

# SMOKE INJECTION HEIGHTS FROM FIRES IN NORTH AMERICA: TOWARDS A 1-D PLUME-RISE MODEL PARAMETRIZATION

**Maria Val Martin**<sup>1</sup> (mvalmart@seas.harvard.edu), J. Logan<sup>1</sup>, R. Kahn<sup>2</sup>, S. Freitas<sup>3</sup>, C. Ichoku<sup>2</sup>, D. Nelson<sup>2</sup>, D. Diner<sup>2</sup>, F.-Y. Leung<sup>4</sup> and A. Cantin<sup>5</sup>  
<sup>1</sup>Harvard University <sup>2</sup>NASA <sup>3</sup>INPE (Brazil) <sup>4</sup>Washington State University <sup>5</sup>Canadian Forest Service

## 1. Introduction

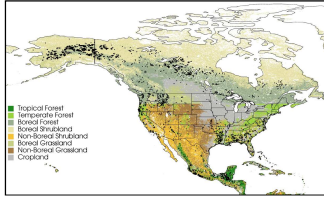
Satellite observations of MISR aerosol plume heights and MODIS fire radiative power (FRP) demonstrate the large variability in fire smoke injection heights in the North American biomes, and the important effect of both buoyancy generated by the fires and local atmospheric structure in the ultimate rise of these fire emissions [1]. Chemical transport model (CTM) parameterizations of fire emission injection heights are independent of such as physical processes, and often assume a constant altitude [e.g., 2, 3].

Here, we present results from a 1-D plume-rise model [4] driven by fire properties and local meteorology, using MISR plume heights and MODIS FRP measurements. The objective is to develop a non-computational expensive parameterization of fire emission injection heights over North America for CTMs.

## 2. MISR plumes and 1-D Plume-rise Model

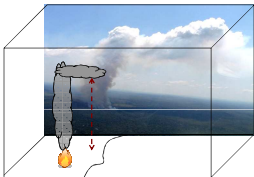
### MISR Plume Climatology (Val Martin et al., 2009 [1])

Location of MISR plumes from 2002 and 2004-2007



About 3400 smoke plume heights are derived with the MINX tool [5] using MISR stereo-height retrievals. Fire characteristics of these plumes are obtained from measurements of FRP from MODIS. Plumes are observed from 11:00 to 14:00 local time.

### 1-D Plume-rise Model (Freitas et al., 2006 [4])

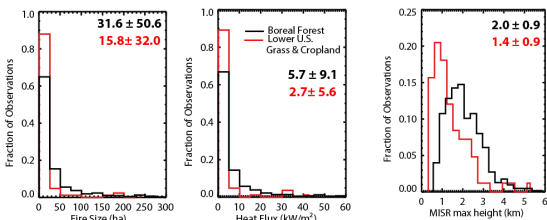


Vertical resolution is 100 m (top at 20 km); temporal resolution is < 5 sec, with microphysics resolved at 1/3 of dynamic time; and steady state is reached within 60 min

Model Input Parameters	Approach
Meteorology	GEOS-4 & GEOS-5
Instant fire size [C. Ichoku personal communication]	Scaled MODIS FRP by max observed MODIS FRP in each biome (e.g., in boreal forest, max FRP = 1710 W/m <sup>2</sup> → area=1 km <sup>2</sup> ; then FRP = 800 W/m <sup>2</sup> → area=0.47 km <sup>2</sup> )
Total heat flux	Total observed MODIS FRP in each plume x 10 [6,7]
Fuel moisture content	Canadian Fire Weather Index Model [8]

### Model Main Input Values and MISR Plume Heights

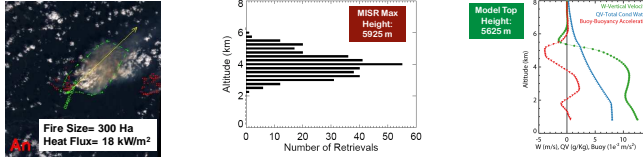
Distribution of values used in the simulations for two extreme cases: large boreal forest fires and relatively smaller grassland and cropland fires in the lower 48 states. Also, shown is the observed MISR maximum heights above sea level.\*



