Smoke Forecast Model Performance

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Wouldn't It be Nice:

A system that forecasts the exact timing and hourly concentrations of smoke from wildfires at all locations 60 hours into the future.

Realistic?   No.

How good does it have to be?

What are the questions we are trying to answer?

What decisions are we trying to make?

Review of smoke forecast models: What can they do?
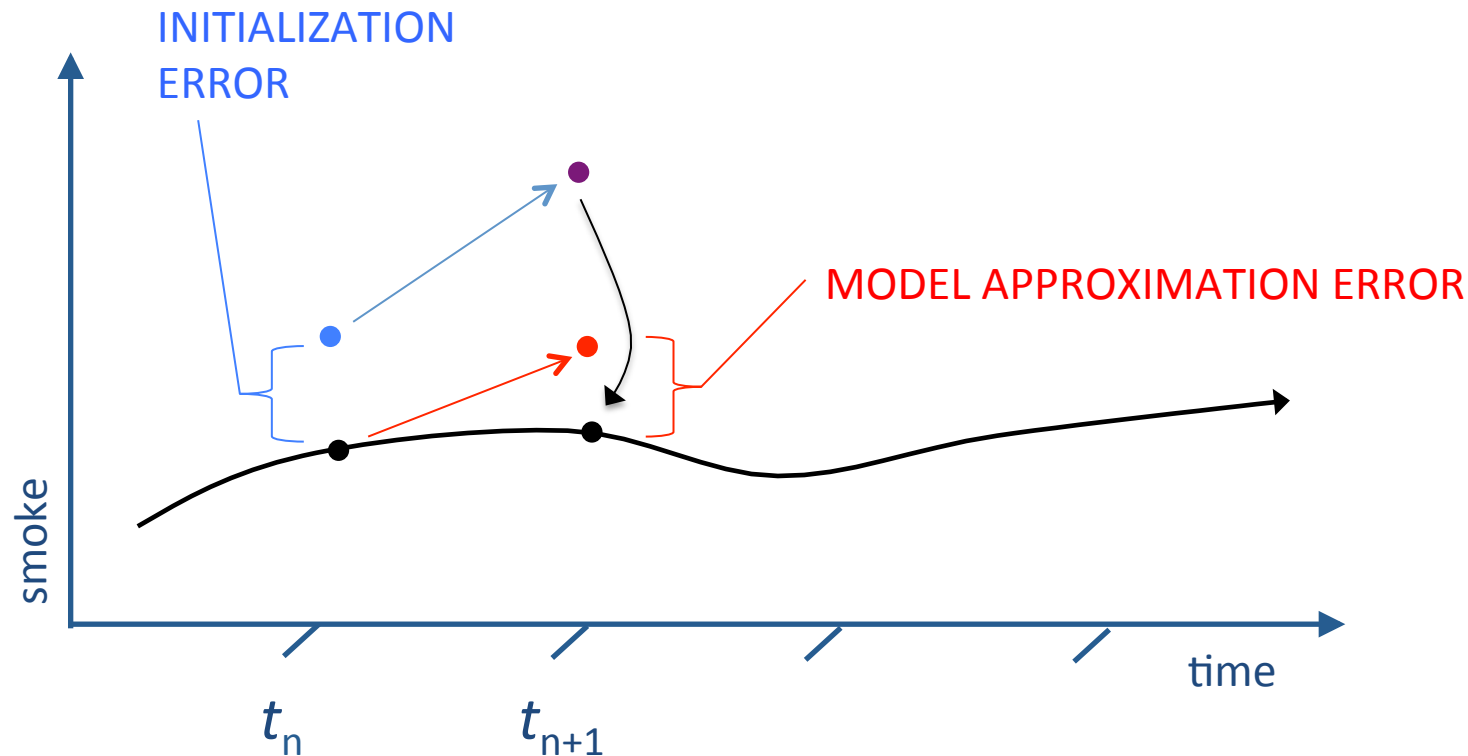## (from Larkin, 2013)

Well:

- Overall plume shape

- Overall regional impact levels

Less well:

