



Polar Stratospheric Clouds Detectability Test Plan



UPOS-BH3-06

25 February 2004

Version 1.0

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1 Introduction

Polar stratospheric clouds (PSCs), which are often present at high latitudes during winter, pose a number of threats to operations. They form in the stratosphere from near the tropopause to altitudes of roughly 30 km. When optically thick, especially when viewed at long slant look angles, they have the potential to inhibit operations that require optical transmission in the atmosphere, including missile detection and kill, satellite -based intelligence, and satellite -based atmospheric temperature profiling.

PSCs are common at high southern latitudes and occur intermittently in the Northern Hemisphere, persistently reducing optical transmission over large areas. The principal component of PSCs is nitric acid (HNO_3) trihydrate (NAT), and PSCs form when the *in situ* temperature drops below the NAT saturation temperature (T_{NAT}), which is a function of the HNO_3 and H_2O vapor pressures. PSCs are also composed of a ternary mixture of HNO_3 , sulfuric acid (H_2SO_4), and water and also water ice at colder temperatures. *Hanson and Mauersberger [1988]* provided a detailed description of the phase diagram of the $\text{HNO}_3/\text{H}_2\text{O}$ system. Moreover, the documented stratospheric trends of decreasing temperature and increasing HNO_3 and H_2O suggest that PSCs will occur more frequently and with greater optical depth in the future.

We have developed a forecast model , based on standard Air Force Weather Agency (AFWA) MM5 model runs, that computes the probability of PSC existence by comparing forecast *in situ* temperatures with T_{NAT} derived from either satellite climatologies of HNO_3 and H_2O or assuming constant mixing ratios, which are typically very uniform in the polar lower stratosphere. Several climatologies have been considered. A zonally averaged monthly HNO_3 climatology has been taken from CLAES measurements at 16 levels throughout the stratosphere and lower mesosphere. For H_2O , we have used two climatologies. The first is from the POAM satellite at 16 stratospheric levels, from November through March. The other is from HALOE/MLS, analogous to the CLAES HNO_3 climatology. We have also experimented with using fixed mixing ratios (e.g., 10 ppbv HNO_3 and 5 ppmv H_2O).

MM5 temperatures are generated on six pressure levels, from 150 to 10 mb. Temperature and trace gas fields are uniform in the polar lower stratosphere, so this relatively coarse altitude resolution is sufficient to capture the vertical structure.

Comparisons with solar occultation measurements made by the Polar Ozone and Aerosol Measurement (POAM) III satellite instrument during the Southern Hemisphere 2003 winter have shown that the model does an excellent job predicting when and where PSCs will occur.

2 Applicable Documents

"*Polar Stratospheric Cloud Detectability Functional Requirements Document*", Linda. M. Burke, William H. Swartz, Michael A. Kelly, Steven A. Lloyd and Bruce A. Toth, February 20, 2004.

"*Polar Stratospheric Cloud Detectability Test Report*", TBD.

3 Scope

The Polar Stratospheric Cloud Detectability test strategy divides the evaluation into two parts: 1) accuracy and correctness of computations and 2) general operation. The Polar Stratospheric Cloud Detectability test procedures will comprise tests of a selected set of cases that fully evaluate these parts. For completeness the test procedures are included in this document in Appendix B. The test procedures and the requirements cross-reference matrix will also be included in the *Polar Stratospheric Cloud Detectability Report*, a UPOS deliverable document.

3.1 Accuracy and Correctness of Computations

The Polar Stratospheric Cloud Detectability software uses as input MM5 forecast files. To verify that the UPOS version of the Polar Stratospheric Cloud Detectability software duplicates the accuracy and correctness of the original APL version, the UPOS software will be executed using the same data and the output results compared.

3.2 General Operation

The Polar Stratospheric Cloud Detectability software must read MM5 forecast data from an input file *ll.d1.yyyymmddhh.nc*, where yyyy = year, mm = month, dd = day of month, and hh is forecast hour, and a series of Postscript and JPEG files which contain temperature, water vapor, and PSC probability calculations on 24 pressure levels from 1001 to 10 mb (t_tnat and psc only on top 6 levels, from 150 to 10 mb) as output. Program execution is controlled via an executive script to generate the desired output results. Tests will be executed to ensure that the proper normal outputs are generated given the proper inputs. In addition, the executive script and Polar Stratospheric Cloud Detectability software will be tested for the correct identification and output of error messages given erroneous input or configuration.

The structure of the netcdf file (obtained by executing “ncdump –h ll.d1.yyyymmddhh.nc”) is shown in Table 1.

netcdf ll.d1.yyyymmddhh	
dimensions	ntim = 1 nlons = 360 nlats = 90 nlevs = 24
variables	double LAT(nlats) LAT:units = "degrees" double LON(nlons) LON:units = "degrees" double PRES(nlevs) PRES:units = "pascals" double TMP(ntim, nlevs, nlats, nlons) TMP:units = "kelvin" ; double MIXR(ntim, nlevs, nlats, nlons) MIXR:units = "kg/kg" ;

Table 1

4 Test Configuration

The Polar Stratospheric Cloud Detectability software will be installed on the UPOS/SWXS User Support System. The software will execute on the UPOS/SWXS User Support System and remotely access a copy of the input parameter files located on the UPOS/SWXS Development System. Output text will be written to the UPOS/SWXS User Support System.

