

**Impacts of Ocean Currents and Waves on the
Wind Stress Drag Coefficient: Relevance to HYCOM**

By

BIROL KARA AND JOE METZGER

Naval Research Laboratory (NRL)

Stennis Space Center

MARK BOURASSA

Center for Ocean–Atmospheric Prediction Studies (COAPS)

Florida State University

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INTRODUCTION

Surface ocean currents and waves influence the **wind stress drag coefficient** as shown in the literature.

- Ocean models have current speeds but typically they do not include wave information
- Wind stress formulation for input to HYCOM excludes both current and wave effects.

We would like to answer two questions:

- (1) What is the impact of currents and waves on the drag?
- (2) Are these effects negligible over the global ocean?

WIND STRESS FORMULATION

- Wind stress (τ) is parameterized as

$$\tau = \rho_a C_D V^2$$

- Thus, τ depends on

- (1) density of the air: ρ_a
- (2) drag coefficient: C_D
- (3) squared wind speed V^2

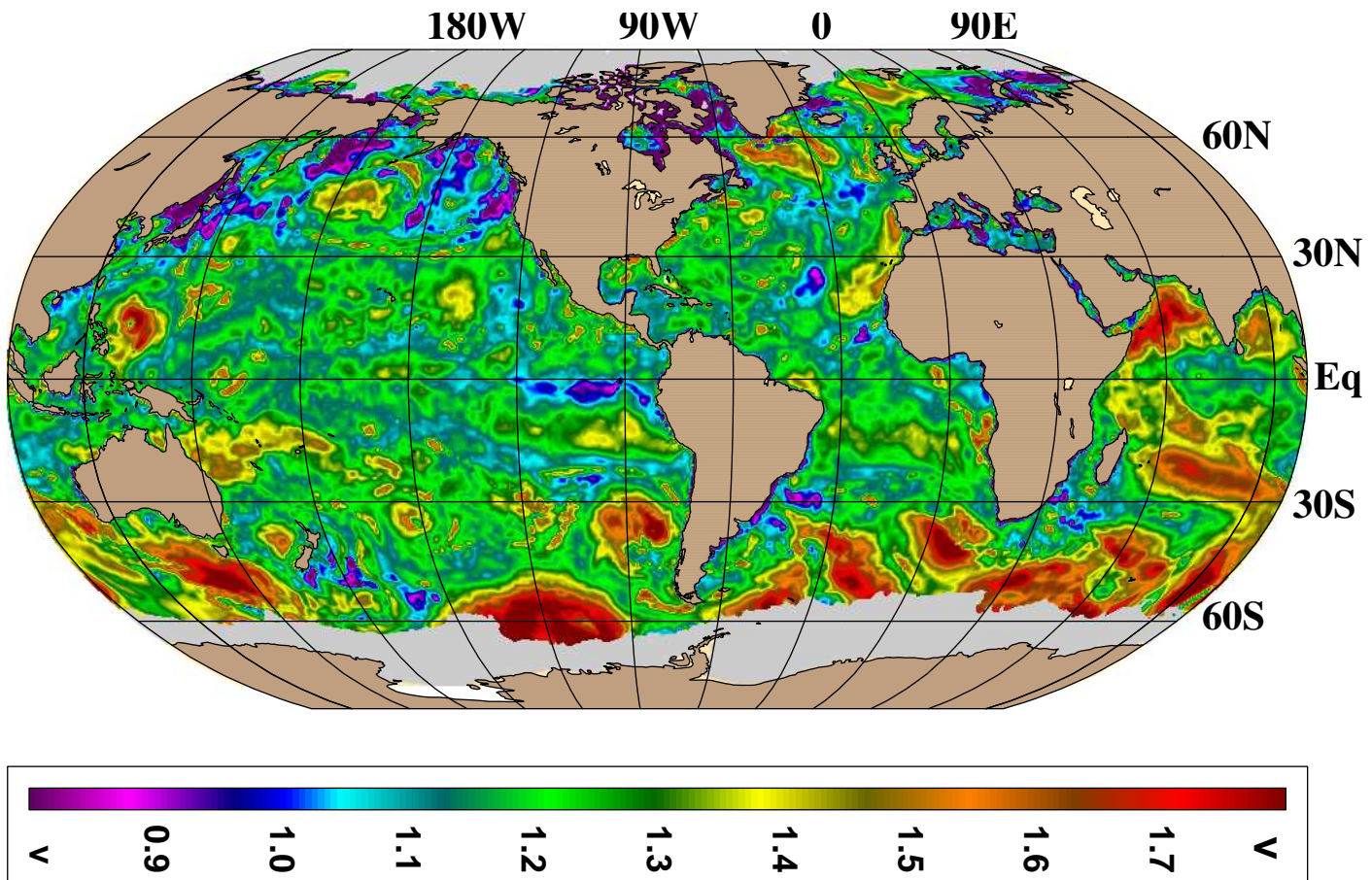
- ρ_a and V are well-known but C_D is NOT.

