**Supplementary Information: The triggers of the disaggregation of Voyeykov Ice Shelf (2007), Wilkes Land, East Antarctica, and its subsequent evolution**

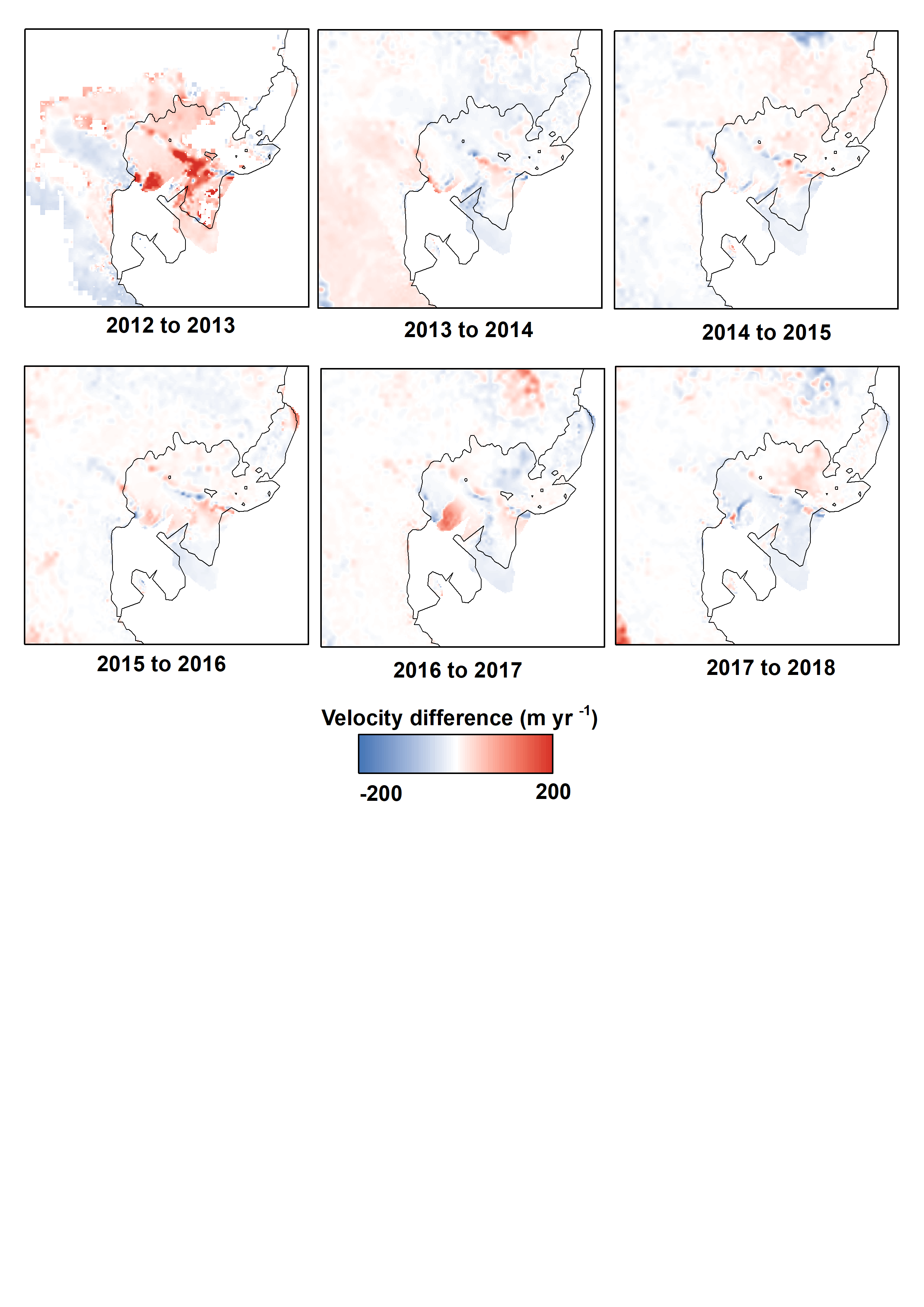
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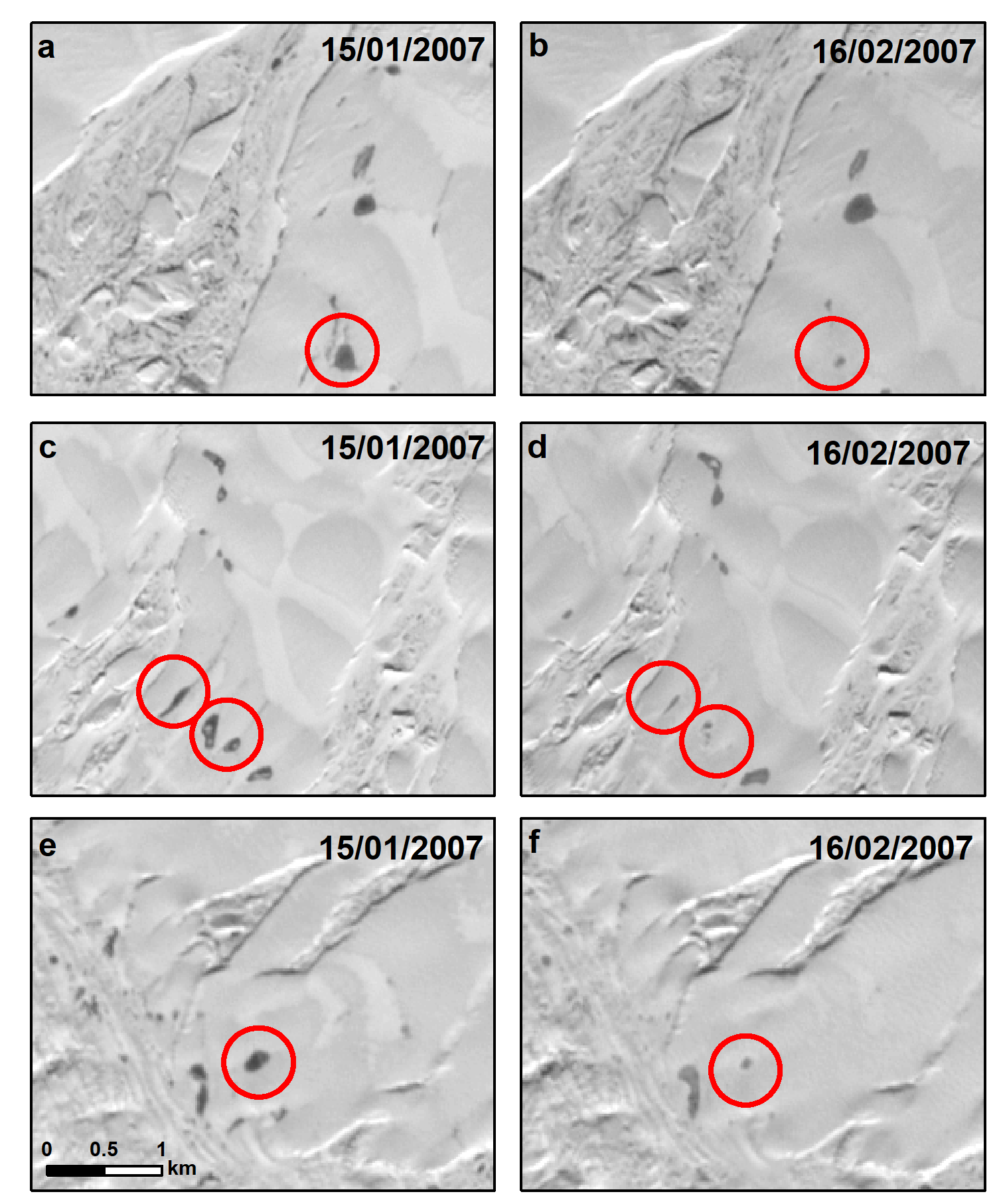
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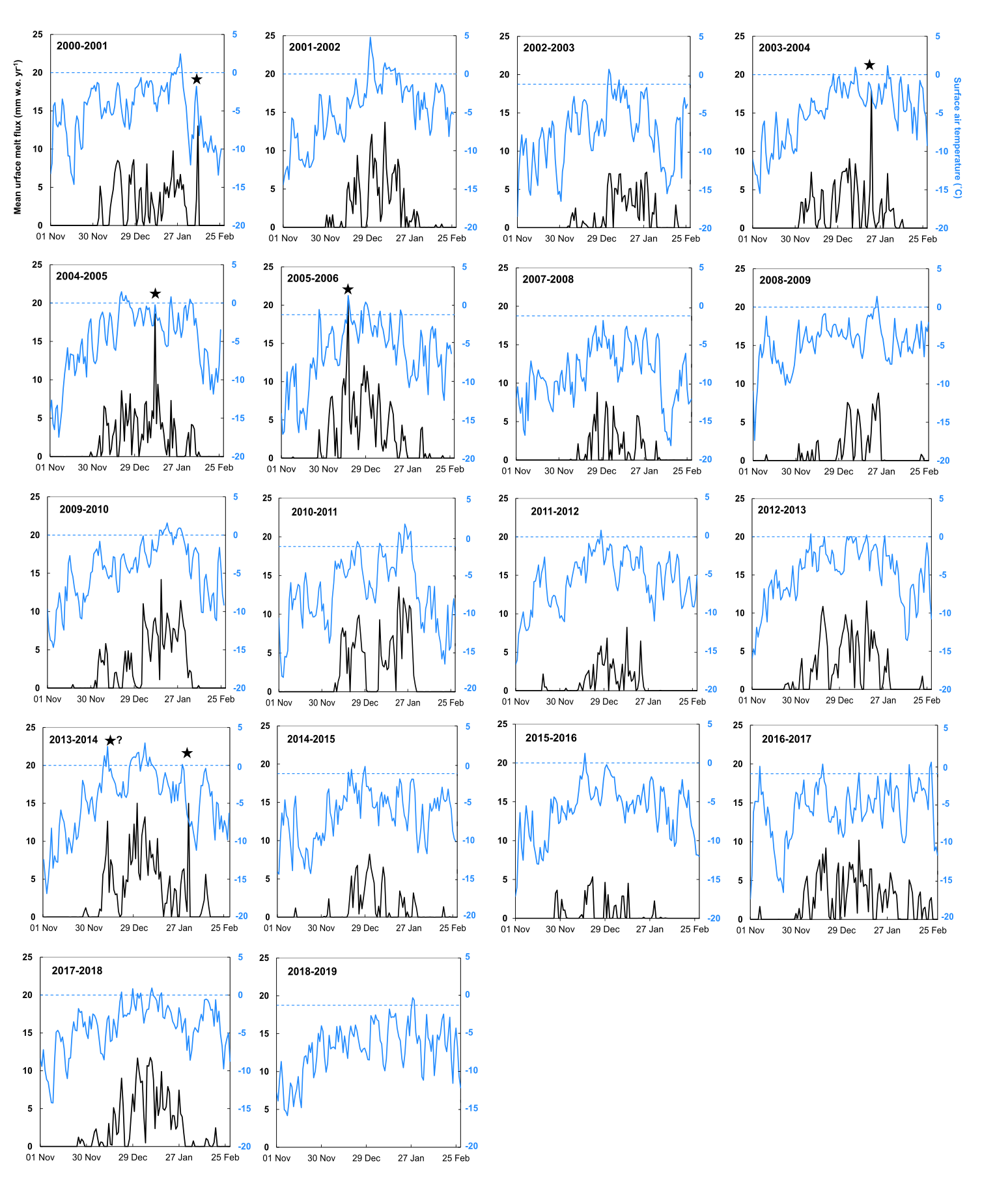
**Supplementary Figure S1**. Velocity differences between annual ITS\_LIVE velocity mosaics on Voyeykov Ice Shelf between 2012 and 2018. Also note the apparent loss of Bell Glacier floating tongue from 2016 onwards represents data scarcity, not a calving event. No velocity data are available covering the eastern portion of the ice shelf fed by Bell Glacier.

