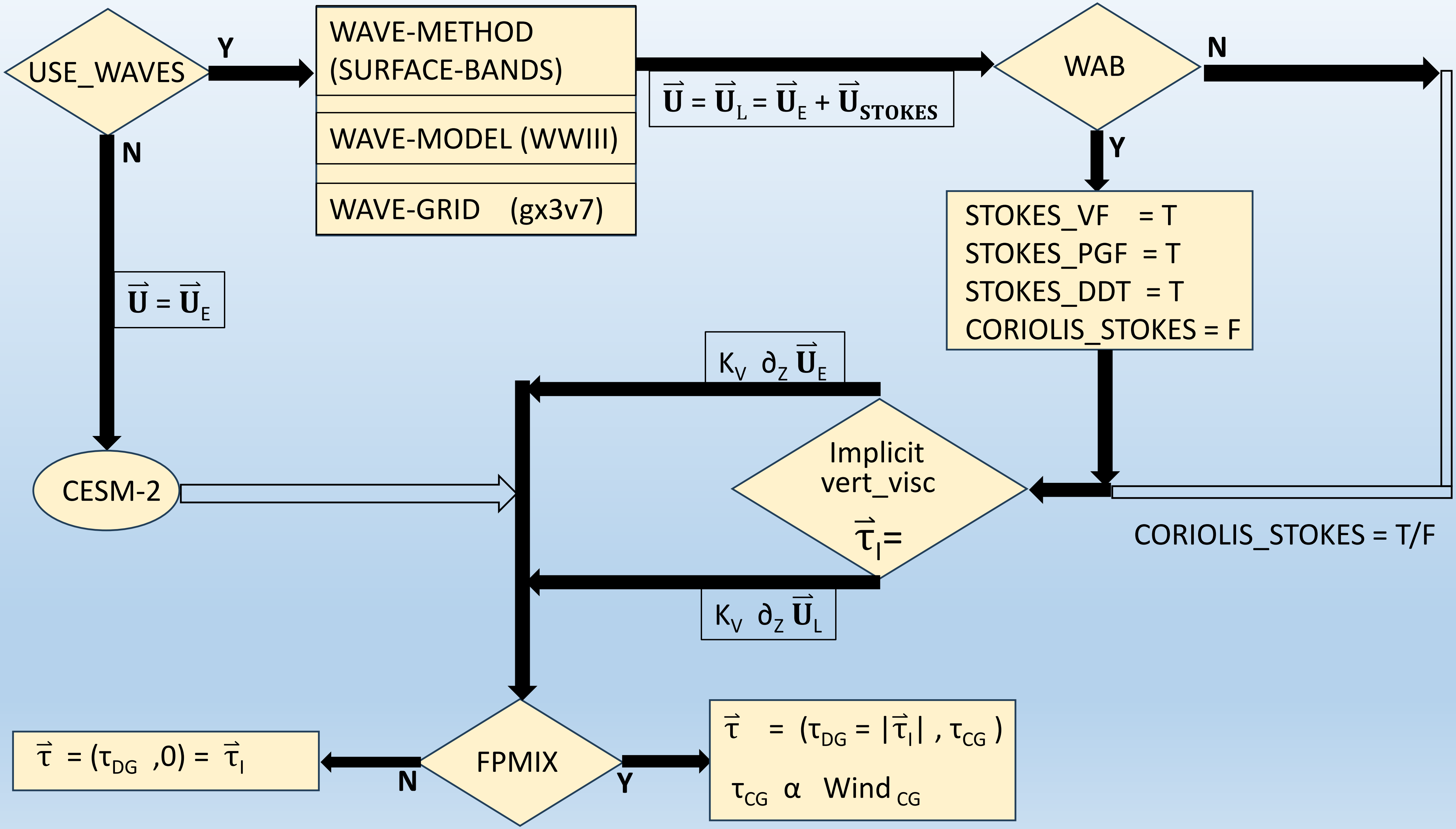
A consistent set of boundary layer wave and vertical mixing options for CESM3

W. G. Large, Gustavo Marques, Alper Altunas

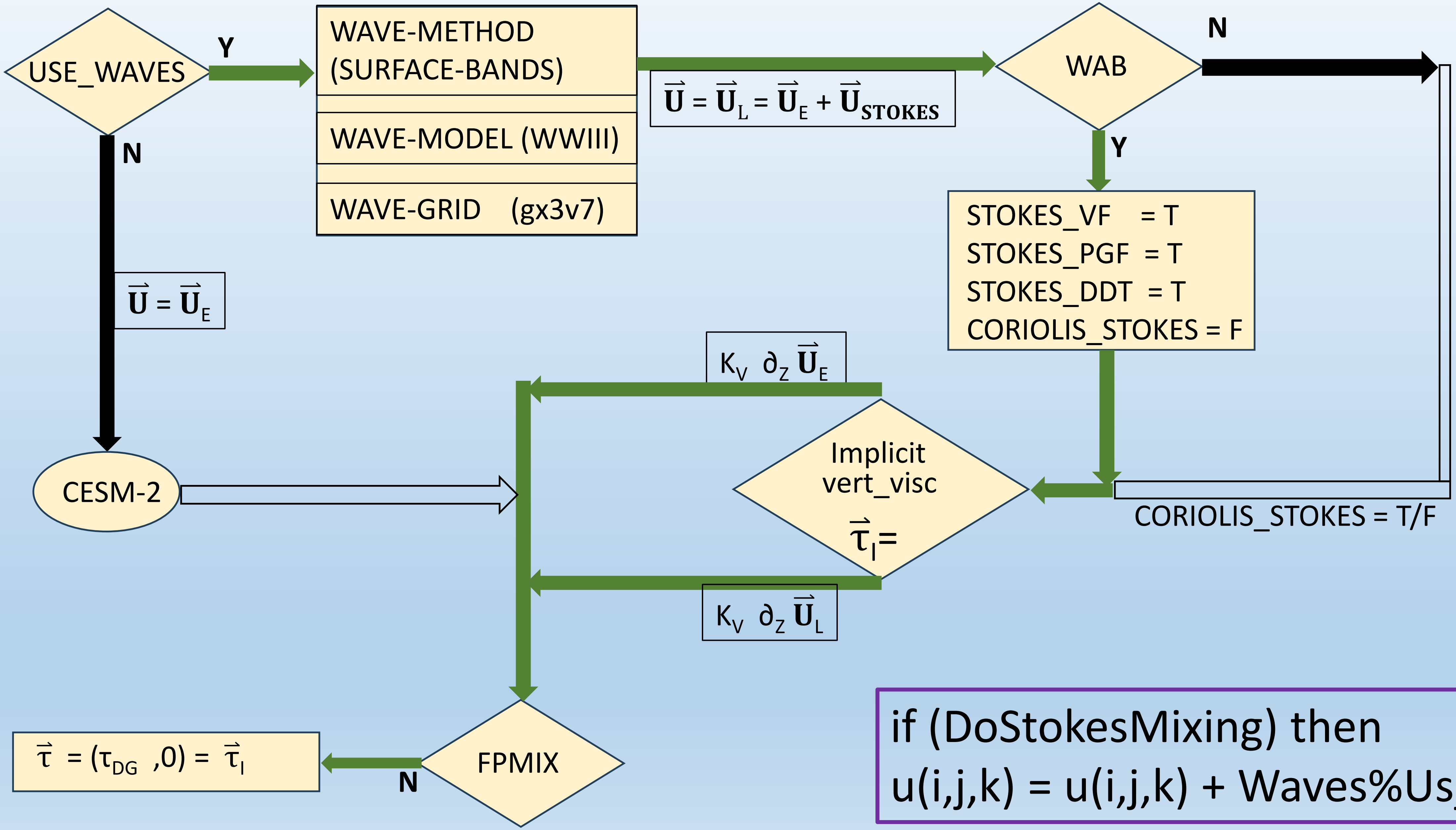
PREMISE: A critical exercise in the art of climate modeling is to have errors compensate for each other, for the forcing and for model numerics (e.g. spurious mixing), in order to reproduce observed history.

