Combining Passive and Active Microwave Remote Sensing Data to Assess the Impact of Forest Fires on the Hydrology of Boreal Forests

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Chaire de recherche industrielle du CRSNG sur la valorisation des observations de la Terre en ressources hydriques

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Introduction

- Observed increase of temperatures in boreal regions has led to an increase in frequency and intensity of forest fires
- Fires can have numerous consequences on ecosystems and water cycle.
- Hydrological models can be usefull to assess the impacts on the hydrological regimes.
- They necessitate sufficient input data to produce reliable results.
- Ground measurements are very scarce in remote regions like boreal forests.
- Remote sensing can provide useful information in this context.

Introduction

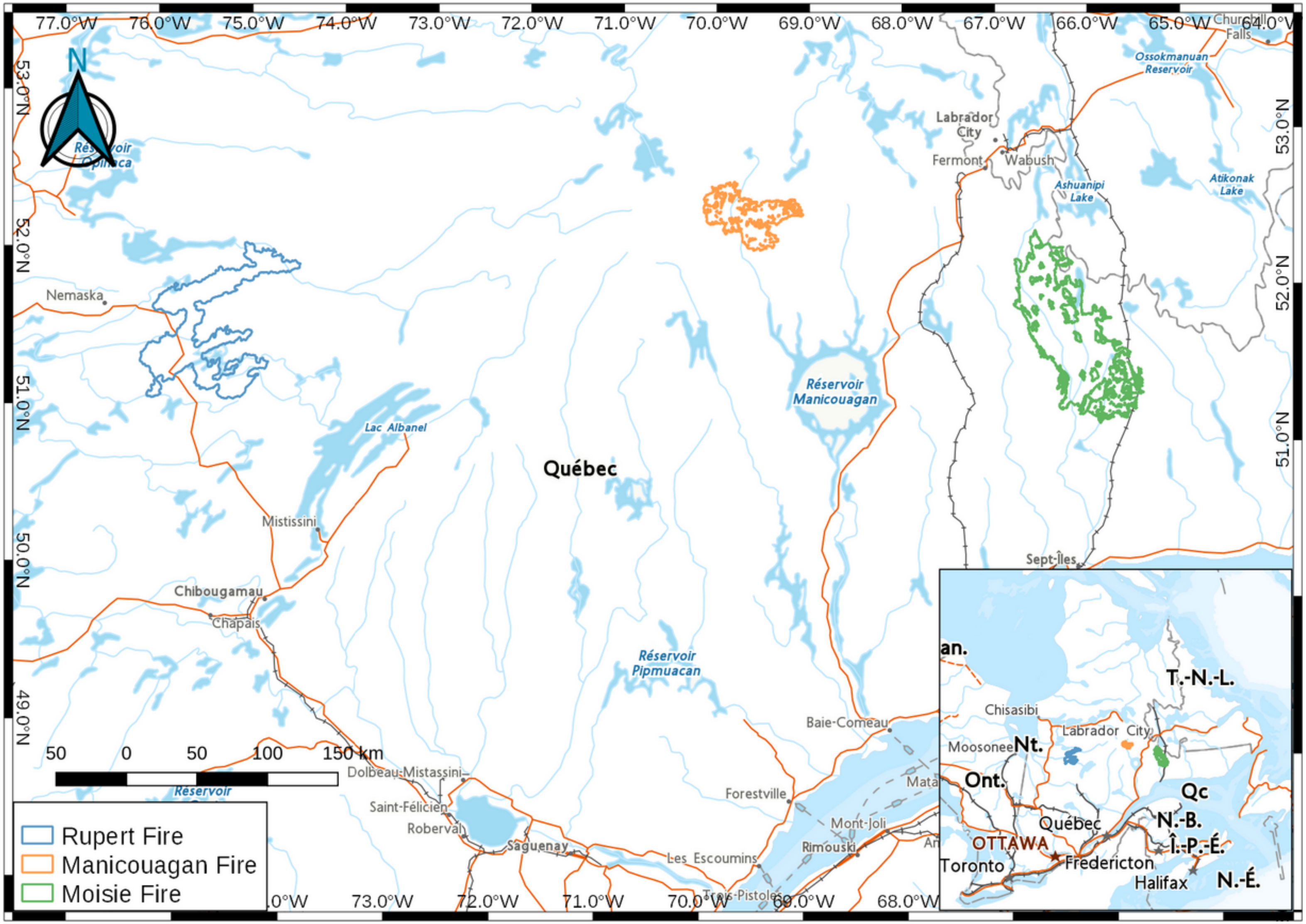
Project objectives:

- Estimate the impact of forest fires on hydrology of boreal forests
  - Analyze the impact of forest fires on SMOS and SMAP soil moisture products
  - Downscale SMOS and SMAP soil moisture products using Sentinel-1
  - Introduce downscaled SM products into hydrological models