DRAG COEFFICIENT

- C_D depends on
 - dynamic stability at the air–sea interface, i.e.
 - air–sea temperature difference, and
 - relative humidity at the air–sea interface
- HYCOM includes preceding effects (full stability)
- C_D also depends on the sea state
 - sea surface current speed**
 - ocean wave speed**

Our focus is on the effects of sea state!

DRAG COEFFICIENT on 1 Aug 2005 (00Z)



• $C_D \times 10^3$ is

- o based on polynomial equations (Kara et al. 2005),
- o based on the COARE (v3.0) algorithm, and
- o formulated using air-sea stability.

NOTE: Currents and wave speeds are NOT included in C_D .

METHODOLOGY

- We would like vector averages of

$$\vec{V} - \vec{V}_C - \vec{V}_W$$

- Drop vector notation for simplicity

- Wind speed at 10 m: V

- Surface current speed: V_C

- Primary wave speed: V_W

- Use zonal and meridional components for V , V_C and V_W

GLOBAL DATA

- **Data sources:**
 - **V from 1° NOGAPS**
 - **VC from 1/12° HYCOM**
 - **VW from 1° WW3 model**

- **NOGAPS winds are used because**
 - **(1) its resolution is consistent with WW3, and**
 - **(2) it provides 3 hourly data (important for stability)**

Note: We apply 1° binning to VW for consistency.

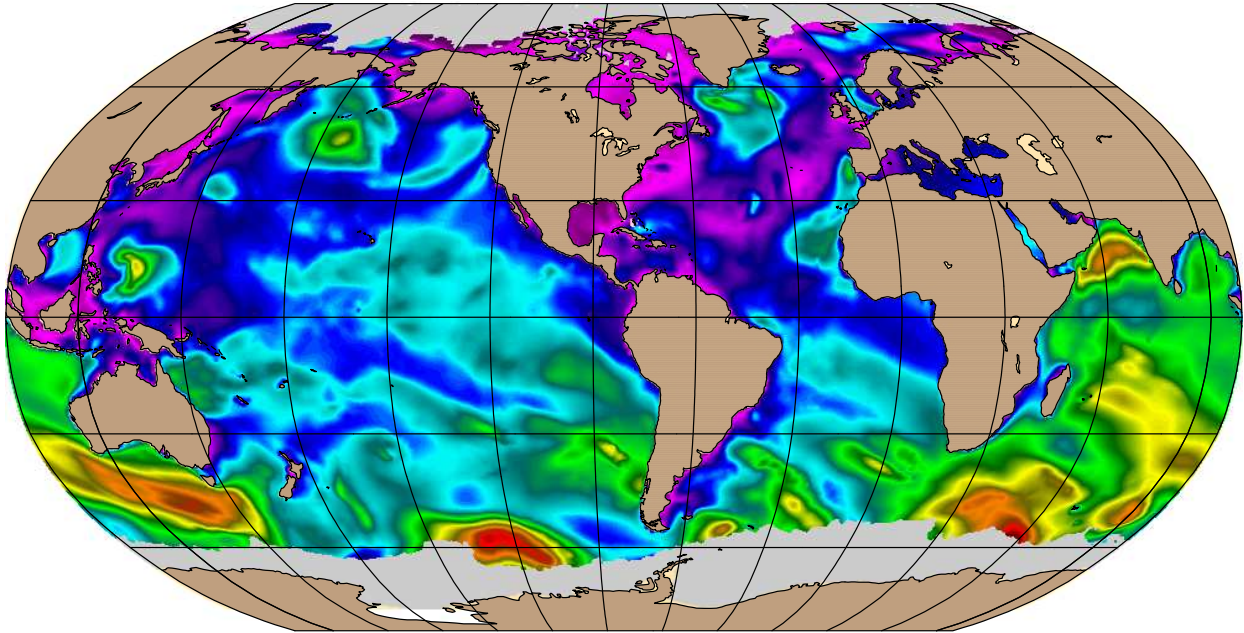
NOGAPS: Navy Operational Global Atmospheric Prediction System

