MLS Observations of Fire Smoke in the Lower Stratosphere

Extra-Tropical UT/LS Workshop
Boulder, CO
October 19-22

Steven Massie (NCAR)

Outline

NCAR

Smoke is present in the lower stratosphere 2 days after the Australian fires start

Is deep convection by itself sufficient to inject smoke into the lower stratosphere?

If not, is absorptive aerosol heating sufficient to help get the smoke into the lower stratosphere?

<u>Smoke in the lower stratosphere</u>

NCAR

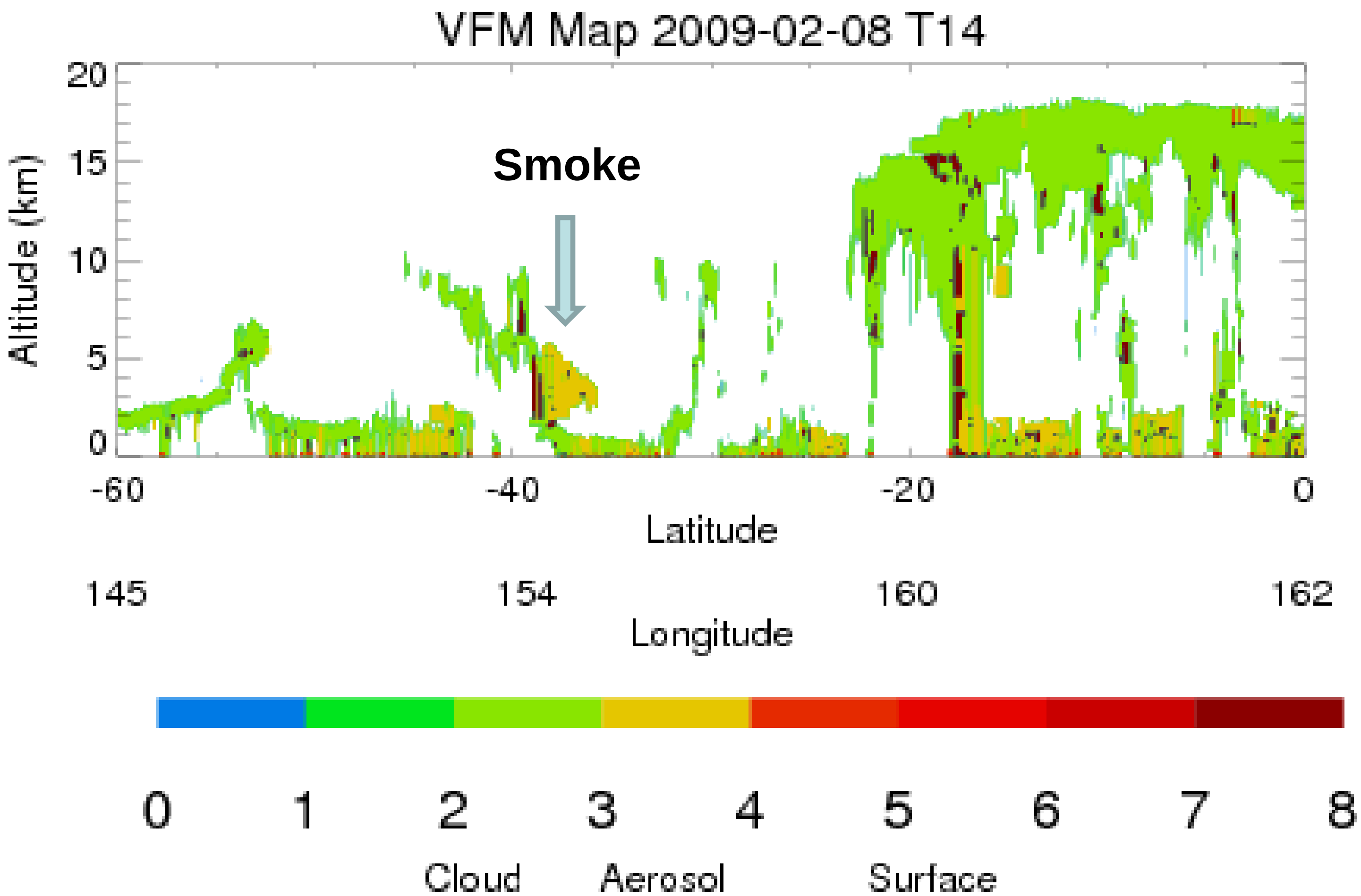
Jost et al. "In-situ observations of mid-latitude forest fire plumes deep in the stratosphere", GRL, <u>31</u>, 2004

Fire smoke 2 km above the tropopause on June 29, 2002

FLEXPART Lagrangian transport calculations (Stohl)

"..the model does not inject high enough. The altitude difference of 2 km between the FLEXPART model results and the POAM profile is highly significant .."

