Project of Strategic Interest NEXTDATA

Deliverable 2.5.1:
Report on the census of available climate simulations

Resp: Silvio Gualdi, CMCC

Summary

1. Introduction

One of the main objectives of NextData is the creation of an extensive database, which contains the most up to date and scientifically advanced climate data, paleo-climatic and environmental products from observations, analyses and numerical simulations. This database will be made available to the scientific community and users (stakeholders and policy and decision makers) to carry out studies, analyses, forecasts and assessments related to climate, its variability, its possible changes and their impacts.

WP2.5 aims at building an archive of data from climate simulations at global, regional and local scales, and from ocean reanalyses. These results are both from existing simulations and from the numerical experiments designed and carried out in the framework of NextData.

With regard to the climatic data obtained with global models, the archive will contain the results of the simulations for the pre-industrial period (before 1850), the twentieth century (1850-2005) and future projections (eg, A1B, A2, RCP 4.5, RCP 8.5, RCP 3-PD) for the 21st century. The simulations have been performed using the different global climate models available at the participating centers, such as the CMCC Earth system model used at CMCC and the EC-Earth model used by CNR-ISAC. Some of the simulations include also the results on the distribution of aerosols, which are essential in many of the regions of interest for the NextData project. All these simulations will provide an ensemble of modeling results, which allow the investigation and the characterization of the large-scale climate variability and change. The results of the global models will be used also as boundary conditions for the simulations at regional and local levels performed with limited area, high-resolution models.

Beside the data from the global models, the archive will also provide high-resolution climate data obtained with limited area models, for specific areas of interest. In particular, the archive will contain the results of non-hydrostatic simulations for areas with complex orography such as the Alpine region, the Hindu-Kush-Karakorum-Himalaya area, the Andes of South America and the Ruwenzori region. The archive will contain the results of a set of multi-model numerical experiments, reproducing the climate of the Mediterranean basin performed with both regional atmosphere-only and coupled atmosphere-ocean models.

Moreover, the archive will contain a reanalysis of the global ocean in two different spatial resolutions (2 ° and 1/4 °) produced by the CMCC for the period 1960-2010. In the framework of the project, this data set will be possibly extended over time, depending on the availability of observational data to be acquired and of the atmospheric forcing used to run the reanalyses.

The archive will contain also information and references (metadata) to the climate data products made available within several initiatives, such as EU-Projects (e.g., ENSEMBLES, CIRCE or PRUDENCE) or international programmes (e.g., CMIP5, CORDEX).

This report contains a survey of the climatic data obtained from the simulations carried out and made available by the project partners and those available from international projects. It describes in detail, for each partner, the data sets (size, time-range, etc.), the models used to produce them and provides also an extensive bibliography.

2. Inventory of climate experiments performed at CMCC

This document describes the climate experiments performed at CMCC-INGV : paragraphs 1 to 6 refer to simulations performed using fully Coupled General Circulation Models (CGCMs) and Earth System Models (ESMs) following the IPCC (Intergovernmental Panel on Climate Change) Coupled Models Intercomparison Project (CMIP) phase 3 (CMIP3) or phase 5 (CMIP5) protocols. Paragraphs 7 to 9 refer to Global Ocean Simulations and Reanalyses.

2.1. INGV-SXG (CGCM - CMIP3 generation)

Model version: INGV-SXG (2007).
All runs at T106L19 (ECHAM4.6 - Atmosphere) + 2°-0.5° ORCA2 (OPA8.2 Global Ocean) resolution.
Raw output files are in grib (ECHAM4.6) + netcdf (OPA8.2)
See 'appendix A' for the model description.

Completed runs:

- preindustrial (CMIP3 picntrl).

- Time period: (1761-1860)
- Approximate size of the raw output archive (grib+netcdf): 1 TB
- CMOR archive available: ~0.2 TB

- historical (CMIP3 20c3m).

- Time period: (1870-2000)
- Approximate size of the raw output archive (grib+netcdf): 1.3 TB
- CMOR archive available: ~0.2TB

- A1B scenario (CMIP3 sresa1b).

- Time period: (2001-2100)
- Approximate size of the raw output archive (grib+netcdf): 1 TB
- CMOR archive available: ~0.2 TB

- A2 scenario (CMIP3 sresa2).

- Time period: (2001-2100)
- Approximate size of the raw output archive (grib+netcdf): 1 TB
- CMOR archive available: ~0.2 TB

- 1% increase to 2XCO2 (CMIP3 1pctto2x)

- Time period: (1870-2030)
- Approximate size of the raw output archive (grib+netcdf): 1.6 TB
- CMOR archive available: ~0.2 TB

- 1% increase to 4XCO2 (CMIP3 1pctto4x)

- Time period: (1870-2100)
- Approximate size of the raw output archive (grib+netcdf): 1.6 TB
- CMOR archive available: ~0.2 TB

References:

- Gualdi, S., E. Scoccimarro, and A. Navarra, 2008: Changes in tropical cyclone activity due to global warming: Results from a high-resolution coupled general circulation model. Journal of Climate, 21, 5204–5228.
- Bellucci, A., S. Gualdi, E. Scoccimarro, and A. Navarra, 2008: NAO–ocean circulation interactions in a coupled general circulation model. Climate Dynamics, 31, 759–777.

2.2. CMCC-MED (CGCM with high resolution for the Mediterranean Sea)

Model version: CMCC-MED (2009).
All runs at T159L31 (ECHAM4.6 - Atmosphere) + 2°-0.5° ORCA2 (OPA8.2 Global Ocean) + 1/16° NEMO Med. (Mediterranean Sea) resolution.
Raw output files are in grib (ECHAM4.6) + netcdf (OPA8.2) + netcdf (NEMO).
See 'appendix B' for the model description.

Completed runs:

- historical+A1B (CMIP3 20c3m+sresa1b).

- Time period: (1951-2100)
- Approximate size of the raw output archive (grib+netcdf): 55 TB

- historical+A2 (CMIP3 20c3m+sresa2).

- Time period: (1951-2100)
- Approximate size of the raw output archive (grib+netcdf): 55 TB

References:

- Gualdi S., S. Somot, L. Li, V. Artale, M. Adani, A. Bellucci, A. Braun, S. Calmanti, A. Carillo, A. Dell'Aquilla, M. Déqué, C. Dubois, A. Elizalde, A. Harzallah, B. Lheveder, W. May, P. Oddo, P. Ruti, A. Sanna, G. Sannino, F. Sevault, E. Scoccimarro and A. Navarra, 2012: The CIRCE simulations: a new set of regional climate change projections performed with a realistic representation of the Mediterranean Sea. *Bull. Amer. Meteo. Soc.*, DOI: 10.1175/BAMS-D-11-00136.1.

- Scoccimarro E, Gualdi S, Bellucci A, Sanna A, Fogli PG, Manzini E, Vichi M, Oddo P, Navarra A, 2011: Effects of tropical cyclones on ocean heat transport in a high resolution coupled general circulation model. *Journal of Climate* 24:4368–4384.

2.3. CMCC-CM (CGCM, CMIP5 generation)

Model version: CMCC-CM (2010).
All runs at T159L31 (ECHAM4.6 - Atmosphere) + 2°-0.5° ORCA2 (OPA8.2 Global Ocean) .
Raw output files are in grib (ECHAM4.6) + netcdf (OPA8.2)
See 'appendix C' for the model description.

Completed runs:

long term:

- preindustrial (CMIP5 piControl).

- Time period: (1550-1849)
- Approximate size of the raw output archive (grib+netcdf): 43 TB
- CMOR archive available: 1 TB

- historical (CMIP5 historical).

- Time period: (1850-2005)
- Approximate size of the raw output archive (grib+netcdf): 22 TB
- CMOR archive available: 1.7 TB

- RCP4.5 scenario (CMIP5 RCP4.5).

- Time period: (2006-2100)
- Approximate size of the raw output archive (grib+netcdf): 14 TB
- CMOR archive available: 2.8 TB

- RCP8.5 scenario (CMIP5 RCP8.5).

- Time period: (2006-2100)
- Approximate size of the raw output archive (grib+netcdf): 14 TB
- CMOR archive available: 2.8 TB

- 1% increase to 4XCO2 (CMIP5 1pctCO2).

- Time period: (1851-1990)
- Approximate size of the raw output archive (grib+netcdf): 20 TB
- CMOR archive available: 0.8 TB

References:

- Scoccimarro E, Gualdi S, Bellucci A, Sanna A, Fogli PG, Manzini E, Vichi M, Oddo P, Navarra A, 2011: Effects of tropical cyclones on ocean heat transport in a high resolution coupled general circulation model. *Journal of Climate* 24:4368–4384.

short term:

- decadal predictions (CMIP5 historical+RCP4.5).

- Time period: (1960-2035) 3-members ensembles of 10- or 30-years simulations, starting at 5-years intervals from 1960 to 2005. Total number of years: 480.
- Approximate size of the raw output archive (grib+netcdf): 69 TB
- CMOR archive available: 38 TB

References:

- Bellucci A., S. Gualdi, S. Masina, A. Storto, E. Scoccimarro, C. Cagnazzo, P. Fogli, E. Manzini, and A. Navarra, 2012: Decadal Climate Predictions with a coupled OAGCM initialized with oceanic reanalyses. *Clim. Dyn.*, DOI: 10.1007/s00382-012-1468-z. .

2.4. INGV-CMCC-CE (ESM, CMIP3 generation)

Model version: ESM-ENSEMBLES (2006).
All runs at T31L19 (ECHAM5.2 - Atmosphere, SILVA - Land Vegetation) + 2°-0.5o ORCA2 (OPA-LIM8.2 Global Ocean - Sea Ice, PELAGOS - Ocean Biogeochemistry) resolution.
Raw output files are in grib (ECHAM5.2) + netcdf (OPA8.2)
See 'appendix D' for the model description.

Completed runs:

- preindustrial (nca01 and nca02).

- Time period: (1555-1859)
- Approximate size of the raw output archive (grib+netcdf): 150 Gb
- CMOR archive available: no

- historical (trc01).

- Time period: (1860-1999)
- Approximate size of the raw output archive (grib+netcdf): 1 Tb
- CMOR archive available: no

- A1B scenario (nsc01).

- Time period: (2000-2099)
- Approximate size of the raw output archive (grib+netcdf): 800 Gb
- CMOR archive available: no

- ENSEMBLES E1 scenario (nsc02).

- Time period: (2000-2099)
- Approximate size of the raw output archive (grib+netcdf): 800 Gb
- CMOR archive available: no

References:

-Vichi M., E. Manzini, P.G. Fogli, A. Alessandri, L. Patara, E. Scoccimarro, S. Masina and A. Navarra, 2011: Global and regional ocean carbon uptake and climate change: Sensitivity to a substantial mitigation scenario. Clim Dyn 37:1929-1947 DOI 10.1007/s00382-011-1079-0

-Patara L., Vichi M, Masina S., 2012: Impacts of natural and anthropogenic climate variations on North Pacific plankton in an Earth System Model. Accepted for publication in Ecological Modelling

-Fogli, P. G., E. Manzini, M. Vichi, A. Alessandri, L. Patara, S. Gualdi, E. Scoccimarro, S. Masina, and A. Navarra, 2009: INGV-CMCC Carbon (ICC): A Carbon Cycle Earth System Model, CMCC Res. Pap. 61, Centro Euro-Mediterraneo per i Cambiamenti Climatici, Bologna, Italy.

2.5. CMCC-CMS (CGCM, CMIP5 generation, including stratospheric dynamics)

Model version: CMCC-CMS (2010).
All runs at T63L95 (ECHAM5 - Atmosphere) + 2°-0.5° ORCA2 (OPA8.2 Global Ocean/LIM Sea Ice) .
Raw output files are in grib (ECHAM5) + netcdf (OPA8.2/LIM)
See 'appendix E' for the model description.

Completed runs:

long term:

- preindustrial (CMIP5 piControl).

