Terrestrial Observation and Prediction System: Development of a Biospheric Nowcast and Forecast Capability

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Collaborators:

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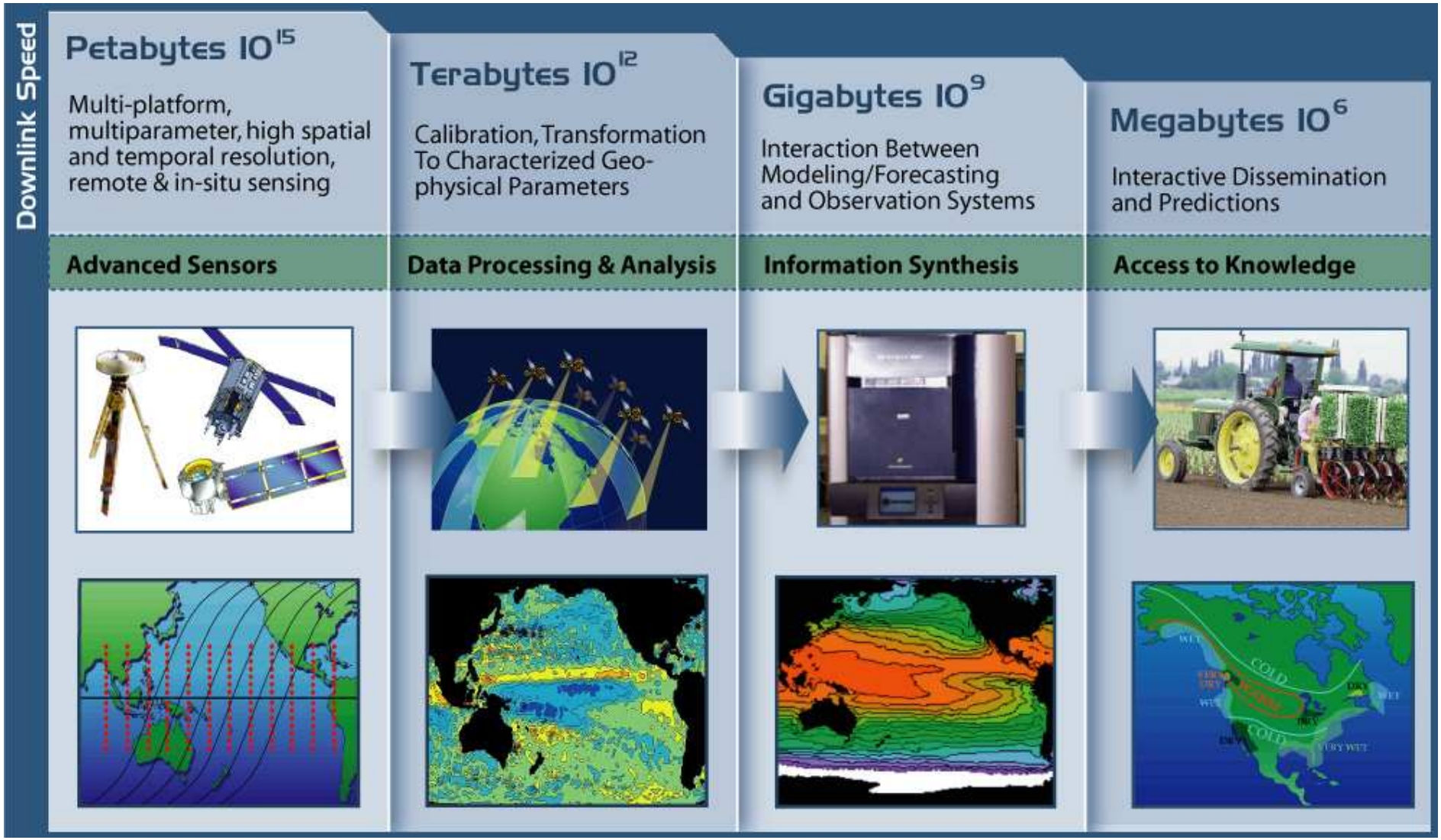
March 29, 2005
Ecological modeling workshop, Asilomar, CA

Turning Observations Into Knowledge Products



GOAL

The project goal is to develop a data and modeling system that enables operational production of biospheric nowcasts and forecasts of ecosystem states and functions,

such that management strategies and options can be developed to prevent or reverse declining trends, reduce risks, and to protect important ecological resources and associated processes

Objectives

- using internet as a backbone, develop a modeling framework for integrating satellite data, surface meteorology and ecosystem models,

- verify model results and perform hindcasts to produce historical normals for ecosystem states and functions,

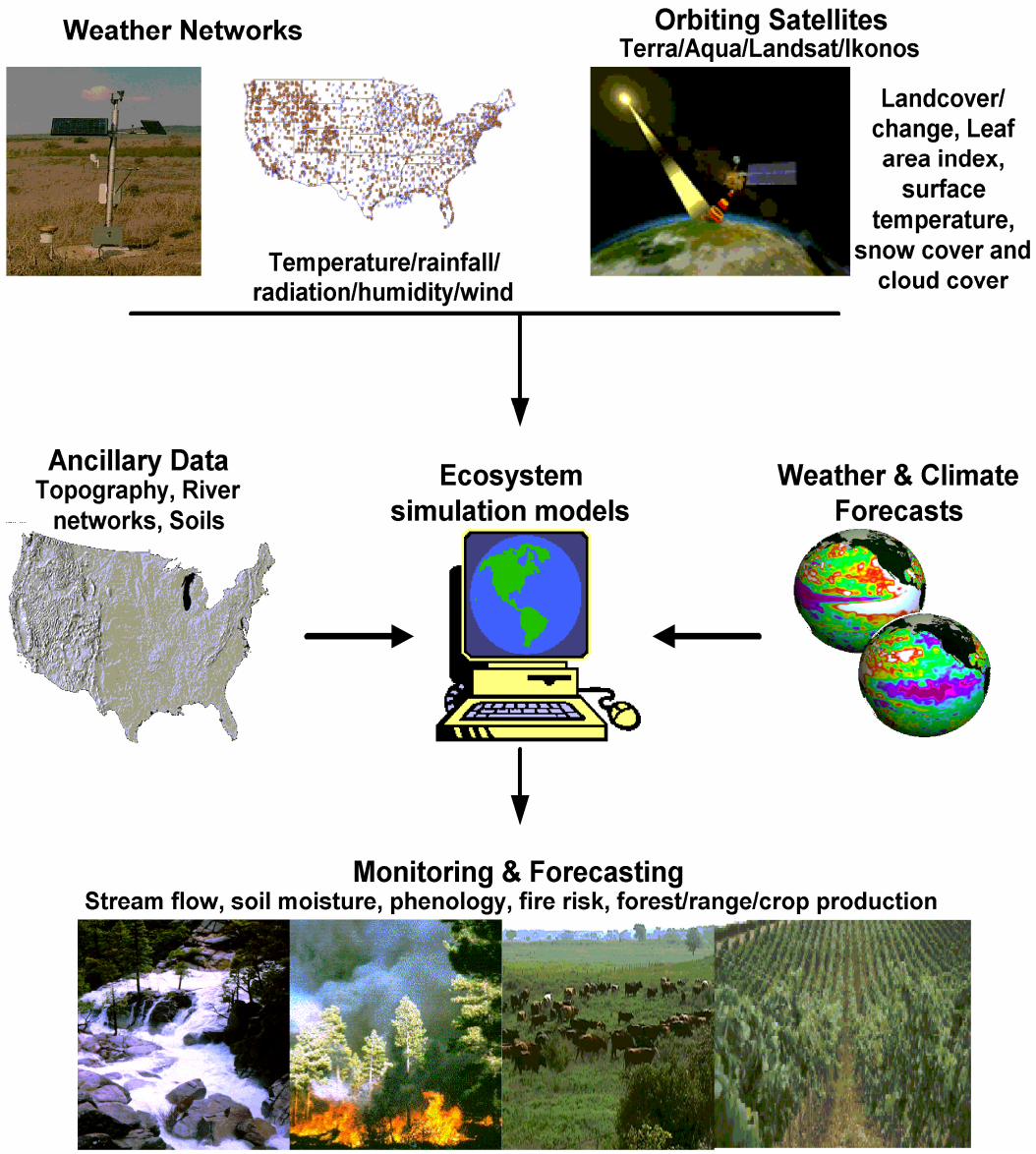
- develop a near-realtime ecosystem analysis methodology for nowcasting ecosystem states and functions,

- explore opportunities of forecasting ecosystem behavior at various lead times.

Need for integration

- Integration of remote sensing, surface meteorology, and ecological models provides the best opportunity for comprehensive assessment of the state and activity of landscape processes
- Disciplines are traditionally separate but can be highly complementary

Terrestrial Observation and Prediction System



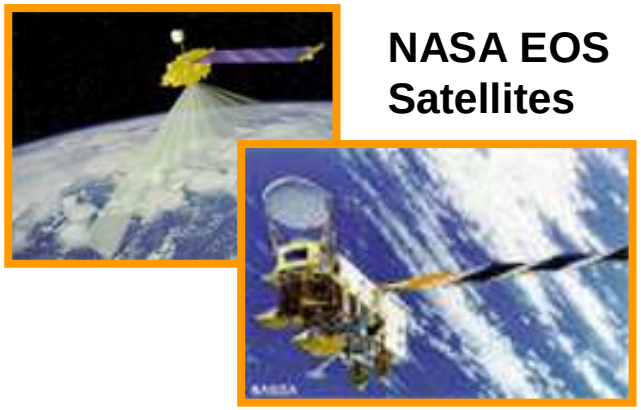
Key elements:

Monitoring

Modeling

Forecasting

Large Data Flows: Extracting Knowledge from Petabytes of Data



NASA EOS Satellites

Observing Networks

Weather, soil moisture, streamflow etc.,

Ancillary Data
Topography, River Networks, Soils, Biodiversity . . .

100 MB/ day

~3 TB/day

EOSDIS

.1 - 10 TB

250+ products, > 3.5 petabytes

TOPS Architecture

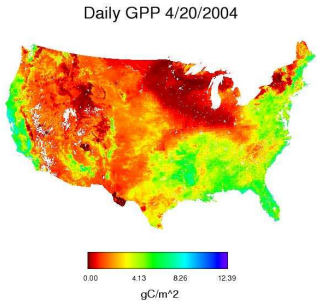
Simulation Models
Biospheric models for ecological monitoring & forecasting

IMAGEbot Planner
Optimizes data processing plans and retrieves appropriate data for analyses

Causal Discovery
Autonomous analysis of data for discovery of novel causal models; integrated with TOPS for model validation

Knowledge: 100K to 10 MB

Nowcast / forecast maps, integrated datasets, images, and causal models



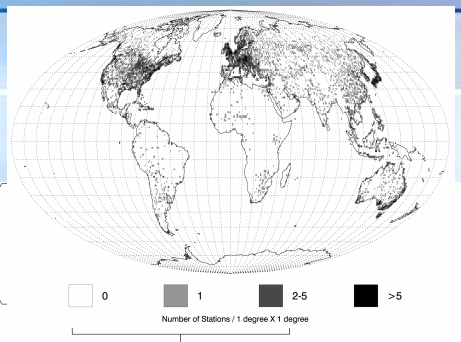
Massive data sets, multiple products, heterogeneous data types.

Criteria for system evaluation:

Effort required to do

- new geographic area
- integrate a new sensor or a new data source
- integrate a new model
- adapt to a new domain
- allow measurement of improvements from new data sources or models.

