Plume Rise from Wildfires:

BlueSky & Large Eddy Simulations

Nadya Moisseeva, Rosie Howard, Frans Liqui Lung, Tim Chui, Roland Schigas & Roland Stull

University of British Columbia (UBC)
Vancouver, Canada

June 2018

Topics:

1. BlueSky
2. Smoke Plume Rise
3. WRF-SFIRE
4. DALES
5. Plume Variations
6. Wind Modification Region of Influence

Presentation for David Lyder, Alberta Ministry of Environment and Parks

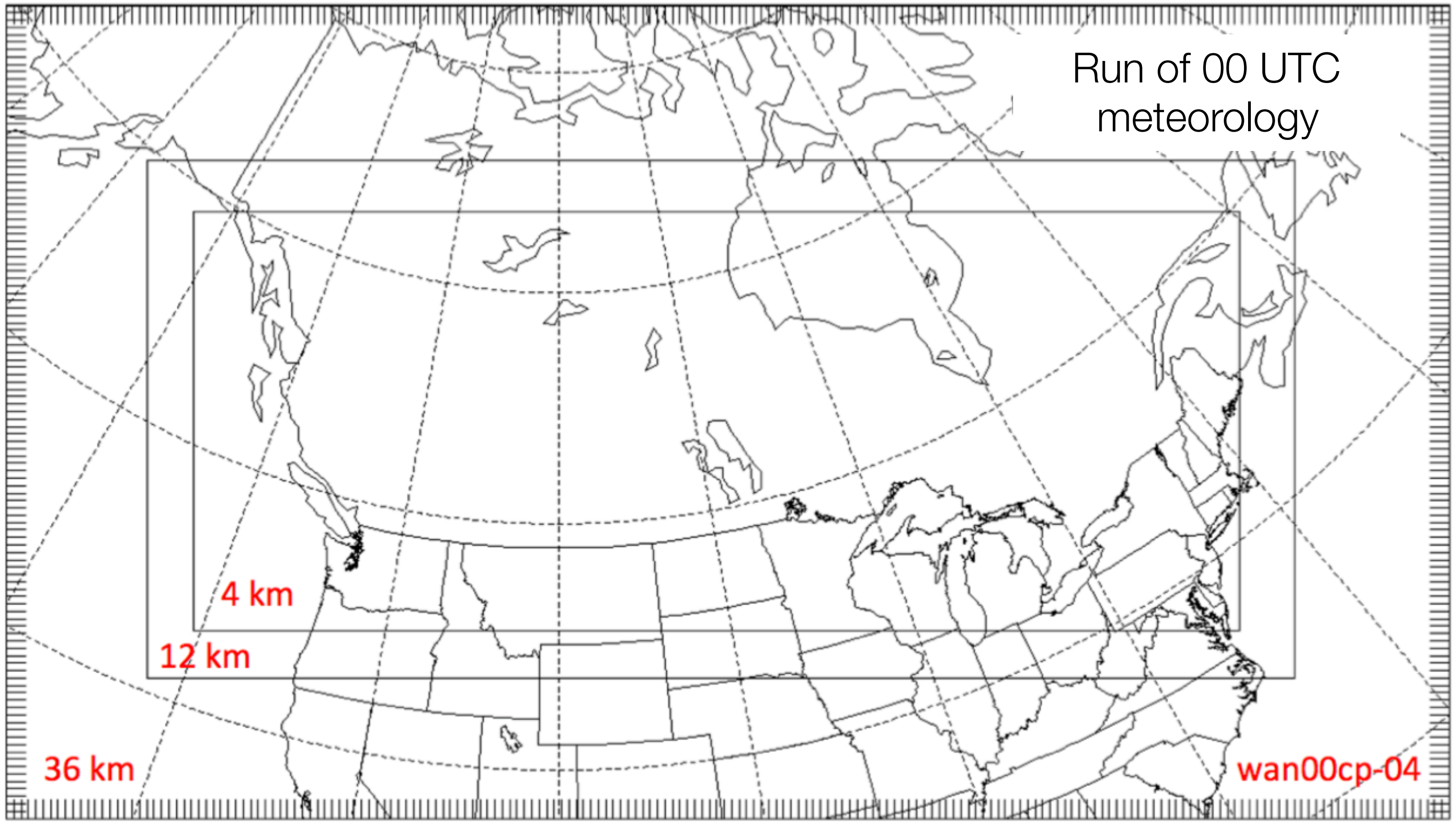
BlueSky-Canada

Operational BlueSky runs made by Roland Schigas at UBC

Sponsored by Provinces BC, AB, SK, ON, NT, and by NSERC & DND/CSSP.

Run 4 times per day at UBC. 1 April thru 31 October.

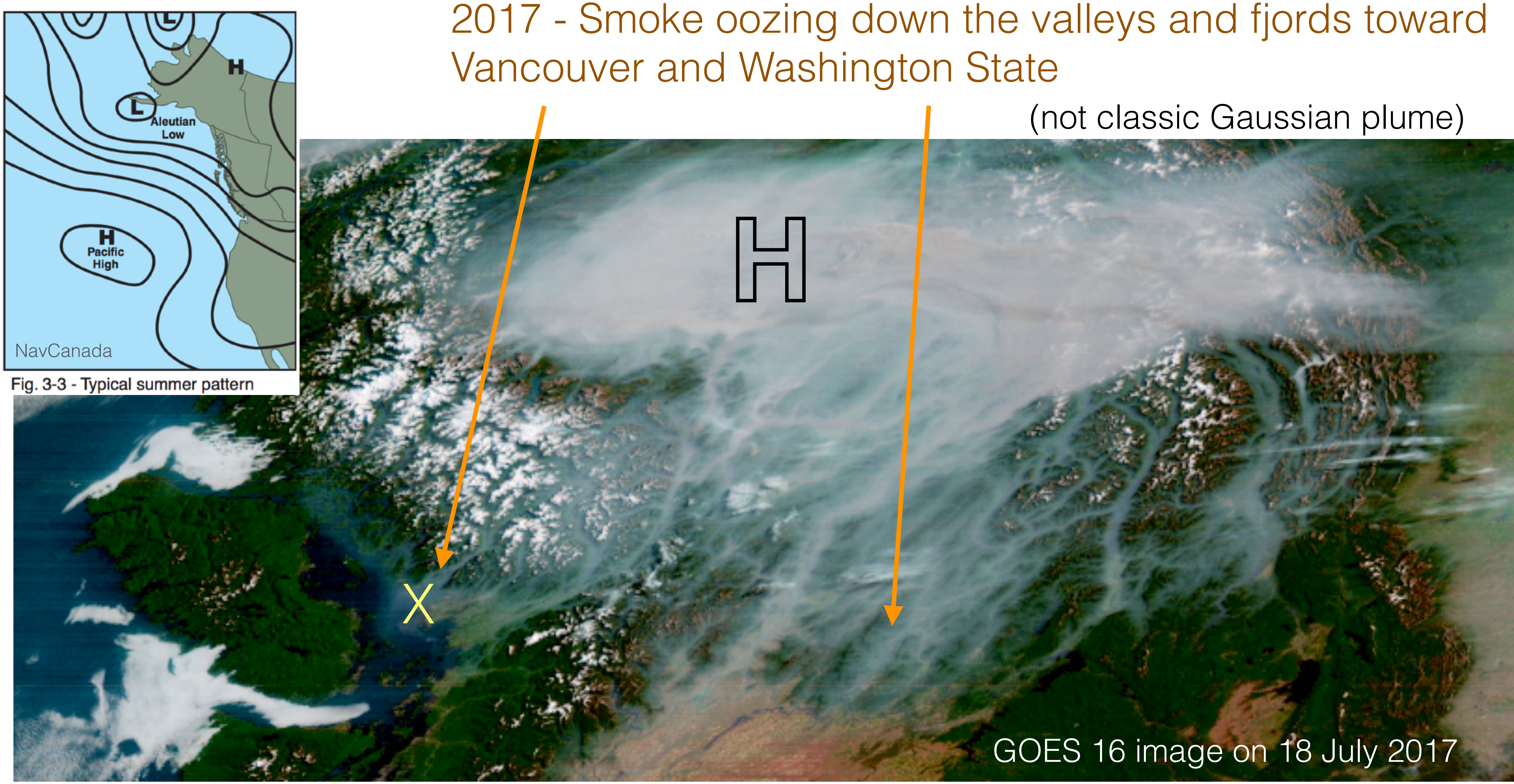
Based on WRF meteorology with NAM initial & lateral-boundary conditions.



Operational WRF runs made by Tim Chui at UBC

2017 - Smoke oozing down the valleys and fjords toward Vancouver and Washington State

(not classic Gaussian plume)



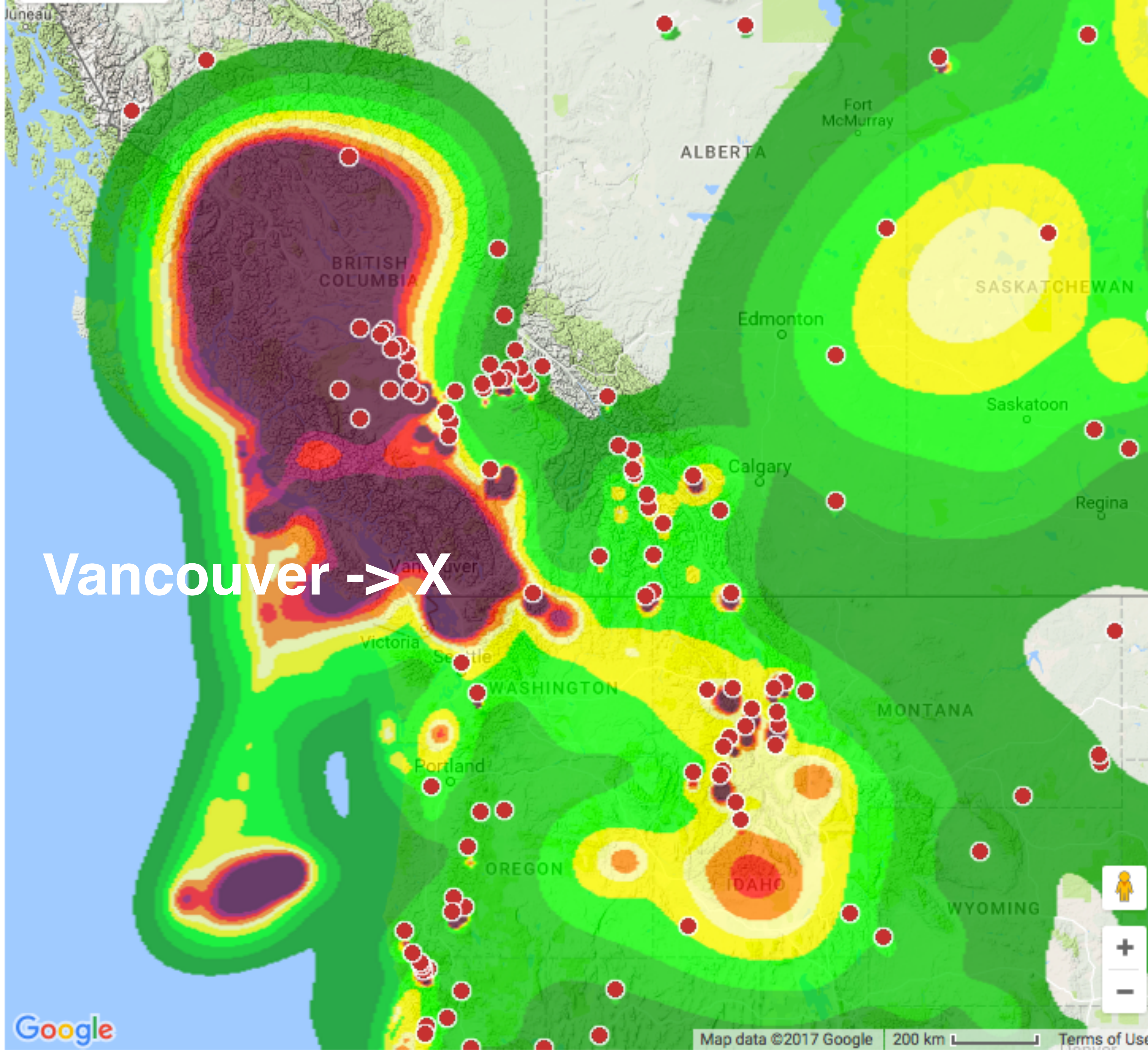
Whistler Ski Resort

BlueSky-Canada

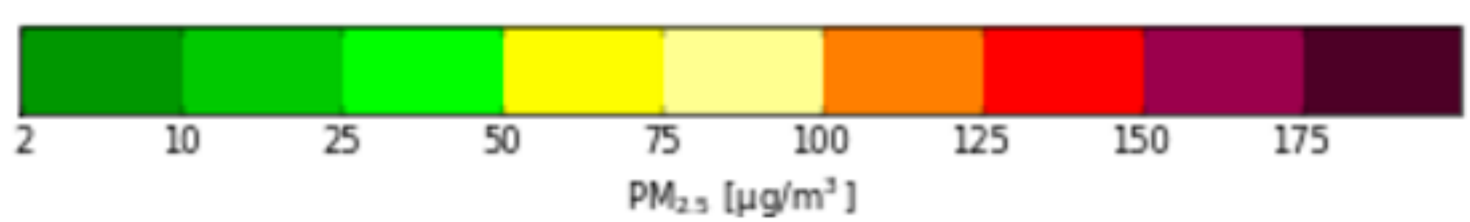
firesmoke.ca

Example of forecast
from summer 2017

- hotspots from satellite
- forest/fuel map
- flame energy & propagation
- smoke emissions
- plume rise <== our research
- meteorology
- dispersion (hysplit model)