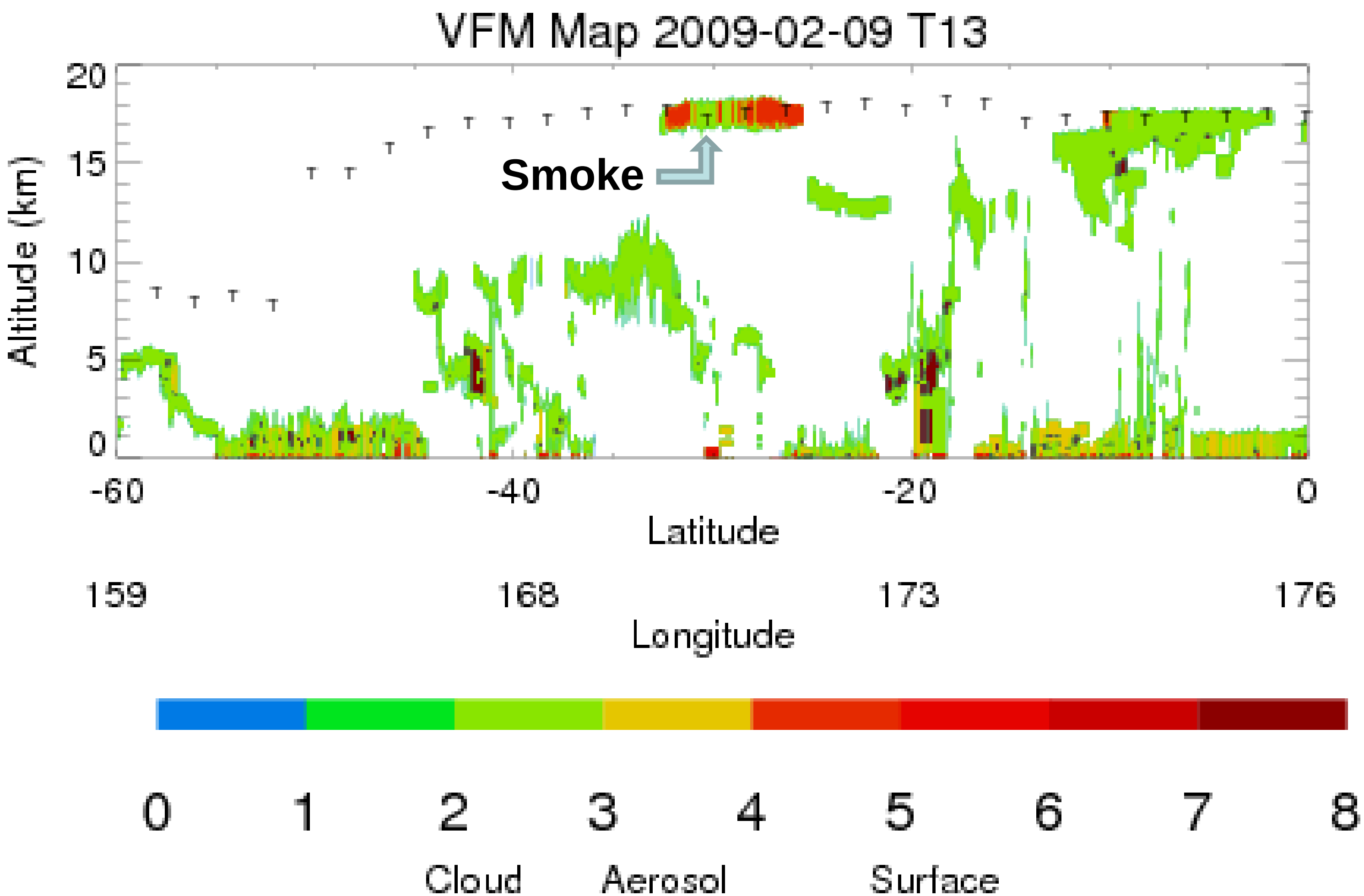
February 8 CALIPSO Image



Smoke is between Australia and New Zealand at Z < 5 km

Fires started on Saturday, February 7