Retrospective to real time gridding climate data



Data Retrieval

Data Retrieval and Processing

Scheduler

Unattended

SQL Database

Storage

Modular

Observations (X,Y,Z,R)

Prediction Points (X0,Y0,Z0)

Interpolation Logic

Prediction (R0)

Crossvalidation Statistics

Interpolation Logic

Prediction Control

Interpolation

Ancillary Inputs

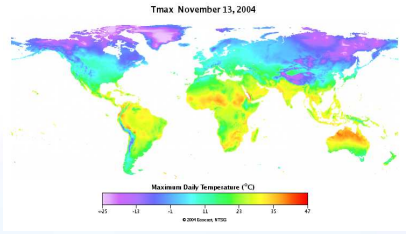
Any user Defined grid

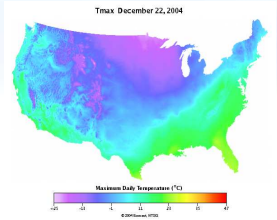
Output Handling

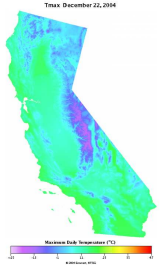
Predictions

Output

Tmax / Tmin
VPD, precipitation
Solar radiation
Daylength







Jolly, nemani, Running…. 2004. Envi. Modeling and Software

Terra Launch on December 18,1999
Aqua Launch on May 4, 2002

Retrospective to real time
Operational remote sensing

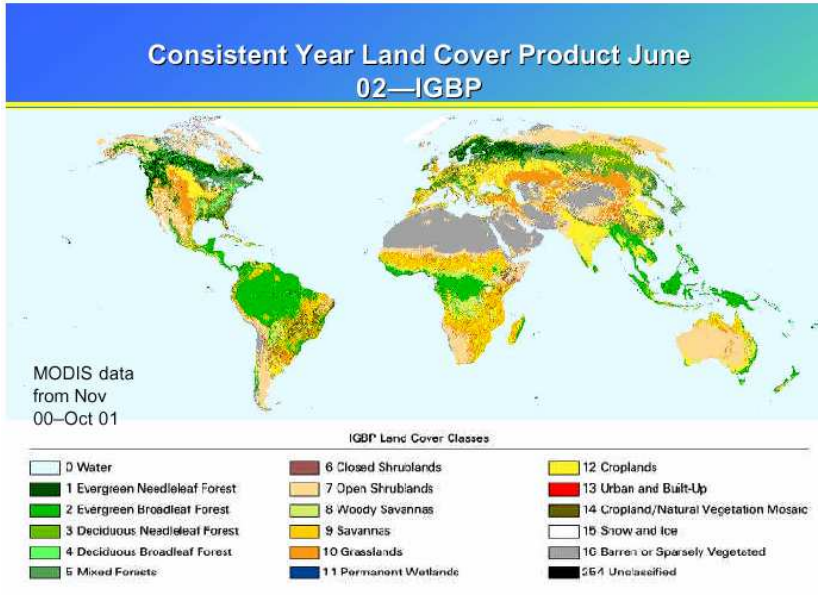
Terra Launch: Dec. 18, 1999
First Image: Feb. 24, 2000

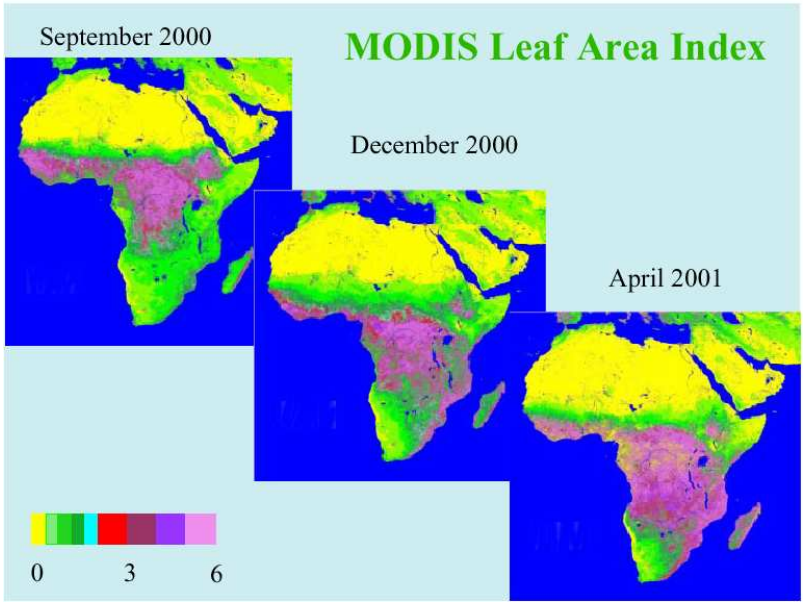
Aqua Launch: May 04, 2002
First Image: June 24, 2002

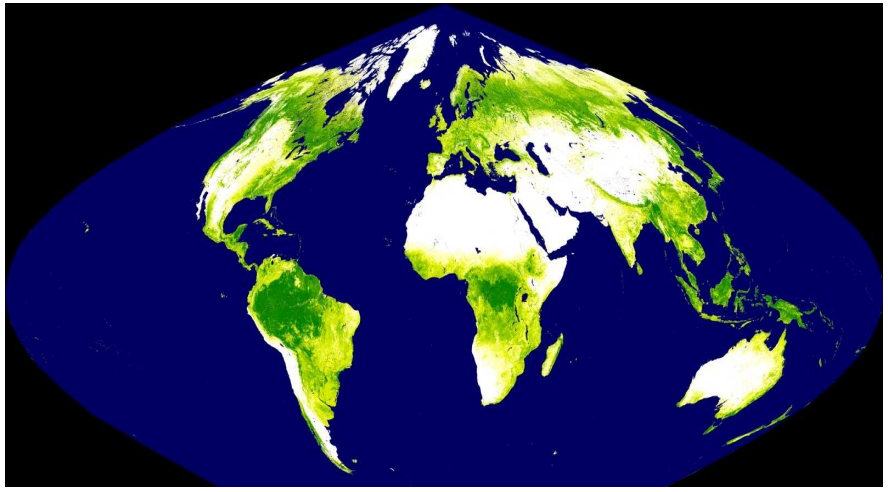
CURRENT MODIS PRODUCTS

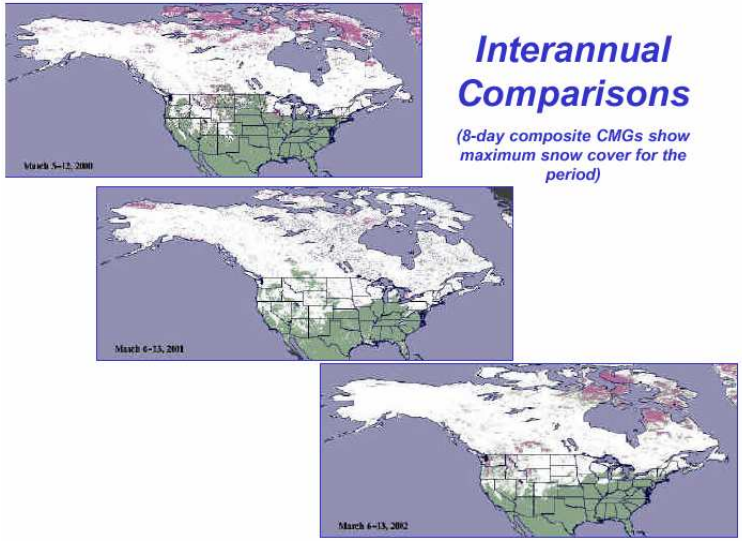
MOD01 Level-1A Radiance Counts
MOD02 Level-1B Calibrated Relocated Radiances
-also Level 1B "subsampled" 5kmX5km product
MOD03 Relocation Data Set
MOD04 Aerosol Product
MOD05 Total Precipitable Water
MOD06 Cloud Product
MOD07 Atmospheric profiles
MOD08 Gridded Atmospheric Product (Level-3)
MOD09 Atmospherically-corrected Surface Reflectance
MOD10 Snow Cover
MOD11 Land Surface Temperature & Emissivity
MOD12 Land Cover/Land Cover Change
MOD13 Vegetation Indices
MOD14 Thermal Anomalies, Fires & Biomass Burning
MOD15 Leaf Area Index & FPAR
MOD16 Surface Resistance & Evapotranspiration
MOD17 Vegetation Production, Net Primary Productivity
MOD18 Normalized Water-leaving Radiance
MOD19 Pigment Concentration
MOD20 Chlorophyll Fluorescence
MOD21 Chlorophyll_a Pigment Concentration
MOD22 Photosynthetically Active Radiation (PAR)
MOD23 Suspended-Solids Conc, Ocean Wat
MOD24 Organic Matter Concentration
MOD25 Coccolith Concentration
MOD26 Ocean Water Attenuation Coefficien
MOD27 Ocean Primary Productivity
MOD28 Sea Surface Temperature
MOD29 Sea Ice Cover
MOD31 Phycoerythrin Concentration
MOD32 Processing Framework & Match-up Database
MOD35 Cloud Mask
MOD36 Total Absorption Coefficient
MOD37 Ocean Aerosol Properties
MOD39 Clear Water Epsilon
MOD43 Albedo 16-day L3
MOD44 Vegetation Cover Conversion
MODISALB Snow and Sea Ice Albedo

Examples of operational MODIS products









% tree cover

0% 100%

Standard TOPS outputs

MODIS PRODUCTS (8 days/Annual)

1. LAI
2. FPAR
3. GPP/NPP*
4. LST-TERRA/AQUA
5. NDVI
6. EVI
7. LANDCOVER/Cont Fields*
8. ALBEDO
9. SNOW
10. FIRE

METEOROLOGY (Daily)

11. MAX TEMPERATURE
12. MIN TEMPERATURE
13. RAINFALL
14. SOLAR RADIATION
15. DEW POINT/VPD
16. DEGREE DAYS

TOPS-NOWCASTS (daily)

17. TOPS-SNOW
18. TOPS-SOIL MOISTURE
19. TOPS-ET
20. TOPS-OUTFLOW
21. TOPS-GPP/NPP
22. TOPS-PHENOLOGY
23. TOPS-VEG STRESS

TOPS-FORECASTS (5 days to 180 days)

24. BGC-LAI/PHENOLOGY
25. BGC-SOIL MOISTURE
26. BGC-OUTFLOW
27. BGC-ET
28. BGC-VEG STRESS
29. BGC-SNOW
30. BGC-GPP/NPP

Applications:

Earthwatch - NPP Anomalies

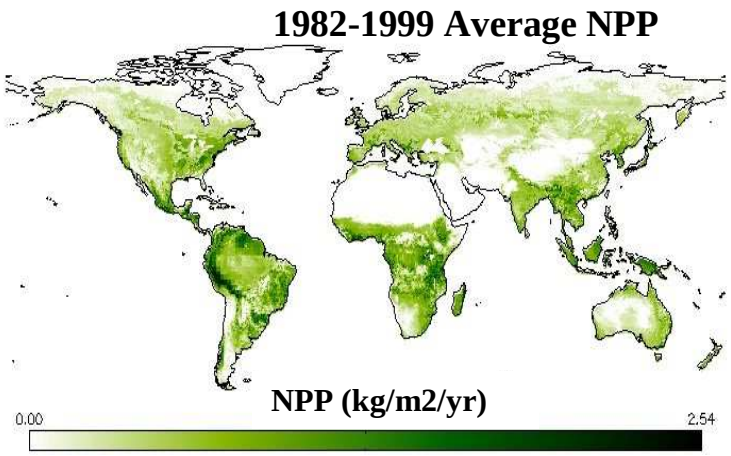
Mapping fire risk at continental scales

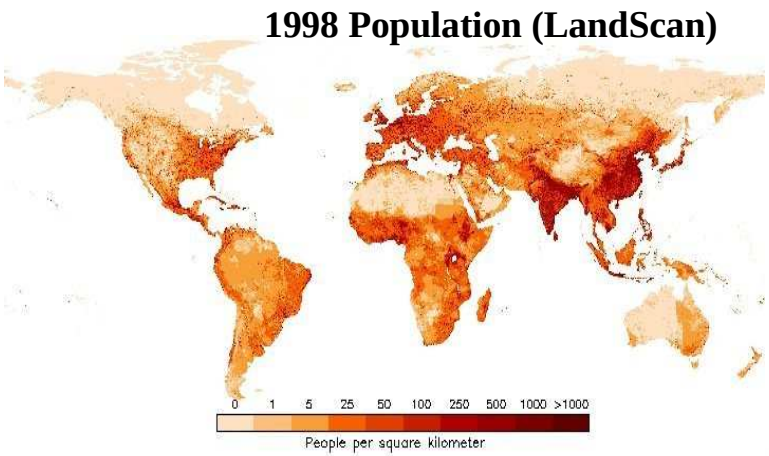
Water resources monitoring

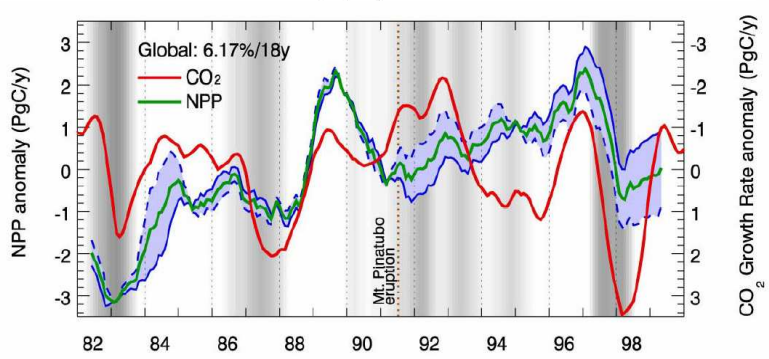
Modeling in viticulture

- Irrigation requirements
- Climate-Wine

Net Primary Production







NPP is the balance between photosynthesis and respiration by plants

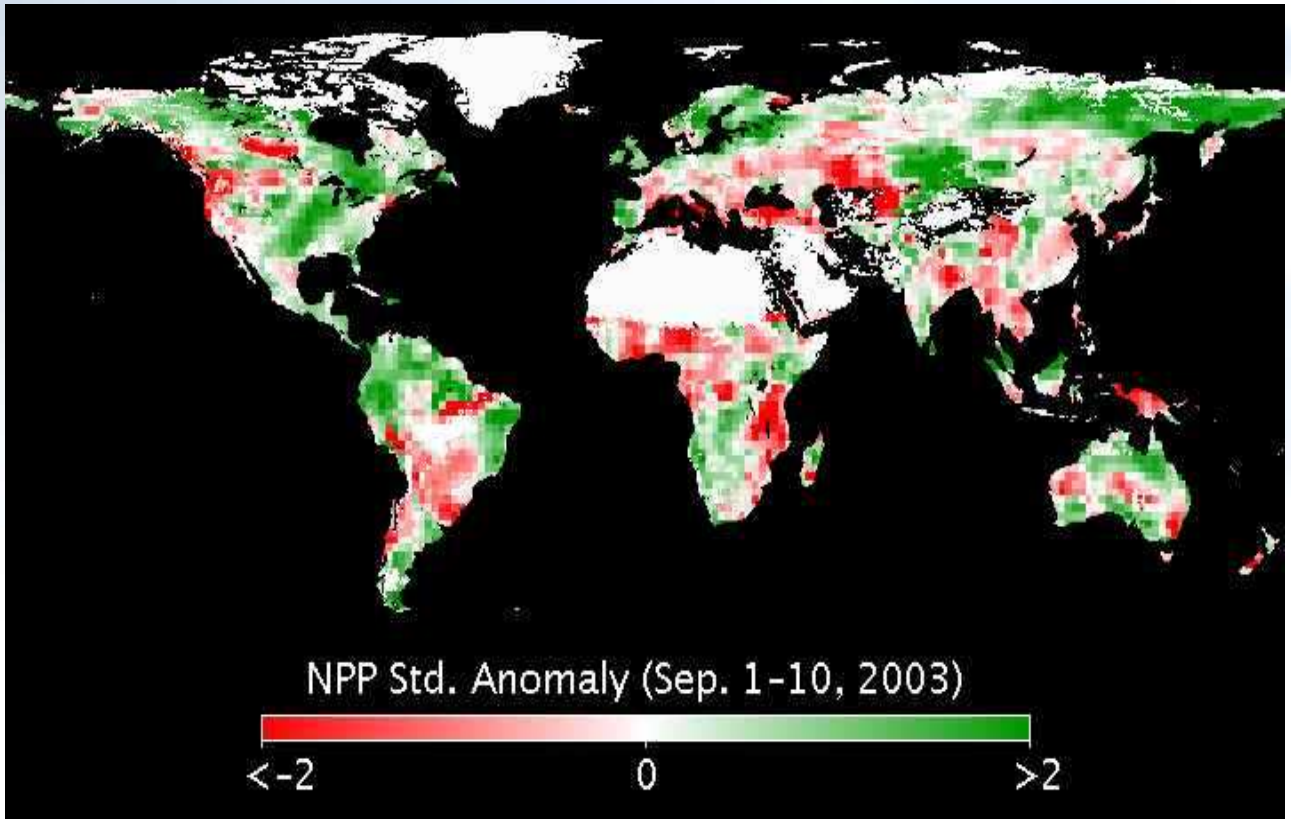
A substantial incentive to understand trends and variability in terrestrial Net Primary Production, because NPP:

-is the foundation of food, fiber and fuel for human consumption

-determines seasonal and interannual variations in atmospheric CO_2

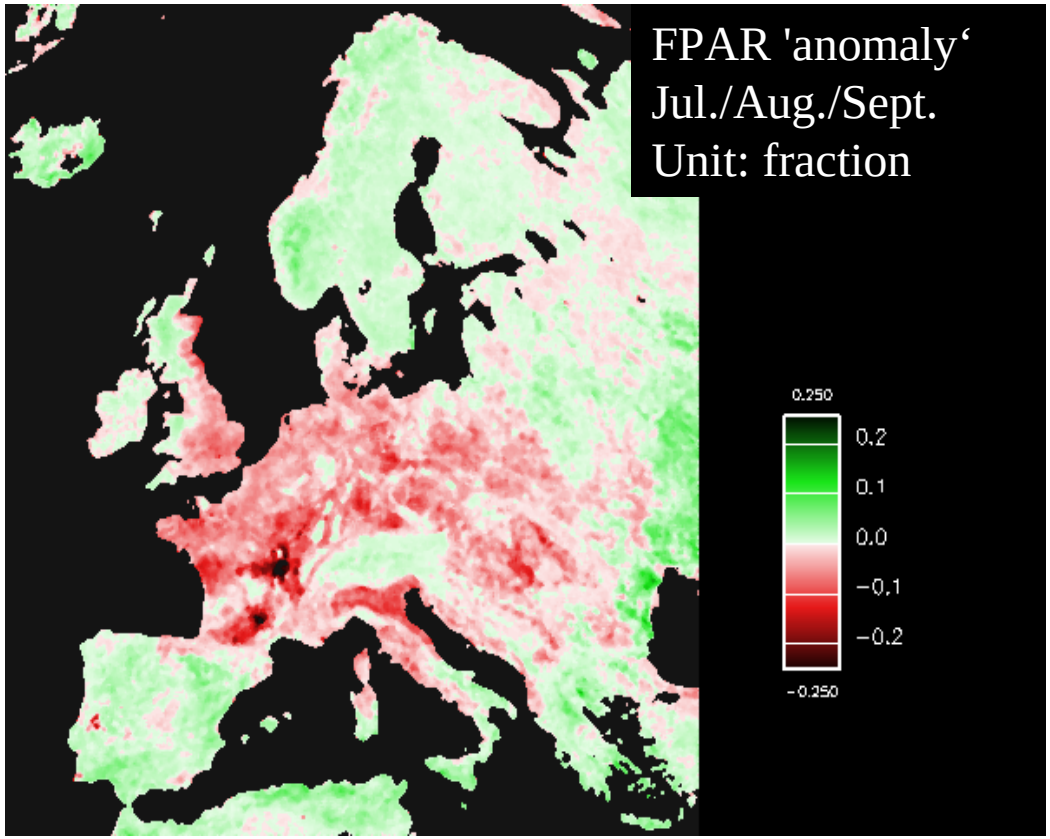
-integrates climatic, ecological, geochemical and human influences on the biosphere

TOPS enables Biospheric Monitoring Near Realtime



Based on Running, S.W and R.R. Nemani et al., Bioscience, 2004

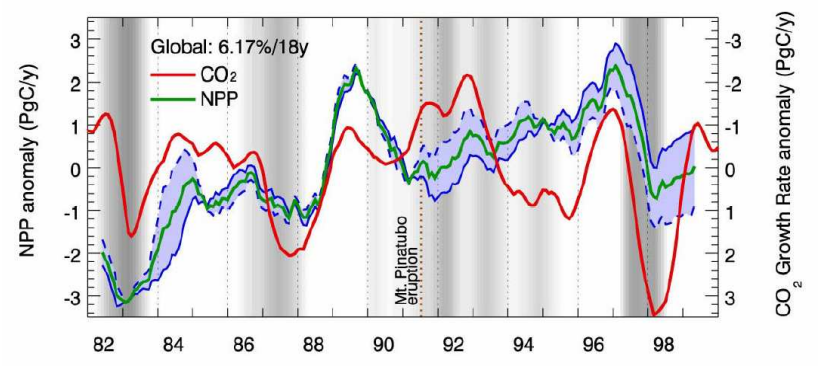
Summer 2003 European Heatwave

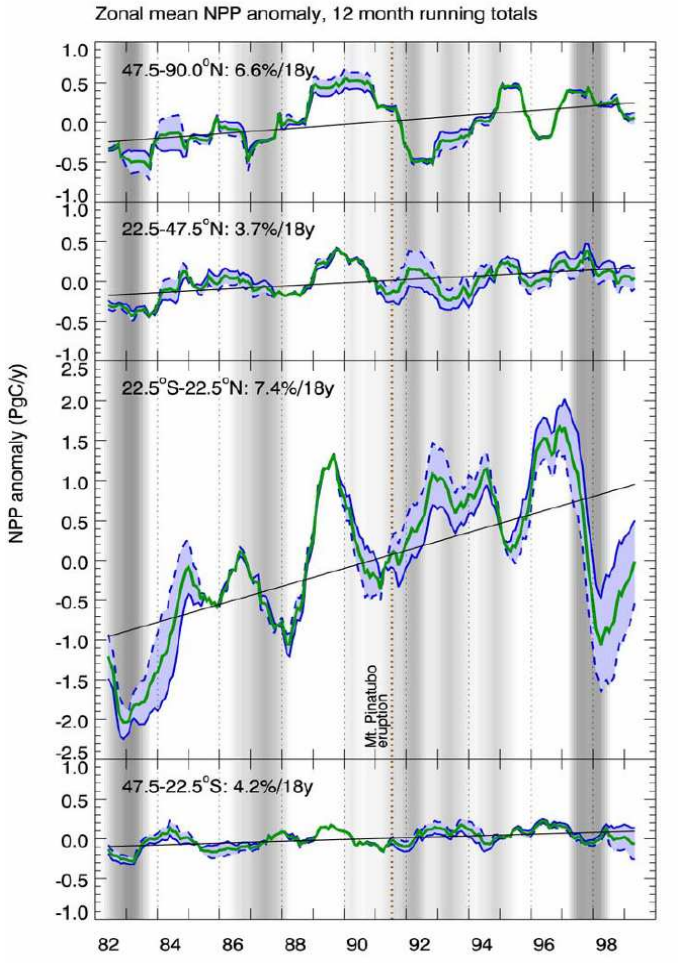


- **Warmest summer in 500 years**
- **Large scale declines in plant growth**
- **High elevation Alps did better**
- **May have contributed to the record CO_2 increase in 2003 (2.54ppm)**

Markus Reichstein, Carboeurope

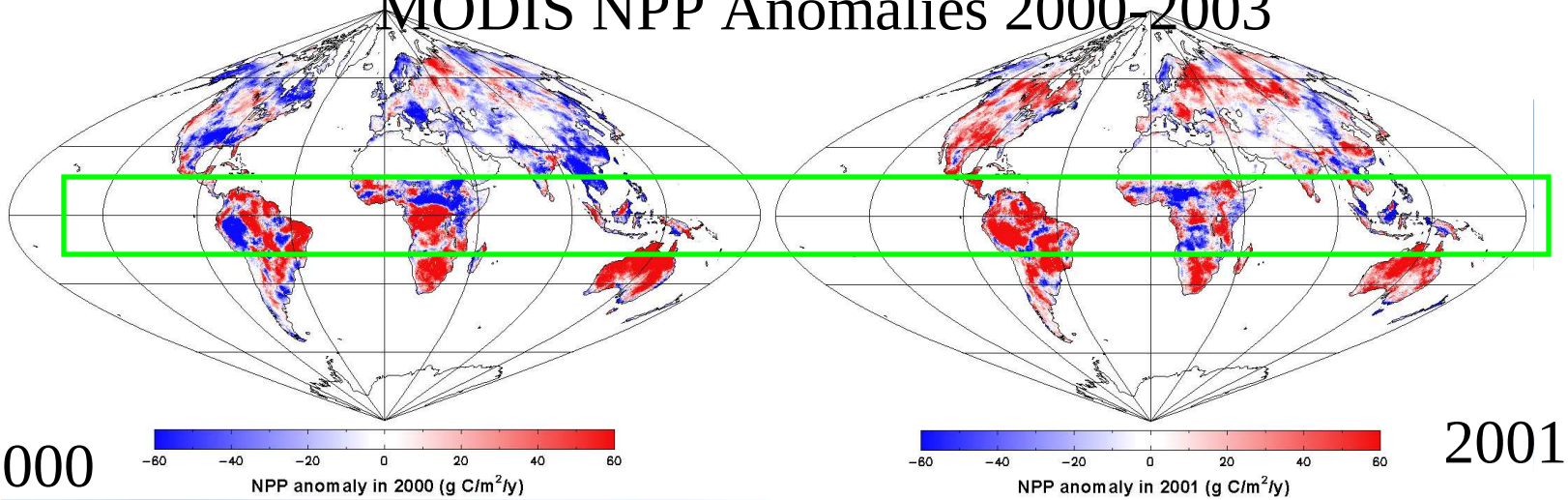
Tropical regions dominate global carbon cycling