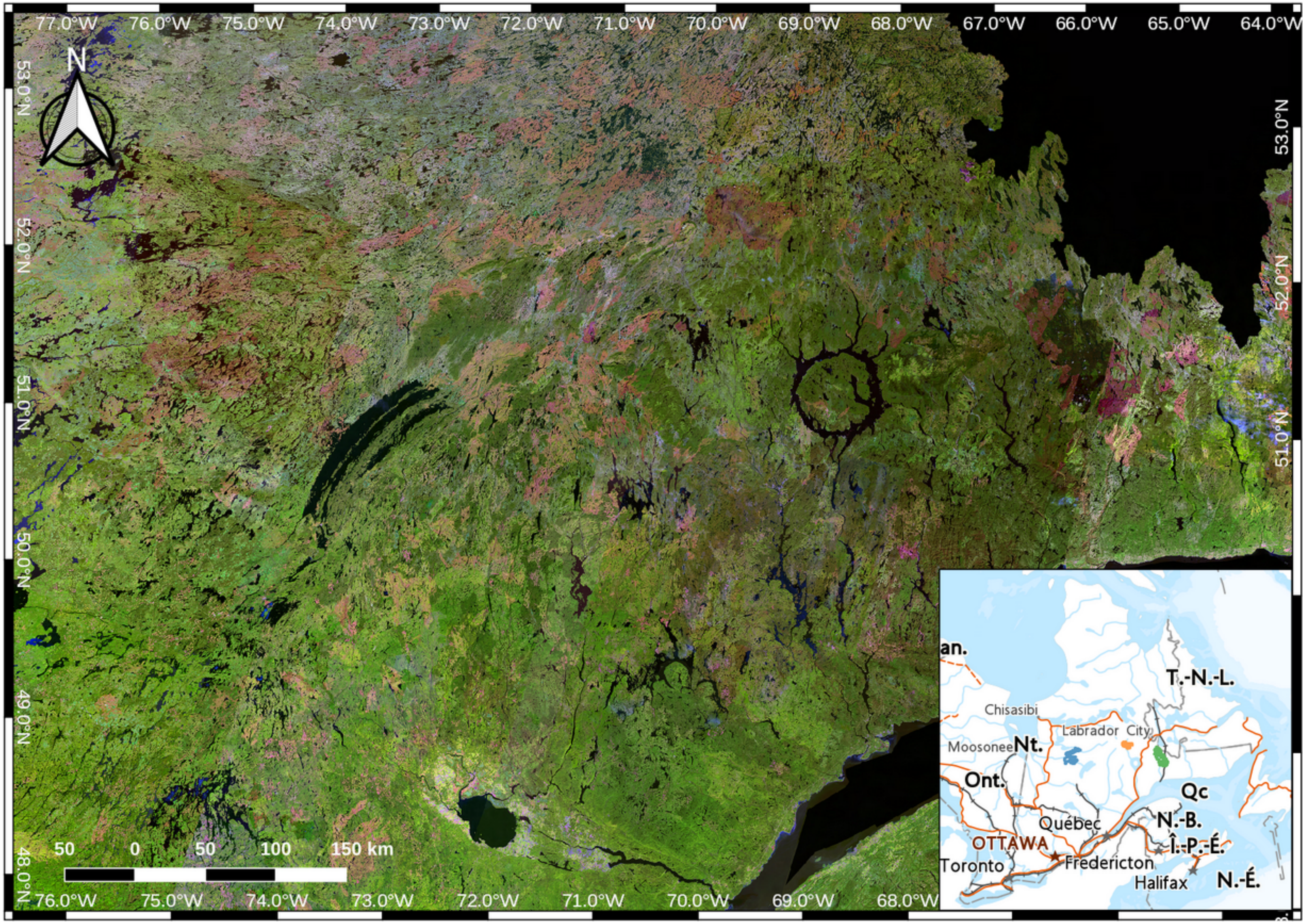
Forest Fires

- Major fires in Northern Quebec in 2013
  - Total of 3 023 150 hectares burned during that summer.
  - Most of them caused by lightning and some caused by human activity.
  - Most of the fires during June and July
  - 3 main fires of interest: Rupert watershed (457k ha), Manicouagan watershed (238k ha) and Moisie watershed (473k ha).

Forest Fires



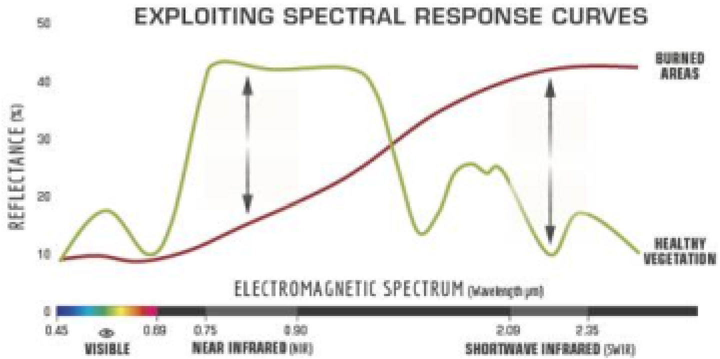
Forest Fires



Forest Fires

- Estimate fire intensity using Normalized Burn Ratio (NBR)

$$NBR = \frac{NIR - SWIR}{NIR + SWIR}$$



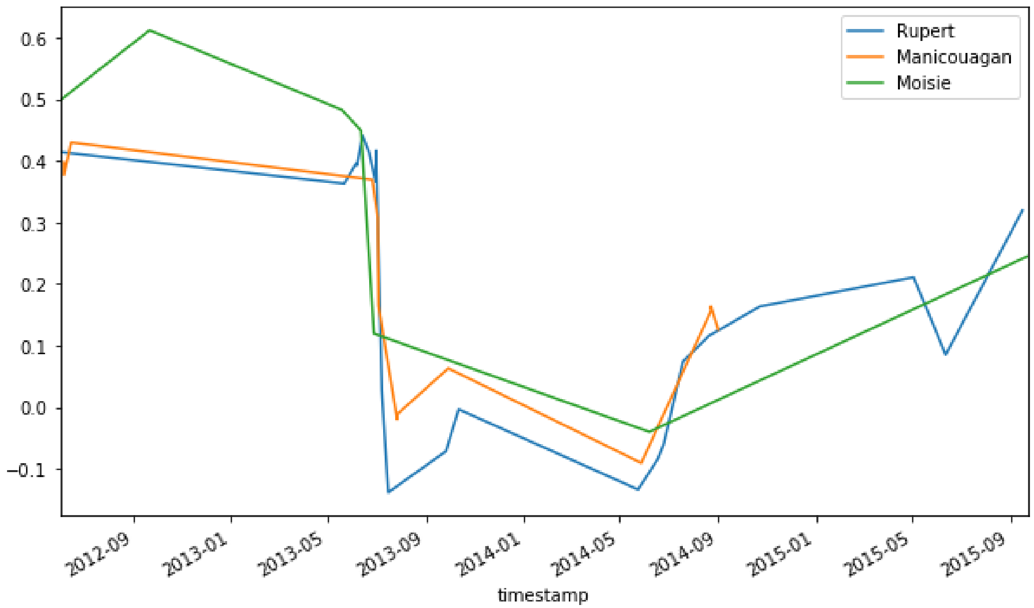
Source: U.S. Forest service.