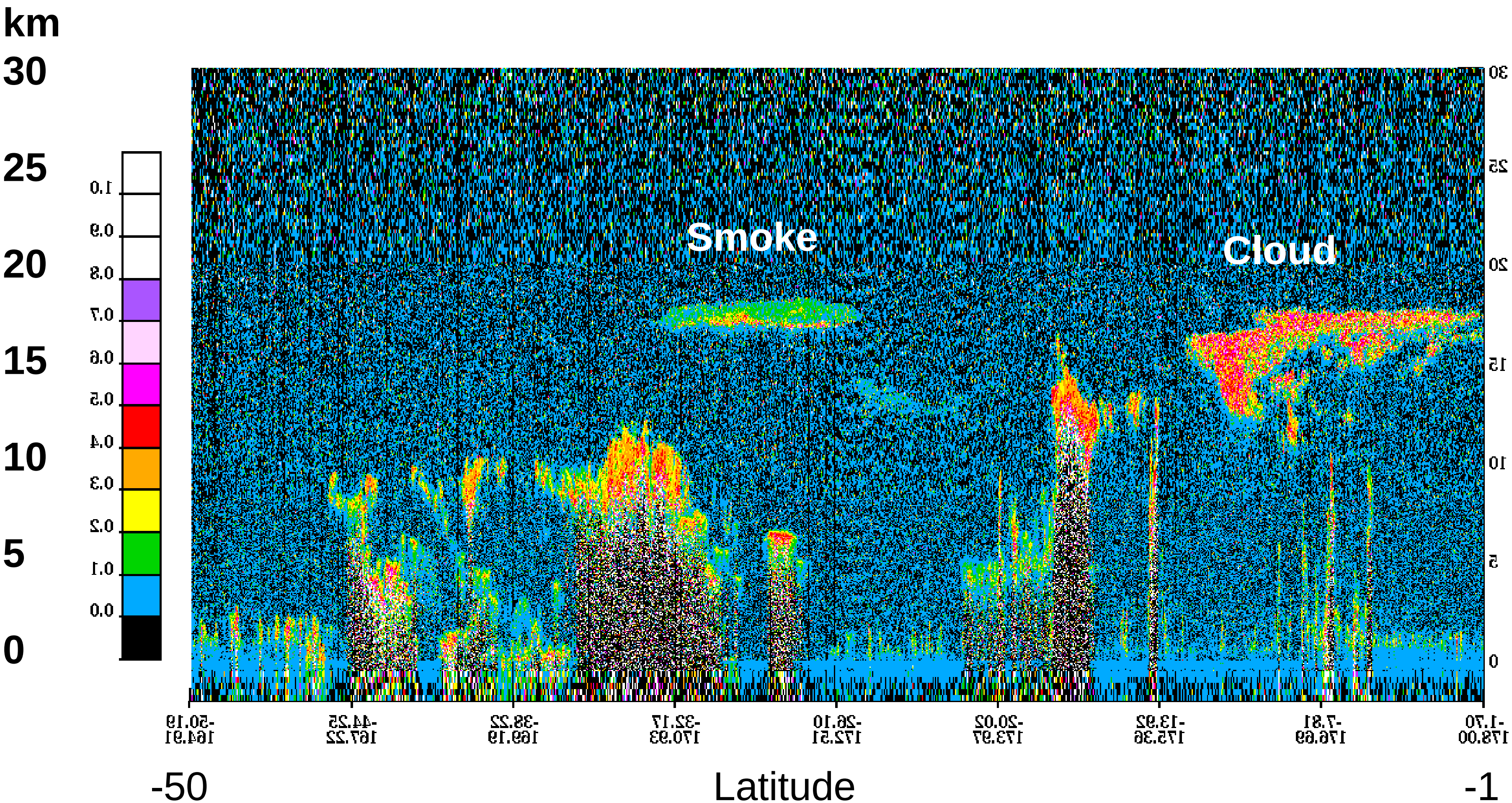
February 9 CALIPSO image



Smoke top is at 18.5 km

T = thermal tropopause (from NCEP GFS)

