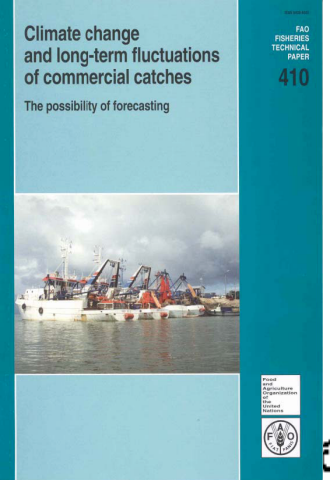
Climate & Marine Ecosystems (or Axel Ljungman, where are you when we need you?)

Woody Turner
NASA Science Mission Directorate

NOAA-NASA Workshop on Integrating Satellite Data into Ecosystem-based Management of Living Marine Resources
Monterey Bay Aquarium Research Institute
Moss Landing, CA
May 3, 2006



Climate, Fish, and Time

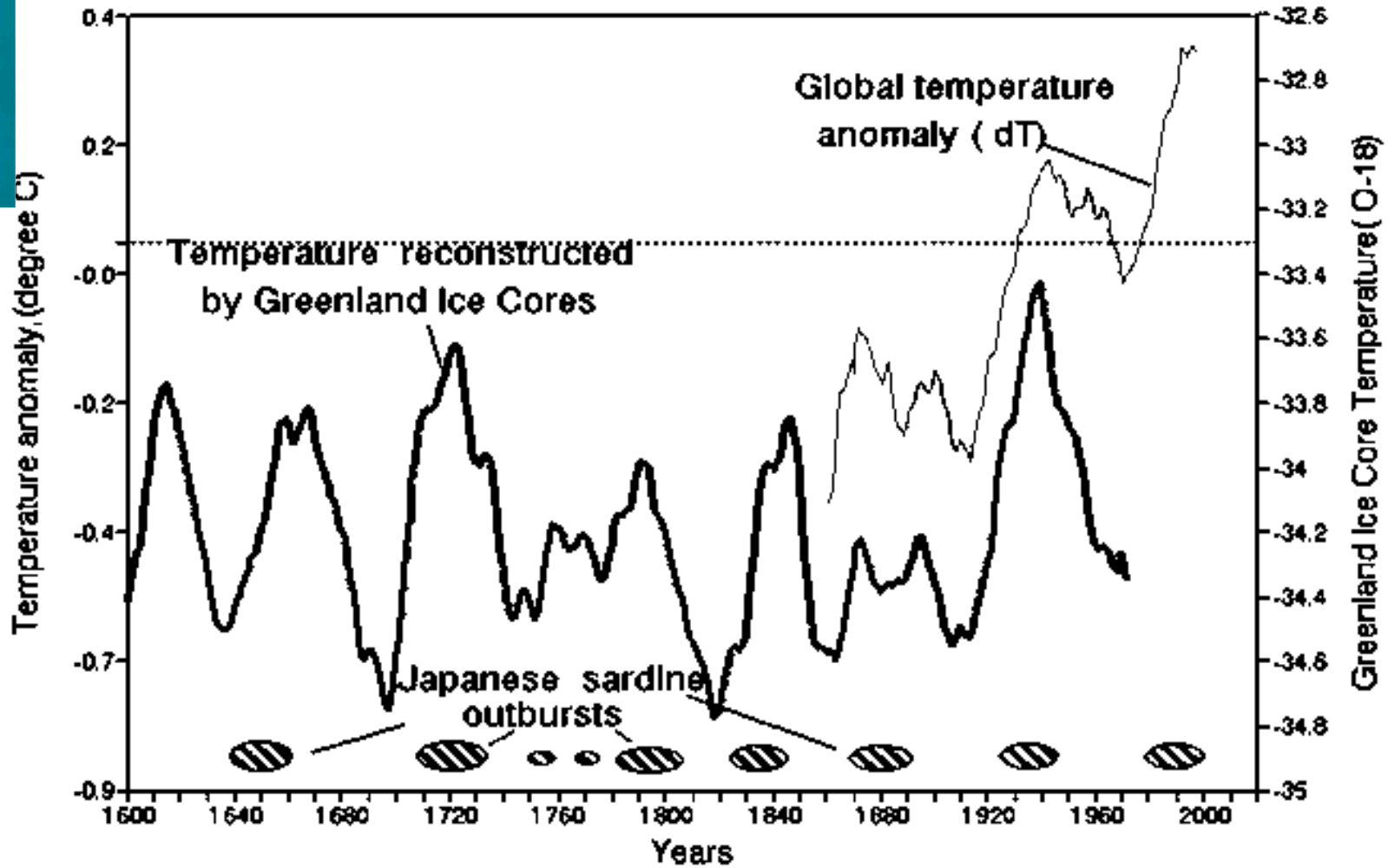
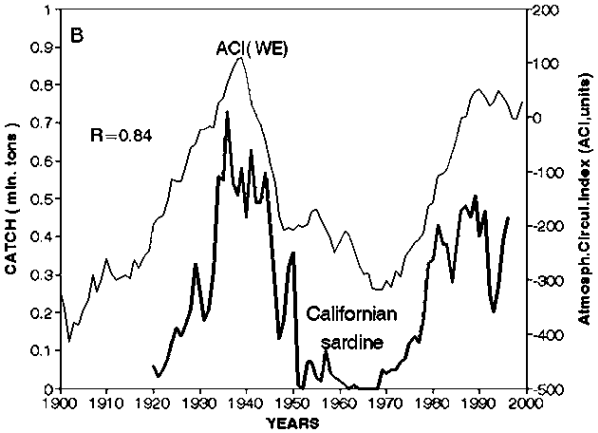
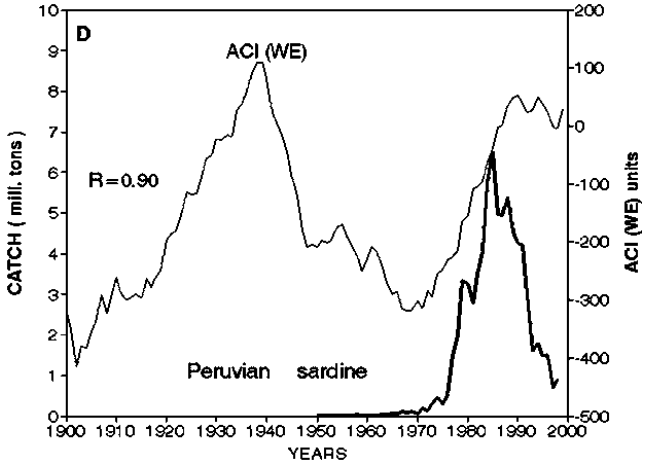


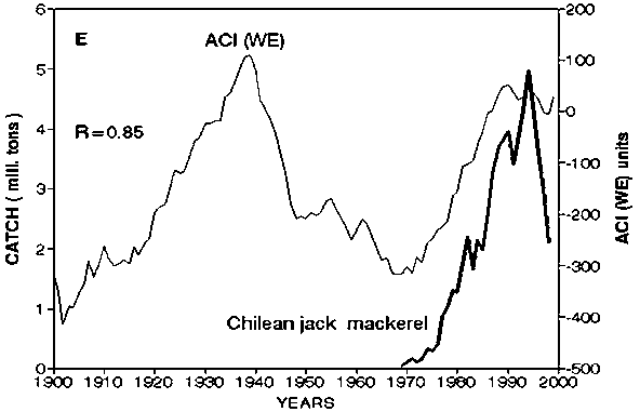
Figure 6.2 Cyclic temperature fluctuations and Japanese sardine outbursts for last 400 years by Japanese historic chronicles 1640-1880 and for 1920-1998 from fisheries statistics. !

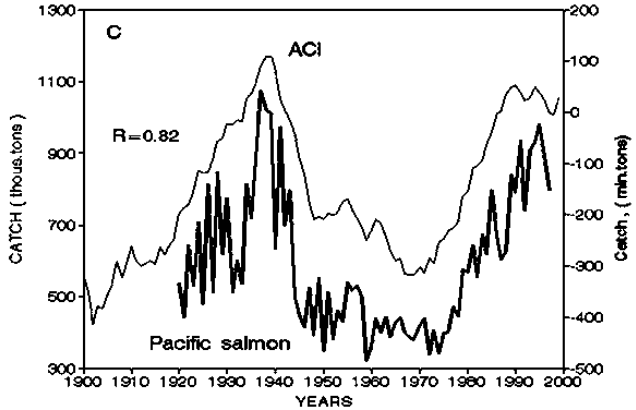
(From: FAO. 2001. Climate change and long-term fluctuations of commercial catches: the possibility of forecasting, by L.B. Klyashtorin. FAO Fisheries Technical Paper No. 410. Rome. 86 pp. Thanks to Gary Sharp for the reference)

