# How, where and when the 'stratospheric intrusion' take place during the passage of tropical cyclone: Results inferred from Indian MST Radar and satellite observations

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The stratospheric ozone ($O_3$) regulates the amount of ultraviolet radiation coming from the Sun to the Earth's surface. In addition, $O_3$ is an important greenhouse gas, which acts as an oxidant in the troposphere and has a vital role in the climate forcing. One of the major consequences of the tropospheric ozone enhancement is on living organisms, as it acts as a toxic agent. Increase in the tropospheric ozone is considered to be due to (1) in situ photochemical formation (e.g. lightning, advection, anthropogenic activities), and (2) stratospheric intrusion. The increase in stratospheric intrusion not only increases the tropospheric ozone, but also decreases the stratospheric ozone. The ozone present in the troposphere reacts with water vapour which further destroys the tropospheric ozone and as a result the total columnar ozone decreases. In general, stratospheric intrusions are observed over the middle and higher latitudes due to dissipation of extra-tropical planetary and gravity waves. In addition to it, cutoff lows, high/low-pressure systems, the tropopause folds, convections, thunderstorm and tropical cyclone are also responsible for stratospheric intrusion. The present paper discusses different plausible mechanisms to account for the intrusion of dry ozone-rich stratospheric air into the troposphere during the passage of tropical cyclones. In this context, many special experiments were designed by operating Indian Mesosphere-Stratosphere-Troposphere (MST) Radar located at a tropical station Gadanki (13.5$^o$N, 79.2$^o$E) along with simultaneous ozonesonde and space borne observations. The present study shows that the overshooting convection associated with the tropical cyclone is found to be the prime candidate for the generation of turbulence in the vicinity of tropopause (VOT). The presence of strong updraughts and downdraughts in the VOT also weakened the stability of the tropopause which is also a responsible mechanism stratospheric intrusion. Significant modulation of the tropopause structure is observed which is found to be accompanied by structures linked with shear instability. Simultaneous ozone measurements also indicate the intrusion of stratospheric air mass into the upper and middle troposphere. Space-borne observations of relative humidity indicate the presence of sporadic dry air in the upper and middle troposphere over the cyclonic region. Moreover, the spatio-temporal structure of stratospheric air intrusion associated with cyclone weather is also simulated using Advanced Research-Weather Research and Forecast (WRF-ARW) model. The focus of this paper is to present and discuss some of the unique features of stratospheric intrusion associated with tropical cyclone.