Applications of Satellite Surface Vector Winds (SVW) in Models and Syntheses of Tropical and Sub-Tropical Atmosphere-Ocean Interactions

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Four (loosely connected) Sub-Projects:

- **Mesoscale Convective System (MCS) Detection;**
  a multi-platform evaluation of SVW signals (i.e. convergence and divergence) that correlate with MCS development and rain events.
  *Brian Mapes and David Long; consultants.*

- **SVW Cross-Validation in Hurricanes;**
  comparisons of satellite SVW (wind and rain) retrievals with in-situ ocean drifters deployed in developing TC systems of the sub-tropical N. Atlantic.
  *David Long; consultant. Peter Niiler, Thomas Bengtsson; collaborators.*

- **[SVW] 4DVAR in the Intra-Americas Seas (IAS);**
  exploit [SVW] to guide ocean model 4DVAR assimilation and forecasts in the IAS.
  *A. Moore (and IAS ROMS team); collaborators.*

- **[SVW] and Ocean General Circulation Model (OGCM) Uncertainty;**
  OGCM uncertainty quantification in global and regional simulations.
  *Bill Large and Gokhan Danabasoglu; collaborators.*
The Mesoscale Convective System (MCS) life cycle

Major processes (expressed as GCM parts & parameterizations):
- dynamics, PBL
- PBL, shallow cumulus
- PBL, cumulus, stratiform cloud
- stratiform cloud & precip

Key variables measured by TropSat:
- SST, $\nabla^2$SST
- $\nabla \cdot V_{sfc}$ inflows, gravity waves
- $\nabla \times V_{sfc}$ Ekman pumping
- $\nabla \cdot V_{sfc}$, column vapor, cloud top, rainrate & rainwater
- net latent heating, momentum effects
- production of atm & ocean cold pools
- SST, $\nabla^2$SST rain, flux effects
- $\nabla \cdot V_{sfc}$ outflows, gravity waves
- $\nabla \times V_{sfc}$ cyclogenesis, planetary waves

preconditioning and triggering

several hours
Zonal Wind Posterior Mean Fields for a Single MJO Event

OLR Anomaly; November 2000

10 Nov 15 Nov 20 Nov 25 Nov

Longitude

0.0 0.5 1.0 1.5

-110 -90 -70 -50 -30 -10 10 30 50 70

NOAA-CIRES/Climate Diagnostics Center
Surface Convergence and Atmospheric Deep Convection

left panel: daily composite convergence (blue) and divergence (red)

right panel: daily average OLR (red → deep conv)
SVW Cross-Validation in Hurricanes:

Ultra-high resolution wind (and rain) retrievals vs. Minimet and other drifters

Estimate drag coefficient functional form (and uncertainty) in hurricane winds
Ocean Drifter Dataset: 2004 Hurricane Season, NW Atlantic

Air-Sea Bayesian Hierarchical Model

Milliff et al. (2003) JTech; Bengtsson et al. (2005) JGR
Ocean General Circulation Model (OGCM) and Ocean Forecast Model Applications of [SVW] from Bayesian Hierarchical Models (BHM)

Use SVW abundance and precision, and precisely characterized uncertainty, to deduce and distribute ocean model uncertainties (less well known)

- **OGCM Uncertainty Distribution (review)**
  CCSM Ocean Model Component response to [SVW] forcing during an MJO

- **Variational DA**
  Regional Ocean Model System (ROMS) 4DVAR in Intra-Americas Seas (IAS)

- **Sequential DA**
  Mediterranean Forecast System (MFS) Kalman Filter and Ensemble Initial Conditions
20 Nov; Zonal Velocity and Temperature Equatorial Sections

τ_x(x)
50-member ensemble winds
(mean, standard deviation, range)

U(x,z)
Standard Deviation Max = 5.9 cm/s

T(x,z)
Standard Deviation Max = 0.2°C
[SVW] to Identify Model Error in ROMS 4DVAR for the IAS
MFS-Wind-BHM  *Markov Process Assumption → time dependence*

**Data Stage Distributions** (likelihoods)
\[
\prod_{t=1}^{T} [S_t | W_t, \theta_S] \times \prod_{t=1}^{T} [A_{t|W_t, \theta_{AW}}^w | P_t, \theta_{AP}] \times \prod_{t=T+1}^{T+L} [F_{t|W_t, \theta_{FW}}^w | F_t^p | P_t, \theta_{FP}].
\]

QSCAT  ECMWF analyses  ECMWF forecasts

**Process Model Stage Distributions** (priors)  "*Stochastic Geostrophy*
\[
[b_0] \times \prod_{t=1}^{T+L} [W_t | P_t, \theta_W] [P_t | b_t, \theta_P] [b_t | b_{t-1}, \theta_b]
\]

Where \([P_t | b_t, \theta_P]\) is given by \(P_t = \Phi b_t + \varepsilon_p\) for spatial eigenvectors \(\Phi\) and amplitude coefficients \(b\).

In turn, \([b_t | b_{t-1}, \theta_b]\) is an autoregressive model for \(b\) as in \(b_t = G b_t + \varepsilon_b\)

**Parameter Distributions**
\[
\theta_{S,AW,FW,AP,FP} = \{H_{S,AW,FW,AP,FP}, \sigma_{S,AW,FW,AP,FP}^2\}; \quad \theta_P = \{\Phi, \varepsilon_p\}; \quad \theta_b = \{G, \varepsilon_b\}; \ldots
\]

**Posterior Distribution**
\[
[W_t, P_t, b_t, \theta_{W,P,H,S,AW,FW,AP,FP} | S_t, A_t^W, A_t^P, F_t^W, F_t^P]
\]
BHM Ensemble Winds

10 members selected from the Posterior Distribution (blue)

20050207 - time step: 3

Ensemble mean wind (green); ECMWF Analysis wind (red)
10 realizations from BHM posterior distribution (blue); ensemble mean (green), ECMWF analysis (red)
Ensemble Initial Conditions

Day 14A

SSH Standard Deviation (cm)

SST Standard Deviation (°C)
MFS Ensemble Forecast Response

Day 10F

SSH Ensemble Mean (cm)

SSH Standard Deviation (cm)
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