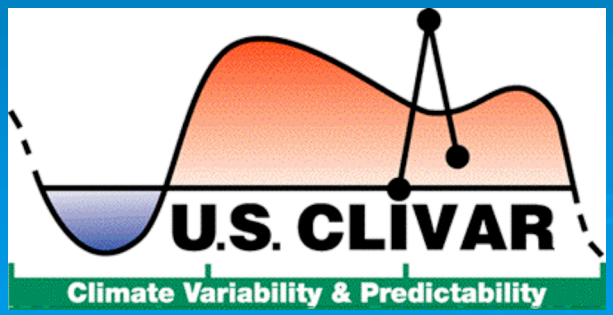
U.S. CLIVAR



VPM7 Guayaquil 22-24 March 2004

CLIVAR
Climate Variability and Predictability

- What causes the variability of the earth's climate on time scales from seasons to centuries and can we predict it?
- Can we distinguish natural from anthropogenic induced variability?

- Science Plan - 1995
- U.S. CLIVAR SSC formed - Summer 1998
- International CLIVAR Conference - December 1998
- International CLIVAR Conference - June 2004
- CLIVAR more than half way

US CLIVAR

The CLIVAR Vision...

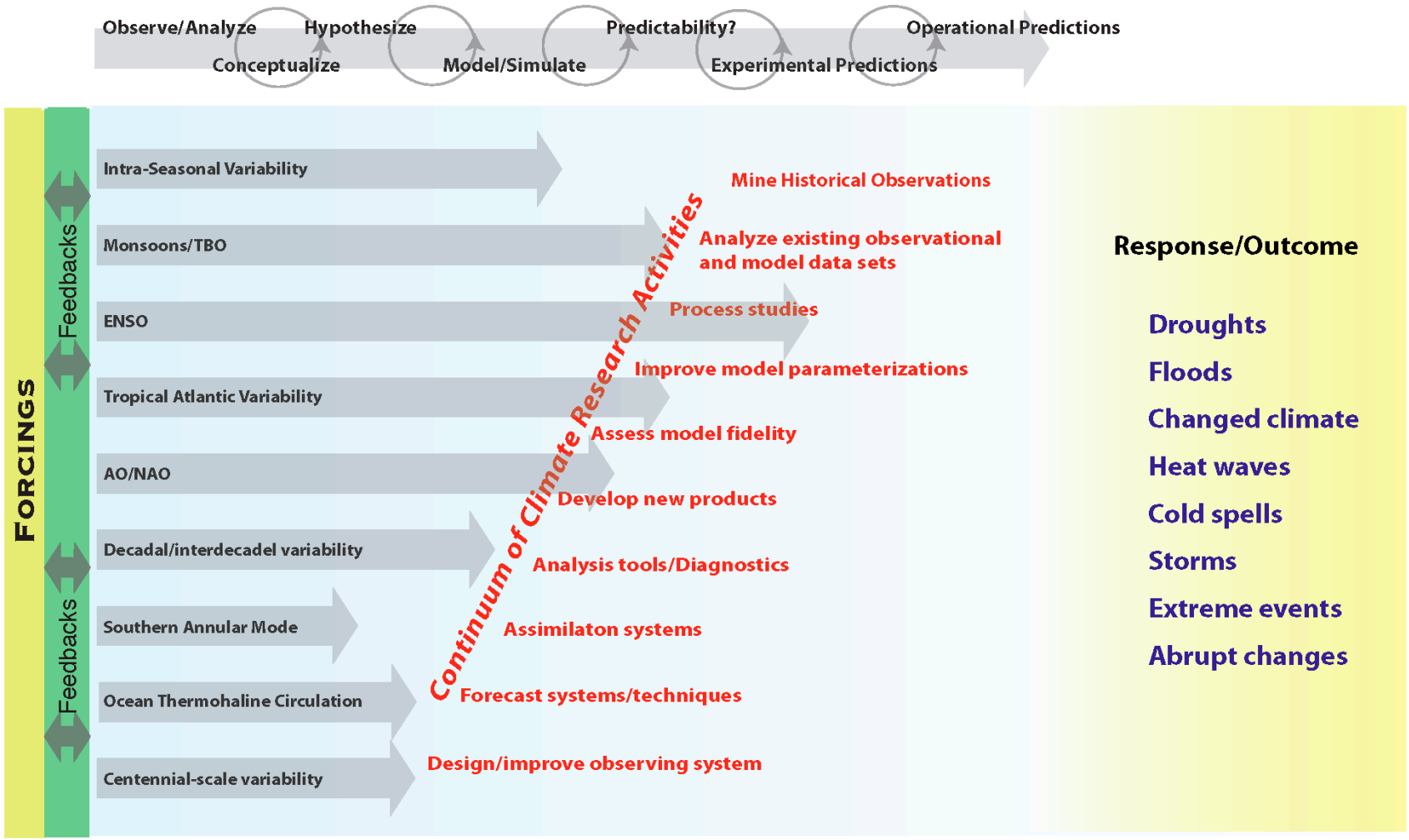
An important legacy of CLIVAR will be an improved climate observing system,as well as a more comprehensive and useful climate record

CLIVAR will contribute the fundamental underpinnings of critical physical processes that lead to reducing uncertainties in coupled climate models used for prediction

CLIVAR will contribute to the development of robust dynamical frameworks for understanding and predicting climate changes

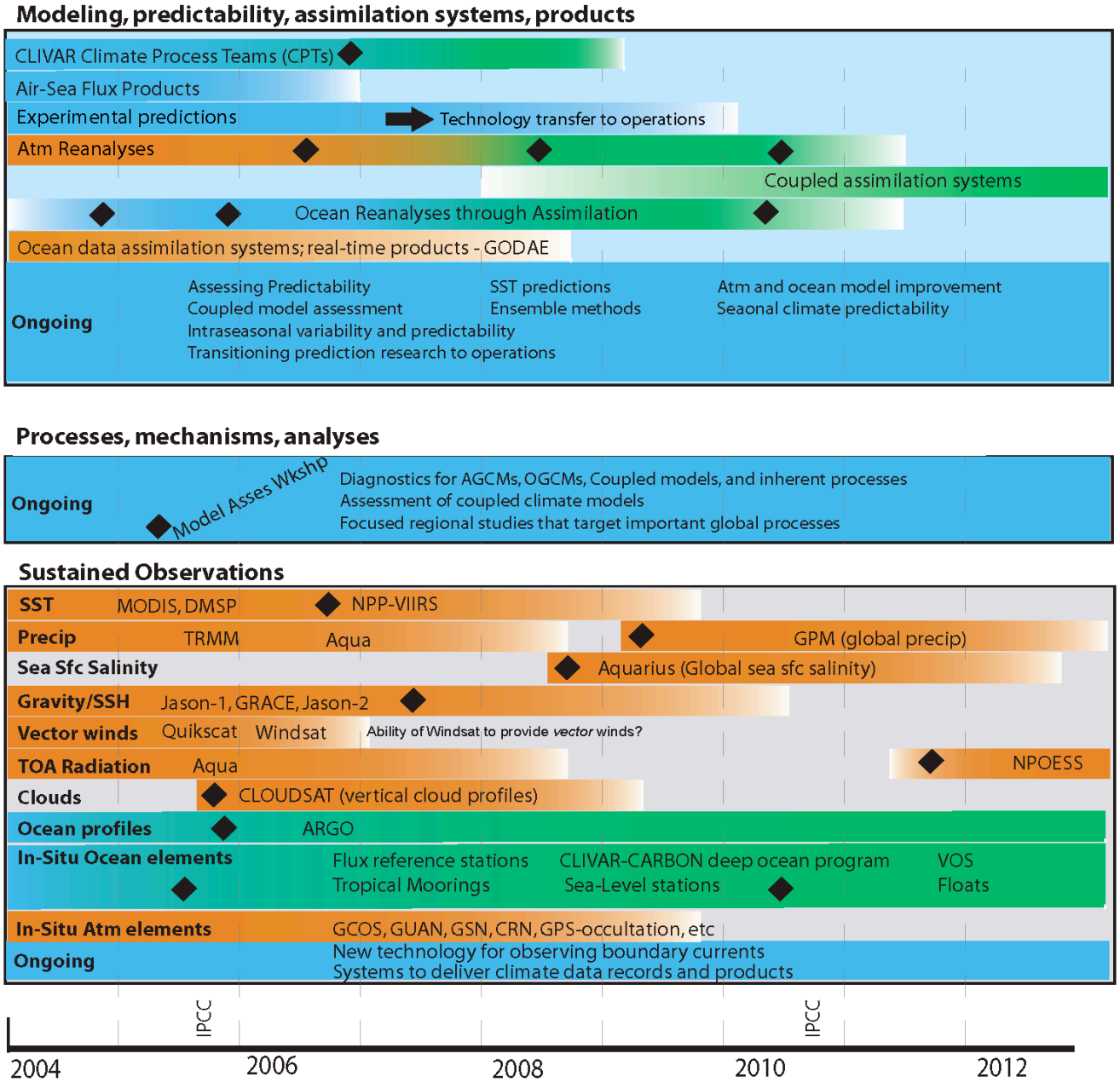
US CLIVAR

Scientific Progress in Climate Variability Systems



US CLIVAR

U.S. CLIVAR Roadmap: Global Elements



Achievements

1) Demonstrated predictions of ENSO

2) Initiated pilot CPTs focusing on critical global climate model deficiencies

3) Began CLIVAR-CARBON deep ocean measurement program

4) Attribution of observed sea-level trends

5) Detected change in N. Atlantic thermohaline circulation

6) Completed 10-yr ocean data assimilation product

Future Outcomes

1) Improved predictions of ENSO

2) Global ocean observing system

3) Improved estimates of global storage, transport, and exchange of heat and freshwater

