MODIS Semi-Annual Report
Snow and Ice Project
Reporting Period: January - June 2001
Submitted by: Dorothy K. Hall/974 (7/11/01)

Introduction

In addition to delivering more code, several papers and presentations have been submitted, accepted and presented, respectively. The snow albedo algorithm is nearly ready to be delivered by Andrew Klein/Texas A&M, and a new 5-km climate-modeling grid (CMG) product (including fractional snow cover) has been developed and coded. Development of a "thermal mask," to eliminate some spurious snow cover has begun. Detailed comparisons between the MODIS snow products and operational NOAA products are ongoing. Finally, problems have been encountered due to spurious snow cover in warm areas (e.g., Africa), and workstation problems have occurred as well.

MODIS-related presentations during the reporting period:

Hall, D.K., "MODIS snow and ice algorithm outstanding issues," Polar Oceans DAAC Advisory Group (PoDAG) meeting, Boulder, CO, 25 April 2001.

Riggs, G.A., "Utility of the MODIS cloud mask for the MODIS snow and ice products," Terra Cloud-Masking Meeting, Madison, WI, 8 May 2001.

Hall, D.K., "Analysis of a Time Series of Snow-Cover Maps of North America Derived from the Moderate Resolution Imaging Spectroradiometer Instrument," Eastern Snow Conference, Ottawa, Ontario, 18 May 2001.

Riggs, G. "Initial Evaluation of MODIS Sea Ice Observations, "Eastern Snow Conference, Ottawa, Ontario, 18 May 2001.

Hall, D.K., "Assessment of the relative accuracy of hemispheric-scale snow-cover maps," Fourth International Symposium on Remote Sensing in Glaciology, College Park, Maryland, 6 June 2001.

Hall, D.K., "MODIS Snow Products," Workshop for Earth Science satellite remote sensing data processing, analysis and applications, George Mason University, Fairfax, VA, 12 June 2001.

Riggs, G.A., "MODIS Sea Ice Products and Processing," Workshop for Earth Science satellite remote sensing data processing, analysis and applications, George Mason University, Fairfax, VA, 12 June 2001.

Hall, D.K., "Snow and Ice and Global Climate Change," undergraduate professors workshop at GSFC, Greenbelt, MD, 14 June 2001.

The following is a list of the peer-reviewed and the proceedings papers that have been written since 1999:

Peer-Reviewed Papers (submitted, accepted and in press):

Hall, D.K., G.A. Riggs, V.V. Salomonson, N.E. DiGirolamo and K.J. Bayr, submitted: "MODIS Snow-Cover Products," *Remote Sensing of Environment.*

Hall, D.K., R.E.J. Kelly, G.A. Riggs, A.T.C. Chang and J.L. Foster, in press: "Assessment of the Relative Accuracy of Hemispheric-Scale Snow-Cover Maps," *Annals of Glaciology*.

Kaufman, Y.J., R.G. Kleidman, D.K. Hall and V.J. Martins, "Remote sensing of subpixel snow cover using 0.66 and 2.1 μm channels, submitted to Geophysical Research Letters (submitted January 2001).

Tait, A.B., D.K. Hall, A.T.C. Chang, International Journal of Remote Sensing, accepted for publication, May 2000.

Hall, D.K., G.A. Riggs, V.V. Salomonson and G.R. Scharfen, in press: Earth Observing System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS) Snow-Cover Maps, Proceedings of the IAHS Hydrology 2000 Conference, 2-8 April 2000, Santa Fe, NM.

Tait, A.B., J.S. Barton and D.K. Hall, in press: "A Prototype MODIS-SSM/I Snow Mapping Method," Proceedings of the IAHS Hydrology 2000 Conference, 2-8 April 2000, Santa Fe, NM.

Hall, D.K., J.L. Foster, V.V. Salomonson, A.G. Klein and J.Y.L. Chien, 2001: "Development of a Technique to Assess Snow-Cover Mapping Errors from Space," IEEE Transactions on Geoscience and Remote Sensing, 39(2):432-438.

Hall, D.K., A.B. Tait, J.L. Foster, A.T.C. Chang and M. Allen, 2000: "Intercomparison of satellite-derived snow-cover maps," Annals of Glaciology, 31:369-376.

