Application of Atmospheric Transport Models at the new atmospheric Ebre Delta station (ClimaDat network) in Eastern Spain

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Abstract:

The Ebre Delta atmospheric station (DEC3) was installed in Eastern Spain, within the framework of the ClimaDat project of the Institut Català de Ciències del Clima (IC3). This station offers continuous measurements of greenhouse gases and tracers concentrations (CO_2, CH_4, CO, N_2O and SF_6), along with atmospheric concentrations of the natural radioactive gas ^{222}Rn. Meteorological parameters, such as humidity, temperature, wind speed and wind direction are also measured at DEC3 site.

This qualitative analysis aims to use the FLEXPART and the HYSPLIT models, with meteorological input of ECMWF and with spatial resolution of 0.2 degrees, to perform back trajectories at DEC3 station and qualitatively analyze how different air masses coming from the Northern Western Europe or from the Mediterranean Sea influence observed gases concentrations.

Key words: *ClimaDat, HYSPLIT, FLEXPART, back trajectory, source*

INTRODUCTION

The need for accurate measurements of greenhouse gases (GHG), such as CO_2 and CH_4, is growing rapidly. These requirements are being driven by the necessity to understand global warming, conduct climate modeling and to comply with protocols, international agreements, and national and local commitments. Furthermore, these measurements are also needed to investigate metabolic processes going on in the environment.

The radon gas (^{222}Rn) has proven to be very useful as a tracer to understand GHGs behavior in the atmosphere and their interchange with the soil. ^{222}Rn is also used to validate the Atmospheric Transport Models (ATM) and it is studied by several researchers (Arnold et al., 2010, Grossi et al., 2011).

Several projects and programs were started in the last years to create and develop a network for monitoring atmospheric GHGs over Europe (e.g. InGOS project - www.ingos-infrastructure.eu, ICOS project - www.icos-infrastructure.eu, TTorch program - www.ttorch.lsce.ipsl.fr). At a Spanish national level the ClimaDat project (www.climadat.es), which started in 2010 and is funded by the “Obra Social La Caixa”, aims at creating a network of 8 stations over Spain for studying climate change effects from local to regional scales. Continuous measurements of GHGs, meteorological parameters and other climatic variables are performed within this project. The Ebre Delta site (DEC3) has been the first operational ClimaDat station.

In order to understand the behaviour of measured ^{222}Rn, CO_2 and CH_4 concentrations at the DEC3 station, two specific scenarios have been selected for this study and several back trajectories have been run using the FLEXPART and the HYSPLIT models with ECMWF meteorological input. Models results and pressure maps from the Wetter Zentrale (www.wetterzentrale.de) have allowed for a qualitative understanding of the main atmospheric conditions present during these scenarios.

METHODS

Site: Ebre Delta

The Ebre Delta station (DEC3) (latitude 40.74N; longitude 0.79E) is located in the Natural Park of the Ebre Delta River, close to Tarragona, Spain (Figure 1). The Ebre Delta Natural Park is located in a frontier region between the Mediterranean Sea and an area of 300 km^2 of rice fields, which remains completely flooded during some periods of the year.

The DEC3 station is reached from strong winds coming from the North of Spain (Gantoiti et al., 2002; Valdenebro et al., 2011). These winds are channelized through the Ebre River watershed, which extends from the North of Spain crossing the valley between the Iberic System and the Pyrenees. Since the DEC3 station is in a coastal area it is also influenced by breeze phenomena (Martin et al., 1991).

