Date: October 31, 2024

Document: LENDPaperSoftware_README_Ver2: Updated from Version 1 document, below

Description: Document includes a description of supplemental study that supports the Paper below results by predicting the WEH observation of PSRs and the influence of PSR areal density on instrumental blurring of PSR WEH. The study shows evidence of PSR Hydrogen enhancement to 71 S. The new software system Software/WEH_vs_MaxTemp.pro is described below.

Edited README from Version 1, below

Date: July 17, 2024

Document: LENDPaperSoftware_README: Summary of archived software programs and how to access and run, version 1:

Both the data and software repositories are available at:

10.5281/zenodo.10027812

In support of Planetary Science Journal Paper titled:

"*Evidence for Widespread Hydrogen Sequestration within the Moon's South Polar Cold Traps*, T.P. McClanahan , A.M. Parsons, T.A. Livengood, J.J. Su, G. Chin, D. Hamara, K. Harshman, R.D. Starr"

Corresponding Author and Archive Developer:
Timothy P. McClanahan, D. Sc.
Build. 34, Rm E108
NASA /Goddard Space Flight Center
Greenbelt MD, 20771
Contact: timothy.p.mcclanahan@nasa.gov

The following document reviews the software repository.

LENDPaperSoftware_README.pdf

The software has been approved for public release by NASA's software release authority as documented in the top level of this archive.

NASA Open Source Agreement: NOSA GSC-19191-1.pdf

Note: To run this archives software you will need to acquire an Interactive Data Language (IDL) license. The software was developed using IDL 8.8.3. An IDL license can be purchased or obtained from:

https://www.nv5geospatialsoftware.com/Products/IDL

Description:

All of the software in this archive is in this **LEND_Paper_Software.tar.Z** file associated with this archive.

1. Download the LEND_Paper_Software.tar.Z

   To unpack the archive the following Unix commands will unpack it.

   ```
   > uncompress LEND_Paper_Software.tar.Z
   > tar -xvf LEND_Paper_Software.tar
   ```

Note that the software assumes the following local directory configurations and settings to run.

1. Setting up your software environment

The software in this package assume you have a similar directory as below for reading and writing data products.

<*path*>:

```
    /Software    ; Directory contains the software repository w several programs
    /Data        ; Directory contains data directories for reading and  writing
        /CSETN_FOV_Model    ; Contains CSETN and SETN field of view datasets
        / CSV    ;  Comma,separated, variable files from several paper results
        /CountsMaps    ;  Count rate, statistics,  maps for mission years
        /DerivedMaps   ;  Processed maps, WEH, neutron suppression, stats
        /Figures       ; Figures derived for the paper
```

/LRO_Maps ; Max temp, topo, slope azimuth angle, illum maps
/MissionLists ; Listings of LEND PDS files required for mission coverage maps
/SaveSets ; IDL savesets used in the paper, color table, etc.

Local Settings:
In the ./Software directory is a command procedure called "dirsets" listed below. That file needs to be edited to define where needed directories are located on your platform. dirsets is called at the start of each program to define these directories.

```
dlddir = '/Volumes/OWC HD/LEND_UA_Data/'        ; Where you store your LEND DLD files
dir = '~/merrimac/LENDproc/LEND_Paper/'         ; root directory for Data and Software dirs
CSETN_FOV = dir + 'Data/CSETN_FOV/'             ; CSETN_FOV directory
CountsMaps = dir + 'Data/CountsMaps/'           ; Counts Maps dir
DerivedMaps = dir + 'Data/DerivedMaps/'         ; DerivedMaps dir
LRO_Maps = dir + 'Data/LRO_Maps/'               ; LRO Maps dir
SaveSets = dir + 'Data/SaveSets/'               ; SaveSets dir
MissionLists = dir + 'Data/MissionLists/'       ; Listings of LEND PDS files for coverage maps
Software = dir + 'Software/'                    ; Software directory
Figures = dir + 'Data/Figures/'                 ; Figures files
CSV = dir + 'Data/CSV/'                         ;  CSV files
Data = dir + 'Data/'                            ; Data Directory
```

> ./Software directory. The listing below provides a brief abstract for each program and its output products developed in the paper. Follow the configuration guidelines in this archives root directory to set up your local environment and to download LEND, LOLA and Diviner products.

