Statistical Analysis of Double Tropopause Events Utilizing HIRDLS Temperature Data

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Abstract

Two main questions are addressed by this study. First, how sensitive is HIRDLS to changes in the double tropopause event classification criteria? The algorithm implemented in this work uses spatial latitudinal distance to isolate the number of double tropopause events in a day, month or year. A statistical analysis is performed to determine what minimum spatial distance corresponds to a strong probability that what I am looking at is a double tropopause. Second, does HIRDLS capture more double tropopause events than GEOS-5.1.0 and NCEP GFS data? HIRDLS produces high vertical resolution data, temperature and ozone and three other species, of 1 km in the UTLS region. GEOS-5.1.0 and NCEP GFS resolution decreases with altitude, thus potentially missing small scale features. This step, quantifying the benefits of the high vertical resolution provided by HIRDLS, is needed before extending this project further into climatological studies.

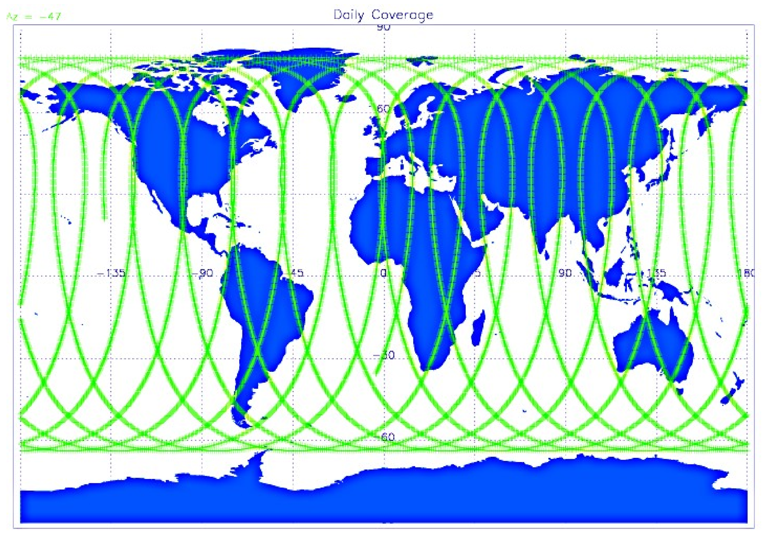
Introduction

Multiple studies have focused on the Upper Troposphere Lower Stratosphere (UTLS) region, in an effort to quantify its influence on tropospheric climate and weather. The thermal profile of this layer shows intrusions by stratospheric air and the poleward transport of tropospheric air, forming the double tropopause structure. This atmospheric structure may be a marker for Stratosphere-Troposphere Exchange (STE) at mid-latitudes. The overarching goal of this project is to better understand double tropopause activity by performing a broad systematic study of double tropopause characteristics, such as their seasonal tendencies and spatial extent.

- Instrument

- Launched July 15th 2004 on the Aura Satellite
- Infrared (IR) Limb Scanning Radiometer
- Sun-Synchronous Limb View
- IFOV: 1 km (V) x 10 km (H)
- View is 47 ° off the orbit plane
- 14 orbits/5550 profiles per day
- Coverage is from 65°S to 82°N.
- Vertical Resolution: ~1 km