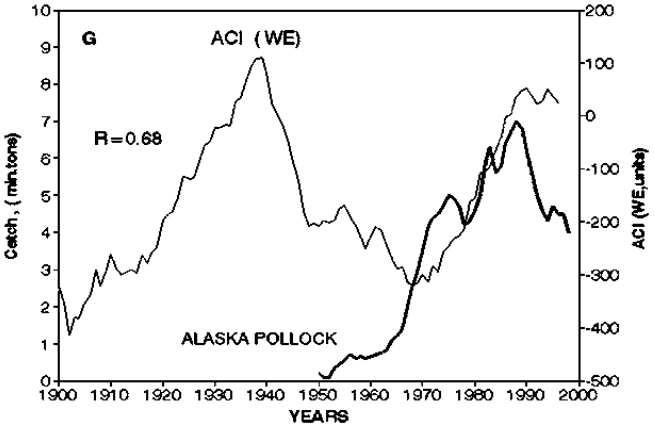
ACI "Zonal" Species

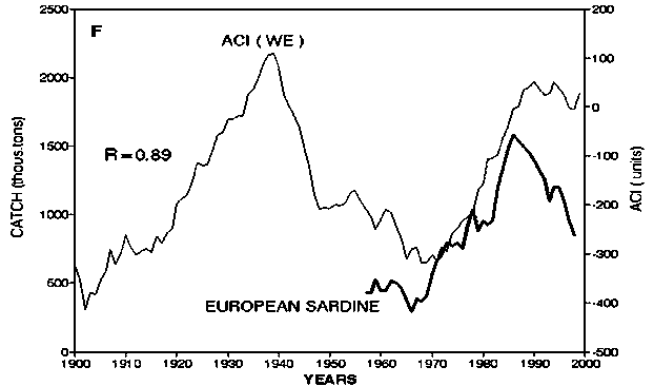


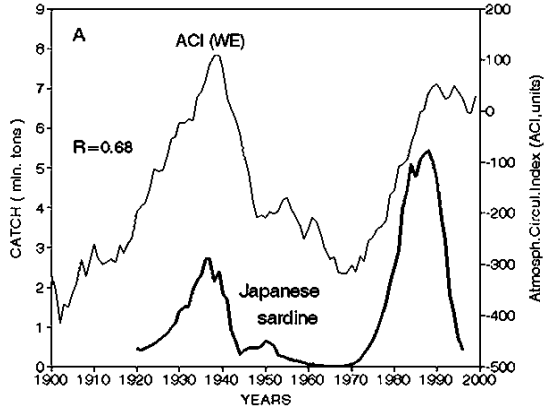






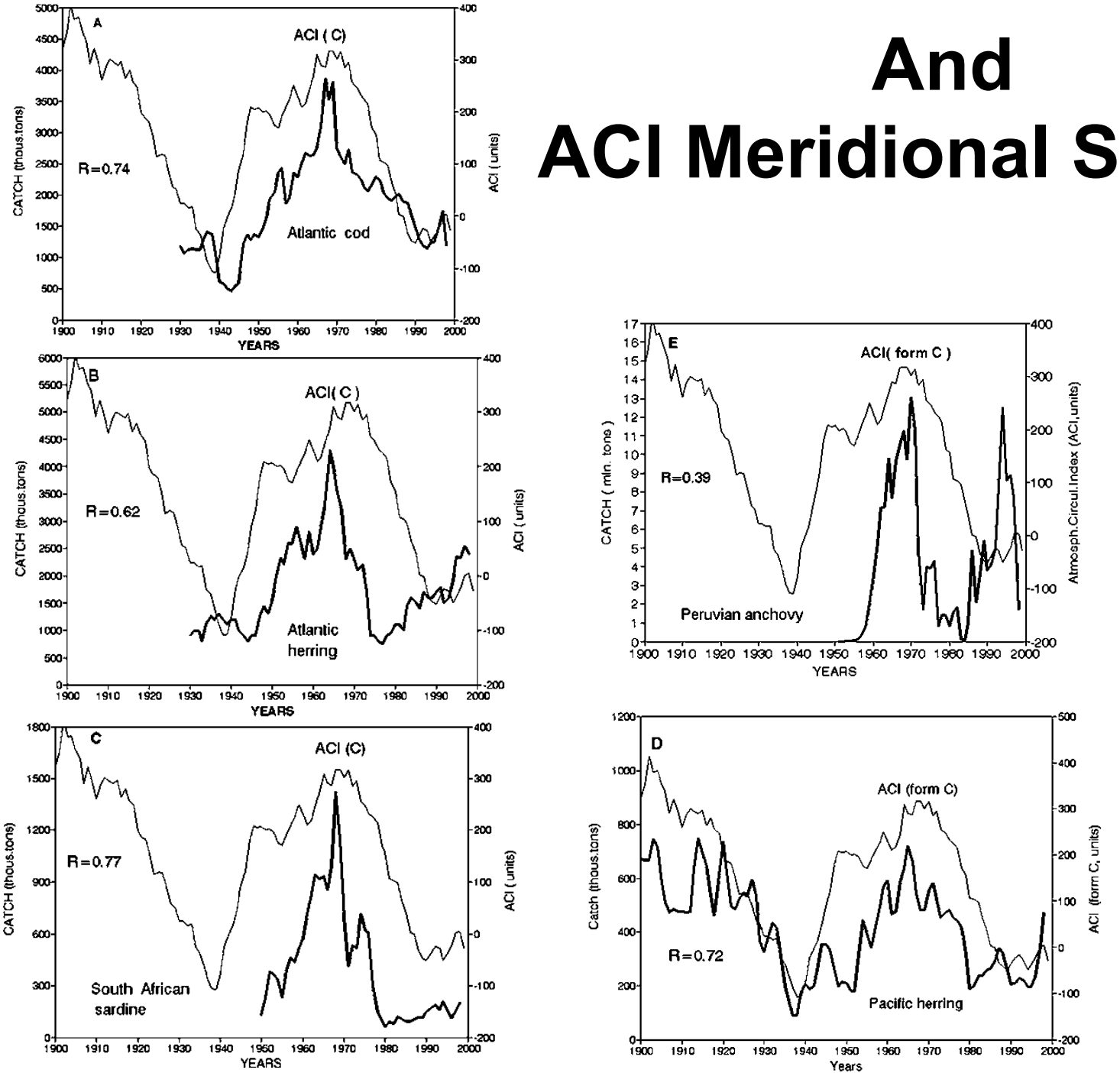






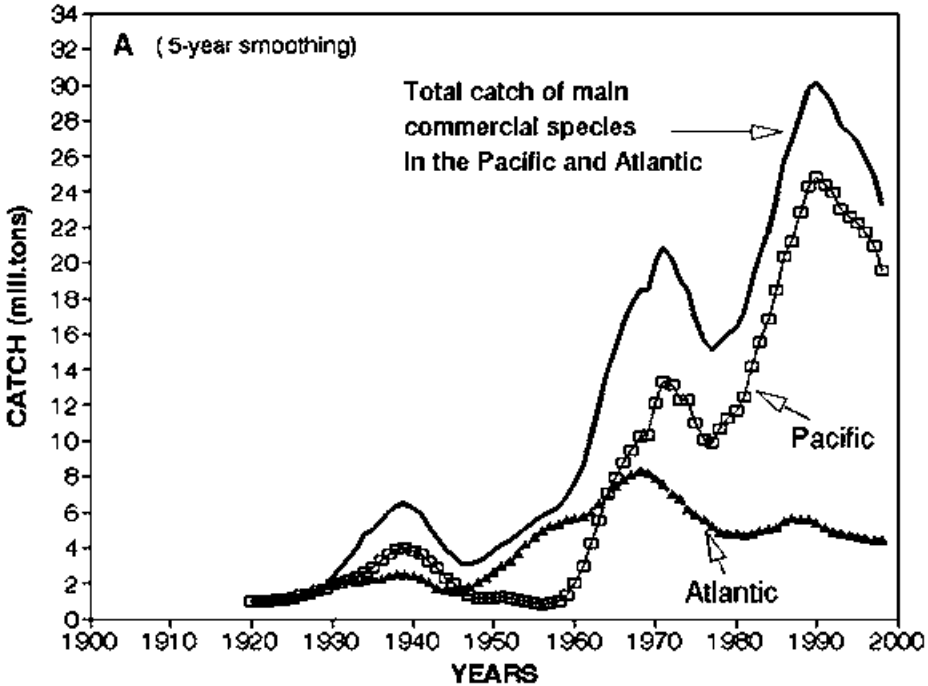
(From: FAO. 2001. Climate change and long-term fluctuations of commercial catches: the possibility of forecasting, by L.B. Klyashtorin. FAO Fisheries Technical Paper No. 410. Rome. 86 pp.)

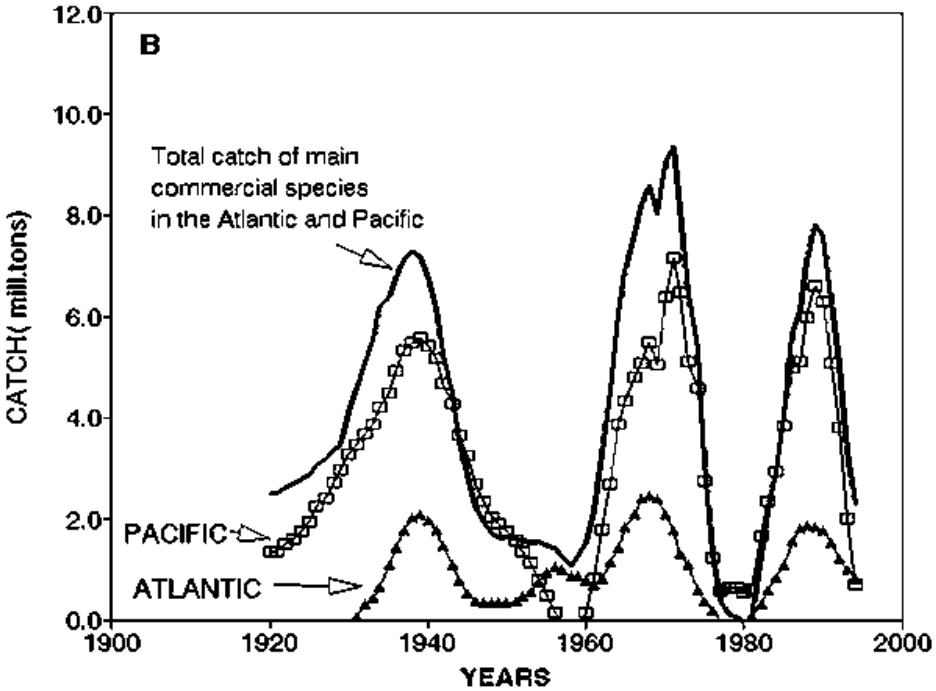
And
ACI Meridional Species



(From: FAO. 2001. Climate change and long-term fluctuations of commercial catches: the possibility of forecasting, by L.B. Klyashtorin. FAO Fisheries Technical Paper No. 410. Rome. 86 pp.)

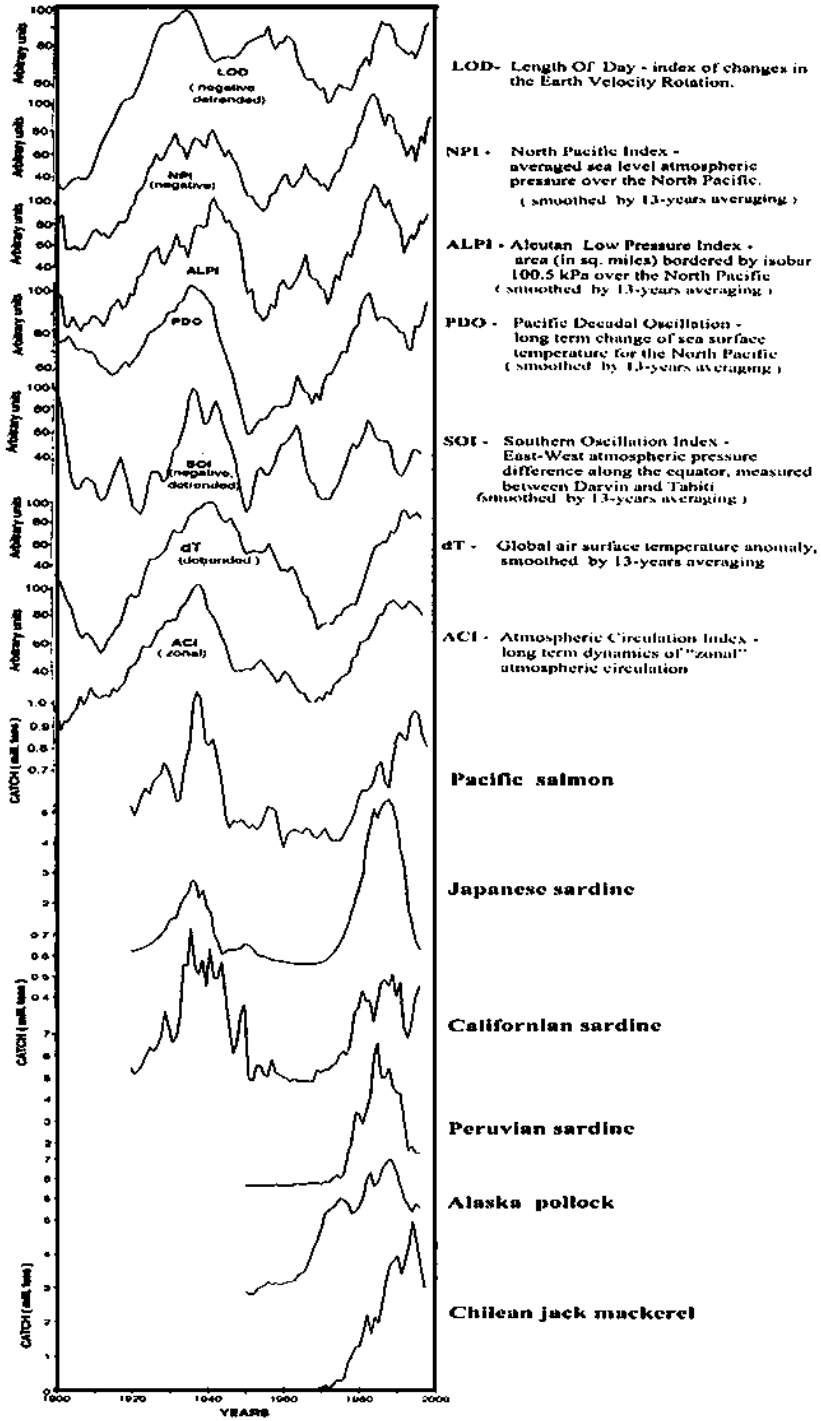
After Removing the LT Trend of Increasing Catch



