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SATELLITE DETECTION OF PRECIPITATION OVER THE NORTH PACIFIC

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1. INTRODUCTION

Intense extratropical winter cyclones often impact the West Coast of North America with strong winds and heavy precipitation. Several times during a winter season, short-term forecasts (up to 48 hours) of these storms are seriously deficient with central pressure errors in the 10's of hPa and surface low position errors in the 100's of km. For example, 48-hr sea level pressure errors (forecast - observation) at buoy 46005 off the Oregon coast for the 2001 - 2002 winter season is plotted in figure 1. In addition, the average error and two times the standard deviation of the error at this buoy are also shown. It is evident from this figure that large forecast errors (i.e. greater than 10 hPa) occurred about 10 times this past winter at buoy 46005 with three events where the errors were 20 hPa.

In addition to large forecast errors of sea level pressure, numerical forecasts of precipitation for land falling cyclones can be flawed. This is due in large part to the lack of accurate precipitation information over the ocean. Therefore, remote sensing techniques are the most viable option for obtaining accurate information on the distribution and intensity of precipitation over the North Pacific.

Due to the radiative characteristics of precipitation sized hydrometeors at microwave frequencies, microwave sensors are able to detect precipitation over oceanic regions. Past studies have demonstrated the utility of passive microwave rain rate data for locating intense rainfall in rapidly deepening cyclones (McMurdie and Katsaros 1996), in detecting developing polar mesocyclones (McMurdie *et al.* 1997) and in determining frontal bands (Katsaros et al. 1989).

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There are currently many sources of microwave rain rate data: the Special Sensor Microwave Imager (SSM/I) (currently flying on three platforms) (Wentz and Spencer, 1998), the Advanced Microwave Sounding Unit (AMSU-B) (currently flying on NOAA-15, NOAA-16, and NOAA-17) (Zhao *et al.,* 2001), and the Tropical Rainfall Measuring Mission Microwave Imager (TMI) (Kummerow *et al.,* 1998). Soon data from the Advanced Microwave Radiometer for EOS (AMSR-E) will be available from the Aqua platform.

In this paper, we present a new technique for mapping rain rate distribution over the North Pacific utilizing rain rate estimates from several microwave sensors and upper-tropospheric winds derived from Geosynchronous satellite IR images. The goal of this work is to develop a way to obtain high temporal and spatial rainfall information over the North Pacific. This information will be used to support the verification of model derived precipitation distributions and to support the analysis of in situ measurements of rainfall during the Improvement of Microphysical Parameterization through Observational Verification Experiment (IMPROVE) field campaigns. (http://improve.atmos.washington.edu)

2. TECHNIQUE

Previous attempts have been made to combine microwave and IR data from geostationary satellites to get quasi-global precipitation estimates (Huffman *et al.*, 2001, Huffman *et al.*, 2002), but the rain rate estimates in stratiform regimes using IR data remain difficult. Additionally, these schemes combine data with a three hour time resolution, in which time precipitation systems can move a considerable distance. We have developed a new technique which does not rely upon rain rate estimates from IR data, although such combinations may be beneficial in the future. The present procedure is confined to the North Pacific where our microwave precipitation composites have a 0.125° spatial and 1 hour time resolution.

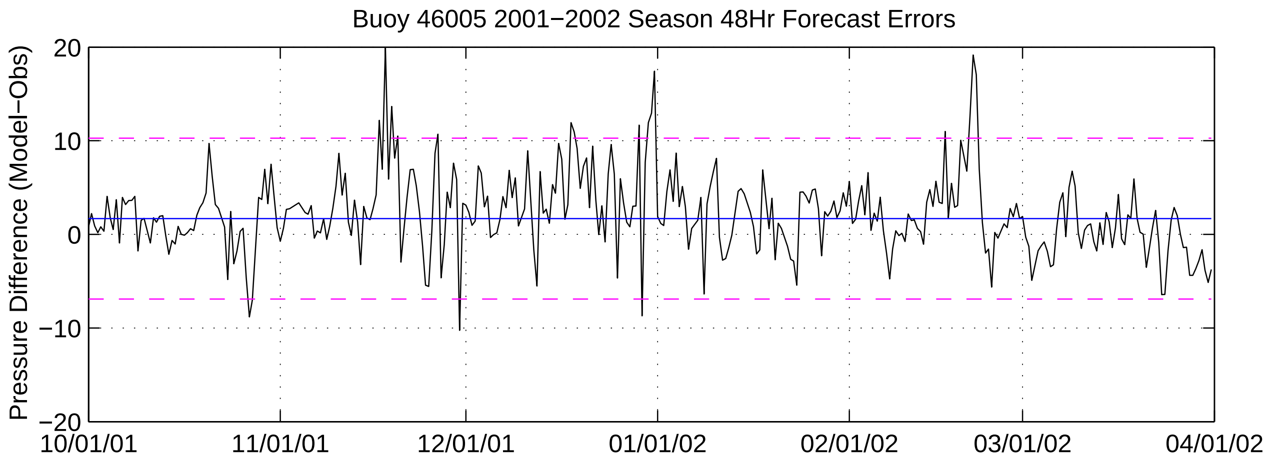

Figure 1 Pressure differences between 48 hr operational forecasts and coastal observations during the winter of 2001-2002. The dashed lines show two standard deviations. *Note that ~20 mb errors occurred in three major storms of this season alone!* [From McMurdie and Mass (2002)]

We are using data from SSM/I on three platforms, AMSU-B on NOAA-15 and NOAA-16, and TMI on TRMM, the microwave sensors available during the IMPROVE field campaigns. When any one of these sensors detect rain over our region of interest (-180°W to -110°W and 25°N to 65°N), the swath is gridded to a 0.125° grid. This is done for each satellite, for each overpass.

