

## Digital Earth and Finland: In Situ and Remote Sensing Data for Environmental Applications

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**ABSTRACT** We discuss the availability of environmental in situ and remote sensing data in Finland for the Digital Earth concept. Various databases are presented and detailed information on their contents and size are given.

**KEY WORDS** Digital Earth, Environment, In Situ Data, Remote Sensing, Satellite Data.

### 1. Introduction

One of the tasks in realizing the concept of Digital Earth is to make available presently existing data. In this presentation we concentrate on the databases of environmental in situ and satellite data in Finland. In order to get information on what data are available we have conducted a survey and present our findings below. This information has been obtained through discussions and documents. The authors are responsible for correctness of this information.

Present operational remote sensing applications are briefly reviewed together with those under development.

### 2. National Collection Of Environmental Data

#### 2.1. Institutes

The main national organizations that collect and archive environmental data in Finland include the following:

- Finnish Meteorological Institute (FMI) ([www.fmi.fi/ENG](http://www.fmi.fi/ENG))
- Finnish Environment Institute (FEI) ([www.vyh.fi/eng/fei/fei](http://www.vyh.fi/eng/fei/fei))
- National Land Survey (NLS) ([www.nls.fi](http://www.nls.fi))
- Forest and Park Service ([www.metsa.fi](http://www.metsa.fi))
- Finnish Forest Research Institute (METLA) ([www.metla.fi](http://www.metla.fi))
- Finnish Institute of Marine Research (FIMR) ([www.fimr.fi](http://www.fimr.fi))
- Geological Survey (GTK) ([www.gsf.fi](http://www.gsf.fi))
- Finnish Geodetic Institute (FGI) ([www.fgi.fi](http://www.fgi.fi))

The location of Finland in the boreal forest zone between 60°N and 70°N next to the Baltic Sea is reflected in the tasks of the research institutes: Forest, marine (including sea ice) and hydrological (including snow) data are important.

#### 2.2. Information Provided by Government Institutes

Table 1 depicts examples on the climatological parameters observed by FMI. These data are stored in the FMI database.

Parameter	Observation Stations
Air pressure at sea level	Automatic stations Weather stations Aviation weather stations Observatories
Dry bulb temperature	Automatic stations Climatological stations Weather stations Aviation weather stations Observatories
Wet bulb temperature	Automatic stations Climatological stations Weather stations Aviation weather stations Observatories
Dew point	Automatic stations Climatological stations Weather stations Aviation weather stations Observatories
Daily maximum and minimum air temperature	Automatic stations Climatological stations Weather stations Aviation weather stations Observatories
Minimum air temperature (at ground level)	Automatic stations Climatological stations Weather stations Aviation weather stations Observatories
Relative humidity	Automatic stations Climatological stations Weather stations Aviation weather stations Observatories
Wind speed and direction	Automatic stations Climatological stations Weather stations Aviation weather stations Observatories
Precipitation	Precipitation stations Climatological stations Weather stations Aviation weather stations Observatories
State of ground and snow depth	Precipitation stations Climatological stations
Total cloudiness, low/middle/high clouds	Climatological stations Weather stations Aviation weather stations Observatories
Visibility	Weather stations Aviation weather stations Observatories
Past and present weather code	Weather stations Aviation weather stations Observatories
Sunshine duration	Stations observing sunshine duration

In the following, information on the type and intensity of environmental in situ observations is presented. The Finnish Meteorological Institute

provides information about the atmosphere above and around Finland in order to ensure public safety regarding the atmospheric and airborne hazards and to meet the requirements for specialized meteorological products. Using a total of 451 observation stations (in 1995), FMI

- Observes the physical state and chemical composition of the atmosphere, and the Earth's magnetic field,
- Produces information concerning the past, present and future state of the atmosphere, and
- Carries out research in meteorology, air physics and chemistry, space physics and geomagnetism.

Table 2. Observation stations of the Finnish Meteorological Institute related to Table 1.

Station Type	Number of Stations	Frequency of Observations	Data Since
Observatory and sounding station	3	Every 3 hours	1959
Aviation weather station	24	Every 3 hours	1959
Weather station	25	Every 3 hours	1959
Climatological station	62	Daily 06, 12, 18 UTC	1959
Precipitation station	320 <sup>(1)</sup>	Daily 06 UTC	1971 <sup>(2)</sup>
Automatic station	107	Real-time, sent every hour	1980's
Stations observing sunshine duration	25	Daily	1950

<sup>(1)</sup>FMI and jointly operated stations, <sup>(2)</sup>Mostly from 1960's

In addition to observations listed in Table 1, FMI makes regular observations on air quality in several locations, Table 3.