- Time period: (500 years)
- Approximate size of the raw output archive (compressed grib+netcdf): 21 TB
- CMOR archive available: 250 GB

- historical (CMIP5 historical).

- Time period: (1850-2005)
- Approximate size of the raw output archive (compressed grib+netcdf): 11 TB
- CMOR archive available: 300 GB

- RCP4.5 scenario (CMIP5 RCP4.5).

- Time period: (2006-2100)
- Approximate size of the raw output archive (compresssed grib+netcdf): 7.4 TB
- CMOR archive available: 185 GB

- RCP8.5 scenario (CMIP5 RCP8.5).

- Time period: (2006-2100)
- Approximate size of the raw output archive (compresssed grib+netcdf): 7.4 TB
- CMOR archive available: 185 GB

short term:

- potential predictability runs (CMIP5 historical+RCP4.5).

- Time period: (1960-2035) 2-members ensembles of 35-years simulations, starting at 1960 and 2005. Total number of years: 140.
- Approximate size of the raw output archive (grib+netcdf): 12 TB
- CMOR archive available: 0 TB

References:

-Weare, B. C., C. Cagnazzo, P. G. Fogli, E. Manzini, and A. Navarra, 2012: Madden-Julian Oscillation in a climate model with a well-resolved stratosphere, *J. Geophys. Res.*, 117, D01103, doi:10.1029/2011JD016247.

-Manzini, E., C. Cagnazzo, P. G. Fogli, A. Bellucci, and W. A. Müller (2012), Stratosphere-troposphere coupling at inter-decadal time scales: Implications for the North Atlantic Ocean, *Geophys. Res. Lett.,* 39, L05801, doi:10.1029/2011GL050771.

-Fogli, P. G., E. Manzini, M. Vichi, A. Alessandri, L. Patara, S. Gualdi, E. Scoccimarro, S. Masina, and A. Navarra, 2009: INGV-CMCC Carbon (ICC): A Carbon Cycle Earth System Model, CMCC Res. Pap. 61, Centro Euro-Mediterraneo per i Cambiamenti Climatici, Bologna, Italy.

2.6. CMCC-CESM (ESM, CMIP5 generation)

Model version: CMCC-CESM (2010).
All runs at T31L39 (ECHAM5 - Atmosphere) + 2°-0.5° ORCA2 (OPA8.2 Global Ocean/LIM Sea Ice) .
Raw output files are in grib (ECHAM5) + netcdf (OPA8.2/LIM)
See 'appendix F' for the model description.

Completed runs:

long term:

- preindustrial (CMIP5 piControl).

- Time period: (275 years)
- Approximate size of the raw output archive (compressed grib+netcdf): 7.5 TB
- CMOR archive available: 0 GB

- historical (CMIP5 historical).

- Time period: (1850-2005)
- Approximate size of the raw output archive (compressed grib+netcdf): 4 TB
- CMOR archive available: 0 GB

- RCP8.5 scenario (CMIP5 RCP8.5).

- Time period: (2006-2100)
- Approximate size of the raw output archive (compresssed grib+netcdf): 2.5 TB
- CMOR archive available: 0 GB

- 1% CO_2/year (CMIP5 1pctCO2).

- Time period: (1850-2020)
- Approximate size of the raw output archive (compresssed grib+netcdf): 5 TB
- CMOR archive available: 0 GB

References:

-Fogli, P. G., E. Manzini, M. Vichi, A. Alessandri, L. Patara, S. Gualdi, E. Scoccimarro, S. Masina, and A. Navarra, 2009: INGV-CMCC Carbon (ICC): A Carbon Cycle Earth System Model, CMCC Res. Pap. 61, Centro Euro-Mediterraneo per i Cambiamenti Climatici, Bologna, Italy.
-Cagnazzo C., E. Manzini, P. Davini, P.G. Fogli and M. Vichi, Role of stratospheric ozone changes in the global carbon uptake, as simulated by the CMCC-Carbon Earth System Model, in preparation

2.7. CMCC/INGV CIGODAS Global Ocean Data Assimilation System

Model version: CIGODAS (2010).
All runs at 2°-0.5° ORCA2, 31 vertical levels (OPA8.2 Global Ocean) .
Raw output files (monthly means) are in netcdf (OPA8.2)
See 'appendix G' for the model description.

Completed runs:

- Forced run (CIGODAS Control).

- Time period: (1958-2010)
- Approximate size of the raw output archive (netcdf): 25 GB

- OI1 Reanalysis (CIGODAS OI1).

- Time period: (1962-2001)
- Approximate size of the raw output archive (netcdf): 18 GB

- OI2 Reanalysis (CIGODAS OI2).

- Time period: (1962-2001)
- Approximate size of the raw output archive (netcdf): 18 GB

- OI3 Reanalysis (CIGODAS OI3).

- Time period: (1958-2006)
- Approximate size of the raw output archive (netcdf): 22 GB

- OI4 Reanalysis (CIGODAS OI4).

- Time period: (1958-2006)
- Approximate size of the raw output archive (netcdf): 22 GB

- OI5 Reanalysis (CIGODAS OI5).

- Time period: (1958-2011)
- Approximate size of the raw output archive (netcdf): 26 GB

References:

- Masina, S., P. Di Pietro, A. Storto and A. Navarra, 2011, Global ocean re-analyses for climate applications, Dynamics of Atmospheres and Oceans. Vol. 52, Issue: 1-2 pp 341-366. doi:10.1016/j.dynatmoce. 2011.03.006.

2.8. CMCC - OceanVar

Model version: OceanVar (2010).
All runs at 2°-0.5° ORCA2. 31 vertical levels (OPA8.2 Global Ocean) .
Raw output files (daily means) are in netcdf (OPA8.2)
See 'appendix H' for the model description.

Completed runs:

- LR01 Reanalysis (OceanVar LR01).

- Time period: (1961-2005)
- Approximate size of the raw output archive (netcdf): 90 GB

- LR04 Reanalysis (OceanVar LR04).

- Time period: (1961-2005)
- Approximate size of the raw output archive (netcdf): 90 GB

- MDT1 Reanalysis (OceanVar MDT1).

- Time period: (1992-2005)
- Approximate size of the raw output archive (netcdf): 30 GB

- MDT2 Reanalysis (OceanVar MDT2).

- Time period: (1992-2005)
- Approximate size of the raw output archive (netcdf): 30 GB

- MDT3 Reanalysis (OceanVar MDT3).

- Time period: (1992-2005)
- Approximate size of the raw output archive (netcdf): 30 GB

- MDT4 Reanalysis (OceanVar MDT4).

- Time period: (1992-2005)
- Approximate size of the raw output archive (netcdf): 30 GB

References:

LR01,LR02

- A. Bellucci, S. Gualdi, S. Masina, A. Storto, E. Scoccimarro, C. Cagnazzo, P. Fogli, E. Manzini, and A. Navarra, 2012: Decadal Climate Predictions with a coupled OAGCM initialized with oceanic reanalyses. In review for Climate Dynamics.

MDT1,MDT2,MDT3,MDT4

-Storto A., Dobricic S., Masina S. and Di Pietro P., 2011. Assimilating Along-Track Altimetric Observations Through Local Hydrostatic Adjustment in a Global Ocean Variational Assimilation System. Monthly Weather Review, 139, 738-754.

2.9. C-GLORS GLOBAL OCEAN REANALYSES AT 0.25 DEGREES RESOLUTION

Model version: C-GLORS (CMCC Global Ocean Reanalysis System): NEMO 3.2.1 + LIM2 + Global OceanVar
All runs at 0.25° ORCA25, 50 vertical levels.
Output files are in NetCDF (model outputs + diagnostics) and for the C-GLORS v2 run, also weekly means are available.
See appendix 'I' for the model description.

Completed runs:

- FORCED1 (SPINAUX_NEW_CORR_BB). Forced run for testing ocean model for MyOcean

- Time period: (1989-2009)
- Approximate size of archived outputs : 0.5 TB

- FORCED2 (SPINAUX_NEW_CORR_BB_PC2). Forced run for testing ocean model for MyOcean

- Time period: (1989-2009)
- Approximate size of archived outputs : 0.5 TB

- FORCED3 (CTRL03). Forced run for testing ocean model for MyOcean

- Time period: (1979-2010)
- Approximate size of archived outputs : 0.1 TB

- CORR1 (CTRL). Test correction on forcing fields

- Time period: (1979-2010)
- Approximate size of archived outputs : 0.2 TB

- CORR2 (GWX). Test correction on forcing fields

- Time period: (1989-2007)
- Approximate size of archived outputs : 0.1 TB

- CORR3 (EiGWX). Test correction on forcing fields

- Time period: (1989-2010)
- Approximate size of archived outputs : 0.1 TB

- CORR4 (WINDSTRESS). Test correction on forcing fields

- Time period: (1989-2010)
- Approximate size of archived outputs : 0.1 TB

- CORR5 (BESTRUN). Test correction on forcing fields

- Time period: (1979-2010)
- Approximate size of archived outputs : 0.2 TB

- FLUXES (E40). Forcing strategy

- Time period: (1958-2001)
- Approximate size of archived outputs : 0.3 TB

- BULK (BULKEI). Forcing strategy

- Time period: (1989-2009)
- Approximate size of archived outputs : 0.1 TB

- CHLA (CHLOROP). Ocean model tuning

- Time period: (1989-2009)
- Approximate size of archived outputs : 0.1 TB

- C-GLORS v1 (REANAL04). V1 for MyOcean reanalysis production

- Time period: (1993-2009)
- Approximate size of archived outputs : 33 GB

- C-GLORS v2 (REANAL10). V2 for MyOcean reanalysis production

- Time period: (1993-2010)
- Approximate size of archived outputs : 0.3 TB

References:

- Ferry N., Masina S., Storto A., Haines K., Valdivieso M., Barnier B., Molines J.-M., 2011, MyOcean Product User Manual for Global Physical reanalyses, Myocean Report MYO-WP4-PUM-GLOBAL-REANALYSIS-PHYS-001-004, available at www.myocean.eu.

- Storto, Andrea, Srdjan Dobricic, Simona Masina, Pierluigi Di Pietro, 2011: Assimilating Along-Track Altimetric Observations through Local Hydrostatic Adjustment in a Global Ocean Variational Assimilation System. *Mon. Wea. Rev.*, **139**, 738–754.

- Storto A., Russo I., Masina, S., 2012, Interannual response of global ocean hindcasts to a satellite-based correction of precipitation fluxes. *Ocean Sci. Discuss*., **9**, 611-648, Under review for Ocean Sci.

2.10. COSMO-CLM regional model

Model version: COSMO-CLM 4.8
All runs at T106L19 (ECHAM4.6 - Atmosphere) + 2°-0.5° ORCA2 (OPA8.2 Global Ocean) resolution.
Raw output files are in netcdf
See 'appendix J' for the model description.

