U.S. NAVAL RESEARCH LABORATORY

Effects of Elevation Errors on the Calculation of Station Pressure

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Why care about elevation errors?

Station pressure is not reported in METARs

- Some SYNOP surface stations and most METARs only report altimeter setting and sea level pressure, where altimeter setting is calculated by

$$p_{alt} = p_{sfc}\left[1+\left(\frac{1013.25\,hPa}{p_{sfc}}\right)^{\frac{R_d\gamma_s}{g}}\frac{\gamma_s z_{sfc}}{288.15\,K}\right]^{\frac{g}{R_d\gamma_s}}$$

where z_{sfc} is the station elevation is the station pressure.

- Station pressure can be calculated from the METAR-reported altimeter setting using the reversed altimeter setting equation

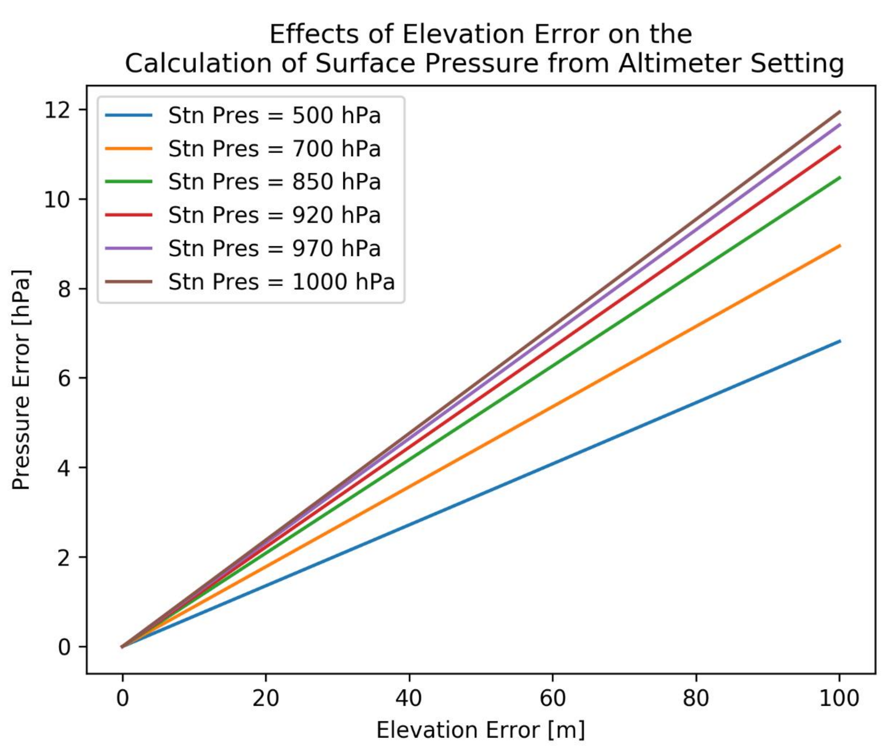
$$p_{sfc} = \left[p_{alt}^{\frac{R_d\gamma_s}{g}} - 1013.25\,hPa^{\frac{R_d\gamma_s}{g}}\left(\frac{\gamma_s z_{sfc}}{288.15\,K}\right)\right]^{\frac{g}{R_d\gamma_s}}$$

where station pressure can be calculated given an altimeter setting value and a station height.