The Finnish Environment Institute is the national environmental research and development center and it provides information on the state of the environment and its development, as well as factors affecting it. Assessments are made about alternative scenarios and measures to influence future development. The tasks of FEI include the following:

- To monitor and assess the state of the environment and the pollution load, land use and water resources,
- To maintain and develop information systems within its remit.

FEI maintains a hydrological database HYTREK that contains information on various hydrological parameters, Table 4. The total number of archived observations is 20 million.

The National Land Survey collects, refines and sells information concerning land and properties and promotes joint use of GIS data. Unlike most other environmental institutes, NLS's biggest customer group is households. NLS produces and updates national maps, most being presently available on CD-ROM, including 1: 20 000 basic maps (houses, roads, water, farmland, other terrain features and elevation data) based on aerial photography and ground-based information; 1:50 000 maps, 1:500 000 maps and topographic 1:20 000 maps.

Table 3. Examples of air quality observations made by the Finnish Meteorological Institute.

Parameter	Frequency of Observation	Number of Observation Sites	Information Since	Comments
Major ions in precipitation (SO <sub>4</sub> <sup>2-</sup> , NO <sub>3</sub> <sup>-</sup> , Cl <sup>-</sup> , NH <sub>4</sub> <sup>+</sup> , Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup> , K <sup>+</sup> ); pH and conductivity	Daily	5	1973	Concentration in precipitation and deposition per square meter
Major ions in precipitation (SO <sub>4</sub> <sup>2-</sup> , NO <sub>3</sub> <sup>-</sup> , Cl <sup>-</sup> , NH <sub>4</sub> <sup>+</sup> , Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup> , K <sup>+</sup> ); pH and conductivity	Monthly	11	1981	Concentration in precipitation and deposition per square meter
Trace elements in precipitation (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, V, Zn)	Monthly	8	1989	Concentration in precipitation and deposition per square meter
Trace elements in aerosols	Weekly	1	1996	
SO <sub>4</sub> <sup>2-</sup> in aerosols	Weekly	5	1973	
HNO <sub>3</sub> +NO <sub>3</sub> <sup>-</sup> in air and aerosols	Weekly	5	1989	
NH <sub>3</sub> +NH <sub>4</sub> <sup>+</sup> in air and aerosols	Weekly	5	1989	

Table 4. Hydrological database HYTREK of the Finnish Environment Institute.

Parameter	Frequency of Observations	Number of Observation Sites in 1999	Information Available Since/Total Number of Observations by 1996/Total Number of Stations Used	Comments
Water level	Daily at 08	305	1847 / 13 100 000 / 859	Real-time data from 45 stations to hydrological database
Discharge	Daily update	265	1840's / 6 000 000 / 542	Real-time data from 60 stations to hydrological database
Runoff	Daily update	45	Early 1960's / 550.000 / 48	Observed at small natural catchments
Precipitation	Daily at 08	450	1911 / 125 000 / 252 areas, 600 stations	Areal values computed for 110 catchments, presented as 5-day values
Snow water equivalence	Monthly	165	1930/ 205 000 / 177 stations 1946 / 57 000 / 245 areas	Based on snow course measurements, daily areal values computed for 110 catchments
Evaporation (Class A pan)	Daily during summer season	22	Late 1950's / 120 000 / 46	
Water surface temperature	Daily during summer season	30	1924 / 320 000 / 59	Measurement depth 20 cm
Ice formation and melting in lakes		83	1833/ 600 / 114	Both ice formation and melting include 4 phases that are observed
Ice thickness in lakes	10, 20 and 30 of each month in winter	45	1910's/ 30 000 / 140	
Ground water level and related parameters	Twice per month	50	Early 1970's / 22 000 / 51	Integrated quantity and quality observations at natural ground water basins
Frost depth	1, 16 and 26 of each month in winter	40	Early 1900's / 41 000 / 41	

The pixel size of the national numerical elevation model is 25 m by 25 m (also 200 m by 200 m available) and its average vertical accuracy has been determined to be 1.76 m and standard deviation 1.39 m. A total of 63,000 reference points were used for this task.

