New Insights into the Subtropical Mode Water Interannal Variability from the KESS Profiling Float Program

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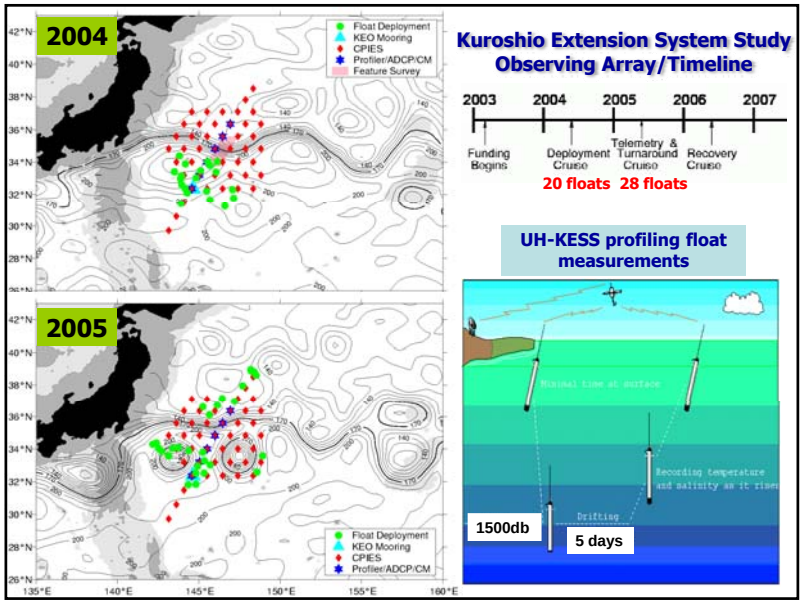
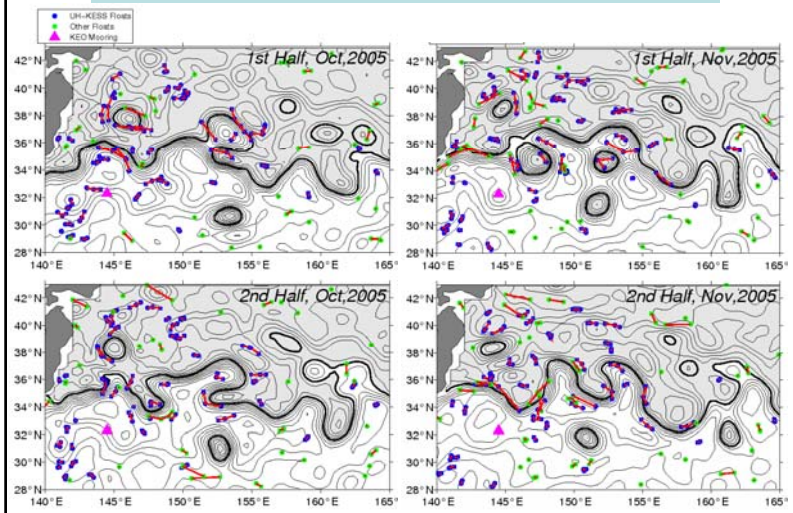
U.S. CLIVAR
Climate Variability & Predictability



