Cloud Base and Flight Category Climatology of WFO Tucson TAF Sites

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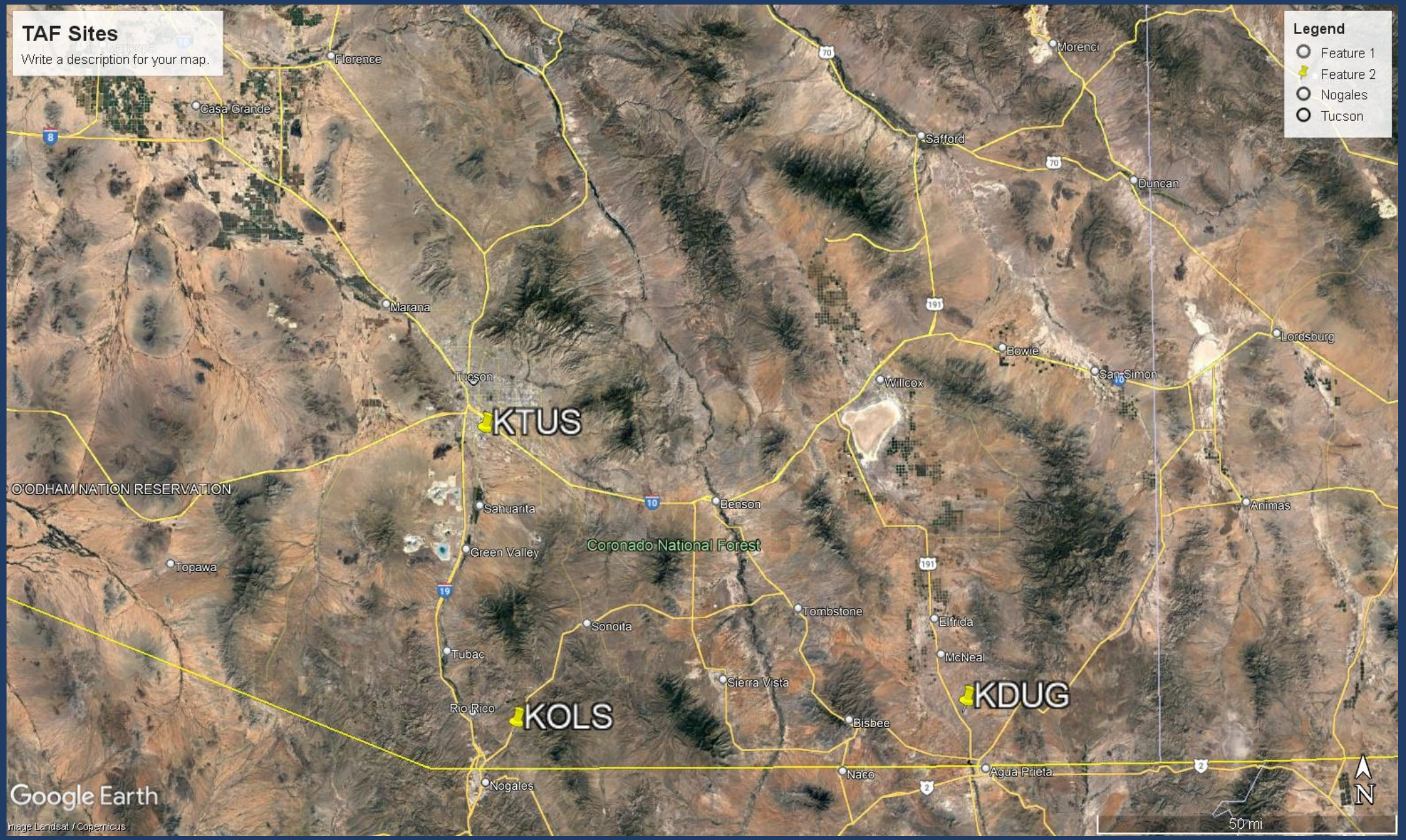
SAWS 10

Goals/Motivation

- Put cloud bases used for Digital Aviation Services (DAS) from model output in a climatological perspective when needed.
- Help train new forecasters on typical cloud base patterns at each TAF site.
- Learn the most likely time period during the day climatologically that MVFR and IFR ceilings occur at each site as well as when the lowest cloud bases occur.
- In a case study compare NBM cloud base output to observations from ASOS stations during a time period when there are low clouds at the TAF sites to see how the NBM performed.

