



# Updating ECCCC's Ventilation Index Forecast



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# Current FLCN39 (BC) Ventilation Index

- Mainly used to plan burning operations which require lead times
- Based on the Vent Factor:
  - **VF** = mixing depth (m) × mean wind speed in mixing layer (m/s)
  - **VI = 9 + 0.02VF – 0.0000017VF<sup>2</sup> + 0.000000000068VF<sup>3</sup>**
- Categorical forecast

- Issued daily by PSPC (FLCN39)
- 43 point locations
- Forecaster intervention outside of summer months
- Un-intervened PNR legacy forecast (FLCN40) at a few locations
- Venting forecasts issued in Atlantic Canada too

**Good (VI>54)**



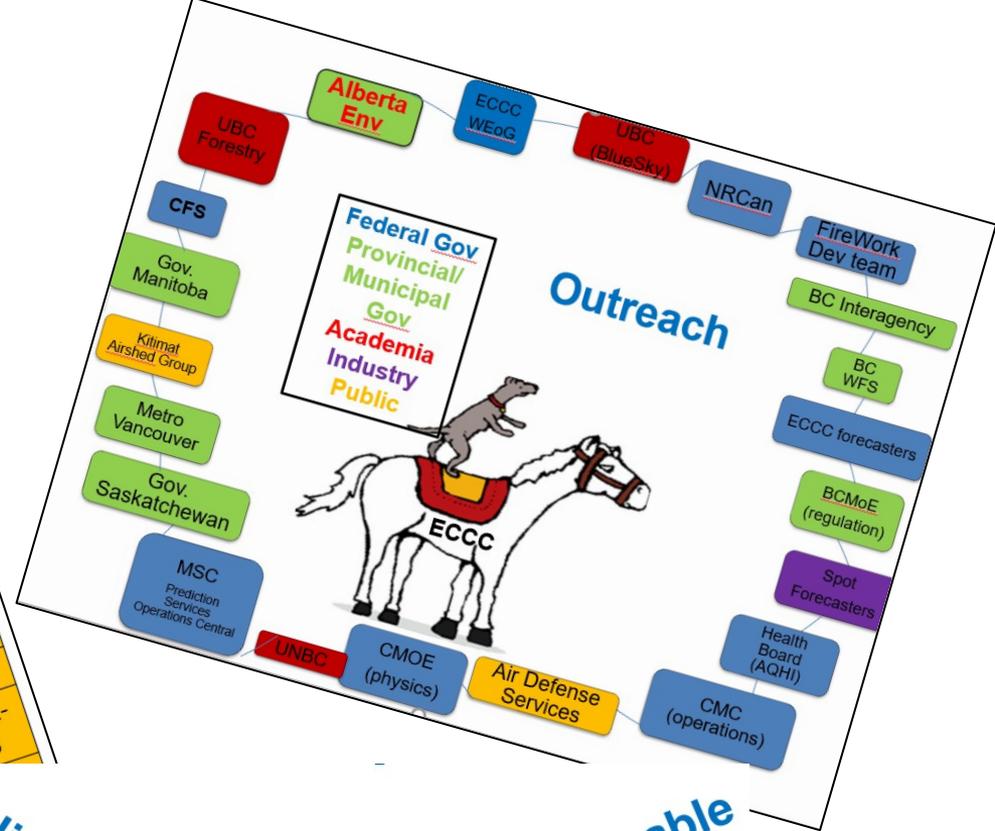
**Fair (33<VI<=54)**



**Poor (VI<=33)**



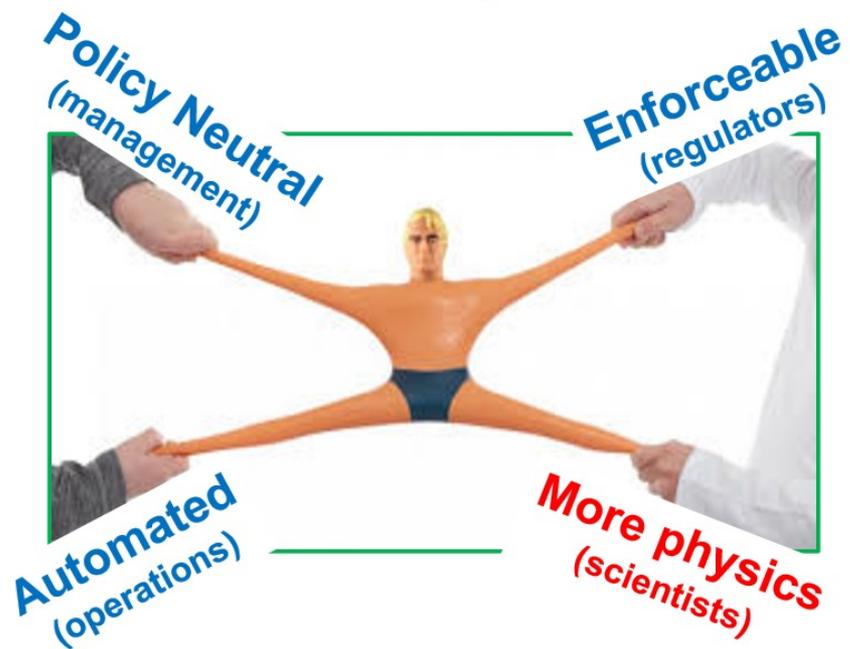
# Public Consultation around VI renewal



## Survey

49 respondents  
19 questions – 4 broad areas:

Background/reason for consulting VI forecast	Q1-Q2-Q3-Q6
VI science and related information	Q7-Q8-Q9-Q10
VI Delivery	Q4-Q5-Q11-Q12-Q14-Q15
VI and regulations	
Call for participation in follow-up meeting/focus group	



# Venting products from other jurisdictions

Location	Formula	Categories	Notes
ECCC FLCN39 (BC)	$VI = 9 + 0.02VF - 0.0000017VF^2 + 0.000000000068VF^3$ $VF = H \text{ (m)} \times U \text{ (m/s)}$	Good, Fair, Poor	H (am): MLD @ time of Tmin H (pm): MLD @ time of Tmax U: Weighted avg of wind speed of the first 4 model levels
Washington, USA	$VI = H \text{ (m)} \times U \text{ (m/s)}$	Good, Marginal, Poor and Very Poor	U is transport velocity
Indiana, USA	$VI = H \text{ (ft)} \times U \text{ (mph)} / 100$	Excellent, Good, Fair, Poor	U is transport velocity
Utah, USA	$\text{Clearing Index} = H \text{ (100 ft)} \times U \text{ (kts)}$	Good, Fair, Poor	U is transport velocity
Alaska, USA	$VI = H \text{ (m)} \times U \text{ (m/s)}$	None given	U is transport velocity
Parts of Missouri, Kansas, Illinois, Indiana and Kentucky USA	$VI = H \text{ (ft)} \times U \text{ (kts)}$	Excellent, Very Good, Good, Fair, Poor	