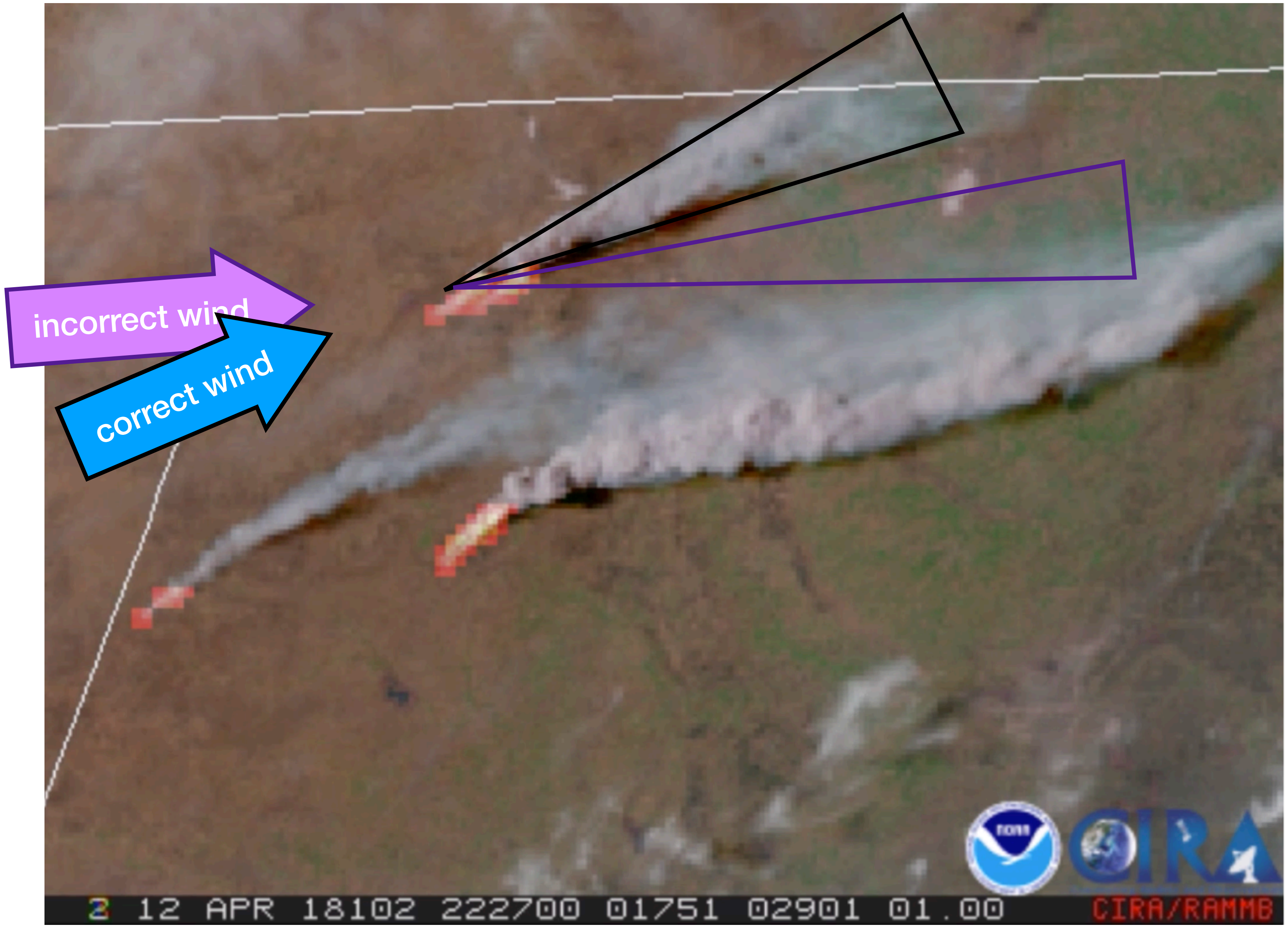


● = fire hotspot



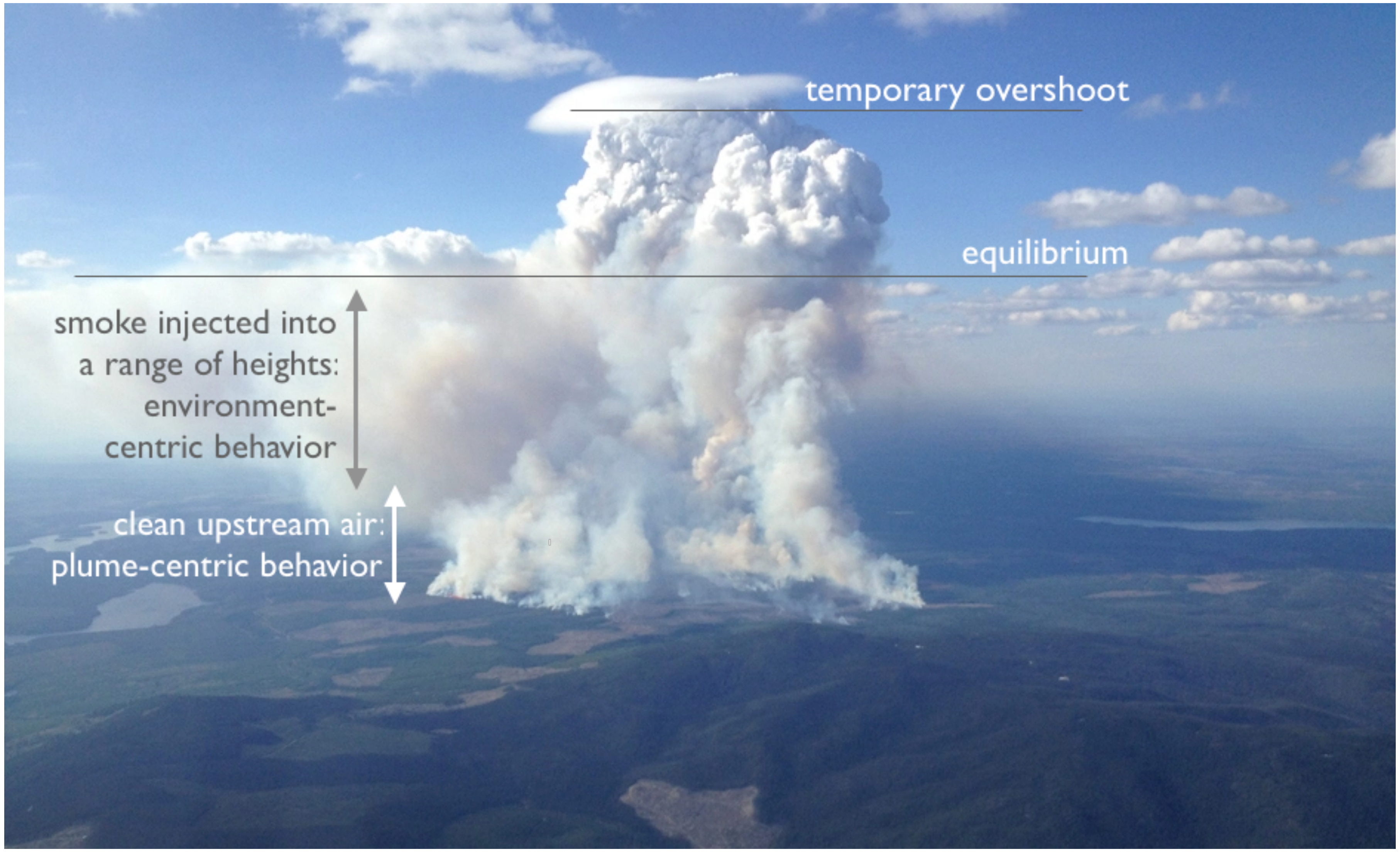
Motivation for Plume-Rise Studies

Smoke injected into the incorrect altitude experiences winds of incorrect directions & speeds, causing erroneous plume-forecast locations...



...resulting in smoke warnings and evacuations of the wrong communities.

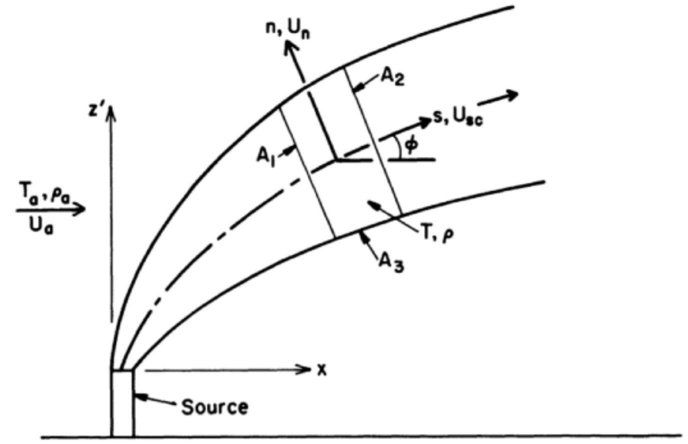
Focus: Distribution of PM2.5 injection below equilibrium height.



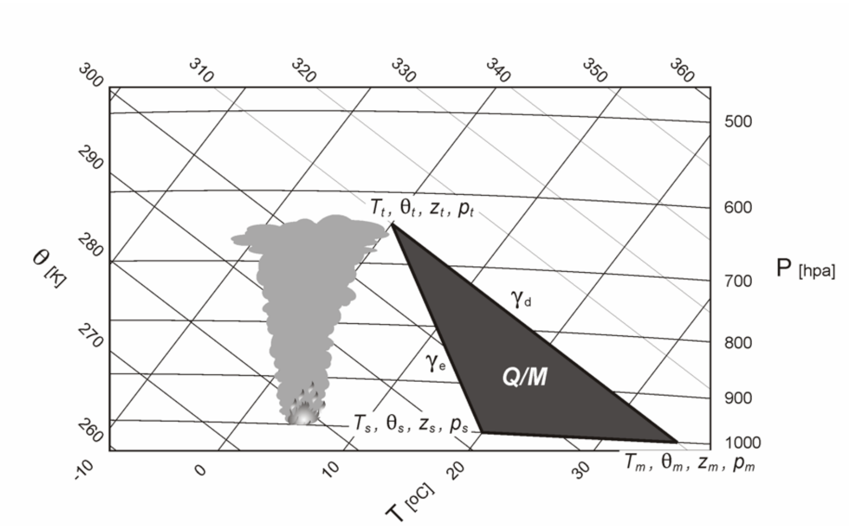
Goal: to devise an improved, simple, plume-rise approximation for BlueSky

Plume Rise Models

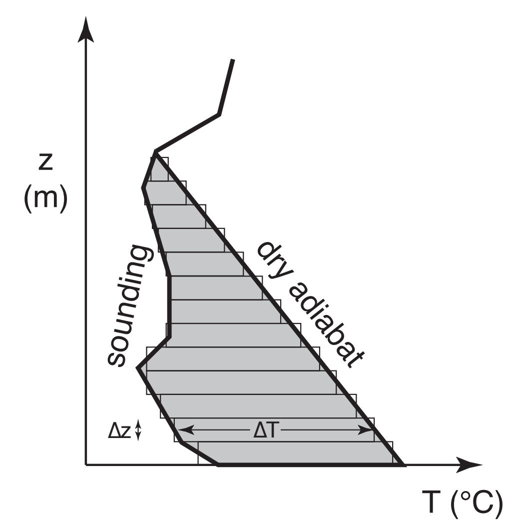
- BlueSky currently uses Gary Brigg's (1969 - 1975) eqs for smoke-stack plumes, as enhanced by Jeff Weil (1974-1988).



