Satellite Remote Sensing of Glaciers and Ice-dammed Lakes: Pragmatic Issues and Case Studies

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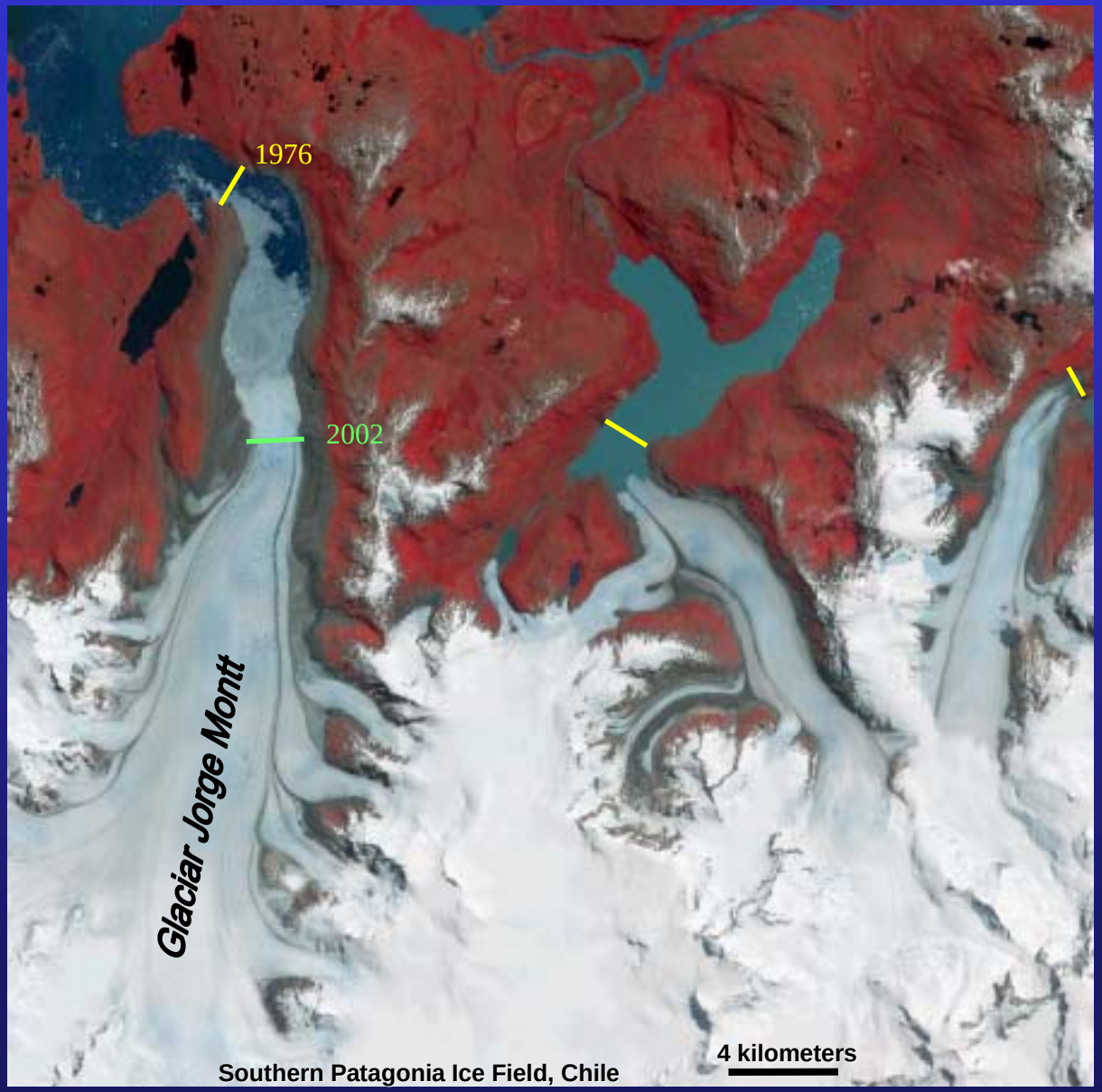

Southern Patagonia Ice Field, Chile

ASTER L1B 2002 Jan 18

www.GLIMS.org

IGARSS, 2002 June

Global Land Ice Measurements from Space

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- **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.

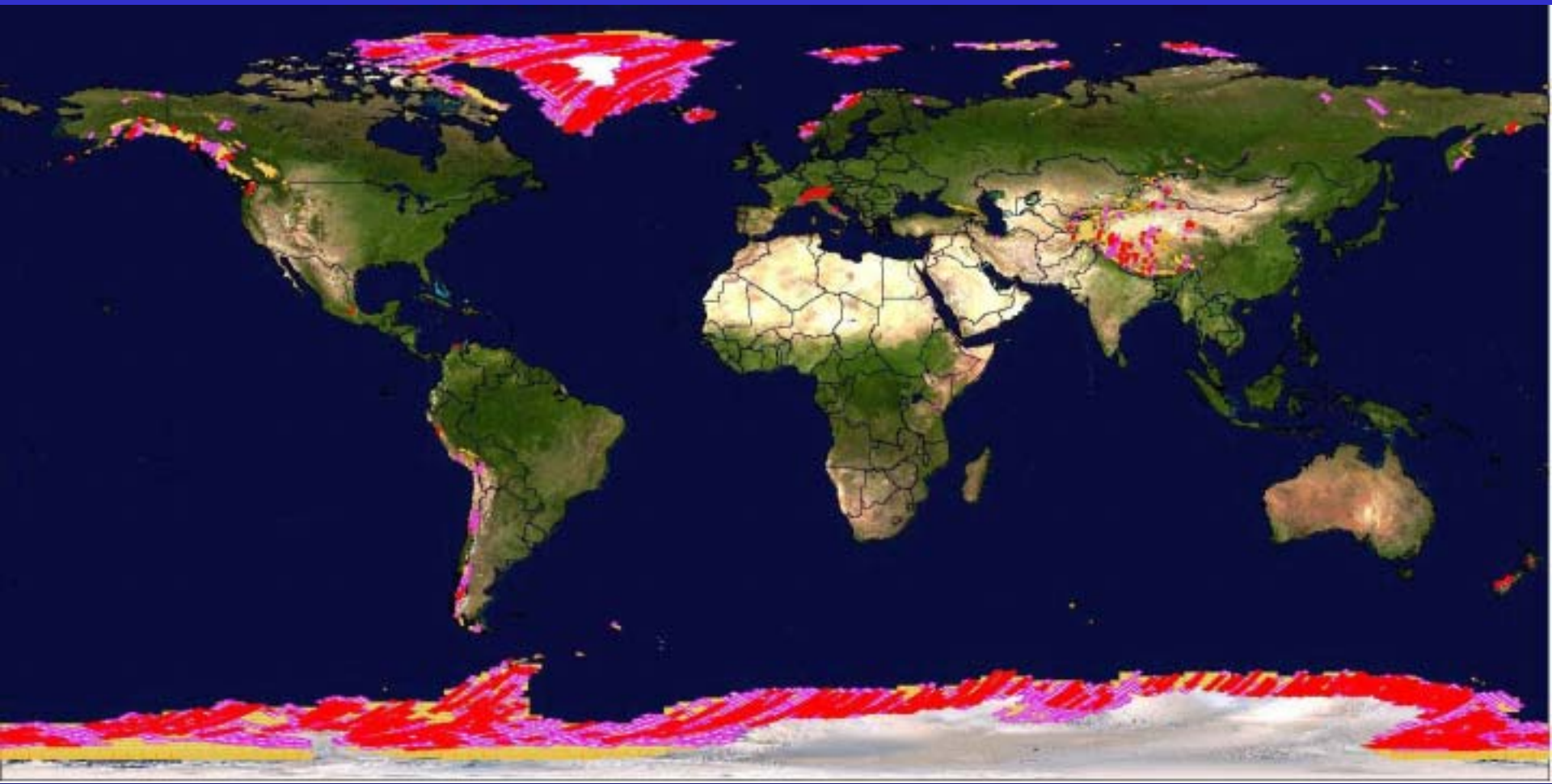
- **Principal observing instruments: ASTER (Advanced Spaceborne Thermal Emission and reflection Radiometer) and Landsat ETM+.**

- **GLIMS is an international consortium of 23 regional centers**

Content

- **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



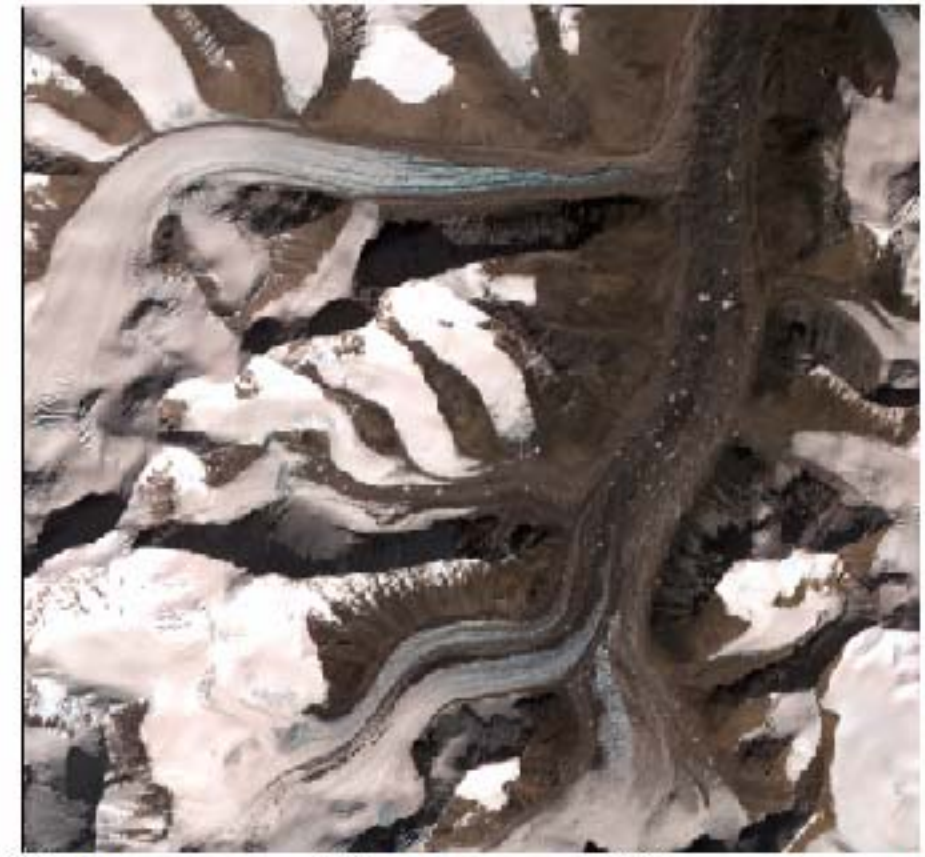
Total scenes over glacier STARs: >25,087 L1A, >4107 L1B