Tait, A.B., D.K. Hall, J.L. Foster, A.T.C. Chang and R.L. Armstrong, 2000: "Utilizing multiple datasets for snow cover mapping," Remote Sensing of Environment, 72:111-126.

Riggs, G., D.K. Hall and S.A. Ackerman, 1999: " Sea ice extent and classification with the Moderate Resolution Imaging Spectroradiometer Airborne Simulator (MAS)," Remote Sensing of Environment, 68(2):152-163.

Polissar, A.V. P.K. Hopke, P. Paatero, Y.J. Kaufman, D.K. Hall, B.A. Bodhaine, E.G. Dutton and J.M. Harris, 1999: "The aerosol at Barrow, Alaska: long-term trends and source locations, Atmospheric Environment," 33:2441-2458.

Winther, J.G. and D.K. Hall, 1999: "Satellite-derived snow coverage related to hydropower production in Norway - present and future," International Journal of Remote Sensing," 20(15&16):2991-3008.

Proceedings Papers:

Riggs, G.A., D. K. Hall, J. R. Key, in press: "Initial Evaluation of MODIS Sea Ice Observations," *Proceedings of the 58th Eastern Snow Conference*, 14-18 May 2001, Ottawa, Canada.

Hall, D.K., G.A. Riggs and V.V. Salomonson, in press: "Analysis of a Time Series of Snow-Cover Maps of North America Derived from the Moderate Resolution Imaging Spectroradiometer Instrument," *Proceedings of the 58th Eastern Snow Conference*, 14-18 May 2001, Ottawa, Canada (Abstract only).

Barton, J.S., D.K. Hall and G.A. Riggs, 2001: "Fractional snow cover from the MODIS snow-mapping algorithm," Proceedings of the 57th Annual Eastern Snow Conference, 17-19 May 2000, Syracuse, NY.

Klein, A.G., D.K. Hall and A. Nolin, in press: "Development of a prototype snow albedo algorithm for MODIS," Proceedings of the 57th Annual Eastern Snow Conference, 17-19 May 2000, Syracuse, NY.

Hall, D.K., A.B. Tait, J.L. Foster, A.T.C. Chang and M. Allen, 2000: "Comparison of snow-cover maps from multiple data sets," Proceedings of the 56th Annual Eastern Snow Conference, 2-4 June 1999, Fredericton, N.B., Canada, pp. 71-74.

Klein, A.G. and D.K. Hall, 2000: "Snow albedo determination using the NASA MODIS instrument," *Proceedings of the 56th Annual Eastern Snow Conference*, 2-4 June 1999, Fredericton, N.B., Canada, pp. 77-85.

Hall, D.K., G.A. Riggs, V.V. Salomonson and G.R. Scharfen, 2000: "Early results from the Moderate Resolution Imaging Spectroradiometer (MODIS) global snow and ice cover products," Proceedings of IGARSS'00, 23-28 July 2000, Honolulu, HI, pp. 1763-1765.

Justice, C. and 20 others (including D. Hall), 2000: "Preliminary land surface products from the NASA Moderate Resolution Imaging Spectroradiometer (MODIS)," Proceedings of IGARSS'00, 23-28 July 2000, Honolulu, HI, pp. 1157-1162.

Scharfen, G.R., Hall, D.K., S.J.S. Khalsa, J.D. Wolfe, M.C. Marquis, G.A. Riggs and B. McLean, 2000: "Accessing the MODIS snow and ice products at the NSIDC DAAC, "Proceedings of IGARSS'00, 23-28 July 2000, Honolulu, HI, pp. 2059-2061.

Ackerman, S.A., C.C. Moeller, W.P. Menzel, J. Spinhirne, D. Hall, J. Wang, H. Revercombe, R.A. Kuteson, E. Eloranta, A. Nolin and M. King, 1999: "**WINCE**: A **WINt**er **C**loud **E**xperiment," Proceedings of the American Meteorological Society Conference.

Hall, D.K., S. Li, A. Nolin and J.C. Shi: 1999: "Pre-launch validation activities for the MODIS snow and sea ice algorithms," Earth Observer, 11(4):31-35.

Klein, A.G., D.K. Hall and K. Seidel, 1999: "Algorithm intercomparison for accuracy assessment of the MODIS snow-mapping algorithm," Proceedings of the Eastern Snow Conference, 2-3 June 1998, Jackson, NH, pp.37-45.