4) Better characterization of uncertainties in climate models

5) Improved representation of key physical processes in climate models

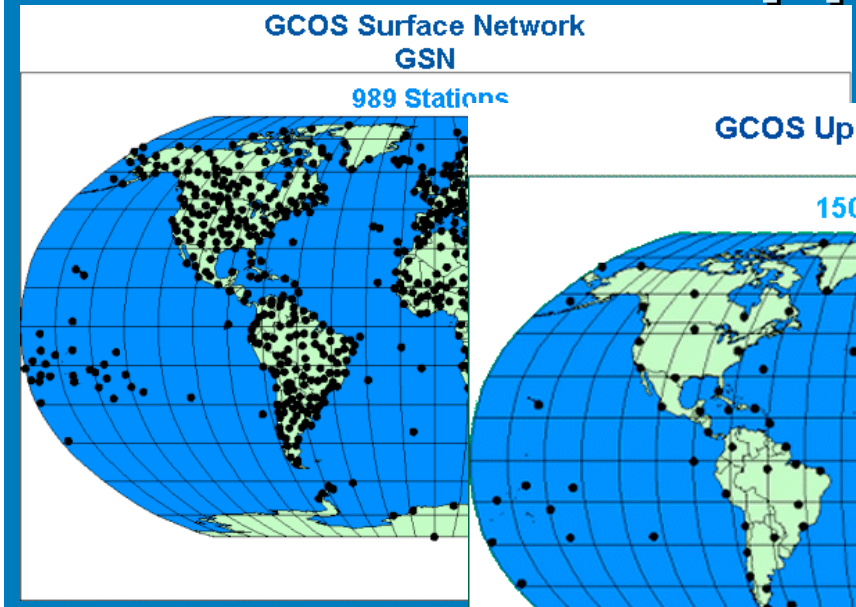
Roadmap Key

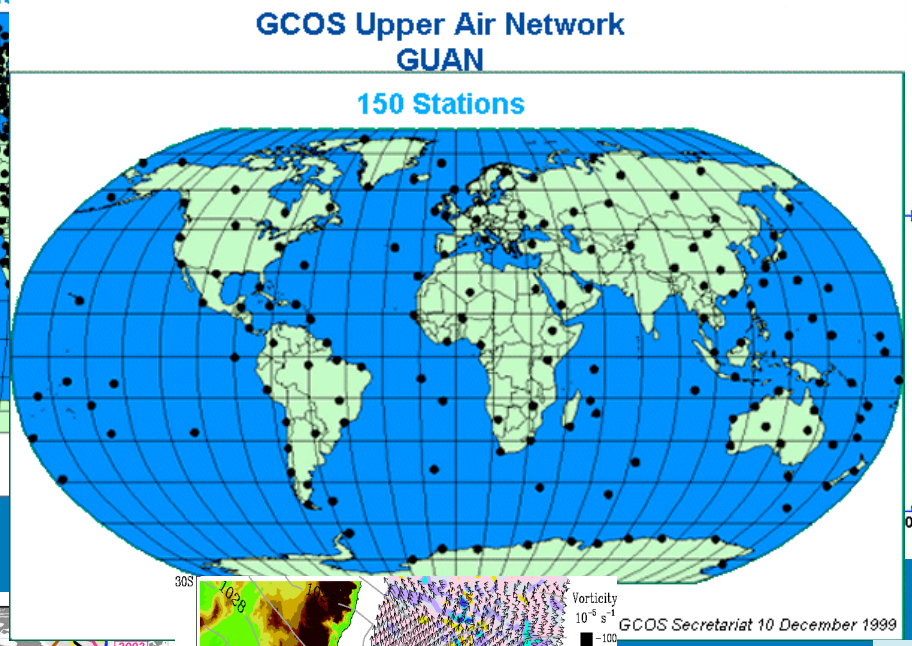
CLIVAR Activity ◆ Milestone

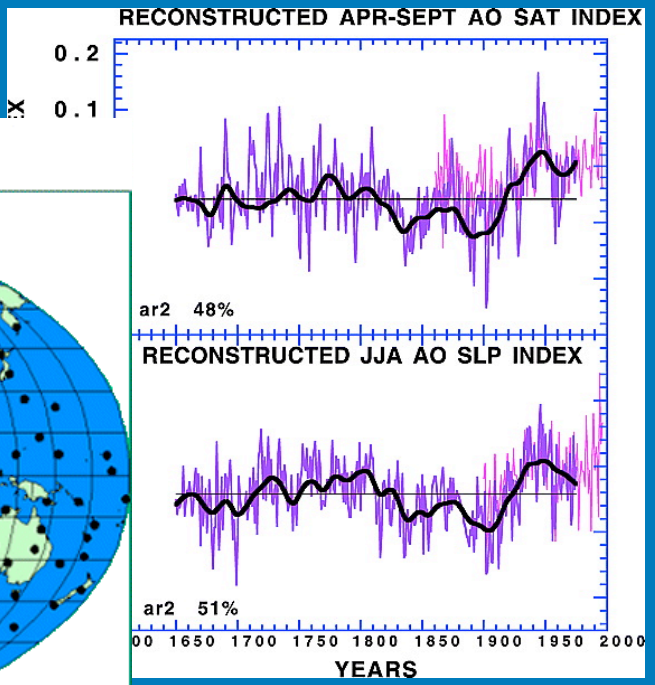
Unfunded | Contributing Activity

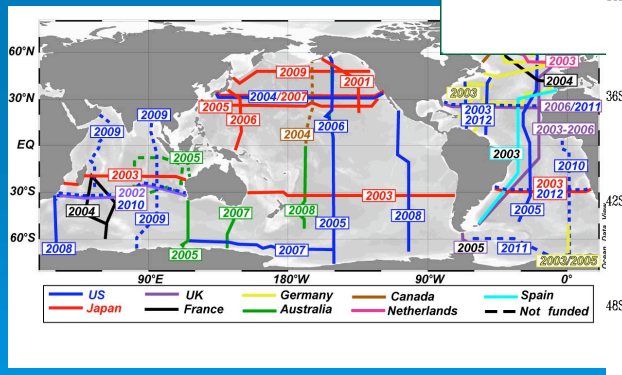
3/5/04 DML

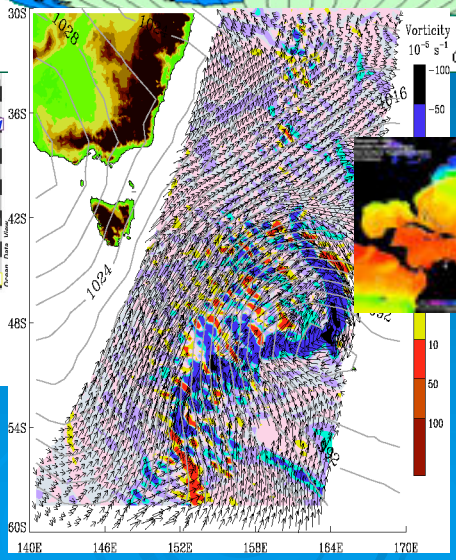
Required Observations & Products

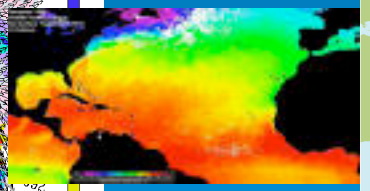


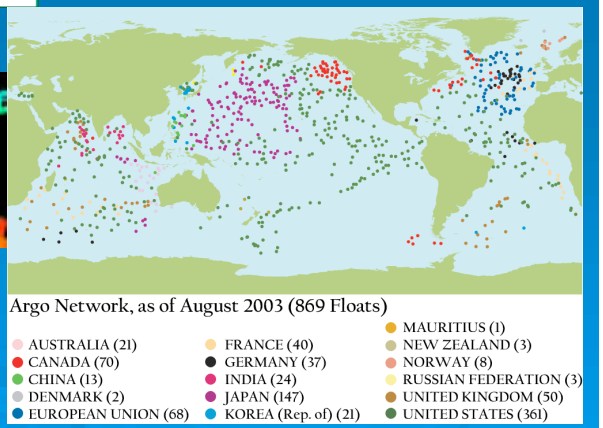






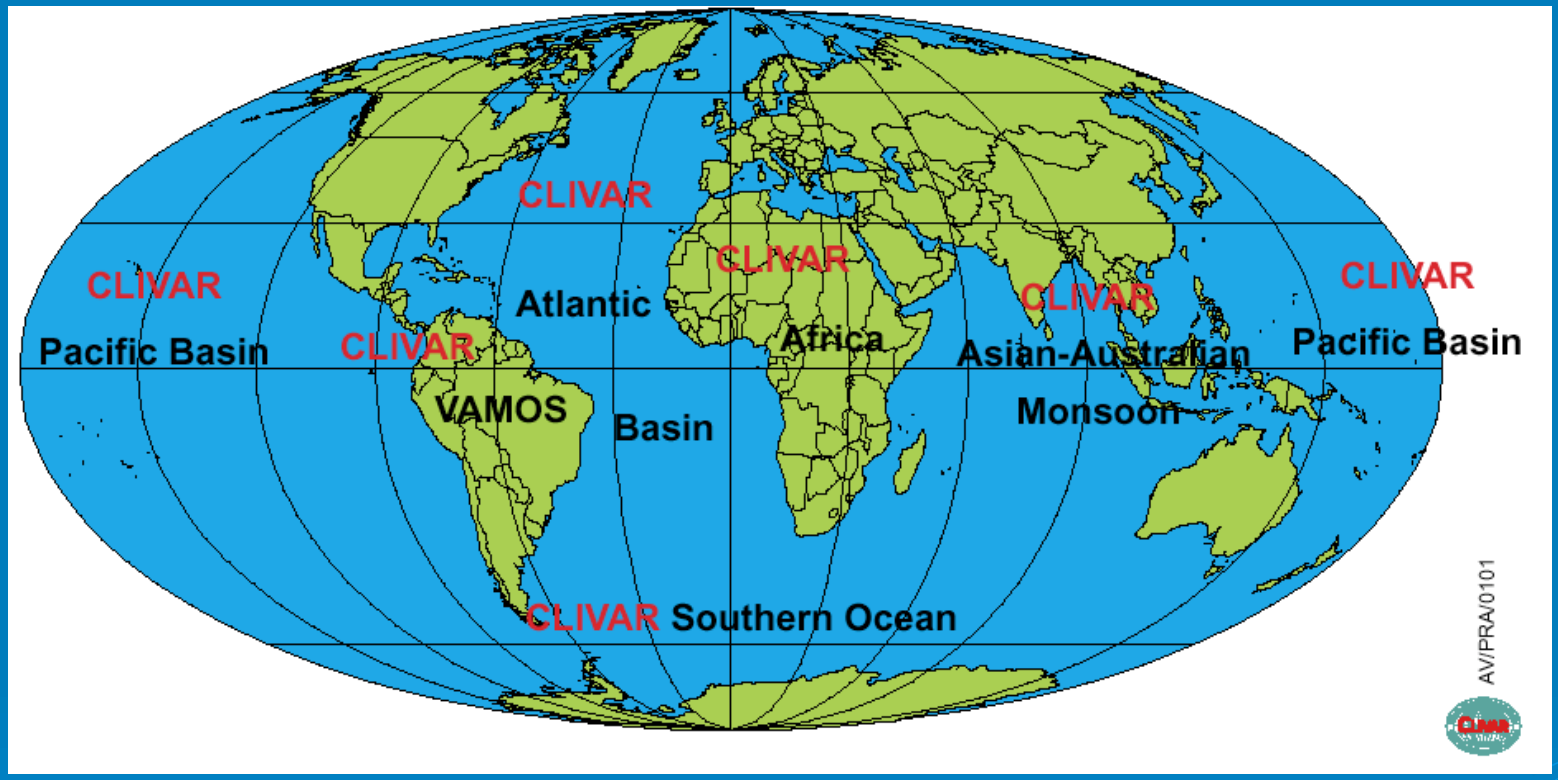






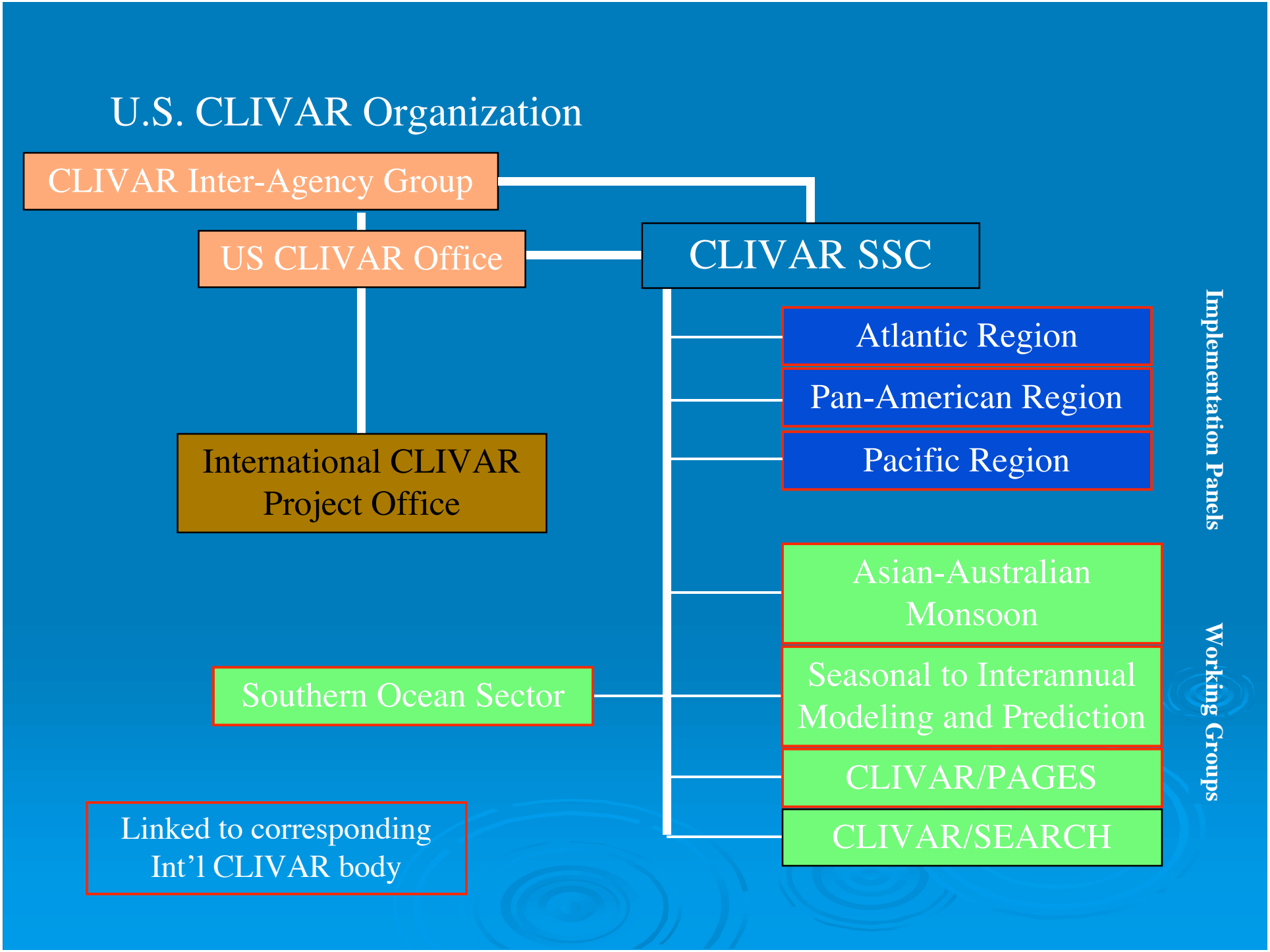
US CLIVAR

CLIVAR Implementation

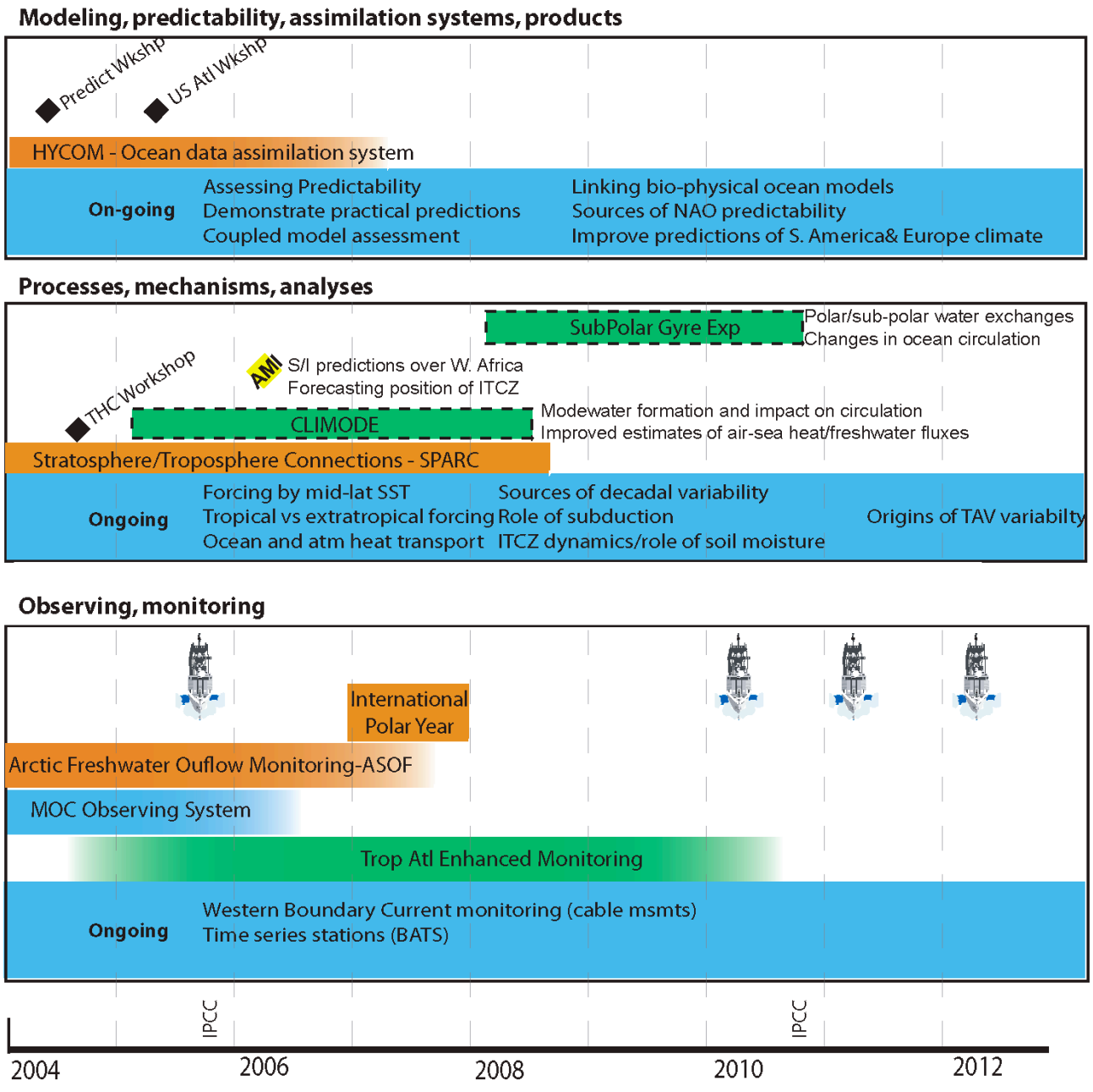


Working groups address global synthesis, basins modeling, and prediction

US CLIVAR


U.S. CLIVAR Organization
CLIVAR Inter-Agency Group
US CLIVAR Office
CLIVAR SSC
International CLIVAR Project Office
Atlantic Region
Pan-American Region
Pacific Region
Implementation Panels
Asian-Australian Monsoon
Seasonal to Interannual Modeling and Prediction
CLIVAR/PAGES
CLIVAR/SEARCH
Working Groups
Southern Ocean Sector
Linked to corresponding Int'l CLIVAR body

U.S. CLIVAR Roadmap: Atlantic Regional Elements



Achievements

1) Models simulate Indian Ocean warming crucial to the forcing of the North Atlantic Oscillation

2) AGCMs demonstrate skillfull forecast of the equatorial SST

3) Atlantic Marine ITCZ migration determines seasonal distribution of rainfall over Africa and South American

4) Accurate precipitation forecasts depend on accurate SST forecasts

Future Outcomes

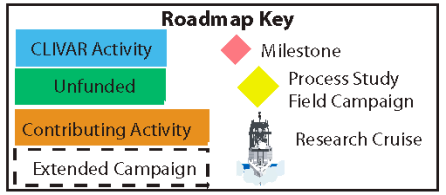
1) Improved Atlantic SST and SSTA gradient predictions

2) Demonstrations of practical climate forecasts for adjoining continental regions