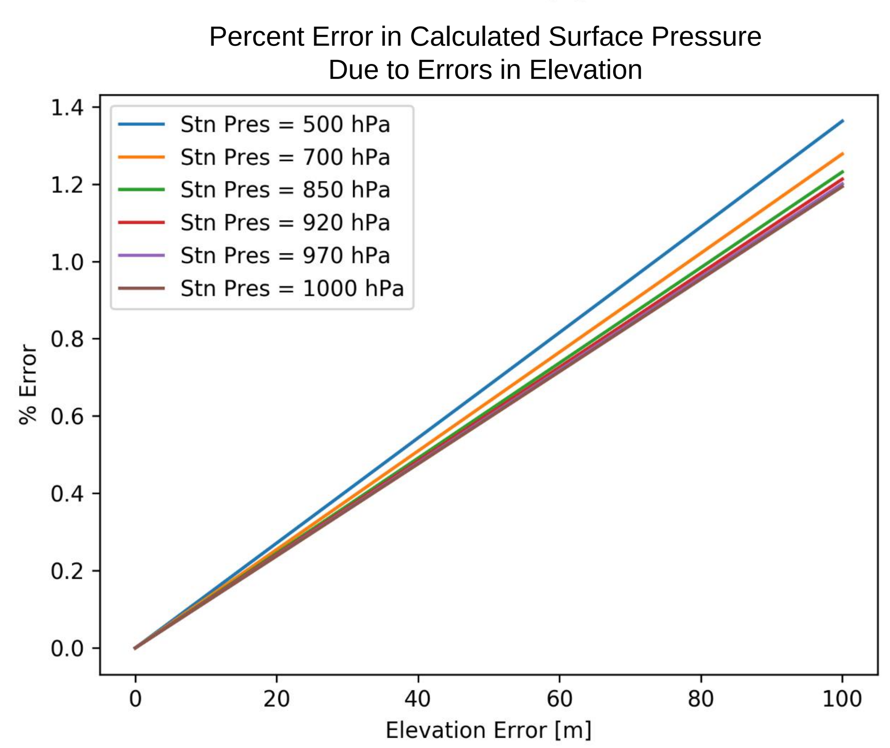
The Problem

- Since METAR reports do not contain metadata, the station metadata must be gathered from separate lookup tables.
- Lookup tables have errors, including typos, misidentified stations, and outdated information.
- Using incorrect elevation to calculate station pressure from altimeter setting introduces a bias in the station pressure values.
- With multiple different look-up tables, data decoders, and other sources of metadata errors, tracking down and fixing elevation errors is a difficult and time-consuming process.
- Extremely large elevation errors are easier to locate and resolve, but smaller errors that can slip through quality control can go on to cause consistent biases in calculated surface pressure values.

How much do elevation errors affect surface pressure?



Larger elevation errors cause larger pressure errors, which is to be expected. The magnitude of the pressure error for a given elevation error is largest at elevations closest to sea level and smaller for higher elevations. For example, stations whose correct station pressure is 925 mb would experience a calculated surface pressure bias of over 2 mb for a 20 meter elevation error.



While the magnitude of the pressure error increases as correct elevation decreases, the percent error in calculated station pressure increases. Elevation errors cause more significant pressure errors at higher base elevations.

Elevation error sources

Metadata Tables

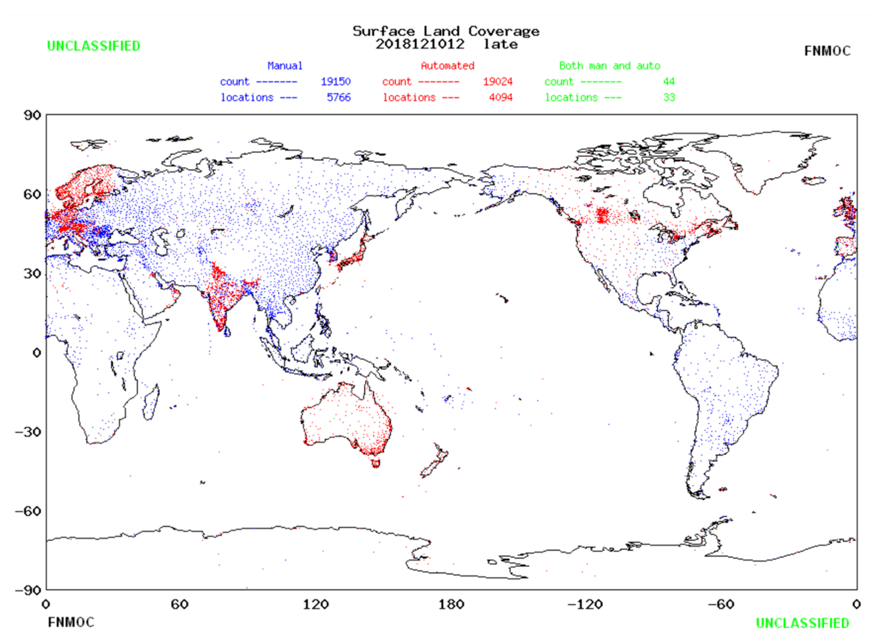
KGFK 242253Z 35014KT 10SM OVC015 M05/M08 A2990 RMK AO2 SLP142 T10501078

