P1.20 SIMULATION OF VISIBLE/INFRARED IMAGER/RADIOMETER SUITE (VIIRS) OBSERVATIONS FOR APPLICATION TO MESOSCALE ANALYSIS AND FORECASTING

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1. INTRODUCTION

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) has been designed to collect information about the earth's atmosphere, land and oceans using multiple sensors. One of the instruments on board the NPOESS satellites will be the Visible/Infrared Imager/Radiometer Suite (VIIRS). VIIRS is designed to include features of the Operational Line Scanner (OLS) of the Department of Defense (DOD), the Advance Very High Resolution Radiometer (AVHRR) of the National Oceanic and Atmospheric Administration (NOAA) and the Moderate Resolution Imaging Spectroradiometer (MODIS) of National Aeronautics and Space Administration (NASA) (Byerly and Miller 2002). Therefore the instrument will have 16 moderate resolution bands (M1-M16), 5 imagery resolution bands (I1-I5) and a day-night band (DNB). The imagery bands are designed to have about 400 m resolution at nadir while the moderate resolution band will have a resolution twice the size.

As part of the NPOESS Preparatory Project (NPP) our objective is to simulate imagery of severe thunderstorms and tropical cyclones from mesoscale model output using appropriate radiative transfer models. These simulations will enable us to design new products for precipitation estimation and tropical cyclone intensity diagnosis (an advance Dvorak technique; Dvorak 1984). As the VIIRS instrument includes features from MODIS and therefore has overlapping bands we use select MODIS bands for which spectral response functions are currently available to conduct our study.

We present below a detailed description of our methodology as well as examples from a simulated thunderstorm experiment.

2. MODELS USED

There are two components to the simulation of the satellite imagery. The first part involves actual simulation of the weather event using a mesoscale model. The second part is the computation of radiances in the selected domain using the mesoscale model output. The actual models are described below.

2.1 **MESOCALE MODEL**

The numerical cloud model used for this study is RAMS43 (Pielke et al. 1992). To simulate a mesoscale weather event the model is run non-hydrostatically and is compressible (Tripoli and Cotton 1982). Momentum is advanced using a leapfrog scheme while scalars are advanced using a forward scheme with both methods using second order advection. The vertical and horizontal turbulence coefficients are parameterized using the Smagorinsky (1963) deformation based eddy viscosity with stability modifications (Lilly 1962). Hydrometeors are predicted with a two-moment bulk microphysical scheme (Meyers et al. 1997). Mass mixing ratio and number concentration are prognosed for six of the seven hydrometeor types while the mean diameter is diagnosed. Cloud droplet mass mixing ratio, however, is predicted using a one-moment scheme. (Work is ongoing to include cloud droplets into the two-moment scheme.) Cloud droplets, rain droplets, aggregates, graupel, hail, snow, and pristine ice are the hydrometeor types considered. Both graupel and hail are mixed phase; that is, liquid water may exist on the surface of each particle. Snow and pristine ice are each divided into five habit categories namely columns, hexagonal, dendrites, needles, and bullet rosettes. Other prognostic variables are the three velocity components, perturbation Exner function, total water and ice-liquid potential temperature (Tripoli and Cotton 1981). RAMS uses the Arakawa fully staggered C grid (Arakawa and Lamb 1981). Perturbation Exner function tendencies, used to update the momentum variables, are computed using a time split scheme--similar to Klemp and Wilhelmson (1978). Lateral boundaries use the Klemp-Wilhelmson condition; that is, the normal velocity component specified at the lateral boundary is effectively advected from the interior. A wall with friction layers is specified at the top boundary. Land Ecosystem Atmospheric Feedback model, version 2 (LEAF2) (Walko et al. 2000) is also employed.

2.2 RADIATIVE TRANSFER MODELS

We have developed a forward observational operator consisting of multiple models that can compute atmospheric gas and cloud optical properties and then compute radiances across both visible and infrared wave-

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lengths. Effectively there are three stages to the radiance computation using the mesoscale model output.

The first stage is the computation of gaseous absorption. As simulating satellite imagery requires calculations in multiple vertical columns with different gaseous and cloud optical properties single band models are generally the only practical option. If the spectral band is narrow, which is the case with satellite measurements, single-band models are expected to provide sufficient accuracy. For computation of gaseous absorption we use the OPTRAN (Optical Path Transmittance) model (Mcmillin et al. 1995). This model uses regression coefficients dependent on various combinations of pressure and temperature to compute transmittance through a fixed amount of absorber. The gaseous absorption coefficient in a model atmospheric layer is computed with OPTRAN using the model output layer temperature, pressure and water vapor mixing ratio.

The second stage is the computation of cloud optical properties. For clouds we require an extinction coefficient, a single-scatter albedo and the scattering phase function. The extinction coefficient and single-scatter albedo is computed using a modified form of the anomalous diffraction theory (MADT; Mitchell 2000; van de Hulst 1981). As the mesoscale model predicts only two moments of the particle size distribution namely the mixing ratio and the number concentration we use a gamma distribution to characterize the hydrometeor distribution. Non-spherical particles are considered using appropriate projected area and mass-dimension relationship (Mitchell 1996), material density and refractive index. The asymmetry parameter for infrared wavelengths is obtained from anomalous diffraction theory while an empirical parameterization is used for the visible (Greenwald et al. 2002). The asymmetry parameter is sufficient for radiative transfer calculations at infrared wavelengths but the full scattering phase function needs to be specified at solar wavelengths. The Henyey-Greenstein phase function, a smooth function, is used to allow for faster computation.

