Summary of Pre-Industrial (A.D. 0-1865) Meteorological Driver Datasets

Bjorn Brooks[1,2], Michael Dietze[1]

1. University of Illinois, Urbana-Champaign, Dept. of Plant Biology
2. currently at University of Wisconsin-Madison, Ctr. for Climatic Research

May 11, 2011

Basic Concepts of Meteorological Driver Data

- A variety of pre-industrial GCM simulations have been completed ... but continuous meteorological forcing data from these runs are hard to come by
- Often these studies examined transient intervals related to prominent climatic events
- Or only spanned the last millennium

Basic Concepts of Meteorological Driver Data: Prognostic Atmosphere Models

- Studies examining responses to climatic forcing have used meteorological data generated using either stochastic weather generators or process-based atmospheric models
- Typically process based atmospheric models (*e.g.*, Community Atmosphere Model) use finite volume discretization or spectral methods to represent model *dynamics* in physical space
- Model *physics* (radiation, cloud microphysics, chemistry) calculated in on-line mode from initialization states (but some things can be prescribed in stand-alone mode like SST)

Basic Concepts of Meteorological Driver Data: Prognostic Atmosphere Models

- Output from atmosphere models suitable for use by terrestrial biosphere models may consist of variables for:
  surface temp.,
  radiative fluxes (*e.g.*, SW, LW, LH*),
  convective/precipitable water,
  surface water flux*,
  cloud cover,
  GHG's, aerosols (*e.g.*, dry/wet deposition species)

Major Signals in Meteorological Data Over A.D. 0-1865 period

- Medieval Warm Period *ca.* 950-1250, North Atlantic region
- Little Ice Age *ca.* 1550-1850
- Volcanic aerosol events affecting atmospheric optical depth (*e.g.*, Vesuvius 79, Vesuvius 1631, Tambora 1815)

Other Historical/Pre-Industrial Model Intercomparison Projects

1. VEMAP intercomparison project
   Kittel et al., Clim. Res., 2004; cgd.ucar.edu/vemap
   - VEMAP used common meteorological drivers to compare terrestrial biosphere models. Orographically-adjusted temp. and precip. generated from stochastic WGEN simulations. Daily solar radiation and humidity empirically estimated using CLIMSIM
   - Common driver dataset
   - AD 1895-1993, daily and monthly time steps
   - 0.5° grid for conUS

Other Historical/Pre-Industrial Model Intercomparison Projects

2. Paleo Model Intercomparison Project-2, pmip2.lsce.ipsl.fr
   - Common meteorological drivers not used but boundary conditions prescribed in the fully coupled simulations
   - Last Glacial Maximum (21 Ka), mid-Holocene (6 Ka) events (and pre-industrial 1750 tie point) to benchmark OA-GCM's and OAV-GCM's (see experiment list).
   - T21 resolution (5.6°) and higher
   - OAV models run with interactive vegetation– modern ice sheets, orography and coastlines– GHG's prescribed to pre-industrial levels (*ca.* 1750, view boundary conditions)– parameterized insolation– and prescribed SST and salinity from Levitus 1998 datasets
   - OAV models:
     1) ECBILT-CLIO-VECODE, 2) ECHAM53-MPIOM127-LPJ, 3) FOAM, 4) HadCM3M2, 5) MRI-CGCM2.3.4fa, 6) MRI-CGCM2.3.4nfa, 7) UBRIS-HadCM3M2

Summary of Pre-Industrial Model Simulations

1. Max Planck Institute-Earth System Model
   mpimet.mpg.de/en/science/internal-projects/millennium.html
   Brovkin and others, *Tellus*, 2010
   - Model set-up: AD 800-2005, T31 resolution (3.75°)
   - Historical (1700-1992) land-cover change based on Pongratz (2008) with agriculture quantified using population-based for AD 800-1700; ECHAM5 orbital forcing; solar irradiance forcing; volcanic forcing (Crowley and others, 2008)
   - GHG forcing: prognostic CO_2 & CH_4, prescribed N_2O and prescribed present day O_3
   - Aerosol forcing: anthropogenic sulphate dry mass 1850-1980 uses historical reconstructions (Lefohn and others, 1999)

Summary of Pre-Industrial Model Simulations

2. CCSM-3, Zhong and others, *Clim. Dyn.*, 2010
   - Model set-up: AD 1150-1700, T42 resolution (2.8°) with volcanic forcing only
3. CCSM-4, earthsystemgrid.org (available in May)
   - Model set-up: AD 850-2005, T85 resolution (1°) transient Last Glacial Maximum simulation using fully coupled CCSM with solar and volcanic forcing (also part of CMIP5/PMIP3 suite)

Summary Table of Pre-Industrial Simulations

Table: Details of continuous driver data sets from pre-industrial simulations.

Model	Res.	Time Range	Time Step	File Sz. (/mo.)	Availability
MPI-ESM	3.75°	800-2005	sub-daily	NCDC*	
CCSM-3	2.8°	1150-1700	monthly	<150 MB	NCAR
CCSM-4	1°	850-2005	monthly	150 MB	ESG

Options for Meteorological Driver Data

- There are no clear winners given needs of PalEON modeling group
- If existing GCM output were used, spatial and/or temporal downscaling of monthly meteorological data will be necessary before use in participating PalEON biosphere models
- But new GCM simulations would still be needed to supplement intervals/gaps not covered (*e.g.*, A.D. 0-1000)

Space-Time Downscaling Approaches

- Dynamic spatio-temporal: Nested mesoscale models
  - ☺ Informed by climate trends from GCM & local specifics
  - ☹ High computational cost; Possibly hundreds of TB of data
- Statistical spatial: Weather Typing; Transfer Functions between model and station data (*e.g.*, MLR, PCA, ANN)
  - ☺ Low computational cost; Can be used to produce higher resolution gridded output
  - ☹ Can be adversely affected by the GCM's accuracy
- Statistical spatio-temporal: Stochastic Weather Generators
  - ☺ Low computational cost; Generate time series of unlimited length even in areas of data sparsity; Adjustable param's for different climate scenarios
  - ☹ Typically used for temporal downscaling; Spatial downscaling using weather generators typically disaggregates local (sites) from area-averaged rather than downscaling a coarse grid to a fine grid