February 9 CALIPSO Image

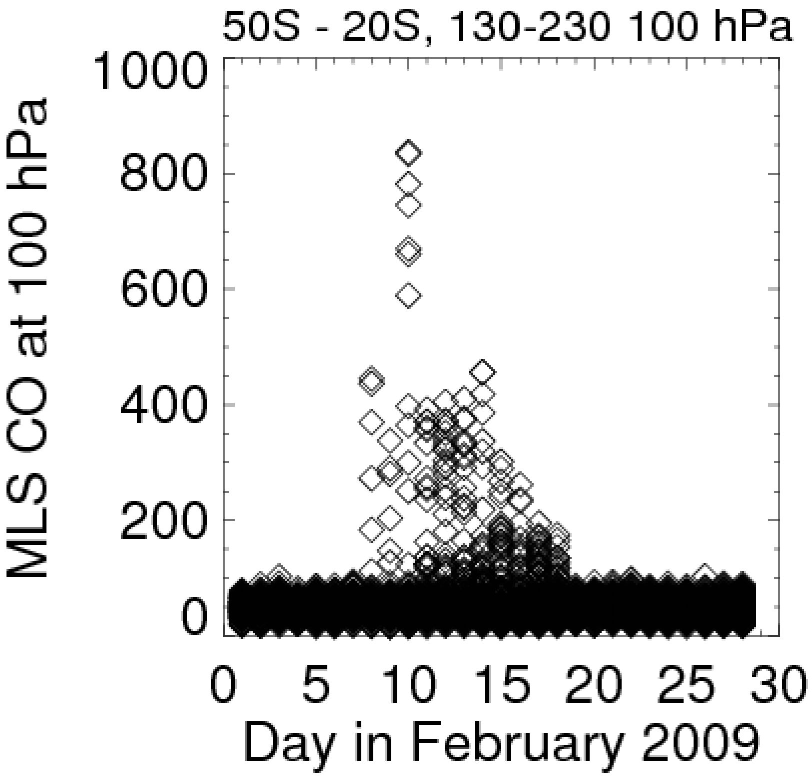


Depolarization Ratio: Cloud 0.4 Smoke 0.1

MLS CO Time Series

100 hPa

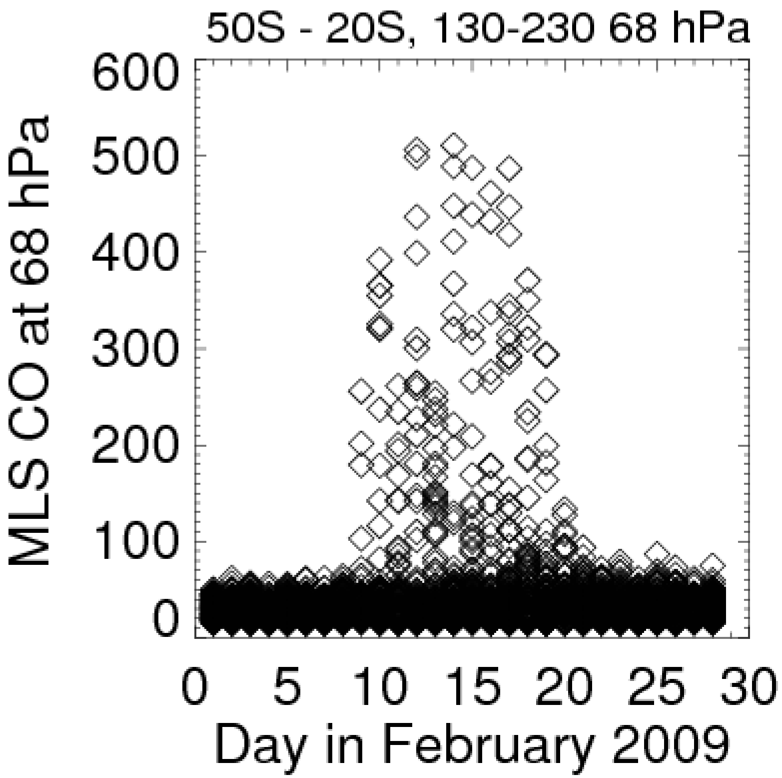
68 hPa



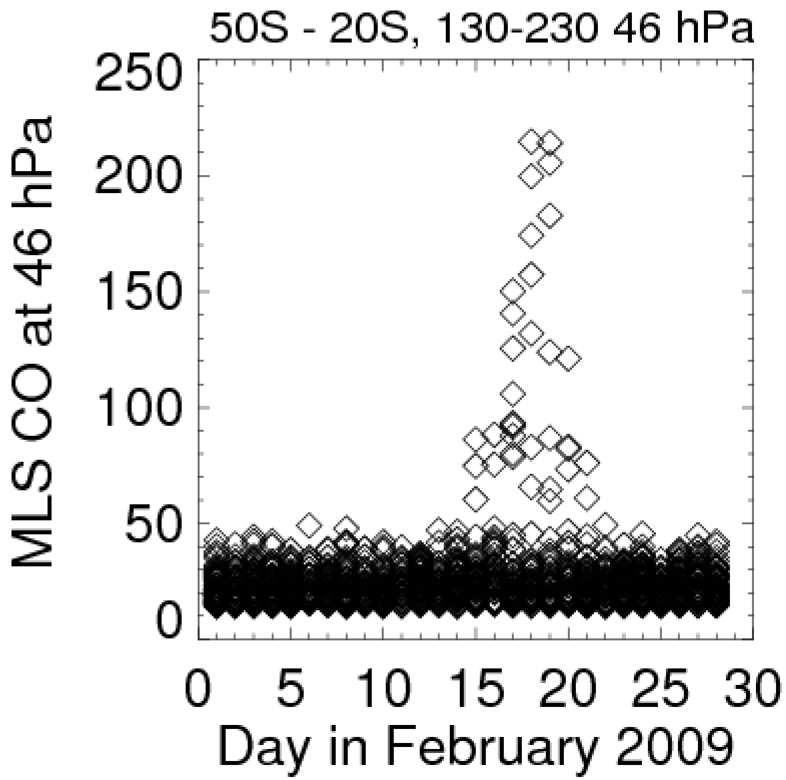
Note: MLS has 4 Km FWHM triangle averaging kernel

