TROPICAL PACIFIC OCEAN MODEL PARAMETERIZATIONS

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GOAL ? : Exploit global predictability arising from Tropical Pacific variability (e.g. ENSO, MJO)

OBJECTIVE ? : Improve sub-seasonal to annual predictions over the U.S.

PREMISE ? : Forecasts are an **initial value problem** that depend on

1) Observations ………………………. TPOS Backbone and Global Observing Systems (e.g. satellites)

2) Data Assimilation ……………….. Tropical Pacific has potential for **coupled data assimilation**

3) Prognostic Coupled Models …. , **Model drift** leads to systematic forecast error

OCEAN MODEL PARAMETERIZATIONS

TPOS Opportunity

Sustained (Backbone) observations to:

1) the **<u>initial condition</u>** via **<u>data assimilation</u>** (DA)
2) the **<u>drift metric (DA increments)</u>**
3) the **<u>context</u>** for process and regional models

Breakouts 4-5 ?

Embedded "process" studies to :

1) improve (reduce drift) the prognostic models (e.g. parameterizations)
2) develop coupled data assimilation
3) inform "Backbone" decisions

Breakouts 2-5-6 ?

Outline

1) The Grand Challenge
2) "Parameterization" basics (e.g. non-linear advection)
3) Some common ocean model parameterizations & schemes
4) A framework
5) Transition to Operations (Not Today)

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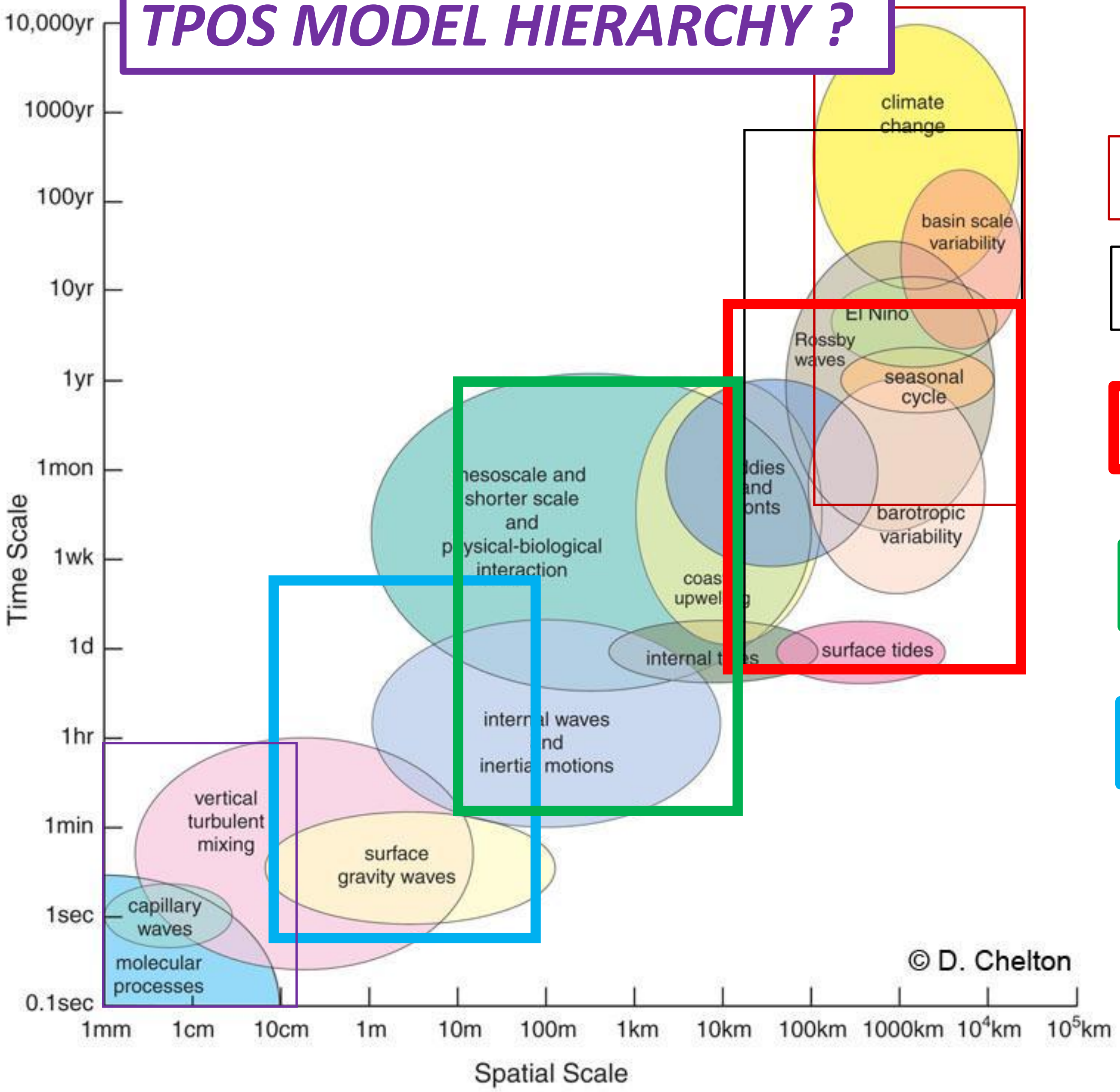
1) The Grand Challenge

