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SNOWCARBO

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List of abbreviations

COSMOS	Community Earth System Models (network for earth system modelling)
EC	Eddy Covariance (micrometeorological technique)
FMI	Finnish Meteorological Institute
MPI-M	Max Planck Institute on Meteorology, Hamburg
JSBACH	Jena Scheme for Biosphere-Atmosphere (model describing biosphere-atmosphere interaction)
ECHAM5	European Centre Hamburg Model (global circulation model, atmosphere)
REMO	Regional climate model

1 Summary

This report describes the data used for running and evaluating the climate models. Two different data sets are prepared for these purposes. The input data, i.e. the gridded data set, are collected from various global data sources and they are synthesised to global grids. The validation data (i.e. the *in situ* data set) such as, CO_2 fluxes and concentrations, have routinely been measured at stations maintained by FMI for several years. The former is used as boundary and initial conditions for model runs, whereas the latter will be facilitated in assessing the reliability of the model predictions.

The models facilitated in SNOWCARBO project are regional climate model (REMO2008), global circulation model (ECHAM5) and the ecosystem model (JSBACH) describing the CO_2 circulation within various ecosystems and soils and its exchange between the surface and the atmosphere. All these models belong to COSMOS model family which is developed by Max Planck Institute, Hamburg. While the project aims at estimating the terrestrial ecosystem CO_2 source and sink strengths with detailed process models, for reliable balance of CO_2, its exchange by oceans and fossil fuel sources have to be prescribed with appropriate emission data bases. Furthermore, both models need to be initialised and the regional model continuously forced from the domain boundaries with observed weather data. Additionally, in order to keep the weather similar to the actual one the models can be nudged with gridded meteorological data.

In order to estimate the performance of the models, CO_2 fluxes and concentrations they predict will be compared to point measurements at certain sites located at Boreal ecosystems. Data characteristics of the measurement sites maintained by FMI together with data availability and general data quality will be given in this report.

2 Data

2.1 Gridded data

The input data set needed for weather and tracer transport simulations consists of initial and boundary forcing data. This input data for the models (REMO2008, ECHAM5 and JSBACH) are given in the form of meteorological fields and as maps of surface properties. In addition to the standard meteorological fields such as air temperature, liquid water content and 3D velocity fields, also needed for estimating CO_2 balance are the initial atmospheric CO_2 concentration fields, fire information, anthropogenic sources and sea ecosystem CO_2 balance. Various possibilities for the initial and boundary forcing data fields were explored. The selected data sources are presented in Table 1. Below the table, a more detailed description of the contents of each data and address of the database are given. As the all the boundary and initial data needs to be processed from observations to gridded form most resent years are always lacking from the data series. Nevertheless, most of the data is collected from ongoing projects and consequently the various data bases will be updated as soon as new data is available. Presently all the collected boundary data extends at least up to year 2005.

Table 1. Datasources of the initial and boundary forcing data for the models (REMO2008, ECHAM5 and JSBACH)

Name of the dataset	Source, provider	Included data types	Limitations/ Drawbacks	Spatial/Time resolution	Time coverage
EDGAR4.0	European Commission Joint Research Centre and the Netherlands Environmental Assessment Agency	Surface fluxes due to fires and anthropogenic sources	Limited time coverage	0.1° Annual	2001-2005
TM3	TM3 model results from The Atmospheric Tracer Transport Model Intercomparison Project (TransCom) Christian Rünebeck	3D concentration fields due to all the relevant surface fluxes	No obvious drawbacks	1.875° Six-hourly	2001-2007
CarbonTracker	National Oceanic and Atmospheric Administration, US Department of Commerce Global Monitoring Division	3D concentration fields due to all the relevant surface fluxes	Coarse resolution for Europe	4°-6° Three-hourly	2001-2007
CarbonTracker Europe	Wageningen University	3D concentration fields due to all the relevant surface fluxes	Limited time coverage	1° Three hourly	2007
ECHAM5	Existing general circulation model runs with the MPI global model presently possessed by FMI	3D concentration fields and meteorology	Does not represent real years. No anthropogenic or oceanic sources.	Approx. 2° Six-hourly	2001-2006
ECMWF analysis data	European Centre for Medium Range Weather Forecast	Detailed meteorology derived from observations	No obvious limitations	Processed into 0.167° grid Six-hourly	2001-2008
Takahashi database	Carbon Dioxide Information and Analysis Center (CDIAC), Oak Ridge, National Laboratory	Oceanic CO2 fluxes	No limitations	4° × 5°	Present (2000)