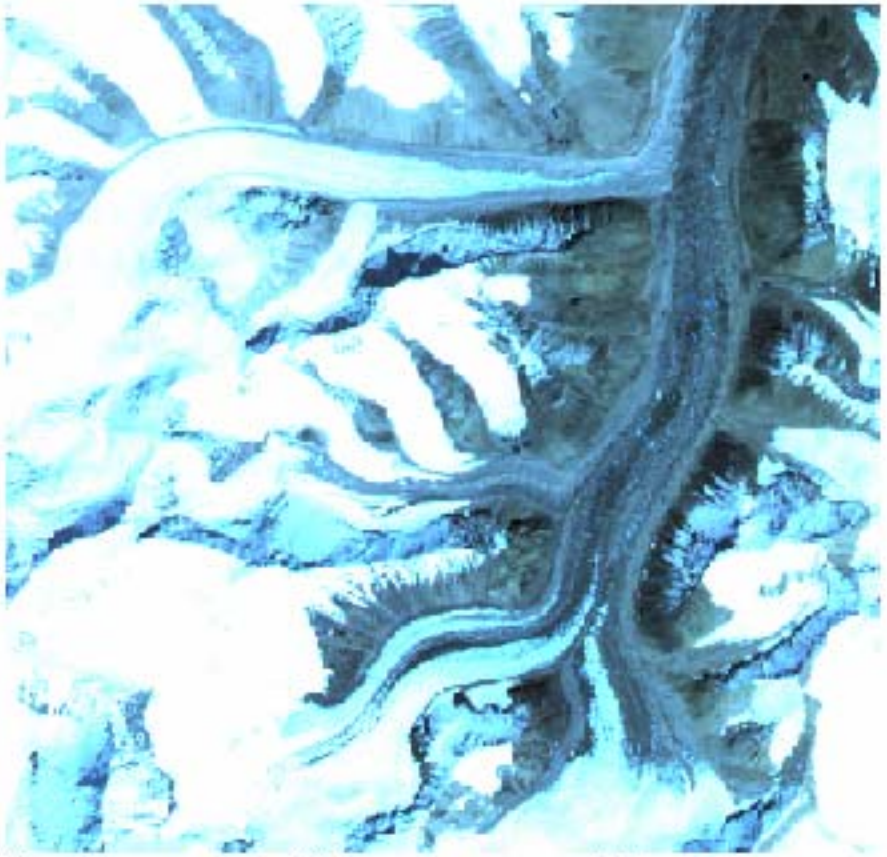
- **Scenes with current PGE version, scenecc <= 25%, and NOR or LOW VNIR gains**
  - **6400 L1A, 2200 L1B**
- **Distributing 105 Landsat 7 scenes over glaciers spanning 2000-2001**

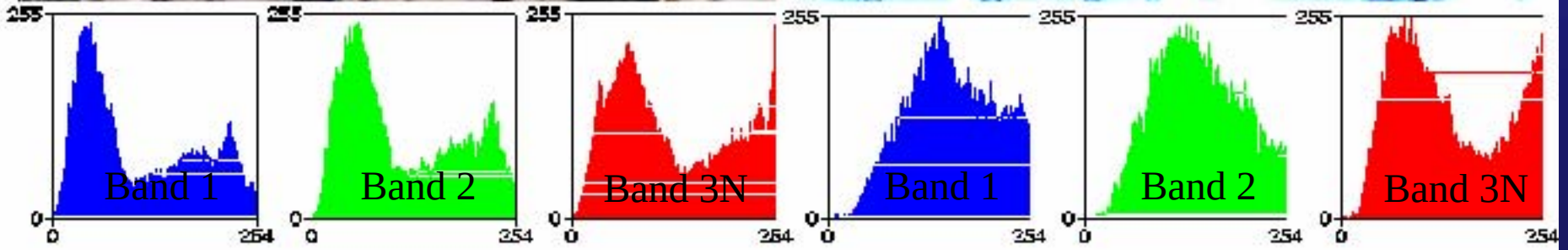
Effect of ASTER gain settings over bright areas