3) Validated coupled models of Atlantic climate variability

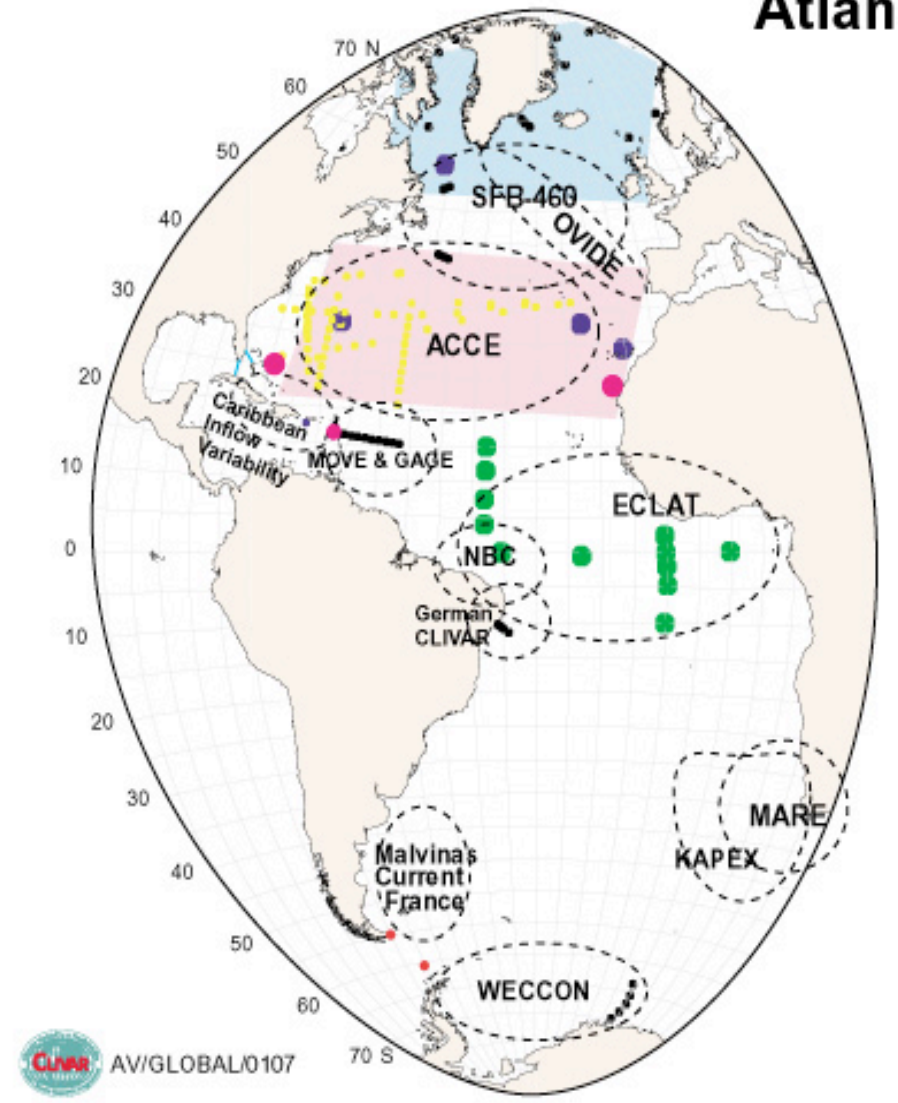
4) Fully three-dimensional models of Atl thermohaline circulation

5) Observing system for S. Ocean sector



3/3/04 DML

CLIVAR related projects in the Atlantic Sector



- Floats
- Hydro-Series
- PIRATA
- Moorings
- Cable measurements
- Deep Pressure Gauge
- CTD Profiler
- Abrupt Climate Change (UK)
- ASOF Arctic SubArctic Ocean Flux Array

CORIOLIS: operational oceanography whole Atlantic (France)

SFB-460: Subpolar North Atlantic Study (Germany)

NBC: North Brazil Current Ring Experiment (USA)

OVIDE: Observation of the interannual and decadal variability of the subpolar gyre in the N. Atlantic (France)

MOVE: Meridional Overturning Variability Experiment (Germany)

GAGE: Guyana Abyssal Gyre Experiment (USA)

ACCE: Atlantic Circulation and Climate Experiment (USA)

ECLAT: Tropical Atlantic Climate Study (France)

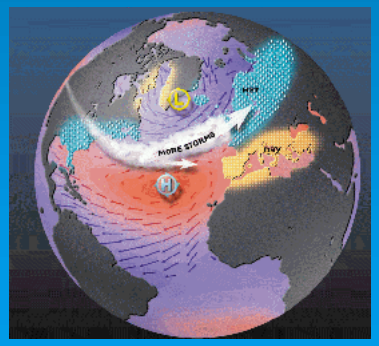
MARE: Mixing of Agulhas Rings Experiment (S. Africa and NL)

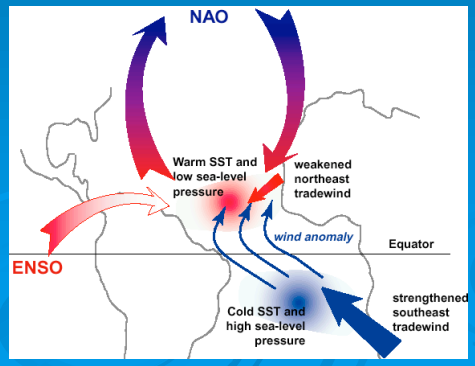
KAPEX: Observing the Intermediate Flow at the tip of Africa (Germany S. Africa)

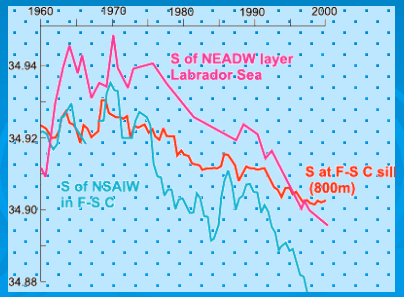
WECCON: Weddell Sea Convection Control (Germany)

Atlantic Panel

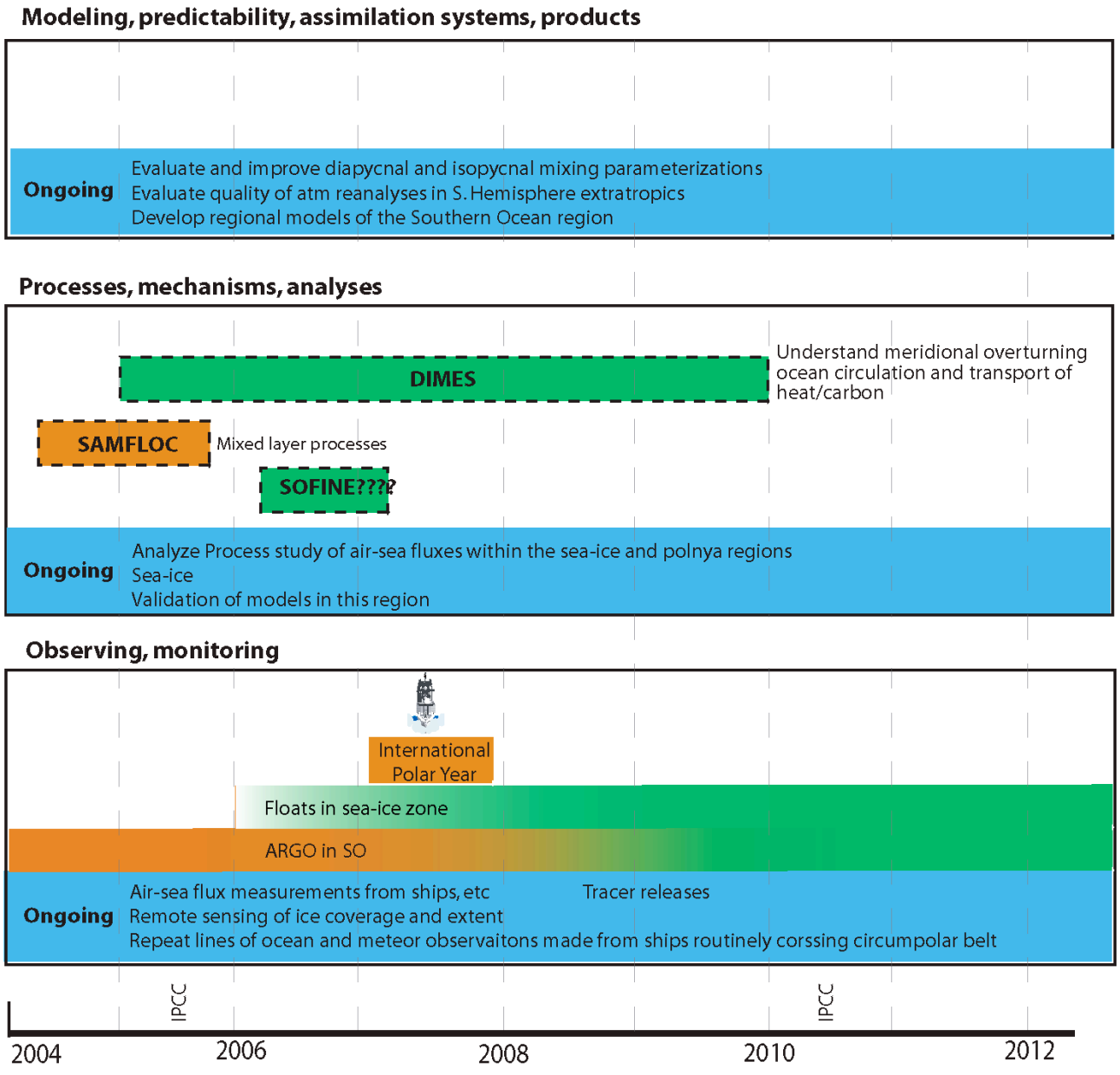
- NAO/AO/AM
  - Mechanisms that govern its variability?
  - Low-frequency trends?
  - Ocean, land, sea-ice feedbacks?
  - Numerous applications
- TAV
  - Influence of ENSO, NAO?
  - Role of coupling in TNA? Of subtropical cells?
  - Extent of *land* influences?
  - Climate predictability
- MOC
  - Variability of ocean heat transport?
  - Sensitivity to sfc forcing?
  - Role of thermohaline circulation in abrupt climate change?