Completed runs:

- Adaptalp

- Time period: 1971-2000
- Domain: 2 -20 E; 40 - 52 N
- grid points: 207 x 211, 40 vertical levels
- Horizontal resolution: 0.0715° (about 8 km)
- Driving data: ERA40 (resolution 1.125°, about 128 km)
- Approximate size of the raw output archive (netcdf): 2.4 TB

- Italy

- Time period: 1965-2100 (A1B scenario)
- Domain: 4 -23 E; 35 - 51 N
- grid points: 224 x 230, 40 vertical levels
- Horizontal resolution: 0.0715° (about 8 km)
- Driving data: CMCC-MED (resolution 0.75°, about 80 km)
- Approximate size of the raw output archive (netcdf): 5.7 TB

- Mediterranean

- Time period: 1970-2100 (A1B scenario)
- Domain: 13W - 40 E; 29 - 50 N
- grid points: 380 x 190, 40 vertical levels
- Horizontal resolution: 0.125° (about 14 km)
- Driving data: CMCC-MED (resolution 0.75°, about 80 km)
- Approximate size of the raw output archive (netcdf): 15.8 TB

- Mediterranean

- Time period: 1971-2000
- Domain: 13W - 40 E; 29 - 50 N
- grid points: 380 x 190, 40 vertical levels
- Horizontal resolution: 0.125° (about 14 km)
- Driving data: ERA40 (resolution 1.125°, about 128 km)
- Approximate size of the raw output archive (netcdf): 7.8 TB

- West Africa

- Time period: 1950-2050 (RCP4.5 and RCP8.5)
- Domain: 19W - 12 E; 2 – 19 N
- grid points: 447 x 248, 40 vertical levels
- Horizontal resolution: 0.0715° (about 8 km)
- Driving data: CMCC-MED (resolution 0.75°, about 80 km)
- Approximate size of the raw output archive (netcdf): 27 TB

- Lower East Africa

- Time period: 1950-2050 (RCP4.5 and RCP8.5)
- Domain: 35 - 41 E; 12 – 2 S
- grid points: 95 x 135, 40 vertical levels
- Horizontal resolution: 0.0715° (about 8 km)
- Driving data: CMCC-MED (resolution 0.75°, about 80 km)
- Approximate size of the raw output archive (netcdf): 3.1 TB

- Upper East Africa

- Time period: 1950-2050 (RCP4.5 and RCP8.5)
- Domain: 35 - 43 E; 6 – 12 N
- grid points: 120 x 90, 40 vertical levels
- Horizontal resolution: 0.0715° (about 8 km)
- Driving data: CMCC-MED (resolution 0.75°, about 80 km)
- Approximate size of the raw output archive (netcdf): 2.6 TB

- Mauritius

- Time period: 2001-2070 (RCP4.5 and RCP8.5)
- Domain: 54 - 65 E; 23 – 19 S
- grid points: 160 x 60, 40 vertical levels
- Horizontal resolution: 0.0715° (about 8 km)
- Driving data: CMCC-MED (resolution 0.75°, about 80 km)
- Approximate size of the raw output archive (netcdf): 2 TB

References:

-E. Bucchignani, A. Sanna, S. Gualdi, S. Castellari, P. Schiano, "Simulation of the climate of the XX century in the Alpine space", Natural Hazards , DOI 10.1007/s11069-011-9883-82010, 2011.

-D. Bellafiore, E. Bucchignani, S. Gualdi, S. Carniel, V. Djurdjeviæ, and G. Umgiesser, Assessment of meteorological climate models as inputs for coastal studies, Ocean Dynamics, 62 (4) 555-568, 2012.

- A. Benetazzo, F. Fedele, S. Carniel, A. Ricchi, E. Bucchignani, M. Sclavo, Wave climate of the adriatic sea: a future scenario simulation, *Natural Hazards and Earth System Sciences,* **12**, 2065-2076, 2012. doi:10.5194/nhess-12-1-2012

- L. Comegna, L. Picarelli, P. Mercogliano, E. Bucchignani, Potential effects of incoming climate changes on the behaviour of slow active landslides in clay, *Landslides,* 2012, DOI: 10.1007/s10346-012-0339-3.

- F. Baruffi, A. Cisotto, A. Cimolino, M. Ferri, M. Monego, D. Norbiato, M. Cappelletto, M. Bisaglia, A. Pretner, A. Galli, A. Scarinci, V. Marsala, C. Panelli, S. Gualdi, E. Bucchignani, S. Torresan, S. Pasini, A. Critto, A. Marcomini, 2012. Climate change impact assessment in Veneto and Friuli plain groundwater. Part I: an integrate modeling approach for hazard scenario construction. *Sci. Total Environ.*, **440**, 154-166, 2012

3. Inventory of climate experiments performed at ENEA UTMEA-CLIM

ENEA-PROTHEUS

Model version PROTHEUS 1.0 (Artale et al 2010)
All runs at uniform horizontal grid spacing of 30 km on a Lambert conformal projection
1/8°x1/8°, oceanic resolution.
Atmosphere 18 vertical sigma levels + Ocean 42 vertical zeta levels
Postprocessed output files are in netcdf: atmospheric 3D fields interpolated onto 14 pressure levels. Oceanic fields onto the original 42 zeta levels
See 'appendix K' for the model description.

Completed runs:

- ERA40_2:

Time period 1958-2000
BC: ERA40 reanalysis
Approximate size of postprocessed output: 300 GB
Lateral Boundary conditions from ERA40 for the 43-year period 1958-2000 (Simmons and Gibson, 2000). SST over the Atlantic are taken from the Global Ice and Sea Surface Temperature (GISST) dataset released by the UKMO (Rayner et al., 2006). The water mass characteristics in the ocean outside the Strait of Gibraltar are 3D relaxed to the Levitus climatology (Levitus 1982). The ocean model is initialized at rest with the MEDATLAS II data (MEDAR Group, 2002). The spin-up is done by using a 3D relaxation of temperature and salinity to the climatological values. An Interactive River Scheme (IRIS) has been implemented, to provide a more consistent simulated hydrological cycle. The so called *natural boundary conditions* are implemented at the ocean surface.

- ERA40_1:

Time period 1958-2001
BC: ERA40 reanalysis
Approximate size of postprocessed output: 80 GB
Same as ERA40_2 but with climatological values for the river runoff

- EH5OM_20C3M:

Time period 1951-2000
BC: ECHAM5-MPIOM 20c3m run3
Approximate size of postprocessed output: 350 GB
Same as model configuration employed for ERA40_2. The lateral boundary conditions for the atmosphere (1951-2000) are taken from the ECHAM5-MPIOM 20c3m global simulation (run3) included in the IPCC-AR4.

- EH5OM_A1B:

Time period 2001-2050
BC: ECHAM5-MPIOM SRESA1B run3
Approximate size of postprocessed output: 350 GB
Same as for EH5OM_20C3M but the lateral boundary conditions are taken from the SRESA1B r3 global simulation (2001-2050). Temperature and salinity outside the Strait of Gibraltar are relaxed to the monthly means obtained from the oceanic component of the coupled global run.

4. Inventory of climate experiments performed at ICTP

(Please see the appendices for a more detailed description of the models and of the experimental configurations)

4.1. RegCM3

Model version: RegCM3 (Giorgi et al 1993a,b)
Atmosphere 18 vertical sigma levels.
Raw output files are in binary + netcdf (to be converted)
See "appendix L" for a description of the model. and for the spatial plots of the domains.

Completed runs:

- Alpine Region
  - Time period: (1951-2050)
  - BC: RegCM3 at 25km of resolution (ECHAM5 boundary, A1B scenario)
  - Horizontal Resolution: 15km
  - Approximate size of the raw output archive (netcdf): 5TB

- African Region
  - Time period: (1980-2100)
  - BC: ECHAM5 boundary, A1B scenario
  - Horizontal Resolution: 50km
  - Approximate size of the raw output archive (netcdf): 9TB

4.2. CORDEX simulations with the regional climate model RegCM4.3

Model: RegCM4.3 (Giorgi et al.2012)
All runs at 50km of horizontal resolution.
See appendix M for a description of model and for the spatial plots for all the domains.

The following table summarizes the experiments which have been performed

Domain	Boundary conditions (GCMs)	period	approx. size (Tb)
South Asia	GPCP scenarios: RCP4.5, RCP8.5	1970-2100	3.4
South Asia	MPI ECHAM6 scenario RCP8.5	1970-2100	3.4
Africa	HadGEM scenarios: RCP4.5, RCP8.5	1970-2100	6.3
Africa	MPI ECHAM6 scenario RCP8.5	1970-2100	3.4
Central America	HadGEM scenarios: RCP4.5, RCP8.5	1970-2100	3.8
Central America	MPI ECHAM6 scenario RCP8.5	1970-2100	5.2
South America	HadGEM scenarios: RCP4.5, RCP8.5	1970-2100	6.4
South America	GDFL, scenario RCP8.5	1970-2100	3.5
South America	MPI ECHAM6 scenario RCP8.5	1970-2100	2.6
Mediterranean	HadGEM scenarios: RCP4.5, RCP8.5	1970-2100	6.0
Mediterranean	MPI ECHAM6 scenario RCP8.5	1970-2100	5.0

5. Inventory of climate experiments performed at ISAC-CNR

(Please see the appendix for a more detailed description of the models and of the experimental configurations)

5.1. EC-Earth

Model version: EC-Earth v. 2.3 (2011).
All runs at T159L62 (Atmosphere) + 1° / ORCA1 (Ocean) resolution.
Raw output files are in grib (IFS) + netcdf (NEMO)
See appendix N for a description of boundary conditions and climate forcing fields.

Completed runs:

- Historical run.

- Time period: (1850-2005)
- Approximate size of the raw output archive (grib+netcdf): 15 TB
- CMOR2 archive available: 1.5 TB

- RCP 2.6 scenario

- Time period: (2006-2100)
- Approximate size of the raw output archive (grib+netcdf): 15 TB
- CMOR2 archive available: 1 TB

- RCP 4.5 scenario

- Time period: (2006-2100)
- Approximate size of the raw output archive (grib+netcdf): 15 TB
- CMOR2 archive available: 1 TB

- RCP 8.5 scenario

- Time period: (2006-2100)
- Approximate size of the raw output archive (grib+netcdf): 15 TB
- CMOR2 archive available: 1 TB

Runs currently in progress

- Decadal experiments for CMIP5

- Time periods:
  10-yr simulations initialized 1960, 1965, 1970 ... 2000 and 2005 +
  30-yr simulations starting 1960, 1980 and 2005
- Initial state of the ocean: ORA-S4 (NEMOVAR) from ECMWF
- Initial state of the atmosphere: from IFS taken from MARS (ECMWF)
- Anomaly initialization: Compute anomalies from NEMOVAR and add it to model climate + Sea-ice: compute anomalies from a DFS forced NEMO run.

5.2. ECHAM-HAM

Model: ECHAM 5.5 + HAM 2 (Stier et al. 2005, Lohmann et al. 2009)
See appendix O for a description of the emission datasets, experiments and model parametrizations.

The following table summarizes the experiments which have been performed.

Emissions	**Reference period**	**Resolution**	**Dust-scheme**	**Nudged?**
ACCMIP	1999-2009	T42L19	Balkansky	Yes, ERA-Interim
ACCMIP	1999-2009	T42L19	Balkansky	No
ACCMIP	1999-2009	T42L19	Tegen (HAM2)	No
ACCMIP+ Bourgeois et al. mod.	2001-2006	T42L19	Balkansky	Yes, ERA-Interim
ACCMIP+GFED3	2001-2006	T42L19	Balkansky	Yes, ERA-Interim
ACCMIP+GFED3+ Bey et al. mod.	2001-2006	T42L19	Balkansky	Yes, ERA-Interim
ACCMIP+GFED3+ REAS mod. + Bey et al. mod.	2001-2006	T42L19	Balkansky	Yes, ERA-Interim
ACCMIP+GFED3+ REAS mod.	2001-2006	T42L19	Balkansky	Yes, ERA-Interim
Aerocom 2000	2001-2003	T63L31	Balkansky	Yes, ERA-Interim
Aerocom 2000	2001-2006	T42L19	Balkansky	No
Aerocom 2000	2001-2006	T42L19	Balkansky	Yes, ERA-Interim
Aerocom 2000+ Bey et al. mod.	2001-2006	T42L19	Balkansky	Yes, ERA-Interim

