Invest in our future

Summary of Work on ISECA **Atmospheric Modelling**

September 2011– 12 July 2012

G. Djambazov, K. Pericleous, M. Patel

Centre for Numerical Modelling and Process Analysis, University of Greenwich, London, SE10 9LS, UK

Meteorological data

- ECMWF Reanalysis data set *ERA Interim* identified as most suitable for the needs of the project
    - Downloading data from NCEP (U.S., Final Analysis, 1 degree resolution) was considered for a while (in connection with WRF) and remains a spare option
- The spatial resolution available from ECMWF (0.75 degrees) assumed for the initial trials
    - Briefly, refinement with a meso-scale model (WRF) was considered but work on that was suspended until proven necessary
- Decoding interface (GRIB API) for the ECMWF data installed and tried on a Linux machine
- Daily weather data (for the whole of 2011 and, additionally for April 2008, 2009, 2010, on 60 model levels) downloaded from ECMWF decoded and examined

Pollutant tracers

- Flexpart open-source Lagrangian Particle Dispersion (LPD) Model software (http://transport.nilu.no/flexpart) was chosen for its flexibility (to adjust the code) and ability to work with ECMWF data.
    - The code has a wide range of physical/chemical phenomena (related to transport, removal/deposition) already implemented.
    - It can approximate boundary-layer and vertical/meso-scale motions internally – avoids immediate need for WRF, and
    - has a library of species behaviour (e.g. NO_X, NH_3)
- Both Linux and Windows versions installed adjusted and tested
- Initial runs with the sample emission data completed

- Weather data rearranged in the sequence required by Flexpart
    - Alternative plain text format also implemented for portability.
- Plain text result output added to Flexpart as more suitable for ISECA – considering portability and that the resulting files are not very big
- Test model runs with assumed pollutant sources were presented at the Oostende Meeting in February 2012.

Graphical output

- Physica3g graphical output routines adjusted for a geographical region, coastline data, country boundaries and cities added.
- Plots of concentration and deposition produced from Flexpart results (showing also meteorological isobars and wind vectors)

Geographical region

Since the meteorological data is available on a latitude-longitude grid with 0.75 degree spacing, a suitable geographical area with the 2Seas Region in the middle and including the surrounding land and seas had to be chosen. Avoiding too wide a region meant less downloading time for the weather data. Bearing in mind that nitrogen oxides will be one of the main species whose transport needs to be modelled, the domain was extended eastwards to include the heavily industrialised West Germany (12 deg E). Similar span was chosen to the west of the Dover Straights (9 deg W) and the south and north boundaries were chosen to include most of France and Britain (44 deg N to 57 deg N).

Emissions

The main nutrients for the phytoplankton are nitrogen, phosphorus and silicon. Of these only nitrogen becomes airborne in sufficient quantities, mainly as ammonia and nitrogen oxides. The following freely available information sources about those emissions were found so far:

- UK National Atmospheric Emissions Inventory (NAEI) maintained by the Department for Environment, Food and Rural Affairs (naei.defra.gov.uk): freely available emissions data for all major pollutants at 1 km resolution covering the UK only
- European Monitoring and Evaluation Programme (EMEP) under the Convention on Long-range Transboundary Air Pollution – the Centre on Emission Inventories and Projections (http://www.ceip.at) offers free data on all major pollutants on a 50x50km grid covering the whole of Europe, a large part of Asia and the parts of the surrounding seas.
- European Pollutant Release and Transfer Register (E-PRTR): contains data reported annually by some 28,000 industrial facilities covering 65 economic activities across Europe and 91 key pollutants including heavy metals, pesticides, greenhouse gases

and dioxins for the year 2007, 2008 and 2009 (prtr.ec.europa.eu). Data is reported by individual facilities to the relevant competent authorities on an annual basis.

The EMEP emissions dataset was selected for the initial runs of the atmospheric transport model within ISECA because it is gridded with a resolution that matches the one of the chosen weather data.

An auxiliary Fortran program was composed to extract the emissions data from the EMEP files and to prepare it in the format needed for Flexpart where only the emissions in the chosen region (9 deg West to 12 deg East and 44 to 57 deg North) are included as 'releases' for Flexpart. An example distribution of these emission sources is shown in Figure 1.

