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| LEAF-DEC Landscape Evolution and Forecasting Toolbox – Digital Earth Canada |  |
|  | User Requirements |

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## Introduction

The Landscape Evolution and Forecasting (LEAF) Toolbox is a computer application capable of producing geo-coded raster layers for a set of vegetation biophysical parameters from either Sentinel 2 Multispectral Imager (MSI) , Landsat 8 Operational Land Imager (OLI) satellite imagery, Landsat 7 Enhanced Thematic Imager Plus or Landsat 5 Thematic Mapper. LEAF is bow being implemented within the Government of Canada Digital Earth Canada (DEC) pilot, hereafter LEAF-DEC.

The purpose of this document is to provide the user requirements for the LEAF-DEC.

### Vegetation Biophysical Parameters

Required vegetation biophysical parameters have been identified by the SEN4SCI user consultation exercise (Malenovsky et al. xx) ,the Global Climate Observing System (GCOS, 2016) and the Government of Canada’s Space Earth Observations Requirements (CSA, 2021) (Table 1). The spatial, temporal and thematic performance requirements of these parameters are given in Table 2.

Table . Definition of vegetation biophysical parameters produced by LEAF. Rows in green are core requirements for the Government of Canada, rows in blue are requirements from GCOS, and rows in grey are inputs included as output products.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Abbrev. | Definition | Units | Range |
| Directional hemispherical albedo | Albedo | Ratio of upper hemisphere reflected to incident direct solar illuminaton at local overpass time. | ratio | [0,1+]  May exceed one exceptionally |
| Fraction absorbed PAR | fAPAR | Fraction of incident PAR absorbed by vegetation at ~10am local standard time for direct solar illumination. | fraction | [0,1] |
| Fraction cover | fCoverover | Fraction of canopy cover projected on local horizontal datum. | fraction | [0,1] |
| Hemispherical directional reflectance | Rho | Ratio of sunlight reflected in direction of sensor to incident illumination at local overpass time | ratio | [0,1+]  May exceed one exceptionally |
| Land Cover | LC | Land cover. | NALCMS legend | 19 classes |
| Leaf Area Index | LAI | Have the total foliage surface area per unit ground area projected on local horizontal datum. | M2 foliage/m2 horizontal ground area | 0-20 |
| Leaf chlorophyll content | Cab | Mass of chlorophyll a and b per unit LAI. | gG chlorophyll a+b/m-2 half foliage surface area | 0-100 |
| Leaf water content | Cw | Mass of H20 per unit LAI. | g G H20/m-2 half foliage surface area | 0-10 |

Table . User requirements for biophysical parameters, Ordinal thematic requirement corresponds to estimates within a user defined mapping region that, after bias correction, meets threshold requirements (i.e. relative ranking of estimates is correct).

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Param. | Spatial (ha) | | | Temporal | | | Thematic | | |
|  | Base | Thresh | Goal | Base | Thresh | Goal | Base | Thresh | Goal |
| Albedo | 25 | 6.25 | 0.5 | Peak | 16d | 1d | Ordinal | (0.01,10%) | 0.005, 5% |
| Cab | 10 | 1 | 0.5 | Peak | 30d | 10d | Ordinal | 20 | 10 |
| Cw | 10 | 1 | 0.5 | Peak | 30d | 10d | Ordinal | 0.2 | 0.1 |
| fAPAR | 10 | 1 | 0.5 | Peak | 5d | 1d | Ordinal | (0.1,10%) | 0.05,5% |
| fCover | 10 | 1 | 0.5 | Peak | 30d | 10d | Ordinal | (0.2,20%) | 0.1,10% |
| LAI | 10 | 1 | 0.5 | Peak | 30d | 10d | Ordinal | (1,20%) | 0.5,10% |
| LC | 10 | 1 | 0.5 | <5yr | 5yr | 1ya | 20% | 15% | 5% |
| Rho | 10 | 1 | 0.5 | Peak | 5d | 1d | 5%+0.005 | 5%+0.005 | 5%+0.005 |

### System Output

The system is required to output user requested mosaic vegetation products in cloud accessible georeferenced raster format conforming to CEOS ARD specifications (Level 3A) or as cloud accessible tables that can be parsed using open source modules such as Pandas or GEOJson. The mosaicking rules should permit restriction of the product to a single Level 2A input so that effectively the output corresponds to a Level 2B geophysical product. Table output is targeted for debug, development and scientific studies.

