1. **Title page**

Diagnosing and quantifying uncertainties of the reanalyzed clouds, precipitation and radiation budgets over the Arctic and SGP using combined surface-satellite observations

A proposal submitted in response to NOAA-OAR-CPO-2013-2003445 (CFDA 11.431) (MAPP Priority Area 1: Research to Advance Climate Reanalysis→Outstanding issues in atmospheric reanalysis)

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2. Abstract: This proposal is in response to the FY13 call of NOAA-OAR-CPO-2013-2003445, **MAPP-Research to Advance Climate Reanalysis**, with focus on addressing some outstanding issues in atmospheric reanalysis (type-II). We will use an innovative diagnostic method to quantify the uncertainties of reanalyzed cloud-precipitation-radiation over the Arctic and US SGP regions. We will work closely with Type-I team to perform NOAA MAPP Reanalysis Task Force and enhance reanalysis research activities. In particular, we will primarily evaluate the NCEP CFSv3 reanalyzed cloud-radiation-precipitation results over the Arctic and SGP regions using both satellite and surface observations, and provide some feedbacks to improve the CFSv3 model. Other four reanalyses being evaluated in this study are (i) 20CR, (ii) MERRA, (iii) ERA-I, and (iv) JRA-25. We will compare the reanalyzed results with observations, find their similarities and differences, and finally investigate how these differences relate to large-scale dynamic patterns and variables using the Self Organizing Maps (SOM) method. **Therefore, we propose the following two objectives.**

Objective 1: Quantifying the uncertainties of reanalyzed Arctic cloud-radiation properties

Reanalyzed cloud properties, such as cloud macrophysical (total/low/middle/high cloud fractions and vertical distribution) and microphysical properties (particle size, LWP/IWP, optical depth) will be evaluated with NASA CERES Ed4 and CloudSat/CALIPSO results over entire Arctic region and locally at the ARM NSA ground-based observations. The reanalyzed surface and TOA radiation fluxes will be evaluated with NASA CERES EBAF results and ARM/BSRN observations. The reanalyzed cloud properties will be compared with CERES-MODIS retrievals for the period 2000-2011. Then we will identify key discrepancies in the comparison for different regions and seasons. To discriminate between these potential problems, Self Organizing Maps (SOM) will be used to classify the atmospheric state from the reanalyses. Intercomparisons of classified atmospheric states between different reanalyses will allow us to determine how the reanalyzed cloud-radiation biases vary with model dynamics.

Objective 2: Investigating the reanalyzed hydrological cycle at SGP

In this objective, we will compare the monthly mean cloud fractions and accumulated precipitations from five selected reanalyses with different observational platforms, such as ARM, Oklahoma mesonet system, GPCP, NEXRAD Q2, TRMM, and UND hybrid radar/GOES product over the SGP region during the period 1997-2011 (as we did in Figs 3 and 4). For this study, we will use OK mesonet system and its covering region (entire OK state) as a baseline. Other datasets, such as GPCP, NEXRAD Q2, TRMM, and UND hybrid product will be averaged over the entire OK state (~ 5^{o}x5^{o}). Since the ARM SGP observations can cover only one point, it will be used as reference. Through this comparison, we will statistically evaluate the strength and weakness in cloud fractions, precipitation strength, frequency occurrence, and areal coverage for each reanalysis.

The two proposed objectives build on our experience in evaluating both GCM/SCM simulations and reanalyses using both surface-satellite observations, and are a natural extension of our current research. They are strongly relevant to one of the NOAA NGSP goals: *Assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions*. In particular, the two proposed objectives fit in the following MAPP targeted areas: *1) the hydrological cycle, 2) the quality and uncertainties of reanalyses over the Arctic regions, 3) Representation of surface fluxes.*

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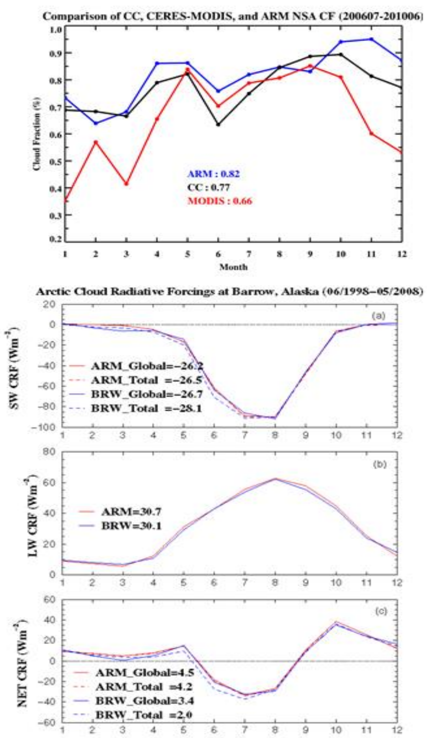
3. Results from prior research

The listed papers are relevant to the proposed research, and were supported by the NASA MAP, CERES, NEWS projects, NOAA GOES-R project and DOE ASR program. The datasets and results can be accessed by the scientific community through three ways: a) posted results on PI's personal webpage (http://people.aero.und.edu/~dong/result.html); b) submitted products to the NOAA data archive center as Value Added Product (for example, submitted the Merged Radar product to DOE ARM), and c) placed on a ftp site or through email for interested readers (such as Huang et al. 2012, Wood et al. 2012 etc). These papers have demonstrated our previous success from funded projects, as well as sharing the results with the scientific community. In the meantime, they also provide documented experience related to the proposed objectives.

3.1 Arctic Cloud and Radiation, and Evaluation of Reanalyzed Results.

1) Dong, X., B. Xi, K. Crosby, C.N. Long, R. Stone and M. Shupe, 2010: A 10-yr Climatology of Arctic Cloud Fraction and Radiative Forcing at Barrow, Alaska. J. Geophys. Res., 115, D12124, doi:10.1029/2009JD013489.
2) Zib, B., X. Dong, and B. Xi, A. Kennedy, 2012: Evaluation and Intercomparison of Cloud Fraction and Radiative Fluxes in Recent Reanalyses over the Arctic using BSRN Surface Observations. J Clim., 25, 2291-2305.
3) Giannecchini, K., X. Dong, B. Xi, A. Kennedy, P. Minnis, and S. Kato, 2012: Validation of CERES-MODIS Cloud properties Over Arctic regions using ARM and Cloudsat/CALIPSO Observations. Submitted to JGR.



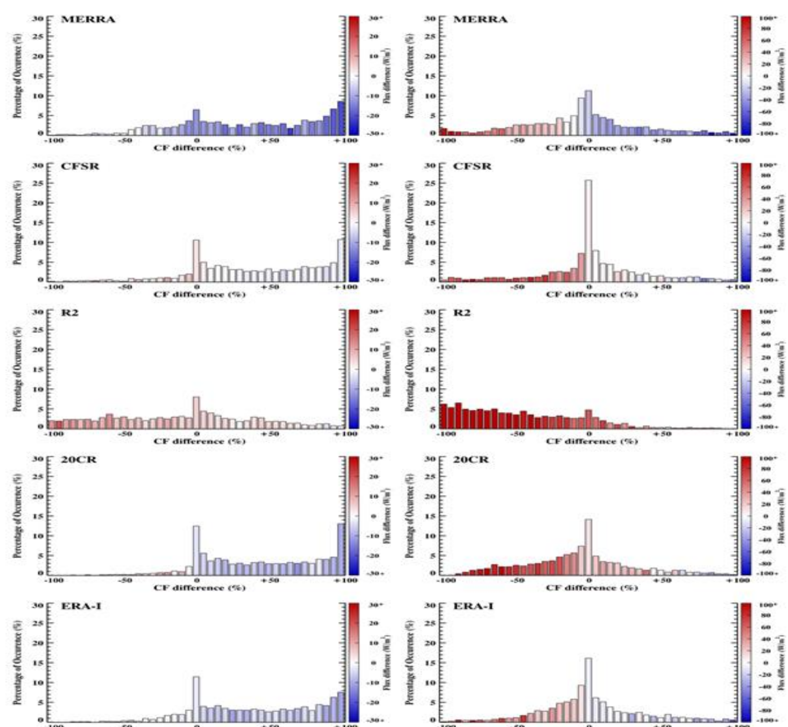


Figure 1 (left). Monthly means of cloud fractions derived from ARM NSA and CC radar-lidar measurements and CERES-MODIS retrievals during the period of July 2006-June 2010 (Figure 1 of Giannecchini et al. 2012). Monthly means of all-sky (a) SW, (b) LW, and (c) NET Cloud Radiative Forcings (CRF) at the ARM NSA and NOAA BRW sites, 06/1998-05/2008. (Figure 3 of *Dong et al. 2010*).

Figure 2 (right). Frequency distributions of CF differences (Reanalysis – Observation) for February-March (left-column) and June-July (right-column) over Barrow, Alaska. Shaded within each 5% ΔCF bin is the associated SW-flux differences (Reanalysis – Observation) for each dataset. The red colors represent the overestimated radiative flux from reanalysis, while the blue color is the underestimated flux. Ordinate is percentage of occurrence for each ΔCF bin and based on 11 years (1998-2008) of 6-hr mean samples. (Figure 8 of *Zib et al. 2012*).

3.2 ARM SGP clouds and precipitation, and evaluation of reanalyzed Results

4) Xi, B. and X. Dong, P. Minnis, M. M. Khaiyer, 2010: A 10-year climatology of cloud cover and vertical distribution derived from both surface and GOES observations over the DOE ARM SGP Site. JGR, 115, D12124, doi:10.1029/2009JD012800.

5) Dong, X., B. Xi, A. Kennedy, Z. Feng, J. Entin, P. Houser, B. Schiffer, W. Olson, T. L'Ecuyer, T. Liu, K-L Hsu, B. Lin, Y. Deng, and T. Jiang, 2011: Investigation the 2006 Drought and 2007 Flood Extreme Events at the SGP through an Integrative Analysis of Observations. *J. Geophys. Res.* 116, D03204, 10.1029/2010JD014776.

