

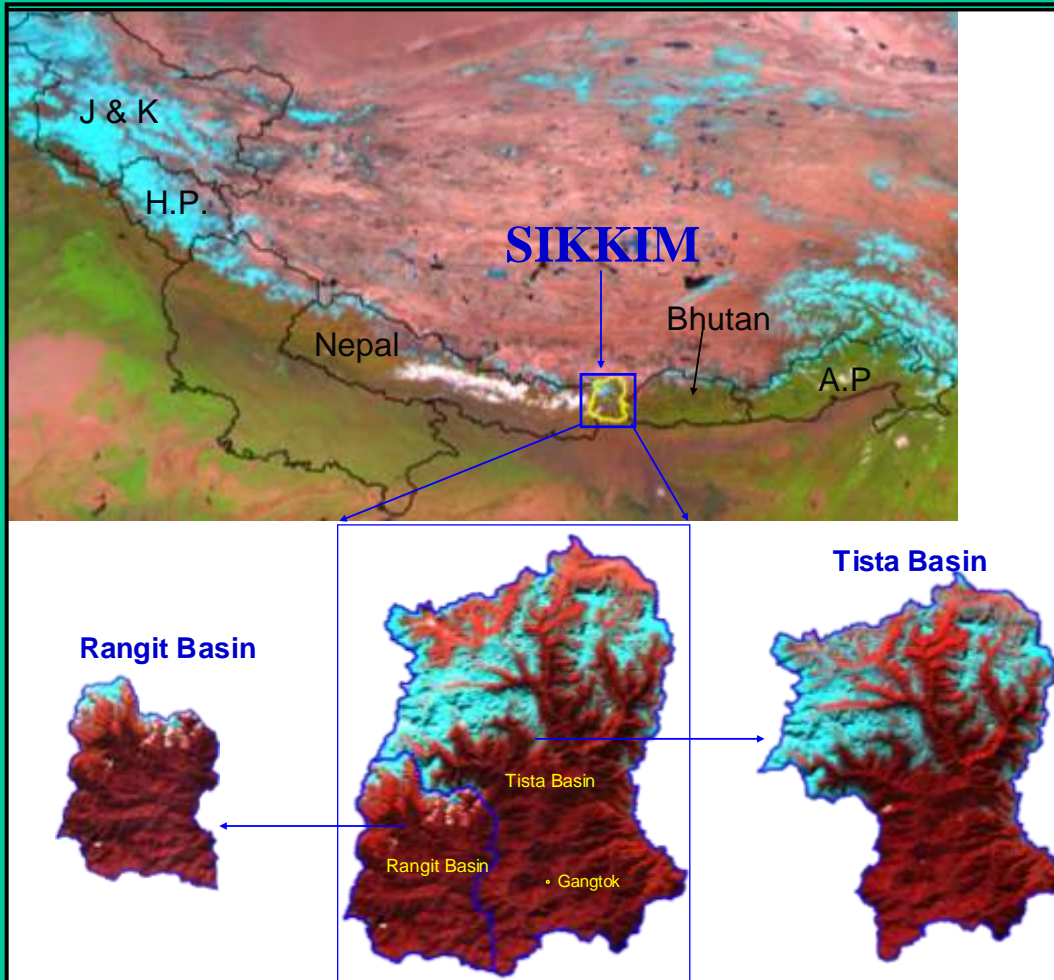
# **Monitoring Sikkim Himalayan Cryosphere.**

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**INTERNATIONAL SYMPOSIUM  
BENEFITING FROM EARTH OBSERVATION**

**4 - 6 OCTOBER 2010, KATHMANDU, NEPAL.**

# Study Area: Sikkim ,Eastern Indian Himalayas.



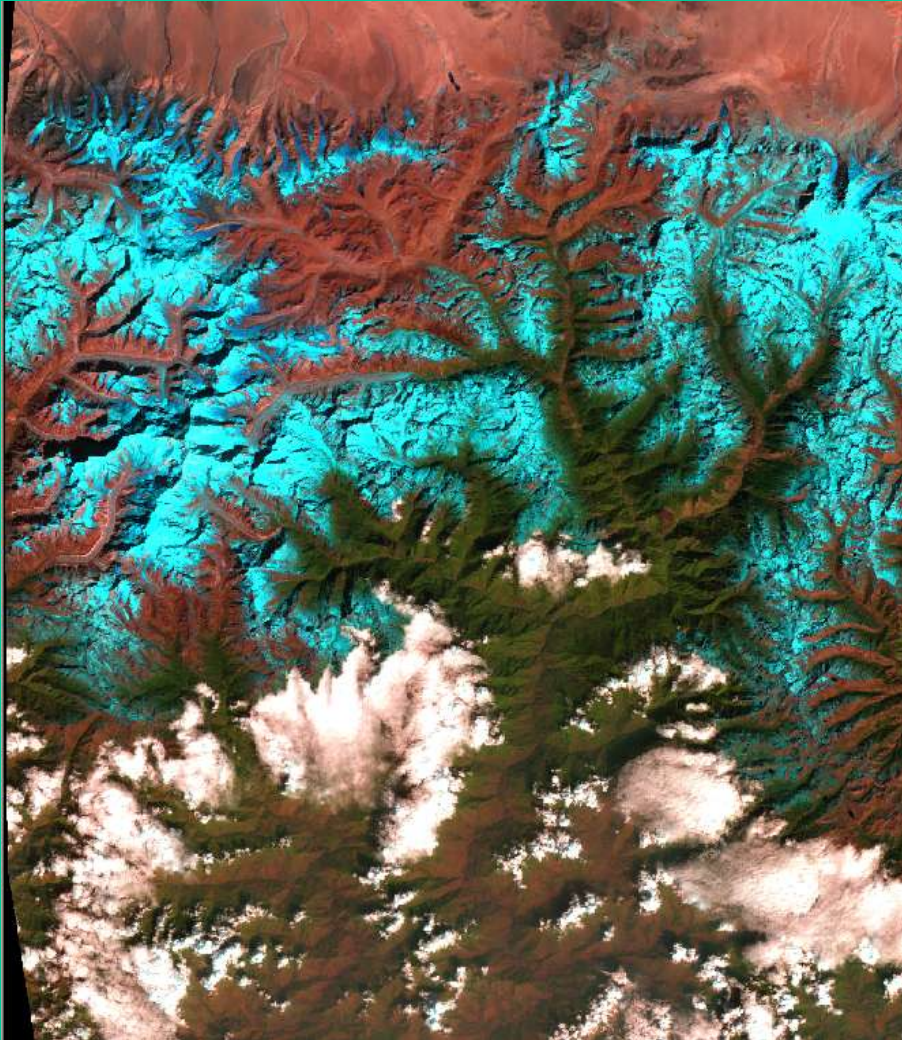
- Sikkim occupies 7096sqkm.
- Two sub basins of Tista are
  - Tista sub basin (5466sqkm)
  - Rangit sub basin (1630sqkm)

- Sikkim Himalaya is located in Eastern India between Nepal and Bhutan .
- The state has large concentration of glaciers and permanent snowfields.