EDGAR 4.0 will be used as fossil fuel emission data source in this project. The Emissions Database for Global Atmospheric Research (EDGAR) provides gridded global past and present day anthropogenic emissions of greenhouse gases and air pollutants. The current development of EDGAR is a joint project of the European Commission JRC Joint Research

Centre and the Netherlands Environmental Assessment Agency (PBL). Presently the SNOWCARBO team possess all the years of EDGAR 4.0 CO_2 emission data presently available. The terms of condition include giving appropriate reference and acknowledging the EDGAR team according to the instructions at the EDGAR webpage: http://edgar.jrc.ec.europa.eu.

TM3 model results from The Atmospheric Tracer Transport Model Intercomparison Project (TransCom) will be used as CO_2 concentration boundaries. The concentration fields are only given for those years where atmospheric data are available to constrain the assimilation (presently up to 2006). Only in the last year some measurement records may end earlier, and the very last weeks may be affected by edge effects of the inversion. Therefore, fields from this year should be handled with more care. 3D concentration fields are provided as NetCDF files. The data is in parts per million [ppm] concentration units. Terms of use are given at the webpage: http://www.bgc-jena.mpg.de/~christian.roedenbeck/download-CO2-3D/.

CarbonTracker is an optional source for initial and boundary CO_2 fields in SNOWCARBO. CarbonTracker data may also serve as a comparison data set for the CO_2 balance predictions in the later stages of the project. Provided is the daily average of the pressure-weighted mean mole fraction of carbon dioxide in the free troposphere. Additionally, a Carbon Tracker Europe group of University of Wageningen, the Netherlands provides data for Europe with higher resolution than that of standard CarbonTracker (http://www.carbontracker.eu/). Available is data for year 2007 and earlier years can be made available upon request.

ECHAM5 coupled with its ecosystem scheme JSBACH would provide the regional model with most complete and internally consistent set of boundary and initial data as it contains both CO_2 concentration fields and complete meteorology. The ECHAM5 data that FMI presently posses, is forced merely with sea surface temperature (SST). Thus, even thought the climate it predicts is close to actual, the weather conditions do not match with observed ones. The use of runs as boundary for regional model runs is furthermore restricted by the lack of ocean and fossil fuel sources. At this stage of the project the existing ECHAM5+JSBACH simulation results of FMI will not be considered to be used as boundary data.

ECMWF (The European Centre for Medium-Range Weather Forecasts) operational data will be used for boundaries and initial fields of meteorology. ECMWF provides the WMO (World Meteorological Organisation) members various data products of which operational data and re-analysis data can be facilitated in climate modelling. MPI-M has provided the project with operational data pre-processed to the domain intended for regional model runs. Web pages of ECMWF: http://www.ecmwf.int/.

Ocean fluxes from so called Takahashi database will be used to prescribe oceanic CO_2 emissions. A climatological mean distribution for the surface water pCO_2 over the global oceans in non-El Niño conditions are presented with spatial resolution of 4° (latitude) x 5° (longitude) for a reference year 2000 based upon about 3 million measurements of surface water pCO_2 obtained from 1970 to 2007 (Takahashi et al., 2009). Web pages of the project:
http://www.ldeo.columbia.edu/res/pi/CO2/carbondioxide/pages/air_sea_flux_2000.html
http://www.ldeo.columbia.edu/res/pi/CO2/carbondioxide/air_sea_flux/month_flux_2006a.txt

2.2 Validation data

The validation data set is based on the CO_2 flux and concentrations measurements from various flux and concentration measurement stations of Finnish Meteorological Institute (Table 2). Longest running flux sites, Kaamanen wetland and Sodankylä Scots pine forest, provide data sets of about 10 years. Shorter multi-year flux data sets are available from a spruce forest and a wetland at Pallas area and several sites in southern Finland on peatlands in different agricultural and forestry use. The background concentration measurements are conducted at Pallas-Sodankylä GAW station.