# Issues with VF: H and Utran

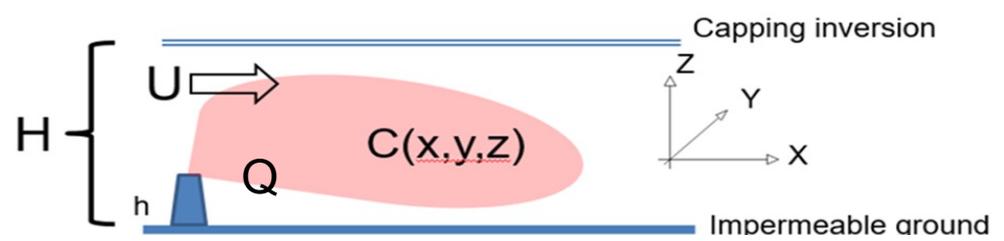
## Transport velocity

- For surface release, Utran will over-estimate mixing close to source
- Properly calculating Utran looks to be computationally expensive
- Using  $k$ -bottom layers winds over/under estimates Utran and its influence will change with changing model vertical resolution

## Mixed Layer Depth

- H not best length scale at close range
- Diagnostic not prognostic variable
- Forecast H can be quite low ( $\sim$  meters) and is the variable most often changed during forecaster intervention

# Dispersion insights



$$C(x, 0, 0) = Glc(x) = \frac{Q}{\sqrt{2\pi}\bar{U}H\sigma_y(x)}$$

- Gaussian Plume relationship shows concentrations linearly related to emission and & inversely related to “mixing”
- The ratio of concentration to emissions has units of  $[s/m^3]$  e.g.  $\sim 1/dV/dt$
- But current vent factor ( $UH$ ) has dimensions  $[m^2s^{-1}]$ 
  - It is dimensionally incomplete
- GP mixing shows there is an extra length scale ( $\sigma_y$ ) which gives cross-wind dispersion
  - $\sigma_y$  arises from turbulent mixing
  - $\sigma_y \sim$  (stability,  $u^*$ ,  $L$ ,  $dU/dZ$ , TKE,  $Ri$ )
- Furthermore above relationship ignores turbulent shear in the surface layer

$$\frac{C}{Q} = \frac{1}{\text{Mixing}}$$

$$\frac{C}{Q} \left[ \frac{g}{m^3} \cdot \frac{s}{g} \right] = \left[ \frac{s}{m^3} \right] = \frac{1}{\frac{dV}{dt}}$$

$$\frac{C}{Q} \sim \frac{1}{UH\sigma_y(x)}$$

# Development/Renewal Strategy

## Goal

- Develop Venting Index that is **calibrated** via C/Q relationship

## Approach

- Simulate dispersion and use forecast fields to parameterize its output (“**model of a model**”)

## Issues

### Q1: What measure of dispersion to use as a proxy for “mixing”?

1. Based on **ground level concentrations** (relevant to ECCC’s mandate around air quality and health)
2. Based on **residence time**: *how long does it take for a particle to stray from its source* (easy to calculate)

### Q2: What meteorological fields to parameterize this “mixing”?

- Existing VI formulation would suggest: **U**tran and **H**
- Science would suggest other variables/scales, especially for surface releases

### Q3: How to set up venting scale?

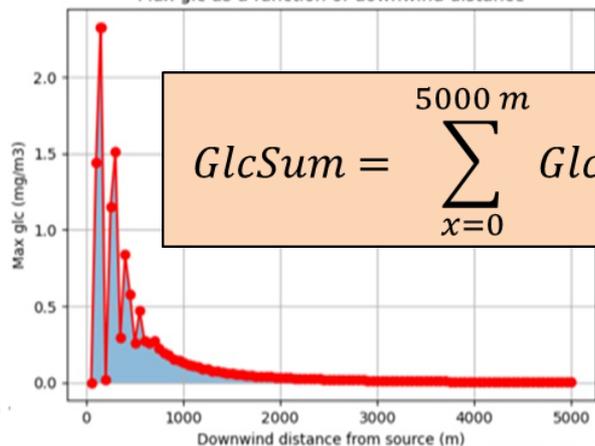
- Traditionally, ventilation metrics are set-up such that as venting increases, impacts decrease.
- Should scale be **linear** or **logarithmic** with *1/impacts*?

# GlcSum

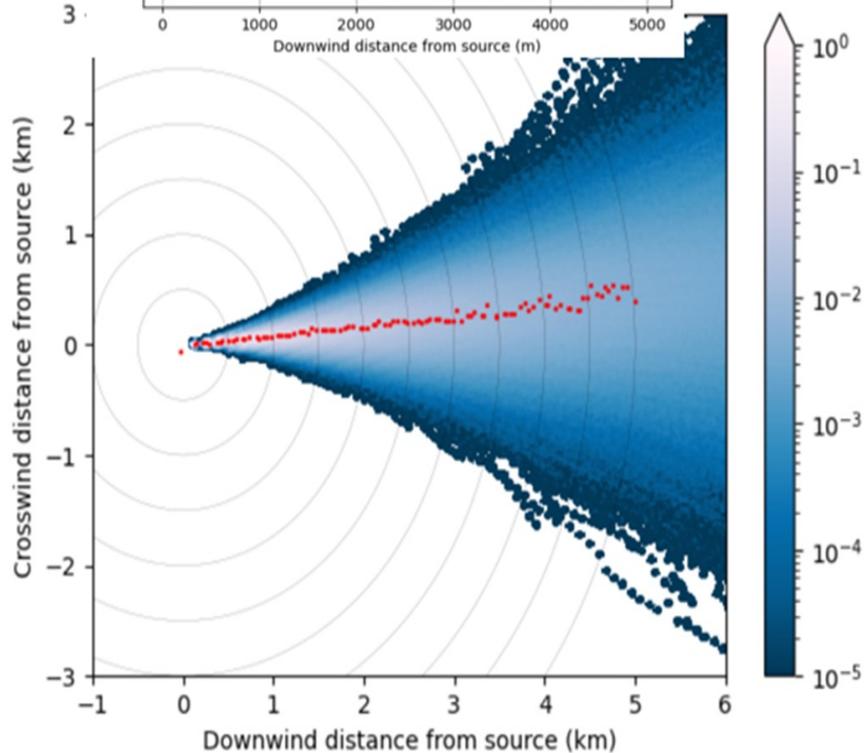
## Answer 1: Two choices for "Mixing" proxy

# ResTime

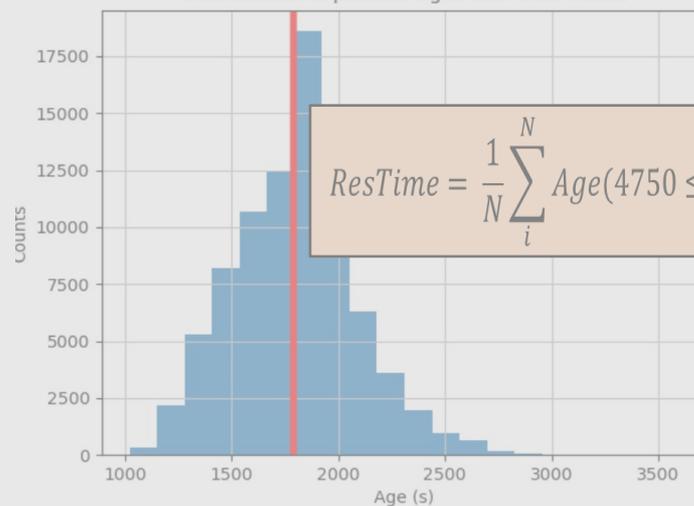
Max glc as a function of downwind distance