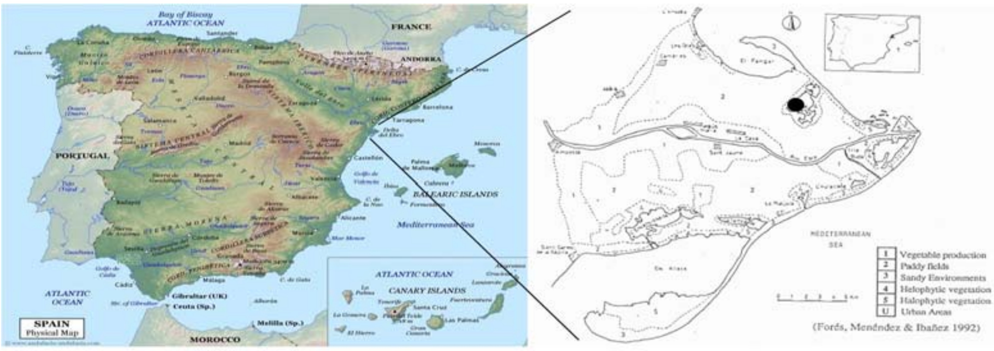

Figure 1 Physical map of Spain (left figure) and DEC3 station (black spot on the right figure) located in the Ebre Delta Natural Park, Eastern Spain (http://geographyfieldwork.com/EbroEvolution.htm).

Atmospheric Continuous Measurements

Atmospheric ^{222}Rn concentration

Atmospheric ^{222}Rn concentration is hourly measured at DEC3 station using an **A**tmospheric **R**adon **Mon**itor (ARMON). The monitor, designed and calibrated by the research group INTE-UPC, is based on alpha spectrometry of positive ions of ^{218}Po which are electrostatically collected on a Passivated Implanted Planar Silicon (PIPS) detector surface by an electrostatic field inside a spherical volume (Grossi et al., 2011). The collection efficiency of ^{218}Po on the detector surface is strongly influenced by the humidity of the sample air and a drying system with low maintenance has been designed and mounted at the DEC3 site by the IC3 group.

Atmospheric CH_4 and CO_2 concentration

CO_2 and CH_4 measurements are continuously performed by a G3201 analyzer (Picarro Inc., USA). This device is based on the cavity ring-down spectroscopy technique (CRDS) (Crosson, 2008) and offers simultaneous and precise measurements of CO_2, CH_4 and H_2O. In order to avoid water influence on CO_2 and CH_4 measurements, the air is dried through a system which consists of a Nafion dryer and cryotraps, reaching a final content in water of 10 ppm. The precisions of the instrument are of 0.03 ppm for CO_2 and 0.3 ppb for CH_4. The instrument accuracy is lower than 0.05 ppm for CO_2 and 0.9 ppb for CH_4 with a calibration every 20 days.

Back Trajectories

Back trajectories analyses at DEC3 station were performed using two of the most common transport models, FLEXPART and HYSPLIT. In this study models were used with meteorological inputs from operational analyses from the European Centre for Medium-Range Weather Forecasts (ECMWF, 2002). A horizontal resolution of 0.2 degrees and 60 vertical levels were used. Back trajectories of 72h were performed each night at 04.00h.

HYSPLIT

Version 4 of the HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) model (Draxler and Hess, 1998) was used in this study. The HYSPLIT4 model computes simple air mass trajectories, as well as complex dispersion and deposition simulations. The HYSPLIT model was chosen for this analysis because it has been widely validated (Draxler and Hess, 1998). Some advantages of this model are the following ones: (1) it can be run with multiple nested input data grids; (2) there is additional software to convert ECMWF, MM5, RAMS, COAMPS, WRF, and other meteorological data to an input for HYSPLIT; (3) there are several utility programs to display and manipulate meteorological data.

FLEXPART

The Lagrangian particle dispersion model FLEXPART version 6.2 (http://transport.nilu.no/flexpart) was also used in this study. This model has been extensively validated (Stohl et al., 1998) and has been used in many long-range transport applications (Stohl et al., 2005). Basically, this model computes the trajectories of a large number of released fictitious particles which are transported and dispersed by the mean wind plus a turbulent contribution (Stohl et al., 1998). Nested output maps in the Ebre Delta region have a grid size of 0.05 degrees.

Selected Scenarios

Time series of atmospheric gases concentrations measured continuously at DEC3 station during two periods (spring and autumn 2012) were selected and reported in Figure 2. These series were selected taking in mind the different phases of the cycle of the rice crop, which strongly influence gases emissions, and the different synoptic conditions present in this area, which can drive gases transport from remote regions or local sources. One week of measurements was selected for each episode of study and high/low concentration days were selected to perform back trajectories in order to understand air masses influence on the observed gases concentrations, both when the gases behaviour was coherent or not between them. Gases concentrations have also been compared with meteorological variables measured at DEC3 station.

