

An Overview of ECCO Version 4 Release 3's ftp Site

<ftp://ecco.jpl.nasa.gov/Version4/Release3/>

Ou Wang, Ichiro Fukumori, Ian Fenty

Jet Propulsion Laboratory, California Institute of Technology

November 5, 2017

1. Introduction¹

This note describes the directory structure and content of ECCO Version 4, Release 3's (v4r3) ftp site <ftp://ecco.jpl.nasa.gov/Version4/Release3/>. Covering the time period from 1992 through 2015, ECCO v4r3 synthesizes a general circulation model (MITgcm) and most of available satellite and in situ data to produce a physically consistent ocean estimate of which property budgets can be closed. The data that are used to constrain the model include satellite altimetry (sea surface height, SSH), GRACE ocean bottom pressure (OBP), AVHRR sea surface temperature (SST), Aquarius sea surface salinity (SSS), Argo, CTD, XBT, mooring temperature and salinity data, sea-ice measurements, and global mean SSH and OBP. The estimate uses the adjoint method to iteratively minimize the squared sum of weighted model-data misfits and control adjustments. A detailed summary of the estimate can be found in Fukumori et al. (2017).

2. Model

The model that is used to produce v4r3 is MITgcm version checkpoint66g. Wang (2017) gives a detailed description about how to download the code, data, and any needed auxiliary files to reproduce v4r3.

The grid used in v4r3 is the so-called LLC90 (Lat-Lon-Cap 90) grid (Fig. 1a) that has five faces covering the whole globe, with simple latitude-longitude grid between 70°S and 57°N and an Arctic cap (Forget et al., 2015). The dimensions for the five faces are [90x270], [90x270], [90x90], [270x90], and [270x90] where each face consists of tiles dimensioned 90x90 (thus LLC90) (Figs. 1a & 1b). The horizontal resolution varies spatially from 22km to 110km, with the highest resolution in high latitudes and lowest resolution in mid latitudes. The deepest ocean bottom is set to 6145m below the surface, with the vertical grid spacing increasing from 10m near the surface to 457m near the ocean bottom.

3. Directory Structure

In this section, we describe the directory structure of v4r3's ftp site <ftp://ecco.jpl.nasa.gov/Version4/Release3/>. Each subdirectory has a short README file that lists all the sub-directories and files in that directory along with a brief description. The directory structure is similar to that of Release 2's (Forget et al., 2016).

3.1 Documentation

The directory **doc** contains a few useful documents that include an overview of the ftp site (v4r3_overview.pdf, this document), a summary of v4r3 ([v4r3_summary.pdf](#), Fukumori et al., 2017), a note about how to reproduce v4r3 results (ECCOv4r3_reproduction.pdf, Wang, 2017), a set of analysis plots ([v4r3_depiction.pdf](#)) generated using gcmfaces (see **Software** below), and a note on analyzing budgets ([evaluating_budgets_in_eccov4r3.pdf](#), Piecuch, 2017). Also included are summary files of all cost functions (costfunction*) and a "standard output file" (STDOUT.0000) that the model creates during its integration with information about the model configuration and useful measures of the model state.

