Ceilometers for smoke Forecasting and Nowcasting: Early Plans

Ceilometer backscatter profile for CWSK between 2021-08-01 23:54:10 and 2021-08-02 23:54:05
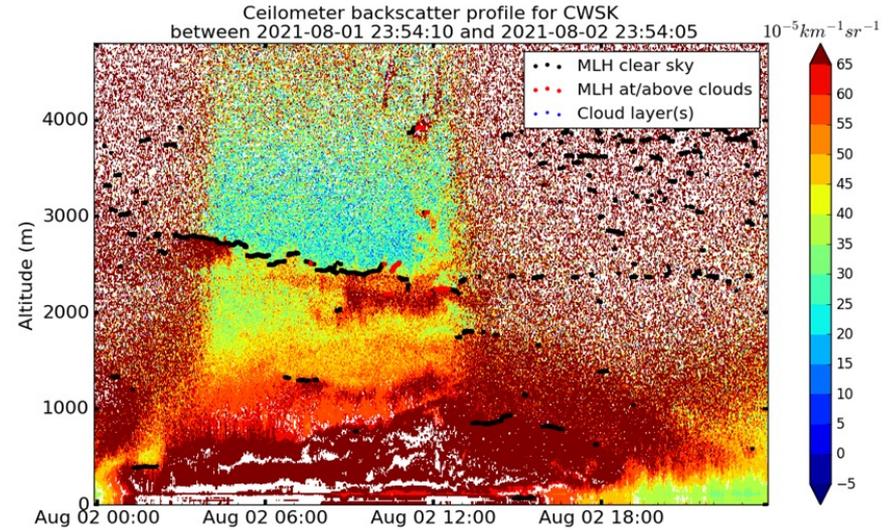
Bruce Ainslie
Shannon Hicks-Jalali
Dan McLennan
Corinne Schiller
Keith Jones
June 21, 2023
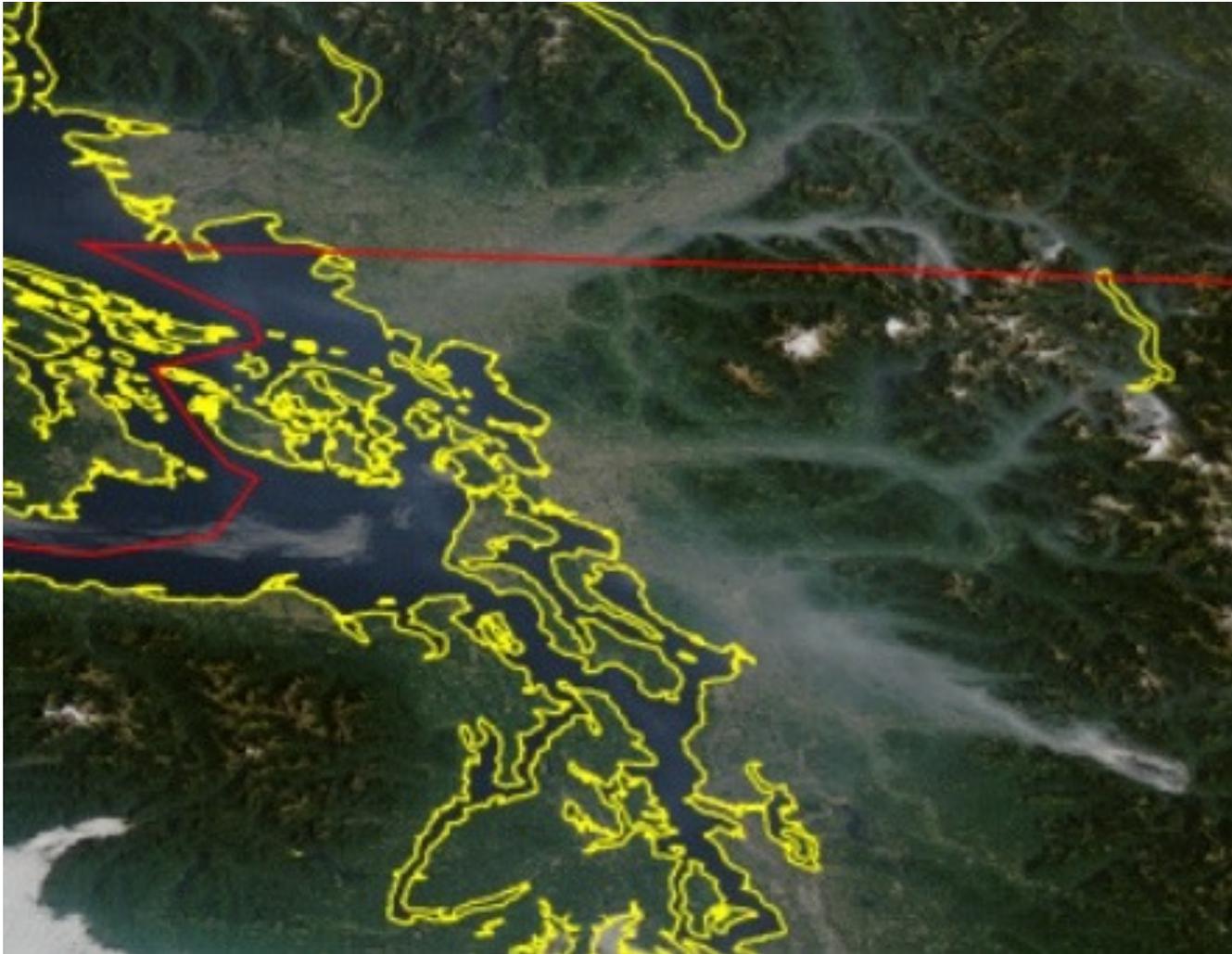
Canada