Improved physics or numerics can degrade solutions relative to observational metrics.

MOM-6 DYNAMICS CORE : Wave Decisions



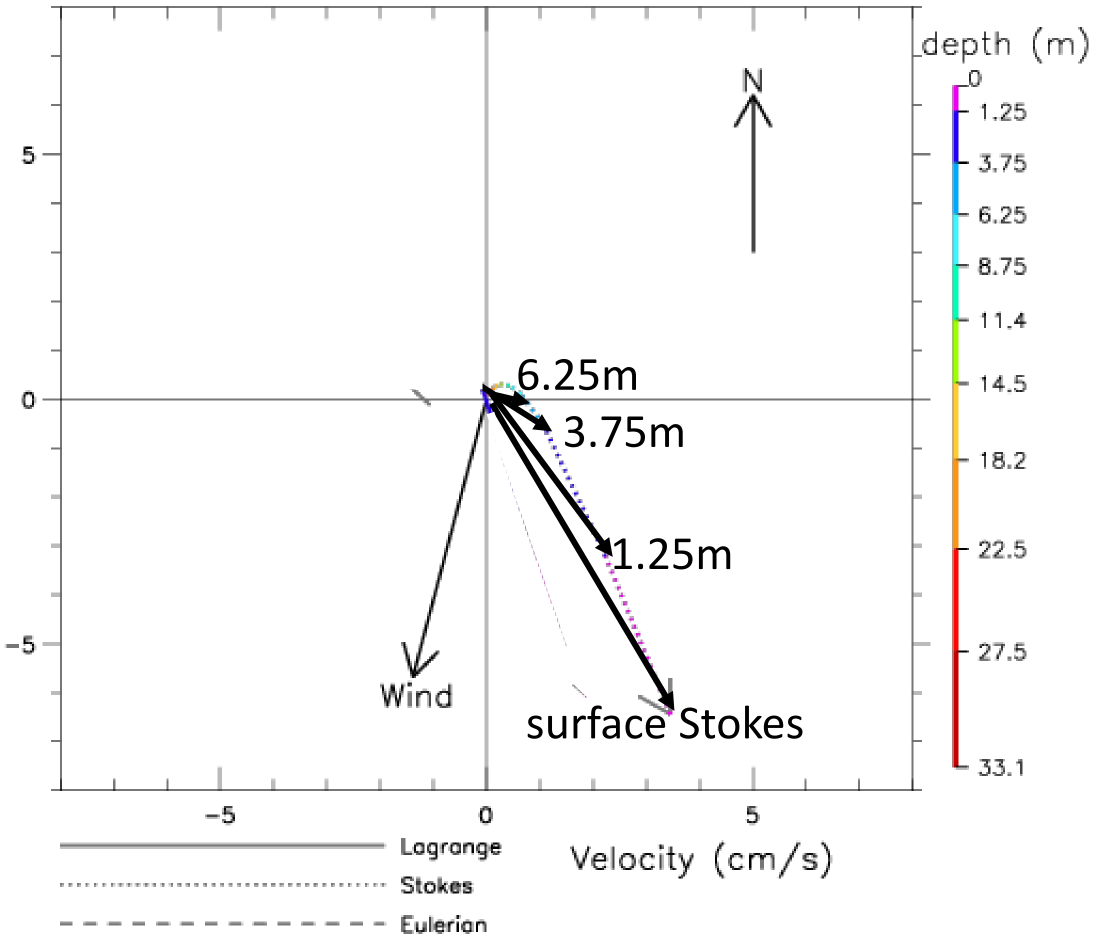
Lagrangian versus Eulerian Shear Mixing




```
if (DoStokesMixing) then
u(i,j,k) = u(i,j,k) + Waves%Us_x(i,j,k)
```