TPOS MODEL HIERARCHY ?



	(Throughput)
Intermediate Complexity	(100-1000 years/day)
Global Earth System	(10-100 y/day) (1 yr/day Hi Res)
Operational Forecast Models	(10 days/day)
Regional Process Models	(100 days/day)
Large Eddy Simulation (LES)	(0.1 day/day)
Direct Numerical Simulation (DNS)	

NCAR CGD Climate & Global Dynamics NSF

2) Parameterization Basics

For a quantity $Q = \{\, U,\ V,\ W,\ T,\ S,\ \text{etc.}\ \}$:

$$\partial_t Q \sim -\boldsymbol{U} \bullet \nabla Q = -\partial_x(UQ) - \partial_y(VQ) - \partial_z(WQ)$$

Reynolds' decomposition into mean + fluctuation ➔ $Q = \mathrm{Q} + \mathrm{q} : \langle \mathrm{q} \rangle = 0$

Model discretization into resolved + unresolved ➔ $Q = \mathrm{Q} + \mathrm{q}$: $\underline{\boldsymbol{\langle \mathrm{q} \rangle \neq 0}}$

$$(WQ) = (\mathrm{WQ}) + \boxed{\mathrm{wQ} + \mathrm{Wq} + \mathrm{wq}}$$
$$(UQ) = (\mathrm{UQ}) + \boxed{\mathrm{uQ} + \mathrm{Uq} + \mathrm{uq}}$$
$$(VQ) = (\mathrm{VQ}) + \boxed{\mathrm{vQ} + \mathrm{Vq} + \mathrm{vq}}$$

Parameterize,
Specify (e.g. boundary conditions),
Negligible
Ignored

Discussions & Breakouts: TPOS Priorities ?

Correlations

$$\text{e.g. } \langle wq \rangle = \int \varphi_{wq}(f,k)\ df\ dk = \Sigma \text{ processes}$$

Different processes occupy different regions of frequency–wavenumber space, so "Process Parameterizations" are additive.

"Parameterization schemes" (e.g. mixed layer, diurnal cycling) can encompass a variety of regions of frequency–wavenumber space.

Discussions & Breakouts: TPOS Priorities ? Double Counting ?

MEET TPOS NEEDS ? HOW TO QUANTIFY ?

