An Investigation of Cloud Cover Probability for the HysPIRI Mission Using MODIS Cloud Mask Data

August 26th, 2010

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2010 NASA summer Space Grant worked performed at Jet Propulsion Laboratory, California Institute of Technology
• Visible Shortwave Infrared Imager (VSWIR)
  – Specifications
    • 60 m spatial resolution
    • 145 km swath width
    • 380-2500 nm, 10 nm sampling
    • **19 day revisit**
      – Global seasonal coverage
      – Allows for better knowledge of the planets ecosystem changes
  – Current spacecraft orbit to fulfill coverage specifications
    • Sun Synchronous
    • 626 km LEO
    • 1030 UTCG Descending
    • 98° Inclination
Objectives

• Data Sampling Requirements from the Whitepaper:

  – **Baseline**: <20 day revisit to provide >60% seasonal and >80% annual coverage of the terrestrial and shallow water regions of the Earth.

  – **Minimum**: <20 day revisit to provide >50% seasonal and >70% annual coverage of the terrestrial and shallow water regions of the Earth

• A *probability science retrieval model shall provide a better understanding of the feasibility regarding these requirements.*
Inputs (2007-2009)

Overpasses
- STK data product
- Averaged seasonally
- 1 degree spatial resolution

Cloud Fraction
- Giovanni data product
- Averaged seasonally
- 1 degree spatial resolution

Data Collection Probability Model
**Overpasses**

- Defined: The number of times VSWIR’s swath comes in contact with the centroid of a 1x1 degree cell.
- Bounded -50m elevation map derived from NOAA ETOPO5 data

**Example**

- Uncolored: No overpasses
- **Blue: 1 overpass**
- **Aqua: 2 overpasses**

**Limitations**

- Partial swath-to-cell contacts not counted
- Produces artifacting in results.
- Remedied by increasing grid resolution at the cost of processing time.
Overpasses (2007)

Jul-Sep

Oct-Dec

Bounds of VSWIR Coverage

Plot Credit: Michael Mercury
Cloud Fraction

• Defined:
  – Count of cloudy and probably cloudy pixels divided by the total number of pixels.

• Compiled using Giovanni
  – Web-based application developed by Goddard
    • http://disc.sci.gsfc.nasa.gov/giovanni
  – Uses MODIS-Terra monthly (L3 data product MOD_M3)
    – 1x1 degree pixels
  – Day pixels only, averaged seasonally
Cloud Fraction
(Blue denotes high cloud fraction)
Probability Science Collection

Inputs

MATLAB Scripts
- Probability
  - Probability Calculations
  - Global Probability Map Creation
- Coverage
  - Surface Coverage Calculations
  - Distribution Plot Creation

Data Collection

Probability Model

Outputs

Probability Maps
- Seasonal
- Averaged across 3 years

Coverage Plots
- Seasonal
- Averaged across 3 years
• Probability of Science Retrieval: $P(s)$
  
  $P(s) = 1 - C^n$

  • $C$ = Cloud Fraction (Giovanni Output)
  • $n$ = Number of VSWIR overpasses (STK Output)

  • Example Calculation
    
    – 25% cloud fraction, 4 overpasses
    – $0.25 \times 0.25 \times 0.25 \times 0.25 = 0.0039$
    – $P(s) = 1 - 0.0039 = 99.6%$

• $P(s)$ is calculated for each 1x1 degree cell

• Any missing “C” values from the MOD_08 dataset are ignored.

Probability of Successful Retrieval Map for January - March

Probability of Successful Retrieval Map for April - June

Probability of Successful Retrieval Map for July - September

Probability of Successful Retrieval Map for October - December
• Fraction of the terrestrial surface viewed by VSWIR: \( F(s) \)
  – Random number generator with a threshold based on \( P(s) \) to determine if a point is cloudy or not
  – Weighted each grid point by the associated block area
  – Divided the clear area by the total area

• Simulated the entire grid 5000 times to create the probability mass function of \( F(s) \)
Coverage Plots (2007-2009)

Seasonal coverage never drops below 60%
Brazilian Amazon Seasonal View
Conclusions

• Based on initial results VSWIR meets the current baseline requirements of >60% seasonal and >80% annual coverage of the terrestrial and shallow water regions of the Earth.

• Future Work
  – Similar analysis completed for TIR
  – Model with higher than one-degree resolution MODIS-Terra data.
  – Increase the resolution of the STK grid.
Acknowledgements

National Space Grant Consortium

JPL Education Office

Linda Rodgers    Bogdan Oaida
Robert Greene    Sarah Lundeen
Carl Bruce       Diane Evans
Hannah Goldberg  Danielle Nuding
Michael Mercury

The data used in this effort were acquired as part of the activities of NASA’s Science Mission Directorate, and are archived and distributed by the Goddard Earth Sciences (GES) Data and Information Services Center (DISC).
Questions?

Initial Design -> Presentation -> Improved Design

Audience
Back-up Slides
Giovanni Cloud Fraction Data \rightarrow \text{Retrieval Probability Calculation} \rightarrow \text{Plot} \rightarrow \text{Repeat for all grid boxes} \rightarrow \text{Probability of Retrieval Map} \rightarrow \text{STK Overpasses}
Probability of Retrieval

Random Number Generator

Successful Retrieval

Weight by Area

Successfully Retrieved Area

Total Area

Repeat for all grid points

Histogram

×5000