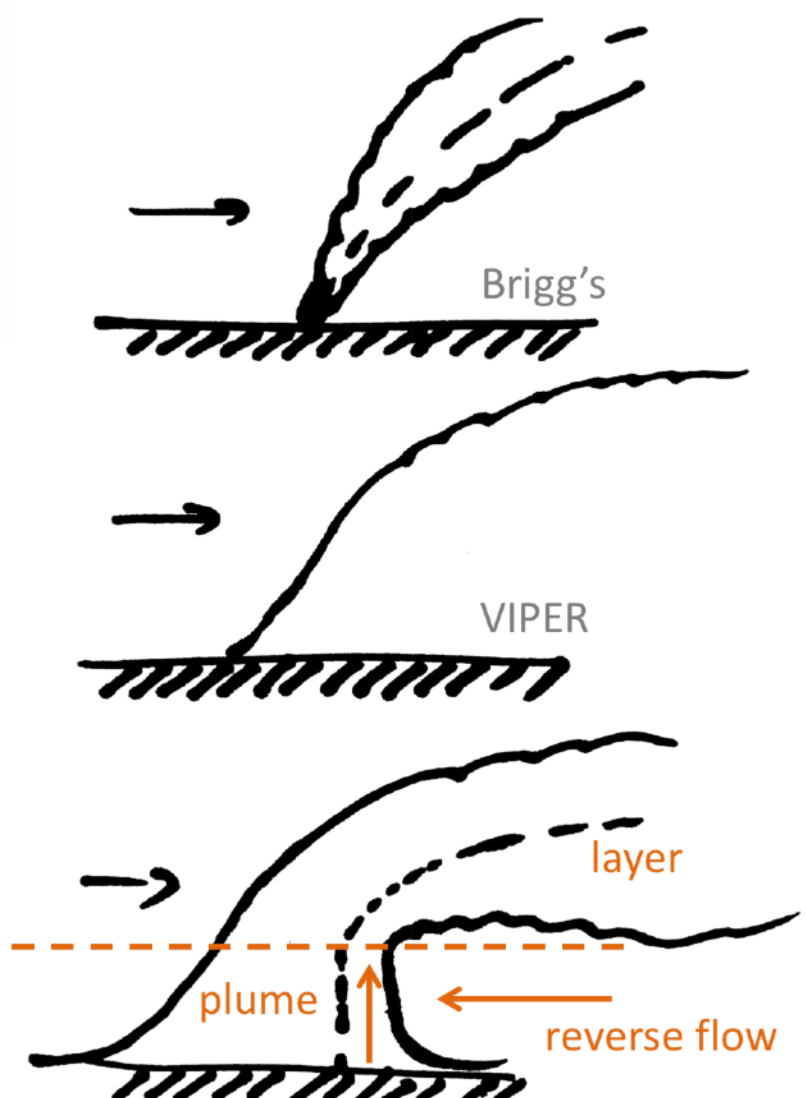
- Kerry Anderson, Al Pankratz & Curtis Mooney (2011-2014): Thermodynamic Approach, based on amount of heat that warms a conical volume.



- Roland Stull & Rosie Howard: Vertical Injection of Particulates Emitted from Wildfires (VIPER), based on rate of heat that creates a mixed layer.

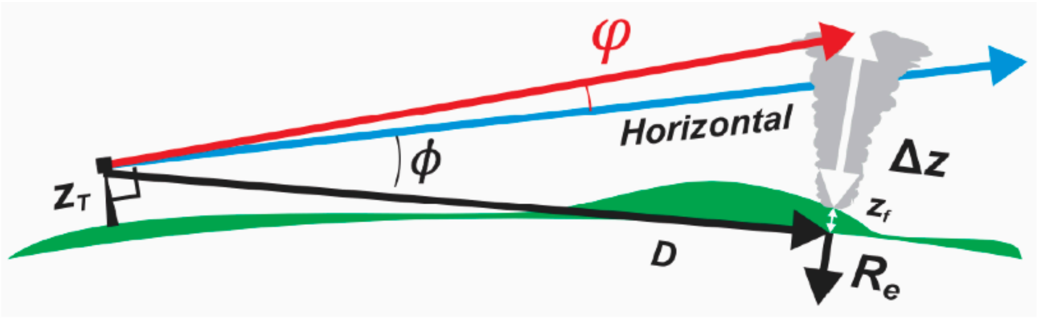


- UBC new research => Hybrid conceptual model

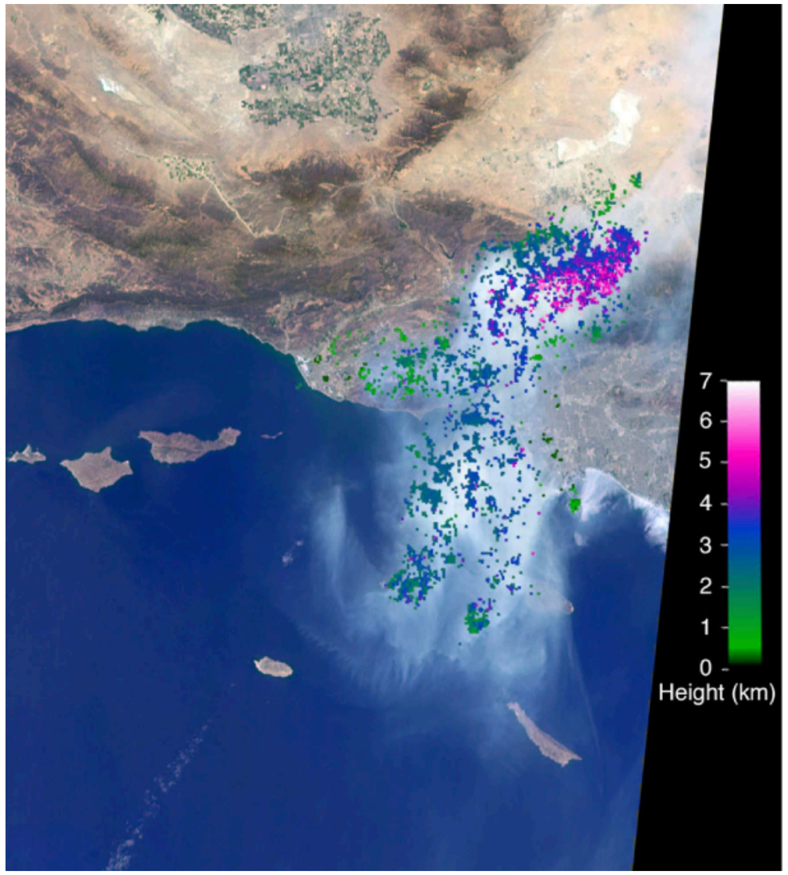


Plume Rise Observations

- Kerry Anderson, Al Pankratz, Curtis Mooney & Kelly Fleetham, 2018: "The Alberta smoke plume observation study". Based on inclinometer obs from fire towers.



- Multi-angle Imaging SpectroRadiometer (MISR): Satellite aerosols. Stereoscopic analysis of multiple camera angles is used to estimate the height of the smoke plume.

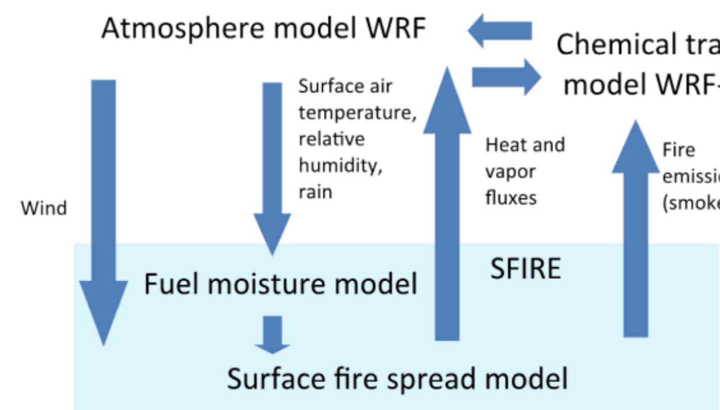


- But the resulting plume heights were unreliable. Try LES instead, to get surrogate "data" to test plume-rise-models.