6. Inventory of climate experiments available from international projects

Project Name & link	Short Description	Atmos/Ocean	Global/ Regional	Link to the data
CMIP5 http://cmip-pcmdi.llnl.gov/cmip5/	International Programme for the production of coordinated multi-model climate simulations of the past and future climate change projections used for the 5th IPCC assessment report.	Coupled	Global	http://cmip-pcmdi.llnl.gov/cmip5/data_portal.html
PMIP http://pmip.lsce.ipsl.fr/	International coordinated experiments aimed at assessing the ability of climate models to reproduce the paleoclimate and improve our comprehension of the climate changes occurred in the past.	Coupled	Global	http://pmip.lsce.ipsl.fr/ (select "Database" on the table on the left)
ENSEMBLES http://ensembles-eu.metoffice.com/	EU-FP6 Project devoted to the development of climate predictions and climate change projections based on the multi-model ensemble approach, with high-resolution global and regional models and with a focus on the European continent.	Coupled and Atmosphere	Global and Regional	http://ensembles-eu.metoffice.com/data.html http://www.ecmwf.int/research/EU_projects/ENSEMBLES/data/data_dissemination.html
PRUDENCE http://prudence.dmi.dk/	EU project devoted to the production of high-resolution climate change projections for the European region.	Atmosphere	Regional	http://prudence.dmi.dk/ (select "Data distribution front page" on the left)
CORDEX http://wcrp.ipsl.jussieu.fr/cordex/about.html	International programme for the production of high-resolution climate change projections performed with regional models over a number of different domains.	Coupled and Atmosphere	Regional	http://cordex.dmi.dk/joomla/
ACQWA http://www.acqwa.ch/	EU Project aimed at assessing the changes in the river discharge induced by the climate change and variability in the timeframe 1960-2050 and their impacts on economy and society.	Atmosphere, hydrology, cryosphere and biosphere	Regional	Data available on request from the project partners
SODA http://soda.tamu.edu/	Coordinated global ocean re-analyses aimed at the reconstruction of the ocean variability observed in the second half of the 20th century.	Ocean	Global	http://soda.tamu.edu/data.htm
ENACT http://www.ecmwf.int/research/EU_projects/ENACT/	EU-Project aimed at the production of multi-decadal global ocean analyses with a multi-model system.	Ocean	Global	http://www.ecmwf.int/research/EU_projects/ENACT/ocean_analyses/index.html
CMIP3 http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php	International Programme for the production of coordinated multi-model climate simulations of the past and future climate change projections used for the 4th IPCC assessment report.	Coupled	Global	https://esg.llnl.gov:8443/about/registration.do

ERA-40 ERAI http://www.ecmwf.int/research/era/	Global atmospheric re-analyses for the period 1958-2001 (ERA-40) and 1979-present (ERA-Interim)	Atmosphere	Global	http://www.ecmwf.int
NCEP http://www.esrl.noaa.gov/psd/data/reanalysis/reanalysis.shtml	Global atmospheric re-analyses for the period 1948-present	Atmosphere	Global	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
MACC http://www.caricom.org/jsp/projects/macc%20project/macc.jsp?menu=projects	Climate change and impacts in the island environments of the CARICOM states.	Dynamical and statistical downscaling; impactsi and risk ssessment	Regionale	http://data-portal.ecmwf.int/data/d/macc_reanalysis/
MEDCLIVAR http://www.medclivar.eu/	Networking programme aimed at the coordination and promotion of studies of the Mediterranean climate, with special focus on past and current climate variability, extremes and theitr possible future changes.	Observations and models	Global and Regional	http://www.medclivar.eu/ (select “Search and Contribute Data & References” on the left)
CLIMATE-EXPLORER http://climexp.knmi.nl/start.cgi?id=someone@somewhere	Webtool for the research and study of climate statistics based on observations, re-analyses and model data.	Observations	Global	http://climexp.knmi.nl/start.cgi?id=someone@somewhere
AEROCOM http://aerocom.met.no/Welcome.html	An international model comparison initiative for the understanding of the global aerosol and its impact on climate. Compares observation datasets and global circulation models including aerosol dynamics.	Atmosphere	Global	http://aerocom.met.no/cgi-bin/AEROCOM/aerocom/surfobs_annualrs.pl

Appendix A: INGV-SXG model description

INGV-SXG (Gualdi et al. 2008) CGCM (fully coupled General Circulation Model), is an evolution of the SINTEX and SINTEX-F models (Gualdi et al. 2003a,b; Guilyardi et al. 2003; Luo et al. 2003; Masson et al. 2005; Behera et al. 2005).

The ocean model component is the reference version 8.2 of the Océan Parallélisé (OPA; Madec et al. 1998) with the ORCA2 global ocean configuration. To avoid the singularity at the North Pole, it has been transferred to two poles located in Asia and North America. The model latitude–longitude resolution is 2°x2° cosine (latitude), with increased meridional resolutions to 0.5° near the equator. The model has 31 vertical levels, 10 of which lie in the upper 100 m of the ocean.

The model physics includes a free-surface configuration (Roullet and Madec 2000) and the Gent and McWilliams (1990) scheme for isopycnal mixing. The horizontal eddy viscosity coefficient in open oceans varies from 40 000 m^2s^{-1} in high latitudes to 2000 m^2s^{-1} at the equator. Vertical eddy diffusivity and viscosity coefficients are calculated from a 1.5-order turbulent closure scheme (Blanke and Delecluse 1993). For more details about the ocean model and its performance, readers are referred to Madec et al. (1998; information also available online at http://www.lodyc.jussieu.fr/opa/).

The evolution of the sea ice is described by the Louvain-La-Neuve sea ice model (LIM; Fichefet and Morales Maqueda 1999), which is a thermodynamic– dynamic snow–sea ice model, with three vertical levels (one for snow and two for ice). The model allows for the presence of leads within the ice pack. Vertical and lateral growth and decay rates of the ice are obtained from prognostic energy budgets at both the bottom and the surface boundaries of the snow–ice cover and in leads. When the snow load is sufficiently large to depress the snow–ice interface under the seawater level, seawater is supposed to infiltrate the entirety of the submerged snow and freeze there, forming a snow–ice cap. For the momentum balance, sea ice is considered as a two-dimensional continuum in dynamical interaction with the atmosphere and ocean. The ice momentum equation is solved on the same horizontal grid as the ocean model. LIM has been thoroughly validated for both Arctic and Antarctic conditions, and has been used in a number of process studies and coupled simulations (Timmermann et al. 2005, and references therein).

The atmospheric model component is the latest version of ECHAM4 (Roeckner et al. 1996). We adopted a T106 horizontal resolution, corresponding to a Gaussian grid of about 1.12° x 1.12°. In the pantheon of long coupled climate simulations, this is a considerably high horizontal resolution. A hybrid sigma–pressure vertical coordinate is used with 19 vertical levels. The parameterization of convection is based on the mass flux concept (Tiedtke 1989), modified following Nordeng (1994). The Morcrette (1991) radiation scheme is used with the insertion of greenhouse gases (GHGs) and a revised parameterization for the water vapor and the optical properties of clouds. A detailed discussion of the model physics and performances can be found in Roeckner et al. (1996).

The ocean and atmosphere components exchange SST, surface momentum, heat, and water fluxes every 1.5 h. The coupling and the interpolation of the cou- pling fields is made through the Ocean Atmosphere Sea Ice Soil (OASIS) version 2.4 coupler (Valcke et al. 2000). No flux corrections are applied to the coupled model.

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Appendix B: CMCC-MED model description

The CMCC_MED (Scoccimarro et al. 2011, Gualdi et al. 2012) coupled atmosphere-ocean general circulation model, has been implemented and developed in the framework of the European CIRCE Project (Climate Change and Impact Research: the Mediterranean Environment, http://www.circeproject.eu/). For this reason, the model has a focus on the Mediterranean region and a very high resolution model of the Mediterranean Sea has been introduced as a component of the coupled atmosphere-ocean system in order to better represent the dynamical processes that characterize this region (Gualdi et al., 2012). The model is an evolution of the INGV-SXG (Gualdi et al. 2008, Bellucci et al. 2008) and the ECHAM-OPA- LIM (Fogli et al. 2009, Vichi et al. 2011) models. In the CMCC_MED model the ocean component is simulated through a coarse-resolution global ocean model and a high-resolution eddy-permitting model of the Mediterranean Sea.

The global ocean component is OPA 8.2 (Océan PArallélisé, Madec et al. 1998), in its ORCA2 global configuration. The horizontal resolution is 2^o x 2^o with a meridional refinement near the equator, approaching a minimum 0.5^o grid spacing. The model has 31 vertical levels, 10 of which lie within the upper 100 m. ORCA2 also includes the Louvain-La-Neuve (LIM) model for the dynamics and thermo- dynamics of sea-ice (Fichefet and Morales-Maqueda 1999). Ocean physics includes a free-surface parameterization (Roullet and Madec 2000) and the Gent and McWilliams (1990) scheme for isopycnal mixing. For more details about the ocean model and its performance, readers are referred to Madec et al. (1998; information also available online at http://www.lodyc.jussieu.fr/ opa/).

The Mediterranean Sea model (Oddo et al. 2009) is a regional configuration of the NEMO (Nucleus for European Modeling of the Ocean) model (Madec 2008), with a $1/16^o$ horizontal resolution and 71 levels along the vertical.

The atmospheric model component is ECHAM5 (Roeckner et al. 2003) with a T159 horizontal resolution, corresponding to a Gaussian grid of about 0.75° x 0.75°. This configuration has 31 hybrid sigma-pressure levels in the vertical and top at 10 hPa. The parameterization of convection is based on the mass flux concept (Tiedtke 1989), modified following Nordeng (1994). Moist processes are treated using a mass conserving algorithm for the transport (Lin and Rood, 1996) of the different water species and potential chemical tracers. The transport is resolved on the Gaussian grid. A more detailed description of the ECHAM model performance can be found in Roeckner et al. (2006).

The communication between the atmospheric model and the ocean models is carried out with the OASIS3 coupler (Valcke 2006). Every 160 minutes (coupling frequency), heat, mass and momentum fluxes are computed and provided to the ocean model by the atmospheric model. Sea Surface Temperature (SST) and sea surface velocities are provided to the atmospheric model by both ocean models. The global ocean model provides also sea-ice cover and thickness to the atmospheric model. The relatively high coupling frequency adopted allows an improved representation of the interaction processes occurring at the air-sea interface. No flux corrections are applied to the coupled model.

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Appendix C: CMCC-CM model description

The CMCC_CM (Scoccimarro et al. 2011) coupled atmosphere-ocean general circulation model is an evolution of the INGV-SXG (Gualdi et al. 2008, Bellucci et al. 2008) and the ECHAM-OPA-LIM (Fogli et al. 2009, Vichi et al. 2011) models. The global ocean component is OPA 8.2 (Océan PArallélisé, Madec et al. 1998), in its ORCA2 global configuration. The horizontal resolution is 2° x 2° with a meridional refinement near the equator, approaching a minimum 0.5° grid spacing. The model has 31 vertical levels, 10 of which lie within the upper 100 m. ORCA2 also includes the Louvain-La-Neuve (LIM) model for the dynamics and thermo-dynamics of sea-ice (Fichefet and Morales-Maqueda 1999). Ocean physics includes a free-surface parameterization (Roullet and Madec 2000) and the Gent and McWilliams (1990) scheme for isopycnal mixing. For more details about the ocean model and its performance, readers are referred to Madec et al. (1998; information also available online at http://www.lodyc.jussieu.fr/ opa/).

The atmospheric model component is ECHAM5 (Roeckner et al. 2003) with a T159 horizontal resolution, corresponding to a Gaussian grid of about 0.75° x 0.75°. This configuration has 31 hybrid sigma-pressure levels in the vertical and top at 10 hPa. The parameterization of convection is based on the mass flux concept (Tiedtke 1989), modified following Nordeng (1994). Moist processes are treated using a mass conserving algorithm for the transport (Lin and Rood, 1996) of the different water species and potential chemical tracers. The transport is resolved on the Gaussian grid. A more detailed description of the ECHAM model performance can be found in Roeckner et al. (2006).

The communication between the atmospheric model and the ocean model is carried out with the OASIS3 coupler (Valcke 2006). Every 160 minutes (coupling frequency), heat, mass and momentum fluxes are computed and provided to the ocean model by the atmospheric model. Sea Surface Temperature (SST) and sea surface velocities are provided to the atmospheric model by the ocean model. The global ocean model provides also sea-ice cover and thickness to the atmospheric model. The relatively high coupling frequency adopted allows an improved representation of the interaction processes occurring at the air-sea interface. No flux corrections are applied to the coupled model.

