EUROPEAN SCIENCE FOUNDATION

SETTING SCIENCE AGENDAS FOR EUROPE

RESEARCH NETWORKING PROGRAMME

TALL TOWER AND SURFACE OBSERVATION RESEARCH NETWORK FOR VERIFICATION OF CLIMATE RELEVANT EMISSIONS OF HUMAN ORIGIN IN EUROPE (TTORCH)

Standing Committee for Life, Earth and Environmental Sciences (LESC)

www.esf.org

Introduction

The European Science Foundation (ESF) is an independent, non-governmental organisation, the members of which are 79 national funding agencies, research performing agencies, academies and learned societies from 30 countries.

The strength of ESF lies in the influential membership and in its ability to bring together the different domains of European science in order to meet the challenges of the future.

Since its establishment in 1974, ESF, which has its headquarters in Strasbourg with offices in Brussels and Ostend, has assembled a host of organisations that span all disciplines of science, to create a common platform for cross-border cooperation in Europe.

ESF is dedicated to promote collaboration in scientific research, funding of research and science policy across Europe. Through its activities and instruments ESF has made major contributions to science in a global context. The ESF covers the following scientific domains:

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- **Social Sciences**
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- **Materials Science and Engineering**
- **Nuclear Physics**
- **Polar Sciences**
- **Radio Astronomy**
- **Space Sciences**

TTORCH (Tall Tower and surface Observation Research Network for verification of Climate relevant emissions of Human origin in Europe) is an ESF Research Networking Programme focusing on measurements and modelling of non-CO_2 greenhouse gases (CH_4, N_2O, SF_6) and related tracers (e.g., CO, H_2, $^{14}CO_2$, O_2/N_2).

The main purpose of TTORCH is to support and help improve the European network of observations of greenhouse gases through communication, workshops, grants for exchange visits and summer schools.

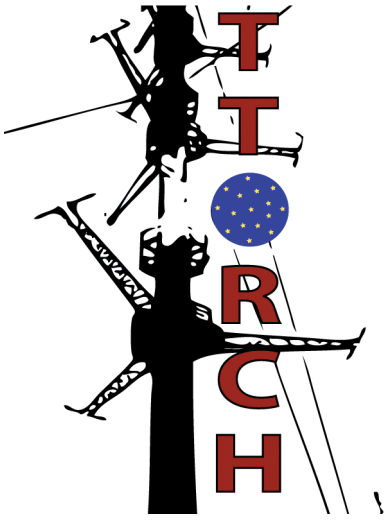
In the current context, where the European measurement network has little financial support for non-CO_2 greenhouse gases, TTORCH will assist in maintaining and consolidating quality and consistency within the measurement network.

TTORCH will work, by capacity building, towards extension of the measurement network in poorly covered areas, like Eastern Europe.

The Programme will also contribute to strengthening the connection between measurement and modelling scientists by organising joint workshops and publications.

The running period of the ESF TTORCH Research Networking Programme is for five years from March 2009 to March 2014.

Keywords:
Climate change • Earth system observations • Greenhouse gases • Emission verification • Inverse methods



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Non-CO_2 greenhouse gases and related tracers

Methane (CH_4) is the second most important anthropogenic greenhouse gas after CO_2 in terms of radiative forcing. Anthropogenic sources account presently for more than 60% of the total emissions to the atmosphere, including: energy production, waste disposal in landfills, raising ruminant animals, rice agriculture and biomass burning. CH_4 natural sources include wetlands, cud chewing animals, biomass burning, termites, oceans and volcanoes. Because of its relatively short lifetime, CH_4 emission reduction can have rapid effects on atmospheric concentration. On the other hand, global warming could lead to huge quantities of CH_4 being suddenly released from permafrost and from sea floor methane hydrates, which would further contribute to the global warming loop.

