NGOs, the Nordic Geodetic Observing System

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SUMMARY

We describe the status and plans of the Nordic Geodetic Observing System (NGOS). NGOS integrates fundamental geodetic techniques for the long term observation of Earth system parameters that are important in the context of change in and on our planet. The Nordic Geodetic Commission (NKG) established a Task Force with the mission to prepare the plan and the practical implementation of the NGOS. NGOS is planned to be a regional implementation and densification of the Global Geodetic Observing System, GGOS. NGOS will contribute to the GGOS and other IAG Services; European activities such as EUREF, ECGN, EUVN, and ESEAS; provide the reference frames for the Nordic countries, as well as contribute to the global ones; support scientific projects related to the geodynamics of the Nordic area and provide ground-truth for satellite missions.

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ABSTRACT

We describe the status and plans of the Nordic Geodetic Observing System (NGOS). NGOS integrates fundamental geodetic techniques for the long term observation of Earth system parameters that are important in the context of change in and on our planet. The Nordic Geodetic Commission (NKG) established in 2002 a Task Force with the mission to prepare the plan and the practical implementation of the NGOS. NGOS is planned to be a regional implementation and densification of the Global Geodetic Observing System, GGOS. NGOS will contribute to the GGOS and other IAG Services; European activities such as EUREF, ECGN, EUVN, and ESEAS; provide the reference frames for the Nordic countries, as well as contribute to the global ones; support scientific projects related to the geodynamics of the Nordic area and provide ground-truth for satellite missions.

BACKGROUND

Recent development on the global level has been very rapid. Most importantly, the fundamental role of geodesy as the provider of the global reference frame and observations of the Earth's shape, gravity field and rotation is currently acknowledged. Since 2004, IAG has participated in the preparation of the GEOSS (Global Earth Observation System of Systems) Implementation Plan. With the establishment of the Group on Earth Observations (GEO) in 2005, a more permanent mechanism on this has been possible. IAG was approved as a GEO Participating Organization. The regional system aligns with international efforts such as the Global Observing Systems and adheres to the Integrated Global Observing Strategy (IGOS). The efforts of GGOS lead also to the membership in the Integrated Global Observing Strategy Partnership (IGOS-P).

Over the last years, the European Commission and the European Space Agency have jointly proposed a programme for Global Monitoring for Environment and Security (GMES). The GMES represents a concerted effort to bring data and information providers together with users, so they can better understand each other and agree on how to make environmental and security-related information available to the people who need it.

A challenge for GMES is to gather relevant data and provide services, which will enable decision-makers to better anticipate or integrate crisis situations issues relating to the management of the environment and security.

The GMES is based on four inter-related components, namely services, observations from space, in-situ (including airborne) observations, and data integration and information management capacity. The range of services available by 2008 will be developed progressively. Services relies on the space and in-situ data providers. The data integration and information management will enable user access and the sharing of information.

In addition, access to socio-economic and other statistical data will be important. GMES is meant to be an open system that can easily accommodate new elements. The needs of GMES can be expected to be a major driver for the development of observation networks and applications in Europe and worldwide over the next decade and it will have a great impact also on geodesy and geodetic observing systems.

Current development means a unique opportunity for the geodetic community. Ignorance of the global development will be fatal for geodesy pushing it out from the mainstream of the development. Inside of the community we know that geodesy and geodetic methods will be an essential component in global monitoring.
There are two main contributions of geodesy to global monitoring

- the maintenance of a highly accurate references frame as the backbone for all other observation systems, and
- observations of key variables of the Earth system, such as changes in its figure and gravity field, and variations in the Earth's rotation.
- These quantities are related both to mass movements in the different parts of the Earth, from the inner core to the upper atmosphere, as well as the dynamics of the system.
- The space-based technologies allow us now to determine positions in a globally coherent and highly accurate reference frame. Key variables of the Earth system such as the movements of the tectonic plates, land movement, Earth rotation, changes in the gravity field, and sea level changes are now observable in a globally consistent reference frame. There is an increasing demand for accurate and reliable geodetic observations for many scientific and non-scientific applications. However, the accuracy level achieved reveals inconsistencies between the global reference frame and the regional and national frames established for practical use.
- GGOS will be geodesy‘s central interface to the scientific community and to society in general, and it will contribute to large international observation and science programs. Large parts of the physical observing network of the GGOS are already in place through the efforts of the national mapping authorities and other institutions involved in operational monitoring. The role of GGOS is to collect existing products, services, and act as a contact point to the outside world, promote techniques, and also coordinate that parameters, products and data are consistent with each other. GGOS must internally keep all its data, products and parameters on highest possible quality, independently of user needs, which sometimes may be quite modest. GGOS itself will not be the producer, but data and products are made in services (IAG or other sources). In this respect regional observing systems (e.g. NGOS) are in an essential role.