The Forest and Park Service manages, uses and protects the land (8.8 million hectares or one third of Finland), forest and water owned by the government. Most of this land is in eastern and northern Finland. All forested land has been divided into homogeneous forest stands (total number: over 1 million) using aerial photography. About 50 attributes, including those for both the site and trees (basal area, height, stem volume, species). The latest inventory was carried out in 1985-1998 and field work for updating this information has been started. Annual updates are provided computationally using various models.

The Finnish Forest Research Institute is the national central forest research organization. It has substantial know-how on basic and applied forest research and it provides services for both private companies and governmental institutes. The purpose of the National Forest Inventory (NFI) for

which the Institute is responsible for, is to continuously provide information about the state of Finnish forests. The government, industry and forest owners use this information for planning future activities.

The first inventory covering the entire Finland was carried out in 1921-1924. The latest, ninth inventory, was started in 1996 and it will be completed in 2000. NFI is presently based on multi-source data and utilizes field measurements (numerous sample plots), satellite images (Landsat TM) and digital map (arable land, urban areas and buildings, roads, digital boundaries of computation units, digital terrain model, peat land) data.

NFI produces forest resource statistics (distribution of land use classes, distribution of forest land, distribution by stand characteristics like site fertility, age, species, development classes, and silvicultural quality) and maps on forest areas, stem volumes, forest health condition and forest ecosystem. The statistics are normally computed at municipal level (on the order of 10,000 ha) and, by request, for smaller areas.

The primary tasks of the Geological Survey are mapping the Earth's surface using geological,

Table 5. Examples of sea water and ice observations made by the Finnish Institute of Marine Research.

Parameter	Frequency of Observations / Number of Stations	Comments
Sea surface temperature	Manual stations: daily to 2 per week / 30 Automatic stations every 10 minutes / 5	Aerial IR survey (every 10 days) from October to January Satellite observations: AVHRR IR channel data
Wave height	10 minutes / 4 buoys	Real-time data relay to FIMR; status: semi-operational Buoys removed before ice formation
Water level	Every 10 minutes / 13	Stations established in 1887-1993
Algae information	Continuous monitoring / ships	Satellite images employed presently
Ice extent	Daily / 30	Also satellite monitoring: all NOAA overpasses (AVHRR channels 2 and 4); 100 RADARSAT SAR images per winter
Concentration	Daily / 30	
Ice thickness	Daily to weekly / 30	
Snow depth	Daily to weekly / 30	

geophysical and geochemical methods, and searching exploitable resources in both bedrock surface deposits, including peat reserves. Its database contains information on all aspects within its expertise. Geological Survey also conducts airborne measurements using magnetic, electromagnetic and gamma sensors.

The Finnish Geodetic Institute is the national mapping research institute, whose main task is to carry geodetic, gravimetric and astronomic basic measurements in Finland. Additionally the Institute conducts research in the fields of geodesy, geosciences, photogrammetry, remote sensing, cartography and geoinformatics. Its observatory operates satellite lasers, GPS receivers and gravimeters.

The Finnish Institute of Marine Research conducts marine research on the Baltic Sea, provides information to the public, companies and decision makers, and participates in international cooperation, including arctic areas. The Ice Service operates within FIMR and provides sea ice information for winter shipping traffic. Examples of information contained in the database of FIMR are shown in Table 5.

### 2.3. Examples of National Environmental Databases

Our survey proves that large amounts of environmental information spanning both space and time are available in Finland. The data have been and still are mostly collected using in situ methods, due to the developed national infrastructure.

Examples of the sizes of the various databases are depicted in Table 6. In the case of the largest databases the size increases with an annual rate of gigabytes.

## 3. National Work on Remote Sensing

### 3.1. Universities

Academic laboratories working in the field of remote

Table 6. Examples of national databases and their sizes.