**A close up of a map

Description automatically generatedSupplementary Figure S2**. Positions of six major rifts (A1-5, B1-5, C1-5, D1-4, E1-5, F1-5) tracked manually between 2001 and 2019 from Landsat-7 scenes on the floating tongues of Blair Glacier and Bell Glacier. Rift position were used to calculate annual rates of rift propagation (the change in rift tip position divided by the time between subsequent satellite images) as an independent check against changes in rates of ice flow speed derived from ITS\_LIVE velocity mosaics (Supplementary Table 6).



**Supplementary Figure S3**. Supraglacial lake drainages over a 1-month period on Voyeykov Ice Shelf captured by Landsat-7 imagery.

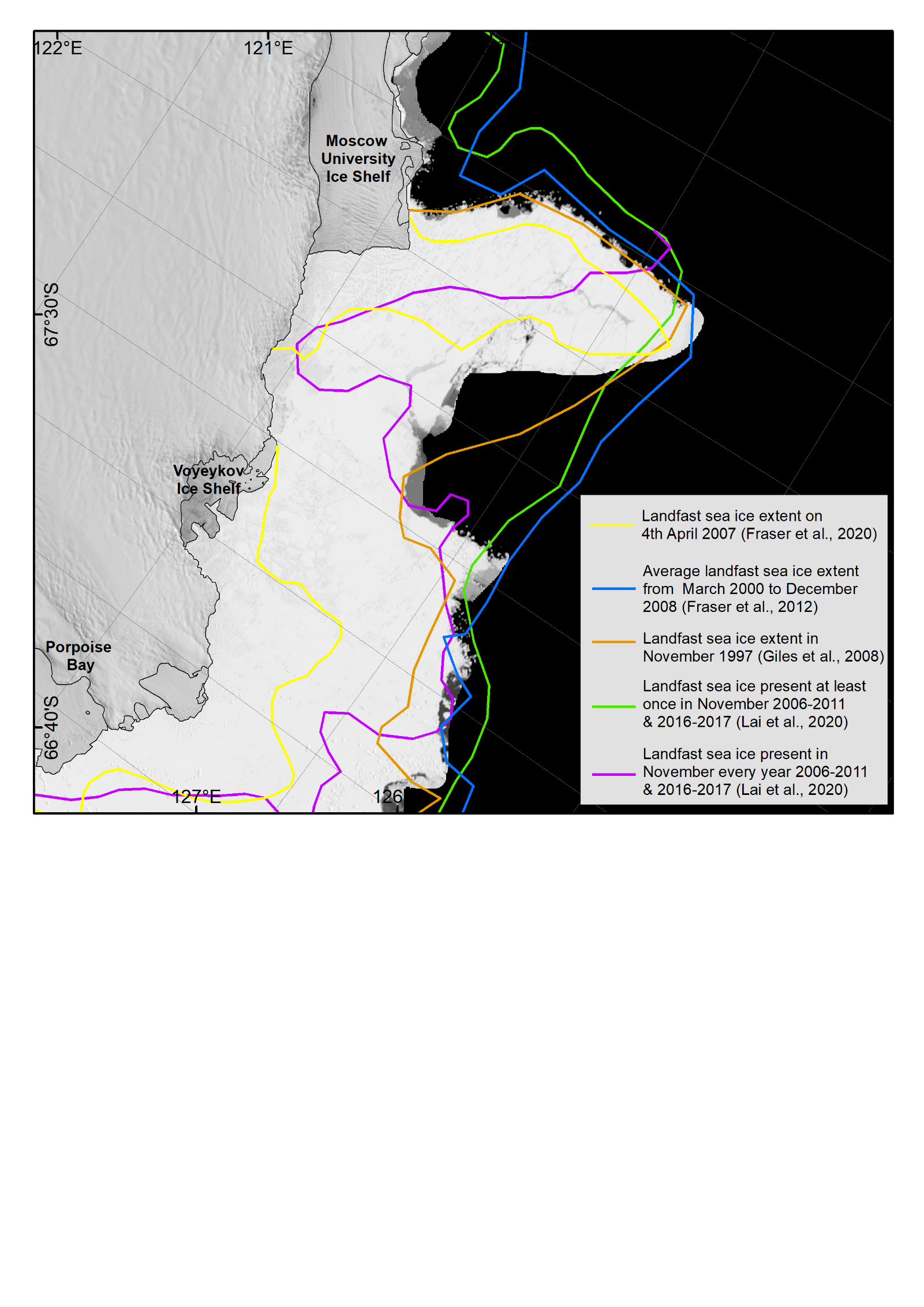


**Supplementary Figure S4**. Time series of mean average surface melt flux (RACMO2.3) and near surface air temperature (ERA5) for the 2000-2018 summer melt seasons. The 2007 time series is shown in Figure 7 of main paper. Short-lived, intense high magnitude snowmelt events are marked with a black star.