Bands 123N = NOR
30 Oct. 2000

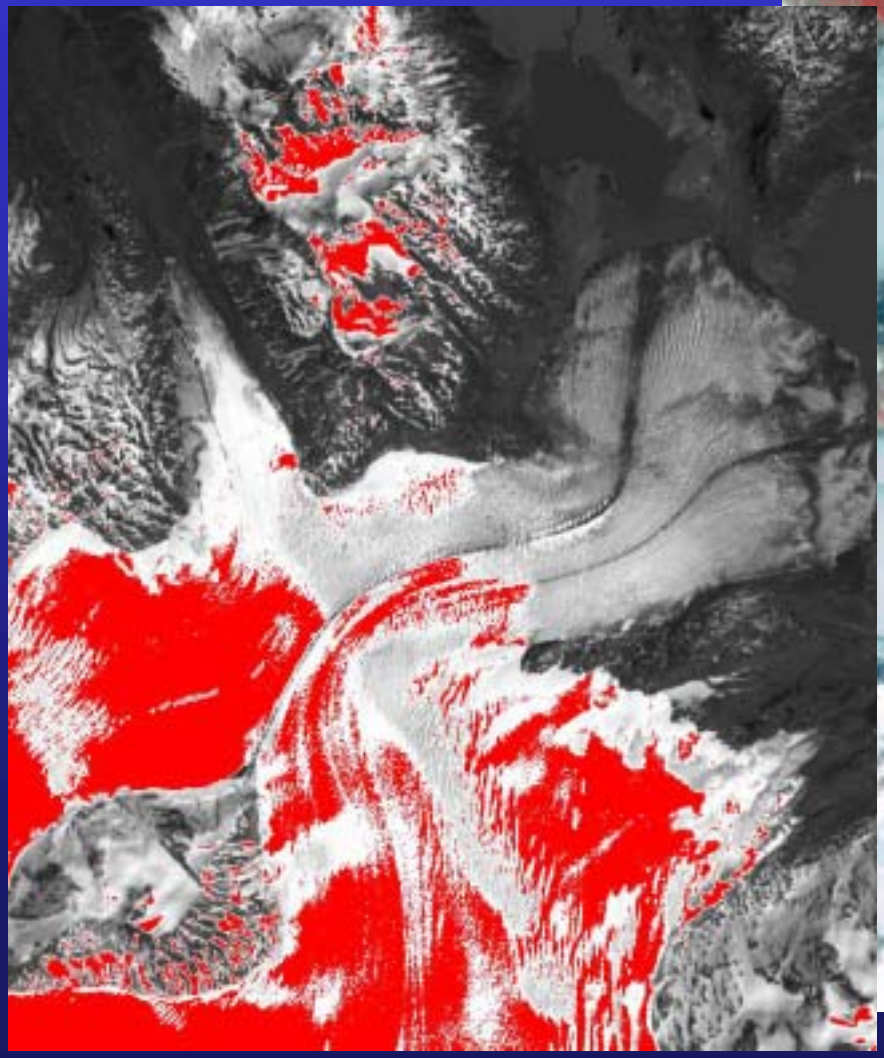
Bands 12 = HGH, 3N =NOR
28 Sep. 2000



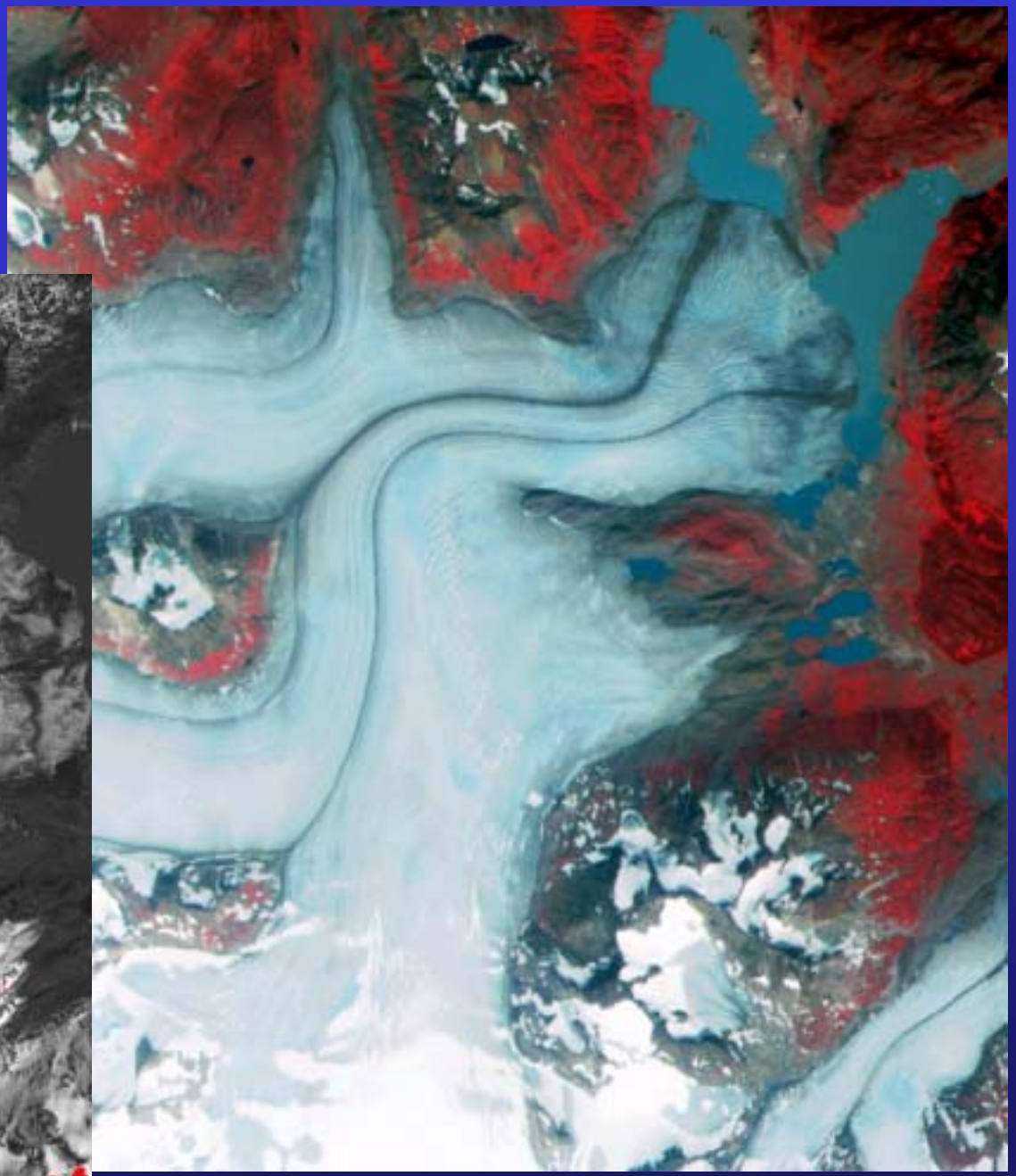




Landsat 7 vs. ASTER



Landsat 7 pan, 2000-Jun-2



ASTER 321 Low gain, 2001-Sep-13

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

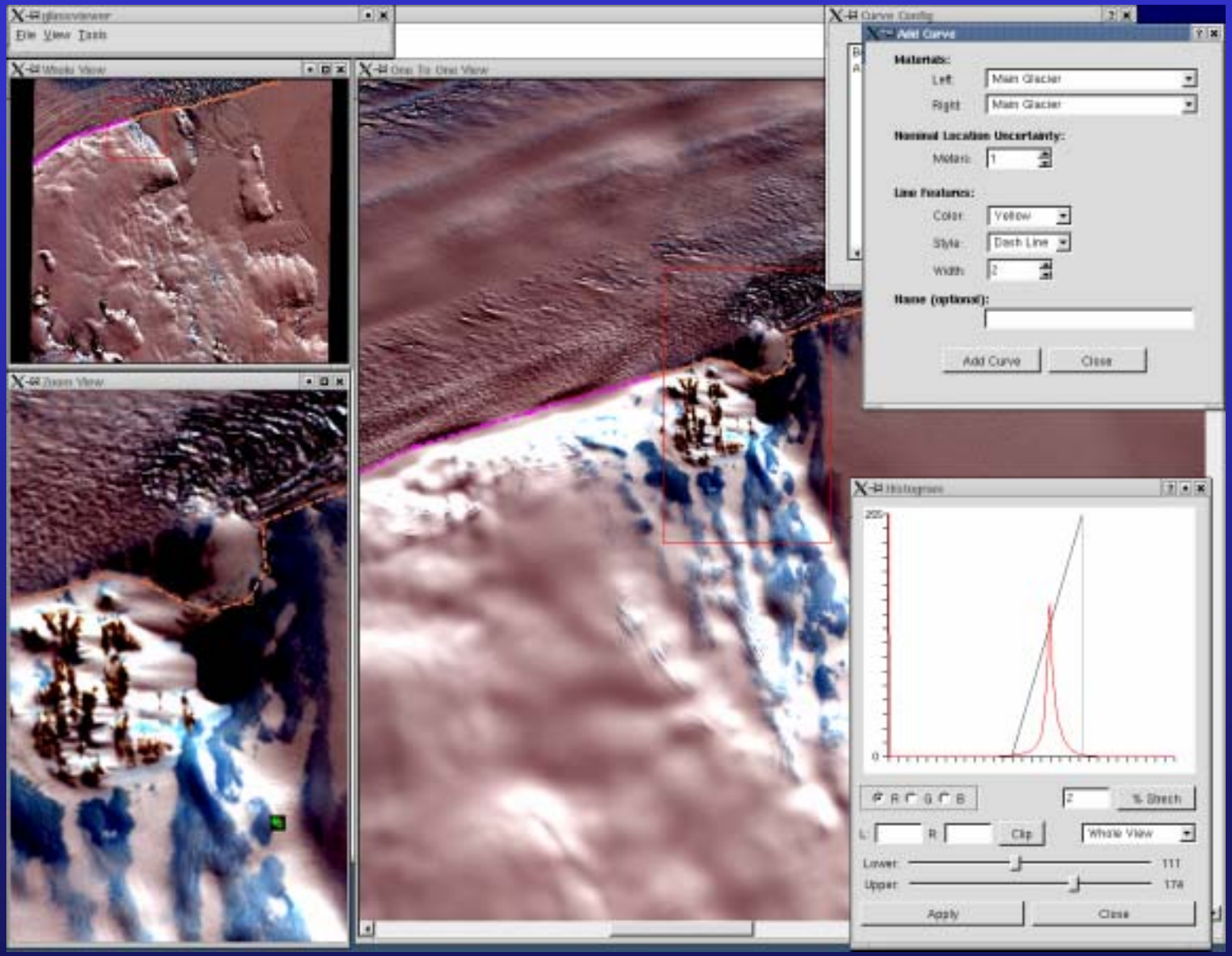
Free tool in development at USGS Flagstaff

Platforms

- Windows
- Linux
- Solaris
- Other unix

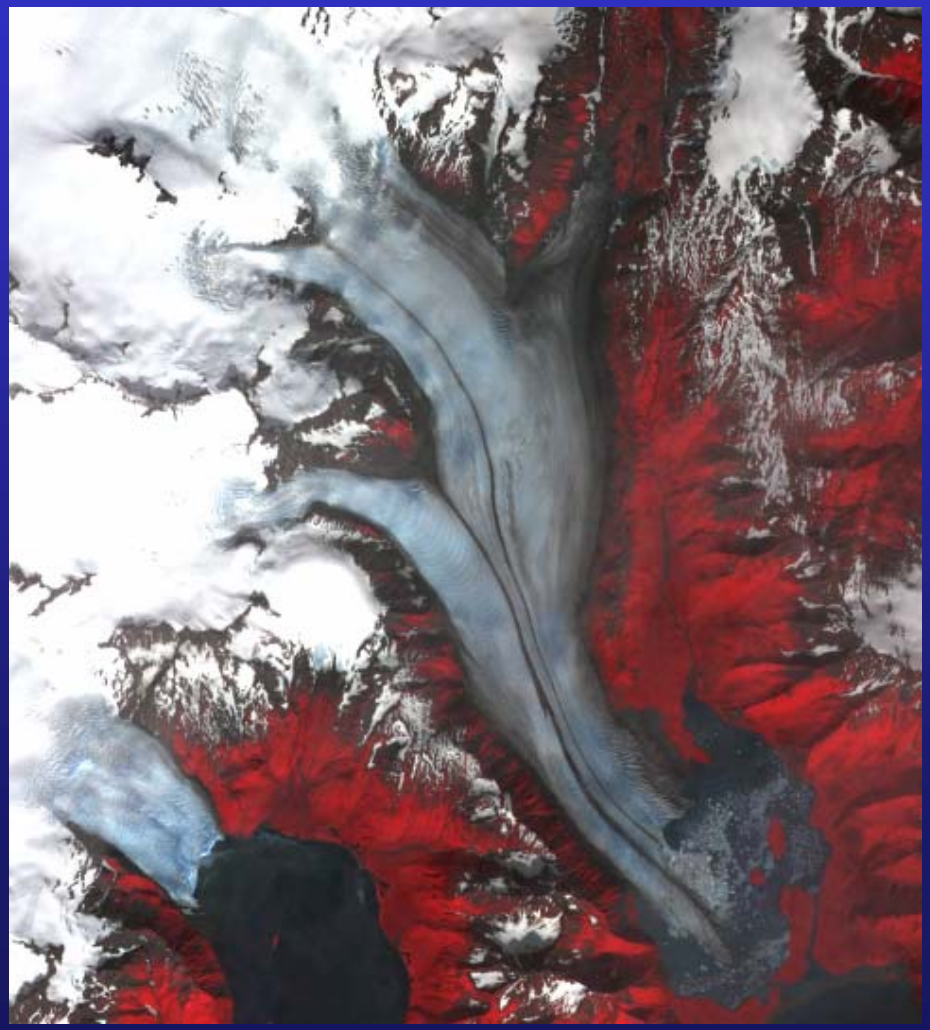
Data Formats

- ASTER L1A and L1B
- NLAPS
- Fast Format
- Geotiff



GLIMS ASTER > Southern Kenai

ASTER 321(LOW gain)
2001-Sep-06



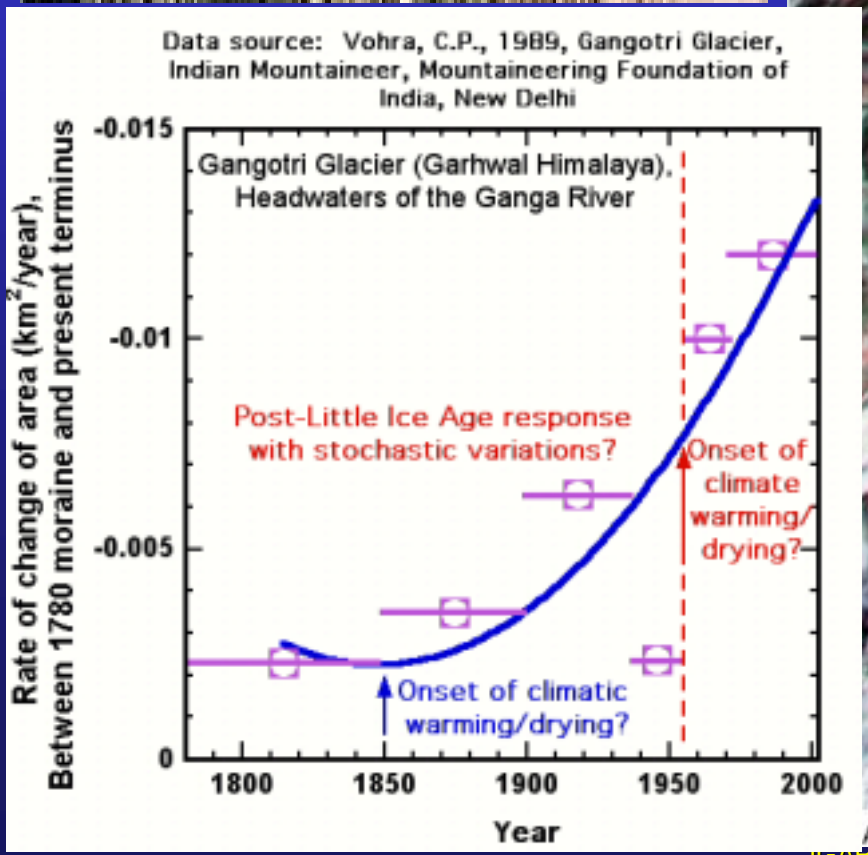
Monitoring changes in glaciers and glacier lakes

