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INFERRING CONVECTIVE MOMENTUM FLUXES WITHIN SATELLITE DATA

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1 INTRODUCTION AND OVERVIEW

The primary goal of this work is the development of techniques that allow for robust estimates of convective momentum fluxes on storm- to mesoscales. New approaches toward the evaluation of convective momentum fluxes [i.e. $(\overline{u'w'})$ and $(\overline{v'w'})$] from satellite data are being developed. Data this study has utilized up to now are Tropical Rainfall Measuring Mission (TRMM) precipitation radar (PR) and microwave imager rain drop size estimates (TMI). New research is already focussing on the use of information within GOES visible and infrared cloud-motion winds, and near-surface scatterometer winds from QuikSCAT, that can be used to describe the perturbation winds as a result of organized and precipitating convective storms.

Momentum flux signatures in TRMM data that our methods key in on are precipitation (i.e. rainfall signature; Mecikalski 2003) patterns, and highly divergent/convergent surface and upper tropospheric flows near convective clouds as observed by cloud-motion and scatterometer winds. Use of rainfall accumulation/rate estimates from TRMM (products "2A12" and "2A25") will soon provide our methods important information to analytically derive vertical velocities within precipitating convection (i.e. w'; see Austin and Houze 1973). Using convective heating (i.e. stratiform versus convective rainfall flag), and rainfall rate measurements will be input into our analytical procedures. [‡]

An additional aspect of this work couples the satellite flux estimates to a numerical model (run in non-cloud resolving mode) through the use of a cumulus parameterization. This represents a preliminary approach to the assimilation of these data into numerical models. Specifically, modification of the Wu and Wanai (1994) parameterization scheme is being tested so to allow for the direct assimilation of the above satellite information into numerical simulations by relating these information to model variables (tendencies of u, v and w winds).

The main goals as part of this research over the coming 2-3 years are:

1. Develop single- and multi-sensor algorithms that estimate the gross momentum flux characteristics for radar- and satellite- observed;
2. Develop layer-averaged, geographical maps of momentum fluxes that cover regions of active convection, from the storm scale to the regional scales (O(10^5-10^6 km^2); Use the flux maps to decribe momentum flux regimes, and flux behaviours as convection evolves;

As a means of validating these flux estimates, cloud resolving numerical model simulations (at 1-2 km resolution) over the Kwajalein Atoll Experiment (KWAJEX), the TExas-FLorida UNderflights-B (TEFLUN-B), and ITCZ domains are used to estimate "truth" momentum budgets for the same regions our satellite data analyses are performed. Evaluation of the convective momentum budgets of the KWAJEX, TEFLUN-B and SCSMEX regions are an additional outcome of the cloud resolving modeling component of this project.

2 DATA AND METHODOLOGY

To assess the convection-relative, line-normal wind $\mathbf{v}'_{LN}$, the relationships

$$\begin{aligned}\mathbf{v}'_{LN} &= \mathbf{v}_{LN} - \overline{\mathbf{v}_{LN}} \\ &= \frac{\partial h}{\partial t} - \mathbf{v}_{SV},\end{aligned} \quad (1)$$

can be used. In (1), $\partial h/\partial t = \mathbf{v}_{LN}$, and $\mathbf{v}_{SV} = \overline{\mathbf{v}_{LN}}$. Here ∂h is the depth of the cloud, and ∂t is the fall time of precipitation. $\mathbf{v}_{SV}$ is the convective cloud

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velocity (as estimated from an NWP model, mean winds within the lowest ~8-10 km, or through observation) that is subtracted off prior to estimating $\mathbf{v}'_{LN}$. We make the assumption that the difference between $\mathbf{v}_{LN}$ and $\mathbf{v}_{SV}$ represents the *perturbation* winds within convection. Velocities u' and v' are then obtained as

$$u' = \mathbf{v}'_{LN} cos(\theta_{SD}) \quad (2)$$
$$v' = \mathbf{v}'_{LN} sin(\theta_{SD}),$$

where θ_{SD} is the direction of storm motion (in degrees) in polar coordinates. For estimating w', the procedure is summarized as

$$w' = (w_D - K[2.436\{Z(R)\}^{0.182}]). \quad (3)$$

$Z(R)$ represents the use of an appropriate "$Z - R$" relationship for obtaining rainfall (R) from reflectivity (Z) measurements. Equations (1)-(3) effectively compute u' and v' using a wind-drift correction for falling precipitation, and estimate w' within clouds using hydrometeor terminal fall speed relationships (see Spilhaus 1948; Rogers 1966).

Ongoing research is applying this technique to TRMM PR and TMI (for drop size estimates) data. The "2B31" TRMM product is in turn used to evaluate true drop size by the formula $D = \hat{D}/\hat{R}^{-0.155}$, where $\hat{D}$ and $\hat{R}$ are the correlated-corrected mass-weighted mean drop diameter and rain rate (mm h^{-1}), respectively. These drop size estimates are used in Eq. (3). Storm-motion corrected fluxes ($\overline{u'w'}$) and ($\overline{v'w'}$), retrieved from TRMM, are now being produced (Fig. 1; with storm motion estimates obtained from cloud-resolving model simulations, used to validate our technique).

3 ACKNOWLEDGEMENTS

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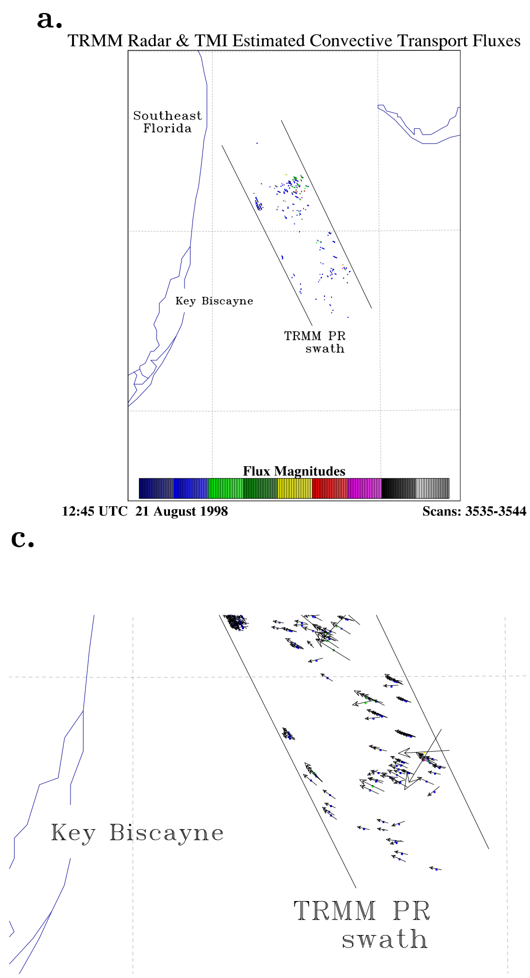

Figure 1: TRMM PR-estimated convective momentum fluxes plotted as magnitude and vectors as $\mathbf{Q}_3 = \sqrt{\overline{u'w'}^2 + \overline{v'w'}^2}$). Figure a) show flux magnitudes scans 3535–3544 at 1750 m AGL for a TRMM overpass of convection occurring on 21 August 1998 at approximately 12:45 UTC. Figure b) shows a close-up centered on approximately -79.5° W, 25.5° N with $\mathbf{Q}_3$ vectors. In a) flux magnitudes are <50 m^{2}s^{-2} for blue colors, >50–250 m^{2}s^{-2} for green and yellow colors, and near 500 m^{2}s^{-2} for magenta and black colors.