Modeling and Monitoring Carbon Fluxes with the NASA Terrestrial Observation and Prediction System (TOPS)

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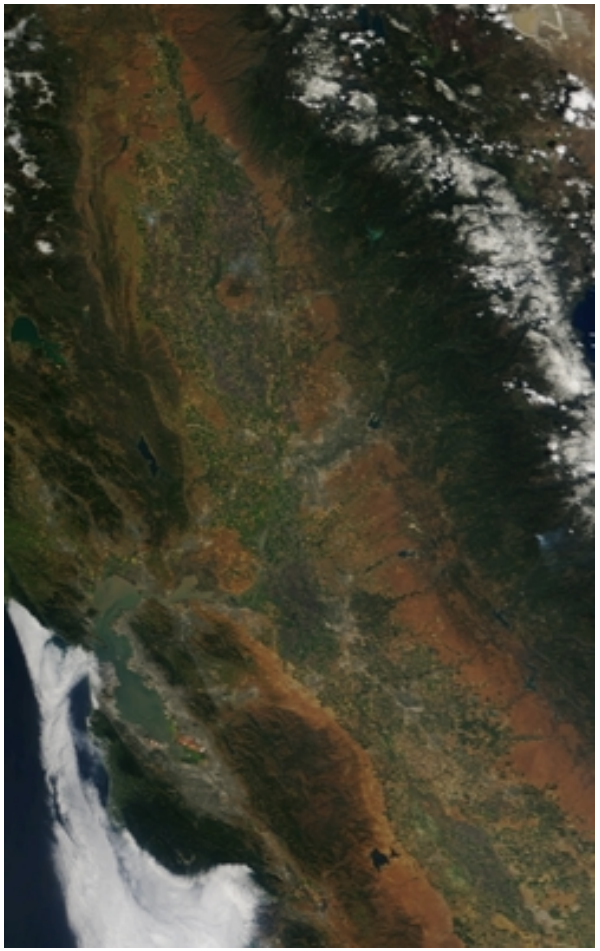
NASA Terrestrial Ecology; NACP; NASA Land Use Land Cover Change Program; NASA Applied Sciences Program: ACCESS Award, Decision Support through Earth Science Research Results Awards



Central California, MODIS Direct Broadcast

Overview

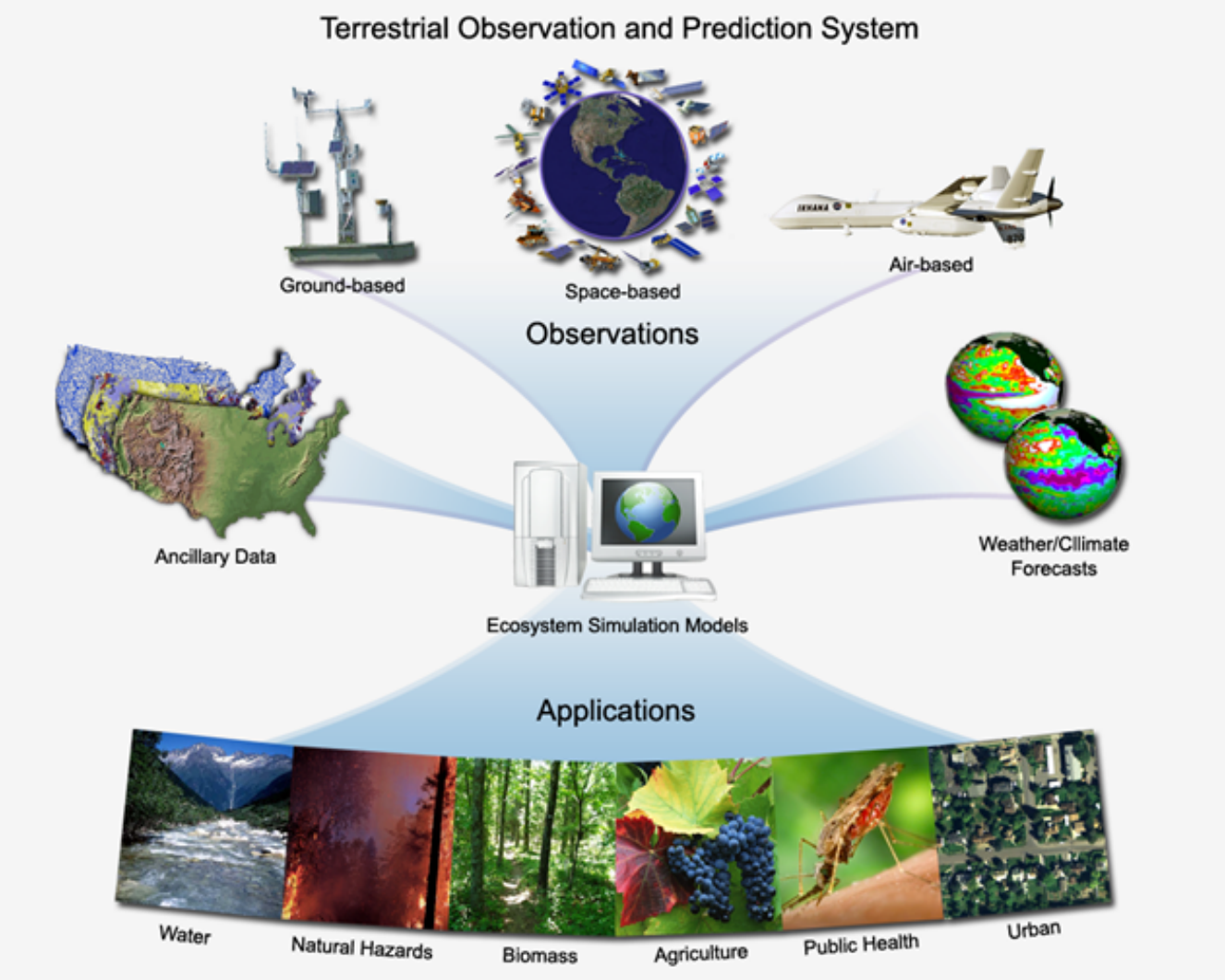
- TOPS architecture and key components
- TOPS data products
- Monitoring ecosystem conditions and terrestrial carbon flux
- Model intercomparison studies for North America
- Monitoring and forecasting long-term trends in ecosystem conditions
- Future directions

TOPS: Common Modeling Framework

Monitoring, modeling, & forecasting at multiple scales

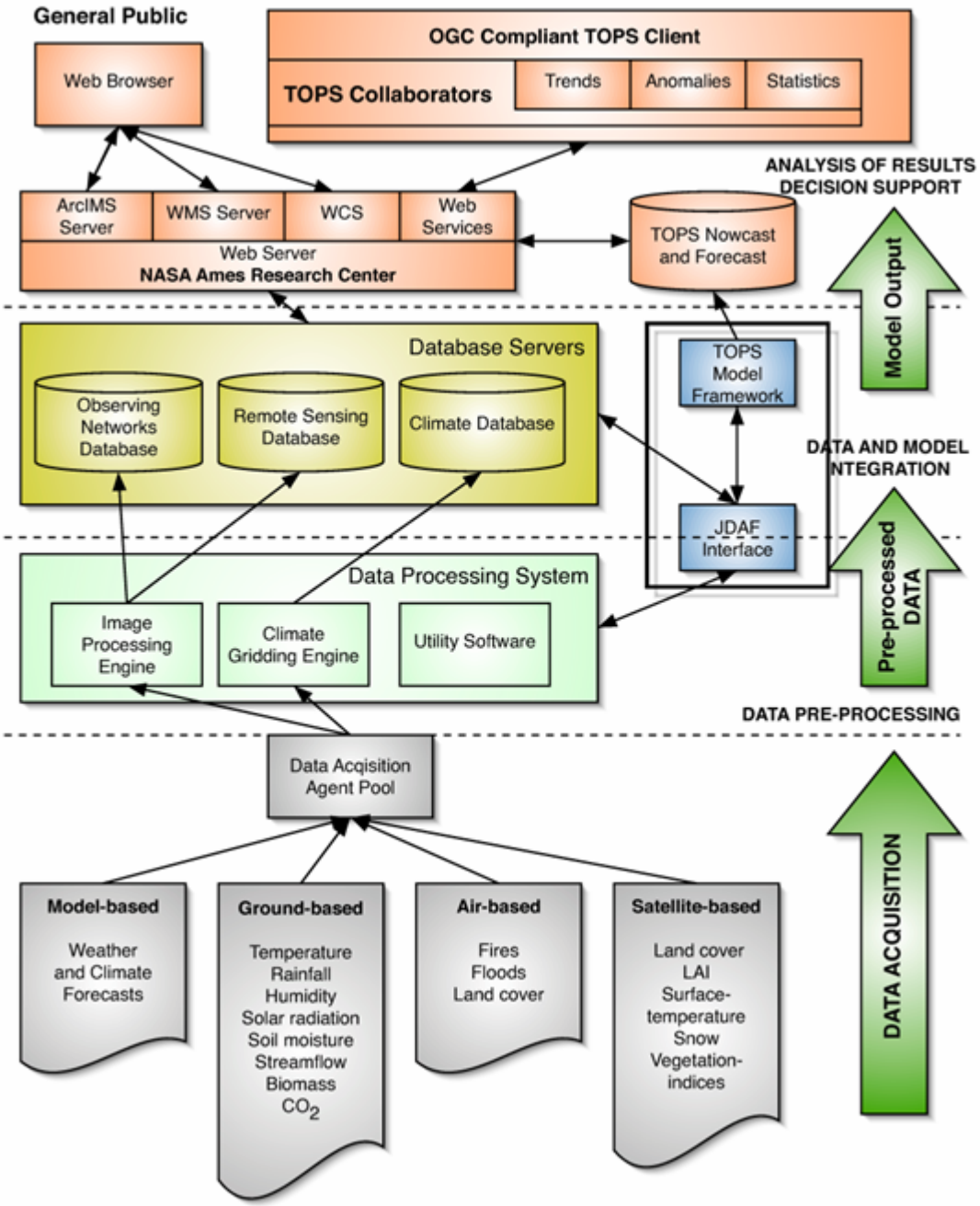
Predictions are based on changes in biogeochemical cycles in response to forcings from physical, chemical and biological environments

