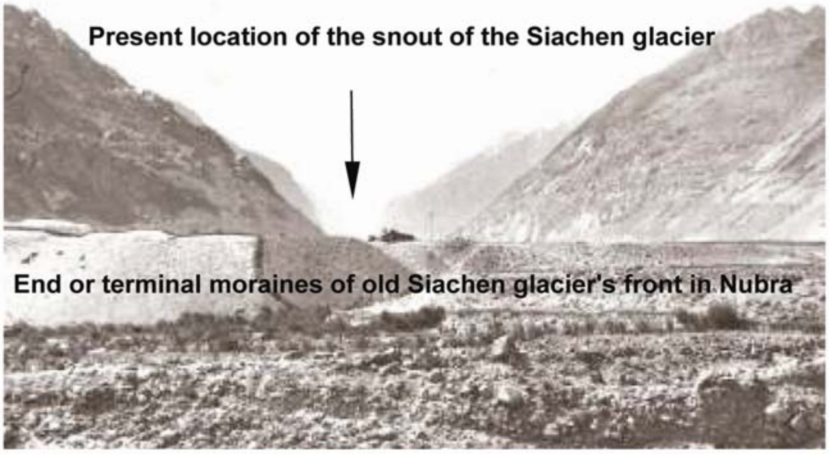

Figure 6. Photograph showing a thick accumulation of end or terminal moraines of the snout front of the Siachen glacier, formed sometime during the inter-glacial period, as seen between the villages of Sasoma and Changlung in the Nubra Valley. The present snout of the glacier is situated about 40–45 km north of this point.

Siachen glacier between North India, Central Asia and the adjoining Tibetan Plateau, further detailed multidisciplinary work is required to understand the periodicity of advance/retreat or 'rest mode', if any, of the Siachen glacier since the beginning of last inter-glacial period. Thus a well-constrained palaeoclimatic data-based model would definitely help towards better understanding the climatic change vis-à-vis monsoonal variation in the Indian subcontinent, Tibetan Plateau and adjoining Central Asian region.

1. Raina, V. K. and Sangewar, C., *J. Geol. Soc. India*, 2007, **70**, 11–16.
2. Strachey, R., *Proc. R. Soc. Edinburgh*, 1848, **2**, 196.
3. Longstaff, T. G., *Geogr. J.*, 1910, **35**, 622–658.
4. Upadhyay, R. and Sinha, A. K., *Palaeobotanist*, 2001, **50**, 213–224.
5. Mayewski, P. and Jeschke, P. A., *Arctic Alpine Res.*, 1979, **11**, 267–287.
6. Hasnain, S. I., ICIMOD, Kathmandu, Nepal.
7. Ageta, Y. and Katota, T., *Ann. Glaciol.*, 1992, **16**, 89–94.
8. Nakawo, M., Fujita, K., Ageta, Y., Shankar, K., Pokhrel, A. P. and Tandong, Y., *Bull. Glacier Res.*, 1997, **15**, 53–58.
9. Hasnain, S. I., *Himalayan Glaciers: Hydrology and Hydrochemistry*, Allied Publishers. Ltd, New Delhi.
10. Naito, N., Nakawo, M., Kadota, T. and Raymaond, C. F., In *Seattle Symposium-2000 on Debris Covered Glaciers*, 2000, pp. 245–264.
11. Vohra, C. P., In Proceedings of the National Seminar on Resources Development and Environment in the Himalayan Region, DST, New Delhi, pp. 441–460.
12. Kotlia, B. S., Dumka, R. K., Miral, M. S., Joshi, L. M. and Kumar, K., *En Books*, 2008 (in press).
13. World Wildlife Fund Report, 14 March 2005.
14. Hasnain, S. I., *The Times of India*, Chandigarh, 29 July 2005.
15. Taylor, J. M., *Environment and Climate News*, The Heartland Institute, 11 January 2006.

ACKNOWLEDGEMENTS. I thank the Head, Department of Geology, Kumaun University, Nainital for providing facilities for research under UGC-SAP and DST-FIST programmes.

Received 15 December 2008; accepted 21 January 2009

RAJEEV UPADHYAY

Department of Geology,
Kumaun University,
Nainital 263 002, India
e-mail: Rajeev_up@yahoo.com

Present state of the three tidal inlets of the Pulicat Lake: facts from remote sensing and field surveys

A recent scientific correspondence in these columns noted with concern that one of the tidal inlets of the Pulicat Lake has been considerably narrowed, which could be detrimental to the lake[1]. But a more recent satellite image of the area, which is presented here, does not indicate any reason for raising such an alarm. Our intention is to provide a realistic picture of the conditions prevailing at the Pulicat Lake, based on the remote sensing image analysis and more importantly, enquiries in the field.