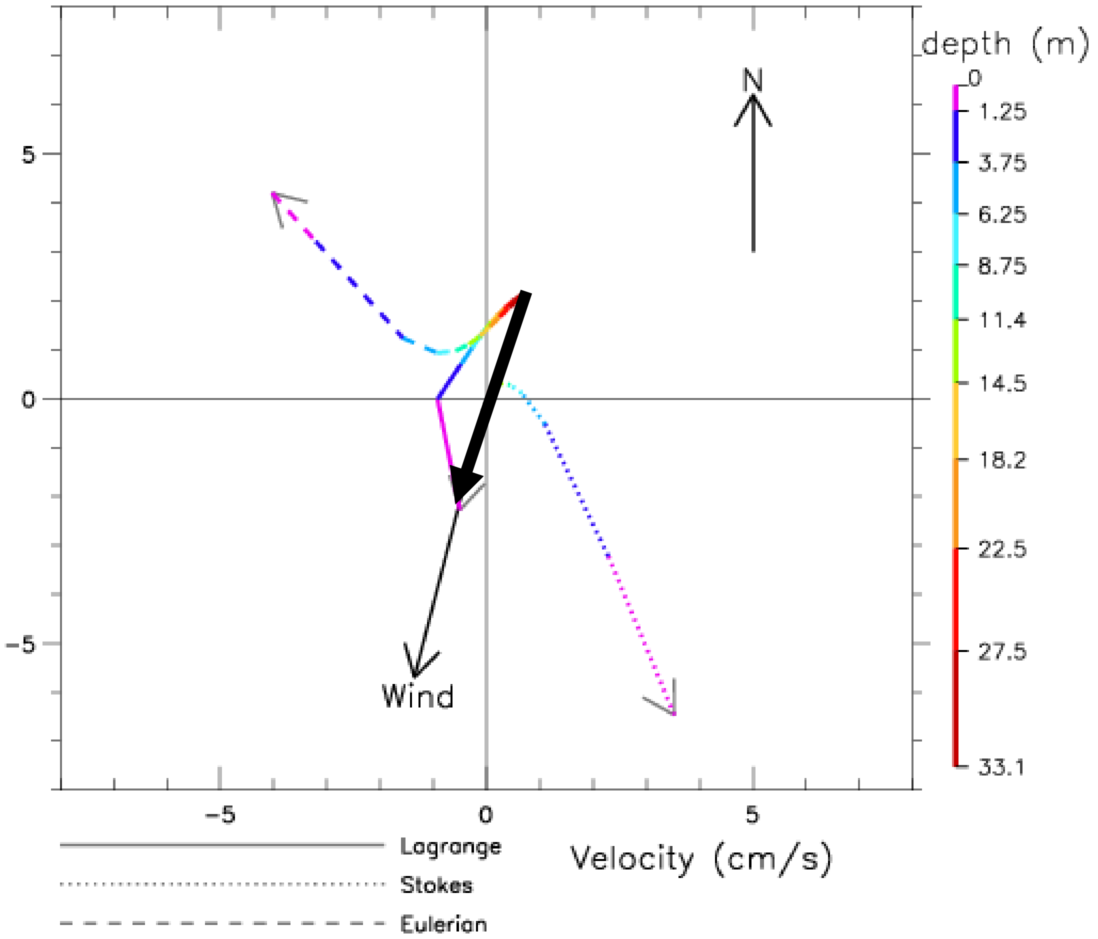
Lagrangian ($K_V\ \partial_Z(\vec{U}_E + \vec{U}_{STOKES})$) versus Eulerian ($K_V\ \partial_Z\vec{U}_E$)

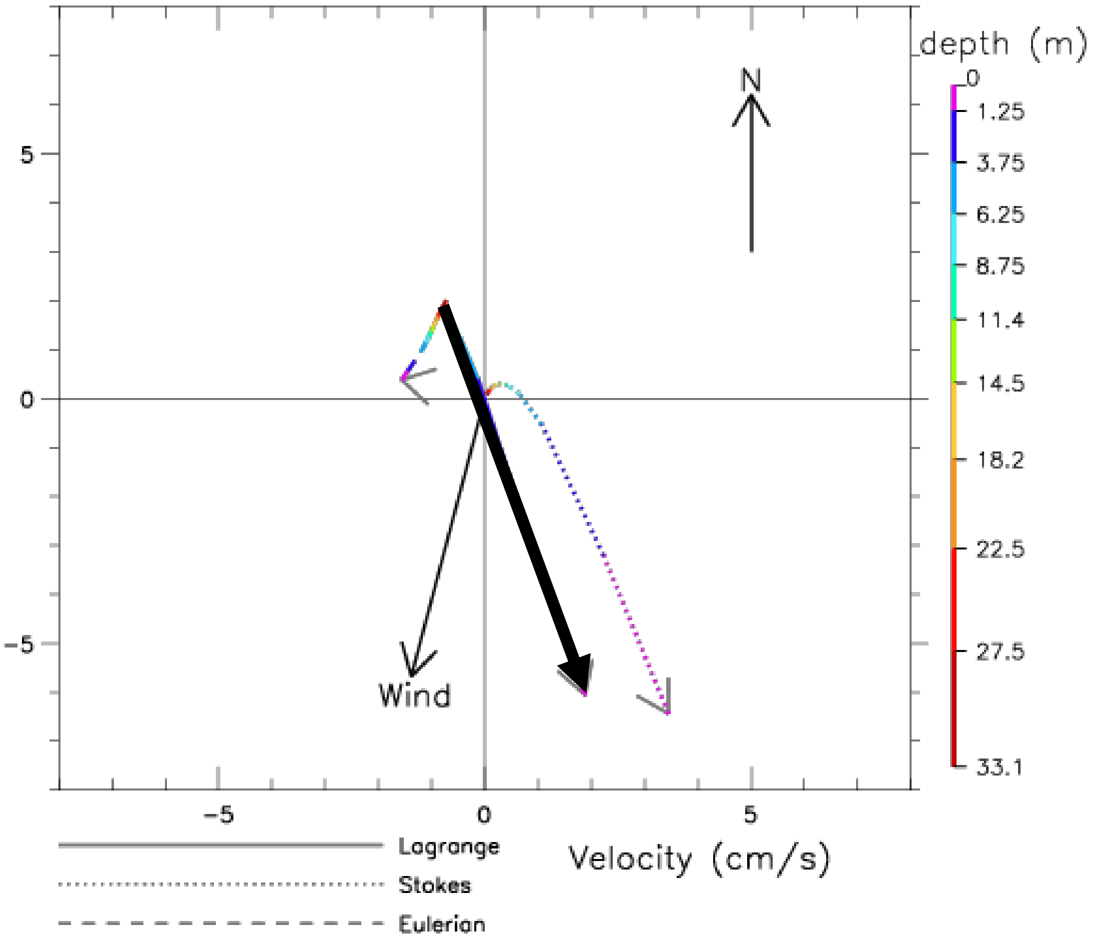
JRA DAY 3, INERTIAL PERIOD AVERAGE CURRENT HODOGRAPHS



Lagrangian ($K_V\ \partial_Z (\vec{U}_E + \vec{U}_{STOKES})$) versus Eulerian ($K_V\ \partial_Z \vec{U}_E$)

JRA DAY 3, INERTIAL PERIOD AVERAGE CURRENT HODOGRAPHS





"Consistency" with LES of WAB equations

In the surface-layer (depths, $d < 0.1\,h$) of a wind, wave, buoyancy forced boundary layer of depth, h :

