Supplement of

Tracing glacier changes since the 1960s on the south slope of Mt. Everest (central Southern Himalaya) using optical satellite imagery

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Table S1. A complete set of data on glacier surface area (Surf), terminus (Term), snow-line altitude (SLA) and debris cover area (DebrisCov) for all analysed glaciers.

| Glacier      | Surf 1962 (km²) | Surf 1975 | Surf 1992 | Surf 2000 | Surf 2008 | Surf 2011 | Surf 1962-75 | Surf 1975-92 | Surf 1992-00 | Surf 2000-08 | Surf 2008-11 | Surf 1962-11 | Debris-cover area (%) |
|--------------|-----------------|-----------|-----------|-----------|-----------|-----------|---------------|---------------|---------------|---------------|---------------|---------------|-----------------------|
| Ama Dablam   | 10.6            | 10.5      | 10.4      | 9.8       | 9.6       | 39        | -44           | -56           | -86           | -39           | -186          | 5183         | 5199                  |
| Bhote Koshi  | 43.7            | 43.6      | 43.2      | 42.9      | 42.7      | -140      | -215          | -80           | -146          | -42           | -623          | 5224         | 5382                  |
| Chhule       | 10.2            | 9.8       | 9.1       | 8.8       | 8.0       | -65       | -40           | -152          | -169          | -7            | -433          | 5139         | 5231                  |
| Chhutingpo   | 8.5             | 9.3       | 7.6       | 6.5       | 7.0       | -78       | -136          | -168          | -45           | 0             | -427          | 5224         | 5257                  |
| Cholo        | 2.3             | 2.9       | 1.9       | 1.5       | 1.4       | 234       | 212           | -74           | -15           | 0             | 357           | 4987         | 4946                  |
| Cholotse     | 2.5             | 1.7       | 1.5       | 1.5       | 1.5       | 0         | 96            | 0             | -98           | -28           | -30           | 5078         | 5141                  |
| Duno         | 2.2             | 2.2       | 2.1       | 2.1       | 2.1       | 182       | 172           | -99           | 0             | 0             | 255           | -            | 4984                  |
| Imja         | 28.1            | 28.0      | 27.0      | 27.2      | 26.4      | 25.5      | -862          | -458          | -336          | -235          | -207         | -2119        | 5340                  |
| Khdu_gr125   | 1.9             | 1.7       | 1.5       | 1.4       | 1.0       | 0.9       | -182          | -153          | -88           | -123          | -601          | 5444         | 5462                  |
| Khdu_gr38    | 2.8             | 2.1       | 1.6       | 0.9       | 0.8       | 0.7       | -142          | -420          | -192          | -345          | -1143        | 5208         | 5305                  |
| Khangri      | 18.6            | 19.1      | 18.6      | 17.9      | 18.5      | 17.2      | 0             | 0             | 0             | 0             | 0             | 5352         | 5383                  |
| Khumbu       | 40.1            | 38.9      | 38.0      | 38.4      | 38.4      | 37.5      | 0             | 54            | -14           | 0             | 41            | 5403         | 5545                  |
| Kyajo        | 1.6             | 1.7       | 1.2       | 1.0       | 1.0       | 1.0       | 65            | -110          | 0             | 0             | 0             | 5433         | 5385                  |
| Langlak      | 3.0             | 2.6       | 2.0       | 2.3       | 2.1       | 2.2       | -117          | -426          | -103          | -115          | -103         | 5193         | 5094                  |
| Langmueche   | 5.5             | 4.9       | 3.7       | 3.3       | 2.9       | 2.8       | -598          | -350          | -27           | -203          | -112         | -1290        | 5184                  |
| Lhotse       | 15.6            | 16.8      | 15.9      | 15.3      | 14.6      | 0         | 231           | -63           | -188          | -42           | -62           | 5346         | 5429                  |
| Lobuje       | 2.0             | 1.7       | 1.7       | 1.8       | 1.7       | 1.7       | 0             | -20           | -37           | 0             | -57           | 5347         | 5350                  |
| Lumsamba     | 20.4            | 21.6      | 22.9      | 20.8      | 19.3      | 18.4      | 0             | 0             | 0             | 0             | 0             | 5445         | 5518                  |
| Machhermo    | 2.1             | 2.5       | 1.9       | 1.1       | 1.2       | 1.2       | -166          | -302          | 25            | 105           | 0             | -339         | 5361                  |
| Melang       | 12.0            | 11.6      | 11.4      | 11.3      | 10.9      | 10.8      | -234          | -425          | -45           | -170          | -46           | -919         | 5263                  |
| Nare         | 9.3             | 7.6       | 6.9       | 6.6       | 6.0       | 5.8       | -359          | -48           | -329          | -165          | -66           | -966         | 5332                  |
| Nareyaqap    | 6.9             | 6.1       | 6.4       | 5.9       | 5.5       | 5.5       | -186          | -74           | -74           | 0             | 0             | -301         | 5361                  |
| Ngomjura     | 98.7            | 98.7      | 98.3      | 98.0      | 97.7      | 97.3      | -82           | -176          | -48           | -125          | -24           | -455         | 5381                  |
| Nopre        | 9.2             | 9.2       | 8.8       | 8.0       | 8.1       | 7.9       | -79           | 92             | 0             | 0             | 14            | 5515         | 5505                  |
| Phunki       | 2.0             | 1.7       | 1.7       | 1.8       | 1.7       | 1.6       | -156          | -296          | -189          | -174          | -815         | -            | -902                  |
| Thyangbo     | 15.3            | 14.7      | 13.6      | 12.1      | 8.8       | 8.6       | -210          | -36           | -72            | 0             | -143         | 5079         | 5049                  |
| Tingbo       | 1.5             | 1.4       | 1.3       | 1.2       | 1.1       | 1.2       | -169          | 68             | -64           | 0             | -165         | 5402         | 5262                  |
| W-Lhotse     | 5.6             | 5.0       | 4.7       | 5.0       | 4.5       | 4.4       | -52           | 114            | 16           | -46           | -70           | -39          | 5299                  |
| Other glaciers (< 1 km²) | 21.0   | 19.4   | 19.0   | 16.7   | 12.4   | 12.1 | - | - | - | - | - | - | 5492 |

