Operational River Ice Monitoring in Canada using Earth Observation Data

FEWS User Days

Alberta Environment and Parks + Deltares

Background – The Alberta River Forecast Centre

- Based in Edmonton, Alberta, Canada
- 9 full time river forecasters, including **3 dedicated river ice specialists**
  - That's us!
- 24/7 operations year round
  - Maintaining situational awareness of Alberta's Rivers and weather conditions
  - Anticipating flood events
  - Communicating river conditions

River ice can cause a number of issues for communities and infrastructure operators, but the most significant of these are **ICE JAMS**

Ice Jam

- An accumulation of ice at a given location which, in a river, restricts the flow of water (IAHR 1980).
- In Alberta, ice jams can cause severe flooding by rapidly increasing water levels

Peace River: Ice Jam Flooding of Fort Vermilion (April 2020)

Challenges for ice forecasting in Alberta

- Alberta has a large and varied geographical area
  - Regulated/unregulated rivers, steep rivers/flat rivers, rivers that freeze in November/rivers that remain open all year
  - Ice jams and other ice issues may occur throughout the ice season
- Ice jam impacts are localized
  - But they can travel hundreds of kilometers
  - Alberta's robust river gauging network is not always sufficient
- Seeing is believing
  - An ice jam's length, location, and the history of the ice are all important factors in assessing the risk to communities