Non-dimensional Shear $\Psi_m = (\kappa\, d/u^*)\, \partial_Z|\vec{\mathbf{U}}| = \phi_m(\zeta)\ \ \chi_m(\xi)$,

and the buoyancy Similarity Function, $\phi_m(\zeta)$, of the stability parameter, ζ

➔ Stokes Similarity Function, $\chi_m(\xi)$, of a Stokes parameter, ξ

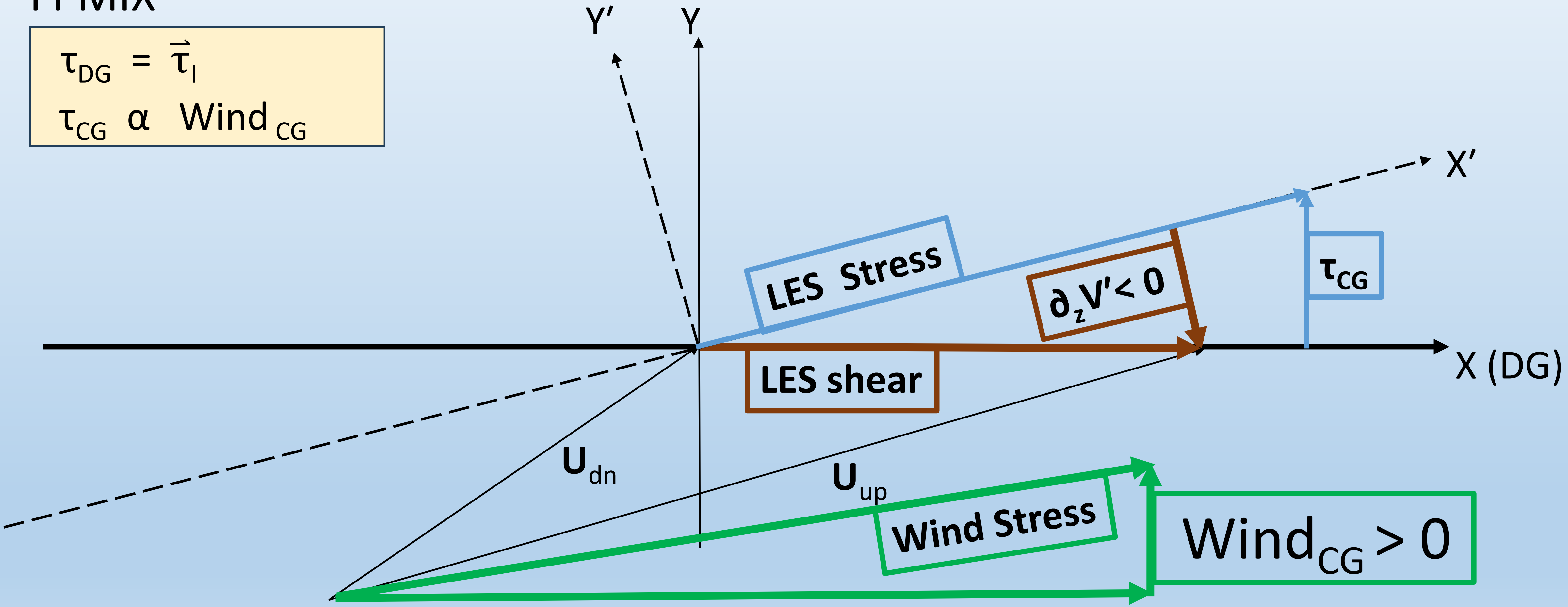
✦ Lagrangian shear, $\partial_Z|\vec{\mathbf{U}}_L|$, triples standard deviation of $\chi_m(\xi)$

LES (WAB) of a boundary-layer of depth, h

Stress and Shear Vectors NOT aligned, $\vec{\tau} = (\tau_{DG}, \tau_{CG})$; Non-zero, $\partial_z V'$

- FPMIX

$\tau_{DG} = \vec{\tau}_I$
$\tau_{CG} \; \alpha \;$ Wind $_{CG}$



Lagrangian ($\overrightarrow{\tau_L} = K_V \ \partial_Z \overrightarrow{U_L}$) versus Eulerian ($\overrightarrow{\tau_E} = K_V \ \partial_Z \overrightarrow{U_E}$)