Table 2. Measurement stations of Finnish Meteorological Institute

Site	Vegetation type	Latitude/ Longitude	Data coverage	Measur. height (m)	Vegetation height (m)
Sodankylä	Scots pine forest	67°21.712'N 26°38.270'E	Jun 1999 onwards	23.5	12–18
Kaamanen	Aapa mire	69°08.441'N 27°16.230'E	April 1997 onwards	5	0 – 0.5
Kenttärova	Spruce forest	67°59.234'N 24°14.583'E	Jan 2003 onwards	23	13
Lompolojänkkä	Aapa mire	67°59.832'N 24°12.551'E	April 2005 onwards	3	0–0.5
Alkkia, Karvia	Afforested peat field, Scots pine, managed	62°11.001'N 22°47.008'E	Sept 2002 - July 2004	18	12
Kalevansuo, Loppi	Forestry drained peatland, Scots pine, managed	60°38.810'N 24°21.3'E	Aug 2004 onwards	21.5	15–18
Jokioinen	Agricultural peat field, managed	60°53.956'N 23°30.933'E	Oct 2000 - July 2003	3	0–0.6
Sammaltunturi	Sparsely vegetated fjeld, low vascular plants, moss, lichen	67°58.4'N 24°06.967'E	Oct 1996 onwards	565m.a.s.l., 4m above ground	0–0.3

2.2.1 Flux measurements

The flux measurements are conducted by the eddy covariance (EC) technique which provides a direct measurement of the net exchange of CO_2, water vapour and sensible heat between the biosphere and the atmosphere. In this technique the vertical flux of a scalar constituent is obtained as (e.g., Baldocchi, 2003)

$$F = \overline{w'c'}, \qquad (1)$$

where w is the vertical wind speed and c is the quantity of interest (e.g., CO_2 concentration, temperature or humidity). The overbar denotes the time average, and a prime denotes the fluctuation of an instantaneous value from this average. With the eddy covariance technique the measurements are carried out using fast-response instruments sampled typically at 10–20 Hz in order to cover the entire frequency range of turbulent variations. The EC method has become common during the most recent decade, and there have been various extensive research projects on CO_2 exchange in different ecosystems and in different areas in Europe (e.g., CARBOEURO-IP, CARBOEUROPE, GREENGRASS). Together with similar projects conducted on other continents (e.g., AMERIFLUX, FLUXNET-CANADA, ASIAFLUX), these projects form a global network of micrometeorological measurements, FLUXNET (Baldocchi *et al.*, 2001).

The main advantage of micrometeorological methods over the alternative enclosure methods is their ability to continuously measure the surface exchange of matter and energy. This makes it possible to study both the short-term variations (e.g., diurnal cycle) and the long-term balances. The micrometeorological measurements do not disturb the surface under investigation and provide fluxes on an ecosystem scale, thus avoiding the difficult up-scaling problems. The markedly smaller target area of chamber measurements, however, enables a spatially detailed study on different components of the ecosystem, which could complement the micrometeorological measurements.

The instrumentation used presently for the flux measurements include USA-1 sonic anemometer (METEK) and LI-7000 CO_2/H_2O analyzer (Li-Cor). The fluxes are calculated as block averages with a 30-min averaging period. A double rotation of the coordinate system is performed according to McMillen (1988). The lag between the time series resulting from the transport through the inlet tube is taken into account in the on-line calculation of the flux quantities by maximizing the absolute value of the covariance in question. The density correction related to the sensible heat flux is not needed (Rannik et al., 1997), but as the LI-7000 does not take into account humidity variations, a partial density correction was performed (Webb et al., 1980). Corrections for the systematic flux loss owing to the imperfect properties and setup of the sensors (insufficient response time, sensor separation, damping of the signal in the tubing and averaging over the measurement paths) were performed off-line using transfer functions with empirically-determined time constants (Aubinet et al., 2000). The data handling procedures have been explained in more detail by Aurela et al. (2002) and Aurela (2005).