Meteorological Services of Canada

- Applied Science to improve Prediction and Services – Air Quality
  - Model improvements
    - Data ingestion, objective analysis…
  - Model validation
  - Tools to improve Nowcasting
  - Tools to improve Situational Awareness

Gaps Identified by Prediction and Services Meteorologists

- Surface Observations
  - Need more surface observations to validate model and for situational awareness
  - Developed a PurpleAir Pilot Program which included real time mapping tools and automated reporting.
- Upper Air Observations
  - Need to know where the smoke is to determine when it will reach the surface
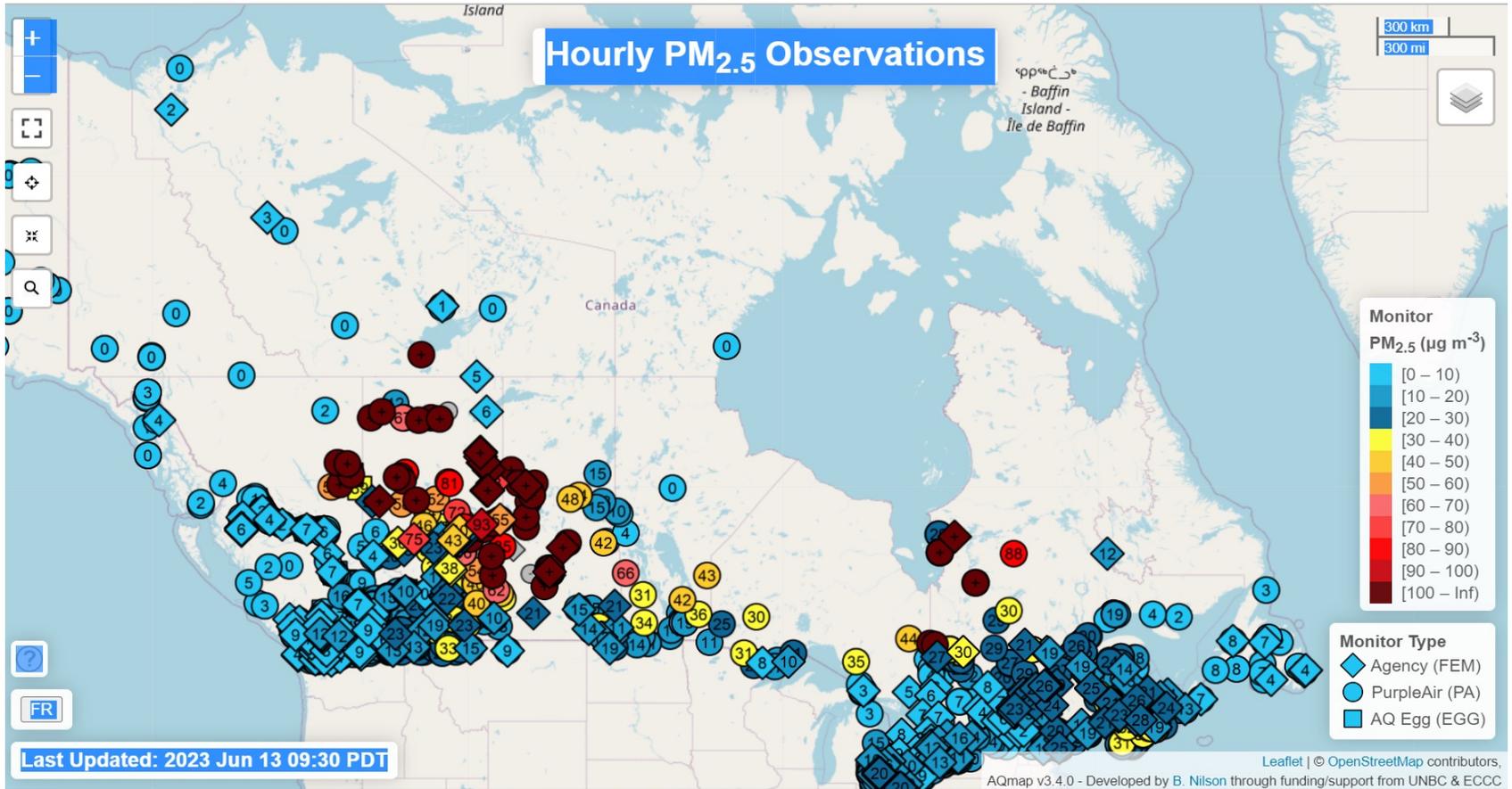
Smoke on the ground