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

Gangotri Glacier, India

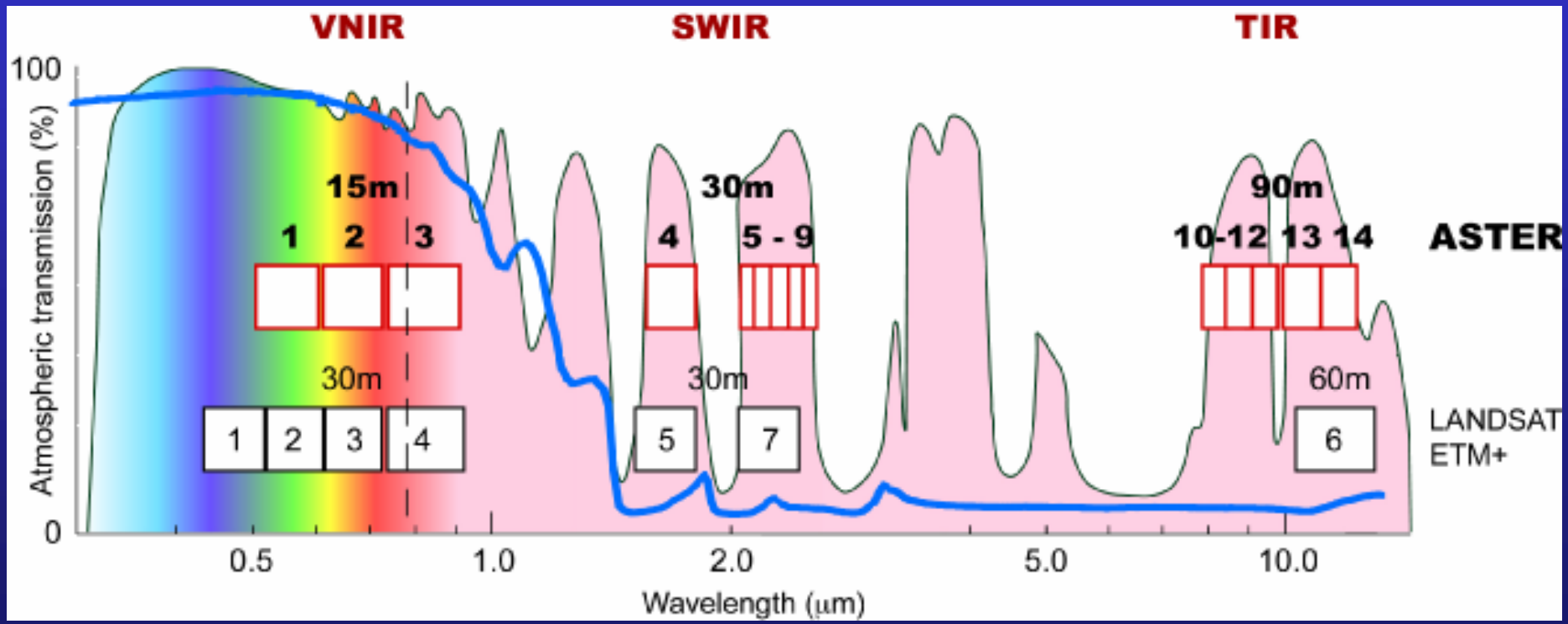
Gangotri Glacier, India

Terminus retreat

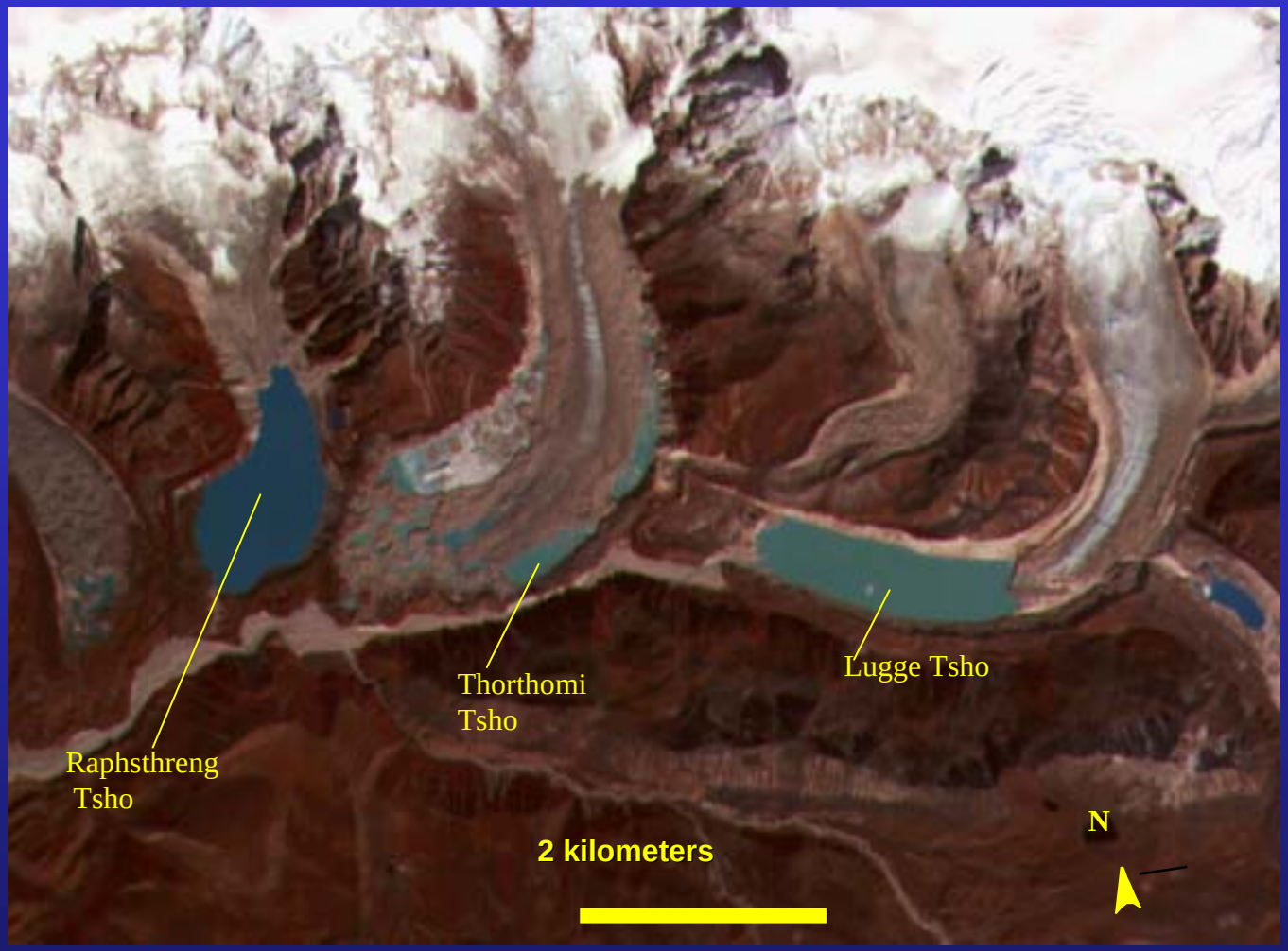


ASTER

Ice detection



Monitoring Supraglacial and Proglacial Lakes



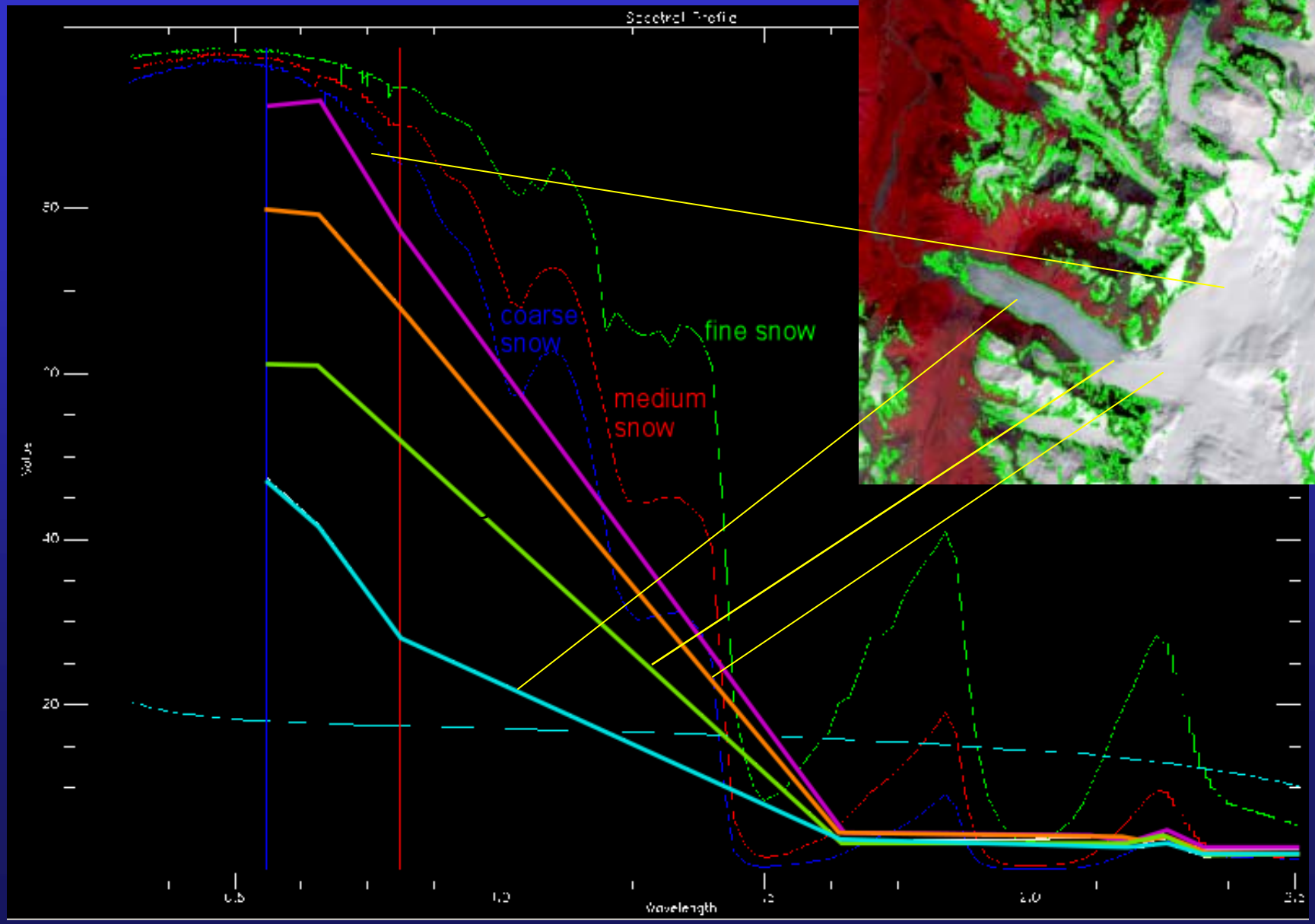
The stagnating termini of glaciers in the Bhutan Himalaya. Glacial lakes have been rapidly forming on the surfaces of debris-covered glaciers worldwide during the last few decades.