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Appendix D: INGV-CMCC-CE model description

The INGV-CMCC Carbon cycle Earth system model (here after INGV-CMCC-CE) consists of an atmosphere-ocean-sea ice physical core coupled to models resolving carbon cycle on land and ocean, respectively. The technical description of the atmosphere-ocean coupling as well as the coupling of the carbon cycle models into the physical core are described in Fogli et al. (2009). The model components are: the ECHAM5 model for the atmosphere (Roeckner et al. 2006); the SILVA land surface model (Alessandri 2006); the OPA8.2 model for the ocean (Madec et al. 1999); the LIM2 model for the sea ice (Timmermann et al. 2005), and the PELAGOS model for the ocean biogeochemistry (Vichi et al. 2007a,b; Vichi and Masina 2009). The software used to couple the atmosphere (including the land-vegetation model) component and the ocean (including the biogeochemistry) is OASIS3 (Valcke 2006).

The ECHAM5 model (Roeckner et al. 2003; 2006) in this application has horizontal triangular truncation T31, while in the vertical 19 vertical levels and the top at 10 hPa are used. The OPA8.2 model is a primitive equation ocean general circulation model that is numerically solved on a global ocean curvilinear grid known as ORCA (Madec and Imbard 1996). In this application, we use ORCA2, with a resolution of 2 degrees of longitude and a variable mesh of 0.5-2 degrees of latitudes from the equator to the poles. The vertical grid has 31 levels (the 31st level is below the bottom) with variable layer depth and a constant 10 m step in the top 100 m. The atmosphere is coupled to the ocean and sea ice models with a coupling step of one day and the exchanged fields and coupling procedures are fully detailed in Fogli et al. (2009). With respect to the previous ECHAM/OPA coupled model (INGV-SXG, Gualdi et al. 2008), in the coupling interface with OPA8.2, here it is made use of the capability of ECHAM5 to compute surface heat fluxes for both the ocean and sea ice surfaces at the same grid point and then to combine them according to an ocean and sea ice fractional mask (see Fogli et al. 2009, for the detailed description of the technical implementation). The coupling time step between the LIM2 sea ice model and the OPA8.2 ocean model is 8 hours. The ocean state variables are accumulated and averaged at every ocean-sea ice coupling time step.

The Surface Interactive Land VegetAtion model (SILVA, Alessandri 2006, Alessandri et al. 2007) simulates land surface processes and their associated variability. The biophysical version of the SILVA model, which includes also carbon and vegetation dynamics, is discussed in Alessandri et al. (in preparation). The vegetation and carbon dynamics and the CO2 flux exchange are derived from the core parameterizations of VEGAS (VEgetation-Global-Atmosphere-Soil, Zeng et al. 2004).

The PELAGOS model (PELAgic biogeochemistry for Global Ocean Simulations model, Vichi et al. 2007a,b) has been further extended to incorporate a full description of the dissolved inorganic carbon (DIC) dynamics and adequately simulate the ocean components of the carbon cycle. The PELAGOS model consists of the global ocean version of the Biogeochemical Flux Model (BFM, http://bfm.cmcc.it) and its coupling to the OPA OGCM. For the current application, the model also includes dynamics of dissolved inorganic carbon and the computation of surface exchange fluxes according to the carbonate chemistry equations and air-sea gas transfer interactions. The model is written in a generalized mathematical formulation that allows the description of lower trophic levels and major inorganic and organic components of the marine ecosystem from a unified functional perspective (Vichi et al. 2007a). The pelagic state variables of PELAGOS are three unicellular planktonic autotrophs (picophytoplankton, nanophytoplankton and diatoms), three zooplankton groups (nano-, micro- and meso-) and bacterioplankton. The other chemical functional families are nitrate, ammonium, orthophosphate, silicate, dissolved bioavailable iron, oxygen, carbon dioxide and dissolved and particulate (non-living) organic matter (POM, DOM), for a total of 44 state variables. The implementation of carbonate chemistry for the closure of the carbon cycle adds 2 dynamically transported variables (total alkalinity and total dissolved inorganic carbon) and 5 diagnostic variables for the carbonate speciation (CO2, bicarbonate and carbonate concentrations, CO2 partial pressure and pH).

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Appendix E: CMCC-CMS model description

The CMCC-CMS model is based on the INGV-CMCC-CE model and consists of the ECHAM5 atmosphere (Roeckner et al. 2006) and OPA8.2/LIM ocean/sea-ice (Madec et al. 1999) models and the OASIS3 coupler (Valcke 2006). The coupling methodology and implementation is described in Fogli et al. (2009). The incorporation of the resolved stratospheric component implies the use of the middle atmosphere version (Manzini et al. 2006) of the atmospheric model in the couple system. The model has high vertical resolution (95 levels from the surface up to 80 km) and a horizontal resolution of T63 (about 1.9 x 1.9 deg). In this configuration the model internally generates the QBO in the equatorial stratosphere (Giorgetta et al. 2006). The middle atmosphere version has top at 80 km (0.01 hPa) and includes the parameterization of momentum conserving orographic and non-orographic gravity wave drag. The shortwave radiation scheme covers the 185-4000 nm spectral interval with a spectral resolution of 6 bands separating the UV and visible ozone absorption (Cagnazzo et al. 2007). A source of water vapor in the stratosphere and mesosphere by methane oxidation has been added. The oceanic component has a resolution of about 2 degrees in horizontal and 31 vertical levels.

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Appendix F: CMCC-CESM model description

The CMCC-CESM is based on the INGV-CMCC-CE model and consists of the ECHAM5 atmosphere (Roeckner et al. 2006) and OPA8.2/LIM ocean/sea-ice (Madec et al. 1999) models and the OASIS3 coupler (Valcke 2006). The coupling methodology and implementation is described in Fogli et al. (2009). The model has the top of the atmosphere at 80 km, with 39 vertical levels and a horizontal resolution of T31 (3.75 deg x 3.75 deg). In this version, the model does not reproduce a spontaneous QBO but it reproduces a realistic extra-tropical stratospheric variability. The model is designed to simulate the carbon cycle for climate change research. The CMCC-CESM (Fogli et al. 2009) includes processes related to the biological and geochemical parts of the carbon cycle: SILVA land and vegetation model (Alessandri 2006) and PELAGOS ocean biogeochemistry (Vichi et al. 2007a,b).

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Appendix G: CMCC/INGV CIGODAS model description

The Ocean Model

The ocean general circulation model used to produce the ocean reanalyses is a global implementation of a free-surface version of the Océan Parallélisé (OPA) model (Madec et al. 1998). The horizontal resolution is 2^o x 2^o cosφ everywhere, except for the 20°N–20°S latitude belt, where the meridional grid spacing is progressively decreased to 0.5° to better resolve the equatorial dynamics. The grid is irregular, featuring two poles in the Northern Hemisphere, both located over the continents so as to avoid the North Pole singularity, while the Southern Hemisphere grid pole is naturally located over Antarctica. There are 31 unevenly spaced levels along the vertical with the top 20 levels concentrated in the upper 500 m, and the last temperature level under the ocean floor. The vertical mixing parameterization is based on a turbulent kinetic energy prognostic equation (Blanke and Delecluse 1993). The horizontal viscosity coefficient is space dependent: a typical value of 40 000 m2 s-1 is applied poleward of the 20°N–20°S belt, while it gradually decreases to 2000 m2 s-1 in the equatorial region, except for the western boundary regions. Tracers are diffused along isopycnal surfaces with an eddy-mixing coefficient of 2000 m2 s-1. Lateral diffusion is supplemented with the Gent and McWilliams (1990) eddy-induced velocity parameterization (Lazar et al. 1999). A typical strength of the eddy-induced velocity is 2000 m2 s-1, but it is decreased in the equatorial region. The time step is 1 h 36 min for both dynamics and tracers. There is no thermodynamical sea ice model coupled to the ocean model, a simple ice “if model” , driven by Sea Surface Temperature (SST), is used.

The Optimal Interpolation (OI) scheme

The data assimilation system used to produce the ocean reanalyses is based on SOFA (De Mey and Benkiran 2002) and has been implemented for the assimilation of in situ (vertical profiles of temperature and salinity) data for the Global Ocean in Bellucci. Et al. (2007). The details of CIGODAS can be found in Di Pietro and Masina, (2009) technical report.

Assimilated dataset

The observed temperature and salinity used in our re-analyses are taken from the EN (ENACT Quality Checked) dataset (Ingleby and Huddleston, 2007). The profiles are obtained primarily from the WORLD OCEAN DATABASE 2005, supplemented using data from other sources: GTSPP from 1990 onwards and the USGODAE Argo Global Data Assembly Centre (GDAC) for Argo data from 1999 onwards.

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Appendix H: CMCC OceanVar model description

The Ocean Model

The oceanic general circulation model (OGCM) used within the analysis system is version 8.2 of the free-surface Ocean Parallèle (OPA) model (Madec et al. 1998). The spatial resolution of OPA is 2° × 2° cos(latitude) × 31 vertical levels, though in the tropical band the meridional resolution increases up to 0.5°.

Assimilation scheme

The three-dimensional variational assimilation methods (3DVAR) iteratively solve the assimilation problem by minimizing a cost function.

The formulation of the background term of the cost function follows Dobricic and Pinardi (2008): the background-error covariance matrix is decomposed in a sequence of linear operators that account separately for horizontal correlations and vertical covariances, which are assumed to be independent. Horizontal correlations are modeled by means of an application of four iterations of a first-order recursive filter (Hayden and Purser 1995) with horizontally homogeneous but vertically varying correlation length scale.

The vertical component of the background-error covariance matrix is eigendecomposed to obtain vertically uncorrelated eigenvectors. We use empirical orthogonal functions (EOFs), which are bivariate in temperature and salinity, at full model resolution in both the horizontal and the vertical. To reduce computational cost and avoid noisy vertical correlations, the vertical modes are truncated to 10 from the original 62 modes. The EOFs were calculated from the model seasonal climatology (Bellucci et al. 2007; Di Pietro and Masina 2009).

To impose cyclic conditions on the global ocean domain, the minimization is performed over an extended domain, with duplicated points before the western and after the eastern boundaries. Observations in the extension zones are duplicated from the corresponding area of the original domain. The extension zone is 20 grid points long on both boundaries (about 5000 km), which makes sure that analyzed fields at the inner boundaries of the extension zones are exactly the same at the western and eastern boundaries after the minimization.

The data assimilation step is performed every 10 days, using all the observations included in the temporal range of ±5 days before and after the assimilation time. The ocean model is then used to project the analyzed fields forward to the next assimilation step.

Assimilated Data

The set of in situ observations consists of vertical profiles of temperature from the expandable bathythermographs (XBTs), buoys, sea stations [temperature, salinity, and current (TESAC)], Argo floats (from late 1990s onward only), and salinity profiles from buoys, sea stations, and Argo floats. Data have been provided by the Met Office's Hadley Centre within the framework of the European Union (EU) funded project ENSEMBLES (EN3). EN3 is a collection of in situ data that have been quality checked according to the method of Ingleby and Huddleston (2007). For XBT data, a time-dependent fall-rate correction was used (Wijffels et al. 2008).

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Appendix I: C-GLORS, the CMCC Global Ocean Reanalysis System

CGLORS consists of a weekly three-dimensional variational analysis (3DVAR), followed by a 1-week Ocean General Circulation Model (OGCM) integration, which brings the analysis forward to the next assimilation step. The three-dimensional variational data assimilation system is a global implementation (Storto et al., 2011) of OceanVar (Dobricic and Pinardi, 2008), the assimilation system used within the MyOcean Mediterranean Monitoring and Forecasting Center. The OGCM is NEMO (Madec, 2008) in its ORCA025 configuration, coupled with the Louvain La Neuve Sea-Ice model (LIM2, Fichefet and Morales Maqueda, 1997). Details of the two steps are given below.