6) Feng, Z., X. Dong, and B. Xi, 2009: A Method to Merge WSR-88D Data with ARM SGP Millimeter Cloud Radar Data by Studying Deep Convective Systems. *J. Atmos. Oceanic. Technol*. 26, 958-971.

7) Feng, Z., X, Dong, B. Xi, and C. Schumacher, P. Minnis, and M. Khaiyer, 2011: TOA Radiation Budget of Convective Core/Stratiform Rain and Anvils from Deep Convective Systems. JGR, 116, D23202, doi:10.1029/2011JD016451.

8) Feng, Z., X. Dong, B. Xi, S. McFarlane, A. Kennedy, B. Lin, and P. Minnis, 2012: Life cycle of deep convective systems in a Lagrangian Framework. *J. Geophys. Res*. 117, D23201, doi:10.1029/2012JD018362.

9) Kennedy, A.D., X. Dong, B. Xi. S. Xie, Y. Zhang, and J. Chen, 2011: A Comparison of MERRA and NARR Reanalysis Datasets with the DOE ARM SGP Continuous Forcing data. J. Clim. 24, 4541-4557.

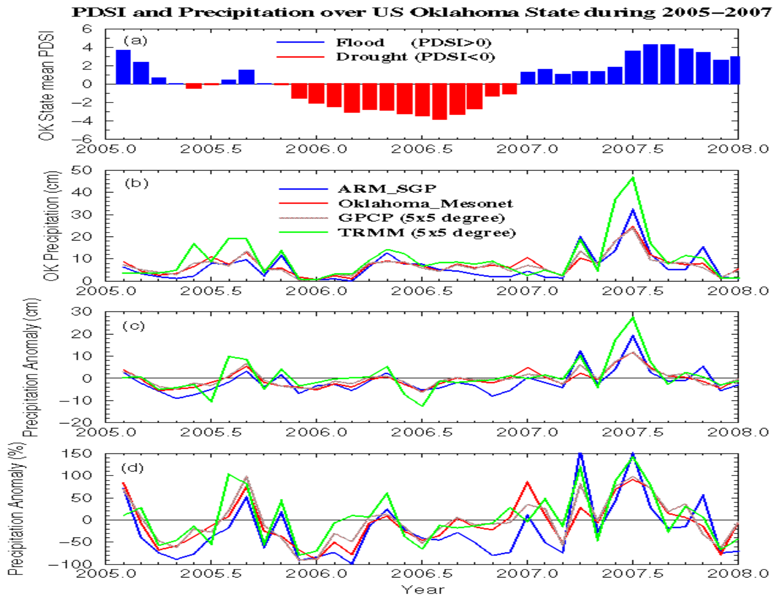


Fig. 3. (a) Monthly mean PDSI over Oklahoma state, (b) monthly accumulated precipitations measured at the DOE ARM SCF site, over the entire state measured by Oklahoma mesonet system, and over a 5°x5° grid box (32.5-37.5°N, 100-95°W) derived from GPCP and TRMM observations. (c) and (d) are the same as (b) but for the monthly anomaly values and percentages (relative to corresponding averages for the period 1997-2007 except for TRMM from 1998-2007). (Figure 1 of *Dong et al. 2011*)

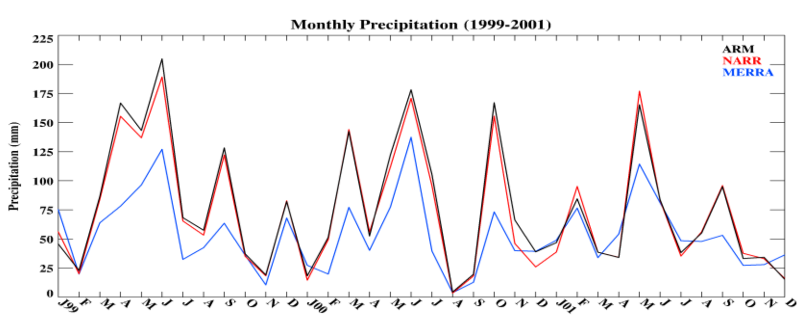


Figure 4. Monthly total precipitation measured over the ARM SGP domain by ARM (black), NARR (red) and MERRA (blue) during the period 1999-2001 (Figure 8 of *Kennedy et al. 2011*).

3.3 Evaluation of SCM/GCM Results using Surface-satellite Observations

10) Kennedy, A, X. Dong, B. Xi, P. Minnis, A. Del Genio, A. Wolf and M. Khaiver, 2010. Evaluation of the NASA GISS Single Column Model Simulated Clouds Using Combined Surface and Satellite Observations. J. Clim., 23, 5175-5192, doi: 10.1175/2010JCLI3353.1

11) Kennedy, A., X. Dong, B. and Xi, 2012: Self Organizing Maps as a tool for modeling and observations studies. In preparation for J. Clim.

4. Statement of work

4.1 Motivation and Rationale

Over the past few decades, atmospheric reanalysis datasets have provided a long-term, gridded representation of the state of the atmosphere while offering a resource for investigating climate processes and predictability. Reanalyses utilize observations through state-of-the-art data assimilation systems. Combined with the underlying models, they provide a continuous data record that consists of various atmospheric variables describing (diagnosing) past weather conditions. Reanalyses are used for a variety of applications including as a source for the development and verification of climate models, forcing data for numerous user models, examining forecast skill, estimation of renewable energy resources, investigation of extreme weather and climatic events, and health risk assessments. These datasets may also be an essential tool for performing studies in data-sparse regions such as the Arctic. Given its unique environmental characteristics and extreme surface conditions, observations are often difficult to obtain and are thus limited in the polar regions. As the Arctic system continues to experience significant environmental changes at a greater rate than the rest of the world (Solomon et al. 2007; Serreze and Francis 2006), it has become an area of escalating attention and focus. While reanalyses offer a potential resource for the recognition and analysis of change in a sensitive and complex coupled Arctic climate system, the uncertainty in their reanalyzed variables must first be addressed, particularly over the polar regions (Rienecker, et al. 2011a).

The accuracy of re-analysis product is critical for diagnosing past weather and climate events, especially extremes that occur over regions where observational network is sparse. To have a reliable application of reanalyzed cloud and radiation fluxes in the study of the Arctic climate change, it is important to have a reasonable estimate of the errors and accuracies of the reanalyzed cloud and radiative properties. There are a number of such evaluation studies in the recent MERRA special issue [Bosilovich et al., 2011; Rienecker et al., 2011a; Robertson et al., 2011], some actually focused on the Arctic regions [Cullather and Bosilovich, 2011a&b; Vavrus et al., 2012]. As Rienecher et al. (2011b) pointed out, although one of the strengths of the most recent reanalyses is overall better representations of the inter-annual variability in the atmospheric state on monthly to seasonal time scales, the accuracy of the representation strongly depends on both the specific variables and regions under consideration. Robertson et al. (2011) analyzed the effects of the changing observing system on MERRA's energy and water fluxes where the re-analyzed results are still quite sensitive to observing system changes. For example, the MERRA re-analyzed precipitation has a series of jumps and different trends that are mainly associated with the SSM/I and AMSU-A changes (see table 1 of Rienecker et al. 2011a). Applying principal component regression to the data largely reduces the jumps and different trends in MERRA precipitation and radiative fluxes, making the adjusted MERRA precipitation compare more favorably with the Global Precipitation Climatology Project [*Robertson et al.*, 2011].

Several studies have investigated the performance of reanalyses over the Arctic for a variety of fields including atmospheric moisture budgets (Bromwich et al. 2000 and 2002), upper-level winds (Francis 2002), precipitation (Serreze and Hurst 2000), cloud fraction and radiative fluxes (Walsh et al. 2009), and general tropospheric assessments (Bromwich and Wang 2005; Bromwich et al. 2007). These studies, however, were based on the earlier generations of reanalyses (e.g., Kalnay et al. 1996; Uppala et al. 2005; Onogi et al. 2007). With the recent advancements in data assimilation systems, changes in observing systems, and improvements in model parameterizations, several new reanalysis datasets and observational datasets (such as CERES EBAF and CloudSat/CALIPSO (CC)) have recently become available. Before using these new reanalyses it is important to assess the advantages and disadvantages of each reanalysis and identify the strengths and underlying biases associated with each dataset using NASA CERES EBAF and CC as a ground truth.

To quantify the errors and uncertainties in the re-analyzed clouds and radiation budget over the Arctic regions, we evaluated the five reanalyzed results over two surface sites using more than a decade of ground-based (Zib et al. 2012) as shown in Figure 2. Zib et al. (2012) compared cloud fractions (CFs) and surface radiative fluxes in several of these latest reanalyses over the Arctic using 15 years (1994–2008) of high-quality Baseline Surface Radiation Network (BSRN) observations from Barrow (BAR) and Ny-Alesund (NYA) surface stations. The five reanalyses being evaluated in this study were (i) MERRA, (ii) CFSR, (iii) 20CR, (iv) ERA-I, and (v) NCEP–DOE R2. All of the reanalyses have considerable bias in reanalyzed CF during the year, especially in winter. The large CF biases are reflected in the surface radiation fields, as monthly biases in SW) and LW fluxes are more than 90 (June) and 60 Wm^{-2} (March), respectively, in some reanalyses. ERA-I and CFSR performed the best in reanalyzing surface downwelling fluxes with annual mean biases less than 4.7 (SW) and 3.4 W m^{-2} (LW) over both Arctic sites. Even when producing the observed CF, radiation flux errors were found to exist in the reanalyses suggesting that they may not always be dependent on CF errors but rather on variations of more complex cloud properties, water vapor content, or aerosol loading within the reanalyses. A broad study over the entire Arctic region as we proposed in Objective 1 is warranted given that the Zib et al. (2012) analysis was only for two surface sites.

In addition to cloud and radiation properties, the hydrological cycle is also one of the most important parameters for studying extreme climate and weather events. Therefore it is necessary to extend the Kennedy et al. (2011, Figure 4) study from the time period of 1999-2001 to 1997-2011, the spatial domain of ARM SGP site (~ 1^ox1^o) to a large region (such as Oklahoma state or a grid box of 5^ox5^o), the NARR and MERRA reanalyses to the proposed five reanalyses, and the ARM precipitation to Oklahoma mesonet system, GPCP, TRMM, NOAA NEXRAD Q2 precipitation.