LEND Paper Software
./Software Directory Listing: Interactive Data Language (IDL) Programs and abstracts

BandPass.pro – Generates the Uncollimated filter profile described in Section 2.1.
- Objective: The profile defines CSETNs expected spatial response to uncollimated neutrons as a function of distance km from nadir at 0.0 km. The profile is extrapolated to a 2-D kernel in CSETN_FOV_Kern function at the start of CSETN_Map70.pro.

Cabeus_Haworth_PSR_Profiles.pro – Generates PSR longitude profiles, Figs. 5a1,4 and 5b1,4
- Objective: The program validates the methods and the bandpass filter. Reads in CSETN neutron suppression, WEH wt%, topography and maximum temperature maps to isolate

and plot co-registered profiles of CSETNs observed neutron suppression and plots of correlated profiles along a 150 km long longitude profile through Cabeus and Haworth PSR's. The study correlates areas of neutron-enhanced flux and neutron-suppressed flux to topography and maximum temperature.

ColdTrapAnal.pro – Generates Figs 7 and 8.

- Objective: The study generates Figure 7, the PSR vs non-PSR WEH wt% latitude band comparison study. The program 1) makes a comparison of WEH in PSR and non-PSR surfaces as a function of 2 deg latitude bins to 77 S, Fig. 7 and 2) Correlates the PSRs WEH observations to their diameters in Fig 8 scattergram. Fig 8 shows the correlation between PSRs diameter vs. their observed WEH. Two consistent linear correlations from two latitude band studies infer that the PSRs are similarly hydrogen enhanced. Instrumental blurring causes the linear correlations.

CSETN_Map70.pro - Generates CSETN maps for Fig 3. The maps have the full latitude extent to 70 S that are used in all subsequent studies, poleward of 70 S:
Objective: Fig. 3 maps a) CSETN Collim WEH, b) CSETN Collim statistical uncert. c) CSETN Uncollim WEH d) CSETN Suppression. Subtracts the Uncollim. Map. These maps are correlated to topography and max. temperature maps for the paper.

Civitisct.pro – Generates civitis color table used in Fig. 3ad maps

- Objective: Generates and loads the civitis color table for Figs 3ad.

csetn_map82_Fig.pro - Generates Figs. 3ad maps

- Objective: Generates paper Figs 3ad, four maps to 82 S: a) CSETN Collim WEH, b) CSETN Collim statistical uncert. c) CSETN Uncollim WEH d) LOLA topography w PSR outlines in *olive.* Map values for color bars are read from this program and included in the final figure Fig 3ad.

DilatePSR_n_WEH_Props123.pro – Produces Figs 9a, b, and text files in CSV

- Objective: Demonstrate Properties I), II), and III) in the neutron emission flux (instrumental blurring of hydrogen enhanced PSR). Applies image processing operators to the binary PSR map to generate Figs 9a, b. Study shows Property I, II, III in several independent latitude bands poleward of 77 S. Property II) is shown in the enhanced WEH within PSR areas. Property III) is shown in the instrumental blurring of PSR areas. The study shows the expected WEH in PSR and non-PSR areas is reduced as the area fraction of PSR in CSETN's FOV is reduced with distance from any PSR areas. Property I) is demonstrated as the lowest expected WEH is correlated to the greatest distances from PSR areas.

gcr_correlate2.pro

- Objective: Supporting study, as a model to demonstrate the positive correlation between collimated and uncollimated neutrons. This study determines if a positive correlation coefficient exists between collimated and uncollimated neutrons. A positive correlation coefficient between collimated and uncollimated neutron count rate variances enables the subtraction of their covariance when their variances are added quadrature. See paper section 2 for discussion, SOM Appendix B for the corresponding analysis and results.