# Snow Cover Monitoring

- A WiFS data of RESOURCESAT-I was used.
- Data from Oct - June ,for years 2004 to 2008,at an interval of 5 days was monitored.
- Approximately 200 A WiFS imageries were browsed and 75 scenes were used in the analysis.
- Composite Snow Products were generated for two sub basins and the entire state of Sikkim :-

# IRS Satellite Data used



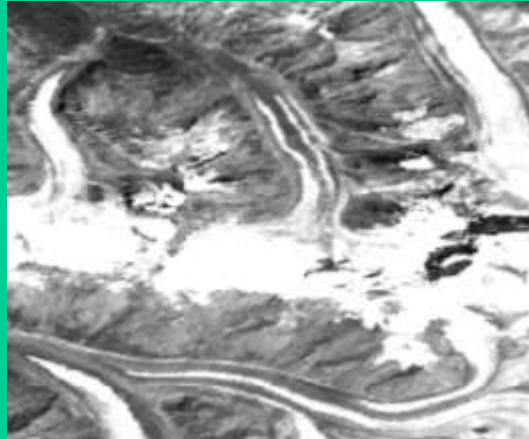
Parameter	AWiFS			
Spatial Resolution	56 m			
Swath	740 Kms			
Bands (um)	B2	B3	B4	B5
	0.52-0.59	0.62-0.68	0.77-0.86	1.5-1.70

# Methodology

- Normalized Difference Snow Index(NDSI)

$$\text{NDSI} = \frac{(\text{Green reflectance (B2)} - \text{SWIR reflectance (B5)})}{(\text{Green reflectance (B2)} + \text{SWIR reflectance (B5)})}$$