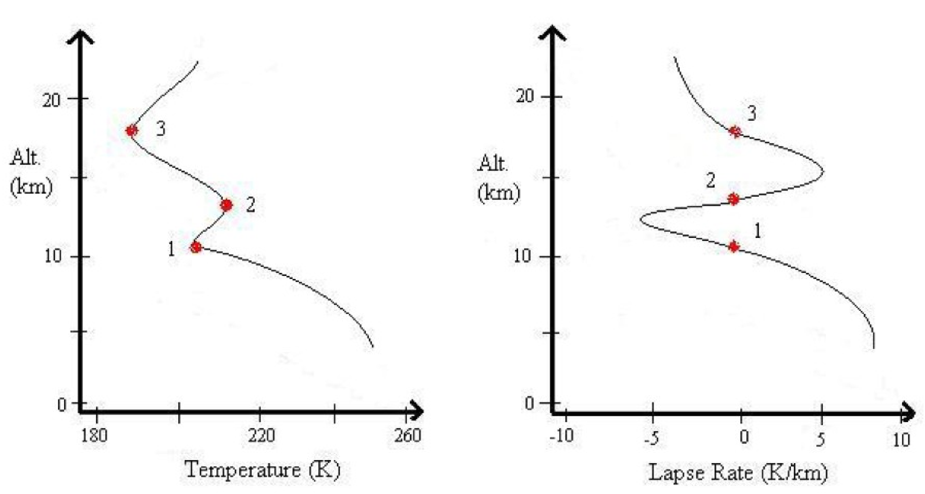
Figure 1: HIRDLS Instrument



- Global Coverage: day and night
- 25 degrees of Longitudinal separation between each orbit track.
- Obtained graph from V004 HIRLDS Data Quality Document

Figure 2: Orbit Track for 1 day of HIRDLS data

- WMO Definition



Points on Figure 3

3) $-(\partial T/\partial z) < 2°C/km$ for 2 km

2) $-(\partial T/\partial z) > 3°C/km$ for 1 km

1) $-(\partial T/\partial z) < 2°C/km$ for 2 km

Figure 3: Schematic to visually explain the WMO Thermal Definition, which uses Lapse Rate ($\partial T/\partial z$) to identify a Double Tropopause.

Intrusion Example

A Day with substantial double tropopause events have been isolated using HIRDLS data and compared to GEOS-5.1.0 and NCEP GFS data. All three data sets are analyzed using the WMO definition of the tropopause and are in good agreement.

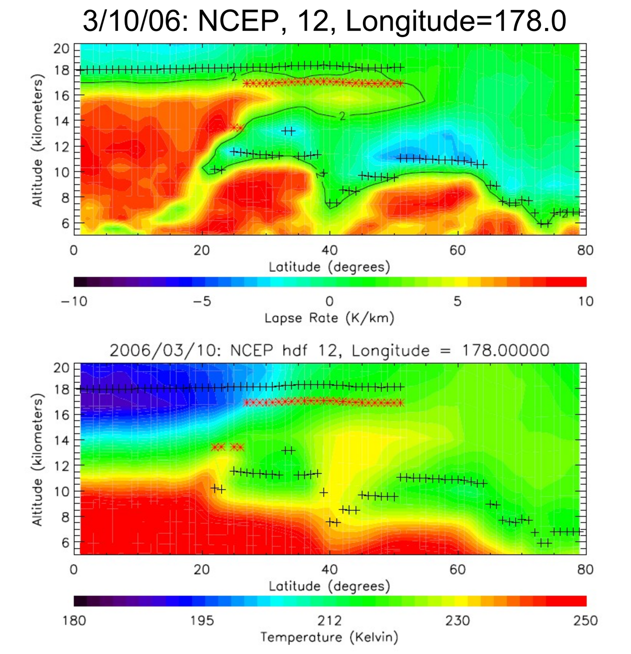


Figure 4: NCEP Data for 3/10/06. Top Plot – Temperature, Bottom Plot – Lapse Rate.

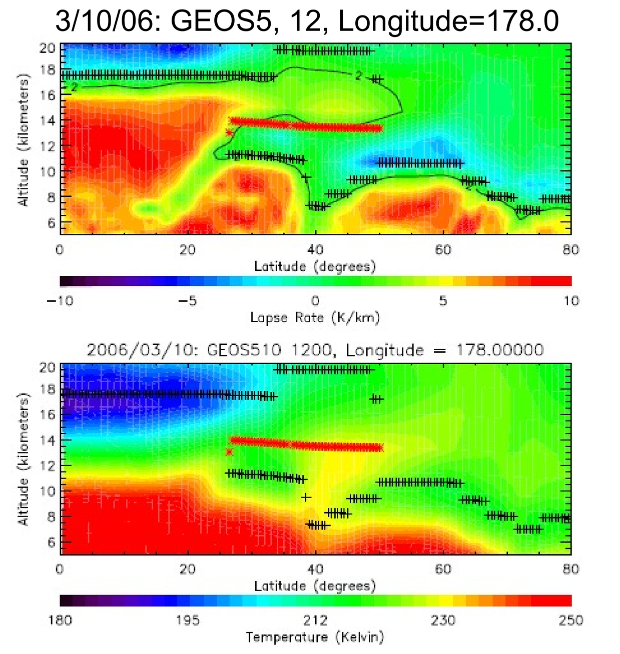


Figure 5: GEOS5 Data for 3/10/06. Top Plot – Temperature, Bottom Plot – Lapse Rate.