Demands for GGOS are quite challenging. One has to find stabilization of global geodetic infrastructure on political level to ensure a stable GGOS for 30+ years. At the same time development of observing techniques require unification on the level of 10^{-9} in g and reference frames. Currently, IAG activities are based on voluntarily participation of various authorities and institutions. There are already threats to close national facilities, and there is no guarantee that existing infrastructures will be preserved. An ultimate goal is to achieve a high-level political intergovernmental agreement, possibly under UN science programs to guarantee the continuation of geodetic networks on National level. Such an agreement, however, is not yet in view.

Definitions and principles of NGOS should follow those of GGOS as closely as possible. The concern on the political decisions are common, and downgrading National facilities are not in hands of the scientific community. Therefore, even in the Nordic area, a high-level intergovernmental agreement and commitment on the national level is the most preferable to guarantee the continuation of the Nordic geodetic frames, infrastructure and facilities.
The vision and mission of GGOS (http://www.ggos.org) can serve also as a general guideline for the planning of the NGOS.
The vision of GGOS is as follows:

- GGOS integrates different techniques, different models and different approaches in order to achieve a better consistency, long-term reliability and understanding of geodetic, geodynamic and global change processes.
- GGOS provides the scientific and infrastructure basis for all global change research in Earth sciences.
- In the frame of GGOS, the Earth system is viewed as a whole by including the solid Earth as well as the fluid components, the static and time-varying gravity field in its products.
- GGOS is geodesy's contribution (products and discoveries) to Earth sciences and the bridge to the other disciplines; it asserts the position of geodesy in geosciences.
- GGOS integrates the work of IAG and emphasizes the complementarity of the broad spectrum of geodetic research and application fields.
- The mission of GGOS is:
- to collect, archive and ensure the accessibility of geodetic observations and models;
- to ensure the robustness of the three fundamental fields of geodesy, namely geometry and kinematics,
- Earth orientation and rotation, and gravity field and its variability;
- to identify a consistent set of geodetic products and to establish the requirements concerning the products' accuracy, time resolution, and consistency;
- to identify IAG service gaps and develop strategies to close them;
- to stimulate close cooperation between existing and new IAG services;
- to promote and improve the visibility of the scientific research in geodesy;
- to achieve maximum benefit for the scientific community and society in general.
- NGOS aims to provide geodetic observations for the Nordic area that are of sufficient quantity and quality to serve most of the needs of global Earth observation as well as practical and scientific applications in the region. For the Nordic countries, a main focus will be on crustal motion, dynamics of glaciated areas and sea level.
- In particular, NGOS
- will contribute to the GGOS and other IAG Services

- will contribute to global Earth observation systems,
- will contribute to European activities such as EUREF, ECGN, EUVN, and ESEAS,
- will coordinate the work on the reference frames for the Nordic countries, and the region as well as contribute to the global ones,
- will support scientific projects related to the geodynamics of the Nordic area,
- will provide ground-truth for satellite missions.

Figure 1. Relations of NGOS to other activities.
ECGN: European Combined Geodetic Network;ESEAS: European Sea-Level Service; EUREF: Reference frame subcommission for Europe;G3OS: Global Observing Systems; GGOS: Global Geodetic Observing System; GMES: Global Monitoring for Environment and Security;IAG: International Association of Geodesy; IGOS: Integrated Global Observing Strategy; NGOS: Nordic Geodetic Observing System.

NGOS is envisaged to provide the necessary observations to determine

- geodetic positions and to infer the kinematics of the Earth surface,
- gravity and its temporal changes, and
- Earth orientation parameters, i.e. precession, nutation, length of day, and polar motion.

Plans of the NGOS were published in Poutanen *et al.*, (2006, 2005a,b) based on the work of the NKG Task Force. In this document we summarise the structure and plans of the NGOS, make an inventory of existing infrastructure, and make a proposal for the NKG for the future tasks to implement the NGOS on the practical level and ensure its compatibility to the GGOS project. This document is more or less the same as Poutanen (2006) but with an updated meta data table (Table 4) as well as maps presenting the meta data table (Figure 1 and 2).