Large-Eddy Simulation (LES) Models

DALES = Dutch Atmospheric LES

WRF-SFIRE = coupled Weather Research & Forecast and FIRE-spread

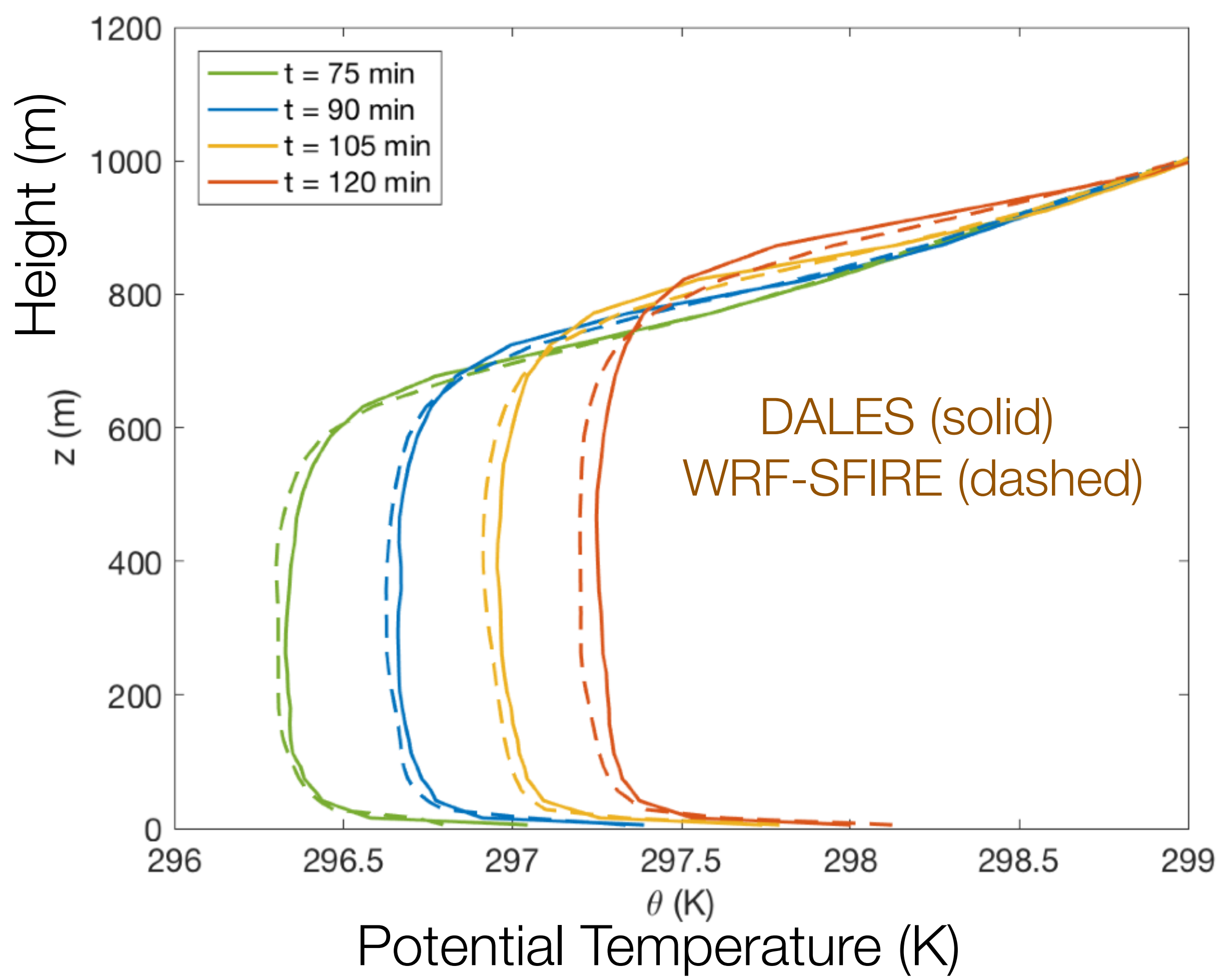


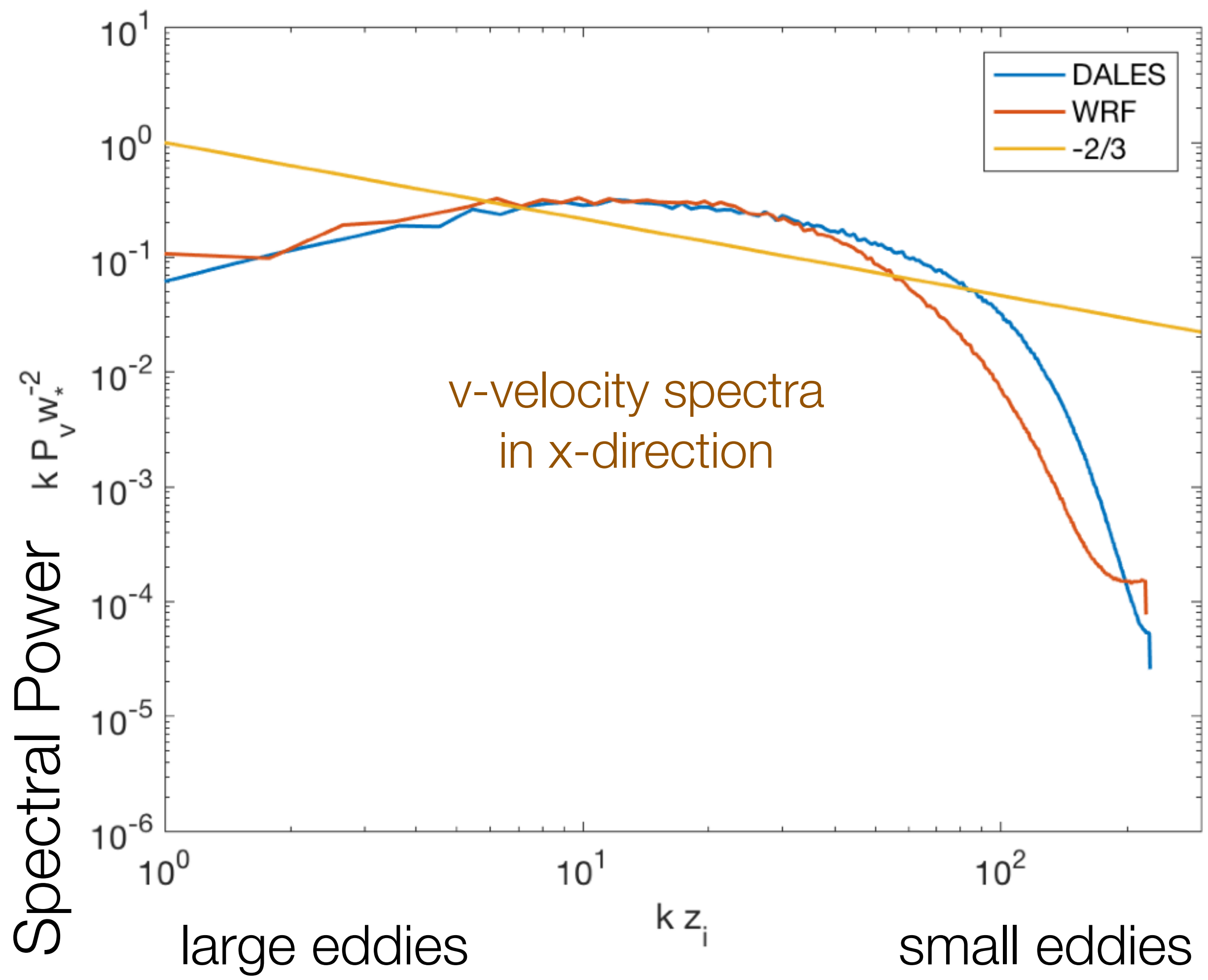
Mandel et al, 2014: Nat. Hazards Earth Syst. Sci., 14, 2829–2845, 2014 www.nat-hazards-earth-syst-sci.net/14/2829/2014/ doi:10.5194/nhess-14-2829-2014

DALES	WRF-SFIRE
Non-hydrostatic	Non-hydrostatic
Boussinesq approximation	Fully compressible
FFT Pressure solver	Prognostic P eq.
Imposed net zero vertical velocity	
Cartesian height levels	Pressure eta levels
Subgrid Turb.: K theory based on TKE	Subgrid Turb: 3-D 1.5 order TKE closure
Handles multiple tracers	Moisture is surrogate for smoke emissions
Flat or simple sloped terrain only	Complex terrain
Δx = 10 m	Δx = 40 m for WRF, with 4 m for SFIRE
55 layers in vertical, up to 2.8 km	50 layers in vertical, up to 2.5 km
Cyclic lateral boundary conditions	Cyclic lateral boundary conditions
Fireline approximated by enhanced surface heat flux	Models fire spread & heat & H_2O
Infinitely long fireline	Finite length fireline

Model Comparison of PBL Evolution

LES spin-up comparison by Frans Liqui Lung at UBC & Delft

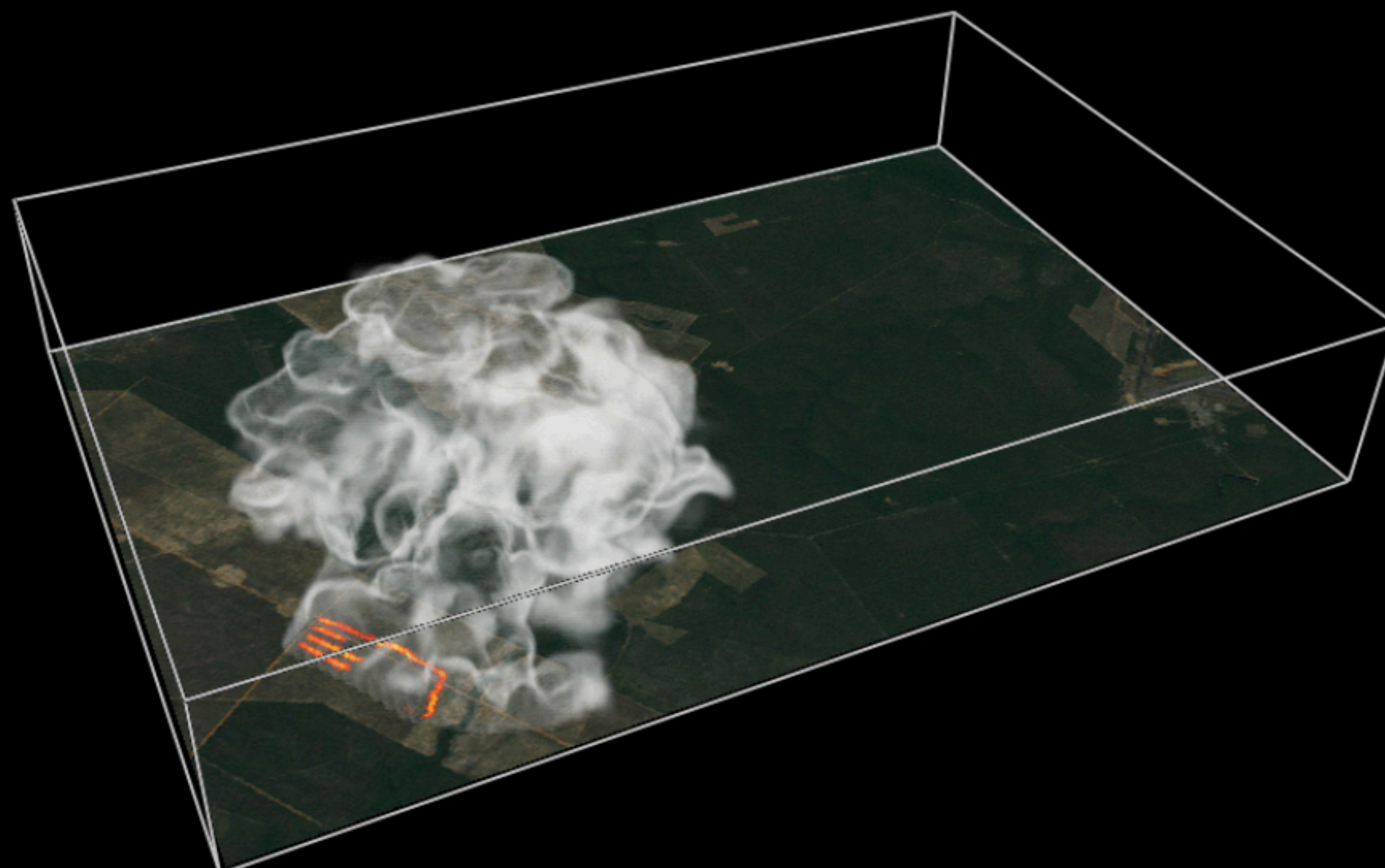




Large-Eddy Simulation (WRF-SFIRE): first experiments

- research by Nadya Moisseeva at UBC.

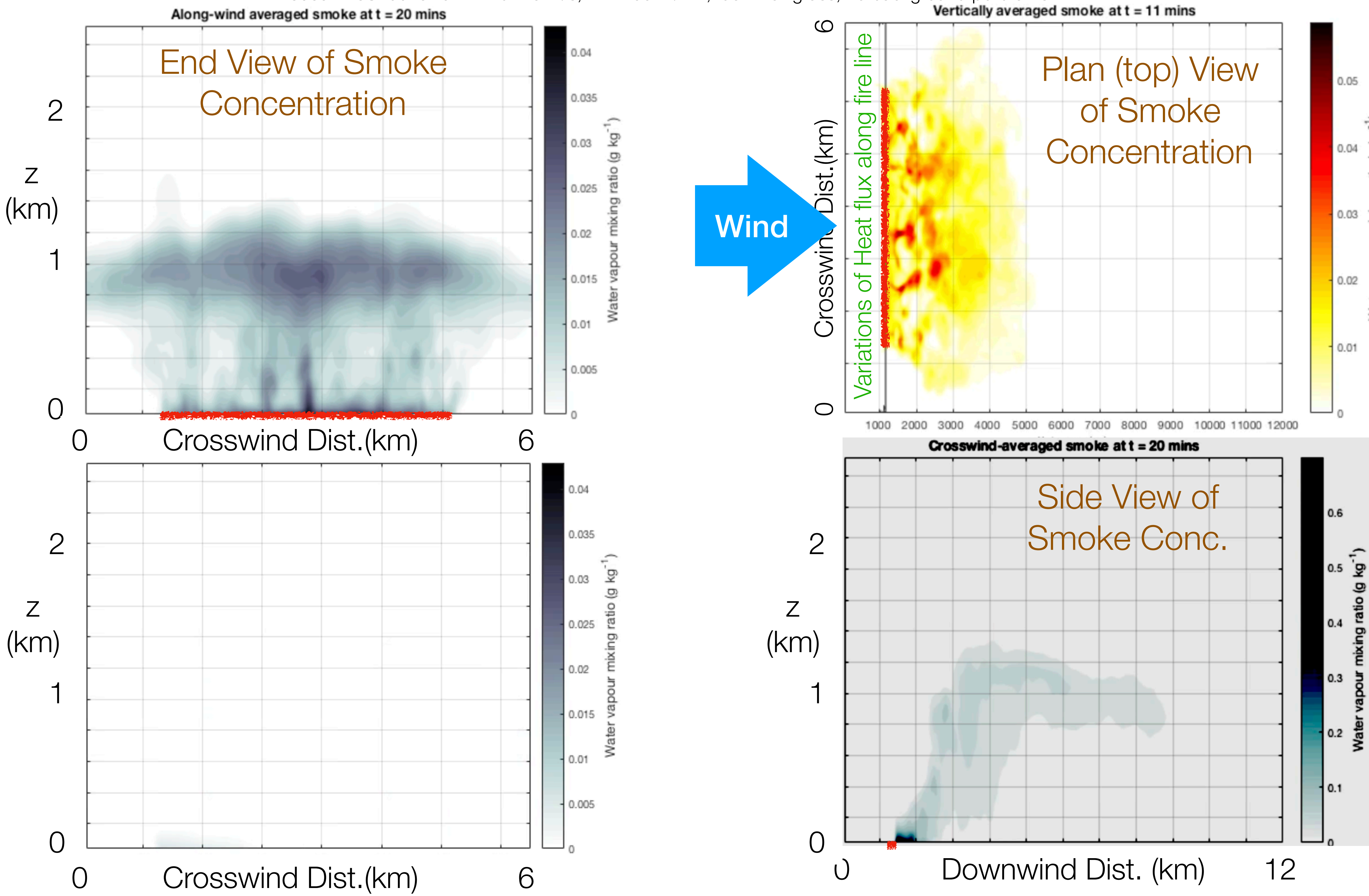
- Simulating the prescribed burn: RxCADRE 2012 (Nov 10, 2012 – Elgin Air Force Base, Florida) two large lots (shrub/forest). Surface/air measurements of emissions, including H2O vapor