CO_2 growth rate (ppm/y)	
2000	**1.17**
2001	**1.56**
2002	**2.04**
2003	**2.54**

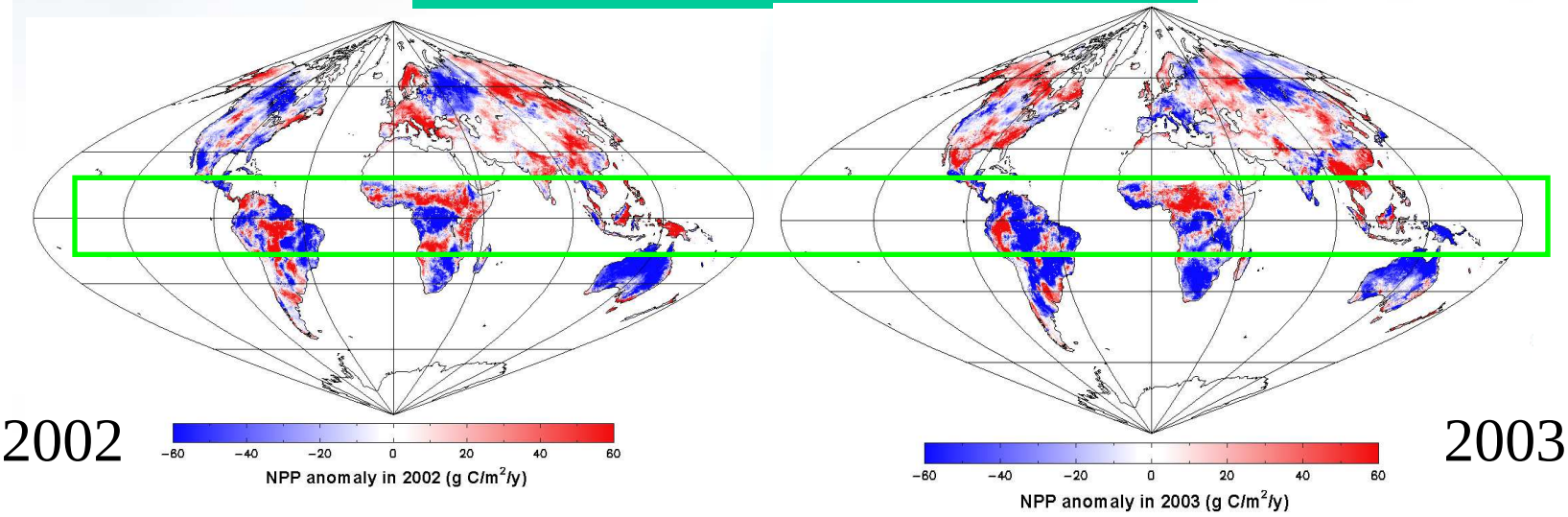
MODIS NPP Anomalies 2000-2003



2000

2001

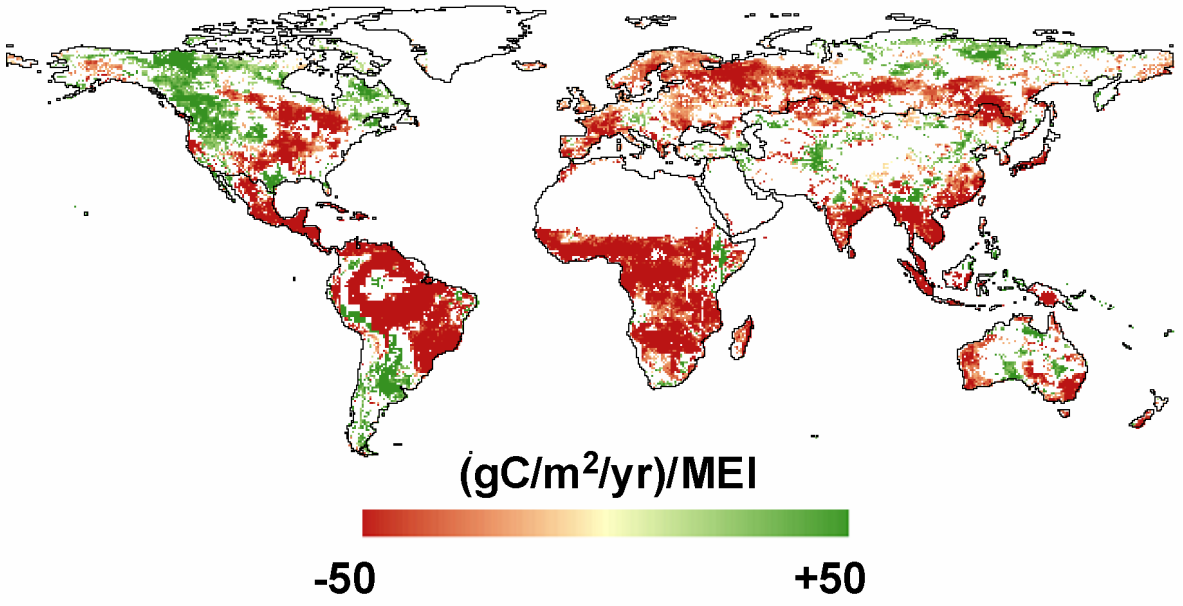
Year	NPP (Gt/y)	Trop. NPP (Gt/y)	CO2 growth rate (ppm/y)
2000	**56.06**	**32.88**	**1.17**
2001	**57.74**	**33.21**	**1.56**
2002	**55.53**	**31.97**	**2.04**
2003	**54.80**	**31.25**	**2.54**



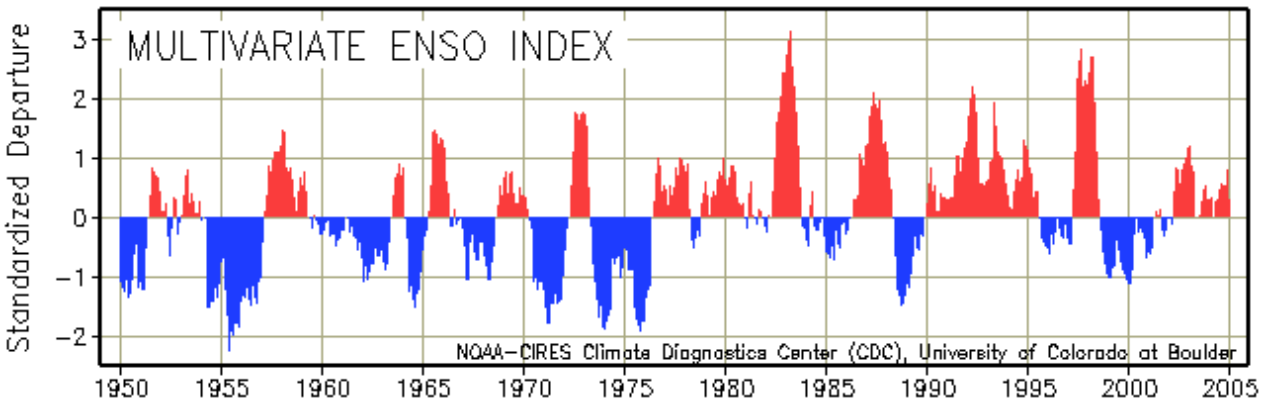
2002

2003

ENSO as a possible mechanism for the enhanced behind CO_2 growth rates during 2002-2003



Global distribution of El Nino impacts on NPP based on data from 1982 to 1999



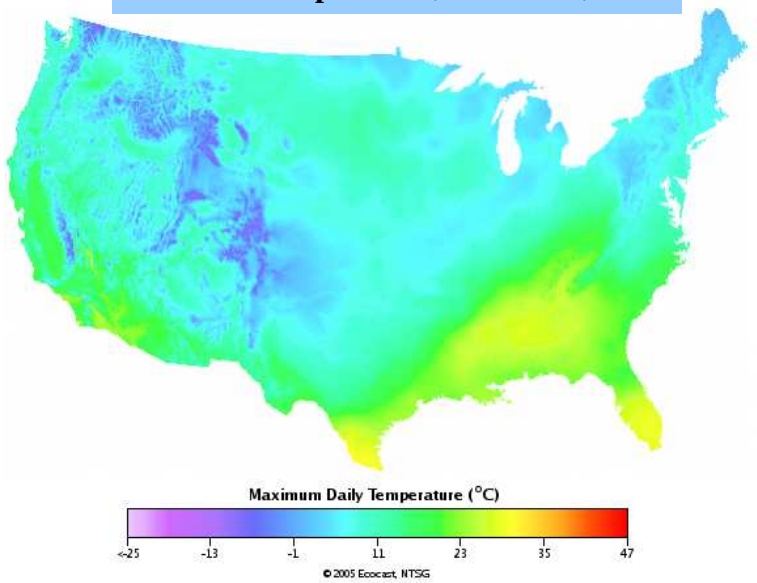
2002-2003 a mild El Nino

Hirofumi et al., JGR-atm, december, 2004
Milesi et al., Glob. Pl. Change, 2005

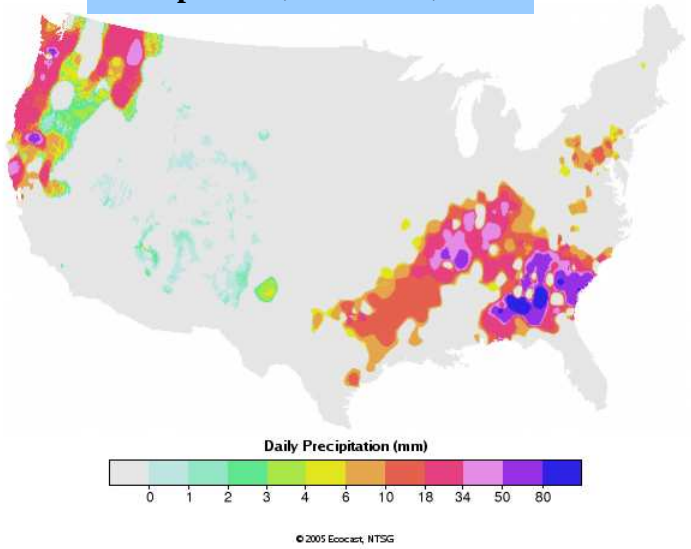
China!
Increased fire activity!

Continental Scale Nowcasts (8km)

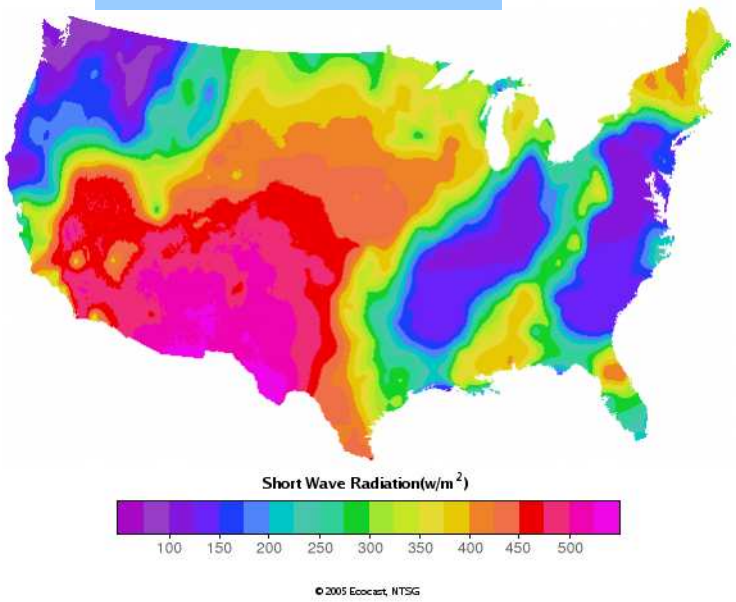
Max. Air temperature, March 27, 2005



Precipitation, March 27, 2005

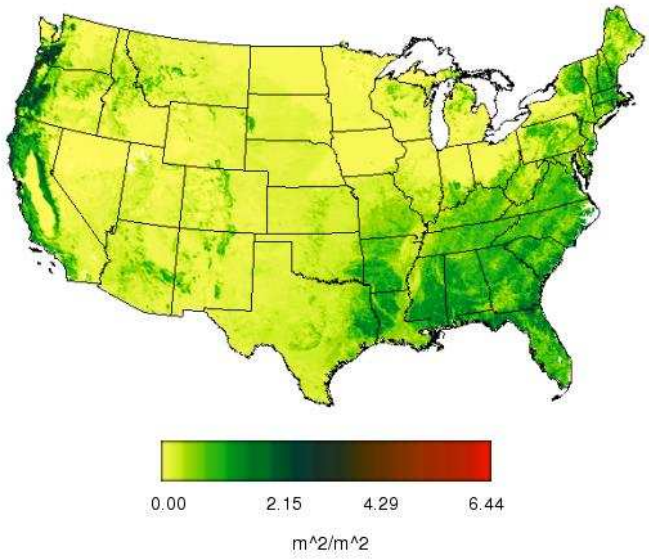


Insolation, March 27, 2005



Leaf Area Index
USA - 8km

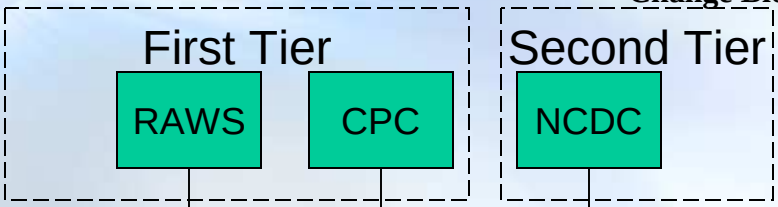
Feb 10, 2005



The Growing Season Monitoring System

based on

Jolly, M., R. Nemani and S.W. Running. 2005. A general model to predict foliar phenology in response to climate. Global Change Biology (in press).



