Flood maps and satellite, case study Kittilä

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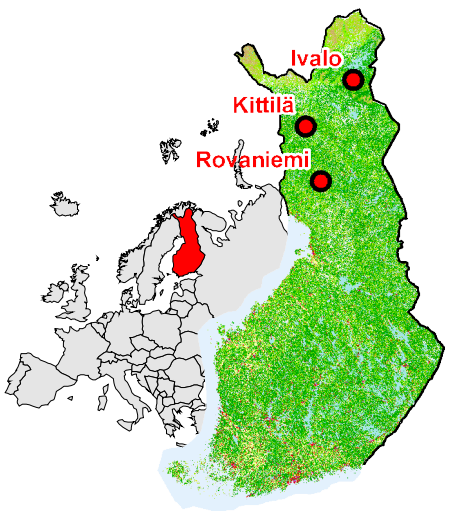
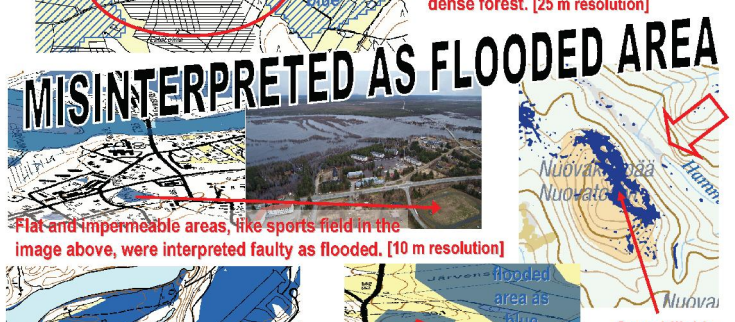
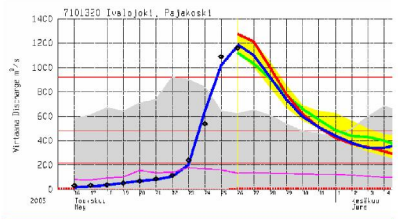


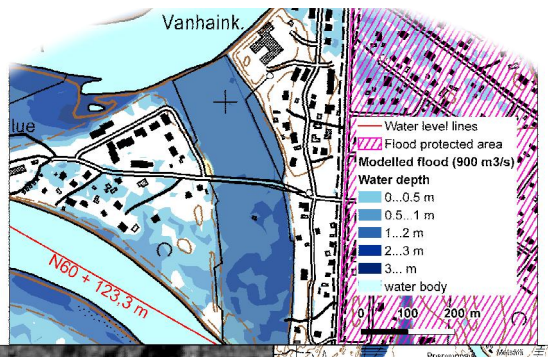
- Two severe floods in Finland in the last two years
  - **August 2004:** series of heavy rainfalls caused 10 M€ damages in southern part of Finland
  - **May 2005:** an exceptional snowmelt flood occurred in Lapland, in the northern part of Finland
- FloodMan-EU-project managed to acquire satellite scenes from these floods
  - objective was to develop and demonstrate a prototype information system for cost effective near-real time flood forecasting, warning and management using earth observation data, in particular radar satellite images, hydrological and hydraulic models and in-situ data
  - **August 2004**: analysis using archived earth observation data (25 m resolution Envisat/ASAR-images and low oblique aerial photos), **May 2005**: successful near real-time demonstration
- Results of the flood extent algorithm were good in large and open areas
- End users were mostly satisfied with the satellite based flood maps
  - the usage of the satellite based flood maps were mainly seen valuable in post crisis phase while analysing inundated areas, spatial coverage was seen excellent
  - a real-time (automatic processing) and more accurate method (better resolution, a method for fixing analysing errors e.g. by using reference data) would enhance the usability of the images
  - e.g. rescue services and operative flood prevention forces could piggyback the products better
  - temporal coverage should be better, ordering system very simple, and it should be possible to order the images in budget, also only in 1…2 days before the predicted flood
  - the need of costly field measurements during a flood event can be decreased substantially using satellite images
  - in a case of an exceptional flood a map based on satellite image can substitute modelled flood plain map



Apr 2005:
Advertising of the possibility to acquire satellite images
- for regional environment centres
- the demonstration web-page
  - flood maps and flood forecasts



Forecasted discharge for the city of Ivalo on 26 May 2005. Previous record was around 900 m³/s (gray area, observed 1961-2003). The middle blue line is the average forecasting curve. Points area discharge observations.



18 May 2005: Flood warning
- hydrological watershed models
  - forecasts are made daily to internet
  - covering 85% of the country
- forecast: a major flood will occur in the northern part of Finland in 10 days
  - the cities of Ivalo, Kittilä and Rovaniemi
  - water equivalent of snow was over 180 kg/m² (150% of the average)
  - snowmelt later and faster than normal
  - heavy rains same time (precipitation on May 80 mm, 275% of the average)

Set of images from the City of Ivalo. **Above:** Flood hazard map. **Left:** Radarsat 1 (Fine) scene, 27 May 2005 18:50, 10 m resolution. **Right:** flood extent on the base map derived from the Radarsat image using the FloodMan flood extent algorithm. **Below:** Photograph from the same site. Road was blocked as can be seen from the maps and images.