- Burn severity → ΔNBR
  - ΔNBR = prefireNBR – postfireNBR
  - Two images from similar growth period

Forest Fires

- Total of 42 Landsat 8 & 7 images :
  - 21 for Rupert, 14 for Manicougan, 7 for Moisie

Evolution of NBR for 3 fires in 2013

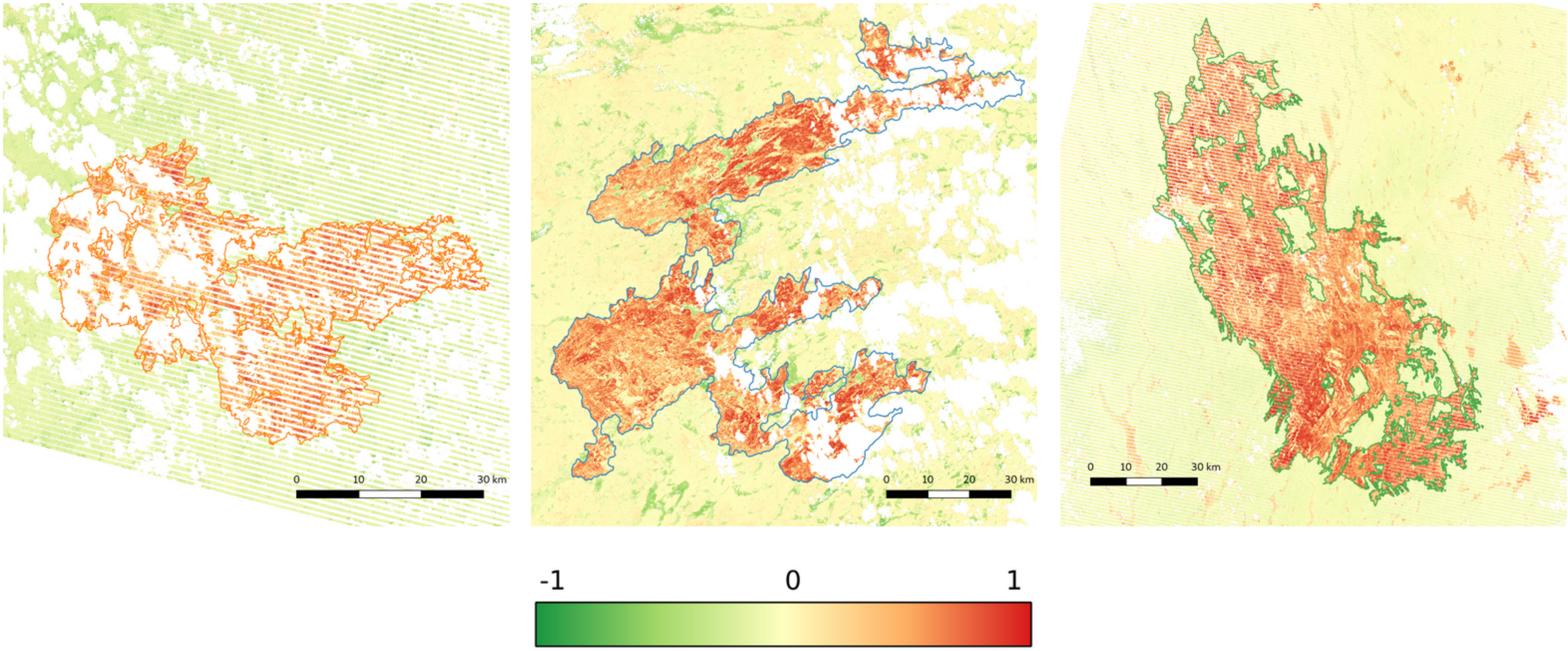


Selected ΔNBR couples

Fire	Dates	ΔNBR
Manicouagan	2012/06/06 2013/07/27	0.39
Rupert	2013/06/06 2014/05/24	0.53
Moisie	2013/06/12 2014/06/07	0.49