It is well known that convection is a weak point in reanalyses. Precipitation is often two light yet too frequent, and the diurnal cycle is wrong. To study these properties we will incorporate our merged dataset of ARM MMCR, WSR-88D radar, and GOES data (Feng et al. 2009, 2011) to produce a 3-D product of convective structure and precipitation. This product includes the partitioning of convective clouds, such as precipitation region (convective core and stratiform region) and non-precipitation region (anvil clouds). We chose the ARM SGP region to evaluate the reanalyzed cloud and precipitation because our hybrid radar-GOES product can provide both precipitation and cloud regions within DCS. Also DOE ARM ground-based cloud observations, OK mesonet precipitation system and several well-calibrated precipitation products are also available, those can cover different spatial domains and relatively longer time periods. These combined products provide a good constraint on convection for comparison purposes with reanalyses.

4.2 Specific Objectives

Based on our previous studies, we found that the reanalyzed cloud-precipitation-radiation properties, on global average, agreed well with long-term surface and satellite observations. However, there are significant discrepancies over some regions and seasons. Therefore we propose the following two objectives to diagnose and quantify the uncertainties of regionally reanalyzed properties using the ground-based ARM, BSRN, Oklahoma Mesonet and NEXRAD observations and space-based CERES, MODIS, GOES, CC, GPCP and TRMM results.

This proposal is in response to the FY13 call of NOAA-OAR-CPO-2013-2003445, **MAPP-Research to Advance Climate Reanalysis**, with focus on addressing some outstanding issues in atmospheric reanalysis (type-II). We will use an innovative diagnostic method to quantify the uncertainties of reanalyzed cloud-precipitation-radiation over the Arctic and US SGP regions. We will work closely with Type-I team to perform NOAA MAPP Reanalysis Task Force and enhance reanalysis research activities. In particular, we will primarily evaluate the NCEP CFSv3 reanalyzed cloud-radiation-precipitation results over the Arctic and SGP regions using both satellite and surface observations, and provide some feedbacks to improve the CFSv3 model. Other four reanalyses being evaluated in this study are (i) 20CR, (ii) MERRA, (iii) ERA-I, and (iv) JRA-25. We will compare the reanalyzed results with observations, find their similarities and differences, and finally investigate how these differences relate to large-scale dynamic patterns and variables using the Self Organizing Maps (SOM) method. **Therefore, we propose the following two objectives.**

Objective 1: Quantifying the uncertainties of reanalyzed Arctic cloud-radiation properties

Reanalyzed cloud properties, such as cloud macrophysical (total/low/middle/high cloud fractions and vertical distribution) and microphysical properties (particle size, LWP/IWP, optical depth) will be evaluated with NASA CERES Ed4 and CloudSat/CALIPSO results over entire Arctic region and locally at the ARM NSA ground-based observations. The reanalyzed surface and TOA radiation fluxes will be evaluated with NASA CERES EBAF results and ARM/BSRN observations. The reanalyzed cloud properties will be compared with CERES-MODIS retrievals for the period 2000-2011. Then we will identify key discrepancies in the comparison for different regions and seasons. To discriminate between these potential problems, Self Organizing Maps (SOM) will be used to classify the atmospheric state from the reanalyses. Intercomparisons of classified atmospheric states between different reanalyses will allow us to determine how the reanalyzed cloud-radiation biases vary with model dynamics.

Objective 2: Investigating the reanalyzed hydrological cycle at SGP

In this objective, we will compare the monthly mean cloud fractions and accumulated precipitations from five selected reanalyses with different observational platforms, such as ARM, Oklahoma mesonet system, GPCP, NEXRAD Q2, TRMM, and UND hybrid radar/GOES product over the SGP region during the period 1997-2011 (as we did in Figs 3 and 4). For this study, we will use OK mesonet system and its covering region (entire OK state) as a baseline. Other datasets, such as GPCP, NEXRAD Q2, TRMM, and UND hybrid product will be averaged over the entire OK state (~ 5^ox5^o). Since the ARM SGP observations can cover only one point, it will be used as reference. Through this comparison, we will statistically evaluate the strength and weakness in cloud fractions, precipitation strength, frequency occurrence, and areal coverage for each reanalysis.

4.3 Anticipated results and relevance to NOAA's long-term goal and Benefit to public and scientific community

The proposed two objectives build on our experience in processing long-term surface and satellite observations and evaluating the GCM/reanalyzed results using both surface-satellite observations, and are a natural extension of Dr. Dong's current research. Through this comprehensive study, our physical and dynamical understanding of what controls reanalyzed cloud-radiation properties in Arctic regions will be improved by understanding how the reanalyzed cloud-radiation biases vary by dynamic state. The reanalyzed hydrological cycle over the SGP region will be evaluated through multiple data sets. An innovative diagnostic method has been proposed to quantify the uncertainties of reanalyzed cloud-precipitation-radiation over the Arctic and US SGP regions, which will advance our knowledge of clouds-radiation-precipitation processes and parameterizations in the five reanalyses.

This proposed research is designed to address some key scientific issues and to help bridge gaps between reanalyses and observations, and explore possibilities for improving the NOAA and other reanalyzed cloud-radiation-precipitation products. This proposed research will leverage the NOAA and other reanalyses to study Arctic climate change and the mid-lat. hydrological cycle. This proposed research is strongly relevant to one of the NOAA NGSP goals: *Assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions*. In particular, the two proposed objectives fit in the following MAPP targeted areas: *1) the hydrological cycle, 2) the quality and uncertainties of reanalyses over the Arctic regions, 3) Representation of surface fluxes.* The scientific community will greatly benefit from the quantified uncertainties of these five reanalyses in order to mitigate and adapt to a changing climate, particularly over Arctic region. This study will also significantly benefit UND and its research capabilities by funding and training graduate students and a post- doctorate.

4.4 Satellite, Surface, Reanalysis datasets and SOM technique

The datasets used in this proposed study can be divided into three parts: the satellite, surface, and reanalysis datasets. The satellite datasets mainly consist of NASA CERES Edition 4 cloud retrievals, EBAF radiation products, Cloudsat/CALIPSO cloud products over Arctic regions, and TRMM and GPCP precipitation products over ARM SGP region. The surface dataset includes the DOE ARM ground-based observations over ARM NSA and SGP sites, Oklahoma mesonet precipitation, NEXRAD observations, and UND hybrid radar/GOES product over SGP region. We will also retrieve the five selected reanalysis datasets for intercomparison and evaluation.

Satellite products

The satellite datasets used in this study will primarily be the NASA CERES Ed4 polar orbit (MODIS) and geostationary (GOES) cloud retrievals [Minnis et al. 2010 and 2011]. Minnis et al. [2008, 2010] developed a set of algorithms for CERES Edition 4 to derive cloud phase, effective cloud height (H_e) and temperature (T_e), water-droplet effective radius (r_e) or ice-crystal effective diameter (D_e), optical depth (τ), and liquid water path (*LWP)* or ice water path (*IWP*) for each imager pixel (1 km resolution) if it has been classified as cloudy by the CERES cloud mask. In addition to the CERES Ed4 cloud results, we have also collected the Cloudsat/CALIPSO cloud results to provide cloud vertical distributions over Arctic regions for this study. The recently available CERES EBAF radiation product is a perfect product to evaluate the reanalyzed surface and TOA radiation budgets where the EBAF TOA radiation

Budget is temporally interpolated using geostationary observations to infer the diurnal variations among CERES measurements. The EBAF surface radiative fluxes are calculated using Langley modified Fu-Liou radiative transfer model with the input of MODIS cloud properties retrieved by CERES Science team.

The monthly GPCP Version 2 precipitation product will be used in this study. This product is produced by merging a variety of satellite and ground precipitation measurements, including passive microwave retrievals from SSM/I, infrared-based estimates from geostationary satellites, and gauge observations gridded on 2.5^ox2.5^o latitude-longitude scale (Adler et al., 2003). All of the measurements are combined with inverse error variance weighting to produce the merged analysis. In this study, the monthly GPCP data are averaged over a grid box of 5^ox5^o latitude-longitude covering 32.5^o-37.5^oN, 100^oW-95^oW during 1997-2011. The TRMM precipitation products are the TMI-based TRMM 2A12 rainfall product (Kummerow et al., 2000), which are also averaged over the same grid box as GPCP during 1998-2011. The CloudSat and CALIPSO cloud properties used in this study are the CALIPSO Vertical Feature Mask (VFM; Version 3) and CloudSat Level 2B Cloud Scenario Classification (CLDCLASS; Revision 4) products.

Surface dataset

The cloud properties observed and retrieved from ARM radar-lidar-radiometer measurements over the ARM surface sites in this proposed study have been collected during the period 1997-2011. The ARM cloud radar-lidar can provide the vertical profiles of clouds in a vertically pointing mode and measures continuous reflectivity profiles as clouds and hydrometeors pass over the radar field of view (Clothiaux et al., 2000; Dong et al. 2010, Xi et al. 2010). It records radar reflectivity with a 90-m vertical resolution, a total of 167 levels starting from 105 m above ground level. The cloud microphysical property retrievals over the ARM NSA site will be performed by the PI using Dong and Mace 2003 method. The surface SW and LW radiation fluxes are collected at a resolution of 5 min from up-looking standard PSP and PIR measurements at both ARM NSA and NOAA BSRN Barrow site as we used in Dong et al. 2010.