HYCOM: HYbrid Coordinate Ocean Model

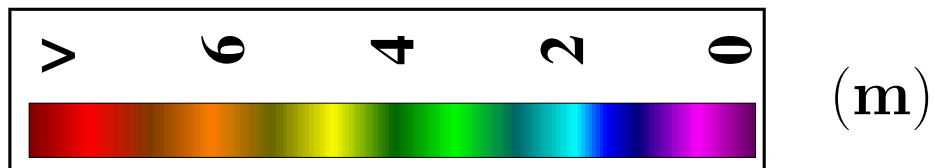
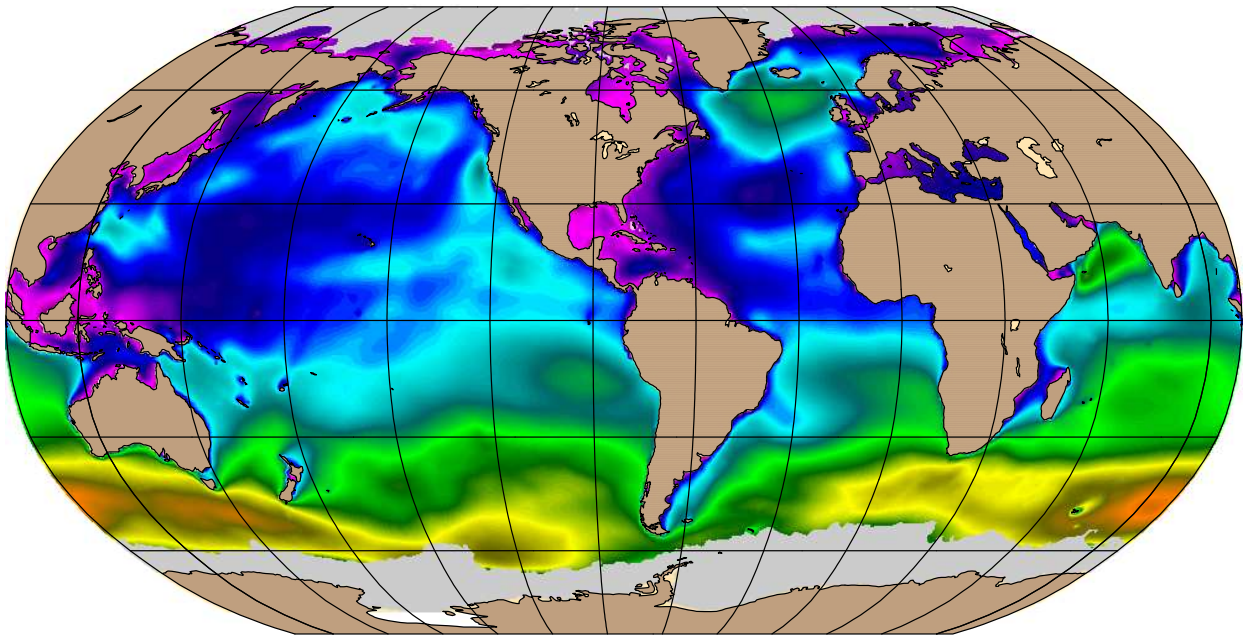
WW3: Wave Watch 3, a third generation wave model

SIGNIFICANT WAVE HEIGHT FROM WW3

(a) 1 Aug 2005 (00Z)



(b) Aug 2005 Mean



These are needed for wave speed calculation.

