# Determining planetary boundary layer (PBL) depth via integrated data viewer (IDV) from atmospheric sounding profile data

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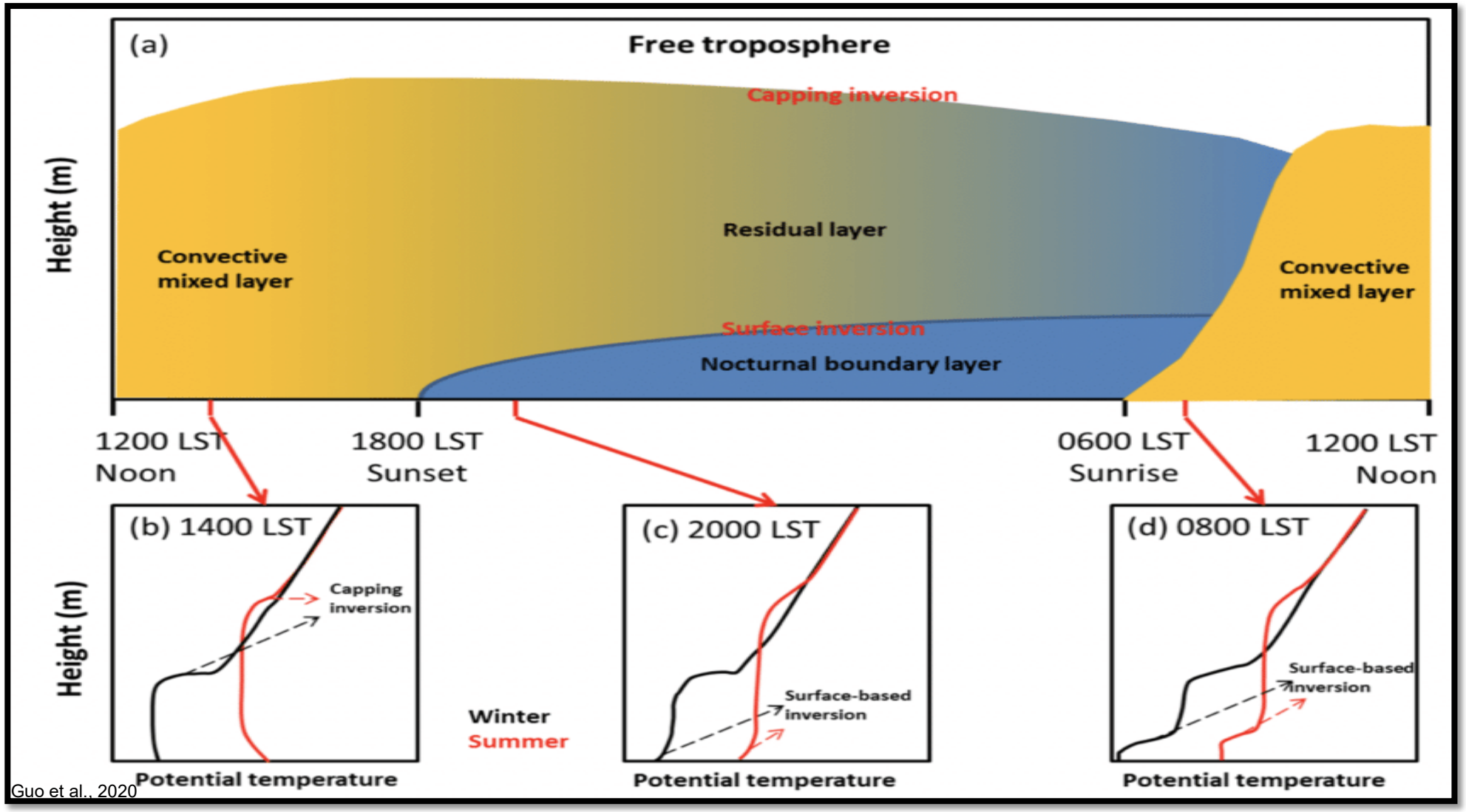
# Planetary Boundary Layer depth: What is it?