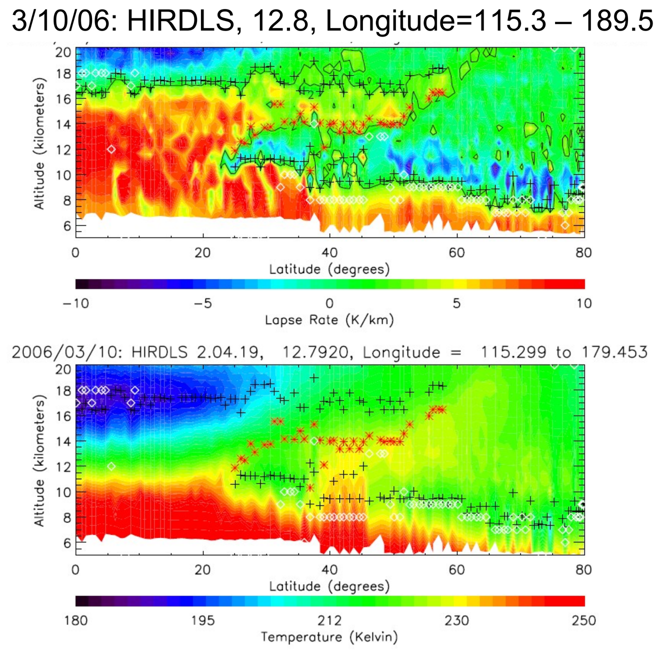


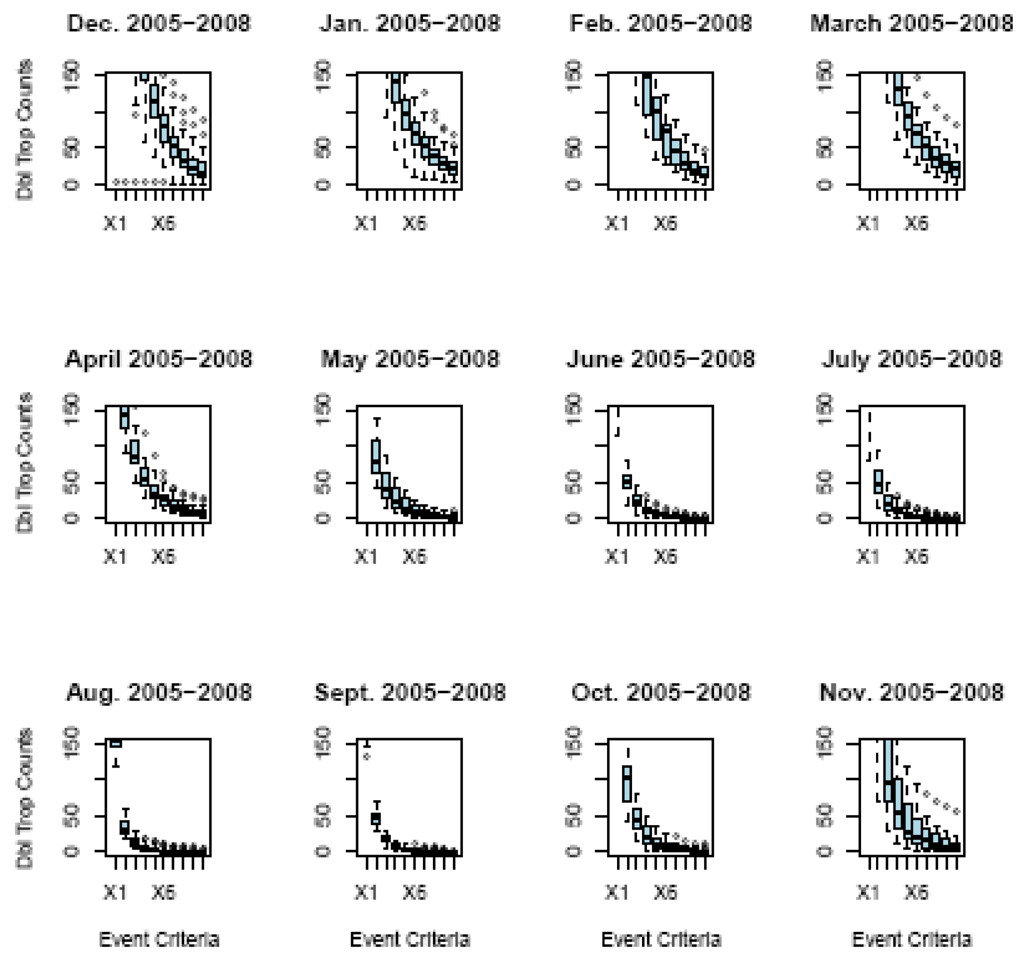
Figure 6: HIRDLS Data for 3/10/06. Top Plot – Temperature, Bottom Plot – Lapse Rate.