Finally we compute radiances using an appropriate 1-dimensional radiative transfer model based on wavelength. For infrared wavelengths greater than 3 μm where the angular scattering characteristics of particles is relatively smooth we use a two-stream method based on the Eddington approximation (Deeter and Evans 1998) which uses Delta-M scaling for highly peaked phase functions (Wiscombe 1977). For computing cloudy sky radiance with a solar source, for wavelengths less than 5 μm, we use the Spherical Harmonics Discrete Ordinate Method (SHDOM; Evans 1998) which uses discrete ordinates while characterizing the angular radiance field using spherical harmonics. While SHDOM is a multidimensional model we adapt it for use in 1-dimensional calculations (Greenwald 2002).

3. MODEL RUNS

As an initial test of our system we simulated a severe thunderstorm case. For this simulation RAMS was initialized horizontally homogeneously with an idealized sounding. Convection was initialized with an instantaneous warm bubble on all grids. Three grids were used for this study with the horizontal grid spacing decreasing from 4000 m (grid 1) - approximately the footprint of GOES to 800 m (grid 2), and 400 m (grid 3) - approximately the footprint of VIIRS. The output was saved every 300 s.

As imagery from VIIRS will be available from channel I1-I5 at 400 m resolution we chose to simulate satellite imagery in channel I5 (10.5 – 12.4 μm) as our initial test case. To do this we used MODIS Terra channel 32 (11.77 – 12.27 μm) for our radiative transfer calculations as OPTRAN coefficients are available for this channel. As this channel overlaps with channel I5 it is expected that actual VIIRS imagery will be similar.

4. RESULTS AND FUTURE WORK

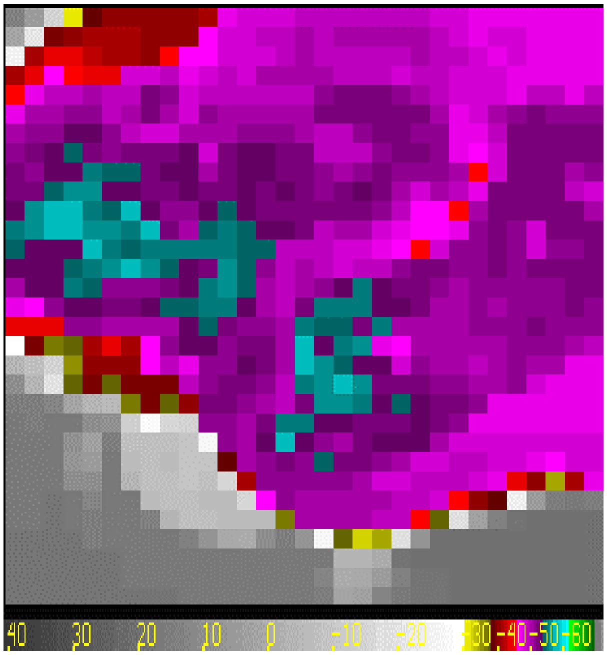

Fig 1: MODIS channel 32 imagery for a simulated thunderstorm using RAMS output at 4 km horizontal resolution. This image was generated to match currently operational GOES channel 4resolution.

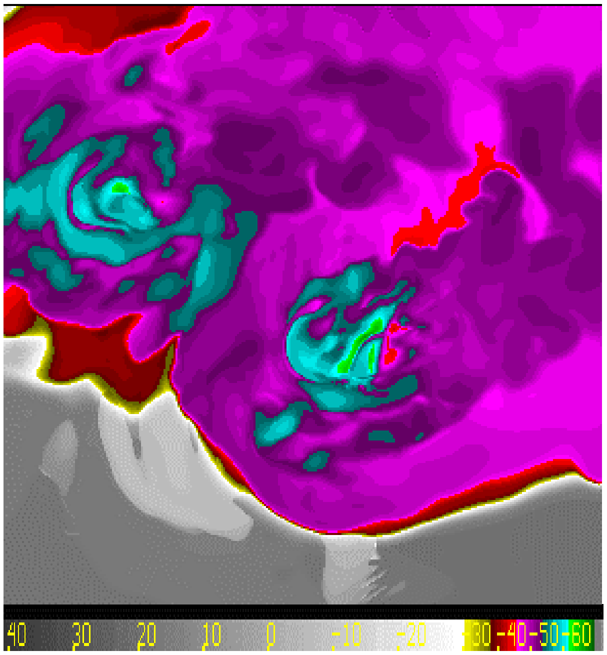

Fig 2: MODIS channel 32 imagery for a simulated thunderstorm using RAMS output at 400 m horizontal resolution. This image was generated to match VIIRS imagery resolution.

Figure 1 represents the imagery for the thunderstorm simulation at 4 km horizontal resolution. This figure shows how this thunderstorm can currently be viewed using operational GOES satellite imagery in the infrared. Figure 2 on the other hand shows the same thunderstorm when the image was generated at 400 m resolution to match what the VIIRS instrument would see. It is obvious that small scale features will be better resolved from the higher resolution imagery and will allow for a better analysis of severe weather.

Future studies will include generating imagery for MODIS channels 1, 2, 6, 20 and 31 to match VIIRS imagery channels 1-5. Also moderate resolution VIIRS channel imagery will be simulated. In addition we plan to use our capabilities to study an actual severe weather event. Further studies will also involve investigation of the possibility of analyzing brightness temperature- rain rate relationships from various case studies.

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Acknowledgments and disclaimer: This material is based on work supported by the National Oceanic and Atmospheric Administration under Grant NA67RJ0152. Special thanks to Jack Dostalek for generating the image files in this abstract.