In order to fill gaps in the satellite coverage, we use upper-tropospheric winds derived from the GOES-10 infrared and water vapor observations (Velden *et al.*, 1997) to estimate the movement of the storms. Satellite-derived winds are available at three hour intervals. We use all winds between 700 and 300 hPa to obtain a layer averaged wind estimate and then grid the winds to the same 0.125° grid. We then linearly interpolate between the grids to get hourly estimates of winds.

We then use these gridded winds to move the storms detected by the microwave sensors. We find the location of each rain pixel in each microwave sensor swath and group rain pixels into storms. These storms are then advected using the median of the winds found in each storm cell. All storms in each microwave sensor swath are advected to the nearest hour, then to the next hour, continuing to a maximum of four hours from the time of the satellite overpass. Motion is both forward and backward in time. All of the advected storms are averaged together at each hour to give one grid of rainrates per hour.

It should be noted that this technique works well for slow-developing storms such as frontal systems, which do not change greatly over 4 hours. In situations with storms which change more rapidly, this technique may have to be modified.

4. RESULTS

Using this technique, we can get a complete picture of rain over the North Pacific. A sample composite is shown in Fig. 2a. In this composite, all swaths within four hours of 17 UTC on 4 December 2001 (a total of 15 swaths) are first moved to this time using satellite-derived winds, then averaged together to create this image. Compare this to Fig. 2b where all the swaths are simply averaged together and not moved. The infrared image at 17 UTC is shown in Fig. 2c. In comparing composites to the infrared image, it is clear that the composite incorporating the satellite-derived winds preserves the shape of the front much more clearly than simply averaging together the swaths. Additionally, localized maxima in the front appear to be better preserved using the current technique.

5. CURRENT WORK

Currently, we are creating composite microwave rainfall distributions at 1 hour intervals to coincide with the IMPROVE field campaigns of January-February 2001 and November-December 2001. This will provide us with two unique opportunities: 1) Validation of the microwave rainfall distributions using the NOAA P-3 airborne radar and the S-Pol coastal radar in place during the first IMPROVE period and 2) The ability to a