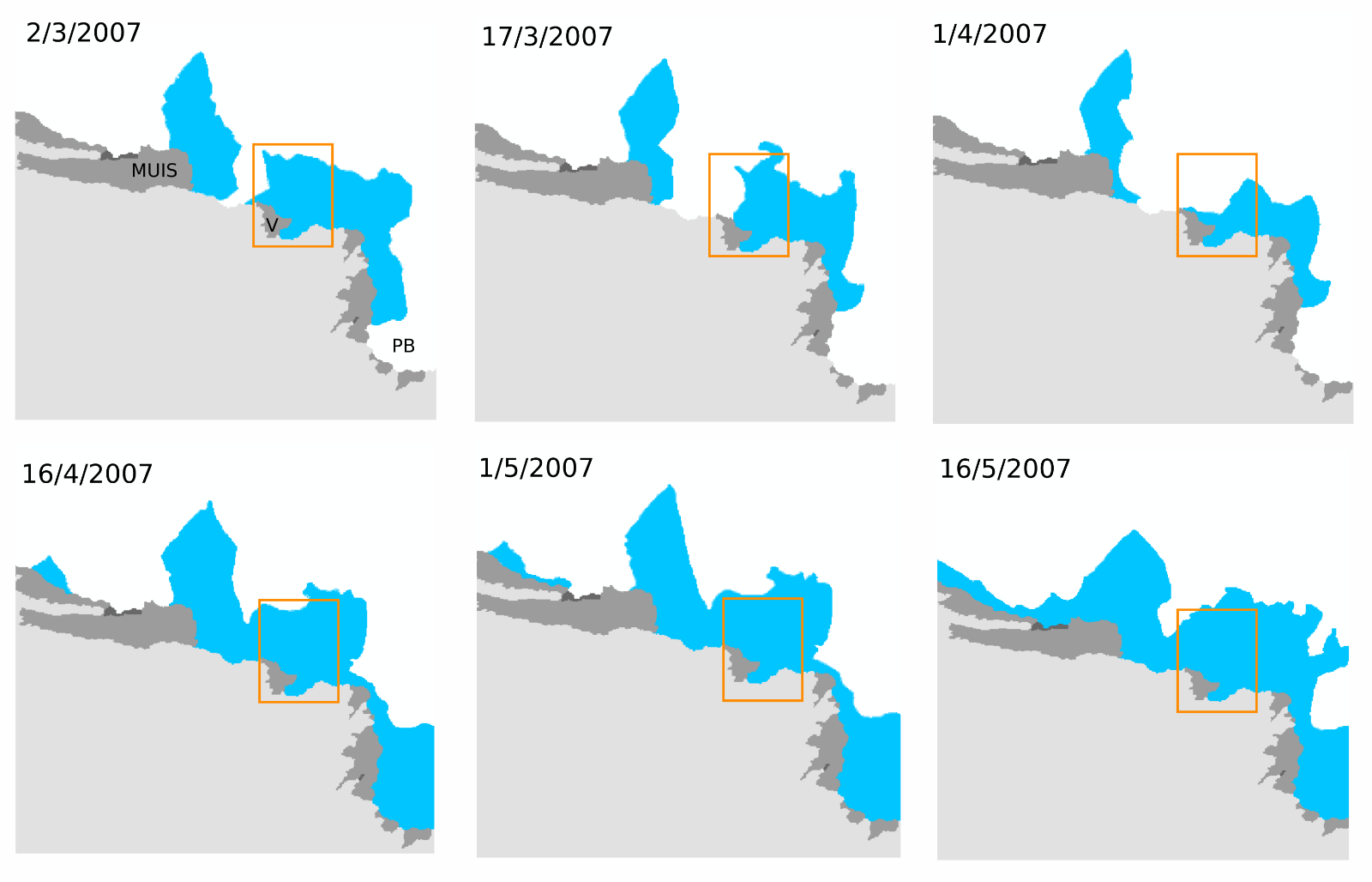
A close up of a map

Description automatically generated

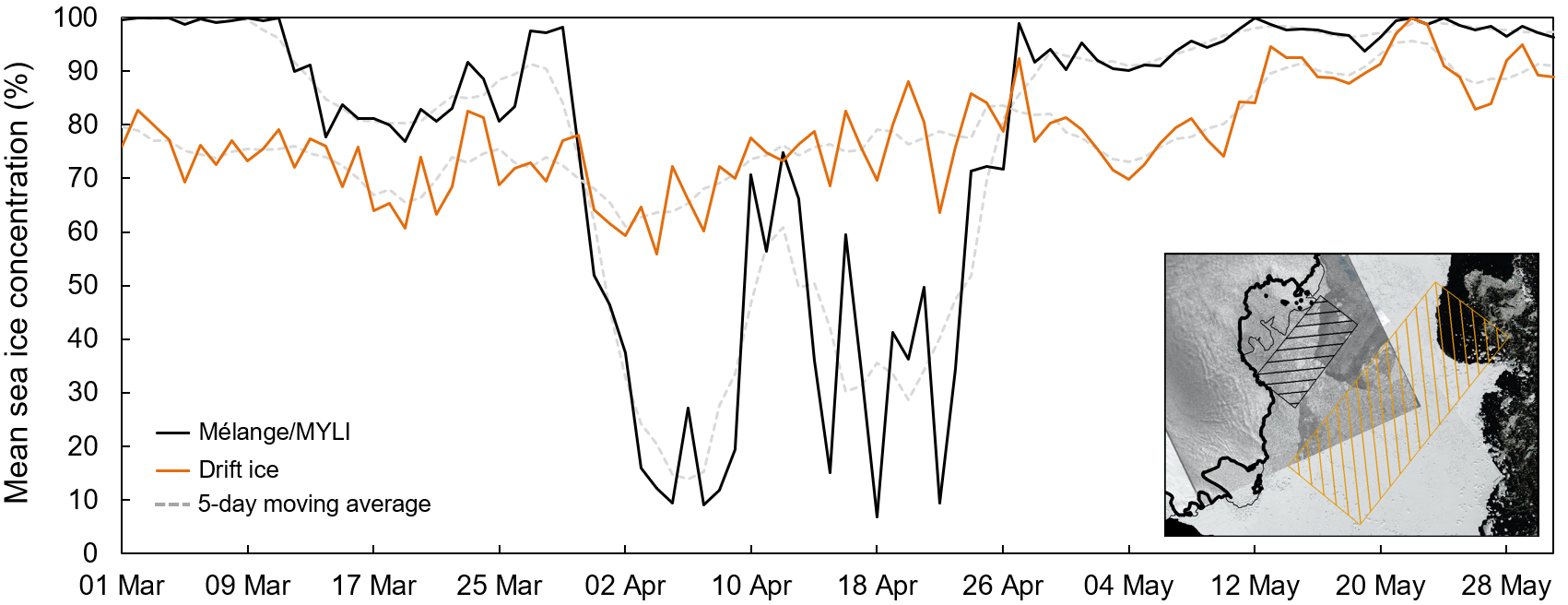
**Supplementary Figure S5**. Landsat-4 image from 31st December 1989 showing the presence of mélange and large kilometre-scale calved ice blocks bound by multiyear landfast sea ice in front of Voyeykov Ice Shelf, as well as mélange-filled rifts in the heavily fractured main portion of the ice shelf.



**Supplementary Figure S6**. Landfast sea ice extents derived from MODIS (Fraser et al., 2012, 2020), RADARSAT ScanSAR (Giles et al., 2008) and ENVISAT and Sentinel-1A/B imagery (Lai et al., 2020), showing extensive persistent landfast sea ice cover around Voyeykov Ice Shelf. The background image is the MODIS mosaic of Antarctica.



**Supplementary Figure S7**. Landfast sea ice extents (blue) derived from MODIS (Fraser et al. 2020) confirming the break-out of multiyear sea ice in early April 2007 around Voyeykov Ice Shelf (orange box). MUIS = Moscow University Ice Shelf, V = Voyeykov Ice Shelf, PB = Porpoise Bay.



**Supplementary Figure S8**. Mean daily AMSR-E sea ice concentrations extracted from the region of mélange /MYLI in front of Voyeykov Ice Shelf (black line and hatched black box) and the region of drift ice further offshore (orange line and hatched orange box). Background images in inset are an Envisat ASAR image taken on 23rd April 2007, and the Landsat Image Mosaic of Antarctica (Bindschadler et al., 2008).