Nemani et al., 2003, 2007, 2008

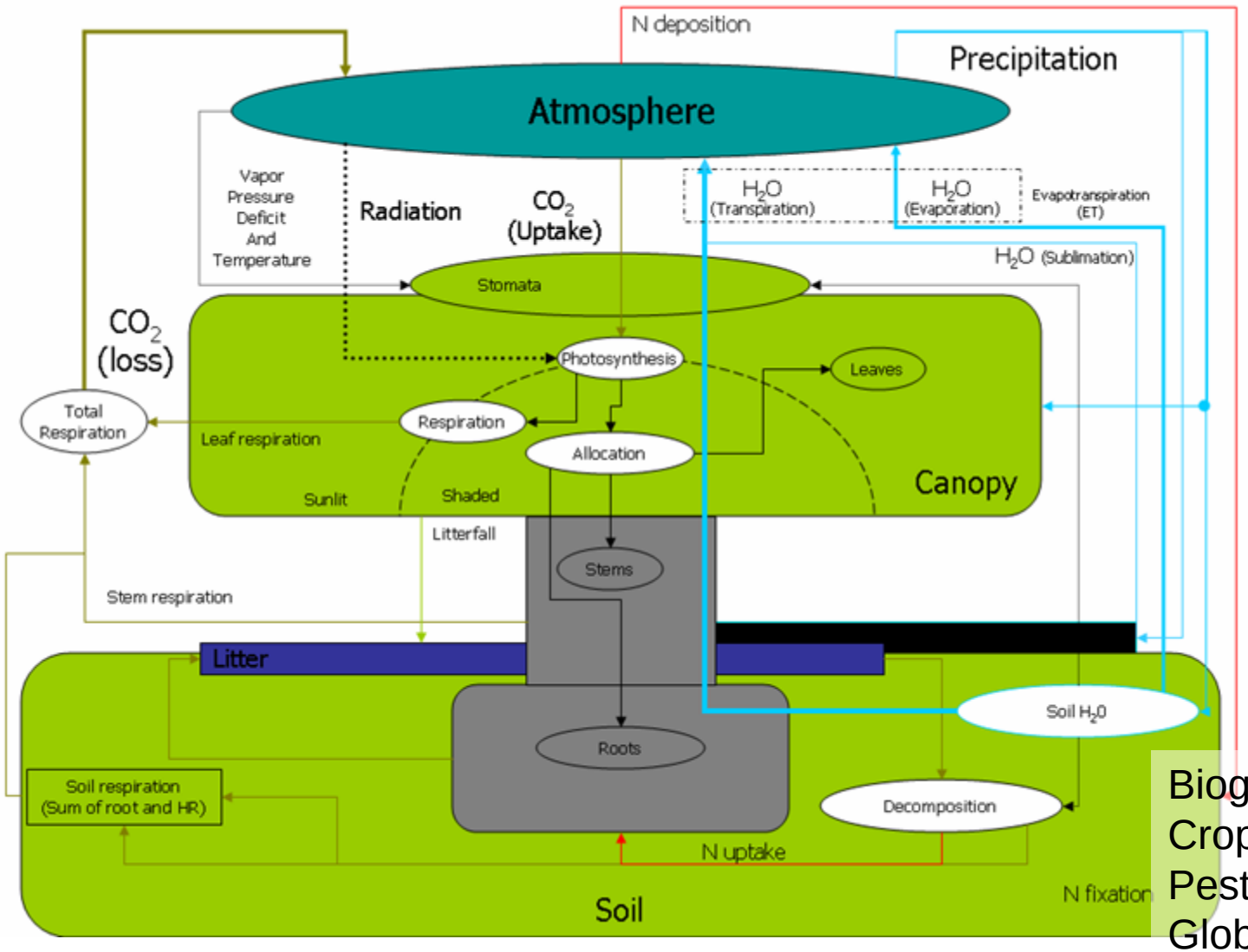


TOPS Architecture

Integration across platforms, sensors, and products is non-trivial

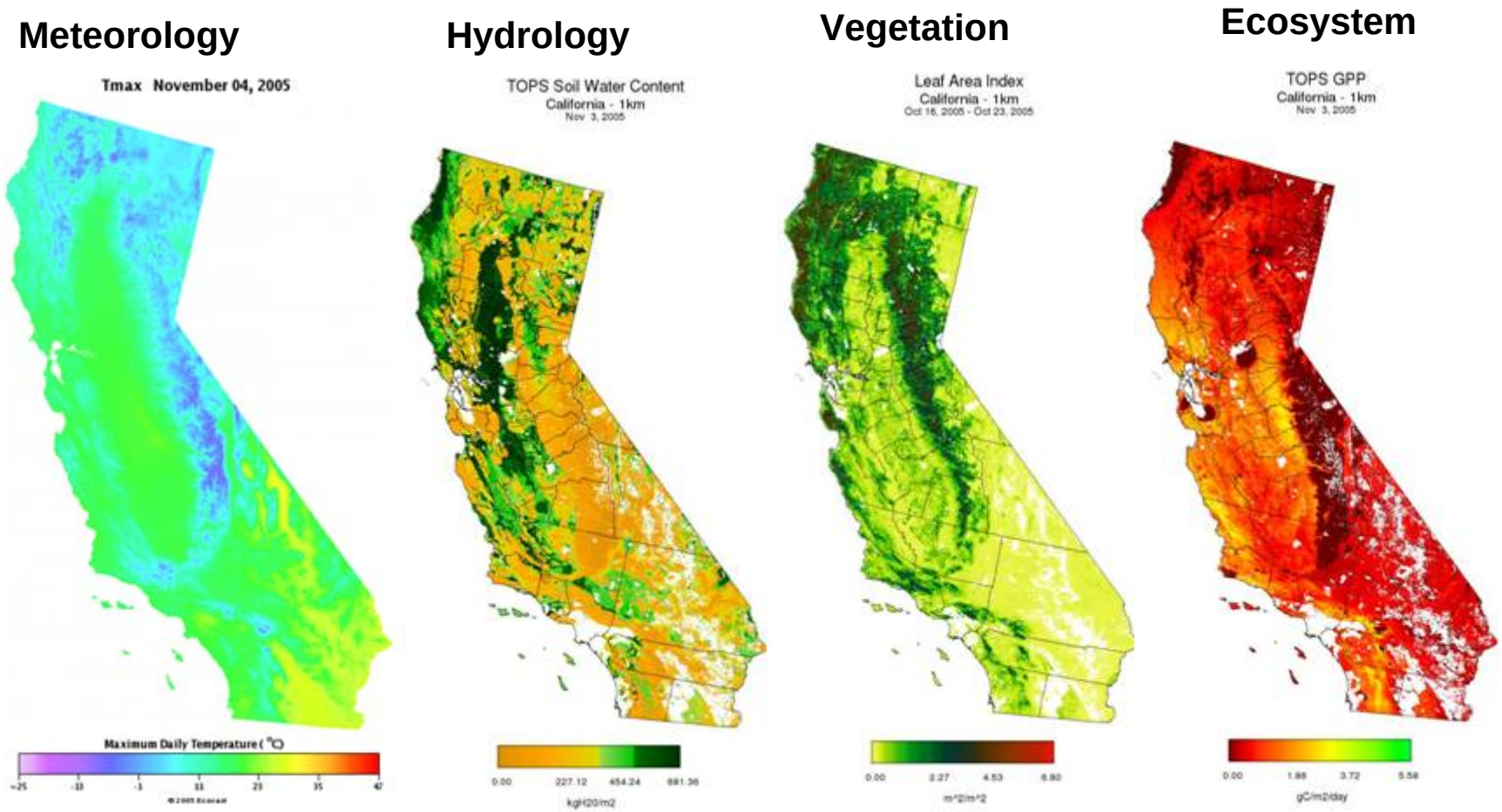


Ability to Integrate a Variety of Models



Biogeochemical cycling
Crop growth/yield
Pest/Disease
Global carbon cycle

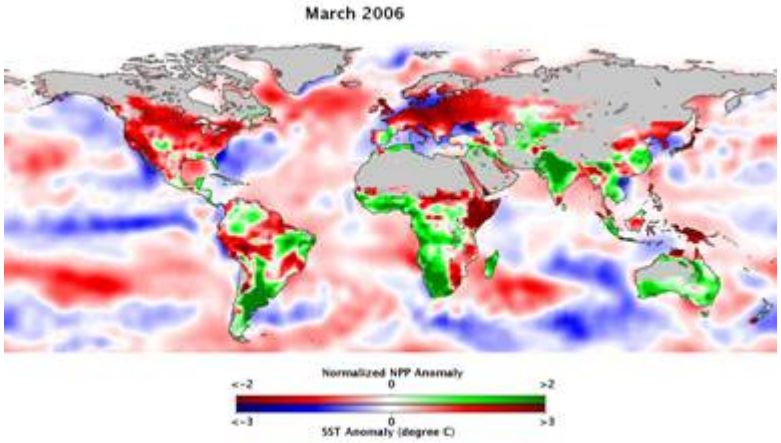
TOPS Data Products



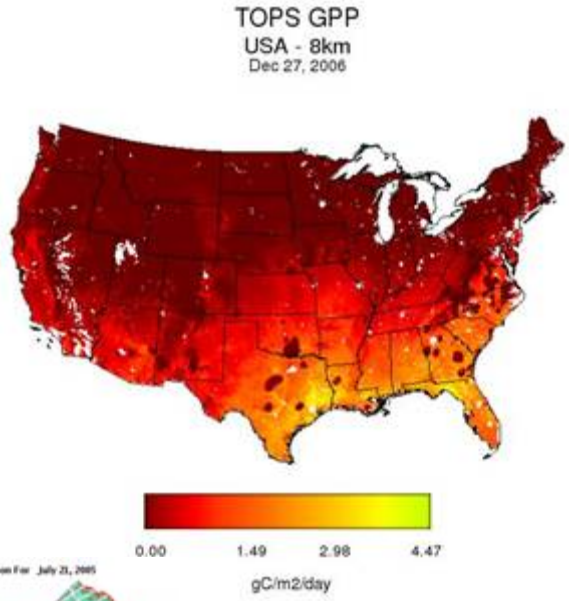
Examples of the TOPS-30 data products, which include daily measures of climate, hydrology, vegetation and ecosystem conditions produced for California at 1km spatial resolution.