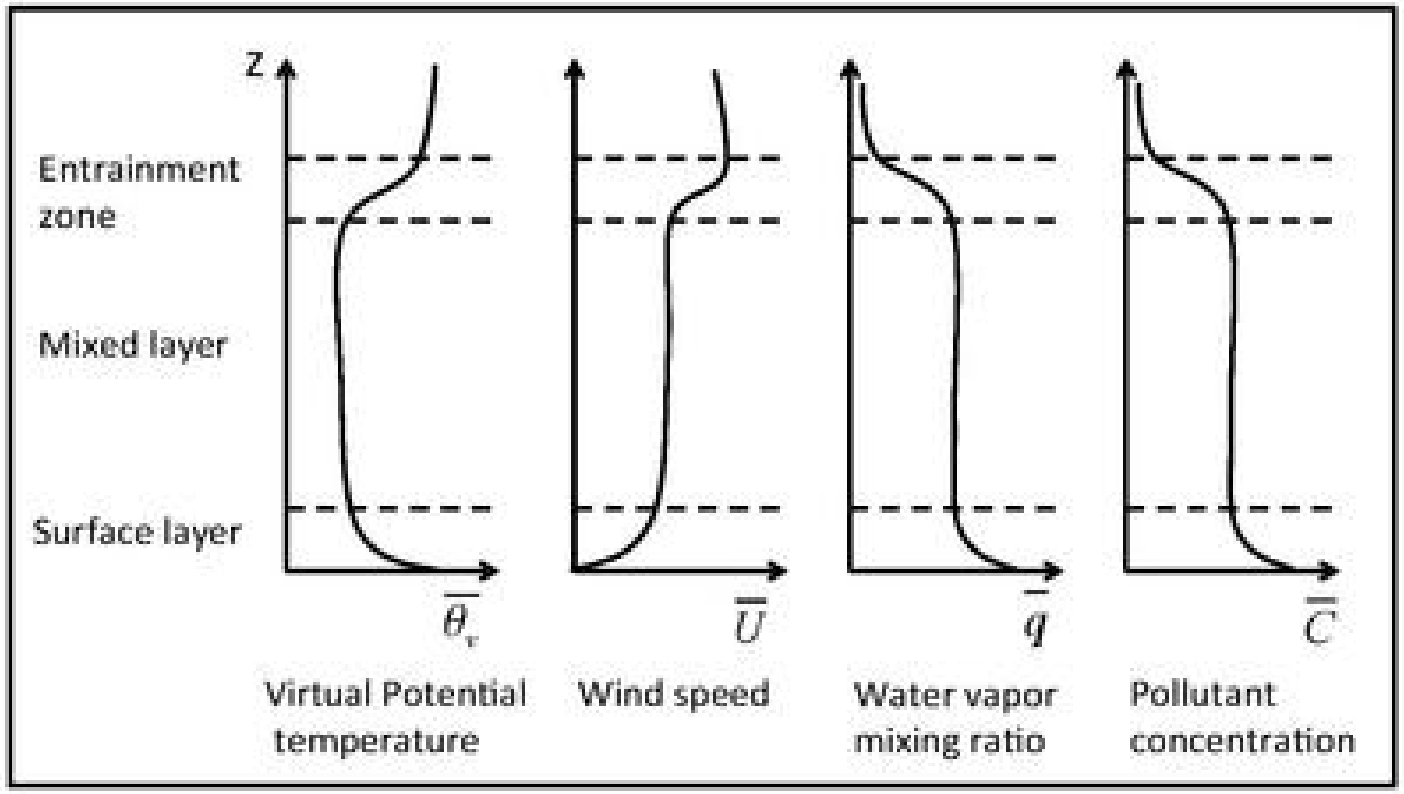

Guo et al., 2020

# PBL : Why should we care?

- Weather forecasting & climate modeling
- Surface air pollution
- Urban heat island intensity(UHII)

## Visualization for wider users

- Aviation
- Urban form



# PROJECT AIM

- Retrieve boundary layer information from sounding type data in IDV
- Point-by-point spatial and temporal verification with high-frequency boundary layer measurements