MLS CO Time Series

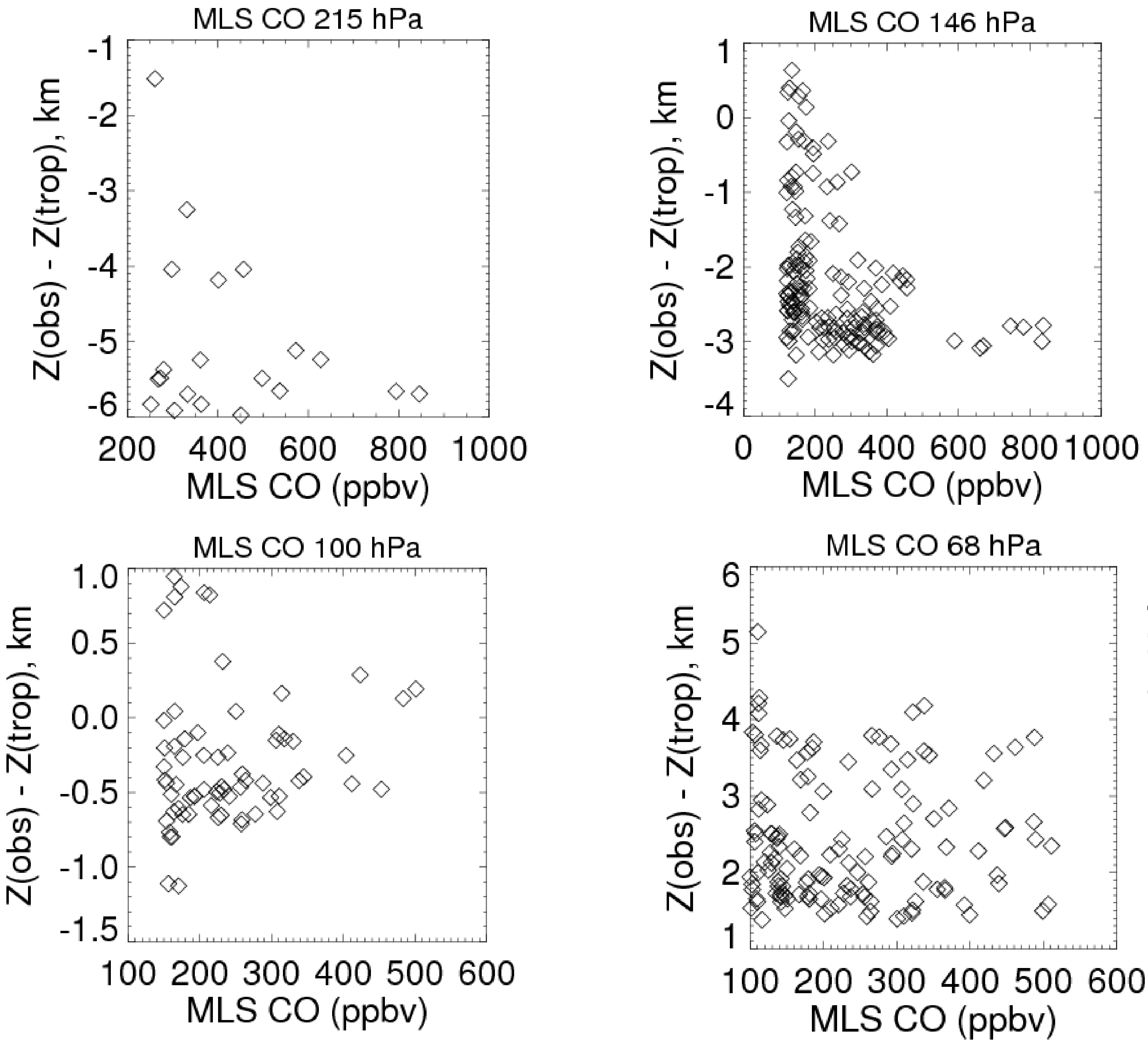
68 hPa (~18.6 km)



46 hPa (~20.9 km)