CALCULATION OF WAVE SPEED

$$V = VC + VW$$

- **V and VC are directly obtained (NOGAPS and HYCOM)**
- **However, VW has to be calculated (WW3)**
- **VW is calculated following Bourassa (2006)**

$$VW = f V_{orb}$$

f is constant (0.8), and

V_{orb} is the orbital velocity

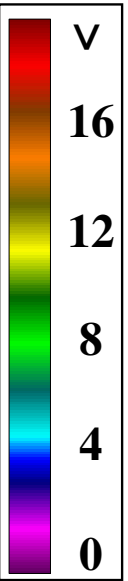
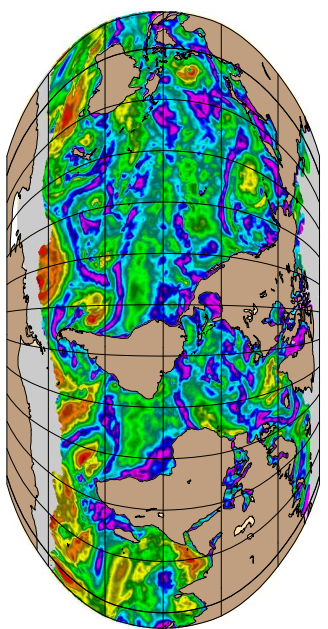
$$V_{orb} = 3.14 H/T$$

significant wave height (H)

dominant wave period (T)

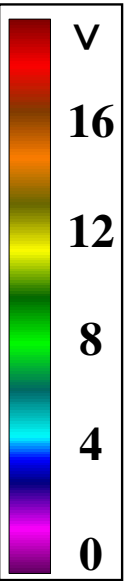
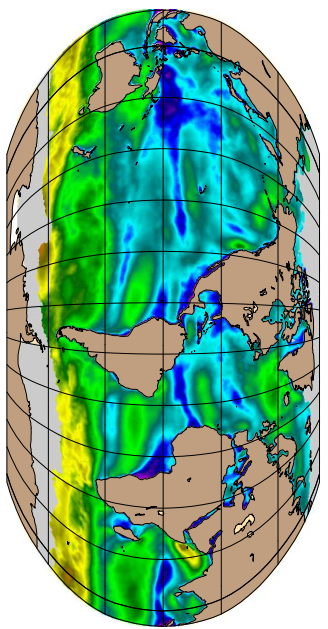
FIELDS USED FOR CALCULATIONS

(a) 1 Aug 2005 (00Z)



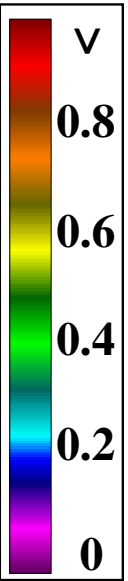
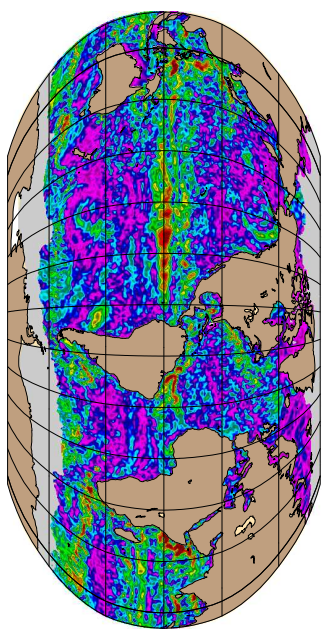
V (m s⁻¹)

(b) Aug 2005 Mean



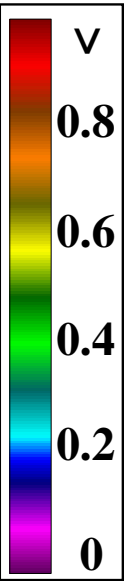
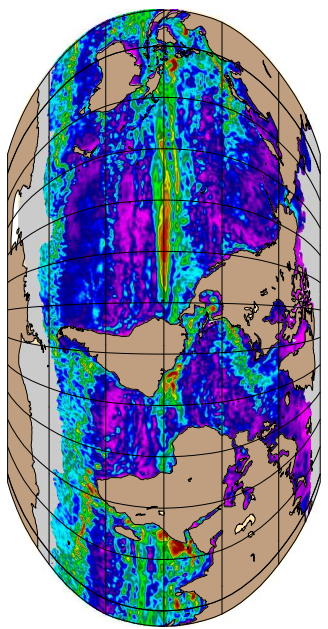
V (m s⁻¹)

