Flow dynamics and mass balance of the ice sheet above the southern part of subglacial Lake Vostok

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Summary A detailed knowledge of the flow dynamics of the ice sheet above the World's largest and most outstanding subglacial lake, Lake Vostok, is crucial for the understanding of the hydrological, limnological and sedimentation processes in this water cavity. Furthermore, the specific conditions of the floating ice sheet obeying the hydrostatic equilibrium provide a unique opportunity for the determination of height changes and the present-day mass balance of the ice sheet. In the Antarctic field season 2001/2002, geodetic GPS markers were installed in and around Vostok station and first GPS observations were carried out. In the subsequent field season, these observations were repeated for the first time. During the field season 2006/2007, these markers have been observed for the third time by GPS. These repeated in-situ measurements provide the basis for the precise determination of the local flow direction and velocity of the ice sheet, as well as height change rates in a global reference frame. A strain analysis of the changes of the internal geometry between the markers yields the quantification of the convergence/divergence and acceleration of the ice flow around Vostok station. Here, we combine the geometrical marker displacements determined by geodetic means with precise ice thickness data based on ground-based radar-echo sounding and representative surface accumulation rates in order to conclude the mass balance state of both the floating ice sheet and the subglacial water body.

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Introduction

Detailed knowledge of the flow dynamics of the ice sheet above the World's largest and most outstanding subglacial lake, Lake Vostok, is crucial for the understanding of the hydrological, limnological and sedimentation processes in this water cavity (Wendt et al., 2005). Furthermore, the specific conditions of the floating ice sheet obeying the hydrostatic equilibrium provide a unique opportunity for the determination of height changes and the present-day mass balance of the ice sheet.

Previous results

In the Antarctic field season 2001/2002, geodetic GPS markers were installed in and around Vostok station (Figures 2, 3) and first GPS observations were carried out. In the subsequent field season, these observations were repeated for the first time. Since 1997/1998, ground-based radar-echo profiling has been performed around Vostok station yielding very precise ice thickness information of the local ice sheet.

The analysis of the two GPS observation epochs have revealed a detailed pattern of the ice flow velocity field for the southern part of the subglacial Lake Vostok (Wendt et al., 2006), see Figure 1 with the obtained displacement vectors. Furthermore, the strain parameters for a local network in the vicinity of Vostok station (Figure 3) were determined (Wendt et al. 2006).

Field observations in 2006/07

In December 2006 and January 2007, the GPS observations at Vostok station and at the local deformation network were repeated (Figures 3, 4). All sites were occupied with GPS receivers for several days. In addition, RES surveys were carried out (Figure 5).

Analysis and interpretation

The GPS data were analysed with the BERNESE software, version 5.0. For all sites, horizontal and vertical velocities are obtained. The horizontal velocities are then used for a precise determination of strain parameters. These geodetic quantities are one input source for the glaciological interpretation.

The geodetic results are combined with dense RES profiles of ice thickness (Masolov et al. 2006, Mandrikova et al. 2005, Popov et al. 2005) and with surface accumulation information for the area (Ekaykin 2003, Ekaykin et al.

2002 and 2004). These investigations, which are still in progress in May 2007, will provide new estimates on the mass balance at this location with implications on the ice-water interaction.