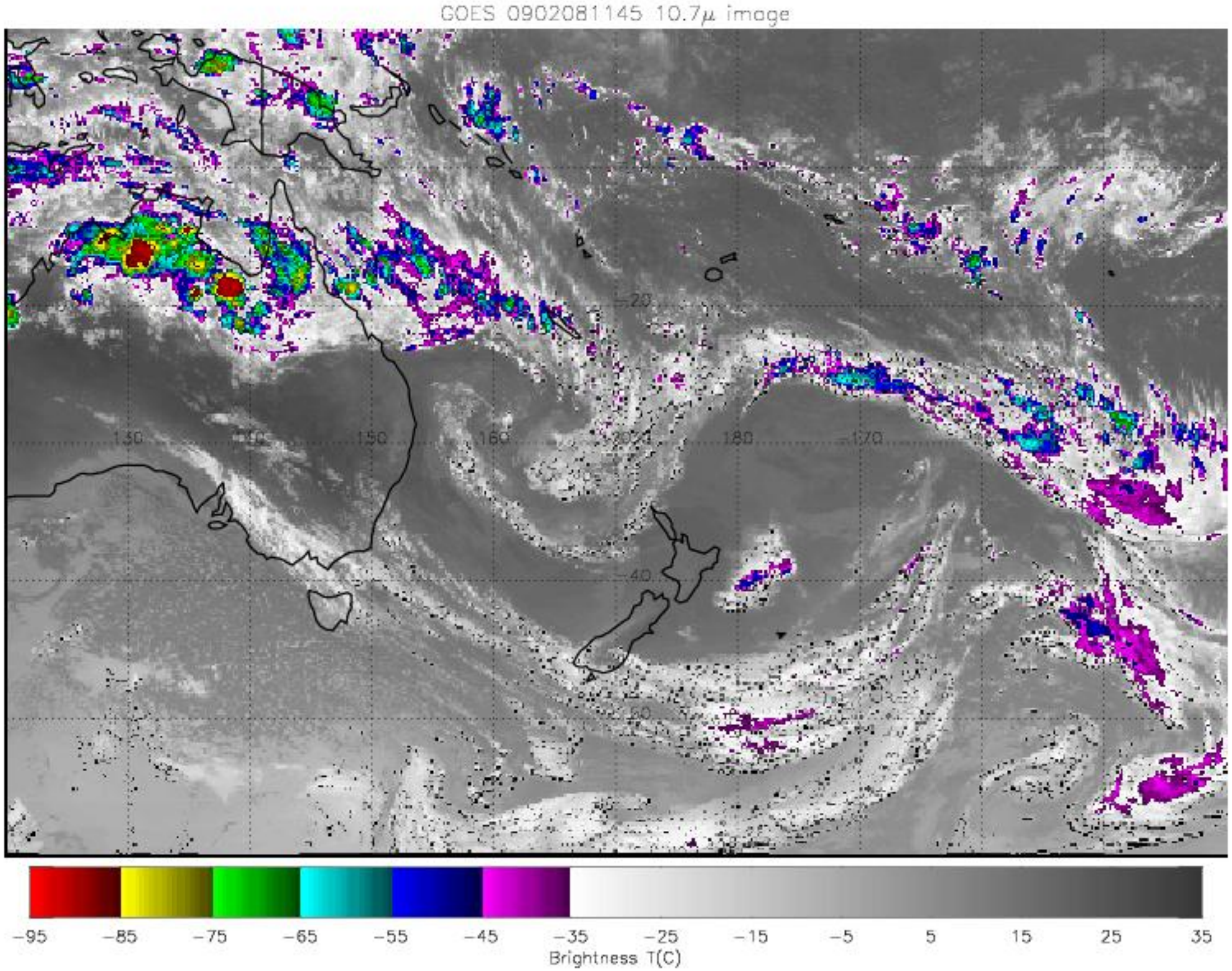
Note: MLS has 4 Km FWHM triangle averaging kernel



Z(trop) from GFS tropopause pressure

Z(obs) - Z(trop) > 2 km at 68 hPa on February 11 (fires erupted on February 7)

GOES Imagery, February 8



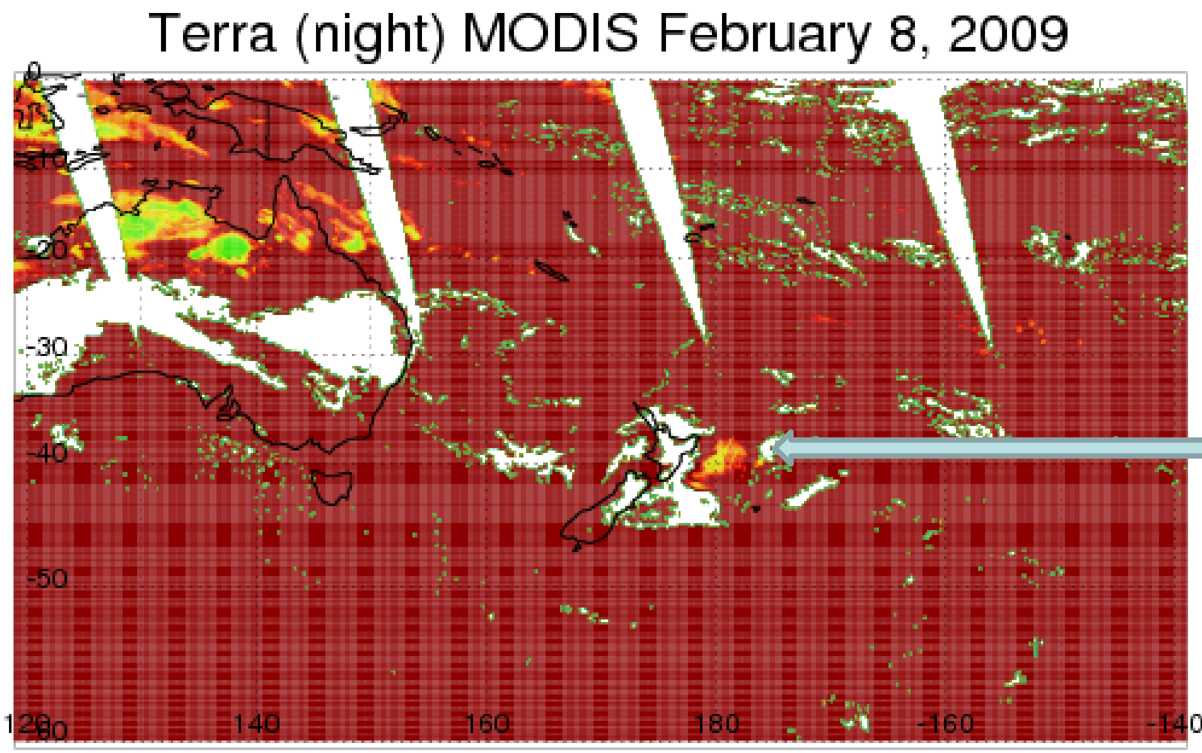
Brightness Temperature (C)