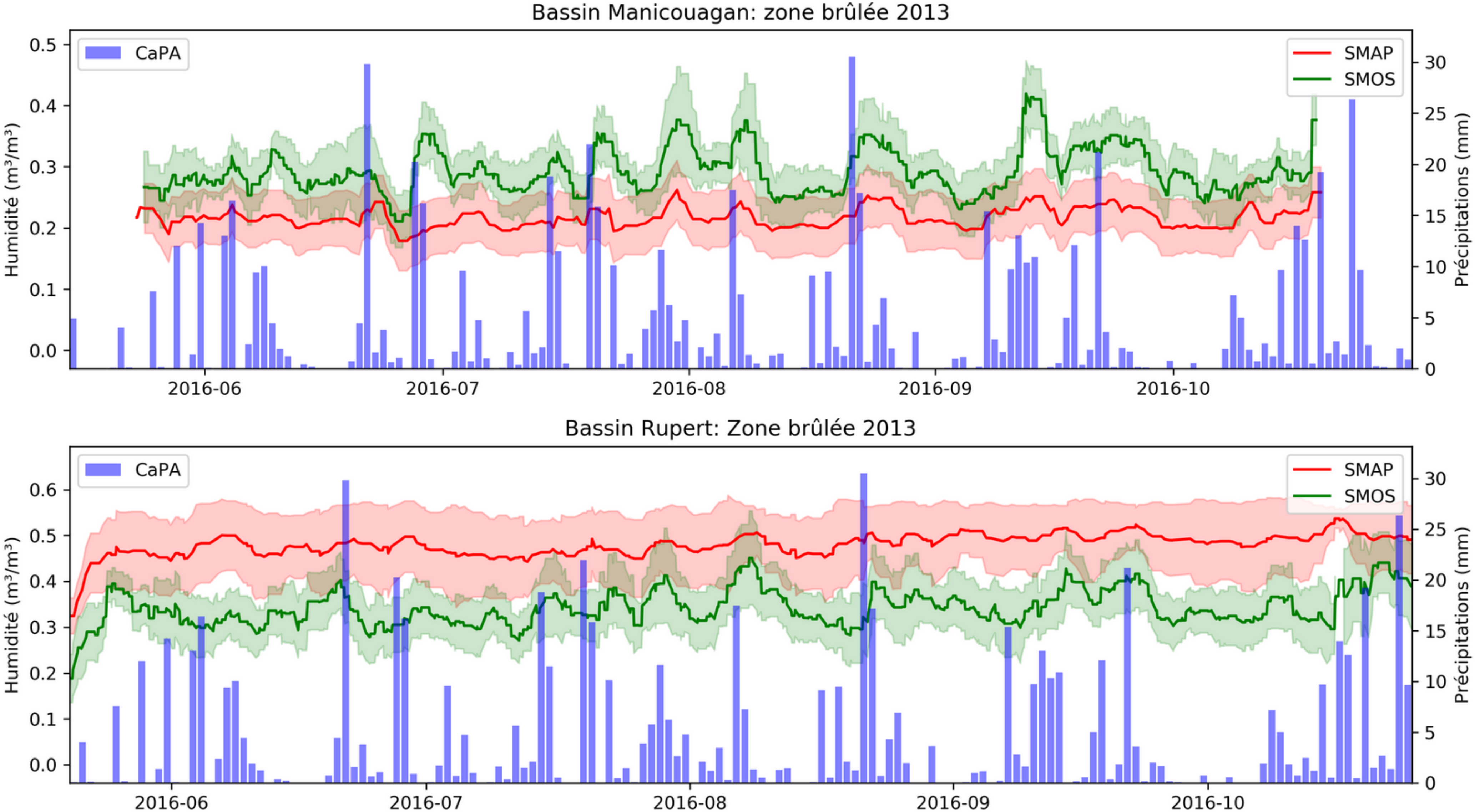
ΔNBR Maps

Manicouagan | Rupert | Moisie



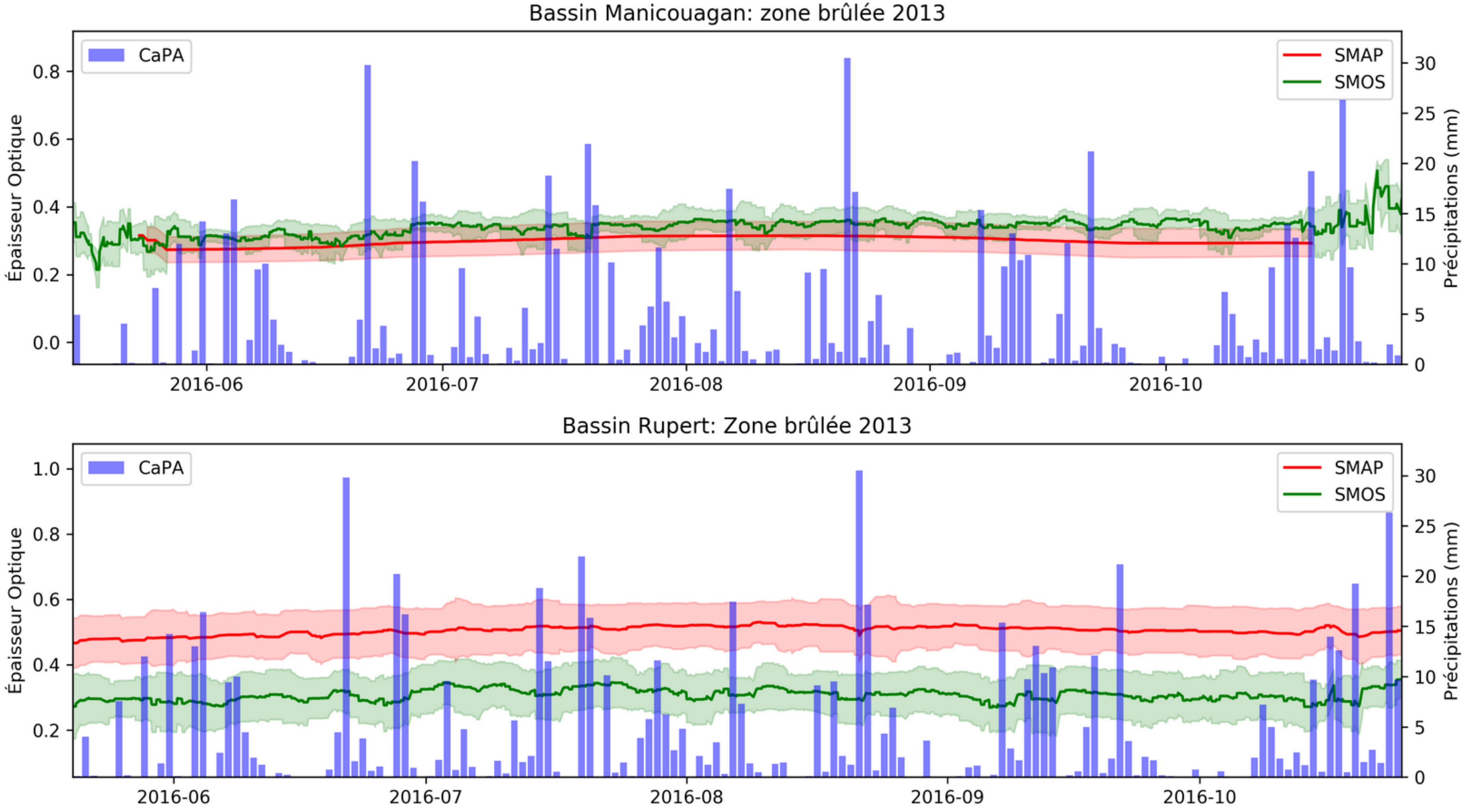
Forest Fires

Soil moisture SMOS and SMAP 2016



Forest Fires

Optical Depth SMOS and SMAP 2016

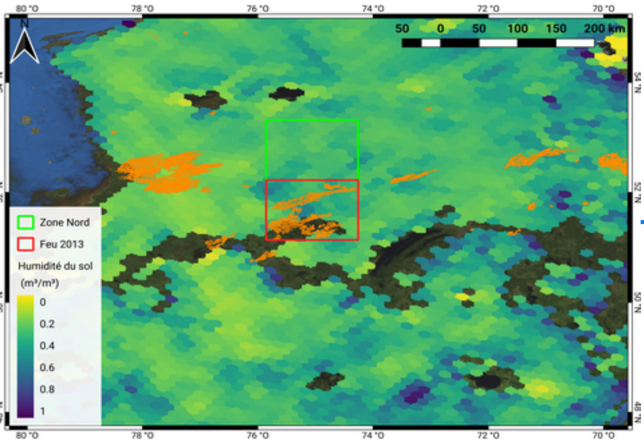


Downscaling

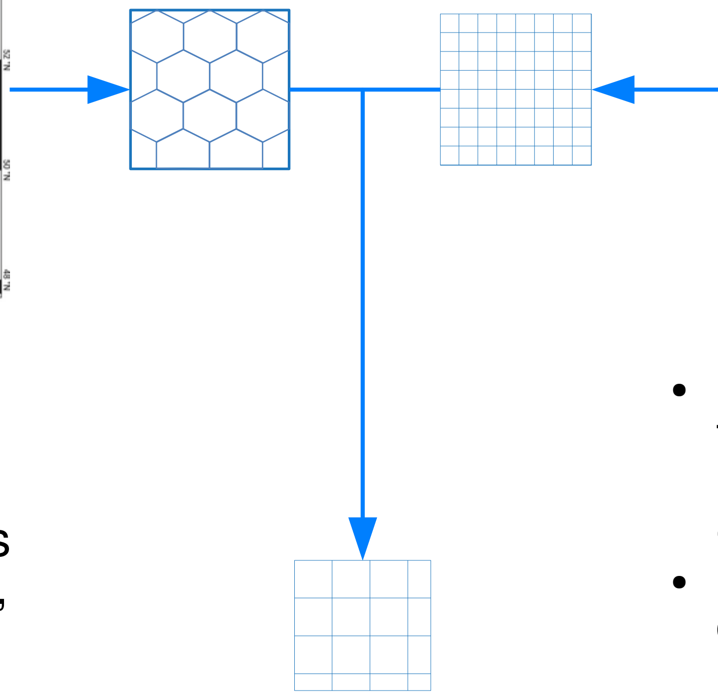
- Combine Passive Microwave with Sentinel-1 SAR to improve spatial resolution.
- C-band Sentinel-1 data does not penetrate the forest canopy very well so very little influence from soil moisture.
- Use the relationship between SAR backscattering and forest biomass to relate Sentinel-1 with SMOS Optical depth.
- Establish the relationship using machine learning.

