Verification of COAMPS® Clear-Sky Forecasts over the Pacific

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LONG-TERM GOALS

The primary goal of this work is to evaluate, describe, and improve the performance of COAMPS®[1] cloud forecasts in terms of their ability to predict clear skies for airborne intelligence and reconnaissance operations.

OBJECTIVES

The objective of this work is to quantitatively verify the quality of COAMPS® clear-sky forecasts in terms of the position and timing of clear-sky events primarily over the Pacific Ocean. The results will be communicated in terms of the systematic biases as well as the ability to predict clear periods over a range of spatial scales. The feasibility of applying statistical forecasts and/or physics-based corrections will also be investigated.

APPROACH

Clear skies typically occur either as irregularly shaped areas between cloudy regions or as wide zones during quiescent periods. The complexity of the cloud patterns requires a broad range of measures to fully evaluate the numerical forecasts against the satellite cloud observations. User needs also play a critical role in determining forecast performance. Statistics such as the bias and spatial/temporal (lag) correlations provide basic information regarding cloud timing, occurrence, and relative frequency. More sophisticated methods, such as spatial compositing and neighborhood averaging provide information regarding structural errors in the cloud field.

To provide customized statistics, the Center for Naval Analysis (CNA) was contacted. Based on guidance provided by David Ruskin, verification was conducted on COAMPS® forecasts in the Western Pacific centered near Taiwan (Fig. 1). Horizontal grid spacing ranged from 45 km on the outer grid to 5 km on the inner grids. Convective storms were explicitly resolved on the 5 km grids; the Kain-Fritsch convective parameterization scheme was used to represent convective effects on the

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[1] COAMPS®, the Coupled Ocean/Atmosphere Mesoscale Prediction System, is a registered trademark of the Naval Research Laboratory.

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outer grids. Observational cloud data consisted of liquid water path and cloud cover retrievals from the GOES satellites, as well as CloudSat and MODIS measurements. The observations were quality controlled and adjusted for biases and measurement error. Clear sky forecasts were validated based on liquid water path thresholds relevant to CNA operations.

Jason Nachamkin (NRL code 7533) was responsible for the verification work.   COAMPS® forecasts were supplied by FNMOC[2] as well as by John Cook and Dan Geiszler (NRL code 7542). Satellite cloud observations were provided by Kim Richardson (NRL code 7541)

