# Extending CMORPH to the Poles: Preliminary Results

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## Introduction

Current combined satellite precipitation algorithms are geographically restricted to latitudes equator-ward of 60 N/S. One reason for this restriction is the latitudinal limitation of geostationary satellite retrievals to Tropics and mid-latitudes, from which information is used directly for precipitation estimation (GSFC-TMPA, Huffman et al. 2009), or cloud motion vectors are derived (CPC-CMORPH, Joyce and Xie 2011). Although Passive Microwave (PMW) precipitation retrievals are not limited by latitude, anomalous estimation over snow, sea-ice cover, and cold earth surface (Fig 1.a ) is a severe limitation of its potential utility as an algorithm input. Regardless of these and more obstacles, for many applications, combined satellite precipitation data sets need to be globally complete.

## Objectives:

The objective of this initial investigation is to evaluate both the capabilities and limitations of satellite observations as potential inputs over polar regions in a pole-to-pole combined satellite precipitation algorithm. In addition to observations, model precipitation will be investigated as an algorithm input. This focus of the follow-on of this initial study will be the incorporation of the additional capabilities of unprecedented satellite-based radar precipitation retrievals to the 40-65 N&S latitude belts soon available from the launch of GPM.

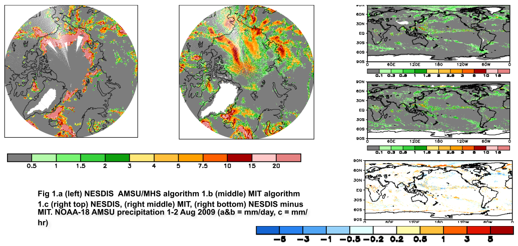



Fig 1.a (left) NESDIS AMSU/MHS algorithm 1.b (middle) MIT algorithm 1.c (right top) NESDIS, (right middle) MIT, (right bottom) NESDIS minus MIT. NOAA-18 AMSU precipitation 1-2 Aug 2009 (a&b = mm/day, c = mm/hr)

## 1. PMW precipitation in polar regions

An investigation of PMW precipitation over polar regions reveals substantial differences in algorithms for even for the same satellite sensor (Fig 1.a and Fig 1.b). Perhaps polar regions exhibit the larges differences between the MIT (Surussavadee and Staelin, 2009 & 2010) and NESDIS (Vila et al. 2007) MHS/AMSU algorithms (Fig 1.c lower panel). Even though snow, sea-ice, and cold surface anomalies are limited in the GPROF-V7 (Kummerow et al. 1996; Olson et al. 1999) SSMI algorithm (Fig 2.a) so are valid retrieval samples (Fig 2.b)

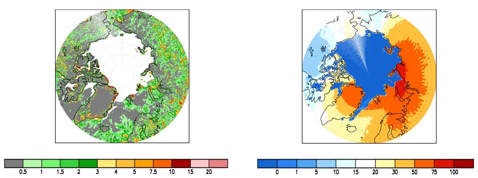



Fig 2.a (left) July 2009 GPROF V7 DMSP-13 (mm/day), (right) valid precipitation retrievals for August 2009.

## 2. AVHRR IRTB

The use of AVHRR in a combined satellite precipitation algorithm to measure of cloud top temperature would be considered indirect for precipitation purposes. However in polar regions, AVHRR benefits from overlapping sampling even from just from a single orbiter (Fig 3.a). Sampling frequency from AVHRR retrievals from combined NOAA satellites and METOP-A provide high rates of sampling in polar regions especially for periods of 90 and 120 minutes, Fig 3.b (bottom left and right) respectively.

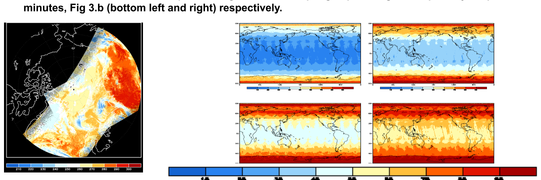


Fig 3.a (left) NOAA-18 AVHRR channel 4 IRTB (K) 03:57-05:52 UTC 18 August 2009, Fig 3.b (right) NOAA 15-19 + METOP-A AVHRR sampling frequency %: 30 minutes (top-left), 60 minutes (top-right), 90 minutes (bottom-left) 120 minutes (bottom-right) 18 – 22 August 2009

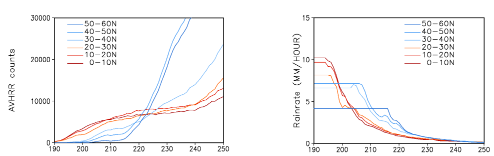



Fig 4.a (left) Counts of combined NOAA+METOP-A AVHRR IRTB over Northern Hemisphere Land 10-21 August 2009 (right) PDF Histogram matching of AVHRR IRTB with CPC MWCOMB for same period.

## 3. AVHRR IRTB & PMW precipitation

Several methods can be considered for utilizing the potential of PMW to derive AVHRR derived precipitation. A PDF method of matching the heaviest PMW precipitation rates with the coldest AVHRR IRTBs is both latitude and surface dependent ( Fig 4.b). AVHRR IRTb counts (190K-250K) over Northern Hemisphere (NH) land are stratified by latitude, almost no counts colder than 215K in northern most latitude band (Fig 4.a). For PDF matching AVHRR precipitation rate profiles derived over NH land (Fig 4.b), highest rates for Tropics more than double those found for northernmost latitude band. A "flat line" in these precipitation rate profiles means no cloud exists for these extremely cold IRTBs, thus the rate is extrapolated from the rate associated with the next valid IRTB. An example of AVHRR IRTB and precipitation is given in Fig 5.