Key:
Black Crosses = 1st and 2nd Tropopause
White Diamonds = Cloud Top
Red Asterisks = Flag for Double Tropopause.

This day is an example of a substantial event. However, not all events are so clear. How should intrusion events be isolated and classified?

Criteria

Figure 7: Monthly Boxplots of HIRDLS Double Tropopause Counts, three years of data was summer. The X-axis indicates which criteria is being used. For example, X2 = 2 profiles in a row (2 red asterisks, as shown in Figure 6) are required for that orbit to be flagged with a Double Tropopause Event. X6 = 6 profiles in a row, X7 = 7 profiles in a row, and so on til X10.



During the summer the means for all x values 1 through 5 are low. In November a shift occurs and the means for higher values of x are starting to increase. This shows that X6 criteria is optimal for identifying Double Tropopause Events.

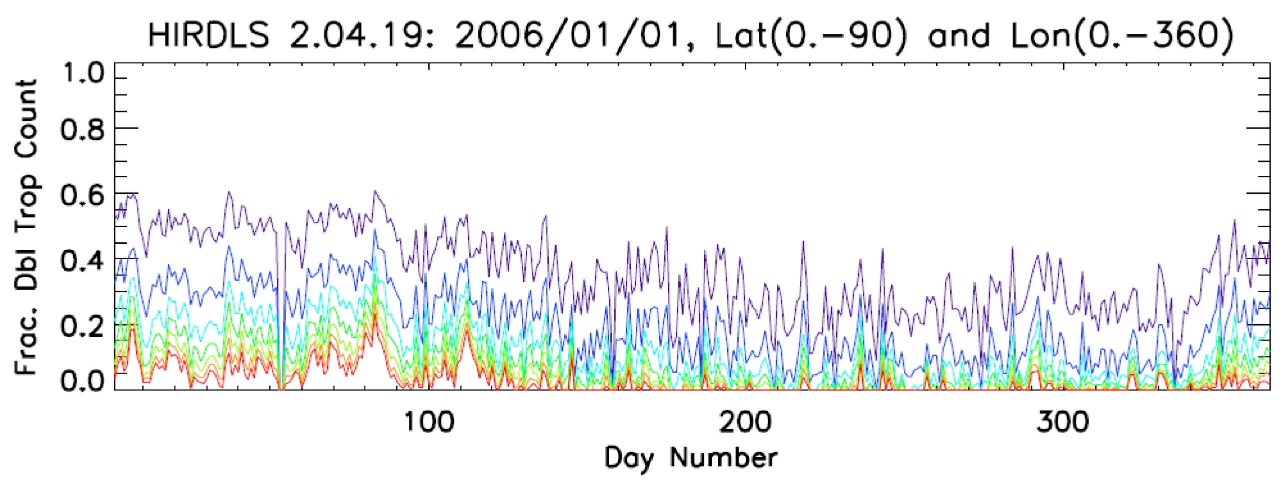


Figure 8: Fractional representation of Double Tropopause Counts using criteria discussed above. Lines from top to bottom go from 2 (X2 in Fig. 7) profiles in a row to 10 (X10 in Fig. 7).

Figure 8 shows that strong Double Tropopause Events can be isolated using this criteria event thought the annual cycle does not vary substantial with the criteria chosen. This criteria had to be established before moving forward with comparisons and future work.