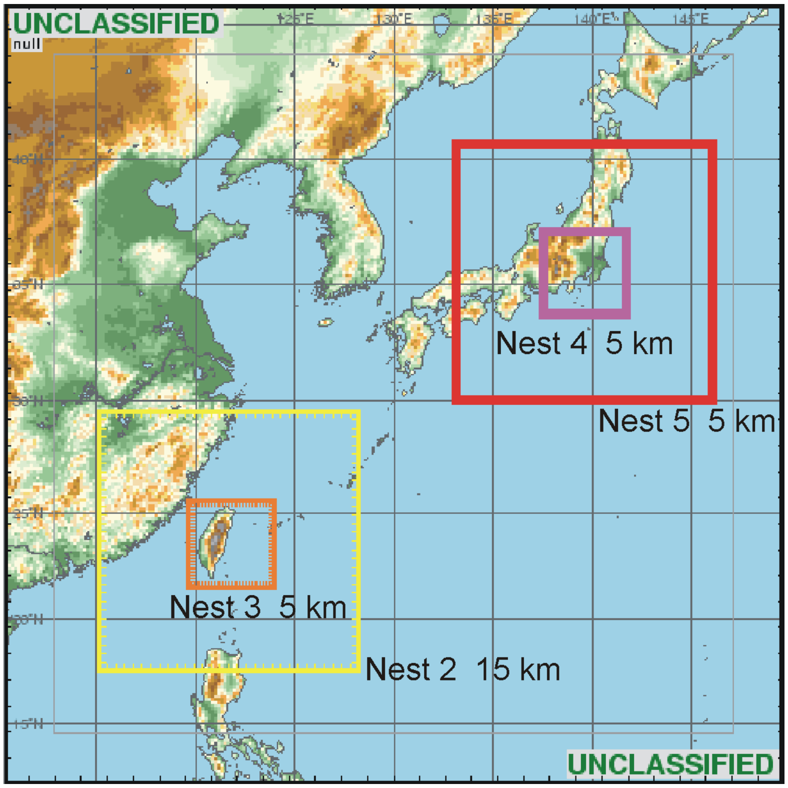

Figure 1. The COAMPS® grid configuration for the western Pacific forecast study. The 45 km parent grid is represented by the mapped area. Nests 2 (yellow) and 3 (orange) with spacings of 15 and 5 km, respecitvely are centered over Taiwan. Nests 4 (red) and 5 (purple) centered over Japan were not evaluated in this study.

WORK COMPLETED

An in-depth verification study of the western Pacific COAMPS® clear-sky forecasts was conducted. Approximately one year of 24-hour forecasts spanning March 2008 to February 2009 were evaluated. As part of the evaluation, the Neighborhood verification method (Roberts and Lean 2008) was implemented to perform probabilistic verification of the spatial distribution of clear skies. Results

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[2] FNMOC is the Fleet Numerical Meteorology and Oceanography Center, the central-site production center for the Navy's many weather products that are derived from automated computer-based data assimilation and modeling systems such as NOGAPS and COAMPS that are run on FNMOC's high-performance computers .

(below) indicate a significant bias exists in the upper tropospheric cirrus cloud cover. A series of sensitivity studies was conducted to investigate the source of the problem. These studies revealed that the Kain-Fritsch scheme was producing an overabundance of moisture in the upper atmosphere. Current work is focused on adjusting the moisture feedback in the Kain-Fritsch software to reduce the amount of cloud cover.

RESULTS

The western Pacific forecasts were focused primarily in the subtropics (Fig. 1), where relatively weakly forced convection dominates. Atmospheric predictability is generally lower in this regime, and as a result the forecast accuracy was reduced in comparison to the mid-latitude eastern Pacific forecasts verified previously. Point-to-point correlations between the predicted and observed LWP fields were on the order of 0.3, while the eastern Pacific values were about 0.5. As noted by Nachamkin *et al* (2009), point-to-point correlations are generally lowered by small-scale variability in the cloud field, and subtropical convection generally contributes to enhanced variability.

To determine the basic properties of the cloud distribution, the COAMPS cloud top heights were verified against the satellite retrievals. Forecast clouds were defined as the highest level with measurable liquid or ice content, while the satellite retrieved cloud-top height was estimated by converting the black-body temperature to a representative atmospheric height. High cloud cover was underestimated by the satellite due to upwelling radiation in areas of thin cirrus. However the positive bias in the forecast cloudiness was still significant due to its large magnitude (Fig. 2). The bias appeared on all grids and all forecast lead times, and was most intense on the high resolution grids. As mentioned above, the Kain-Fritsch parameterization was likely contributing a major portion of the additional moisture. Additional tests indicate that the ice nucleation scheme may have been contributing to the additional moisture on the finest (convective resolving) grid. Both issues are currently being investigated.