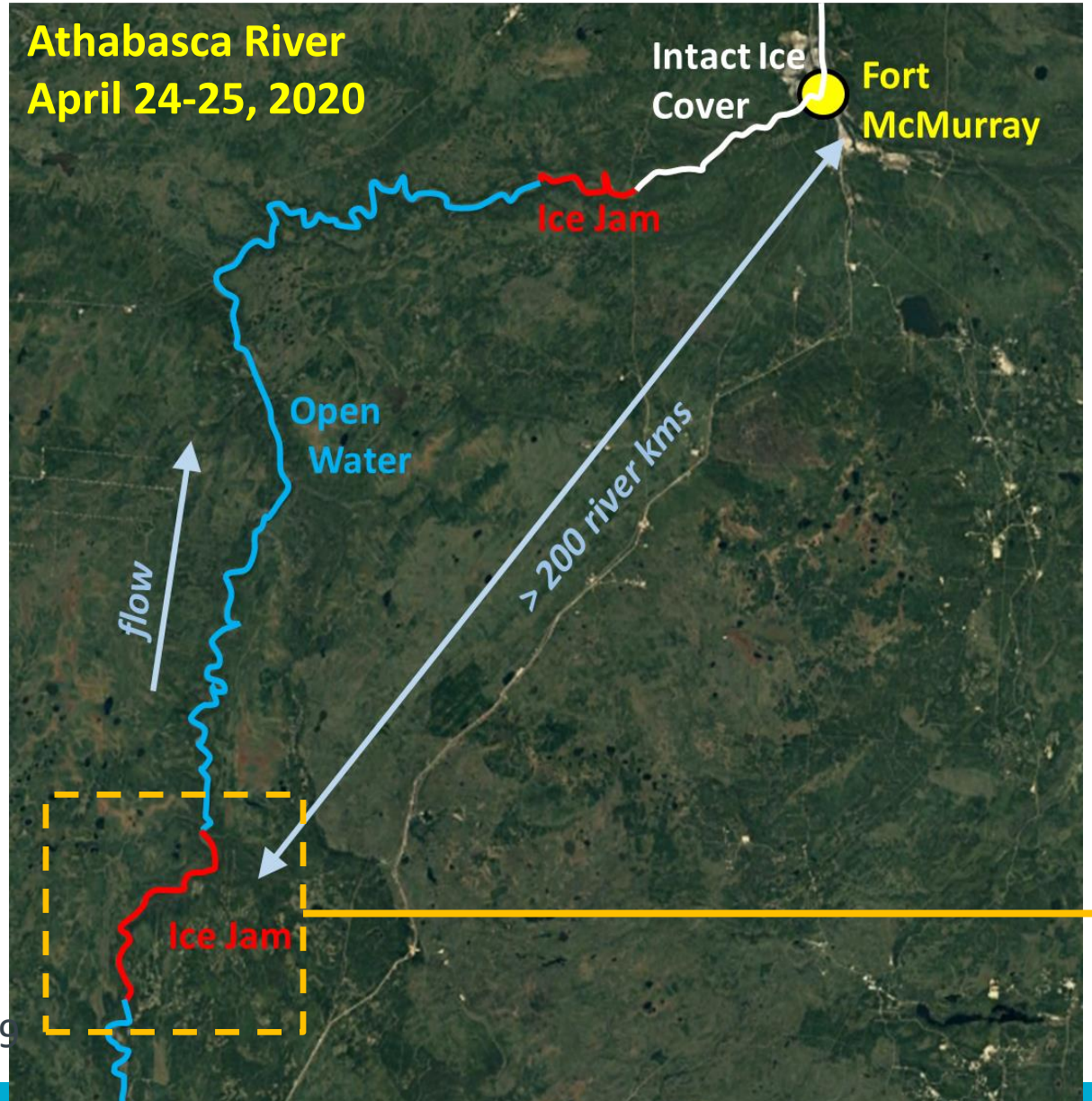
Remote sensing: an important tool

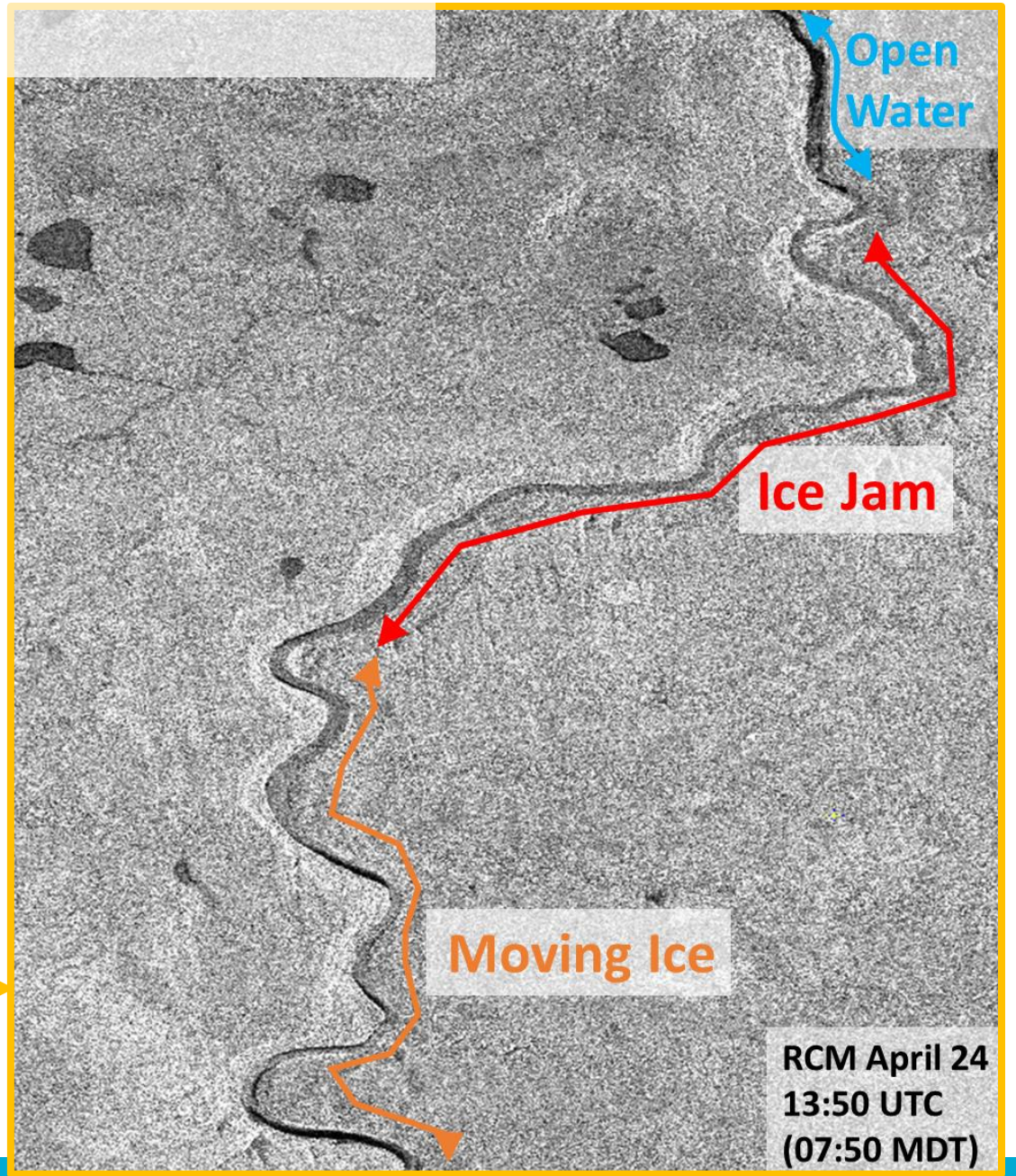
- Satellite images can provide observations where:
  - Gauge data may not be available or fully trustworthy
  - Aircraft observations may be impractical
  - Ground access is impossible
- Sentinel 1
  - European Space Agency RADAR band satellite images (free)
- Sentinel 2
  - European Space Agency visual band band satellite images (free)
- RADARSAT Constellation
  - New set of Canadian satellites

What does an ice forecaster want to know

- Is ice present?
- Is the ice moving or stationary?
  - Is there an ice jam that may move into a populated area?
- When did the ice form?
- Is the ice surface rough or smooth?
- Is the ice thick or thin?
- Is the ice covered with snow or water?

