**Global Carbon Budget: Land modelling protocol (Trendy-v6)**

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**Deadline for submission of simulations:**
**S0, S1, S2, S3 simulations latest: August 1st**

Goal: To calculate the land components of the Global Carbon Project 2017 Budget.

Model simulations

Models can have dynamic vegetation but all will use observed time evolving cropland and grazing (=pasture+rangeland) distribution for S3. The models will be forced over the 1860-2016 period with changing $CO_2$, climate and land use according to the following simulations.

S0: No forcing change (needed to diagnose any issues / drift)

S1: CO2 (time-invariant "pre-industrial" land use mask)

S2: CO2 and climate (time-invariant "pre-industrial" land use mask)

S3: CO2, climate and land use (Using updated annual LULCC maps to 2016)

Criteria for budget inclusion

We apply three criteria for minimum model realism by including only those models with

(1) steady state after spin-up,

(2) net land fluxes ($S_{land}$-$E_{LUC}$) that are a carbon sink over the 1990s as constrained by global atmospheric and oceanic observations (McNeil et al., 2003; Manning and Keeling, 2006; Mikaloff Fletcher et al., 2006)

(3) global net land use flux ($E_{LUC}$) is a carbon source over the 1990s.

Dataset provided

- Climate forcing: 0.5 degree CRU monthly climatology (groups are free to use their own tools to disaggregate to finer temporal resolution, however the monthly totals must be the same as CRU). A 6-hourly, 0.5x0.5° CRU+NCEP historical forcing, 1901-2016 is also available.

- Global atmospheric CO2 from ice core+NOAA annual resolution (1860-2016)

- Land use change: Implementation of Hurtt LULCC dataset (based on latest Hyde) or Hyde (1860-2016). Spatial resolution: 0.5°x0.5°, annual resolution (1860-2016).

To access CRU monthly climatology, CRU-NCEP and LULCC datasets can be directly accessed

**CRU**

https://www.dropbox.com/sh/5hqqrlz5rhn0v02/AACQCpQ4dujDyqR4h7XhMDvBa?dl=0

**CRU-NCEP_v8**

CRU-NCEP can be accessed from Nicolas Viovy's website:

https://vesg.ipsl.upmc.fr/thredds/catalog/store/p529viov/cruncep/V8_1901_2016/catalog.html

**HYDE LULCC**

A permanent DOI with the HYDE 3.2 data:

ftp://ftp.pbl.nl/hyde/tmp/2017/

- LULCC is based on FAOSTAT crop data to 2014, with the TREND function for and 2015, 2016. Note, HYDE 3.1 Pasture category = HYDE 3.2 Grazing category = FAO's Permanent Pasture category. HYDE 3.2 Grazing class is subdivided into a more intensive grazing class, 'Pasture' (More managed; less arid), and extensive grazing, 'Rangeland' (Less managed, more arid) based on an aridity index. Modelers may wish to take advantage of the more intense/less intense management on these grazing areas (e.g. more intense could mean more fertilizer, irrigation, etc).

**LULCC transitions (Hurtt et al.,)**

The dataset extends to 2016 (however land-use values in LUH2 are assumed to be at the beginning of the year). We extend the dataset by a year to cover the whole of 2016.

More information to follow shortly.

**Global Annual $CO_2$ forcing:**

Global CO2 concentration (ppm). Prepared on behalf of C. Le Quere for the Global Carbon Project.

Data from March 1958 are monthly average from MLO and SPO provided by NOAA's Earth System Research Laboratory http://www.esrl.noaa.gov/gmd/ccgg/trends/. When no SPO data are available, SPO is constructed from the 1976-2014 average, MLO-SPO trend and average monthly departure. Data for 2015-2016 are preliminary values. The data from 1980 through 2006 were reprocessed in 2011 to bring them into the WMO X2007 scale. This affected slightly the entire time series from 1958. Data prior to March 1958 are estimated with a cubic spline fit to ice core data from Joos and Spahni 2008 Rates of change in natural and anthropogenic radiative forcing over the past 20,000 years PNAS.

Annual mean fields are generated from these monthly data. DGVMs may also wish to run directly with monthly $CO_2$ fields.

**Misc. Datasets**

Each group will use its own data source for soil properties, and ignition events (if used), Nitrogen deposition, etc.

Experiment protocol

- Model spin up:
    - 1860 $CO_2$ concentration (286.42ppm)
    - recycling climate mean and variability from the early decades of the 20th century (e.g. 1901-1920).
    - constant 1860 crops and pasture distribution.
- 1861-1900 transient simulation:
    - varying $CO_2$ (S0 constant 1860 $CO_2$)
    - continue recycling spin up climate
    - land use fixed in S0, S1, S2 (as in spinup), varying in S3
- 1901-2015 transient simulation:
    - varying $CO_2$ (S0 constant 1860 $CO_2$)
    - varying climate (S2, S3), continue recycling spin up climate (S0, S1)
    - land use fixed in S0, S1, S2 (as in spin up); varying LULCC (S3)

Models having a nitrogen cycle should use their time varying Nitrogen inputs for S1, S2, S3.

Required outputs

- Ascii file with five columns: year, annual global NBP, annual northern extra tropics NBP, annual tropical NBP, annual southern extra-tropics NBP (see excel file for definition and sign convention); one row per year, 1860-2016. Name convention: Model_zonalNBP.dat, e.g. JULES_zonalNBP.dat. Units are $PgCyr^{-1}$. One dataset per simulation S0-S4, four in total. North = north of 30°N; Tropics = 30°N to 30°S; South = south of 30°S.
- List of gridded output variables: See companion Excel file.
    - Level 1 variables: essential
    - Level 2 variables: desirable for additional analysis/studies
    - Additional N-cycle variables where applicable (see end of excel file)
- Time period: 1860-2016
- Time resolution: as specified in the file
- Spatial resolution: 0.5x0.5 (or at a coarser resolution if necessary)
- Format netcdf (see Excel file).

Output file name convention

One file per variable, entire time-series

Model_Simulation_variable.nc (e.g. JULES_S1_mrso.nc)

Please see below for an example netcdf header for variable nomenclature

```
netcdf LPX_S2_nbp {
dimensions:
    longitude = 360 ;
    latitude = 180 ;
    time = 1884 ;
variables:
    float longitude(longitude) ;
        longitude:units = "degrees_east" ;
        longitude:long_name = "longitude" ;
        longitude:axis = "X" ;
    float latitude(latitude) ;
        latitude:units = "degrees_north" ;
        latitude:long_name = "latitude" ;
        latitude:axis = "Y" ;
    int64 time(time) ;
        time:axis = "T" ;
        time:units = "days since 1860-01-01 00:00:00" ;
        time:calendar = "noleap" ;
    double nbp(time, latitude, longitude) ;
        nbp:_FillValue = -99999. ;
        nbp:long_name = "Net Biospheric Productivity" ;
        nbp:units = "kg C m-2 s-1" ;

// global attributes:
        :title = "Net Biospheric Productivity output from LPX-Bern for Trendy/GCP2016" ;
        :institution = "Climate and Environmental Physics, University of Bern" ;
        :source = "Extracted from LPX_S2_enso_02_m.cdf at 2017-03-23T18:19:47.433813" ;
        :contact = "lienert@climate.unibe.ch" ;
}
```