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Southern Patagonia Ice Field, Chile

1976
2002

Glacier Jorge Montt

4 kilometers
Global Land Ice Measurements from Space

GLIMS primary goal: to determine the extent of Earth’s glaciers and the rate at which they are changing.

HOW?

> (1) Acquire global multispectral, stereo satellite images of all land ice near the end of the melt season;
> (2) Map the current global extent of land ice;
> (3) Complete GIS digital database of the world’s glaciers.

Principal observing instruments: ASTER (Advanced Spaceborne Thermal Emission and reflection Radiometer) and Landsat ETM+.

GLIMS is an international consortium of 23 regional centers
- ASTER and Landsat data acquisition
- Glacier mapping and monitoring
- DEM generation and application
- Glacier tracking and velocity
- Issues and future work
Data acquisition results from 1757 GLIMS STARs

Total scenes over glacier STARs: >25,087 L1A, >4107 L1B

- Scenes with current PGE version, scenecc <= 25%, and NOR or LOW VNIR gains
  - 6400 L1A, 2200 L1B
- Distributing 105 Landsat 7 scenes over glaciers spanning 2000-2001

IGARSS, 2002 June
Effect of ASTER gain settings over bright areas

Bands 1 2 3N = NOR
30 Oct. 2000

Bands 12 = HGH, 3N = NOR
28 Sep. 2000
Landsat 7 vs. ASTER

Landsat 7 pan, 2000-Jun-2

ASTER 321 Low gain, 2001-Sep-13

IGARSS, 2002 June
Algorithm and Database Development

- Radiometric correction: L1A Destripe and SWIR registration
- Glacier mapping and tracking algorithms
  - Glacier outline
  - Image classification
  - Ogive frequency analysis
- DEM generation and application in extreme, low contrast terrains
  - Image parallax development at USGS - Flagstaff
  - ASTER orbit and geometry model - Switzerland
- GLIMS Database design in beta (NSIDC – Boulder)
  - Testing data input with several examples from Region Centers (RCs)
  - Developing standardized and minimum input requirements for RCs
GLIMS interactive glacier mapping tool
Free tool in development at USGS Flagstaff

Platforms
- Windows
- Linux
- Solaris
- Other unix

Data Formats
- ASTER L1A and L1B
- NLAPS
- Fast Format
- Geotiff
GLIMS ASTER >
Southern Kenai

ASTER 321 (LOW gain)
2001-Sep-06
Monitoring changes in glaciers and glacier lakes

Tibet Himalaya

Bhutan Himalaya

Image is a portion of an uncalibrated ASTER Level 1A VNIR false-color image (321RGB), acquired on November 20, 2001

IGARSS, 2002 June
Gangotri Glacier, India

Courtesy of GLIMS South Asia Regional Center
Gangotri Glacier, India

Terminus retreat

1971
1962
1935
1891

Data source: Vohra, C.P., 1989, Gangotri Glacier, Indian Mountaineer, Mountaineering Foundation of India, New Delhi

Rate of change of area (km²/year), Between 1780 moraine and present terminus

Post-Little Ice Age response with stochastic variations?
Onset of climate warming/drying?
Onset of climatic warming/drying?
ASTER

Ice detection
The stagnating termini of glaciers in the Bhutan Himalaya. Glacial lakes have been rapidly forming on the surfaces of debris-covered glaciers worldwide during the last few decades.

Image is a portion of an uncalibrated ASTER Level 1A VNIR false-color image (321RGB), acquired on November 20, 2001.
Glacier ASTER reflectance spectra

VNIR bands 321 RGB  2001, Sep. 6

GLIMS GAINS:  123 LOW, 456789 HIGH
Glacier mapping using simple ratios of ASTER
band 7 (2.25) / band 1 (0.56) - 0.25 threshold  (Water mapped with NDWI)

VNIR bands 321 RGB  2001, Sep. 6 -- GLIMS GAINS:  123 LOW, 456789 HIGH

Rick Wessels 12/01

IGARSS, 2002 June
ASTER Ice detection

1973 inventory
1999 TM
2001 ASTER

1 km

Courtesy of Andreas Kaeaeb
Automated feature extraction

Llewellyn and Tulsequah glaciers, British Columbia
ASTER 321 RGB
2001 September 13,
ASTER VNIR gains= LOW and SWIR = HGH.

Water and glacier feature map from enhanced maximum likelihood supervised classification of three derivative bands (After Sidjak and Wheate, 1999)
ASTER DEM in shaded relief base image.
(Areas of no visible relief = null areas in standard ASTER DEM product).
Monitoring Supraglacial and Proglacial Lakes

The stagnating termini of glaciers in the Bhutan Himalaya. Glacial lakes have been rapidly forming on the surfaces of debris-covered glaciers worldwide during the last few decades.

Image is a portion of an uncalibrated ASTER Level 1A VNIR false-color image (321RGB), acquired on November 20, 2001.
Monitoring Supraglacial and Proglacial Lakes

Use ASTER data for:

- Measure lake turbidity
- Measure temperature for larger lakes
- Monitor changes in lake location and size

Ngozumpa Glacier, Nepal

2000 Sept. 28 ASTER L1B Image shows that lake has receded back to 1998 levels in year 2000.

Pre-2000 lake outlines from Benn and others, 2000

Lower brightness temperatures over lakes with higher turbidity

Small lakes prone to temp error because of large TIR pixel size.
Western British Columbia - ASTER RGB draped over ASTER derived DEM

View from top of Llewellyn Glacier

Destriped ASTER L1A version 2

VNIR bands 321 RGB

August 8, 2001

GLIMS GAINS:
123 LOW,
456789 HIGH

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Rick Wessels 10/01
Tasman glacier, New Zealand

Mt. Cook

25 km

Courtesy of Andreas Kaeaeb
ASTER  Ice velocities Apr 00 – Apr 01

Mt. Cook

Courtesy of Andreas Kaeab
ASTER Processing

**Level 1 A**
- destripe
  - coregister bands

**Level 1 B**
- Satellite position and LOS data

- generate GCPs
- bundle adjust
- match parallaxes
- orthorectify

- DEM

- Orthoprojection
  - match velocities

- GIS modelling

- Multispectral analysis

Input data:
- own process
- PCI Geomatica

Output data:
- product

Courtesy of Andreas Kaeaeb

IGARSS, 2002 June
Ice velocity / lake growth

1 km

Courtesy of Andreas Kaeaeb
Outstanding issues regarding ASTER for GLIMS

- Few GLIMS areas yet acquired outside of Antarctica and Greenland.

- 946 (27%) of the 3530 L1A scenes assigned a GLIMS DARID have been processed to L1B. GLIMS will modify all original STARs to request L1B for all areas.

- Many scenes have few clouds, yet have scenecc values > 30%.

- Few L1B images processed over glaciers (fewer than 32% of useful L1A scenes with proper gains and <25% Scenecc).

- Special Data Acquisition Request submissions not properly scheduled – Columbia Glacier, Swiss Alps, etc.
Conclusions

ASTER provides good detail of glacial surface features:
- Lower gain settings
- Higher spatial resolution across 3 bands

ASTER higher resolution, multispectral data can produce detailed glacier outline maps using supervised classification or simple ratios

ASTER stereo band provides DEM capability
- Still need to refine for extreme topography

Landsat 7 provides better repeat coverage over large areas, but has problem with saturation over snow and ice