Distributions of semi-monthly profiling float data

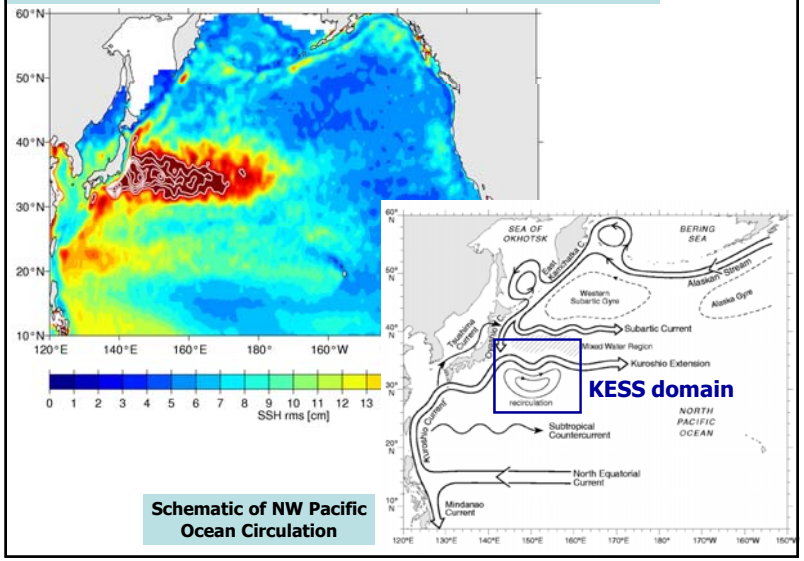


(5-day repeat; all KESS float data are part of the global Argo dataset)

Objectives of Kuroshio Extension System Study (KESS)

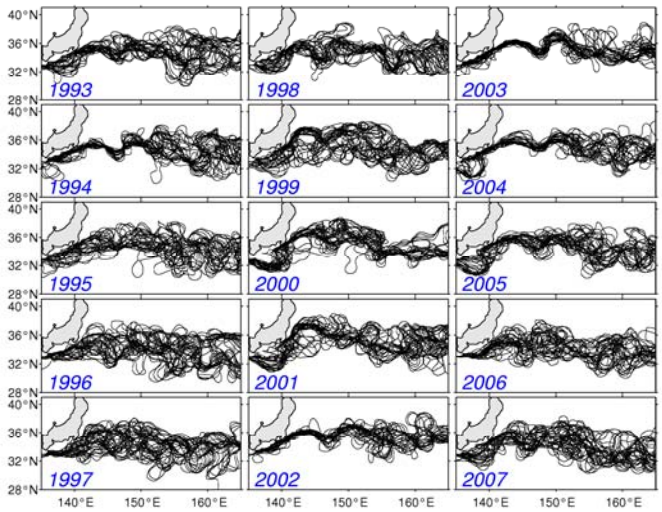
- ❑ Understand SST variability on weekly-to-interannual timescales (atmos. forcing, re-emergence, advection, eddy fluxes…)
- ❑ Provide a midlatitude reference site of surface heat fluxes.
- ❑ Clarify formation/transformation of Subtropical Mode Water
- ❑ Clarify formation processes of WBC recirculation gyre(s)
- ❑ Identify cross-frontal processes of mass, heat, salt, and PV
- ❑ Clarify vertical coupling (barotropitization) processes intrinsic to baroclinic instability
- ❑ Assess SST's influence upon the overlying PBL

Altimeter-derived rms sea surface height variability (cm)



Schematic of NW Pacific Ocean Circulation

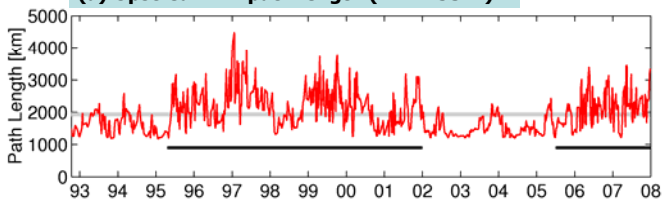
Semi-monthly Kuroshio Extension paths (1.7m SSH contours)



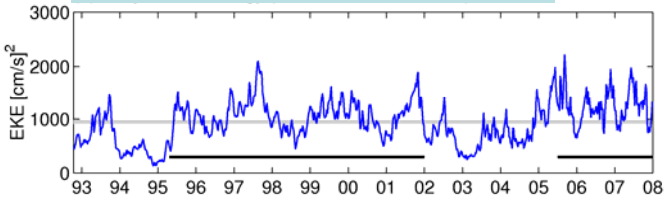
Stable yrs: 1993-94, 2002-04

Unstable yrs: 1996-2001, 2006-07

(a) Upstream KE path length (141-153°E)