20 May 2005:
Updated flood warning
- predicted discharges were very high
  - e.g. Ivalo 1/100-year-flood (1200 m³/s)
  - water was expected to spill over dikes
  - entire city could have been flooded according to the flood hazard map

23 May 2005:
Satellite images were ordered
- **satellite image type**
  - optical ("true color") or radar images
  - radar is able to penetrate clouds and precipitation, day or night ➔ **our choice**
    - however, availability is worse yet now
- **availability**
  - depends on orbit, location, image type, date and time etc.
  - radar-satellites, e.g. ERS, Envisat and **Radarsat 1 (Fine) ➔ our choice (Ivalo 27 May, Kittilä and Rovaniemi 30 May)**
    - revisit time is just a few days by changing incidence angle
    - an image was available from each site for the same day the flood peak was expected to occur at this time
  - the better resolution the smaller coverage: **50 x 50 km²**
  - order can be made e.g. using web service (EOLI, DESCW etc.)
- **resolution (pixel size)**
  - we needed as accurate images as possible in order to test the algorithm
  - **10 m ➔ our choice**
  - at higher incidence angles, inundated areas are better discriminated
- **order day**
  - for successful timing as close the predicted flood peak as possible
  - the later images are ordered the more expensive they are, e.g. prices for Radarsat-scenes for the project:
    - more than 5 days in advance 1300 €
    - 3 days – 29 hrs in advance 3100 €
  - generally archive data is cheaper, but coverage and resolution is not so good
    - by programming beforehand it will be available more scenes

26 May 2005 12:00
Flood peak in Ivalo
- a day before it was forecasted
- no expected dike breach happened
  - sound flood risk management
  - increased dyke elevations
  - no ice blocks increasing water level partly because of the sawing of ice
  - observed discharge lower than forecasted: 1100 m³/s (a 70-year-flood)
- 25 people were evacuated, damages 0.2 M€
  - without dikes 6.9 M€ (600 affected buildings)

27 May 2005 18:50:
Satellite image from Ivalo
- water level was decreased 60 cm from the flood peak
  - timing could have been better!
  - perfect timing is difficult days in advance
- delivery and processing of the image
  - processing at ESA 4-6 hrs
    - rectified the image to WGS84-coordinate system
  - processing at KSAT 1-2 hrs
    - inundated areas were interpreted using FloodMan-algorithm, as a result was generated a classified raster image
  - processing at SYKE 2-4 hrs
    - projected to the national coordinate system (YKJ)
    - improved by combining with water body mask and background map, added borders and metadata etc.
    - manual fixing of the analysing errors
    - uploaded to internet as PDF-files
    - press release was published

28 May 2005 ~ 13:00
Aerial photographs from Kittilä
- 130 high resolution images
- were compared afterwards with flood extents derived from satellite images

29 May 2005 ~ 06:00
Flood peak in Kittilä
- a 100-year-flood
- 130 people were evacuated, damages 4,7 M€
  - 211 affected buildings
  - no dikes, will be constructed 2007-

30 May 2005 07:30
Satellite images from Rovaniemi
- both 10 m and 25 m resolution scenes
- flood was avoided by a good regulation

30 May 2005 19:03
Satellite image from Kittilä
- water level was decreased again significantly from the flood peak
- same kind of action as in the case of Ivalo

COMPARISON BETWEEN RESOLUTIONS OF THE IMAGES

Comparison between 10 m and 25 m resolution flood extent in the city of Rovaniemi. Light blue is area covered naturally by water and dark blue analyzed water extent from the Radarsat 1 (Fine) satellite image. As you can notice from the images, narrow bays can't be detected using 25 m resolution.

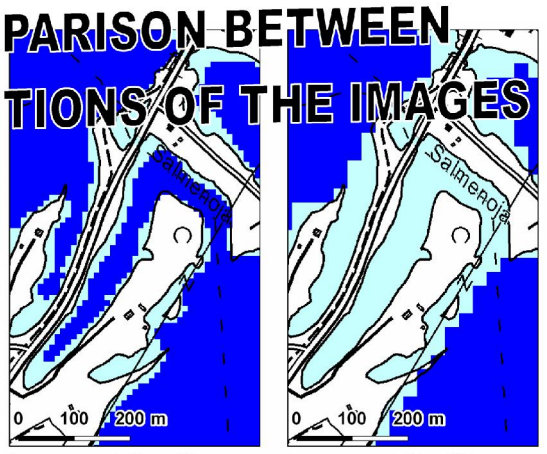
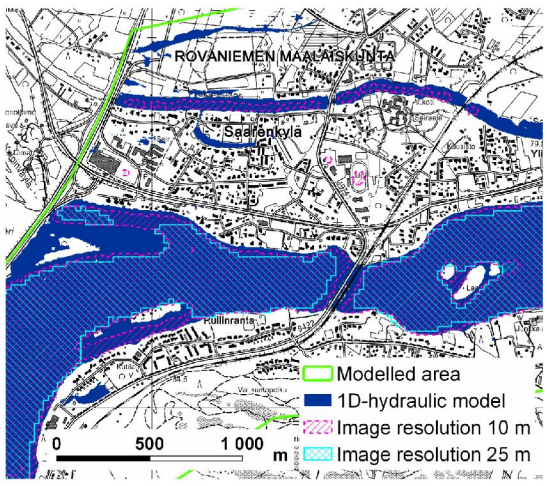


Image resolution 10 m **Image resolution 25 m**
Flood extent derived from the satellite image



1D-hydraulic model and Radarsat-images are compared in the city of Rovaniemi. The narrower a reach, an island or a bridge is, the more likely it is unnoticed. An interesting feature is the northern bank which is not verified by the algorithm. The reason could perhaps be the incidence angle of the satellite. **Around 80% of the inundated area was detected with a 10 meter resolution. As a rule of thumb satellite scene resolution should be at least 1/3 of the river width.**