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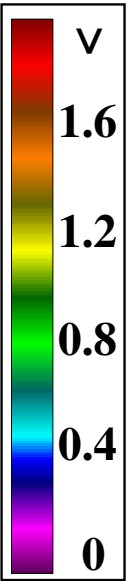
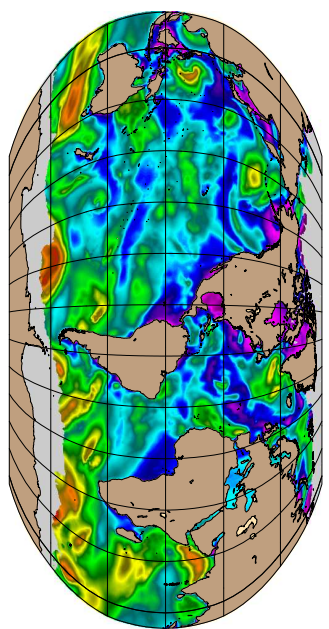
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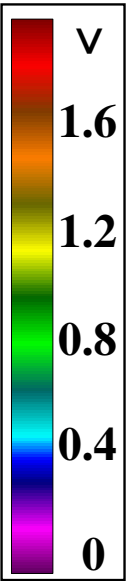
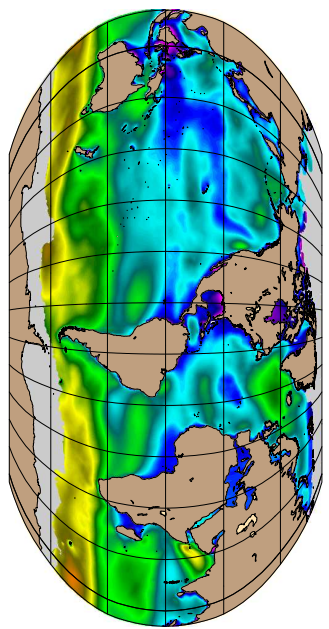
V (m s⁻¹)

(a) 1 Aug 2005 (00Z)



V (m s⁻¹)