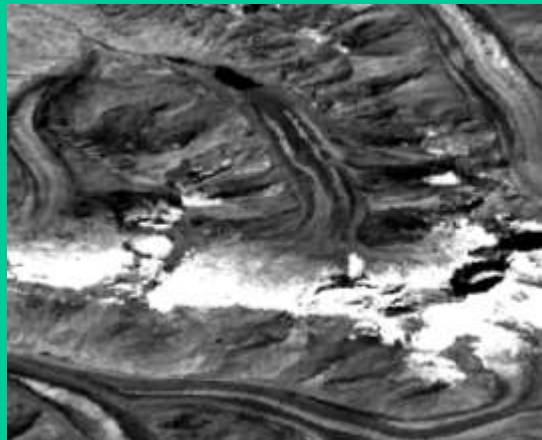
Band 2



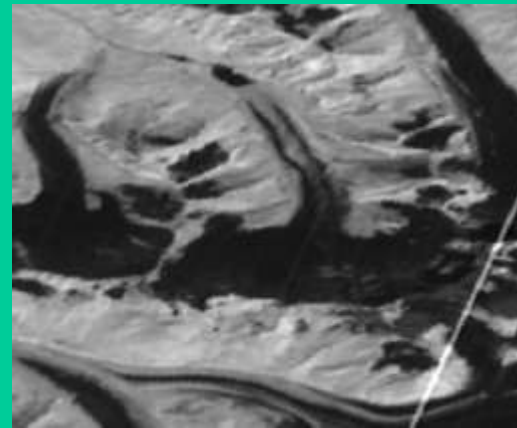
Band 3



Band 4



Band 5



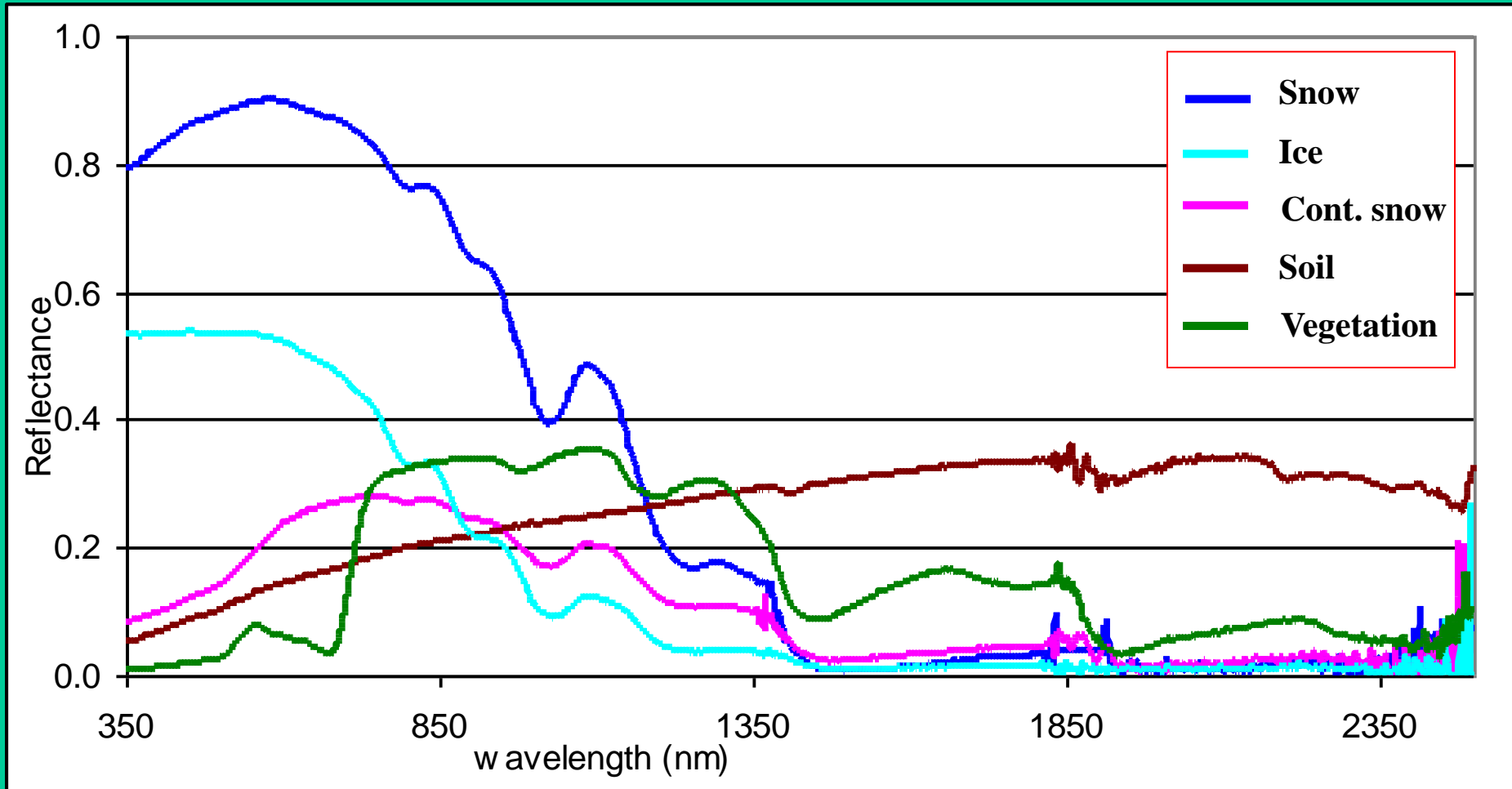
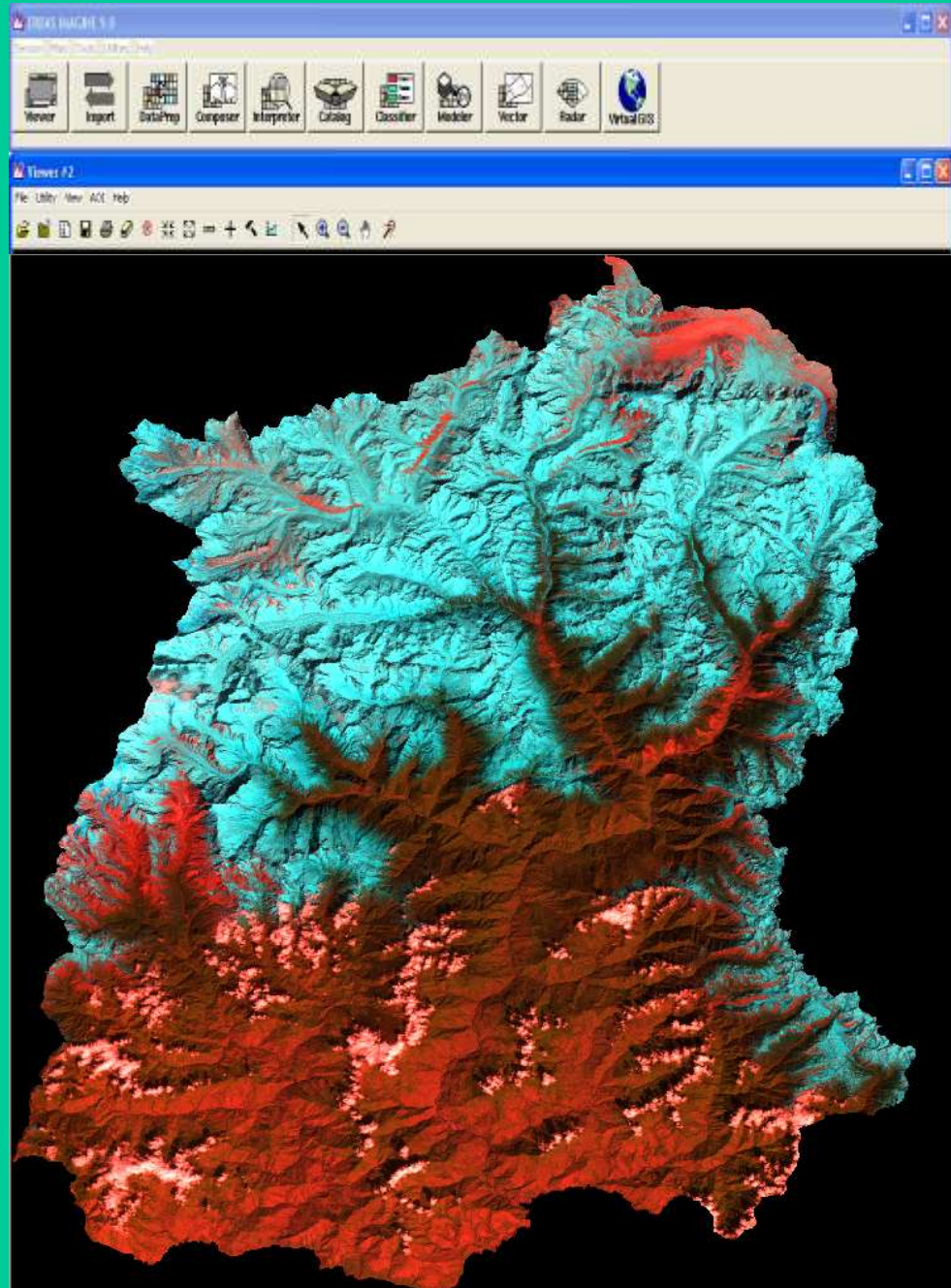


Fig. 2: Spectral reflectance of snow, ice, contaminated snow, vegetation, and soil.

Source:Kulkarni, A.V.et al, Current Science, Vol 92, No. 1, pp 69-74.