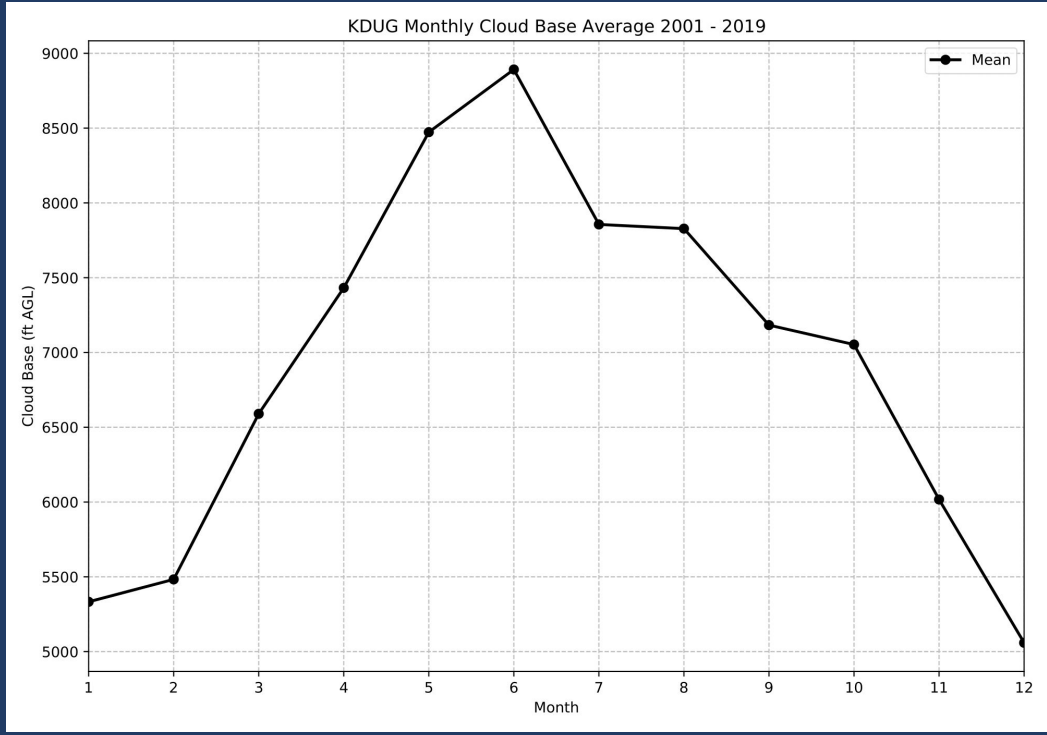
TAF Sites

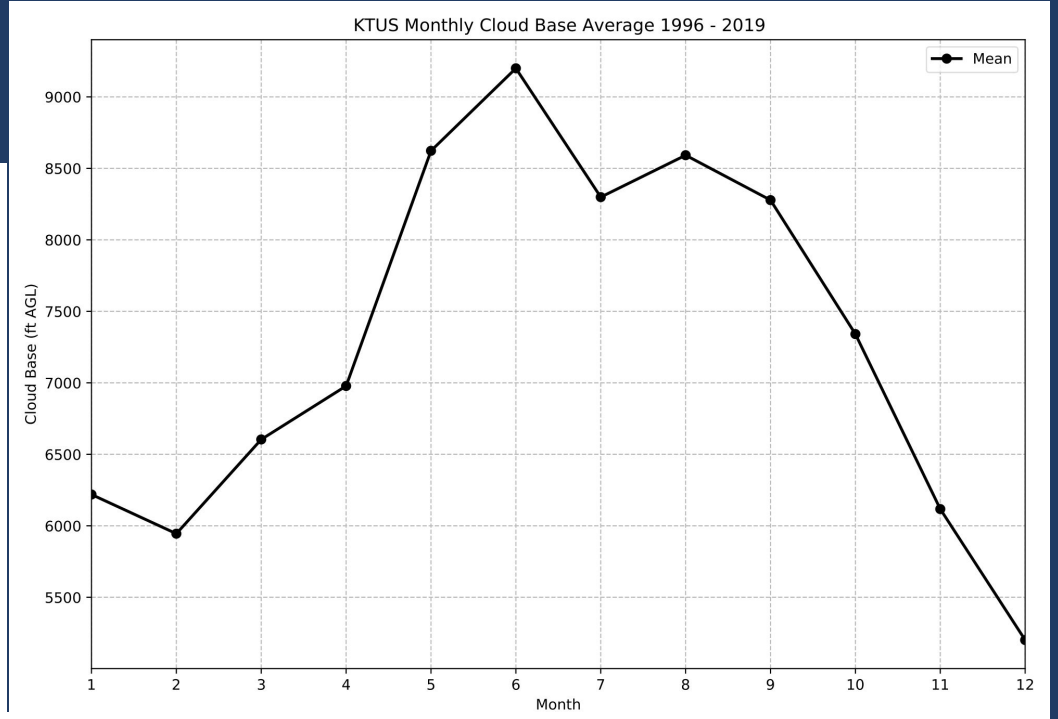

TAF Sites
Write a description for your map.
Legend
Feature 1
Feature 2
Nogales
Tucson
KTUS
KOLS
KDUG
Florence
Casa Grande
Marana
Tucson
Safford
Morenci
Duncan
Bowie
Willcox
San Simon
Lordsburg
Animas
Benson
Sahuarita
Green Valley
Coronado National Forest
Topawa
Tombstone
Elfrida
McNeal
Sonoita
Tubac
Sierra Vista
Rio Rico
Bisbee
Naco
Agua Prieta
Nogales
O'ODHAM NATION RESERVATION
Google Earth
Image Landsat / Copernicus
50 mi
N

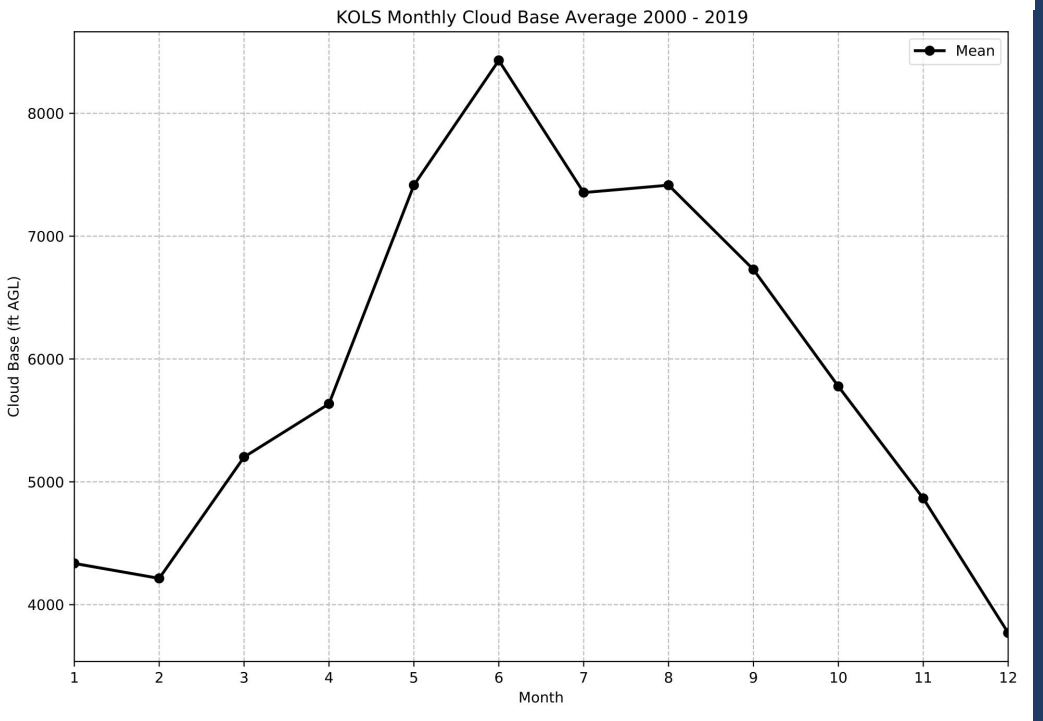
Data

- Routine observations along with specials were used, so data is hourly with the exception of specials.
- KTUS time period 1996-2019.
- KOLS time period 2000-2019.
- KDUG time period 2001-2019.
- Statistics for cloud base height, cloud coverage, and flight category were calculated by year, month, season, and hour.
- Cloud bases are all in feet above ground level (AGL).
- IFR ceilings are defined as BKN or OVC coverage with cloud bases below 1000 ft. MVFR ceilings are defined as BKN or OVC coverage with cloud heights above 1000 ft and less than or equal to 3000 ft.