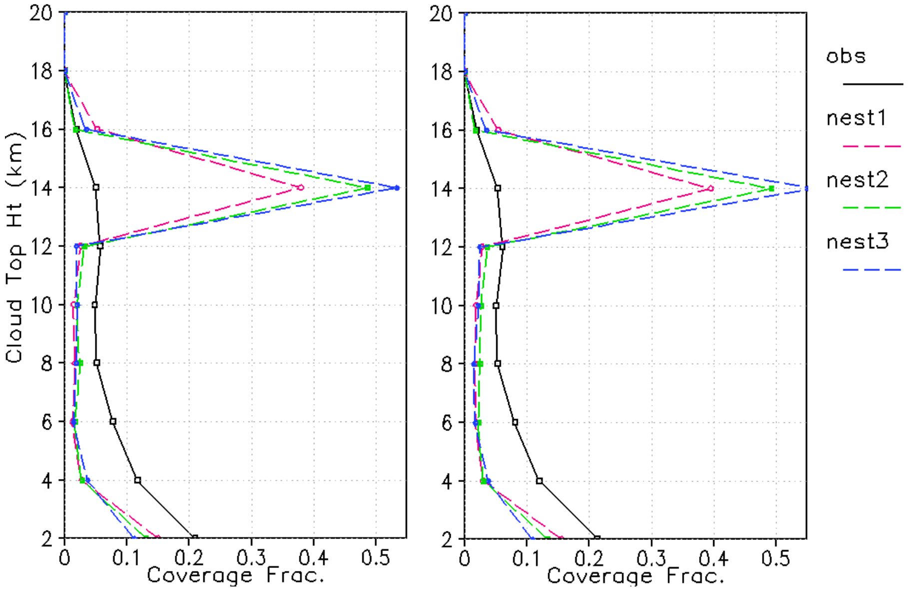

Figure 2. Average Cloud top height profiles for the 5 and 17-hour forecasts.

A major part of forecast verification is determining the added value for the users. In the current application, the users were interested in locating clear skies within specified target zones. Perfect forecasts were not necessary as long as clear skies occurred within an acceptable radius of the initial target. To determine the viability of the forecasts in this situation, the Neighborhood verification method developed by Roberts and Lean (2008) was implemented. The Neighborhood method evaluates forecast reliability at successively increasing scales, starting at a single grid cell (Fig. 3). As the size of the evaluation region increases, the encompassed forecast and observed cloud fractions are less sensitive to small spatial errors. In the example provided in Figure 3, the forecast valid at the single grid cell at the center of the grid is incorrect because clear skies are predicted where clouds were observed. However, the larger bold box encompassing the 5x5 grid domain contains the same number of cloudy grid cells in both fields. If a user is willing to accept the decreased precision incurred from the larger region, they would be able to benefit from the increased reliability. The optimal scale depends on the cost of covering large areas compared to the benefits of completing the mission.

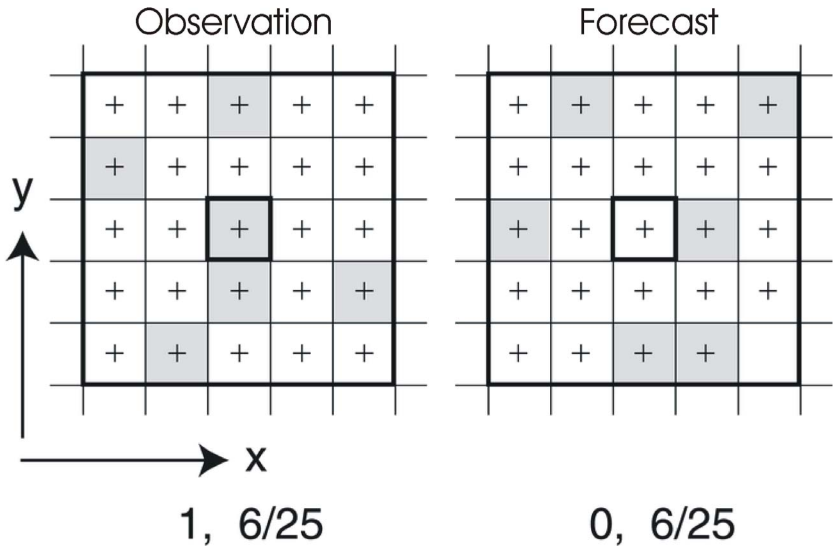

Figure 3. Schematic representation of the Neighborhood verification method as depicted in Roberts and Lean (2008). Gridded observations and forecast values are represented by the small grid squares. Shaded cells represent cloudy grid boxes. Bold boxes represent averaging areas. The numbers beneath each grid represent the cloud fraction within the large and small bold boxes.