PSOW has been asked to help with the **forecast** of wildfire smoke …

Forecasters need to know what smoke is on the ground and when the smoke aloft will reach the ground

ECCC/UNBC Map of small PM2.5 sensor network

https://cyclone.unbc.ca/aqmap/#6/53.586/-116.268

Question:
Given the existing and extensive network of ceilometers at Canadian airports – can we use them to help smoke forecasting?

Map of METAR stations over western Canada

Using Ceilometers to aid in smoke forecasting

Some project ideas:

1. NRT evaluation of FireWork guidance

2. Estimating when smoke aloft will reach the ground

3. Forecast AOD maps and Visibility

4. ???

Collaborators

- Zen Mariani – Research Scientist
  - ECCC – STB

- Robert Sica – Professor Western University
  - Victoria Pennegar – Graduate Student
    - Hiring as an FSWEP student to do preliminary Analysis
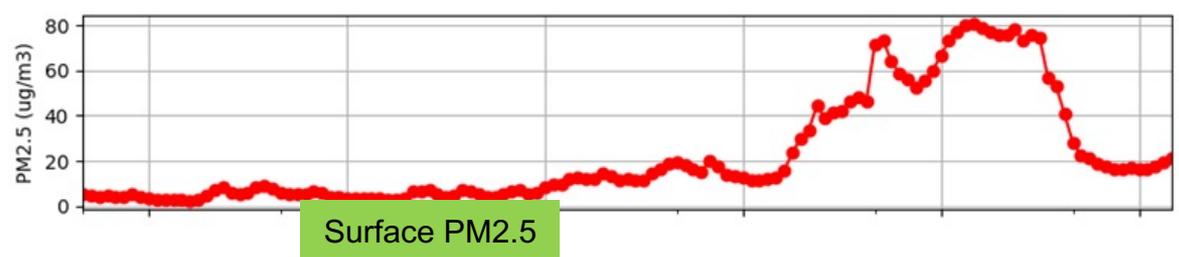
1. Near real time evaluation of FW guidance
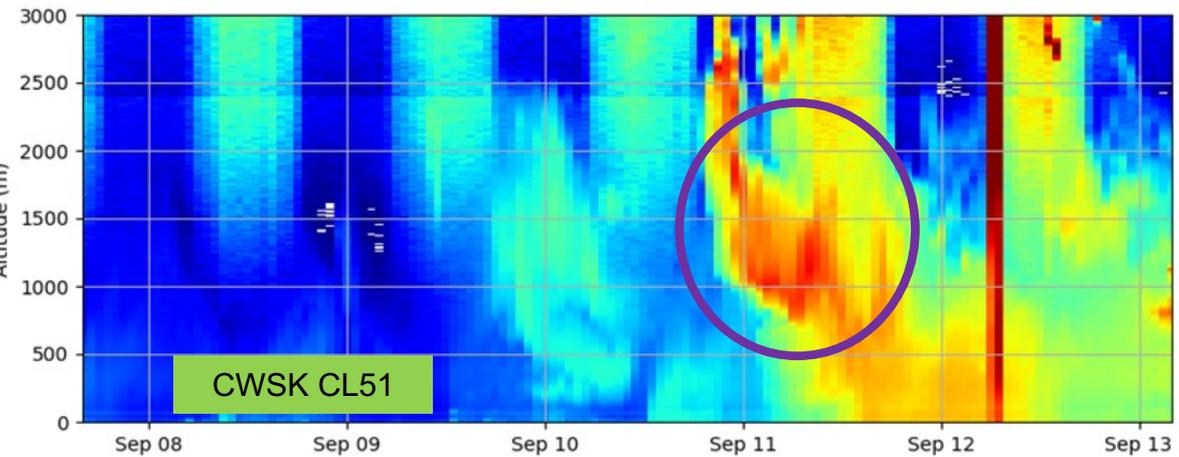
Proof of concept case:
Squamish BC
Sept 11-14 2022