Tracking ice jams from upstream gives forewarning to communities



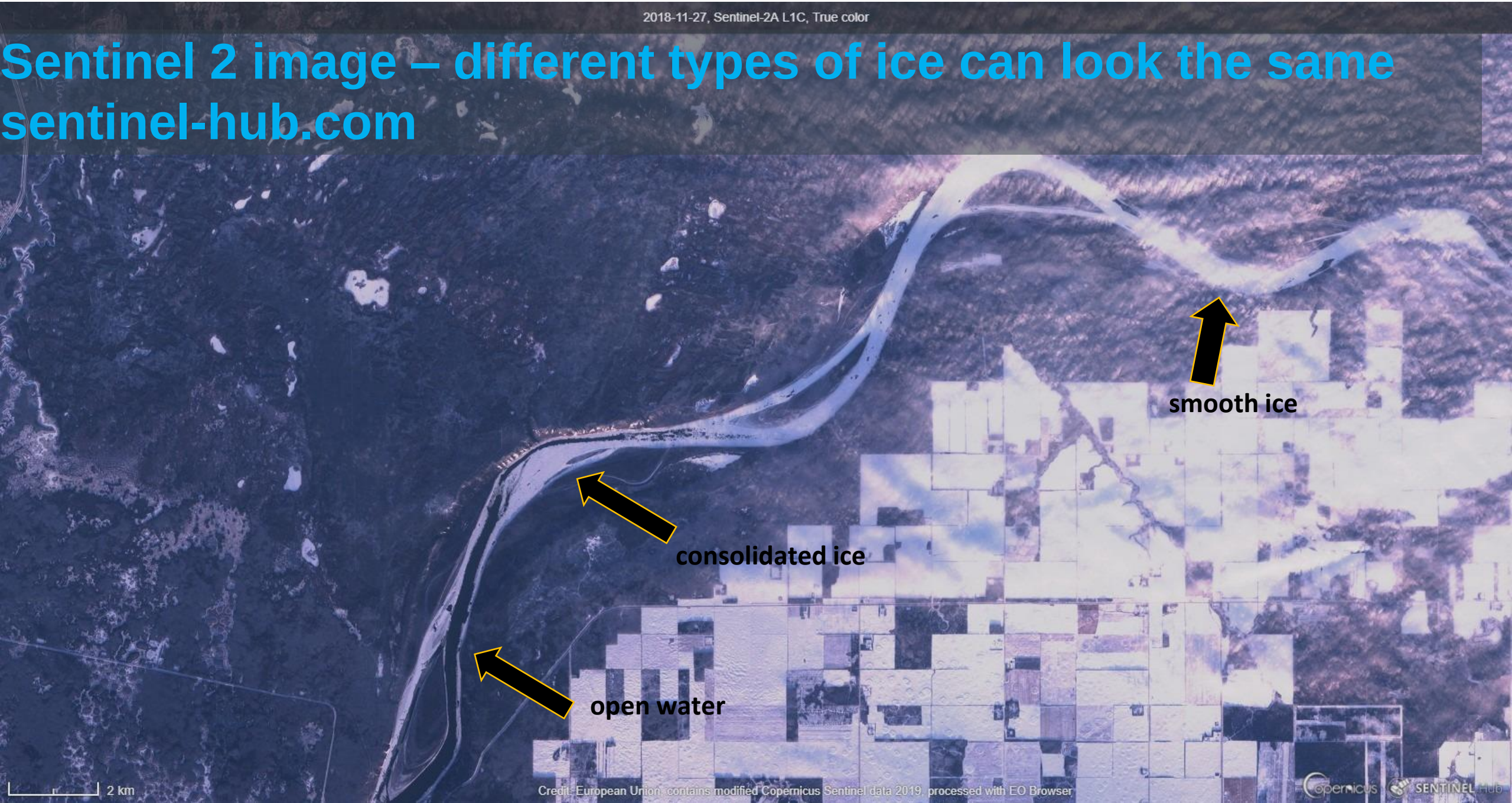


Breakup ice jam flooding
Fort McMurray, 29 Apr 2020

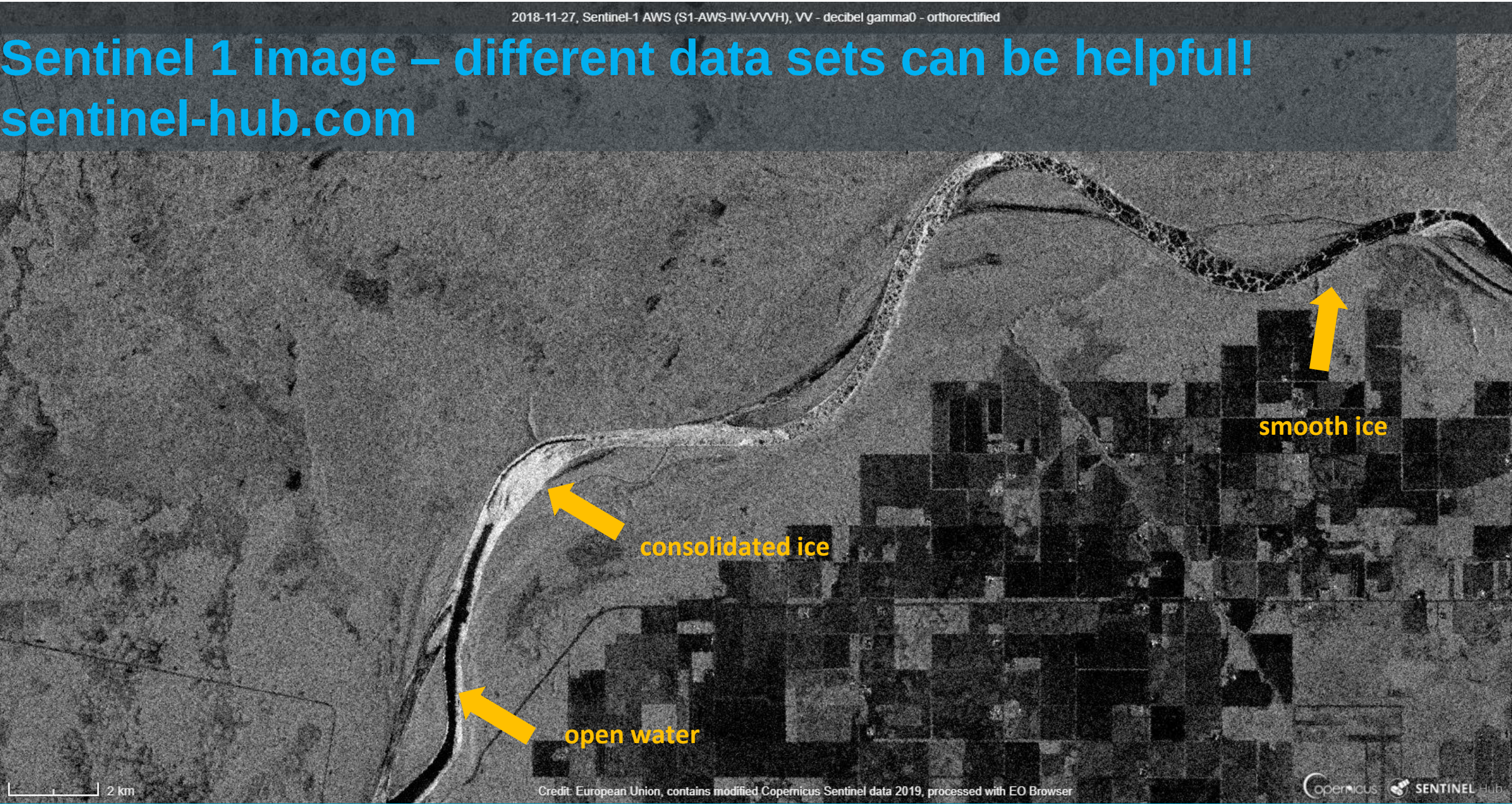
Juxtaposed (smoother) ice on the Peace River

Consolidated (rougher) ice on the Peace River

Sentinel 2 image – different types of ice can look the same
sentinel-hub.com



Sentinel 1 image – different data sets can be helpful!
sentinel-hub.com



The story of how the ice formed can have future impacts

Freeze-up ice jam (consolidation) on the Peace River, January 2018
Photo Credit: BC Hydro

Ice jam at breakup on the Peace River, January 2018
Photo Credit: BC Hydro

In order to provide accurate, advance warning for ice jams:

We want to know as MUCH as possible, as QUICKLY as possible, across as WIDE an area as possible

How can FEWS help us answer these questions?