5 Resources

The following resources are necessary for proper operation and completion of the tests:

- Specific input MM5 forecast file that was previously used at APL in the Polar Stratospheric Cloud Detectability software must reside on the UPOS/SWC Development System.

6 Reporting Requirements

A test report will be produced containing a copy of the as-run procedures with pass/fail indications.

Appendix A - Acronyms and Abbreviations

Acronym	Definition
AFWA	Air Force Weather Agency
APL	Applied Physics Laboratory of Johns Hopkins University
ASCII	American Standard Code for Information Interchange
CLAES	Cryogenic Limb Array Etalon Spectrometer
COE	Common Operating Environment
FTP	File Transfer Protocol
GRIB	Gridded Binary
GSFC	Goddard Space Flight Center
HALOE	Halogen Occultation Experiment
IDL	Interactive Data Language
JHU	Johns Hopkins University
LAN	Local Area Network
MLS	Microwave Limb Sounder
MM5	Fifth Generation Mesoscale Model
NAT	Nitric Acid Trihydrate
netCDF	Network Common Data Form
NWP	Numerical Weather Prediction
PNG	Portable Network Graphics
POAM	Polar Ozone and Aerosol Measurement
ppbv	Parts per billion by volume
ppmv	Parts per million by volume
PSC	Polar Stratospheric Cloud
SD	Space Department of the Applied Physics Laboratory
SDP	Software Development Plan
Tcl	Tool Command Language
Tk	Toolkit
UPOS	University Partnering for Operational Support
UTC	Coordinated Universal Time

XDR

External Data Representation

Appendix B - Test Procedures

1 Accuracy and Correctness of Computations

1.1 Polar Stratospheric Cloud Detectability

Objective: Verify that the program calculates forecasts of PSCs in the lower stratosphere using AFWA MM5 weather data.

Setup:

1. Provide input ncdf file that has MM5 forecast data.
2. Run the existing APL version of the program and produce results for purposes of comparison.

Procedure:

1. Run program and verify that the program correctly calculated a series of Postscript and JPEG files which contain temperature, water vapor, and PSC probability calculations on 24 pressure levels from 1001 to 10 mb (t_tnat and psc only on top 6 levels, from 150 to 10 mb) by inspecting the output in the JPEG output file generated by the APL version of the program.

Results:

Pass/Fail: Program results must agree with the APL version.

2 General Operation

2.1 Input Files

2.1.1 No input MM5 netcdf file

Objective: Verify that the program detects lack of an input MM5 netcdf file, gives an error message, and terminates gracefully.

Setup: 1. Remove the input parameter file from the data directory located in the base installation directory.

Procedure: 1. Run the program and verify by inspecting the error file that the program correctly reports no setup file exists.

Results:

Pass/Fail: Program must produce an error message describing the problem.

2.2 Output Files

2.2.1 Create all requested output files

Objective: Verify that the program produces the proper set of output files.

Setup: 1. Execute the program given a valid input MM5 forecast file.

Procedure: 1. Run the program and verify by inspecting the output files that the program correctly produces results for the time range specified.

Results:

Pass/Fail: Program must produce JPG files for the Polar Stratospheric Cloud Detectability process.
1. There should be no error messages produced in the error log file.
2. There should be jpg forecast file.

Appendix C - Requirements Cross-Reference Matrix

Verification methods are (A) analysis, (I) inspection, (D) demonstration, and (T) test.

Requirement Paragraph	Test Procedure Paragraph	Verification Method
2 Executive Script		
2.1 Functional Requirements		
2.1.1 manage the execution	All tests	T
2.2 Interface Requirements		
2.2.1 produce status and error messages	All tests	T,D
2.2.2 editable using at least one UNIX compatible editor	All tests	D
2.3 Operational Requirements		
2.3.1 run under the Solaris operating system	All tests	T,D
2.3.2 begin execution upon direction	All tests	T,D
2.3.3 terminate upon direction	All tests	T,D
3 Polar Stratospheric Cloud Detectability		
3.1 Functional Requirements		
3.1.1 ingest MM5 netcdf weather data	1.1	T,D
3.1.2 produce polar stereographic maps	2.2.1	T,D
3.1.3 use color overlays to show PSC probability, temperature, temperature relative to T_{NAT} , and water vapor mixing ratio	2.2.1	T,D
3.1.4 Output jpg images of probabilities of PSC occurrence	2.2.1	
3.2 Interface Requirements		
3.2.1 ingest MM5 weather data	1.1	T,D
3.2.2 produce JPEG files which contain temperature, water vapor, and PSC probability calculations on 24 pressure levels from 1001 to 10 mb (t_tnat and psc only on top 6 levels, from 150 to 10 mb).	2.2.1	T,D
3.3 Operational Requirement		
3.3.1 run under the Solaris operating system	1.1	T,D
3.3.2 execute upon direction of the executive script	1.1	T,D