget

1. The aerosols may also serve as Cloud Condensation Nuclei (CCN), leading to large numbers of small cloud droplets and (after homogeneous nucleation) ice crystals

• PyroCb anvils have been shown to persist longer than “normal” convective anvils

1. Longer anvil lifetimes presents evidence for the cloud lifetime effect, an aerosol indirect effect identified by the most recent IPCC report
Lots of unanswered questions

- How much does stratospheric smoke contribute to the Earth’s Radiation Budget?
- Does it provide a net warming or a net cooling?

1. How will climate change affect the frequency of wildfires, and will this potentially provide a feedback due to more aerosols?