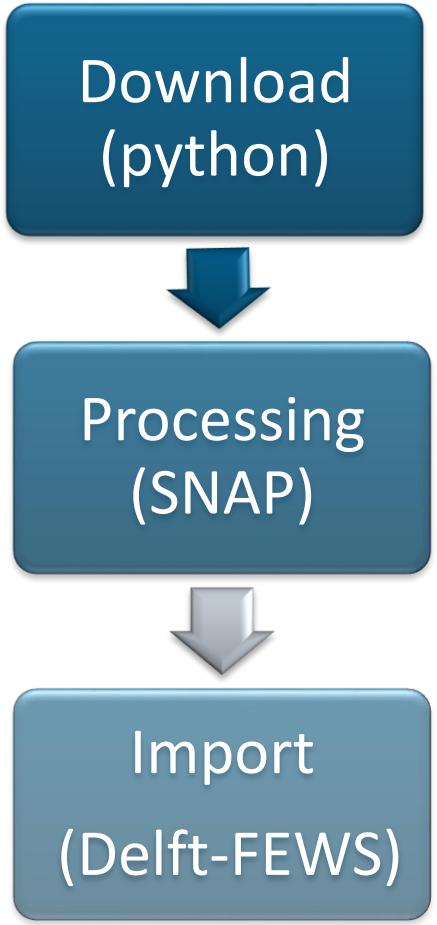
- Is ice present? Is there an ice jam in place that may threaten populated areas?
  - FEWS can ingest large quantities remote sensing data and display spatial data
- Is the ice moving or stationary? When did the ice form?
  - Display spatial data from remote sensing as a time series, and integrate different remote sensing data sources
- Is the ice surface rough or smooth? Is the ice thick or thin? Is the ice covered with snow or water?
  - These are the emergent questions for us
  - FEWS ability to integrate processing scripts and open source nature could help us answer them
  - Work is underway now by FEWS users to find new ways to analyze remote sensing data

Operational considerations

- Large volumes of data
  - 1 image ~ 1-2 GB
- Download from external servers
- Processing of raw satellite imagery to common data format
  - E.g. NetCDF

Operational considerations

- Three steps:
  1. Download of imagery using stand alone Python module
  2. Processing of data using SNAP (Sentinel Application Platform)
  3. Import and visualize data in Delft-FEWS