Institute Database	Size of Database (Gigabytes)
Finnish Forest Research Institute: National Forest Inventory	12 satellite data 10 digital maps 40 output maps
Geological Survey	50
Finnish Meteorological Institute	12 climate 25 real-time (14 days)
Finnish Institute of Marine Research	25 general 11 satellite SAR data
Forest and Park Service	15
National Land Survey: SLAM-3 land use/land cover SLICES land use / land cover (land use 2000, land cover later)	0.45 1.4 land use (25 m) 6 land use (10 m) 1.4 land cover (25 m)
Finnish Environment Institute: HYTREK hydrological database	0.5

sensing include the following (remote sensing group at least five persons):

- Helsinki University of Technology/Laboratory of Space Technology ([www.space.hut.fi](http://www.space.hut.fi))
- University of Turku/Laboratory of Computer Cartography ([www.utu.fi/ml/kartografia/compcart](http://www.utu.fi/ml/kartografia/compcart))
- University of Joensuu/Faculty of Forestry (<http://gis.joensuu.fi>)
- University of Helsinki/Department of Forest Resource Management (<http://hymla.helsinki.fi/mmvar>)
- University of Kuopio/Laboratory of Atmospheric Physics and Chemistry ([www.uku.fi](http://www.uku.fi)).

Additionally, many universities have small groups working on remote sensing.

### 3.2. Research Institutes

Research Institutes working in the field of remote sensing include the following (remote sensing group at least five persons):

- Finnish Meteorological Institute (FMI) ([www.fmi.fi/ENG](http://www.fmi.fi/ENG))
- National Land Survey (NLS) ([www.nls.fi](http://www.nls.fi))
- Forest and Park Service ([www.metsa.fi](http://www.metsa.fi))

- Finnish Geodetic Institute (FGI) ([www.fgi.fi](http://www.fgi.fi))
- Forest Research Institute (METLA) ([www.metla.fi](http://www.metla.fi))
- Technical Research Centre of Finland / Automation / Measurement Techniques / Remote Sensing Group (<http://www.vtt.fi/aut/mit/kaukokartoitus/indexe.html>)
- Finnish Institute of Marine Research (FIMR) ([www.fimr.fi](http://www.fimr.fi))
- Geological Survey (GTK) ([www.gsf.fi](http://www.gsf.fi))
- Finnish Environment Institute (FEI) ([www.vyh.fi/eng/fei/fei](http://www.vyh.fi/eng/fei/fei)).

Comparison of the above list with that in Section 2.1 shows that practically all environmental institutes are also involved in the development of data collection methods based on remote sensing.

### 3.3. Companies

The number of companies working on remote sensing is still quite small in Finland (many others use aerial photography). Some of them are listed below:

- FM-Kartta Ltd.
- Space Systems Finland Ltd. ([www.ssf.fi](http://www.ssf.fi))
- Patria Finnavitech Ltd. Systems
- Stora Enso Forest Consulting ([www.storaenso.com/forestconsulting](http://www.storaenso.com/forestconsulting))
- Finnish Consulting Engineers Ltd.

## 4. Environmental Applications Based On Remote Sensing

### 4.1. Operational Applications

Some methods used to collect environmental information already employ satellite/airborne data.

- Finnish Meteorological Institute receives data from the NOAA and Meteosat satellites and employs it for weather forecasting
- National Land Survey together with several other institutes has developed a Landsat TM-based method to classify land use and land cover in Finland (SLAM-3 finished in 1997)
- Finnish Forest Research Institute employs Landsat TM data as part of its multisource-based National Forest Inventory
- Ice Service (Finnish Institute of Marine Research) employs RADARSAT SAR images and, occasionally, NOAA images to produce ice charts for the Baltic Sea
- Finnish Institute of Marine Research together with other national institutes and environmental centers and the Estonian Marine Research Institute has set up a NOAA image-based Internet service to provide information on sea surface temperature and surface accumulations of algae

- Finnish Environment Institute operates jointly with the Finnish Frontier Guard two Dornier 228 airplanes to monitor illegal oil emissions from ships. Each aircraft is equipped with a side-looking radar (SLAR), an IR/UV/VIS scanner, and a Forward Looking Infrared Radar (FLIR).
- Stora Enso Forest Consulting operates an aerial imaging system (infrared video camera or digital still camera) and image processing system (images are mosaicked using PC-based software) to obtain information for forest inventory and land use planning
- Novosat (formerly National Land Survey/Satellite Image Centre) uses a SAR interferometry-based method to produce digital elevation information with an accuracy ranging from 10 m (two images) to up to 2 m (several images)
- Several companies use aerial photography for mapping and cartography.

Table 7. Presently used satellite data in Finland. Note that some sensors are operated in various modes not listed here.