- Timing

- Site specific concentrations

- Terrain influenced flows

Smoke Forecast Models: Sources of Error
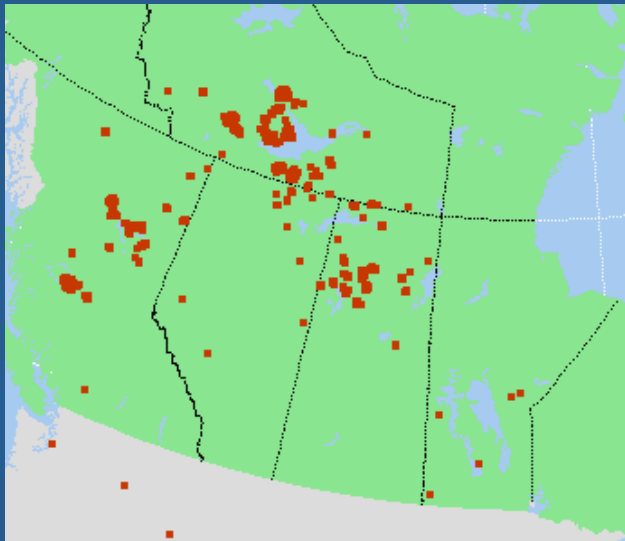## (from Larkin, 2013).

INITIALIZATION ERROR

MODEL APPROXIMATION ERROR

smoke

time

t_n

t_{n+1}

INITIALIZATION ERROR:
wildfire location, fuel consumption, smoke pattern at start of forecast

MODEL APPROXIMATION ERROR:
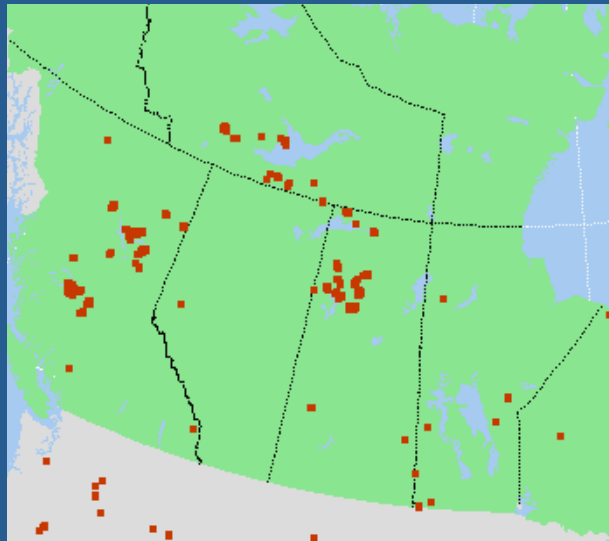inadequate physics in model (plume rise, meteorology, dispersion…)

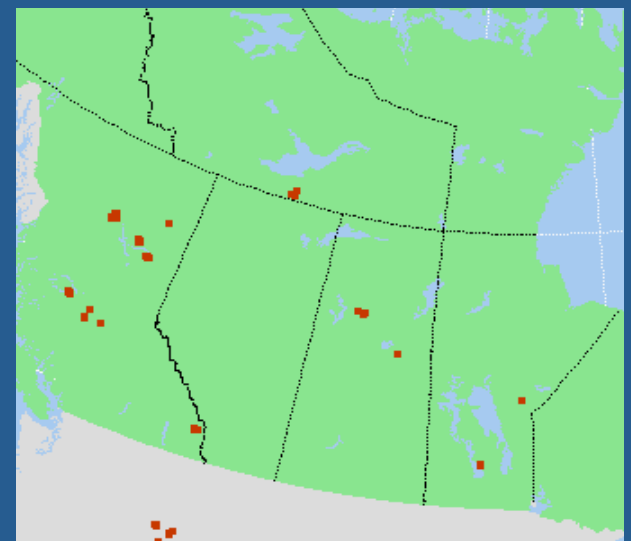# Initialization Error: Example - Wildfire Locations