U.S. CLIVAR Roadmap: Southern Ocean Elements



Achievements

1) Simulations of float and tracer dispersion
2) ENSO - SO ice edge relationship established

Future Outcomes

1) Role in long-term climate
2) Understand the role of the ACC region in the MOC
3) Improve parameterization of fluxes in coupled climate models
3) Understanding and predicting ocean freshening
4) Carbon

Roadmap Key

- CLIVAR Activity
- Unfunded
- Contributing Activity
- Extended Campaign
- Milestone
- Process Study Field Campaign
- Research Cruise

3/5/04 USCO

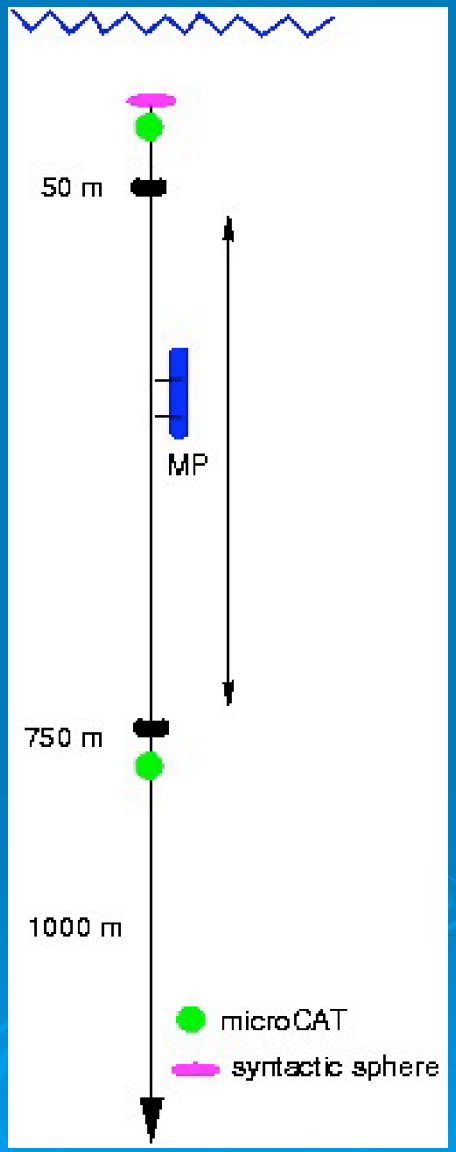
Bernadette Sloyan

Talley and Chereskin hydrography ARGO floats

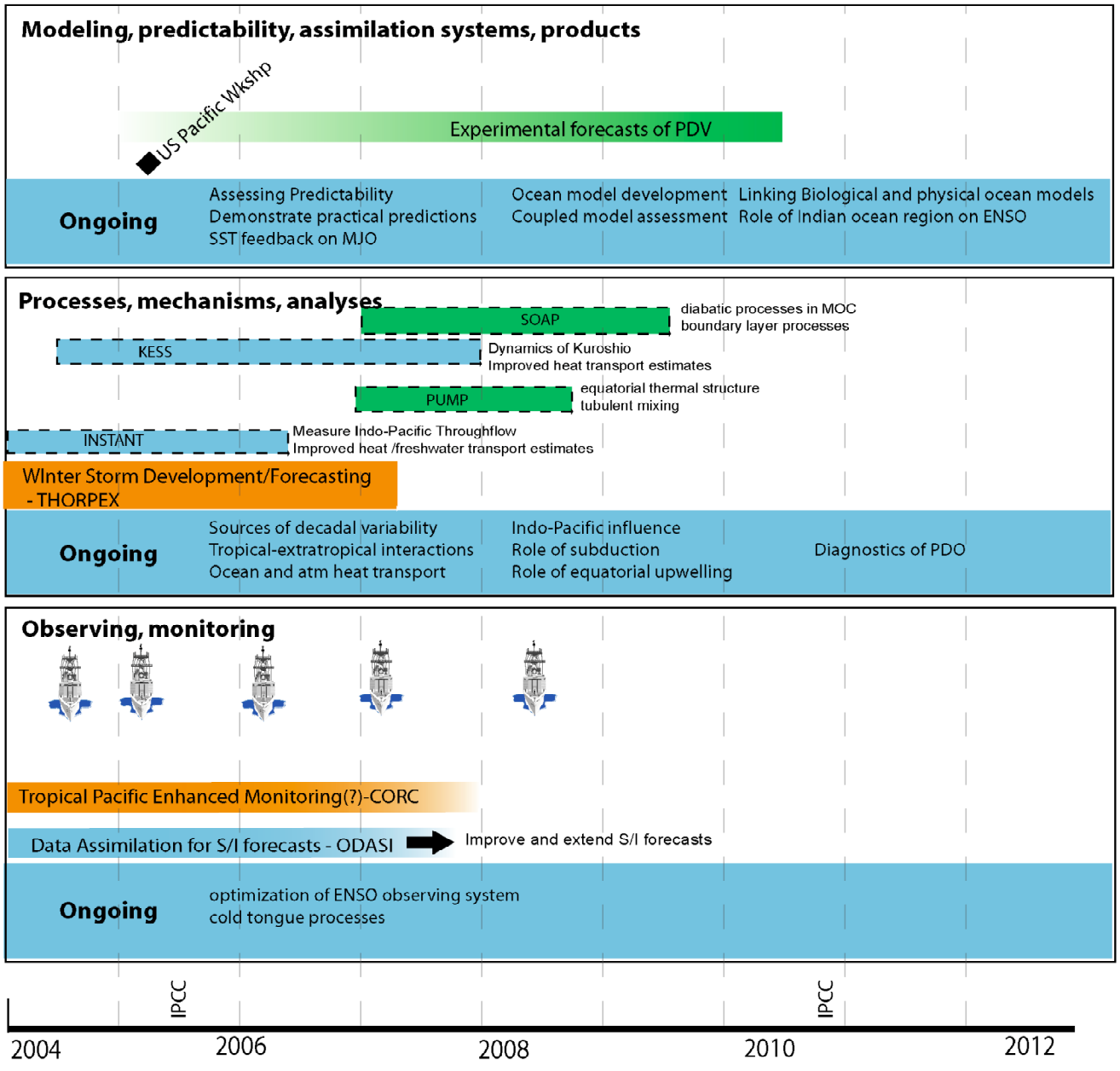
81 W, 57S 77W, 59S

Two ten month deployments, begin March-April 2005

AAIW, SAMW, Ekman transport, eddy and fine structure statistics
Heat and salt advection, mixed layer evolution by air-sea fluxes
mixing



U.S. CLIVAR Roadmap: Pacific Regional Elements

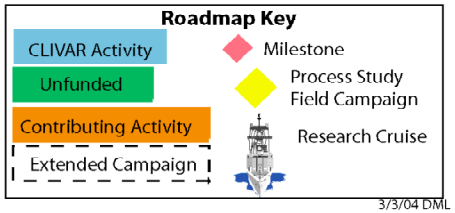


Achievements

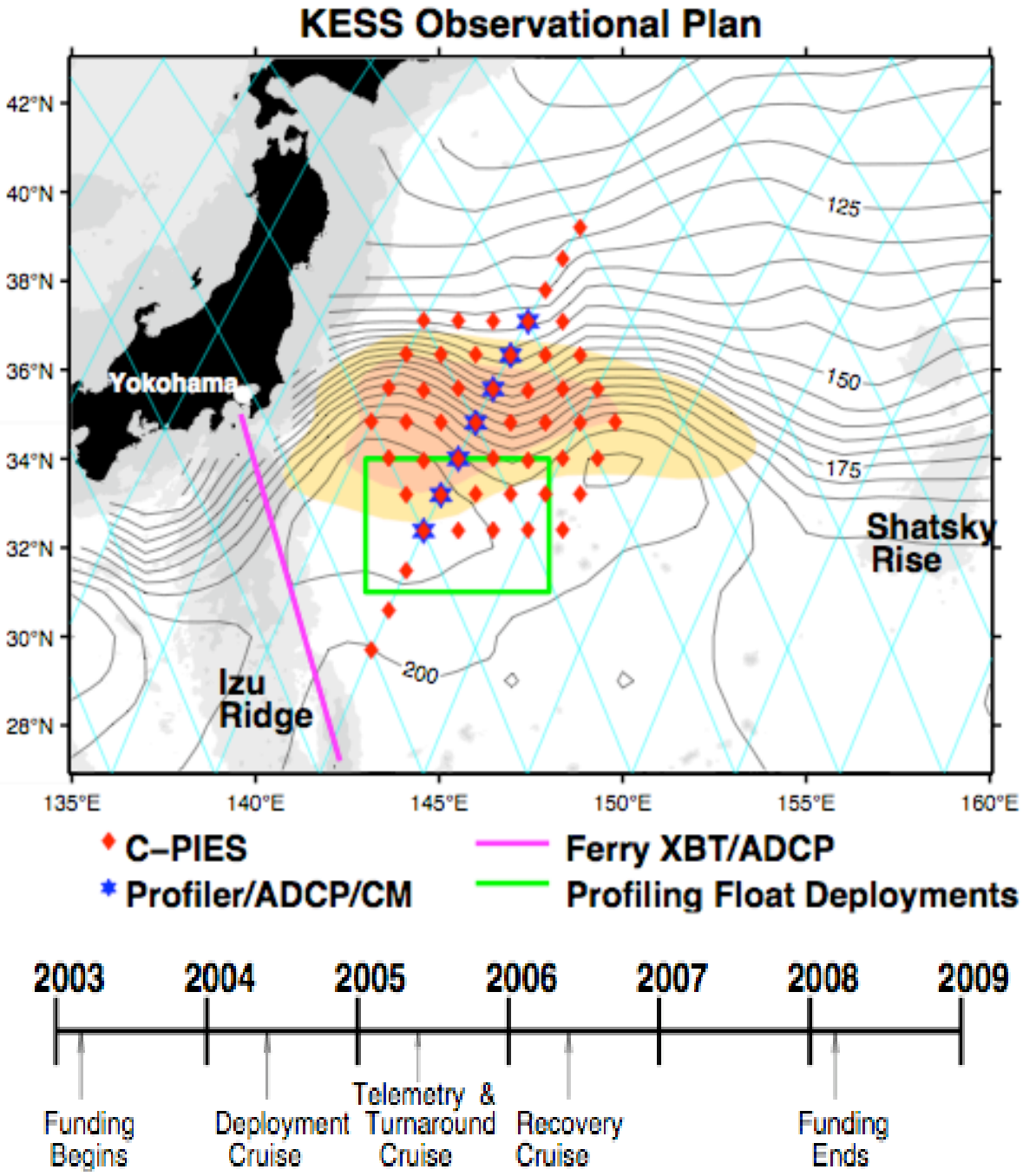
1) Demonstrated hindcasts of strong ENSO events
2) Inital ENSO observing system
3) Detected strong decadal basin-scale variability (PDV) in climate as well as in ecosystems data
4) Observations and models suggest importance of phytoplankton on tropical SST

Future Outcomes

1)Quantify and predict variability of tropical Pacific SST, especially for ENSO
2) Better characterize and predict basin-scale decadal variability
3) Better quantify and predict effects of basin-scale variability (ENSO, decadal variability) on regional climate
4) Improve parameterizations of diabatic processes in the critical vertical branches of the MOC.
5)Improve air-sea fluxes of heat and freshwater in high-wind regions and other critical areas (Kuroshio)
6)Characterize effects of basin-scale variability on plankton and carbon fluxes, and feedbacks between biology and physics.