Algorithm and Coding Work

MOD29

Progressed with development and analysis of the MODIS sea ice algorithms. New coefficients for the estimation of sea ice surface temperature (IST) were integrated into the algorithm and data product. Analysis of algorithm results, extent of sea ice and IST was done. A version of MOD29 for the consistent year processing, collection version 3, was delivered to SDST in March 2001.

MOD10_L2

Investigated and analyzed false snow detection in the MOD10_L2 snow products. Began investigating ways to alleviate false snow detection. Specific cases of false snow detection along coastlines, in tropical jungles, and in clouds formations interspersed with gaps. Case studies were built for selected occurrences of those problems, including the acquisition and analyses of MODIS inputs to the snow algorithm. Studied the relationship and registration of the land/water mask used in the MOD10_L2 algorithm to MOD10_L2 and the MOD02HKM swath imagery. Found significant disagreement between the land/water mask and MODIS imagery in several locations. The disagreement is a cause of false snow detection in coastal regions. Investigated situations of snow and cloud confusion in the MOD35_L2 product and in the MOD10_L2 product. Perused how the snow and cloud confusion causes errors in the snow product.

Development of a "thermal mask" to attempt to eliminate spurious snow cover has begun.

The MOD10 Version 3, collection level, algorithm for the consistent year processing was delivered to SDST in May 2001.

MOD10A1
MOD10A1 V2.2.1 code was delivered to SDST in February 2001.

MOD10C1 and MOD10C2
Significant progress was made in the development and analysis of the MODIS snow global climate modeling grid (CMG) algorithms and data products, MOD10C1 and MOD10C2. Time series of these products were generated for the time period 1 November 2000 – 25 January 2001. Separate time series using MOD10A1 or MOD10A2 as inputs were generated and analyzed. MODIS Terra/Aqua compatibility was integrated into both the daily (MOD10C1) and the 8-day (MOD10C2) snow CMG algorithms. MODIS data products inputs were acquired by searching and ordering data via EDG at NSIDC and or at MODAPS then downloading and staging the data for runs of the algorithms. Comparative analysis of the MOD10C1 and MOD10C2 products was undertaken; results were discussed with the ATR. Several versions of the algorithm and product were tested. A new version of the CMG code that runs much faster was developed. A snow CMG algorithm at 5 km resolution spatial resolution and eight-day temporal period was developed and tested on an eight-day period. Decision was made to change to an eight-day, 5 km resolution MODIS snow CMG product.

Drafted and posted the setting for the ScienceQualityFlag and ScienceQualityFlagExplanation for the snow and sea ice products prior to public release of the products.

IDL procedures were revised or written to support analysis of the snow products. Procedures written; produce an MPEG animation of CMG snow data, the animation displays snow cover on a spinning globe; daily combined snow/cloud images, and eight-day period maximum, minimum and change in snow extent images. Imagery was generated for use in presentations and publications. IDL procedures to reproject data, especially MOD10A1 and MOD10A2, and to write out reprojected images using latitude and longitude fields were developed.

Installed updated version of MODIS Reprojection Tool (Version 2.0).

Snow product web pages
Updates to the snow project website were made as needed. Minor corrections were made to the website as needed. Installed all security patches, banners, and service/port restrictions in order to launch system. Successive website re-launches were completed. Publication webpages were added and existing publication webpages were improved to include interactive access to publication figures, tables, and references. In total, 4 publication webpages were added or improved.

An excessed CPU was acquired and a Debian Linux operating system was installed on it to serve as the snow project web server. The system was set up following follow NASA mandated IT security policies for hosting a web server. Security patches, banners, and service/port restrictions were installed prior launching the system.

Webmaster attended one-day NASA information technology security and system administration conference describing NASA specific IT policies to follow for incident reporting procedures, as well as proactive maintenance and attack prevention strategies.

Transferred ‘Sea Ice User Guide’ document into HTML and PDF format. HTML version is fully interactive, with inline hyperlinks to related sections, charts, figures, and other references. PDF version was made easily downloadable and printable. Also updated navigational page for user guide documents.

Develop education activities
Created new “Educational and Outreach Activities” web page and links to existing EOS-based educational activities developed for the Event-Based Science middle-school curriculum.

A snow/EOS video focusing on MODIS and Landsat data of global snow cover was completed with Code 588.

