Derived Meteorological Products, Tropopapuses Characterization, and Jet Identification

Data Format

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Document Version **1.1**

Document Revision History

version 1.0: Original version

version 1.1: Describes minor changes in labelling for two DynEqL variables.

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1 Introduction

This document describes the derived meteorological products, tropopause characterization and jet identification found at https://mls.jpl.nasa.gov/dmp/. These dynamical diagnostics are computed using the JETPAC (Jet and Tropopause Products for Analysis and Characterization) package described in detail by *Manney et al.* [2011, 2014, 2017] and *Manney and Hegglin* [2018].

2 Data Format

The data are stored in the netcdf version 4 on the same granularity as the original data (e.g., per occultation for SAGEIII-ISS, per profile for ozonesondes, per flight for IAGOS, or per mission for ACE-FTS data)

There are three types of these files.

```
<Identifier>_<MetInfo>_DynEqL_jv<vvv>.nc4
<Identifier>_<MetInfo>_Trops_jv<vvv>.nc4
<Identifier>_<MetInfo>_Jets_jv<vvv>.nc4
```

where `<Identifier>` is a unique instrument identifier (which may include the instrument name, date, occultation, data version, etc), where `<MetInfo>` is the meteorological fields used (e.g., GEOS5MERRA2 or ERA-Interim), and `<vvv>` is the JETPAC version (for example, 300 where the first number is the version number and the last two numbers are the subversion).

3 Data Characteristics

All files include the following variables:

`Lat`	Latitude	degrees
`Lon`	Longitude	degrees
`Date`	Date	YYYY-MM-DD
`Hour`	Time	seconds into day
`Met_Info`	Meteorological Fields Used	(i.e. GEOS5MERRA2)

The first four variables should match the input data provided by the mission or measurement.

3.1 DynEql Files

These files contain the derived meteorological products. The derived meteorological products are simply the meteorological fields interpolated to the measurements' times and locations, as well as several derived meteorological products such as static stability and equivalent latitude (EqL). As described in *Manney et al.* [2007], interpolation of the meteorological fields is done linearly in time and bilinearly in latitude and longitude. Vertical interpolations are linear in $\log(\theta)$ for PV or log(pressure) for the other products. EqL is calculated on standard isentropic surfaces (chosen to have resolution comparable to the reanalyses being used) and interpolated linearly in log(θ).

The variables included in these files are listed below:

`Pressure`	Pressure	hPA
`U`	Zonal wind	m/s
`V`	Meridional wind	m/s
`Temperature`	Temperature	K
`Theta`	Potential temperature	K
`GPH`	Geopotential height	km
`Altitude`	Altitude	km
`PV`	Potential vorticity	K m^2 $(kg\ s)^{-1}$
`sPV`*	Scaled PV	s^{-1}
`RV`	Relative vorticity	10^4 s^{-1}
`dT_dZ`	Lapse Rate	K km^{-1}
`Static_Stability`*	Static stability	s^{-2}
`EqL`*	Equivalent Latitude	degrees
`HorsPVgrad`*	Normalized Horizontal (Isentropic) sPV Gradient	unitless
`avgsPVgrad`*	Normalizing factor for Horizontal sPV Gradient	s^{-1}
`Tgrad`*	Horizontal (isobaric) Temperature Gradient	K km^{-1}
`MSF`*	Montgomery Stream Function	m^2 s^{-2}
`AssimO3`	Ozone	ppmv

*see descriptions below.

`sPV`: To facilitate examination, PV is scaled by dividing by a standard value of static stability as described by *Dunkerton and Delisi* [1986] and *Manney et al.* [1994].

`Static_Stability`: The buoyancy (Brunt-Väisälä) frequency, N^2, that is, the stability of the atmosphere in hydrostatic equilibrium with respect to vertical displacements.

`EqL`: A quasi-Lagrangian coordinate widely used in stratospheric studies (e.g., *Butchart and Remsberg* [1986]). Simply put, EqL is the latitude that would enclose the same area between it and the pole as the corresponding potential vorticity contour.

`HorsPVgrad`: The normalized (by the global average on that isentropic level) magnitude of the horizonal gradient of sPV on isentropic surfaces.

`AvgsPVgrad`: The average value of the magnitude of the sPV gradient on each isentropic surface that is used to normalize `HorsPVgrad`.

`Tgrad`: Magnitude of horizontal gradient of temperature on pressure surfaces.

`MSF`: The Montgomery stream function [*Montgomery*, 1937] $M = gz + c_pT$ where g is the acceleration due to gravity, z the height of the isentropic surface used, c_p the specific heat of air at constant pressure, and T is temperature.

All these variables are arrays of size $[nh, nl]$ where nh is the number of vertical levels and nl is the number of locations / profiles. Note that the order of the array dimensions will depend on the language used to ingest the files.