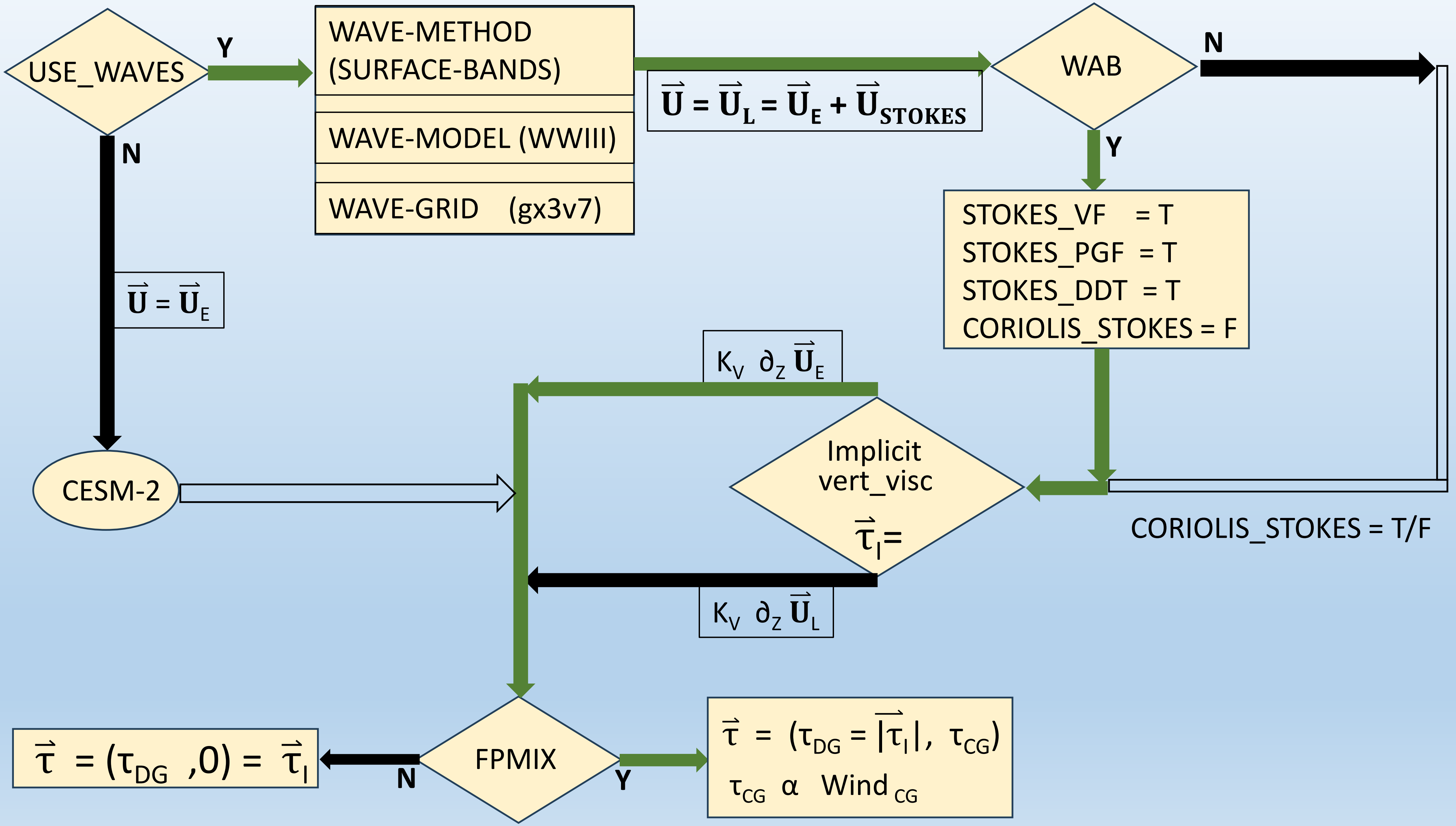
"Consistency" with LES of WAB equations

Non-local viscosity = $\tau_{CG} / \partial_Z V'$

Boundary-layer Shape Function : $G_m(\sigma = d/h) = \tau_{CG} \Psi_m / (\kappa\, h\, u^* \partial_Z V')$

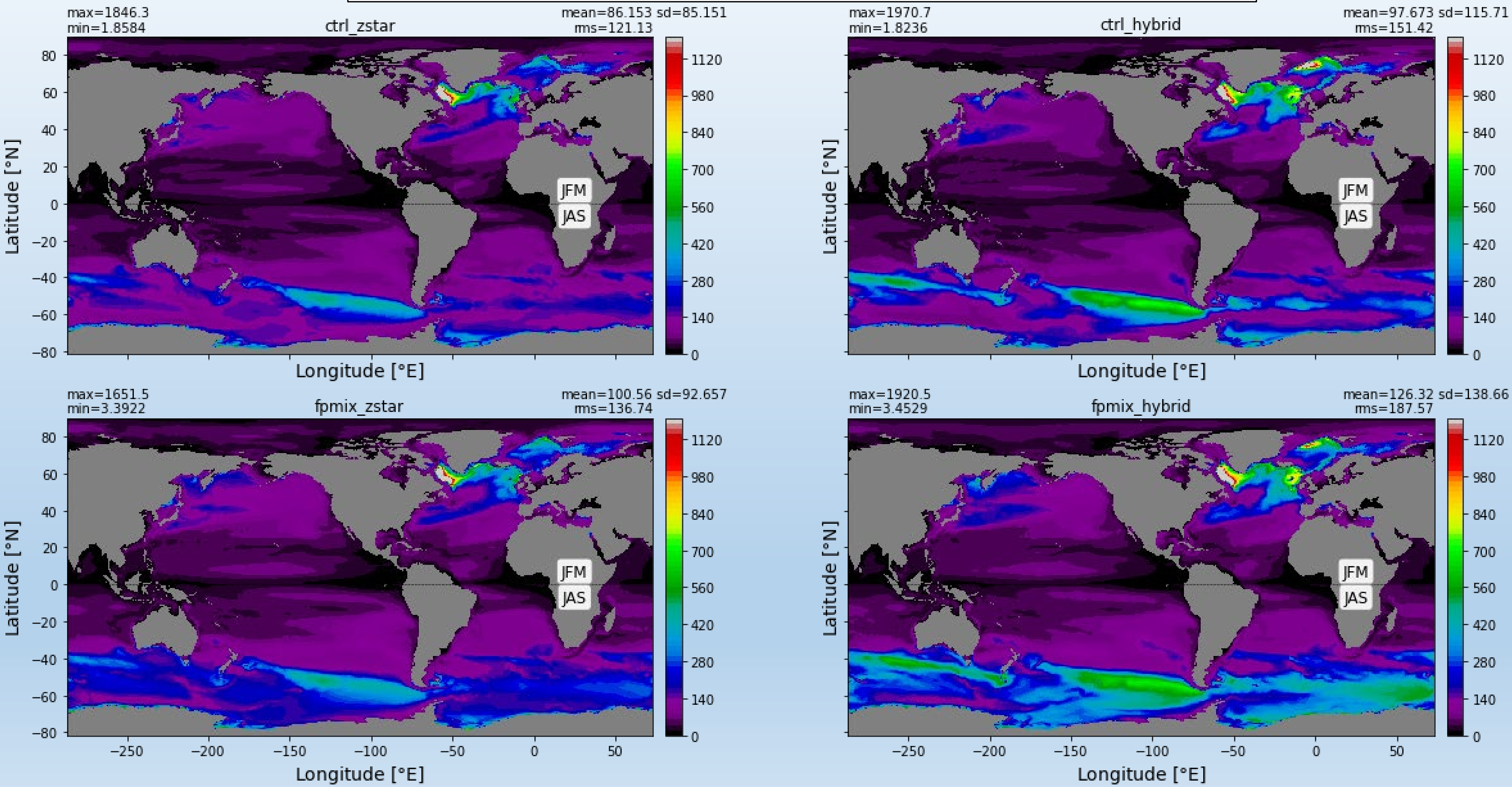
	Lagrangian	Eulerian
	• $G_m(\sigma) > G_s(\sigma)$	• $G_m(\sigma) \approx G_s(\sigma)$ ✦
• G_m peaks at σ_p =	• 0.35	• 0.25
• $G_m(\sigma_p)$ =	• 0.48	• 0.12

MOM DYNAMICS CORE : Wave Decisions



zstar versus hybrid

MEAN WINTER MIXED LAYER DEPTHS (last 30 years of first JRA cycle)