$$GlcSum = \sum_{x=0}^{5000 \text{ m}} GlcMax(x)$$

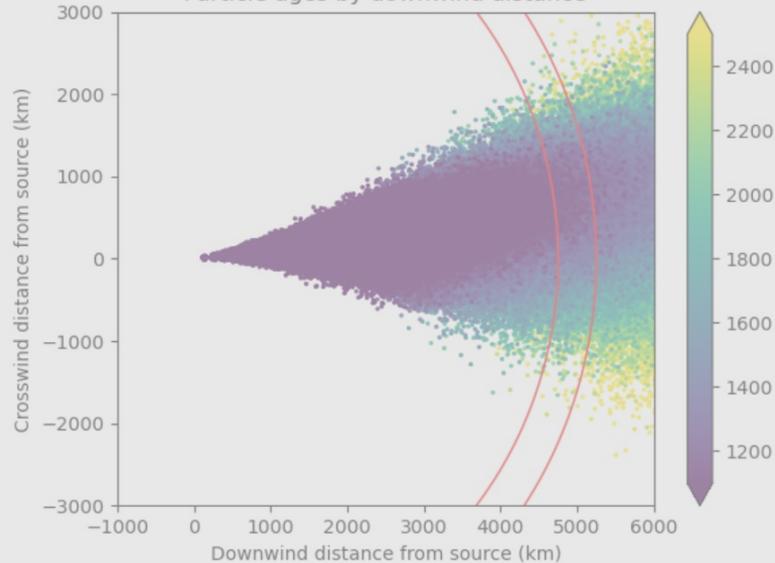


Distribution of particle ages and their mean



$$ResTime = \frac{1}{N} \sum_i^N Age(4750 \leq x_i \leq 5250 \text{ m})$$

Particle ages by downwind distance



## Answer 2:

### Meteorological variables under consideration in the nVI

Variable	NV	Units
Richardson number	RI	-
Friction Velocity	UE	m/s
Vertical diffusion coefficient. for heat	KT	m <sup>2</sup> /s
Mixed layer depth	H	m
Sfc Wind speed	UU, VV	m/s
Transport velocity	UU,VV	m/s
Monin-Obukhov length	IO	m <sup>-1</sup>
Roughness length	z0	m

# Answer 3:

## Two choices for venting scale

### Inverse Linear

$$nVI \sim 1/Impacts$$

- **Doubling** in *vent units* implies **halving** impacts
- **Halving** of *vent units* implies **doubling** impacts
- Leads to power-law type relationship w/ met variables
- More conventional scale
- Scale gets compressed at small venting values

### Inverse Log-linear

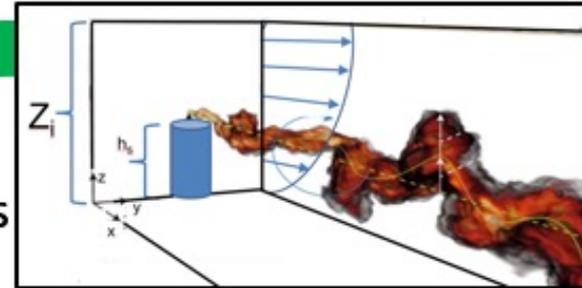
$$nVI \approx k/\log_2(Impacts)$$

- **Increase** in *k-vent units* implies **halving** impacts
- **Decrease** of *k-vent units* implies **doubling** impacts
- Leads to additive type relationship w/ met variables
- Richter-type scale
- Avoids compression of scale at small and large venting values

# Ventilation Renewal Workflow

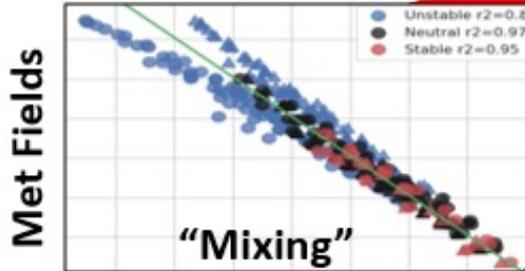
**A**

Controlled dispersion runs



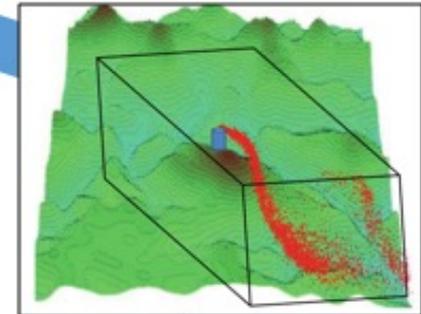
**B**

Regression Analysis



**C**

Calibration dispersion runs



Final Ventilation Formula

$$nVI = \begin{cases} 14.3 \times U_s^{0.53} \times KT^{0.51} & \text{Stable} \\ 6.9 \times U_s^{0.43} \times KT^{0.30} & \text{Neutral} \\ 2.9 \times U_s^{0.45} \times KT^{0.31} & \text{Unstable} \end{cases}$$

# Workflow

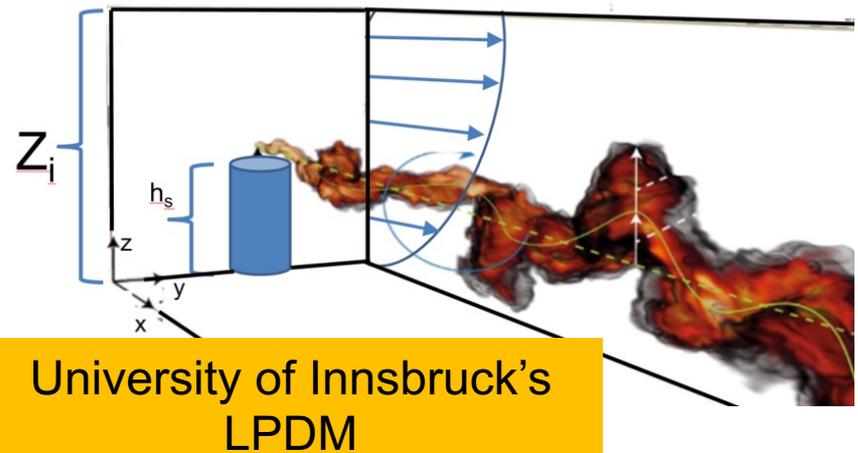
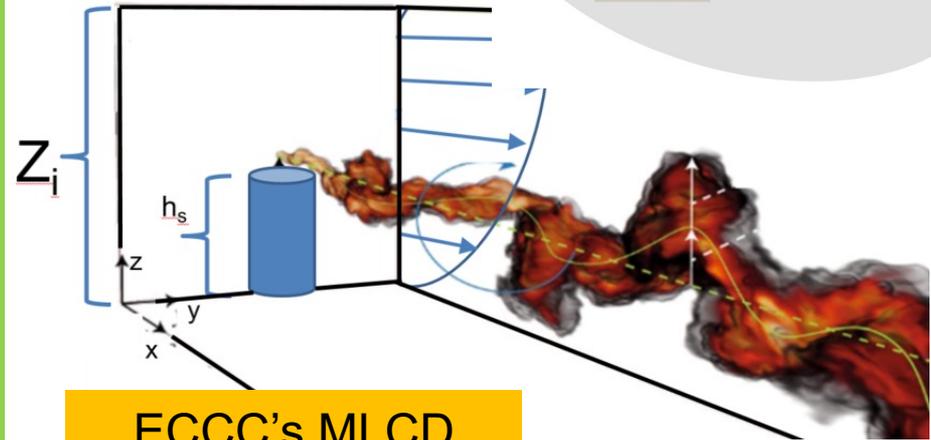
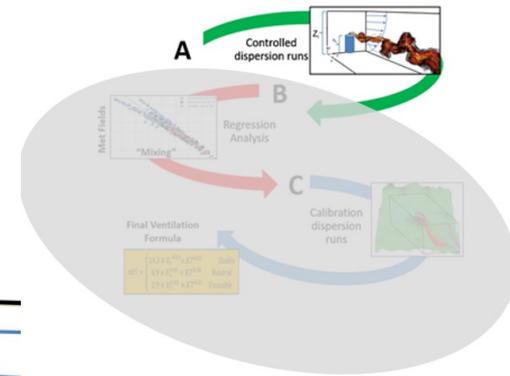
## A. Controlled Dispersion runs