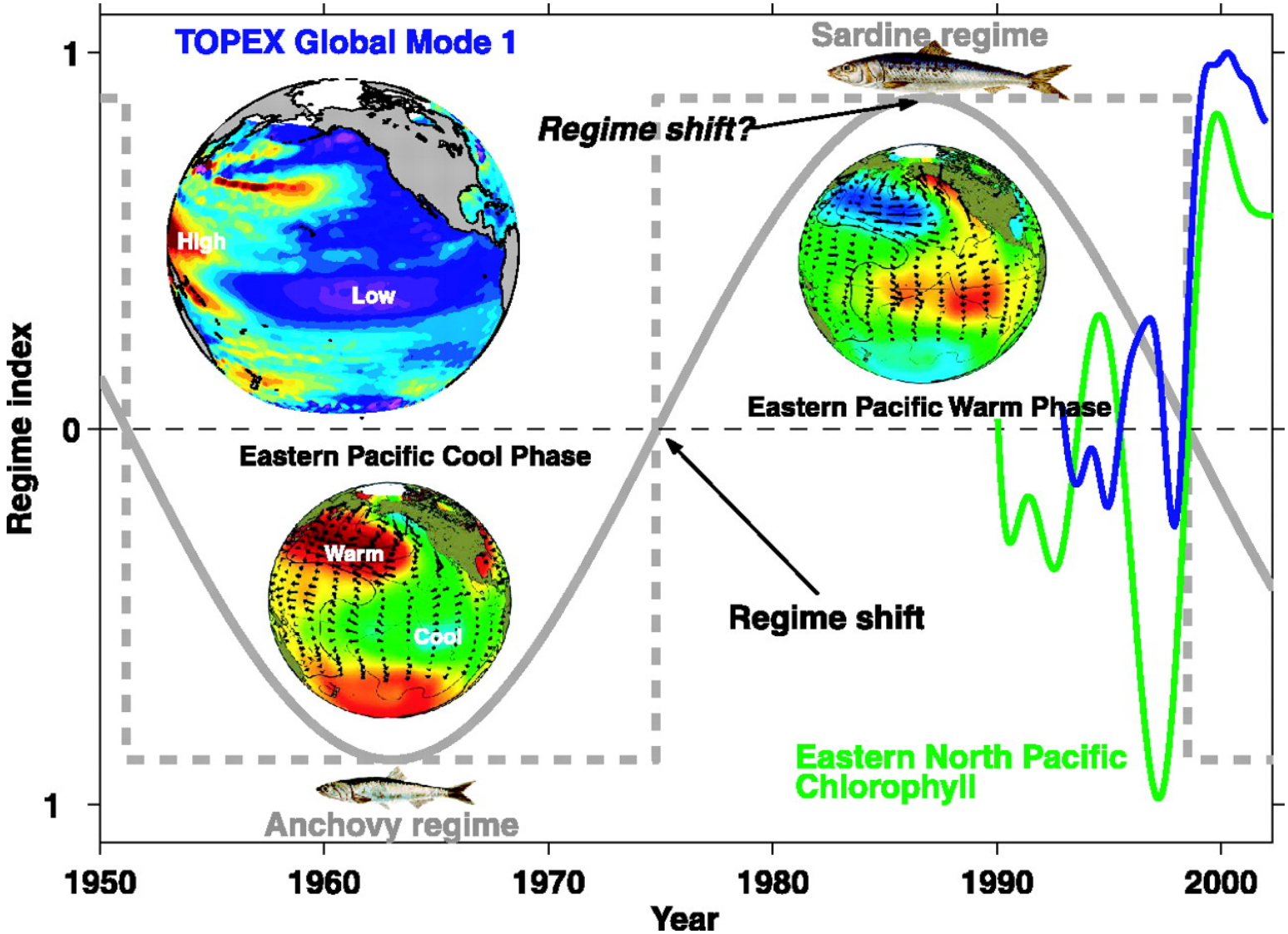


(From: FAO. 2001. Climate change and long-term fluctuations of commercial catches: the possibility of forecasting, by L.B. Klyashtorin. FAO Fisheries Technical Paper No. 410. Rome. 86 pp.)

A Global ACI & Regional Indices



El Viejo and La Vieja



(Chavez et al. 2003 *Science* 299:217-221. From Anchovies to Sardines and Back: Multidecadal Change in the Pacific Ocean)

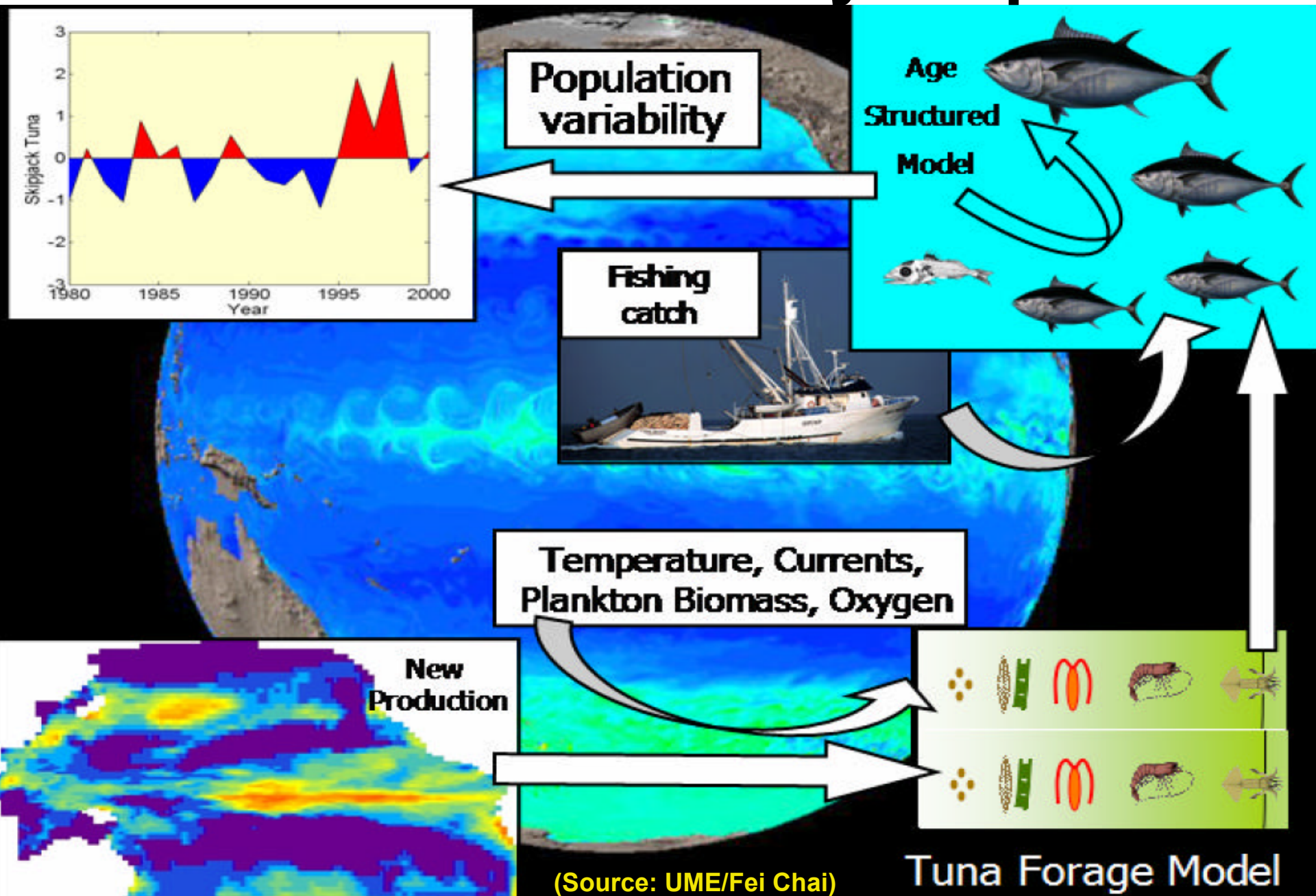
Seeing Patterns but How Do We Get to Processes?

"Based on these correlations, the case is persuasive that the changes in atmospheric circulation led to changes in ocean circulation, which in turn led to changes in the productivity of fish stocks. …

However, one feature of the correlations is that there are often time lags of several years between the physical changes and the shifts in population biomass. For each stock, it will be necessary to trace the changes in food webs induced by the physical environment, and test the plausibility of the observed time lags."

(Mann, K.H. & J.R.N. Lazier. 2006, *Dynamics of Marine Ecosystems* p.439)

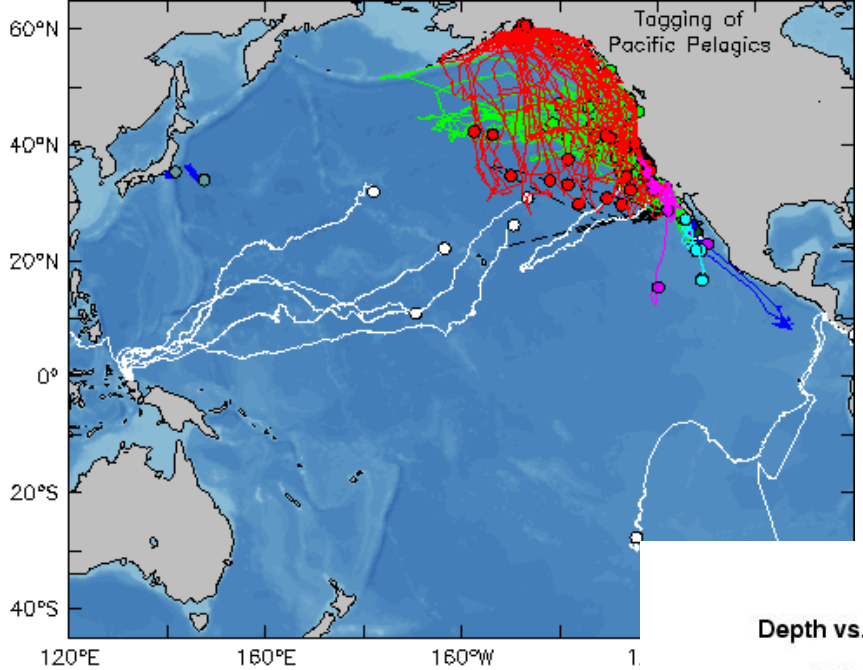
Models Definitely Help

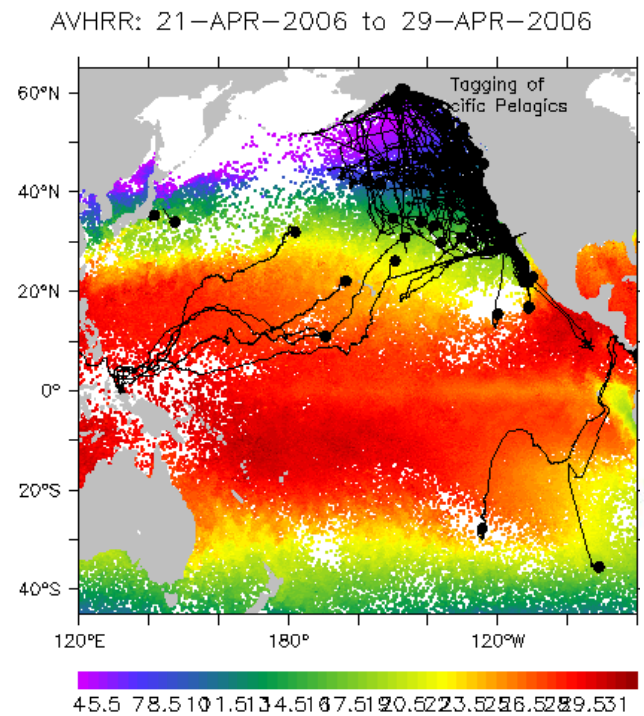


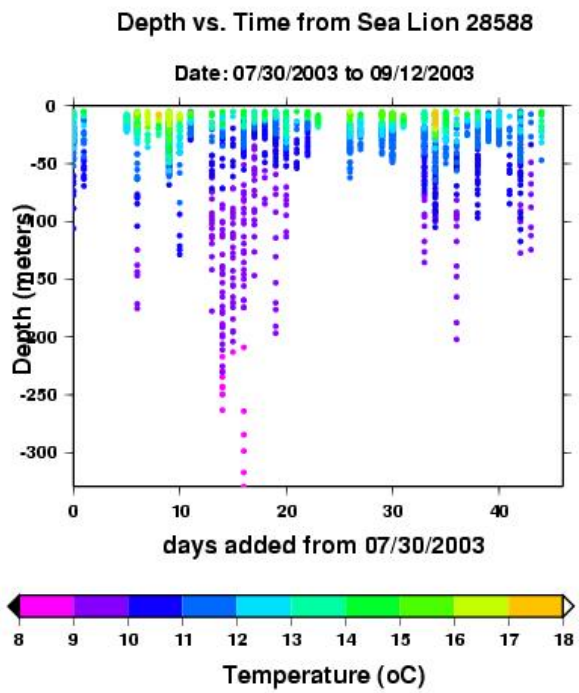
(Source: UME/Fei Chai)

Need: Observations of Organisms & Subsurface Answer: TOPP!