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

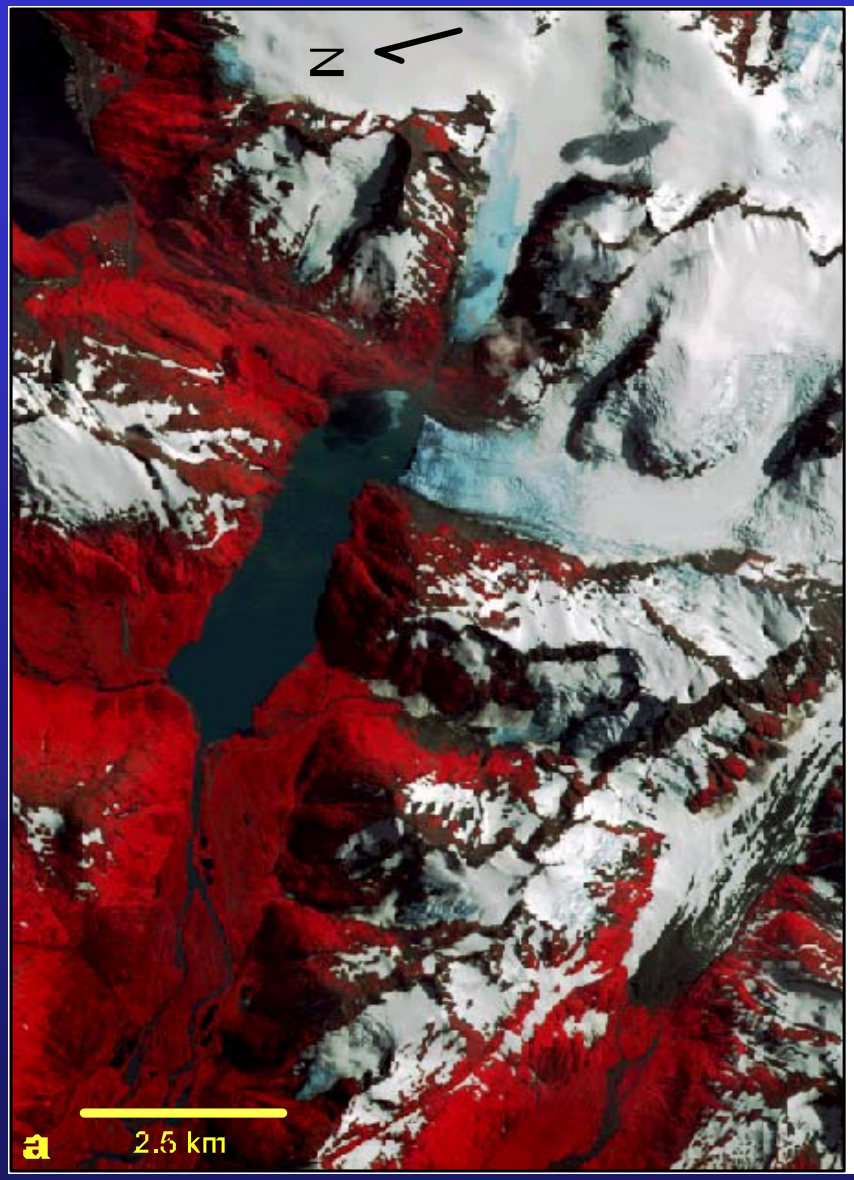
Glacier ASTER reflectance spectra

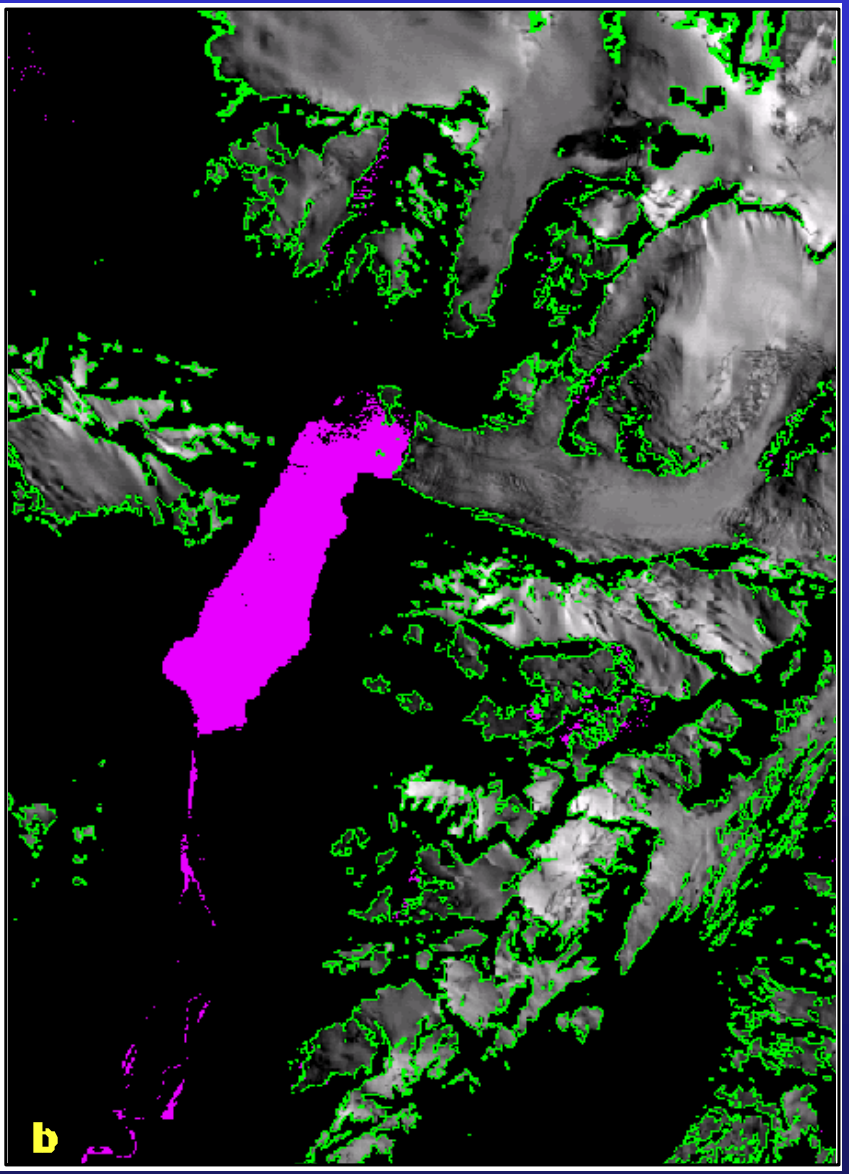
VNIR bands 321 RGB 2001, Sep. 6

GLIMS GAINS: 123 LOW, 456789 HIGH



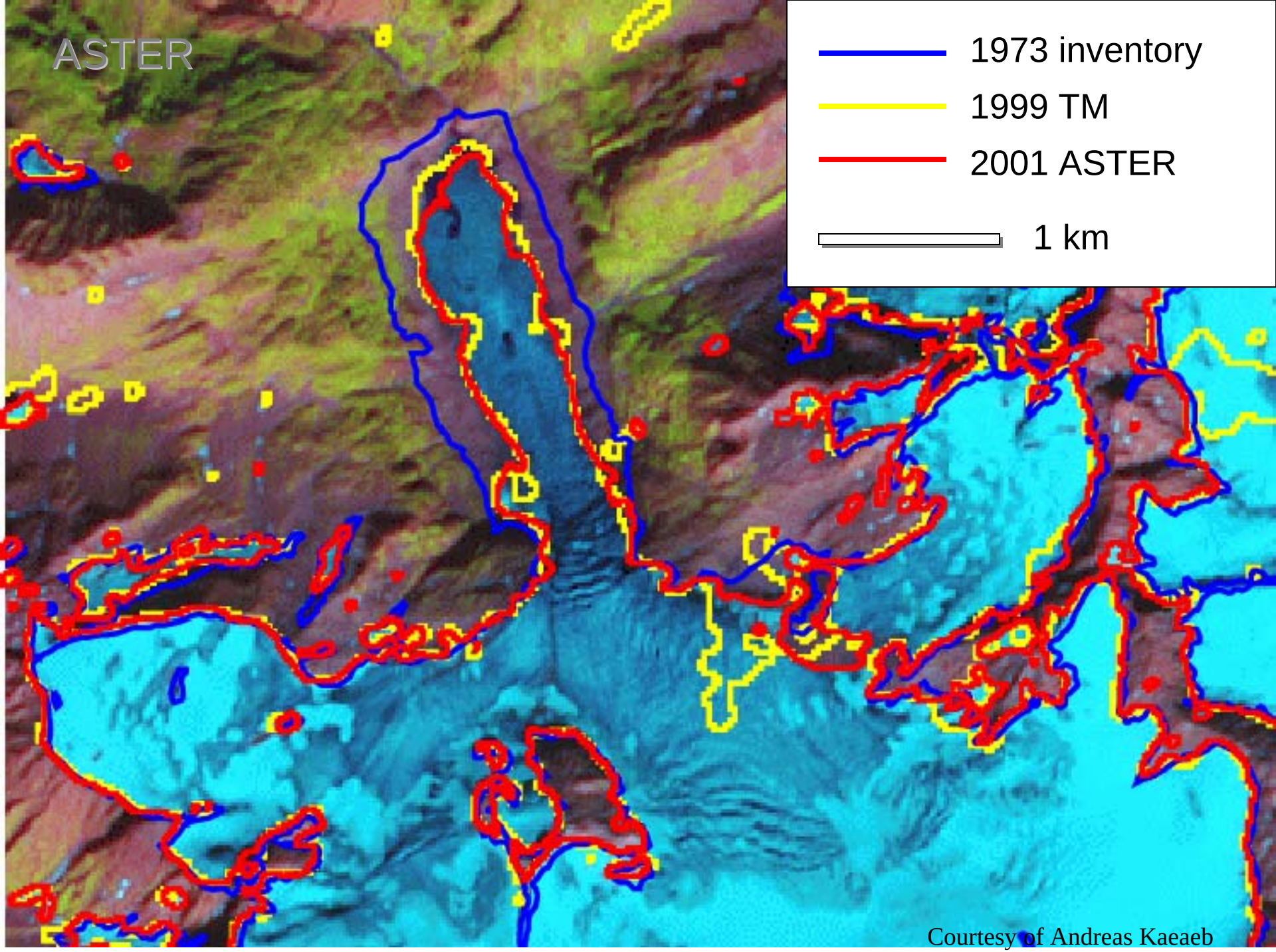
Glacier mapping using simple ratios of ASTER band 7 (2.25) / band 1 (0.56) - 0.25 threshold (Water mapped with NDWI)