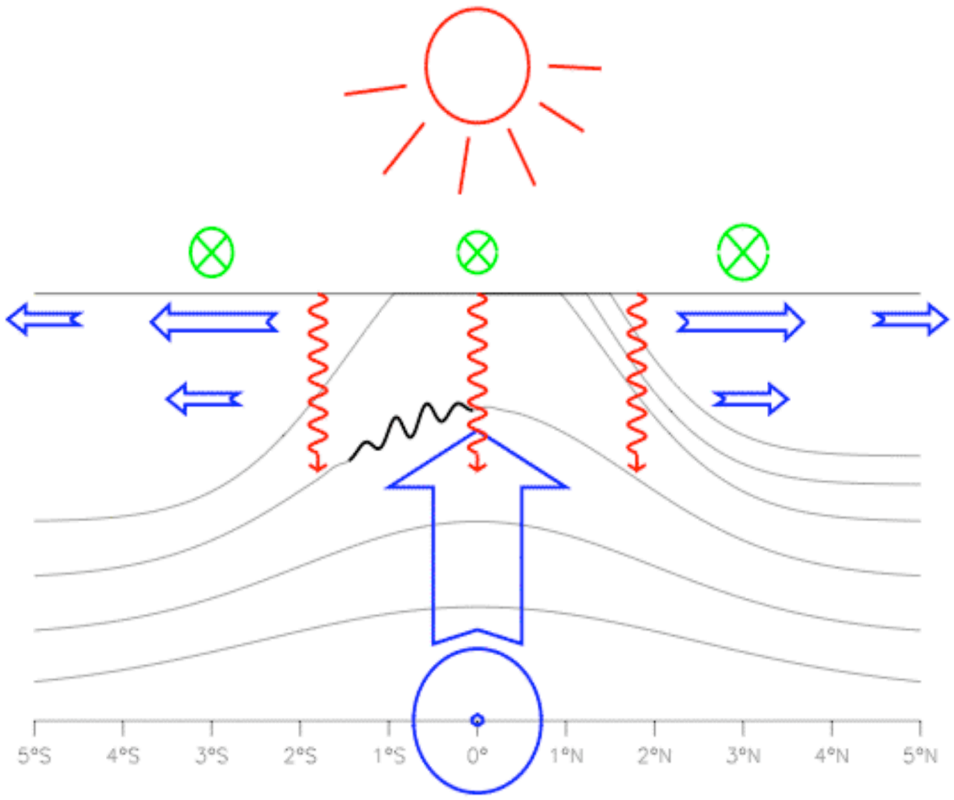
3/3/04 DML



- A study of dynamic and thermodynamic processes in the Kuroshio Extension System.
- To be augmented with an air/sea flux mooring

US CLIVAR

Pacific Upwelling and Mixing Physics (PUMP)



- Study the balance that maintains the equatorial thermal structure:
  - Near-surface divergence
  - Upwelling
  - Heating from the atmosphere
  - Turbulent mixing
- These processes are currently quantifiable only as integrals over very large areas.
- Correctly modeling equatorial circulation and SST variability requires the ability to accurately represent all of these processes.

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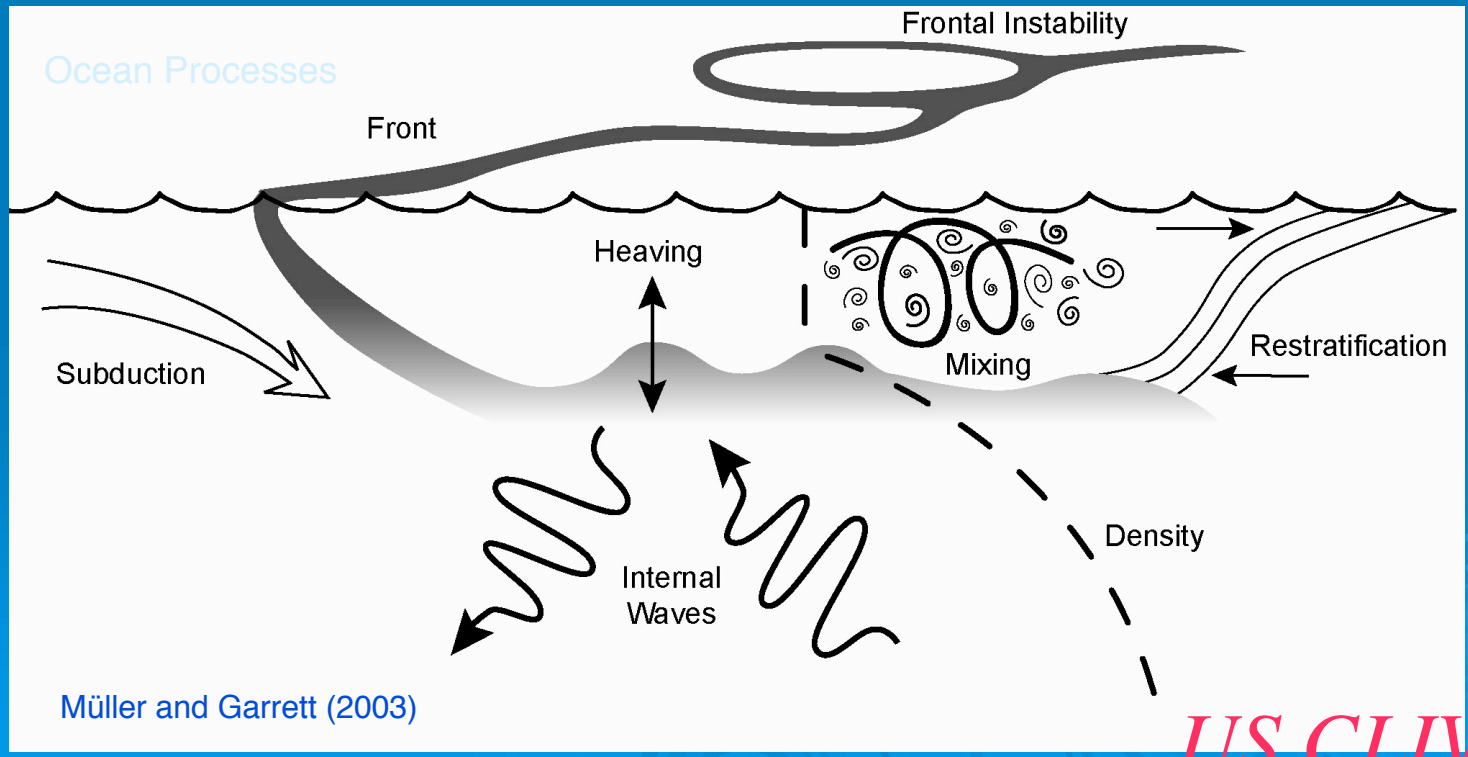
Subtropical Ocean-Atmosphere Processes (SOAP)

•Subtropical ocean – downward branch of shallow meridional overturning cell (MOC)

Focus – diabatic processes that set initial water properties in MOC

•Subtropical atmosphere – air/sea interaction dominated by winter storms

Focus – boundary layer processes in region of strong wind



Müller and Garrett (2003)

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El Nino Southern Oscillation (ENSO): Accomplishments (State of Science)

- *El Nino Mechanisms*: Good understanding of the evolution once events have begun; Theory and coupled models are maturing with high community interest and involvement.
- *El Nino Monitoring*: Good coverage in the Eastern Pacific; TAO measurements (in-situ) and TOPEX altimetery and QuikSCAT winds (from space) are indispensable.
- *ENSO Predictions*: Operational & Experimental predictions are routinely made; Useful prediction of strong events.
- *ENSO Impacts-I*: Seasonal hydroclimate impacts over North America from strong events are well predicted; Underlying mechanisms are being rapidly identified
- *ENSO Impacts-II*: Human health impacts (e.g., cholera, malaria, and dengue outbreaks), and that on Heat waves, and Forest fires are being actively investigated

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El Nino Southern Oscillation (ENSO): Challenges (Goals)

- *El Nino Mechanisms*: Origin/initiation of events remains obscure; subtropical Pacific and Indian ocean sectors, and stochastic forcing appear influential in the genesis phase; theories/models will need to be more inclusive.
- *El Nino Monitoring*: Synoptic monitoring needs enhancement in the W. Pacific so that precursor signals (e.g., westerly wind bursts) can be readily identified
- *El Nino Predictions*: Forecasting of weak-to-modest ENSO events remains challenging; Develop an operational multi-model, multi-member, super-ensemble forecasting system
- *El Nino Impacts*: Downscaling with regional coupled biogeochemical models