**Supplementary Table S1**: Details of satellite imagery used in this study.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Satellite | Date | Path | Row | Scene Identifier |
| Landsat-7 | 3/1/2000 | 97 | 107 | LE07\_L1GT\_097107\_20000103\_20170215\_01\_T2 |
| Landsat-7 | 29/2/2000 | 96 | 107 | LE07\_L1GT\_096107\_20000229\_20170213\_01\_T2 |
| Landsat-7 | 21/1/2001 | 97 | 107 | LE07\_L1GT\_097107\_20010121\_20170208\_01\_T2 |
| Landsat-7 | 23/1/2001 | 95 | 107 | LE07\_L1GT\_095107\_20010123\_20170208\_01\_T2 |
| Landsat-7 | 14/11/2001 | 96 | 107 | LE07\_L1GT\_096107\_20011114\_20170202\_01\_T2 |
| Landsat-7 | 9/12/2001 | 95 | 107 | LE07\_L1GT\_095107\_20011209\_20170202\_01\_T2 |
| Landsat-7 | 21/11/2006 | 95 | 107 | LE07\_L1GT\_095107\_20061121\_20170107\_01\_T2 |
| Landsat-7 | 21/12/2006 | 97 | 107 | LE07\_L1GT\_097107\_20061221\_20170105\_01\_T2 |
| Landsat-7 | 15/1/2007 | 96 | 107 | LE07\_L1GT\_096107\_20070115\_20170105\_01\_T2 |
| Landsat-7 | 24/1/2007 | 95 | 107 | LE07\_L1GT\_095107\_20070124\_20170105\_01\_T2 |
| Landsat-7 | 7/2/2007 | 97 | 107 | LE07\_L1GT\_095107\_20070124\_20170105\_01\_T2 |
| Landsat-7 | 16/2/2007 | 96 | 107 | LE07\_L1GT\_096107\_20070216\_20170105\_01\_T2 |
| Landsat-7 | 24/11/2007 | 95 | 107 | LE07\_L1GT\_095107\_20071124\_20170101\_01\_T2 |
| Landsat-7 | 8/12/2007 | 97 | 107 | LE07\_L1GT\_097107\_20071208\_20170101\_01\_T2 |
| Landsat-7 | 10/12/2007 | 95 | 107 | LE07\_L1GT\_095107\_20071210\_20161231\_01\_T2 |
| Landsat-7 | 2/1/2008 | 96 | 107 | LE07\_L1GT\_096107\_20080102\_20161231\_01\_T2 |
| Landsat-7 | 26/11/2008 | 95 | 107 | LE07\_L1GT\_095107\_20081126\_20161223\_01\_T2 |
| Landsat-7 | 3/12/2008 | 96 | 107 | LE07\_L1GT\_096107\_20081203\_20161223\_01\_T2 |
| Landsat-7 | 12/12/2008 | 5 | 107 | LE07\_L1GT\_095107\_20081212\_20161224\_01\_T2 |
| Landsat-7 | 11/1/2009 | 97 | 107 | LE07\_L1GT\_097107\_20090111\_20161223\_01\_T2 |
| Landsat-7 | 13/1/2009 | 95 | 107 | LE07\_L1GT\_095107\_20090113\_20161223\_01\_T2 |
| Landsat-7 | 11/11/2009 | 97 | 107 | LE07\_L1GT\_097107\_20091111\_20161219\_01\_T2 |
| Landsat-7 | 20/11/2009 | 96 | 107 | LE07\_L1GT\_096107\_20091120\_20161219\_01\_T2 |
| Landsat-7 | 27/11/2009 | 97 | 107 | LE07\_L1GT\_097107\_20091127\_20161216\_01\_T2 |
| Landsat-7 | 31/12/2009 | 95 | 107 | LE07\_L1GT\_095107\_20091231\_20161218\_01\_T2 |
| Landsat-7 | 7/1/2010 | 96 | 107 | LE07\_L1GT\_096107\_20100107\_20161217\_01\_T2 |
| Landsat-7 | 3/1/2011 | 95 | 107 | LE07\_L1GT\_095107\_20110103\_20161210\_01\_T2 |
| Landsat-7 | 3/12/2011 | 97 | 107 | LE07\_L1GT\_097107\_20111203\_20161204\_01\_T2 |
| Landsat-7 | 4/1/2012 | 97 | 107 | LE07\_L1GT\_097107\_20120104\_20161203\_01\_T2 |
