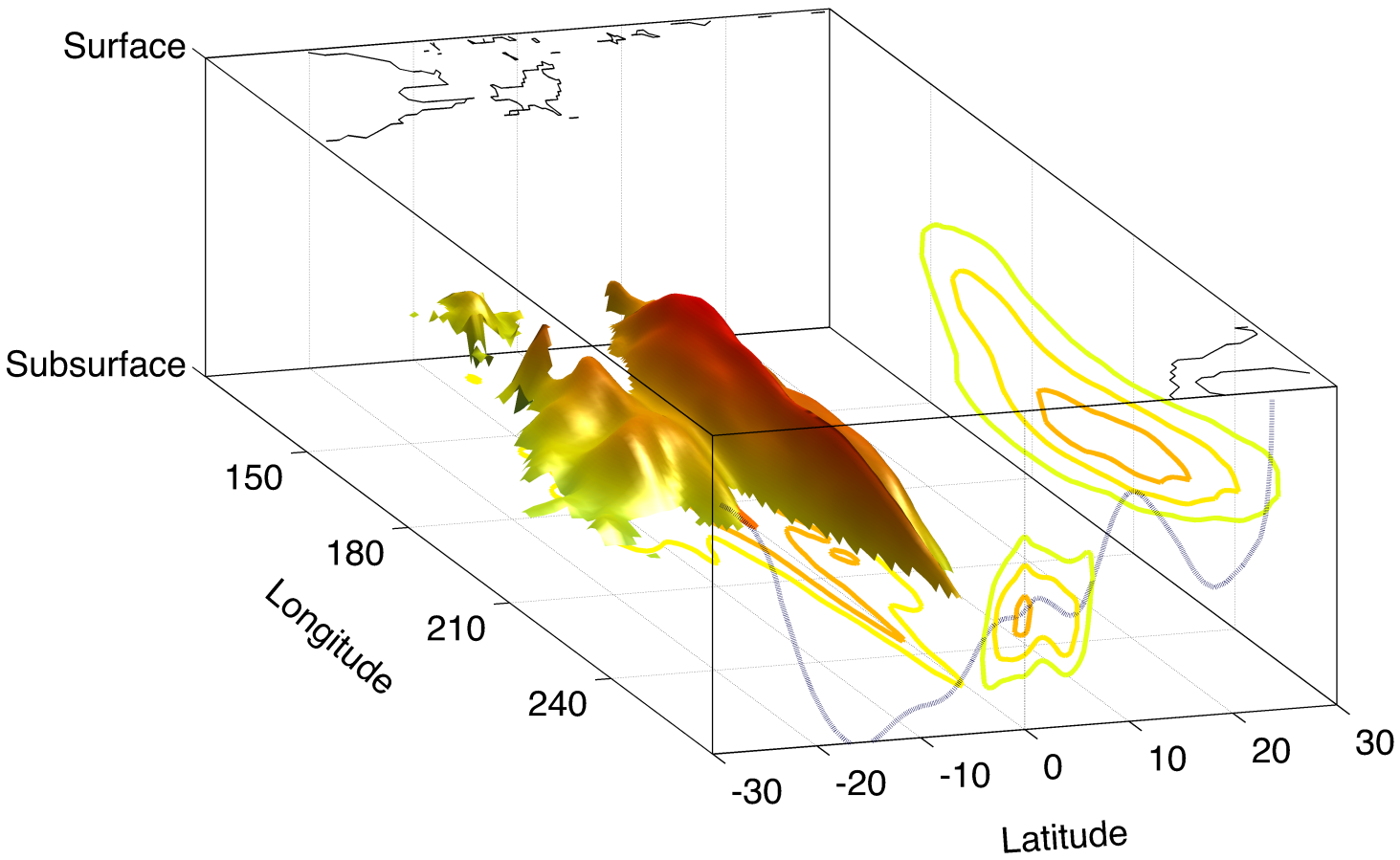
ENSO precursors and building an operational ENSO monitoring system