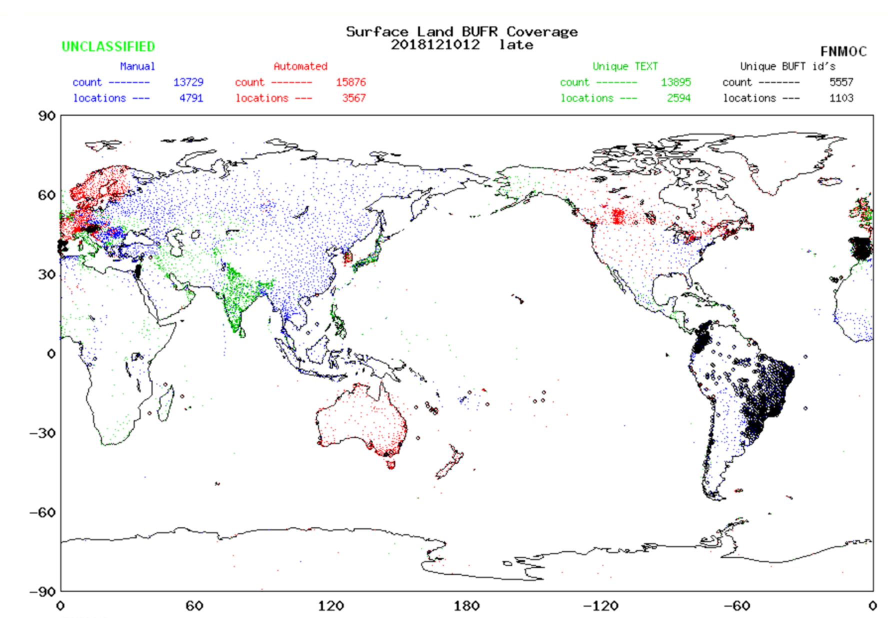
METAR reports, such as this one from Grand Forks, ND (KGFK), contain no metadata. Any information about the elevation or location of KGFK must be found in separate metadata tables. Metadata tables, including the WMO Pub9 VolA list (now superseded by WMO's OSCAR/Surface), have errors including typos and out-of-date information.

BUFR

In 2003, the WMO members approved a migration from Traditional Alphanumeric Codes (TAC) to the Binary Universal Form for the Representation of meteorological data (BUFR) for data distribution on the Global Telecommunications System (GTS), the primary communications pathway countries use to share data. Metadata are contained in the BUFR message itself, eliminating (ideally) the need for metadata tables. However, some of the metadata being put into the BUFR messages is incorrect, leading to elevation errors.

The official BUFR transition timetable called for TAC distribution to cease in November 2014, however not all countries have started producing BUFR and only a small fraction of TAC has actually stopped. While some countries are producing both TAC and BUFR to enable users to transition between the two formats, other countries are still only producing TAC. The BUFR Migration Tool (BMT) converts TAC messages to BUFR, and since the TAC messages contain no metadata, the BMT uses a metadata table to match metadata to the report. Errors can arise here because the BMT can match incorrect metadata to a station.





- Surface SYNOP coverage, including manual reports (blue), automated reports (red), and both manual and automated reports (green).
- Surface station coverage, including manual reports (blue) and automated reports (red) in both TAC and BUFR, unique TAC reports (green), and unique BUFR reports (black circles).