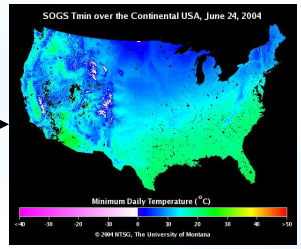
SOGS

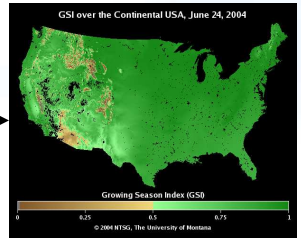
GSI Phenology Model

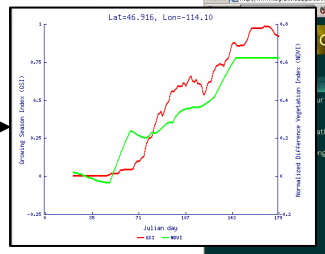
MODIS NDVI And RG / DA product Retrieval

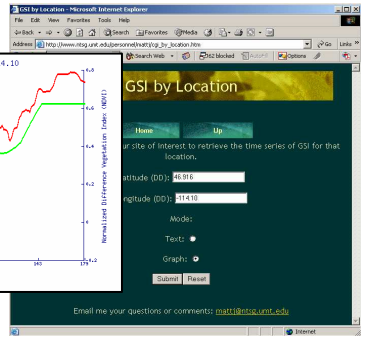
Point Retrieval Interface

Image Generator



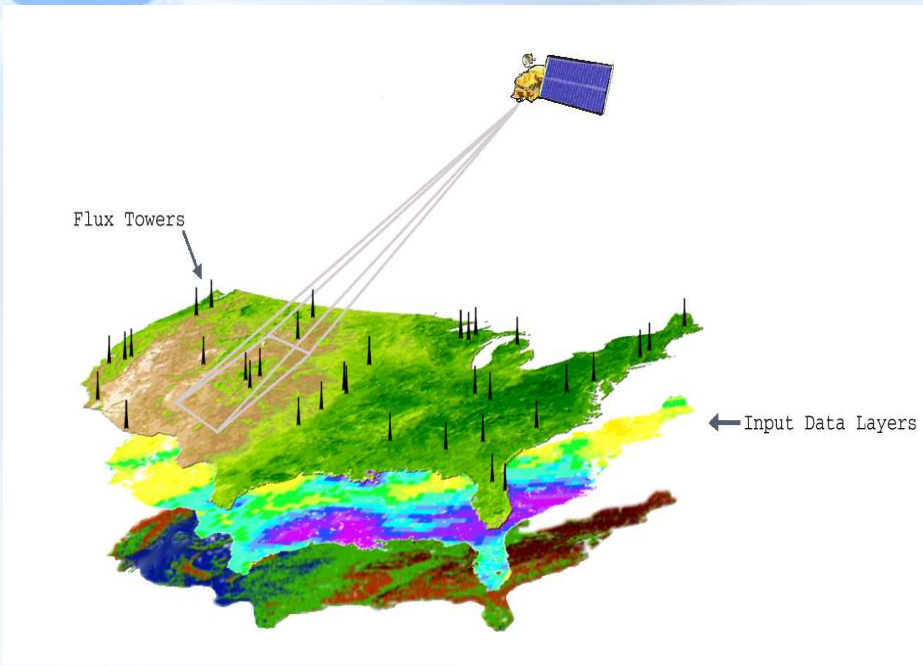






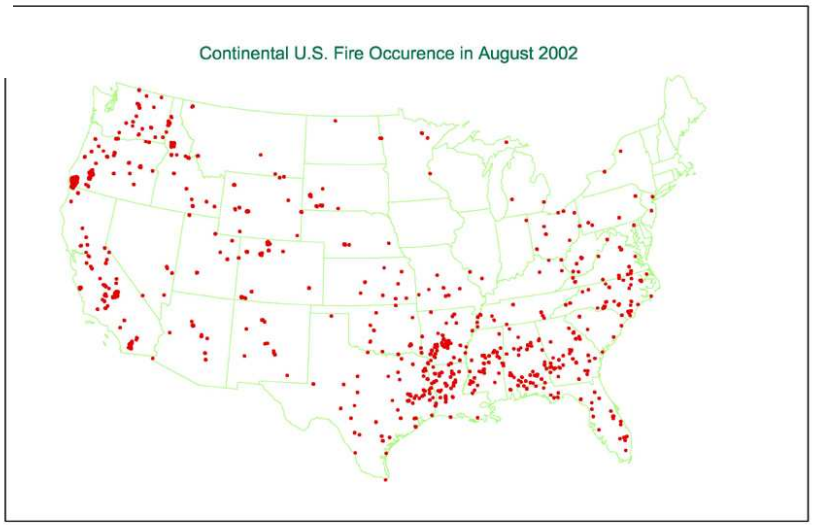
Data-driven models

TOPS data in mapping wildland fire risk



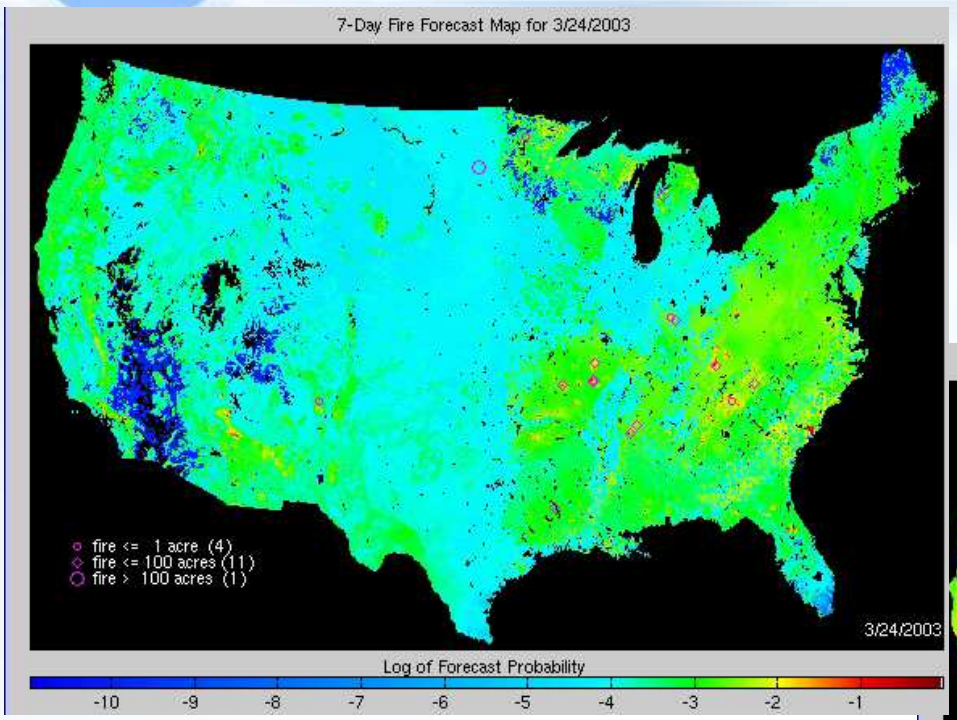
Train the algorithms on all the non-arson fires during 2000-2002

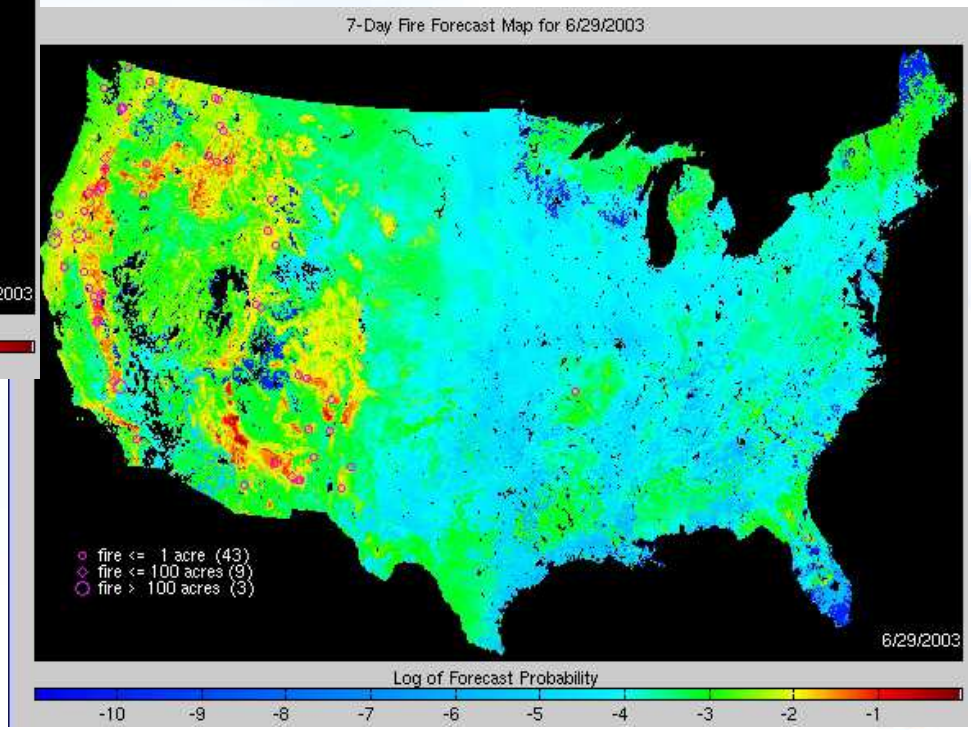
Methods include:
Support Vector Machines
Artificial Neural Networks
Logistic Regression