WSK

Sept 10th
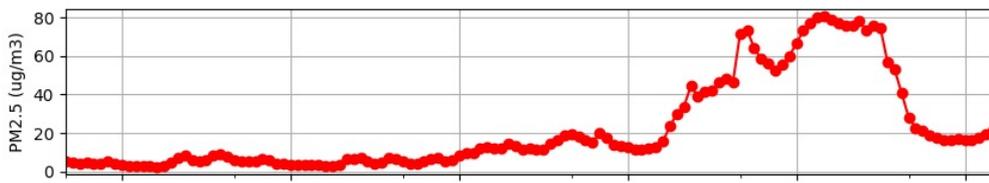~1300 PST
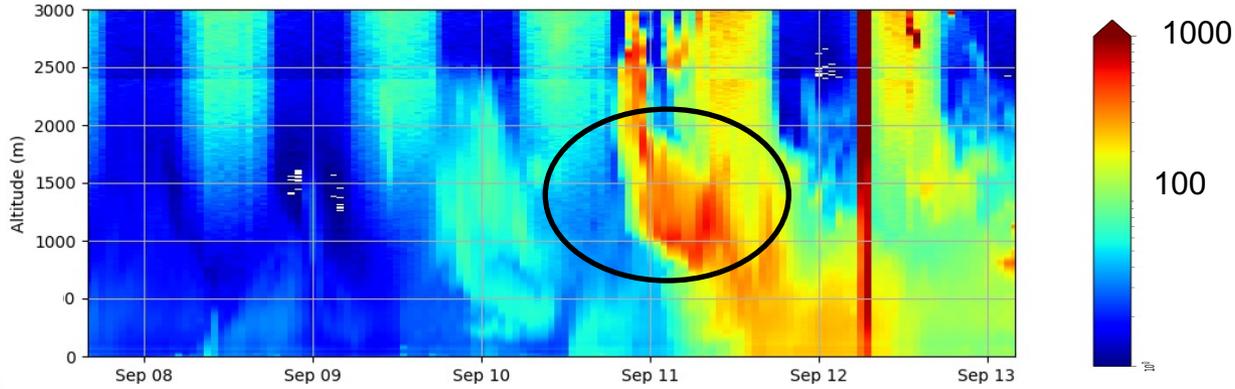
WSK
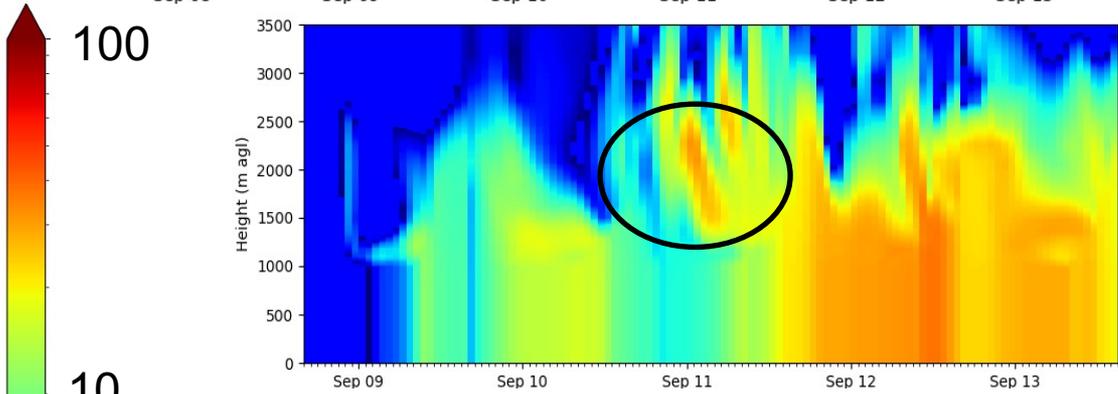
Sept 11th
~1300 PST