Bruce T. Anderson
Dep't. of Earth & Environment
Boston University

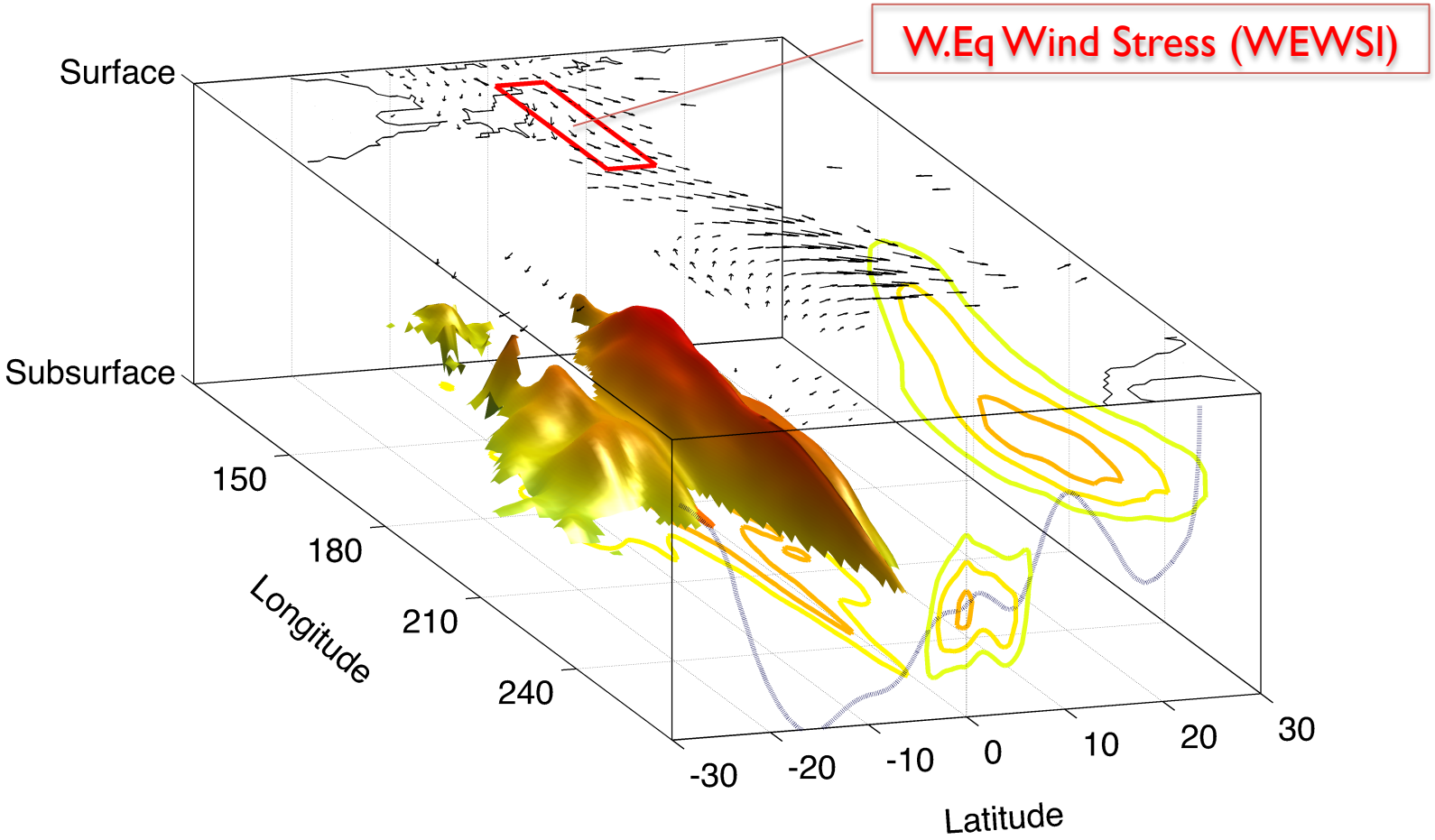
Laying the Groundwork

- ***Validation Time***
  - Extended Boreal Winter (~Nov.-Mar.)
  - Robust ENSO signal
  - Relatively high impact (particularly on North America)
- ***Initialization Time***
  - "Quantitative ENSO Forecast" (QEF): 0-6 Months prior to event
    - Post-Spring Predictability Barrier
    - First-order feedbacks are predominantly positive
    - Can still be substantial "unforced" ENSO development during this time
    - Monitoring region is "relatively" well constrained
  - *"Medium Range ENSO Forecast" (MREF): 6+ Months prior to event*
    - Pre-Spring Predictability Barrier
    - Substantially more *potential* initiation mechanisms
    - Need to discern which processes and metrics are worth monitoring
- ***Target***
  - Magnitude *and* Structure
    - Both characteristics modulate local and far-field climate responses to ENSO
    - Both have "preferred" precursors, suggestive of different initiation mechanisms