The data assimilation step is used to correct three-dimensional fields of temperature and salinity. The analysis is performed every 7 days. Within the 3D-Var scheme, we minimise a cost function given by the sum of the distance between the analysis state, unknown, and a prior knowledge of the state of the ocean (the background) and the distance between the analysis state and the observations, in observation space, scaled by the background- and observational error covariance matrices, respectively. Since the observations are compared to the background field closer in time to the observations within 3-hourly time slots of the weekly assimilation time-window, this scheme is usually referred to as 3DVAR/FGAT (First Guess at Appropriate Time).

The background-error covariance matrix is decomposed onto two linear terms accounting, respectively, for vertical covariances and horizontal correlations. In our scheme, vertical covariances are represented by a 1-degree resolution set of 10-mode seasonal bivariate Empirical Orthogonal Functions (EOFs) of salinity and temperature at full model vertical resolution. Horizontal correlations are modelled by means of a four-iteration first-order recursive filter, with three-dimensional, parameter- and direction- dependent correlation length-scales. Thus, the problem of defining the background-error covariance matrix simplifies to the three-dimensional definition of the horizontal correlation length-scales and a coarse-resolution computation of vertical bivariate EOFs. Both the vertical EOFS and the correlation length-scales were calculated from the seasonal anomalies (with respect to the climatology) of an observation-blind OGCM run for the same reanalysis period.

In order to impose cyclic condition on the western and eastern boundaries, the global domain is replaced by an extended domain, with symmetric extension zones westward of the western boundary and eastward of the eastern boundary. Within these extension zones, observations are duplicated in order to have very close analysis increments at the two boundaries.

In this version of the global ocean data assimilation system, there is no assimilation of sea-ice observations. Furthermore, observations close to the sea-ice are rejected in order to avoid unrealistic analysis increments, inconsistent with the OGCM and the sea-ice model.

CGLORS assimilates all the in-situ observations of temperature and salinity from moorings, ARGO floats, Expandable Bathy Termographs (XBTs) and Conductivity-Temperature-Depth (CTDs). The data used in this reanalysis are collected, quality-checked and distributed by the U.K. Met Office Hadley Center. The dataset is called EN3 and the version used is the v2a. XBTs fall rates are corrected according to the time-dependent bias-correction scheme of Wijffels et al. (2008).

CGLORS also assimilates SST observations from the NOAA high-resolution daily analyses, which uses AVHRR and (from 2002) AMSR-E radiances.

Observations pre-processing includes i) a background quality-check – which rejects observations for which the ratio between the squared departure from the background and the sum of the observational and background error variances exceeds an observation type-dependent threshold; ii) an horizontal data thinning in order to reject observations too close in space, provided that observations are assumed to be spatially (and temporally) uncorrelated and iii) a vertical data thinning for in-situ observations only, to avoid that several assimilated observations from a same platform lie within the same vertical model layer.

The observational errors for in-situ observations were initially set equal to those found by Ingleby and Huddleston (2007) and subsequently tuned via the Desroziers' method (Desroziers et al., 2005). The latter iteratively adjusts the observational error standard deviations by using assimilation output statistics. Maxima of the observational errors are located approximately in correspondence of the mixing layer depth and at the surface for temperature and salinity, respectively.

The CGLORS forecast model step is performed by the NEMO ocean model in configuration ORCA025. The version of the model is the release 3.2.1. The model has a resolution of about a ¼ of degree.

Initialization strategy

The strategy for initializing the reanalysis has been chosen as follows: a 1979-1989 assimilation-free run initialized with:

1. monthly climatology of temperature and salinity fields from the NODC World Ocean Atlas 1998 Series (Levitus et al., 1998) blended with the PHC2.1 climatology for the Arctic region;
2. sea-ice parameters (se-ice cover and ice temperature) from the ERA-Interim reanalysis.

From 1990 onwards, the data assimilation was switched on.

<u>Surface forcing fields</u>

The CORE bulk-formulas forcing method (Large and Yeager, 2009) has been adopted.

The following atmospheric variables have been used:

1. 3-hourly turbulent variables (wind vector at 10 m above mean sea-level; temperature and specific humidity at 2 m above mean sea-level)
2. daily-hourly radiative fluxes variables (downward short-wave and long-wave radiation) with shortwave radiation modulated to have a diurnal cycle.
3. daily fresh water flux variables (total precipitation and snow).

All the forcing fields are provided by the European Centre for Medium-Range Weather Forecast (ECMWF) ERA-Interim atmospheric reanalysis project (Simmons et al., 2007).

<u>Corrections of surface forcing fields</u>

ERA-Interim radiative fluxes and wind fields have been corrected as follows:

- large-scale short-wave and downward long-wave radiation fluxes have been corrected by means of a large-scale climatological correction coefficient derived by the GEWEX Surface Radiation Budget project (Garric and Verbrugge, 2010);

- precipitation fields were corrected by using a climatological coefficient derived from the REMSS/PMWC dataset (Storto et al., 2012).

Furthermore, in order to avoid artificial drifts of the globally-averaged sea-surface height due to the unbalanced fresh water budget, the evaporation minus precipitation minus runoff has been set equal to zero at each model time-step.

Runoff

The runoff files used in the simulation has been created by Bourdalle-Badie and Treguier (2006) and provided by MERCATOR-Ocean. It is a monthly climatology that includes 99 major rivers and coastal runoffs.

No specific treatment at rivers mouths has been applied. Runoff has been set equal to zero in Arctic and Antarctic regions.

Boundary conditions

The lateral boundary condition on momentum allows for a partial slip. For the upper boundary a filtered free-surface formulation has been used.

At the ocean bottom, a linear friction is assumed and no geothermal heat flux has been considered as a bottom boundary condition. Neither diffusive nor advective bottom boundary layer parametrization for tracers and momentum have been used.

Damping

No relaxation to sea-surface salinity nor to sea-surface temperature has been used. Similarly no 3D damping on water column to tracers climatology has been activated.

LIM2 sea-ice model

The sea-ice model used in the reanalyses is the LIM2: only ice thermodynamics and not dynamics has been activated.

Physics

The Turbulent Eddy Kinetic (TKE) dependent vertical diffusion scheme has been used to compute the eddy vertical mixing coefficient.

The vertical parametrizations include: i) the Enhanced Vertical Diffusion (EVD) scheme, ii) double diffusion mixing parametrization for temperature and salinity, iii) a mixing length scale surface value as function of wind stress.

The advection scheme used for tracers is the Total Variation Diminishing (TVD) scheme.

For lateral diffusion a laplacian isopycnal diffusion scheme has been used with horizontal eddy diffusivity rn_aht_0 = 300 m^2/s (the coefficient is grid size dependent).

A bilaplacian operator has been used for lateral viscosity of momentum, with horizontal eddy viscosity coefficient rn_ahm_0 = -1.0e11 m^2/s. The coefficient is grid size power 3 dependent.

Computational details

C-GLORS has run on a NEC-SX9 vectorial machine 12-processor node.

The domain has been decomposed into 12 MPP subdomains, equally distributed as 4 processors along the x- and the y- directions.

Wall-clock time for the simulation was about 36 hours per year of simulation, depending on observations amount and number of 3DVAR iterations performed, of which about 60% spent on the OGCM run and the rest on the assimilation part. The time-step is set equal to 900 s (96 steps/day) for both dynamics and tracers.

The frequency of surface forcing and LIM2 sea-ice model couplings is set equal to 6 time-steps (1.5h). The model outputs have been saved as weekly means, subsequently post-processed to generate monthly means.

Changes from V1 to V2

In the following paragraphs, the changes introduced from the version V1 to the version V2 of the CMCC Global Ocean Reanalysis product are described. The reader can refer to the DR1 (MYO-WP04-ScCV-rea-CMCC-V1) for all the other aspects of the reanalysis configuration.

Forecast Model Configuration

The changes introduced in the NEMO model configuration are listed below:

- Use of chlorophyll data (SeaWiFS climatology) within the Red-Green-Blue solar light penetration scheme;
- Increase of temporal resolution of ERA-Interim turbulent fluxes (u10m, v10m, t2m, q2m) from 6-hourly to 3-hourly frequency;
- Use of daily radiative fluxes with analytical diurnal cycle for shortwave radiation (Bernie et al., 2007);
- Increase of surface coupling (forcing and LIM2) frequency from 3 hours to 1.5 hours;
- Correction of ERA-Interim precipitation fields by using Remote Sensing (REMSS) Passive Microwave Water Cycle (PMWC) data (Storto et al., 2012):
- Nudging to sea-ice concentration data from NOAA AVHRR daily analysis at high-resolution (1/4 degree) with 15 days restoring;
- Restoring to World Ocean Atlas 2009 sea-surface salinity on ice-covered areas;
- Removal of QuickScat-based wind stress correction, as it was calibrated on an older model configuration.

Data Assimilation System

The changes introduced in the 3DVAR assimilation system are listed below:

- Assimilation of SST observations (NOAA daily ¼ degree analysis; Reynolds et al., 2007) from AVHRR (1993-2002) and AVHRR+AMSR-E (2002-onwards);
- Removal of the sea-level anomaly assimilation due to physically inconsistent analysis increments in some regions;
- Use of nonuniform seasonal background-error horizontal correlation length-scales computed from the control experiment anomalies by using the Belo-Pereira and Berre (2006) approximation;
- Tuning of in-situ observational error through the Desroziers et al. (2005) diagnostics-based method;
- Added periodic conditions in the recursive filter for global domain analyses.

Initialization

The reanalysis was initialized by using the 1989 initial conditions from a free run initialized in turn in 1979 from rest and without climatological spinup and forced for the period 1979-1989 by the ERA-Interim (recently extended back to cover also the 1979-1988 period).

Forced runs without data assimilation

Further to the assimilative experiments previously reported, a number of forced run were performed with the aim of testing the ocean model configuration. The completed experiments are FORCED1 and FORCED2, without and with the correction of the precipitation fluxes from ERA-Interim (as described in Storto et al., 2012), and FORCED3, which has the same ocean model configuration of C-GLORS V2 and serves the purpose of verifying the effect of data assimilation. Furthermore, FORCED2 owns the same ocean model configuration of C-GLORS V1, namely FORCED2 and FORCE3 are the non-assimilative counterpart experiments of MyOcean V1 and V2, respectively.

Furthermore, a number of forced experiments without data assimilation were performed with the specific objective of testing different strategies for correcting the ERA-Interim forcing fields. These experiments are: i) CORR1: a 1979-2010 experiment that uses all the uncorrected forcing fields from ERA-Interim; ii) CORR2: a 1989-2007 experiment where GEWEX/SRB radiative fluxes replace ERA-Interim radiative fluxes; iii) CORR3: a 1989-2010 experiment with radiative fluxes corrected by means of a daily climatological (1999-2007) coefficient derived from GEWEX/SRB dataset; iv) CORR4: a 1989-2010 experiment with wind stress corrected by means of a QuickScat derived climatology, and v) CORR5: a 1979-2010 experiment with all the corrections as in CORR3, CORR4 and FORCED2 applied.

Other completed simulations

Other non-assimilative experiments were performed with the aim of tuning the configuration of the NEMO ocean model and comparing different strategy for air-sea interface formulation. The completed and archived simulations are detailed below.

FLUXES is a 1958-2001 experiment that uses prescribed fluxes from the ERA-40 atmospheric reanalysis (Uppala et al., 2005), namely radiative and freshwater fluxes were imposed from the ERA-40 atmospheric reanalysis without feedback from the ocean. FLUXES was the first long-term run using the NEMO model in configuration ORCA025. The NEMO model version used for this run was 2.3 and no sea-ice model was coupled to NEMO.

BULK was the first 1989-2009 experiment that used ERA-Interim (Simmons et al., 2007) instead of ERA-40 fluxes, the CORE bulk formulation (Large and Yeager, 2009) for the air-sea fluxes. The use of the CORE bulk formulation allowed the coupling between NEMO and the LIM2 sea-ice model (Fichefet and Morales Maqueda, 1997).

CHLA is another 1989-2009 that uses a spatially-varying Chlorophyll climatology derived from SeaWiFS within the RGB solar penetration scheme (Lengaigne et al., 2007) rather than a uniform value.