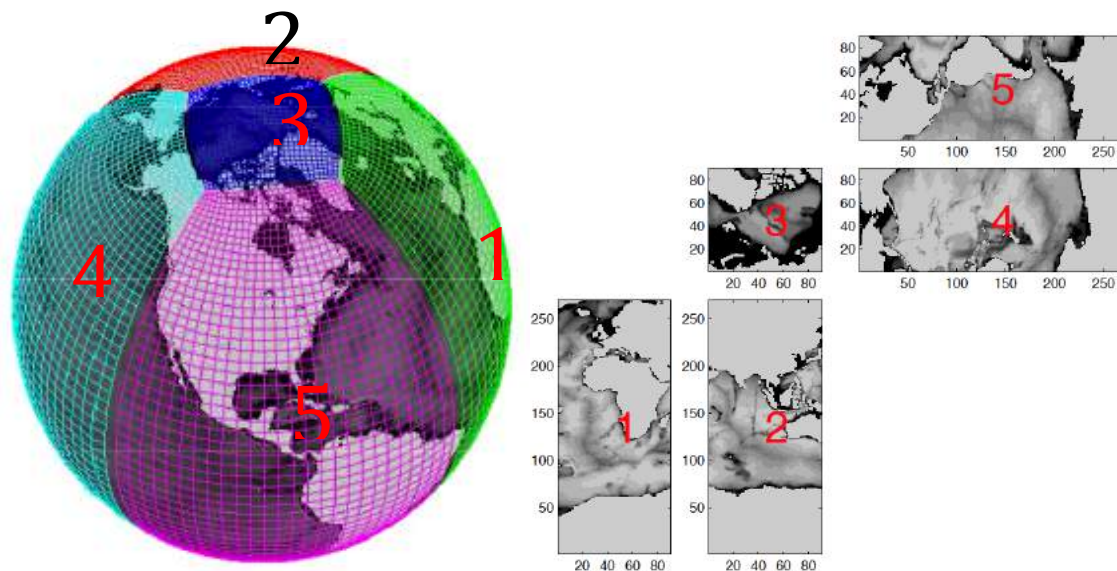


Figure 1. a) V4r3's lat-lon-cap (llc) grid with five faces; b) The dimensions of the five faces. The figures are modified from Forget et al. (2015).

3.2 Model Grid

The model grid information can be found in the subdirectory [nctiles_grid](#). The globe is split into 13 regional tiles (Fig. 2, courtesy of Gaël Forget), with variables of which are saved in separate individual files in netCDF format. In Section **Software**, we provide an example MATLAB script to read in the model grid by making use of [gcmfaces](#), a MATLAB toolbox developed by Gaël Forget from Massachusetts Institute of Technology (MIT) (Forget, 2017).

3.3 Monthly Average Model fields

The nominal model output is its monthly fields ([nctiles_monthly](#)). Each subdirectory inside [nctiles_monthly](#) contains netCDF files for a particular variable, as indicated by the name of the subdirectory, split into 13 files as described above. Some of the most commonly used fields, like velocity components, potential temperature, salinity, SSH, and OBP are [UVEL](#), [VVEL](#), [THETA](#), [SALT](#), [SSH](#), and [OBP](#), respectively. An example of MATLAB script is provided in Section **Software** to read and display these netCDF files (Box 2).

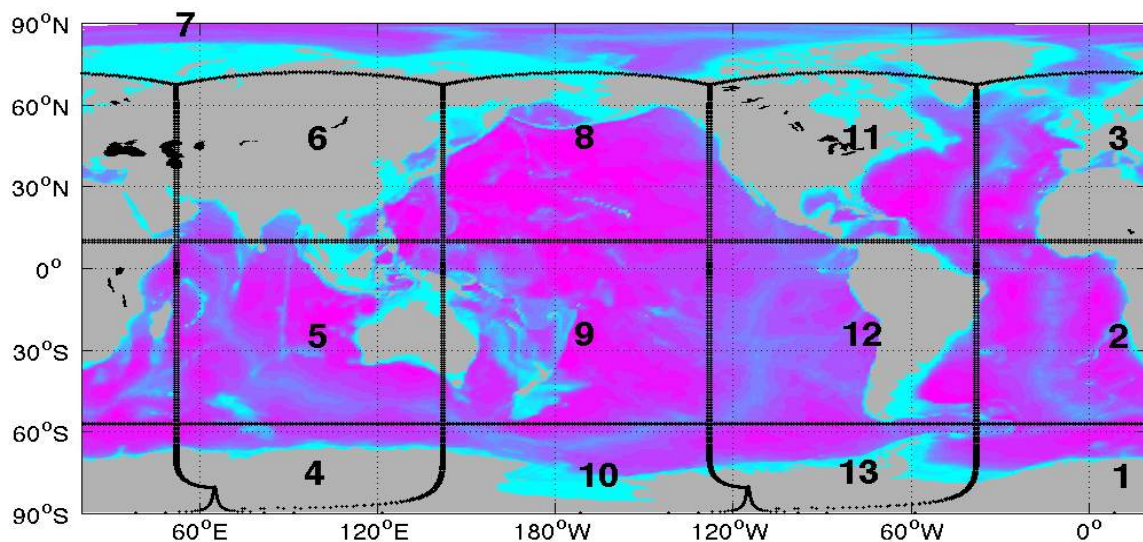


Figure 2 The partitioning of the globe into 13 regional tiles.