Precursor *Nonpareil*: Subsurface Heat Content



Subsidiary Precursors



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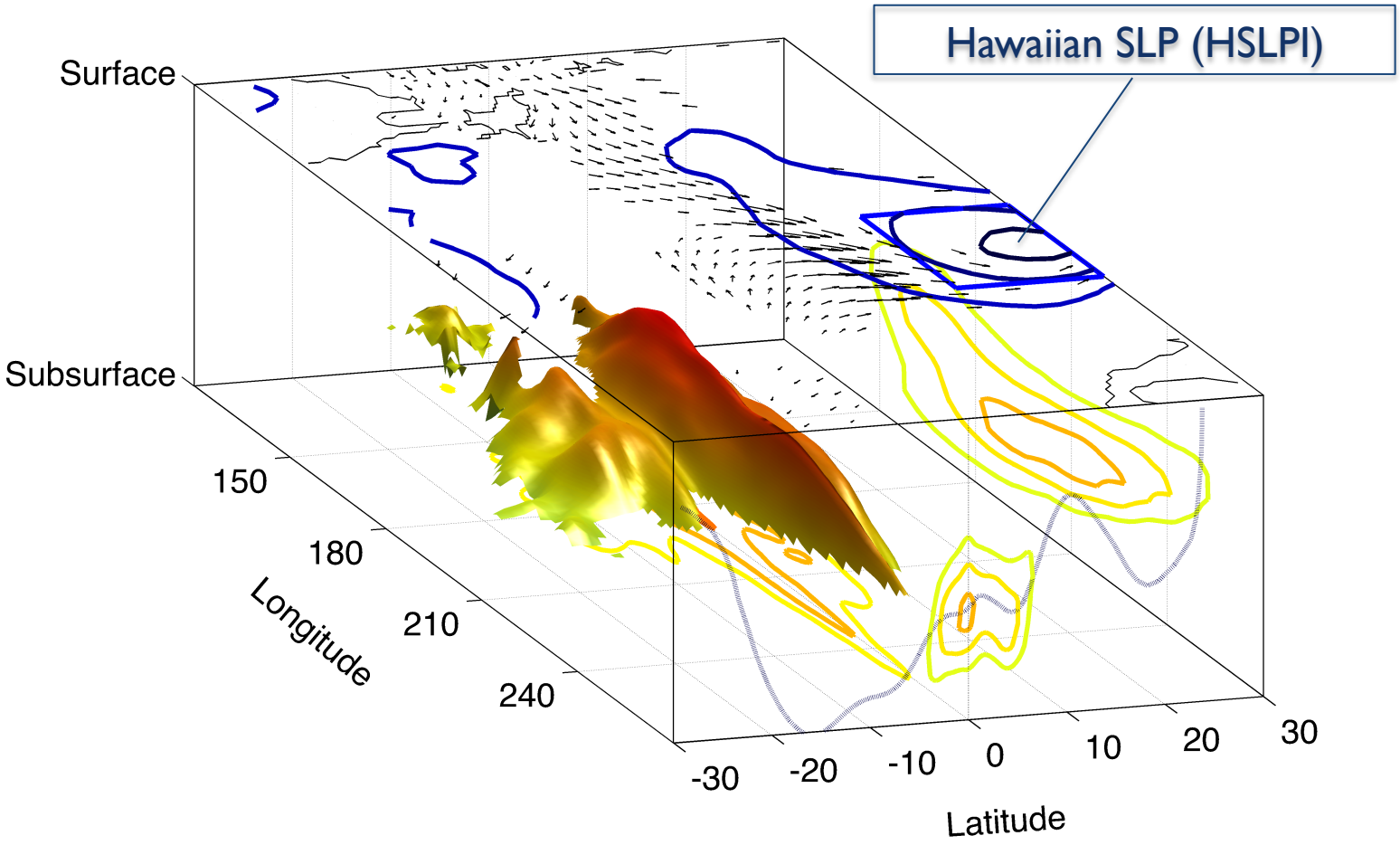