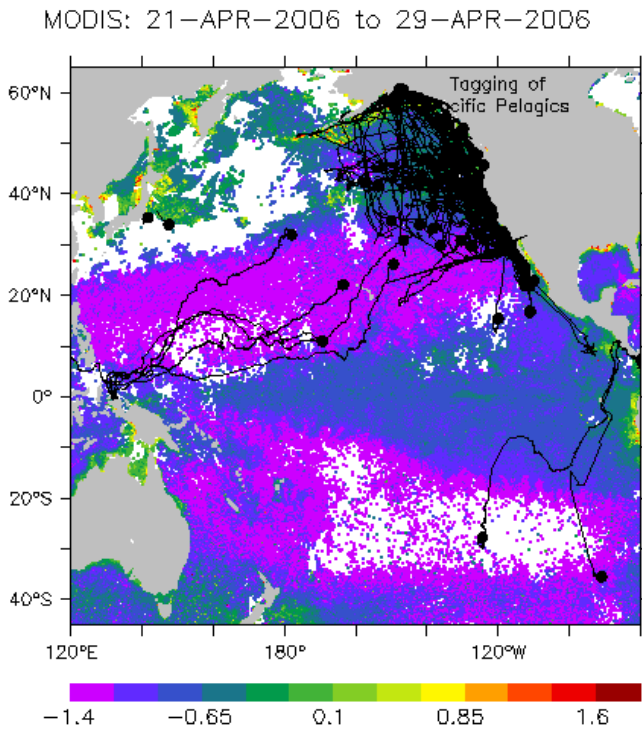
(From: http://las.pfeg.noaa.gov/TOPP_recent/index.html)



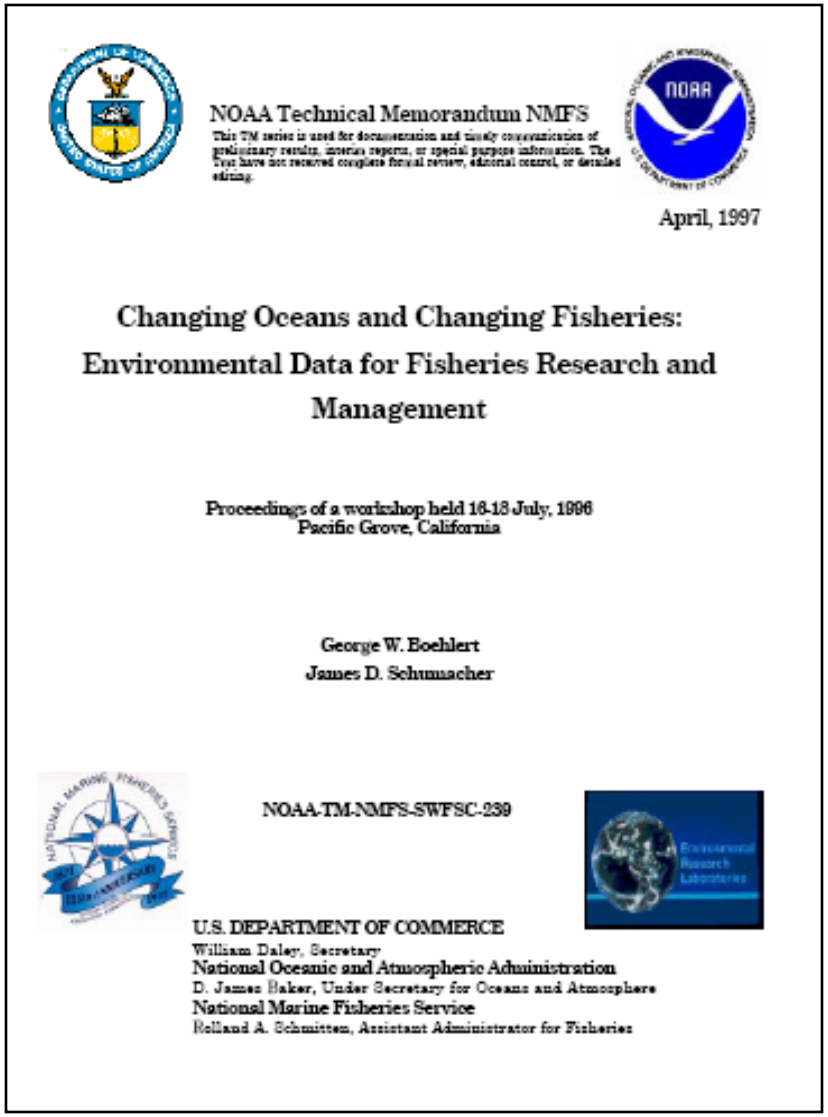




(From JPL OurOcean Portal http://ourocean.jpl.nasa.gov/cgi-bin/topp_plot.cgi)



Another Workshop?!



NOAA Technical Memorandum NMFS

This TM series is used for documentation and timely communication of preliminary results, interim reports, or special purpose information. The TM have not received complete formal review, editorial control, or detailed editing.

April, 1997

Changing Oceans and Changing Fisheries: Environmental Data for Fisheries Research and Management

Proceedings of a workshop held 16-18 July, 1996
Pacific Grove, California

George W. Boehlert
James D. Schumacher

NOAA-TM-NMFS-SWFSC-239

U.S. DEPARTMENT OF COMMERCE
William Daley, Secretary
National Oceanic and Atmospheric Administration
D. James Baker, Under Secretary for Oceans and Atmosphere
National Marine Fisheries Service
Rolland A. Schmitten, Assistant Administrator for Fisheries

- Pacific Grove, CA 16-18 July 1996
- NOAA, NASA, Navy, NSF, Canada, UK, Academia
- Focus on Information Sharing (We will do this too.)
- Also, a high priority recommendation for a "Demonstration of the benefits of applied environmental data in fisheries" associated with a call for projects
- This is where this workshop picks up the ball from 1996 & attempts to run with it!
- After exchanging information about our observations, models, & data systems, we will use the break-out groups to talk about projects
- Goal: 1-4 draft reports describing specific, detailed project concepts for NOAA/NASA to consider and potentially begin in FY06-07

One Way Forward

Earth System Models

Break-out Topics:

1. **Potential for Improving Stock Assessments & Fisheries Models with Satellite Data**
2. **Satellite & Model Data Usage & Habitat Classification**

What are the requirements for observations & models for decision support?

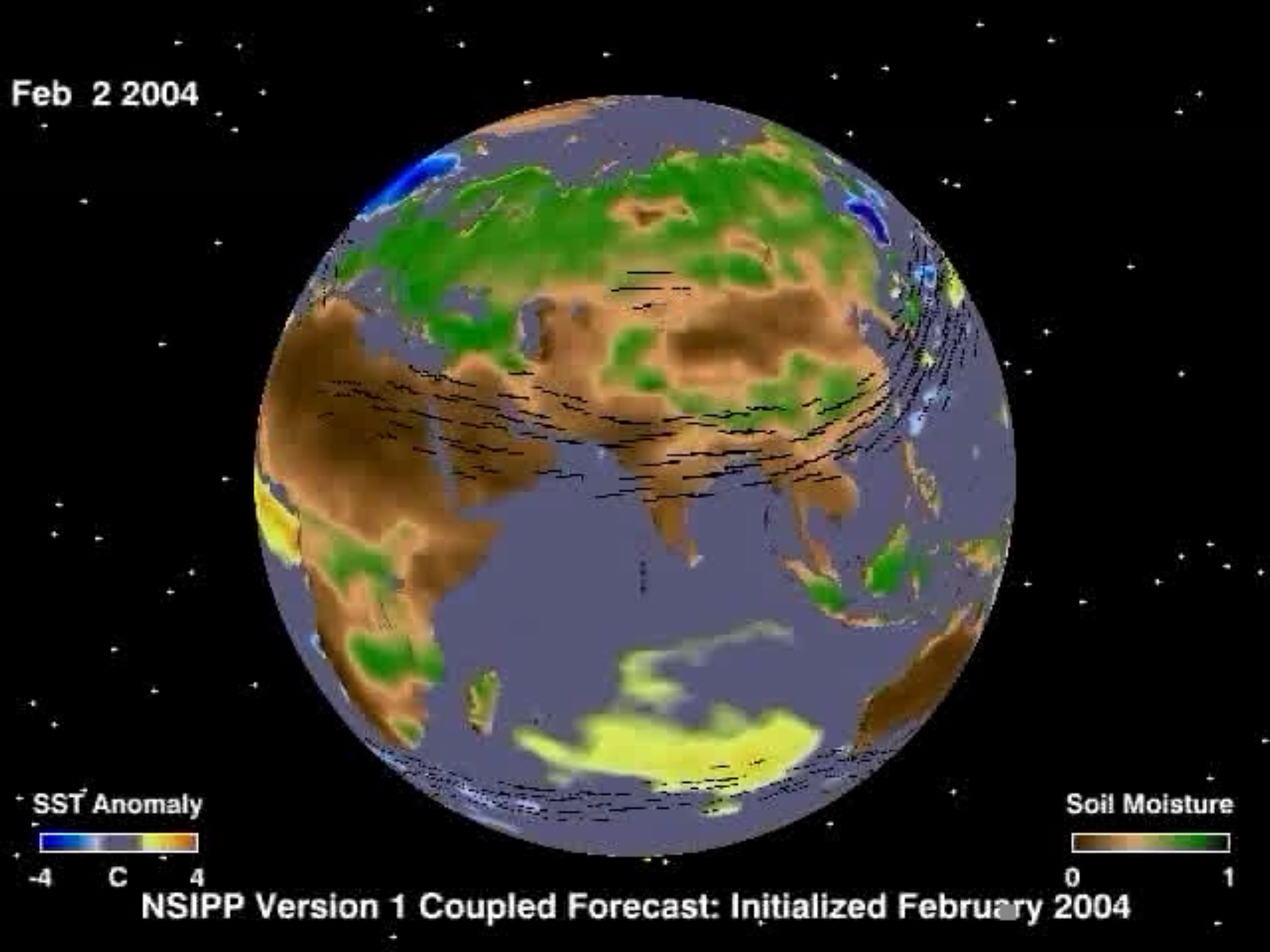
CAUTION: Please Don't Forget *In Situ* Data!