3.2 Trops Files

These files contain the tropopause characterizations. That is, at each measurement location, the dynamical (DYN) tropopause is identified using four PV values (2.0, 3.5, 4.5, and 6.0 potential vorticity units) and the thermal tropopause using the WMO definition [e.g., *Homeyer et al.*, 2010], that is to say, where the temperature lapse rate falls below $2\,\mathrm{K\,km^{-1}}$ for at least 2 km. In addition, multiple thermal tropopauses are identified above the primary tropopause every time the WMO criteria is fulfilled [see *Manney et al.*, 2011, for details of multiple tropopause identification].

The variables included in the Trops files are listed in table 1.

The WMO variables (e.g., `Altitude_at_WMO_Tropopauses`) are arrays of sizes $[4, nl]$ where 4 is the maximum number of tropopauses for which information will be stored for each location and nl is the number of locations / profiles in each file.

The DYN variables (e.g., `Altitude_at_Dyn_Tropopauses`) are arrays of sizes $[5, 4, nl]$ where 5 is the number of PV's used to identified the tropopauses (listed in the variable called `PVs_used`), 4 is the the maximum number of tropopauses for which information will be stored for each location and nl is the number of locations / profiles.

Note that the order of the array dimensions will depend on the language used to ingest the files.

Table 1: Swaths included in the Trops files

`WMOPHigh`	Cutoff high pressure for WMO calculations.	hPa
`WMOPLow`	Cutoff low pressure for WMO calculations.	hPa
`WMOZLow`	Lower cutoff altitude for WMO tropopause calculations.	km
`DynPHigh`	Cutoff high pressure for DYN calculations.	hPa
`DynPLow`	Cutoff low pressure for DYN calculations.	hPa
`DynZLow`	Lower cutoff altitude for DYN tropopause calculations.	km
`PVs_used`	List of PV values used to calculate the Dynamical Tropopause	PVU (10^{-6} K m^2 kg^{-1} s^{-1})
`NumWMO`	Number of WMO tropopauses found at a given location.	unitless
`Altitude_at_WMO_Tropopauses`	Altitude at WMO tropopauses	km
`Temp_at_WMO_Tropopauses`	Temperature at WMO tropopauses	K
`Press_at_WMO_Tropopauses`	Pressure at WMO tropopapuses	hPa
`PV_at_WMO_Tropopauses`	Potential vorticity at WMO tropopapuses	K m^2 (kg s)$^{-1}$
`Theta_at_WMO_Tropopauses`	Potential Temperature at WMO tropopauses	K
`SS_at_WMO_Tropopauses`	Static stability at WMO tropopauses	s^{-2}
`NumDyn`	Number of DYN tropopauses found at a given location.	unitless
`Altitude_at_Dyn_Tropopauses`	Altitude at DYN tropopauses	km
`Temp_at_Dyn_Tropopauses`	Temperature at DYN tropopauses	K
`Press_at_Dyn_Tropopauses`	Pressure at DYN tropopapuses	hPa
`DynFlag`	0: if tropopause is determined by PV, 1: if it is determined by the 380 K theta surface	unitless
`Theta_at_Dyn_Tropopauses`	Potential Temperature at DYN tropopauses	K
`SS_at_Dyn_Tropopauses`	Static stability at DYN tropopauses	s^{-2}
`dT_dZ_at_Dyn_Tropopauses`	Lapse rate at DYN tropopauses	K km^{-1}

3.3 Jet Files

These files include the characterization of both upper tropospheric and subvortex jets. Figure 1 illustrates the jets identification.

At each measurement longitude, upper tropospheric jet cores are identified in latitude/height slices where the reanalysis wind speed maximum exceeds 40 ms^{-1}. The jet boundaries are the grid points surrounding that core (both vertically and horizontally) where the wind speed drops below 30 ms^{-1}. When there is more than one wind speed maximum greater than 40 ms^{-1} within a given 30 ms^{-1} contour, they are identified as separate cores if the minimum wind speed between them is at least 30 ms^{-1} less than the wind speed value at the strongest core, or if the latitude distance between them is greater than 10°.

The subvortex jet maximum is identified as the most poleward westerly windspeed maximum of over 30 ms−1 at each measurement longitude, and is identified at levels (typically the measurement levels, but in some cases the reanalysis model levels) from about 250 to 20 hPa. When the bottom of the subvortex jet merges into an upper tropospheric jet (as in Figure 1), the bottom of the subvortex jet is defined as the lowest level where the windspeed is still decreasing with decreasing height. When the polar vortex is shifted entirely off the pole the polar vortex edge will cross some longitudes at two latitudes, and there will thus be two subvortex jets identified, with the most poleward one being easterly.