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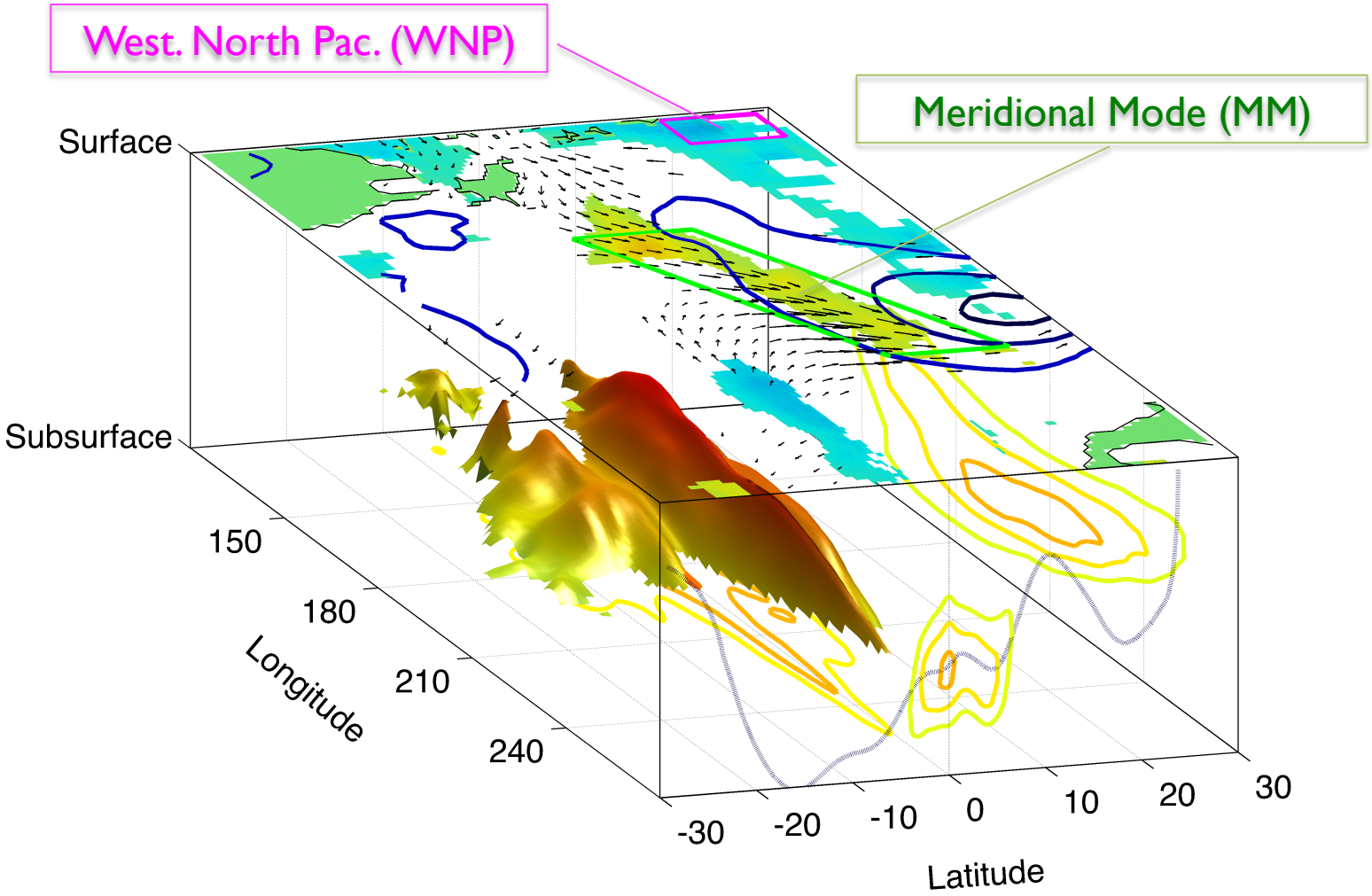

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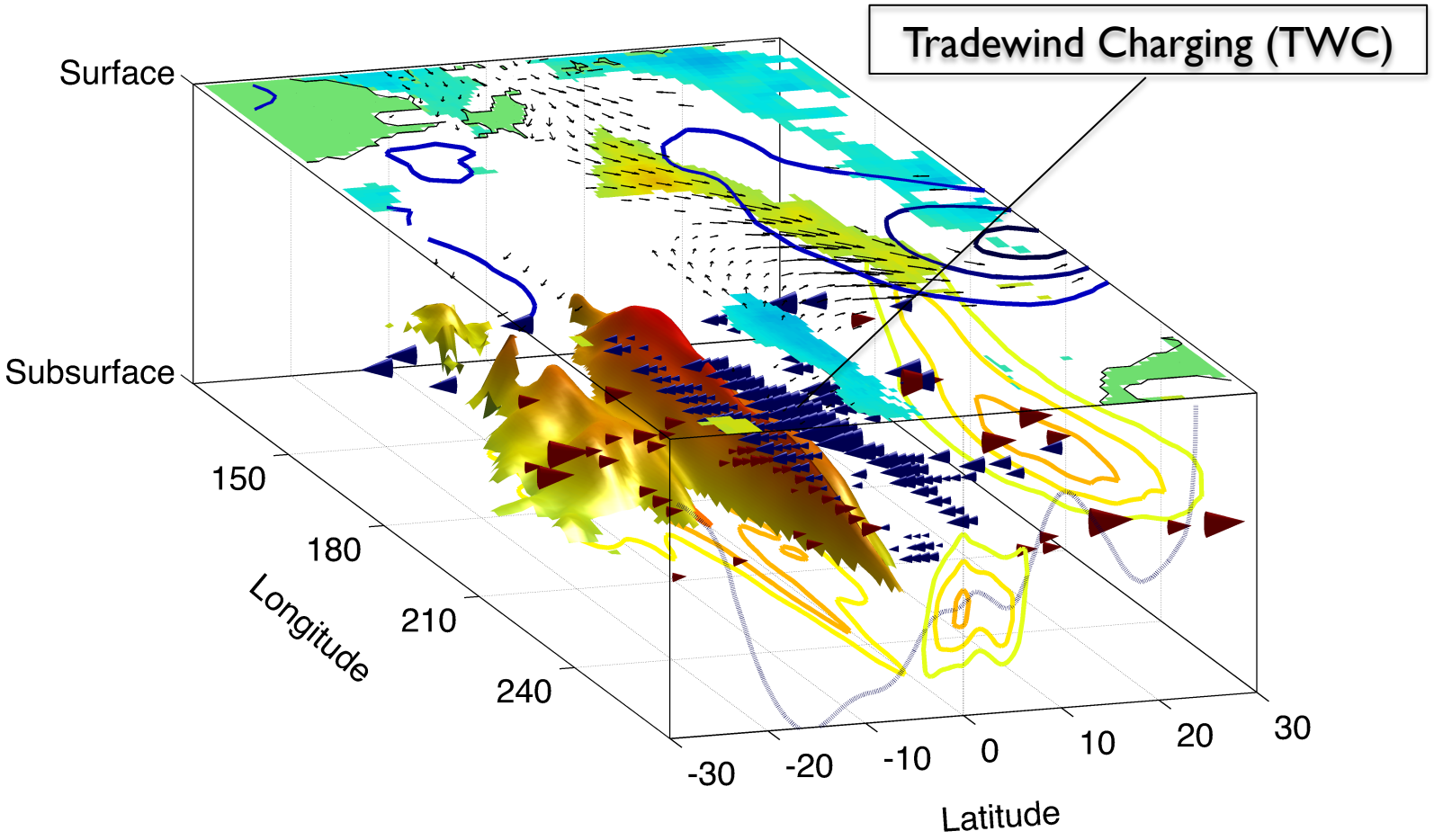