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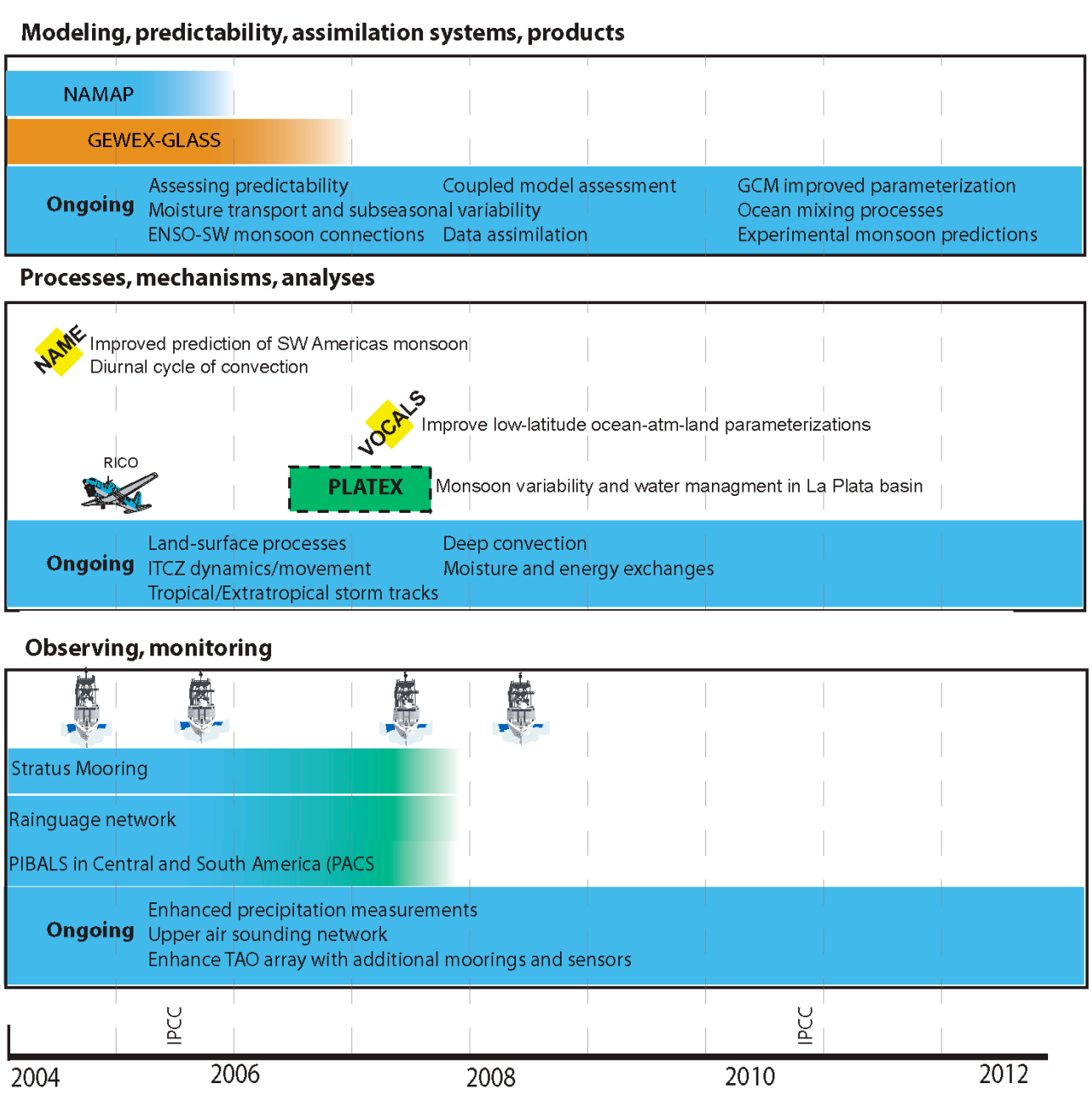
Pacific Decadal Variability: Goals

- ***PDV Structure*: Characterize from climate and ecosystem data**
- ***PDV Mechanisms*: Elucidate from analysis, modeling, and predictability studies**
- ***PDV Links*: Analyze linkage with Global Warming**
- ***PDV Impacts-I*: Model and Predict impacts on North American Precipitation, Drought, Streamflow**
- ***PDV Impacts-II*: Biophysical Ecosystem Modeling of impacts on Pacific fisheries, Western water, Energy supply/demand, Fire potential, Air-quality**
- ***PDV Monitoring*: Develop an integrated observing strategy**

PDO background (Nigam et al., *EOS*, 1999)

U.S. CLIVAR Roadmap: PanAmerican Elements



Achievements

1) Enhanced monitoring along TAO lines

2) 1st dianosis of diurnal cycle of SA Low Level Jet

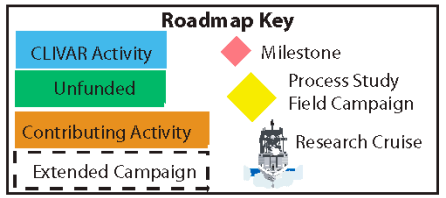
3) Improved understanding of cold tongue/ITCZ complex

4) Benchmark data sets now exist for evaluating models and numerical weather products and satellite fields

5) New parameterizations and improved GCMs of eastern tropical Pacific.

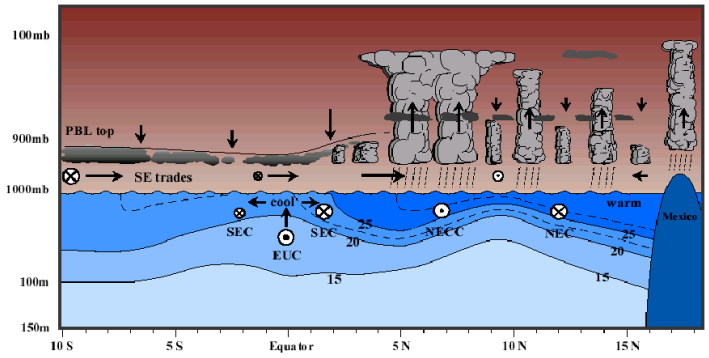
Future Outcomes

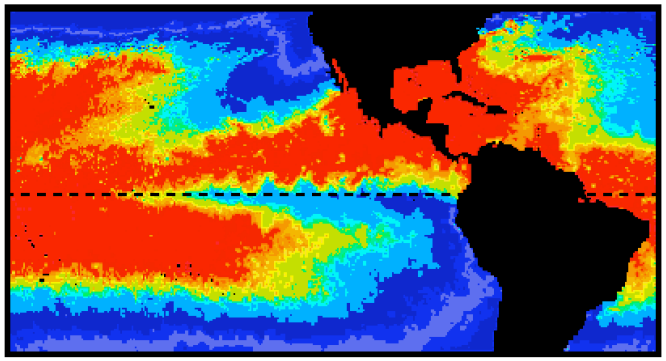
1) Improved SST prediction
2) Warm season precipitation prediction
3) Enhancd observing system in the eastern tropical Pacific focusing on convection



3/5/04 USCO

A Science and Implementation Plan for EPIC:
An Eastern Pacific Investigation of Climate Processes
in the Coupled Ocean-Atmosphere System



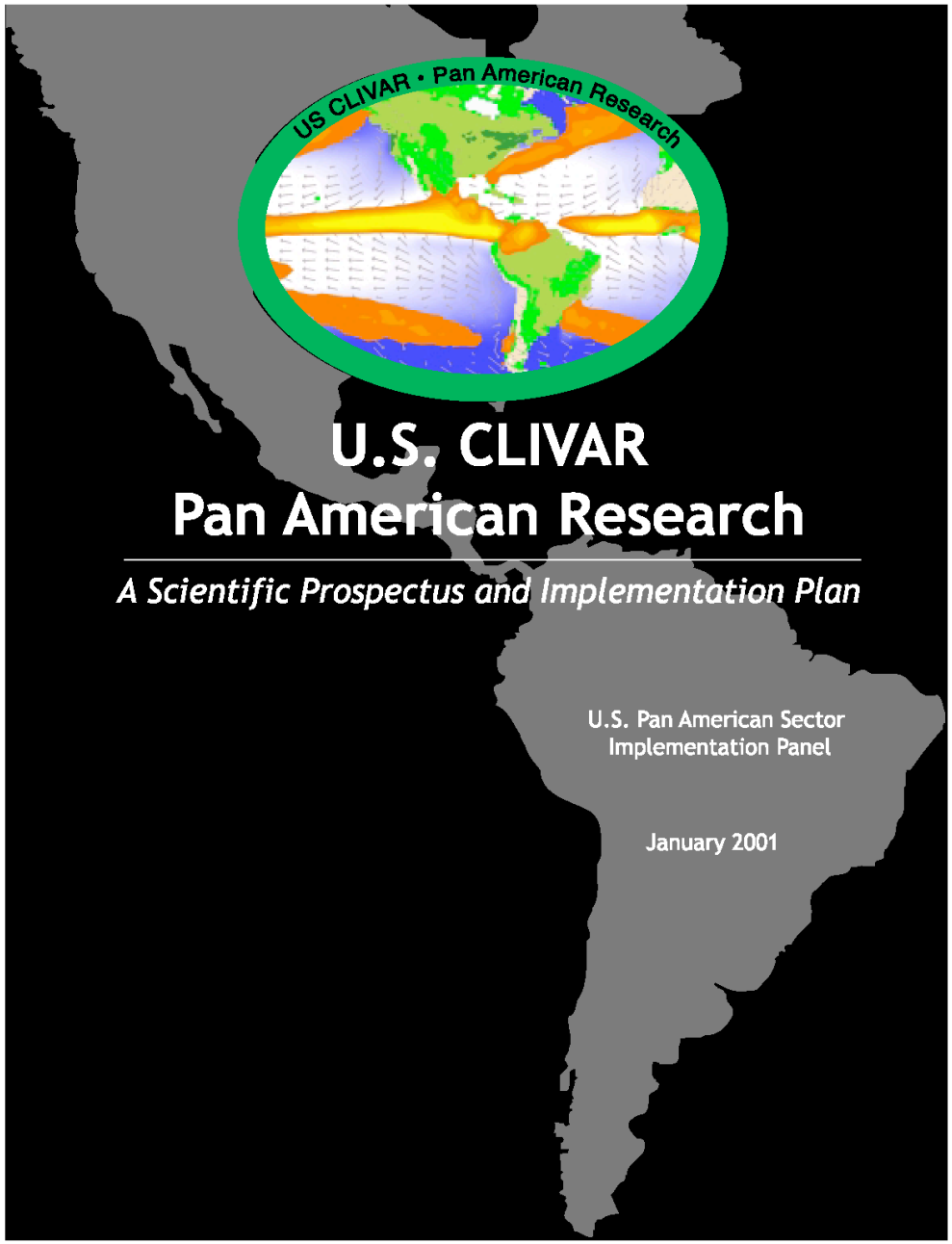


EPIC -

The first U.S. CLIVAR Enhanced Monitoring Project

The first U.S. CLIVAR Process Study

US CLIVAR



PACS

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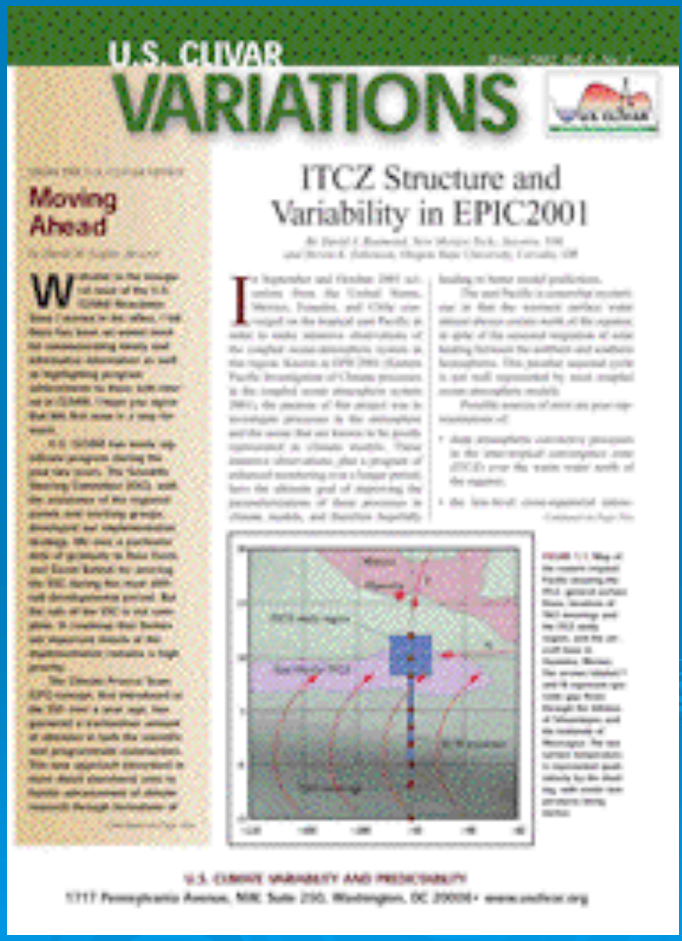
U.S. CLIVAR Newsletter Focus on EPIC