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Appendix J: COSMO-CLM model description

The COSMO-CLM is the climate version of the COSMO LM model which is the operational non-hydrostatic mesoscale weather forecast model developed initially by the German Weather Service and then by the European Consortium COSMO. Successively, the model has been updated by the CLM-Community, in order to develop also a version for climate application (COSMO CLM). It can be used with a spatial resolution between 1 and 50 km even if the non hydrostatic formulation of the dynamical equations in LM made it eligible especially for the use at horizontal grid resolution lower than 20 km. These values of resolution are usually close to those requested by the impact modellers; in fact these resolutions allow to describe the terrain orography better than the global models, where there is an over- and underestimation of valley and mountain heights, leading to errors in precipitation estimation, as this is closely related to terrain height. Moreover the non-hydrostatic modelling provides a good description of the convective phenomena, which are generated by vertical movement (through transport and turbulent mixing) of the properties of the fluid as energy (heat), water vapour and momentum. The mathematical formulation of COSMO-CLM is made up of the Navier-Stokes equations for a compressible flow. The atmosphere is treated as a multicomponent fluid (made up of dry air, water vapour, liquid and solid water) for which the perfect gas equation holds, and subject to the gravity and to the Coriolis forces. The model includes several parameterizations, in order to keep into account, at least in a statistical manner, several phenomena that take place on unresolved scales, but that have significant effects on the meteorological interest scales (for example, interaction with the orography).

It is the only limited area numerical model system in Europe which has a range of applicability encompassing operational numerical weather prediction and regional climate modelling (past, present and future); it is applicable for downscaling in all regions of the world and of most of the Global Climate simulations available.

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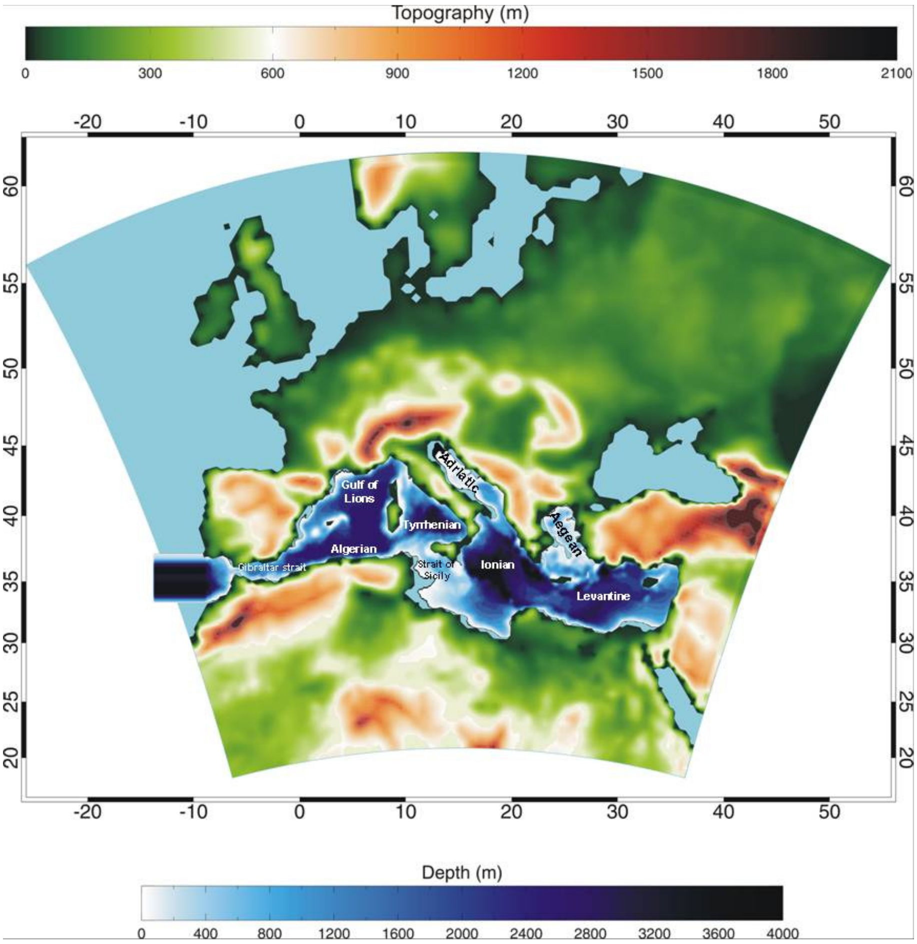
Appendix K: PROTHEUS model description

The PROTHEUS coupled model is presented in Artale et al. 2010. In Fig. 1 we report the chosen domain. The configuration employed in CIRCE project for the atmospheric component has a uniform horizontal grid spacing of 30 km on a Lambert conformal projection. The model domain is centered at 41N and 15E with 160 grid points in the meridional direction, 150 grid points in the zonal direction. We post processed the 3D atmospheric fields onto 14 vertical pressure levels. The configuration for the oceanic component has a resolution of 1/8°x1/8°, which is equivalent to rectangular meshes of variable resolution in which the meridional side is about 14 Km while the zonal one ranges from about 9 Km in the northern part of the domain to about 12 Km in southern part. 42 vertical Z-levels are used, with a resolution varying from 10 m at the surface to 300 m in the deeper part of the basin, with an intermediate resolution of about 40-50 m between the depths 200-700 m.



Domain for the PROTHEUS CIRCE simulation with corresponding topography and bathymetry. Units are m.

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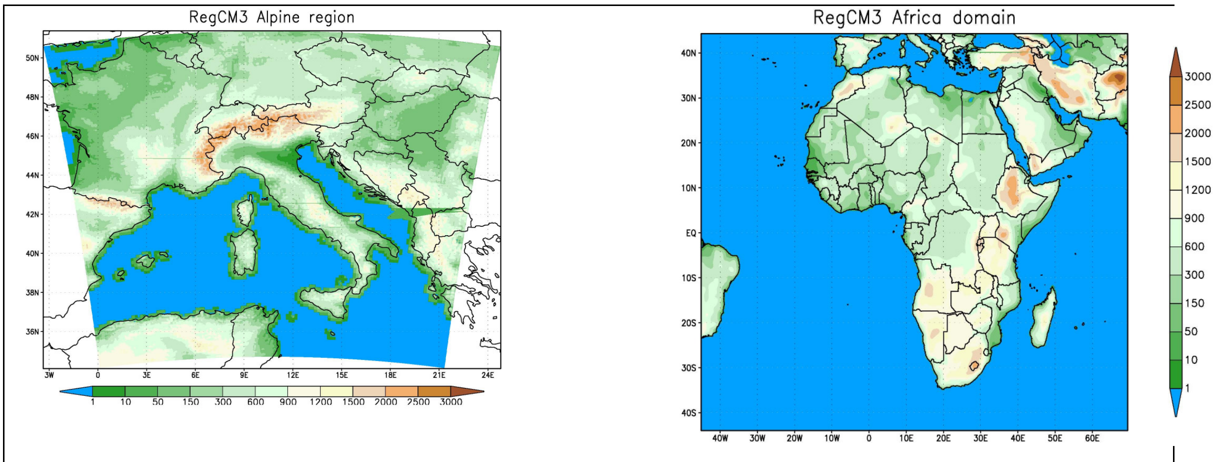
Appendix L: RegCM3 model description

The ICTP regional climate model, RegCM3, is described in Giorgi et al. 1993a, b; Pal et al. 2007. RegCM3 is a primitive equation, sigma vertical coordinate, regional climate model based on the hydrostatic version of the dynamical core of the NCAR/PSU's mesoscale meteorological model MM5 (Grell et al. 1994). Radiation is represented by the CCM3 parameterization of Kiehl et al. (1996) and the planetary boundary scheme is represented by the scheme of Holtslag et al. (1990) in the implementation of Giorgi et al. (1993a). Interactions between the land surface and the atmosphere are described using the biosphere atmosphere transfer scheme (BATS1E; Dickinsonet al. 1993). For the ocean flux parameterization with two schemes were used: Zeng et al. (1998) and BATS (Dickinson et al. 1993).

Convective precipitation is computed using one of three schemes: (1) Modified-Kuo scheme Anthes (1977); (2) Grell scheme (1993); and (3) MIT-Emanuel scheme (Emanuel, 1991; Emanuel and Zivkovic-Rothman, 1999). In addition, the Grell parameterization is implemented using one of two closure assumptions: (1) the Arakawa and Schubert closure Grell et al. (1994) and (2) the Fritsch and Chappell closure Fritsch and Chappell (1980), hereafter refered to as AS74 and FC80, respectively.

The Large-Scale precipitation scheme Subgrid Explicit Moisture Scheme (SUBEX) is used to handle nonconvective clouds and precipitation resolved by the model. SUBEX accounts for the subgrid variability in clouds by linking the average grid cell relative humidity to the cloud fraction and cloud water following the work of Sundqvist et al. (1989) and it also includes simple formulations for raindrop accretion and evaporation. For a more detailed description of SUBEX and a list of the parameter values refer to Pal et al. (2000).



Spatial plots for all the domains with RegCM3: 50km for the Africa domain, 15km for Alpine region.

Appendix M: RegCM4.3 model description

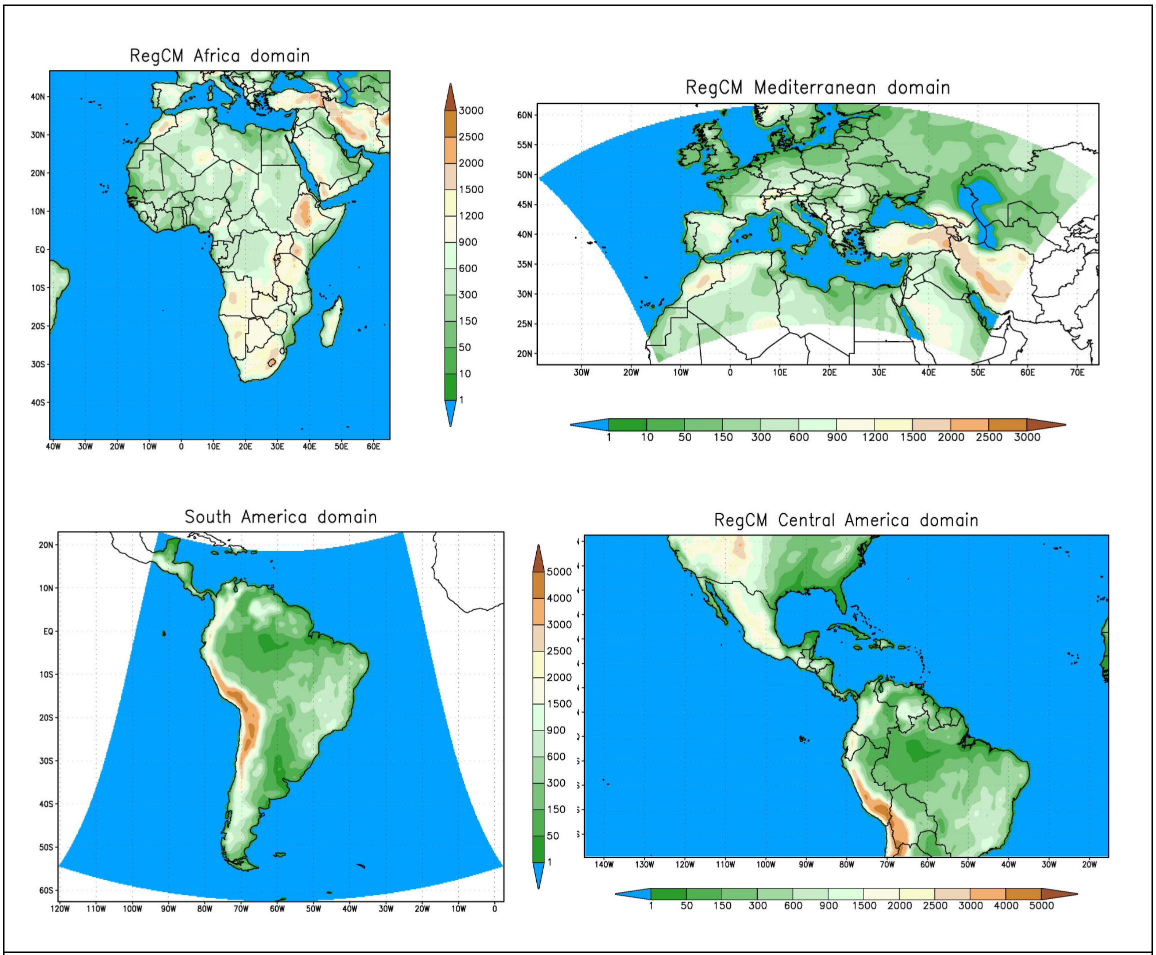
A new version of the regional climate modeling system, RegCM4, has been recently developed in the Abdus Salam International centre for Theoretical Physics (ICTP), described in Giorgi et. al., 2012. Compared to previous versions, RegCM4 includes new land surface, planetary boundary layer, and air–sea flux schemes, a mixed convection and tropical band configuration, modifications to the pre-existing radiative transfer and boundary layer schemes, and a full upgrade of the model code towards improved flexibility, portability, and user friendliness.