PROPOSED STRUCTURE OF NGOS

The geographic extent of NGOS is currently defined as the Nordic region, including Iceland, Greenland and Svalbard. It is recommended that the geographical region is extended to include also the area of Baltic States. This covers the area of the ice-covered part of the Northern Europe during the last ice age, and therefore of the common geophysical interest.
Only the ground components of the geodetic observation techniques and infrastructures are considered in NGOS. Densifications, e.g. in special target areas such as glaciers, tectonically active structures, or near tide gauges, can be accomplished using remote sensing techniques, such as space and airborne radar and laser systems. Sea level can be monitored using satellite

altimetry. The large scales of the gravity field and its changes are studied using observations of the motions of satellites by SLR and GPS or by dedicated gravity satellite missions.

In the next chapter we will discuss on the current existing infrastructure. In Table I, extracted from the original NGOS plan we have summarised the proposed techniques considered in NGOS. Geodetic VLBI and SLR are only on a few stations in the area, but they form the most fundamental part of the network. They cannot be replaced with any other techniques, and due to their nature, they are the most vulnerable components if budget cuts or national network downgrades are made. Doris stations are controlled by CNES, and there are only two Doris station in the NGOS area. GNSS technique has a lot of redundancy, receivers are relatively cheap and maintaining of a permanent reference network is simple. Spatial coverage of the GNSS network is good.

Concerning spatial variations of gravity and its temporal changes, we propose concentration on the use of modern, absolute gravimeters as expressed in NGOS/Absolute Gravimetry plan (Scherneck et al., 2002) and "Draft plan for absolute gravity campaigns in the Fennoscandian land uplift area" by Mäkinen (2003). The absolute gravity measurements in the Nordic area is made as a co-operation of Danish National Space Centre, The Finnish Geodetic Institute, Norwegian Mapping Authority, National Land Survey of Sweden, Onsala Space Observatory (Sweden), Norwegian University of Life Sciences in Aas, University of Hannover (Germany), and Federal Agency for Cartography and Geodesy (BKG, Germany). Relative and especially superconducting gravimetry is an important part of the gravity net. Temporal variation can be tracked with a superconducting gravimeter, the number of which is only 3 in the area.

We also emphasize the importance of geoid determination. By nature, it is not limited to the NGOS stations or NGOS plan. In the future, the new gravity satellite missions, especially GRACE and GOCE will give their contribution also to the Nordic geoid models.

Levelling as a traditional technique is slow and expensive but accurate, and in some circumstances cannot be replaced by any other method. National levelling networks exist with a number of repeated nationwide precise levellings. More national levelling projects, however, seems quite unlikely in the future.
Tide gauges are mostly out of the control of the geodetic community, because they are maintained by other authorities. Tide gauges are essential in study of global change, and one should assure access to the tide gauge data, either via PSML, ESEAS or by (bilateral) agreements with authorities owning the tide gauges.

CURRENT EXISTING INFRASTRUCTURE

NKG has tried to act as a platform for sharing the knowledge concerning construction of various geodetic networks and in co-operation of geodetic campaigns. However, at the end it has always been the responsibility of an individual country or a research team to implement the work in practice. The Nordic countries have historically been building up their geodetic networks quite independently. There has been only a limited amount of co-operation between the countries or techniques. Inside the countries even collaboration between organizations has not been optimal. Tide gauges are typical examples, because institutions taking care of them are generally outside of the geodetic community.

In each country there are networks of permanent GNSS stations which partly are operated by the national geodetic authorities. The co-ordination concerning e.g. location, construction, facilities and products was not optimal when the stations were built. This means e.g. that the stations have different monumentation, have different types of equipment, produce slightly different products and possibly are not optimally spread over the Nordic Area. However, the basic observables are the same at all stations, thus allowing e.g. the common Nordic computation of the EPN block, or the collaboration in the projects like BIFROST. Another form of collaboration exists between Denmark, Norway and Sweden since the year 2000, concerning exchange of data and various products for navigation and real-time application purposes.

Table 1.:Summary of techniques considered in NGOS.

Technique	Objective	Accuracy	Component(s)
VLBI	Point positioning relative to the network of quasars	0.001 ppb 0.1 mas	Surface displacement; Earth rotation; Reference frame orientation
SLR	Point positioning relative to satellites	< 1 cm (range) 1-2 cm	Surface displacement; Earth rotation; Reference frame origin
GNSS	Point positioning relative to a satellite system	E: 1-2 cm *) C: 1-2 mm	Surface displacement; Reference frames, densification
DORIS	Point positioning relative to satellites	1-5 cm	Surface displacement; Reference frame
Levelling	Height differences of points relative to the geoid	< 1 mm/km$^{1/2}$	Surface displacement; Height differences
Tide gauges	Height of points relative to sea level	E: 10 cm C: 1 cm	Surface displacement; Sea level variation
Absolute gravimeters	Absolute gravimetric accelerations	2-3 μGal	Surface displacement; Earth rotation; Gravity; Reference frame
Superconducting gravimeters	Relative gravimetric accelerations	0.1 μGal (< 1 nGal periods)	Surface displacement; Earth rotation; Gravity; Reference frame
Spring gravimeters	Relative gravimetric accelerations	2-3 μGal	Gravity; Reference frame
*) *E means episodical and C continuous measurements*			