Using freely available software

Step 1: Download

- Executable in Python, which downloads Sentinel 1 and 2 data for certain bounding box and time window from Copernicus Open access Hub
- Scheduled daily to download latest imagery


```
<exportRunFileActivity>
  <exportFile>%WORK_DIR%\get_sentinel1.xml</exportFile>
  <properties>
    <string key="destinationDir" value="$IMPORT_FOLDER$\Sentinel-1\raw"/>
    <string key="user" value="$USERNAME_COPERNICUS$"/>
    <string key="secret" value="$PW_COPERNICUS$"/>
    <string key="mission" value="Sentinel-1"/>
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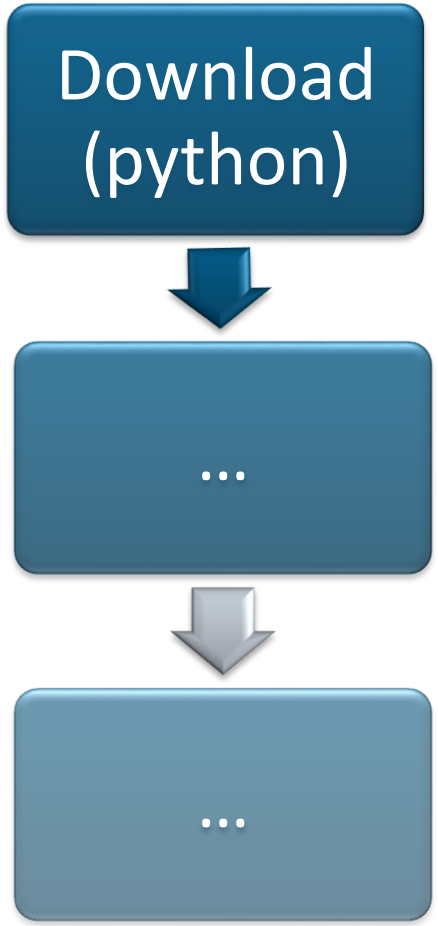


→ Currently working on similar scripts to download RCM data

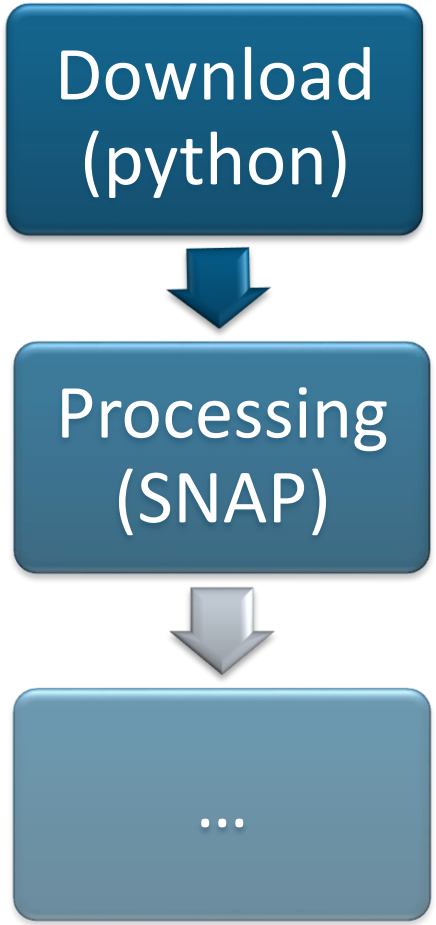
Step 2: Processing

- Processing of raw satellite image and export as NetCDF