b

c

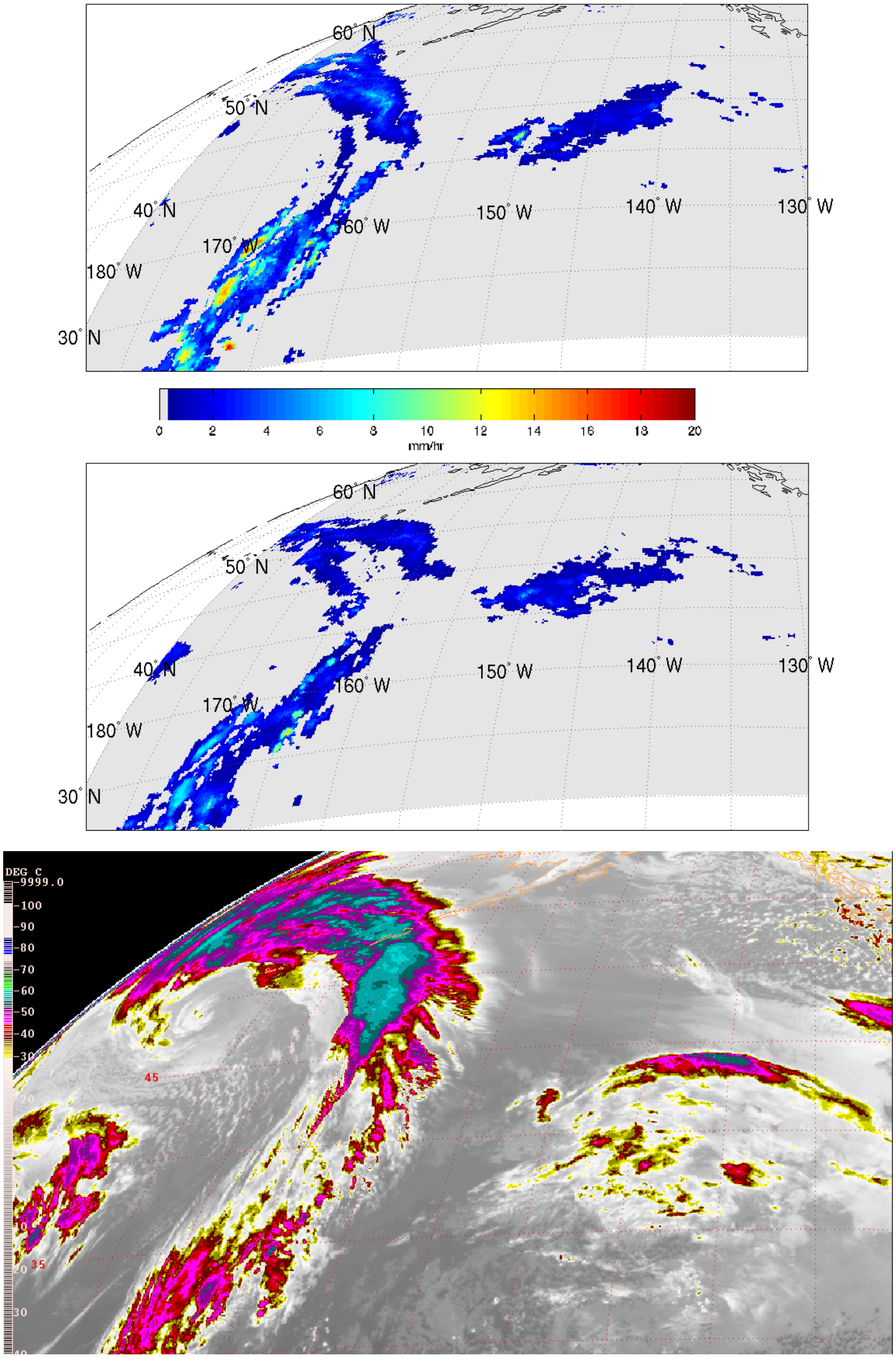

Figure 2 a) Sample composite from SSM/I, NOAA-15 and NOAA-16, and TMI microwave radiometers. Sample time is 17:00 UTC 4 December 2001. Satellite overpasses are within four hours of this time and storms were moved using GOES-derived winds. **b)** Same as **a**, but composite produced by simply averaging swaths together, without first moving them. **c)** GOES-10 infrared imagery at 8 km horizontal resolution obtained at 17:00 UTC on 4 December 2001.

provide detailed precipitation information over the ocean in support of the IMPROVE effort to provide quantitative precipitation distributions. Satellite derived precipitation will be compared to rainfall prediction from the Pennsylvania State/NCAR mesoscale model version 5 (MM5) operationally run at the University of Washington (http://www.atmos.washington.edu/mm5rt).

This technique can ultimately assist the combination of rainfall data such as those that will come from diverse satellites in the Global Precipitation Mission ensemble.

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Huffman, G.J., R.F. Adler, M.M. Morrissey, D.T. Bolvin, S. Curtis, R. Joyce, B. McGavock, J. Susskind, 2001: Global Precipitation at One-degree Daily Resolution from Multisatellite Observations, *J of Hydromet*., **2**, 36-50.

Huffman, G.J., R.F. Adler, E.F. Stocker, D.T. Bolvin, and E.J. Nelkin, 2002: A TRMM-based system for real-time quasi-global merged precipitation estimates. *Preprints, TRMM International Science Conference,* Honolulu, HI, NASA, 7.

Katsaros, K.B., I. Bhatti, L.A. McMurdie, and G.W. Petty, 1989: Identification of atmospheric fronts over the ocean with microwave measurements of water-vapor and rain. *Weather and Forecasting*, **4**, 449-460.

Kummerow, C. , W. Barnes, T. Kozu, J. Shiue, and J. Simpson, 1998: The Tropical Rainfall Measuring Mission (TRMM) sensor package. *J. Atmos. and Ocean Tech.*., **15**, 808-816.

McMurdie, L.A. and K.B. Katsaros, 1996: Satellite-derived integrated water vapor and rain intensity patterns: Indicators for rapid cyclogenesis. *Weather and Forecasting,* **11**, 230-245.

McMurdie, L.A., C. Claud, and S. Atakturk, 1997: Satellite-derived atmospheric characteristics of spiral and comma-shaped southern hemisphere mesocyclones. *J. Geophys. Res.,* **102**, 13889-13905.

McMurdie, L.A. and C.F. Mass, 2002: Major numerical forecast failures in the Northeast Pacific and North American West Coast. *In Preparation.*

Velden, C.S., C.M. Hayden, S.J. Nieman, W.P. Menzel, S. Wanzong, and J.S. Goerss, 1997: Upper-Tropospheric Winds Derived from Geostationary Satellite Water Vapor Observations. *Bull. Amer. Meteor. Soc.,* **78**, 173-195.

Wentz, F.J. and R.W. Spencer, 1998: SSM/I rain retrievals within a unified all-weather ocean algorithm, *J. Atmos. Sci*, **55**, 1613-1627.

Zhao, L., F. Weng, and R. Ferraro, 2001: A physically-based algorithm to derive surface rainfall rate using Advanced Microwave Sounding Unit-B (AMSU-B). *Preprints, 11th conference on Satellite Meteorology and Oceanography*, Madison, WI., P3.44.