Parameters & Products

Workshop Goals & Products

- **Goals:**
  - Document potential for current & proposed satellite observations & related Earth system models to support NOAA ecosystem-based management
  - Identify models & assessments in use by NOAA Fisheries that could be improved by satellite data & related models
  - Identify requirements & gaps & develop strategies to facilitate the utilization of satellite data & related models for NOAA Fisheries
- **Products:**
  - Evaluation report for NOAA & NASA identifying potential projects
  - Articles on workshop results

Backup Charts


Feb 2 2004
SST Anomaly
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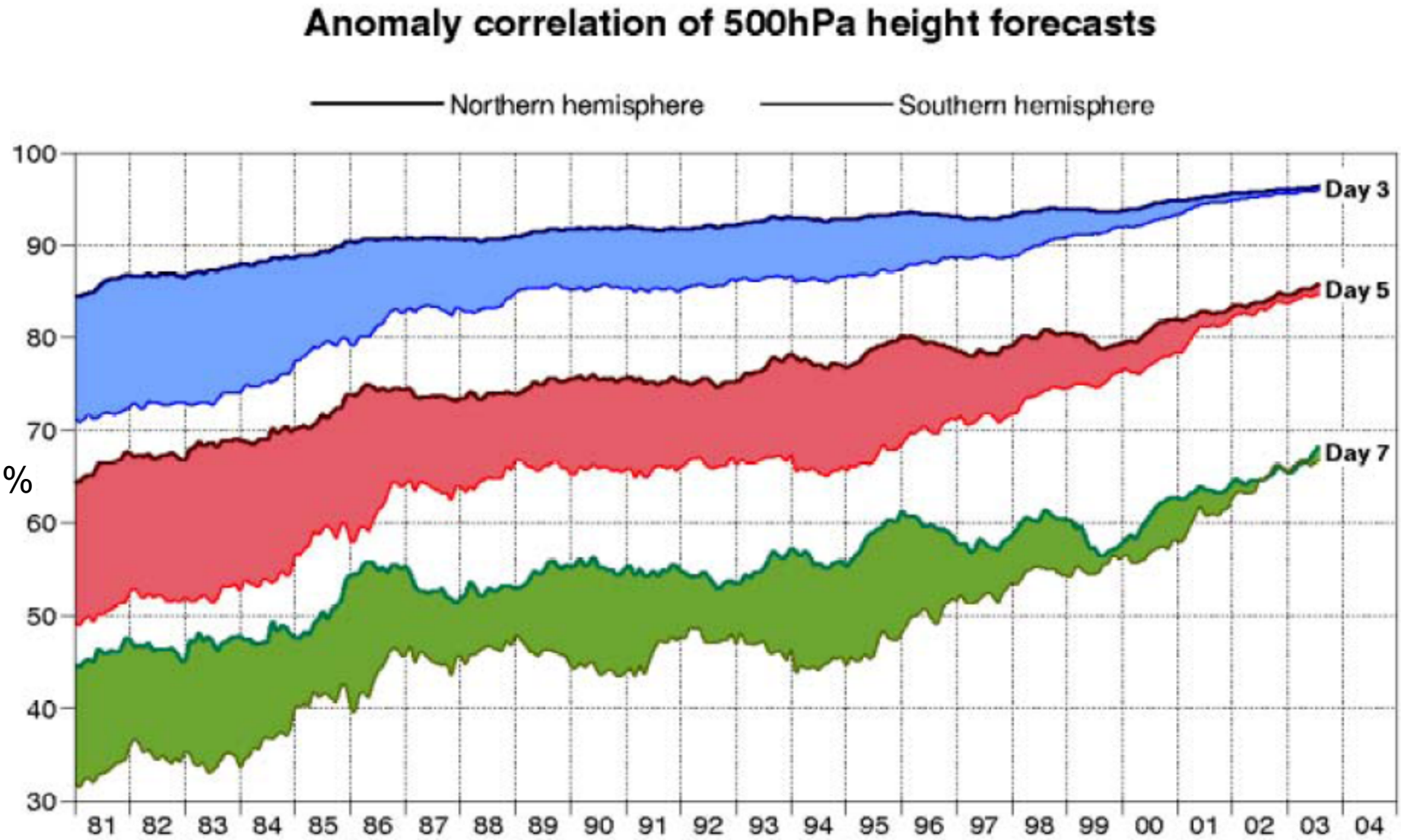
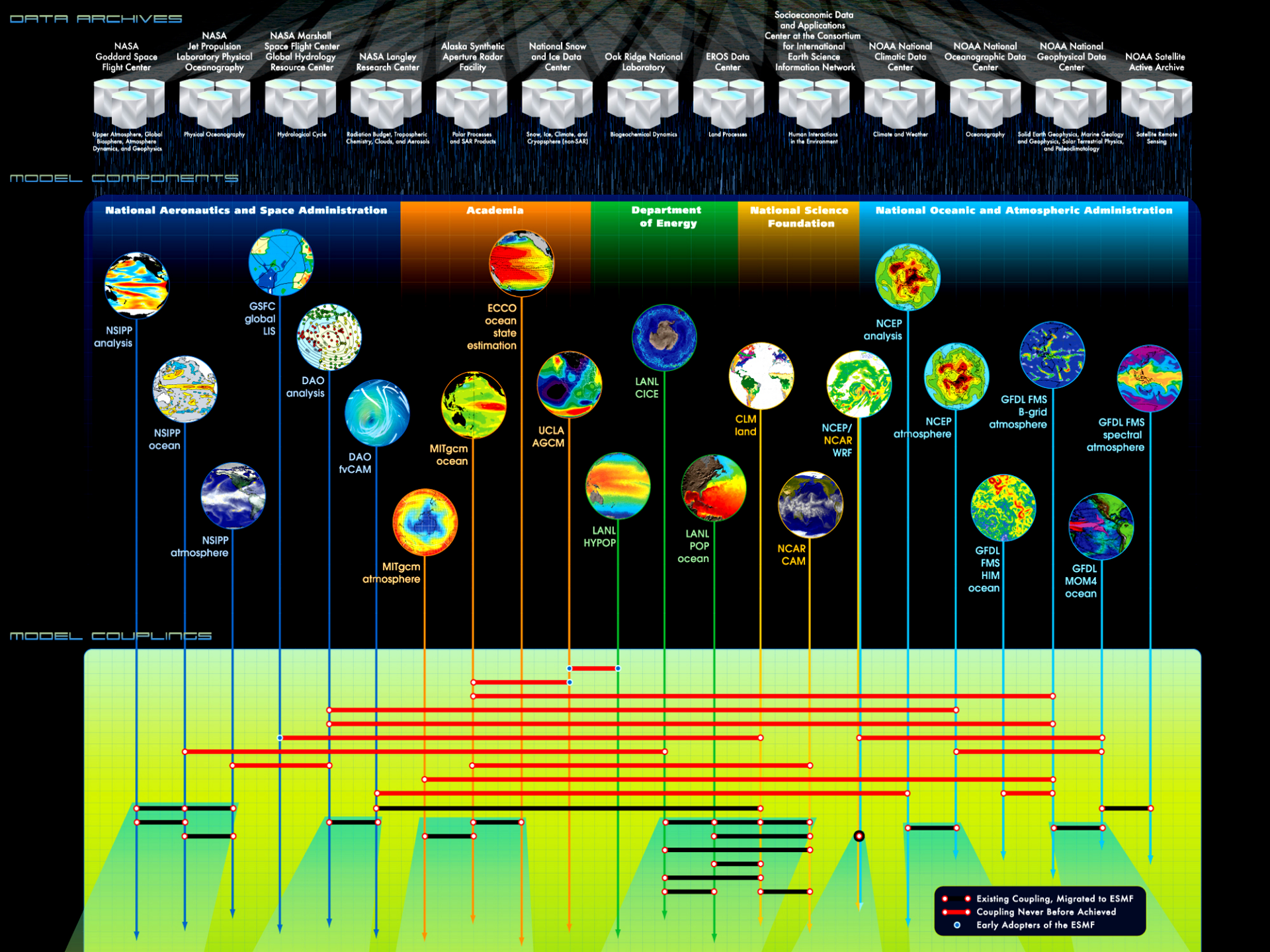
NSIPP Version 1 Coupled Forecast: Initialized February 2004

ECMWF forecasts 1981-2003



(chart courtesy of NASA/Tsengdar Lee)


Jason-1
QuikSCAT
ACRIMSAT
Landsat 7
NMP/EO-1
SAGE III/METEOR-3M
TRMM
Aqua
EP-TOMS
Terra
GRACE
SORCE
ICESat
Aura


DATA ARCHIVES
NASA Goddard Space Flight Center
NASA Jet Propulsion Laboratory Physical Oceanography
NASA Marshall Space Flight Center Global Hydrology Resource Center
NASA Langley Research Center
Alaska Synthetic Aperture Radar Facility
National Snow and Ice Data Center
Oak Ridge National Laboratory
EROS Data Center
Socioeconomic Data and Applications Center at the Consortium for International Earth Science Information Network
NOAA National Climatic Data Center
NOAA National Oceanographic Data Center
NOAA National Geophysical Data Center
NOAA Satellite Active Archive
Upper Atmosphere, Global Biosphere, Atmosphere Dynamics, and Geophysics
Physical Oceanography
Hydrological Cycle
Radiation Budget, Tropospheric Chemistry, Clouds, and Aerosols
Polar Processes and SAR Products
Snow, Ice, Climate, and Cryosphere (non-SAR)
Biogeochemical Dynamics
Land Processes
Human Interactions in the Environment
Climate and Weather
Oceanography
Solid Earth Geophysics, Marine Geology and Geophysics, Solar Terrestrial Physics, and Paleoclimatology
Satellite Remote Sensing
MODEL COMPONENTS
National Aeronautics and Space Administration
Academia
Department of Energy
National Science Foundation
National Oceanic and Atmospheric Administration
NSIPP analysis
NSIPP ocean
NSIPP atmosphere
GSFC global LIS
DAO analysis
DAO fvCAM
MITgcm atmosphere
MITgcm ocean
ECCO ocean state estimation
UCLA AGCM
LANL HYPOP
LANL CICE
LANL POP ocean
CLM land
NCAR CAM
NCEP/ NCAR WRF
NCEP analysis
NCEP atmosphere
GFDL FMS HIM ocean
GFDL FMS B-grid atmosphere
GFDL MOM4 ocean
GFDL FMS spectral atmosphere
MODEL COUPLINGS
Existing Coupling, Migrated to ESMF
Coupling Never Before Achieved
Early Adopters of the ESMF

Data Rich But Analysis Poor?

SPECIAL SECTION

DISTRIBUTED COMPUTING

NEWS

Grassroots Supercomputing

What started out as a way for SETI to plow through its piles of radio-signal data from deep space has turned into a powerful research tool as computer users across the globe donate their screen-saver time to projects as diverse as climate-change prediction, gravitational-wave searches, and protein folding

SETI HOME

observatories to donate their help. But
he mid-1990s, several SETI projects
secured observing time, heralding a
problem: how to deal with the huge
volume of data. One Berkeley SETI project,
called SERENDIP, uses the Arecibo
Observatory in Puerto Rico, the largest
radio telescope in the world, to passively
scan the sky around the clock, listening
to 168 million radio frequencies at
once. Analyzing this data would
require full-time use of the Yokohama
Earth Simulator, working at its top
speed of 35 teraFLOPS (10^{12} calculations per second).

Gedye and his friends approached
the director of SERENDIP, Berkeley
astronomer Daniel Werthimer, and posed
this idea: Instead of using one super-
computer, why not break the problem down
into millions of small tasks and then solve
those on a million small computers running
at the same time? This approach, known as
distributed computing, had been around
since the early 1980s, but most efforts had
been limited to a few hundred machines
within a single university. Why not
expand this to include the millions of
personal computers (PCs) connected to
the Internet? The average PC spends
most of its time idle, and even when in use
most of its computing power goes untapped.

