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The Helsinki Testbed: A four-season mesoscale research and development facility

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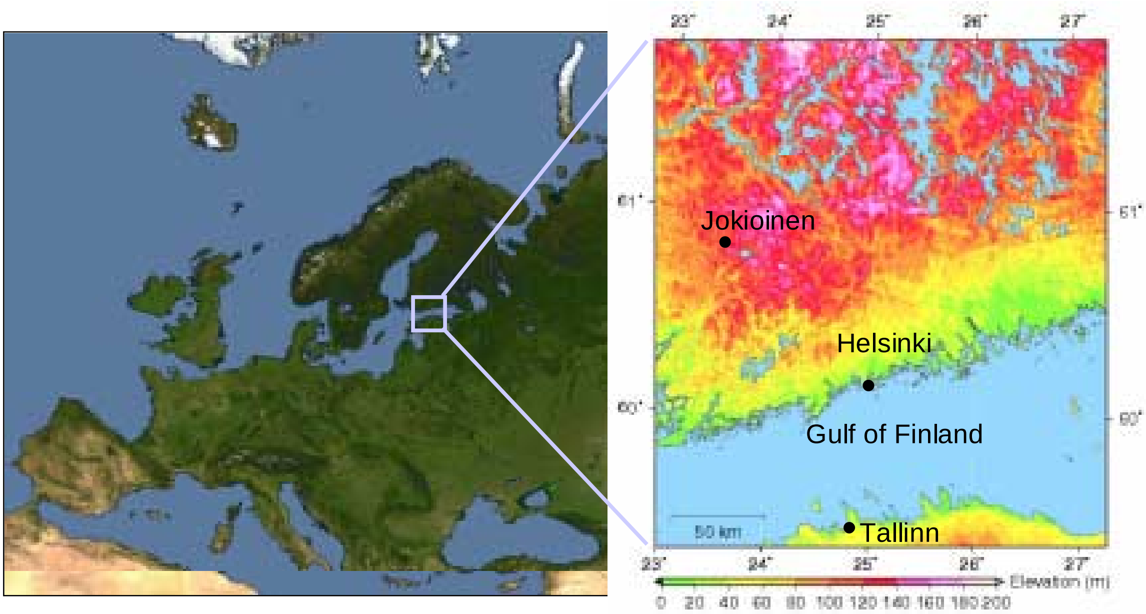

Figure 1 *Location and topography of Helsinki Testbed Area in southern Finland*

1. INTRODUCTION

The Finnish Meteorological Institute (FMI) and the Vaisala meteorological measurements company have initiated a program to establish a new mesoscale observational network in Southern Finland. The Helsinki Testbed is expected to provide new information on observing systems and strategies, mesoscale weather phenomena and applications in a coastal high-latitude environment. The goal of this project is to provide input and experience for mesoscale weather research, forecast and dispersion model development and verification, information systems integration, end-user product development and data distribution for the public and the research community.

According to Dabberdt et al. (2005), a testbed can be defined as a working relationship in a quasi-operational framework among measurement specialists, forecasters, researchers, the private sector, and government agencies aimed at solving operational and practical regional problems with a strong connection to end-users. Outcomes from testbeds are more effective observing systems, better use of data in forecasts, improved services, products, and economic/public safety benefits. Testbeds

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accelerate the translation of R&D findings into better operations, services, and decision-making. A successful testbed requires physical assets as well as long-term commitments and partnerships.

The Helsinki Testbed core project has funding from Technology Agency of Finland (TEKES) and partners from many sides of the society: e.g. Finnish Road Enterprise and Road Administration, Radiation and Nuclear Safety Authority, Helsinki Metropolitan Area Council (Air Quality Authority) and some partners from industry. Additional research projects are welcome to use the data.

2. INSTRUMENTATION

FMI and the Road Authority have reasonably good existing observation networks in the area. For the Testbed campaigns, these will be supplemented with numerous new sites.

A dense network of nearly 60 stations equipped with Vaisala WXT510 weather transmitters will be installed. Of these stations, 42 are cellphone base station masts that have been converted to meteorological towers by installing weather transmitters on them (two or three transmitters at different heights, to get bulk profiles of temperature, humidity and stability).