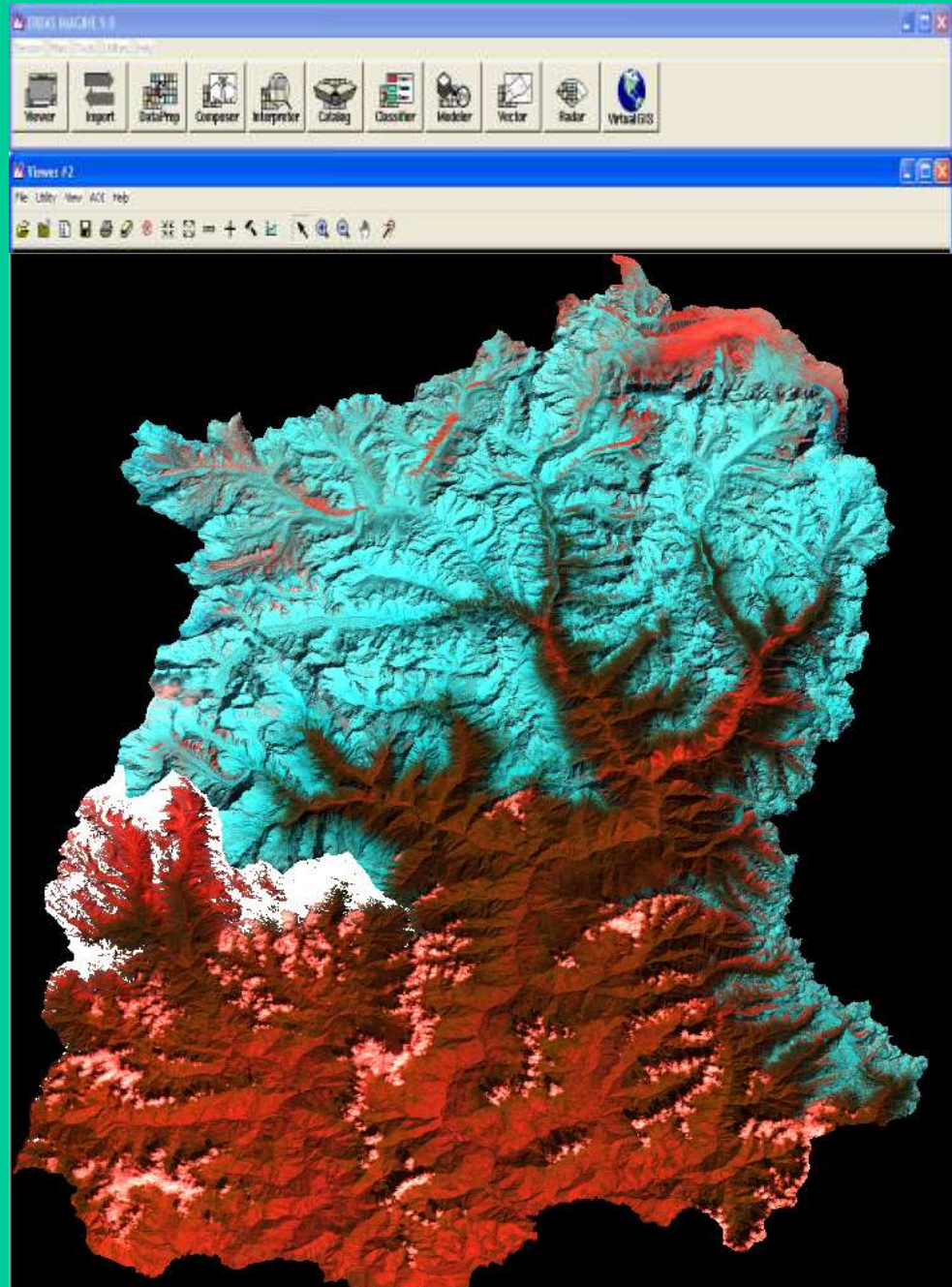
# SNOW MONITORING

- Algorithm is run on a fully automated mode.(Kulkarni et al 2006)
  - It generates snow and cloud for 5 daily products
  - Maximum snow extent for Composite(10 daily) product.
- Slight modification in the algorithm.