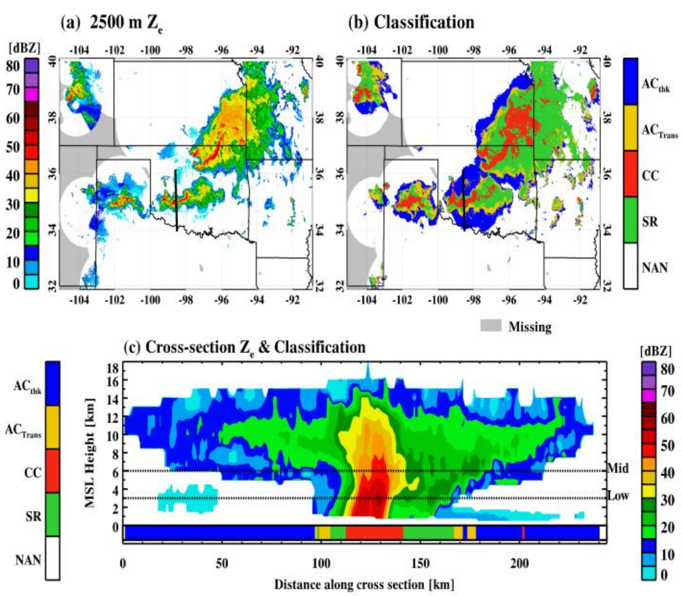


Figure 5. An example of the 3D radar classification over the study region (32-40°N, 91-105°W). (a) NEXRAD horizontal reflectivity at 2500 m MSL, the gray shaded areas near the western boundary represent no radar data at this height due to elevated terrain, (b) classified DCS components based on radar observations from surface to top, (c) vertical cross-section radar reflectivity, with the classification color-coded underneath. The cross-section is taken along the black solid line in (a) and (b), the two dash lines in (c) shows the low and mid-level heights. (Fig. 3 of Feng et al. 2011)

The OK Mesonet is a statewide monitoring network, and consists of over 110 automated weather stations covering the entire state of Oklahoma (Brock et al., 1995). The OK Mesonet is a system designed to measure the environment at the size and duration of mesoscale weather events. Feng et al. (2009, 2011) developed a merged/hybrid dataset of ARM MMCR, WSR-88D precipitation radar, and GOES satellite data to produce a 3-D product of convective structure (Figs. 5 and 6). Feng et al. (2011) further used these results to study the diurnal cycle and cloud radiative forcings of DCSs and their associated precipitation. Feng et al. (2012) adopted a tracking system and used this product to investigate the life and diurnal cycles of DCS, as well as the relationship between the anvil cloud and the parent convective properties in the central United States region.

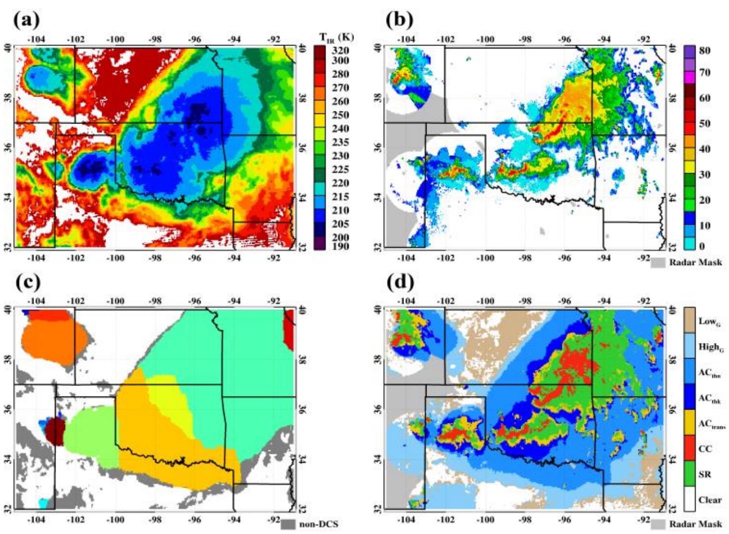


Figure 6. An example of the hybrid classification process. (a) GOES IR temperature, (b) NEXRAD radar reflectivity aggregated onto the hybrid grid, (c) cloud patch segmentation, the color patches are identified as deep convective systems (DCSs) and the gray patches are other high clouds, both GOES IR temperature and NEXRAD indicated precipitation features are used to identify DCSs, and (d) the final hybrid classification output (Fig. 5 of Feng et al. 2011).

Reanalysis Datasets

The five reanalyses being evaluated in this study (MERRA, CFSR, 20CR ERA-I, and JRA-25) are made available at a variety of horizontal and vertical resolutions. Variables are output at different temporal resolutions ranging from hourly to six-hourly. These properties are summarized in Table 1 of Zib et al. (2012). A more detailed summary of each of the reanalyses being evaluated in this study can be found in Zib et al. (2012).

TABLE 1. Reanalysis' spatial and temporal resolutions

Reanalysis/ Resolution	MERRA	CFSR	JRA-25	20CR	ERA-I
Horizontal Resolution	Global Gaussian Grid (540x361) 0.66^{o} x 0.5^{o}	Global Gaussian Grid (1152x576) 0.31^{o} x 0.31^{o}	Global Gaussian Grid (320x160) 1.125^{o} x 1.125^{o}	Global Gaussian Grid (192x94) 1.875^{o} x 1.9^{o}	Global Gaussian Grid (240x121) 1.5^{o} x 1.5^{o}
Vertical Resolution	72 levels (to 0.01 hPa)	64 levels (to 0.26 hPa)	40 levels	28 levels	60 levels (to 0.1 hPa)
Temporal Resolution	1 hour time avg.	1 hour time avg.	6 hour time avg.	3 hour time avg.	6 hour time avg.

The Self Organizing Map (SOM) technique and its application

SOM is a competitive neural network (Kohonen 2001). Unlike other techniques, classes are related to each other in a 2-D matrix (feature map). Instead of clustering (fitting) data, it creates classes that span the entire distribution of data as illustrated in Figure 7. If we remove the neighborhood function, the SOM is reduced to a k-means clustering technique.

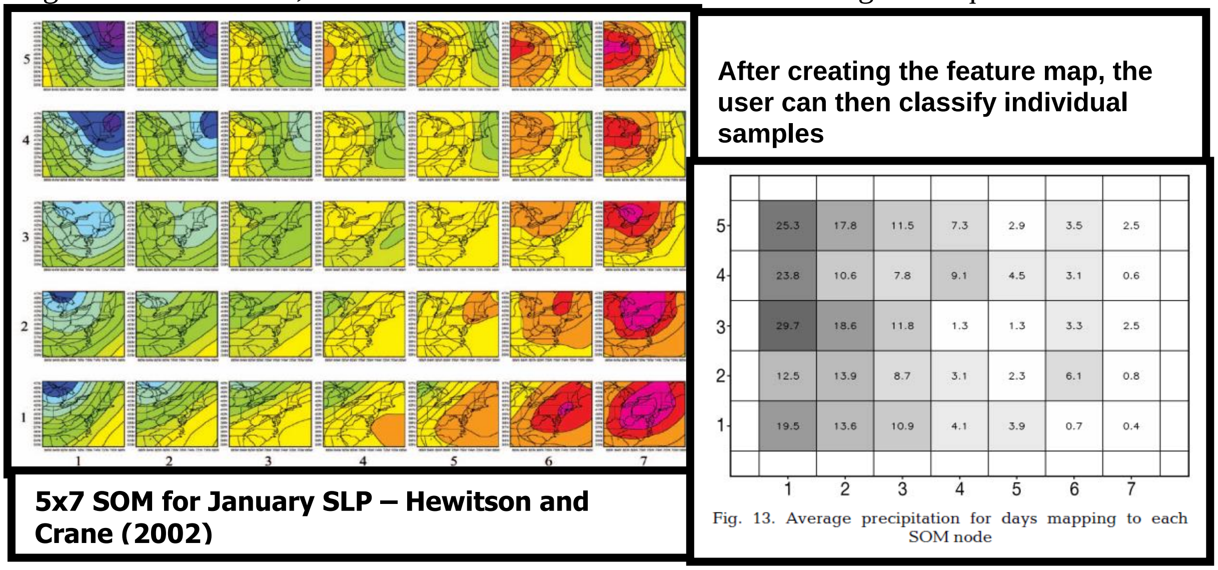


Figure 7. Example of a 2-D SOM. Figure is adapted from Cavazos (1999).

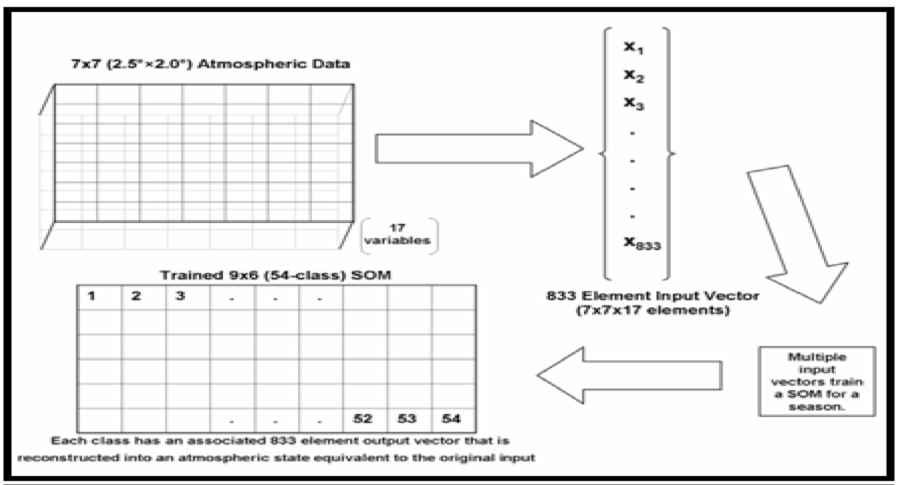


Figure 8. The process of creating a SOM from 3-D atmospheric data such as NARR. (Figure 2 of Kennedy et al. 2012)

In Kennedy et al. (2012), NARR (Mesinger et al. 2006) data were averaged to a 7°×7° (2.5°×2°) grid centered on the ARM SGP site (Figure 8). To classify the atmosphere state, MSLP, and geopotential height, relative humidity, and the horizontal wind components at multiple pressure levels were used. Although some studies such as Marchand et al. (2007) have sought to limit the number of classes, Kennedy et al. (2012) assumed that the atmosphere was capable of producing an infinite number of meteorological states and as such, chose SOMs with a large number of classes. 54-class SOMs were developed for time periods of disagreement between cloud observations and reanalyzed results from MERRA. These included the months of winter (DJF), June, and August.