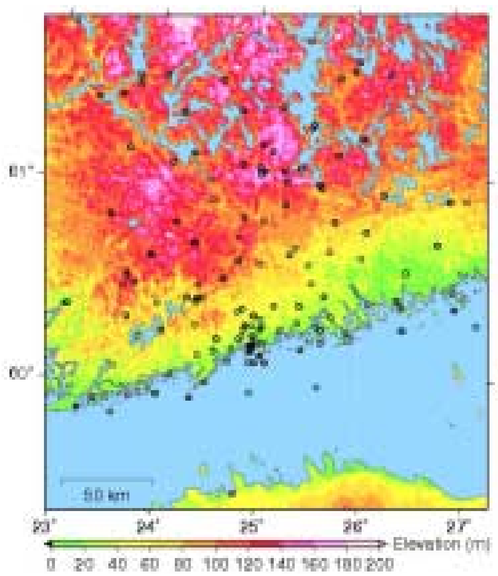

Figure 2 *All Helsinki Testbed stations, except the road weather stations.*

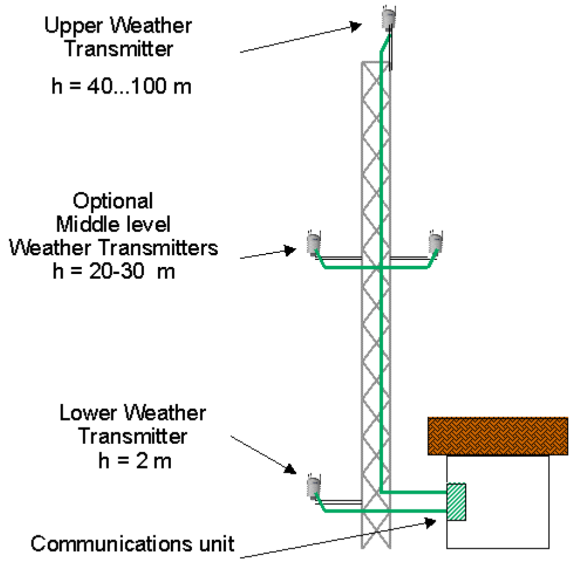

Figure 3 *Cellphone base station mast utilised as a meteorological tower with 2-4 WXT510 weather transmitters.*

Additional weather transmitters will be installed in urban areas, e.g. along the marathon route of the World Championships in Athletics 2005 and on ferries sailing on the Helsinki-Tallinn route.

The number of radiosoundings and wind profiler observations will be increased. A network of Vaisala laser ceilometers will be established to map both cloud base and boundary-layer structure. The existing precip-itation stations will be supplemented with several automatic weighing gauges, capable of measuring both liquid and solid precipitation. Satellite and C-band weather radar data will be extracted from FMI and research equipment, and saved at high resolution.

Also, other weather-related data will be collected during the campaigns if they are freely obtainable from the region of interest. Such data could include flow measurements of Vantaa River, ice cover maps and ice analysis with six parameters, wave-height observations at three points and gridded wave-height forecasts, satellite-based sea surface temperatures for the Gulf of Finland as well as sea water temperature measurements from ships and buoys, or sea-level height in Helsinki harbor.

Numerical forecasts are being extracted from HIRLAM model fields. Synoptic analyses will be performed by FMI and stored in easily browsable images so that offline end-users can pick interesting weather situations for case studies.

Table 1 *Weather stations in Helsinki testbed*

46	FMI weather stations
34	FMI precipitation stations
5	new weighing gauges
13	off-line temperature loggers
10	Weather Transmitters in urban area
191	Road weather stations
299	**Surface weather stations, total**
42	Instrumented towers (telecommunication masts) with Weather Transmitters at 2 or 3 levels each
3	Mobile ship weather stations
5	Optical backscatter profilers (ceilometers)
4	Doppler radars
1	Dual-polarization Doppler radar
3	RAOB sounding stations
1	Wind profiler with RASS

3. MEASUREMENT CAMPAIGNS

Interest focuses on meteorological observations and forecasting directed towards meso-gamma scale phenomena that typically last from a few minutes to several hours. The most intense activities will concentrate on specific, usually month-long measurement campaigns. For convinience, each of the campaigns has been named with a typical mesoscale phenomena or activity of that season.