Nitrous oxide (N_2O) is a greenhouse gas which had a globally averaged atmospheric concentration of about 270 parts per billion (ppb) in pre-industrial time and has reached about 320 ppb at present. Although it has a lower concentration than CO_2, N_2O is an important greenhouse gas because of its long residence time in the atmosphere and its high global warming potential (GWP). Anthropogenic N_2O sources include biomass burning, fossil fuel combustion, industrial production of adipic and nitric acids and the use of nitrogen fertiliser in agriculture, and account at present for about half of the total N_2O sources. The main N_2O sinks are photo-dissociation in the stratosphere and reactions with excited atomic oxygen, affecting in this way the stratospheric chemistry.

Sulphur hexafluoride (SF_6) is the strongest greenhouse gas that has been evaluated, having a global warming potential of 22 800 over a 100-year period, and an atmospheric lifetime of 3 200 years. Atmospheric SF_6 is entirely of anthropogenic origin, being used mainly as a dielectric medium for high voltage equipment, in the semiconductor industry as an etchant, and in the magnesium and aluminium industries. With a present atmospheric mixing ratio of about 7 parts per trillion (ppt), SF_6 is not a major contributor to global warming. However, atmospheric SF_6 is increasing at a rate of 0.2 ppt/year and, due to its very long atmospheric lifetime, the present accumulation is practically irreversible for thousands of years. Its chemical stability, the possibility to measure it with high precision and the relatively well-known sources have made SF_6 one of the most attractive tracers for atmospheric transport and mixing studies.

Chlorofluorocarbons (CFCs) are organic compounds containing carbon, chlorine and fluorine. Many CFCs are potent greenhouse gases, and some have very long atmospheric lifetimes. CFCs have been widely used as refrigerants, propellants and solvents. Because of their contribution to ozone depletion, the fabrication and use of CFCs was regulated by the Montreal Protocol and dramatically reduced after 1990. Atmospheric concentration of most important CFCs has visibly declined during the past decade.

Species	Atmospheric lifetime (years)	GWP 100 years
CO_2	50-200	1
CH_4	12	25
N_2O	114	298
SF_6	3200	22800
CFC-11	45	4750
CFC-12	100	10900
CFC-13	640	14400
CFC-113	85	6130

Atmospheric lifetimes and global warming potentials (GWP) over 100-year time horizon, as assessed by IPCC 2007.

Carbon monoxide (CO) is a trace gas with an average atmospheric lifetime of about 60 days. Anthropogenic sources include fossil fuel burning and oxidation of hydrocarbons and account at present for more than 50% of the total emissions. In the troposphere CO is the main controller of the concentration of hydroxyl (OH) radicals and thus of the oxidation capacity of the troposphere. CO affects in this way the global cycles of natural and anthropogenic trace gases that are removed from the atmosphere by reaction with OH, for example methane. The direct radiative impact of CO on the atmosphere (the "direct" greenhouse effect) is not significant. However, CO is important because of its indirect greenhouse effect by increasing tropospheric ozone and methane concentrations, and because of its multiple effects on tropospheric chemistry. CO has been used as an indicator for anthropogenic emissions, helping with interpretation of other trace gases measurements, particularly carbon dioxide (CO_2).

Hydrogen (H_2) is one of the important constituents of the atmosphere, with an average mole fraction of about 530 ppb. Some of the main sources, both natural and anthropogenic, are photo-oxidation of hydrocarbons, and emissions from fossil fuel and biomass burning. H_2 reacts with the OH radicals, affecting the atmospheric lifetime of other species including methane, which constitutes an indirect greenhouse effect. The expected future use of H_2 as an energy carrier could lead to a significant increase in emissions, affecting the actual balance of H_2 atmospheric budget and having multiple effects on atmospheric chemistry.