Processes :

- Gent McWilliams : **u**T, **u**S (mesoscale) ; for an unresolved "bolus" velocity **u***
- **Vertical "Mixing"** : wq (high f,k) ; entrainment velocity = $\partial_t h + w(-h)$
- **Lateral Viscosity** : [uQ + Uq + uq + vQ + Vq + vq] (Numerics)

"Phenomenon" (schemes)

- "Pipes" over or through unresolved topography (slopes) (ITF)
- Boundary (Mixed) Layer
- **Diurnal Cycling** (SST, S, U) ;
- Lateral boundary conditions

3) Eddy Viscosity

A **parameterization** of the deviatoric component of the stress tensor σ_{ij} ;
in terms of the resolved shear $[\nabla_k U_l + \nabla_l U_k]$:
Symmetries $T_{ijkl} = T_{jikl} = T_{ijlk} = T_{klij}$ leave only 21 independent elements

Models typically specify a vertical K_v plus one (K_u) or two (e.g. A_H downstream, B_H, cross-stream) grid-dependent lateral viscosities

K_u ,B_H control of equatorial zonal currents ?

Sufficient for equatorial dynamics ?
($\sigma_{23} \neq 0$, where $[\nabla_3 U_2 + \nabla_3 U_2] = 0$)

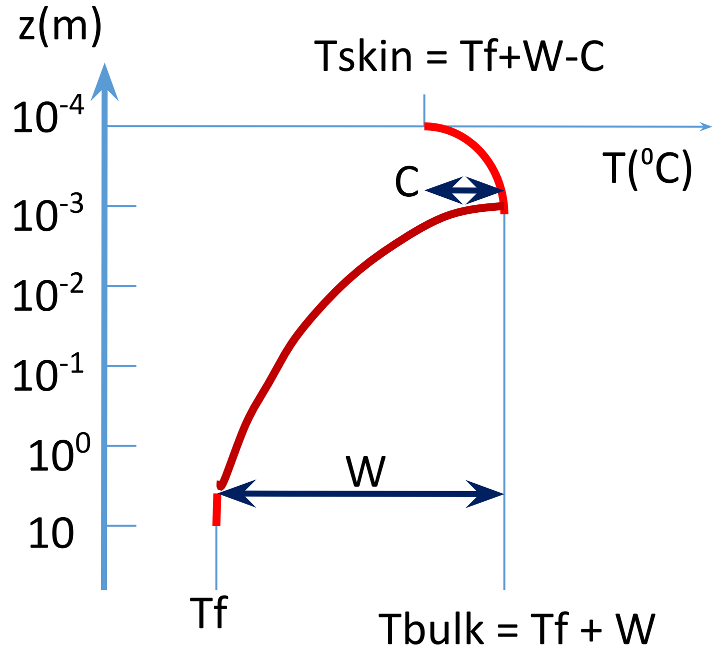
What do observations say ?

Are there numerical constraints ?