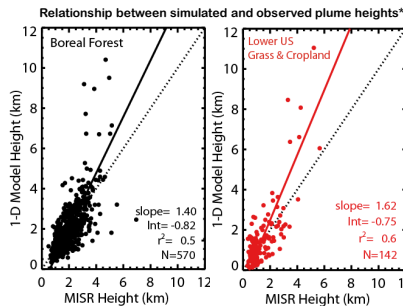
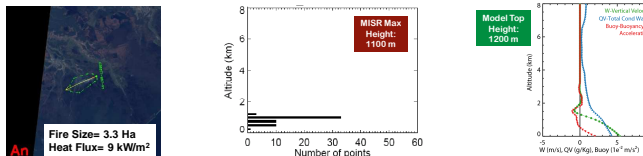
## 3. Plume Injection Height Simulations

### Example of Boreal Forest Fire Plume in Alaska

MISR image and MODIS fire pixels Vertical distribution of MISR height retrievals 1-D plume-rise model simulation



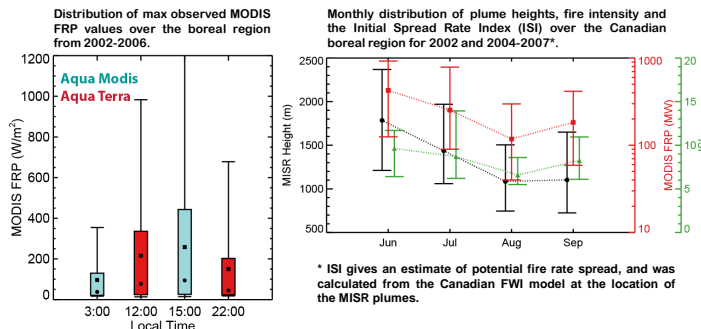
### Example of Grassland Fire Plume in Southeastern U.S.



We find that the model simulates the observed maximum plume heights fairly well (r<sup>2</sup> = 0.5-0.6) for the ensemble of plumes, although a small fraction of plumes are overestimated.

\*Regression lines are derived from the reduced major axis two-sided regression technique [9]. We include MISR plumes with a good data quality flag, and plumes in which the residual MODIS FRP relative to MISR height does not deviate from the mean by more than one standard deviation.

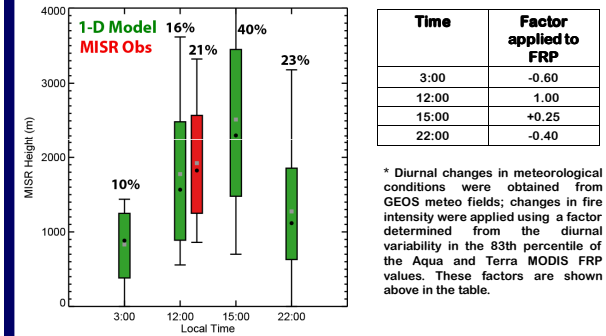
## 4. Diurnal and Seasonal Variability of Fire Intensity



There is a diurnal variability in MODIS FRP, with larger values during late afternoon, when fires are at their maximum intensity [e.g., 10,11], and after the MISR overpass time. Also, a seasonality is apparent in the plume heights, driven mainly by fire intensity [1], which in turned is related to fire weather conditions (i.e., ISI).

## 4. Accounting for Diurnal Variability

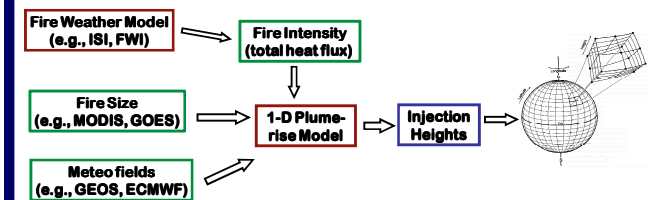
Simulated diurnal injection height variability over the boreal region, taking into account changes in meteorological and fire conditions. Also, shown is the percentage of the plumes, in which the top of the plume is in the free troposphere [12]\*



Larger injection heights and higher percentage of plumes located above the boundary layer are simulated at the fire intensity peak.

Overall, it is clear that the 1-D plume-rise model is able to simulate the injection height of pollution from late morning-early afternoon fires over North America.

## 5. Towards a Parameterization



## REFERENCES

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## ACKNOWLEDGEMENTS

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