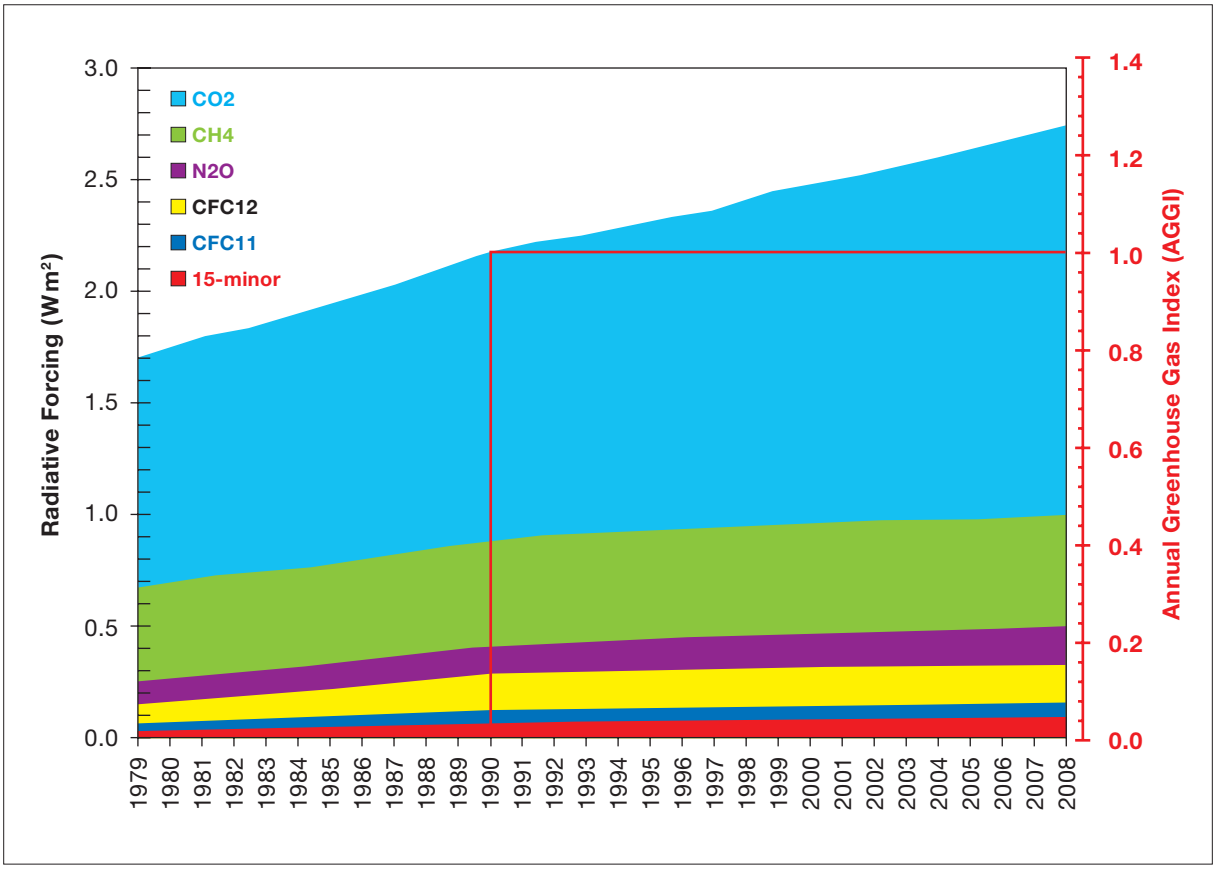
Scientific Background

Non-CO_2 greenhouse gases currently contribute about 30% to the anthropogenic enhancement in radiative forcing since pre-industrial times. The major long-lived greenhouse gases, including CH_4, N_2O and SF_6, are subject to regulation under the Kyoto Protocol, which came into force in 2005.

Observations of the long-lived non-CO_2 greenhouse gases and related tracers are an essential part of the Earth observation system, and are recognised as Essential Climate Variables (ECVs) by the Global Climate Observing System (GCOS). By combining observations of atmospheric concentration variations with atmospheric transport models, it is in principle possible to derive the location and magnitude of the fluxes that induced the observed signals. This gives the possibility to detect trends in concentrations and emissions, to validate estimations of natural and anthropogenic emissions for large areas of Europe (independently checking the evolution of emissions) and to test and improve process-based emission models.