The Pulicat Lake is the second largest coastal lagoon after the Chilika Lake along the east coast of India. The lake appears to have occupied a natural depression bound by major lineaments on its three landward margins[2], while on the east, a prominent barrier spit (linear shore-parallel sand bank deposited by wave/longshore current activity), known as the Sriharikota Island (where the satellite launching station is located), separates it from the sea (Bay of Bengal). The lake spreads over an area of about 620 km^2 (measured within its boundary traced from the topographic maps), excluding the 120 km^2 area of numerous islands that lie in it[2]. Out of the total area of the lake, about 360 km^2 in the southern part is active, whereas the rest of the lake area in its northern part is desiccated due apparently to tectonic upliftment, which is evident from the displacement of subsurface sediment sequences of recent origin[3]. At present, the northern part of the lake appears more or less like a mudflat (Figure 1 *a*) with a thin water column, if any, especially during the monsoon.

The Pulicat Lake is connected to the sea through three tidal inlets, one each at Tupilipalem, Rayadoruvu and Pulicat villages respectively, from north to south (Figure 1 *a*). The inlets near the first two locations enter the northern part of the lake, while the third one is at the extreme southeastern end of the lake. We present here three remote sensing images each of the three inlets of the Pulicat Lake. For this purpose, the remote sensing images in the near-infrared band (band 3 of IRS P6-LISS III of Path 102, Row 063 in digital form covering the Pulicat Lake area) of 17 April 2004, 25 January 2006 and 20 April 2008 were chosen, since the land–water boundary is sharper in that band. The images of the three dates selected were geocoded, edge-enhanced and then resampled using cubic convolution method to smoothen the pixels, so that accurate measurements could be made using digital techniques. In the 2004 image (upper panel, Figure 1 *b*), the Tupilipalem inlet was almost closed, while it was as wide as 144 m in the 2006 image, but at a different location about 2.24 km south of its 2004 position (middle panel, Figure 1 *b*). By 2008, the inlet was completely closed at the location where it was found in 2006 image, but a new 161 m-wide opening was seen for the inlet at about 1.06 km north of its 2006 position (bottom panel, Figure 1 *b*). The reason for this major shift in the location of the mouth was revealed in our field enquiries. A cross-section of villagers, including the *sarpanch* of Tupilipalem informed us on 10 December 2008, that they cut the sand bank almost every year at its narrowest part to flush the flood waters during rainy season, which otherwise maroon their village. They have been forced to take up this work because the sand bank became so thick that it is not breached naturally even in the monsoon season during the past four years. Earlier, the sand bank was closed in pre-monsoon and breached during monsoon floods. Thus, the 144 m and 161 m wide openings respectively, found in the 2006 and 2008 images (Figure 1 *b*) were the ones artificially made by the locals. But on 10 December 2008, when we visited the area, the mouth was hardly 25 m wide.

The inlet near Rayadoruvu also underwent changes at its mouth. It was about 23 m wide in April 2004, increased to 101 m as seen from the January 2006 image and then decreased to 62 m by April 2008 (Figure 2 *a*). Similarly, the inlet near Pulicat village was about 71 m wide in April 2004 (left panel, Figure 2 *b*), and increased to 123 m in January 2006 (middle panel, Figure 2 *b*). However, the opening of this inlet was divided into two as seen in the image from April 2008, due to sand accumulation in the form of a barrier island across its mouth. The northern opening was about 90 m wide, while the southern opening was about 69 m wide (right panel, Figure 2 *b*). Evidently, the tidal inlets exhibit dynamic changes at their mouths with alternating deposition and erosion, including shift in their locations depending upon the variations in the wave and tide regimes. The wave direction changes seasonally with consequent changes in drift directions. The longshore drift is usually towards north during the SW monsoon and towards south in winter monsoon. As a result, sand banks grow across the mouths of the tidal inlets as well as the distributaries of many rivers along the east coast of India, mainly in the dominant drift direction, causing deflection and overextension of the