### System Loading

The system should be able to sustain parallel service requests (Table 3). Denials of service at a threshold or goal level should be at the point of request rather than upon point of failure. Note that output scenes can exceed input scenes due to the use of scene forecasting and prediction.

Table . System load requirements.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Category | Baseline | Threshold | Goal | Description |
| Number of systems running | 2 | 10 | 100 | Number of deployed systems on single cloud service. |
| Number of users per system | 10 | 100 | unlimited | Number of registered users |
| Maximum number of parallel service requests per system | 2 | Max(10,1% of user base) | Max(100,10% of user base) | Number of active service requests within system. |
| Maximum number input of L1A scene per request | 1000 | 1500 | 1500 | Assumes processing begins at L1B. Number of scenes in one request (~1500 scenes cover Canada for one sensor; 5000 ensures coverage from both sensors and territorial water). Includes scenes produced by temporal interpolation. |
| Maximum number output scenes per request | 1000 | 1500 | 5000 | Includes scenes produced by temporal interpolation. |

### System Latencies

Service requests should be ingested, verified with respect to data, storage and compute availability (e.g. request satisfies system load requirements) and accepted within 10minutes threshold (5minutes goal). For accepted requests, final products should be saved to a designated archive within 24hrs threshold (8 hrs goal) of attempted resource allocation. Table 4 provides a list of latencies for a single product. Noinally, the same latencies apply to requests for table output spanning multiple products. The list includes latencies that are asynchronous or may not be required for a given instance, such as L2A Product generation. The list does not explicitly envision system caches for input and output products.

Table . System latency requirements (hours:minutes). Note that some processes may be asynchronous or not required (e.g. L2A Product generation).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Service | Trigger | Baseline | Threshold | Goal | Description |
| Product request accepted | User submits product request | 0:10 | 0:10 | 0:10 | System verifies it has compute and data resources. |
| Data Ingest | Product request accepted | 12:00 | 8:00 | 3:00 | Required data is ingested and staged for compute |
| L3B product generated | Data Ingest completed. | 4:00 | 2:00 | 1:10hr | Generation of L2A products from L1A input |
| L3B Product archived | L3A Product generated | 1:00 | 1:00 | 0:10 | Intermediate L3A produyct arrives at archive |
| Training Database Produced | User submits product request | 2:00 | 2:00 | 1hr | Training data generated as required using simulations and input data. |
| Calibration of inversion algorithm | Training database completed | 2:00 | 1:00 | 0:10 | Inversion algorithm calibrated using training data. |
| Initial estimation of biophysical parameters | Inversion algorithm calibrated | 1:00 | 1:00 | 0:10 | Initial products estimated using inversion algorithms. |
| Regularization of inversion algorithm | Initial estimation completed | 1:00 | 1:00 | 0:10 | Inversion algorithms revised using initial estimates and ancillary data. |
| Product generated | Inversion algorithm regularized | 1:00 | 1:00 | 0:10 | Final product estimated using revised inversion algorithms. |
| Product archived | Product generated | 12:00 | 8:00 | 3:00 | Final product arrives at dedicated archive. |
| Total |  | 33:00 | 22:10 | 8:00 |  |

### System Resources

Resources are to be provisioned by free and open access on local compute and as a non-proprietary cloud service assuming the user has ensured appropriate access (via internet connections and/or cloud fees) to code and data repositories. Code and data repositories are to be open access and code repositories are to be free.

The user should have the option for executing the system at low, debug, nominal, high and maximum performance/cost levels. These levels are described in table 5.

Table . System resource levels.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Resource Level | Processing | Parallel | End-to-End Latency | Target |
| Low | Synchronous | No | unconstrained | Training, entry level users |
| Debug | Asynchronous | No or Yes | Baseline | Developers, acceptance testing |
| Nominal | Asynchronous | Yes | Threshold | Systematic production |
| High | Asynchronous | Yes | Goal | Episodic production, monitoring |
| Maximum | Asynchronous | Yes | unconstrained | Benchmarking |

### User Interface

The system is designed to provide an interactive operator interface (GUI) but should be extendable to an event based user interface driven by open geospatial consortium compliant messaging. The provision of an interactive user interface or visualization tools of intermediate products is outside the scope of this system. Table 6 list user interface requirements.