Surface PM2.5

CWSK CL51

The ceilometer sees a smoke plume - how on track is the FW fcst for this event?
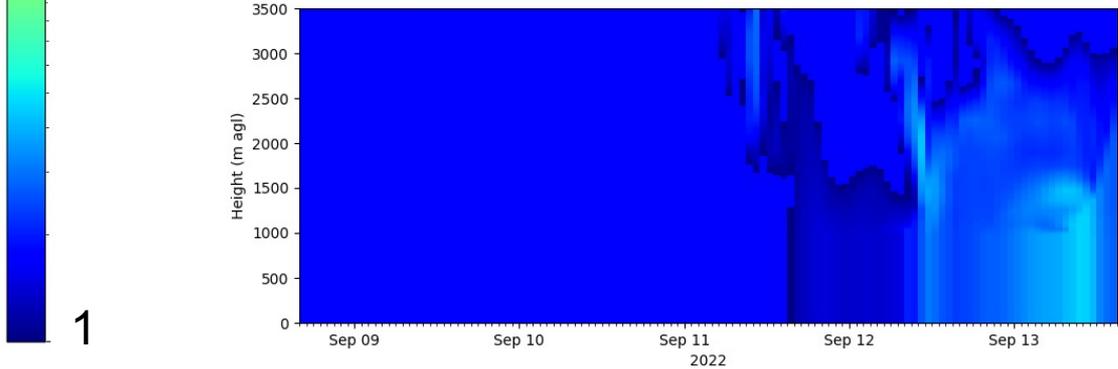
Sfc PM2.5

CL51

1000

100

Does the FW blob match up well with the CL51?
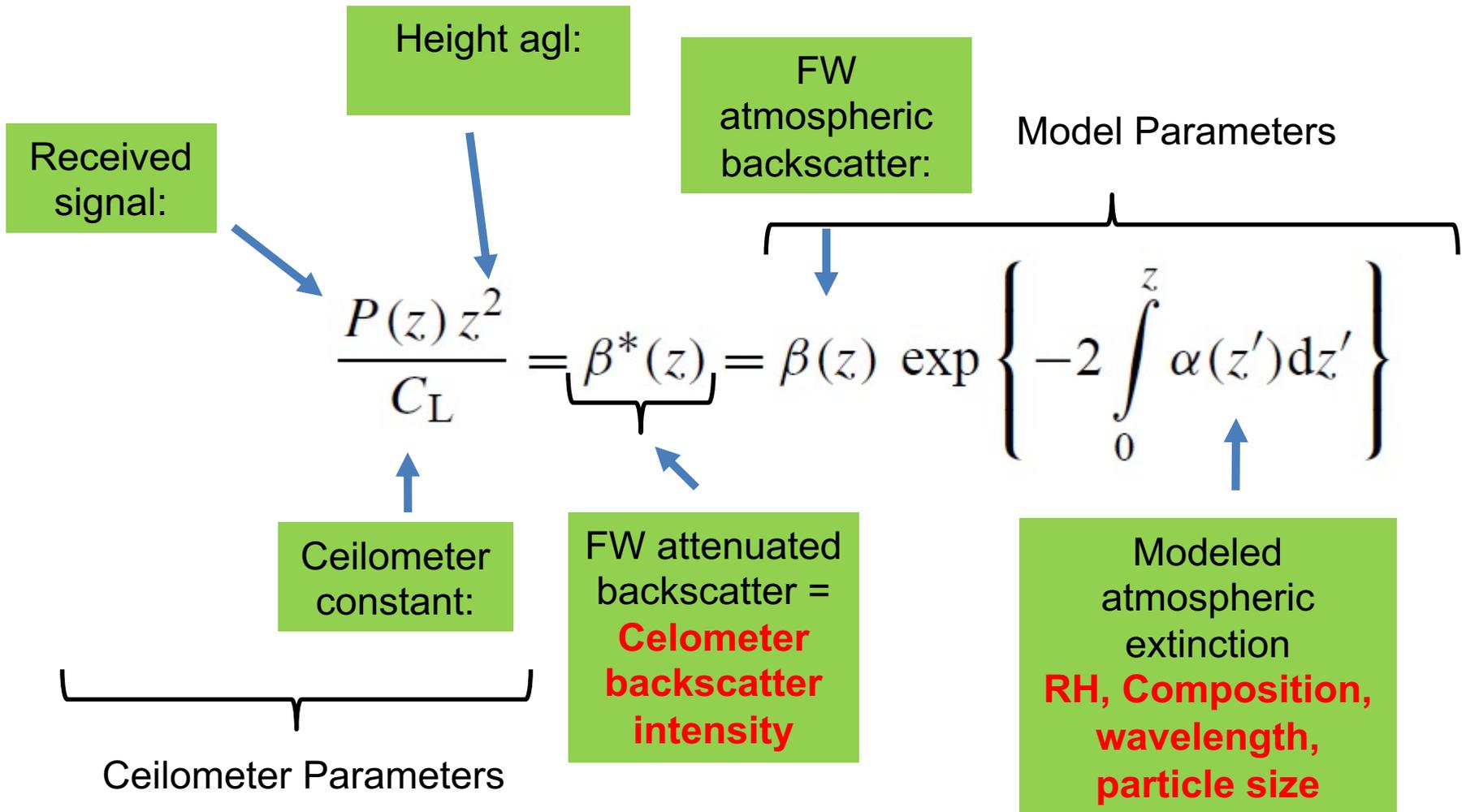
2.5

GM PM2.5

Inner Issues

Issue:

- Forecasters like to have high "glance value" imagery
- Comparing between modeled PM2.5 concentrations and observed backscatter intensity could be confusing – especially if the relationship between the two is not linear

Question:

- How to convert forecast output to look like ceilometer data? *OR*
- How to convert ceilometer observations to look like model PM2.5?