The Finnish Geodetic Institute has been active in absolute gravimetry and has been performing measurements on stations over the Nordic Area for many years. Groups from

USA and Germany have also made absolute gravity measurements in the Nordic Area. The current NGOS AG plan clearly demonstrates the current co-operation in this field. Since 2003, also Norwegian University of Life Sciences in Aas has an absolute gravimeter, and the National Land Survey of Sweden has purchased an absolute gravimeter in 2006, which are substantial increase in the resources. Most of the measurements in Finland and Sweden have been performed at stations with other geodetic techniques, such as permanent GNSS stations and/or tide gauges.

There is a superconducting gravimeter at Metsähovi and Ny-Ålesund and a new site is planned in Onsala. These three stations are also equipped with a geodetic VLBI. These three stations are internationally important fundamental resources since several specific techniques are collocated to these stations. Metsähovi has additionally collocated other two space geodetic equipment, namely the SLR and DORIS. Since 1978 Metsähovi has participated the SLR programme, and is currently the Northernmost SLR station. Stations in geodetic VLBI and SLR contributes to the work of IVS and ILRS which are the IAG services.
GNSS data of some Nordic stations are used in IGS, but a more wide selection of Nordic GNSS stations belong to the EPN, the European Permanent GPS Network, coordinated by EUREF. EUREF has during the last decade become active concerning European co-operation and examples of this are:

- the European reference frame ETRS89
- the European Network of permanent GNSS stations EPN
- the European vertical network EUVN
- the European height network UELN and the height system EVRS 2000
- ECGN

The Nordic countries have adopted national ETRS89-realisations as their national reference systems. NKG is responsible for one of the EPN analysis centres and the responsible organization is currently National Land Survey in Sweden. NKG has urged the countries for Nordic co-operation concerning the Nordic height systems. The joint Nordic adjustment of the levelling networks is headed towards the common vertical datum in the area. NGOS is in line with these initiatives towards Nordic co-operation concerning the national geodetic networks and geodetic stations.

Table 2. Components and associated services

Components	IAG service(s)	Other service(s)
Surface displacement	IVS, ILRS, IGS, TIGA, WEGENER	PSMSL, ESEAS
Earth rotation	IERS	
Gravity	BGI, IGeS, ICET	
Reference frame	EUREF, IERS	

Table 3. Infrastructure and data

Technique	**Stations**	**Responsible institutes**[1]	**Data archive / availability**
VLBI	Metsähovi,	FGI, OSO, SK	IVS / free availability of results

Technique	**Stations**	**Responsible institutes**[1]	**Data archive / availability**
	Onsala, Ny Alesund		
SLR	Metsähovi (+ Riga)	FGI	ILRS / free availability of results
GNSS	many (permanent), episodic	FGI, LM, OSO, SK, KMS, DNSC	EPN, OSO, National authorities / partly free (EPN), partly restricted
DORIS	Metsähovi, Ny Alesund	FGI, SK	IDS, CNES / free
Levelling	National levelling networks	FGI, LM, SK, KMS, DNSC	Nordic Data Bank and UELN / restricted availability
Tide gauges	many	SMHI, FIMR, SK, DMI	PSML, national authorities / free (PSML), restricted, commercial
Absolute gravimeters	three instruments, many points, episodic	FGI, UMB, LM	no joint data bank / restricted
Superconducting gravimeters	Metsähovi, Ny Alesund (+ Onsala (summer-08))	FGI, NMA (+OSO)	GGP / for members free
Spring gravimeters	many, national networks	FGI, LM, SK, KMS, GTK	national data banks / restricted

Abbreviation of institutes:

DMI	Danish Meteorological Institute
DNSC	The Danish National Space Center
FGI	Finnish Geodetic Institute
FIMR	Finnish Institute of Marine Research
GTK	Geological Survey of Finland
KMS	National Survey and Cadastre of Denmark
LM	National Land Survey of Sweden
OSO	Onsala Space Observatory
SK	Norwegian Mapping Authority
SMHI	Swedish Meteorological and Hydrological Institute
UMB	Norwegian University of Life Sciences

