2023 CIRES Rendezvous

EOMF-06

Deriving PBL Properties with Aircraft Data and Comparing to the HRRR model

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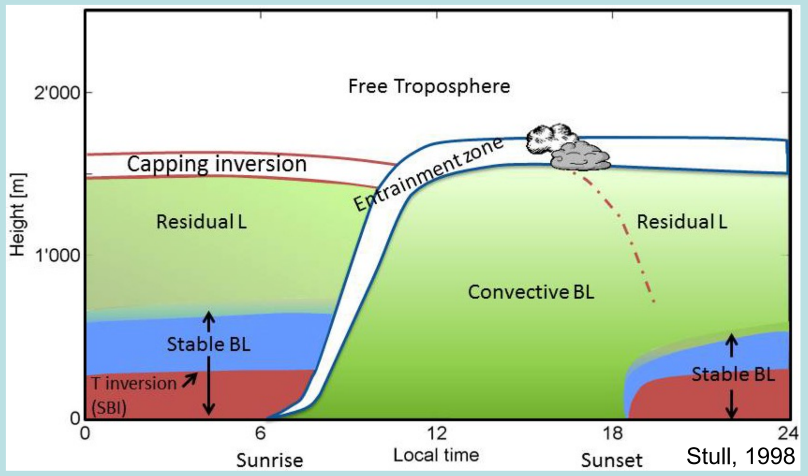
1. PBL Height as a Metric

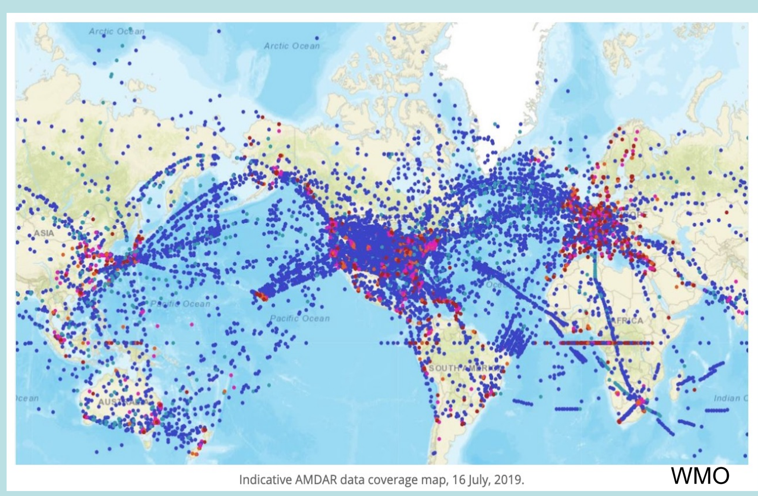
- The Planetary Boundary Layer (PBL) is the well mixed, lowest layer of the atmosphere
- The PBL Height (PBLH) is driven by a complex combination of lower atmosphere and surface processes (radiative heating, sfc roughness, etc)
- Getting PBLH correct is important for many applications (pollution, fog, severe weather/turbulence, wind energy, etc)



- Due to radiative heating, the PBL transitions from a nocturnal/stable (low) PBLH to a daytime/convective (high) PBLH each day
- PBLH is a simple metric that can effectively evaluate a model's ability to represent many of these processes, which are often lacking in model verification

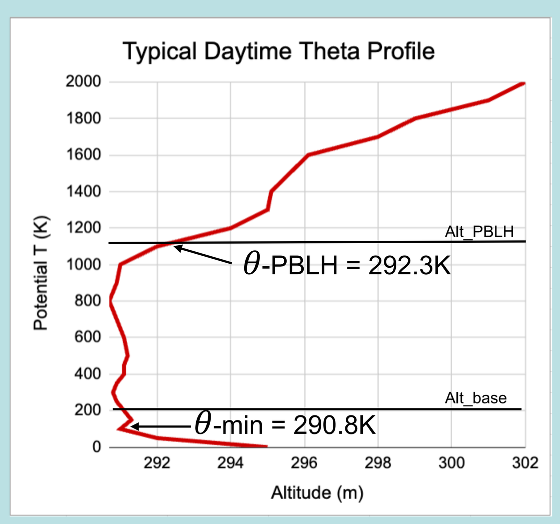
2. AMDAR Aircraft Data

- Aircraft data is the most important DA source (James et al. 2020), but is not well utilized for model verification
- Aircraft Meteorological DAta Relay (AMDAR) data is one of the only sources of lower atmosphere profiles with temporal frequency (which is needed to represent the PBL)
- AMDAR provides thousands of T, humidity, and wind measurements per hour [hourly netcdf files with 1-d fields]