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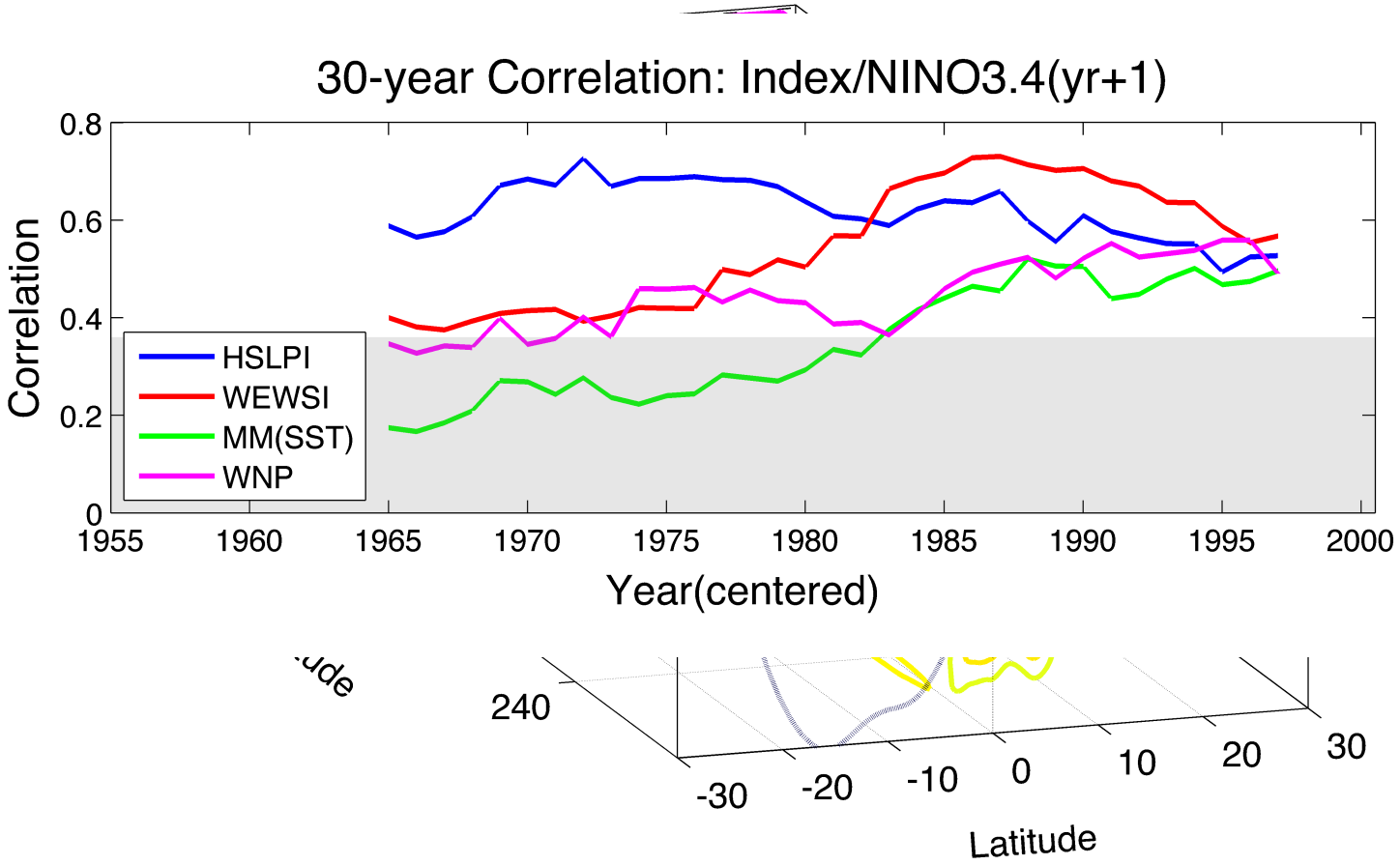