- EPIC
  - ITCZ Variability in EPIC 2001
  - Stratocumulus Study: Is drizzle a swizzle?
  - Variations in cold-tongue/ITCZ complex


U.S. CLIVAR
VARIATIONS
Moving Ahead
ITCZ Structure and Variability in EPIC2001
U.S. CLIVAR VARIABILITY AND PREDICTABILITY

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Process Studies Considered by US CLIVAR SSC

- NAME: North American Monsoon Experiment
- KESS: Kuroshio Extension System Study
- SALLJ: South America Low-Level Jet experiment

- MITZ: Maritime ITCZ Experiment
- PUMP: Pacific Upwelling and Mixing Physics Study
- VEPIC: VAMOS East Pacific Investigation of Climate
- TAV-STC: Tropical Atlantic Variability-SubTropical Cells
- EDW: Eighteen Degree Water experiment
- SPG: SubPolar Gyre experiment
- DIMES: Diapycnal and Isopycnal Mixing Experiment
- GASEX: Gas Exchange in the S. Hemisphere
- SAMFLOC: Subantarctic Mixed Layers, Fluxes & Overturning Circulation

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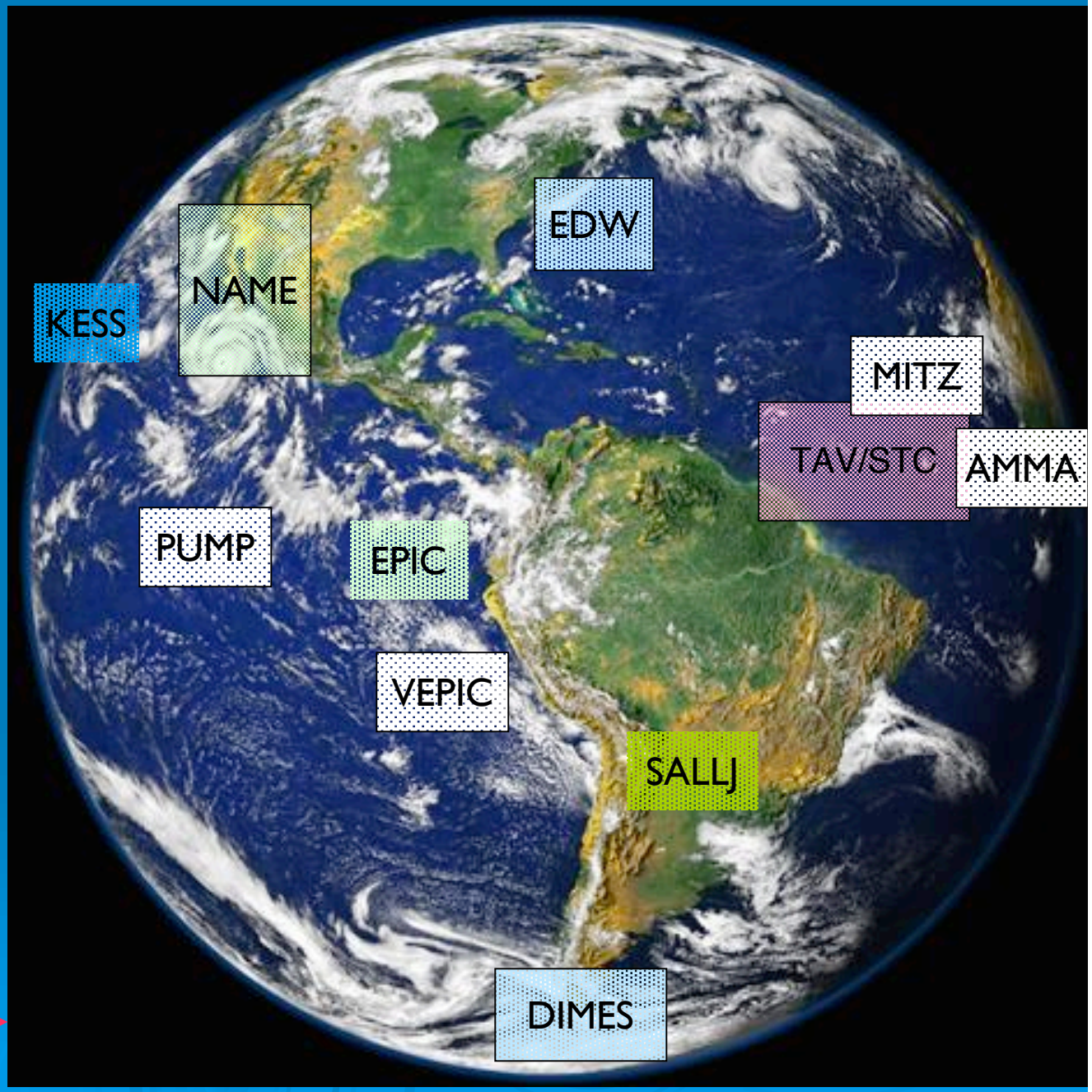
U.S. CLIVAR Process Studies

- Ocean-Land-Atm Studies
- Ocean Mixing Studies
- Ocean Dynamics
- Atm Dynamics
- Enhanced Monitoring
- Still Developing



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Climate Process Modeling and science Teams (CPTs)

- Teams of observational scientists, diagnostic scientists, process modelers, and (one or more) coupled model developers and data assimilation system developers to speed the improvement of coupled models, data assimilation systems by:
  - Parameterizing the important processes not included explicitly in climate models;
  - Transferring theoretical and process-model understanding into improved treatment of processes in climate models;
  - Sharpening our understanding of how particular physical processes impact the climate system;
  - Identifying sustained observational requirements required by climate models for these parameterizations; and
  - Identifying additional process studies necessary to reduce uncertainties associated with important climate model processes/parameterizations.
  - CPT whitepapers available on U.S. CLIVAR website

CPT concept being adopted by U.S. as a framework for linking observations and modeling

CPT Pilot Program

- Demonstration of concept with a 2-3yr pilot activity
- NSF-NOAA (& NASA) $2.5M, 2-4 teams
- Topics
  - Improving the treatment of mixing in ocean circulation models
  - Climate feedback processes and climate sensitivity for understanding and reducing uncertainties in climate model predictions and projections
    - deep atmospheric convection
    - water vapor and cloud (e.g. boundary-layer clouds) processes

Modeling Activities

Some Objectives:

- Improve predictions on seasonal-to-interannual time scales
- Assess predictability of decadal variability
- Evaluate and enhance the reliability of models used to project climate change

  U.S. teams of modelers, observationalists, and diagnosticians will address two major areas of uncertainties in climate change models

  - Ocean mixing and low-latitude cloud feedbacks
- Development of robust dynamical synthesis frameworks (e.g. data assimilation) for understanding climate variability and predictability and to guide observation system design

  - Recent (2003) workshops on
    - Ocean data assimilation
    - Atmospheric data assimilation/reanalyses
    - Coupled data assimilation

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U.S. CLIVAR Modeling

- *Assessing Directions*
  - *relative to US CLIVAR goals and overarching themes*
  - *modeling workshops*
- *Ensuring Linkage*
  - *process studies-models*
  - *basin and global scale testing of hypotheses*
- *Making Transitions*
  - *CPTs*
  - *partnerships with modeling centers*

US CLIVAR

What Next for U.S. CLIVAR?

- Developing a roadmap of U.S. CLIVAR implementation
  - Predictability and predictions
  - Sustained observing system
  - Process studies/Enhanced monitoring
  - Data/product management and access
  - Reanalyses - coupled data assimilation
  - Abrupt climate change

US CLIVAR

What Next for U.S. CLIVAR?

- Developing a roadmap of U.S. CLIVAR implementation
  - When
  - What
  - Resource needs - timing/phasing
  - Explicit interconnectivity of activities with

    Improvement to predictions

    Development of products

      Using improved predictive skill

      Based on improvements to observing systems

      Based on new understanding of climate variability

      For example -

        improved warm season precipitation forecast

        improved drought forecast

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Questions for VAMOS

- Activities beyond 2006? (For last phase of CLIVAR)
- What aspects of predictability is VAMOS addressing, with what success?
- VEPIC/VOCALS other planning?
- Global applications of research (modeling) - the tier 3 activities in NAME, for example
- Transitions to operational predictions
  - Especially seasonal to decadal
- Linkage to products

US CLIVAR

Program

- Short-term (seasonal-to-interannual) prediction
- The monsoon systems
- The challenge of decadal prediction
- Understanding long-term climate variations
- The role of the oceans in climate
- Human influence on climate
- CLIVAR science and societal benefits
- Future challenges for CLIVAR

Illustrative questions for CLIVAR

- How can we better predict El Niño and its impact on climate?
- What are its links to higher frequency (e.g., MJO) and to decadal variability?
- Decadal variability has been shown to impact climate in many regions…can we ever predict this variability?
- What are the some of the mechanisms than can lead to abrupt climate change?
- How does El Niño change under a changing climate?