(b) Aug 2005 Mean

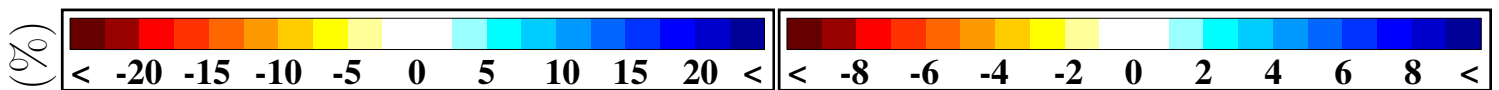
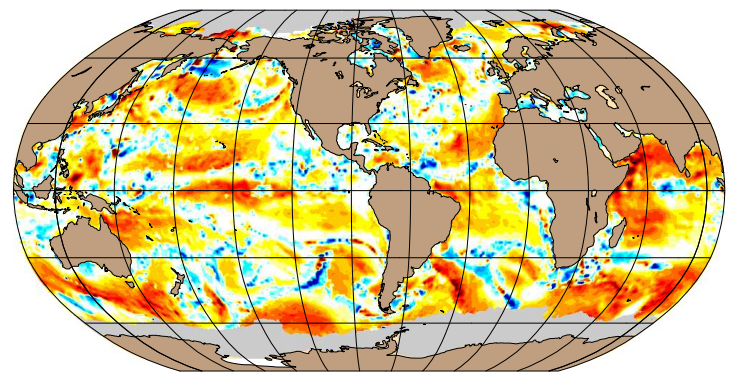
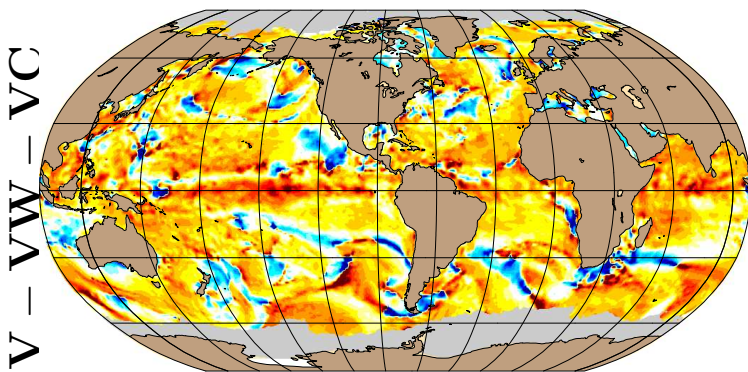
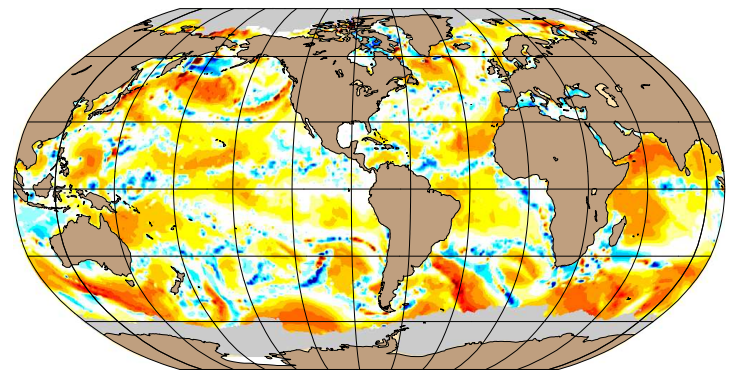
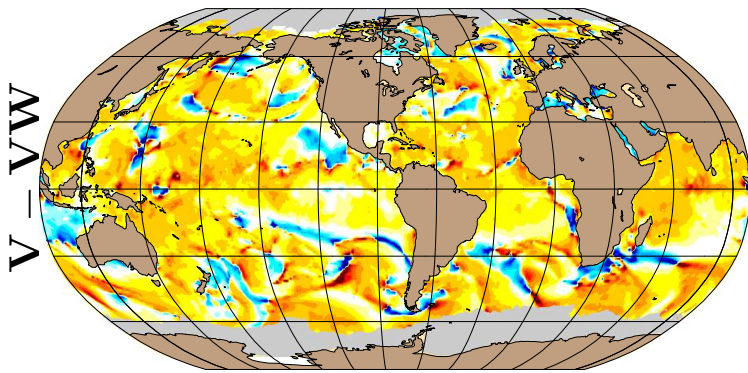
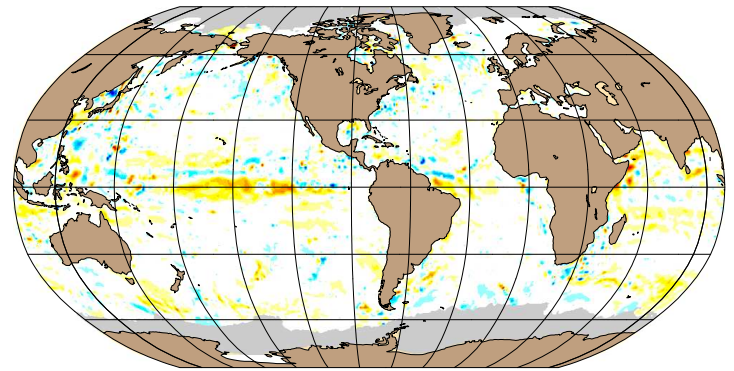
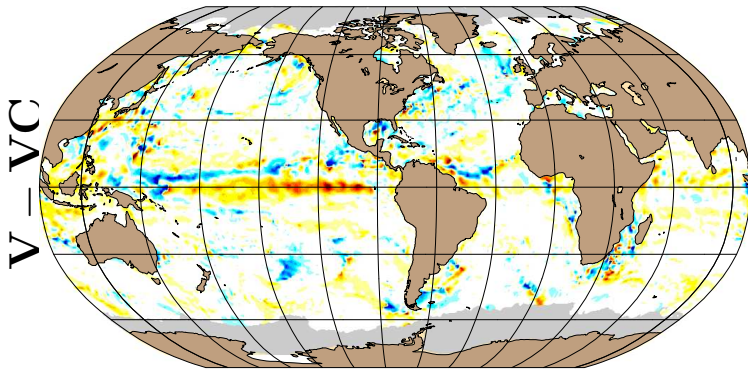


V (m s⁻¹)

PERCENTAGE CHANGES (1 Aug 2005)