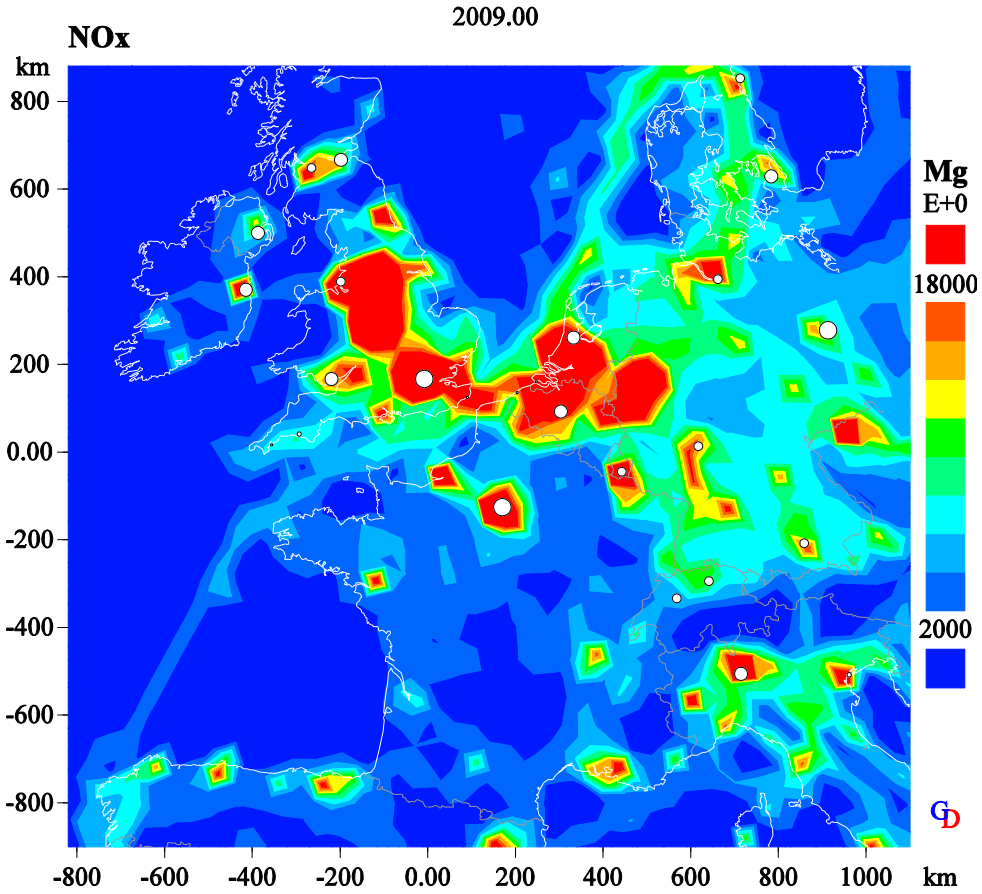

Figure 1. Emission of nitrogen oxides as used in EMEP models (tonnes/year) in 2009.

First Results

As a first run, the Flexpart atmospheric transport model was applied to the months of April 2009 and April 2010 (the latest year with EMEP data available) because the blooms most often occur in April. The EMEP emission rate data (www.ceip.at) are per year, so it was assumed the April emission rates are close to the year averages and the numbers were divided by 12. The quantities of nitrogen oxide emissions (NO_X) are presented in the EMEP dataset as tonnes (Mg) of NO_2 per year with no indication what the relative proportion of NO is, so in the Flexpart run, all nitrogen oxide was also assigned to the NO_2 species. That resulted in

deposition rate about 23 mg/m^2 for the whole of April 2009 around both Oostende and Dover (Figure 2). For April 2010 the corresponding amounts are about 16 and 13 mg/m^2 for these two points.