The idea of exploiting spare capacity on
PCs was not a new one. Fueled by friendly
competition among hackers, as well as cash
prizes from a computer security company,
thousands of people were already using their

other projects. "Doing this kind of
experiment wasn't even being consid-
ered," recalls Stainforth, a computer
scientist here at Oxford University. So
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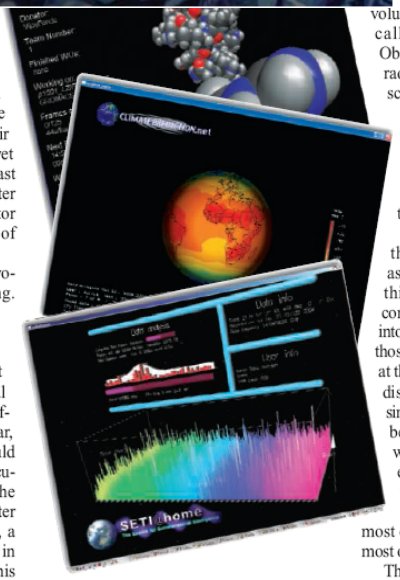
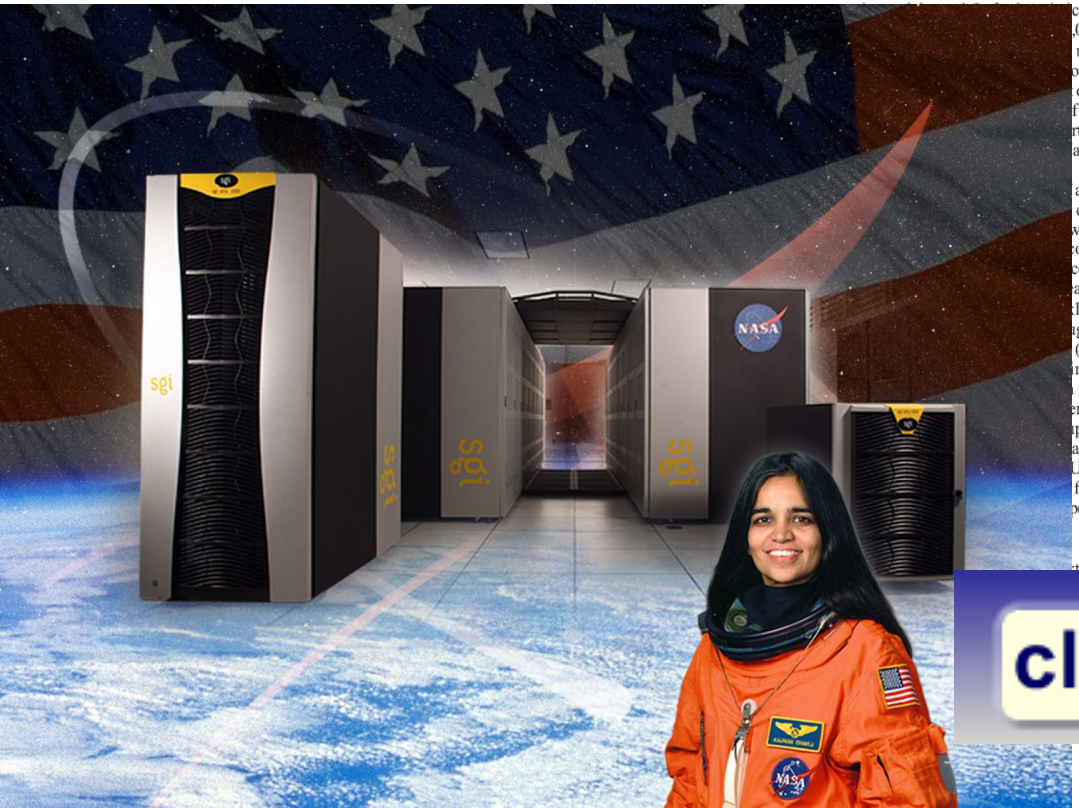


Strength in numbers. Millions of computers now crunch data for diverse research projects.



climateprediction.net

Published by AAAS

GEO: A Global Framework?

A Plethora of Biodiversity Data

Consortium for the Barcode of Life

NCBI GenBank

USDA Forest Inventory and Analysis National Program

Species 2000

IUCN Red List

nbii National Biological Information Infrastructure

iabin Inter-American Biodiversity Information Network

Global Biodiversity Information Facility

World Database on Protected Areas

LTER

The Species Analyst

neon National Ecological Observatory Network

Global Mammal Assessment

IUCN The World Conservation Union

SSC Species Survival Commission

Global Amphibian Assessment

Applications of National Priority

Agricultural Efficiency

Air Quality

Aviation

Carbon Management

Coastal Management

Disaster Management

Ecological Forecasting

Energy Management

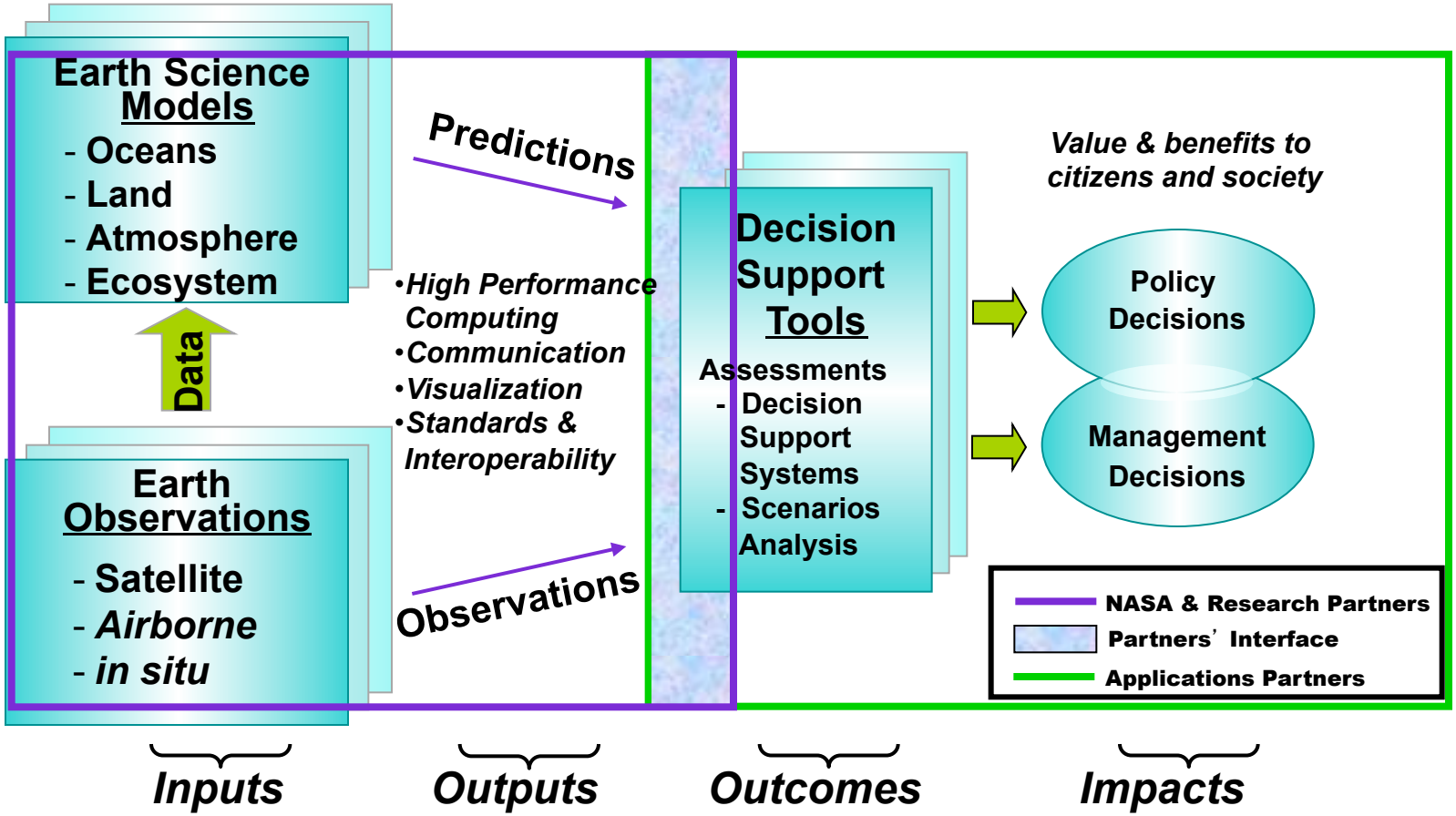
Homeland Security

Invasive Species

Public Health

Water Management

NASA Applied Sciences Paradigm (& Also GEO)



Ecological Forecasting at NASA

EARTH SYSTEM MODELS

- *Ecological Niche* (GARP)
- *Scalable spatio-temporal models* a la CSU's NREL
- *Regional Ocean Models & Empirical Atmospheric Models coupled with ecosystem trophic models*
- *Ecosystem* (ED, CASA)
- *Population & Habitat Viability Assessment* (VORTEX, RAMAS GIS)
- *Biogeography* (MAPSS, BIOME3, DOLY)
- *Biogeochemistry* (BIOME-BGC, CENTURY, TEM)

Predictions

- Species Distributions
- Ecosystem Fluxes
- Ecosystem Productivity
- Population Ecology
- Land Cover Change

Data

EARTH OBSERVATORIES

- *Land cover*: MODIS, AVHRR, Landsat, ASTER, ALI, Hyperion, IKONOS/QuickBird
- *Topography/Vegetation Structure*: SRTM, ASTER, IKONOS, LVIS, GLAS, Radars
- *Primary Productivity/Phenology*: AVHRR, SeaWiFS, MODIS, Landsat, ASTER, ALI, Hyperion, IKONOS, QuickBird, AVIRIS
- *Atmosphere/Climate*: AIRS/AMSU, TRMM (PR, LIS, TMI), AVHRR, MODIS, MISR, CERES, QuikScat, AMSR-E, CloudSAT
- *Ocean*: AVHRR, SeaWiFS, MODIS, TOPEX/Poseidon, JASON, AQUARIUS
- *Soils*: AMSR-E, AIRSAR

(Future Mission)

- Land Cover/Land Use & Disturbances (e.g., fire)
- Species Composition
- Biomass/Productivity
- Phenology
- Vegetation Structure
- Elevation
- Surface Temperature
- SST, SSH, Circulation, Salinity, & Sea Ice
- Atmospheric Temp.
- Soil Moisture
- Precipitation
- Winds

Observations

DECISION SUPPORT TOOLS

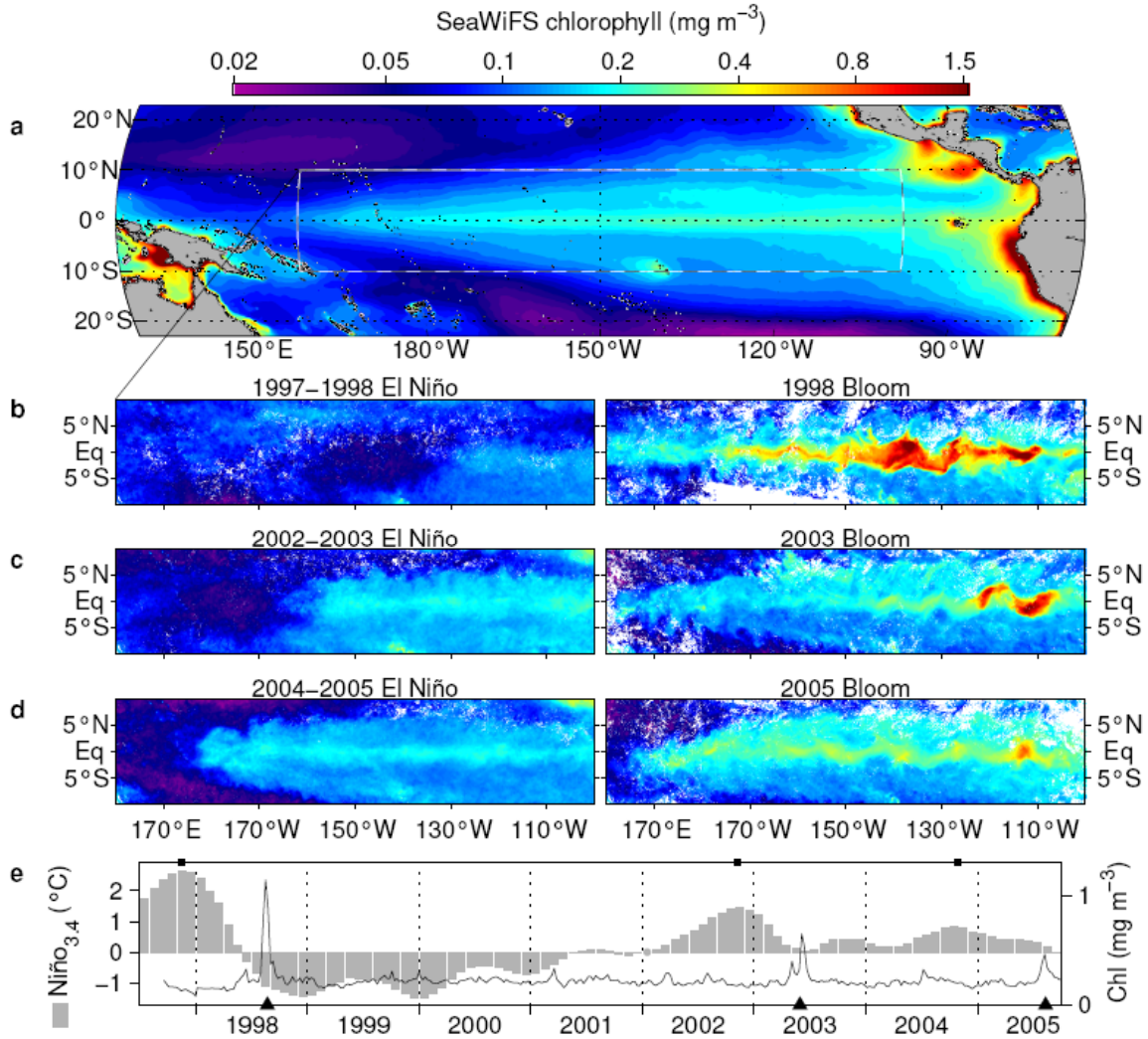
- **SERVIR (Spanish acronym for Regional Visualization & Monitoring System) for sustainable environmental management**
  - MesoStor Data System
  - Online Mapping
  - Decision Support
  - Visualization Tools
- **Protected Area Management**
  - Terrestrial Observation & Prediction System (TOPS)
  - NatureServe Vista
  - Fire Information for Resource Management
  - Albertine Rift DSS
- **Marine Fisheries Forecasting**
  - Combine physical ocean & ecosystem trophic-level models to predict how climatological changes driven by ENSO & PDO events will affect regional fisheries