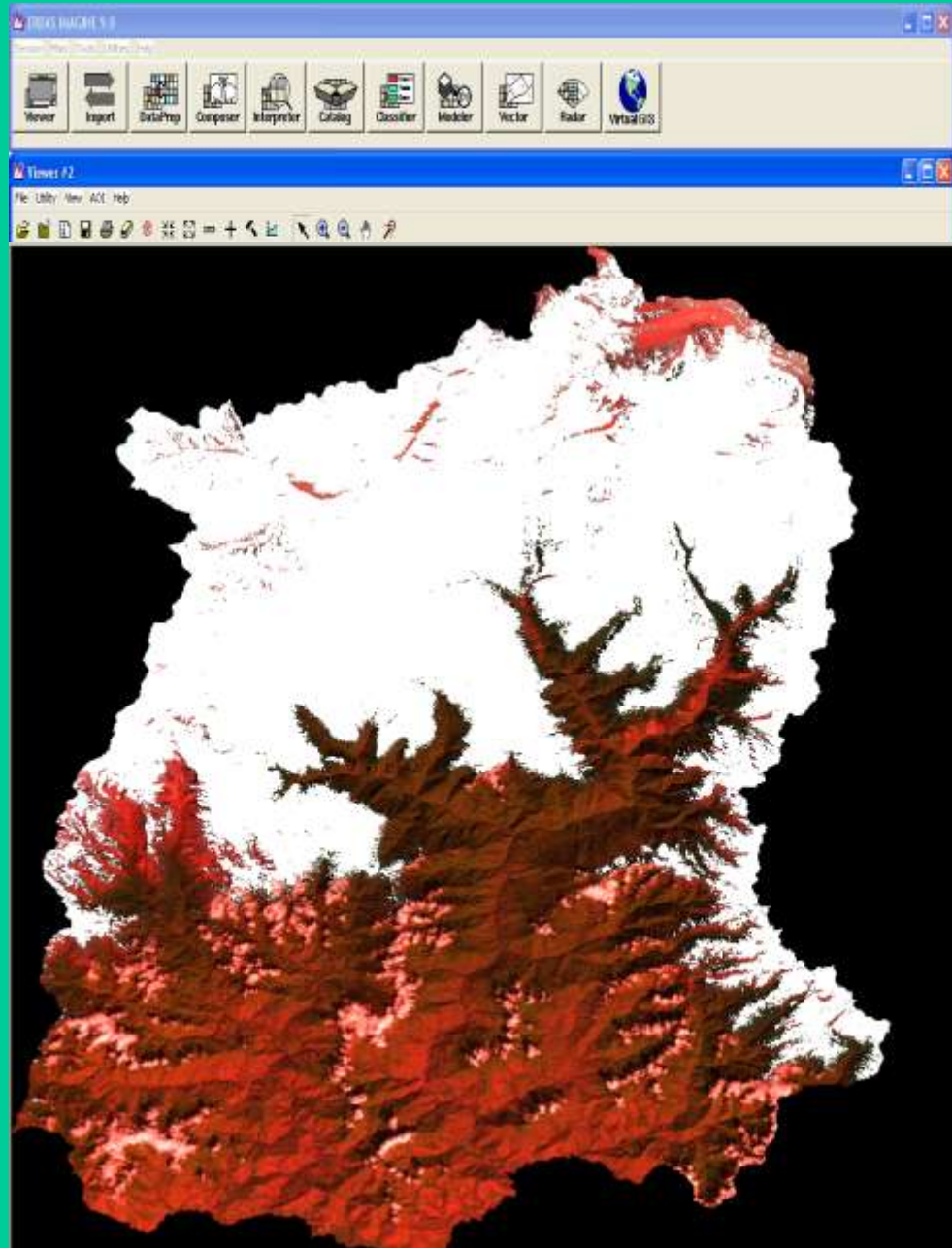
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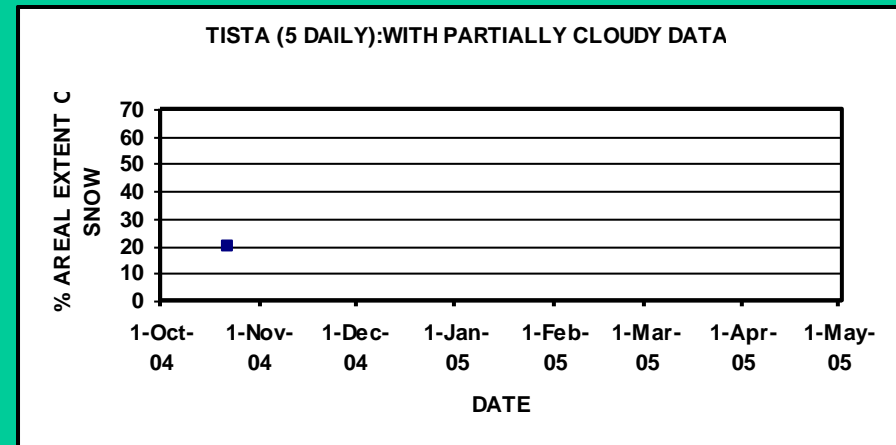
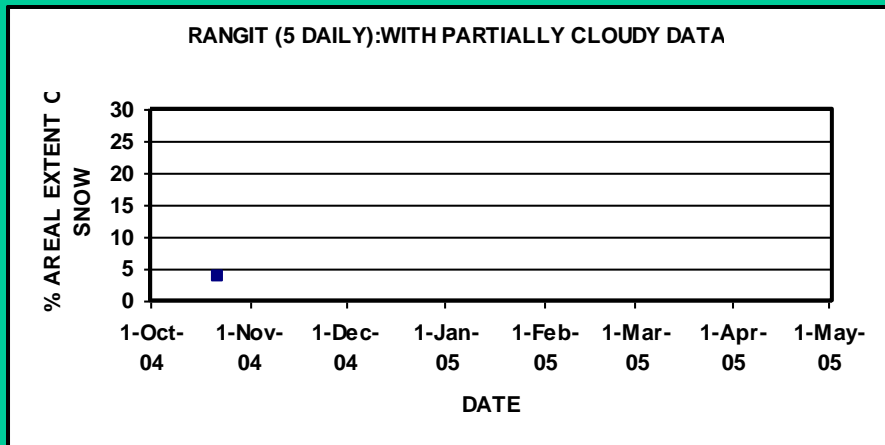
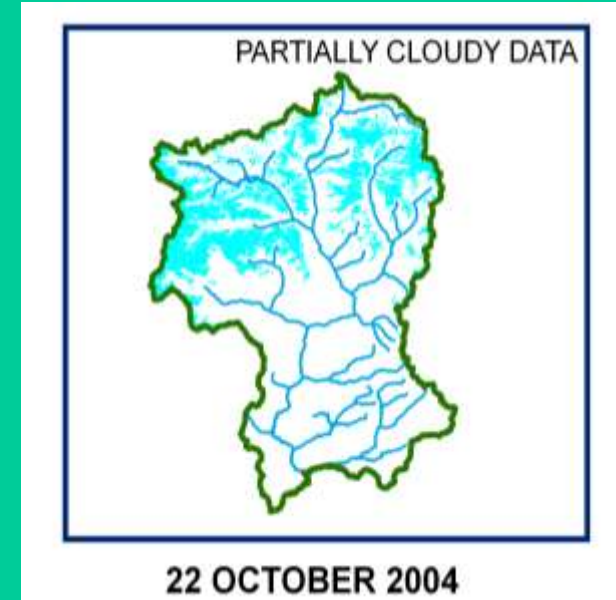
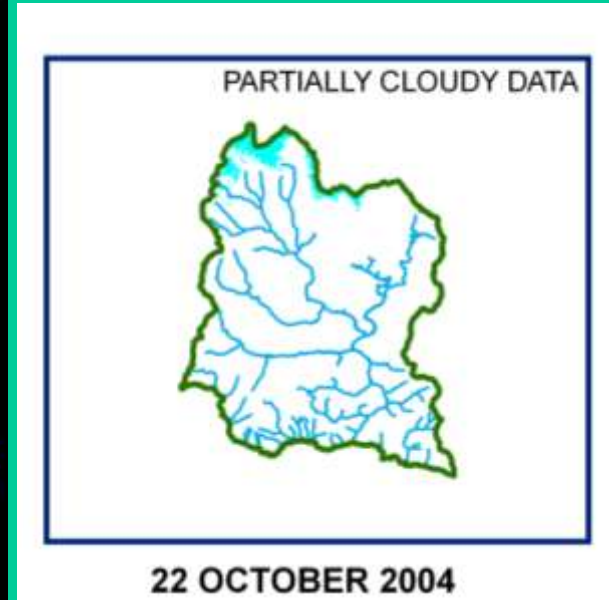