(b) Eddy kinetic energy (141-153°E, 32-38°N)



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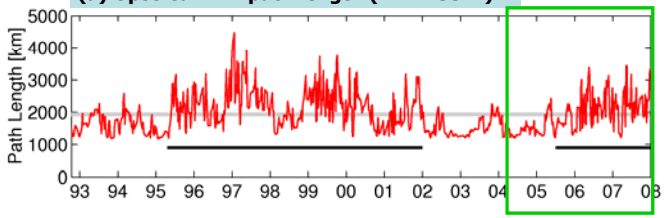
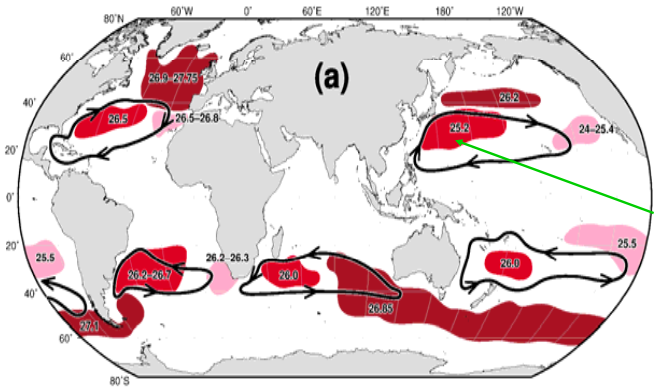


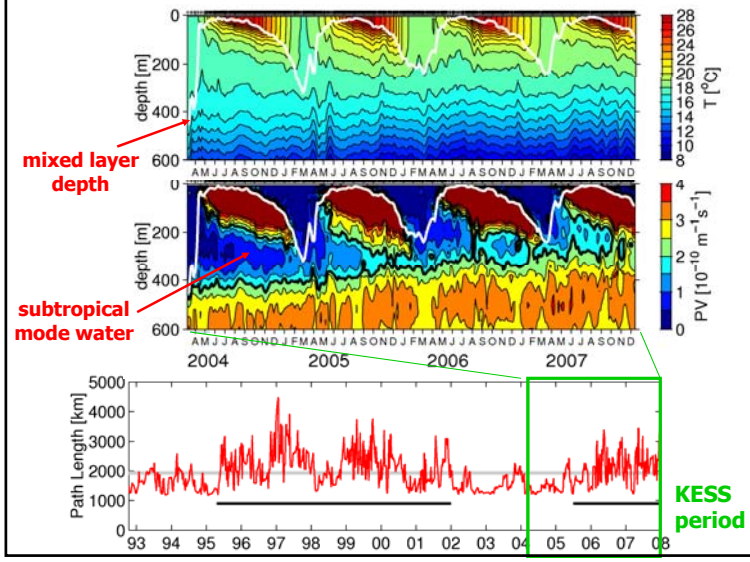
KESS captured the transition from a stable to an unstable state.

Impact of the bimodal modulation of the Kuroshio Extension system: Subtropical mode water (STMW)