Parameterization being developed using 2 models:

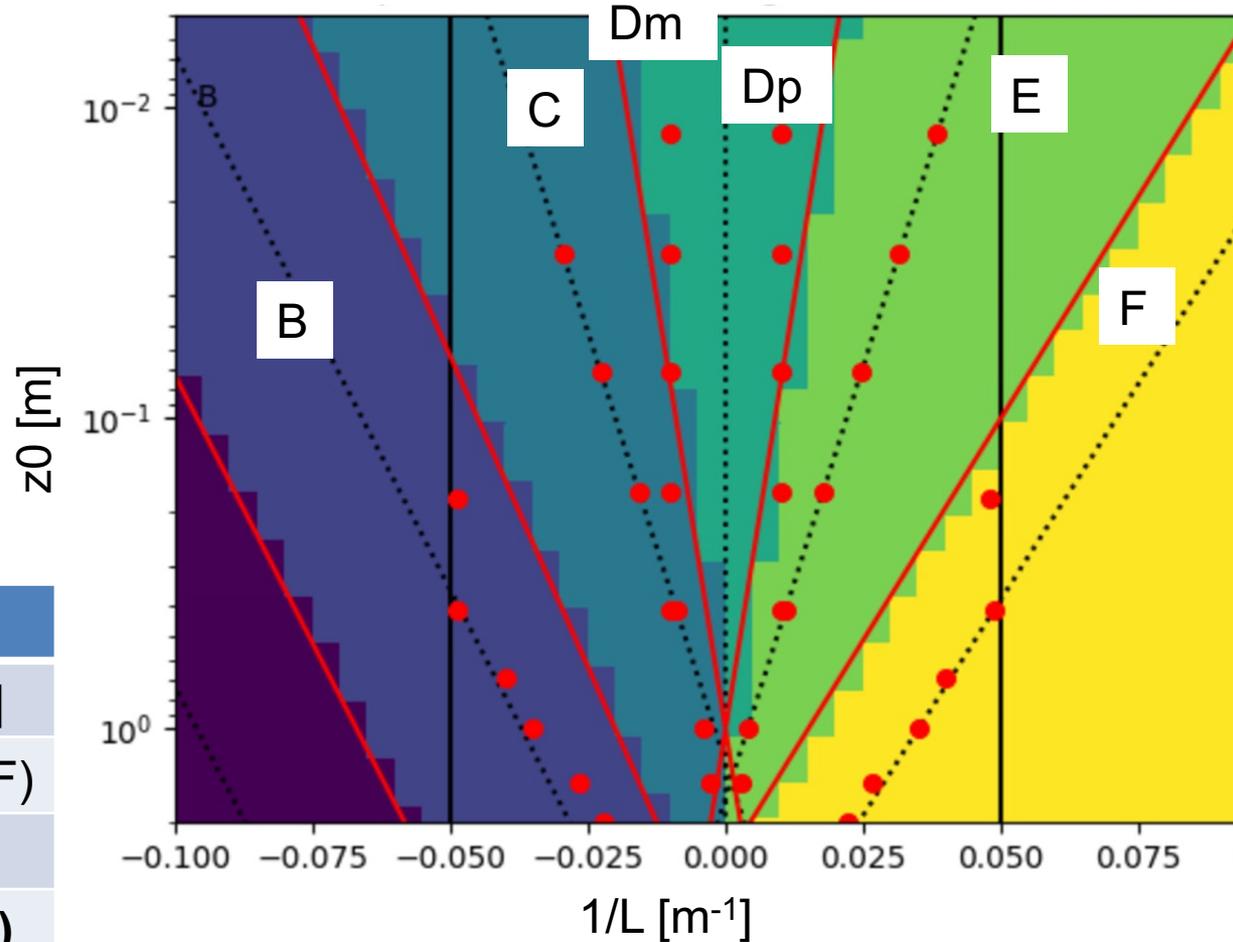
1. ECCC's MLC
2. Univ. of Innsbruck's LPDM

For each model, simulations with:

- Prescribe  $U_{10m}$ ,  $Z_i$  and stability
- Vertical wind profile calculated from stability and  $U_{10m}$
- Flat terrain
- Fixed  $Z_i$
- Uniform land use
- Horizontally homogeneous meteorology
- Meteorological conditions are constant in time



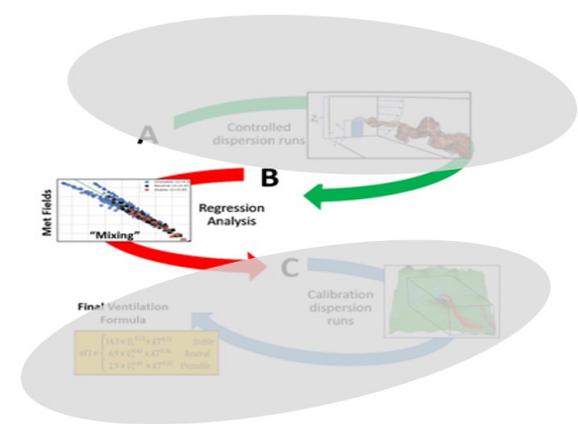
# Modeling Strategy: Environmental and meteorological matrix



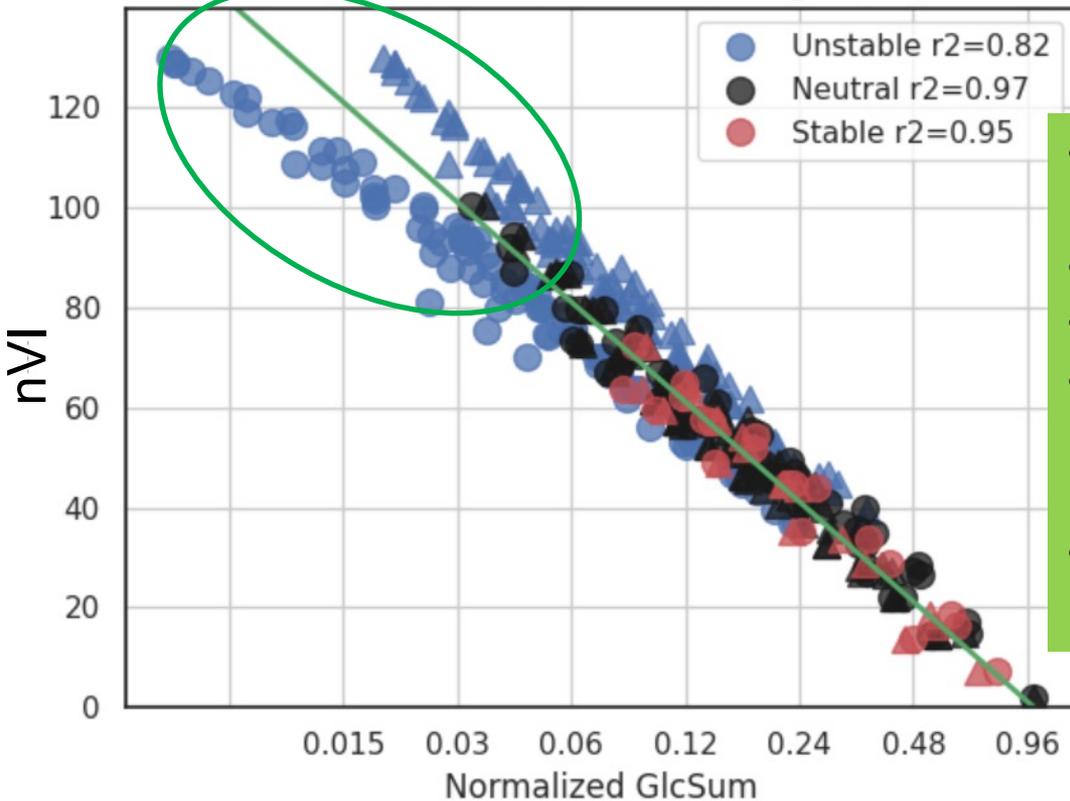
Variable	Cases
Wspd	1,2,3,4,5 [m/s]
Stability	(B,C,Dm,Dp,E,F)
Zo/L	6 values
<b>Total</b>	<b>180 (5 X 6 X 6)</b>