Many meteorological conditions are saved at the jet locations, including horizontal winds, distance from the tropopause, PV, temperature, and static stability.

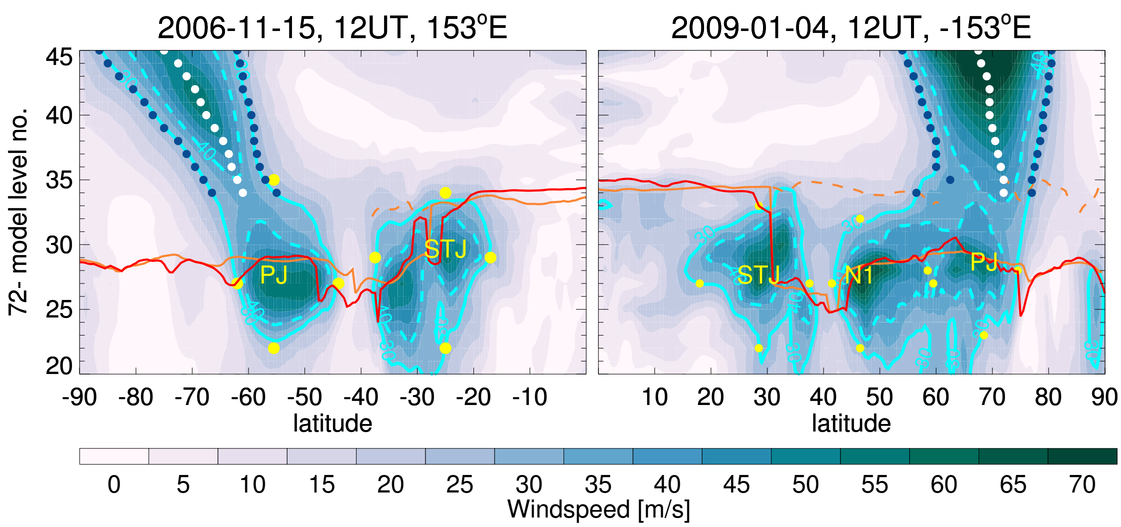

Figure 1: Cross-sections of MERRA2 wind speed with jet and tropopause classification information overlaid. Yellow letters/numbers indicate the locations of jet cores; lowest numbers are for strongest jets in each hemisphere; yellow dots indicate the identified locations of the edges of the jet region (at grid-points, thus not exactly matching contours). The red line shows the 4.5 PVU dynamical tropopause, and orange lines the WMO (thermal) tropopause (dashed orange lines show the secondary thermal tropopause). White dots show the subvortex jet maximum, and blue dots the edges of the subvortex jet. Figure based on *Manney et al.* [2011].

These files may contain the following swaths:

`NHJet`	Northern hemisphere Jet information
`SHJet`	Southern hemisphere Jet information
`NHSubV`	Northern hemisphere SubVortex information
`SHSubV`	Southern hemisphere SubVortex information
`JetDelta`	Differences between the measurement location and the Jet location
`SubVDelta`	Differences between the measurement location and the SubVortex location

3.3.1 (NH/SH)Jet Swaths

These swaths store the information about the upper tropospheric jet cores (e.g., the yellow letter/numbers in Figure 1). The (NH/SH)Jet swaths have the following variables:

`Lon`	Longitude
`NumCores`	Number of Cores at a particular location
`Type`	Type of jet (PJ: polar jet; STJ: subtropical jet; null character string: for jets that are not identified as either of these)

and the following swaths:

`Maximum`	Information about the jet core
`PwEdge_Inner`	Information about the jet inner poleward edge
`PwEdge_Outer`	Information about the jet outer poleward edge
`EqEdge_Inner`	Information about the jet inner equatorial edge
`EqEdge_Outer`	Information about the jet outer equatorial edge
`UpEdge_Inner`	Information about the jet inner upper edge
`UpEdge_Outer`	Information about the jet outer upper edge
`DnEdge_Inner`	Information about the jet inner lower edge
`DnEdge_Outer`	Information about the jet outer lower edge

The variables in each of these swaths are listed in table 2.

These variables are arrays with size $[5, nl]$ where 5 is the maximum number of jets identified for which information will be saved at each measurement location and nl is the number of locations / profiles.

Note that the order of the array dimensions depends on the language used to ingest the files.

The edges of the jet regions are defined by the 30 ms^{-1} wind contours. The inner and outer edges give the values at the gridpoints (on the model grid of the reanalysis dataset used) adjacent to this contour on the inside (windspeed > 30ms^{-1}) and outside (windspeed < 30ms^{-1}) of this contour.