The model can be interactively coupled to a 1D lake model, a simplified aerosol scheme (including organic carbon, black carbon, SO4, dust, and sea spray), and a gas phase chemistry module (CBM-Z). The new version RegCM4.3 can be used in multiple 2-way nested mode.

In the table are reported the model options available in RegCM4.

Model aspects	**Available options**
Dynamics	Hydrostatic, σ-vertical coordinate (Giorgi et al. 1993a)
Radiative transfer	Modified CCM3 (Kiehl et al. 1996)
PBL (planetary boundary layer)	Modified Holtslag (Holtslag et al. 1990) UW-PBL (Bretherton et al. 2004)
Cumulus convection	Simplified Kuo (Kuo et al. 1986) Grell (Grell et al. 1993) MIT (Emanuel and Zivkovic-Rothman 1999) Tiedtke (Tiedtke 1989, in progress)
Resolved scale precipitation	SUBEX (Pal et al. 2000)
Land surface	BATS (Dickinson et al. 1993) Sub-grid BATS (Giorgi et al. 2003) CLM (Steiner et al. 2009)
Ocean fluxes	BATS (Dickinson et al. 1993) Zeng (Zeng et al. 2008) Diurnal SST (Zeng and Beljaars 2005)
Interactive aerosols	OC,BC, SO4 (Solmon et al. 2006) Dust (Zakey et al. 2006) Sea salt (Zakey et al. 2008)
Interactive lake	1D diffusion/convection (Hostetler et al. 1993)
Tropical band	Coppola et al. (2011)
Coupled ocean (not in public version)	MIT (Artale et al. 2010) ROMS (Ratnam et al. 2009)

A series of global climate simulations has been completed with RegCM4.3, in coordination with the RegCNET community (Giorgi et al. 2006), to produce climate change projections within the CORDEX framework (Giorgi et al 2009) for at least 6 domains: Africa, Europe, Central America, South America, East Asia, and South Asia. The emissions from the CMIP5 GCMs were used for these experiments. The main reference is the CMIP5 website: http://cmip-pcmdi.llnl.gov/cmip5/forcing.html



CORDEX domains: Spatial horizontal resolution 50km

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Appendix N: EC-Earth model description

EC-Earth represents a state-of-the-art, high-resolution earth-system model, developed by a large consortium of european research institutions and researchers..The model contains advanced, robust and validated components for the atmosphere (the ECMWF IFS cycle 31r1 model), the ocean (NEMO version 2; Madec 2008), sea ice (LIM2; Fichefet and Morales Maqueda 1997) and land processes (H-Tessel; Balsamo et al. 2009). EC-Earth has been validated and applied in a series of recent publications (Hazeleger 2000 and 2011; Johnston 2011; Sterl 2011; Wouters 2011).
The horizontal resolution of the model is currently of 1.125° for the atmosphere (T159L62) and 1° for the ocean (ORCA1), corresponding to a resolution of about 120 km at mid-latitudes. A list of model output parameters saved in CMOR2 format is enclosed.

A series of global climate simulations has been completed with EC-Earth (summarized at http://www.to.isac.cnr.it/ecearth/), following the CMIP5 standards (Moss et al., 2010). In particular the simulations are for the control period (1850-2005) using historical emissions and for three future emission scenarios (2006-2100), RCP 2.6, RCP4.5 and RCP8.5. The initial condition for the historical runs was a 700-year long pre-Industrial experiment.
The data produced with these simulations have been included in the CMIP5 archives (Climate Model Intercomparison Project 5; http://cmip-pcmdi.llnl.gov/cmip5/), which compares current climate models and which will provide a scientific support for the next IPCC report. Detailed documents describing the current model configuration (version 2.3) and the CMIP5 experiments are available at http://www.knmi.nl.
The emissions used for the CMIP5 experiments are summarized below.
The main reference is the CMIP5 website: http://cmip-pcmdi.llnl.gov/cmip5/forcing.html

Aerosols
The aerosol concentration fields that are used for the historical CMIP5 experiments come from a simulation that was performed using CAM3.5 with a bulk aerosol model driven by CCM3 (CMIP4) sea-surface temperatures and the 1850-2000 IPCC emissions.
There is a representation of SO4, SOA, BC and OC concentrations + Sea-salt and Dust.
Data sources:
http://www.iiasa.ac.at/web-apps/tnt/RcpDb/download/Aerosols/
ftp://ftp-ipcc.fz-juelich.de/pub/emissions/gridded_netcdf/tarfiles/

Greenhouse gases
Historical concentrations of anthropogenically affected greenhouse gases come from the website of IIASA. The annual concentrations of chlorofluorocarbons CFC-11 and CFC-12 are computed with use of their annual emissions.
Scenarios prepared by the IAMC group on RCP concentrations and extensions:
M. Meinshausen (PIK), K.Riahi (IIASA), S. Smith (PNL), Allison Thomson (PNL),
D. van Vuuren (PBL)
Data source: http://www.iiasa.ac.at/web-apps/tnt/RcpDb/download/CMIP5RECOMMENDATIONS/
For further details and background information see also: http://www.pik-potsdam.de/~mmalte/rcps/

Solar forcing
The solar forcing data is made by the SPARC working group on solar variability. Before 1850, the mean of the reconstruction of the total solar irradiance during the period 1844-1856 is

used. Up to 1882, monthly interpolated values of the yearly means are used and from 1882 till 2008 monthly-varying values are used. After 2008 the last solar cycle is repeated.

Stratospheric volcanic aerosols
Volcanic aerosols are taken into account using data of the NASA Goddard Institute for Space Studies (GISS).
Data source: http://data.giss.nasa.gov/modelforce/strataer/

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Appendix O: ECHAM-HAM model description

The ECHAM5-HAM model couples the global climate model ECHAM (version 5.5) (Roeckner et al. 2003) with the HAM module (Hamburg Aerosol Module; Stier et al. 2005, Lohmann et al. 2009), which models the dynamics, the microphysics and the transport of the main atmospheric aerosols and their radiative feedbacks. In particular HAM contains the microphysical core M7 (Vignati et al. 2004), based on the representation of particle distributions as the superposition of log-normal modes peaked at different particle size classes, and reproduces the main aerosol emission, sedimentation and wet and dry scavenging processes. The aerosol compounds included are sulfates, black carbon, organic matter, sea salt and mineral dust. The emissions of dust, sea salt and oceanic dimethyl sulfide (DMS) are computed on-line, while other natural and anthropogenic emissions are prescribed. Secondary Organic Aerosols (SOA) emissions are prescribed monthly and added to Particulate Organic Matter emissions, as described in (Stier et al. 2005). The main optical and microphysical properties of the aerosols, such as optical depth, and their number and mass concentrations are simulated by the model.

The spatial resolutions used were T42 and T63 in spectral space (corresponding to resolutions of about 2.8° and 1.8° respectively on a Gaussian grid).

Some ECHAM-HAM model runs were performed using a "nudging" technique to force the model to stay close to the dynamical wind fields provided by the ECMWF ERA-Interim database. The nudging fields were prepared using the INTERA package (Ingo Kirchner, \url{http://wekuw.met.fu-berlin.de/~IngoKirchner/nudging/nudging/}).

Different aerosol emission databases have been used as boundary conditions for ECHAM-HAM, as summarized in the list of experiments.

In particular we used the AeroCom-I (Dentener et al. 2006) and the ACCMIP (Atmospheric Chemistry and Climate Model Intercomparison Project, Lamarque et al. 2010) inventories, both for the year 2000. Anthropogenic fossil-fuel and bio-fuel emissions for sulfur, black and organic matter are annual data. Wildfire burning emissions are represented as monthly climatologies.

We also explored ACCMIP emissions using the more recent GFED3 monthly biomass burning emission database (van der Werft 2010) and we allowed these emissions (sulfur, black carbon and organic matter) to vary annually instead of using a climatological mean.

In a further modification, the ACCMIP 2000 anthropogenic sulfur emissions in the region 95-135°E-10-50°N were rescaled to the same level as found in the REAS database (Ohara et al. 2007) averaged over the years 2001-2006 (i.e. we multiply the ACCMIP anthropogenic sulfur emissions in this region by a factor 1.7).

In all configurations, injection heights of emissions are prescribed in the model as described in (Stier et al. 2005) and (Dentener et al. 2006).

The Balkansky et al. 2004 scheme or the Tegen et al. 2002 schemes for on-line dust emissions were used. The scheme by Schultz et al. 2004 was used for on-line sea-salt emissions.

Other emissions and parametrizations are as described in Stier et al. 2005 amd in Lohmann et al. 2009.

Some runs include a modification of the wet aerosol scavenging parametrization in HAM, reducing the corresponding scavenging coefficients and thus increasing aerosol lifetimes described in Bourgeois et al. 2011.

ECHAM-HAM: Summary of emission datasets:

Label	Emission inventories	Description	Reference
EAERO	AeroCom I	Anthropogenic: annual climatology (year 2000). Wildfire emissions have a monthly climatology.	Dentener et al. (2006) Stier et al. (2005)
EIPCC	ACCMIP	Anthropogenic: annual climatology; Wildfires: monthly clim.	Lamarque et al. (2010)
EGFED	ACCMIP+GFED3	ACCMIP + wildfires (monthly) with interannual variations.	van der Werf et al. (2010)
EREAS	ACCMIP+GFED3+REAS	Sulfur emissions in South-East Asia scaled to REAS average.	Ohara et al. (2007)

ECHAM-HAM: Anthropogenic emissions for each dataset (in [Tg/yr]):

		Global emissions				Emissions north of 10ºN			
		EAERO	EIPCC	EGFED	EREAS	EAERO	EIPCC	EGFED	EREAS
BC	Fossil fuel	3.03	3.06	3.06	3.06	2.58	2.53	2.53	2.53
	Biofuel[a]	1.63	2.09	2.09	2.09	1.14	1.57	1.57	1.57
	Wildfire	3.04	2.61	2.07	2.07	0.54	0.61	0.45	0.45
OC[d]	Fossil fuel	2.44	4.25	4.25	4.25	1.96	3.17	3.17	3.17
	Biofuel[a]	6.47	8.45	8.45	8.45	4.53	6.28	6.28	6.28
	Wildfire	24.7	23.2	18.1	18.1	5.38	6.99	5.32	5.32
SU	High[b]	95.2	91.0	91.0	104.4	85.5	77.6	77.6	91.1
	Low[c]	13.0	12.7	12.8	15.7	11.5	10.9	10.9	13.8
	Wildfire	4.09	3.83	2.29	2.29	0.74	1.07	0.62	0.62

[a] Biofuel=biomass burning + agricultural waste + fuelwood; [b] SU high= sulfur from industry + powerplants + shipping; [c] SU low= sulfur from domestic + roads + off road; [d] Particulate organic matter = 1.4 x Organic Carbon

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