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

Rick Wessels 12/01

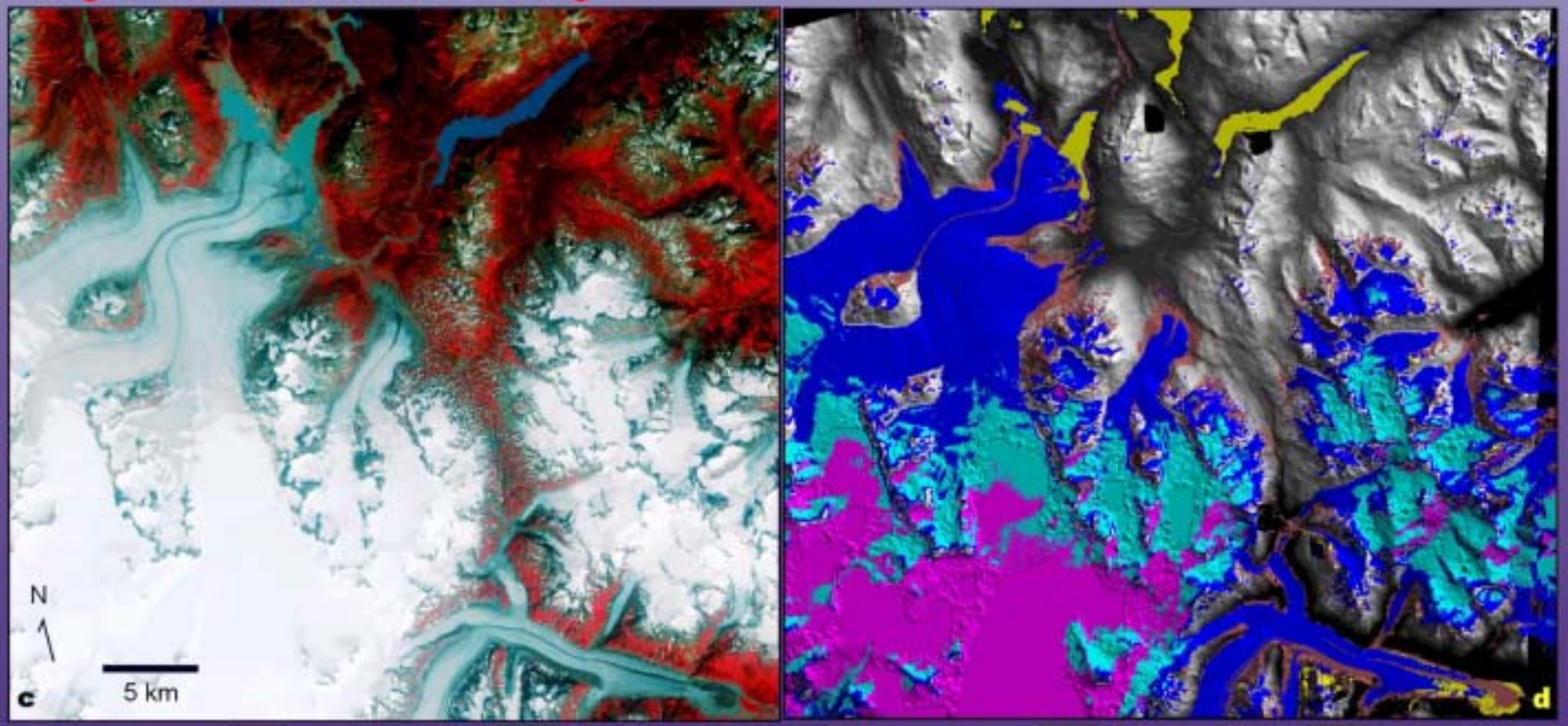


Courtesy of Andreas Kaeaeb

Automated feature extraction

GLIMS

Flagstaff Center for Remote Sensing

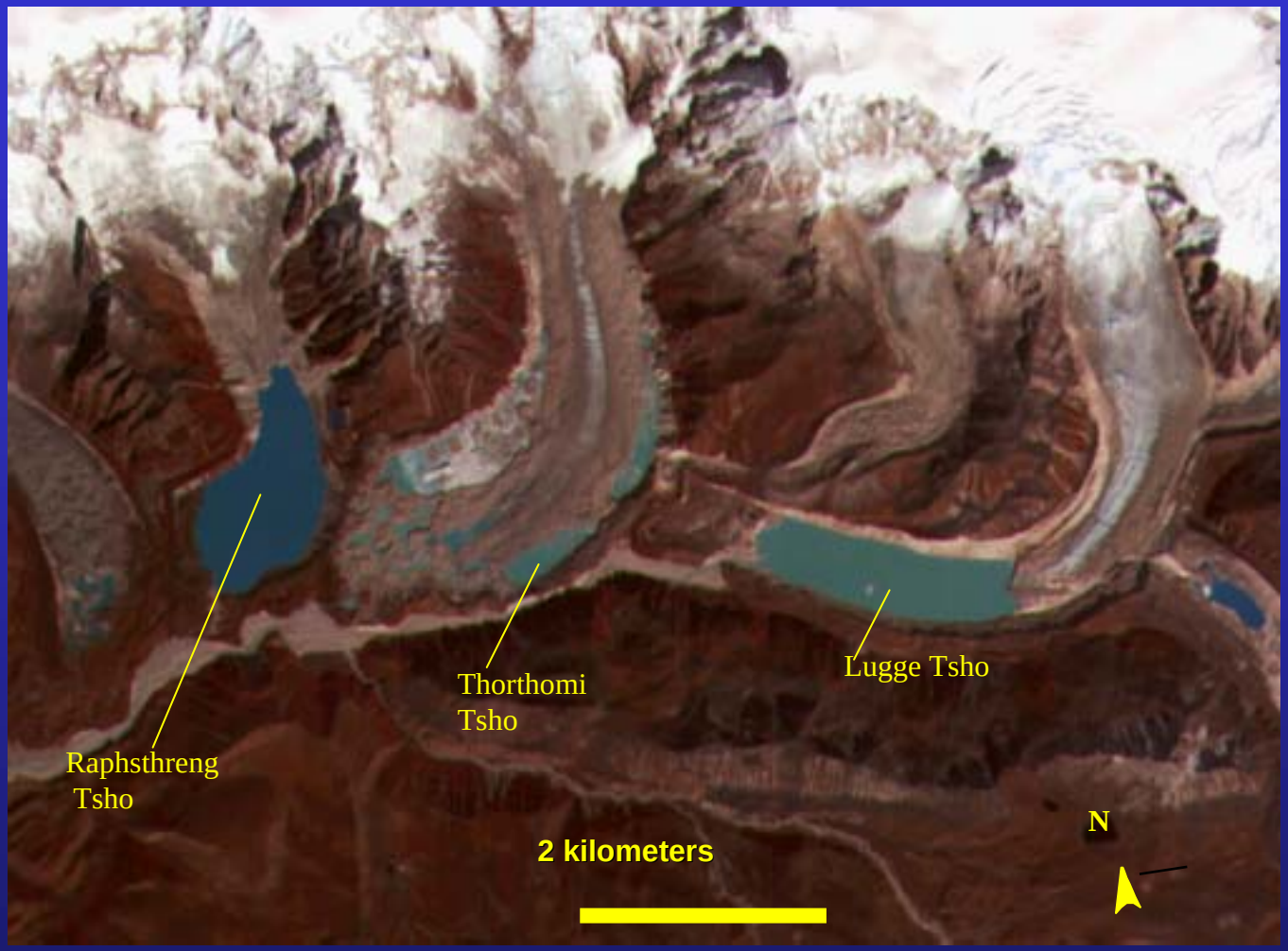


snow (accumulation) firn / wet snow bare ice (ablation) moraine/debris covered ice water

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



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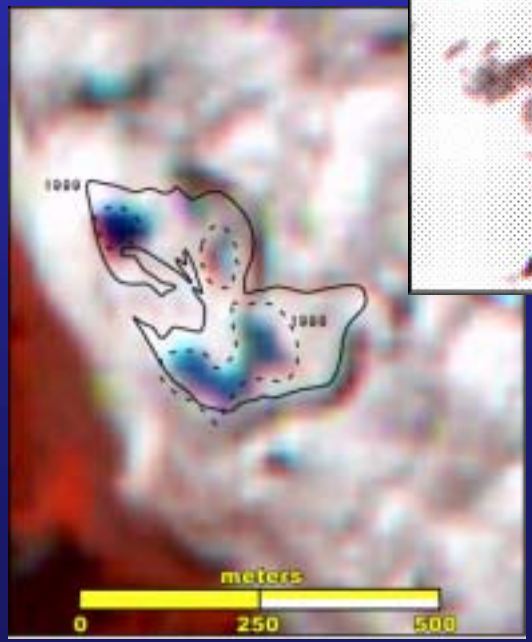
Monitoring Supraglacial and Proglacial Lakes

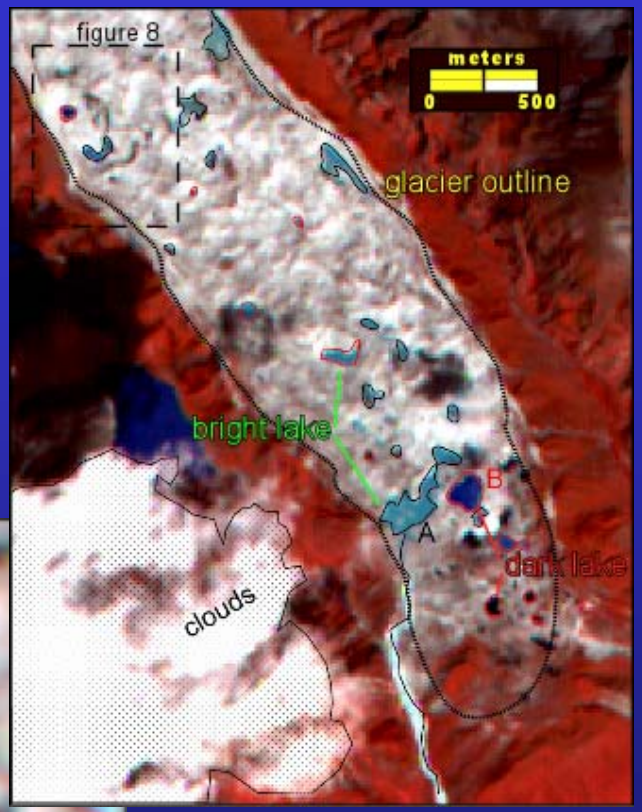
Ngozumpa Glacier, Nepal

Use ASTER data for:

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

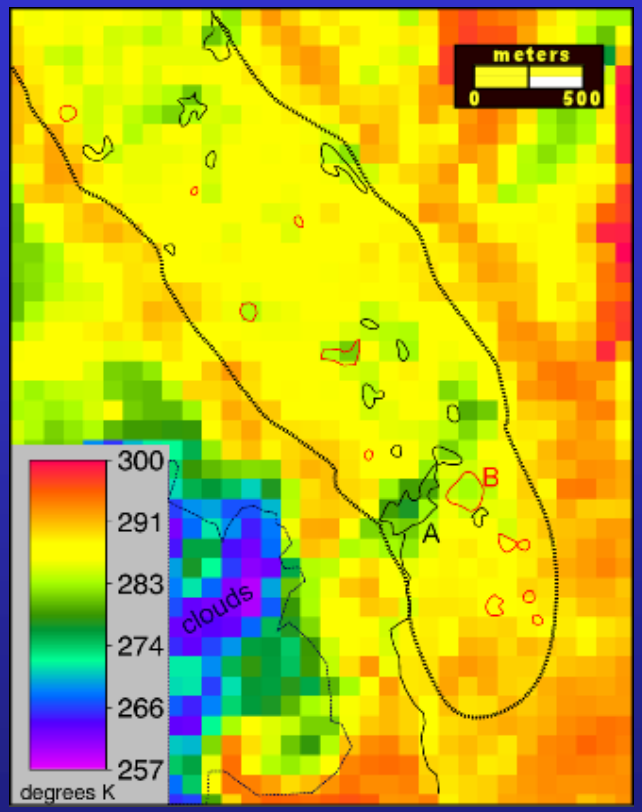


Pre-2000 lake outlines from Benn and others, 2000



2000 Sept. 28 ASTER L1B

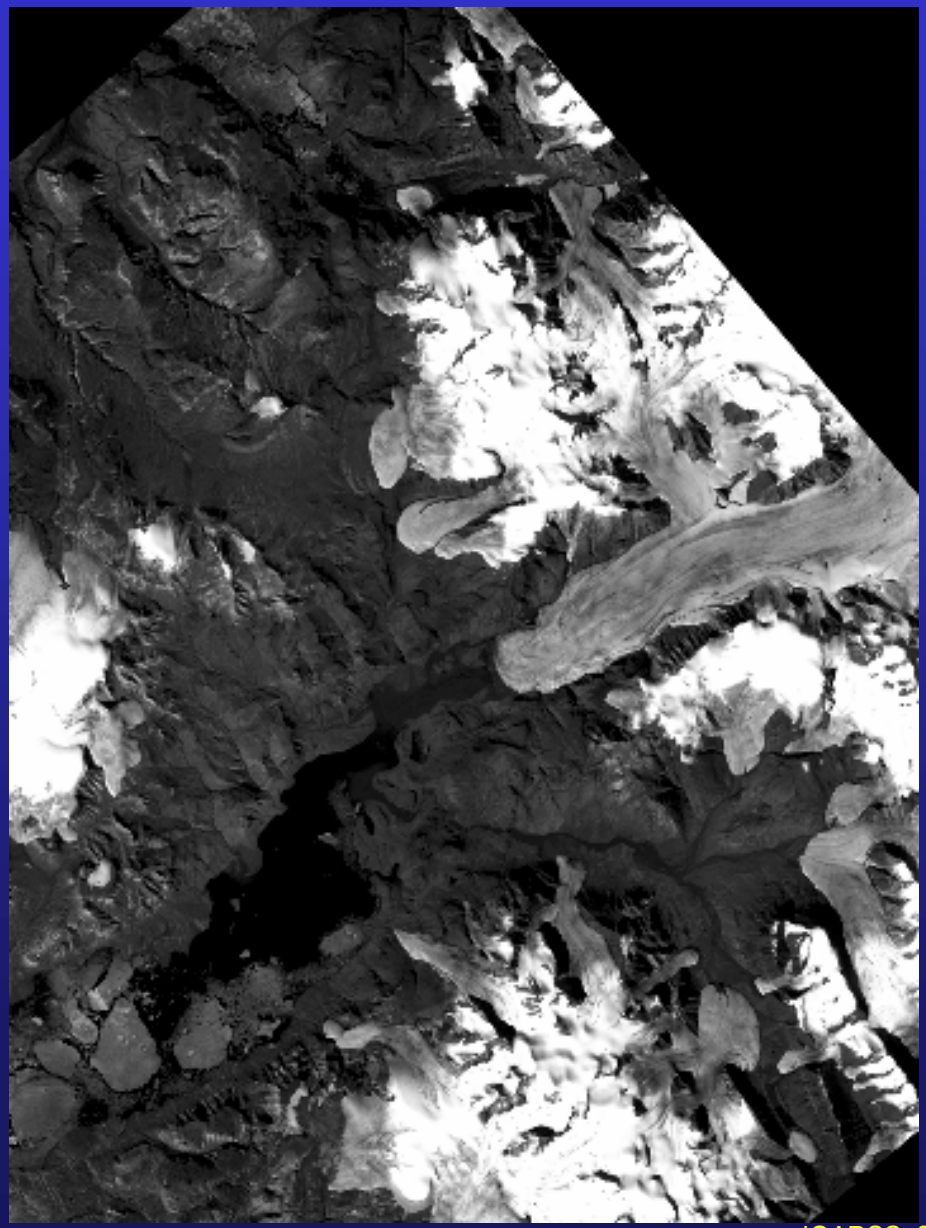
Image shows that lake has receded back to 1998 levels in year 2000.