Standard TOPS Outputs: Local to Global Scales

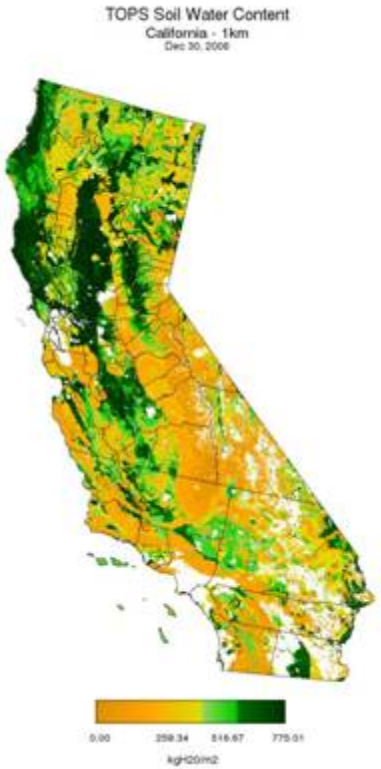
Global NPP Anomalies



U.S. Gross Primary Productivity



California Daily Soil Moisture Estimates

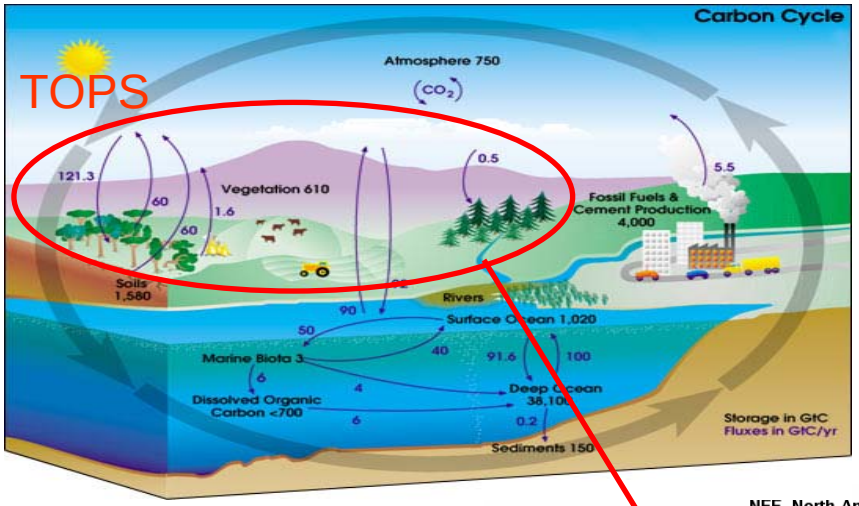


Yosemite Minimum Temperatures

Napa Valley Forecasted Vineyard Irrigation Demands

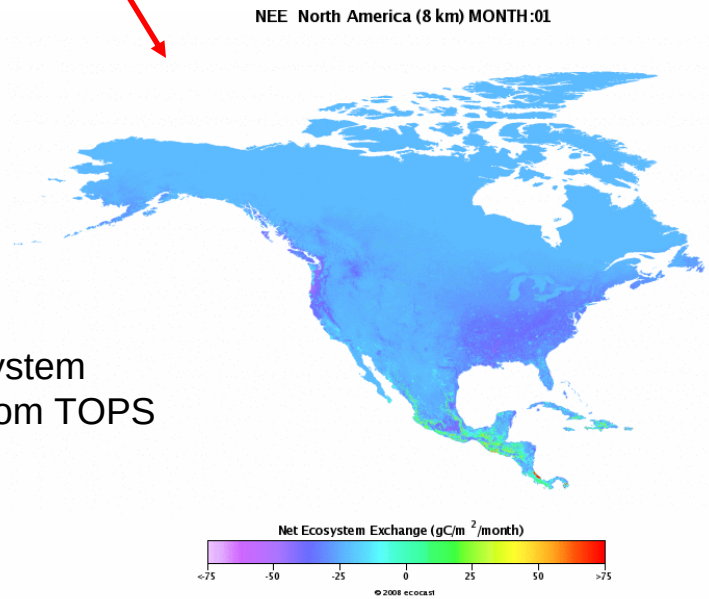
Spatial scales from 0.5 degrees to 4m. Temporal scales from yearly to daily.

Monitoring Carbon Flux from Terrestrial Ecosystems



Credit: NASA Earth Science Enterprise

- Using a suite of component biogeochemical cycle models, TOPS provides estimates of carbon fluxes from terrestrial ecosystems



Average Monthly Net Ecosystem Exchange for N. America from TOPS

- TOPS recently coupled with WRF and a tracer model to simulate transport of CO_2 fluxes from terrestrial ecosystems and model local atmospheric concentrations

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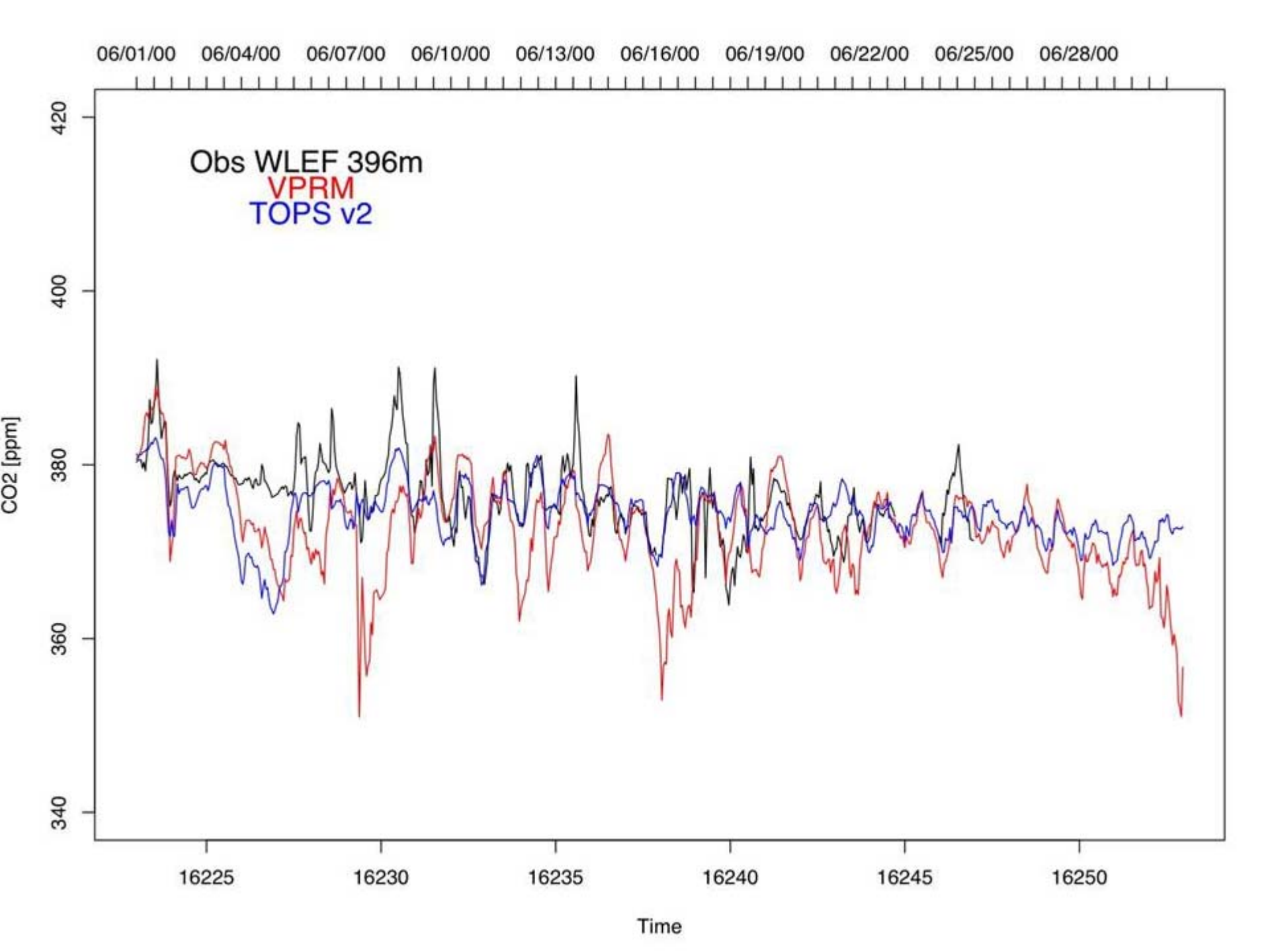
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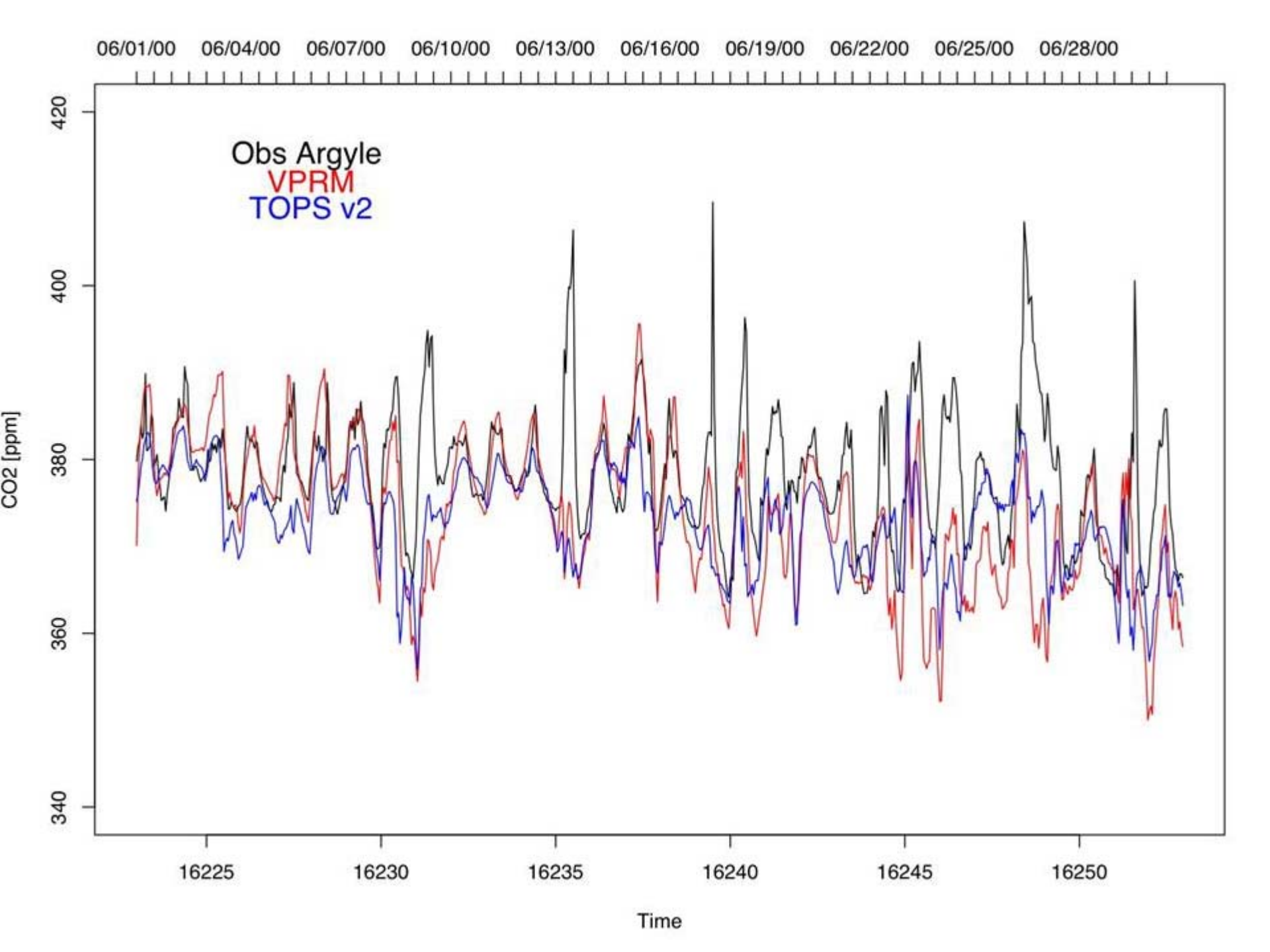
Time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Obs Argyle
VPRM
TOPS v2
420
400
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CO2 [ppm]
16225
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16235
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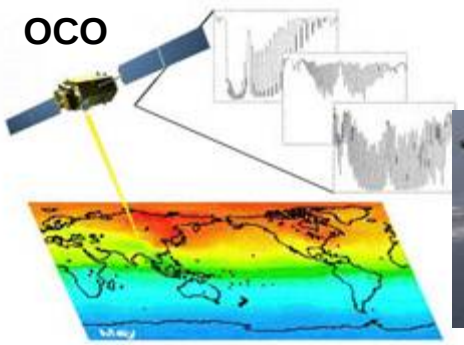
Time