Brian Bonnlander/Clark Glymour/Votava, IHMC/ARC

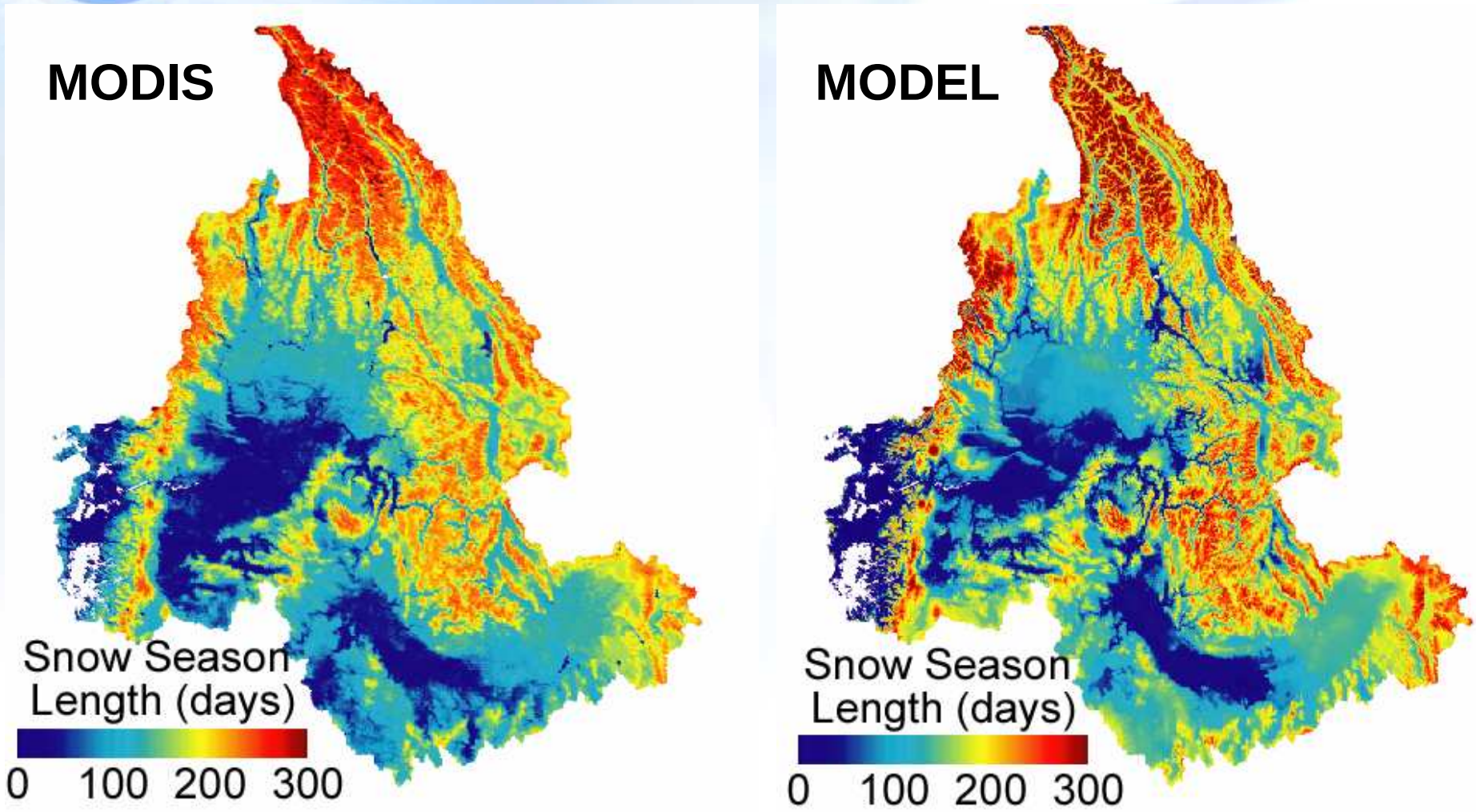
Predicting fire risk





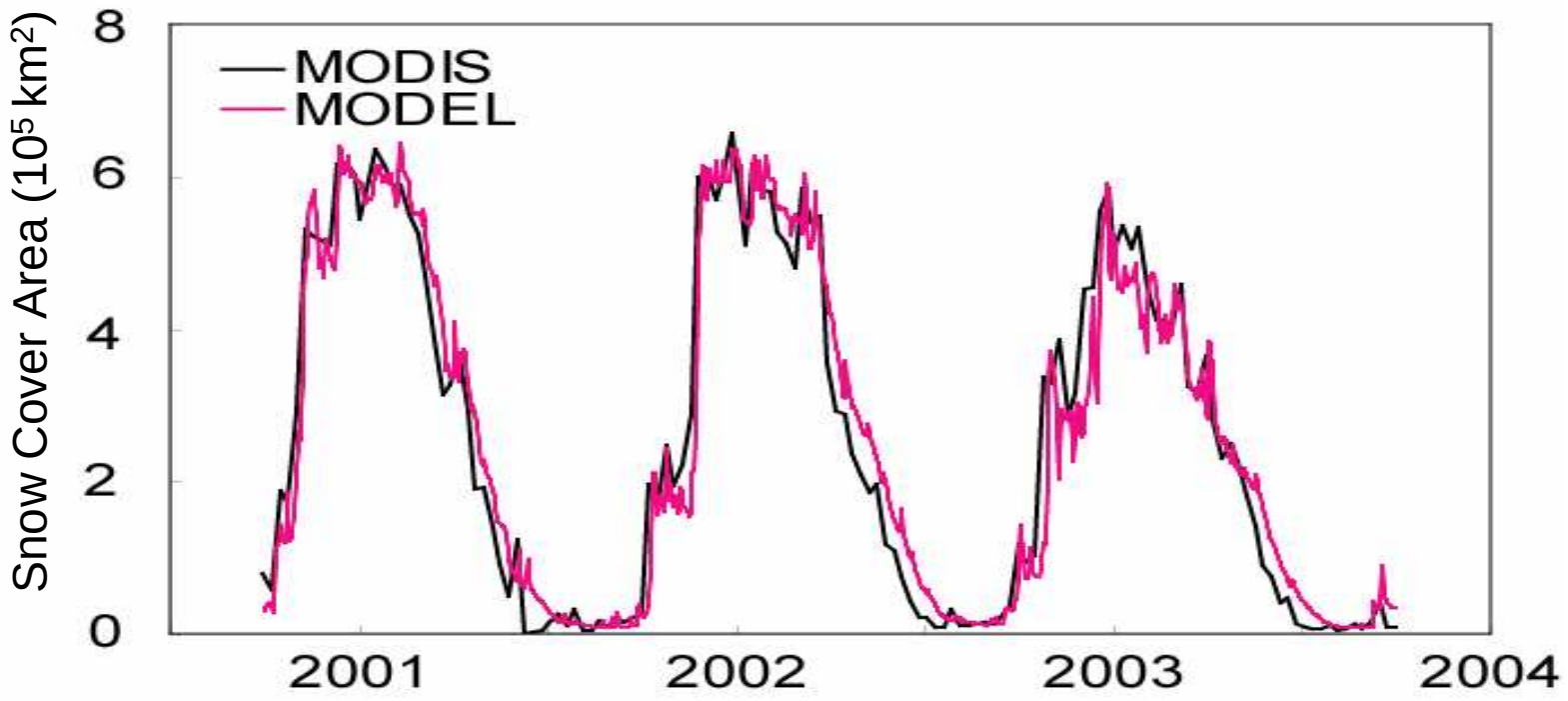
Brian Bonnlander/Clark Glymour/Votava, IHMC/ARC

Hydrologic modeling with TOPS



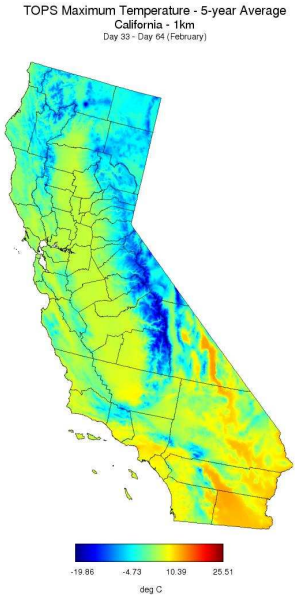
Itchii/ARC/SJSU

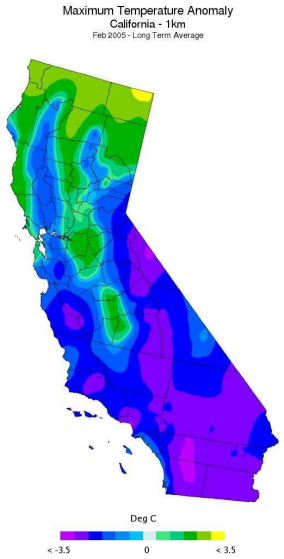
Snow Cover Area : Interannual Variability

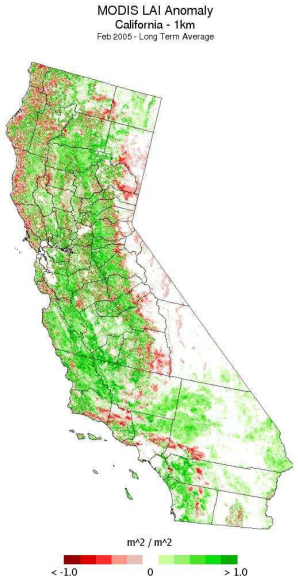


Itchii/ARC/SJSU

TOPS - California







Direct Broadcast
TERRA/AQUA/MODIS

GOES based Insolation at 2km

Seasonal forecasts from Scripps

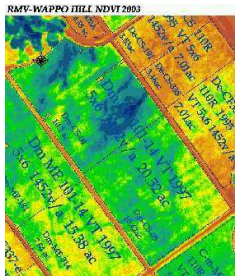
Models include:
BGC, RHESSys, CASA, VSIM

Partners include:
Napa vintners, California Health, Dept. of Water Resources, CIMMIS,

Maintaining optimal water stress for better vintages

TOPS Irrigation Scheduling

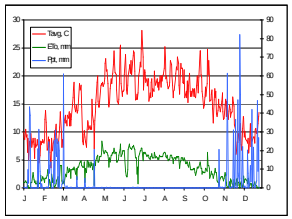
LAI from NDVI Imagery



Limited Farm-scale Soils Data

Crop Params from Variety

Met Data from CIMIS



Forecast from NWS

VSIM Model

Inputs
Climate: ETo, PPt, T
LAI:NDVI
Soils: Geophys. Data

Vine ET
ETv = ETo * kv

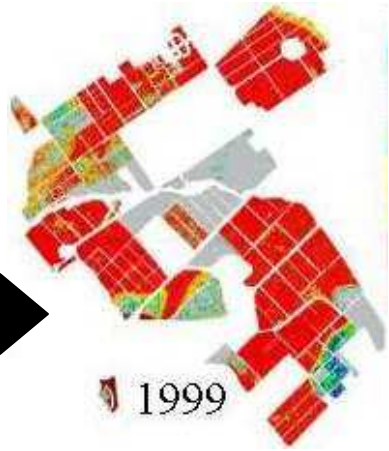
Vine Water Stress = f(Soil Moisture)