3. Theta-Increase PBLH Method

- PBLH can be computed using AMDAR met data by finding an increase in potential temperature (theta) from a base value (typically 1.0 – 2.5 K)



Theta-increase method example

- Step 1: Define alt_base (200 m)
- Step 2: Determine lowest theta value below alt_base (290.8 K)
- Step 3: Specify theta-increase (PT_delta) value (1.5 K)
- Step 4: Find first instance where theta exceeds theta-base + theta-increase (290.8 + 1.5 = 292.3 K)
- Step 5: PBLH is determined to be the altitude at this theta (1142 m)

- This method has been found to be useful for daytime convective PBLH (and is the same method used to compute HRRR model PBLH)

4. Project Goals/Approach

1. Develop a robust algorithm to compute daytime convective PBLH from AMDAR data
   - Download 1 month (1-31 July 2022) of AMDAR (netcdf) and HRRR-op (grib2) files
   - Create standalone python script to test different algorithms/design settings
   - Apply this PBLH algorithm to four airports (Denver, Dallas, Minneapolis, Boston)
   - Analyze/plot various implementations and settle on a final design
2. Integrate the algorithm as a METplus use case available to the DTC community
   - Use a modified point-observations use case (MET tool "point-stat")
   - Convert standalone python script to a METplus use case python script (which creates a pandas dataframe and sends 11-column ASCII table to MET)
   - Create conf file (PointStat_pblh.conf) that calls the python script at specified times and settings
   - Run MET through location masks (using Gen-VX-mask) to filter data near airports
3. Implement the product into GSL's METexpress product
   - Run the METplus use case to generate .stat files for both AMDAR and HRRR
   - Ingest the .stat files into METexpress
   - Allow the selection of various settings in METexpress
     - Airport: Denver, Dallas, Minneapolis, Boston
     - Sounding: Ascent, Descent, All
     - PT_Delta (K): 1.25, 1.75

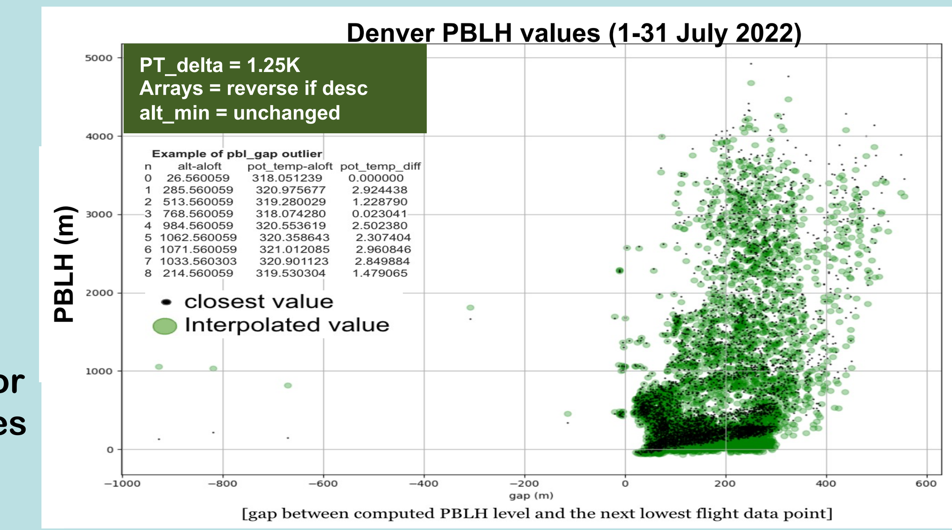
5. PBLH Algorithm Development

Initial Algorithm Settings

- Include the following AMDAR aircraft data:
  - Ascents/Descents (discard all cruising flights)
  - Flights within a 0.7 deg radius (~80km) of the airport [Evaluated 0.3-1.0 deg (30-110 km); 0.3 deg had not enough flights; 1.0 deg was similar to 0.7 deg]
  - Flight must contain at least one data point below alt_min (200 m)
  - Flight must contain at least 4 data points
  - Flight data point below PBLH must be < gap_max (400 + PBLH/20 m)