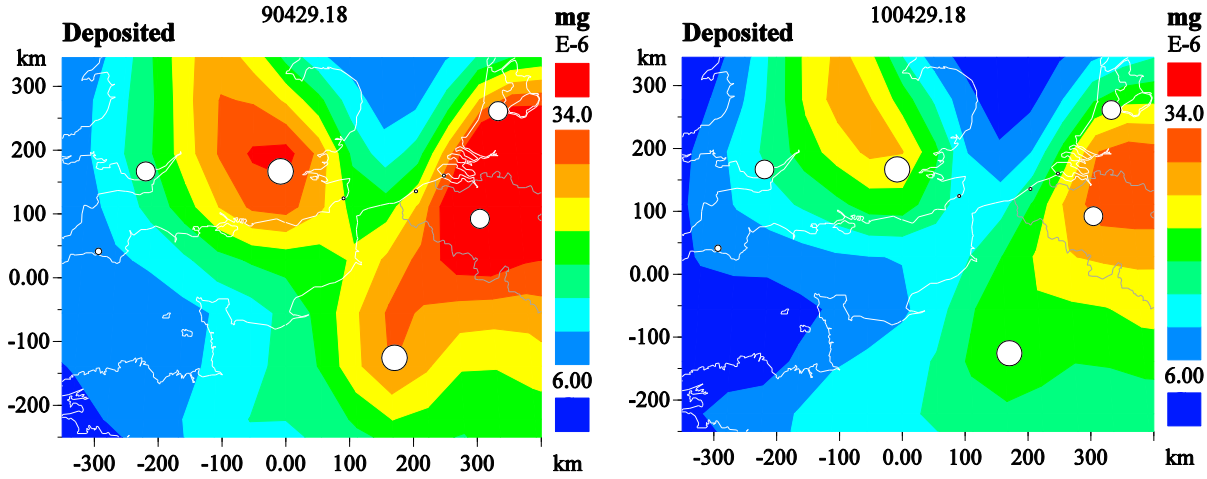

Figure 2. Calculated NO_2 deposition (mg/m^2) in April 2009 (left) and April 2010 (right) from emission sources around the 2Seas region

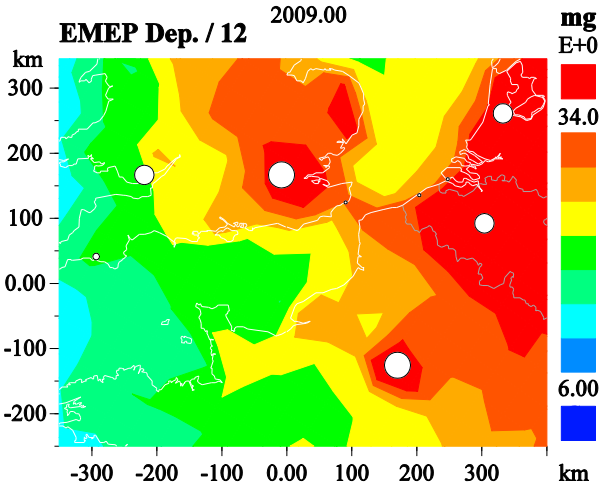

Figure 3. Monthly deposition of NO_X (mg/m^2) from EMEP model results for 2009 (webdab.emep.int)

For 2009 results are also available from the EMEP model (Figure 3). The average calculated monthly rate at Oostende and Dover from these results is about 30 mg/m^2. This is slightly higher that the Flexpart results and there are several possible causes that can explain the difference:

. using only NO_2 in Flexpart (NO has different deposition parameters);
. using a limited geographical region;
. the assumption that April emissions are 1/12th of the annual value;
. the existence of background NO_X values (from remote sources which are partially accounted for in the EMEP model but not in the Flexpart model).

The current setup in Flexpart has been verified for consistency in the sense that the sum of the deposited amounts, the quantities leaving the boundaries of the computational domain and the quantities remaining in the air at the end of the simulation match the total specified emission amounts (not only for NO_2 but also for NH_3 and SO_2).

After the validation of the model set-up is completed, ISECA will have a tool to quickly make weekly or monthly runs whereas the EMEP and OSPAR results are only given on a yearly basis.

Next steps

- Clarify the scope of atmospheric transport modelling for eutrophication within ISECA
    - demonstrational rather than operational capability
- Verify the deposition behaviour (for wet and dry deposition) of the gases of interest (NO, NO_2 , NH_3 and SO_2) and tune the model constants
- Compare calculated concentrations with available data from ground stations and satellites
- Greenwich would like to refine the grid of the atmospheric model (than the current 0.75 degree grid) in the future months using the 'meso-scale' weather modelling code WRF.
- High resolution emission data of NOx (and, possibly NH_3) releases for the shipping routes and the 2Seas countries other than the UK (where DEFRA provides free data):
    - Agreement signed with VITO to supply disaggregated EMEP/ CORINAIR emission inventories to Greenwich for inclusion in the model.
- Run suitable simulations with the selected resolution, compare with the present coarser grid model, analyse.
- Prepare the results from the atmospheric modelling in a form suitable for inclusion in the ISECA Web Application Server.