If-Then Scenarios for Ecosystem Responses To Change

VALUE & BENEFITS

- First-ever effort to manage a global hotspot of biodiversity, i.e. Mesoamerica, at a regional scale through the coordination of the activities of 7 countries – a model for other regions
- Predict the impacts of changing land-use patterns & climate on the ecosystem services that support all human enterprises
- Develop ecological forecasts with reliable assessments of error

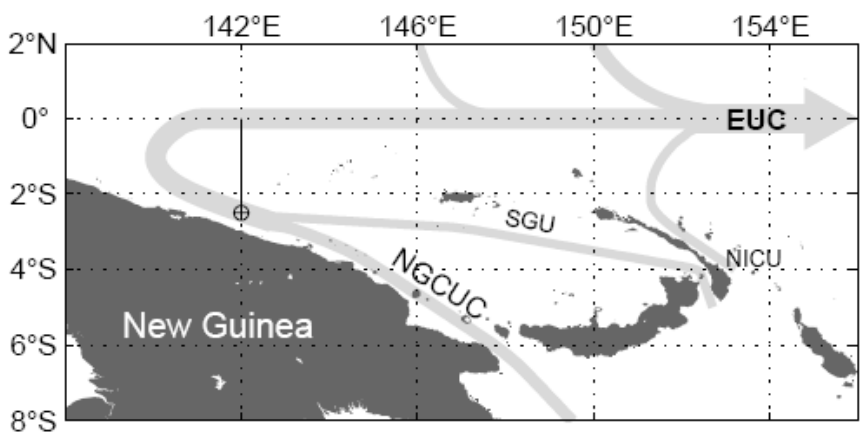
NASA satellites track episodic equatorial Pacific blooms that can be of similar size as the rich Peruvian coastal upwelling system and therefore must have important ecological consequences

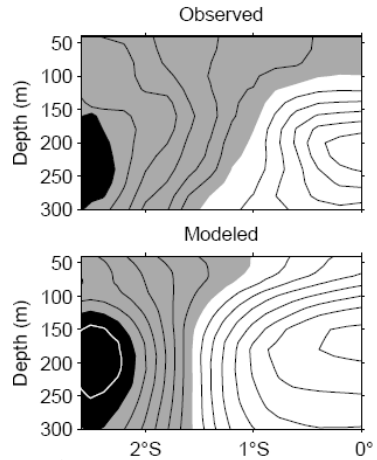


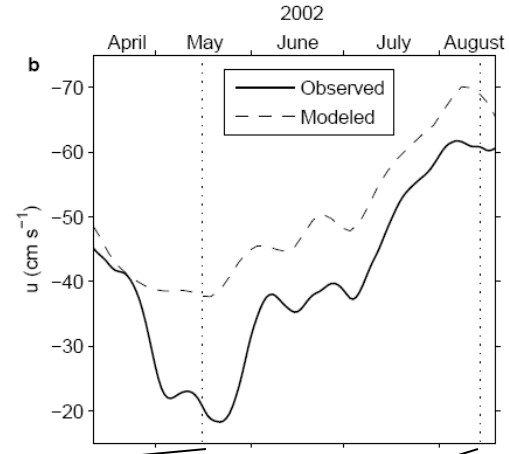
The blooms follow El Niño events and do not seem associated with local processes

Ryan et al., in press, JGR-Biosciences; slide courtesy of MBARI/F. Chavez

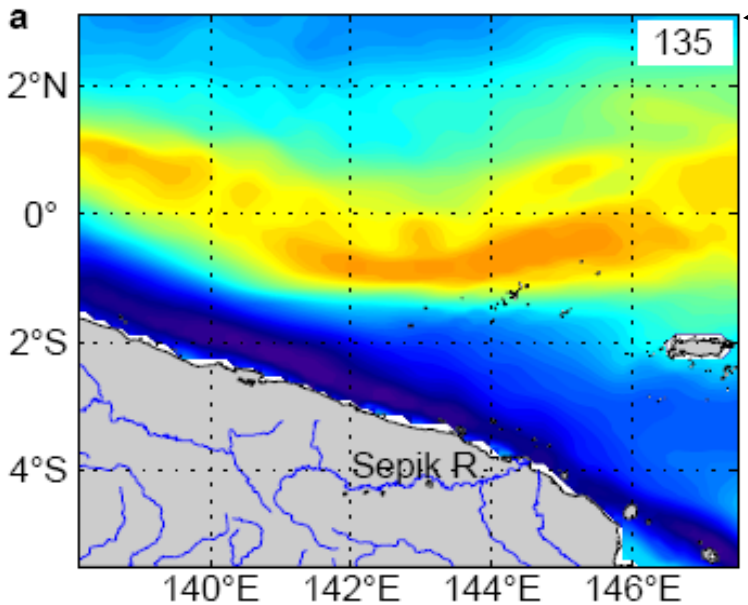
NASA models suggest that the blooms may be associated with an El Niño intensification of the New Guinea Coastal Undercurrent (NGCUC) that scrapes the continental shelf and increases the transport of iron into the equatorial Pacific via the Equatorial Undercurrent (EUC)

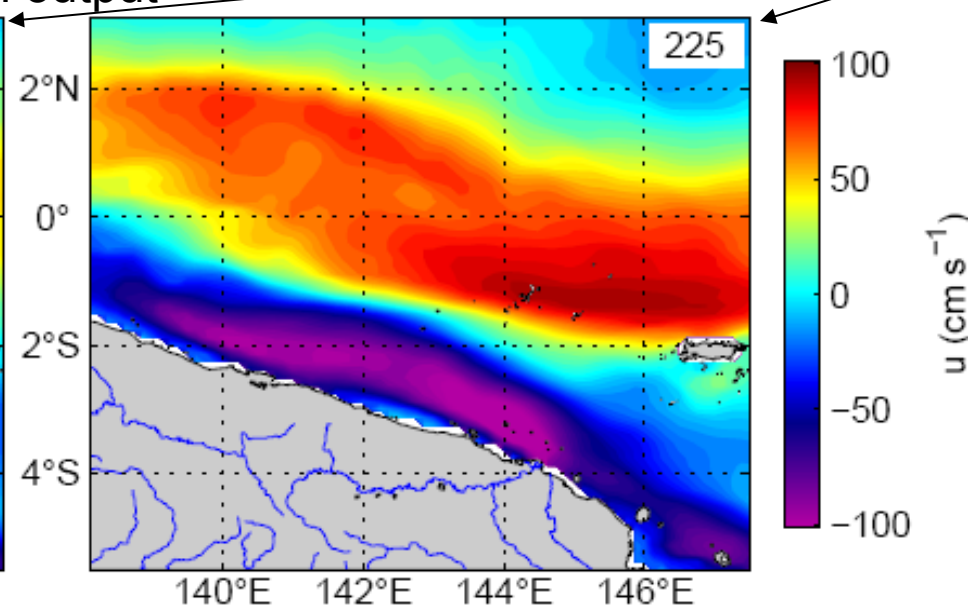






ROMS model output





Before El Niño

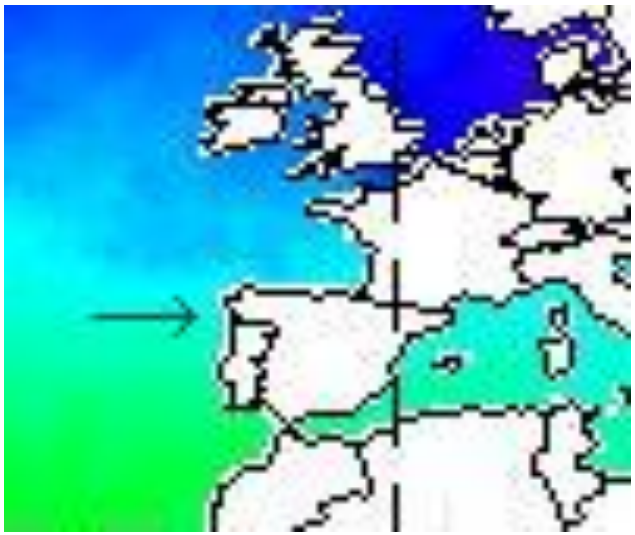
During El Niño

(slide courtesy of MBARI/F. Chavez)

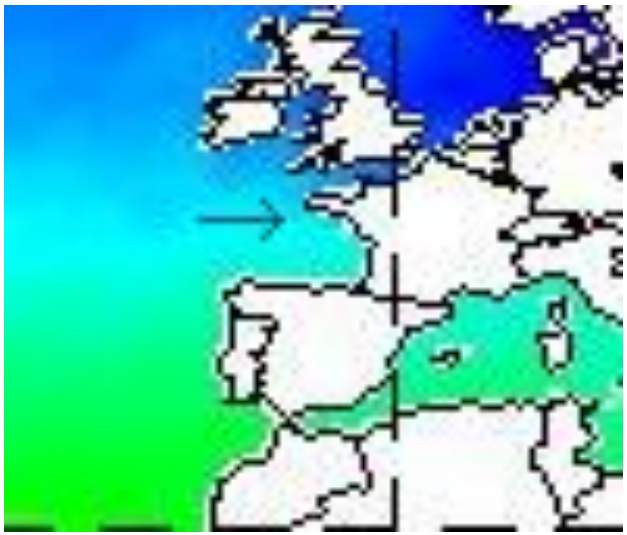
Ecological hindcasting of biogeographic responses to climate change in intertidal ecosystems

Brian Helmuth, David Wethey, Venkat Lakshmi and Jerry Hilbish
University of South Carolina, Columbia