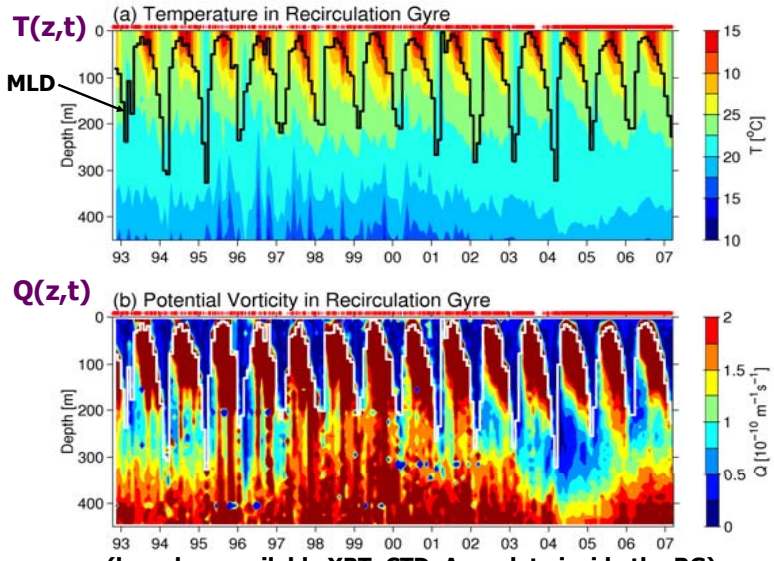


Hanawa and Talley (2001)

T(z) and PV(z) evolution in the KE recirculation gyre

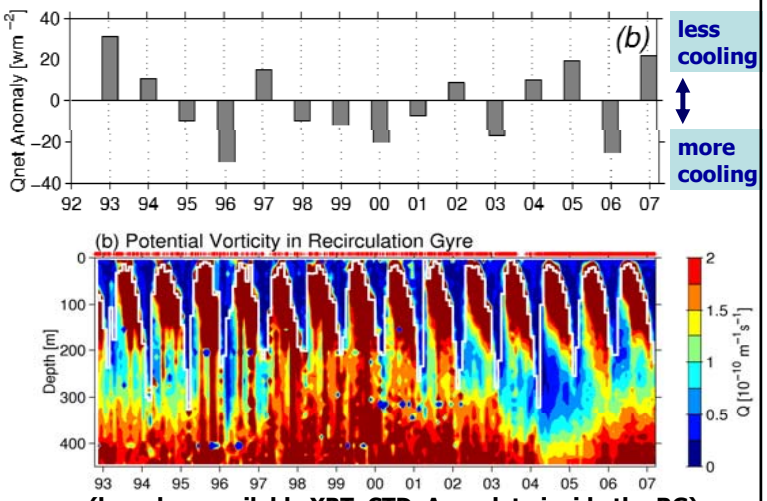


T(z,t) and Q(z,t)



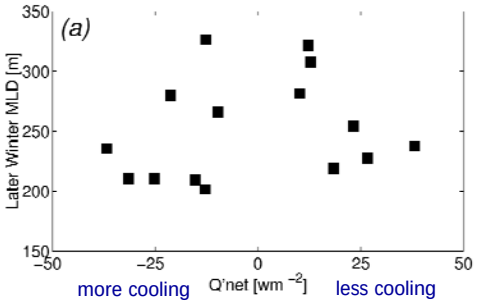
(based on available XBT, CTD, Argo data inside the RG)

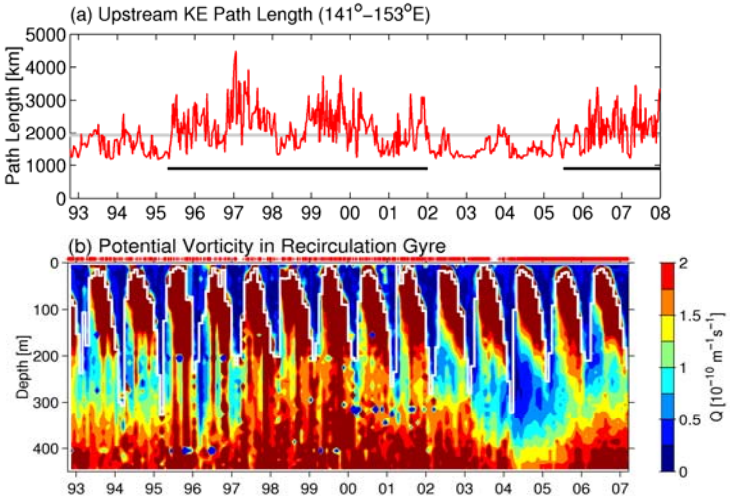
NCEP wintertime Qnet anomalies in the KE/RG region