# Work Flow:

## B. Regression Analysis



GlcSum for Lpdm (circles) and Mlcd (triangles) experiments



- nVI based on regression against  $u^*$  and  $KT$
- 360 (180\*2) simulations
- Using GlcSum as proxy for mixing
- Using logarithmic scale with double/halving for each 20 vent unit change
- Separate formula for Stable, Neutral and Unstable conditions

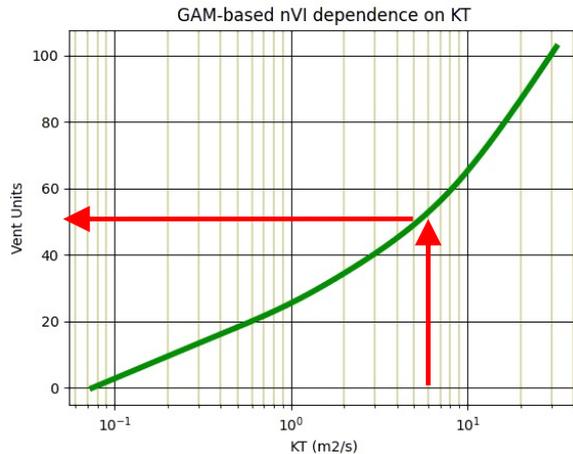
$$nVI = \frac{20}{\log_2(GlcSum)} = \begin{cases} 85.4 + 15.6 \times \log U_* + 15.2 \times \log KT & \text{Stable} \\ 75.3 + 15.7 \times \log U_* + 10.6 \times \log KT & \text{Neutral} \\ 75.7 + 18.0 \times \log U_* + 16.7 \times \log KT & \text{Unstable} \end{cases}$$

# B. Regression analysis

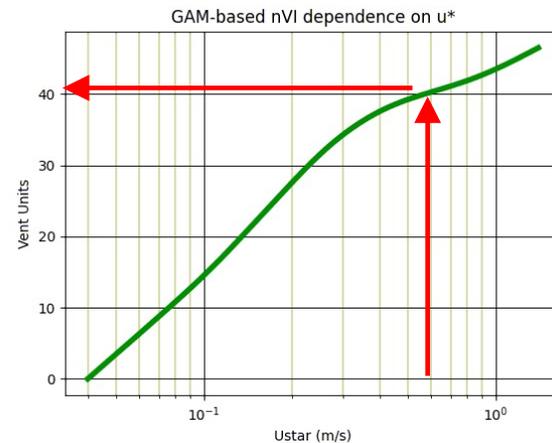
## Non-linear fit

$$nVI \sim \log_2 \left( \frac{1}{GlcSum} \right)$$
$$nVI = f(KT) + g(u_*) + const$$

**nVI =**



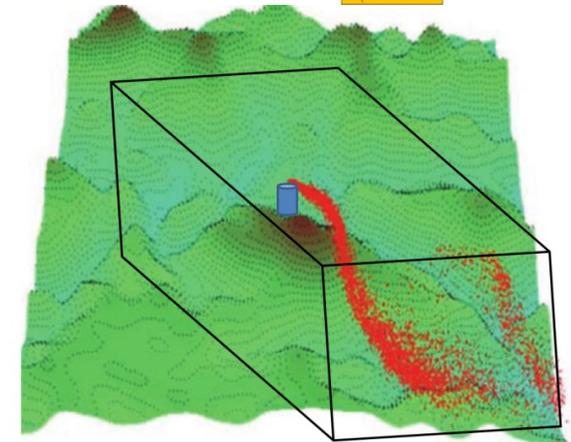
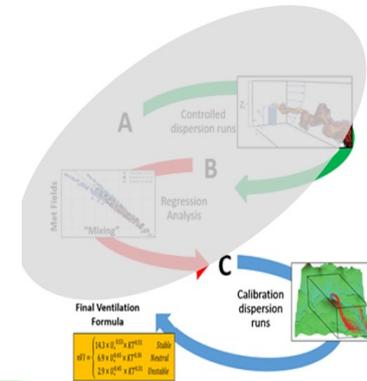
**+**



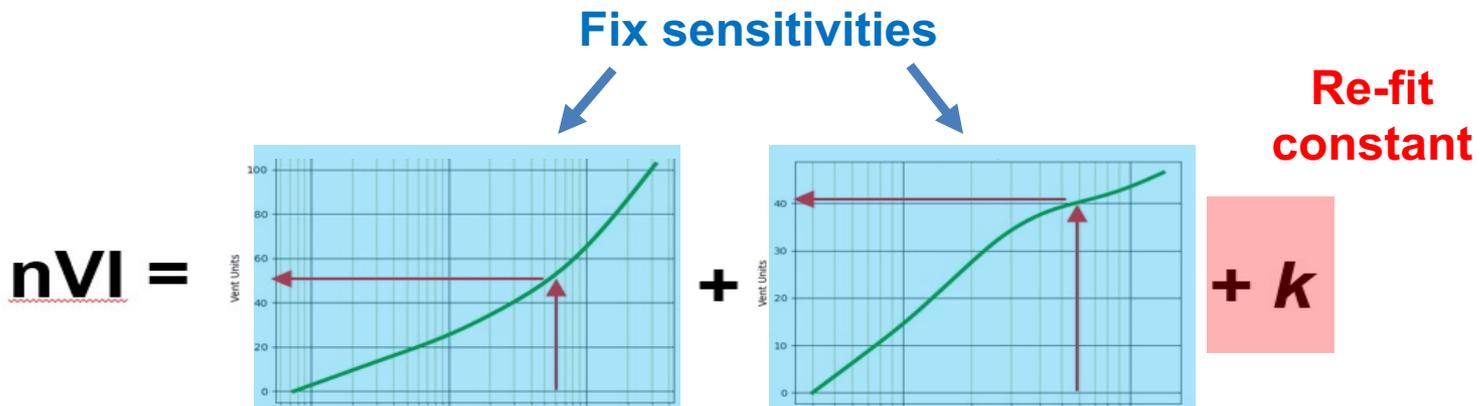
**+ k**

# Work Flow: Calibration dispersion runs

- Use ECCC's MLDPn model to predict GlcSum
- Use forecast meteorological fields for simulations:
  - meteorology now varies in space and time
  - Introduces complex terrain
  - Allows for varying land use and Zi
- Regress GlcSum against forecast  $u_*$  and KT
  - Keep sensitivities but re-fit constant