Did the wildfires suddenly go out?
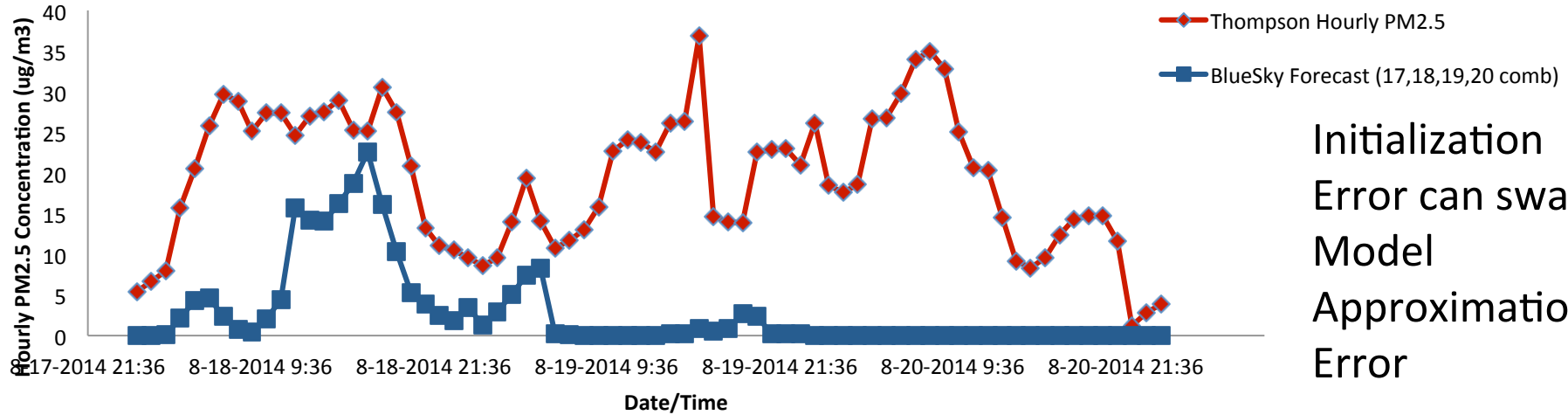

Aug 17

Aug 18

Aug 19

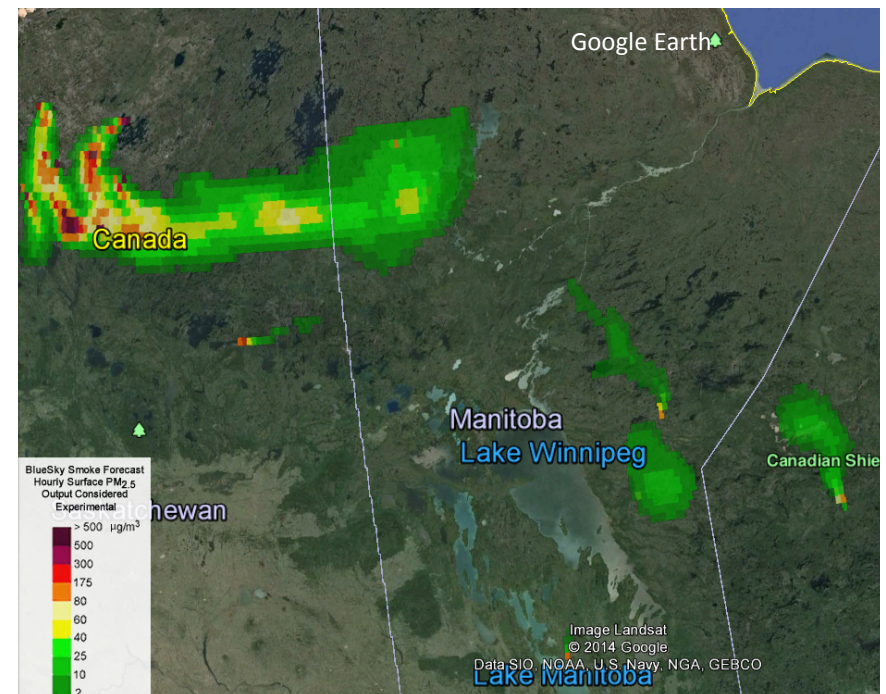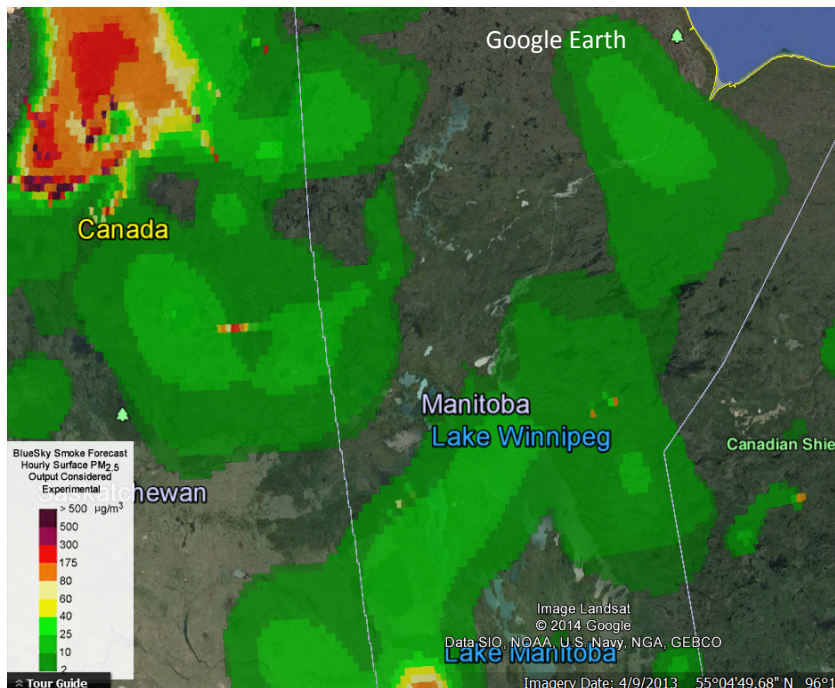Thick Clouds Obscuring Hotspot Detections on the Aug 18,19th