Converting FW output into ceilometer backscatter intensity

Received signal:

Height agl:

FW atmospheric backscatter:

Model Parameters

$$\frac{P(z)\,z^2}{C_{\mathrm{L}}} = \beta^*(z) = \beta(z)\,\exp\left\{-2\int_0^z \alpha(z')\mathrm{d}z'\right\}$$

Ceilometer constant:

FW attenuated backscatter = **Celometer backscatter intensity**

Modeled atmospheric extinction **RH, Composition, wavelength, particle size**

Ceilometer Parameters

Avenues of Exploration

- Once quick glance comparisons between Ceilometer and Firework model is possible
  - Tools for viewing by operations can be developed
- Automated smoke detection using CL51s, CL61s or a combination
  - May include other observational data such as surface or satellite data.

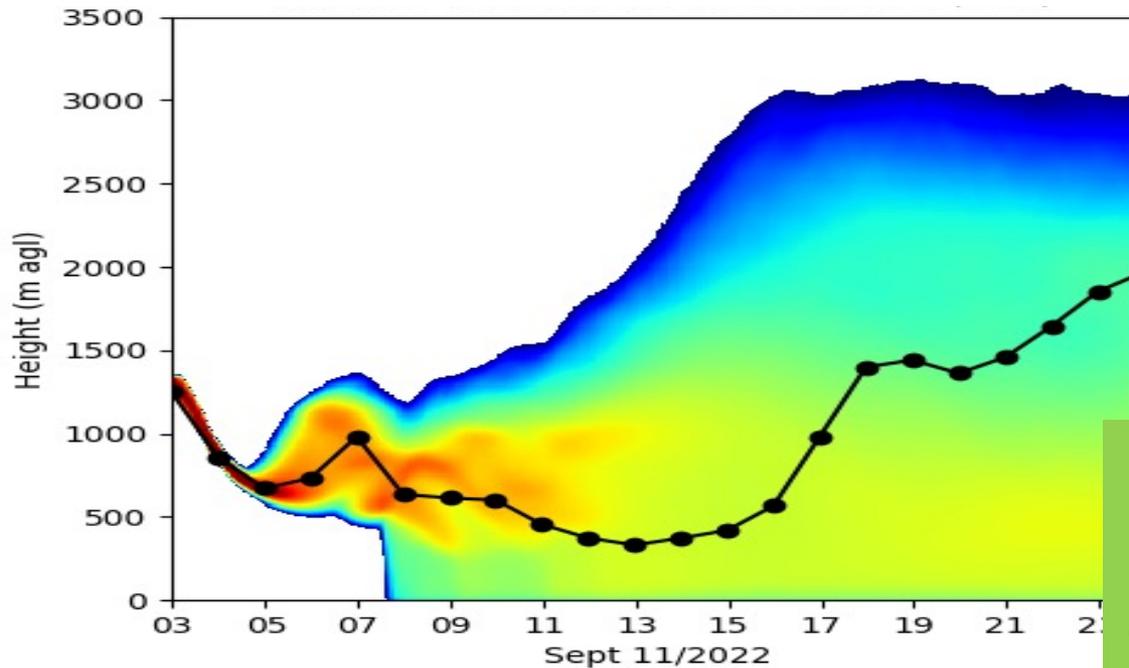# 2. **Estimating when smoke aloft will reach the ground**

- If the ceilometer sees smoke but the models do not, we can still use forecast wind fields to see if a ceilometer-observed "plume" will make it to the ground?

WSK forward release:
(-123.162,49.7817)
1250 m (agl)
Sept 11 0300 (PST)

???