Downscaling

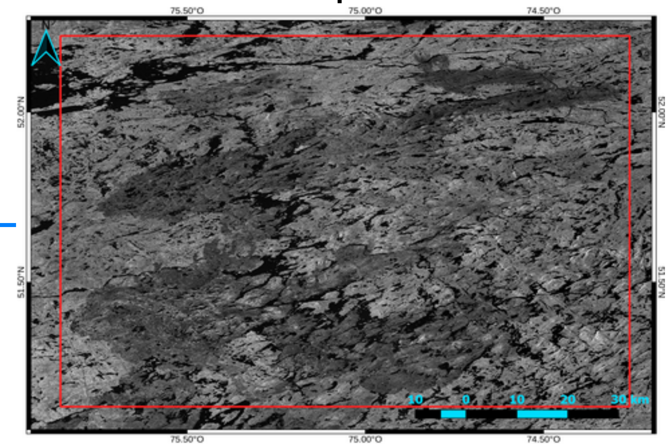
Level-2 SMOS product



- Each Sentinel-1 image is covered by ≈250 SMOS pixels.
- Total of 42 Sentinel-1 images were used to train the model, 2015 to 2017 between April and October



Sentinel-1 Interferometric Wide dual-polarisation



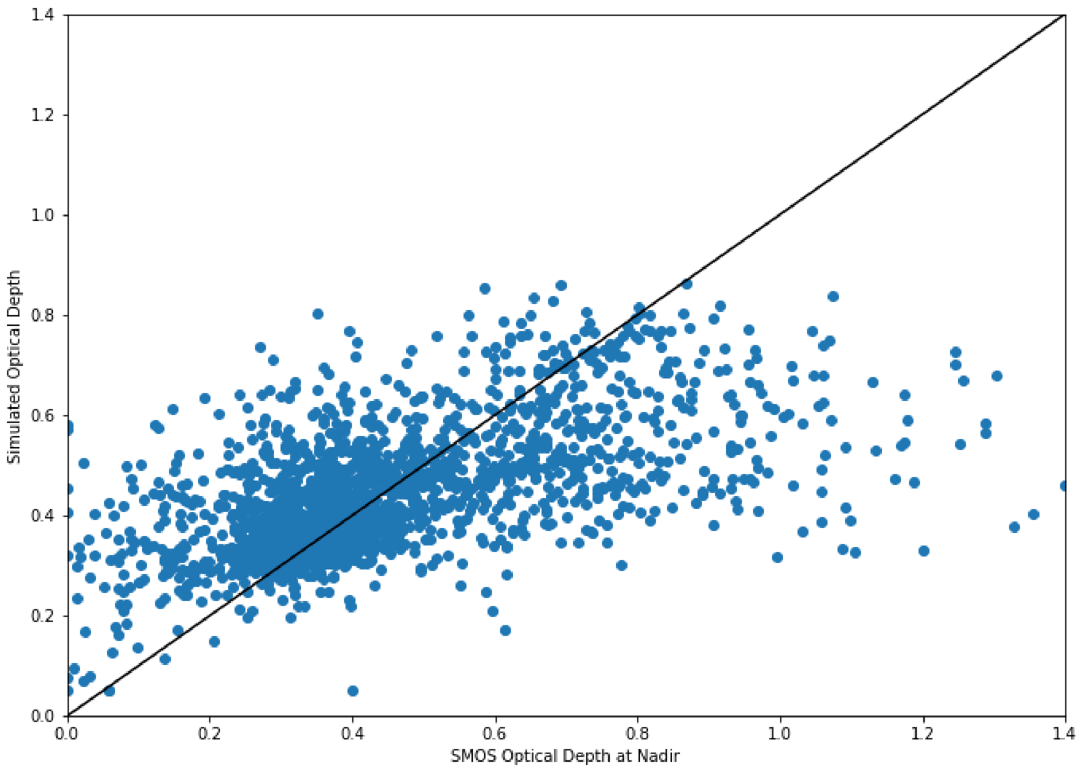
- Use a Random Forest model to establish relationship between sigma and SMOS optical depth
- Use the average and standard deviation of Sentinel-1 backscattering at VV and VH polarisations as well as incidence angle and month as input features

Downscaling results

- Random Forest model: underwhelming...