WFR-SFIRE

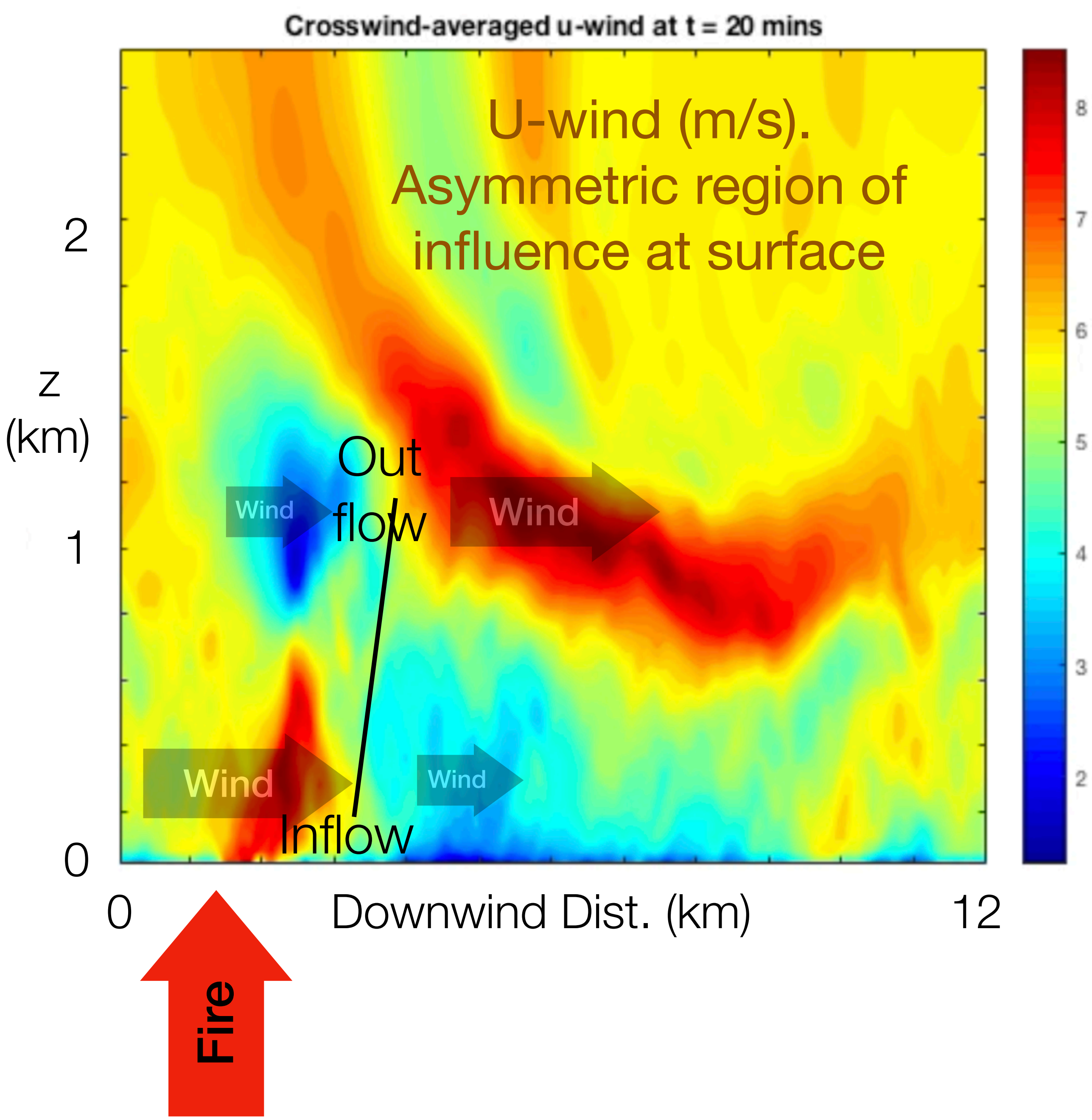
Convective-Structures.   LES runs by Nadya Moisseeva. Analysis by Rosie Howard at UBC

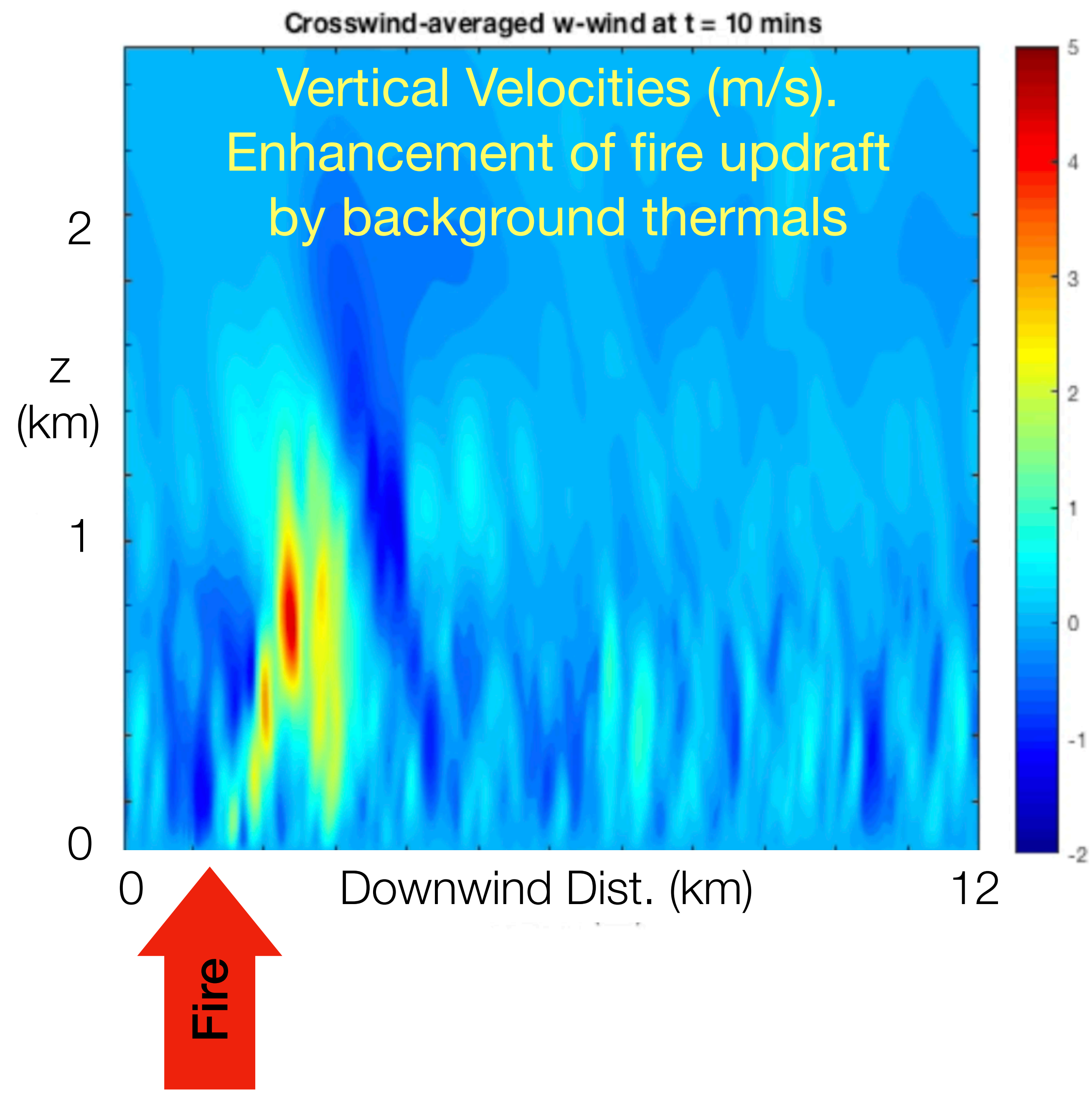
Case: W6S400F3R0 = wind = 6 m/s, H = 400 W/m2, fuel = tall grass, no background pollutants



WRF-SFIRE

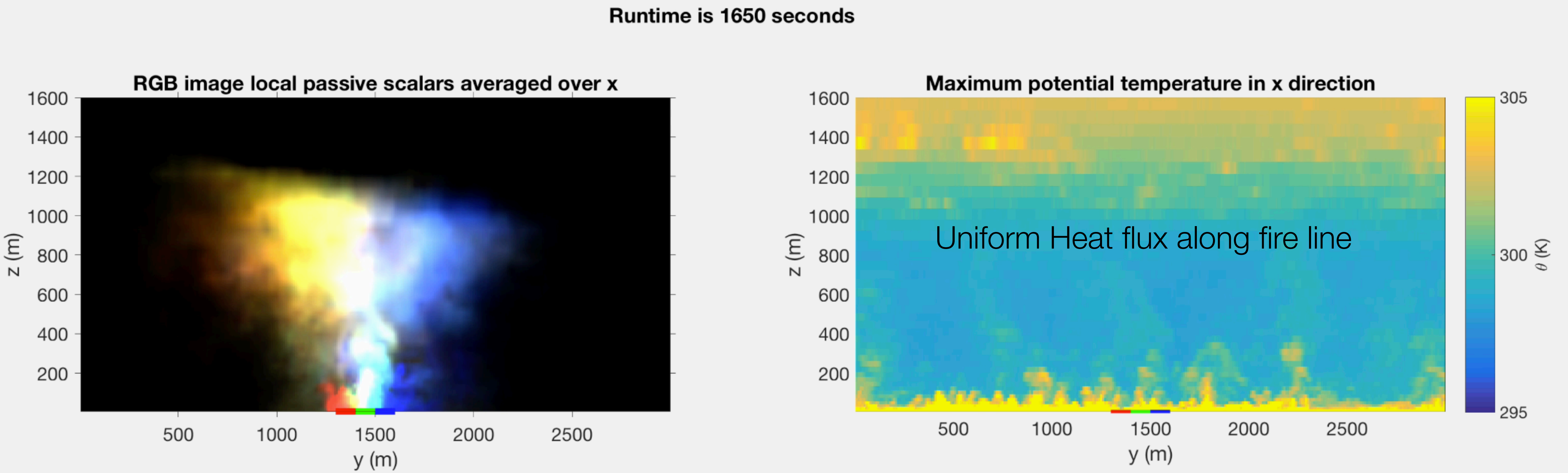
Convective-Structures. LES runs by Nadya Moisseeva. Analysis by Rosie Howard at UBC