Patches
Patched version of the MODIS level-3 daily sea ice algorithm (MOD29A1) fixing various ECS metadata items was delivered.

Snow Albedo
A snow albedo algorithm has been developed for the Moderate Resolution Imaging Spectroradiometer (MODIS) by Andrew Klein/Texas A&M. The algorithm will complement existing MODIS products by providing albedo measurements for areas mapped as snow on a global daily basis by MODIS.

Currently, the algorithm's primary input is the MOD09 daily surface reflectance product. The snow albedo algorithm provides an albedo estimate for the 'best' MODIS observation of snow-covered pixels each day. The MOD09 surface reflectances are adjusted to account for the bi-directional reflectance of snow using a discrete ordinates radiative transfer (DISORT) model are used to correct for anisotropic scattering effects over non-forested surfaces. A narrow-to-broadband conversion scheme is then used to create an integrated broadband albedo.

The algorithm has undergone initial validation through comparisons with broadband albedo measurements made at the NOAA SURFRAD site in Fort Peck, Montana. *In situ* SURFRAD albedo measurements have compared to daily MODIS snow albedo retrievals for the period from November 21 to 26, 2000 using five different five narrow-to-broadband albedo conversion schemes.

Generally, the prototype MODIS algorithm produces reasonable broadband albedo estimates. Maximum daily differences between the five MODIS broadband albedo retrievals and in *situ albedo* is 15 percent. Daily differences between the 'best' MODIS broadband estimate and the measured SURFRAD albedo range from 1 to 8 percent. However, no single conversion scheme consistently provides the closest albedo estimate. As with the other MODIS snow products, correct cloud masking remains problematic.

The comparisons at the Fort Peck site are continuing. The time series of MODIS snow albedo estimates is being extended to allow comparisons over a larger range of solar zenith angles and snow conditions. Further validation is planned for Greenland and other North American sites where broadband albedo measurements are routinely made. Further validation and algorithm development using data from North American and Greenland is ongoing.

Modeling Work (G. Liston/Interworks Consulting)

The spatial distribution of snow-covered area is a key input to atmospheric models used to simulate weather and climate. The overall objective was to test the use of MODIS-SNOMAP remote-sensing products within the climate version of the Regional Atmospheric Modeling System (ClimRAMS). That project used a few days of MODIS-SNOMAP data, and led to a list of recommendations for future work using MODIS snow-cover products.

As part of this work there were two types of climate model simulations performed to test the application of the MODIS-SNOMAP, 1/4 degree by 1/4 degree, climate model grid (CMG) snow-covered fraction data sets: first, the climate model simulated its own snow-cover distribution (equivalent to most current modeling practices), and second, the fractional snow-covered area was defined for each climate model grid cell using MODIS-SNOMAP CMG information. The differences between the two simulations were analyzed.

The results of these simulations were used to make recommendations regarding how the MODIS-SNOMAP products can be used within the context of regional and global weather and climate models. The work was also used to test and quantify the value of MODIS-SNOMAP products, and point to potential improvements in the data products for atmospheric and hydrologic applications.

Task 1) Configure the ClimRAMS regional climate model with a 25 to 100 km grid, to simulate atmospheric and land-surface processes over a domain and time period that corresponds to available (one month or more) MODIS-SNOMAP data sets to be provided by D. Hall. This includes acquiring National Centers for Environmental Prediction (NCEP) reanalysis data, sea-surface temperature, topography, soils, and vegetation-related data sets required to perform the climate model simulations. Perform all required model setup procedures for the simulation and domain of interest, and cast all required model input data sets on the model grid.

To perform climate model simulations over a domain covering most of the United States and Canada, an 80 km horizontal grid increment was used for the regional climate model. The simulation time period was defined to be 1 through 29 November 2000 to correspond to the available MODIS CMG snow-cover data sets. In addition, the MODIS snow map 8-day composites from November 2000 were used in the simulations. Data were made available for 13, 21, and 29 November.

Three figures are provided that describe 1) the ClimRAMS domain and grid configuration, 2) the vegetation distribution, and 3) the model topography for this grid. Additional model configuration information and boundary condition data sets are available on request.