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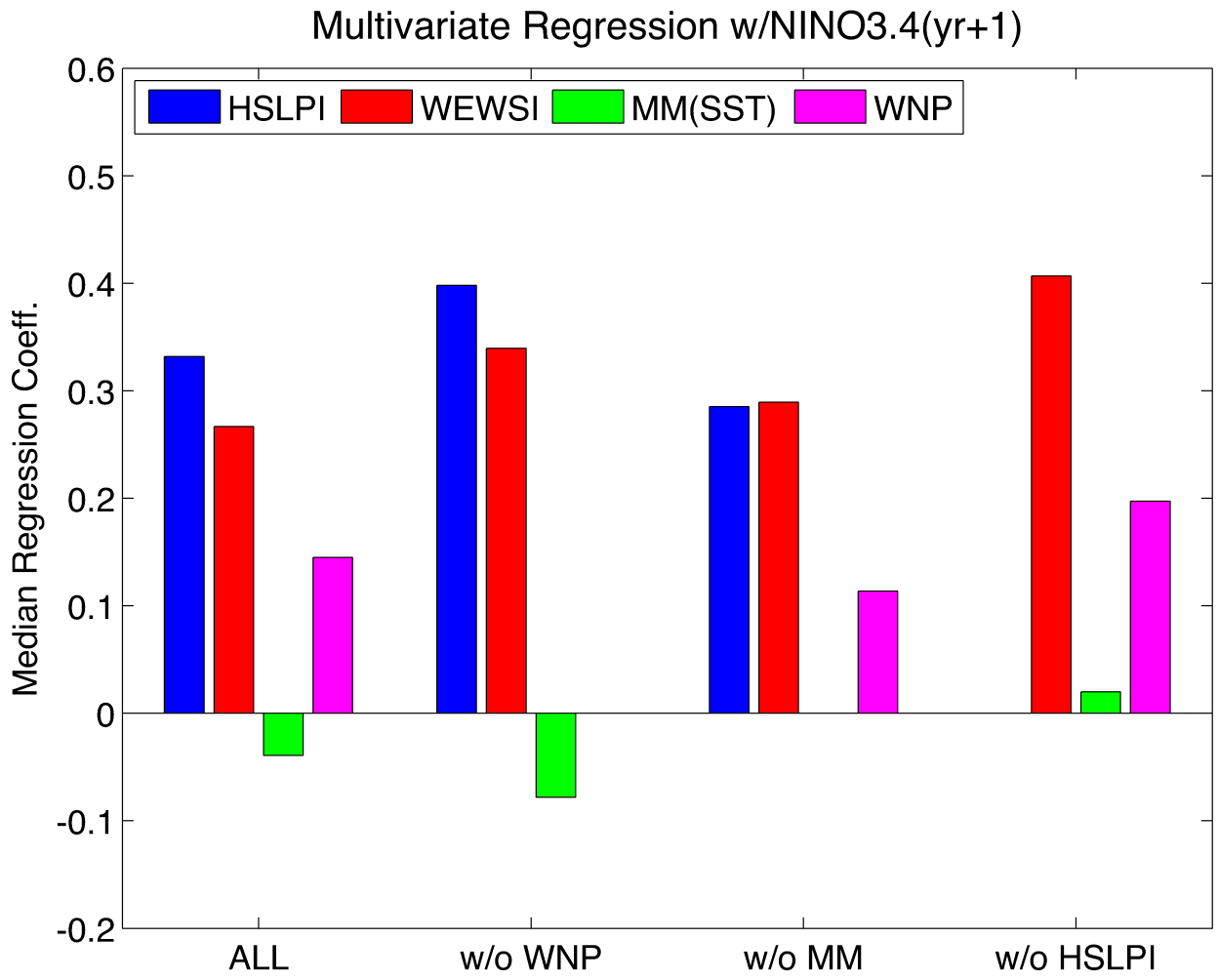