Dual-location Stations

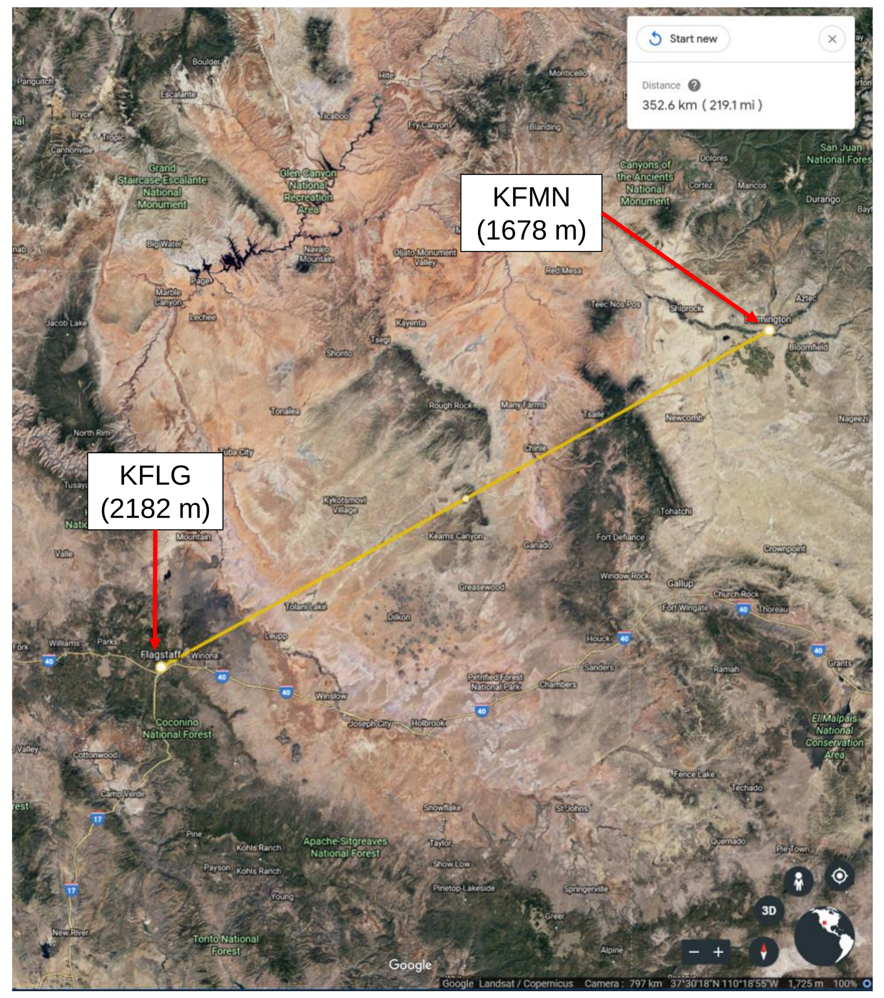
While most surface and upper air stations using the same station identifier are nearly collocated, some can either be many kilometers apart or have elevations that differ significantly. These so-called dual-location stations require two entries in metadata tables: one entry for the upper-air station and another for the surface station.