- August 2005: Nowcasting campaign
- November 2005: Precipitation type campaign
- January-February 2006: Stable boundary layer campaign
- May 2006: Sea breeze campaign
- August 2006: Convection campaign

3.1 Nowcasting campaign

The shorter the forecast period, the more accurate the weather forecast must be. “Nowcasting” is a subset of mesoscale forecasting, and the term is used for forecasts lasting up to the next two hours or so. On this scale, weather information is mainly based on observations and various methods of extrapolation. Beyond a couple of hours, the importance of numerical modeling increases.

Aviation uses mainly short and very short forecasts. Also, the road maintenance people plan their activities sometimes at very short periods. The use of nowcasting by larger audiences has been limited due to limits of media, but mobile phones (especially with color displays), local radio and morning TV have changed this.

In the first testbed campaign, very short-term forecasts will be distributed using modern media (web and mobile devices) during the World Championships of Athletics 2005.

3.2 Precipitation type campaign

In 99% of the cases, the water phase of precipitation is obvious: rain when temperatures are well above the freezing point, and snow when temperatures are below -10 °C. However, at temperatures near zero all precipitation types are possible. Precipitation type is not determined only by near-surface temperature, but also by humidity and temperature profiles aloft. In very dry weather, snow can fall in +4 degrees. In inversion situations, it's not so uncommon to see liquid rain fall in -2 degrees and drizzle even in colder temperatures.. Also, there are often changes in precipitation type in relatively short horizontal distances, depending on local topography.

In Helsinki, the water phase can often change quickly both in space and time. In an average November, half of the days have temperatures below zero at Kaisaniemi station near the coastline, while in continental parts of the testbed area the sub-zero frequency increases.

There are several different methods to determine water phase. Some rely on vertical temperature structure or thickness between pressure levels. Such methods can be applied to sounding, wind profiler (RASS) or weather radar data or NWP fields. AWS temperature and humidity data can be used, but between the stations they have to be interpolated, perhaps with Kriging methods that take topography into account. Dual polarization radar parameters can be used to determine the shape of hydrometeors. Finally, there are present weather sensors at some of the weather stations. In the testbed campaign, various methods will be compared.

3.3 Stable BL campaign

As Helsinki has no permanent radiosounding station, there are no statistics of radiosonde observations of surface inversions in the city proper. Jokioinen (Fig. 1) is the best available reference for Southern Finland; it is located in the northwest corner of the larger testbed area and is used as one of the Testbed sounding sites. According to Huovila et al. (1991), typical inversion heights above ground level are around 300 m in January-February, 200 m other times. The number of inversion nights as well as mean and maximum magnitudes -- defined as difference of temperature at 2 m screen level and the temperature at the top of the inversion -- for Jokioinen ground inversions are given in Table 2. Note that the dataset is rather small due to changes in the measurement instruments.

Table 2 *Inversion statistics of Jokioinen 1982-1988 at 00 UTC for the months of Helsinki Testbed Campaigns (Huovila et al., 1991). Magnitude of inversions is expressed as difference of screen temperature (2 m) and temperature at the top of the inversion.*

	number of nights (min, mean, max)	mean height (m) AGL	mean size (°C)	max size (°C)
Jan	4, 10.7, 22	290.4	7.4	20.1
Feb	3, 12, 20	302.5	6.9	19.5
May	13, 19.4, 26	195.9	4.8	11.4
Aug	14, 19, 29	192.7	3.4	10.2
Nov	3, 6.7 ,12	187.1	2.9	8.5

An important factor for the regional distribution of the stability is the ice cover, both in Helsinki waters and in entire Baltic Sea. Ice winter means the time when the ice is present in the Baltic Sea. The season normally takes place from October-November to May-June. The annual maximum ice extent occurs between January and March, normally in late February – early March. The ice covers on average about 170,000 km², which is almost half of the total area of the Baltic Sea. During extremely mild seasons the maximum extent is well below 100,000 km². The minimum extent was reached in 1989 with only 52,000 km². (Seinä et al., 1991)