Hourly,
9 – 23 UTC

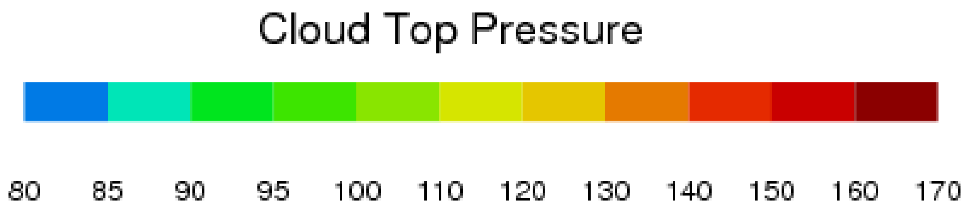
Max Development 11:45 UTC (at night)

Acknowledgement: Marion Legg

Convective uplift, February 8

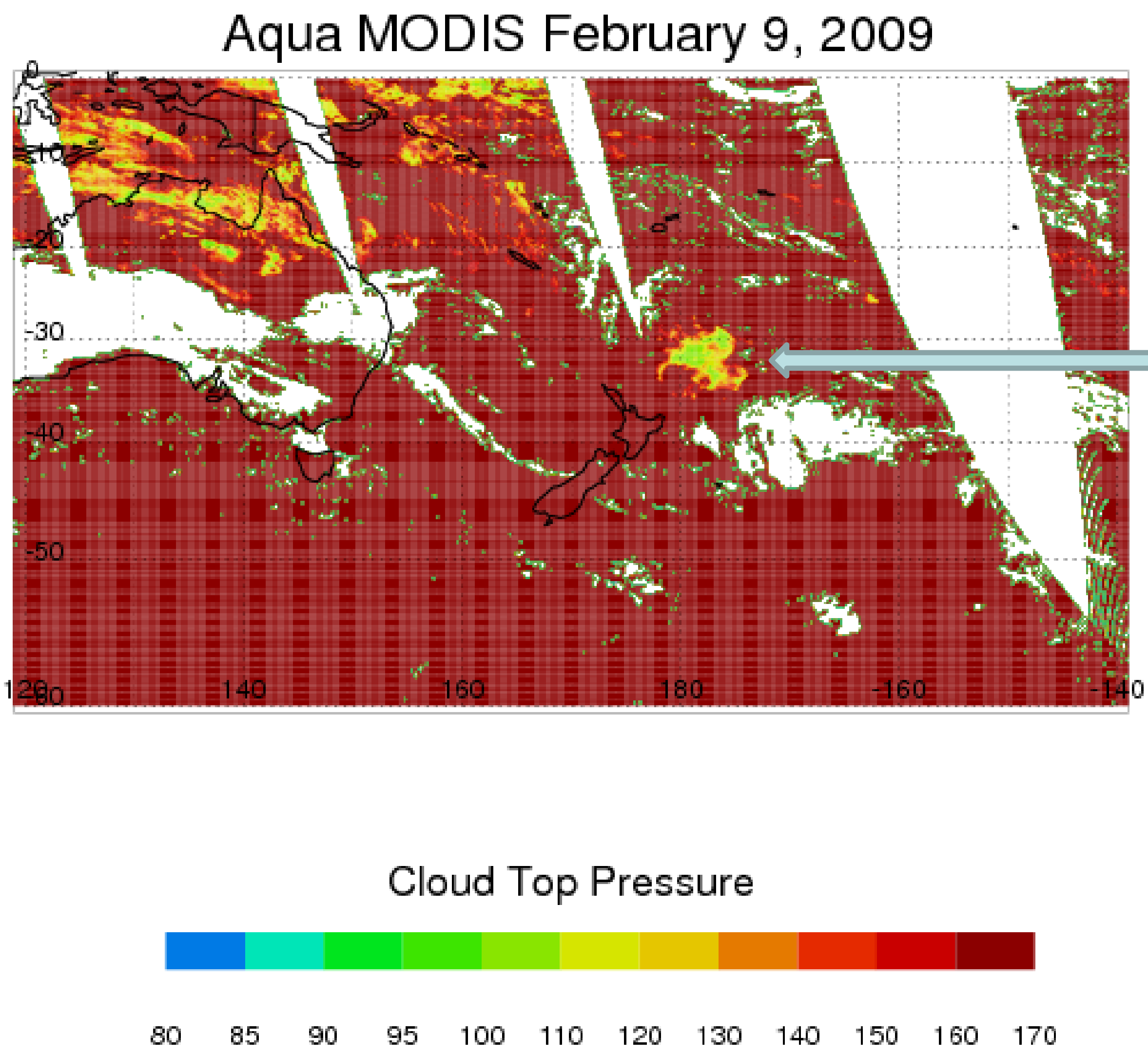


MODIS cloud top pressure ~ 136 hPa (z ~ 15 km)