3.3.1 Corrected Sea Level and Ocean Bottom Pressure

There are two variables, [ETAN](#) and [SSH](#), describing sea surface height. [ETAN](#) is the height of the model's liquid ocean surface, whereas [SSH](#) is the dynamic sea surface height plus global mean steric sea level change. [ETAN](#) is located below sea-ice where it exists, due to pressure loading from the ice and snow on top. [SSH](#) corrects [ETAN](#) for this loading (dynamic sea surface height) and further adds a correction for the global mean steric height change, the so-called Greatbatch correction (Griffies and Greatbatch, 2012). Both variables reflect mass changes caused by freshwater input.

As such, variable [SSH](#) provides the model equivalent of altimetry sea level measurements.

Similarly, there are two variables, [PHIBOT](#) and [OBP](#), for ocean bottom pressure. [PHIBOT](#) represents the model’s ocean bottom pressure (including sea-ice loading), while [OBP](#) corrects PHIBOT for global mean steric height change. Variable [OBP](#) provides the model equivalent of GRACE OBP.

3.3.2 Native and Geographical Velocity Components

Users are advised to be aware of the directional convention used in the model especially when analyzing the vector fields of the model. Figure 1b illustrates the directional convention used in the LLC grid. Within each face (tile), the x- and y-directions point left-to-right and bottom-to-top in the figure, respectively. As such, in faces 4 and 5, the x- and y-directions point to the south and to the east, respectively. In face 3, the x-direction points to the Pacific Ocean away from the Atlantic, whereas y-direction points to North America away from Asia. For user convenience, conventional eastward and northward velocity components ([EVEL](#) and [NVEL](#)) are provided as diagnostic output, in addition to that in the model’s native direction ([UVEL](#) and [VVEL](#)). (See Table 1.)

Table 1. Native and geographical velocity components.

Filename	Description
UVEL	X-component of velocity (m/s).
VVEL	Y-component of velocity (m/s).
EVEL	Zonal component of velocity (m/s). Positive is eastward.
NVEL	Meridional component of velocity (m/s). Positive is northward.

3.3.3 Advective and Diffusive Fluxes

The files with their names starting with “ADV” and “DF” indicate advective and diffusive fluxes, respectively. Similar to velocity, the horizontal components of the native fluxes also follow the model’s directional convention. For instance, DFxE_TH means diffusive flux (“DF”), in the model’s x-direction (“x”), evaluated explicitly (“E”) for potential temperature (“TH”). Table 2 lists all the flux terms for potential temperature. See Picuch (2017) for how to make use of the flux terms along with forcing terms to close budgets.

Table 2. Advective and diffusive flux terms for potential temperature.

Filename	Description
ADV_x_TH	X-component (“x”) of ADV ective flux of potential temperature (“TH”) (°C m ³ /s) at a particular grid (i,j,k). Positive to increase temperature at (i,j,k).

ADV_y_TH	Y-component (“y”) of ADV ective flux of potential temperature (°C m ³ /s).
ADV_r_TH	Z-component (“r”) of ADV ective flux of potential temperature (°C m ³ /s).
DF_xE_TH	X-component of DiF usive flux of potential temperature (°C m ³ /s). Explicit part (“E”).
DF_yE_TH	Y-component of DiF usive flux of potential temperature (°C m ³ /s). Explicit part.
DF_rE_TH	Z-component of DiF usive flux of potential temperature (°C m ³ /s). Explicit part.
DF_rI_TH	Z-component of DiF usive flux of potential temperature (°C m ³ /s). Implicit part (“I”).

3.4 Instantaneous Monthly Model Fields

Besides monthly averages, v4r3 also provides monthly snapshots in the subdirectory [nctiles_monthly_snapshots](#) for [THETA](#), [SALT](#), and [ETAN](#). The main purpose of these snapshots is to facilitate budget calculations (see Section **Budget Calculation**); specifically, monthly mean fluxes that are provided equal changes between these snapshots (as opposed to changes between monthly average states of Section 3.3).

3.5 Daily Averages

Daily averages are also provided for select variables in directory [nctiles_daily](#) (Table 3) to facilitate studies of the ocean’s high-frequency variations.

Table 3. Daily averages of model output.