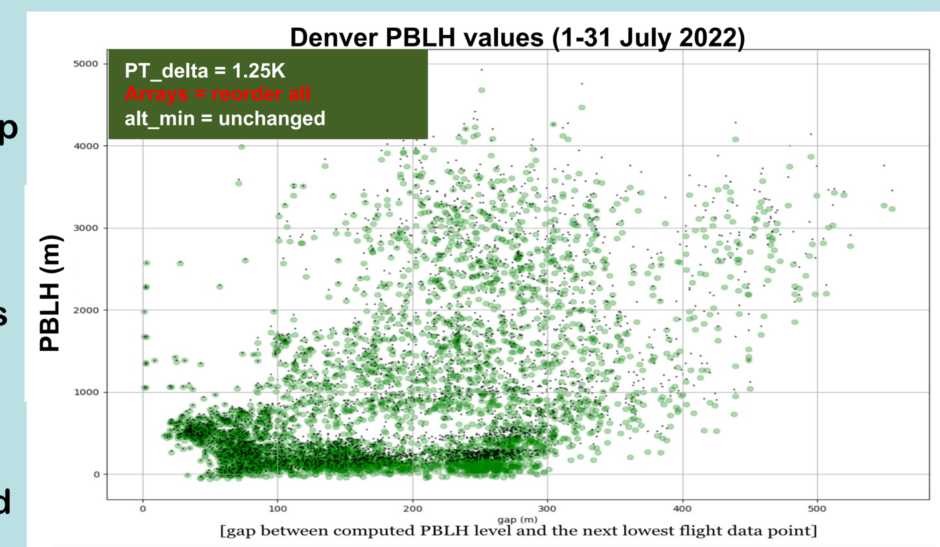
Initial PBLH Scatterplot

- Interpolated values are less than closest values esp at larger gaps
- A few outliers of large negative gaps due to arrays being out of order [this occurs when an ascending or descending flight briefly goes up and down]



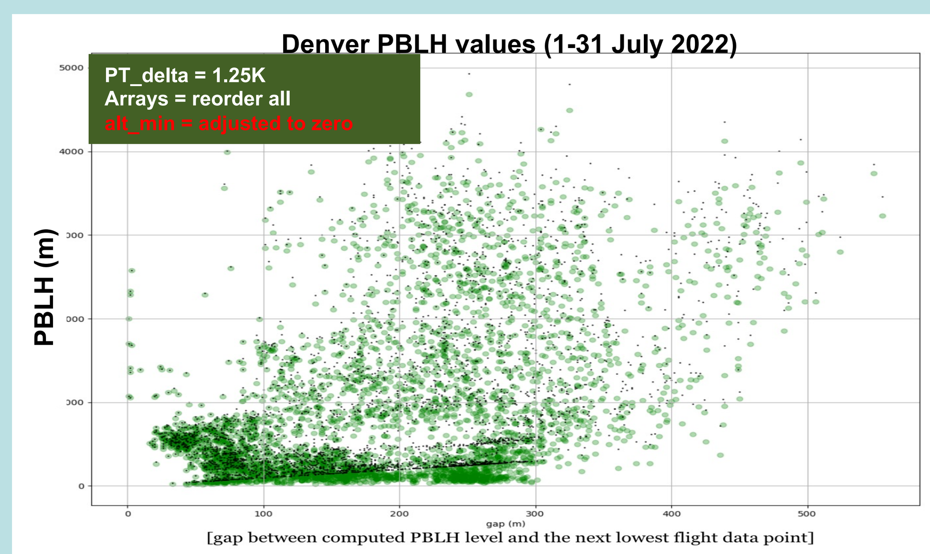
Reordering all arrays

- Reordering all arrays to be ascending eliminates the gap outliers
- Some negative PBLH values due to flight altitude arrays starting with negative values (since ground height is uneven around airport)
- Changing Denver ground ht from 5430 to 5300 ft reduced negative instances