Sep 11
Sep 12

Evolution of particle density vertical profiles of downwind of WSK

Tracing Smoke Aloft Trajectories

- Forward Trajectories at various heights can be run automatically from a location of a ceilometer at Firework model run times

- Data would be available for a limited time then overwritten

- Tools can be developed for Met Ops to be able to observe the trajectories from a point where a ceilometer is located.
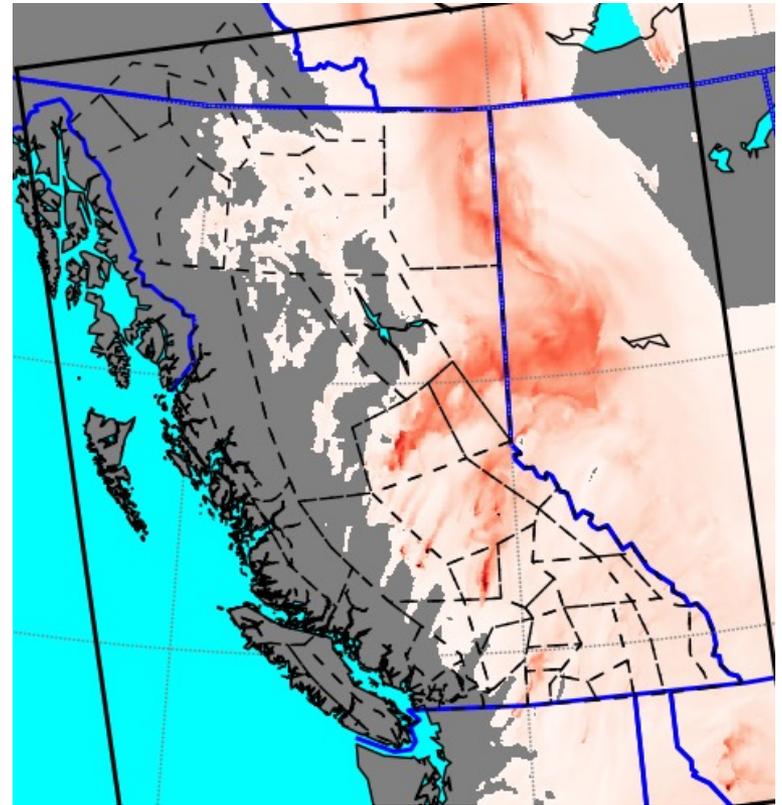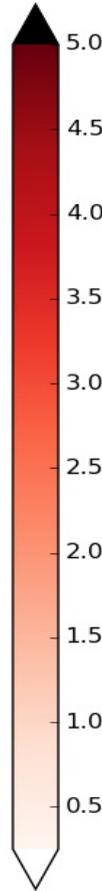
3. **Aerosol Optical Depth and Visibility**

- Utilize ceilometer data to fill in for AOD where satellites are missing data.