Glacier Debris-cover area (%)

Notes: The table includes data for 21 glaciers, with columns for Glacier Name, Surface Area, Terminus, Snow-line Altitude, and Debris Cover Area. The data is presented in a tabular format, with specific values for each parameter across different years (1962 to 2011).
| Glacier          | Slope (deg) | Aspect (deg) | Elevation (m) | Length (km2) |
|------------------|-------------|--------------|---------------|--------------|
|                 | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max |
| Ama Dablam       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Bhoje Khudi      |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Chhola           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
**Table S3.** Additional snow-line altitudes (SLAs) derived from 20 Landsat ETM+ imagery of 2000-2011 period for three selected glaciers: Lobuje, Khangri, and Imja. All these images, acquired in the October-December period, present no or minimum cloud cover.

| Date       | Scene ID                  | SLA position on glacier (m a.s.l.) |
|------------|---------------------------|-----------------------------------|
|            |                           | Lobuje   | Khangri | Imja   |
| 10/14/2000 | LE71400412000288SGS00     | 5521     | 5476    | 5669   |
| 10/17/2001 | LE71400412001290SGS00     | 5514     | 5471    | 5644   |
| 10/20/2002 | LE71400412002293SGS00     | 5494     | 5458    | 5657   |
| 11/8/2003  | LE71400412003312ASN01     | 5575     | 5471    | 5657   |
| 10/25/2004 | LE71400412004299PFS00     | 5555     | 5471    | 5663   |
| 11/10/2004 | LE71400412004315PFS00     | 5568     | 5493    | 5682   |
| 10/28/2005 | LE71400412005301PFS00     | 5548     | 5489    | 5672   |
| 11/13/2005 | LE71400412005317EDC00     | 5591     | 5498    | 5685   |
| 11/16/2006 | LE71400412006320PFS00     | 5581     | 5492    | 5695   |
| 12/2/2006  | LE71400412006336SGS00     | 5571     | 5502    | 5660   |
| 10/18/2007 | LE71400412007291PFS00     | 5564     | 5492    | 5673   |
| 11/19/2007 | LE71400412007323PFS00     | 5579     | 5478    | 5695   |
| 10/20/2008 | LE71400412008294PFS03     | 5524     | 5505    | 5660   |
| 12/7/2008  | LE71400412008342SGS00     | 5576     | 5544    | 5664   |
| 10/23/2009 | LE71400412009296SGS00     | 5545     | 5500    | 5695   |
| 11/8/2009  | LE71400412009312SGS00     | 5549     | 5537    | 5720   |
| 10/26/2010 | LE71400412010299SGS00     | 5558     | 5509    | 5697   |
| 11/11/2010 | LE71400412010315PFS00     | 5549     | 5543    | 5672   |
| 10/29/2011 | LE71400412011302EDC00     | 5593     | 5526    | 5742   |
| 12/16/2011 | LE71400412011350PFS01     | 5612     | 5566    | 5733   |
Table S4. Reference studies on the surface area and terminus glacier changes in the Himalaya and Tibetan Plateau.