4.5 Proposed Research Objectives

In this proposed research, we will use an innovative diagnostic method to quantify the uncertainties of reanalyzed cloud-precipitation-radiation over the Arctic and US SGP regions. The five reanalyses being evaluated in this study are (i) CFSv3, (ii) 20CR, (iii) MERRA, (iv) ERA-I, and (V) JRA-25. We will compare the reanalyzed results with observations, find their similarities and differences, and finally investigate how these differences relate to large-scale dynamic patterns and variables using the Self Organizing Maps (SOM) method. Therefore, we propose the following two objectives.

Objective 1: Quantifying the reanalyzed Arctic cloud-radiation properties

What do we propose?

Reanalyzed Arctic cloud-radiation properties, such as cloud macrophysical (total/low/middle/high cloud fractions and vertical distribution) and microphysical properties (particle size, LWP/IWP, optical depth), as well as surface and TOA radiation budgets will be evaluated with NASA CERES Ed4 and CloudSat/CALIPSO results and locally at the ARM NSA extensive ground-based observations. There are two steps in this objective. First, the five selected reanalyzed results will be compared each other and with observations, such as NASA CERES Edition 4, CC and ARM/BSRN observations during the period 2000-2011. Second, we will identify key discrepancies in the comparisons for different regions and seasons. Long-term radar-lidar observations at the ARM NSA site and from CloudSat/CALIPSO allow for a more detailed comparison of cloud properties to identify the causes of cloud biases. The Self Organizing Maps (SOM) will be used to classify the biases for different atmospheric states. For example, it will be possible to determine how the reanalyses perform under different regimes, such as high pressure or mid-lat. cyclones. The 12-yr period will provide enough samples to give us statistically meaningful results for a variety of atmospheric states.

Motivation

The reanalysis datasets are widely used by atmospheric scientists, which offer a wide variety of application to the scientific community, such as a source for the development and verification of climate models, forcing data for numerous user models, examining forecast skill, estimation of renewable energy resources, investigation of extreme weather and climatic events, and health risk assessments. An accurate re-analysis of these reanalyzed results is important for diagnosing past weather and climate events, especially over extreme climate regions where human presence and observing networks are sparse. For reliable application of reanalyzed results, it is important to have a reasonable estimate of the errors and accuracies in its reanalyzed cloud and radiative properties. For example, we recently submitted a paper to JGR to study the impact of clouds and surface radiation budget on Arctic sea-ice retreat using MERRA reanalyzed results. We examined the critical mechanisms for the formation of the minimum Arctic sea-ice extent and proposed a positive cloud-radiation-vapor feedback in driving the sea-ice extent to a record low in the summer of 2007. Although the analysis method and results were promising in the paper, the MERRA reanalyzed surface radiative fluxes are problematic because a key limitation in MERRA is the seasonally-invariant sea ice albedo (fixed at 0.6, while the observed ones can be up to 0.8-0.9). We followed this reviwer's suggestion, and compared the MERRA downward and upward SW and LW fluxes over Arctic surface, and found that the reviewer's concern is right as shown in Figure 9 where the MERRA reanalyzed SWup flux is much lower than CERES EBAF results. The differences in SWdown and LW fluxes between CERES EBAF and MERRA reanalysis are much less than their SWup comparison (not shown here). Therefore, it is indeed necessary to quantify the uncertainties of reanalyzed clouds and radiation products before applying them to study long-term climate change and extreme events over Arctic regions.

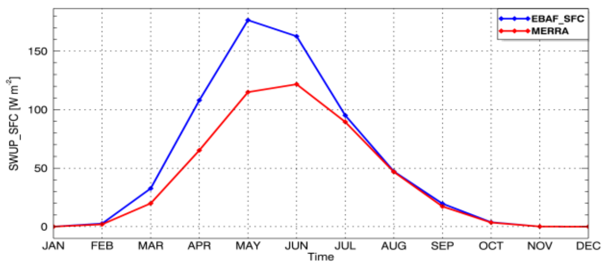


Figure 9: Monthly mean surface SWup flux comparisons between NASA CERES EBAF and MERRA reanalysis over Arctic region (70^o-90^o) during the period 2000-2011.

Approaches

This proposed task is based on our previous results supported by NASA MAP, NEWS and CERES grants and piggybacks on our current study of evaluating NASA GISS AR5 GCM simulations using surface-satellite observations. These previous results provide documented experience for us to evaluate the model results and how to improve them. For this proposed objective, there are two steps that basically follow an approach suggested within Jakob et al. (2003) where key issues are first identified and then investigated in detail. Because the long-term and global NASA CERES Ed4 results are not available at this moment, an example methodology is given for the CERES Ed2 results. The preliminary results of CERES Ed4 presented by Minnis et al. (10/2011 and 05/2012 during NASA CERES ST meetings, available at http://ceres.larc.nasa.gov/science-team-meetings2.php) have shown that they have been improved significantly compared to the Ed2 results, particularly over Arctic regions. Therefore this methodology is robust and will work regardless of how they may change from Ed2 to Ed4. In the following two steps, we are using MERRA reanalyzed total CF as an example. We will use the same or similar method to evaluate different levels of clouds, TOA and surface radiation budgets, as well as other reanalyzed results in this proposed objective.

Step1: Compare the MERRA reanalyzed total CFs over Arctic region with CERES Ed4 results during the period 2000-2011

Figure 10 shows the annual and seasonal (winter and summer) mean total CFs over Arctic regions (70^o-90^o) retrieved by CERES (through MODIS observations) and reanalyzed by MERRA. From the annual CF comparison, the MERRA annual mean CF is 9% higher than observed one (72.8% vs. 63.8%), significantly higher during winter (75.7% vs. 50.7%), and lower during summer (68.5% vs. 77.2%). For the CF differences over the Arctic regions (passive satellites have difficulty distinguishing clouds from highly reflective sea ice or snow, in particular polar night), we have shown the monthly mean CFs computed from ARM, CC, and CERES Ed2 results over the ARM NSA site from July 2006 through June 2010 in Figure 3. The CERES Ed2 CFs agree well with ARM and CC results during warm months (May-Oct.), but are significantly lower during cold months (Nov.-April). We therefore conclude that the passive CERES Ed2 retrieved CFs agree well with those from CC and ARM during warm months, but the CERES Ed2 polar-cloud detection algorithms have trouble distinguishing thin clouds from cold surface temperatures present during winter when only infrared data can be used. The preliminary results of the CERES Ed4 have shown that the global mean CF has increased 7%, with much more increase in Arctic regions, compared to the Ed2 results. The CF differences in Figure 10 may be reduced moderately for annual and winter comparisons, but enlarged for summer comparison. In addition to seasonal differences, there are also significant discrepancies over some regions, for example, the reanalyzed CFs are much lower than observed ones over Greenland/Barents Seas, but much higher over northward of Svalbard. All these discrepancies need to do further study.

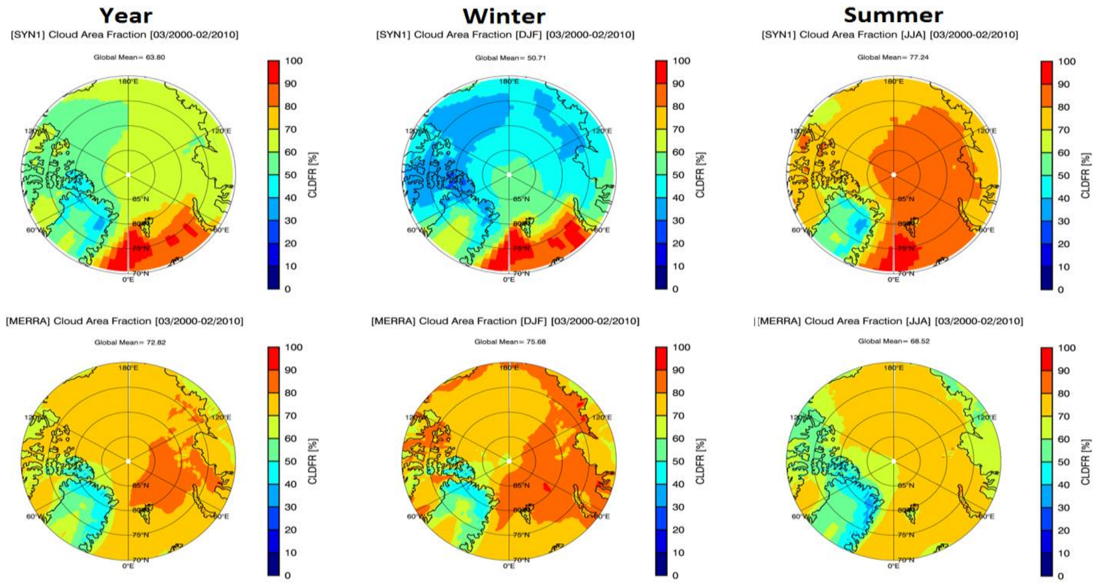


Figure 10. The annual and seasonal mean total CFs retrieved by CERES Ed2 SYN1 (upper panel, will be Ed4 when this proposal is funded) and reanalyzed by MERRA (lower panel) during the period 03/2000-12/2010. The CF comparisons between CERES Ed2 and MERRA are annual (upper), winter (middle) and summer seasons (lower).

Step 2: Investigate the CF discrepancies found in Step 1 and at the ARM NSA site

After identifying the key issues in Step 1 (in this case, cloud biases in the winter and summer seasons, and Greenland/Barents seas regions), we will focus on investigating both these regions and ARM NSA site. The locally extensive surface-satellite observations, MERRA, and the SOM technique will be used to diagnose how cloud biases vary with dynamic state.

As demonstrated in Step 1, there are large differences over some Arctic regions in the CF comparison, as well as during winter and summer. The largest discrepancy (~40%) occurs during the winter season over the Arctic ocean. To determine how cloud biases vary with the atmospheric state, the MERRA reanalysis will be utilized to classify the weather patterns within these regions. SOMs will be adapted by region to best capture the variability in the atmospheric state. In the Arctic regions for example, more levels may be chosen near sea level due to the dominance of low-level clouds. Once the atmospheric states are classified, mean cloud fractions will be computed for each state. This technique has already proven effective in evaluating the NASA GISS ModelE AR5 SCM at the ARM SGP Site (Kennedy et al. 2012).

