P4.5

SYNERGISM BETWEEN A NONLINEAR PBL MODEL AND SATELLITE WIND DATA

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1. INTRODUCTION

The microwave scatterometers, radiometers, Synthetic Aperture Radars (SARs) and altimeters have now provided nearly three decades of surface winds over the global oceans. In many cases these products are revolutionary --- changing the way we view the world.

From 1980 to the present we have used the satellite surface wind as a lower boundary condition on a planetary boundary layer (PBL) model, to infer considerable information about the atmosphere and the PBL.

- The symbiotic relation between surface backscatter data and the PBL model has been beneficial to both.
- The PBL model has established superior 'surface truth' winds (or pressures) for the satellite model functions.
- Satellite data have proven that the nonlinear PBL solution with Organized Large Eddies (OLE) is observed most of the time.

This has been summarized by Brown (2005).

2. STATE OF THE ANALYTIC SOLUTION FOR A PBL

A solution for a PBL in a rotating frame, U (f, K,∇p) was found by Ekman in 1904.

$$fV + K\,Uzz - pz/\rho = 0$$
$$fU - K\,Vzz + pz/\rho = 0$$

Unfortunately, this was almost never observed.

A nonlinear solution, U (f, K,∇p) was found in 1970. OLE are part of the solution for 80% of the observed conditions (near-neutral to convective).

$$fV + K\,U_{zz} - p_z/\rho = 0$$
$$fU - K\,V_{zz} + p_z/\rho = A(v_2 w_2)$$

Unfortunately, this scale was difficult to observe.

The complete nonlinear solution for OLE exists, including 8th order instability solution, variable roughness, stratification and baroclinicity, (Foster, 1997). It is being integrated into MM5 and NCEP models (2005).

3. STATUS OF OLE VERIFICATION; PBL MODEL

- Airplane campaigns in cold air outbreaks (1976 -).
- Ground based Lidar detects OLE (1996 -); Lidar from Aircraft PBL flights (1999 -).

* Satellite derived surface pressures (1997) using nonlinear PBL model are accurate.
* Satellite SAR data of ocean surface shows evidence of ubiquitous OLE (1978; 1986; 1997-).
* SAR stats show Roll signatures 30 - 75% of the time. This is *sufficient* evidence that Rolls are present, not *necessary.*
* Since the nonlinear (Roll-containing) PBL solution yields significantly different wind profiles and fluxes, it must be considered for wind, weather and climate models.

4. SURFACE PRESSURES FROM SPACE

The solution for the PBL boundary layer (Brown, 1974, Brown and Liu, 1982), may be written

$U/V_G = \exp[i\,\alpha] - \exp[-z]\,\{\exp[-iz] + i\exp[iz]\}\sin\alpha + U_2$

where $\mathbf{V_G}$ is the geostrophic wind vector; the angle between $\mathbf{U_{10}}$ and $\mathbf{V_G}$ is $\alpha[u^*, \nabla_H \mathbf{T}, (Ta - Ts,)_{PBL}]$ and the effect of the OLE in the PBL is represented by $\mathbf{U_2}(u^*, Ta - Ts, \nabla_H \mathbf{T})$.

This may be written:

$\mathbf{U/V_G} = f\{\alpha(u^*), \mathbf{U_2}(u^*), \mathbf{u^*}, zo(u^*), \mathbf{V_T(\nabla_H T)}, \Psi(Ta - Ts), \lambda\}$

Or

$\mathbf{U/V_G} = f[\mathbf{u^*}, \mathbf{V}T(\nabla_H \mathbf{T}), \Psi(Ta - Ts), \lambda, k, a] = f\ \{\mathbf{u^*}, \nabla_H \mathbf{T}, Ta - Ts\}$,

For typical values of $\lambda = 0.15$, $k = 0.4$ and $a = 1$.

In particular,

$V_G = f\,(u^*, \nabla_H T, Ta - Ts) \equiv f n(\nabla P, \rho, f)$.

Hence $\nabla \mathbf{P} = f_n\,[u^*(k, a, \lambda), \nabla_H T, Ta - Ts, \rho, f\,] \approx \mathbf{fn(\sigma o)}$

* UW PBL similarity model joins two layers: with $G/u^* = f[\nabla \mathbf{P}, \mathbf{T_{10}}, \mathbf{SST}, \mathbf{q_{10}}, \mathbf{CS}, \mathbf{K}]$

$$U^N_{10} = u^*/k \log[10/z_o(u^*)\,]$$

We use the "inverse" PBL model to estimate U_G from satellite σ_o. Then get the non-divergent field U_G^N. Use Least-Square optimization to find best fit SLP to swaths

There is extensive verification from ERS-1/2, NSCAT, QuikSCAT of ∇ P ((U_G^N)