(a) Daily wind change: ΔV

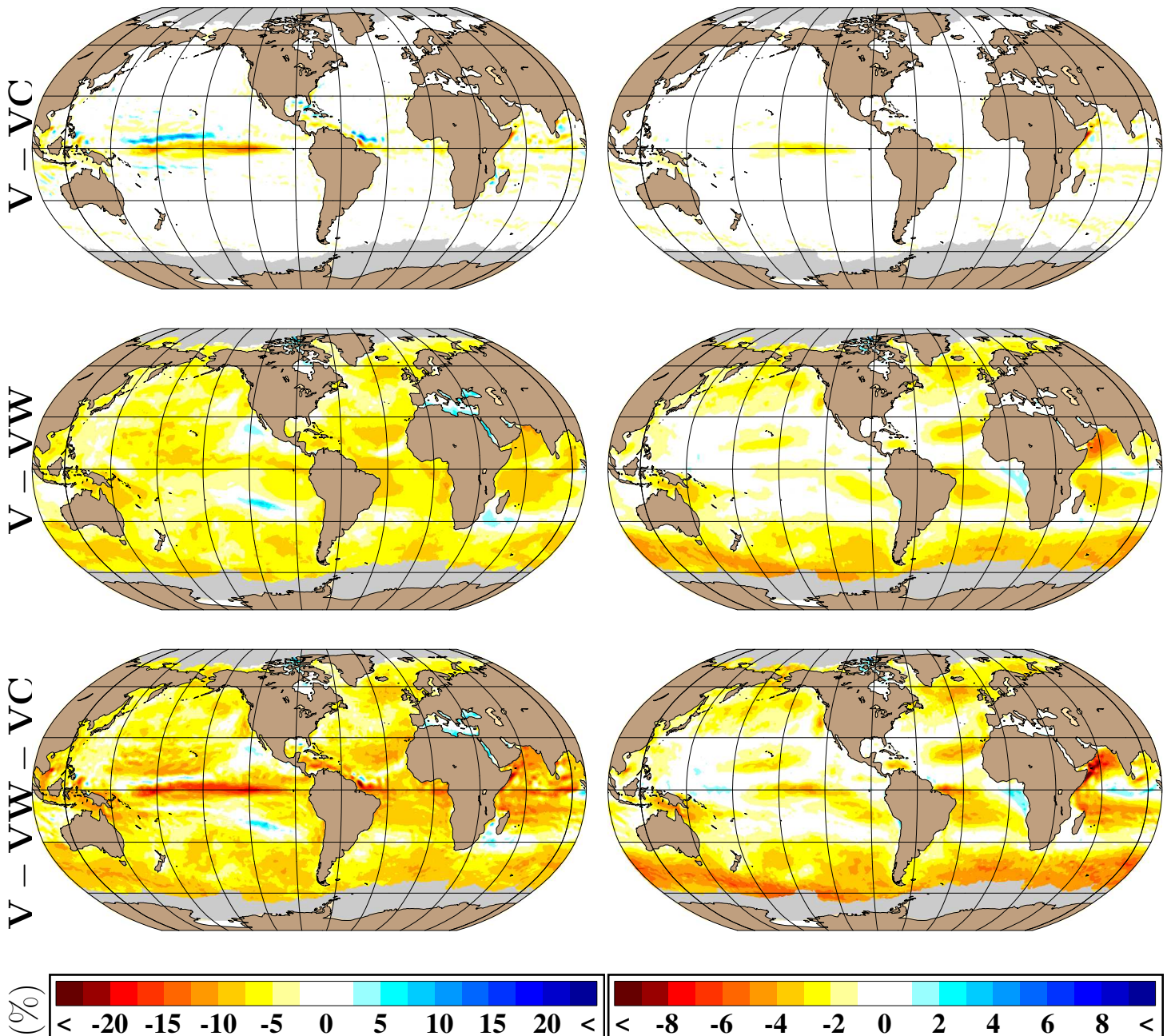
(b) Daily drag change: ΔC_D



VC/VW/VC+WV reduces V by 1.0%/5.4%/6.4% globally
VC/VW/VC+WV reduces C_D by 0.3%/1.7%/1.9% globally

PERCENTAGE CHANGES (Aug 2005 mean)

(a) Monthly wind change: ΔV (b) Monthly drag change: ΔC_D



VC/VW/VC+VW reduces V by 1.4%/5.5%/6.9% globally
VC/VW/VC+VW reduces C_D by 0.4%/1.7%/2.1% globally

CONCLUSION

- Spatial variability in C_D DOES exist
 - HYCOM already includes this variability
 - Wind speed, air–sea temp, relative humidity
- C_D should also include current and wave effects
 - Current speed: available at each model time step
 - Wave speed: what do we do about that?
 - a statistical relationship may be developed
- Globally, **combined outcome** of wind and wave speed:
 - Reduction in C_D by 2% only
 - However, one must note daily spatial variability
 - western boundary currents (current speed)
 - high latitudes (wave speed)