GenSlopeAziAngle.pro

- Objective: This program generates the slope azimuth angle map from the LOLA topography map.

HypothesisInstrumentalBlurring.pro

- Objective: Generates the Figure 1 PSR / non-PSR profiles that demonstrate the hypothesis that if the PSRs neutron suppression is widespread a widespread phenomenon then their joint detection should be correlated to the mixing ration of PSR to non-PSR areas within the field-of-view.

latlonprofiles.pro

- Objective: Study generates latitude and longitude profiles of CSETNs south polar coverage based on mission phase. Results are used in Fig. S2ab.

lend_sp_pds_dld_mapping.pro

This mapping is the first program to be run to generate your own LEND maps.

- Objective: Generates the LEND CSETN counts, count rate and variance maps. Input files are the text listings in files: fname: e.g. "./10+yr_mission.txt" contains the list of calibrated LEND DLD files for each day that are mapped for the paper during CSETNs operations over the ten year span. Internal flags for each record state if a given detector observation is valid or not. Section 2 describes the mapping process. The map at 10.5 years of accumulated coverage is analyzed in the paper.

makepsrmap.pro – generates binary PSR map used in all studies.

- Objective: Generates the Fig. S1 maps to 80 S. Provides a listing of all four hundred and sixty eight PSR's > 80 S, mean lats, mean lons, areas and diameters. Maps are made at the 2 km x 2 km polar pixel resolution. *Note that this listing does not include station keeping zones defined in the paper.

NeutronEnhanced.pro – Generates Figures 4a, 4b

- Objective: Maps where there is a low expectation of water-ice and quantifies the contrasting geophysical properties of neutron enhanced areas relative to neutron suppressed areas. Quantifies that neutron-enhanced areas have significantly lower PSR areal density than neutron suppressed areas. The software analyzes CSETN's collimated neutron suppression map to identify and evaluate the neutron-enhanced pixel distribution for latitudes poleward of 82 S. Low PSR areal densities are consistent with Property I) areas being low WEH, low PSR areal density, warm and are biased towards equator-facing sloped surfaces.

PSR_WEH_vs_Temp.pro – Generates Figs 6a to 6d

- Objective: Analyzes Haworth, Shoemaker and Faustini PSRs internal WEH and correlates their internal WEH distributions to their maximum temperature distributions.

WEH_vs_Temp.pro

- Objective: This supplemental study develops a WEH predict map based on the PSR areal density. We use the map to understand the influence of the PSR areal density on WEH observations. We convolve the binary PSR map with a 30 km diameter disk that represents CSETN's collimated field-of-view (FOV). At each pixel we count the number of PSR pixels in the disk and normalize count by the disk area (149 pixels), thus defining the FOV(PSR%). For latitude studies poleward of 71 S we map the observed WEH vs FOV(PSR%). The studies all show that there an increase in expected WEH as the FOV(PSR%) increases, consistent with the instrumental blurring of PSR WEH. We also show that for all FOV(PSR%) = 0% pixels (areas with no PSR pixels in the FOV) the pixel distribution is only weakly correlated to maximum temperature. So, Maximum temperature does not explain the enhanced WEH observations in the PSR. Results strongly support the associated paper, McClanahan et al, 2024.

Shoemaker_Faustini_PSR_Profiles.pro – Generates PSR profiles, Figs 5c1,4 and 5d1,4

- Objective: Reads in CSETN neutron suppression, WEH, topography and temperature maps to produce co-registered profiles of CSETNs observed suppression along a 150 km long longitude profile through Shoemaker and Faustini PSRs. The study correlates areas of neutron-enhanced flux and neutron-suppressed flux to topography and maximum temperature.