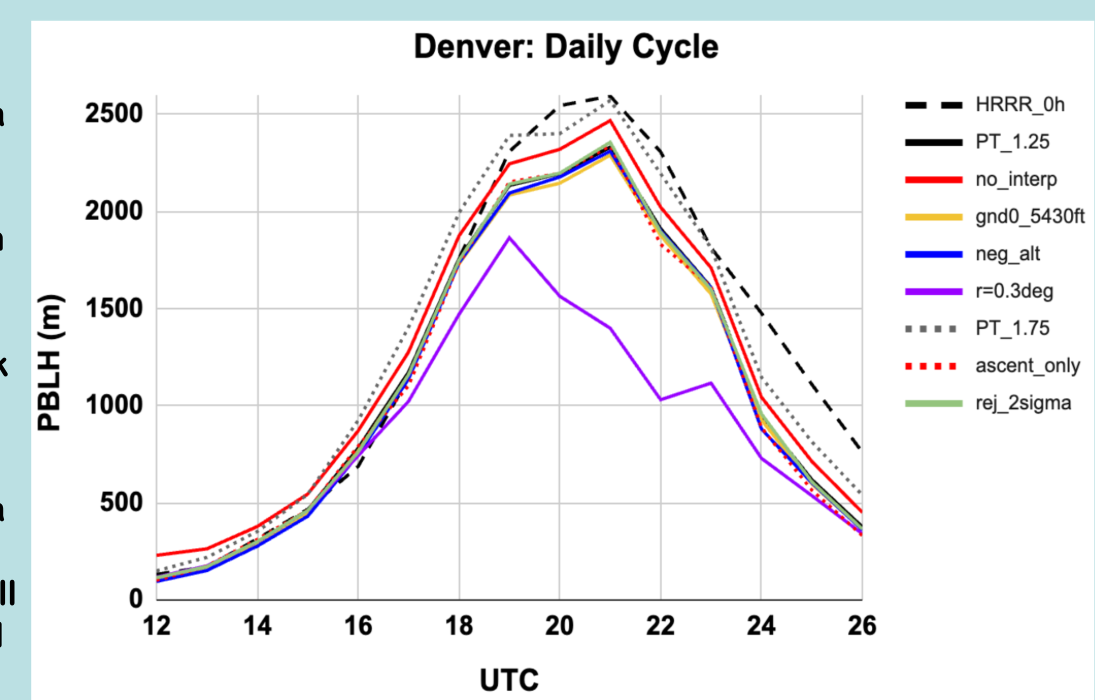
Adjusting alt_min to zero

- Forcing negative altitude arrays to start at zero eliminates the negative PBLH values
- This produces a PBLH "bottom" for closest data point values (and increases interpolated values as well)