Initialization Error for Aug 19.
Forecast doomed to miss even if a perfect model

Thompson Hourly PM2.5, August 18, 19, 20

Initialization Error can swamp Model Approximation Error

Aug 18 am run: Forecast for Aug 19, 1100 CST

Aug 19 am run (missing hotspots) : Forecast for Aug 19, 1100 CST

How Do You Evaluate Performance?
Not a Trivial Exercise

- Compare to Observations – but they have issues.

Evaluate Plume Coverage/Shape:

Compare to satellite images

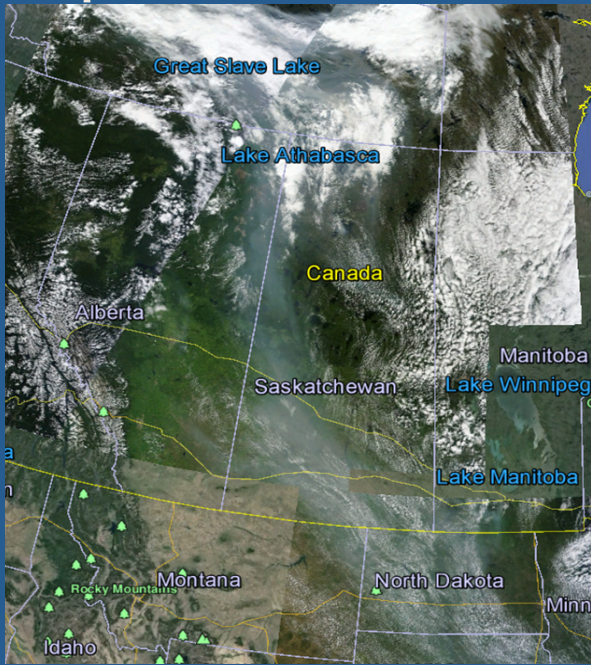- HMS plumes: estimated (error)

- Integrated Column not surface smoke

- Cloud cover

- Daylight periods only

Plume Spatial Agreement

- Qualitative: forecast plume compared to satellite image

- Statistic: Figure of Merit in Space (FMS): forecast plume spatial extent compared to HMS plume shape (0 to 1).

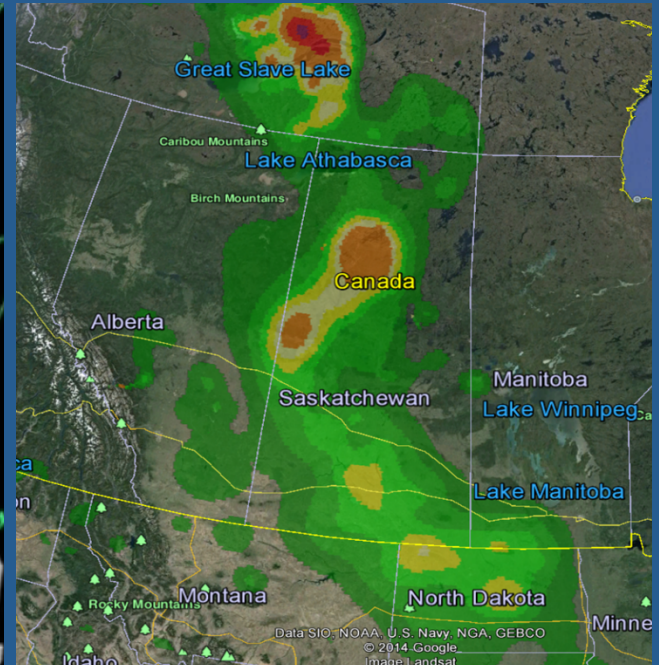# Spatial Smoke Coverage Comparison: July 8, 2014 1700 UTC