Much progress has been made in recent years in the modelling field, using higher resolution transport models with or without coupled process-based flux models. Using these models in inverse mode will allow improved estimates of fluxes to be derived, or possibly even optimised parameters of the flux models from observations of mixing ratios and/or fluxes.

Besides transport and process models with high resolution in time and space, observational data of sufficient density and precision are necessary. The coherence of the measurements from different locations is essential for quantifying the small longitudinal gradients, in order to resolve the fluxes at national and regional spatial scales.



Radiative forcing, relative to 1750, of all the long-lived greenhouse gases. The NOAA Annual Greenhouse Gas Index (AGGI), which is indexed to 1 for the year 1990, is shown on the right axis. Source: http://www.esrl.noaa.gov/gmd/aggi

The Current Network and Measurement Techniques

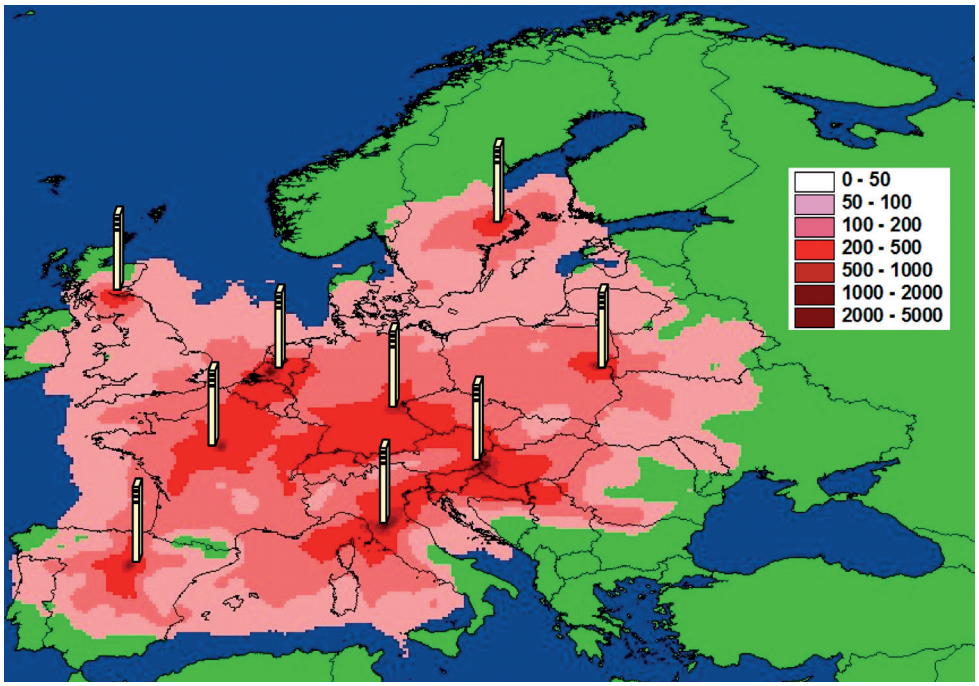
In the past ten years an operational network has been developed in Europe, employing tall tower, surface and flux measurement sites. The focus of this network has been directed strongly to the Carbon cycle, in particular to CO_2. Non-CO_2 greenhouse gases observations are generally collocated with the CO_2 observations, but they are generally performed with lower resources, although the measurements and precision requirements are very demanding and the running costs are high. Precision targets of the measurements for use in the global observation system are set by the World Meteorological Organization Global Atmosphere Watch (WMO-GAW).