Satellite Launch	Sensor Bands	Image Area Image Size Resolution	Applications in Finland
NOAA Series	AVHRR VIS+IR	2400 km 665 kbps 1.1 km	Meteorology Sea temp. Sea ice monit. Water quality Forest fire
Meteosat Series	VIS+IR	Whole Earth: 2500x2500 pix 2.4 km	Meteorology (Geostationary)
Landsat Series	TM VIS+IR	185x185 km MB 30/120 m	Forest invent. Land use Land cover
SPOT-1/2/3 Series	2 x HRV VIS	60x60 km 100 MB 10 m (max)	Forest invent. Land use Land cover
SPOT-4 Vegetation 1998	Vegetation HRVIR VIS+IR	2000x2000 km (max) 1 km (Veget.) 20 m (HRVIR)	Vegetation
Radarsat 1995	SAR Mw	500x500 km 100 MB 100 m, 50x50 km 64 MB 10 m	Sea ice monit.
ERS-1/2 1991/1995	SAR Mw	100x100 km 131 MB 30 m	Sea ice monit. Forest invent. Topography

### 4.2. Applications under Development

In the following, some satellite remote sensing methods presently under development are listed. Only the institute/company leading the team is mentioned.

- National Land Survey together with several other institutes has undertaken an effort to produce a totally new land cover / land use database SLICES. Production for the land use

element was started in 1999 and it will be finished by the end of 2000. The resolution will be 10 m by 10 m.

- Finnish Environment Institute is developing a NOAA image-based method for water quality monitoring. This is especially important, since there are 188,000 lakes in Finland and any method based on sampling cannot properly cover even the main water bodies.
- Finnish Meteorological Institute is developing satellite-based methods to monitor the stratospheric ozone over Finland

Table 8. Satellite data available in the near future with foreseen applications in Finland. Note that some sensors are operated in various modes not listed here. Launch dates are present estimates.

Satellite Launch	Sensor Bands	Image Area Image Size Resolution	Applications
Landsat-7 1999 Launched	ETM+ VIS+IR	183x170 km 3 GB total 15/30/60 m	Forest invent. Land use
IKONOS 1999 Launched	VIS+IR	11 x 11 km 1 m (max)	Cartography
MSG 2000	SEVIRI VIS+IR	Whole Earth 11136x5568 pixels for non- HRV channels	Meteorology (Geostationary)
Envisat 2001	SAR MW	100x100 km 268 MB (alt.pol.) 30 m, Global mode: 400x40000 km 584 MB 150 m	Sea ice monit. Forest invent. Global mapping
Envisat 2001	MERIS VIS+IR	575x575 km 187 MB 300 m (includes 9 products)	Water quality Sea temp. Atmosphere Land applicat.
Radarsat-2 2001	SAR Mw	500x500 km 100 m, 20x20 km 3 m	Sea ice monit. Forest invent.
Metop 2003	8 instr. VIS+IR+ MW	Depends on Sensor	Meteorology Water quality Sea temp. Wind (ocean) Ozone
Shuttle SRTM 2000	SAR Mw	60x450/4500 km 30 m for DEM	Topography 60°N to 56°S (does not cover Finland)

- Finnish Environment Institute is testing a satellite image-based method to monitor snow melt in Finland. The method employs NOAA images (clear weather) and SAR images (cloudy

weather). Snow-free ground can be discriminated from snow-covered ground.

- Technical Research Centre of Finland is testing a forest fire detection system that is based on NOAA images.

### 5. Present and Near-Future Satellite Data

Information on presently available satellite data is shown in Table 7 including the main applications in Finland for both operational and research purposes. Information on satellite data available in the near future is shown in Table 8. The emphasis is on improving spatial resolution, spectral coverage, number of channels (spectrometers) and increasing the swath width, although these improved features are not necessarily available simultaneously.

### 6. Conclusion

Large amounts of environmental information have been collected in Finland since the 1800's. These data are continually collected and archived by various governmental research institutes, each institute within its field of interest. Most of these data have been and are still collected by in situ methods, with the instruments recently becoming more and more automatic.

Environmental data covering the whole Finland are thus available in various scales up to 25 m for the Digital Earth concept. Mostly these data are not free of charge. Spot measurements can in many cases be scaled to regional information using suitable models.

Until recently, the well-developed infrastructure favored in situ data collection, since the methods had been proved to work well. Presently there is pressure to cut data collection costs, improve the timeliness of data, and collect new type of data previously not possible. These aspects together with the rapidly developing remote sensing methods are changing the long-practiced procedures also in many government institutes.

Near-future satellite data offer many advantages over present data, including more geophysical products for the end users.

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