NASA EOSDIS Earth Data MODIS

NOAA HMS Fire and Smoke Product

Google Earth

MODIS July 8 (1625-2100 UTC)

July 8 HMS Analysis

BlueSky Canada July 7 a.m. forecast for July 8 (1800 UTC): surface plume

FMS = 0.47

How Do You Evaluate Performance?

<u>Evaluate Site-Specific Concentrations of PM$_{2.5}$ and Timing</u>

Compare to ground level measurements at monitors.

- Data quality (drift, saturation, different instruments)
- Limited locations at fixed points (local effects)
- Includes both Smoke and Non-Smoke contributions (vehicles, industry….) – what part is smoke?

Measures of agreement between the forecasted concentrations and measurements (unpaired and paired in space and time)

- Statistics: Mean Bias, Root Mean Square Error, Mean Absolute Deviation, Index of Agreement, Pearson Correlation Co-efficient…….
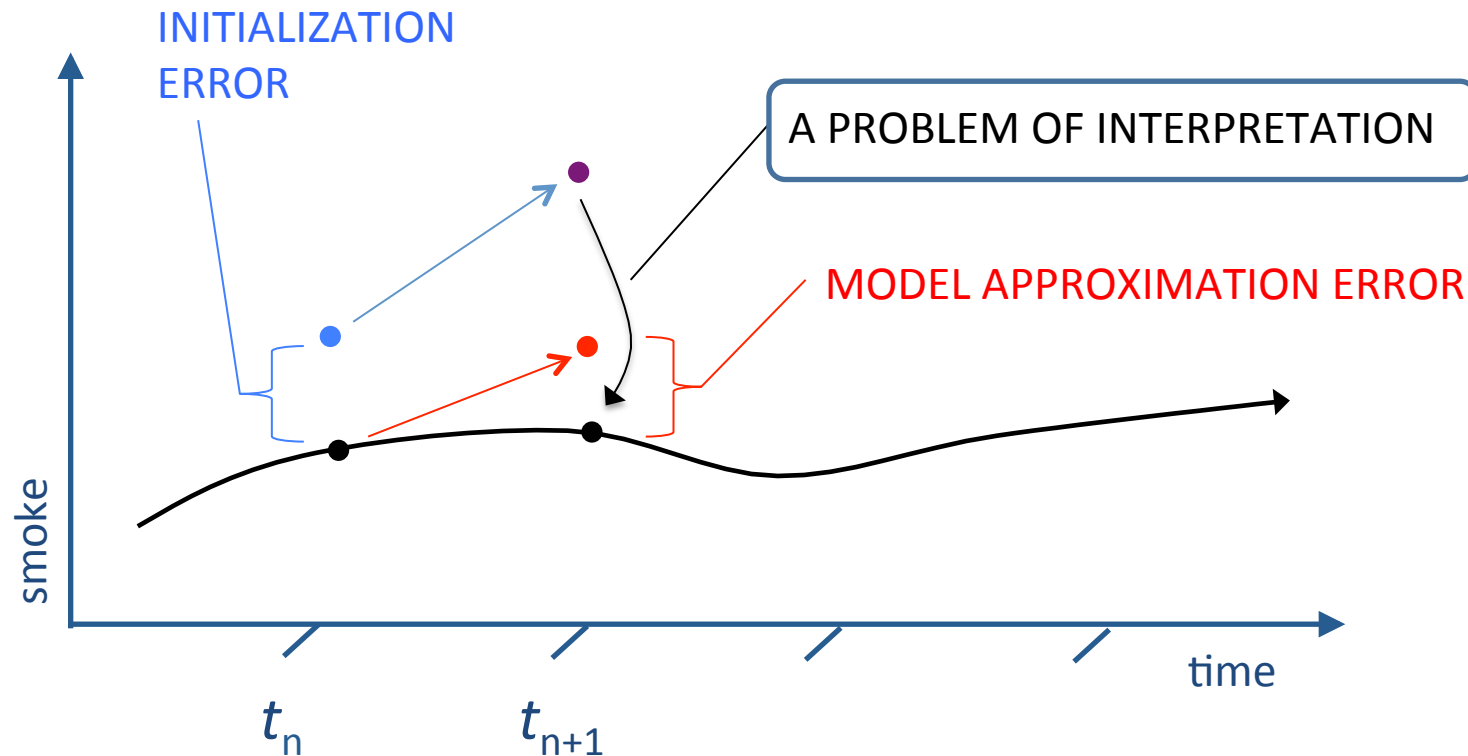
Performance Studies (BlueSky Canada)