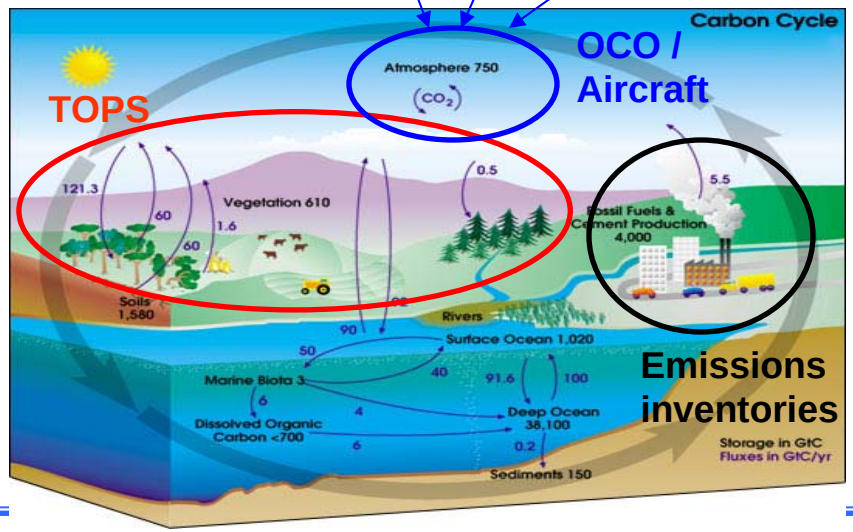
Carbon Accounting and Carbon Flux from Terrestrial Ecosystems



Credit: JPL

NOAA Twin Otter

Altair/Sierra



- Using measurements of atmospheric CO_2 concentrations from the NASA Altair or Sierra UAV, the NOAA Twin Otter, or OCO (re-fly?), we can estimate local anthropogenic emissions by subtracting estimated fluxes from natural ecosystems from TOPS
- Estimates can be used to validate emissions inventories and identify unreported emission sources

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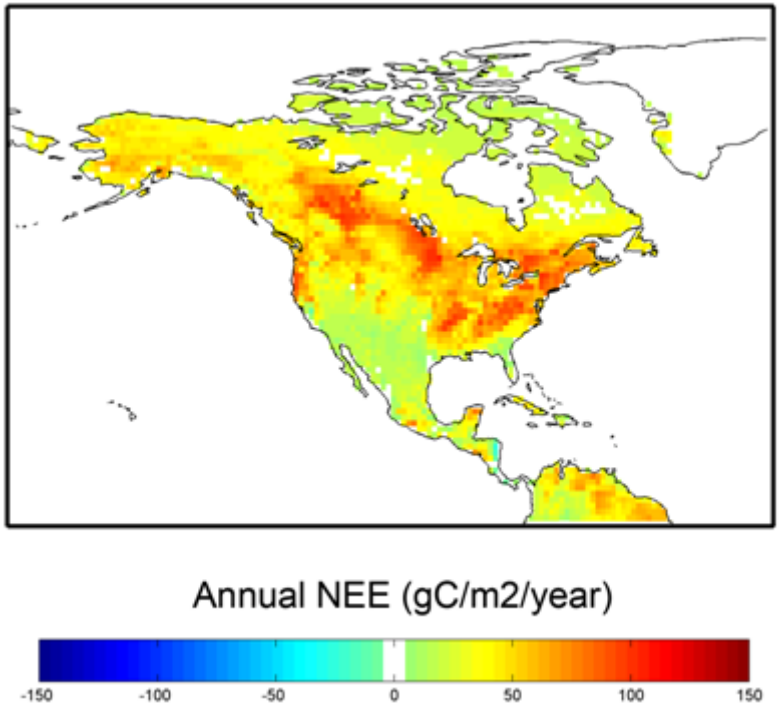
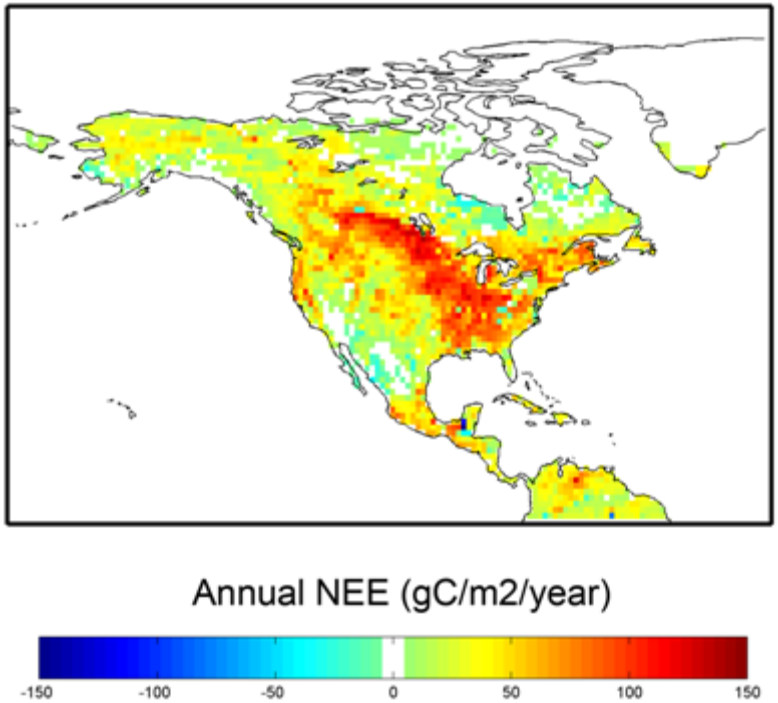
Model Intercomparison Studies

Atmospheric-inversion results are sensitive to the prior fluxes used in their algorithms

Rescaled CASA (Annual Mean)

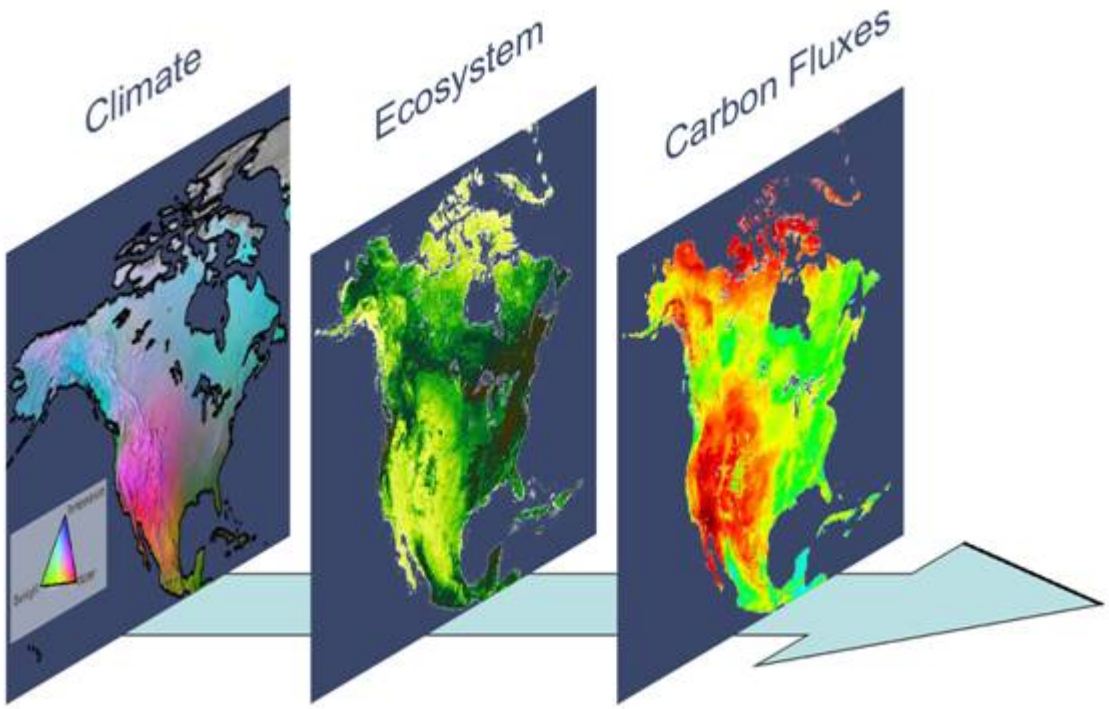


CarbonTracker (Annual Mean)



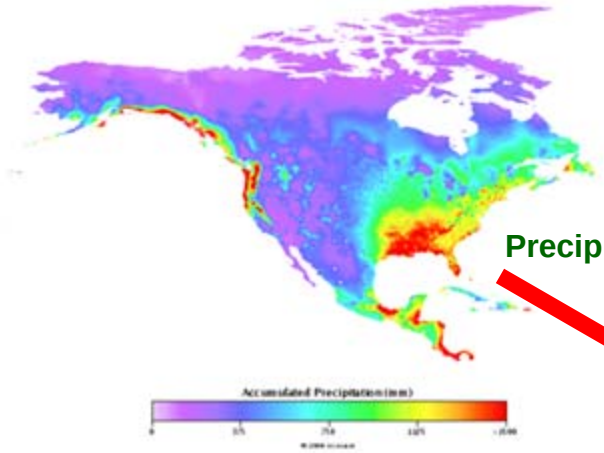
Models and Data Products

- BGC
- FLEX-BGC
- CASA
- LPJ
- BEAMS
- SimCYCLE
- ⋮
- More



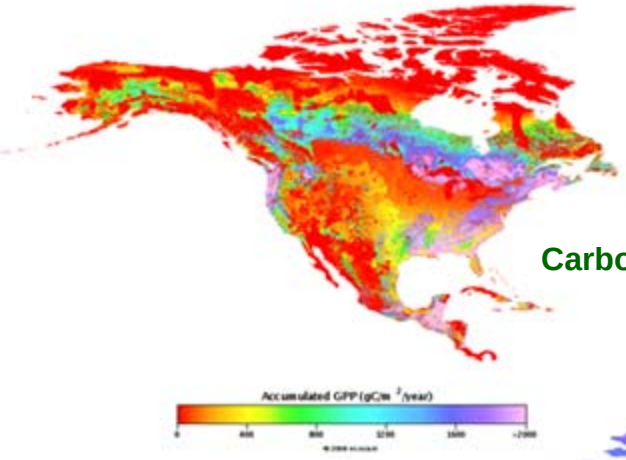
Wang et al.