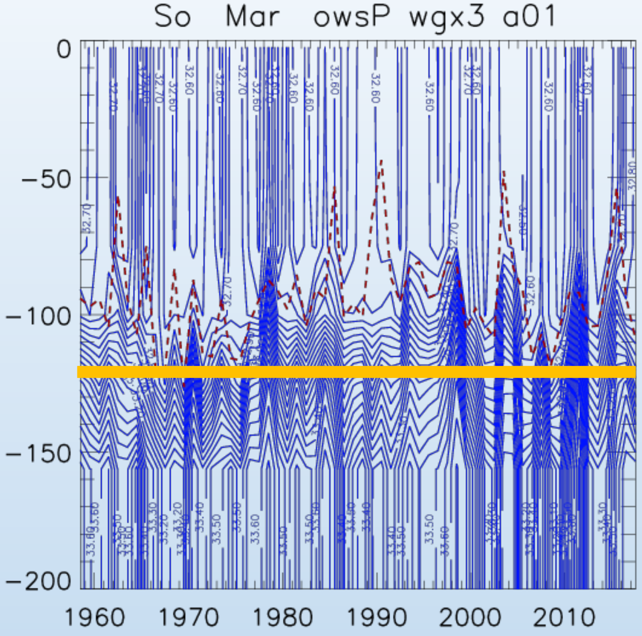
March Salinity zstar hybrid

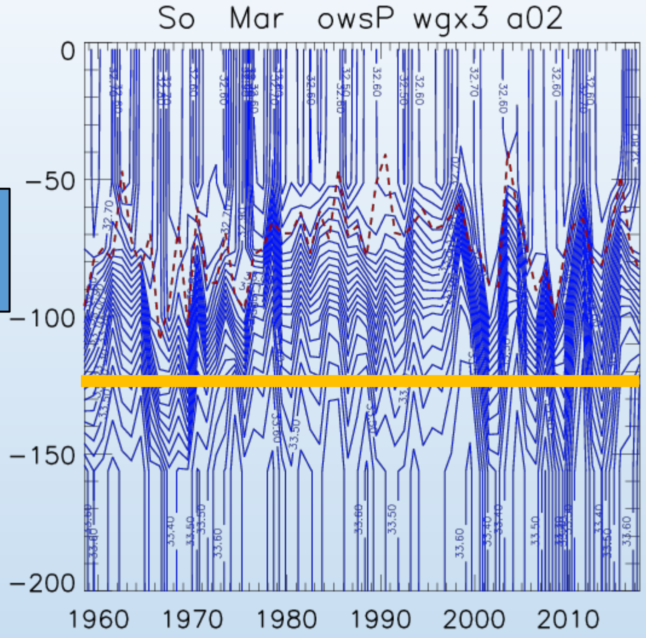
OWS-P
North Pacific

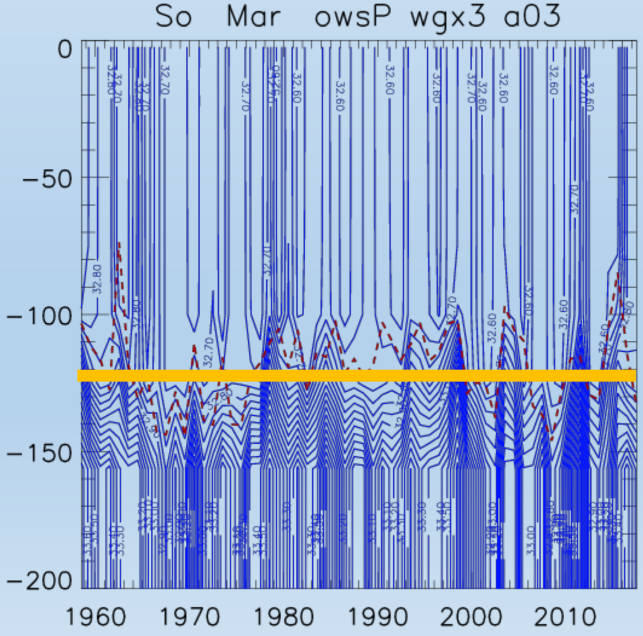
Halocline Top

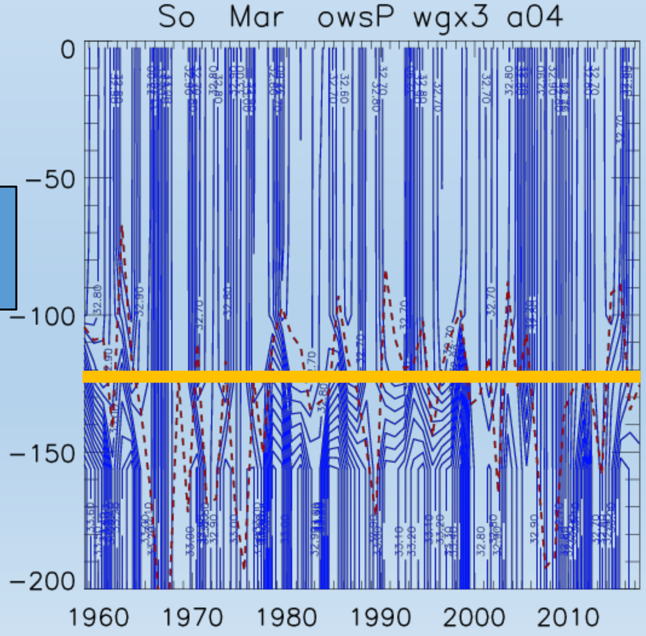
control

FPMIX



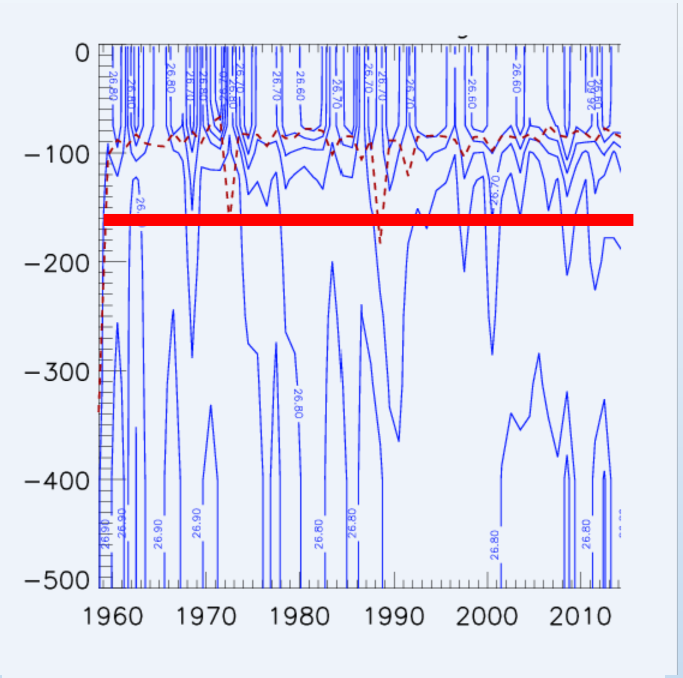




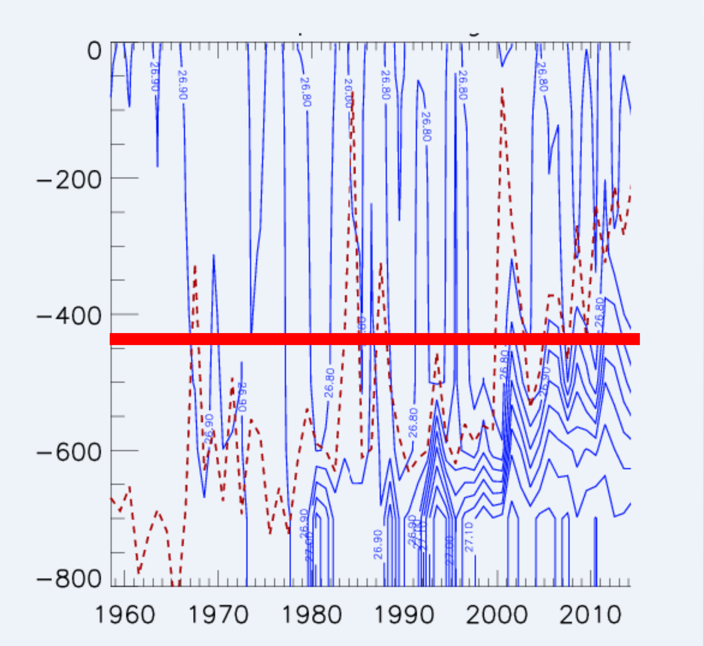


Density	June	hybrid	Sept

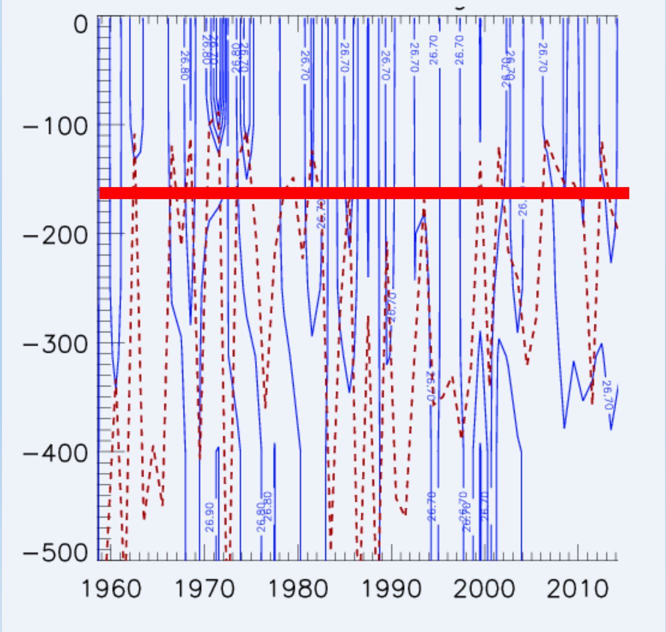
SO: 157°E 50°S
East Pacific



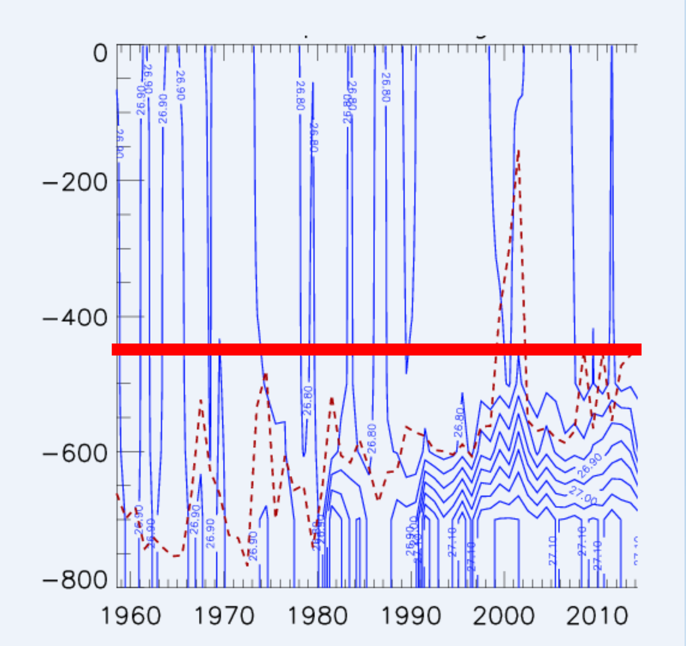
control