## Determining PBL depth

1. Temperature gradient method (TGRD): PBL is defined as the first substantial maximum in the potential temperature gradient from the surface (Stull 1988).
2. Bulk Richardson number method *(Ri)*

*Ri*: an important parameter for diagnosing flow dynamic stability (Stull 1988). For finite differences :

$$Ri_b(z_2) = \frac{g(z_2 - z_1)}{\bar{\theta}_v} \frac{\theta_v(z_2) - \theta_v(z_1)}{[u(z_2) - u(z_1)]^2 + [v(z_2) - v(z_1)]^2}$$

PBL depth = *Ri* first becomes greater than a given threshold (*Ri* = 0.25 - 0.5)

# Temperature Gradient Method

**Organize data in a time-series data frame**

**Find first global maxima of potential temperature gradient with height**

**Find altitude corresponding to the maxima**

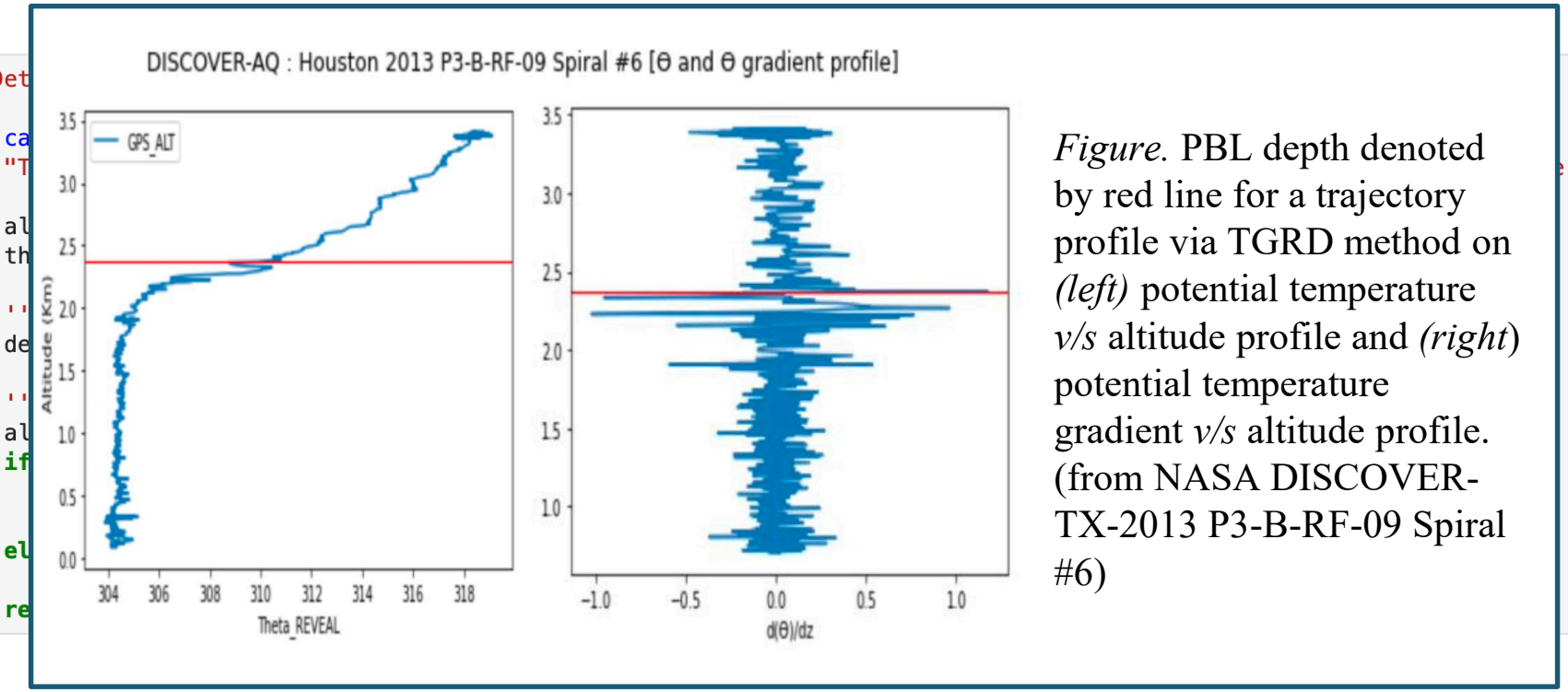



*Figure.* PBL depth denoted by red line for a trajectory profile via TGRD method on *(left)* potential temperature *v/s* altitude profile and *(right)* potential temperature gradient *v/s* altitude profile. (from NASA DISCOVER-TX-2013 P3-B-RF-09 Spiral #6)