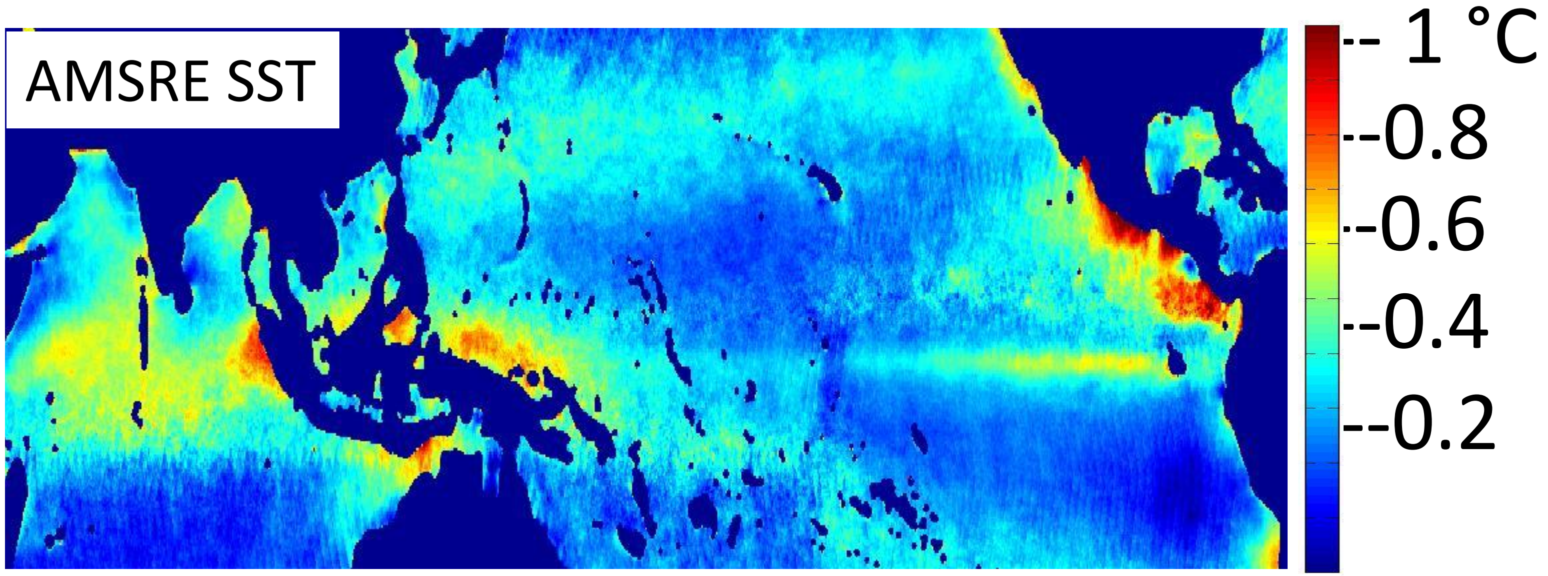
OCEAN MODEL PARAMETERIZATIONS

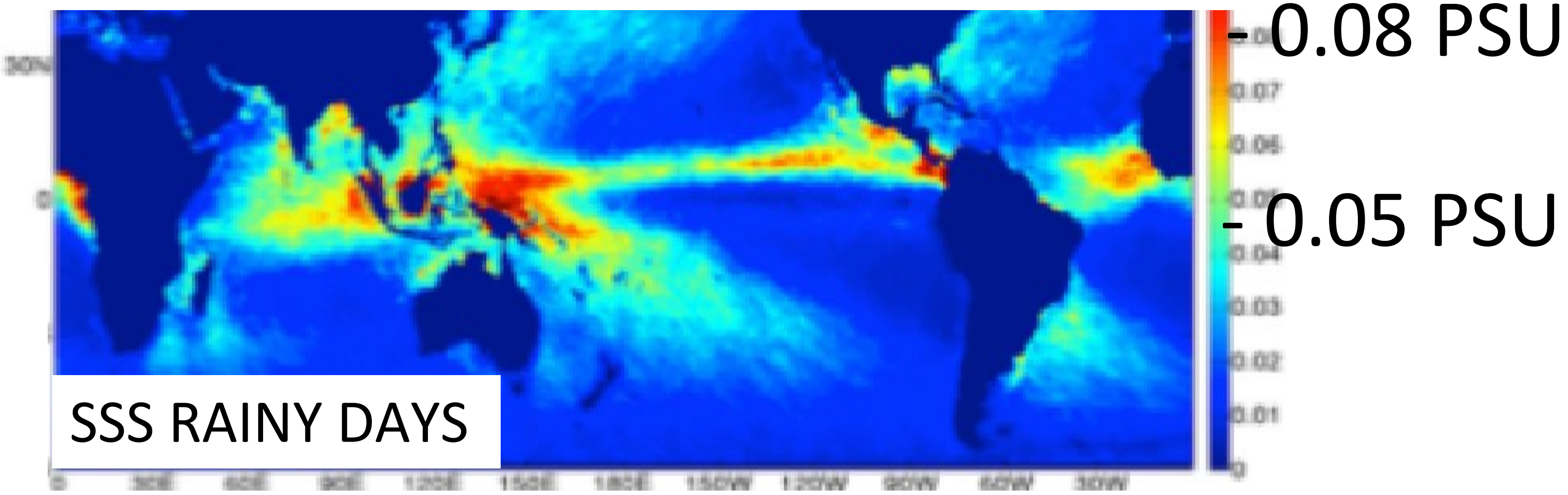
3) Diurnal Cycling (SST & SSS)

Amplitude = W(14:00) + C(0:00)]
(< 4°C) (< 0.2°C)