- Produce Airport visibility forecasts

AOD imagery valid 2017-08-12 (values below 0.25 masked out)
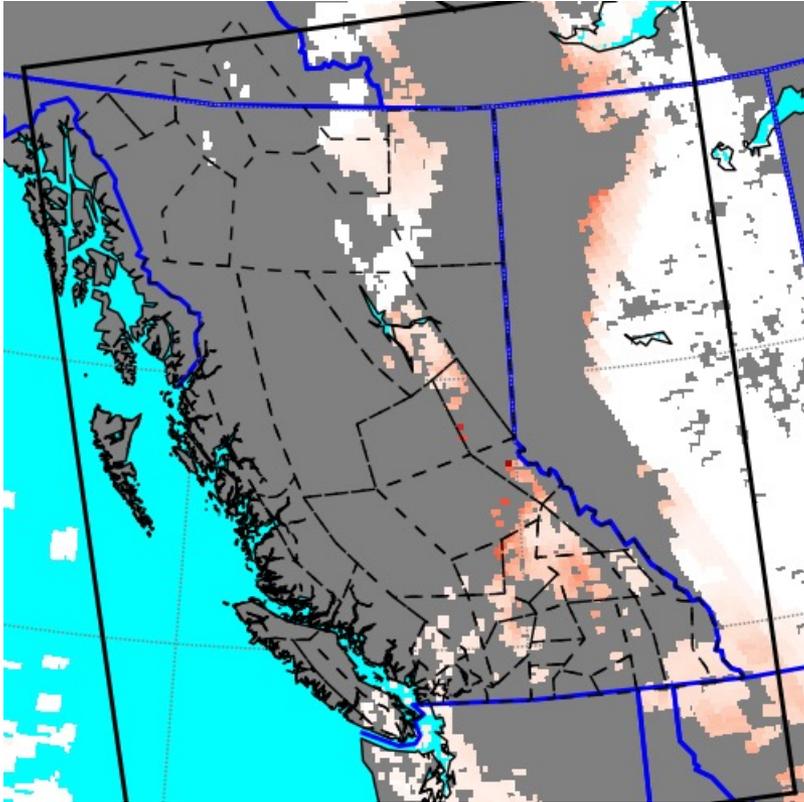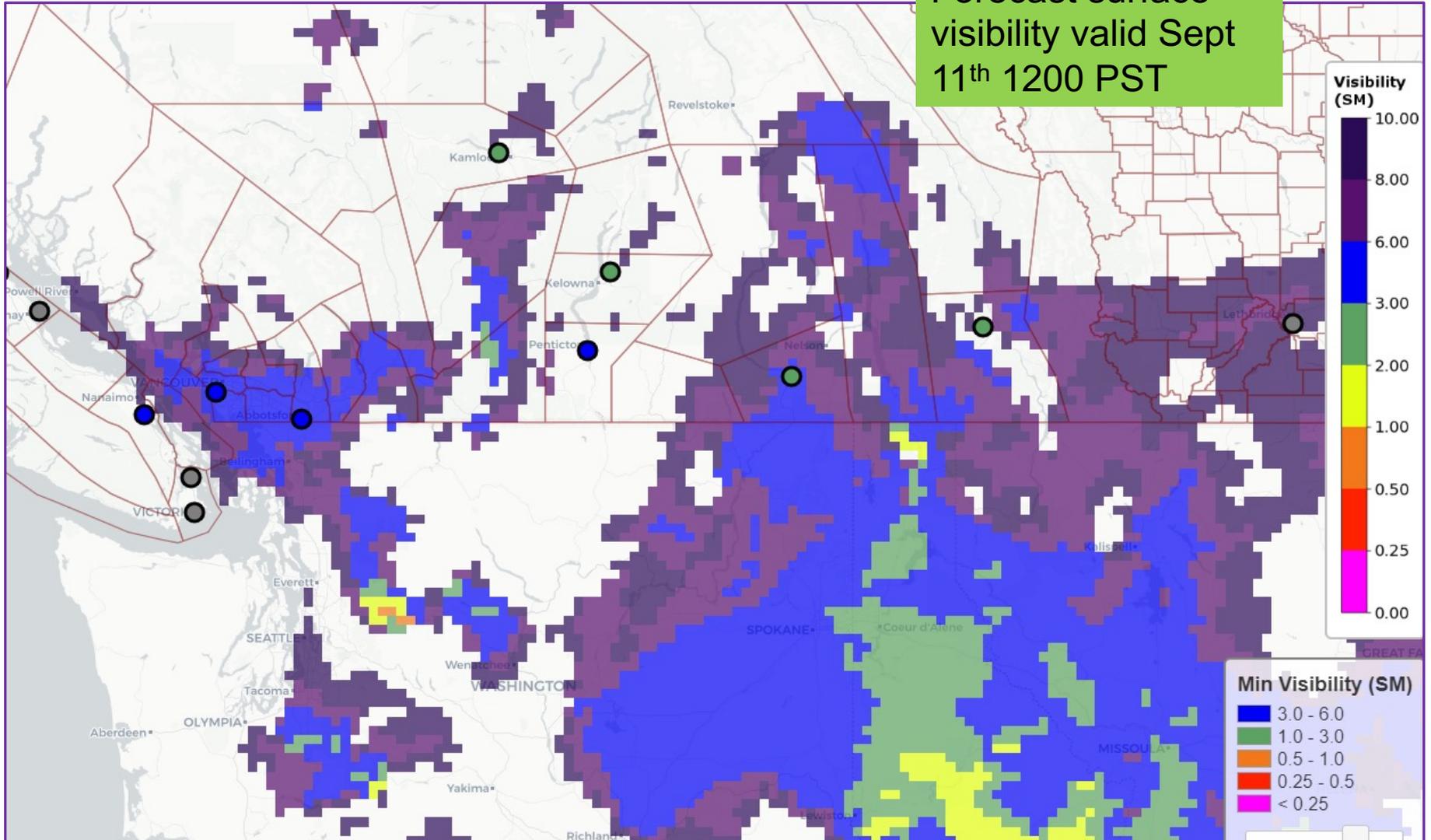
MODIS AOD

FW AOD

3. Aerosol Optical Depth and Visibility

- Utilize ceilometer data to fill in for AOD where satellites are missing data.

- Produce Airport visibility forecasts

Experimental FireWork surface visibility product

https://goc-dx.science.gc.ca/~jac001/FireWork/FW_web/VisFcstMap/

Forecast surface visibility valid Sept 11th 1200 PST

Project Overview

- Utilize CL51 and Cl61 data to produce products for predictions and services within MSC
  - Where smoke is present aloft
  - Does the model correctly predict the height of the smoke aloft
  - Where and when will the smoke aloft reach the surface
  - Other related products