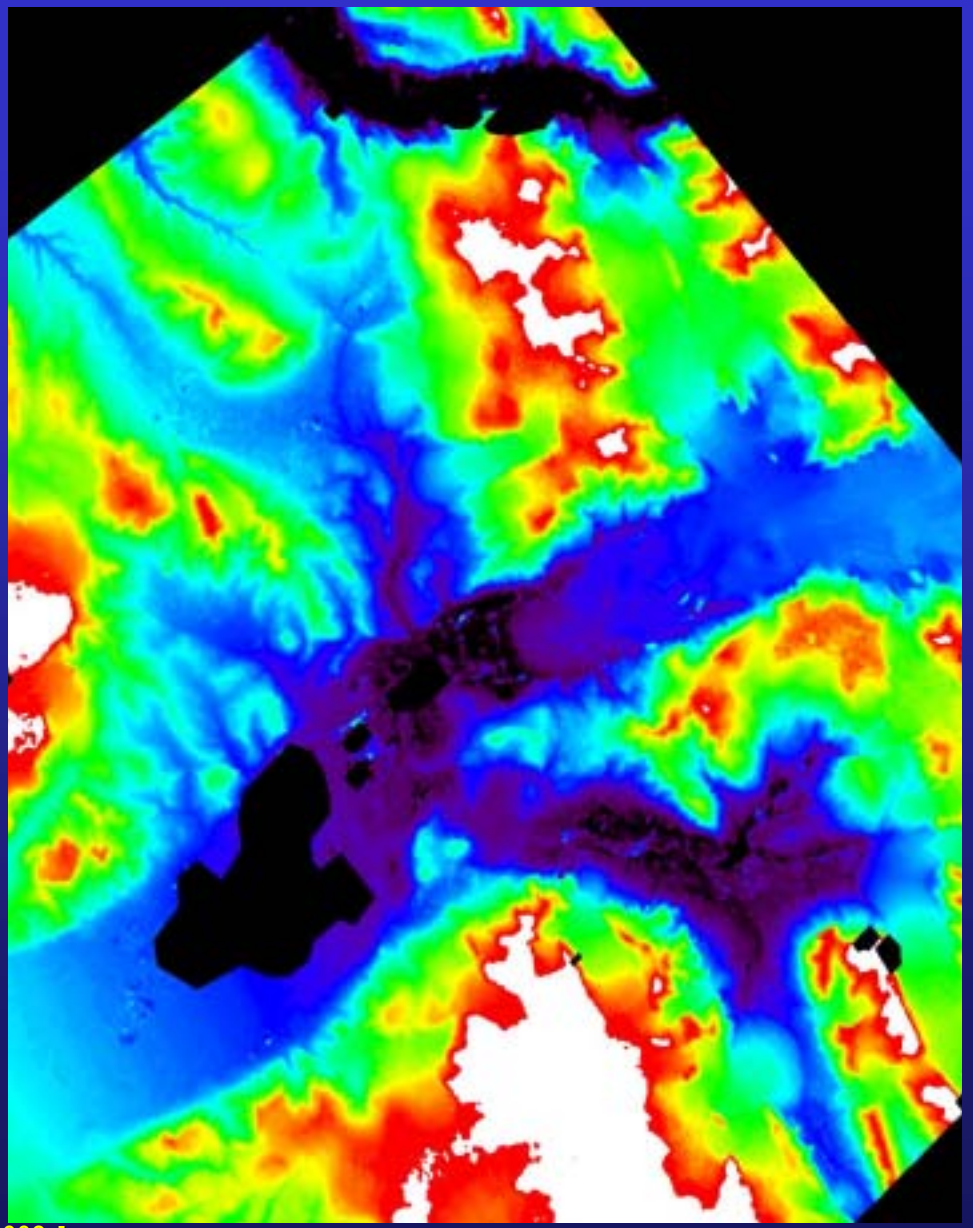


Lower brightness temperatures over lakes with higher turbidity

Small lakes prone to temp error because of large TIR pixel size.

ASTER Level 2 relative DEM over western Axel Heiberg Island glaciers





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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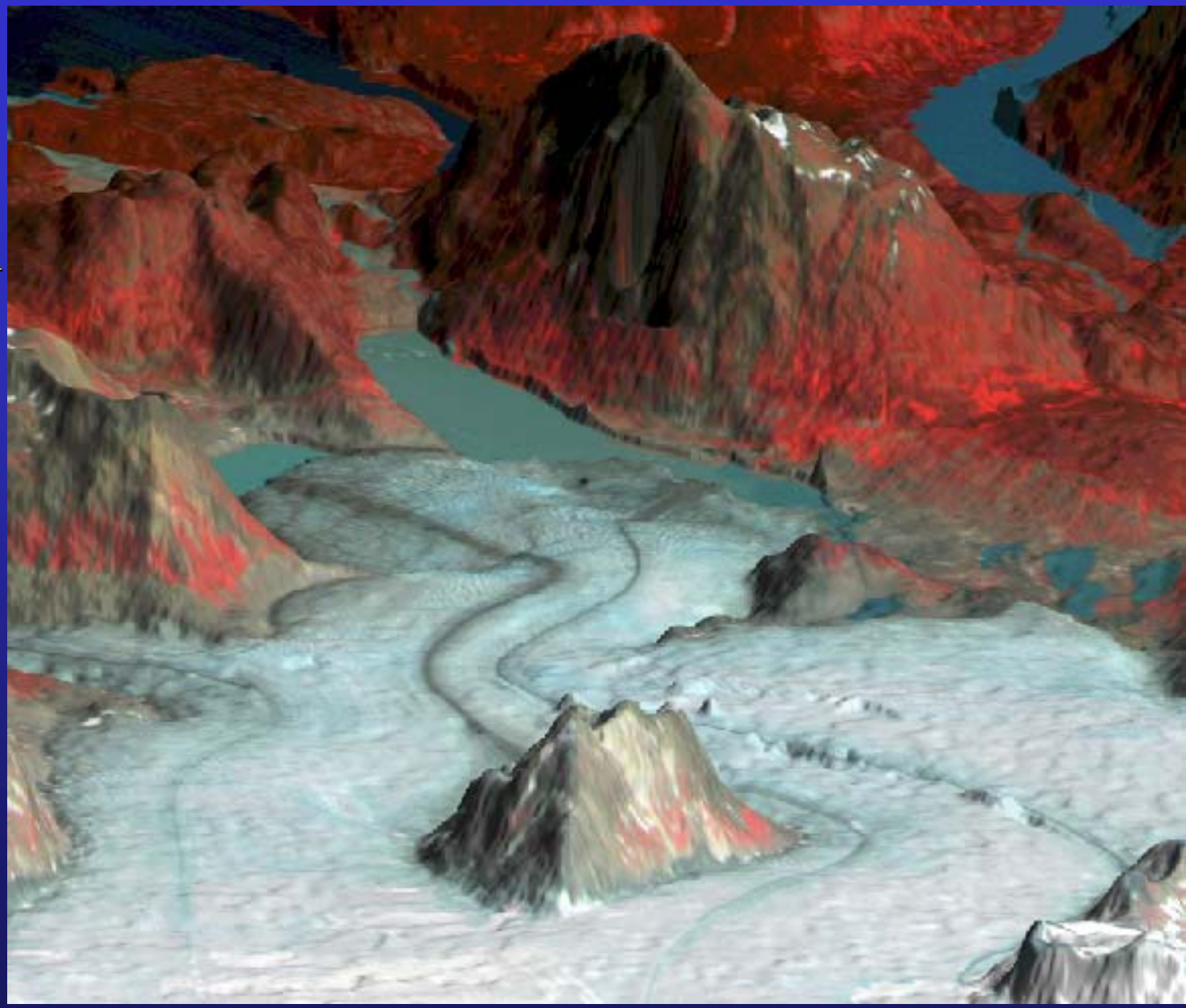
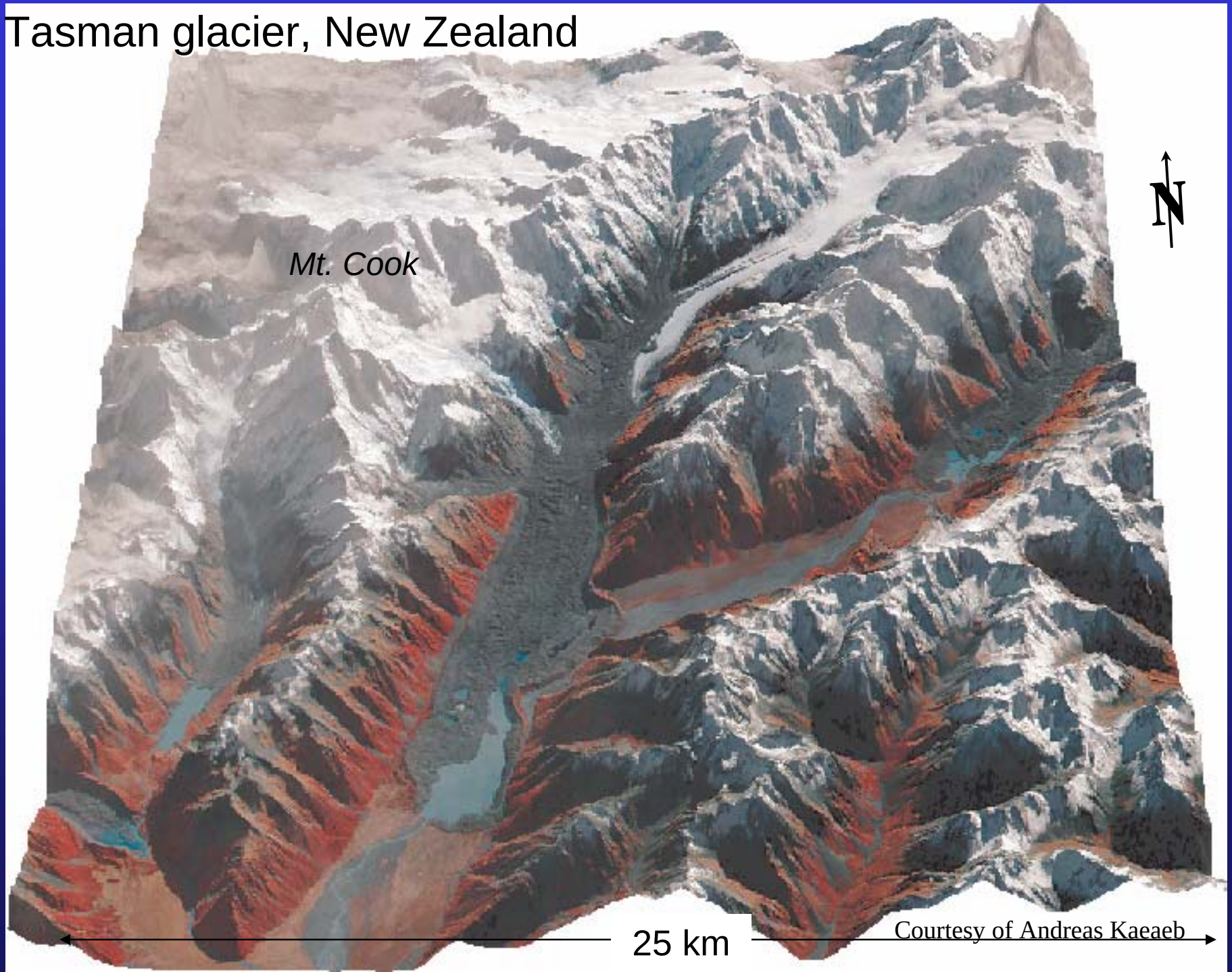
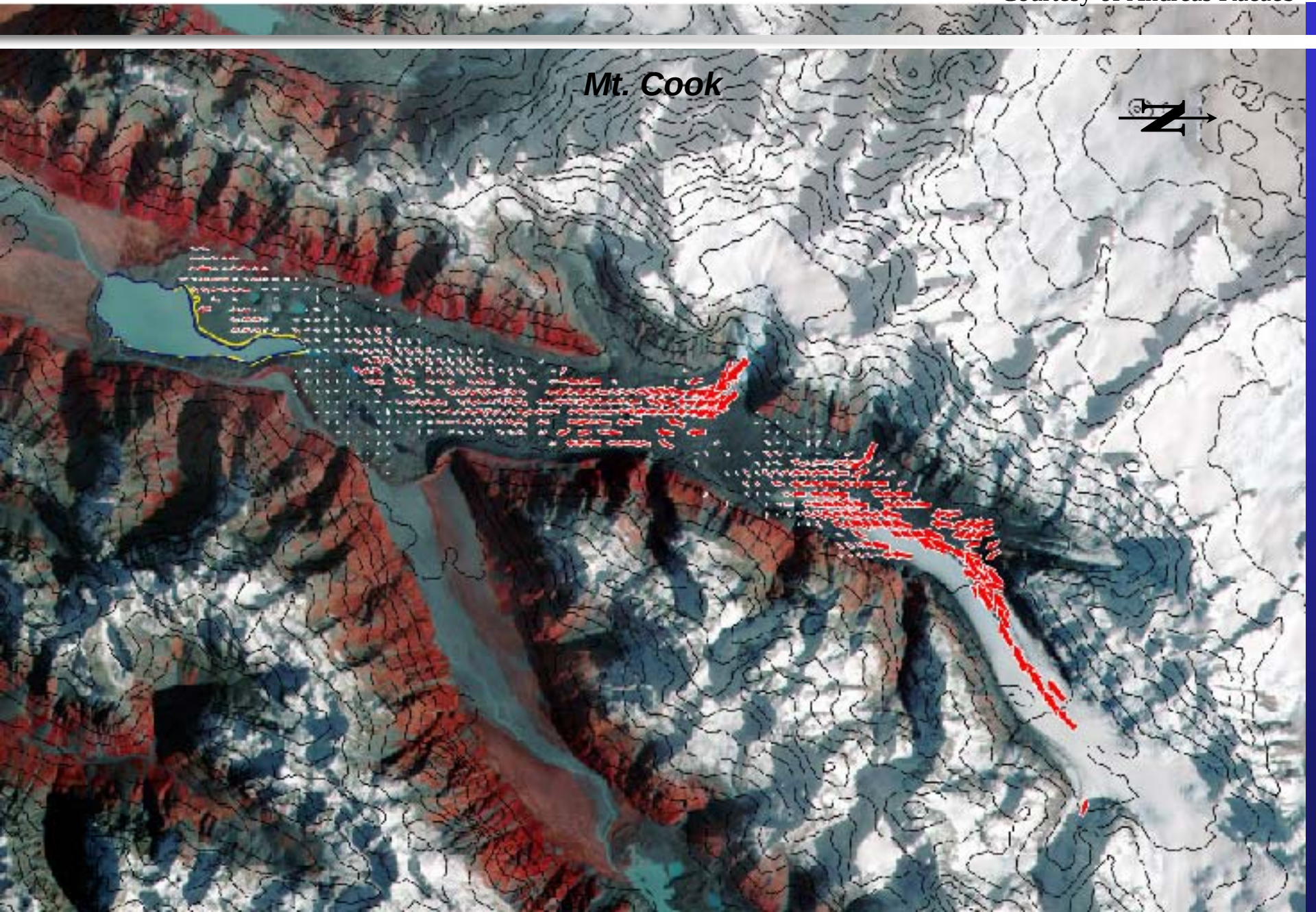