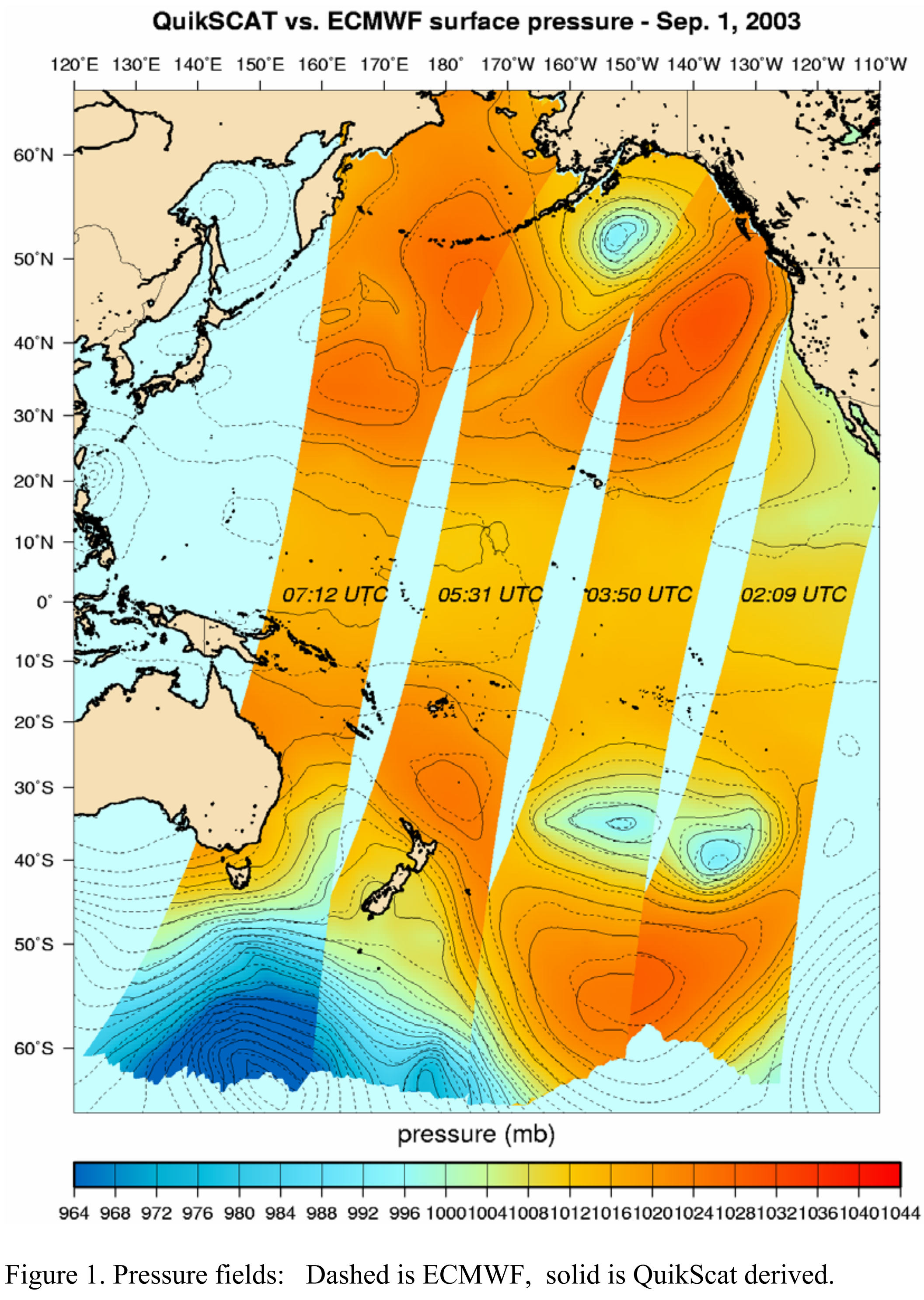

Figure 1. Pressure fields: Dashed is ECMWF, solid is QuikScat derived.

4.1. Conclusions Using Pressure Fields

* The nonlinear solution applied to satellite surface winds yields accurate surface pressure fields. These data show:

*	Agreement between satellite and ECMWF pressure fields indicate that both Scatterometer winds and the nonlinear PBL model (VG/U10) are accurate within ± 2 m/s.
*	A 3-month, zonally averaged offset angle <VG, U10> of 19° suggests the mean PBL state is near neutral (the angle predicted by the nonlinear PBL model).
*	Swath deviation angle observations infer thermal wind and stratification.
*	Higher winds are obtained from pressure gradients and used as surface truth (rather than from GCM or buoy winds).
*	V_G (pressure gradients) rather than U_{10} could be used to initialize GCMs

5. OTHER APPLICATIONS

The pressure fields also can be applied to smooth the model function winds.