Task 2) Acquire and process MODIS-SNOMAP CMG, 1/4 degree by 1/4 degree snow-covered fraction data sets from NASA. Process these into the format required by ClimRAMS, including developing a method to fill in missing data in time and space, and re-grid these data sets to the Task 1 ClimRAMS simulation grid.

This project originally started out with 1 through 30 November 2000 MODIS daily CMG snow cover data. These data contained only minimal snow cover information, with much of the domain covered by cloud on any given day. Figure Package 1 highlights the problem, where daily data are shown for 13, 21, and 29 November.

Because of this lack of complete snow information coverage, MODIS 8-day composite data were obtained and used for this project. Using these new data sets, Figure Package 2 provides North America plots of the original MODIS CMG data that was provided for 13, 21, and 29 November 2000. Also plotted on the same page are plots of the MODIS-defined cloud-cover fraction over the same domain.

To account for the missing snow data due to clouds, all cloud areas were defined to be snow-covered. This results in the snow-cover distributions given in Figure Package 3, showing MODIS Snow Cover (%) on 13, 21, and 29 November 2000. This substitution of clouds for snow is deficient in many obvious regards. It also points to the fact that an improved method to fill in missing snow data is needed, since even the 8-day composite data sets are still not cloud-free. To do this will likely require using additional data sets that are not limited by clouds.

To define the snow-cover distribution for days between 1 and 13 November, 13 and 21 November, and 21 and 29 November, 1 November was defined to have zero snow cover (this seems somewhat reasonable based on some NOAA snow-cover data sets), and the snow-covered area was linearly interpolated between the known days to fill in the days with no data. Since the resulting snow-cover distributions are similar to those defined by the 8-day composite distributions, figures of these distributions have not been included.

Task 3) Perform a ClimRAMS simulation that lets ClimRAMS simulate the snow cover's evolution without the addition of the MODIS-SNOMAP data.

Task 4) Perform ClimRAMS simulations while assimilating the Task 2 MODIS-SNOMAP snow-cover data.

To allow ClimRAMS to develop its own snow-cover distribution for November 2000 (the period of available MODIS snow-cover data), the Task 3 model simulation was started on 1 November 2000 and ran through 29 November 2000. This produced model-generated daily snow-cover distributions that could be compared with the observed MODIS snow-cover distribution data.

The results of these two model simulations are provided in a collection of two kinds of figures which are available on request. The first set plots the snow-covered fraction, air temperature, and precipitation fields from the two model runs. The second set plots the *differences* between the two model runs (*ClimRAMS with MODIS Snow Cover* minus *ClimRAMS Alone*) for each of these variables. To simplify the results presentation, model outputs are only presented for the dates 13, 21, and 29 November 2000, corresponding to the MODIS composite dates. Data and plots for the other dates of the simulation (1 - 29 November) are available upon request.

DISCUSSION:

Climate station air temperature and precipitation data were obtained from the NOAA/NCDC Global Summary of the Day station data archive. The first Figure shows the locations of the climate stations used in the analyses. These temperature and precipitation data were interpolated to the ClimRAMS grid using an objective analysis scheme, for 1 through 29 November 2000. Plotted in Figure Package 1 and 2 are the air temperatures and precipitation, respectively, for 13, 21 and 29 November.

When the station air temperature data are compared with the ClimRAMS simulations (Figure Package 3), we find that the model does a good job in the central United States, but has a cold bias in the western and north-east and upper mid-western United States. These patterns are roughly similar for the *ClimRAMS Snow Cover* simulation and the *ClimRAMS with MODIS Snow Cover* simulation. Because of this it is not clear that using the MODIS snow cover data has led to a significant improvement in the ClimRAMS simulated air temperature fields. We expect that the largest impact of using the MODIS snow cover data will be felt in the spring months when solar angles are higher. This is supported by the ClimRAMS/MODIS simulations performed as part of this project last year, using April 2000 MODIS snow data.

The precipitation differences were not printed because in discontinuous fields like precipitation, small shifts in position of non-zero precipitation values lead to large precipitation difference values, that are hard to interpret.

Task 6) As the research progresses, submit to D. Hall graphics that highlight the effect of incorporating MODIS snow products in the climate simulations. Prepare a draft manuscript for submission to a refereed scientific journal, describing the findings and results of the Tasks 1, 2, 3, 4, and 5. Provide an analysis of the value of using MODIS-SNOMAP data sets in weather and climate model simulations. Also use the model results to make recommendations regarding how MODIS-SNOMAP CMG data products might be improved to have greater applicability to the atmospheric and hydrologic modeling communities.

