that their patterns of flow may at one time been more integrated (Head and Marchant, 2009; Head et al., 2010; Dickson et al., 2008, 2010). As discussed below, new data show that "concentric" may not be the best descriptor for some of the ice-related features confined to the interior of craters at all latitudes, because of evidence for preferential directional flow.

The broad distribution of ice-related features across the northern and southern mid-latitudes raises questions about the nature of periods of regional non-polar deposition of ice (ice ages) during the Amazonian on Mars. Fundamental among these questions is the scope and style of flow during periods when the rate of ice accumulation in the mid-latitudes exceeded the rate of ablation via sublimation (e.g. Levrard et al., 2004; Madeleine et al., 2009) or melting (Dickson et al., 2009; Fassett et al., 2010). For example, did Mars ever host continental-scale ice sheets in either hemisphere? Did the thickness of ice ever reach high enough values so that flow occurred regionally? Or was the accumulation and flow of ice dominated by ice accumulation differences related to local differences in accumulation (e.g., plateaus, scarps, crater rims and interiors)? Deciphering where Mars might fall on this spectrum has implications for the amount of ice deposited at the surface and will help clarify the evolution of the climate.

An important signal that we can measure to test these end-members is the orientation of flow. Orientation measurements have provided insight regarding the distribution and properties of other potentially ice-related features, like gullies (Malin and Edgett, 2000; Milliken et al., 2003; Heldmann and Mellon, 2004; Bridges and Lackner, 2006; Balme et al., 2006; Dickson et al., 2007; Heldmann et al., 2007). Patterns detected through the measurement of flow direction could potentially lead to the mapping of either (a) regional/hemispheric sources that represent the past existence of continental-scale ice sheets, or (b) localized sources that reflect smaller regions of enhanced accumulation of ice. Images obtained from the Context Camera (CTX) on the Mars Reconnaissance Orbiter (MRO) allows us to make this measurement.

2. Methods

Ice-related features on Mars, particularly LDA, LVF and CCF, are most common poleward of 30° in each hemisphere (Head and Marchant, 2009). At latitudes greater than ~55° in the north and south, detailed surface morphology is obscured by a blanket of late Amazonian mantling material that inhibits recognition of past flow features (Kreslavsky and Head, 2000; Mustard et al., 2001; Head et al., 2003). Therefore, we surveyed Mars Reconnaissance Orbiter Context Camera (CTX) images through mission phase B09 (May, 2009) to latitudes between 20° and 60° in each hemisphere (10,261 total images). Images that contained evidence for ice-related flow were added to an ArcGIS database to ensure spatial accuracy and prevent redundant measurements of features imaged multiple times.

Uneven imaging of slopes of different orientation would introduce bias into our results, so we restricted our measurements of ice-related features to those found within impact craters that provide 360° coverage of orientations within the crater. In order to focus on the flow patterns within craters, craters were only

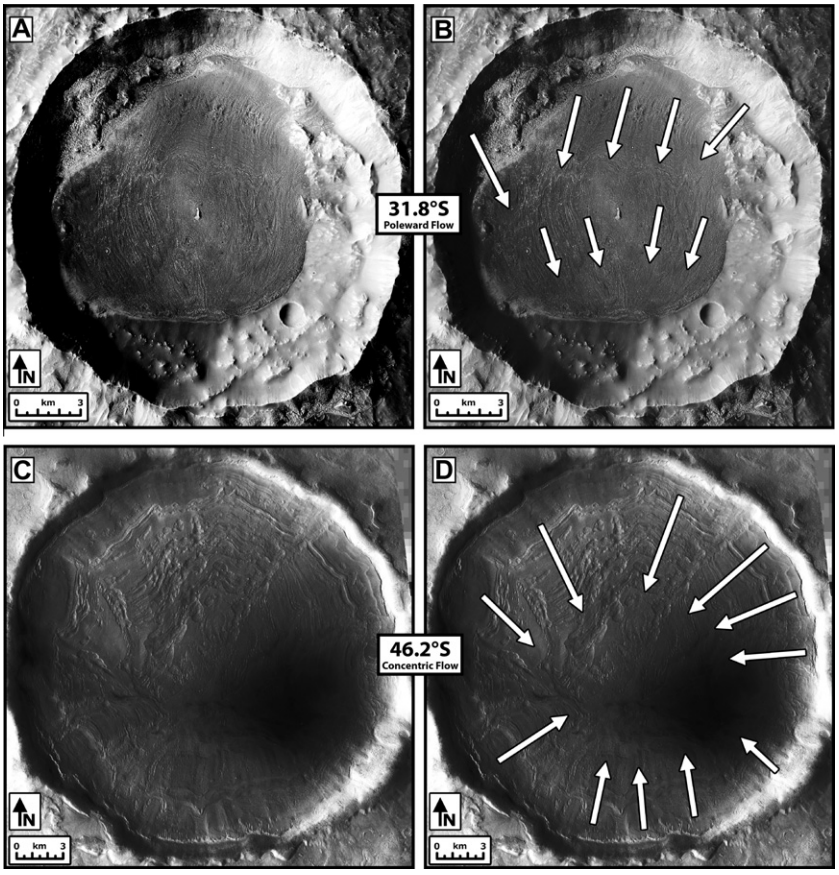

Fig. 2. Type examples of flow orientation in the southern hemisphere. (A) Pole-facing flow of debris-covered ice in an 18 km impact crater at 31.8°S (subframe of CTX orbit P06_003316_1479). Almost all flow directions measured in this latitude band (30–35°S) are pole-facing (89.3%), consistent with flow features in the same latitude band in the northern hemisphere (89.1%). (B) Interpretation of flow directions within the crater. (C) Concentric flow of ice in the southern mid-latitudes (46.2°) (subframe of CTX orbit P19_008308_2265). Flow at this latitude in each hemisphere is generally concentric, with only a slight preference for pole-facing orientations (58.5% in the south, 57.4% in the north between 45° and 50° latitude). (D) Interpretation of flow direction.