UWPBL scheme vs. DIRTH

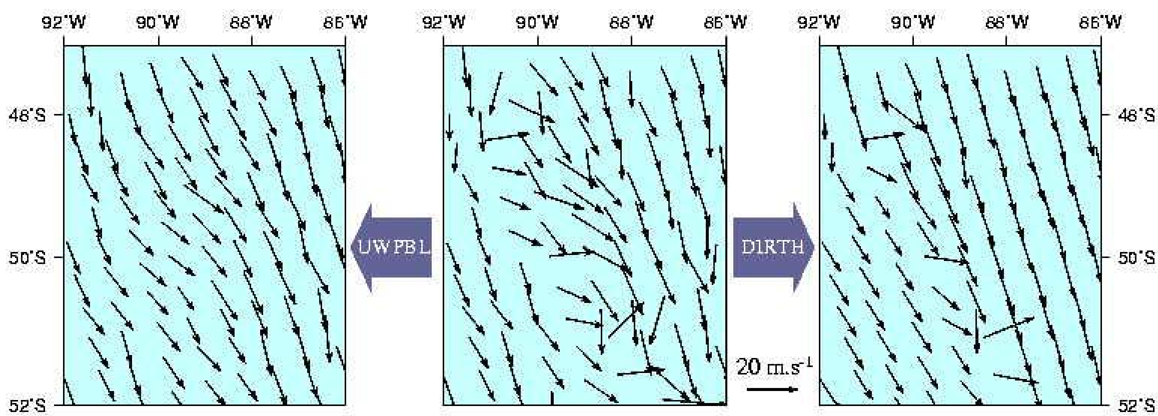

Figure 2.

UW
Pressure field smoothed

Raw scatterometer winds

Local GCM nudged
with ECMWF fields

JPL Project

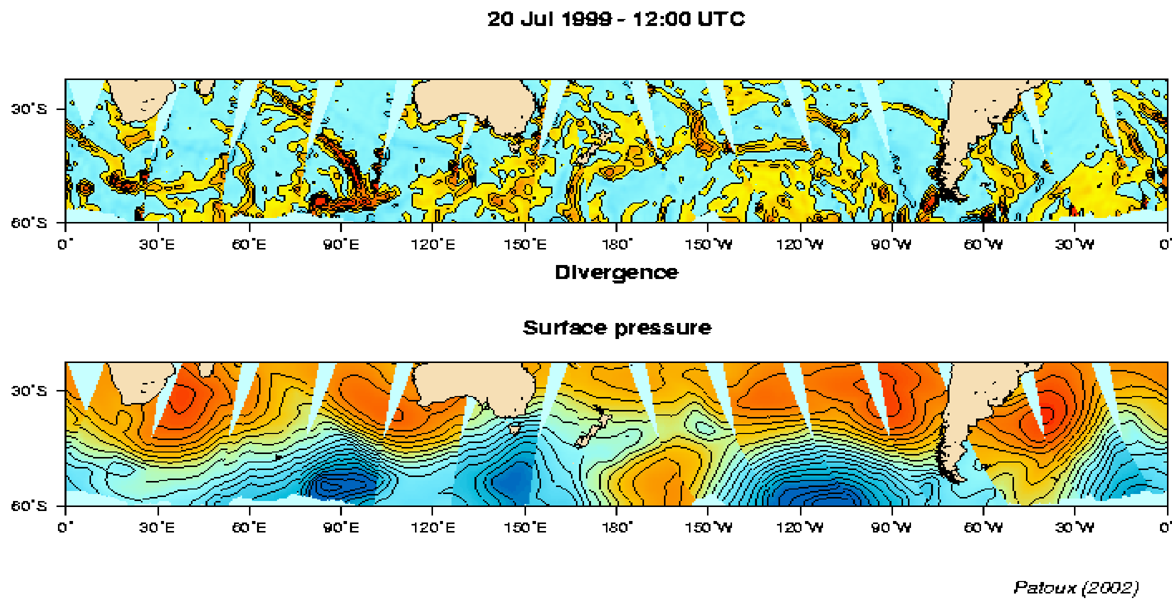

Figure 3. These data allow study of the development of fronts in general and frontal waves in particular: QuikScat reveals mesoscale features that are not captured by numerical models or other satellite-borne instruments, in particular the surface signature of frontal instabilities that sometimes develop into secondary cyclones (predictively?). (Patoux, Hakim & Brown, 2005)

6. THE CONSEQUENCES

1. The nonlinear PBL solution prevails.
2. Global winds are non-homogeneous at the surface over 1-5 km. High velocity winds are advected to the surface in lines.
3. The average wind profile is *different* from the Ekman solution --- nonlinear winds are 10-50% different, depending on stratification and thermal wind. (likewise ocean PBL)
4. The PBL contains *advecting* flow not amenable to *diffusion* modeling. Numerical models cannot portray correct physics of mean flow without extreme increase in resolution.
5. The correct PBL model allows excellent daily global satellite surface pressure analyses from space.

Programs and Fields available on
http://pbl.atmos.washington.edu
Questions to rabrown, neal or jerome@atmos.washington.edu

* Direct PBL model: PBL_LIB. ('75 -'00) An analytic solution for the PBL flow with rolls, $U(z) = f(\nabla P, \Delta To, \nabla Ta, \lambda)$

* The Inverse PBL model: Takes U10 field and calculates surface pressure field $\nabla P (U10, \Delta To, \nabla Ta, \lambda)$ (1986 - 2000)

* Pressure fields directly from the PMF: $\nabla P (\sigma o)$ along all swaths

(exclude 0 - ± 5° lat.?) (2001) (dropped in favor of I-PBL)

* Global swath pressure fields for QuikScat swaths (with global I-PBL model) (2004)

* Surface stress fields from PBL_LIB corrected for stratification effects along all swaths (2005)

7. REFERENCES

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