Quality controlled flux data are also available from certain other Nordic forest sites of CARBOEUROPE network: a 80 years old beech stand in Sorø, Denmark; an average 100 years old mixed site Norunda, Sweden, consisting of Scots pine, Norway spruce and birch; a Scots pine stand in Hyytiälä, Finland planted in 1962.

In addition to the actual CO_2 exchange data the flux stations provide additional meteorological data which may be used for evaluating the representativeness of gridded meteorological data products at each flux measurement site. The most important parameters (air and soil temperature together with different radiation components) are available at all sites. More detailed parameter list is presented in Table 3.

Table 3. Availability of different parameters at the flux measurements sites of Finnish Meteorological Institute

Site / Parameter	CO_2 flux	H_2O flux	CH_4 flux	Sensible heat lflux	Snow depth	Prepicitation	Water table depth	PPFD	Reflected PPFD	Short wave (SW) radiation	Reflected SW radiation	Long wave (LW) radiation	Reflected LW radiation	Net radiation	Air temperature	Soil temperature (profile)	Air humidity	Soil moisture	Soil heat flux	Vegetation inventory data	Soil inventory data	Pressure	Wind
Sodankylä	x	x	-	x	x	x	-	x	x	x	x	x	-	x	x	x	x	x	x	x	x	x	x
Kaamanen	x	x	-	x	o	o	x	x	x		x	x	-	x	x	x	x	-	-	x	x	o	x
Kenttärova	x	x	-	x	x	o	-	x	x	x	x	x	x	x	x	x	x	x		-	-	o	x
Lompolojänkkä	x	x	x	x	x	o	x	x	x	x	x	o	-	x	x	x	x	x	x	x	x	o	x
Alkkia, Karvia	x	x	-	x	o	o	x	x	x	x	x	-	-	x	x	x	x	x	x	x	x	o	x
Kalevansuo, Loppi	x	x	-	x	o	o	x	x	x	x	x	-	-	x	x	x	x	x	x	x	x	o	x
Jokioinen	x	x	-	x	o	o	x	x	x	x	x	-	-	x	x	x	x	x	x	x	x	o	x

2.2.2 Concentration measurements

The CO_2 concentration measurements are conducted on top of Sammaltunturi hill (67°58'24"N, 24°06'58"E, 565m above sea level), about 100m above the treeline. This site is part of the Pallas-Sodankylä global GAW(Global Atmosphere Watch programme of World Meteorological Organization) station,. The Pallas region is characterized by arctic hills, mixed forest (Scots pine, Norway spruce, downy birch) and patches of wetlands and lakes.

The CO_2 concentration is measured using an infra-red gas analyzer by Li-Cor. The inlet for the CO_2 sampling line is located 7m above the ground. The measurements are calibrated once in every 2.5 h against three working standard gases and every 7.5 h also against a reference gas. These gases are calibrated every three months against WMO/CCL (NOAA) standards. In addition to the CO_2 concentration measurements which are used for model validation in this project, an extensive set of additional concentration and meteorological data are measured at Sammaltunturi (Table 4). The measurements are described in more detail by Hatakka et al. (2003).

Table 4. Summary of measurements at Sammaltunturi station. Abbreviations: EML = Environmental Measurement Laboratory, USA; NOAA = National Oceanic and Atmospheric Administration, USA.