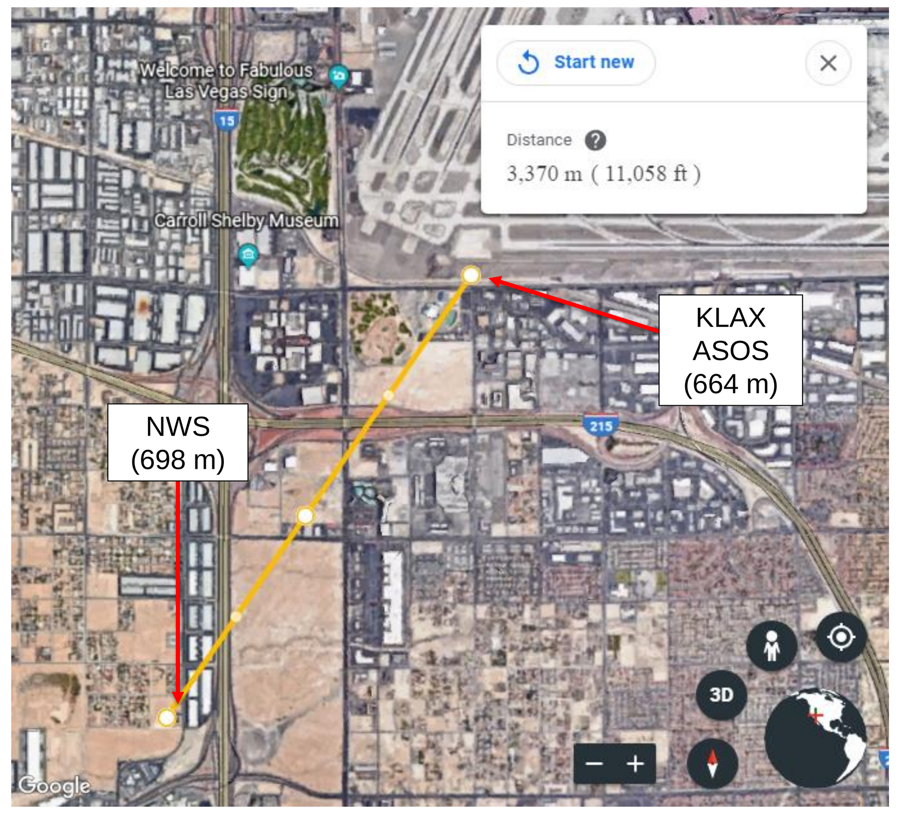
Real cases of elevation error

ICAO ID (Station #)	Correct height (m)	Incorrect reported height (m)	Elevation error (m)	Altimeter setting (mb)	Reported stn pres (mb)	Sea level pressure (mb)	Calculated stn pres with good elev (mb)	Calc stn pres with bad elev (mb)	Pressure error (mb)
KFMN (72376)	1678	2182	-504	1016.9	829.2	1009.8	830.5	780.2	50.3
KPDX (72698)	7	456	-449	1019.3	1018.4	1019.3	1018.5	965.5	53
KLAS (72386)	664	698	-34	1008.8	934.9	1005.3	931.9	928	3.9

Farmington, NM (KFMN)

Farmington, NM (KFMN) is located at an elevation of 1678 m. The BUFR Migration Tool (BMT) incorrectly matches the station metadata for Flagstaff, AZ (KFLG), at an elevation of 2182 m, to the KFMN METAR report. Flagstaff and Farmington are more than 350 km apart and have elevations that differ by over 500 m. Using the incorrect metadata to calculate station pressure for Farmington introduces a pressure error of about 50 mb and places the KFMN ob at Flagstaff.





Las Vegas, NV (KLAS)

The ASOS station at McCarran International Airport in Las Vegas, NV (KLAS) is at an elevation of 664 m, but the elevation is incorrectly reported as 698 m in the converted BUFR surface data. The Las Vegas NWS office/radiosonde station is located 3 km SW of the ASOS station at an elevation of 698 m. The likely source of the elevation error is the BMT incorrectly using the upper-air elevation for 72388 in place of the elevation of the KLAS/72386 ASOS station.

Portland, OR (KPDX)

The correct elevation of the ASOS station at Portland Int'l Airport (KPDX) in Portland, OR is 7 m. The elevation reported in the BUFR data is 456 m; an elevation error of this magnitude would lead to a pressure error of 53 mb. An elevation of 456 m is nowhere to be found near Portland, but it is the elevation for Pendleton, OR (KPDT) suggesting that this might be a case of mistaken identity. In addition, there is some question about which elevation is correct. The difference between the SYNOP sea level pressure and station pressure suggests that the field elevation of 7 m was used in the conversion from METAR. But, the NWS Office of Observations states that the actual station pressure at KPDX is valid at the station elevation of 33 m.

Tucson, AZ (KTUS)

Radiosondes for station KTUS are launched from the University of Arizona in central Tucson, AZ, at an elevation of about 750 m MSL. The surface measurements for KTUS are taken from the Tucson International Airport ASOS station, located 11 km south of the University of Arizona, at an elevation of about 779 m MSL. KTUS is a dual-location station that needs two entries: one for the upper air station and another for the surface station. Currently, the WMO OSCAR/Surface database has only a single entry with a station elevation of 751m and a barometer height of 747m.