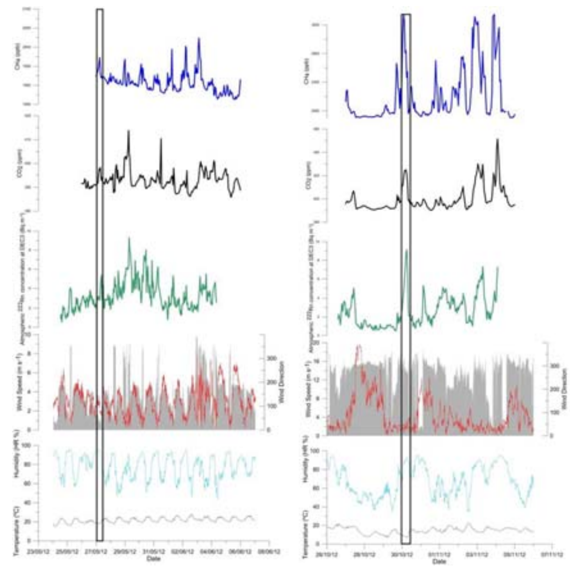

Figure 2 Hourly time series of CO_2, CH_4 and ^{222}Rn concentrations, and meteorological variables measured at DEC3 site at 10 m.a.g.l for the two selected periods: (1) from 23 May 2012 to 6 of June 2012 (left figures); (2) from 29 October 2012 to 3 November 2012 (right figures).

RESULTS

During the May-June episode the environmental parameters showed a well-defined breeze behaviour: wind was coming from the sea during night (25-100º) and going to the sea during day (180-100º). Respectively, this lead to a decrease and an increase of the gases concentrations and average values of 392.29 ppm of CO_2, 1906.2 ppb of CH4 and 3.34 Bq m^{-3} of ^{222}Rn were measured. An increase of the radon baseline concentration was observed between the 28th of May and the 1st of June 2012.

During the October-November episode the atmosphere was more stable and several high concentration peaks were clearly visible for all three gases due to a local contribution. Average concentration values during this episode were: 395.405 ppm of CO_2, 2022.9 ppb of CH_4 and 2.27 Bq m^{-3} of ^{222}Rn. In autumn the background CH_4 concentration was much higher than in spring due to the flood of the rice fields, which increase the methane concentration in this area because of metabolic processes (Huang, 2004). On the contrary, the average radon concentration was lower in this second period because of the huge presence of water over the observed area, which drastically reduces the radon exhalation from the soil. However, the night of the 31st of October a high concentration peak was observed only for the radon maybe due to a remote contribute.

For each scenario only back trajectories for a specific day are presented here. The back trajectory of 72 h (3 days) made by FLEXPART for the 27th May 2012 at 04.00h showed that air masses were coming from the Mediterranean Sea with a residence time of log 2 sec over the sea (Figure 2). According to the results obtained with HYSPLIT, air masses were for 28h under 500 m a.s.l. and over sea. This result is confirmed by the pressure map, which indicates a high pressure system during this day over Eastern Spain (1010 hPa). This could explain the local source contribution in the measured concentrations.

Back trajectories of 72 h made by FLEXPART and HYSPLIT for the 30th October 2012 at 04.00h showed that air masses were coming from the United Kingdom, forced by a high pressure system observed in the Wetter Zentrale pressure map (Figure 4). However, FLEXPART back trajectory indicates a local residence time of the air masses over the Ebre Delta of 2 days and HYSPLIT shows air masses introducing into the Delta region from the troposphere and with pressure conditions of 950 hPa. Under these conditions local emissions could explain the high concentrations. In addition, measured local wind speed values were quite low, which could confirm a local source accumulation.