- B.C. [2] : $PM_{2.5}$ measured at 60 air quality stations (July 24 - Aug 29, 2010)
- Daily avg $PM_{2.5}$ all stations, r = .4
- Plume Shape: FMS = .21 (up to .5 during major fire events) – forecast spatial coverage is less than observed
- "modest agreement"
- Associations between forecast and respiratory health indicators

- Alberta[4]: $PM_{2.5}$ measured at 32 air quality stations (May - Oct, 2 years)
- hourly $PM_{2.5}$, paired in space and time: r = .33
- Plume Shape: good qualitative agreement with observed[3]
- Applied fusion of observations with model output to improve short-term forecast skill: 6 hr forecast, r = .6   (see poster)

Performance Statistics: Only Part of the Story

- Smoke from wildfires 1000 km away

- Compare forecast to observed hourly, site specific concentrations (stringent test): timing off 5 hours, plume location off 50 km.

- poor performance statistics: no value in forecast?

- Human Interpretation: can still *find* value in forecast.

  - regional forecast
  - daily avg
  - source identification,
  - provides "heads-up"
  - explains phenomena ("hazy sky")
  - event duration

Smoke Forecast Models: Sources of Error
(from Larkin, 2013).

INITIALIZATION ERROR

A PROBLEM OF INTERPRETATION

MODEL APPROXIMATION ERROR
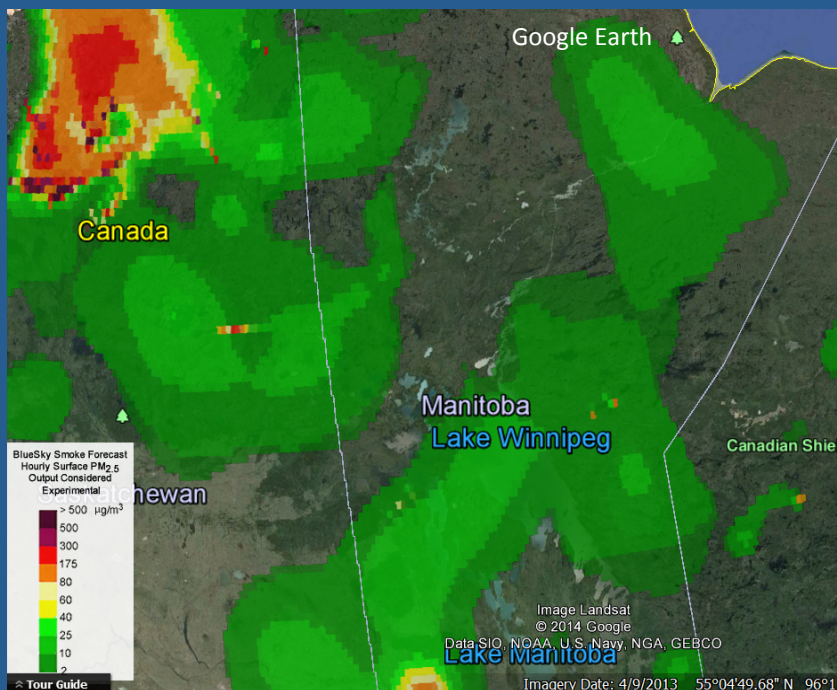
smoke

t_n

t_{n+1}

time

Human Interpretation can *add value* by considering:
- past forecasts , initialization errors, model tendencies (example: short-term bursts of high concentrations), severity of miss (timing, location)…..
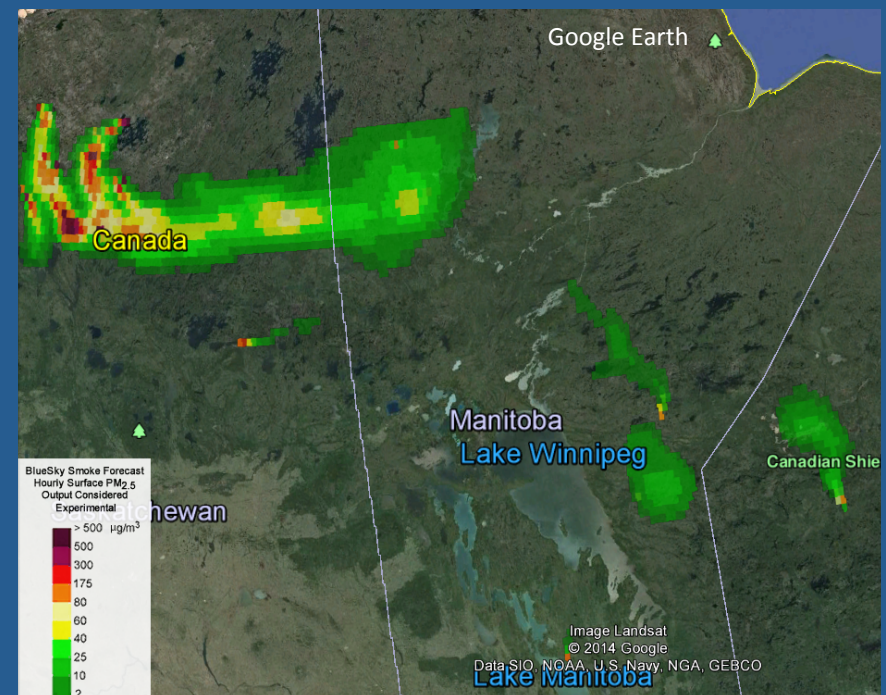
Forecast for Aug 19

- Don't use forecast generated on Aug 19 (large initialization error: missing hotspots)
- Use forecast generated the previous day (more complete hotspots)

Aug 18 am run: Forecast for Aug 19, 1100 CST

Aug 19 am run (missing hotspots) : Forecast for Aug 19, 1100 CST

Human Interpretation:
helps provide a smoke forecast that will benefit decisions

Finds and Adds Value to Smoke
Forecast Model output
Link to decision-makers

Smoke Forecast
Model

past forecasts

model
tendencies

initialization
errors

fire behaviour

Smoke
Resource
Advisor

expert
"experience"

air quality
network obs!

satellite

webcams

local reports

current/future meteorology

Summary

- How good does it have to be? What is needed from the tool?
- Model Error:
  - Approximation: need better science
  - Initialization: critical, need to reduce
- Observations have issues (no gold standard).
- Performance Statistics: important but not the complete picture
- BlueSky Canada:
  - plume shape: generally consistent, coverage underestimated
  - site-specific concentration, timing: can have the right idea, but expect misses
  - forecast "misses" can still have value depending on need
- Fusion of obs with model output can improve short term forecast
- Human Interpretation (Smoke Resource Advisor): can find and add value to model produced smoke forecast to benefit decisions

References

1. Larkin, S. (2013). State of Smoke Models. International Smoke Symposium, University of Maryland, October 24-28, 2013

2. Yao J, Brauer M, Henderson SB. 2013 Evaluation of a wildfire smoke forecasting system as a tool for public health protection. Env Health Perspectives 121:10:1142-1147

3. Klikach, V., Lyder, D., Cheng, L., Sakiyama, S., Hicks, G., Anderson, K. (2012). The Development and Evaluation of the BlueSky framework for Western Canada. Paper 2012-A-507-AWMA, June 19-22

4. Ho, V., Lyder, D., Thi, A. (2014) An Evaluation of the Western Canadian BlueSky Smoke Forecasting System for 2012. Canadian Prairie and Northern Section, Air and Waste Management Association Annual Conference, University of Alberta, Canada. May 21-22
www.cpans.org/assets/2014-CPANS-Conference/Session-12-David-LyderUpdated.pdf