- Done using XML templates read by the SNAP Graph Processing Tool (gpt)
- SNAP launched by General Adapter

graph

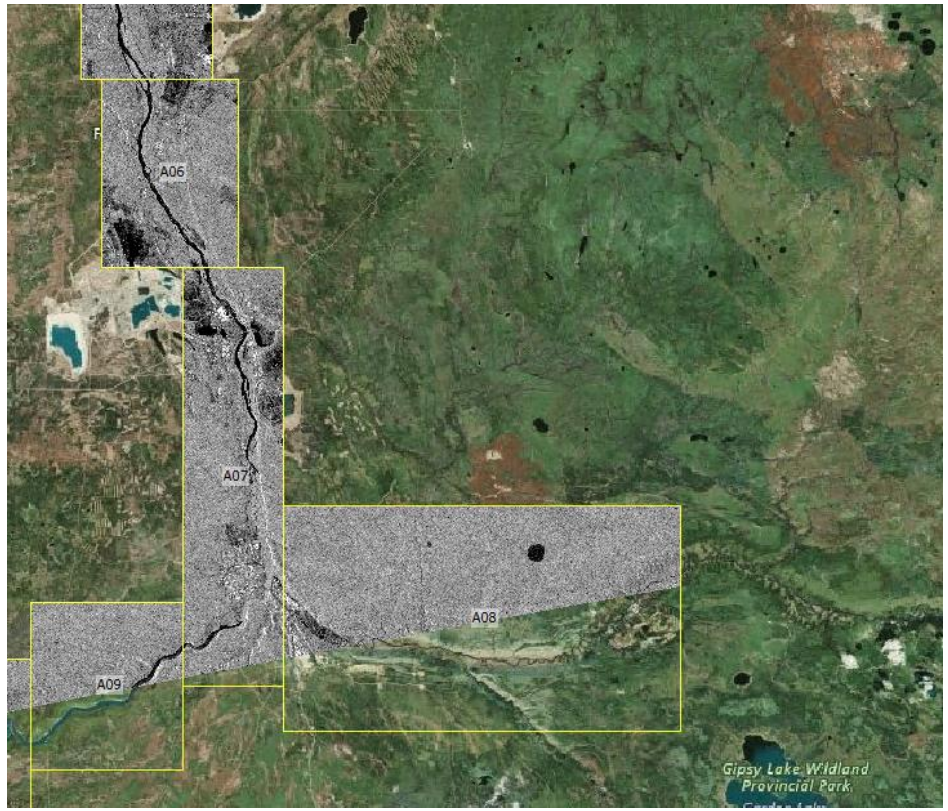
	= id	Graph
	{} version	1.0
	node (8)	

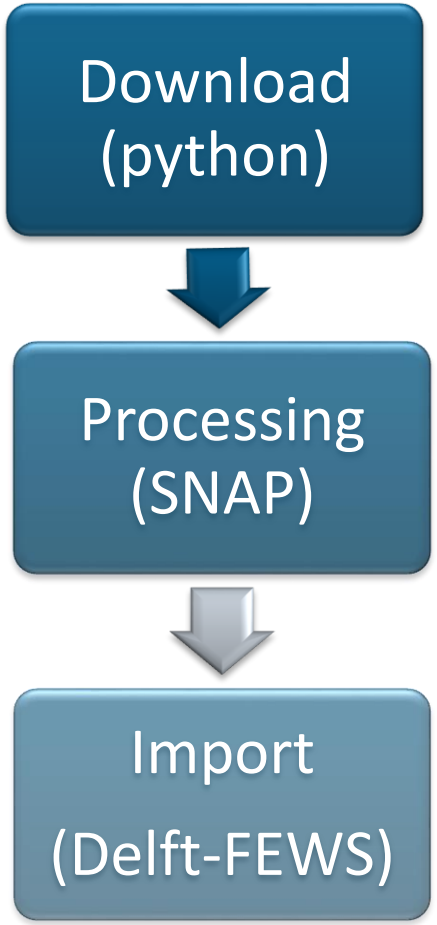
	= id	{} operator	{} sources	{} parameters
1	Read	Read		parameters class=com.bc.ceres.binding.dom.XppDomElement
2	Apply-Orbit-File	Apply-Orbit-File	sources	parameters class=com.bc.ceres.binding.dom.XppDomElement
3	ThermalNoiseRemoval	ThermalNoiseRemoval	sources	parameters class=com.bc.ceres.binding.dom.XppDomElement
4	Calibration	Calibration	sources	parameters class=com.bc.ceres.binding.dom.XppDomElement
5	Terrain-Correction	Terrain-Correction	sources	parameters class=com.bc.ceres.binding.dom.XppDomElement
6	Subset	Subset	sources	parameters class=com.bc.ceres.binding.dom.XppDomElement
7	LinearToFromdB	LinearToFromdB	sources	parameters class=com.bc.ceres.binding.dom.XppDomElement