The SOM methodology will also be implemented at the ARM NSA site regardless of the total CF comparisons. Due to the extensive ground-based observations and retrievals at these locations, the reanalyzed results can be more stringently evaluated as was done at the ARM SGP site in Kennedy et al. (2012). With available long-term retrieved low-level stratus cloud-radiative properties at the ARM NSA site (Dong and Mace 2003 and Dong et al. 2010), we will investigate the relationships between the cloud-radiative properties and meteorological regimes and aerosol sources through the SOM technique. These relationships will help us to modify the current MERRA cloud parameterizations and/or develop new ones.

Objective 2: Investigating the reanalyzed hydrological cycle at SGP

What do we propose?

In this objective, we will compare the monthly mean cloud fractions and accumulated precipitations from five selected reanalyses with different observational platforms, such as ARM, Oklahoma mesonet system, GPCP, NEXRAD Q2, TRMM, and UND hybrid radar/GOES product over the SGP region during the period 1997-2011 (as we did in Figs 3 and 4). For this study, we will use OK mesonet system and its covering region (entire OK state) as a baseline. Other datasets, such as GPCP, NEXRAD Q2, TRMM, and UND hybrid product will be averaged over the entire OK state (~ $5^o x 5^o$). Since the ARM SGP observations can cover only one point, it will be used as reference. Through this comparison, we will statistically evaluate the strength and weakness in cloud fractions, precipitation strength, frequency occurrence, and areal coverage for each reanalysis.

Approaches

This objective is very straightforward. We will use OK state as a grid box (nearly $5^o x 5^o$) because OK mesonet precipitation will serve as a baseline for the precipitation comparison. Our recently developed hybrid NEXRAD radar and GOES product can also cover OK state, which will provide a baseline for total cloud coverage, as well as precipitation and cloud regions over OK state. The five reanalyzed cloud fraction and precipitation are then averaged into the same size as OK state during the comparisons.

Objective 3: Data Dissemination

In the second year of this project, we will start to post the results on our permanent webpage to the scientific community (http://people.aero.und.edu/~dong/result.html) and on our anonymous ftp site (ftp://aero1.aero.und.edu/public/Dong) upon the request. There, two types of datasets will be presented: (1) all available cloud-radiation-precipitation datasets for interested researchers to develop their own study, and (2) An atlas featuring monthly/seasonal means, as well as frequency/cumulative distributions for the modelers. The results of this study will also be presented in the scientific meetings, published in peer-reviewed journals, and used as projects in Professors Dong and Kennedy's undergraduate and graduate courses.

4.6 Management and Evaluation: Responsible personnel and Time frame

The PI (Dr. Dong) will take an overall responsibility to include presenting the scientific results at scientific meetings, writing refereed papers and annual reports, and advising graduate students. The Co-I, Dr. Aaron Kennedy will supervise one graduate student to investigate the mid-latitudes hydrological cycle. Dr. Kennedy is new faculty member in the Department of Atmospheric Sciences at University of Norh Dakota. He will contribute one-month of summer time for the second and third years of this project. The Co-I, Professor Baike Xi, with PI, Dr. Dong, will supervise two Ph.D students to compare the Arctic cloud and radiation results from reanalyses and observations, and to investigate their connections with atmospheric states through SOM technique. It is our hope that these three graduate students will eventually become experts in processing data and evaluating reanalysis results through this project.

The following tasks will be used to evaluate the project progress and to measure whether this research achieved its goals and met our scientific and pedagogical expectations.

FY2013
(1) Attend one NOAA MAPP related meeting to discuss with NOAA MAPP Type-I team members about NOAA MAPP Reanalysis Task Force and collaborate with NCEP CFSv3 modelers.

FY2014
(1) Collect and process all observational datasets and reanalysis datasets those will be used in this study (whole team).
(2) Compare Arctic cloud-radiation results between reanalyses and CERES EBAF, CC, ARM/BSRN datasets (Dong, Xi, two graduate students 1 and 2).
(3) Compare cloud-precipitation over the ARM SGP region between reanalyses and ARM, UND hybrid product, and OK mesonet, GPCP, TRMM datasets (Kennedy and graduate student 3).
(4) Present the results to scientific meetings, such as AMS, AGU, EGU, and NOAA MAPP and reanalysis related meetings, and submit two papers to refereed journals (whole team).

FY2015
(5) Find the similarities and differences in Arctic cloud-radiation between reanalyses and datasets, and link these results with large-scale dynamic patterns and variable through SOM technique (whole team).
(6) Investigate the similarities and differences in SGP cloud-precipitation between reanalyses and datasets to further understand these similarities and differences (Kennedy and graduate student 3).
(7) Present research results to scientific meetings, and submit three papers to refereed journals (whole team).
(8) Hiring web developer to post our results on our webpage (http://people.aero.und.edu/~dong/) (Dong).

4.7 References and Citations

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5. Vitae

Professor Xiquan Dong (PI)

Education and Training

Tianjin University, P.R. China	B.E. Electrical Engineering	1983
Pennsylvania State University	Ph.D Meteorology	1996

Dissertation: Microphysical and radiative properties of stratiform clouds deduced from ground-based measurements.

Research and Professional Experience

2011-2012 Visiting Professor, University of Tokyo
2011- Professor, Department of Atmospheric Sciences, University of North Dakota.
2006-11 Associate professor, Department of Atmospheric Sciences, University of North Dakota.
2002-06 Assistant professor, Department of Atmospheric Sciences, University of North Dakota.
1999-02 Research assistant professor, Department of Meteorology, University of Utah.
1996-99 Research Scientist, NASA Langley Research Center (AS&M, Inc.), Hampton, VA.
1991-96 Graduate Research Assistant, Meteo. Department, Pennsylvania State University. .
1983-91 Electrical Engineer, Chinese Academy of Meteo. Sciences, Beijing, China.

Publications (10 publications most closely related to the proposed project)

(1) Kennedy, A.D., X. Dong, B. Xi. S. Xie, Y. Zhang, and J. Chen, 2011: A Comparison of MERRA and NARR Reanalysis Datasets with the DOE ARM SGP Continuous Forcing data. J. Clim. 24, 4541-4557.

(2) Zib, B., X. Dong, and B. Xi, A. Kennedy, 2012: Evaluation and Intercomparison of Cloud Fraction and Radiative Fluxes in Recent Reanalyses over the Arctic using BSRN Surface Observations. J Clim., 25, 2291-2305.

(3) Giannecchini, K., X. Dong, B. Xi, A. Kennedy, P. Minnis, and S. Kato, 2012: Validation of CERES-MODIS Cloud properties Over Arctic regions using ARM and Cloudsat/ CALIPSO Observations. Submitted to JGR.

(4) Dong, X., B. Zib, B. Xi, R. Stanfield, X. Zhang, B. Lin, and C.N. Long, 2013: Critical Mechanisms for the Formation of Extreme Arctic Sea-Ice Extent in the Summers of 2007 and 1996. Climate dynamics (accepted).

(5) The Impact of Various WRF Single-Moment Microphysics Parameterizations on Squall Line
Precipitation, JGR (In Press).

(6) Kennedy, A, X. Dong, B. Xi, P. Minnis, A. Del Genio, A. Wolf and M. Khaiver, 2010. Evaluation of the NASA GISS Single Column Model Simulated Clouds Using Combined Surface and Satellite Observations. J. Clim., 23, 5175-5192, doi: 10.1175/2010JCLI3353.1

(7) Kennedy, A., X. Dong, B. and Xi, 2013: Self Organizing Maps as a tool for modeling and observations studies. In preparation for TAAC.

(8) Xi, B. and X. Dong, P. Minnis, M. M. Khaiyer, 2010: A 10-year climatology of cloud cover and vertical distribution derived from both surface and GOES observations over the DOE ARM SGP Site. JGR, 115, D12124, doi:10.1029/2009JD012800.

(9) Dong, X., B. Xi, K. Crosby, C.N. Long, R. Stone and M. Shupe, 2010: A 10-yr Climatology of Arctic Cloud Fraction and Radiative Forcing at Barrow, Alaska. J. Geophys. Res., 115, D12124, doi:10.1029/2009JD013489.

(10) Dong, X., P. Minnis, and B. Xi, 2005: A climatology of midlatitude continental clouds from ARM SGP site. Part I: Low-level Cloud Macrophysical, microphysical and radiative properties. *J. Climate*. **18**, 1391-1410.

Synergistic Activities:

- Science Team Member, NASA CERES project (2003-2014), MAP (2006-2009), NEWS (2007-2010), CAN (2011-2014), NOAA GOES-R (2011-2014), and DOE ARM (1999-2015).
- Member, American Meteorological Society and American Geophysical Union.
- 1998, 2003, 2008: NASA Group Achievement Award for the CERES Algorithm Development and Data Management Team. 2008 Golden Reamer Award (for excellent teaching), U. of North Dakota.
- Section Chair or organizing committee: 2006 AMS radiation, 2009 AGU spring, 2009 International Symposium on Atmospheric Light Scattering, and 2010 AMS cloud; 2012 AOGS-AGU (WPGM), 2013 AGU spring and 2013 COAA.
- Co-Chair of NASA NEWS drought and flood extreme working group
- Member, the Working Group Global Energy Balance of the International Radiation Commission
- NASA Panel committee: 2006 NASA Earth Science and 2008 NASA Earth Science
- Review a numerous of proposals for NASA, DOE, NSF, Canada, Europe, Japan, and China; and papers for JGR, GRL, AMS journals (JAS, J. Clim. etc), IEEE (TGRS), and JOC.