Directory name	Description
SSH	Sea surface height (m) that has been corrected for sea-ice load and global steric height change (Greatbatch correction).
OBP	Ocean bottom pressure (m) that has been corrected for global steric height change.
SST	Sea surface temperature (°C).
SSS	Sea surface salinity (psu).
Slarea	Fractional sea-ice covered area (m ² /m ²)
Slheff	Effective sea-ice thickness (m) that is defined as actual sea-ice thickness scaled

Slhsnow	by fractional sea-ice area (Slarea).
sIceLoad	Effective snow thickness (m). Sea-ice and snow loading defined as mass of sea-ice & snow over area (kg/m ²).

3.6 Data Used to Constrain the Model

The subdirectory [input ecco](#) includes the data used to constrain the model (Table 4). Most of the files are in binary format on the model grid. Each 2-d field is of size 90x1170. A sample MATLAB script that reads and displays a 2-d binary field on the model grid is presented in Section **Software** (Box 1).

Table 4. The data used in v4r3 to constrain the model

Directory name	Description
input sla	Daily RADS altimetry SSH data (m).
input bp	Monthly GRACE ocean bottom pressure (OBP) from JPL RL05 mascon solutions (cm).
input insitu	In situ profile data.
input sst	Reynolds daily SST (°C).
input sss	Aquarius monthly SSS (psu).
input nsidc	Daily sea-ice concentration from NSDIC (unitless).
input other	Climatology TS from WOA'09, mean dynamic topography (MDT13) from DTU Space, global mean SSH & OBP etc. See README there.

3.7 Model Equivalent of In-situ Data

The model equivalents of the in situ data in netCDF format are in [profiles](#). The model fields are sampled on the fly at the time and location of the in situ data to generate the model equivalents. For each in situ file in [input ecco/input insitu](#), there is a corresponding file of the model equivalent in [profiles](#).

3.8 Interpolated Monthly Fields

Since v4 grid is not a regular lat-lon grid, we have also provided interpolated monthly averages on a regular 0.5° by 0.5° grid in [interp monthly](#) for user convenience. **However, note that the interpolated fields should not be used for budget calculations, as the interpolation does not preserve integrated quantities.** The fields on the native v4 grid should be used instead. The interpolated files are in netCDF format, with one file for one particular variable.

3.9 Atmospheric Forcing

The atmospheric forcings are in the subdirectory [input forcing](#). The directory contains binary yearly files of 6-hourly forcing on v4 grid (Table 5). All forcings except for wind speed (eccov4r3_wspped_YYYY) are the sum of ERA-Interim forcing and the corresponding control adjustment that has been estimated. Wind speed is not a control variable and is only ERA-Interim wind speed interpolated onto the v4 grid.

Table 5. Atmospheric forcing on v4 grid.

Filename (replace YYYY with year)	Description
eccov4r4_dlw_YYYY	Yearly files for 6-hourly downward longwave (W/m^2) in binary. Positive to decrease ocean temperature.
eccov4r3_dsw_YYYY	Downward shortwave (W/m^2). Positive to decrease ocean temperature.
eccov4r4_rain_YYYY	Precipitation (m/s). Positive to increase sea level.
eccov4r3_spfh2m_YYYY	Specific humidity at 2m above the sea surface.
eccov4r3_tmp2m_YYYY	Air temperature at 2m above the sea surface.
eccov4r3_ustr_YYYY	East-West component of wind stress (N/m^2). Positive from east to west.
eccov4r3_vstr_YYYY	North-South component of wind stress (N/m^2). Positive from north to south.
eccov4r3_wspped_YYYY	Wind speed at 10m above ocean surface (m/s).

3.10 Input Files

The subdirectory [input init](#) includes other files that are needed to reproduce v4r3 (Table 6).

Table 6. Input files are needed to reproduce v4r3.

Directory or file name	Description
NAMELIST	Namelist such as file " data ", " data.ctrl ", etc.
error_weight	Data error (data_error) and control weight (ctrl_weight).
bathy_eccollc_90x50_min2pts.bin	Bathymetry (m).
pickup* files	Initial condition.
xx* files	Control adjustments on v4 grid.
total_diffkr*, total_kap*	Mixing coefficients.

tile* files	Grid files needed to run the model.
smooth* files	Smoothing operator related files.
fenty biharmonic visc v11.bin	Bi-harmonic coefficients (m ⁴ /s).
runoff-2d-Fekete-1deg-mon-V4-SMOOTH.bin	Climatology river runoff (m/s). Positive to increase sea level.
geothermalFlux.bin	Time-invariant geothermal flux (W/m ²). Positive to increase ocean temperature.