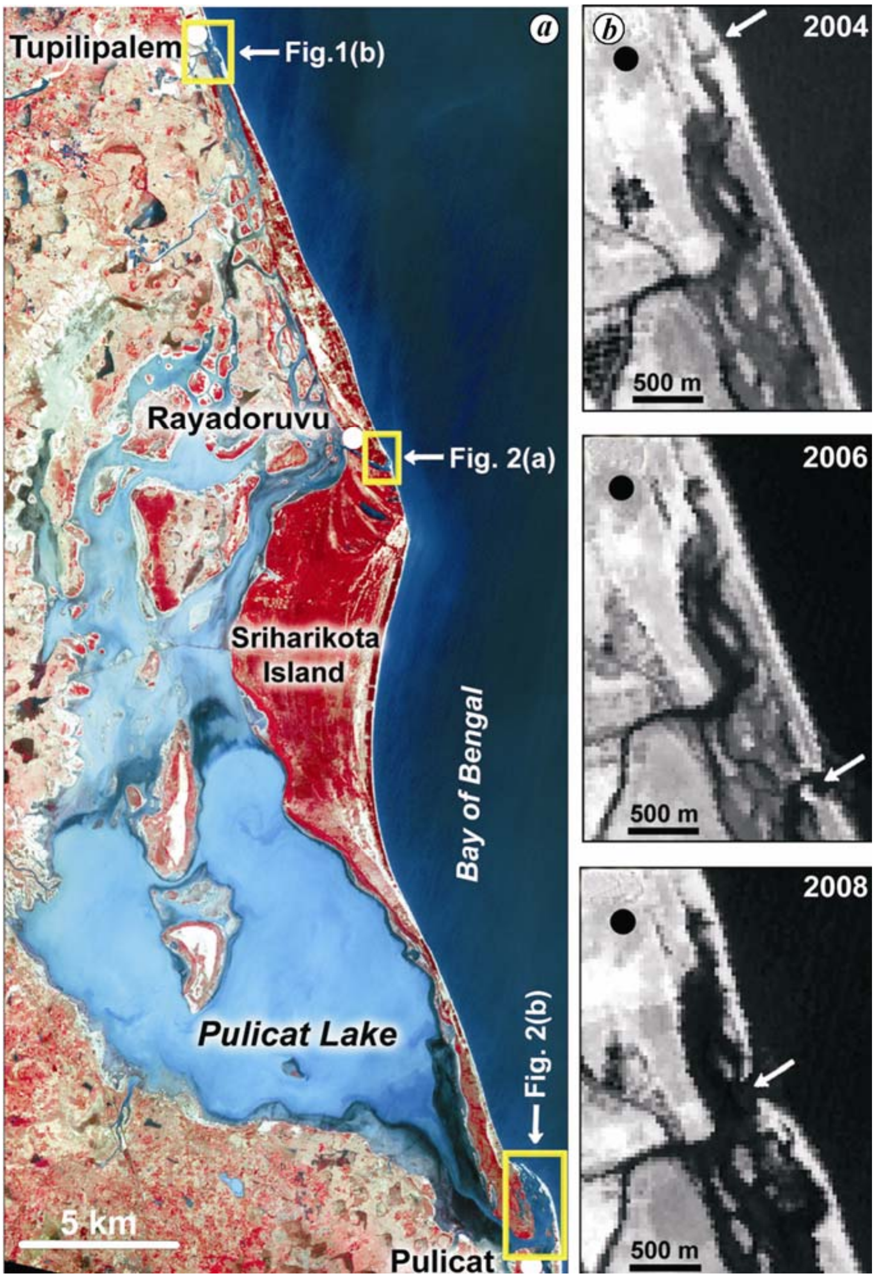

Figure 1. ***a***, Remote sensing image (IRS P6-LISS III of Path 102, Row 063) dated 20 April 2008 showing Pulicat Lake. ***b***, Changes in the mouth of the tidal inlet near Tupilipalem village: (Upper panel) From the IRS P6-LISS image dated 17 April 2004; (Middle panel) From the image dated 25 January 2006; and (Bottom panel) From the image dated 20 April 2008. White arrows in (***b***) show the location of the inlet mouths on the respective dates. Yellow boxes in (***a***) indicate the location of Figures 1 *b*, 2 *a* and 2 *b*.