Tasman glacier, New Zealand

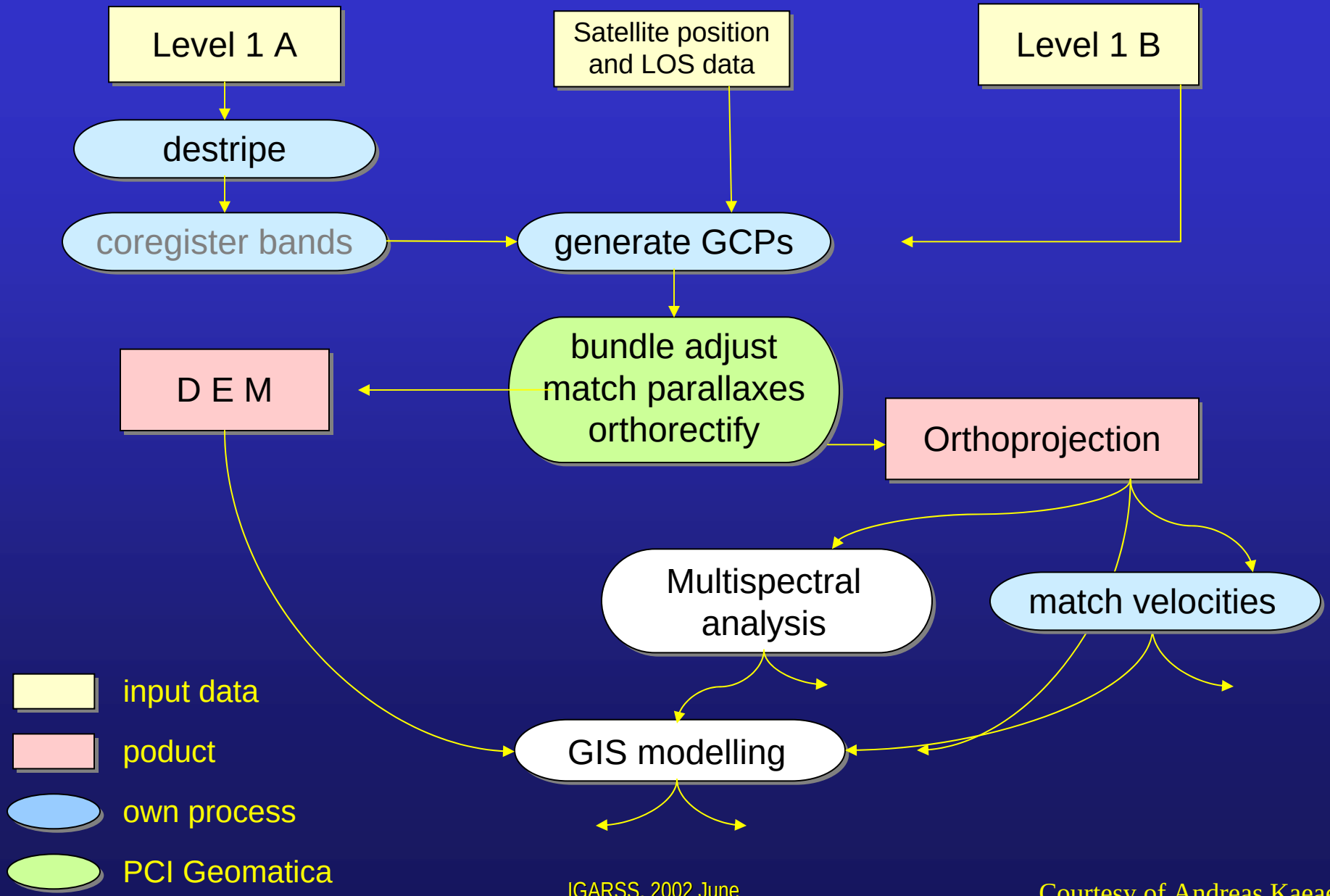


ASTER Ice velocities Apr 00 – Apr 01

Courtesy of Andreas Kaeaeb

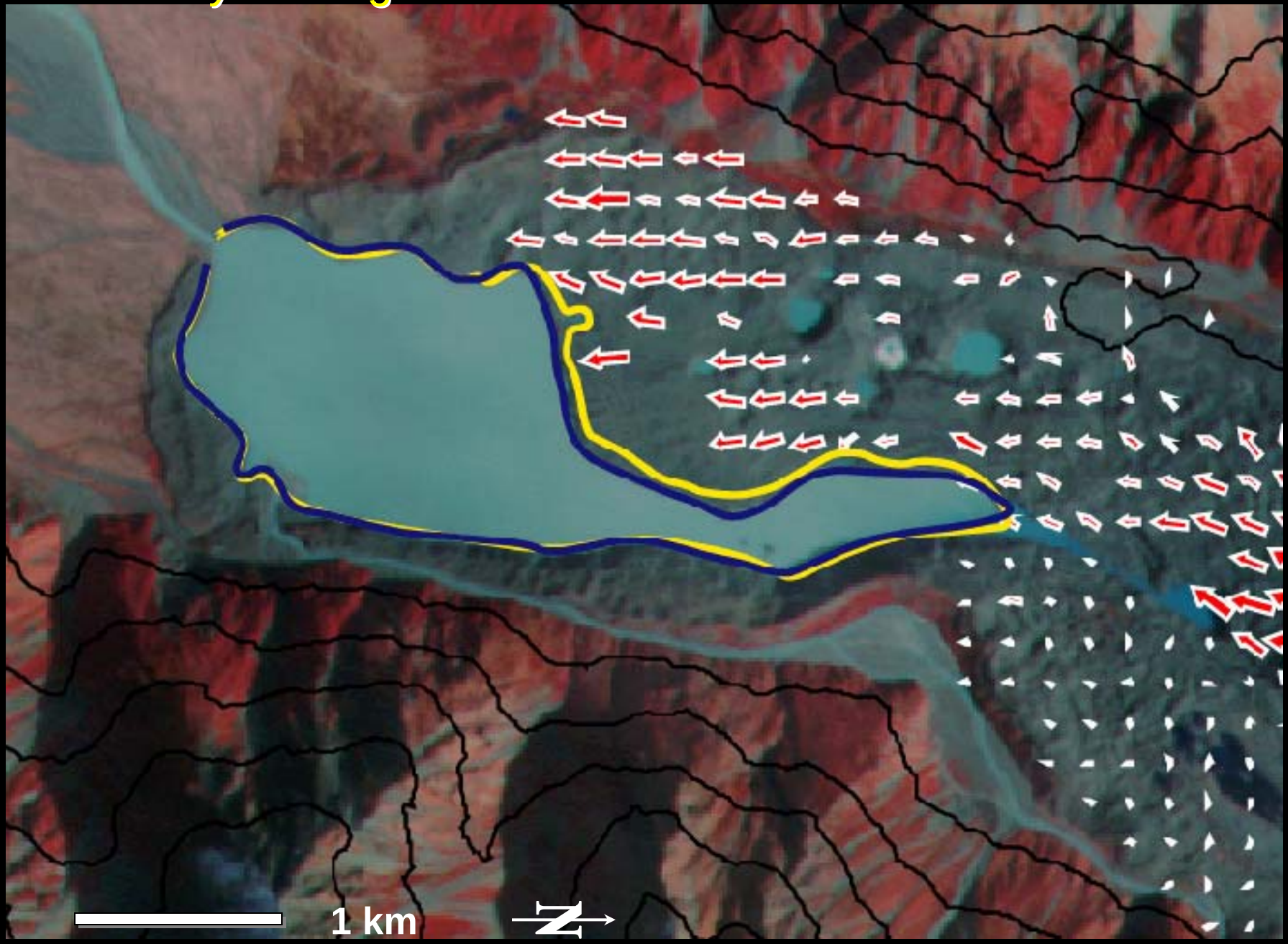


ASTER Processing



Courtesy of Andreas Kaeaeb

Ice velocity / lake growth



IGARSS, 2002 June

Courtesy of Andreas Kaeaeb

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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**