Model Setup and Processing

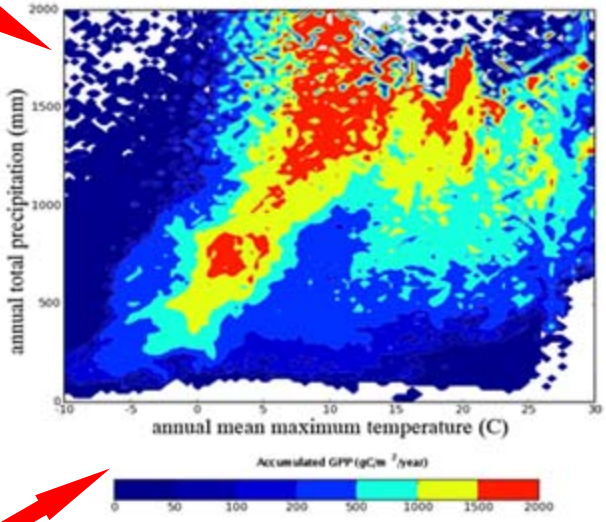


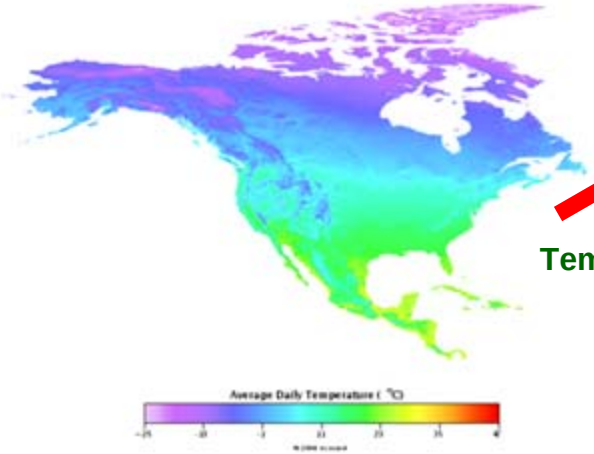
Precipitation

Carbon Fluxes in the T-P Space



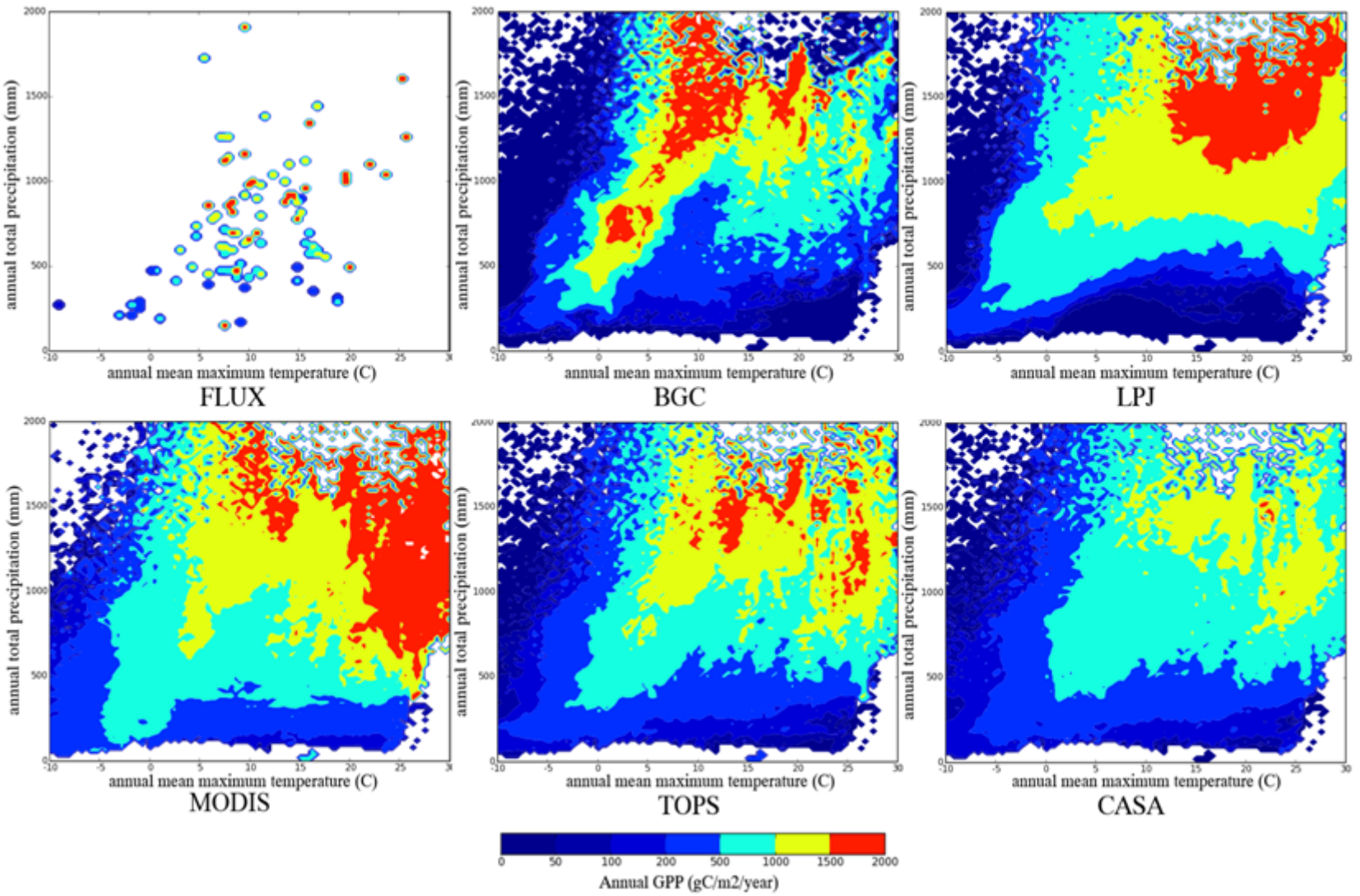
Carbon Fluxes (GPP, NPP, and NEE)