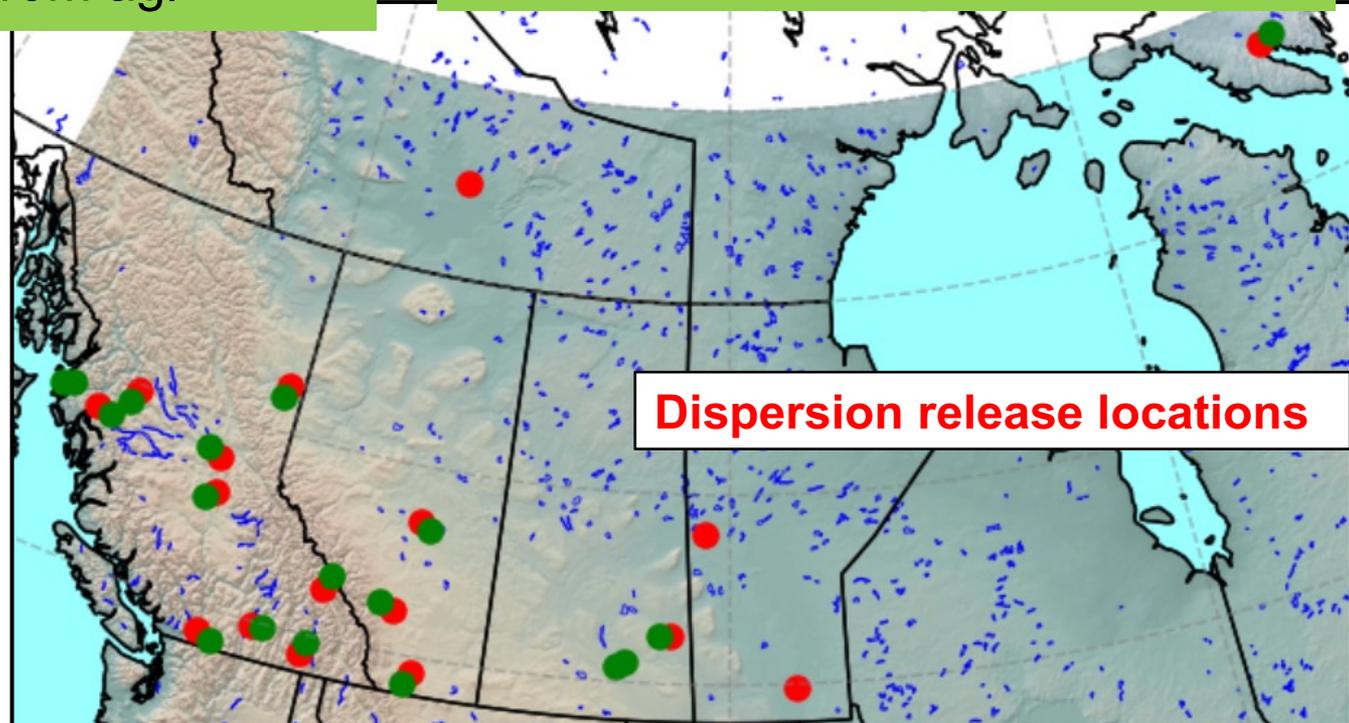
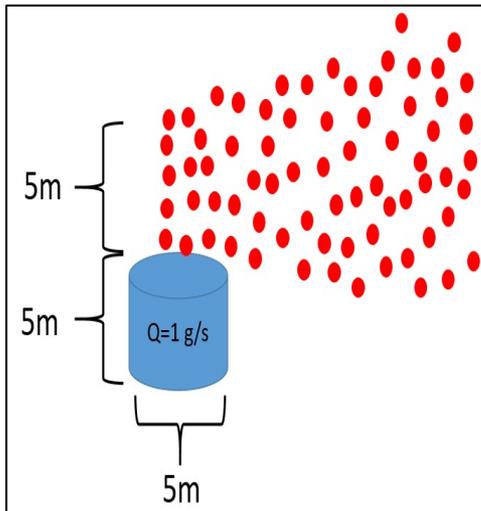
ECCC's MLDPn



# Calibration runs

- Forward particle releases from 18 WCan Scribe locations (**red**) and 14 nearby ridge locations (**green**)
- Short (2-hour long) simulations using 4,000,000 particles
- Continuous emissions from cylinder: 5m radius with base at 5m agl and top at 10m agl

- Hourly releases for every day over four selected months:
  1. Feb (winter)
  2. May (spring)
  3. Aug (summer)
  4. Nov (fall)
- A total of 86400 (= 30 X 24 X [28+31+31+30]) simulations

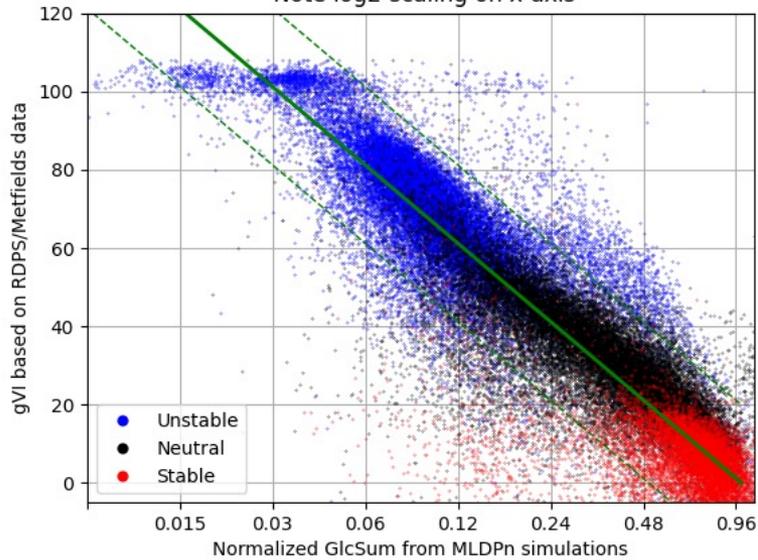


# Re-calibration results

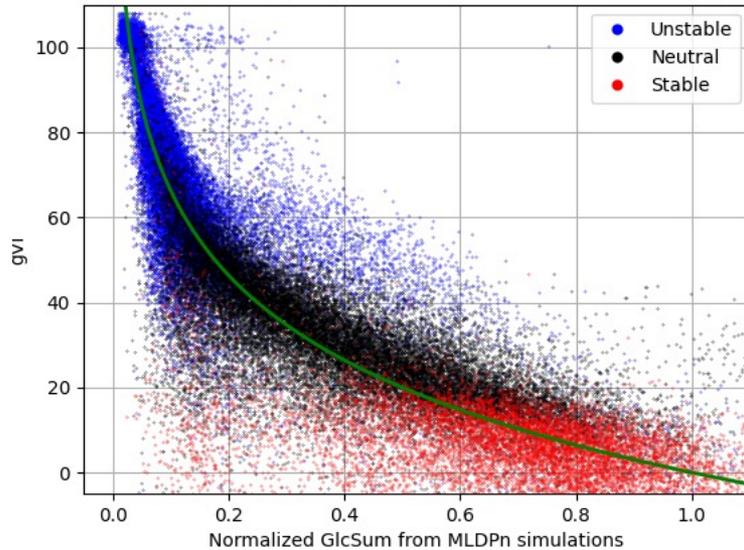
## Log-linear scale:

*“If tomorrow’s VI is 20 vent units higher than today’s, then burning tomorrow will have half the impacts”*

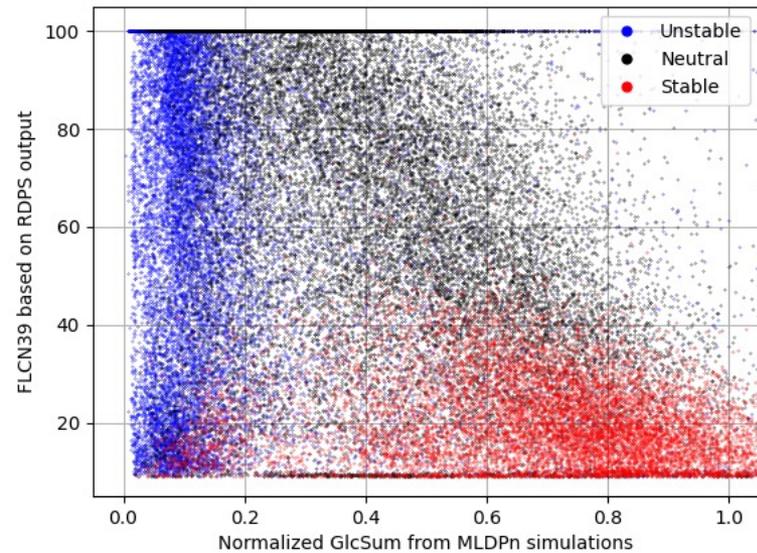
GlcSum-based gVI from MLDPn simulations and RDPS output  
Note log2-scaling on x-axis



GlcSum-based gVI from MLDPn simulations by stability



RDPS-based FLCN39 versus MLDPn-based GlcSum



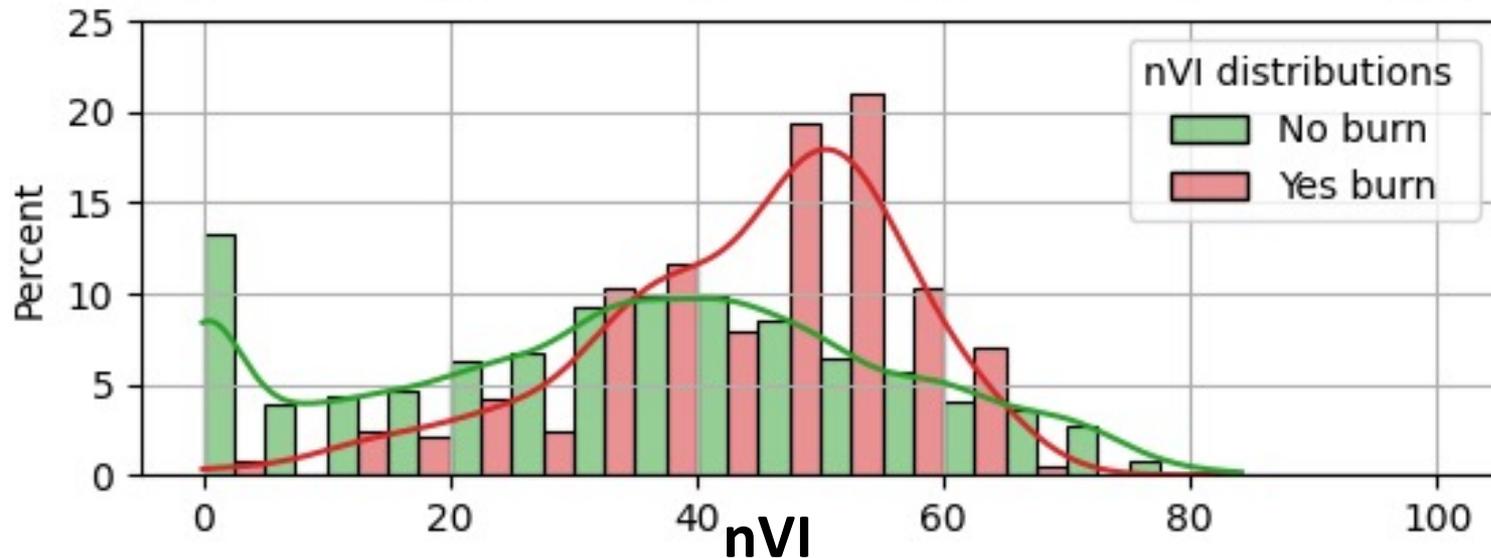
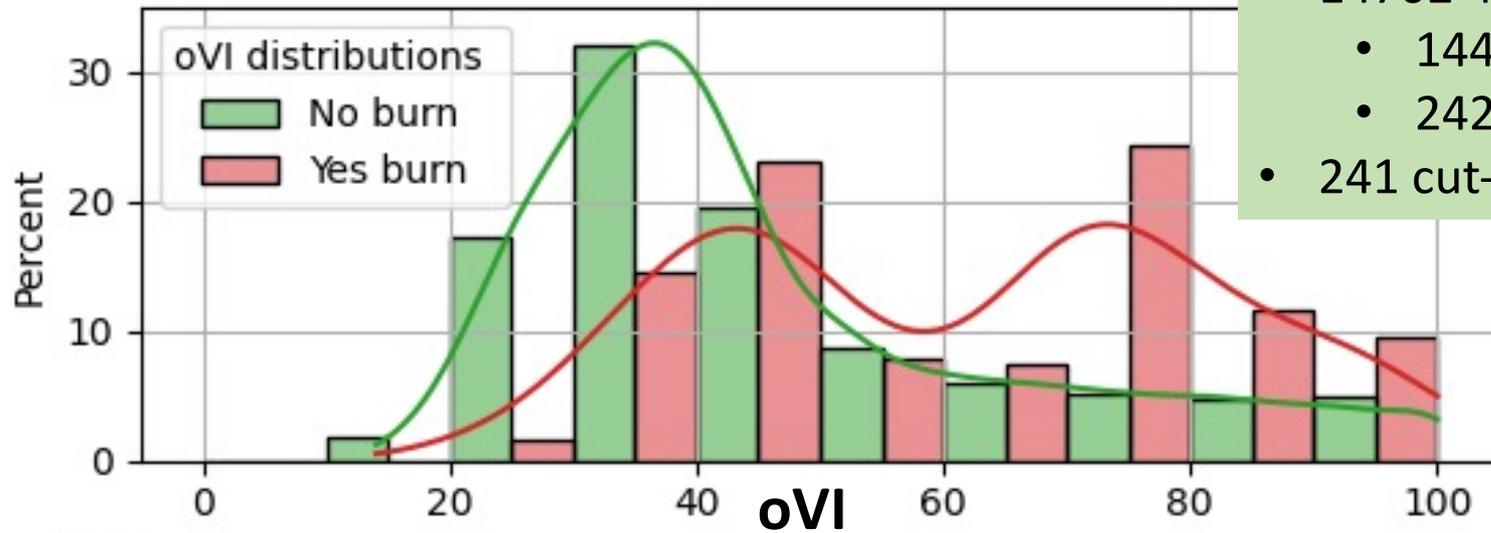
# nVI evaluation (ongoing)