(based on available XBT, CTD, Argo data inside the RG)

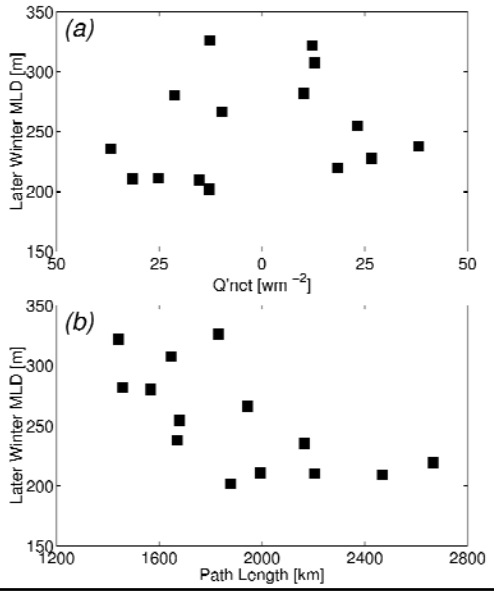
Late winter MLD vs. Qnet anomalies





Late winter MLD vs. Qnet anomalies

Late winter MLD vs. KE path length in the previous year

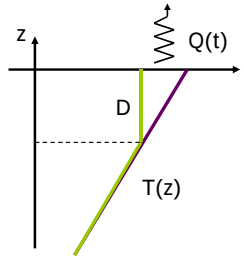


Pre-conditioning vs. convective depth

- **Let the fall season upper ocean stratification be** N **and let surface cooling be** Q(t)<0.

- **The convective depth** D **in this case can be estimated from conservation of heat:**

$$T(D)\,D - \int_{-D}^{0} T(z)\,dz = \frac{1}{\rho\, c_p} \int_t Q(t)\,dt$$

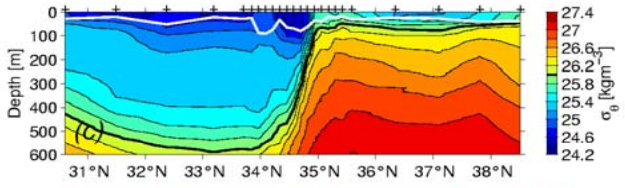


$$D = \frac{1}{N}\sqrt{\frac{-2\alpha\, g}{\rho\, c_p} \int_t Q(t)\,dt}$$

Convective depth (i.e., wintertime STMW thickness) depends not only on the cumulative heat loss, but also on the pre-conditioning stratification.

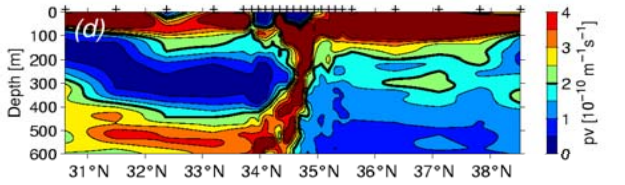
σ_θ and PV sections across the KE jet along 146°E