# Bulk Richardson number method *(Ri)*

**Organize data in a time-series data frame** → **Calculate all the variables (wind, potential temperature, and altitude)** → **Calculate *Ri*** → **Calculate the altitude where *Ri* crosses the threshold for the first time**

```
'''Determination of BL via Bulk Richardson Number technique'''

def calc_bl_richard(dataframe, threshold):

    '''Takes the pandas dataframe for a particular sounding and threshold value of Richardson number for PBL.
       Returns the PBL value in meters.'''

    g = 9.8 #Gravitational Acceleration
    dataframe = dataframe.dropna(subset=['WND','TAS','THETA','GPS_ALT'])
    alt = dataframe['GPS_ALT']*1000

    '''Converting Meteorlogical wind direction to mathematical wind direction'''
    math_wd = 270 - dataframe["WND"]
    wind_dir = [math.radians(i) for i in math_wd]

    '''Finding u and v components of wind'''
    sin_wind = [math.sin(i) for i in wind_dir]
    cos_wind = [math.cos(i) for i in wind_dir]
    u = dataframe["TAS"]*(cos_wind)
    v = dataframe["TAS"]*(sin_wind)

    '''Calculating Bulk Richardson Number'''
    delta_u = u.diff()
    delta_v = v.diff()
    delta_theta = dataframe["THETA"].diff()
    delta_alt = dataframe["GPS_ALT"].diff()
    avg_theta = dataframe["THETA"].rolling(2).mean()
    richard_no = (g * delta_alt * delta_theta)/(avg_theta * (delta_u**2 + delta_v**2))
    richard_no = richard_no.dropna()

    '''Calculating the altitude index where Bulk Richardson number reaches the threshold'''
    ind = np.where(richard_no > threshold)
    if len(ind[0])<1:
        return None
    else:
        alt = alt[1:].to_numpy()
        bl_value = alt[ind[0][0]]
    return bl_value
```

# DATASETS

- **UCAR COSMIC-1 Level 2 data**

Acquired from Amazon Web Services (AWS), generated and processed at the COSMIC DAAC, the Jet Propulsion Laboratory of Caltech, and the Radio Occultation Meteorology Satellite Application Facility (ROM SAF).