Compare nVI and oVI forecasts:

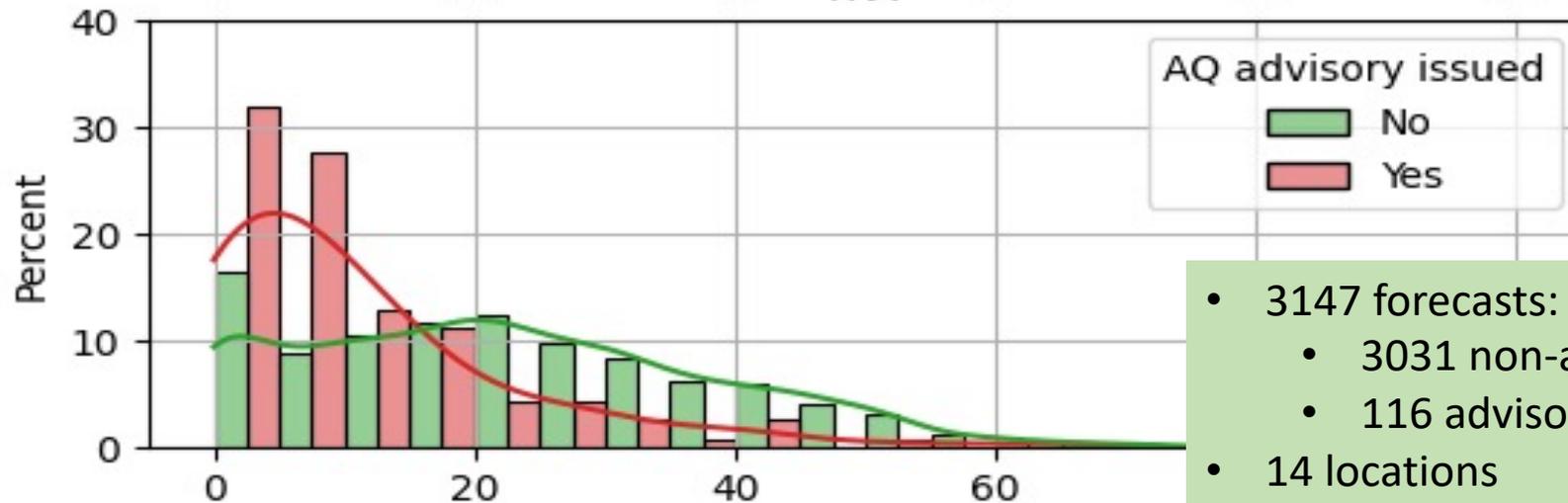
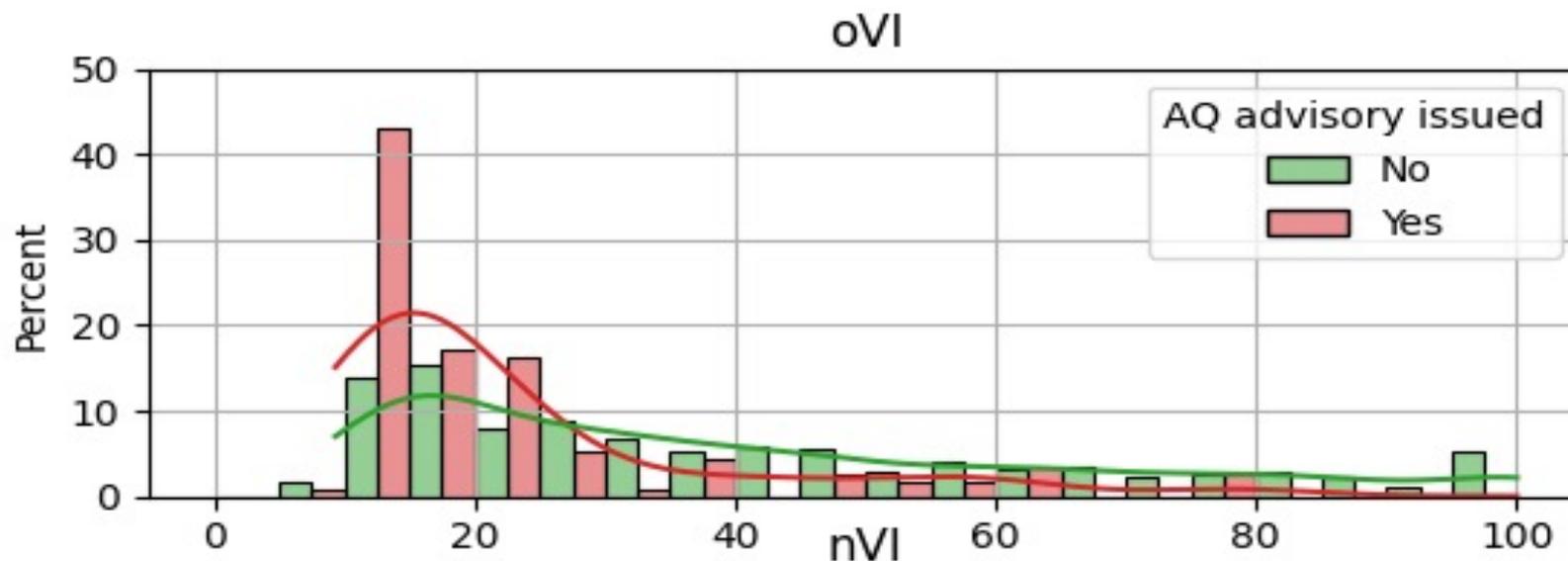
1. Over BC during fall burn season
2. Over PQ winter RWC season
3. Spot forecasts made by certified meteorologists
4. Comparison of valley vs ridge forecasts
5. Over Gagetown NB spring burn season

# VI forecasts over Oct-Nov 2018 slash pile burn season in northern BC

- 14702 forecasts:
  - 14460 no-burn dates
  - 242 burn dates
- 241 cut-block locations



# VI forecasts over 2020-2021 winter months in Quebec



- 3147 forecasts:
  - 3031 non-advisories
  - 116 advisories
- 14 locations
- 147 dates between Nov-Dec 2020 & Jan-Apr 2021

# Summary

- New Ventilation Index is **calibrated** to “**impacts**” simulated from particle dispersion modeling
- Impacts are related to maximum **ground level concentrations** downwind of release
- nVI has been parameterized using  **$u_*$ ,  $KT$**  (and  **$RI$** )
- The nVI is really only applicable for low energy releases in the atmospheric **surface layer**
- The proposed nVI scale is **logarithmic** (base 2) with a 20 VU change implying a doubling/halving of impacts
- nVI formulation makes use of the traditional **Vent Factor**

# Concerns

- We would be only organization not to use a Vent Factor (Utran X MLD) as the basis for Ventilation forecast – is that be a problem?
- Are the  $u_*$  and KT fields too esoteric?
- Stability of forecast  $u_*$ , KT fields
  - Will their prognostic equations/relationships change in the near future?
  - How much confidence is there in their accuracies?
- We based our nVI on simulations from a source height of  $\sim 7.5\text{m}$ , but we know GlcSum values are sensitive to emission height.

**Questions?**