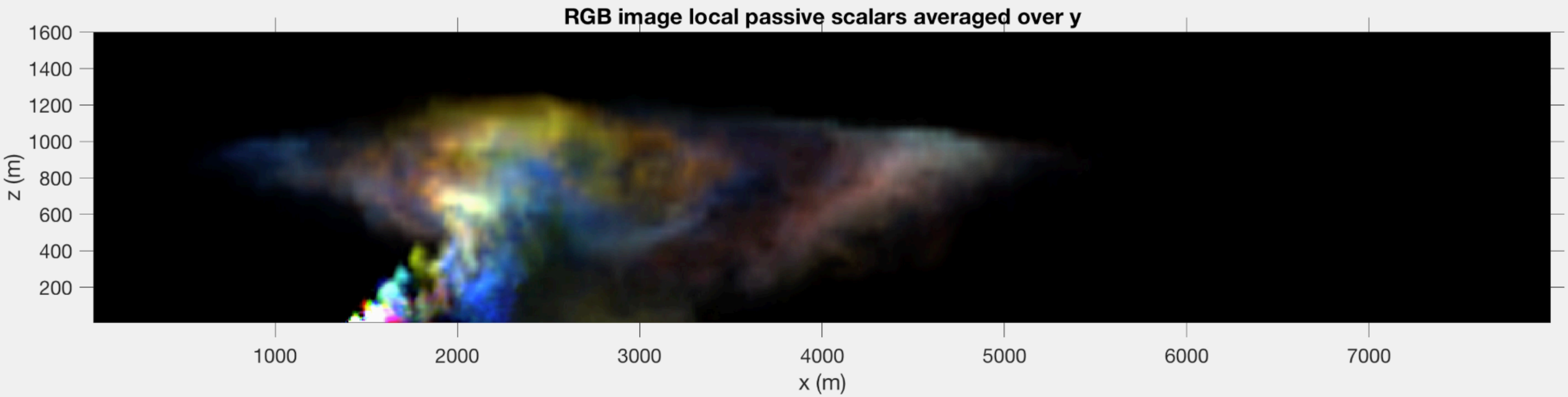


DALES

Convective-Structures. Analysis by Frans Liqui Lung at UBC & Delft

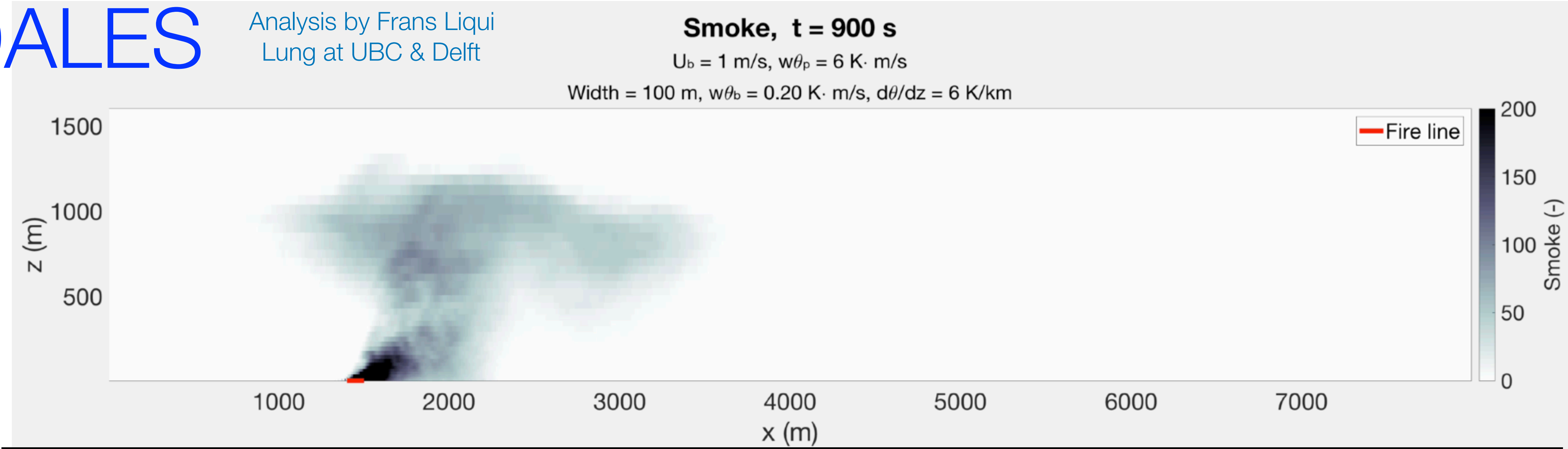


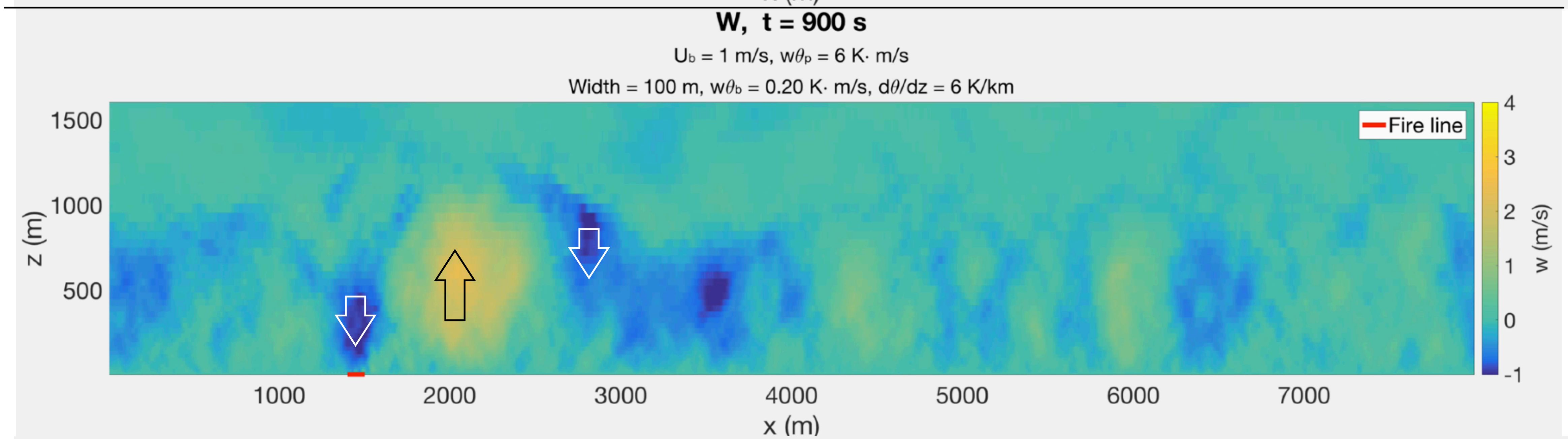
Absolute Concentrations. But emitted from very small portion of fire line.