Reliability diagrams generated by applying the Neighborhood method to the western Pacific cloud forecasts were derived to depict the degree of the match between the observed and predicted cloud fractions (Fig. 4). Forecasts lying on the 45-degree line contain the same cloud fraction as the observations and are thus perfectly reliable. The dashed lines depict the average observed cloud fraction over the one-year period. Forecasts lying along these lines are essentially random and are of little use. The results from the 45-km grid (Fig. 4) indicate that the reliability of the COAMPS® forecasts is relatively low at the at the grid scale, but steadily increases with increasing scale. Due to the cloud bias, cloudy forecasts are overabundant and the greatest improvements occur at high clear fractions. In general, cloud fraction forecasts over regions greater than 495 km (11 Δx) retain appreciable skill, especially when clear skies are predicted. These results will likely improve considerably once the cloud bias is removed.

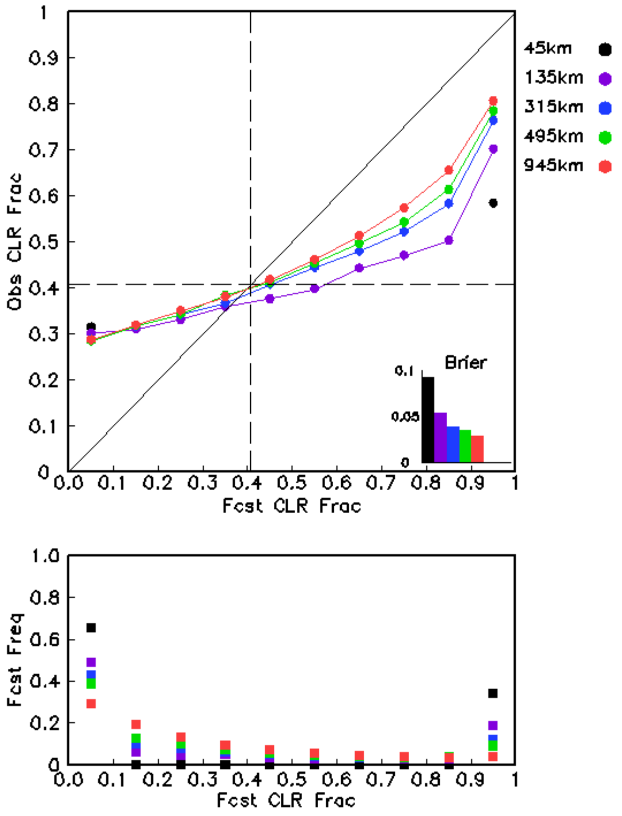

Figure 4. Reliability diagram representing the performance of the forecasts on the 45-km grid at varying scales. Scale is defined by the width of the square averaging region used in the Neighborhood method. The Brier score represents a summary performance measure of forecast reliability. Low Brier scores are desirable, zero represents perfect reliability.

IMPACT/APPLICATIONS

Prior to this project, the systematic statistical performance of the COAMPS® clear sky and cloud forecasts was largely unknown. Cloud prediction is important to a number of military surveillance and aviation applications. These statistics will help both users and modelers to understand and ultimately improve the forecasts for future use.

TRANSITIONS

The verification statistics were delivered to Andrew Slaterbeck (ONR). The results will be used by the Center for Naval Analysis (CNA) to determine the viability of the mesoscale cloud forecasts. The Neighborhood method was implemented as part of the NRL verification package.

RELATED PROJECTS

This project is closely related to the cloud-liquid and ice-water forecast verification and improvement efforts sponsored by the Naval Surface Warfare Center (NSWC) and headed by Jerome Schmidt (NRL code 7533). Many of the statistical methods to compare the cloud forecasts with the observations were developed in conjunction with this project. The eastern Pacific satellite cloud data were also collected under this project.

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