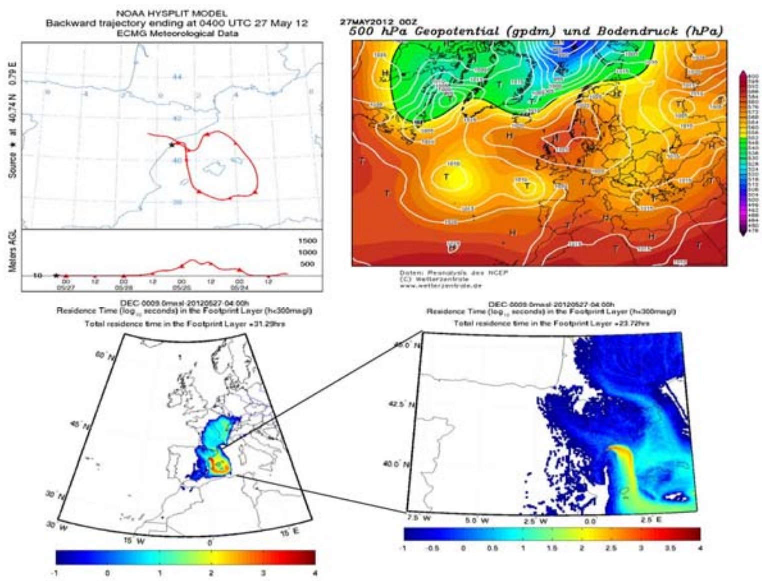

Figure 3 Back trajectories results at DEC3 station at 04:00h of 27th May 2012: HYSPLIT results (upper-left figure) and FLEXPART results for big domain (lower-left figure) and nest domain (lower-right figure). Weather charts at 500 hPa from Wetter Zentrale (upper-right figure).

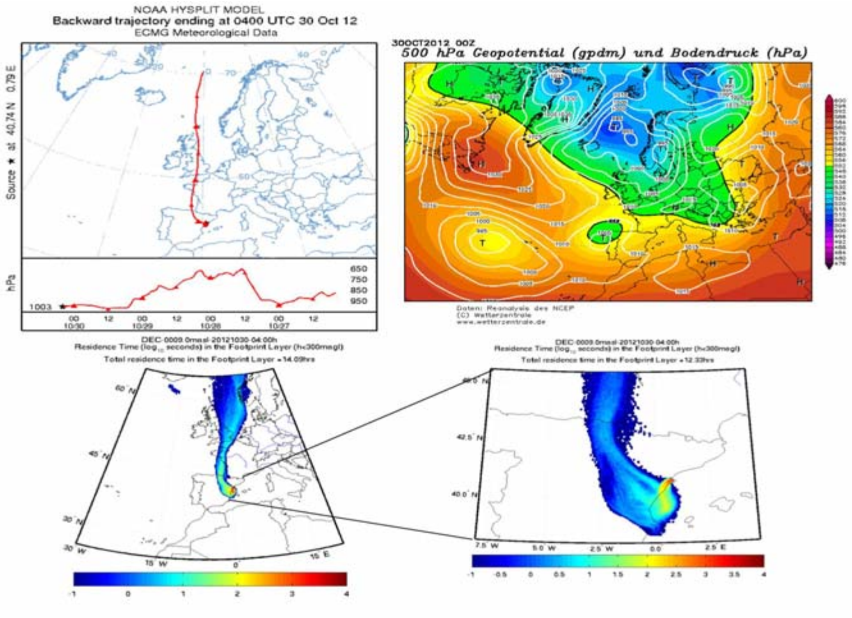

Figure 4 Back trajectories results at DEC3 station at 04:00h of 30th October 2012. HYSPLIT results (upper-left figure) and FLEXPART results for big domain (lower-left figure) and nest domain (lower-right figure). Weather carts at 500 hPa from Wetter Zentrale (upper-right figure).

CONCLUSIONS

A set of 72 h back trajectories have been done by FLEXPART and HYSPLIT models at DEC3 station. The results obtained have been compared with measured gases concentrations of CH_4, CO_2 and ^{222}Rn, and with meteorological variables measured at 10 m a.g.l. at this station. The HYSPLIT model allows to rapidly perform back trajectories and to visualize the result given that it is quite user friendly. The FLEXPART model runs a number of fictitious particles at the same time and allows calculating the probability that each particle spends in each grid. Both models together give an exhaustive idea of atmospheric conditions going on during selected scenarios and allow us to understand if the low/high concentrations observed for these gases were due to local source or remote contribution.

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