σ_θ



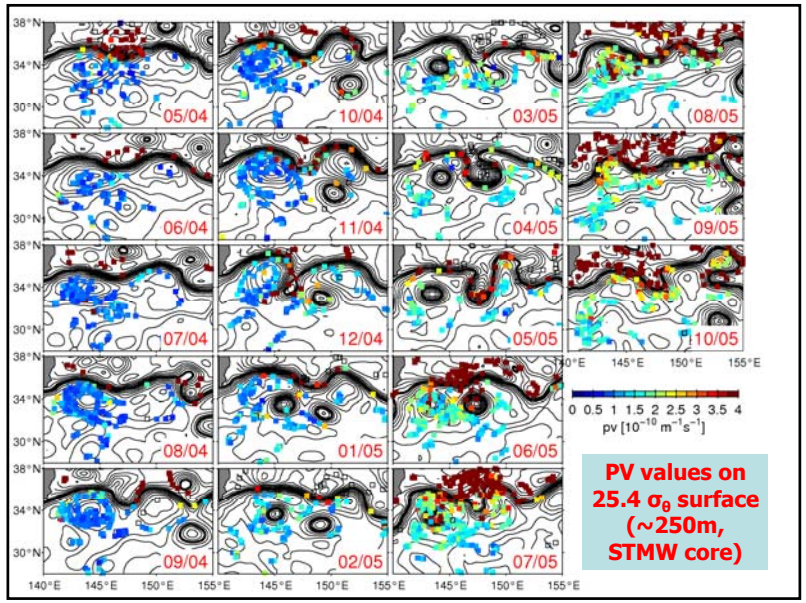
PV

$N^2 = \frac{g}{f} PV$



When KE is in the unstable state, lateral mixing of high-PV KE water into the RG can inhibit the STMW formation through pre-conditioning.

How efficient is this lateral mixing process?

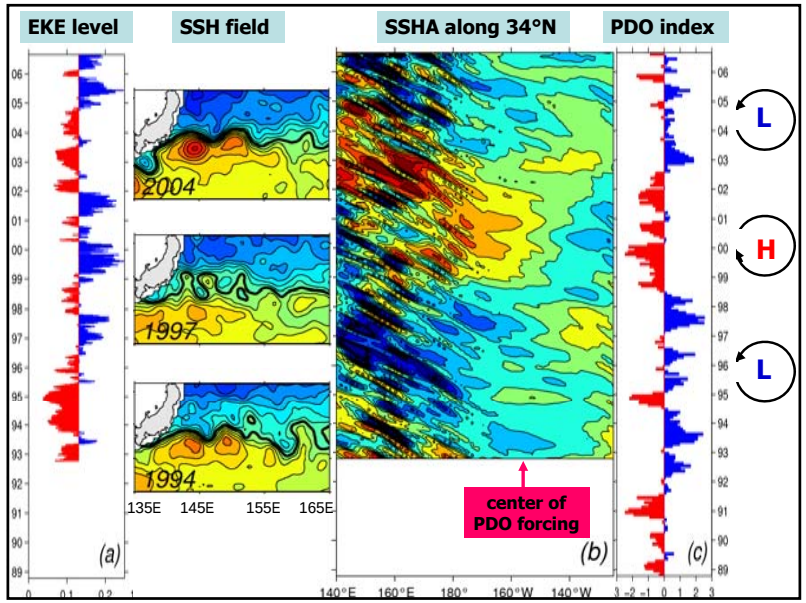


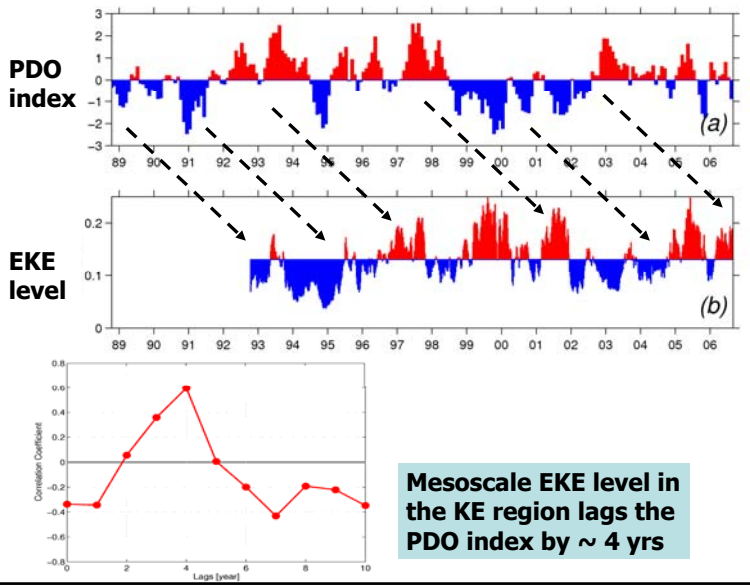
PV values on 25.4 σ_θ surface (~250m, STMW core)