Table 4: The NGOS Network
Columns: = approximate latitude; = approximate longitude, *h* = ellipsoidal height;
VLB = VLBI; SLR = SLR; GNS = GNSS (GPS + GLONASS); DO = DORIS, AG = Absolute gravimeter, SCG = Superconducting gravimeter; TG = Tide gauge; CN = Control network, FP = Footprint; ITR = ITRF point; IVS = IVS point; IGS = IGS point; ILR = ILRS point; ECG = ECGN point; EPN = EPN point; GGP = GGP point; ESE = ESEAS point
Symbols: P = proposed / planned; M = monument available; E = episodic measurements; R = repeated measurements; C = continuous measurements; : = none

Site name	Coordinates			Techniques							Local		Committed to							
			h(m)	VLB	SLR	GNSS	DO	AG	SCG	TG	CN	FP	ITR	IVS	IGS	ILR	ECG	EPN	GGP	ESE
Metsähovi	60.218	24.395	95	C	C	C	C	R	C	:	R	:	C	C	C	C	C	C	C	:
Ny-Alesund	78.930	11.865	78	C	:	C	C	R	C	C	R	R	C	C	C	:	C		C	C
Onsala	57.395	11.926	47	C	:	C	:	R	C	:	R	:	C	C	C	:	C	C	:	:
Riga	56.949	24.059	35	:	C	C	:	R	:	:	:	:	C	:	:	C	:	:	:	:
Trysil	61.423	12.382	730	E	P	C	:	R	P	:	R	R	:	:	:	:	:	:	:	:
Alesund	62.476	6.199	190	:	:	C	:	R	:	C	R	R	:	:	:	:	:	:	:	C
Andoya	69.278	16.009	411	:	:	C	:	E	:	C	:	:	:	:	C	:	:	:	:	C
Andenes	69.320	16.134	35	:	:	C	:	:	:	C	R	:	:	:	:	:	:	:	:	
Arjeplog	66.318	18.125	489	:	:	C	:	R	:	:	E	:	:	:	:	:	:	:	:	:
Bergen	60.289	5.267	94	:	:	C	:	P	:	C	R	R	:	:	:	:	:	:	:	C
Bodo	67.284	14.434	107	:	:	C	:	E	:	C	R	R	:	:	:	:	:	C	:	C
Borås	57.715	12.891	220	:	:	C	:	R	:	:	E	:	:	:	C	:	:	C	:	:
Buddinge	55.739	12.500	:	:	:	C	:	:	:	:	E	E	:	:	:	:	:	C	:	:
Copenhagen	55.7	12.5	:	:	:	:	:	R	:	C	:	:	:	:	:	:	:	:	:	:
Degerby	60.032	20.385	20	:	:	E	:	:	:	C	P	:	:	:	:	:	:	:	:	:
Dombås	62.073	9.114	733	:	:	C	:	:	:	:	R	R	:	:	:	:	:	:	:	:
Furuögrund	64.879	21.048	:	:	:	:	:	:	:	C	:	:	:	:	:	:	:	:	:	:
Göteborg	57.687	11.981	:	:	:	:	:	R	:	:	E	:	:	:	:	:	:	:	:	:
Hässleholm	56.092	13.718	114	:	:	C	:	:	:	:	E	:	:	:	:	:	:	:	:	:
Helsingør	56.045	12.580	:	:	:	:	:	R	:	:	:	:	:	:	:	:	:	:	:	:

Site name	Coordinates			Techniques							Local		Committed to							
Höfn	64.267	-15.198	:	E	:	C	:	E	:	:	E	:	C	:	C	:	C	C	:	:
Holmsund	66.673	20.389	32	:	:	C	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Honefoss	60.144	10.249	181	:	:	C	:	E	:	:	R	:	:	:	:	:	:	:	:	:
Honningsvåg	70.968	25.956	55	:	:	C	:	E	:	:	R	:	:	:	:	:	:	:	:	:
Irbene	57.888	21.852	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Jan Mayen	70.972	-8.491	65	:	:	C	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Joensuu	62.391	30.096	114	:	:	C	:	R	:	:	R	:	C	:	:	:	:	C	:	:
Jönköping	57.745	14.060	260	:	:	C	:	:	:	:	E	:	:	:	:	:	:	:	:	:
Karlstad	59.444	13.506	114	:	:	C	:	:	:	:	E	:	:	:	:	:	:	:	:	:
Kautokeino	69.018	23.017	413	:	:	C	:	E	:	:	R	:	:	:	:	:	:	:	:	:
Kevo	69.756	27.007	:	:	:	C	:	P	:	:	R	:	:	:	:	:	:	:	:	:
Kiruna	67.878	21.060	498	:	:	C	:	R	:	:	E	:	C	:	C	:	:	C	:	:
Kivetty	62.820	25.702	:	:	:	C	:	:	:	:	R	R	:	:	:	:	:	:	:	:
Klaipeda	55.723	21.178	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Kramfors	62.855	18.096	57	:	:	C	:	R	:	:	:	:	:	:	:	:	:	:	:	:
Kristiansand	58.083	7.907	148	:	:	C	:	:	:	C	R	R	:	:	:	:	:	:	:	C