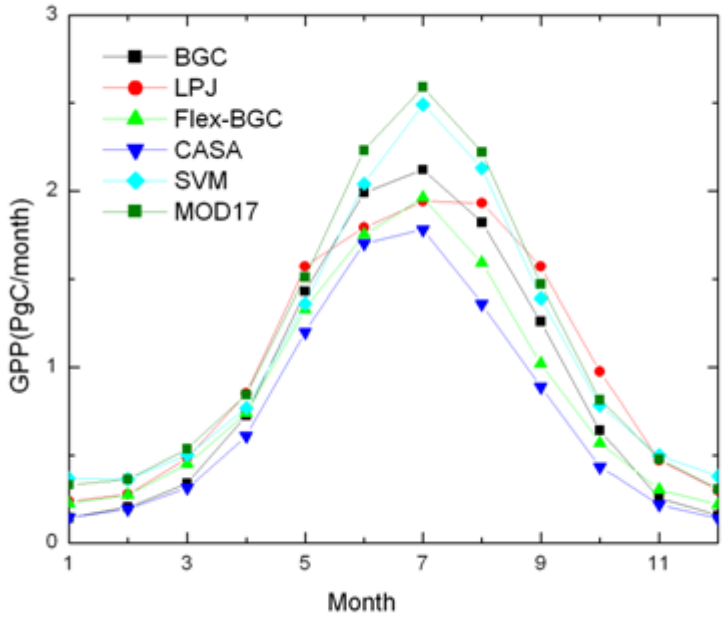


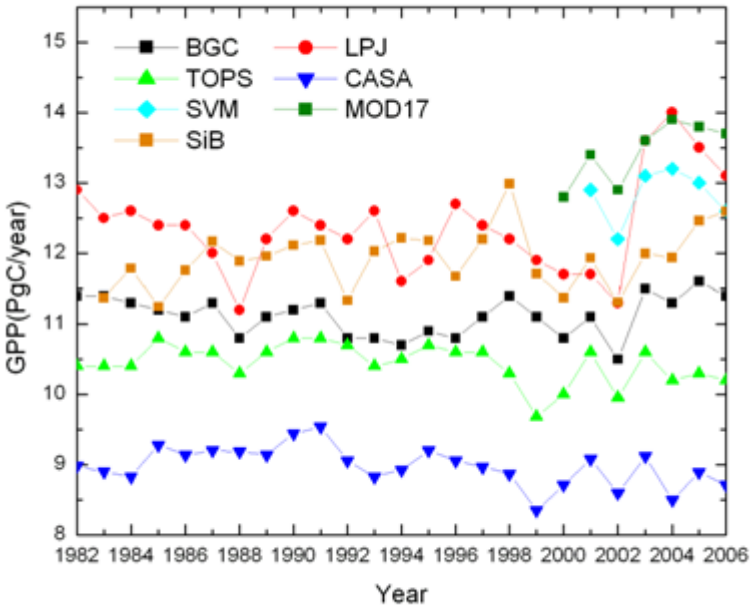
Temperature

Annual Gross Primary Production

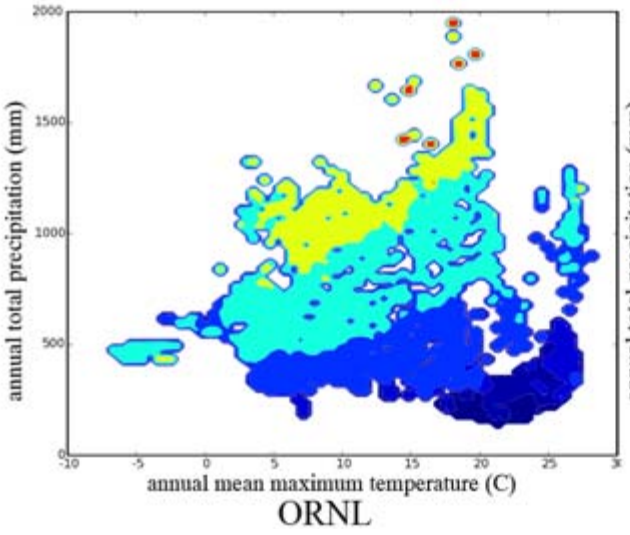


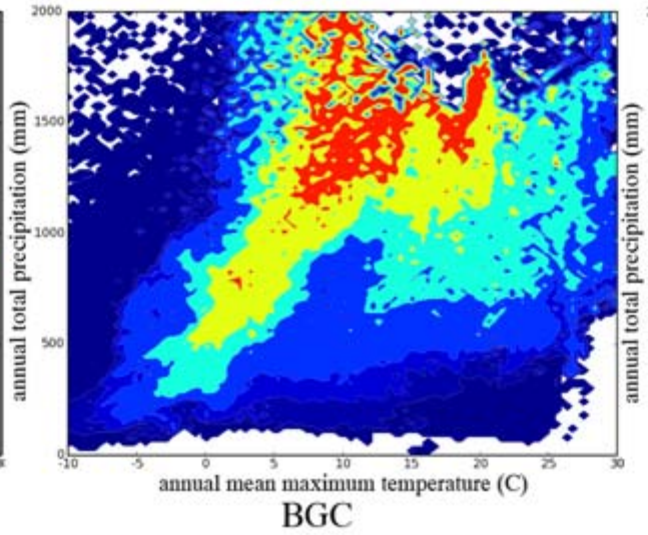
GPP Seasonality and Interannual Variability