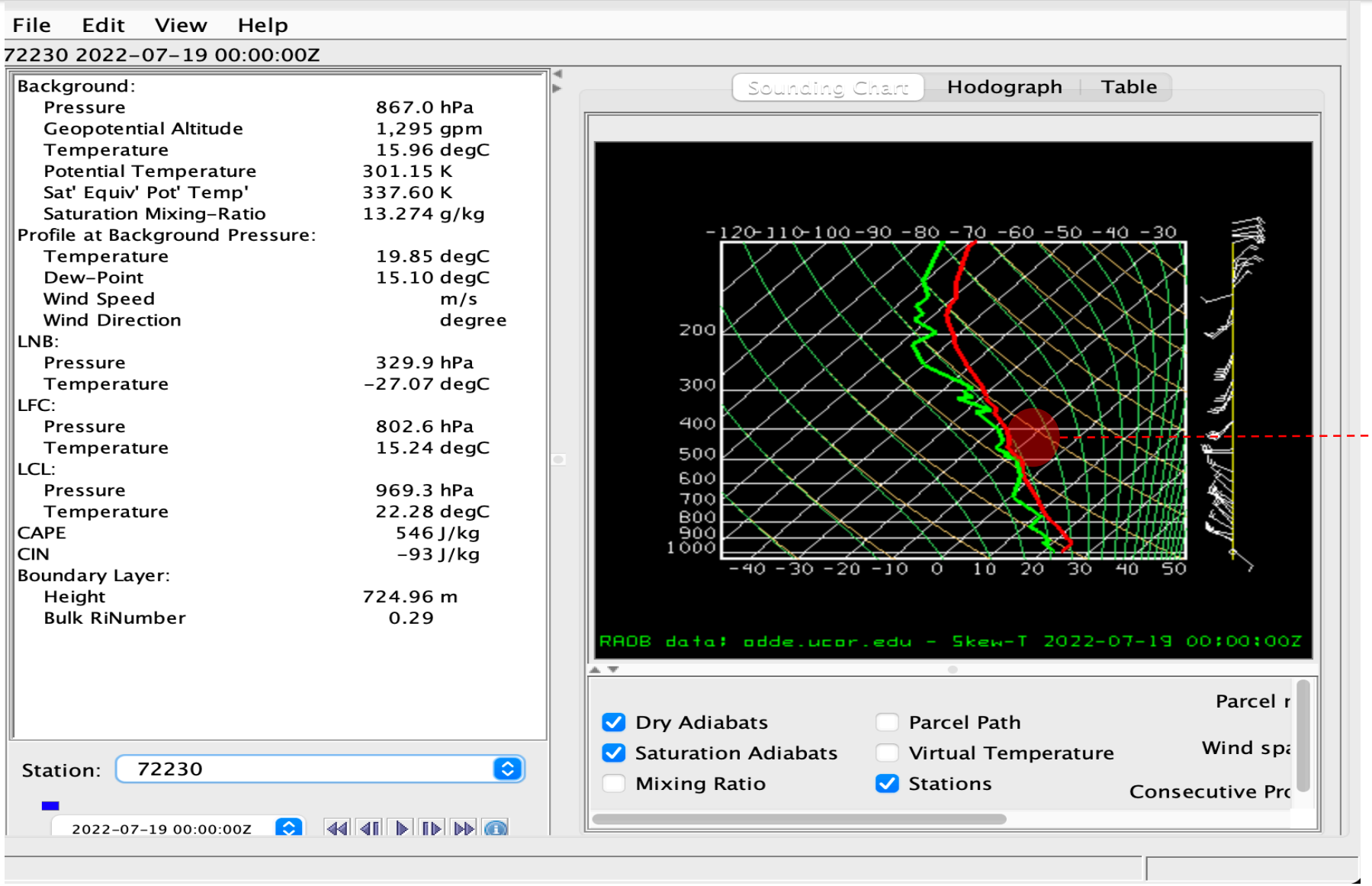
- **COSMIC-2 Level 2 data**

Constellation observing system for meteorology ionosphere and climate (COSMIC), UCAR data achieve.

- **NASA DISCOVER–AQ – TX & CA (2013) P3-B aircraft data**

Aircraft measurements by NASA field project on deriving information on surface conditions from column and vertically resolved observations relevant to air quality (DISCOVER) – Texas and California (2013).