As per discussions with Dorothy Hall in May 2001, the results of this project are not yet ready for publication in a refereed scientific journal. This is partly due to our finding that it is not possible to use the daily MODIS snow cover data sets because of missing data areas under clouds, and that there must be methods developed to use the MODIS 8-day composite snow cover data.

Another important finding of this project/report is that the impact of using MODIS snow cover data as part of atmospheric model simulations may be greater in the late-winter and spring months than in the early winter months. Thus, in order to demonstrate the value MODIS snow cover data on such simulations, spring data sets and simulations should be included as part of any analyses to be used for publication in a refereed journal.

Therefore, this final project report and associated figures have been developed in a presentation format, instead of as a draft manuscript. The previous Task summaries and figures have taken this approach and

are considered part of this report. All of these figures (or any possible modifications to them) and any of the data sets associated with this project are available in electronic form upon request.

Added value provided by the MODIS CMG snow-cover product:

The differences between the MODIS snow distributions and those produced by the regional climate model are significant in terms of their location and character. The model produced a more uniform snow cover, and in some cases the regional climate model had snow where MODIS did not, and in other places MODIS had snow where the model did not. In general I think it is reasonable to assume that the MODIS snow cover is more correct than that simulated by the model. This is true of both the general extent and the more "patchy" character of the MODIS data. Model errors in temperature and precipitation (as seen through the comparison with the station observations) are likely to lead to errors in snow cover distribution. In addition, the model does not directly account for subgrid snow cover distributions as part of snow accumulation processes. Thus, from these perspectives, we expect the MODIS distributions to be more realistic.

We also recognize that there are some aspects of the MODIS snow data that are very likely incorrect. As part of these simulations two significant approximations where made in order to use the MODIS snow data: 1) all cloud-covered areas were defined to be snow-covered areas, and 2) daily data was produced by linearly interpolating the 8-day composite values in time.

The temperature and precipitation difference plots have shown the two different snow-cover representations lead to important differences in these fields. Air temperatures changed by as much as ±5 ∞C, and precipitation amounts changed by as much as ±3 mm day^{-1}.

Significant differences were found in the temperature and precipitation fields of the eastern and south-eastern United States. These areas are either on the eastern United States snow/no-snow boundary or significantly down-wind of the eastern snow-covered area. These temperature and precipitation fields highlight how up-wind snow distributions can influence down-wind areas where there is no snow. They also highlight the importance of realistic snow-covered area representations such as those provided by the MODIS snow products.

Recommendations for improvement of the MODIS CMG snow-cover product:

In general, the November 2000 data used as part of this project are much improved over the April 2000 data used as part of the previous project. There are still some unrealistic features in the daily data, such as the speckled snow-cover distribution in the southern United States (including Florida). These are gone from the 8-day composite data sets.

A fundamental difficulty in using both the daily and 8-day composite data sets is the presence of missing data due to clouds. There needs to be some method developed to get around this problem. One possible solution is to use additional information (like data from a sensor that can see through the clouds) to fill in the missing data. A less restrictive cloud mask may also allow the mapping of more snow cover.

Snow Map Accuracy Investigations

Numerous comparisons with NOAA operational data sets have been accomplished. These results have been presented at scientific meetings during this reporting period, and accepted for publication (see list of presentations and publications). The pre-publication versions of the papers cited below are available on request. While MODIS compares favorably with the operational products, the MODIS maps show more snow cover than do the operational maps. This is partly because MODIS maps all snow cover present (during an 8-day compositing period), and the other maps do not, but also partly because of problems with our algorithm that we have not yet worked out. Analysis continues.

Public Release of Snow Products

Public release of the MODIS snow products (MOD10_L2, MOD10A1 and MOD10A2) was made on 13 September 2000. Prepared documentation for public release of MODIS snow products.

Problems

The group has been plagued with numerous workstation problems. The most recent series of problems began when the workstation, Icecap, was incapacitated during a move in bldg. 22. Several weeks of effort have been involved to get Icecap running, and to keep it running. As of now, work toward keeping Icecap going is continuing. This has resulted in the loss of up to four weeks of efficient work for the group. The problem continues…