PRECIPITATION 5 TIMES MORE EFFECTIVE THAN EVAPORTATION

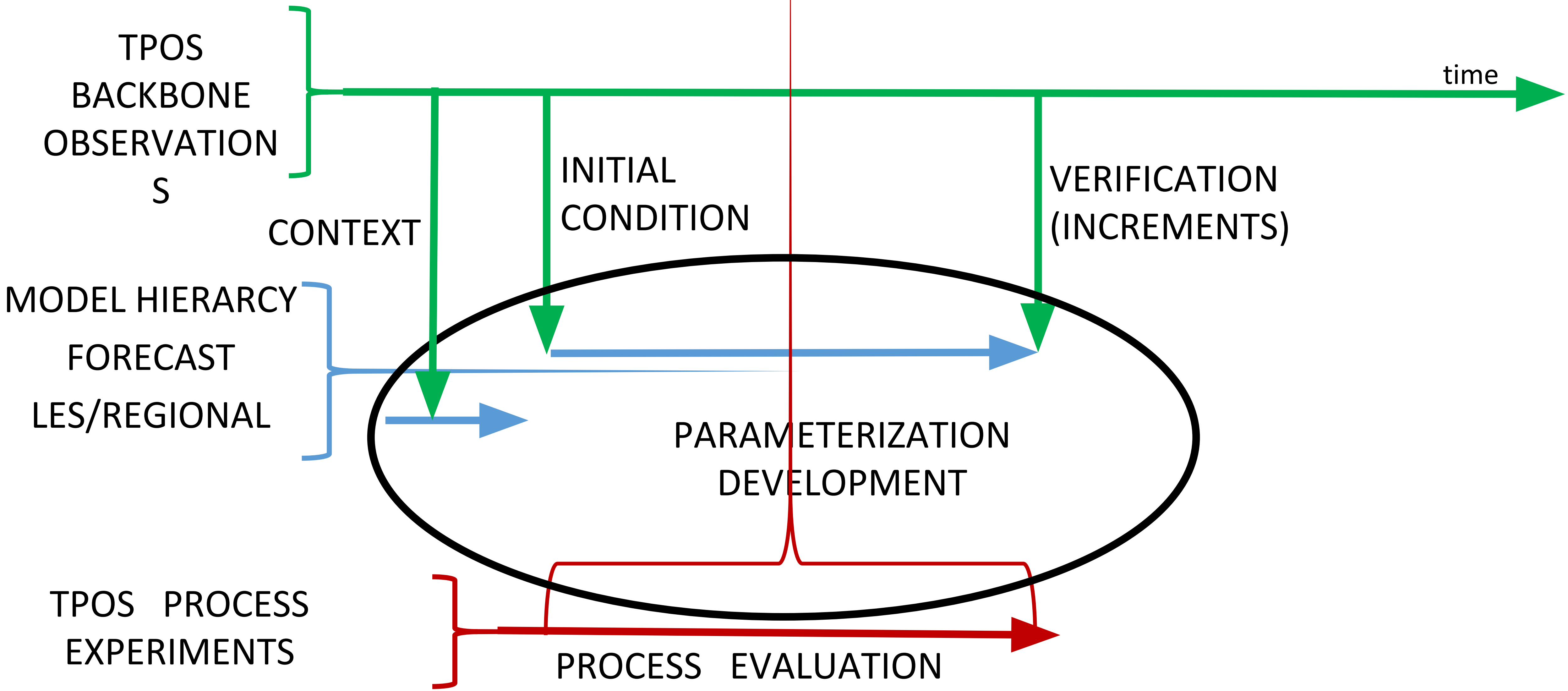




INGREDIENTS ?