8	Write	Write	sources	parameters class=com.bc.ceres.binding.dom.XppDomElement



Step 3: Import

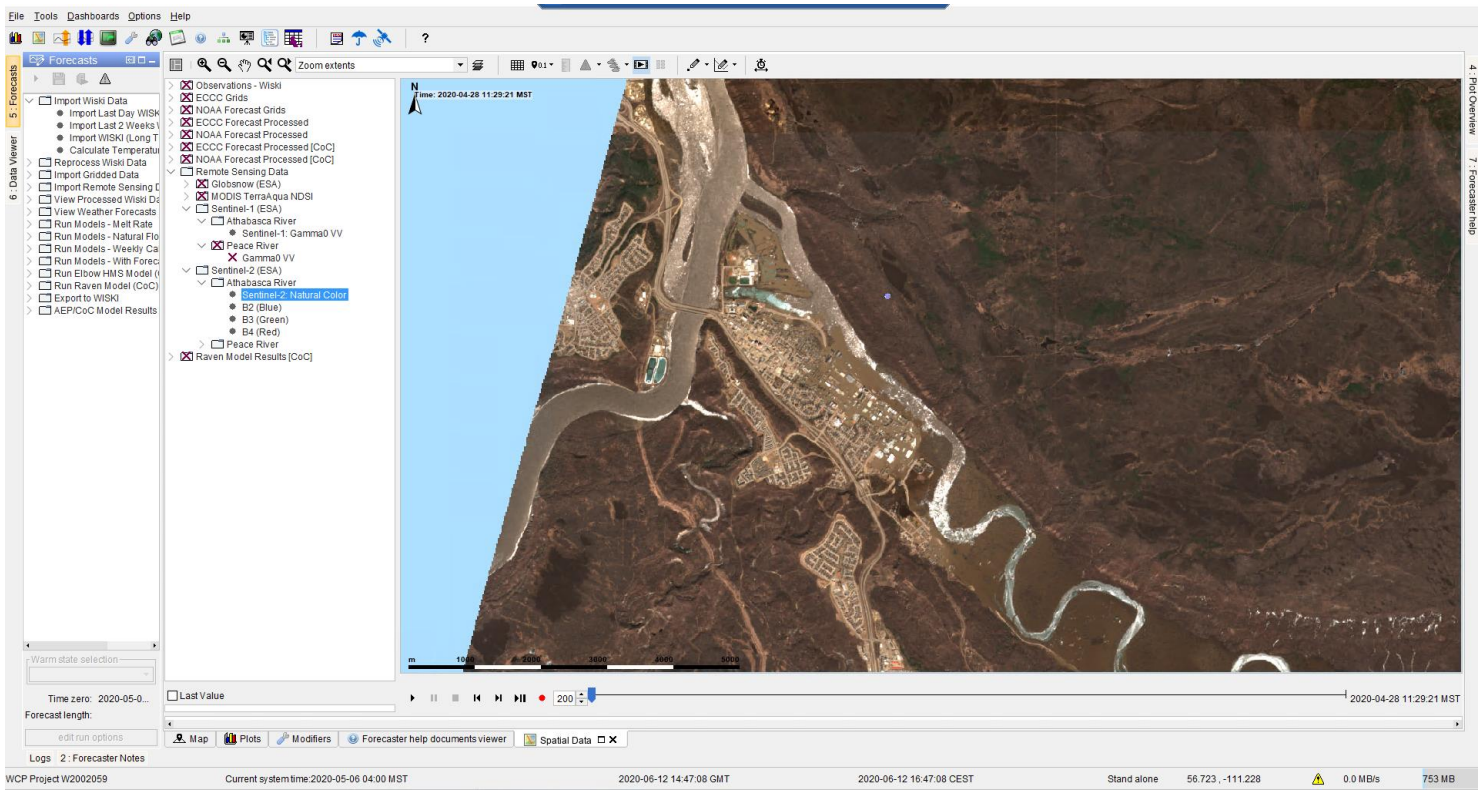
- General NetCDF import module to import processed images
- Clipped into smaller images around river extend to reduce import time





Step 3: Import

- Developed a Natural Color viewer → creates a composite image from 3 bands - RGB (each band represents a different part of the electromagnetic spectrum)

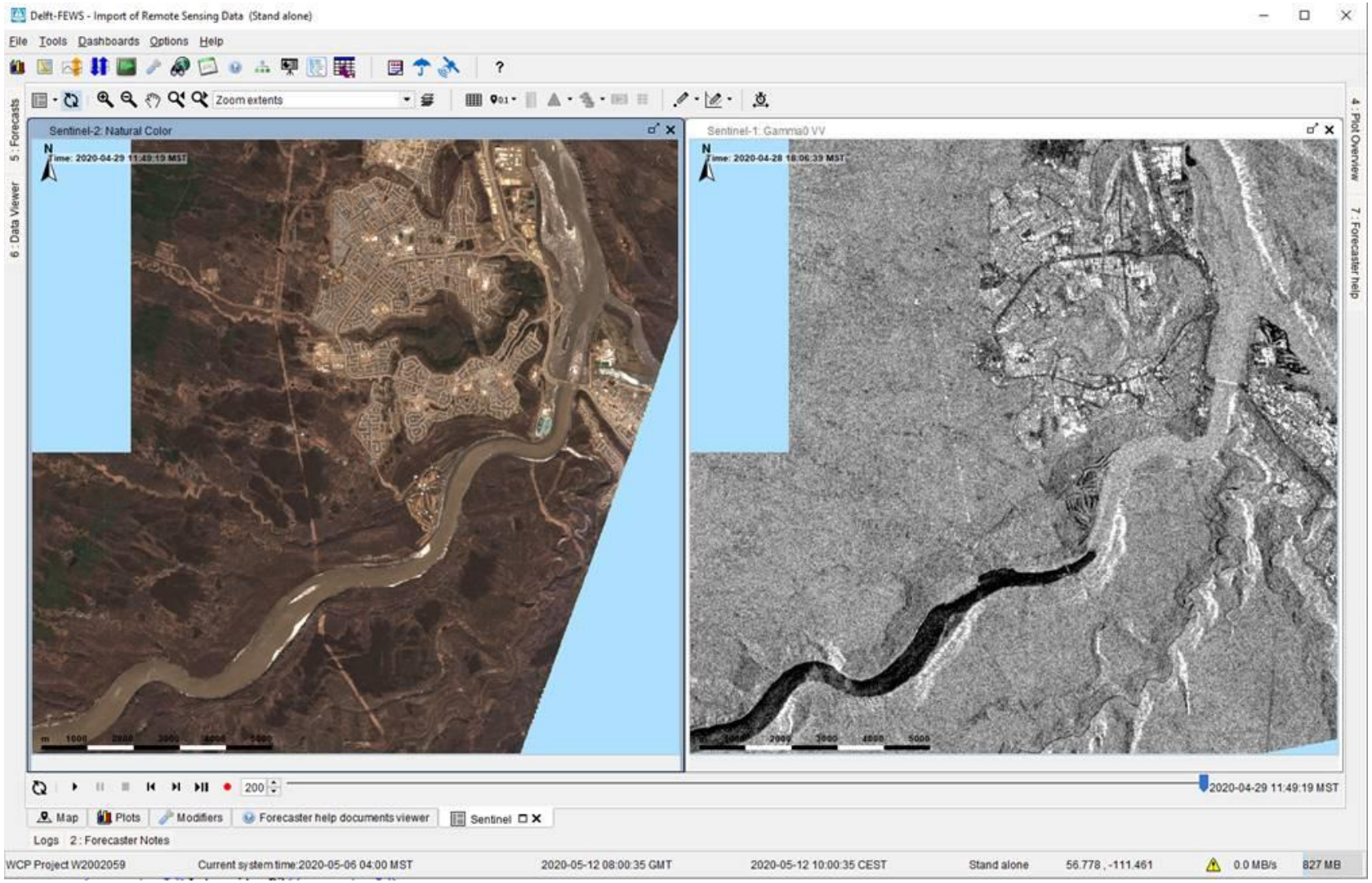


Download (python)

Processing (SNAP)

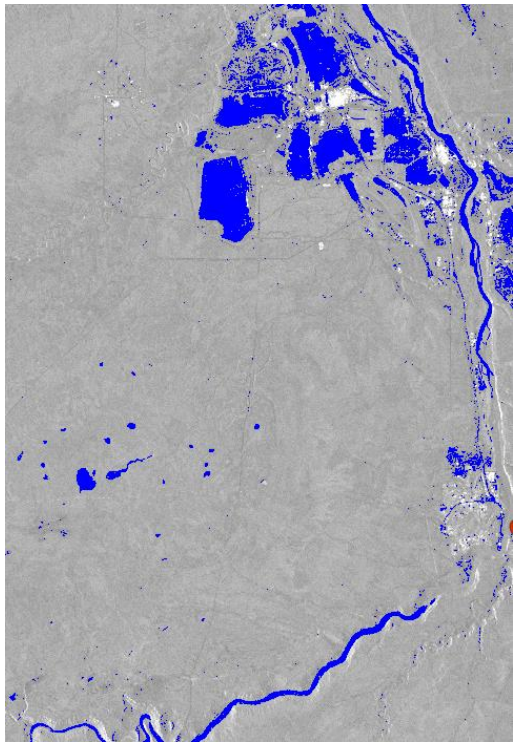
Import (Delft-FEWS)

Earth Observation data in Delft-FEWS



Further applications

- Implement ice detection algorithms
- Water detection (flood mapping, monitoring reservoirs)
- Monitoring water quality



Questions?

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