Collaborators and Co-editors:

G. Mace and T. Garrett (University of Utah); P. Minnis, B. Wielicki, Y.Hu, B. Lin, N. Loeb (NASA Langley Research Center); Tony Del Genio (NASA GISS); T. Ackerman (Uni of Washington); C. Long, Y. Qian (DOE PNNL); Bob Kuligowski (NOAA NESDIS); Y. Liu and D. Huang (DOE BNNL); J.E. Penner and Xianglei Huang (University of Michigan); Z. Li (Uni. of Maryland); P. Yang and C. Schumacher (Texas A&M University); M. Shupe and R. Stone (NOAA ESRL); Tim Liu (NASA JPL); Soroosh and Hsu (UC Irvine); Yi Deng (GIT)

Graduate and Postdoctoral Advisors and Advisees:

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Advisees:

Graduated M.S students: Yang Liu, Julie Popham, Hongchun Jin, Rebecca Obrecht, Tim Logan, Kathy Crosby, Di Wu, Behn Zib, Katie Giannecchini, Ryan Stanfield.

Ph.D students: Aaron Kennedy, Zhe Feng.

Current: Ph.D students: Tim Logan, Jingyu Wang, Ryan Stanfield, Shaoyue Qiu

M.S students: Ericka Dolinar, Adam Schwantes, Jingjing Tian, Ronlad Stenz, Ning Zhou, and Peng Wu.

Dr. Baike Xi (Co-I)

EDUCATION

8/99: Ph.D. in Atmospheric Chemistry, Department of Meteorology, Pennsylvania State University
7/85: B.S. in Atmospheric Physics, Beijing University, P. R. China

WORK EXPERIENCE

08/2008-present, Research Associate Professor, Dept of Atmospheric Sciences, Uni of North Dakota
01/2004-08/2008, Research Assistant Professor, Dept of Atmospheric Sciences, Uni of North Dakota

- Evaluating the cloud vertical distribution and radiation budget of SCM, CAM3 and AM2 modeling outputs by using surface and satellite observations at DOE ARM SGP site.
- Developing sophisticated algorithms/methods to analyzing the observational data for surface observations (DOE ARM SGP, TWP, and NSA sites), and satellites (Terra, Aqua, and GOES), and providing the statistics of relationship between the cloud properties and radiations by using long-term surface and satellite observations;
- Developing algorithm /method to validate the satellite observation by using the surface observation and aircraft measurements, NASA CERES project;
- Processing Oklahoma Mesonet data;
- Establishing and managing different data sets for Dr. Dong's group.
- Supervising all graduate students in Dr. Dong's group.

10/99-12/2003, *Research Associate,* Department of Meteorology, University of Utah

- Satellite data analysis and visualization: focused on TRMM (tropical rainfall measuring mission) PR (precipitation radar) and TMI (TRMM microwave imager) data analysis and visualization. Established 3-year (extend to the lifetime of the satellite) tropical rainfall database.
- Aircraft data analysis and management: developed sophisticated programs to make preliminary analysis of the aircraft measurement data (EDOP, AMPR, MAMS, CMP, etc. on ER-2; ARMAR, PSR, on DC-8; FSSP, 2DC, 2DP/HVPS on UND citation) during TRMM field experiments (including TEFLUN-A, TEFLUN-B/CAMEX3, LBA, KWAJEX, and CEMEX4); Provided user friendly data and software to students/colleagues;
- Radiative transfer modeling and microphysics: developing algorithms to simulate the physical process of mesoscale weather system, and using all the microphysics data (by DC-8, CITATION, and CONVAIR) during KWAJEX as reference field.

08/1993-08/1999, Graduate Research Assistant, Dept of Meteorology, Pennsylvania State University

- Laboratory investigation on heterogeneous interactions between atmospheric trace gases and ice crystal: established the cloud chamber system, obtained the valuable data and succeeded on the Ph.D dissertation;
- Fluid Dynamics modeling: designed schemes to analyze the performance of the cloud chamber.

08/1985-12/91, Research Associate, Chinese Academy of Meteorological Sciences

- Developed operational software for radiosonde sounding system;
- Developed operational code for real-time wind profiler;
- Designed the Ozone sensor.

Graduate advisor: Dennis Lamb**,** Dept of Meteorology, Pennsylvania State University
Advisees: Major advisor of Mr. Tim Logan, and co-advisor of all Dr. Dong's graduate students

Dr. Aaron Kennedy (Co-I)

Education

University of Oklahoma	B.S. Meteorology	2004
University of Oklahoma	M.S. Meteorology	2006

Thesis: A Characterization of Descending Reflectivity Cores in Rear-flank Appendages of Supercells.

University of North Dakota	Ph.D. Atmospheric Science	2011

Dissertation: Evaluation of a Single Column Model at the Southern Great Plains Climate Research Facility

Professional Experience

2013- Assistant Professor, Dept. of Atmospheric Sciences, U.of North Dakota.
2012-2013 NSF Post-doctoral Fellow, Dept. of Atmospheric Sciences, U.of North Dakota.
2011-2012 Post-doctoral research associate, Dept. of Atmospheric Sciences, U. of North Dakota.
2006-2011 Graduate Research Assistant, Dept. of Atmospheric Sciences, U. of North Dakota.
2004-2006 Graduate Research Assistant, Dept. of Meteorology, U. of Oklahoma.
2002-2004 Hail Forensics Worker, Weather Decision Technologies, Norman, Oklahoma

Publications

1. **Kennedy, A**., X. Dong, B. Xi, S. Xie, Y. Zhang, and J. Chen, 2011. A comparison of MERRA and NARR Reanalyses with the DOE ARM SGP data. J. Climate, 24, 4541-4557
2. **Kennedy, A**., X. Dong, B. Xi, P. Minnis, A. Del Genio, M. Khaiver, and A. Wolf, 2010. Evaluation of the NASA GISS Single Column Model Simulated Clouds Using Combined Surface and Satellite Observations. J. Clim, 23, 5175-5192.
3. **Kennedy, A**., J.M. Straka, and E.N. Rasmussen, 2007a: A Statistical Study of the Association of DRCs with Supercells and Tornadoes. Wea. Forecasting, 22, 1191–1199.
4. **Kennedy, A**, E. N. Rasmussen, and J.M. Straka, 2007b: A Visual Observation of the 6 June 2005 Descending Reflectivity Core. E-Journal of Severe Storms Meteorology, North America, 211 09 2007. http://www.ejssm.org/ojs/index.php/ejssm/article/view/16/28
5. Dong, X., B. Xi, **A. Kennedy**, Z. Feng, J. Entin, P. Houser, B. Schiffer, W. Olson, T. L'Ecuyer, T. Liu, K-L Hsu, B. Lin, Y. Deng, and T. Jiang, 2011: Investigation the 2006 Drought and 2007 Flood Extreme Events at the SGP through an Integrative Analysis of Observations. JGR, 116, D03204, doi:10.1029/2010JD014776.
6. Zib, B., X. Dong, and B. Xi, **A. Kennedy**, 2012: Evaluation and Intercomparison of Cloud Fraction and Radiative Fluxes in Recent Reanalyses over the Arctic using BSRN Surface Observations. J Clim., 25, 2291-2305.
7. **Kennedy, A**., X. Dong, B. and Xi, A., 2012: Self Organizing Maps as a tool for modeling and observations studies. In preparation for J. Clim.
8. Giannecchini, K., X. Dong, B. Xi, **A. Kennedy**, P. Minnis, and S. Kato, 2012: Validation of CERES-MODIS Cloud properties Over Arctic regions using ARM and Cloudsat/CALIPSO Observations. Submitted to JGR.

Synergistic Activities

- Student leader and field coordinator for the Student Nowcasting and Observations with the DOW at UND (SNOwD-UNDER) project in 2010. This field campaign studied snow events in eastern North Dakota using multiple Doppler radars and the UND citation aircraft. The project was designed and run by undergraduate and graduate students at UND. The field campaign also included K-12 schools throughout the region by including their observations of snow.

- President of several organizations including the UND Atmospheric Student Graduate Student Association (ASGSA) from 2007-2011 and the Student Chapter of the American Meteorological Society (SCAMS) at the U. of Oklahoma from 2004-2005.

- Recipient of the following awards at UND and OU:
- 2010 - Outstanding Graduate Student - Dept. of Atmospheric Science
- 2009 - Outstanding Service to the Department - Dept. of Atmospheric Science
- 2008 - Outstanding Graduate Student - Dept. of Atmospheric Science
- 2007-2008 - NASA North Dakota Space Grant Fellowship
- 2004 – Director’s service to the department – Dept. of Meteorology at OU
- 2000-2004 - University of Oklahoma Academic Scholarship

Collaborators

(i) Graduate Advisors
Xiquan Dong (University of North Dakota, Ph.D. Advisor)
Jerry Straka (U. of Oklahoma, M.S. Advisor)

(ii) Other Collaborators
Junye Chen (NASA Goddard)
Anthony Del Genio (NASA Goddard Institute for Space Studies)
Zhe Feng (DOE PNNL)
Matthew Gilmore (University of North Dakota)
Jack Kain (National Severe Storm Lab)
Mandy Khaiyer (Analytical Services and Materials, Inc.)
Patrick Minnis (NASA Langley)
Gretchen Mullendore (University of North Dakota)
Matthew Pyle (National Centers for Environmental Prediction)
Erik Rasmussen (Rasmussen Systems LLC)
Morris Weisman (National Center for Atmospheric Research)
Audrey Wolf (Columbia University)
Di Wu (NASA Goddard)
Baike Xi (University of North Dakota)
Shaochenx Xie (Lawrence Livermore National Laboratory)
Yunyun Zhang (Lawrence Livermore National Laboratory)
Behn Zib (University of North Dakota)

CURRENT AND PENDING SUPPORT FOR XIQUAN DONG

Current support

NASA Clouds and the Earth's Radiant Energy System (CERES) project

Title: Validation of CERES-derived cloud properties using DOE ARM surface observations.

10/2003-07/2014 total funding, $1.6M.

PI commitment: 0.083 my

NASA EPSCOR program

Title: Evaluation of NASA GISS ModelE AR5 Simulated Global Cloud Fraction and Radiation Budgets Using the MODIS-CERES Observations and MERRA Reanalysis

10/2011-09/2014 total funding, $750K

PI commitment: 0.083 my

NOAA GOES-R program

Title: Improving GOES-R Precipitation Product Associated with Deep Convective Systems by using NEXRAD Radar Network over the Continental U.S.

