Uncertainty in gap-filled meteorological input forcing:

Impacts on modeled carbon and energy fluxes

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Major focus of NACP site synthesis: *uncertainty*
- Uncertainty among models – structural (large!)
- Flux observation uncertainty covered well (Barr et al.)
- Plans to include within-model uncertainty (e.g., parametric)
- But what about *driver data* uncertainty? Is it important?

Key questions:
- How much model-data mismatch is from errors in forcing?
- Is forcing-driven model prediction uncertainty
  - Significant when compared to other sources of error?
  - Highly model dependent?
Methods

- Collected 10 different forcing datasets
  - Five observational, five reanalysis
  - Extracted nearest station or gridcell for NACP sites

- Analysis of selected forcing variables
  - Focus on two sites: US-Ho1, US-MMSF
  - Focus on interannual variability and seasonal cycle

- Terrestrial carbon cycle model prediction
  - LoTEC model with literature-based parameters
    - 5 soil carbon pools, 4 vegetation pools
    - Rothamsted soil C + Farquhar photosynthesis
  - Model run with all 10 driver datasets at two sites
  - Examine differences in NEE, GPP (interannual and seasonal)
Forcing datasets

Observations

**Hourly / half-hourly site data**
- Gap-filled forcing for NACP
- Gap-filled AmeriFlux files (La Thuile)

*Crude estimate of gap-filling uncertainty*

**Daily climate**
- Nearest NCDC station (T, precip)
- DAYMET (T, precip, SWrad, humidity)
  - 1km interpolation+model product
- Tower observations, averaged to daily

*Temporally downscaled to hourly*

*Other variables filled using site monthly diurnal mean*

Reanalysis

3, 6 or 12-hourly
- ECMWF - interim
- NARR
- NCEP
- NCEP2
- Princeton
Forcing variables

Variables analyzed in detail here:
- SWdown – downward shortwave radiation at surface
- Tair – surface air temperature
- Rainf – precipitation rate

Other necessary variables for modeling:
- Psurf – surface pressure
- LWdown – downward longwave radiation at surface
- Wind – wind speed
- Qair – specific humidity

Currently provided for NACP site synthesis at over 50 sites
Rainfall: interannual patterns

Morgan Monroe

- Large differences in mean
  - Among observations
  - Among reanalyses

- Interannual patterns inconsistent
  - Dry or wet year?
    - Varies among datasets
Rainfall: seasonal patterns

- Differences in seasonal cycle
  - Among observations
  - Among reanalyses

- Winter precip undermeasured?
  - Feature of many cold sites

- High growing season variation

- DAYMET, NCDC inconsistent patterns with tower data
  - growing season bias?
SW Radiation: biases and patterns

- Biases in reanalysis data
  - NCEP, NARR +25-40%
  - ECMWF +10-20%
  - Princeton nearly unbiased
  - Consistent at other NA sites

- Differences in observations
  - NACP vs. La Thuile
  - NACP fills with DAYMET
Air temperature: interannual patterns

- Howland

- Biases in reanalysis data
  - NCEP, NCEP2, Princeton low (representativeness?)
  - NARR, ECMWF good

- 1 degree spread in obs

- Interannual patterns consistent
**NEE: Interannual patterns**

Differences between gap-filling methods
- Average 10% gap-filling
- Significant – up to 50 gC m\(^{-2}\) yr\(^{-1}\)
- Same order as flux uncertainty
- Interannual pattern roughly consistent

Differences among obs
- Up to 150 gC m\(^{-2}\) yr\(^{-1}\) difference
- Interannual patterns different

Differences among reanalyses
- Up to 300 gC m\(^{-2}\) yr\(^{-1}\) difference
NEE: seasonal cycle

- Howland: Better agreement between filling methods
- DAYMET, NCDC show higher growing season uptake
- Reanalysis
  - NCEP extreme bias (SW radiation)
  - NARR, ECMWF, Princeton better
GPP: Interannual patterns

- Slight differences between gap-filling methods
- DAYMET, NCDC 10% higher than tower forcing
- Princeton similar
- NARR, NCEP family, ECMWF 20-30% high bias
- Interannual patterns largely coherent among methods
Modeling results: discussion and caveats

- Results are strongly dependent on site
  - Sensitivity of fluxes to forcing differences
    - Will depends on limiting factors (e.g., is the site water limited?)
    - Will depend on timing, maybe lagged effects
  - Amount of gap-filled data, differences among datasets
  - Consistent themes:
    - High SW radiation bias among reanalysis datasets $\rightarrow$ GPP bias
    - Wintertime precipitation measured at sites often too low

- Results are strongly dependent on model structure
  - Equilibrated fast soil C pools in LoTEC, kept slow pools constant
  - Less variation in NEE among methods if full spinup
  - However – GPP biases should be consistent due to SW bias
Conclusions

- Modeled interannual NEE/GPP is sensitive to:
  - Gap-filling technique
  - Relatively small local climate variations (e.g., tower vs. NCDC station)
  - Variations among reanalysis datasets

- Reanalysis shortwave radiation data display large biases
  - Large impacts on GPP, variable impacts on NEE

- Modeled interannual flux patterns can depend on forcing datasets

- More work to quantify uncertainty across sites and models
  - New NACP analysis to study these effects
  - Likely 5-10 models at 5-10 sites, voluntary effort