In Helsinki, first freezing takes place during December or January. Permanent ice cover is there typically during February and March, but hard winters such as 1995-1996 can last from Mid-December to late April. For final disappearance of ice one has to wait to late March, usually April, latest early May. The average number of real ice days in the main Helsinki harbor is around 90 days; for the Harmaja island archipelago (4 km from the mainland), it is 60 days; and for the open sea (22 km from mainland), it is 30 days. (Seinä et al., 2001 and Vainio, 2005)

3.4 Sea breeze campaign

Sea breeze blows when sea surface is relatively cold compared to land surface. Temperature difference must be 5 to 15 degrees and the basic airflow (ie wind caused by other reasons) must be weak: 0-5 m/s from sea or 0-8 m/s from inland. The temperature difference is created by insolation, so there shouldn't be too much clouds to prevent sunshine.

On an average summer, sea breeze is observed in Helsinki downtown approx. 50 days. How far inlands the sea breeze intrudes, depends mainly on the strength of the basic airflow; in most suitable cases 77 km has been observed.

Sea breeze and its phases of development play an important role in the dispersion of atmospheric constituents.

In the testbed campaign, the observation of sea breeze cases using different in-situ and remote sensing instruments, as well as the parameters crucial to onset of sea breeze, will be studied. Case data will be used in air quality studies and limited area atmospheric forecast models.

3.5 Convection campaign

The last special campaign concentrates on convection and lightning. Thunderstorms occur in Finland mainly during May-September, with the most active period being mid-June to mid-August. The yearly mean number of flashes is about 150,000 and the corresponding density is 0.4 flashes per square kilometre. The mean number of locally observed thunder days is 13 (1998-2004).

Typically, the weather in Finland is dominated by polar-frontal systems that approach from the south-west. They cause comparable numbers of frontal and air-mass thunderstorms whose average activity remains, however, moderate (Tuomi and Mäkelä, 2003).

During the summer season, weather systems of more continental type come from the S-SE sector, causing significantly more active thunderstorms (especially air-mass storms). In those situations, dewpoints are often in range of 15-20°C and sometimes up to 23°C. Mesoscale convective systems (MCS) are observed every summer, and their peak activity is also in late summer.

W-SW thunderstorms are moderated by the traverse over the Gulf of Bothnia (between Finland and Sweden) or the northern Baltic Sea, and rarely reach the south coast of Finland in a very active state. On the other hand, thunderstorms entering the southern coast directly from the south (Estonia) may be very violent. Other storms of the south-eastern type enter the country along the Karelian Isthmus or a more northern route and continue to middle or northern Finland.

The mean flash density on the south coast is only 0.25 to 0.30 flashes per square kilometre. The thunder day number is 15, reflecting the fact that modest or moderate thunderstorms occur relatively frequently. Typically, the highest CAPE values reach 1000...2500 J/kg a couple of days each summer. Those days the lifted index is 3...-6 °C. Radar reflectivities observed in stratiform rain are typically 10..40 dBZ, in showers 20..60 dBZ and in snowfall -10..+30 dBZ. Cloud tops in precipitating systems seldom reach 15 km, and in snowfall they can be as low as 2...4 km.

In the last testbed campaign, nowcasting and data fusion products will be compared in convective weather situations.

4. HELSINKI CLIMATE SUMMARY

All four seasons can be distinctly separated in this northern environment. Weather is dominated by transient eddies connected to the polar front, arriving to Finland from south-west usually in a rather late phase of the occlusion process. Snow cover lasts around 100 days. Climatological statistics for the Testbed campaign months for Helsinki are given in the tables 3 and 4. The Gulf of Finland freezes on average on 1 February, and 2-4 weeks earlier (Leppäranta et al., 1988) along the coasts.