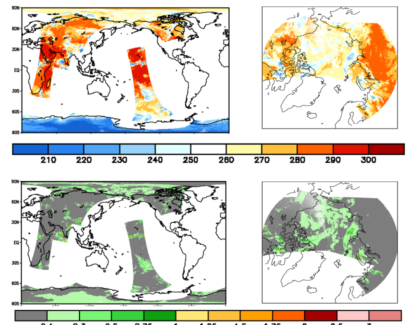



Fig 5.a (upper/lower left) NOAA 15-19 + METOP-A AVHRR IRTB (K) for global/NH polar regions 00:00 UTC 19 August 2009 ). (upper/lower right) AVHRR IRTB derived precipitation (mm/hr) same time.

## 4. AVHRR precipitation

For the 10-21 August 2009 AVHRR derived precipitation estimates were developed from two methods the above described method of PDF matching, and also by deriving precipitation rate profiles by averaging the temporally/spatially matched MWCOMB precipitation rates for each AVHRR IRTB. Correlation of the 0.25 degree 30 minute AVHRR precipitation with MWCOMB is relatively high for finite resolution (Fig 6.a). Latitude cross sections of the AVHRR derived precipitation nearly matches that of the PMW for all latitude bands both ocean (Fig 6.b) and land (fig 6.c)

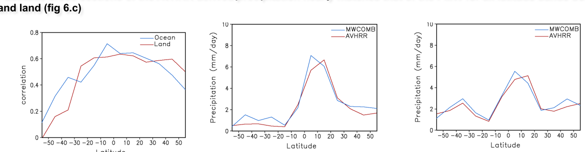


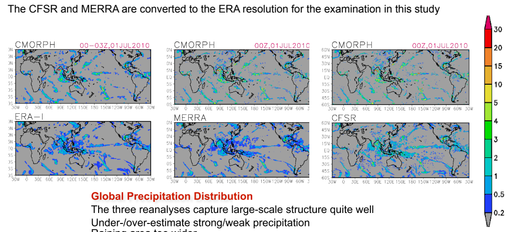

Fig 6.a (upper left) Correlation of 30 minute 0.25 degree AVHRR derived precipitation with CPC MWCOMB for 10-21 August 2009, Fig 6.b/6.c (lower left/right) distribution of AVHRR precipitation and MWCOMB ocean/land.

## 5. Model Rainfall

**Objectives:** To examine the performance of reanalysis precipitation for potential use as inputs to the combined precipitation analysis over high latitudes

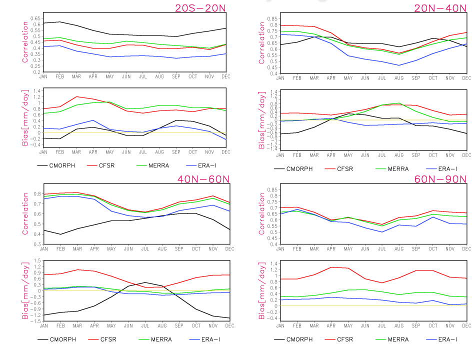
### An Examination of Global Precipitation in the High-Resolution Reanalyses

- CFSR
  - *T382 (~35km)*
  - *Hourly precipitation*
- MERRA
  - *2/3°longitude x 1/2°latitude*
  - *Hourly Precipitation*
- ERA-Interim
  - *1.5°lat/lon*
  - *Three-Hourly precipitation*
- The CFSR and MERRA are converted to the ERA resolution for the examination in this study

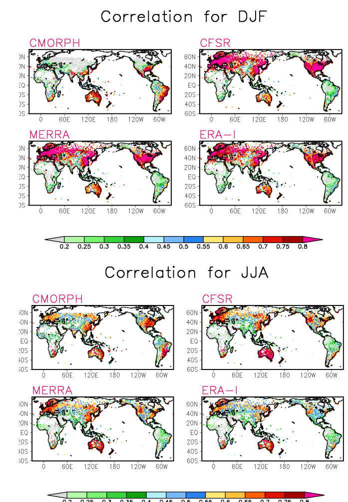



- **Global Precipitation Distribution**
- The three reanalyses capture large-scale structure quite well
- Under-/over-estimate strong/weak precipitation
- Raining area too wider
- CFSR closer to observations

## Correlation with Daily Gauge over Land




## Serial Correlation of Daily Precip




## Summary

- Performance of PMW precipitation algorithms over polar regions depends upon algorithm and sensor type, MIT AMSU/MHS shows promise
- AVHRR instruments provide adequate IRTB sampling over polar regions, observations match well with CPC 4km global 30 minute geostationary satellite IR
- The PDF matching method of heaviest PMW precipitation rates to coldest AVHRR IRTB and averaging PMW precipitation for each IRTB produces accurate AVHRR precipitation estimation with little bias
- The three sets of new generation high-resolution reanalyses present very good skill in depicting global precipitation, especially over high latitudes
- Performance of the reanalyses is superior over the satellite estimates over high-latitude and / or during cold seasons
- Reanalyses, however, exhibit significant systematic in their precipitation, implying the needs to perform bias correction
- Further work needed to explore best strategy to include the reanalysis precipitation information.

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