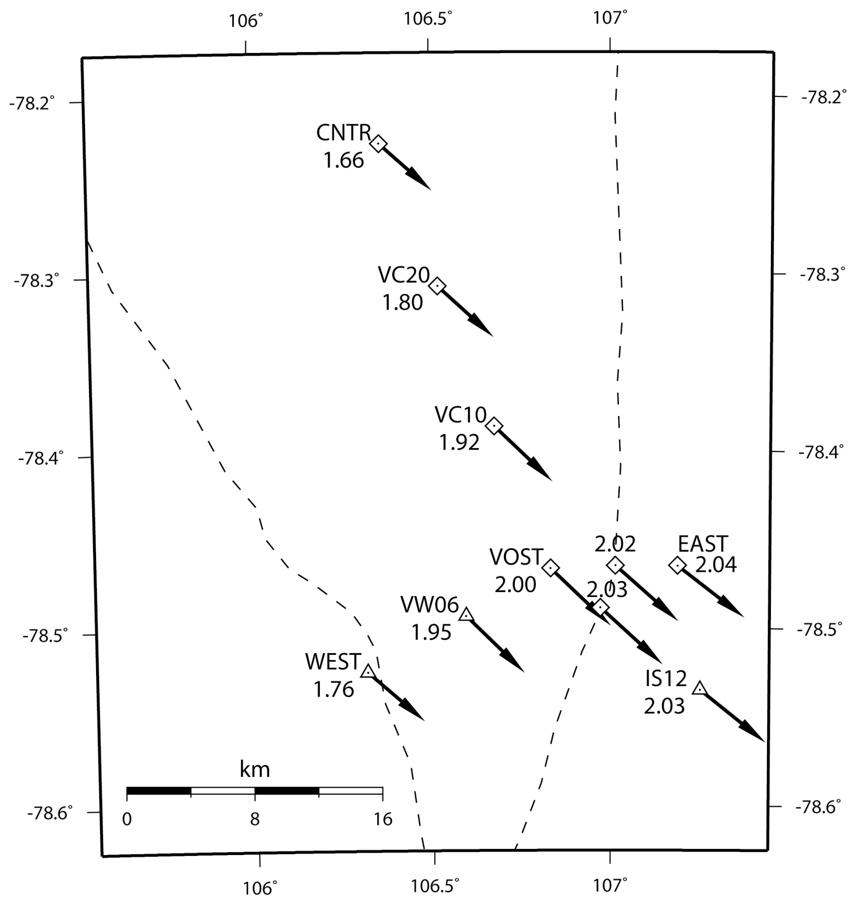

Figure 1. Ice flow vectors in the southern part of subglacial Lake Vostok as determined by repeated geodetic GPS measurements (from Wendt et al., 2006). The dashed line depicts the approximate grounding line of the subglacial lake. For each marker, the marker ID and the displacement velocity (in m/a) are indicated.

Figure 2. Example for a GPS marker in the Vostok station area (marker D110). The marker consists of a wooden post of about 1 m length with about 70 cm below the surface, and a special screw for centring of the GPS antenna.

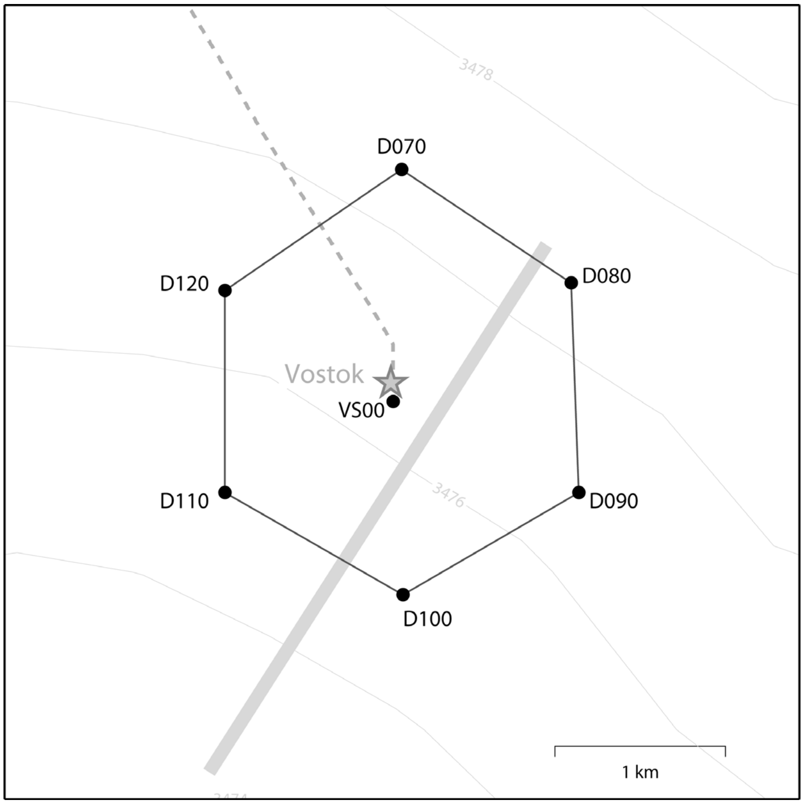

Figure 3. Schematic map of Vostok station and location of the GPS markers of the local network. The star depicts the Russian Antarctic wintering station Vostok. The grey line shows the air strip, the dashed line reflects the convoy route to Mirny station. Black dots represent the GPS markers which were observed. VS00 is the central marker of the point group in the station area, the markers D070 – D120 form a hexagonal strain figure with a radius of 1.2 km. Isolines show ellipsoidal surface heights derived from satellite radar altimetry according to (Roemer et al.. 2007), (equidistance 1 m).

Figure 4. GPS antenna setup during occupation of the strain figure marker D070 in January 2007. On the horizon, parts of Vostok station are visible.

Figure 5. Snow vehicle during combined surface height/ice thickness profiling around the strain figure. On the left, the ice radar antenna is visible. On the right, an aluminium box containing the GPS receiver hardware, and a GPS antenna mounted on one of the deformation figure markers can be seen.

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