Table 3 *Climatological statistics of temperature in Kaisaniemi, Helsinki for the months of Helsinki Testbed Campaigns (Drebs et al., 2002)*

Month	T mean ave	T max ave	T min ave	T max abs	T min abs
Jan	-4.2	-1.7	-6.9	8.5	-34.3
Feb	-4.9	-2.2	-7.7	10.3	-26.0
May	9.9	14.0	6.0	26.3	-3.1
Aug	15.8	19.3	12.6	31.2	3.4
Nov	1.4	3.6	-0.8	11.6	-18.6

Table 4 *Climatological statistics of some other weather parameters in Kaisaniemi, Helsinki for the months of Helsinki Testbed Campaigns (Drebs et al., 2002)*

Month	Days T > 25	Days T < 0	RR ave (mm)	RR max
Jan		26	47	85
Feb		24	36	101
May		1	32	68
Aug	2		78	174
Nov		15	68	160

In Finland, the amount of potential sunshine hours varies greatly due to astronomical factors. Most strikingly, this feature is noticed to the north of the Arctic Circle where the sun does not set at all during mid-summer and does not rise at all during mid-winter. In the Testbed region in south, the yearly variation of possible sunshine hours is pronounced as well, but the sun is above horizon about five hours during the shortest daylight time, and nearly 20 hours in mid-summer. These facts are illustrated in Fig. 4, in which Helsinki approximates conditions in the Testbed area, Jyväskylä in central, and Sodankylä in northern Finland.

The amount of solar radiation also varies due to meteorological conditions, surface type and topographical factors. Generally, yearly solar radiation lessens with increasing latitude, and when approaching inland from sea. Because of cloudiness patterns, the greatest yearly values of solar radiation are usually obtained in early June. The greatest amount of sunshine hours is measured in Finland's south-

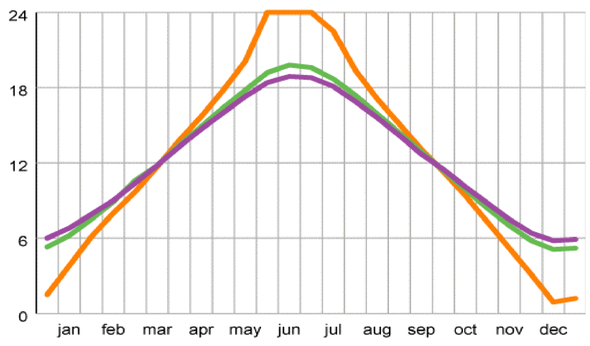

Figure 4 *The annual variation of duration of daylight in hours. Helsinki (purple), Jyväskylä (green), and Sodankylä (orange)*

west coast and sea regions. The best possibility of having clear days is in May-June while the lowest corresponding possibility is in November-December.

5. IT DESIGN, DATA POLICY AND INVITATION

The usability of a large heterogeneous dataset is a challenge to IT and database design. The Helsinki Testbed central data warehouse (CDW) designers have taken the approach of modular interfaces for heterogeneous data producers with the help of XML definitions, named FMML (Finnish Meteorological Markup Language). Data from AWS stations are collected and quality-checked in a separate front-end database and inserted to the CDW through the XML interface. All data feeding and retrieval from the CDW will be based on web services utilizing publicly available FMML schema. The user interface functionality of the website is an outsourced activity of the project, and the full-featured website (http://testbed.fmi.fi) will be launched later on the course of the project.

The Helsinki Testbed is open to researchers around the world to test measurement and modeling systems. Support for non-standard instruments operated by HTB Investigators covers generally[†]:

- Measurement site and basic infrastructure (such as electricity).
- Assistance with practical arrangements.
- Working facilities during campaign.
- Central data warehouse (CDW).
- Access to CDW over Internet.

For further information, contact Jarmo Koistinen (jarmo.koistinen@fmi.fi) at the Finnish Meteorological institute or Walter Dabberdt (walter.dabberdt@vaisala.com) in the Vaisala office in Boulder, Colorado.

All researchers are welcome to register as common data warehouse users, to get access to measurement data over the Internet at http://testbed.fmi.fi. Primary data will be available online in real time; data needing manual interference will be uploaded within a month after the end of each measurement campaign. Data from prototype, non-COTS (commercial, off-the-shelf) instruments will become available within six months.

[†] *Note: Restrictions may apply to any of the guidelines presented. HTB Technical Committee reserves right to alter these policies without notice. Especially, support for Non-Standard Instruments is done case-by-case basis.*

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