Summary

- **Kuroshio Extension system over the past 15 years oscillated between stable and unstable states.**
- **During this period, STMW formation is affected more by the dynamic state of the KE system than by the overlying atmospheric condition.**
- **By transferring high-PV KE water southward, the unstable KE state inhibits the STMW formation through pre-conditioning and lateral erosion.**
- **The eddy erosion process of STMW is effective, occurring on intra-annual timescales.**

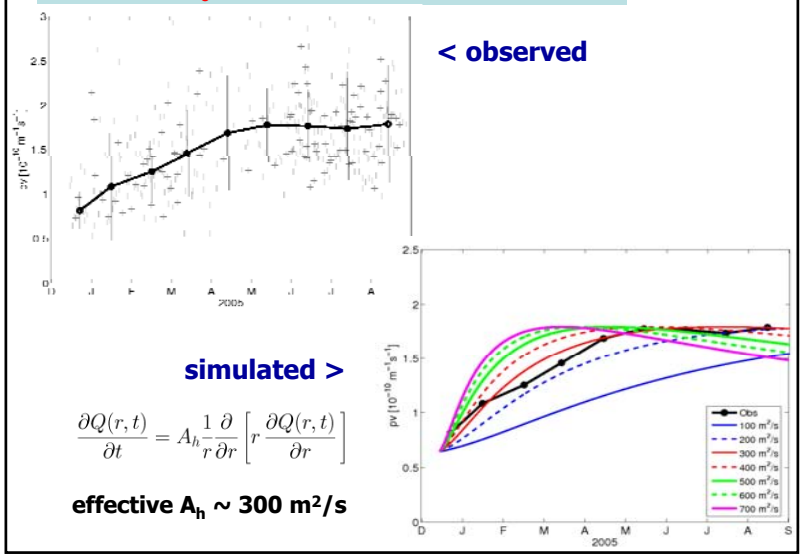
For more details, see Qiu et al. (2007, JPO)





Mesoscale EKE level in the KE region lags the PDO index by ~ 4 yrs

PV on 25.4 σ_θ surface in RG outside of CCR04B



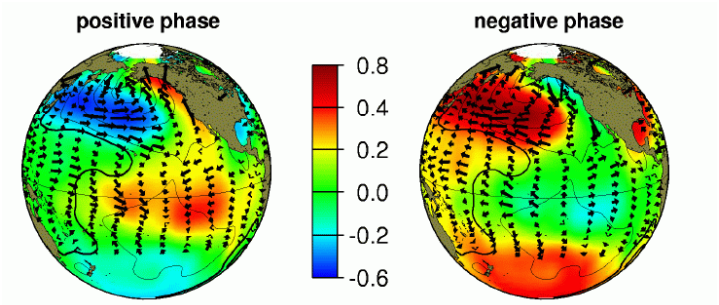
< observed

simulated >

$$\frac{\partial Q(r,t)}{\partial t} = A_h \frac{1}{r}\frac{\partial}{\partial r}\left[r \frac{\partial Q(r,t)}{\partial r} \right]$$

effective A_h ~ 300 m²/s

Pacific Decadal Oscillations (Mantua et al. 1997)



- **Center of action of wind forcing is in the <u>eastern</u> half of the N Pacific basin**
- **Positive (negative) phase of PDO generates – (+) local SSH through Ekman divergence (convergence)**

T, σ_θ and PV sections across the KE jet along 146°E

potential temperature

16-18°C

potential density

25.2-25.5 σ_θ

potential vorticity

Q<2x10^{-10}