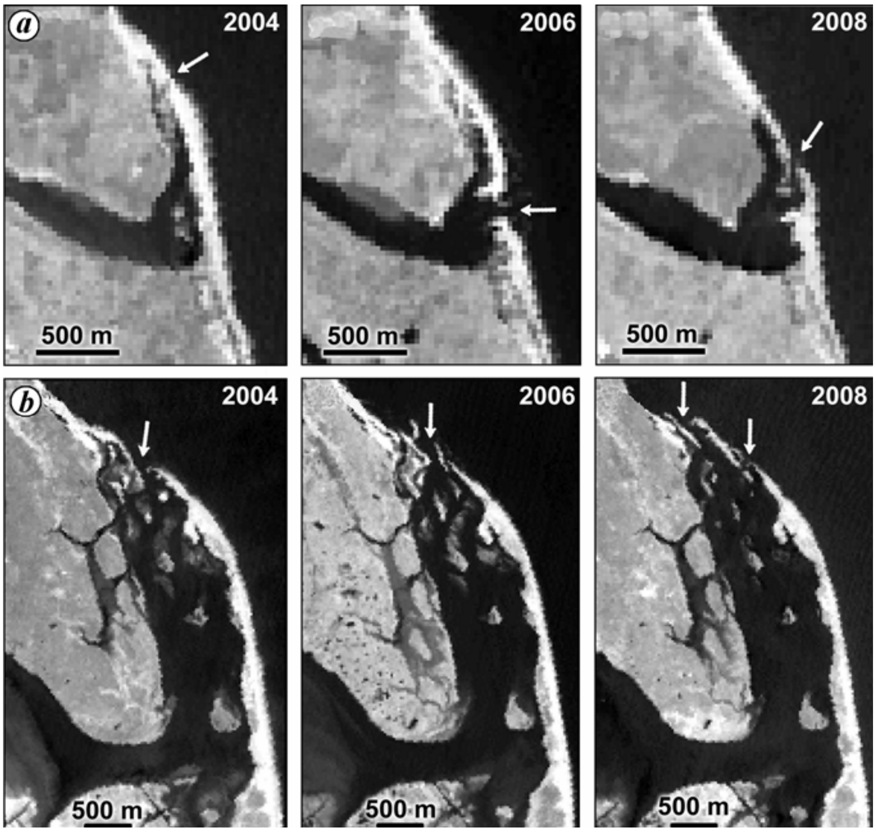

Figure 2. Temporal changes in the mouths of the tidal inlets near Rayadoruvu (***a***), and Pulicat villages (***b***), as appearing in the remote sensing images of the area. The left panels in both (***a***) and (***b***) are images from the 17 April 2004, the middle panels from 25 January 2006, and the right panels from 17 April 2008 of the IRS P6-LISS III of Path 102, Row 063. The white arrows indicate the location of the inlet mouths on the respective dates.

mouths alongshore before meeting the sea. The inlet mouth at Pulicat village is a good example. The apparently northward-growing sand spit overextended the tidal channel northward by about 3.75 km, parallel to the Lake shore, before joining the sea.

On the whole, it appears that the changes at the inlets near Tupilipalem and Rayadoruvu in the northern desiccated part may not have any significant impact on the overall health of the lake, except probably providing passage to the monsoon floodwater into the sea. This is particularly true in the case of Tupilipalem inlet, considering its location in the extreme northeastern end, almost beyond the Pulicat Lake proper (Figure 1 *a*). In fact, our field enquiries at Tupilipalem also revealed that there is hardly any connection to Pulicat Lake from here.

However, the inlet at the Pulicat village, which connects the active part of the lake with the sea, is vital for the survival of the lake. Although this inlet has overextended northward by the growth of a sand bank (spit) from its southern end across the mouth (Figure 1 *a* and 2 *b*), apparently it is still be able to effectively flush the active part of the lake, as evident from the rather unchanged extent of the lake during the past several years. The extent of the southern active part of the lake was about 354 km^2 when measured from the April 2004 image, about 369 km^2 for the January 2006 image, and about 349 km^2 for the April 2008 image. The minor variations in the lake extent between the two images from April (2004 and 2008) could be due to the change in daily tide level at the time of image capture by the satellite, while the change between January and April images (between 2006 image and the other two) is understandably due to seasonal variations in the sea level, since it is known that in the Bay of Bengal the annual lowest sea levels occur in March–April. Therefore, the minor variations in the extent of the lake observed from these measurements could be due to the change in the tide level. However, a straight cut at the southern base of the spit (sand bank) that has grown across the inlet mouth near Pulicat village, if made, would ensure improved flushing of the lake. But there is a catch here. The mouth of this inlet comes within Tamil Nadu, while most part of the lake is in Andhra Pradesh. This is again an interstate issue!

1. Nanda Kumar, N. V., Nagarjuna, A., Reddy, D. C., Mruthyunjaya Reddy, K. and Nageswara Rao, A., *Curr. Sci.*, 2008, **95**, 1405–1406.
2. Nageswara Rao, K. and Sadakata, N., *Laguna*, 1996, **3**, 141–149.
3. Vaz, G. G. and Banerjee, P. K., *Mar. Geol.*, 1997, **138**, 261–271.

ACKNOWLEDGEMENTS. We thank Dr V. S. Hegde, Programme Director, Disaster Management Support Programme, Department of Space for funding a project on coastal vulnerability mapping of Andhra Pradesh which enabled us to acquire satellite images and to conduct fieldwork for the study, and Dr R. R. Navalgund, Director, Space Applications Centre, Ahmedabad for constant encouragement.

Received 16 December 2008; accepted 7 January 2009

K. NAGESWARA RAO[1,]*
P. SUBRAELU[1]
A. S. RAJAWAT[2]
AJAI[2]

[1]*Department of Geo-Engineering, Andhra University, Visakhapatnam 530 003, India*
[2]*Marine and Water Resources Group, Space Applications Centre, Ahmedabad 380 015, India*
**For correspondence.*
e-mail: nrkakani@yahoo.com