# IDV – DATA VISUALIZATION




Move the cursor over line to know the value of *Ri*

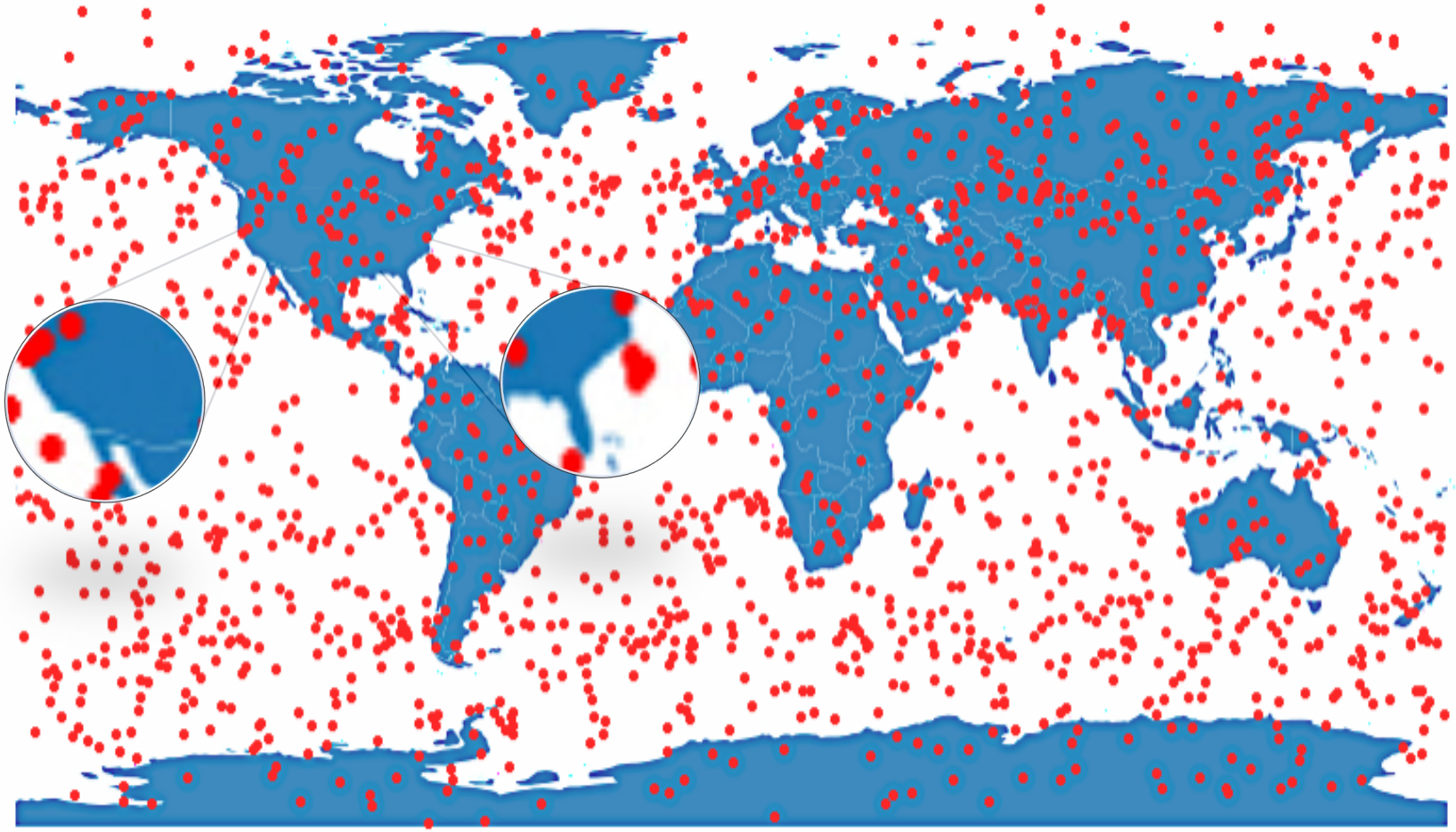
# PBL VERIFICATION

- **Point-by-Point Spatial and temporal PBL correlation**
  - High frequency PBL observations.
  - Spatial and temporal subset of sounding data (radio occultation (RO) COSMIC data).