Site name	Coordinates			Techniques							Local		Committed to							
			h(m)	VLB	SLR	GNS	DO	AG	SCG	TG	CN	FP	ITR	IVS	IGS	ILR	ECG	EPN	GGP	ESE
Kungsholmsfort	56.104	15.589	54	:	:	C	:	:	:	C										
Kuressaare	58.250	22.487	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:

Site name	Coordinates			Techniques							Local		Committed to							
Kuusamo	65.910	29.033	:	:	:	C	:	:	:	:	R	:	:	:	:	:	:	:	:	:
Leksand	60.722	14.877	478	:	:	C	:	:	:	:	E	:	:	:	:	:	:	:	:	:
Lovö	59.338	17.829	80	:	:	C	:	:	:	:	E	:	:	:	:	:	:	:	:	:
Lycksele	64.628	18.667	245	:	:	:	:	R	:	:	:	:	:	:	:	:	:	:	:	:
Mårtsbo	60.595	17.259	75	:	:	C	:	R	:	:	E	:	C	:	C	:	C	C	:	:
Norrköping	58.590	16.246	41	:	:	C	:	:	:	:	E	:	:	:	:	:	:	:	:	:
Olkiluoto	61.240	21.473	:	:	:	C	:	P	:	:	R	R	:	:	:	:	:	:	:	:
Oskarshamn	57.066	15.997	150	:	:	C	:	:	:	:	E	:	:	:	:	:	:	:	:	:
Oslo	59.737	10.368	221	:	:	C	:	:	:	C	R	R	:	:	:	:	:	:	:	C
Östersund	63.443	14.858	490	:	:	C	:	R	:	:	E	:	:	:	:	:	:	:	:	:
Oulu	65.086	25.893	:	:	:	C	:	P	:	:	R	:	:	:	:	:	:	:	:	:
Överkalix	66.318	22.773	223	:	:	C	:	:	:	:	E	:	:	:	:	:	:	:	:	:
Panevezys	55.375	24.360	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Pope	57.403	21.857	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Qaqortoq	60.715	313.952	:	:	:	C	:	P	:	C	E	:	:	:	C	:	C	C	:	:
Ratan	63.986	20.896	31	:	:	C	:	R	:	C	:	:	:	:	:	:	:	:	:	:
Reykjavik	64.139	-21.955	:	:	:	C	C	R	:	C	R	:	C	:	C	:	C	C	:	C
Romuvaara	64.217	29.931	:	:	:	C	:	:	:	:	R	R	:	:	:	:	:	:	:	:
Skellefteå	64.879	21.048	81	:	:	C	:	R	:	:	E	:	:	:	:	:	:	C	:	:
Smidstrup	55.641	9.559	:	:	:	C	:	P	:	:	E	E	:	:	:	:	C	C	:	:
Smögen	58.353	11.218	45	:	:	C	:	R	:	C	P	:	C	:	:	:	:	:	:	:

Site name	Coordinates			Techniques							Local		Committed to							
Sodankylä	67.421	26.389	300	:	:	C	:	R	:	:	R	:	:	:	:	:	:	C	:	C
Stavanger	59.018	5.599	105	:	:	C	:	R	:	C	R	R	:	:	:	:	:	:	:	:
Suldrup	56.842	9.742	:	:	:	C	:	P	:	:	E	E	:	:	:	:	C	C	:	:
Sundsvall	62.232	17.660	32	:	:	C	:	:	:	:	E	:	:	:	:	:	:	:	:	:
Suurupi	59.467	24.383	:	:	:	C	:	E	:	:	E	:	:	:	:	:	:	:	:	:
Sveg	62.017	14.700	491	:	:	C	:	:	:	:	E	:	:	:	:	:	:	:	:	:
Tebstrup	55.968	9.881	:	:	:	:	:	R	:	:	:	:	:	:	:	:	:	:	:	:
Toravere	58.267	26.467	:	:	:	P	:	P	:	:	:	:	:	:	:	:	:	:	:	:
Tromsø	69.663	18.938	132	E	E	C	:	E	:	C	R	R	:	:	C	:	:	C	:	C
Trondheim	63.371	10.319	318	:	:	C	:	R	:	C	R	R	:	:	:	:	:	C	:	C
Trygde	58.006	7.555	48	:	:	C	:	:	:	C	:	:	:	:	C	:	:	:	:	C
Tuorla	60.416	22.443	:	:	:	C	:	P	:	:	R	:	:	:	:	:	:	:	:	:
Umeå	63.578	19.510	54	:	:	C	:	:	:	:	E	:	:	:	:	:	:	:	:	:
Uppsala	59.865	17.590	57	:	:	C	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Vaasa_GPS	62.961	21.771	58	:	:	C	:	R	:	:	R	:	C	:	:	:	:	C	:	:
Vaasa_AA	63.085	21.646	:	:	:	:	:	R	:	:	:	:	:	:	:	:	:	:	:	:
Vänersborg	58.693	12.035	170	:	:	C	:	:	:		:	:	:	:	:	:	:	C	:	C
Vardø (Domen)	70.336	31.031	175	:	:	C	:	:	:	:	R	R	:	:	:	:	:	:	:	:
Vardö (TG)	70.372	31.100	23	:	:	C	:	:	:	C	:	:	:	:	:	:	:	:	:	:
Vilhelmina	64.698	16.560	450	:	:	C	:	:	:	:	E	:	C	:	:	:	:	:	:	:
Vilnius	54.722	25.338	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:

Site name	Coordinates			Techniques							Local		Committed to							
Virolahti	60.539	27.555	:	:	:	C	:	E	:	:	R	:	:	:	:	:	:	:	:	:
Visby	57.654	18.367	80	:	:	C	:	R	:	C	E	:	C	:	C	:	:	C	:	:
Viski	56.067	26.767	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:

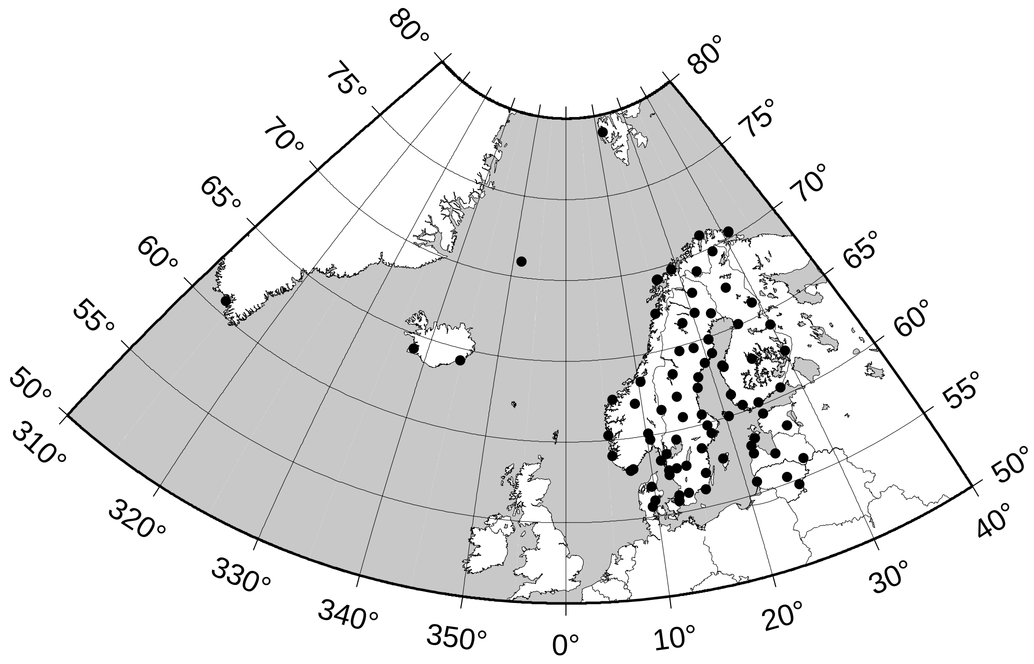

Figure 2. The geographical area covered by the NGOS and proposed NGOS stations

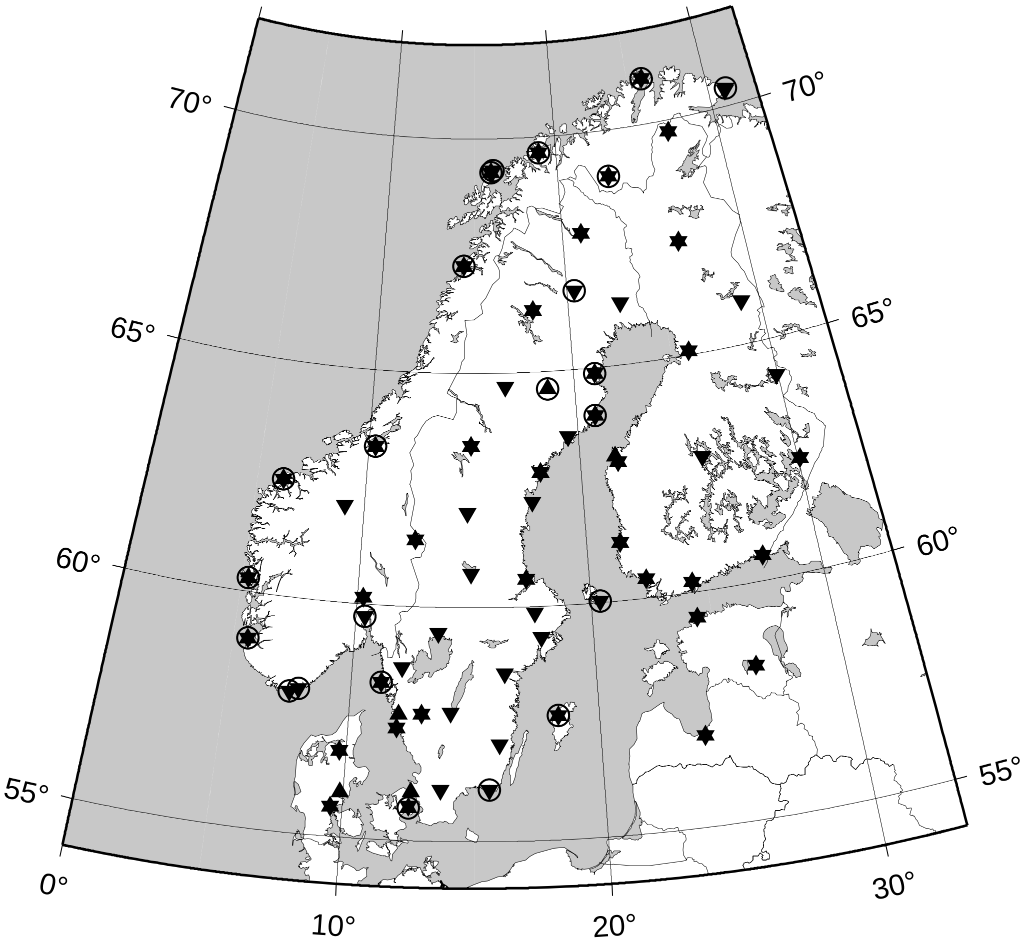

Figure 3. NGOS plan. Absolute gravity points (triangles), Nordic permanent GPS network (upside down triangles) and tide gauges (circles). All absolute gravity points are occupied with a GNSS instrument.

FUTURE OF THE NGOS

NGOS will be one of the key issues of the NKG in coming years. Most of the observational infrastructure is in place. However, it the responsibility of the individual institutions to maintain the instrumentation, infrastructure and networks. Stability is the key issue. There is no common mechanism to guarantee the continuation of the individual parts of the NGOS over next decades. Political or economical changes may be hazardous, and the rest of the community can do very little if some parts are decided to decease nationally.

Data infrastructure of NGOS is more unorganised than the network itself. There are no common data archives, nor there are any common data policy how the data are accessed. Some data are free, some partly free and many have restrictions. Obviously it would be the first task for the NGOS to establish a meta data base for existing data, archives and a common

mechanism for access. With some exceptions, most data are available but standardisation and recommendations for access and use are needed. However, there is the question who will do the actual work, how the access, copyrights, and so on will be arranged.
NGOS should follow as closely as possibly the development of GGOS. NGOS should be a regional implementation and extension of GGOS. Therefore, it would be important that a member of NGOS core group is in the GGOS steering committee.

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BIOGRAPHICAL NOTES

Mikael Lilje graduated in 1993 from the Royal Institute of Technology as a land surveyor with emphasis on Geodesy and Photogrammetry. He is working at Lantmäteriet since 1994, mainly at the Geodetic Research Division. He is the head of a section working with reference frame and co-ordinate system issues since 2001.

Mr Lilje is chair of the Swedish Map and Measuring Technique Society and chair of the FIG Commission 5 Working Group on ”Reference Frame in Practice”. Mr Lilje was also secretary for FIG Commission 5 during the period 1998 – 2002.

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