Comparison

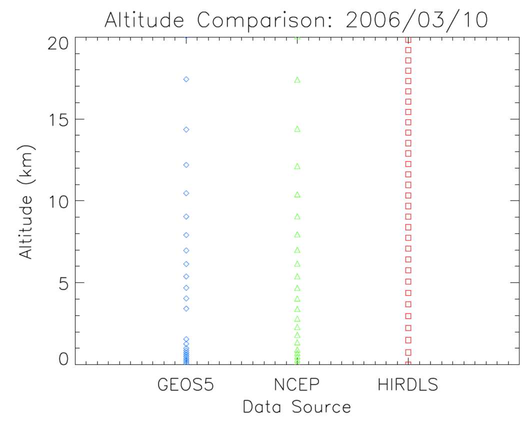


Figure 9: Profile Plots of three data – GEOS5 (Blue), NCEP (Green) and HIRDLS (Red)

Figure 9 highlights the difference in vertical spacing between NCEP, GEOS5 and HIRDLS. The decrease in vertical resolution with altitude of both GEOS5 and NCEP can change how many Double Tropopauses are captured using the WMO definition.

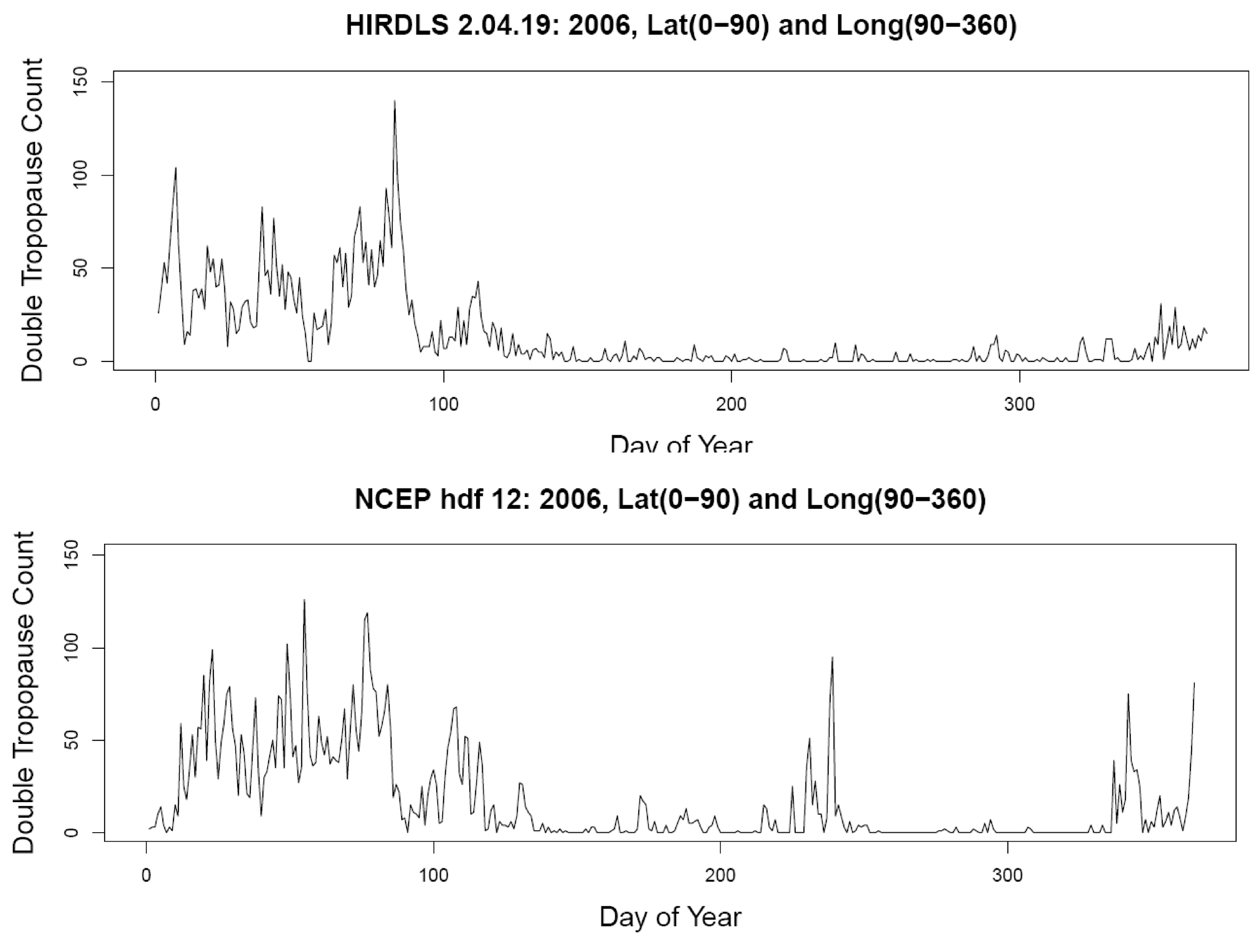


Figure 10: Number of Double Tropopause Counts/Events per day vs Day of Year. Top Plot – HIRDLS for 2006 and Bottom Plot – NCEP for 2006.

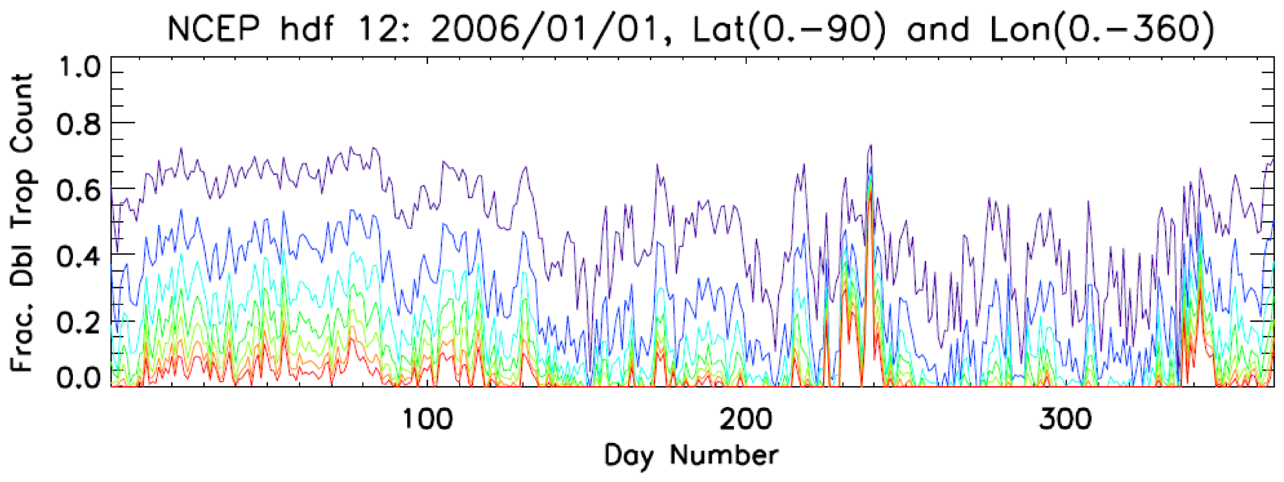


Figure 11: NCEP data for 2006. Fractional representation of Double Tropopause Counts using criteria discussed in Criteria section.

Figure 10 shows that both HIRDLS and NCEP capture the general annual cycle for Double Tropoapause Events. A comparison between Figure 10 and Figure 11 pulls out the tendency of each data set during strong events. As the criteria approaches X8 (yellow) HIRDLS maintains fractional values of 0.20 and greater in areas where NCEP is around 0.10. This relative magnitude is also visible with the X6 criteria.

Conclusions

Both HIRDLS and NCEP, capture the annual cycle of Double Tropopause Occurrences. NCEP shows a few incidents of high Double Tropopause Count in the summer not captured by HIRDLS. Additionally, HIRDLS sees activity in January of 2006 not captured by NCEP.
The basic shape of the annual variation of Double Tropopause Occurrences is not sensitive to criteria chosen. However, the more intense/strong events are tied to the criteria used. Thus it can be used to filter out Double Tropopause Events by their strength. HIRDLS can capture stronger, more intense Double Tropopause events, not seen by NCEP. Thus potentially registering events missed by other data sets.

Future Work

Create a Generalized Linear Model (GLM) of HIRDLS data using the above established criteria of X6 to find correlations between the number of Double Tropopause Events and various parameters, such as vorticity, winds, PV, or upper air pressure. In addition, the criteria will be varied for isolating extreme case during composite analysis.