	R^2	RMSE
Out-of-bag	0.370	0.167
Validation	0.365	0.168

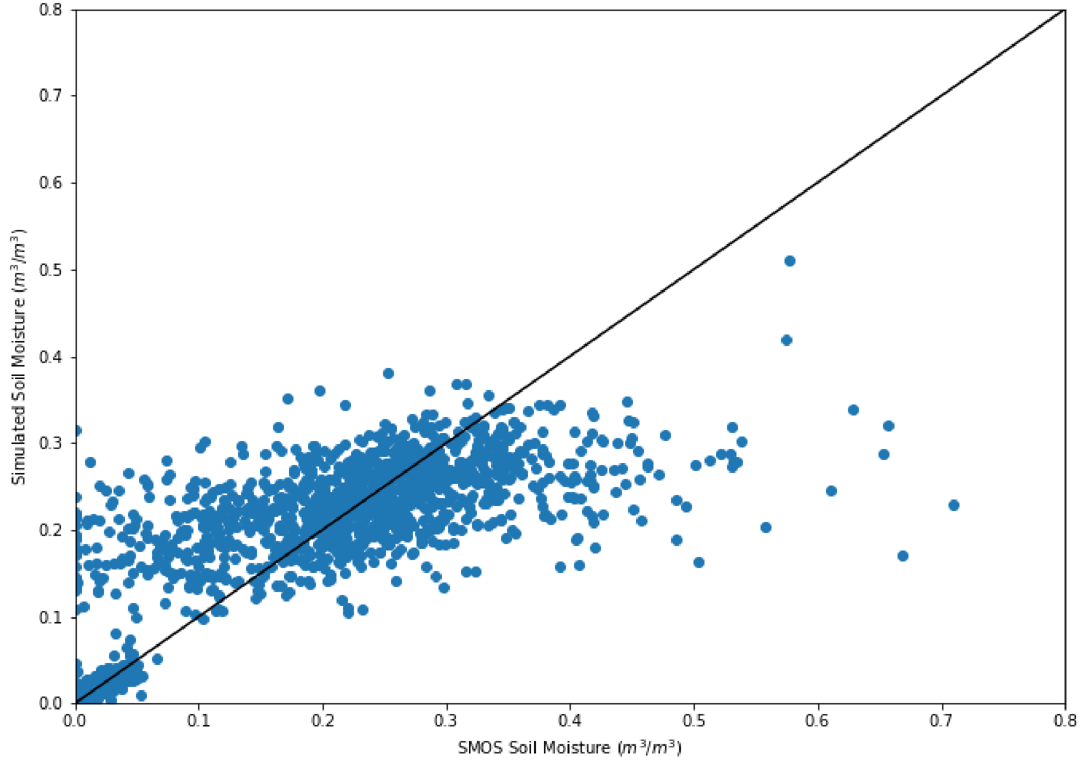
- Model tends to overestimate low values and underestimate high values