ARGO MLD



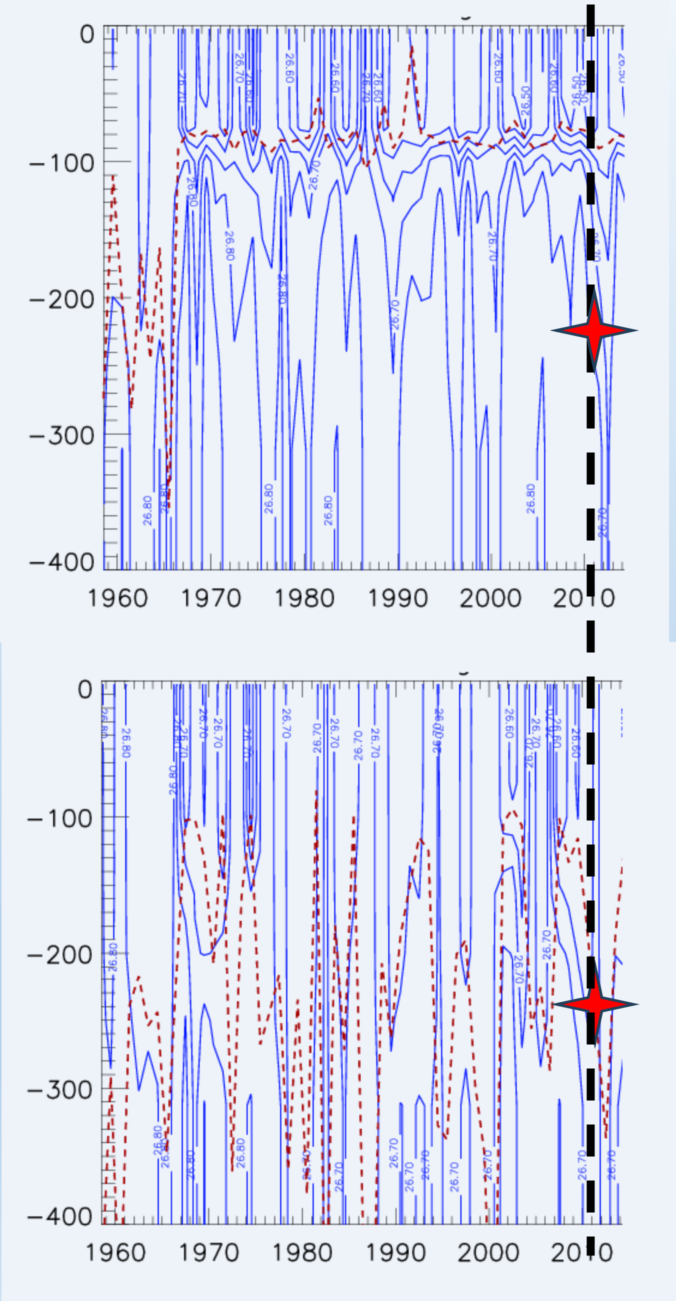
FPMIX



Density June hybrid

SOFS: 120°E 47°S
Australia

ARGO MLD
2010



control

FPMIX

Boundary-layer Mixing : $\partial_t X = - K_x(-\partial_z X) + \Gamma_x$; $X = \{U, V, \Theta, S\}$

$$K_x = w_x \quad h \quad G_x(\sigma) + \nu_x(h) \quad H(\sigma)$$

Interior Forcing

Interior Viscosity at h

Shape Function, $G_m = G_s$: $G_x(1)=0$
Cubic $\sigma < 0.5$ then Quadratic