Data
Water

Cover Crop ET
ETc = ETo * kc

Soil Moisture = Precip + Irrig – ET - Runoff

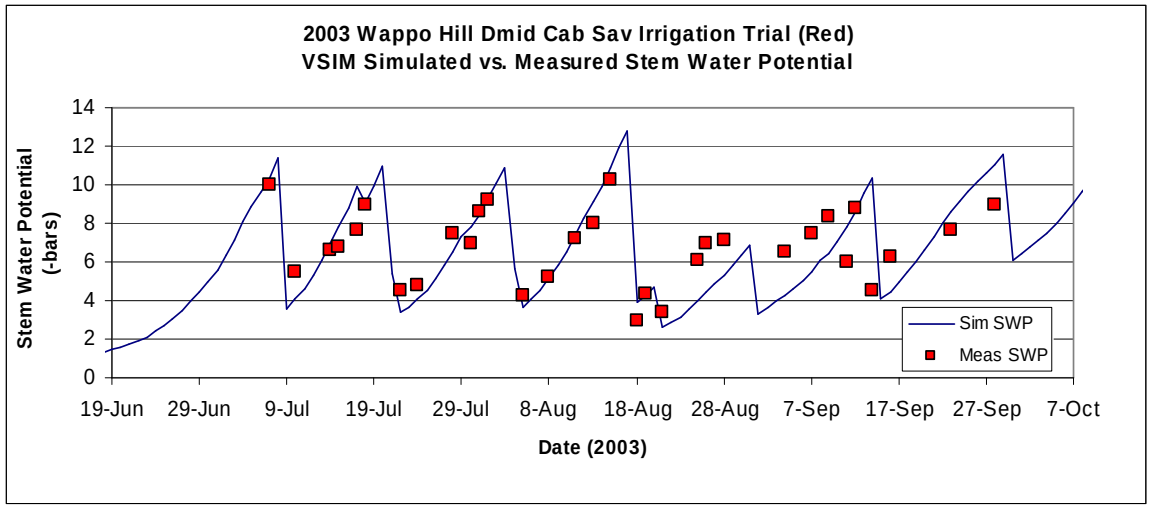
Runoff = SM - SWHC

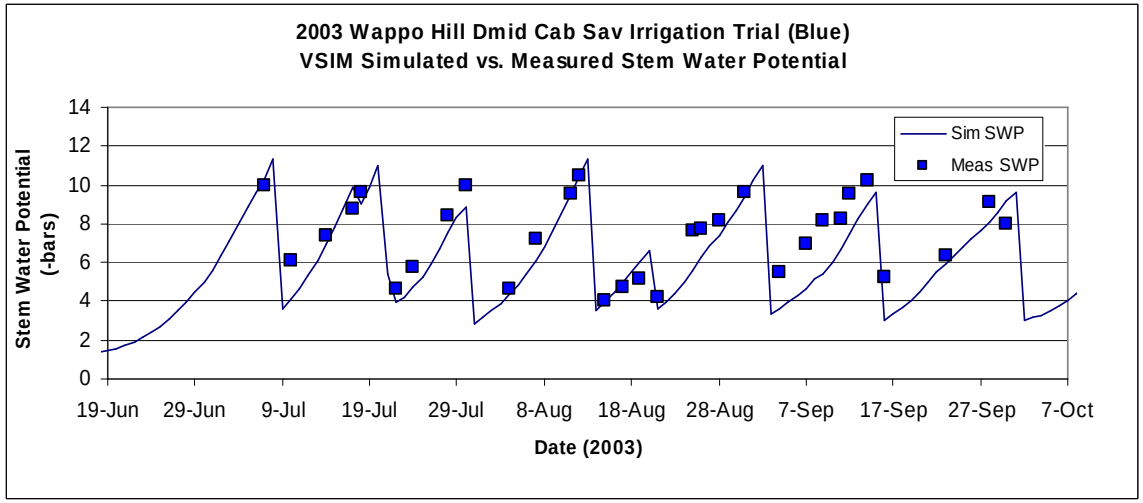


Irrigation Forecasts
Crop Monitoring

Inputs → Modeling → Outputs

Model tests





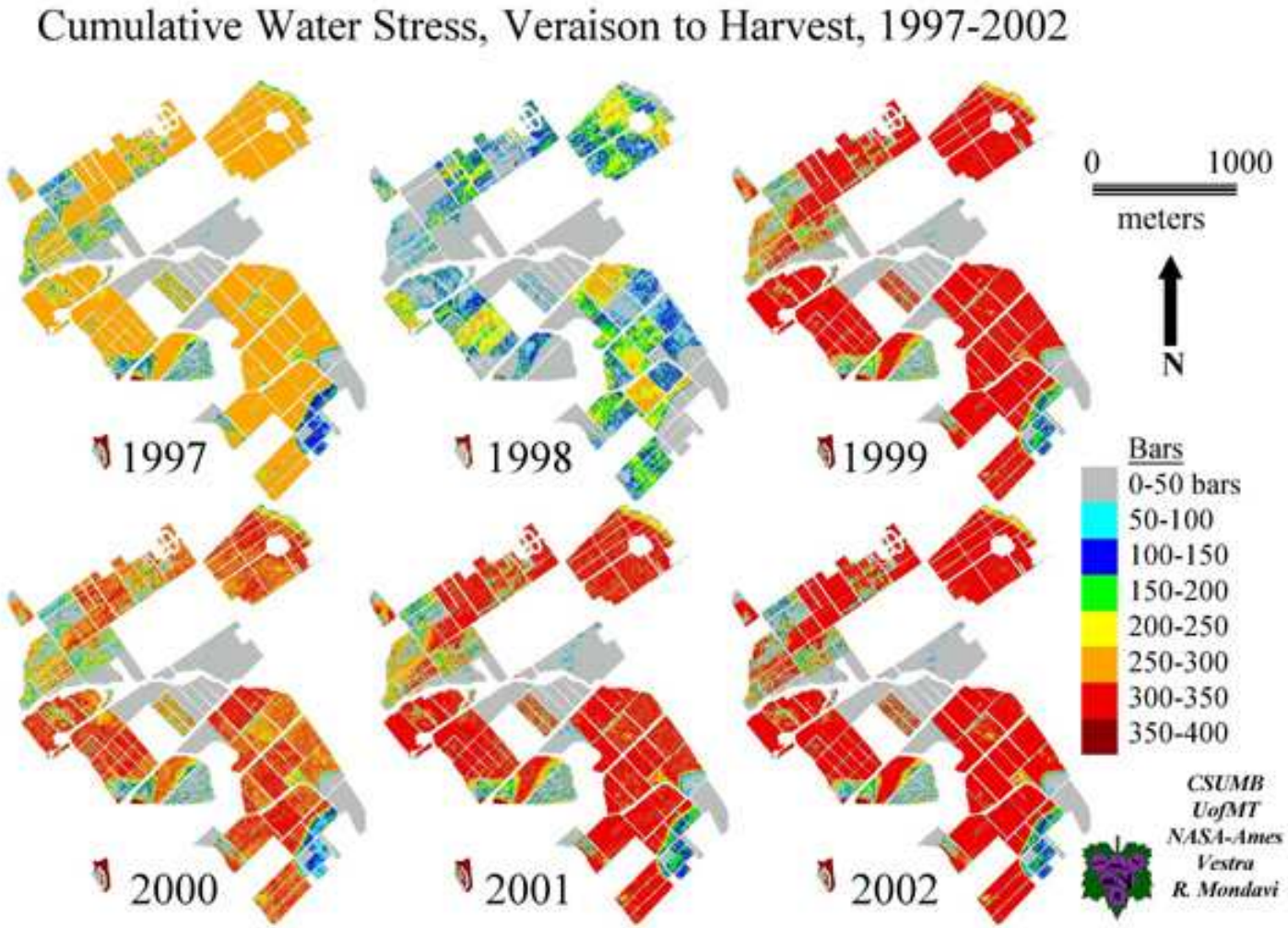
Red & Blue Treatments

$R^2 = 0.85$

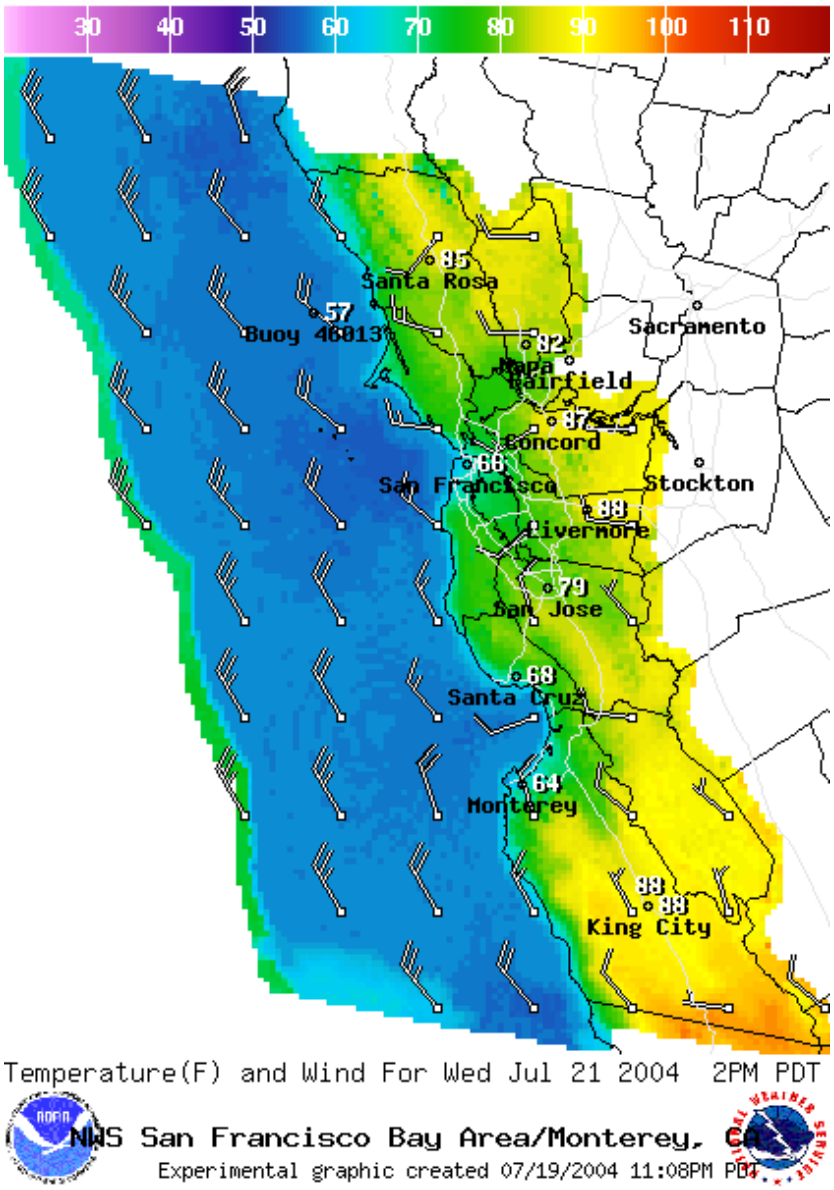
(Stem Water Potential Measurements courtesy of Thibaut Scholasch, RMV)

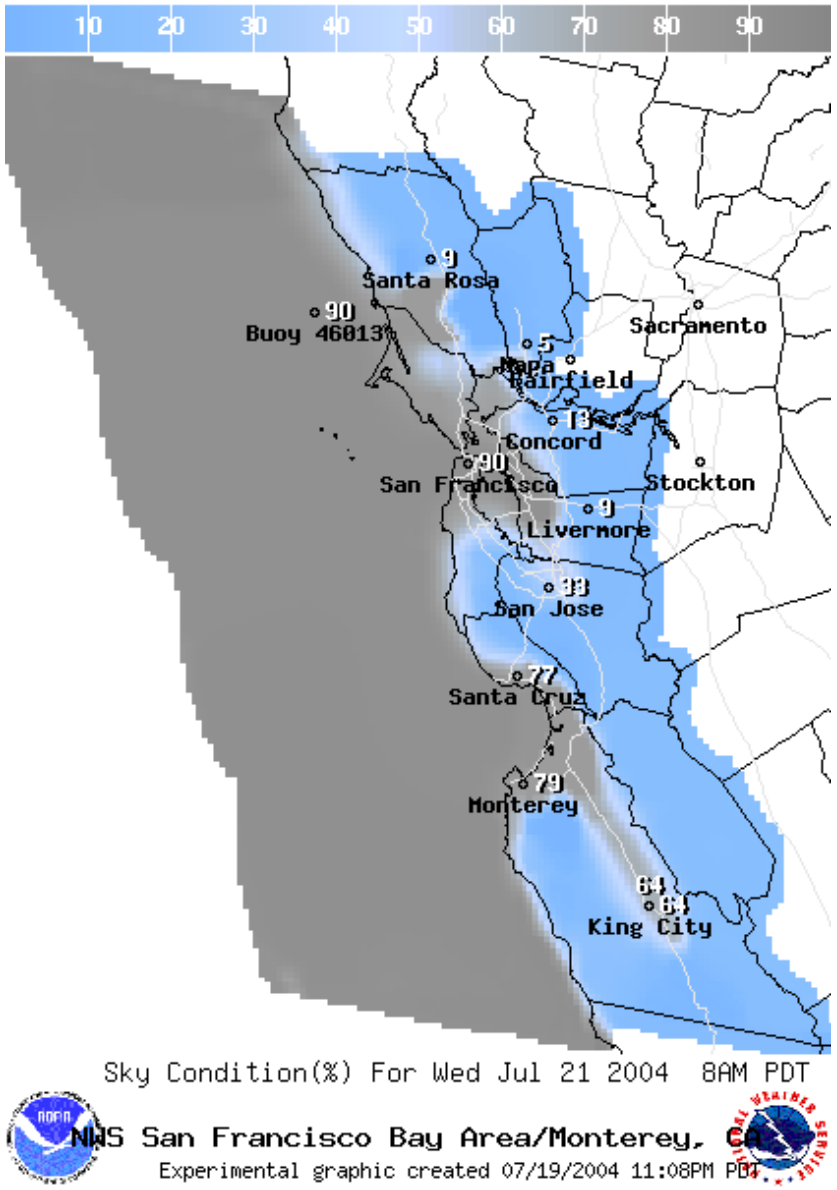
Modeled water stress as a predictor of vintage