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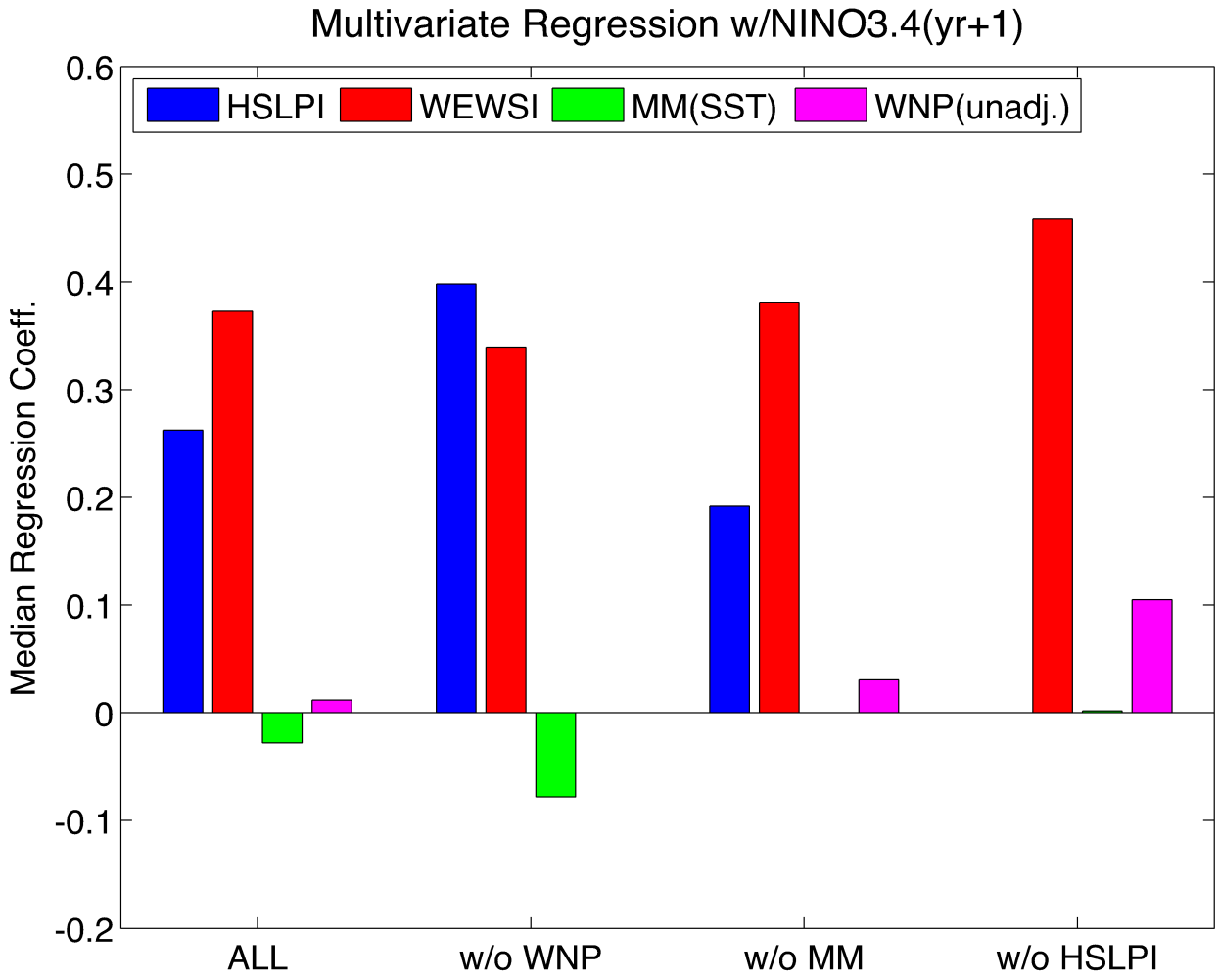


Operational Monitoring System Requirements

- ***"MREF" Precursors: > 6 months***
  - Subsurface ocean temperatures
    - Vertically integrated
    - Horizontal and vertical gradients
  - Western equatorial wind stress
    - Events
    - Accumulated Influence
  - Meridional mass transport
    - ENSO v. Non-ENSO
    - Directly measured
    - Derived: Wind-stress gradients and thermocline depth changes
  - Air-sea interactions (?)
    - N. Pacific Meridional mode
    - Western North Pac. Mode
    - Indian and Atlantic SSTs (see Dayan et al., 2014, 2015 for good review)

- ***"QEF" Precursors: 0-6 Months***
  - Subsurface ocean temperatures
  - Equatorial wind stress
    - Westerly wind burst events
    - MJO
    - Basin-wide modification of trades
  - Air-sea Interactions
    - Convection
    - Surface heat budgets
  - Tropical ocean circulation
    - Equatorial Currents&Upwelling
    - Temperature, Salinity, and Density Gradients
    - Mixing/Diffusion/Entrainment
  - Remote atmospheric circulations
    - Seasonal footprinting SSTs
    - North Pacific Oscillation
    - S.Pacific Meridional Mode
    - Southern Hemisphere "Booster"
    - Tropical Atlantic Variability