| Landsat-7 | 6/1/2012 | 95 | 107 | LE07\_L1GT\_095107\_20120106\_20161203\_01\_T2 |
| Landsat-7 | 21/2/2012 | 96 | 107 | LE07\_L1GT\_097107\_20120221\_20161203\_01\_T2 |
| Landsat-8 | 16/11/2013 | 95 | 107 | LC08\_L1GT\_095107\_20131116\_20170428\_01\_T2 |
| Landsat-8 | 23/11/2013 | 96 | 107 | LC08\_L1GT\_096107\_20131123\_20170428\_01\_T2 |
| Landsat-8 | 2/2/2014 | 97 | 107 | LC08\_L1GT\_097107\_20140202\_20170426\_01\_T2 |
| Landsat-8 | 18/2/2014 | 97 | 107 | LC08\_L1GT\_097107\_20140218\_20170425\_01\_T2 |
| Landsat-8 | 27/2/2014 | 96 | 107 | LC08\_L1GT\_096107\_20140227\_20170425\_01\_T2 |
| Landsat-8 | 17/11/2014 | 97 | 107 | LC08\_L1GT\_097107\_20141117\_20170417\_01\_T2 |
| Landsat-8 | 4/1/2015 | 97 | 107 | LC08\_L1GT\_097107\_20150104\_20180203\_01\_T2 |
| Landsat-8 | 6/11/2015 | 95 | 107 | LC08\_L1GT\_095107\_20151106\_20170402\_01\_T2 |
| Landsat-8 | 13/11/2015 | 96 | 107 | LC08\_L1GT\_096107\_20151113\_20170402\_01\_T2 |
| Landsat-8 | 22/11/2015 | 95 | 107 | LC08\_L1GT\_095107\_20151122\_20170401\_01\_T2 |
| Landsat-8 | 29/11/2015 | 96 | 107 | LC08\_L1GT\_096107\_20151129\_20170401\_01\_T2 |
| Landsat-8 | 6/12/2015 | 97 | 107 | LC08\_L1GT\_097107\_20151206\_20170401\_01\_T2 |
| Landsat-8 | 23/1/2016 | 97 | 107 | LC08\_L1GT\_097107\_20160123\_20170330\_01\_T2 |
| Landsat-8 | 17/12/2016 | 96 | 107 | LC08\_L1GT\_096107\_20161217\_20170316\_01\_T2 |
| Landsat-8 | 24/12/2016 | 97 | 107 | LC08\_L1GT\_097107\_20161224\_20170315\_01\_T2 |
| Landsat-8 | 26/2/2017 | 97 | 107 | LC08\_L1GT\_097107\_20170226\_20170316\_01\_T2 |
| Landsat-8 | 18/11/2017 | 96 | 107 | LC08\_L1GT\_096107\_20171118\_20171122\_01\_T2 |
| Landsat-8 | 11/12/2017 | 97 | 107 | LC08\_L1GT\_097107\_20171211\_20171223\_01\_T2 |
| Landsat-8 | 5/1/2018 | 96 | 107 | LC08\_L1GT\_096107\_20180105\_20180118\_01\_T2 |
| Landsat-8 | 23/12/2018 | 96 | 107 | LC08\_L1GT\_096107\_20181223\_20181227\_01\_T2 |
| Landsat-8 | 24/11/2019 | 96 | 107 | LC08\_L1GT\_096107\_20191124\_20191203\_01\_T2 |
| Landsat-8 | 1/12/2019 | 97 | 107 | LC08\_L1GT\_097107\_20191201\_20191216\_01\_T2 |
| Landsat-8 | 19/12/2019 | 95 | 107 | LC08\_L1GT\_095107\_20191219\_20191226\_01\_T2 |
| Landsat-8 | 2/1/2020 | 97 | 107 | LC08\_L1GT\_097107\_20200102\_20200113\_01\_T2 |
| Landsat-8 | 3/2/2020 | 97 | 107 | LC08\_L1GT\_097107\_20200203\_20200211\_01\_T2 |
| Envisat ASAR | 8/1/2007 | - | - | ASA\_IMP\_1PNESA20070108\_234917\_000000162054\_00302\_25406 |
| Envisat ASAR | 12/2/2007 | - | - | ASA\_IMP\_1PNESA20070212\_234917\_000000162055\_00302\_25907 |
| Envisat ASAR | 23/4/2007 | - | - | ASA\_IMP\_1PNESA20070423\_234917\_000000162057\_00302\_26909 |
| Envisat ASAR | 28/5/2007 | - | - | ASA\_IMP\_1PNESA20070528\_234920\_000000162058\_00302\_27410 |

