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Directional Analysis of Sub-Antarctic Climate Change on South Georgia 1905-2009

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Directional analysis has been used to study changes in the sub-polar climate of the mountainous and glacierised sub-Antarctic island of South Georgia (54-55°S, 36-38°W). Significantly for climate change studies, South Georgia lies in the Scotia Sea between polar and temperate latitudes, and approximately 1000 km northeast and downwind of the Antarctic Peninsula - one of the fastest-warming regions on Earth (Vaughan et al., 2001). South Georgia was chosen for directional analysis because its climate is substantially advected by predominantly westerly circulations, and because it has a long (since 1905) meteorological record from King Edward Point (KEP) on its eastern side. Additional shorter records from Bird Island at the northwest tip of South Georgia allow comparison between windward (Bird Island) and leeward (KEP) climate regimes. The variation of mountain barrier heights with direction from KEP allows climate changes to be studied under different amounts of orographic influence (from ∼700 m to ∼2200 m). Records of glacier advance and retreat provide further independent evidence of climate change for comparison with the meteorological record.

Directional climate analysis is based on a series of monthly-mean pressure fields defining the orientation and strength of synoptic-scale air-mass advection over the Scotia Sea. These fields are used to define directional climatologies for six 30° sectors with bearings from 150-180° to 300-330°; these sectors encompass 99% of recorded months since 1905. The climatologies summarise the frequencies of air masses from each sector, and the accompanying temperatures and precipitation. The 6 sectors can be broadly associated with 4 air-mass types and source regions: (i) sectors 150-210° advect cold polar maritime air that originated over the Antarctic continent before passing over the Weddell Sea, (ii) sectors 210-270° advect warmer, more stable polar maritime air from the Bellingshausen Sea/Antarctic Peninsula region, (iii) sector 270-300° has warmer, drier returning polar maritime circulated from the Bellingshausen Sea and across the Andes, and (iv) sector 300-330° has warm, humid tropical maritime air from the South Atlantic High.

Detailed climatologies are compared for 4 distinct time periods covering: glacier advance (1920-1951), glacier retreat (1951-82), the latest decade (2000-2009), and a reference period (1905-1982). The comparisons show how climate changes between periods are composed of alterations in (i) air-mass frequency from different sectors, and (ii) temperature and precipitation within sectors. The ability of directional analysis to explain climate-change processes is confirmed by comparing directional results for the periods of glacier advance and glacier retreat. Specifically, during the ‘advance’ period the air masses came 20% more frequently from the 4 colder, southerly sectors and correspondingly less frequently from the 2 warmer, northerly sectors. Moreover, the temperature of air coming from each sector was 0.1-0.8°C cooler than during the ‘retreat’ period. Further directional analysis will compare records from the latest decade with previous periods to investigate recent sub-polar climate change, and particularly any advected warming from the Antarctic Peninsula.

Directional analysis and advection climatologies can be used to test climate model performance and to examine atmospheric processes under changing climates. Previous directional analyses in an upland region of northwest England have detected changes in its mid-latitude temperate climate that were masked by directionally unsorted data (Malby et al., 2007, Ferranti et al., 2009); the South Georgia study now shows how similar methods can give insights into sub-polar climate change.

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