Pressure > 170 hPa Is red

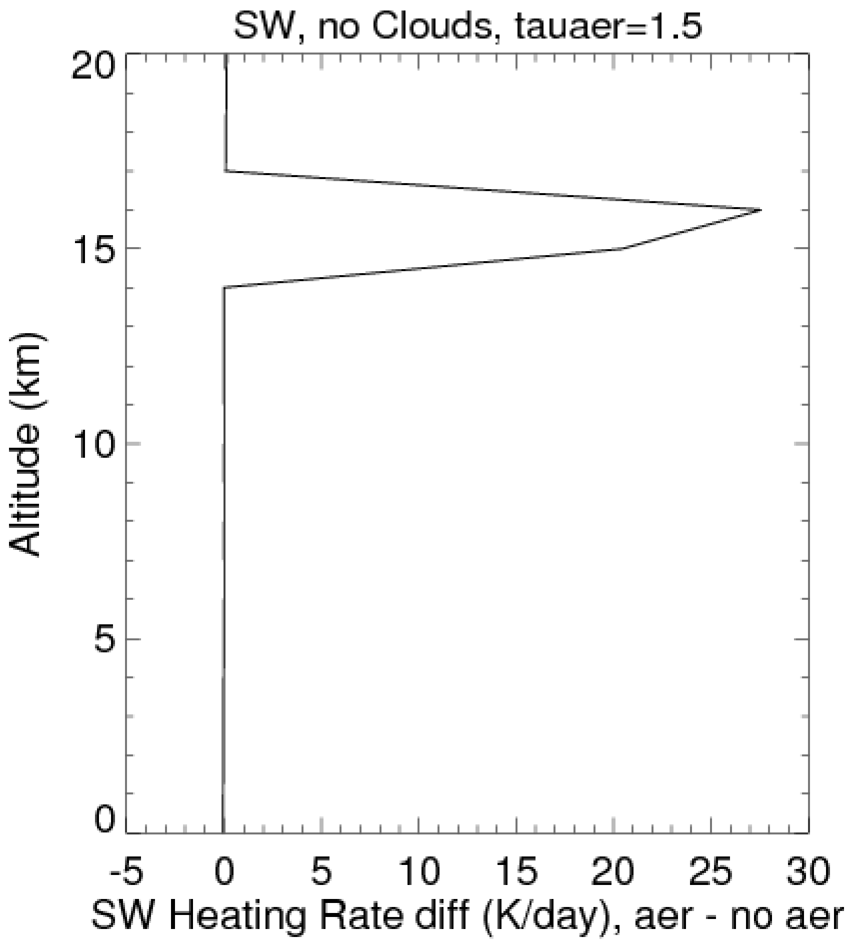
Convective uplift, February 9



MODIS cloud top pressure ~ 114 hPa (z ~ 16 km)

Heating Rate Calculation

NCAR



SBDART Application

Magi (Safari, JGR, 112, 2007)

Smoke Radius~0.09 micron
- **Optical depth = 1.5 (MODIS)**
- **Imaginary index x 1/4**
- **Absorptive AOD = 0.26 (OMI)**

SW = Shortwave calculation

Heating rate ~ 25 K / day
(difference aerosol – no aerosol)

Vertical Velocity

Durran et al., The Meoscale Dynamics of Thin Tropical Tropopause Cirrus, JAS, 66, 2859-2873, 2009.

Analytic solution for vertical velocity (W), horizontal velocity (U), and perturbation potential temperature (θ)

Durran paper

Long wave cirrus heating ~ 3 K / day

W ~ 7 mm / sec , dz ~ 0.6 km / day

Smoke layer

Shortwave smoke layer heating ~ 25 K / day

W ~ (1/2) (25/3) 7 mm /sec = 29 mm / sec

smoke layer rises ~ 2.5 km / day

Conclusions

NCAR

Smoke is present in the lower stratosphere 2 days after the Australian fires start at 18.5 km altitude

Deep convection is sufficiently strong to inject smoke to ~ 16 Km altitude

Smoke absorption (heating) increases the smoke altitude by ~ 2.5 Km / day

Both transport mechanisms are influential

Are analyses and observations capable of noticing when maximum deep convective uplift happens?