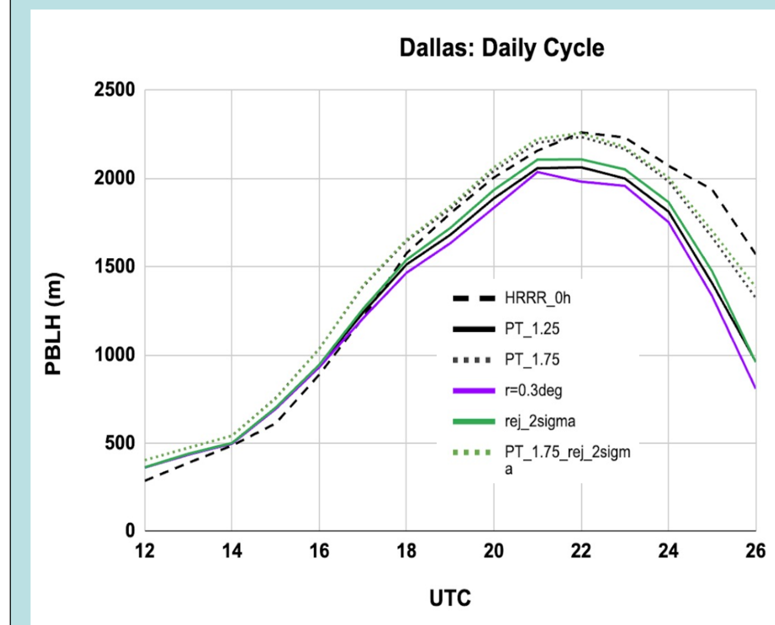
Daily Cycle

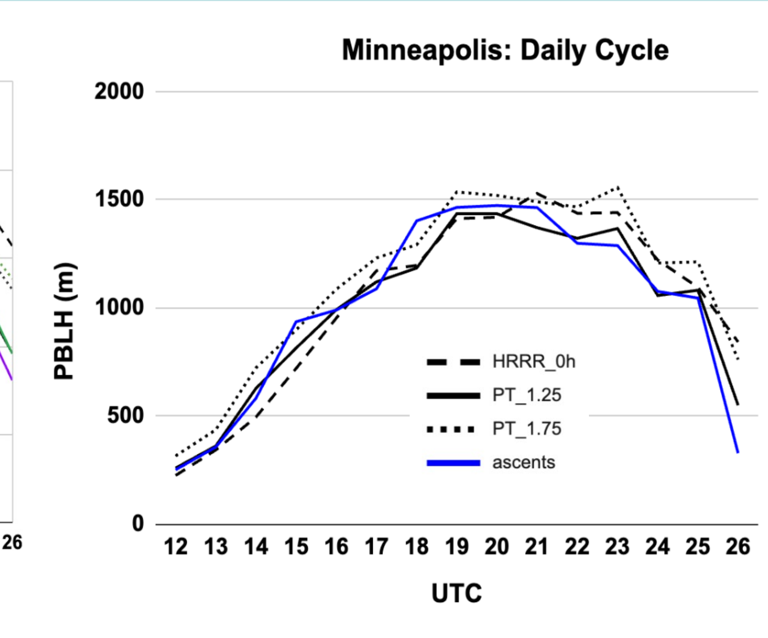
- AMDAR at PT_delta = 1.25 K (same setting as HRRR) compares well with HRRR from 12-18 UTC, but has a lower daytime peak (18-22 UTC) and collapses faster
- AMDAR at PT_delta = 1.75 K daytime peak compares well with HRRR, but still collapses faster

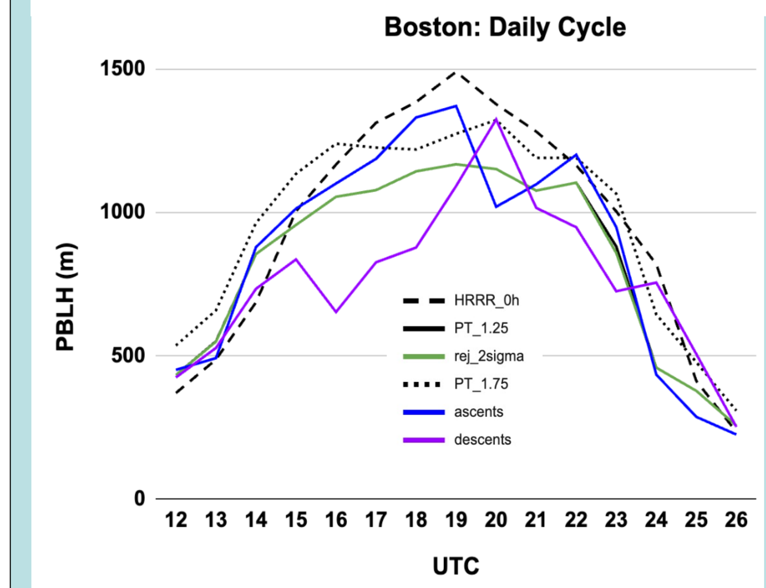


- AMDAR PBLH using a r=0.3 deg radius for flight data is much lower than using a r=0.3 deg radius, due to excluding most flights / large error bars
- Flight sounding (ascents vs descents) produced similar PBLH values
- AMDAR PBLH using closest flight data point (no_interp) compares better to HRRR at daytime peak, but is too high around 12 UTC (and is by definition less accurate)
- The following algorithm changes improved scatterplots and eliminated physically unrealistic outliers, but had only small impacts on monthly average PBLH:
  - Changing ground height from 5430 to 5300 ft
  - Forcing negative altitudes to zero
  - Rejecting outliers (discarding any data points outside of 2_sigma std dev)

6. Other Airports







- Using PT_delta = 1.25 K, AMDAR daytime peak is lower than HRRR at all airports
- Using PT_delta = 1.75 K, AMDAR daytime peak compares better to HRRR at all airports
- Rejecting outliers, and ascents vs descents sometimes changes results
- Minneapolis and Boston have more uncertainty due to fewer flights