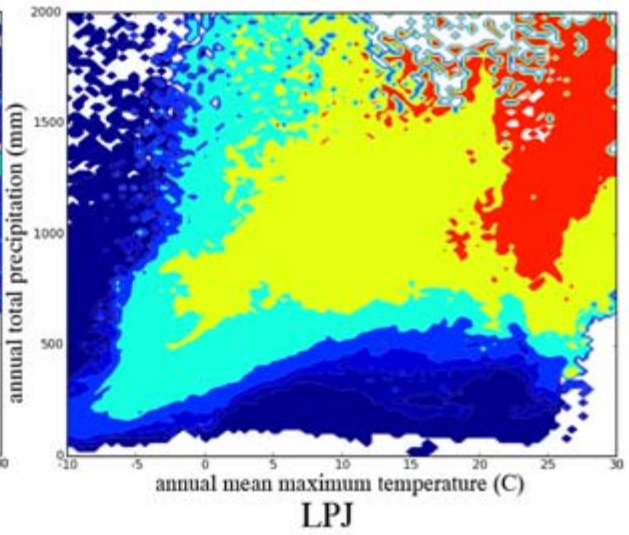


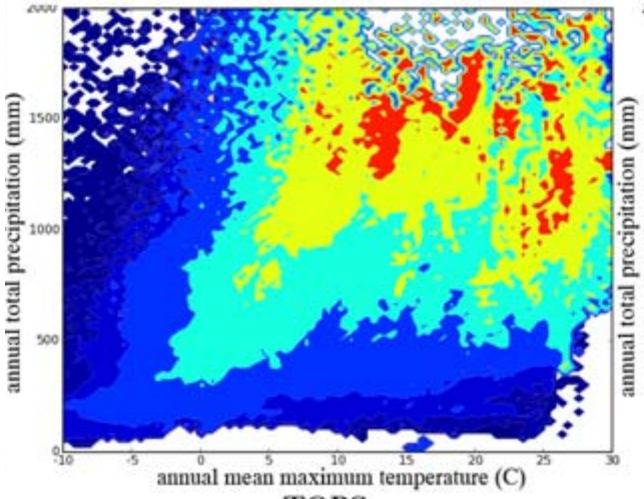


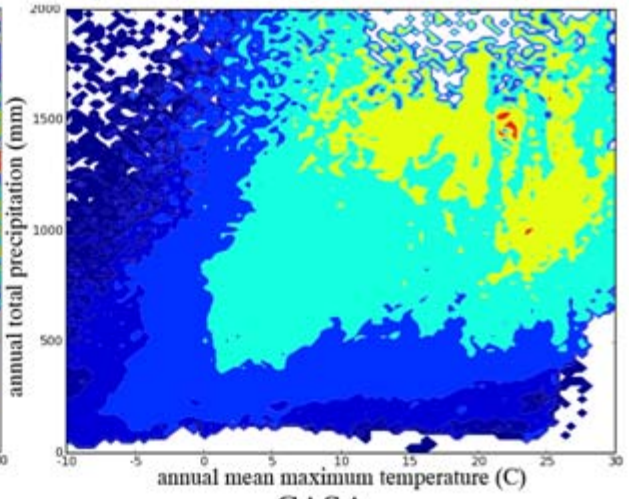
Annual Net Primary Production

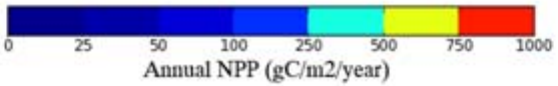




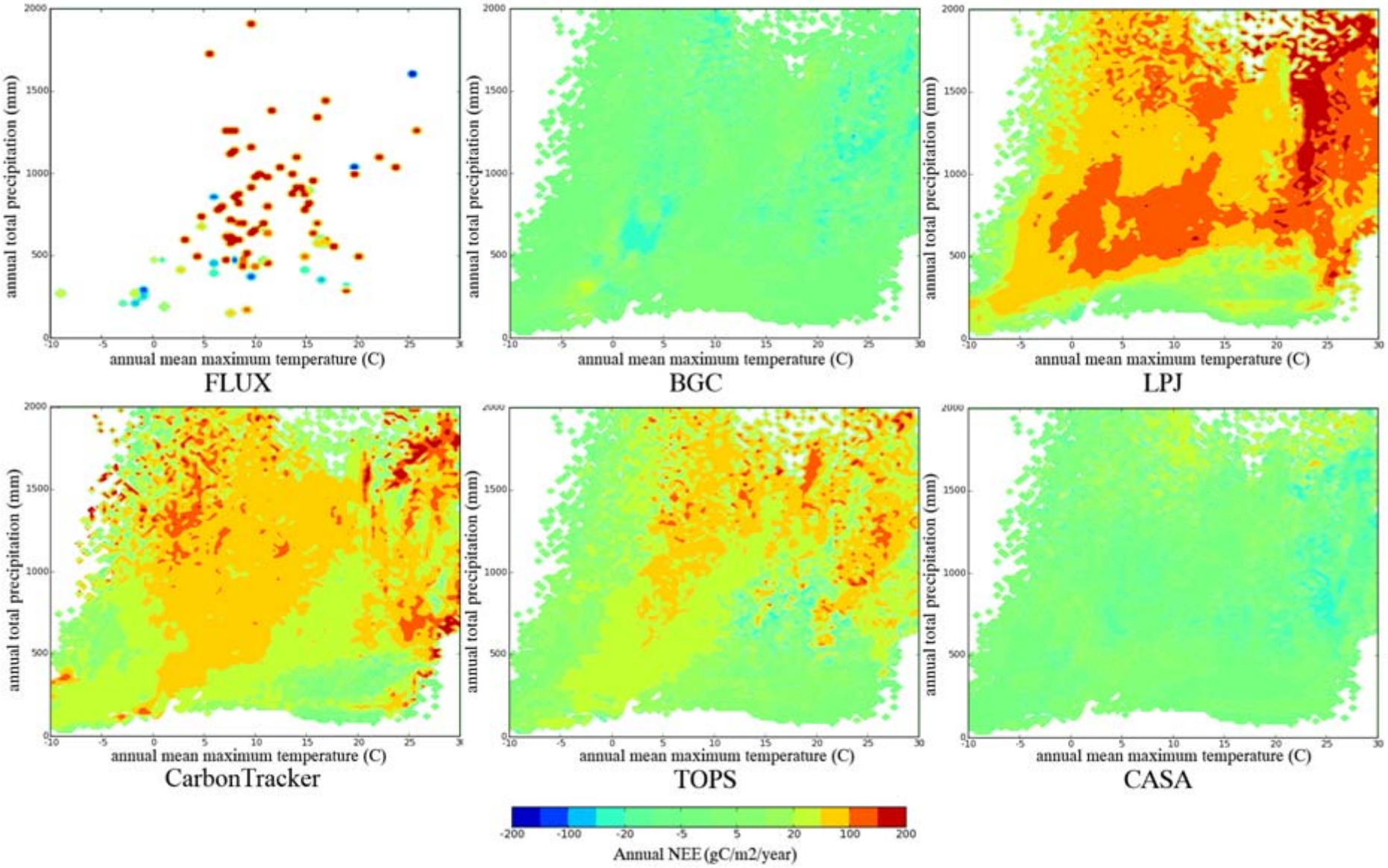




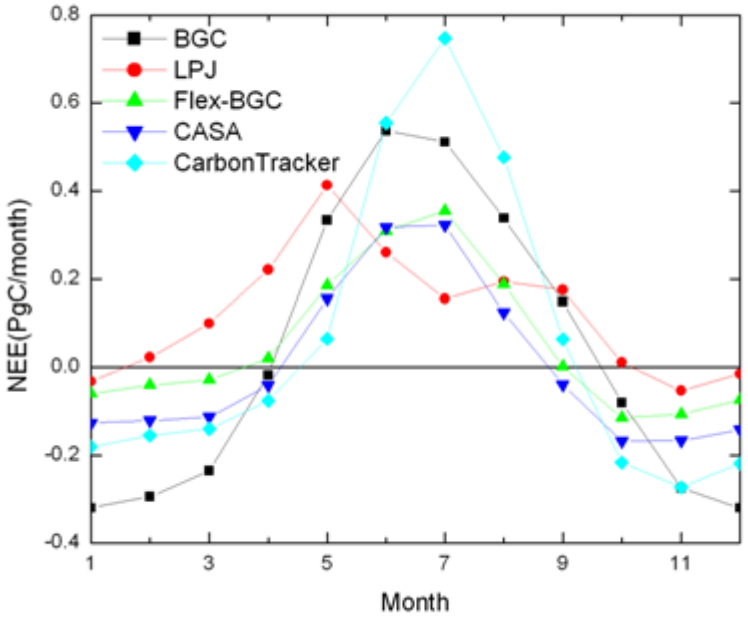


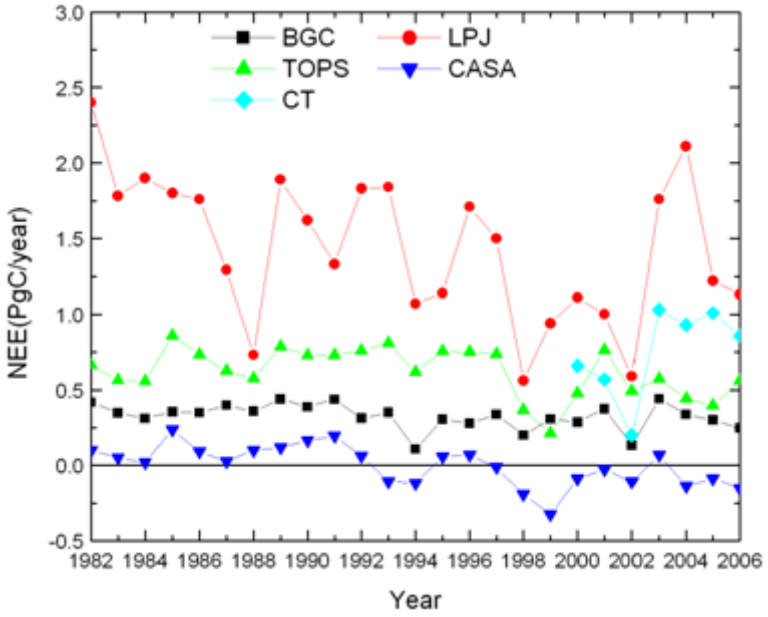


Annual Net Ecosystem Exchange



NEE Seasonality and Interannual Variability





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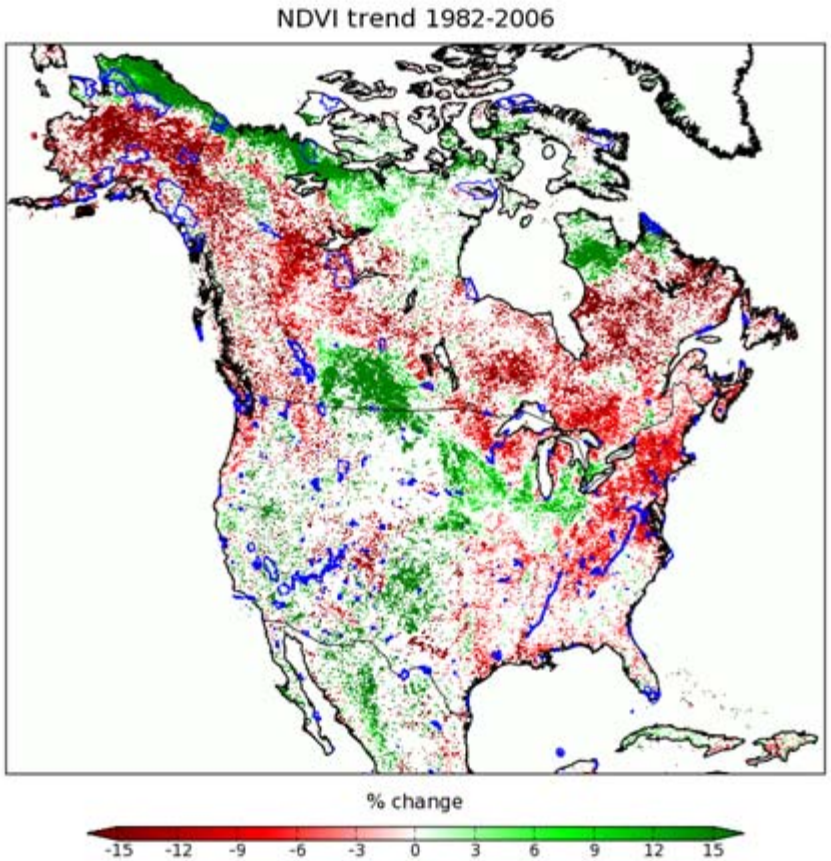
Tracking Long-Term Change: Plant Growth Index

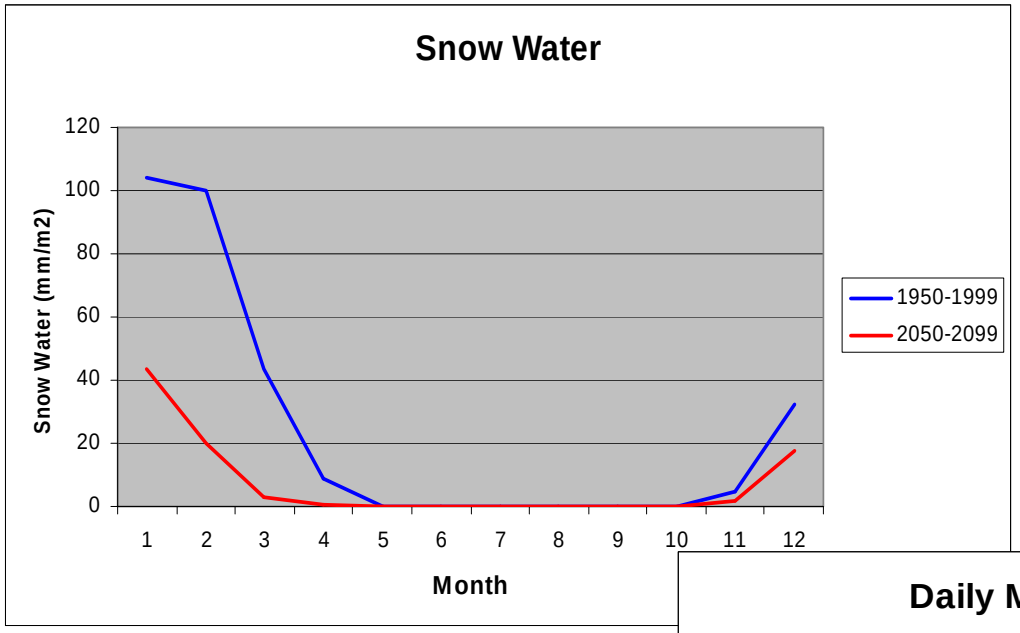


Significant trends in NDVI from AVHRR GIMMS data. Green values represent an increase in index values over the period for a particular 8km pixel, and red values represent a relative decrease. White represents areas with no significant trend up or down.

- Included in the 2008 Heinz Center State of the Nation's Ecosystems Report
- Based on NDVI calculated from AVHRR GIMMS data (1982-2006) and MODIS (2000-present)
- Changes in the amount of energy captured by plants over large areas, as reported in this indicator, may signal significant changes in ecosystem functioning.
- Indicator can provide information about influence of climate, nitrogen deposition, disturbance, etc.

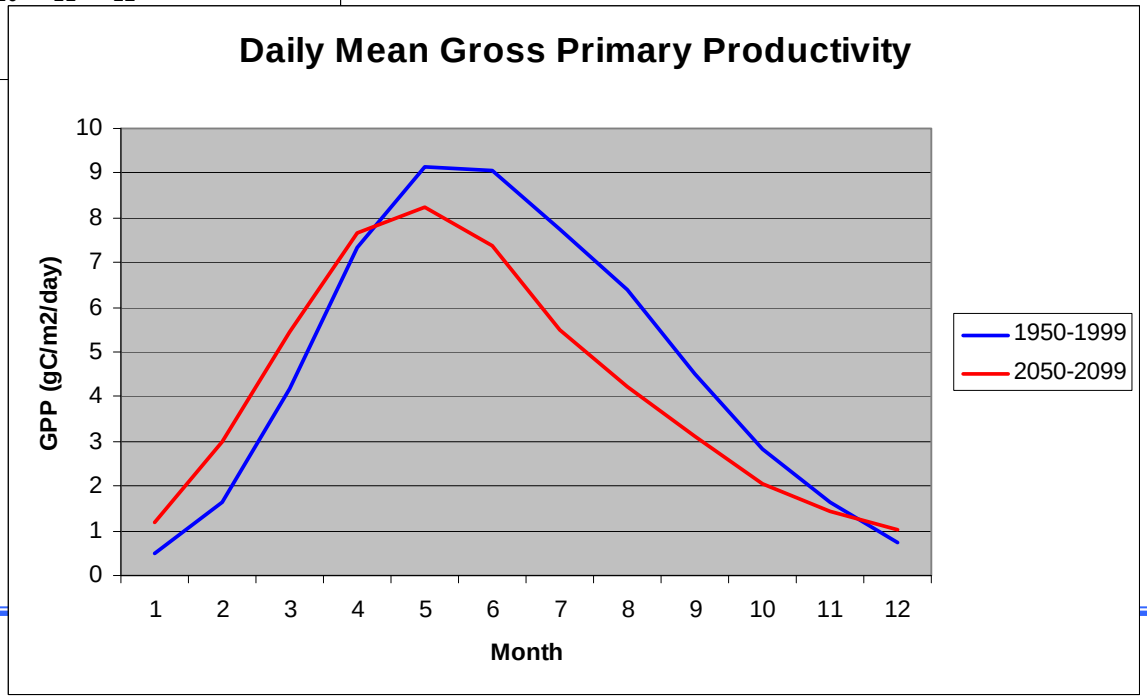
Nemani et al., RSE 113(7), 2008

Forecasting Climate Impacts, TOPS Forecasted Changes in Snow Water and GPP for 2050-2099, Yosemite



- Climate scenarios: CA Climate Change Center's World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset downscaled using the Bias-Corrected Spatial Disaggregation method (Maurer et al., 2007)
- Scenarios integrated into TOPS and used to drive ecosystem models

- Sample forecasts for Yosemite National Park from TOPS for snow water equivalent and GPP using the GFDL A2 (medium-high) emissions scenario