Component	Measurement method	Frequency	Period
Ozone	UV absorption	Continuous	1995 -
Sulphur dioxide	UV fluorescence	Continuous	1995 -
Nitrogen oxide + dioxide	Chemiluminescence	Continuous	1995, 1999-
Carbon dioxide	NDIR analyser	Continuous	1996 -
Carbon monoxide	GC/ Reduction gas analyser	Continuous	2004 -
CH_4, N_2O, SF_6	GC	Continuous	2004 -
Hydrogen	Reduction gas analyser	Continuous	2006 -
Aerosol number concentration	Condensation Particle Counter	Continuous	1996 -
Aerosol number concentration	Da > 0.5 µm, Laser Particle Counter	Continuous	1996 -
Radon-222 (progeny)	Filter collection + beta counting	Continuous	1995 -
Radon-222	Delay chamber --- alpha counting (EML)	Continuous	2002 -
Black carbon	Aethalometer, light absorption	Continuous	1996 -
Aerosol scattering coefficient	Three wavelength integrating nephelometer	Continuous	2000 -
Aerosol size distribution	Differential mobility particle sizer	Continuous	2000 -
Volatile organic compounds	Flask sampling, GC analysis	2 / week	1994 -
CH_4, N_2O, SF_6	NOAA flasks, GC analysis	1 / week	2002 -
Carbon monoxide, hydrogen	NOAA flasks, reduction gas analyser	1 / week	2002 -
Carbon dioxide	NOAA flasks, NDIR analyser	1 / week	2002 -
Wind speed and direction	6 m above ground	Continuous	1995 -
Temperature + rel. humidity	4 m above ground, Pt100 + HUMICAP	Continuous	1995 -
Pressure	2 m above ground, Vaisala DPA21	Continuous	1995 -
Visibility, present weather	Vaisala FD12P present weather sensor	Continuous	1995 -
Global radiation	Pyranometer	Continuous	1995 -
PAR	Photovoltaic detector	Continuous	1995 -

References

Aubinet M., Grelle A., Ibrom A., Rannik Ü., Moncrieff J., Foken T., Kowalski A. S., Martin P. H., Berbigier P., Bernhofer Ch., Clement R., Elbers J. A., Granier A., Grünwald T., Morgenstern K., Pilegaard K., Rebmann C., Snijders W., Valentini R., and Vesala T., (2000) Estimates of the annual net carbon and water exchange of forests: the EUROFLUX methodology. Advances in Ecological Research, 30, 113–175.

Aurela, M, Laurila, T. and Tuovinen, J.-P. (2002) Annual CO_2 balance of a subarctic fen in northern Europe: Importance of the wintertime efflux, J. Geophys. Res. 107, 4607, doi:10.1029/2002JD002055.

Aurela, M. (2005) Carbon dioxide exchange in subarctic ecosystems measured by a micrometeorological technique. Contributions 51, Finnish Meteorological Institute, Helsinki, ISSN 0782-6117, pp. 132 (T. Vesala; University of Helsinki)

Baldocchi, D., Falge, E., Gu, L., Olson, R., Hollinger, D., Running, S., Anthoni, P., Bernhofer, Ch., Davis, K., Evans, R., Fuentes, J., Goldstein, A., Katul, G., Law, B. E., Lee, X., Malhi, Y., Meyers, T., Munger, W., Oechel, W., Paw U, K. T., Pilegaard, K.,

Schmid, H. P., Valentini, R., Verma, S., Vesala, T., Wilson, K., and Wofsy., S. (2001) FLUXNET: A new tool to study the temporal and spatial variability of ecosystem-scale carbon dioxide, water vapor, and energy flux densities. Bulletin of the American Meteorological Society, 82, 2415–2434.

Baldocchi, D. (2003) Assessing the eddy covariance technique for evaluating carbon dioxide exchange rates of ecosystems: past, present and future. Global Change Biology, 9, 479–492.

Hatakka, J., T. Aalto, V. Aaltonen, M. Aurela, H. Hakola, M. Komppula, T. Laurila, H. Lihavainen, J. Paatero, K. Salminen and Y. Viisanen (2003). Overview of atmospheric research activities and results at Pallas GAW station. Boreal Environ. Res., 8, 365-384.

McMillen, R. T. (1988) An eddy correlation technique with extended applicability to non-simple terrain. Boundary Layer Meteorology, 43, 231–245.

Rannik, Ü, Vesala, T., and Keskinen, R. (1997) On the damping of temperature fluctuations in a circular tube relevant to the eddy covariance measurement technique. Journal of Geophysical Research, 102, 12789–12794.

Webb, E. K., Pearman, G. I., and Leuning, R. (1980). Correction of flux measurements for density effects due to heat and water vapour transfer. Quarterly Journal of the Royal Meteorological Society, 106, 85–100.