## NASA DISCOVER–AQ – TX & CA (2013) P3-B aircraft data
## &
## COSMIC 1 data (2013)

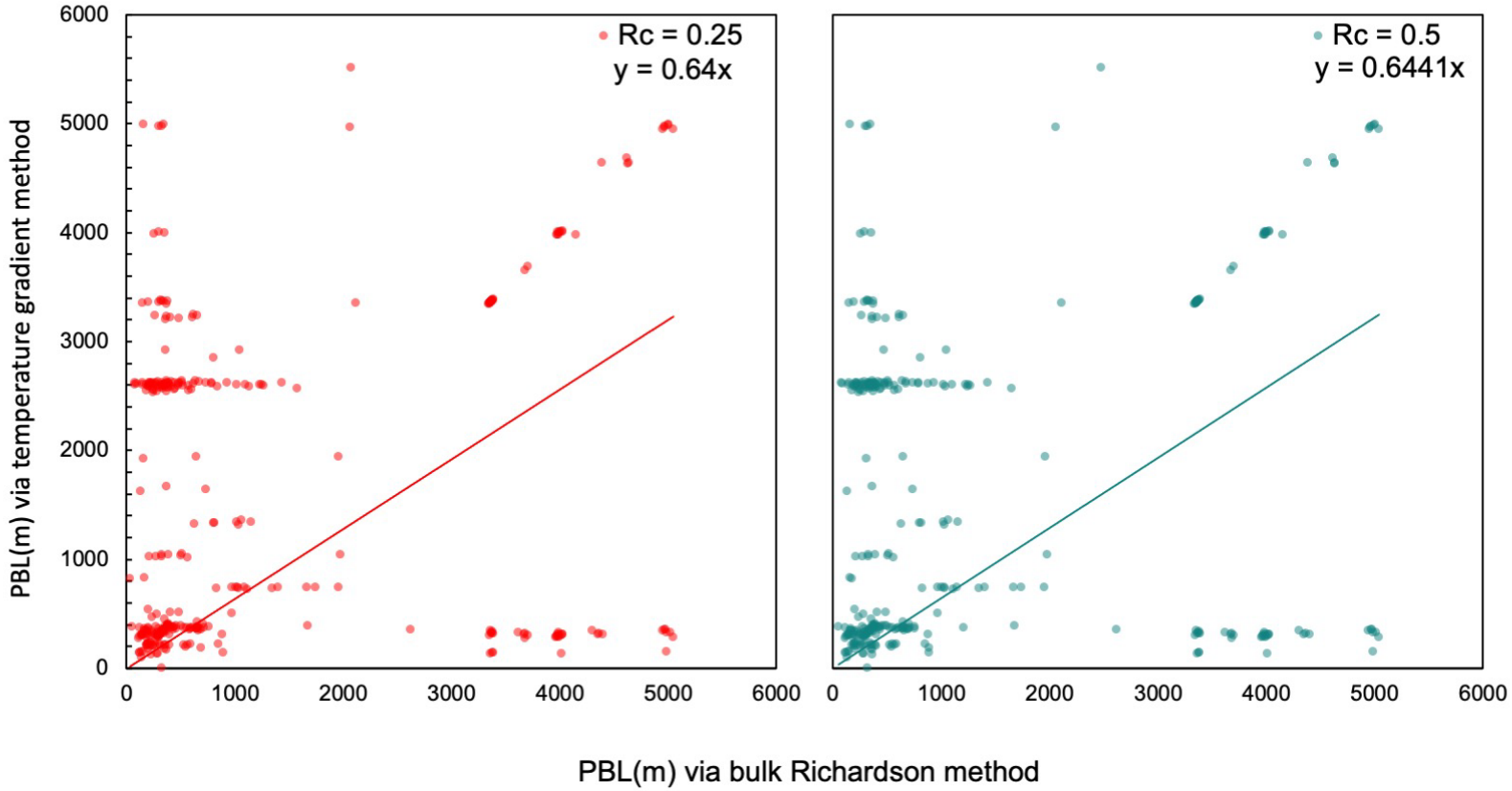
# VERIFICATION

- **Spatial analysis could not be achieved due to lack of RO soundings coinciding with DISCOVER data.**



# VERIFICATION

- **PBL retrieval via critical *Ri* number and TGRD were compared for convective boundary layer.**
  - The change in *Ri* (critical) did not significantly alter the PBL depth for this dataset.
  - The PBL height via TGRD is usually higher than that by critical *Ri* number



# KEY POINTS

- ✓ Integrated Data Viewer is a useful tool for real time retrieval of PBL for the benefit of atmospheric science educators, researchers, aviation, and/or weather forecasters.
- ✓ TGRD method can be used to retrieve PBL from both radiosonde and RO occultation soundings.
- ✓ Effective temporal and spatial sub-setting of COSMIC data can make RO data more accessible.
- ✓ Refractivity gradient and bending angle can be further explored to identify PBL top from RO soundings (Xie et al.,2012).
- ✓ A point-by-point spatial and temporal correlation of PBL depth should be explored for verification.

# THANK YOU

QUESTIONS?