1) What needs to be improved (e.g. sources of drift over a forecast interval) ?
2) What are the observational/theoretical/process model needs (CLIVAR CPTs)?
3) A protocol, including data assimilation (DA)
4) A developmental "testbed"
5) **<u>Objective</u>** Evaluation (process evaluation, analysis of increments)

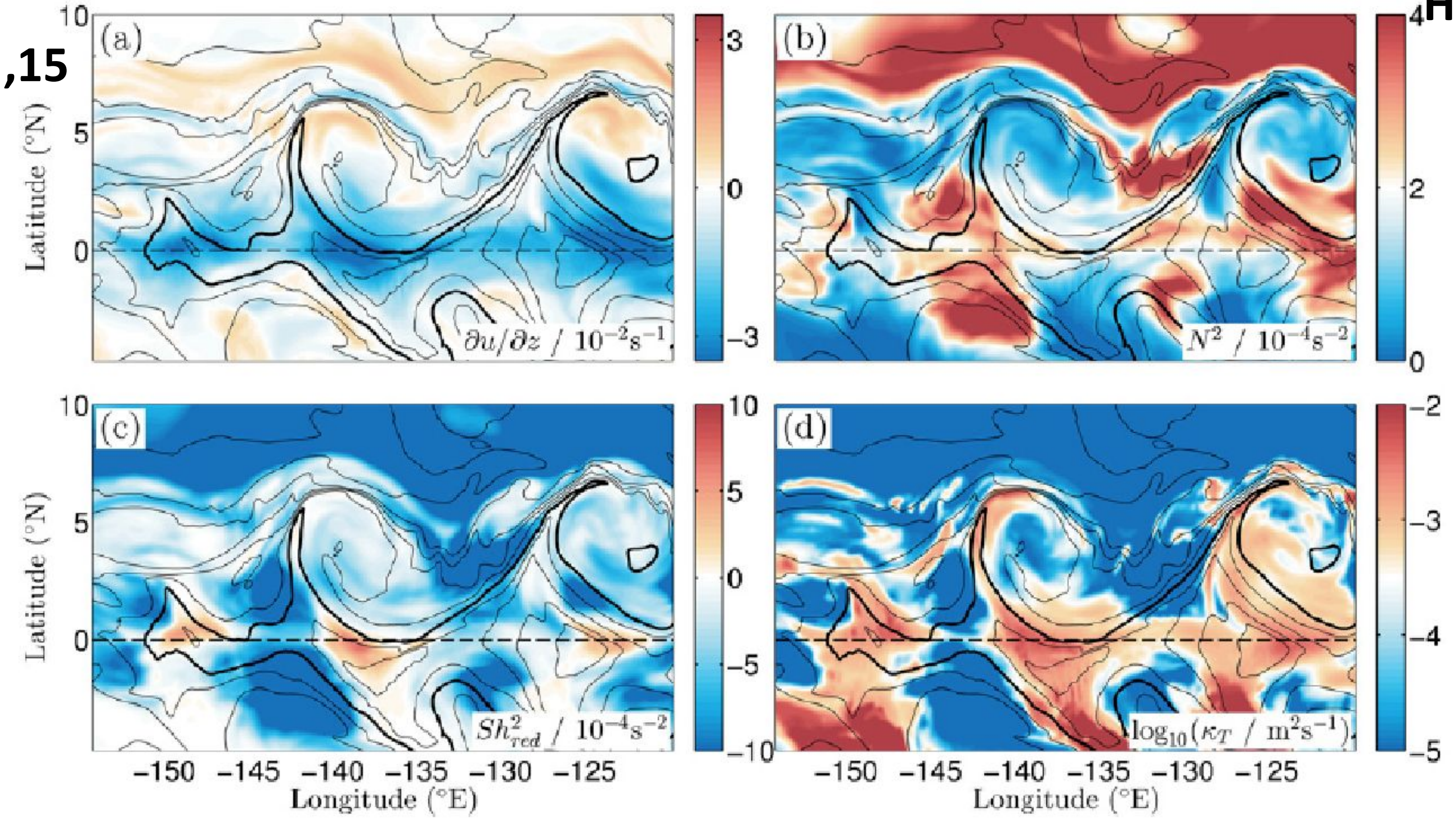
4) Framework



TPOS
BACKBONE
OBSERVATION
S
time
CONTEXT
INITIAL
CONDITION
VERIFICATION
(INCREMENTS)
MODEL HIERARCY
FORECAST
LES/REGIONAL
PARAMETERIZATION
DEVELOPMENT
TPOS PROCESS
EXPERIMENTS
PROCESS EVALUATION