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# 5 Daily Snow Monitoring:2004-2005

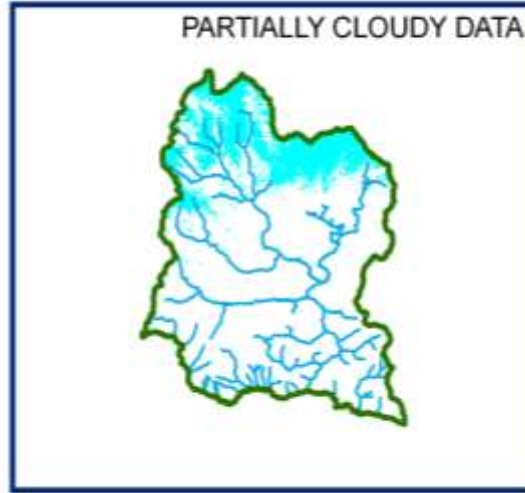


# 5 Daily Snow Monitoring:2004-2005

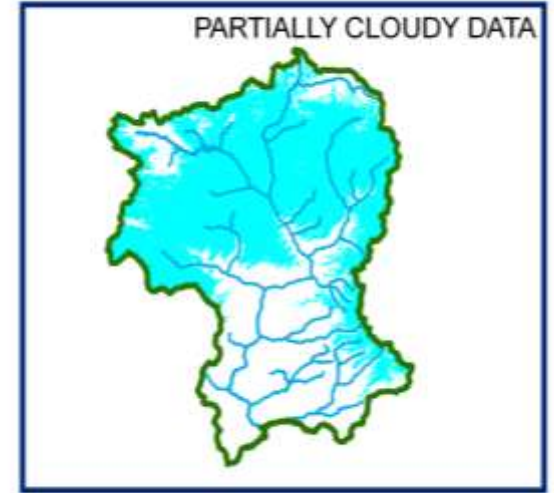


Rangit Basin

Tista Basin

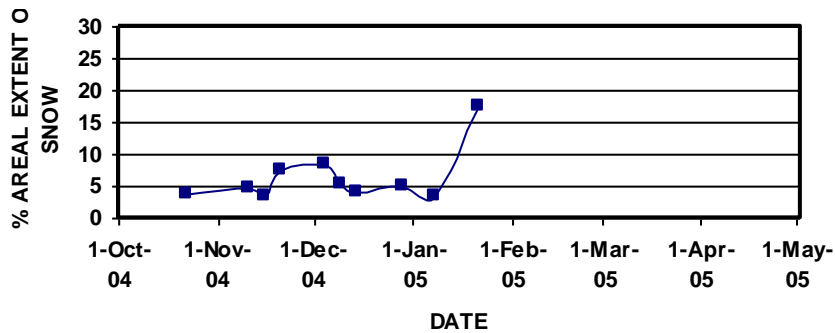


21 JANUARY 2005

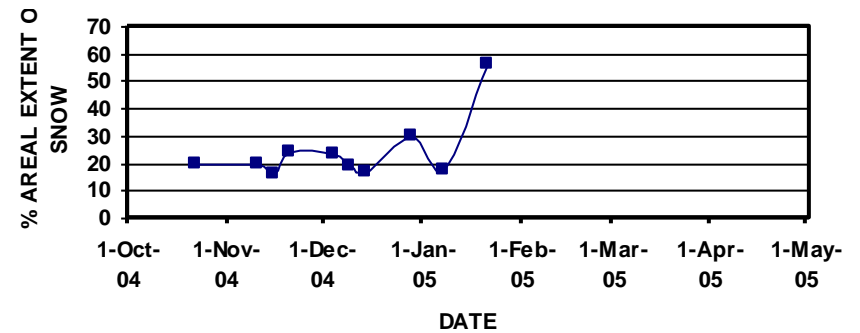


21 JANUARY 2005

RANGIT (5 DAILY):WITH PARTIALLY CLOUDY DATA



TISTA (5 DAILY):WITH PARTIALLY CLOUDY DATA

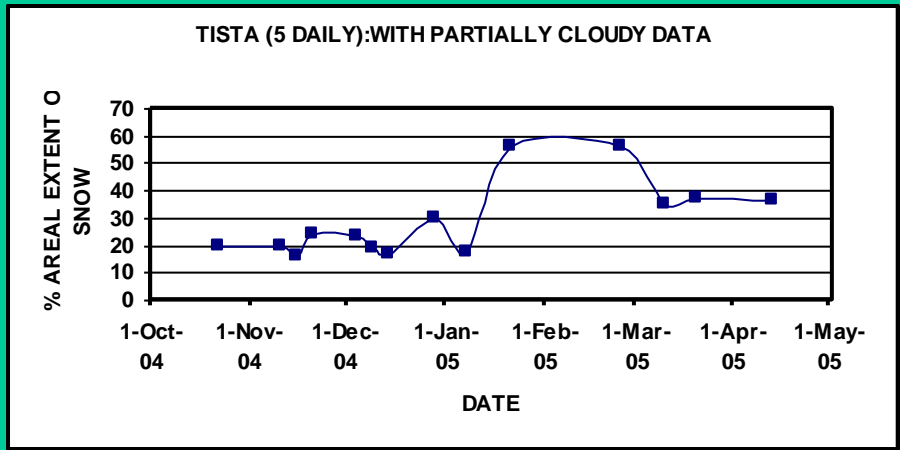
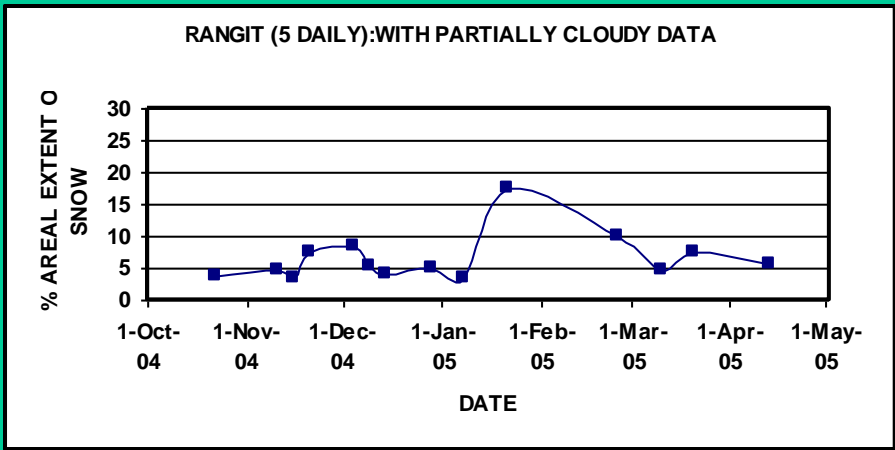
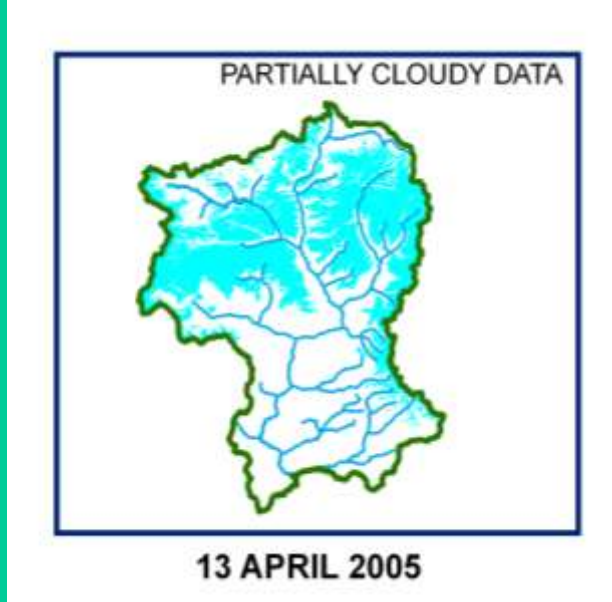
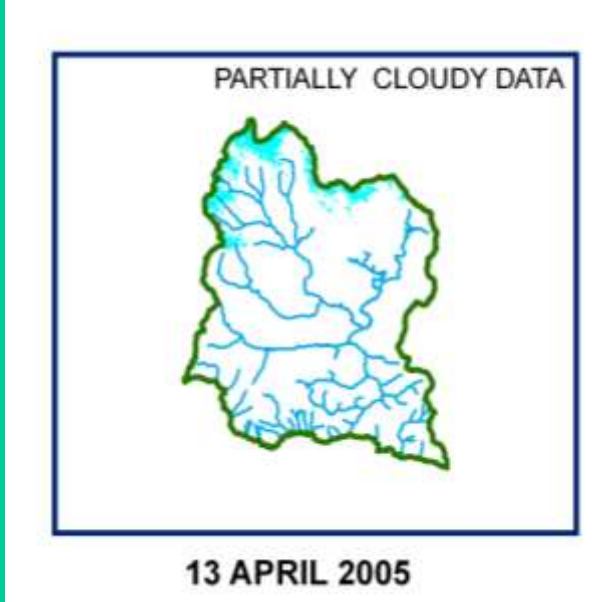


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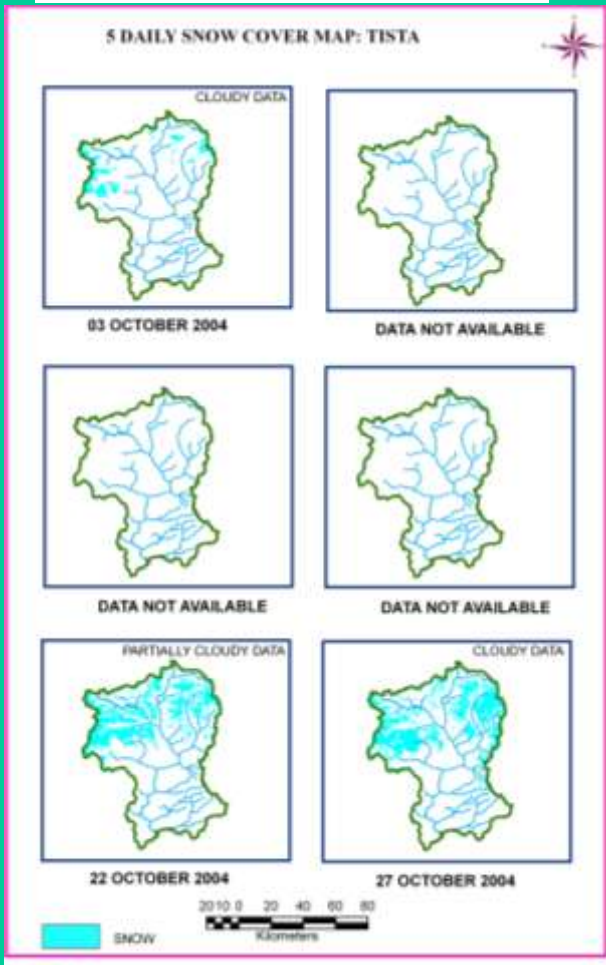
Rangit Basin