A recent initiative directed to the non-CO_2 greenhouse gases was the CHIOTTO project (2002-2005, http://www.chiotto.org), in which eight tall tower based observation sites have been established for continuous high precision observations of CO_2, CH_4, N_2O, SF_6 and CO. CHIOTTO was part of the CarboEurope cluster of projects in the EU 5th Framework programme, later followed up by the CarboEurope-IP (Integrated Project) in the 6th Framework Programme. The tall tower stations, together with other measurement stations in Europe, now form a high-quality network of ground-based continuous, high precision measurements of greenhouse gases and related tracers in Europe.

This network is currently delivering data series. However, not always significant financial support is available or the support is declining. In recent years there was no project or programme to coordinate and use these measurements. Also, although the existing measurement network covers Central and Western Europe pretty well, there are still regions of Europe which are poorly represented.

In the framework of the European large research infrastructure programme, ESFRI, the project ICOS (Integrated Carbon Observing System) is now in its preparatory phase. ICOS will become operational after 2012. ICOS will form for the next 20 years a coordinated network of concentration and flux observation sites for CO_2, CO and CH_4 with central facilities for calibrations, data processing, database, etc. Eventually ICOS will extend the system also for N_2O. TTORCH will coordinate with ICOS to strive for synergy and added value, for example by connecting to the ICOS atmospheric database.

TTORCH is meant to provide a framework to keep the current measurement network alive, even improve it where possible, and to prepare, by capacity building, the extension to other parts of Europe. The partners of the TTORCH network will use the project as a platform for defining and building new projects in cooperation with the research community.



European network of tall tower measurement stations (CHIOTTO) and its influence area (relative units).
All of the red coloured areas contribute to the network observed concentrations with at least 1% of the maximum contribution per unit area and per unit of emission.
Locations of the CHIOTTO towers: Orleans (France), Ochsenkopf (Germany), Hegyhatsal (Hungary), Florence (Italy), Cabauw (The Netherlands), Bialystok (Poland), Norunda (Sweden), La Muela (Spain), Griffin (UK).

TTORCH Topic Areas

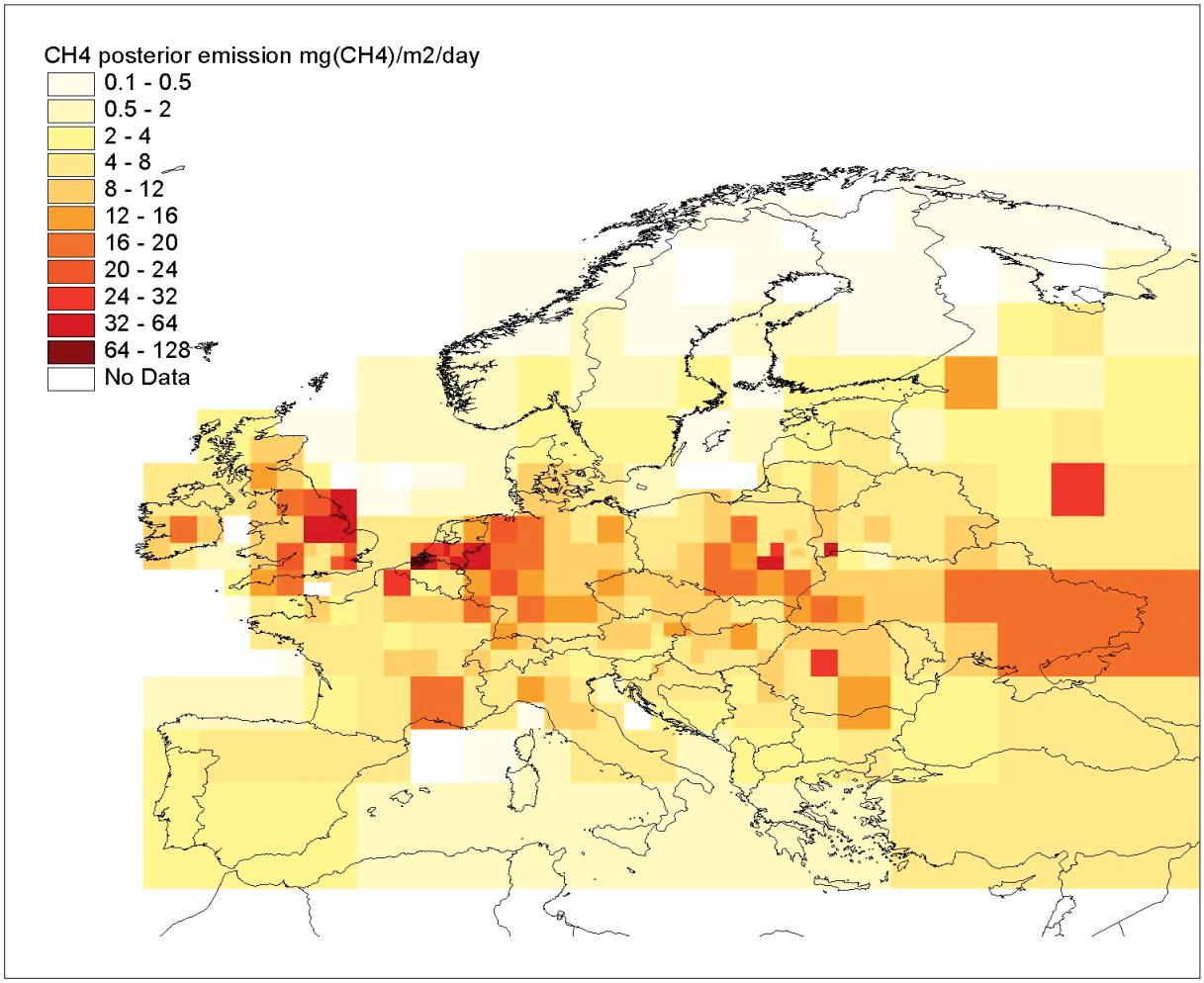
The subject of TTORCH is the wide field of measurements and modeling of non-CO_2 greenhouse gases and related tracers. The main topics, without constituting an exhaustive list, are the following:

- measurement techniques for atmospheric non-CO_2 greenhouse gases and related tracers
- quality and traceability of atmospheric measurements
- interpretation of measurement data
- inverse atmospheric transport modelling
- estimation of fluxes
- detection of trends in concentrations and emissions

TTORCH Objectives

TTORCH will work towards the following long-term objectives:

- contribute to improving the **quality and consistency** of the observational system in Europe
- help **extending the observational network** in areas poorly covered (e.g., Eastern Europe)
- enhance **communication** between scientists
- create a uniform **database** for the atmospheric measurement data



CH_4 emissions in Europe in 2006, as computed by the COMET model, using as input the measurement data from six tall tower stations. The spatial resolution of the resolved emissions is improved where the information content of the atmospheric signal received from the stations is higher.

TTORCH Activities

TTORCH will organise or support a number of activities addressing the topics of interest for TTORCH.

Travel grants

TTORCH offers two types of travel grants: **Short visits** (up to 15 days) and **Exchange grants** (up to 6 months). The purpose of the travel grants offered by TTORCH is to encourage networking between scientists with a focus on observations and modelling of non-CO_2 greenhouse gases and related tracers.

Support for science meetings

Scientists organising meetings focused on observations and modelling of non-CO_2 greenhouse gases in Europe may apply to TTORCH for financial support.

Summer schools

Every two years the TTORCH network will organise a summer school on measurement techniques, interpretation of data series, data selection and the use of data in mesoscale and long-range transport modelling.

International workshops

TTORCH will organise workshops to bring together scientists from observations and modelling communities from within and outside Europe.

Database

TTORCH will bring the measurement data of atmospheric non-CO_2 greenhouse gases and related tracers together in a uniform database, enabling the participants and the modelling community to deploy the shared data relatively quickly and easily.

Communication

The interactive website (**www.ttorch.org**) was created as a tool for communication between scientists and with the interested public. Brochures targeted at the general public will increase awareness of the general problems related to greenhouse gas emissions in Europe.

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