$$Ri(h) = \frac{(B_{SL} - B_h)\, h}{(|\vec{\mathbf{U}}_L|_{SL} - |\vec{\mathbf{U}}_L|_h)^2 + Vt^2} = Ri_C \quad ; \ \kappa L^* > h > 0$$

$N \ w_s \ h \ C_V / Ri_C$

$(B_{up}-B_h)/\Delta z$

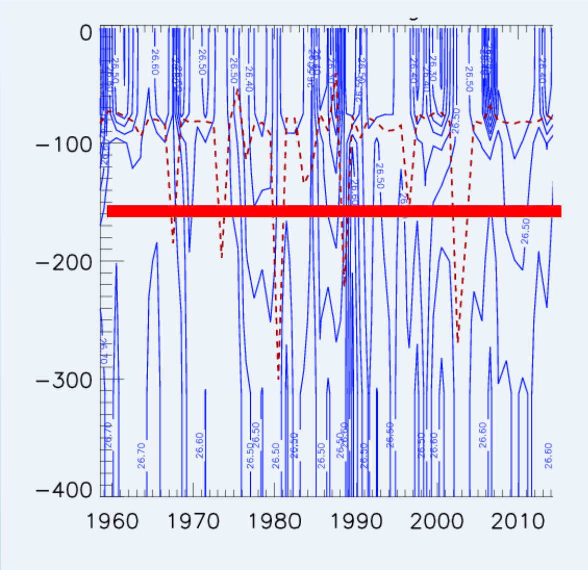
$$\frac{\kappa \ u^*}{\phi_x(\zeta) \quad \chi_x(\xi)}$$

$0 < \xi < 1$; Stokes fraction of SL production of TKE

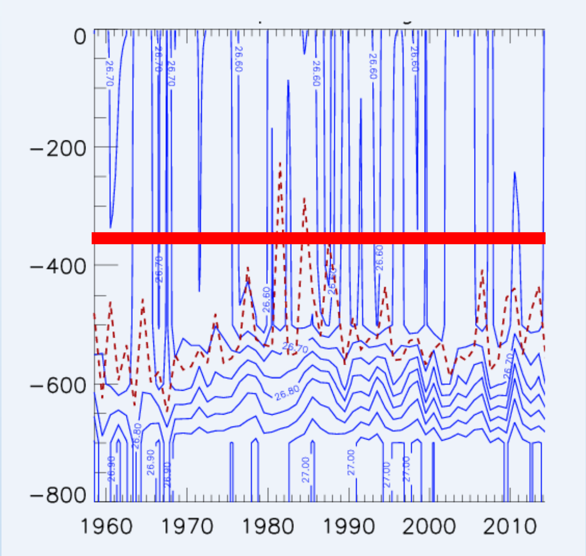
$\chi_x(0)=1$; $\chi_m(1)=.18$; $\chi_s(1)=.25$

Density	June	hybrid	Sept

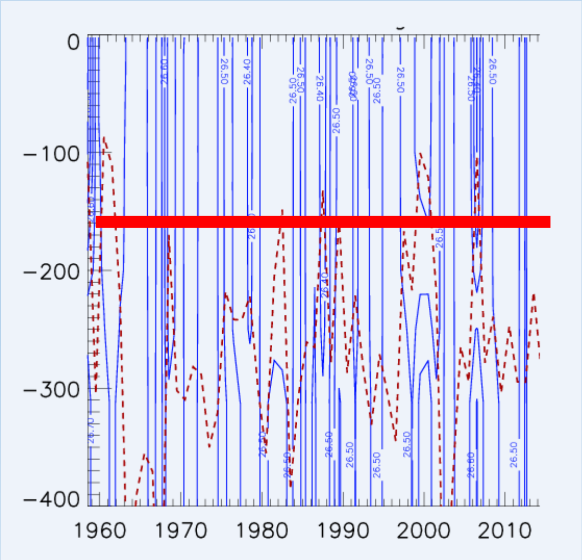
SO: 95°E 45°S
Indian



control



ARGO MLD



FPMIX