| Geographic region\(^a\) | Period       | Rate \(^{b}\) | Area \((\text{km}^2 \text{ approx.})\) \(^b\) | Location                                                | Source                   |
|-------------------------|--------------|--------------|---------------------------------------------|---------------------------------------------------------|--------------------------|
| (a) Surface area loss (% a\(^{-1}\)) |              |              |                                             |                                                         |                          |
| CH-S                    | 1962-2011    | 0.27         | 400                                         | Sagarmatha (Mt. Everest) National Park (SNP) Nepal       | This study               |
| CH-S                    | 1976-2000    | 0.15         | 1100                                        | Koshi basin Nepal                                      | Yao et al. (2012)        |
| CH-S                    | 1950s-1992   | 0.14         | 400                                         | SNP Nepal                                               | Salerno et al. (2008)    |
| CH-S                    | 1962-2005    | 0.12         | 90                                          | North-East of SNP Nepal                                 | Bolch et al. (2008)      |
| CH-N                    | 1976-2006    | 0.50         | 2700                                        | Mt.Qomolangma National Nature Preserve, TP               | Nie et al. (2010)        |
| CH-N                    | 1974-2008    | 0.30         | 150                                         | Mt. Qomolangma region, TP                               | Ye et al. (2009)         |
| CH-N                    | 1970-2001    | 0.29         | 650                                         | Pumqu river basin, Tibetan Plateau                      | Jin et al. (2005)        |
| WH-S                    | 1960-2004    | 0.40         | 6300                                        | Western Himalaya                                        | Kulkarni et al. (2011)   |
| WH-S                    | 1962-2004    | 0.50         | 2077                                        | Chenab, Parbati and Baspa                               | Kulkarni et al. (2007)   |
| WH-N                    | 1969-2010    | 0.34         | 90                                          | Kang Tatze Massif, Ladakh                               | Schmidt and Nusser (2012)|
| WH-N                    | 1976-2003    | 0.30         | 80                                          | Naimona'nyi region                                      | Ye et al. (2006b)        |
| EH-S                    | 1990-2010    | 0.17         | 200                                         | Sikkim Himalaya                                         | Basnett et al. (2013)    |
| EH-S                    | 1997-2004    | 0.38         | 400                                         | Tista basin                                             | Kulkarni et al. (2011)   |
| EH-S                    | 1963-1993    | 0.30         | 130                                         | Bhutan                                                  | Karma et al. (2003)      |
| EH-N                    | 1970-2009    | 0.32         | 150                                         | Boshula, mountain, Southeastern TP                      | Wang et al. (2011)       |
| TP                      | 1970-2001    | 0.20         | 900                                         | Nam Co Basin, Southeast of West Nyainqentanglha         | Yao et al. (2012)        |
| TP                      | 1976-2009    | 0.30         | 800                                         | Nam Co basin                                            | Bolch et al. (2010)      |

| (b) Terminus retreat (m a\(^{-1}\)) |              |              |                                             |                                                         |                          |
| CH-S                    | 1962-2011    | 8.2          | 400 (29)                                    | SNP Nepal                                               | This study               |
| CH-S                    | 1970-1979    | 2.4          | 33 (11)                                     | Khumbu region                                           | Yamada et al. (1992)     |
| CH-S                    | 1974-1999    | 6.9          | 7 (3)                                       | Nepal Himalaya                                          | Yao et al. (2012)        |
| CH-N                    | 1960-2001    | 7.1          | 130 (3)                                     | Mt. Qomolangma region, TP                               | Ren et al. (2006)        |
| CH-N                    | 1980-2001    | 6.4          | 30 (2)                                      | Mt. Xixiabangma, TP                                     | Ren et al. (2006)        |
| WH-S                    | 1962-2008    | 14.4         | 15 (2)                                      | Garhwal Himalaya                                        | Mehta et al. (2011)      |
| WH                      | 1960s-2000   | 16.6         | -- (20)                                     | Garhwal, Kumaun, Himalachal and sourrourding            | Yao et al. (2012)        |
| EH-S                    | 1963-1993    | 27.0         | 130 (66)                                    | Bhutan Himalaya                                         | Karma et al. (2003)      |
| EH-S                    | 1976-2005    | 13.0         | -- (26)                                     | Sikkim Himalaya                                         | Raina (2009)             |
| TP                      | 1970-2007    | 16.3         | 55 (5)                                      | Nyainqentanglha mountain region                         | Yao et al. (2012)        |

\(^a\) CH, WH, EH, and TP represent Central Himalaya, Western Himalaya, Eastern Himalaya and Tibetan Plateau, respectively (suffixes -N and -S indicate the north and south, respectively);  
\(^b\) Numbers in bracket represent the number of glaciers
Fig. S1. The terminus of Khumbu glacier based on the 1962 Corona, 1992 Landsat TM, and 2011 Landsat ETM+ imagery. We can observe that since 1962 there is no retreat of the distal part of the terminus.

Fig. S2. Transition zone between debris cover and debris-free ice area of, (a) Khumbu glacier and (b) Imja glacier. The images clearly show an increase in the debris cover area between 1962 and 2011.
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