3.11 Other Fields

V4r3 has some auxiliary fields in the subdirectory [other](#) (Table 7). These files include the binary yearly files of 6-hourly unadjusted atmospheric forcing (interpolated ERA-interim forcings on v4 grid). By taking the difference between the [total atmospheric forcing](#) and the [unadjusted forcing](#) one could obtain the dimensional atmospheric control adjustments. File “SBO_global.nc” contains hourly core products for Earth rotation of the International Earth Rotation and Reference Systems Service (IERS), including contributions of ocean mass, oceanic angular momentum, and the ocean’s center-of-mass.

Table 7. Other fields

Directory or filename	Description
input_forcing_unadjusted	Unadjusted atmospheric forcings on v4 grid.
adjustments	Dimensional control adjustments for control variables other than atmospheric control variables.
SBO_global.nc	IERS Special Bureau for the Oceans (SBO) core products for Earth rotation.

4. Budget Calculation

[Monthly mean fluxes](#) are provided in directory [nctiles monthly](#). Piecuch (2017) provides a practical [note](#) on how to analyze budgets using these fields, describing the calculation both in pseudo code and in MATLAB ([gcmfaces](#) library; see **Software** below).

5. Software

Gaël Forget from MIT has created a MATLAB toolbox called [gcmfaces](#) to facilitate analysis of gridded earth variables on different grids, including the llc grid used in v4r3. The user guide of gcmfaces at http://www.cvs.mitgcm.org/viewvc/MITgcm/MITgcm_contrib/gael/matlab_class/gcmfaces.pdf?view=co provides a detailed description about the installation and features of gcmfaces and a companion

MATLAB toolbox called MITprof to process and analyze in situ profile data. The gcmfaces toolbox includes a tutorial script called gcmfaces_demo.m that illustrates how to make use of gcmfaces.

Assume that one has downloaded [v4r3 products](#) and successfully installed gcmfaces and all necessary data files according to Section 1 of the [gcmfaces' user guide](#). Provided below are a couple of sample MATLAB scripts in the context of gcmfaces to read and display the **binary** and **netCDF** files of v4r3.

Box 1. Read and display v4r3 binary files.

```
%Add paths
p = genpath('gcmfaces/'); addpath(p);
p = genpath('m_map/'); addpath(p);

%Load the grid.
grid_load;

% Define global variables
gcmfaces_global;

%Type in the path of the grid directory of v4r3 that one has downloaded from
% ftp://ecco.jpl.nasa.gov/Version4/Release3/nctiles\_grid/
% e.g. '/mydir/v4r3/nctiles_grid/';

%Read in binary files
%To read in and display the 15th 6-hourly record of the E-W wind stress for year
1992
%Read in data
dirv4r3 = '/mydir/v4r3/';
ff= [dirv4r3 'input_forcing/' 'eccov4r3_ustr_1992'];
fld = read_bin(ff,15,0); %read in the 15th 2-D record

%Display
figure;
[X,Y,FLD]=convert2pcol(mygrid.XC,mygrid.YC,fld); pcolor(X,Y,FLD);
if ~isempty(find(X>359)); axis([0 360 -90 90]); else; axis([-180 180 -90 90]); end;
dd1 = 1;
cc=[-1:0.1:1]*dd1; % color bar set to -1 to 1 N/m2
shading flat; cb=gcmfaces_cmap_cbar(cc);
%Add labels and title
xlabel('longitude'); ylabel('latitude');
title('display using convert2pcol');
```

Similarly, a MATLAB script to read in the v4r3 netCDF files, such as those under [nctiles_monthly](#) is shown below (Box 2).

Box 2. Read the 13 regional netCDF files.

```
%netCDF files
%Similarly, if one is to read in the 3rd monthly record of the monthly ETAN (netCDF
format)

dirv4r3 = '/mydir/v4r3/';
fileName= [dirv4r3 '/nctiles_monthly/ETAN/' 'ETAN'];
fldName='ETAN';
fld=read_nctiles(fileName,fldName,3); %Read in the 3rd monthly record of ETAN
```

Questions:

ecco-support@mit.edu (please subscribe via <http://mailman.mit.edu/mailman/listinfo/ecco-support>)

Acknowledgement

The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

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