Tista Basin

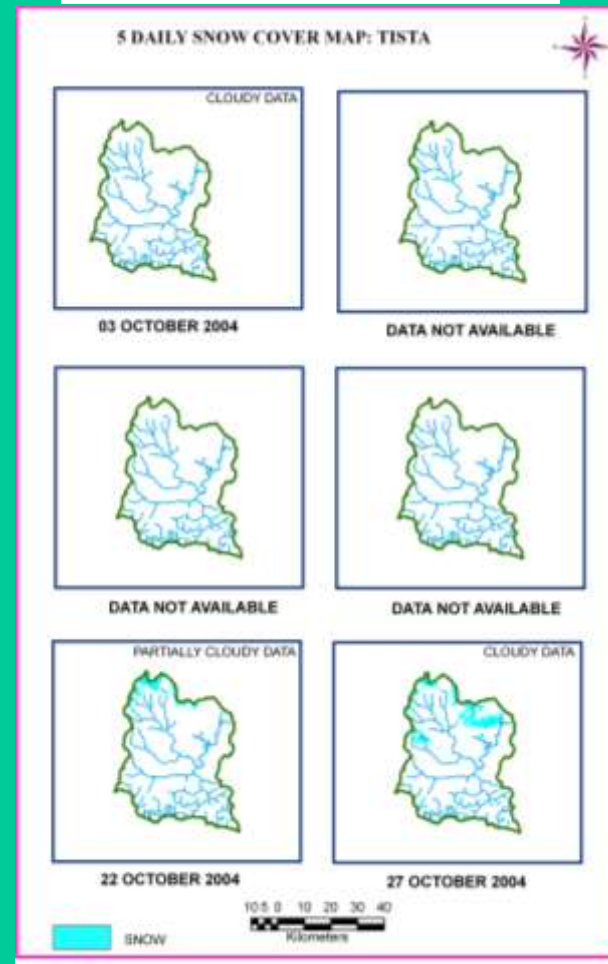


# Snow Cover Atlas

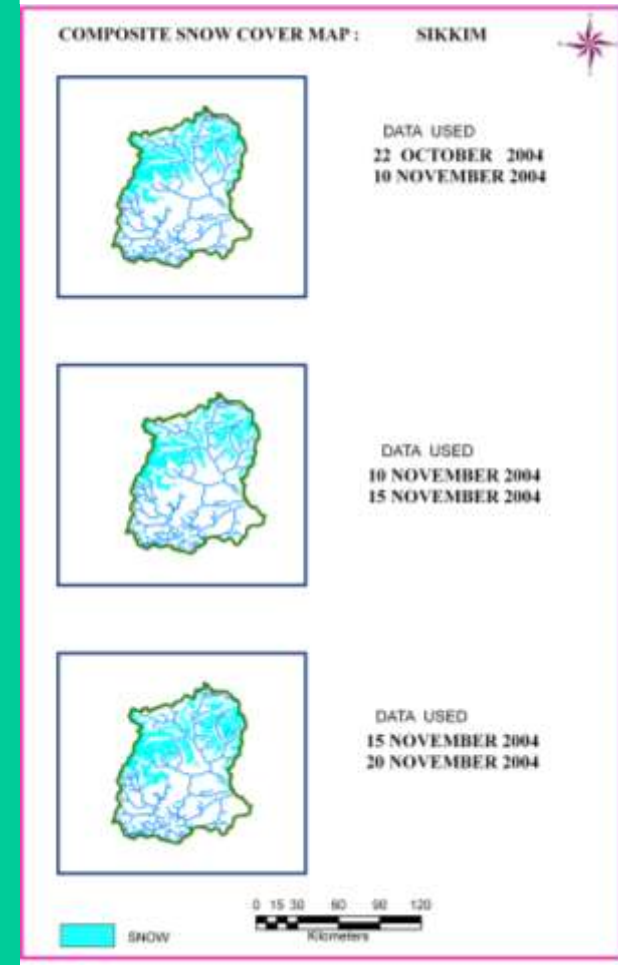
## 5 Daily Snow Map: Tista



## 5 Daily Snow Map: Rangit



## Composite Snow Cover map



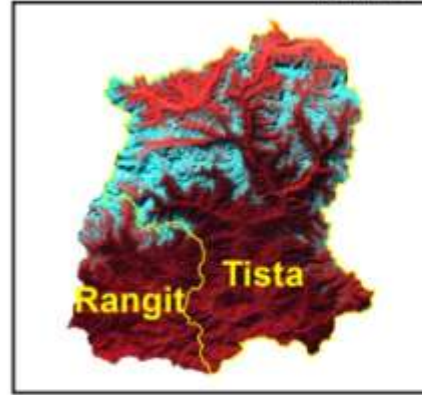
## SNOW COVER MONITORING 2007-2008

### Snow Cover Monitoring in Sikkim: Tista and Rangit Sub basin 2007-2008

AWiFS



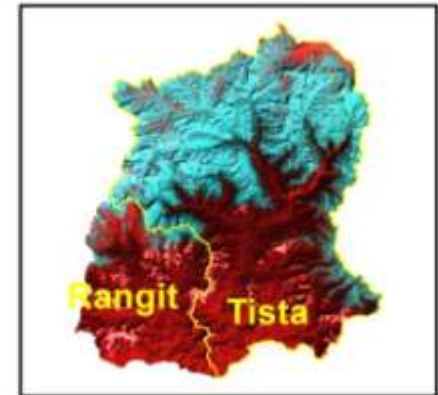
IRS-P6 of 19 Nov 2007



IRS-P6 of 18 Dec 2007



IRS-P6 of 16 Jan 2008

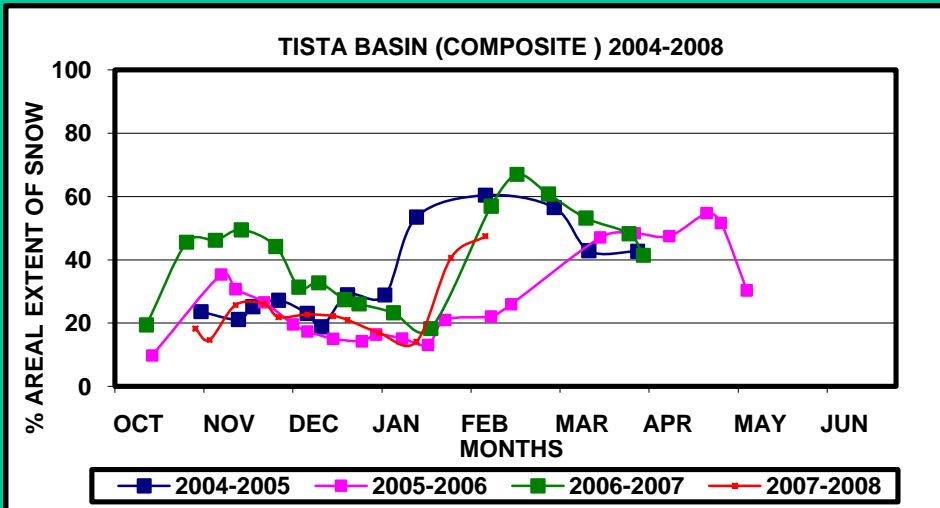
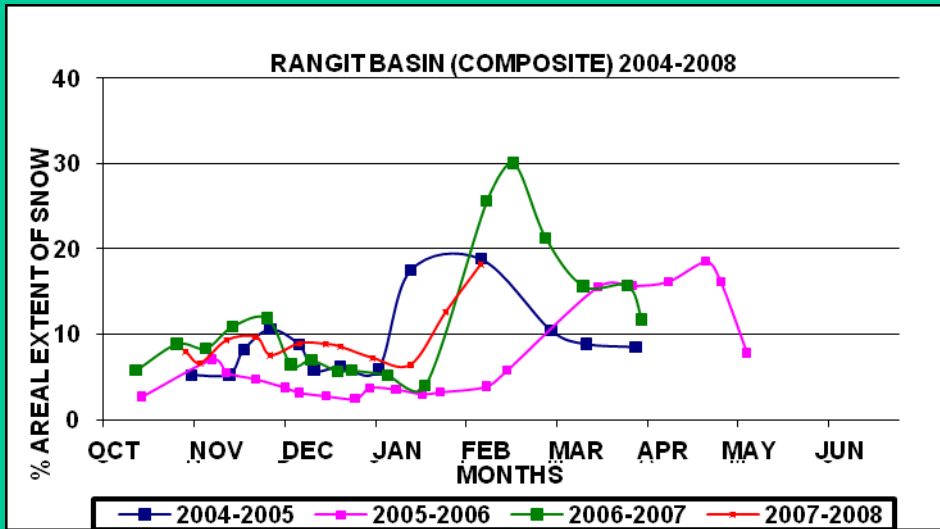


IRS-P6 of 04 Feb 2008

0 0.15 0.3 0.6 0.9 1.2  
Kilometers

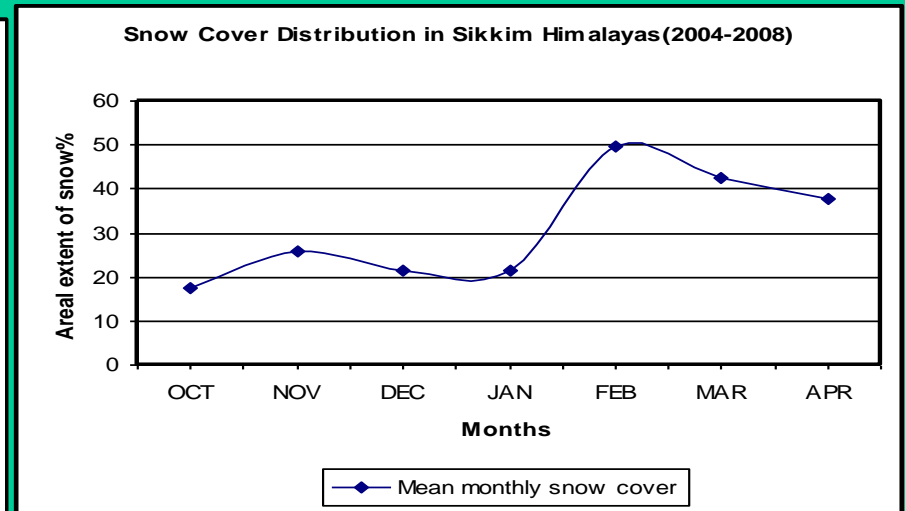
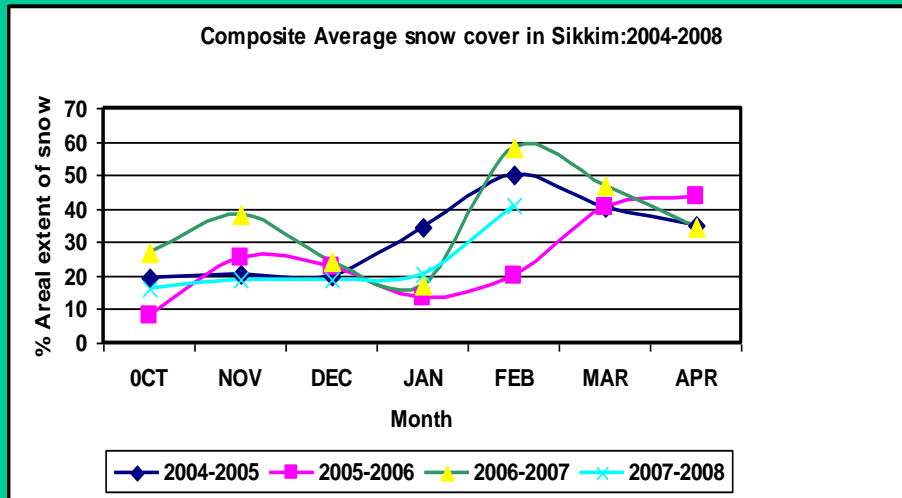
- Accumulation and Ablation of seasonal snow cover in Sikkim; Tista and Rangit sub basins in 2007-2008.
- Seasonal snow cover is maximum in February and minimum in January.

# Results



- Snow ablation and accumulation pattern are similar.
- Maximum snow cover of 67.02% in February, 2007, in Tista Basin
- Maximum snow cover of 30% in Rangit Basin.
- 2005-2006-partially cloudy imageries.
- 2004-2005; maximum snow cover.
- 2006-2007; least snow cover.

# Results & Conclusion



- First study of it's kind in Sikkim Himalayas :-No information on Snow cover extend.
- Almost 3548sqkm is snow cover covered. Maximum ~ 50% in February.
- All four years (2004-2008)have similar snow cover pattern, including the sub-basins.
- Maximum snow extent in February suggests Sikkim receives higher snow precipitation from Western Disturbances than North East Monsoon.
  - also due to less snow melting attributed by lower winter time temperature.
- Continuous snow precipitation even during summer months.
  - Unlike Western Himalayas
  - Different snow accumulation and ablation pattern.

# Challenges

- Problem of Cloud cover :-
  - But with development of newer microwave technique, RISAT data would be of prime importance.
  
- Problem of Vegetation :-
  - Need for a better algorithm to monitor snow under canopy cover.

Rathong:Sikkim

Thankyou