Building an Operational Monitoring System

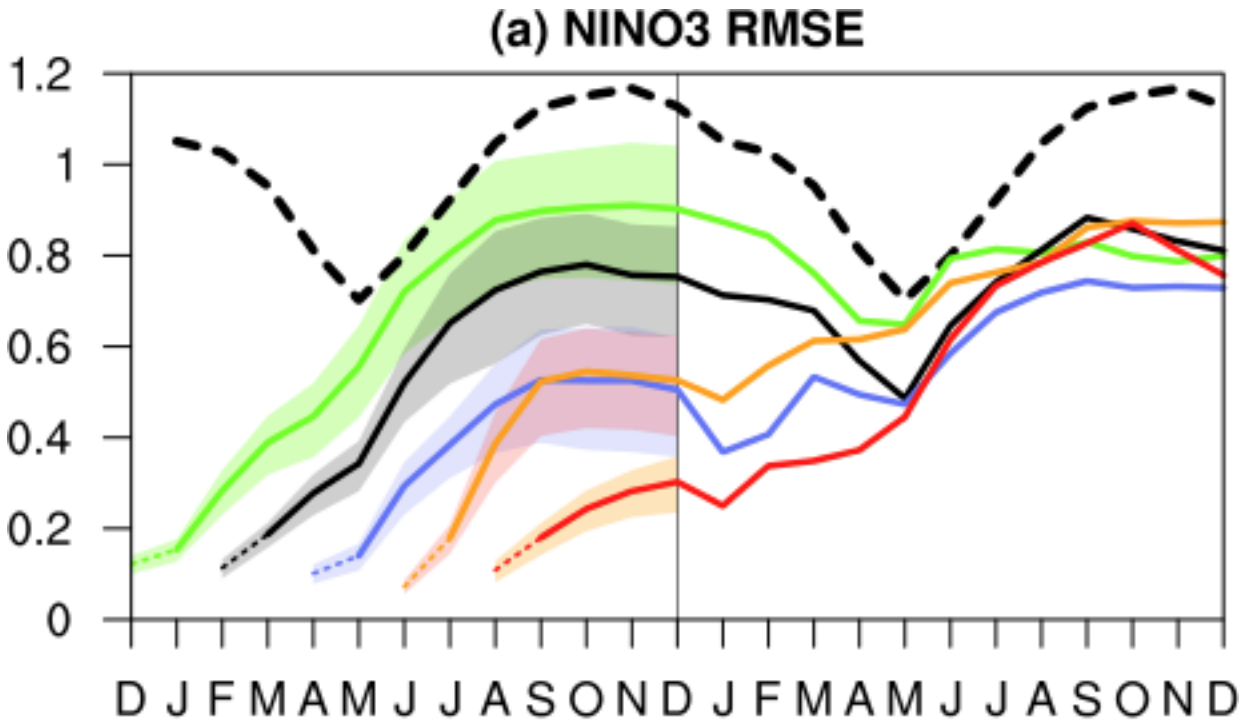
- ***"MREF" Precursors: > 6 months***
  - Subsurface ocean temperatures
    - Direct measurements
    - Satellites
    - Reanalyses
  - Western equatorial wind stress
    - Direct measurements
    - Satellites
    - Reanalyses
  - Meridional mass transport
    - Direct measurements
    - Reanalyses
  - Air-sea interactions (?)
    - Direct measurements
    - Satellites
    - Reanalyses
- ***"QEF" Precursors: 0-6 Months***
  - Subsurface ocean temperatures
  - Equatorial wind stress
  - Air-sea Interactions
    - Direct measurements
    - Satellites
  - Tropical ocean circulation
    - Direct measurements
    - Satellites
    - Reanalyses
  - Remote atmospheric circulations
    - Direct measurements
    - Satellites
    - Reanalyses

Panel Science Strategies and Goals

Monitoring and predicting the evolution of ENSO cuts across the Science Strategies and Goals of all three panels:

- ***POS:*** **Advocate and leverage long-term climate monitoring strategies to better** document, understand, model and **predict climate variability**
  - *What are the most robust monitoring products*
  - *What monitoring strategy best balances the skill/parsimony trade-off*
- ***PSMI:*** **Promote process studies to gain a quantitative understanding of the mechanisms controlling climate variability** and change, and to provide observational data to evaluate and improve models; **Improve climate models, including their representation of processes**, data assimilation approaches, and evaluation
  - *What monitoring products are needed to evaluate processes within models*
  - *What monitoring products are needed to be better initialize models*
- ***PPAI:*** Develop and employ techniques to critically assess improvements in predictions and projections in order to build the confidence of users and to **identify the most likely targets for future improvements; Apply fundamental lessons from research on climate to facilitate knowledge transfer** between the various scientific communities that generate and use information on climate variability and change
  - *What processes should be monitored when?*
  - *Which potential sources of improved ENSO prediction are "Data limited" v. "Science limited"*
  - *What monitoring products can be used to "condition" skill/uncertainty of ENSO predictions?*

Unperturbed ENSO Growth (Larson & Kirtman, 2015)



Proposed Remote SST Precursors (Dayan et al., 2015)