February 1984

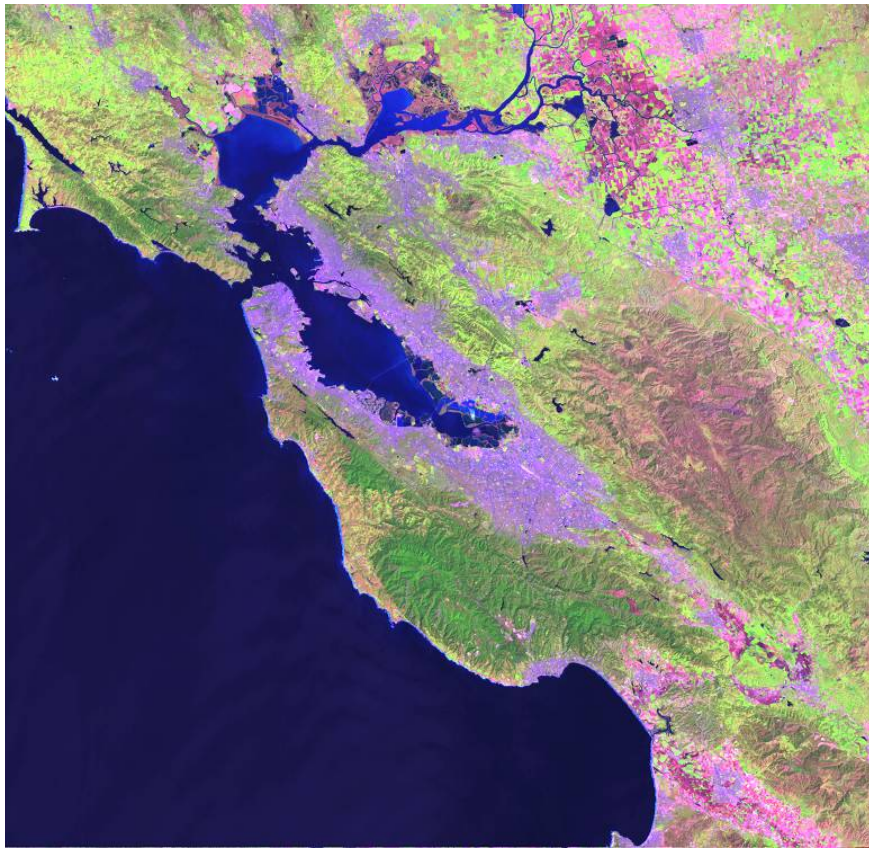


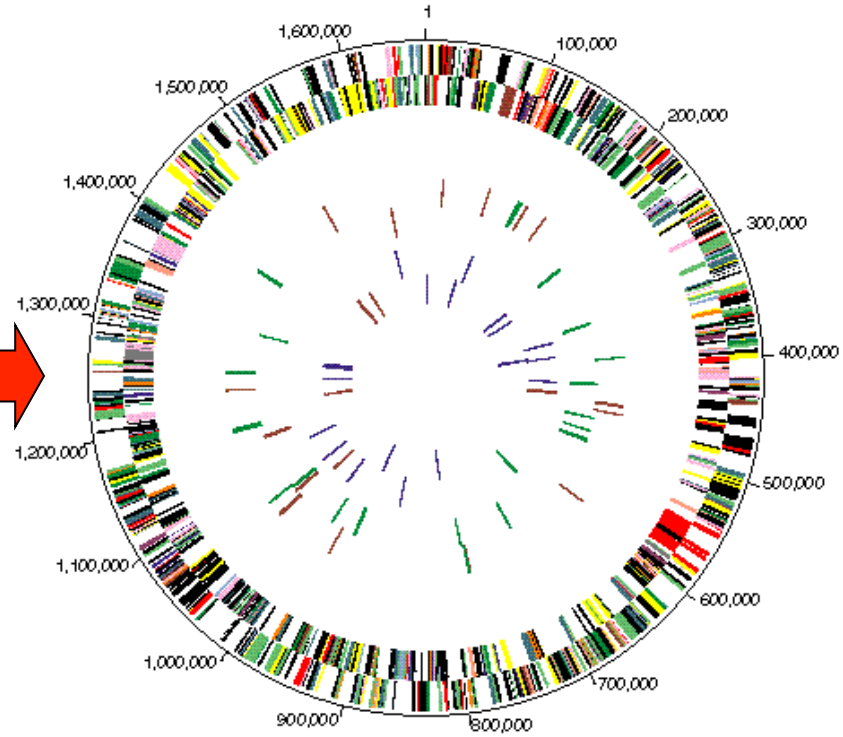
February 1998



•Inputs from multiple R/S platforms are used to generate hindcasts of body temperatures of key coastal invertebrate species
•Body temperatures, coupled with data on physiological tolerances, are used to forecast and hindcast shifts in species ranges
•Here, sea surface temperatures (AVHRR 36km) from February 1984 and 1998 show that the 10°C winter isotherm moved from northern Spain to Brittany. The left arrow is the southern limit of barnacle species in 1985, the right arrow was our prediction for 2003 in our grant proposal.
• 2005 Field surveys conducted by our group indicate our prediction was correct.

And Then Where To?





Helicobacterium pylorii Genome from:
http://biocrs.biomed.brown.edu/Books/Chapters/Ch%2038/Pylori-Genome.gif

A Grand Synthesis for the 21st Century

Molecular Data & Hindcasting Life

Whales Before Whaling in the North Atlantic

Joe Roman and Stephen R. Palumbi*

It is well known that hunting dramatically reduced all baleen whale populations, yet reliable estimates of former whale abundances are elusive. Based on coalescent models for mitochondrial DNA sequence variation, the genetic diversity of North Atlantic whales suggests population sizes of approximately 240,000 humpback, 360,000 fin, and 265,000 minke whales. Estimates for fin and humpback whales are far greater than those previously calculated for prewhaling populations and 6 to 20 times higher than present-day population estimates. Such discrepancies suggest the need for a quantitative reevaluation of historical whale populations and a fundamental revision in our conception of the natural state of the oceans.

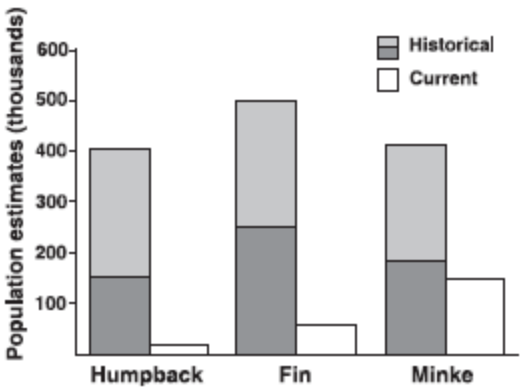
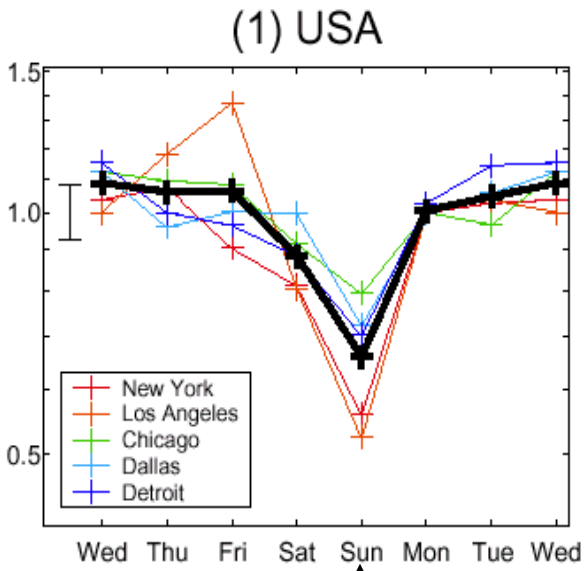


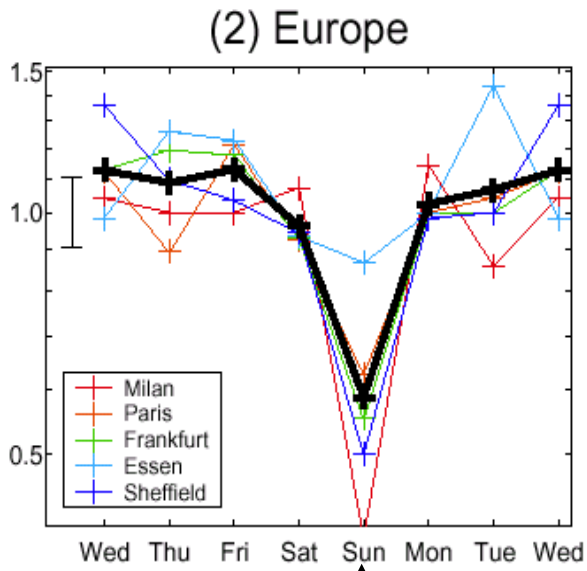
Fig. 1. Genetic estimates and current census sizes (*9*, *25*, *26*) for North Atlantic humpback, fin, and minke whales. The confidence intervals are in light gray.

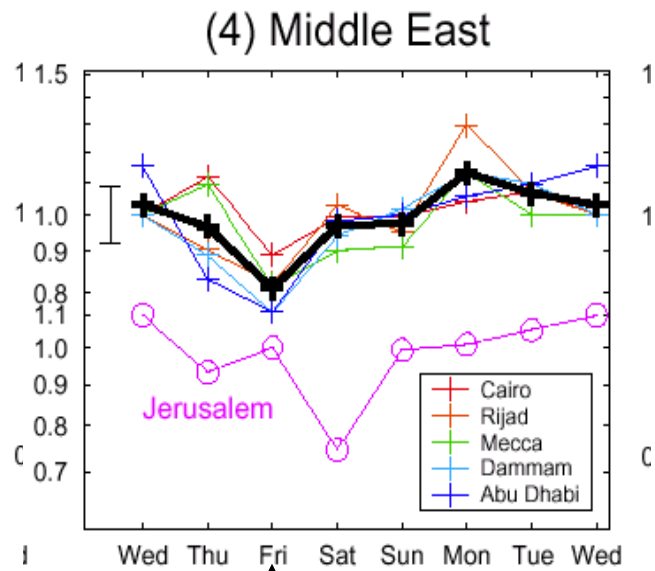
Table 1. Historical population estimates based on genetic diversity and generation time of baleen whales in the North Atlantic Ocean. *n* indicates number of individuals analyzed in the North Atlantic.

Species	*n*	θ mean (95% CI)	Generation time (years)	$N_{e(f)}$ (thousands) (95% CI)	Genetic population estimates (thousands) (95% CI)	Current estimates (thousands)
Humpback whale	188	0.0216 (0.0179–0.0274)	12–24	34 (23–57)	240 (156–401)	9.3–12.1
Fin whale	235	0.0430 (0.0346–0.0526)	25	51 (38–65)	360 (249–481)	56.0
Minke whale	87	0.0231 (0.0161–0.0324)	17	38 (26–57)	265 (176–415)	149.0
Total					865 (581–1297)	214–217

Remote Sensing of the Sabbath
(or Remote Sensing of Anthropogenic Sources)







Sun

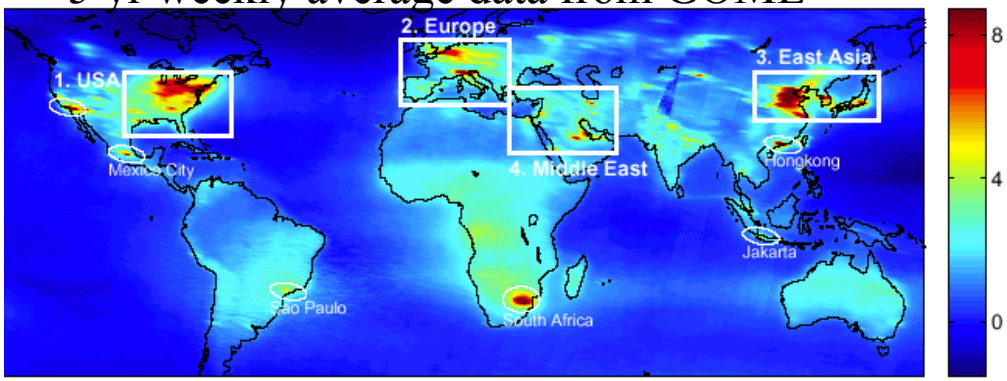
Sun

Fri

Day of Week analysis helps to separate anthropogenic source types.

Five Years from GOME (or 1 week of Geostationary)

5 yr weekly average data from GOME



GOME Data from U of Heidelberg Bierle Atmos. Chem. Phys. Discuss. 2003