Downscaling results

- Test Random Forest model directly on Soil Moisture from SMOS

	R^2	RMSE
Out-of-bag	0.521	0.083
Validation	0.523	0.085

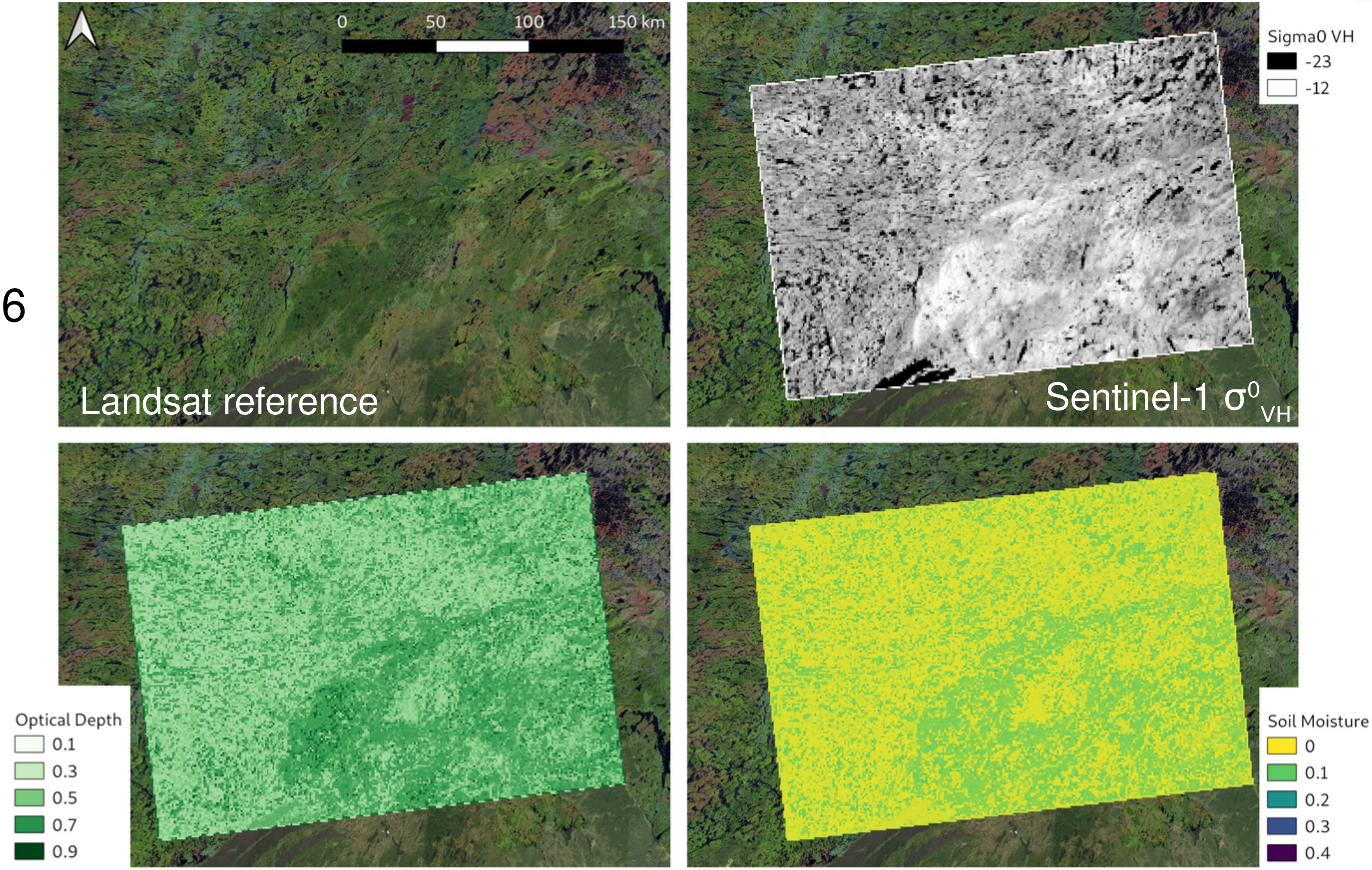


- Again model tends to overestimate low values and underestimate high values

Downscaling results

Test with Sentinel-1 image from July 18 2016

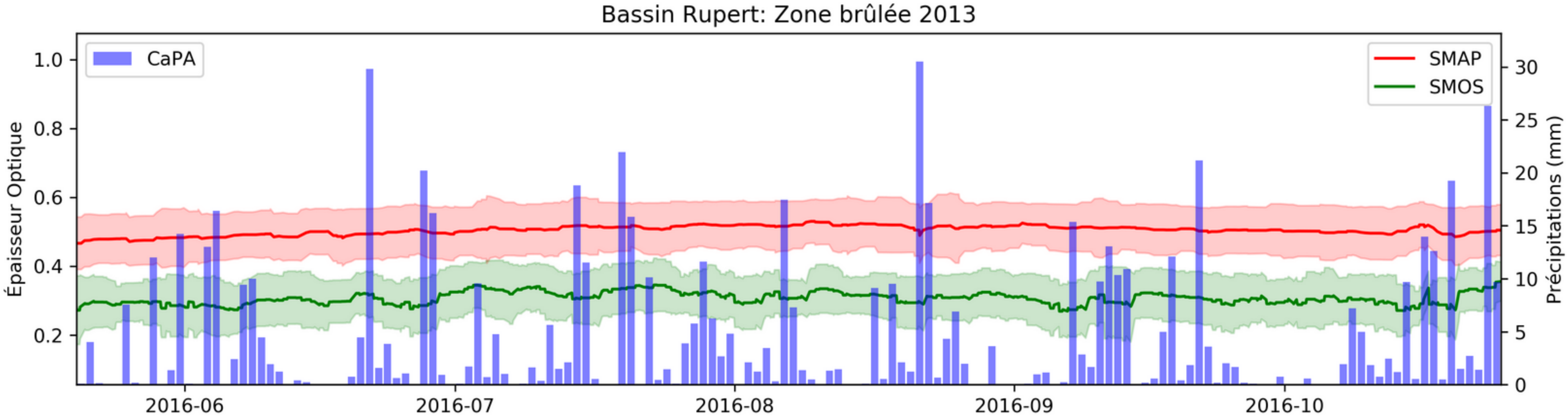
Resampled at 1 km resolution



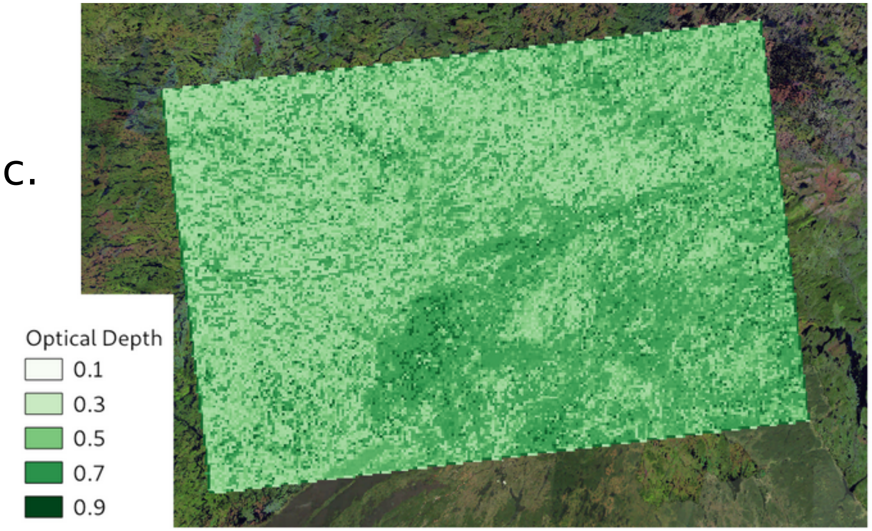
Modeled Optical Depth

Modeled Soil Moisture

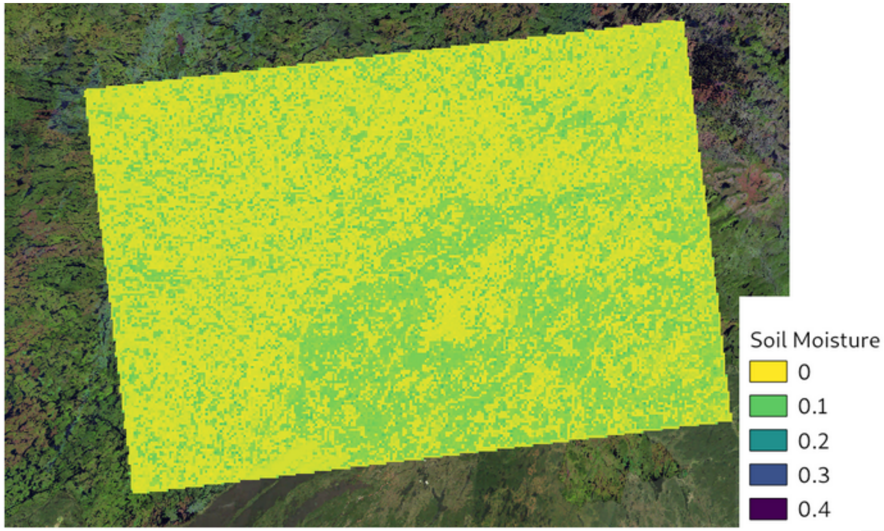
Downscaling results



Range of Optical depth seems realistic.