1997 moderate water stress, best vintage



Enhancing National Weather Service Forecasts





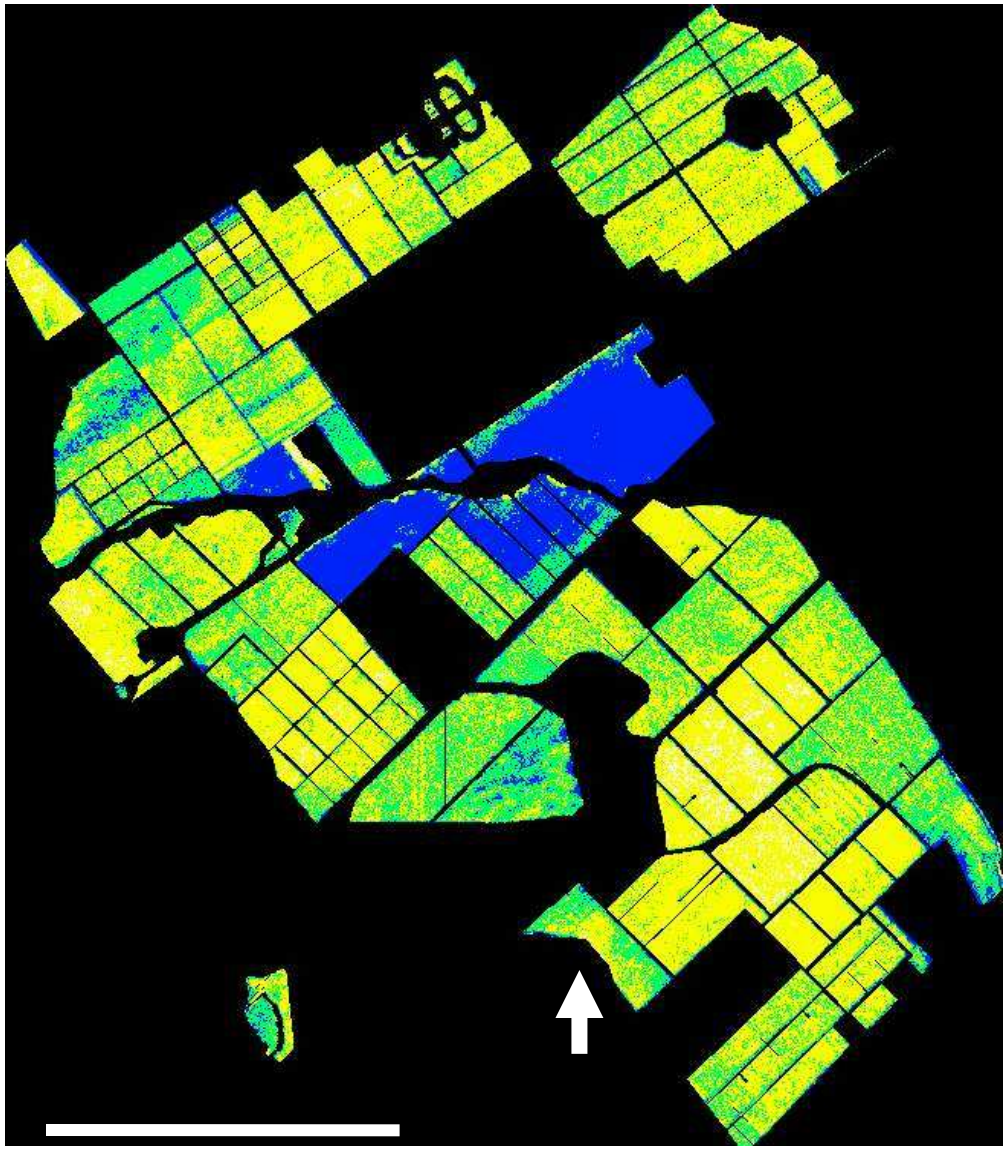
Irrigation Forecast
for week of July 19-26, 2004

Tokalon Vineyard,
Oakville, CA

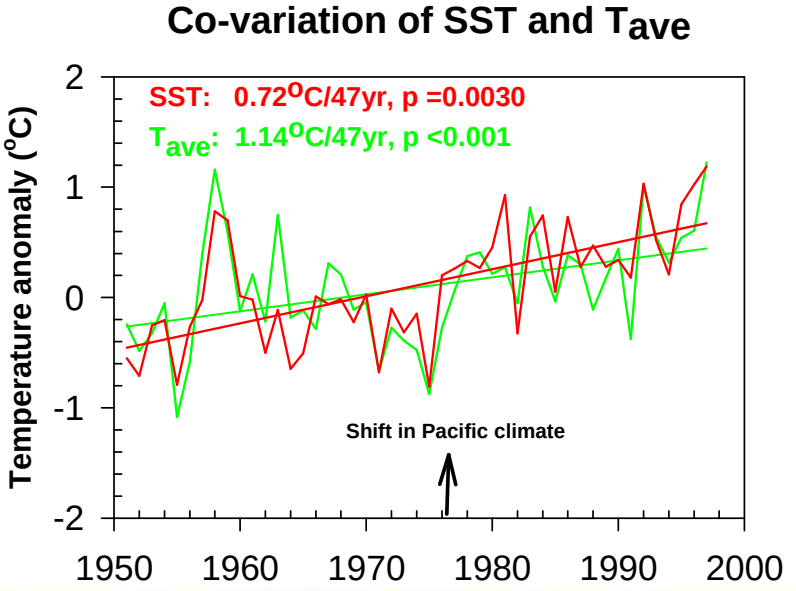
CIMIS Measured Weather Data
through July 18, 2004

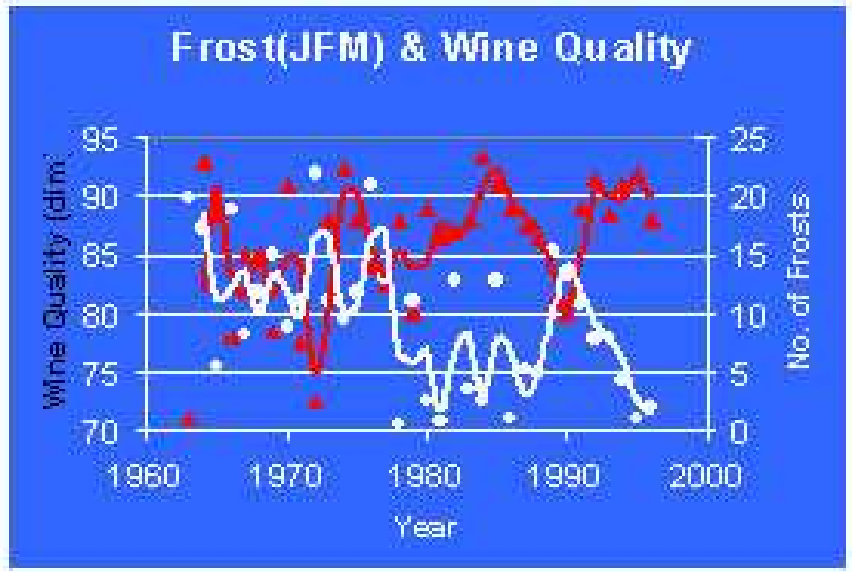
NWS Forecast Weather Data
July 19-26, 2004

Forecast Irrigation (mm)



interannual climate-wine quality

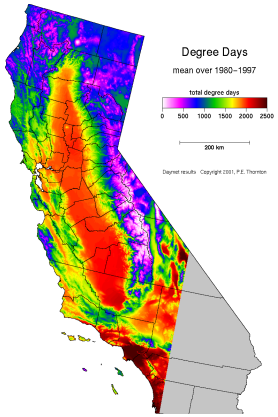


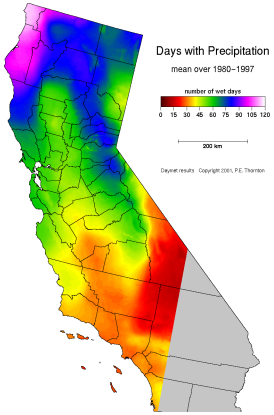


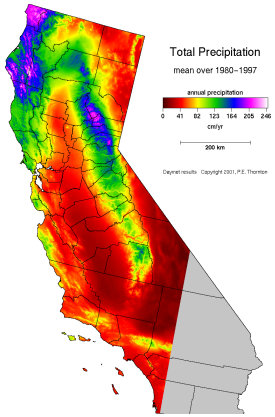
Nemani et al., 2001 Climate Research

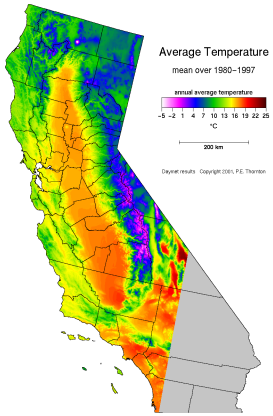
changing appellations!!

Average climatic conditions 1980 - 1997

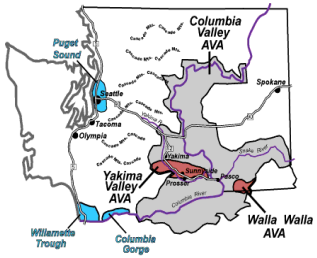


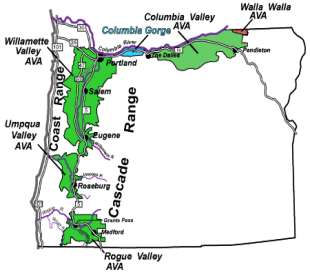


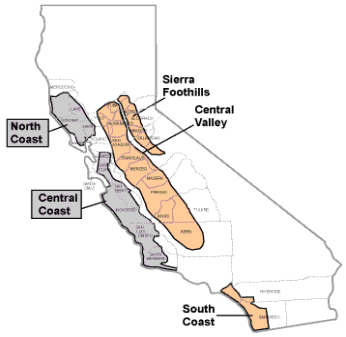


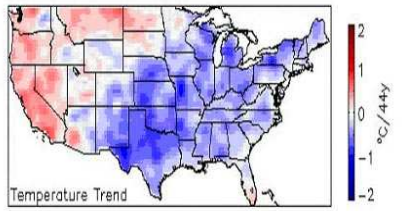


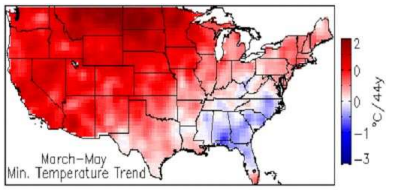
Climatic changes from 1950 - 1993

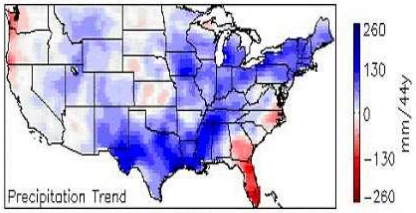












Summary

Unprecedented data volumes and sources need a comprehensive framework

retaining and maintaining data sources is important

Working with large data sets requires robust automation

we can learn a lot from the tech industry

Potential for mimicking the weather service with ecological nowcasts and forecasts of various lead times

weaknesses include rule-based methods, past as indicator of future

Characterizing and communicating the uncertainty in ecological forecasts remains a challenge

non-linear responses, new thresholds, sequence of events complicate uncertainty estimation

more information at: http://ecocast.arc.nasa.gov

the end

http://ecocast.arc.nasa.gov

ECOLOGICAL FORECASTING

Monitoring, Modeling, and Forecasting the Impacts of Climate Variability and Change on Ecosystems

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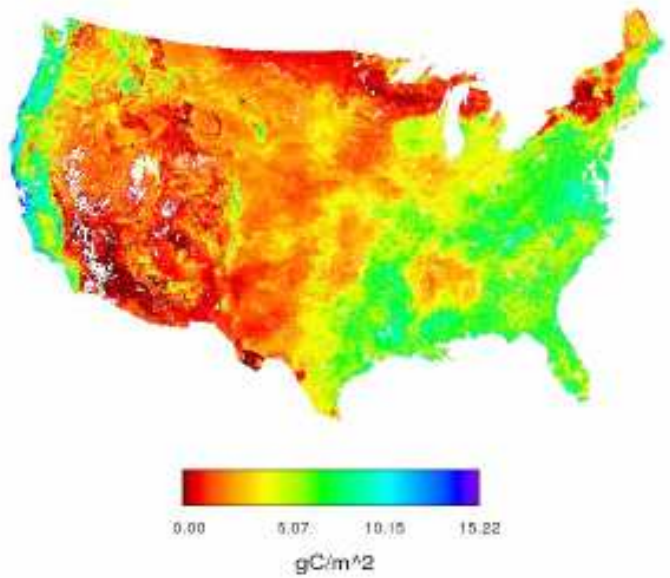
Daily Ecocast

Daily GPP 6/20/2004



< previous | current > more images & data

What is Ecocasting?

Ecological forecasting (or 'ecocasting') is the prediction of ecosystem parameters. NASA Ames is developing advanced computing technologies for converting massive streams of satellite remote sensing data into ecocasts that are easy to read and use.

NASA Ames, UWF IHMC, CMU, CSUMB, UMT, UW, and Fetch Technologies are collaborating to develop a distributed computing architecture for the production of ecocasts from satellite remote sensing data and other ancillary data sources. Applications of the Ecocast technology include fire forecasting, crop quality forecasting, snowpack and flood monitoring, and identification of anomalies in the carbon cycle and other biospheric processes.

News

Daily updates of biospheric parameters are now available. See below for a selection of available parameters. Or download data and images here.

Nowcasts & Forecasts

- Meteorology
- Hydrology
- Carbon Cycle

Questions & Comments
updated 06/18/04

NASA Official: Rama Nemani
Curator: Forrest Melton