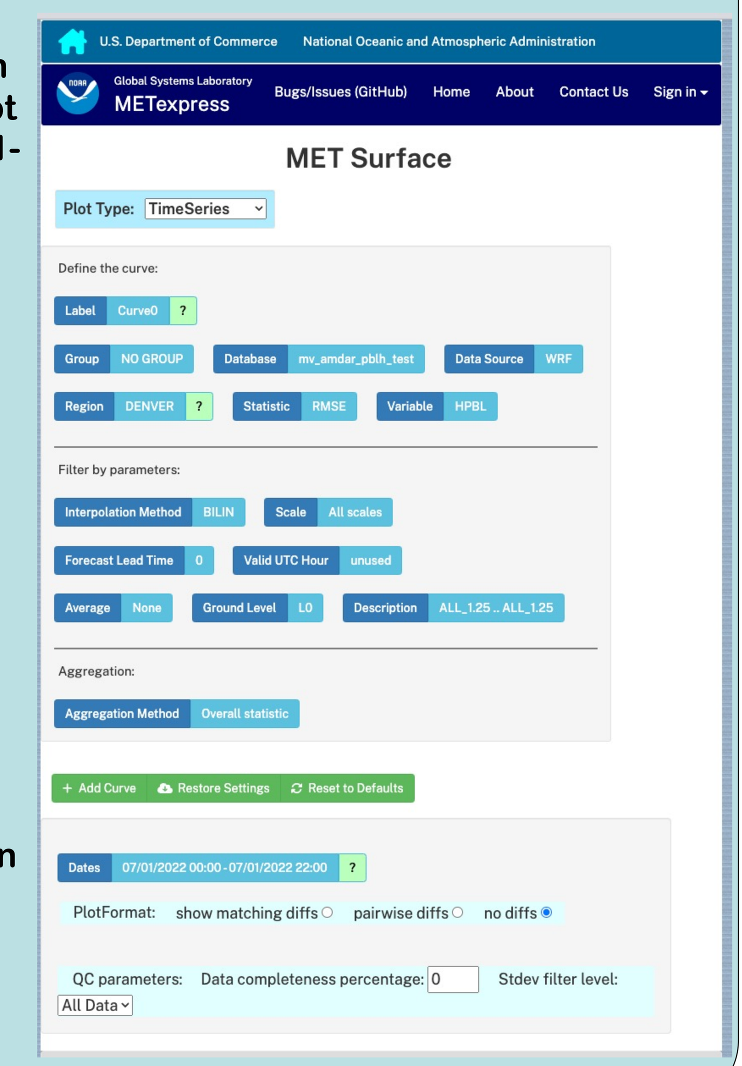
7. METplus / METexpress Integration

METplus

- Successfully converted standalone python script to METplus python embedding script (creates a pandas dataframe and sends 11-column ASCII table to MET)
- Created a PointStat config file which specifies the dates/times to call, PT_delta, airport, and sounding (asc/desc/all)
- Created airport masks (using Gen-VX-mask) which are read every time MET is called to filter a data circle around airport
- Produced 1-day of .stat files with the desired headings/rows needed for METexpress

METexpress

- Successfully ingested 1-day of .stat files
- The user can specify airport via the Region button (e.g. DENVER)
- The user can specify sounding and PT-delta setting via the Description button (e.g. ALL_1.25, ASC_1.75, etc)



8. Summary / Next Steps

- A robust, consistent "theta-increase" algorithm was successfully implemented to compute PBLH from AMDAR aircraft data via potential temperature profiles
- AMDAR PBLH compares fairly well to HRRR-0h at 4 airports (Denver, Dallas, Boston, Minneapolis) but daytime convective peak is lower
- Daytime peak is more similar when using PT_delta = 1.75 K for AMDAR
- The algorithm has been successfully implemented in METplus
- Initial ingest to METexpress was successful as well
- Next Steps
  - Complete creation of METplus use case for the community
  - Complete ingest of 1-month of .stat files to METexpress, and add real-time tool
  - Complete algorithm evaluation at other 3 airports, and submit manuscript
  - Create a tool to re-process AMDAR files for easy community use
  - Implement a new PBLH bulk-Richardson algorithm
  - Look into extending to other types of data (e.g. Mode S aircraft data)