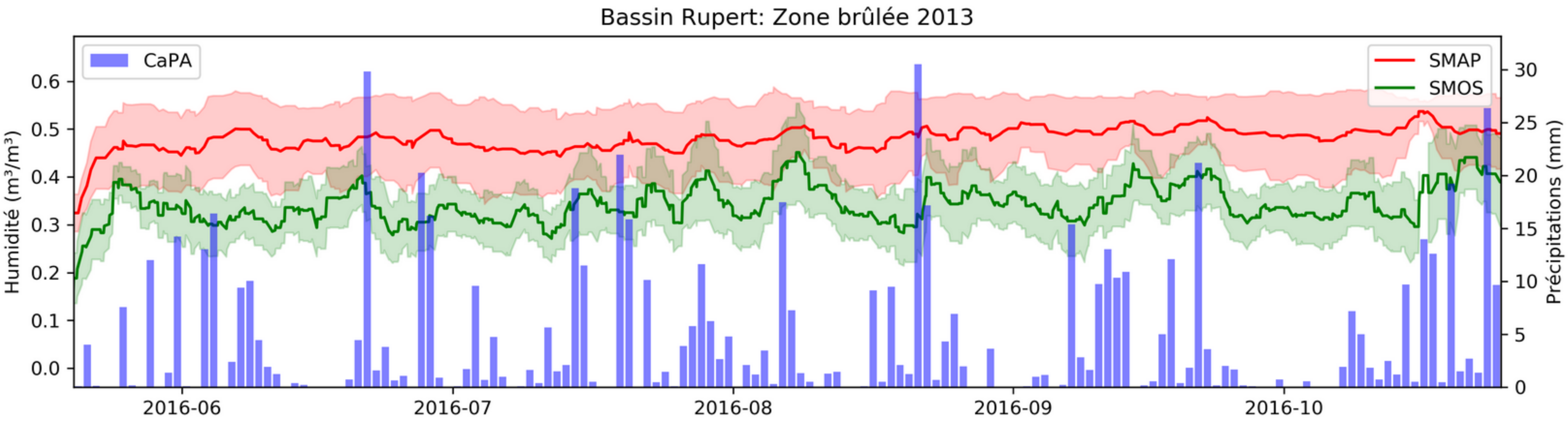


Modeled Optical Depth

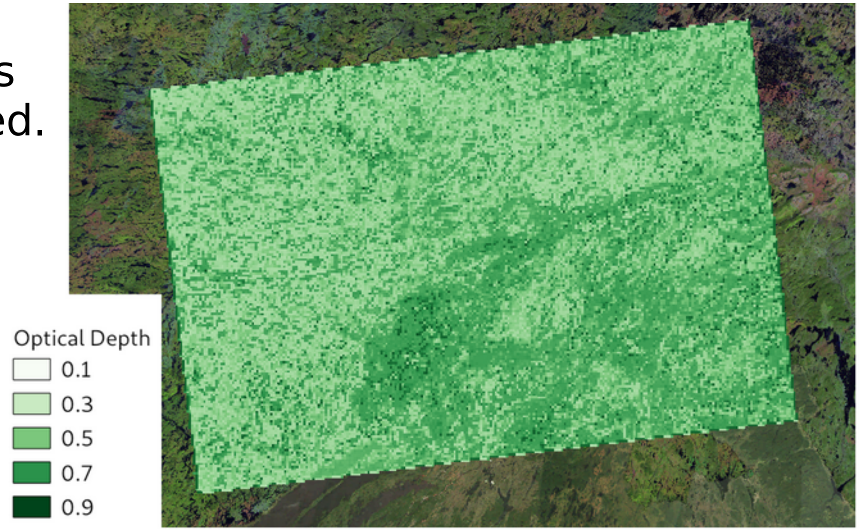


Modeled Soil Moisture

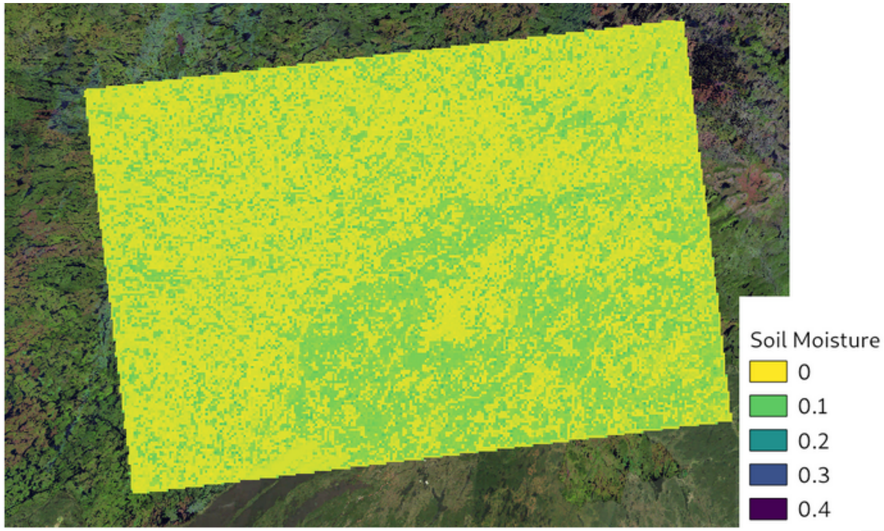
Downscaling results



Soil Moisture is underestimated.



Modeled Optical Depth



Modeled Soil Moisture

Conclusion & perspectives

- Fires have an impact on SMAP soil moisture retrieval in forested areas.
- Future work:
  - Work with more advanced radar image texture analysis to improve random forest model.
  - Test other machine learning methods.
  - Use the Level 3 SMOS data developed by Centre Aval de Traitement des Données SMOS (CATDS).
  - Use downscaled soil moisture information to calibrate a distributed hydrological model to assess the impact of forest fires on hydrological cycle.

Thanks to:

Questions?

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