Nemani et al., RSE 113(7), 2008

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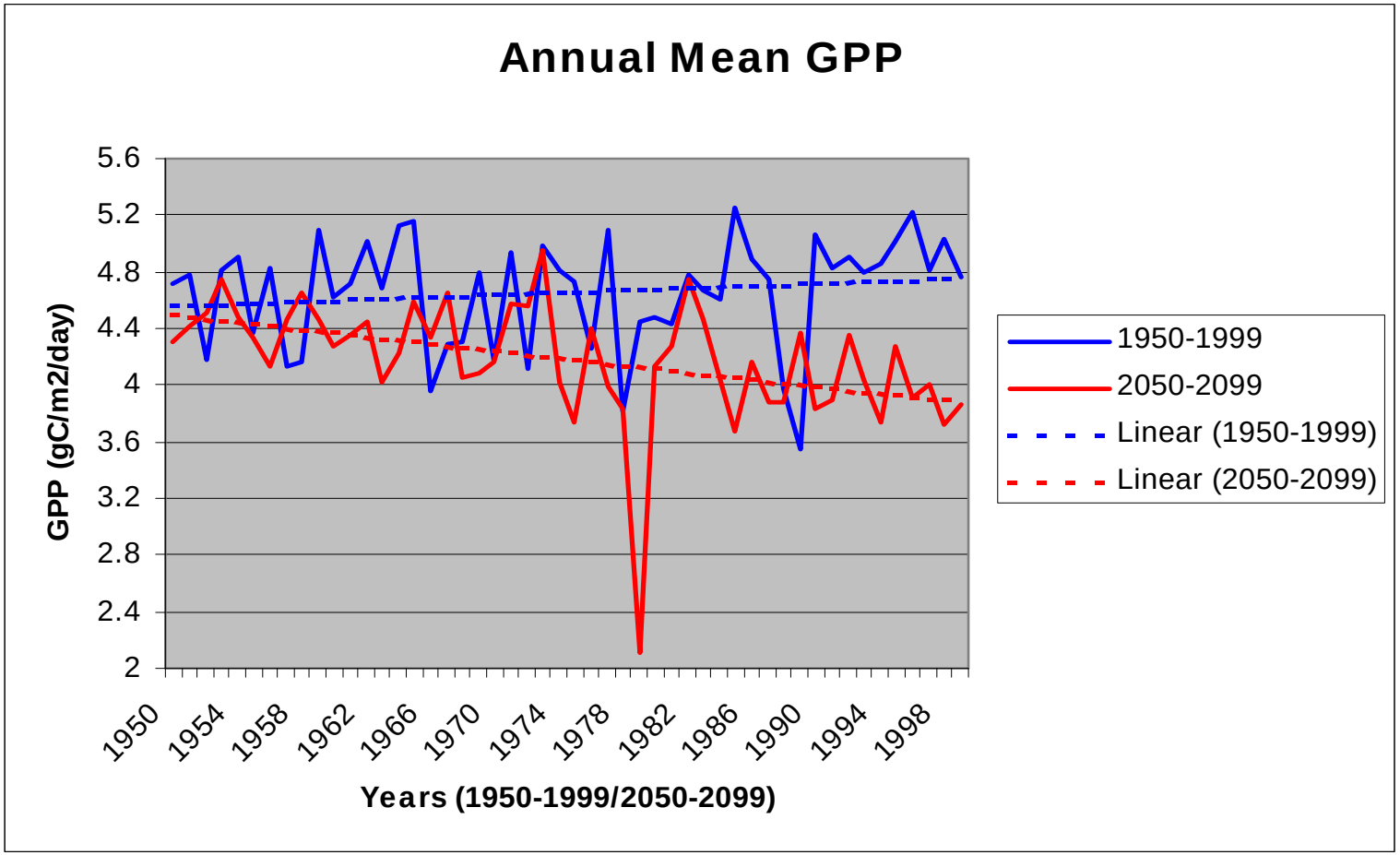
Forecasting Climate Impacts,
TOPS Forecasted Trends in GPP for 2050-2099, Yosemite



Nemani et al., RSE 113(7), 2008

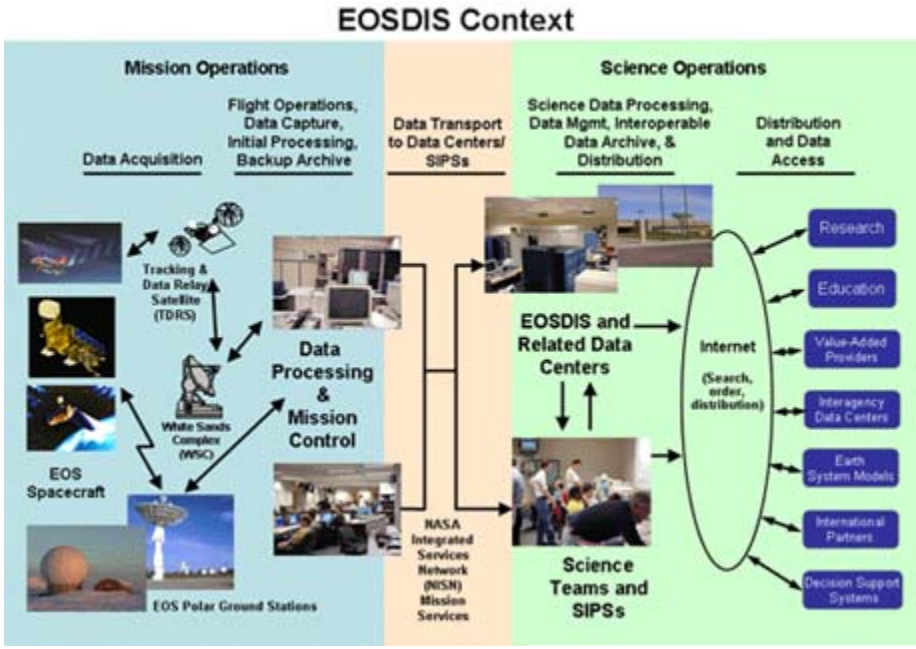
Limitations of Current Standard Practice

- **Data volume:** EOSDIS contains > 5 petabytes of data. Long term analyses of climate and ecosystem change increasingly require retrieval and processing of multiple terabytes of data from a diversity of models and sensors. Many partner agencies have limited data storage / compute resources / bandwidth.

- **Bandwidth:** As the growth in bandwidth begins to flatten, transmission of data from centralized data archives presents an increasing challenge. EOSDIS only transmits 4.2 TB/day.

- **Data management costs and redundant storage and processing:** Costs associated with local storage and management of data and compute resources add significant costs to individual research and application development efforts. Compute hardware required for storage and modeling can easily exceed $100k, plus >$100k/year for system administration.

- **Community**: General lack of unified community platform to share data, process, and knowledge

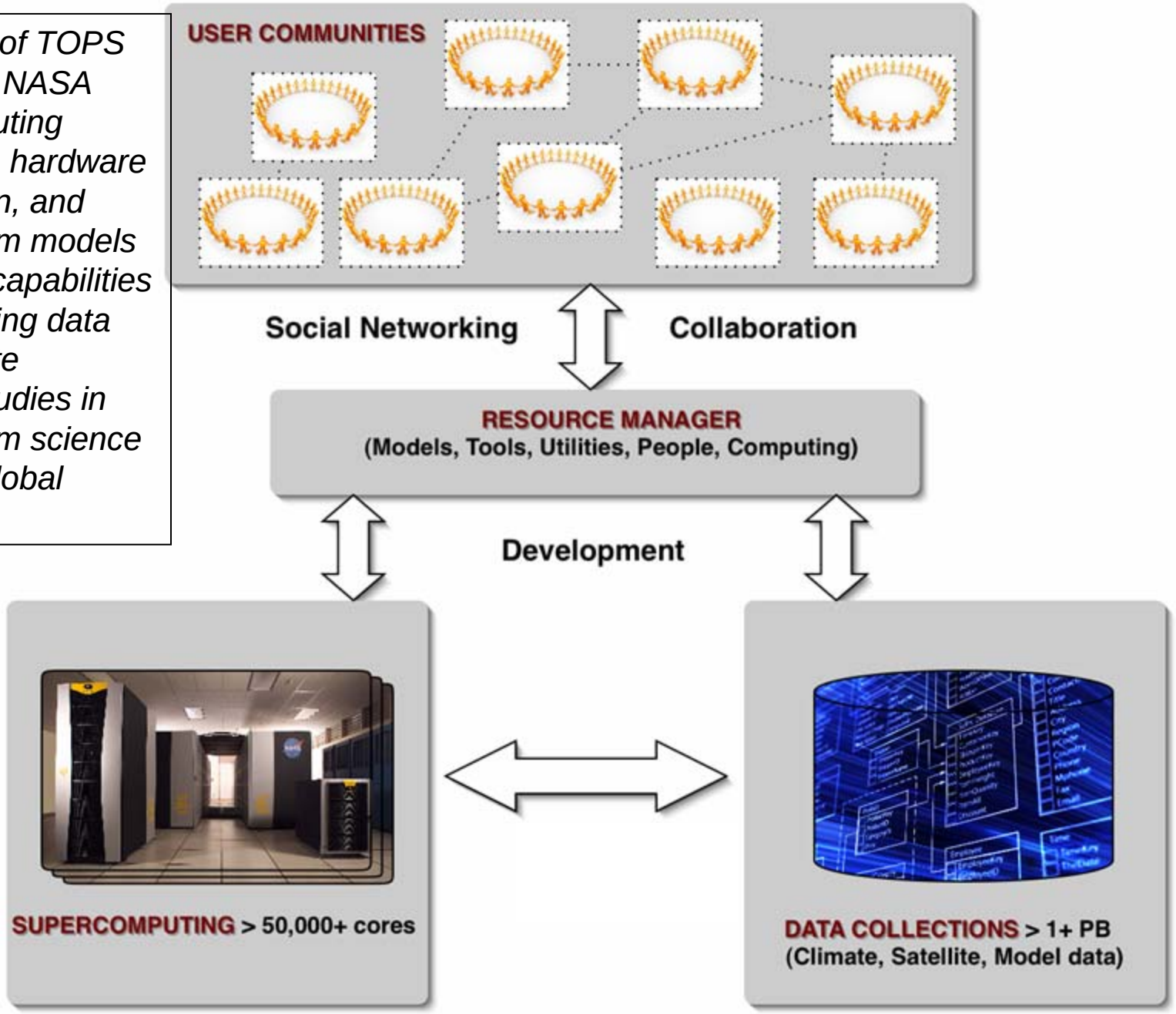


EOSDIS Daily Archive Growth: 3.2 TB

Daily Distribution Volume: 4.2 TB

Average distribution capacity is the equivalent of less than two users downloading each data product daily

Application of TOPS to integrate NASA supercomputing capabilities, hardware virtualization, and Earth system models to develop capabilities for addressing data and compute intensive studies in Earth system science related to global change



TOPS Collaborative

Summary

- TOPS provides a modeling framework for integrating satellite observations and climate data/scenarios to evaluate carbon fluxes at multiple spatial scales
- Provides computational framework for estimation of carbon fluxes from terrestrial ecosystems in near-real-time, as well as modeling of impacts of long-term climate scenarios
- Model intercomparison studies reveal important discrepancies among models at the continental scale
- Potential for climate change to affect productivity of Sierran forests requires further investigation