**Supplementary Table S2**. Average velocity magnitude errors and counts for ITS\_LIVE mosaics extracted from the upper tongue of Blair Glacier (see Figure 4 for location).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Velocity mosaic | Average maximum velocity magnitude error (v\_err\_max) | Average minimum velocity magnitude error (v\_err\_min) | Average maximum count (number of velocities used in weighted average) | Average minimum count (number of velocities used in weighted average) |
| 2000 | 40.3 | 24.3 | 4 | 3 |
| 2001 | 52.1 | 11.8 | 4 | 1 |
| 2002 | 38.9 | 24.4 | 2 | 2 |
| 2006 | 149.5 | 73.3 | 10 | 2 |
| 2007 | 4.9 | 3.6 | 81 | 55 |
| 2008 | 11.6 | 5.2 | 36 | 14 |
| 2009 | 21.2 | 10.0 | 33 | 18 |
| 2010 | 28.4 | 12.8 | 20 | 7 |
| 2011 | 26.6 | 15.3 | 25 | 12 |
| 2012 | 26.4 | 12.9 | 8 | 5 |
| 2013 | 7.3 | 6.4 | 23 | 19 |
| 2014 | 1.7 | 1.5 | 138 | 120 |
| 2015 | 2.1 | 1.6 | 262 | 175 |
| 2016 | 1.2 | 0.8 | 271 | 177 |
| 2017 | 1.1 | 0.8 | 349 | 268 |
| 2018 | 1.2 | 0.7 | 458 | 305 |