Modulation of Equatorial Turbulence by Tropical Instability Waves in a Regional Ocean Model

Holmes and Thomas, JPO ,15



Daily averages at 72 m

a) zonal shear,
b) Stratification (N^2)
c) Shear^2 (reduced)
d) Vertical diffusivity

SST contours @ 0.75°C
----- 25°C isotherm

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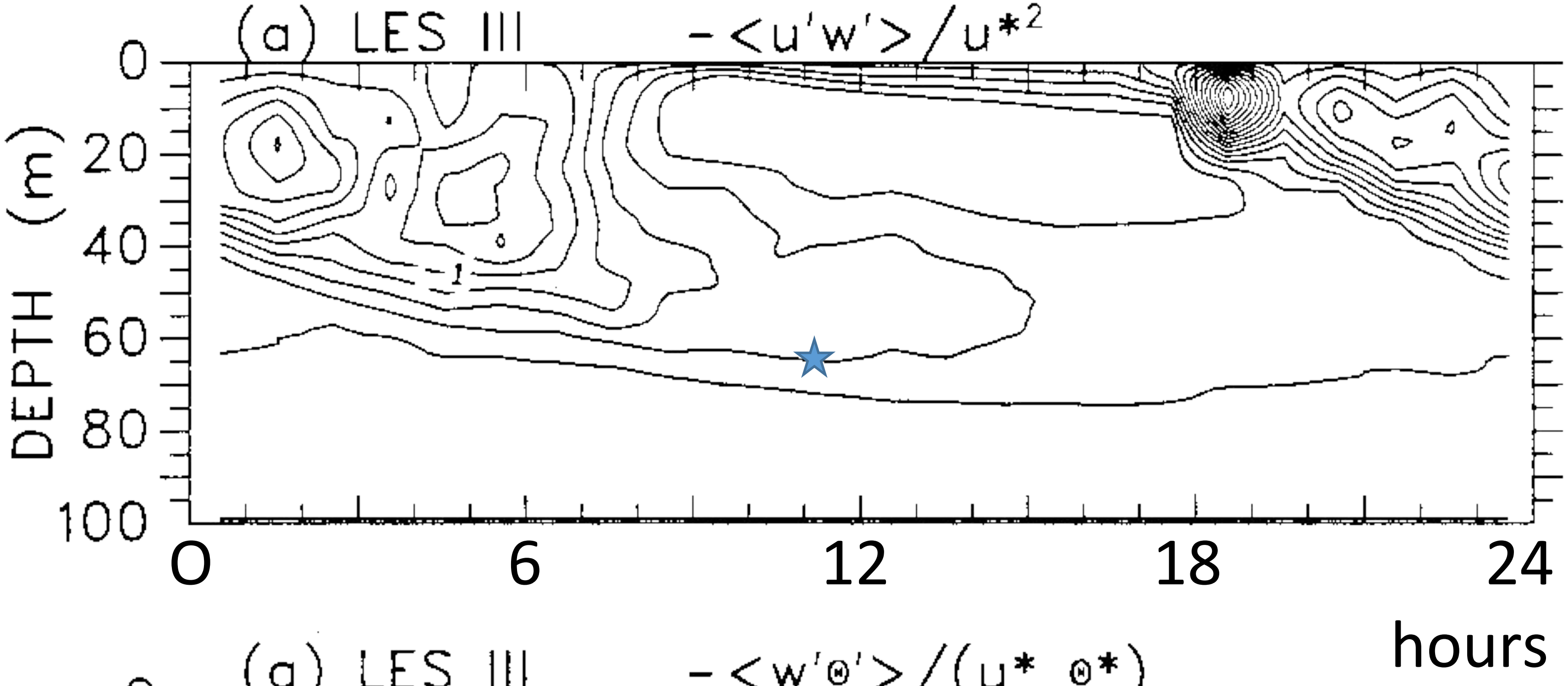
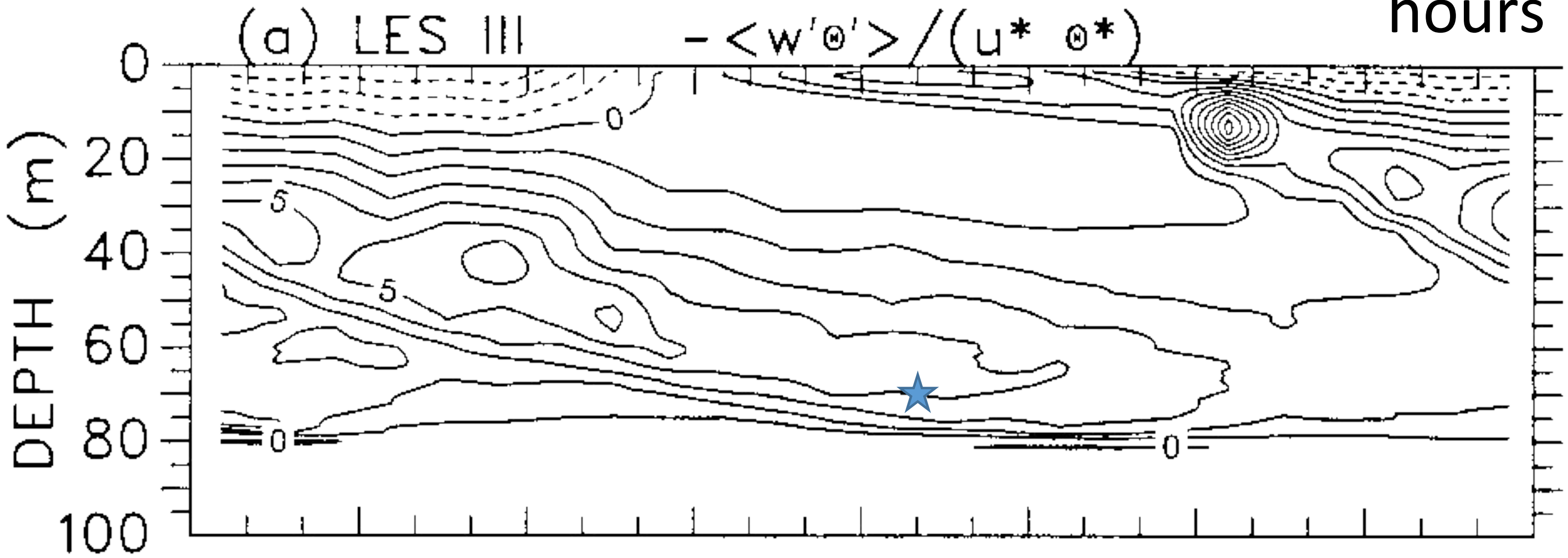
4) Large Eddy Simulation





Interpret μ-structure?

Mixing efficiency, $R_\rho(z,t)$

cross-shear, $\sigma_{23} \neq 0$

Diffusivity where $\langle w\theta\rangle \neq 0$; $\partial_z \Theta = 0$

★ Deep cycle turbulence

THE END

QUESTIONS ?

A **parameterization** of the deviatoric component of the stress tensor σ_{ij} ;
in terms of the resolved shear $[\nabla_k U_l + \nabla_l U_k]$:
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Models typically specify a vertical K_v plus one (K_u) or two (e.g. A_H downstream, B_H, cross-stream) grid-dependent lateral viscosities

$$
\left.\begin{aligned}
T_{1111} = T_{2222} &= 2K_u = A_H + B_H \\
T_{3333} &= K_v + K_u = K_v + A_H \\
T_{1212} &= K_u = B_H \\
T_{1313} = T_{2323} &= K_v \\
T_{1133} = T_{2233} &= K_u - K_v = B_H - K_v
\end{aligned}\right\}
$$

K_u ,B_H control equatorial zonal currents
Sufficient for equatorial dynamics?
$\sigma_{23} \neq 0$, where $[\nabla_3 U_2 + \nabla_3 U_2] = 0$

What do *observations say ?*

Are there numerical constraints ?