Table 2: Variables in the (NH/SH)Jet and (NH/SH)SubV swaths

`Lat`	degrees
`Pressure`	hPa
`Altitude`	km
`U`	m/s
`V`	m/s
`Temperature`	K
`PV`	K m^2 $(kg\ s)^{-1}$
`RV`	1e4 s^{-1}
`dT_dZ`	K km^{-1}
`Static_Stability`	s^{-2}
`Theta`	K
`VTRPWMO`	Altitude of WMO tropopapuses at the Jet or SubVortex location [km]
`VTRPD60`	Altitude of DYN 6PVU tropopapuses at the Jet or SubVortex location [km]
`VTRPD45`	Altitude of DYN 4.5PVU tropopapuses at the Jet or SubVortex location [km]
`VTRPD35`	Altitude of DYN 3.5PVU tropopapuses at the Jet or SubVortex location [km]
`VTRPD20`	Altitude of DYN 2.0PVU tropopapuses at the Jet or SubVortex location [km]
`VTRPD15`	Altitude of DYN 1.5PVU tropopapuses at the Jet or SubVortex location [km]

3.3.2 (NH/SH)SubV Swaths

These swaths store the information about the subvortex jets (e.g., the white dots as well as the blue dots in Figure 1). The (NH/SH)SUBV swaths have the following variables:

`Lon`	Longitude
`NumCores`	Number of subvortex cores
`Flag`	-1: No subvortex jet;
	1: if it is the first subvortex identified at that longitude;
	2: if it is the second subvortex jet identified at that longitude

and the following swaths:

`Maximum`	Information about the subvortex cores
`PwEdge_Inner`	Information about the subvortex inner poleward edge
`PwEdge_Outer`	Information about the subvortex outer poleward edge
`EqEdge_Inner`	Information about the subvortex inner equatorial edge
`EqEdge_Outer`	Information about the subvortex outer equatorial edge

The variables in each of these swaths are listed in Table 2.

These variables are arrays with size $[2, nsb, nl]$ where 2 is the maximum possible number of subvortex jet cores along a longitude at a given time, nsb is the number of levels on which the subvortex is identified (which will vary with the reanalysis used), and nl is the number of locations / profiles.

Note that the order of the array dimensions depends on the language used to ingest the files.

3.3.3 JetDelta Swaths

The JetDelta swath has the following variables:

Levs	Vertical levels (either pressure or altitude)
NumCores	The same as NumCores in the corresponding Jet files
Lev_Units	Vertical levels units (e.g., km)

These swaths store the differences between the measurement location and the jet core/edges locations. As such they include the same swaths as in the `(NH/SH)Jet` swaths (described in section 3.3.1). That is, `Maximum, PwEdge_(Inner/Outer), EqEdge_(Inner/Outer), UpEdge_(Inner/Outer), DnEdge_(Inner/Outer)`.

For each of those swaths the difference in the meteorological conditions is stored for all the variables except for the tropopauses. That is, these swaths contain the difference in latitude, pressure, altitude, zonal wind (U), meridional wind (V), temperature, PV, RV, dT_dZ, static stability, and potential temperature.

3.3.4 SubVDelta Swaths

The SubVDelta swath has the following variables:

Levs	vertical levels (either pressure or altitude)
NumCores	The same as NumCores in the corresponding SubV file
Lev_Units	vertical level units (e.g., km)

These swaths store the differences between the measurement location and the subvortex core/edges locations. As such they have the same swaths as in the `(NH/SH)SubV` swaths (described in section 3.3.2). That is, `Maximum, PwEdge_(Inner/Outer), and EqEdge_(Inner/Outer)`.

For each of those swaths the difference in the meteorological conditions is stored for all the variables except for the tropopauses. That is, these swaths contain the difference in latitude, pressure, altitude, zonal wind (U), meridional wind (V), temperature, PV, RV, dT_dZ, static stability, and potential temperature.

4 Instrument Specifics

4.1 ACE-FTS

The ACE-FTS files also have the following variables:

Orbit	The ACE-FTS orbit number
Sunset Sunrise	The ACE-FTS sunset or sunrise flag
Lat_Lon_Info	Information about which lat/lon was used, that is either from the geolocation files (GLC) or from the 30 km tangent height

5 Errata

In JETPAC version 300 files two variables in the DynEql files were incorrectly labeled. The variables were labeled as:

Name	Description	units
`horpvgrad`	Normalized Horizontal (Isentropic) PV Gradient	unitless
`avgpvgrad`	Normalizing factor for Horizontal PV Gradient	K m2 (kg s)-1 km-1

The variables should have been labeled as:

`horspvgrad`	Normalized Horizontal (Isentropic) sPV Gradient	unitless
`avgspvgrad`	Normalizing factor for Horizontal sPV Gradient	s-1

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