Table . User interface requirements.

|  |  |
| --- | --- |
| Requirement | Description |
| Execution | System execution should be via XML requests or other REST compliant requests. |
| Execution | The user should be able to halt and resume the system on command or by a trigger (e.g. maximum time, data availability) with behaviour specified within the service request. |
| Execution | A facility for visualizing outputs prior to export. |
| Control | Control and parameter inputs and system logs should be recorded in JSON files. |
| Control | A GUI (ideally integrated with the system execution GUI), should be provided for assembling and viewing relevant contents found in JSON files from direct input or input from standard sources (e.g. EXCEL , .txt, .csv tables and OGC compliant products and their headers). |
| Control | A GUI in the form of a LEAF toolbox should be provided for configuring tools, based on available code, for data processing. |
| Administration | Notifications should be provided regarding system operation, resource use and costing, and anomalies to a designed device (and optionally a GUI) in addition to JSON files. |
| Administration | When executed in debug mode the system should also expose intermediate results (training datasets, calibrated inversion algorithms, intermediate products) and supplementary information (as JSON files) to the user in a user provided debug archive. |

### Maintenance and Infrastructure

The system should be provided with an installer or clear installation instructions for deployment on desktop and mobile devices.

The system should be maintained remotely of users either by updates to code repositiories or cloud services. Revisions should preserve the ability to generate previous versions of outputs.

Modifications to data processing algorithms should not have an impact on data ingest and output functions.

The system should be able to operate at “Low” and “Debug” latency level on a desktop workstation with 32Gbytes free RAM and sufficient disk storage after installation of the system on both a Windows linux environment. Users are responsible for installation of ancilliary resources but these should be free or nominal in cost.

The system should be able to operate at “Low” , “Debug” and “Threshold” latency level on a cloud service assuming all inputs are not resident in low latency (<10minutes) cloud storage.

The system should be able to operate at “Goal” latency level on a cloud service assuming all inputs are resident in low latency (<10minutes) cloud storage and model recalibration is not required.

### Documentation and Help Resources

The system should be documented using GITHUB readable formats and indexed in GITHUB (even if the code repository differs). Documentation should include:

1. This document.
2. The System Architecture document.
3. Installation and uninstallation procedures including dependencies.
4. A verification test case and document.
5. A nominal use case document.
6. Debug and troubleshooting document.
7. GITHUB interactive comments and responses.

Help should support command shell and GUI operations. Command shell help should follow the practices of MATLAB. GUI help should involve a hover/pop-up access to GITHUB readable formatted descriptions.

### Use Cases

There are eight current use cases corresponding to service requests described in Table 7 that a system meeting Threshold requirements must meet. Systems meeting baseline requirements must satisfy scaled down versions of use cases corresponding to fewer input products.

The “available product” service requests corresponds to one output product for each input product. The “synthetic product” service request corresponds to multiple output products at a fixed interval based on forecasting using available input products and ancillary high temporal frequency MODIS satellite imagery.

The “nominal algorithm” service request corresponds to the use of an algorithm from the LEAF toolbox for product generation with calibration based on product or user information. The “calibrated algorithm” service request corresponds to the recalibration of an algorithm from the LEAF toolbox based on product or user data provided with the request.

Table . Use cases.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Use Case | Description | #Output Products | Output Product Type | Algorithm Type |
| 1 | Single product, no Interpolation nominal | 1 | Available | Nominal |
| 2 | Single product, no Interpolation calibrated | 1 | Available | Calibrated |
| 3 | Single product, Interpolation nominal | 1 | Synthetic | Nominal |
| 4 | Single product, Interpolation calibrated | 1 | Synthetic | Calibrated |
| 5 | Multiple products, no Interpolation nominal | (1,1000) | Available | Nominal |
| 6 | Multiple products, no Interpolation calibrated | (1,1000) | Available | Calibrated |
| 7 | Multiple products, Interpolation nominal | (1,5000) | Synthetic | Nominal |
| 8 | Multiple products, Interpolation calibrated | (1,5000) | Synthetic | Calibrated |

## References

CSA, 2021. Government of Canada Earth Observation plan 2021. Canadian Space Agency.

GCOS, 2016. The global observing system for climate: implementation needs. GCOS-200, World Meteorological Organization. accessed <https://library.wmo.int/opac/doc_num.php?explnum_id=3417> on January 20, 2021.

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