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The link between the structure of the heating and upwelling in the tropical lower stratosphere

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A feature of the time averaged tropical lower stratospheric upwelling is the double peak structures centred near 70 hPa and 20 N--S which have previously been noted in ERA-Interim and other datasets. We demonstrate using a downward control calculation that the structure of the wave force consistently balances the angular momentum budget. However, the corresponding structures in diabatic heating rates are not related to local temperature anomalies as would be the case if they were relaxational in nature. We find that the enhanced diabatic heating near the centre of these peaks relative to the Equator arises predominantly from the meridional structure in ozone concentrations. Additional contributions arise from the non local absorption of longwave radiation emitted from the relatively warm layers above and below. We suggest that the primary cause of the peaks in upwelling is the externally imposed part of the radiative heating field. This motivates the second part of this study in which a scaling argument shows that an externally imposed zonally symmetric heating can indeed drive steady-state upwelling provided that the wave force (required to satisfy angular momentum constraints) is sufficiently sensitive to changes in the mean flow. The applicability of this regime to the observed double peak structure is confirmed by experiments in a dry dynamical circulation model. Further experiments demonstrate that the regime remains relevant for narrow heating at nearly all latitudes and up to amplitudes nearly an order of magnitude stronger than observed in the tropical lower stratosphere. The regime does not apply when the width of the imposed heating is increased. Similar arguments are also applicable to recently identified compensation between the driving of the Brewer-Dobson circulation by resolved and parameterized waves. These suggest that compensation is expected on general grounds for narrow features in the wave driving.