08/01/211-07/31/2014 total funding, $390K.

PI commitment: 0.083 my

DOE ASR project

Title: Investigation of the relationships between DCS cloud properties, lifecycle, and precipitation with meteorological regimes and aerosol sources at the ARM SGP Site.

10/2012-09/2015 total funding, $364K.

PI commitment: 0.083 my

NOAA MAPP project

Title: Diagnosing and quantifying uncertainties of the reanalyzed clouds, precipitation and Radiation budgets over the Arctic and SGP using combined surface-satellite observations.

08/01/2013-07/31/2016 total funding, $361K.

PI commitment: 5%.

Pending

PI: (Co-Is: Drs. Wood, Polloet, Li, Minnis, Shaw and Hudson): Interactions (MBL-CAI). DOE ARM field campaign proposal. $1.07M for proposing to fly UND Citation aircraft over the ARM Azores site during the summer of 2015. (Have provided detailed budget upon the request of DOE ARM project in May 2013)

PI: (Co-I: Drs. Zhang and Lin): Developing a Climatology of Arctic Sea State and Investigating Impacts of Surface Radiative and Turbulent Heat Fluxes on Arctic Sea-ice Retreat. NASA, 08/16/2013-08/15/2016, ~$597K).

7. National Environmental Policy Act

This proposed research will target on evaluating the five selected reanalyses using both surface and satellite observations. This research will mainly focus on collecting and processing different data sets using computers at University of North Dakota, Grand Forks, North Dakota, USA. Therefore we will NOT generate/produce any materials to impact environment and any environmental concerns from this application, such as the use and disposal of hazardous or toxic chemicals, introduction of non-indigenous species, impacts to endangered and threatened species, aquaculture projects, and impacts to coral reef systems. We will also assistant NOAA in anyway if NOAA determines an assessment is required.

Diagnosing and quantifying uncertainties of the reanalyzed clouds, precipitation and radiation budgets over the Arctic and SGP using combined surface-satellite observations

A proposal submitted in response to the NOAA MAPP FY13 call
(Priority Area 1: Research to Advance Climate Reanalysis➔Outstanding issues in atmospheric reanalysis-better quantify uncertainties in reanalysis)

PI: Dr. Xiquan Dong, Professor
Department of Atmospheric Sciences
University of North Dakota
Grand Forks, ND 58202-9006.
Phone: 701-777-6991
Email: dong@aero.und.edu

Co-I: Dr. Aaron Kennedy, Assistant Professor
Department of Atmospheric Sciences
University of North Dakota
4149 University Avenue Stop 9006
Grand Forks, ND 58202-9006
Phone: 701-740-1390
Email: kennedya@aero.und.edu

Co-I: Dr. Baike Xi, Research Associate Professor
Department of Atmospheric Sciences
University of North Dakota
4149 University Avenue Stop 9006
Grand Forks, ND 58202-9006
Phone: 701-777-2767
Email: baike@aero.und.edu

A total budget: $361,000 from August 1, 2013 to July 31, 2016.

BUDGET AND BUDGET JUSTIFICATION

For period from August 1, 2013 to July 31, 2016.

	Year 1	Year 2	Year 3	Total
1) Direct Labor (salaries, wages, and fringe benefits	0	100,936	103,964	204,900
2) Other Direct Costs:				
a. Subcontracts		0	0	0
b. Consultants		0	0	0
c. Equipment		6,000	0	6,000
d. Supplies		4,500	2,500	7,000
e. Travel	725	6,000	8,000	14,725
f. Data Costs		0	0	0
g. Other (Publication)		4,000	6,000	10,000
h. Other (Tuition Remission)		14,698	13,760	28,458
3) Facilities and Administrative Costs [38%, base=$725 for Yr 1, $115,436 for Yr 2, and $120,464 for Yr 3]	275	43,866	45,776	89,917
4) Total NOAA Cost	1,000	180,000	180,000	361,000

BUDGET JUSTIFICATION

Budgets after the first year have been adjusted for a 3% increase in salary.

	Yr 1	Yr 2 Mo	Yr 3 Mo	Year 1 Budget	Year 2 Budget	Year 3 Budget	Total
1. Direct Labor:							
a. Xiquan Dong	0	0.6	0.6	0	7,030	7,241	14,271
b. Baike Xi	0	0.6	0.6	0	5,212	5,368	10,580
c. Aaron Kennedy	0	1	1	0	7,668	7,898	15,566
d. Graduate Students (3)				0	70,515	72,631	143,146
Fringe Benefits (28% for a-c, 7% for d)				0	10,511	10,826	21,337
Total Salaries & Fringes				0	100,936	103,964	204,900

1a. Senior personnel: Personnel costs include 0.6 month of Professor Dong's summer-salary for the second and third years of this project, including both technical and project management function, consistent with the PI's intended level of effort during summer time. For example, Professor Dong will present the results at scientific meetings, write refereed papers and annual reports, and advise graduate students.

1b. Senior/Key Personnel: 0.6 month of salary for the second and third years of this project is budgeted for Co-I, Professor Xi. Professor Xi will supervise two Ph.D. students and help graduate students to process satellite and surface datasets, and compare them with reanalyses over the Arctic regions. One month of summer salary for the second and third years of this project is budgeted for Professor Kennedy to supervise one graduate to work on Objective 2 and provide SOM results. Professors Xi and Kennedy are experts in processing different kinds of surface and satellite data, reanalyses datasets, especially for large size dataset using IDL.

1c. Other Personnel: Support for three graduate students is required to perform two proposed objectives. Two graduate students will work on proposed Objective 1 under the supervision of Professors Dong and Xi. One graduate student will work on proposed Objective 2 under the supervision of Professor Kennedy. It is our hope that these three graduate students will eventually become experts in processing data and evaluating reanalysis results through this project.

2a. Subcontracts: n/a

2b. Consultants: n/a

2c. Equipment: A large hard disk ($6,000) is required for the second year of this project for the graduate students to process and store the satellite and surface data, as well reanalyses results (see the attached quote). The lease of large hard disk is currently not available, therefore we have to purchase a large hard disk as we did for other funded projects.

2d. Supplies: Three PCs ($4,500) are required for the second year of this project for three graduate students to process and store the satellite and surface data, as well reanalyses results. Other computer and research related supplies are budgeted at $2,500 for the second and third years, such as upgrading IDL software because we need renew our IDL license annually and office supplies (binders, storage media, etc.).

2e. Travel: The travel funding of $725 is budgeted for the first year of this project to attend the NOAA MAPP related meeting. For the second year, funds for two domestic and one international travel are budgeted to attend NOAA MAPP and related science meetings and workshops. The total travel is $6,000 for the second year, which can support about two domestic trips (or two persons each trip) and one international trip depending on the location of meeting. Each domestic trip (~$1,500) includes $600 of airfare, $400 of lodging, $200 of per diem, $100 of ground transportation, $200 for registration fee. One international travel, such as EGU (~$3,000), is required per year. Based on our previous experience, the average cost of each international trip is at least $3,000 (depending on season), including $1,500 for airfare, $600 for lodging, $400 for per diem, $100 for ground transportation, and $400 for registration and abstract fees. For the third year, the $8000 of travel funding is budgeted to support one more graduate student to attend professional meeting.

2f. Data Charges: n/a

2g. Other/Publication charges: $4,000 is required for publishing 2 papers in the second year, and $6,000 is requested for publishing 3 papers for the third year with about 13 pages (~$115 per page+ 1-2 color figures) for the Journal of the Atmospheric Sciences.

2h. Other/Tuition: The UND Department of Atmospheric Sciences will pay a total of 16 credits per year the resident tuition. It is the PI's responsibility to pay the difference between non-resident and resident tuition amounts from funded projects. Therefore, $14,698 and $13,760 are estimated for second and third years, respectively.

3. Facilities & Administrative/Indirect Costs: This rate of 38% is federally approved research rate based on modified total direct costs (excluding equipment greater than $5,000 and subcontracts in excess of the first $25,000 for each award). Notice that the tuitions are excluded from indirect cost.

The budget detail is being submitted for proposal evaluation purposes only. Due to limitations within the University's accounting system, the system does not provide for accumulating and reporting expenses at the level of detail submitted. Expenses will be reported at the category level.

Print Summary

PowerVault MD1200
Direct Attached Storage

Starting Price **$5,693.00**

Use your purchase order number or credit card at checkout for payment.

Preliminary Ship Date: **11/2/2012**

My Selections **All Options**

- **PowerVault MD1200 Direct Attached Storage**

Date	10/24/2012 2:14:53 PM Central Standard Time
Catalog Number	84 Retail 84

Catalog Number / Description	Product Code	Qty	SKU	Id
PowerVault MD1200: PV MD1200,RKMNT,SAS, 12 Bay	MD1200	1	[224-7198]	1
Enclosure Management Module: 2 Encl Mgmt Modules, SAS Only	EMM	1	[330-6058]	9
Server Raid Controller: No PERC H800	NOH800	1	[341-9870]	24
Hard Drives: 2TB 7.2K RPM Near-Line SAS 6Gbps 3.5in Hotplug Hard Drive	2TBNL6	2	[342-0002]	1209
Hard Drives: Hard Drive Filler, Single Blank	HDBLNK	10	[342-0121]	1209
Cables: 6Gb SAS Cable, 1M	2XCB1M	1	[330-6062] [330-6062]	20
Power Cords: No Additional Power Cords	NOPWRCD	1	[310-9057]	38
Rails: No Rails Included	NORAILS	1	[330-3479]	27
Hard Drive: HD Multi-Select	HDMULT	1	[341-4158]	8
Bezel: Bezel ASSY,MD1200	BEZEL	1	[313-8850]	17
Installation Services: No Installation	NOINSTL	1	[900-9997]	32
Hardware Support Services: 3Yr Basic Hardware Warranty Repair: 5x10 HW-Only, 5x10 NBD Onsite	U3OS	1	[907-8368] [907-8597] [908-1692] [909-1729]	29