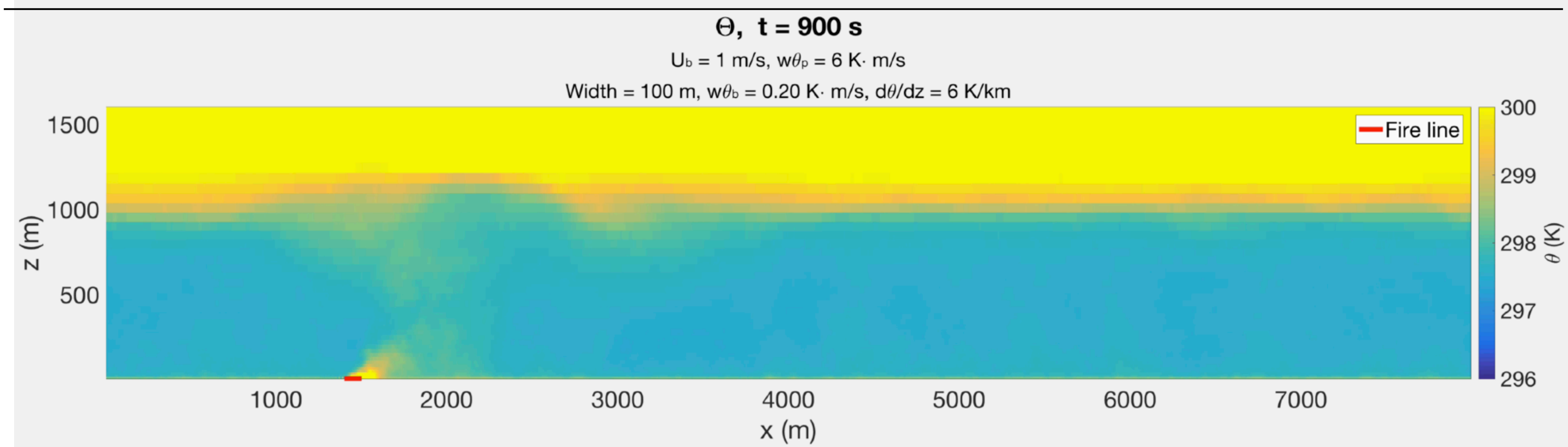


DALES

Analysis by Frans Liqui Lung at UBC & Delft

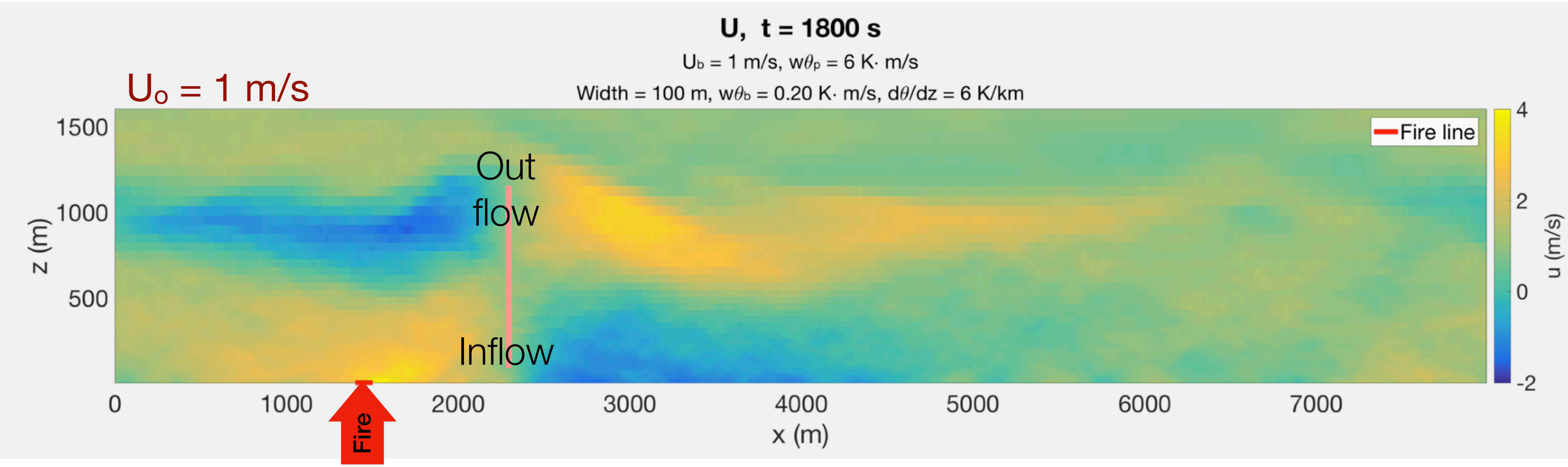


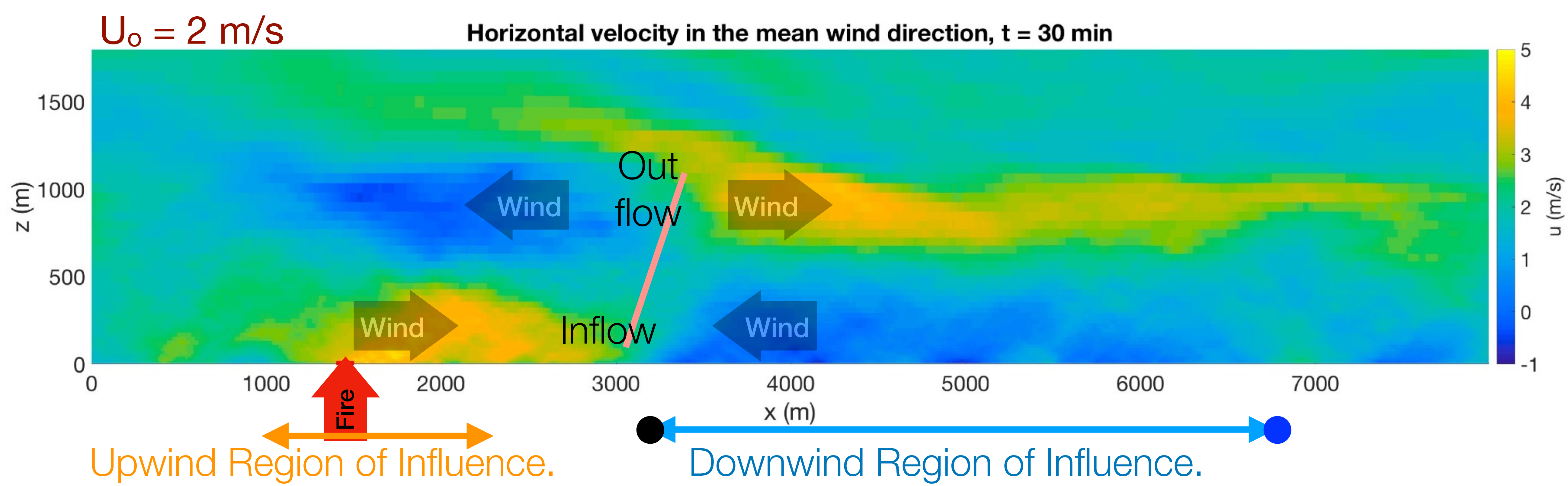




DALES

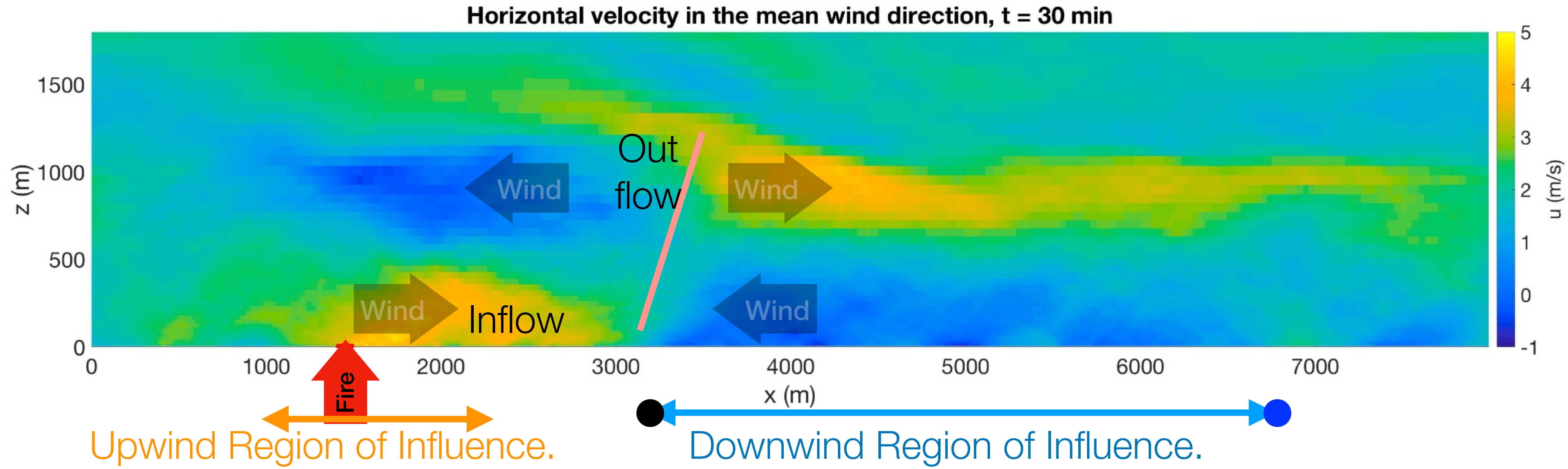
Region of Influence. Analysis by Frans Liqui Lung at UBC & Delft

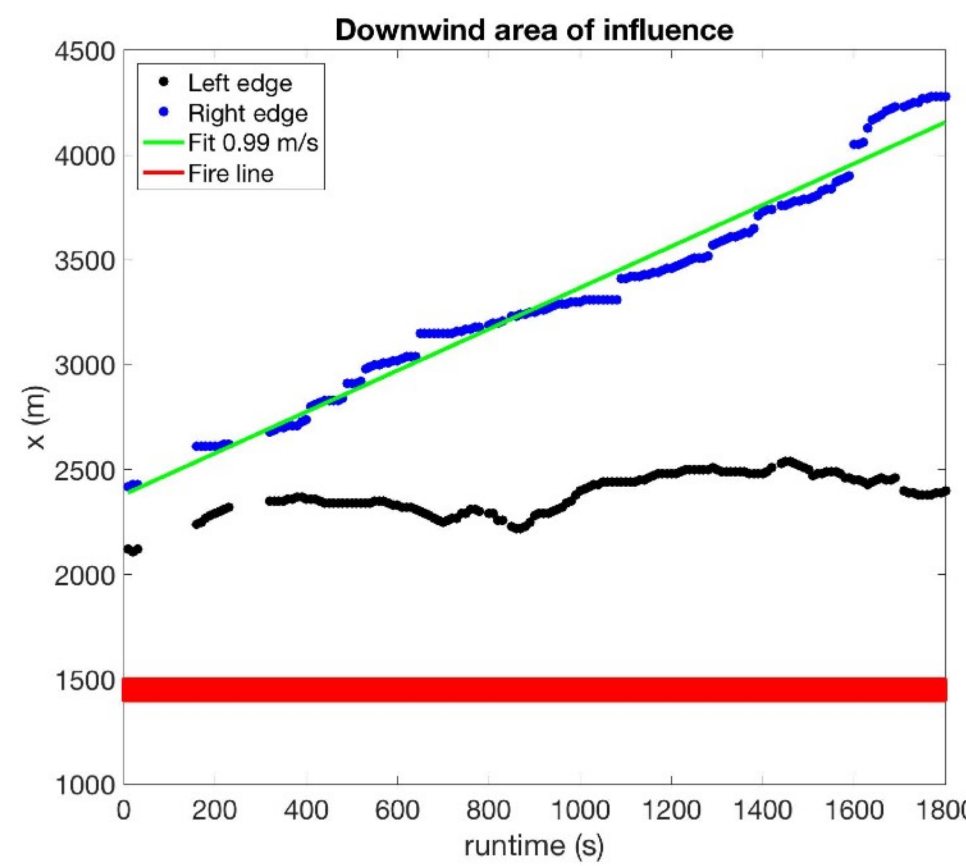




DALES

Region of Influence. Analysis by Frans Liqui Lung at UBC & Delft

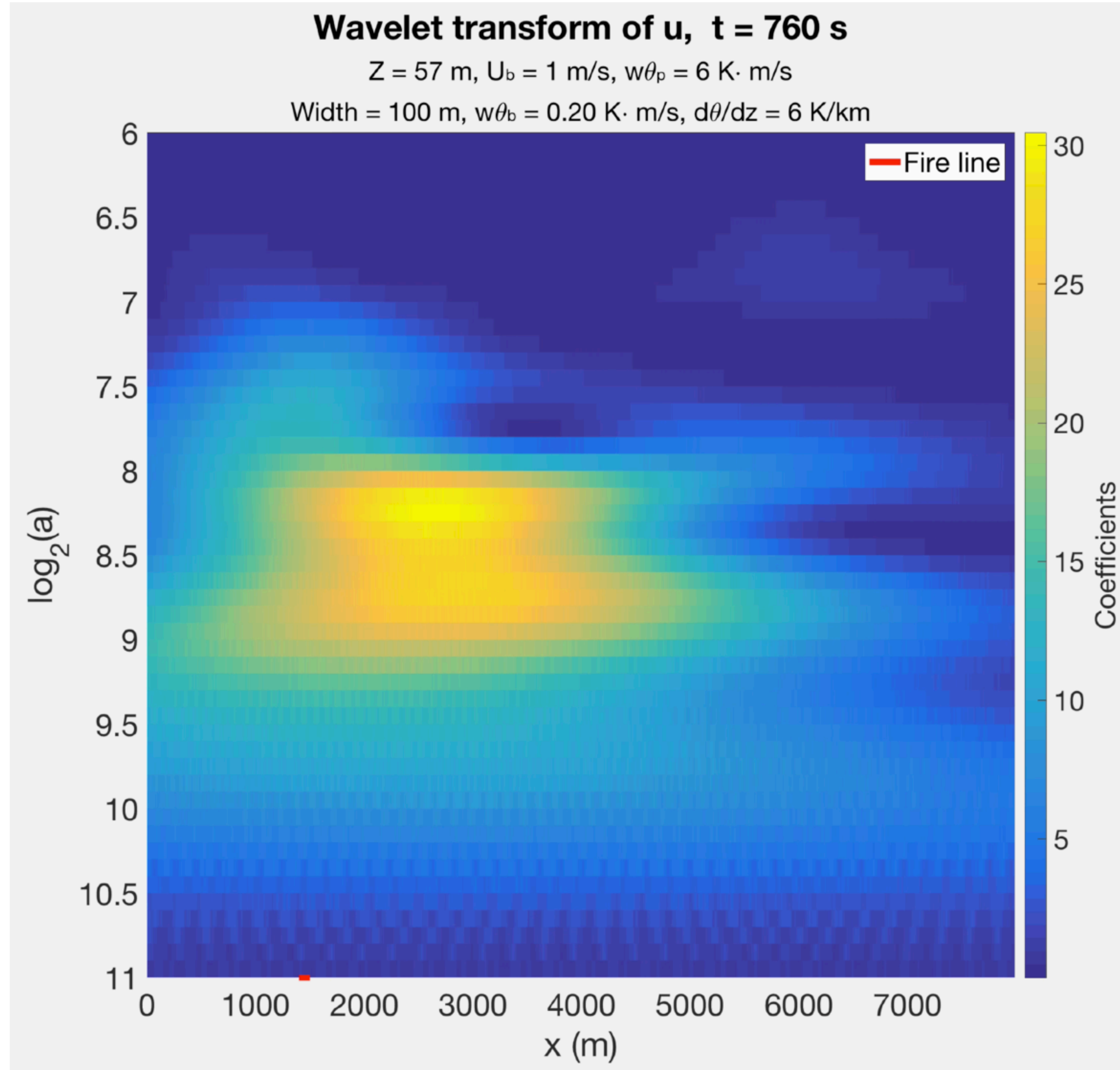




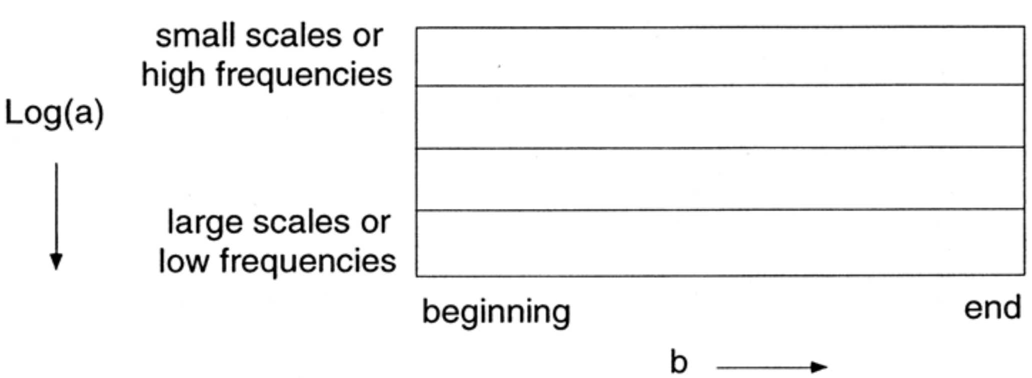
Mean wind is 2 m/s, heat flux plume is 8 K m/s, heat flux environment is 0.2 K m/s. Width fire line is 100 meters.