**Supplementary Table S3**. Average velocity magnitude errors and counts for ITS\_LIVE mosaics extracted from the lower tongue of Blair Glacier (see Figure 4 for location).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Velocity mosaic | Average maximum velocity magnitude error (v\_err\_max) | Average minimum velocity magnitude error (v\_err\_min) | Average maximum count (number of velocities used in weighted average) | Average minimum count (number of velocities used in weighted average) |
| 2000 | 296.8627 | 5.771712 | 4 | 1 |
| 2001 | 603.013 | 12.14847 | 3 | 1 |
| 2002 | 44.48492 | 1.408237 | 1 | 0 |
| 2006 | 379.5804 | 0.620752 | 7 | 1 |
| 2007 | 74.123 | 3.305718 | 69 | 7 |
| 2008 | 584.5261 | 6.50471 | 26 | 0 |
| 2009 | 402.3837 | 0.277142 | 26 | 0 |
| 2010 | 464.7792 | 1.315044 | 8 | 0 |
| 2011 | 705.516 | 13.80475 | 23 | 0 |
| 2012 | 227.7341 | 5.334754 | 4 | 0 |
| 2013 | 23.80803 | 5.362753 | 22 | 9 |
| 2014 | 9.265244 | 0.902916 | 149 | 128 |
| 2015 | 14.4544 | 1.2066 | 243 | 36 |
| 2016 | 15.69187 | 0.233736 | 226 | 20 |
| 2017 | 13.20853 | 0.054486 | 288 | 60 |
| 2018 | 21.32288 | 0.06834 | 458 | 45 |

**Supplementary Table S4.** Average velocity magnitude errors and counts for ITS\_LIVE mosaics extracted from Voyeykov Ice Shelf grounding line (see Figure 4 for location).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Velocity mosaic | Average maximum velocity magnitude error (v\_err\_max) | Average minimum velocity magnitude error (v\_err\_min) | Average maximum count (number of velocities used in weighted average) | Average minimum count (number of velocities used in weighted average) |
| 2000 | 59.24082 | 19.93722 | 4 | 3 |
| 2001 | 80.05841 | 6.968855 | 2 | 1 |
| 2002 | 35.93208 | 23.81696 | 1 | 1 |
| 2006 | 84.58425 | 70.90844 | 13 | 5 |
| 2007 | 3.957485 | 3.731326 | 86 | 76 |
| 2008 | 8.729736 | 5.016824 | 36 | 15 |
| 2009 | 14.75093 | 11.75065 | 27 | 21 |
| 2010 | 17.46221 | 13.22388 | 14 | 13 |
| 2011 | 18.57222 | 16.12627 | 22 | 17 |
| 2012 | 24.13832 | 16.06659 | 6 | 3 |
| 2013 | 7.330036 | 6.583596 | 27 | 21 |
| 2014 | 1.780097 | 1.507876 | 149 | 127 |
| 2015 | 2.447948 | 1.72433 | 256 | 178 |
| 2016 | 1.287815 | 0.969103 | 258 | 177 |
| 2017 | 1.167656 | 0.942702 | 366 | 278 |
| 2018 | 1.134861 | 1.015842 | 395 | 317 |

**Supplementary Table S5**. Annual rates of rift advection derived from manual rift tracking.

|  |  |  |  |
| --- | --- | --- | --- |
| Date | Sensor | Rift feature | Annual advection rate (m yr-1) |
| 9/12/2001 | Landsat 7 | Rift A | n/a |
| 21/11/2006 | Landsat 7 | Rift A | 599.6 |
| 12/09/2007 | Landsat 7 | Rift A | 632.6 |
| 20/11/2009 | Landsat 7 | Rift A | 693.9 |
| 19/12/2019 | Landsat 7 | Rift A | 270.0 |
| 9/12/2001 | Landsat 7 | Rift B | n/a |
| 21/11/2006 | Landsat 7 | Rift B | 786.8 |
| 12/9/2007 | Landsat 7 | Rift B | 840.6 |
| 20/11/2009 | Landsat 7 | Rift B | 733.6 |
| 3/1/2011 | Landsat 7 | Rift B | 768.9 |
| 19/12/2019 | Landsat 7 | Rift B | 781.9 |
| 9/12/2001 | Landsat 7 | Rift C | n/a |
| 21/11/2006 | Landsat 7 | Rift C | 697.9 |
| 12/9/2007 | Landsat 7 | Rift C | 870.4 |
| 20/11/2009 | Landsat 7 | Rift C | 859.2 |
| 3/1/2011 | Landsat 7 | Rift C | 836.7 |
| 19/12/2019 | Landsat 7 | Rift C | 848.4 |
| 9/12/2001 | Landsat 7 | Rift D | n/a |
| 21/11/2006 | Landsat 7 | Rift D | 734.7 |
| 12/9/2007 | Landsat 7 | Rift D | 875.3 |
| 20/11/2009 | Landsat 7 | Rift D | 923.6 |
| 21/11/2006 | Landsat 7 | Rift E | n/a |
| 12/9/2007 | Landsat 7 | Rift E | 469.2 |
| 20/11/2009 | Landsat 7 | Rift E | 648.3 |
| 2/12/2010 | Landsat 7 | Rift E | 613.2 |
| 19/12/2019 | Landsat 7 | Rift E | 690.9 |
| 9/12/2001 | Landsat 7 | Rift F | n/a |
| 21/11/2006 | Landsat 7 | Rift F | 899.5 |
| 12/9/2007 | Landsat 7 | Rift F | 886.5 |
| 20/11/2009 | Landsat 7 | Rift F | 834.5 |
| 19/12/2019 | Landsat 7 | Rift F | 772.7 |