DALES

Wavelet Analysis by
Frans Liqui Lung at
UBC & Delft



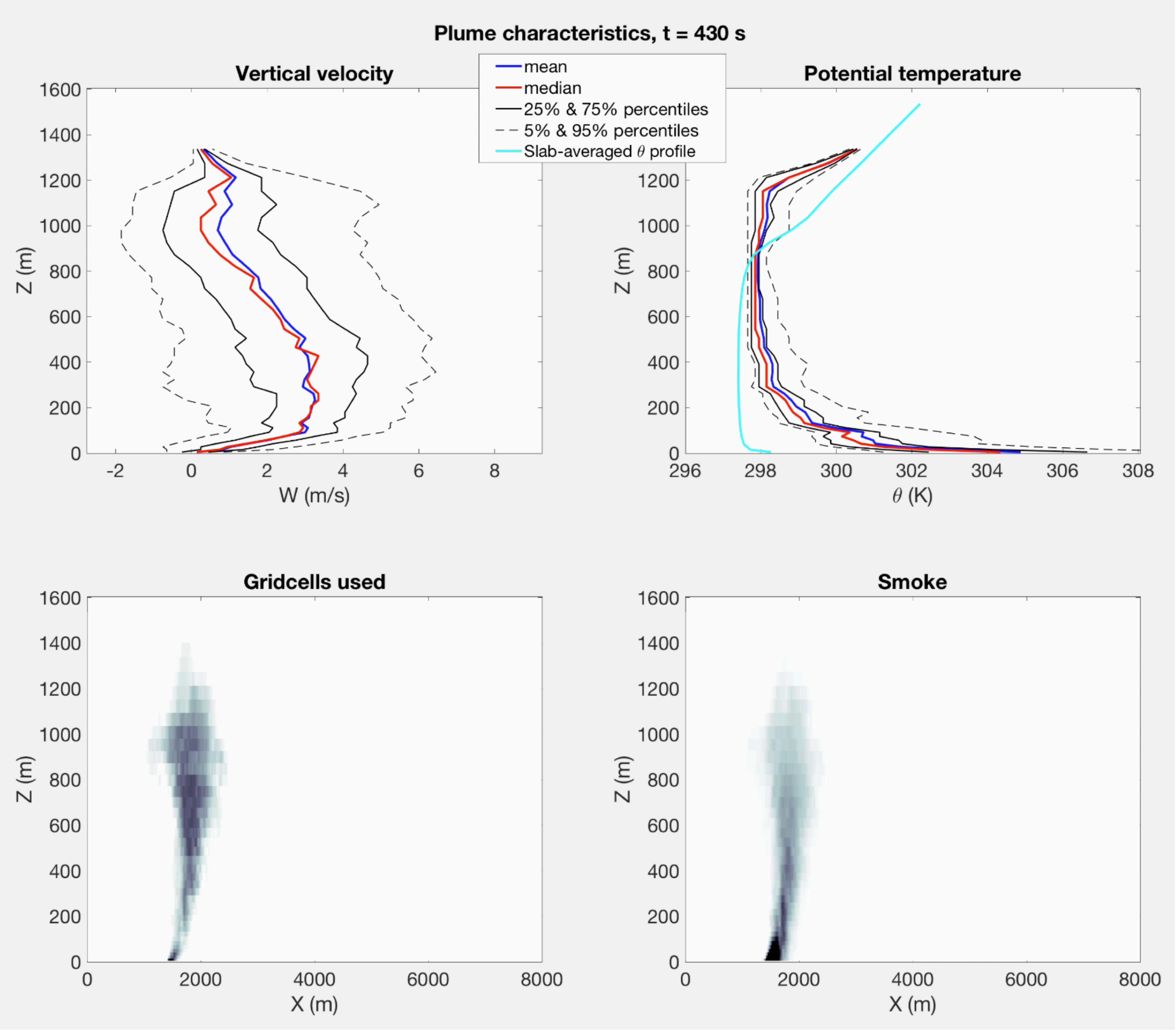
How to interpret a Wavelet Scalogram



DALES

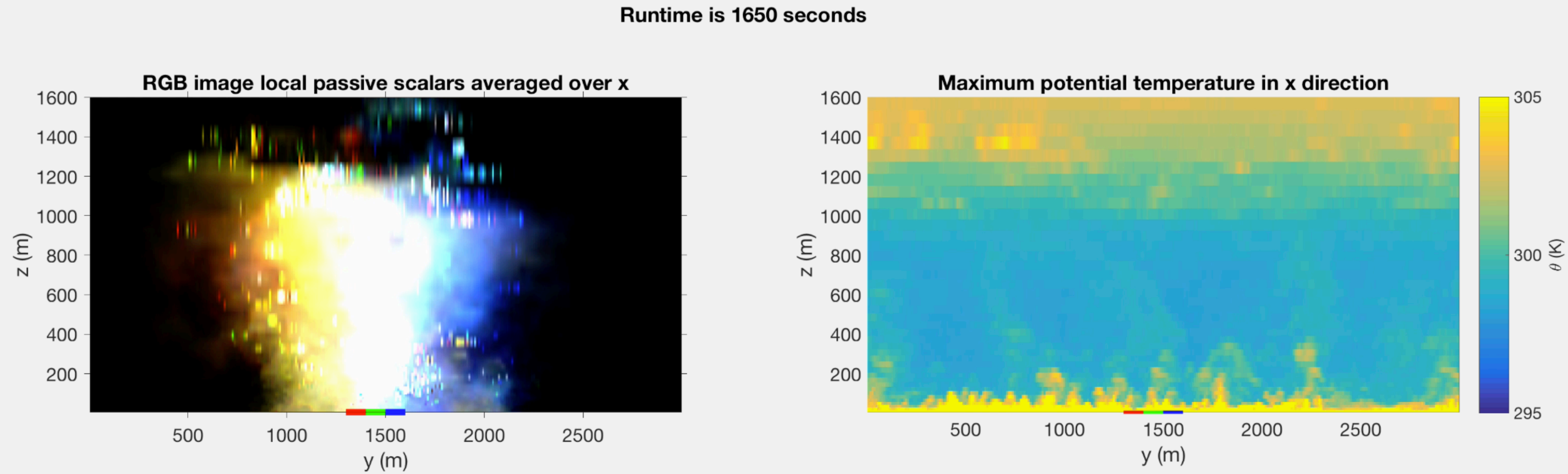
Wavelet Analysis by Frans Liqui Lung at UBC & Delft

Conditional Sampling: For the subset of pixels in the smoke plume, what is the distribution of vertical velocities (W) and potential temperature (theta)?

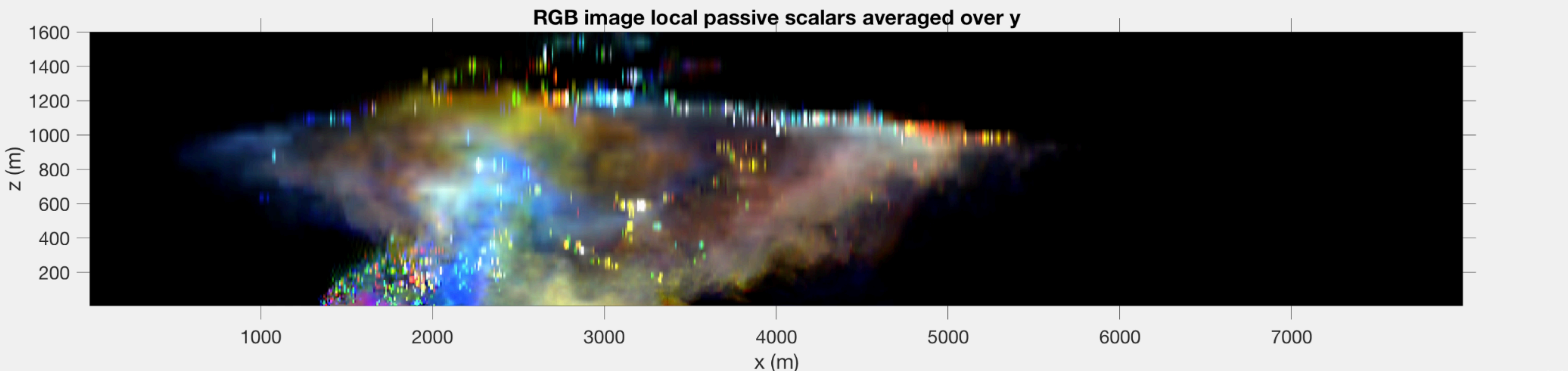


DALES

Convective-Structures. Analysis by Frans Liqui Lung at UBC & Delft



Relative (percentage) Concentration. Reveals backflow toward fireline at surface



2017 Fire season in British Columbia

Image courtesy of BC Wildfire Service. https://www.facebook.com/BCForestFireInfo/videos/10155384746680673/

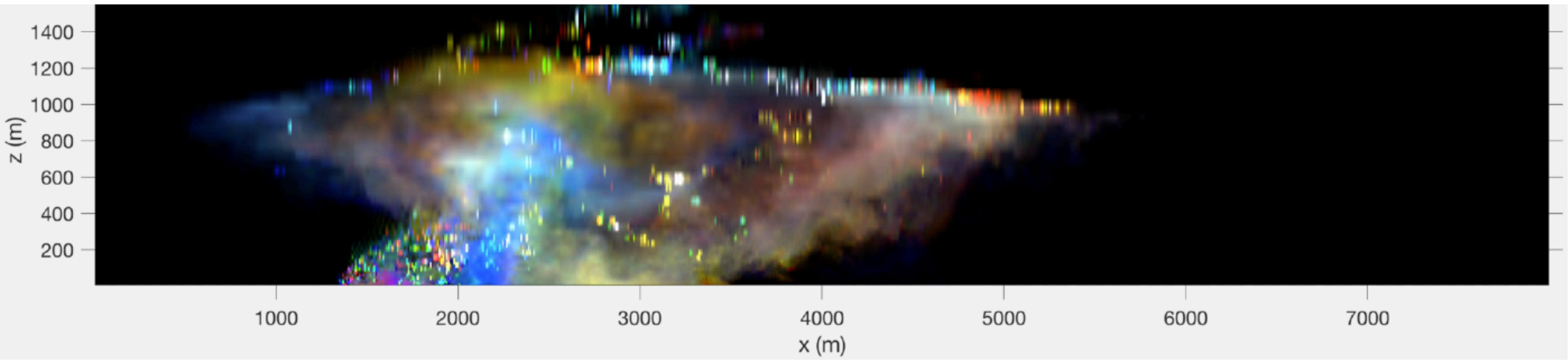
Bishop Bluffs fire in central BC - 13 Aug 2017

Over 65 provincial parks closed.

Dozens of highways closed. Dozens of towns evacuated.

Geophysical Disaster Computational Fluid Dynamics Center

• University of British Columbia – Vancouver • Dept. of Earth, Ocean & Atmospheric Sciences • Weather Forecast Research Team • Directed by Prof. Roland Stull •



Topics:
1. BlueSky
2. Smoke Plume Rise
3. WRF-SFIRE
4. DALES
5. Plume Variations
6. Wind Modification Region of Influence

Plume Rise from Wildfires:

BlueSky & Large Eddy Simulations

Nadya Moisseeva	nmoisseeva@eoas.ubc.ca
Rosie Howard	rhoward@eoas.ubc.ca
Frans Liqui Lung	flung@eoas.ubc.ca
Tim Chui	tchui@eoas.ubc.ca
Roland Schigas	rschigas@eoas.ubc.ca
Roland Stull	rstull@eoas.ubc.ca

Dept. of Earth, Ocean & Atmos. Sci.
University of British Columbia (UBC)
2020-2207 Main Mall
Vancouver,BC, V6T 1Z4, Canada

Conclusions:

1. Fire line "feels" winds faster than ambient.
2. Fire updraft is significant dist. downwind of fire.
3. Smoke plume diameters scale to fire-line width.
4. Variability in smoke injection heights depend both on variation of heat sources and natural variability in air.
5. Downwind region of influence on winds grows larger with time, while upwind becomes const.
6. Smoke sucked down downwind of main updraft

Presentation for AB, June 2018

Thanks to our sponsors: BC, AB, SK, ON, NT, and by NSERC & DND/CSSP.