Monthly Cloud Base Average

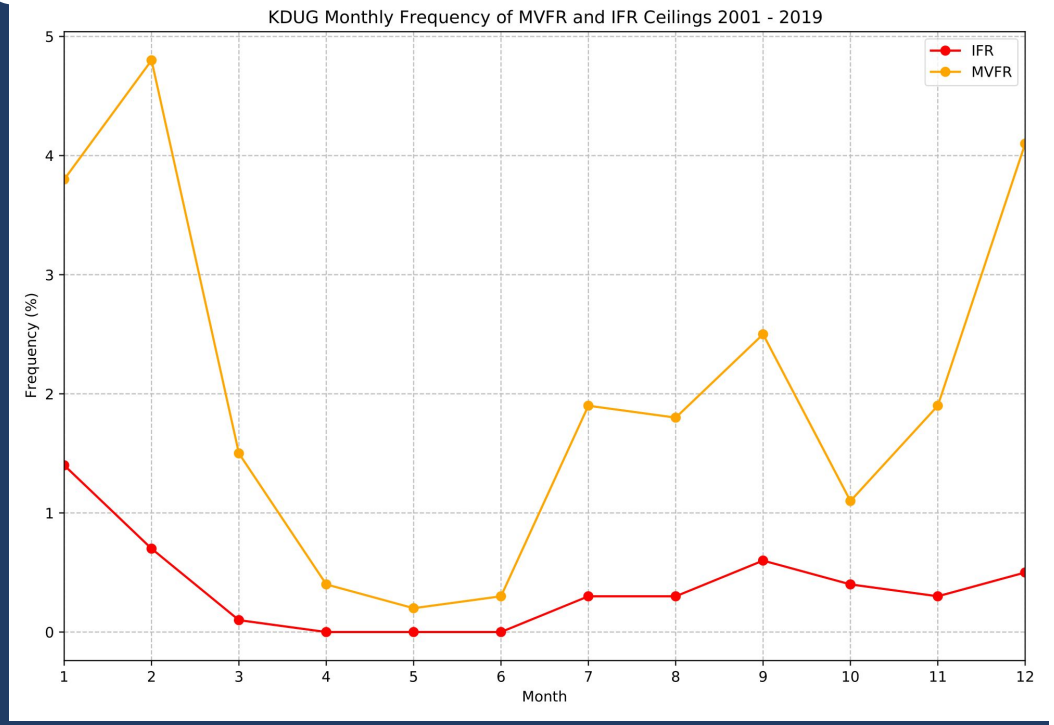


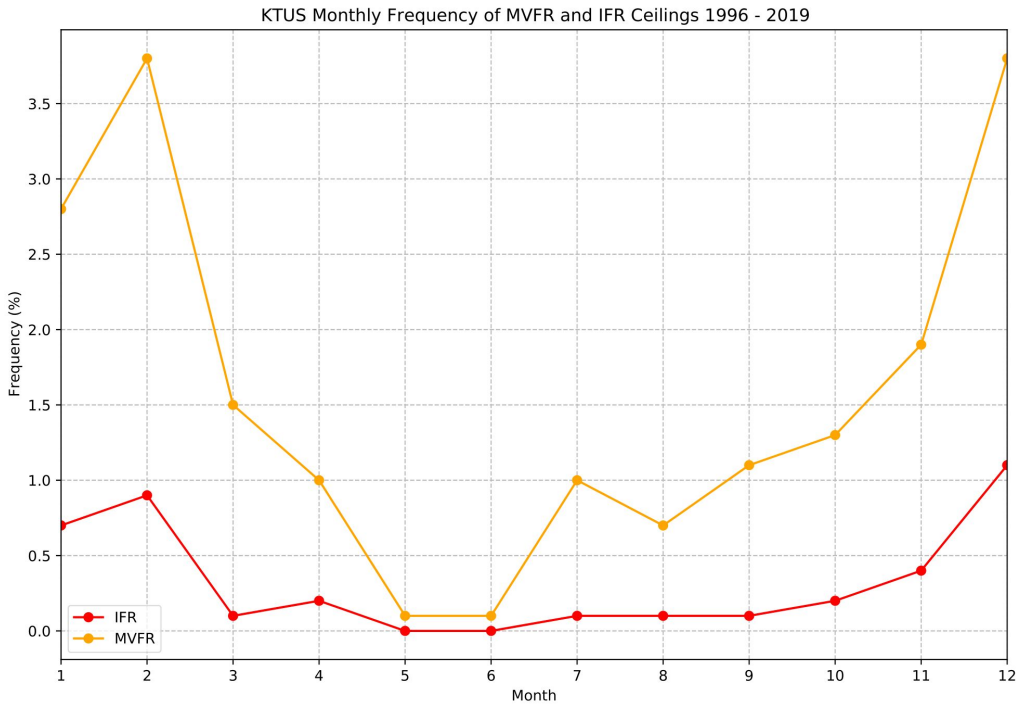


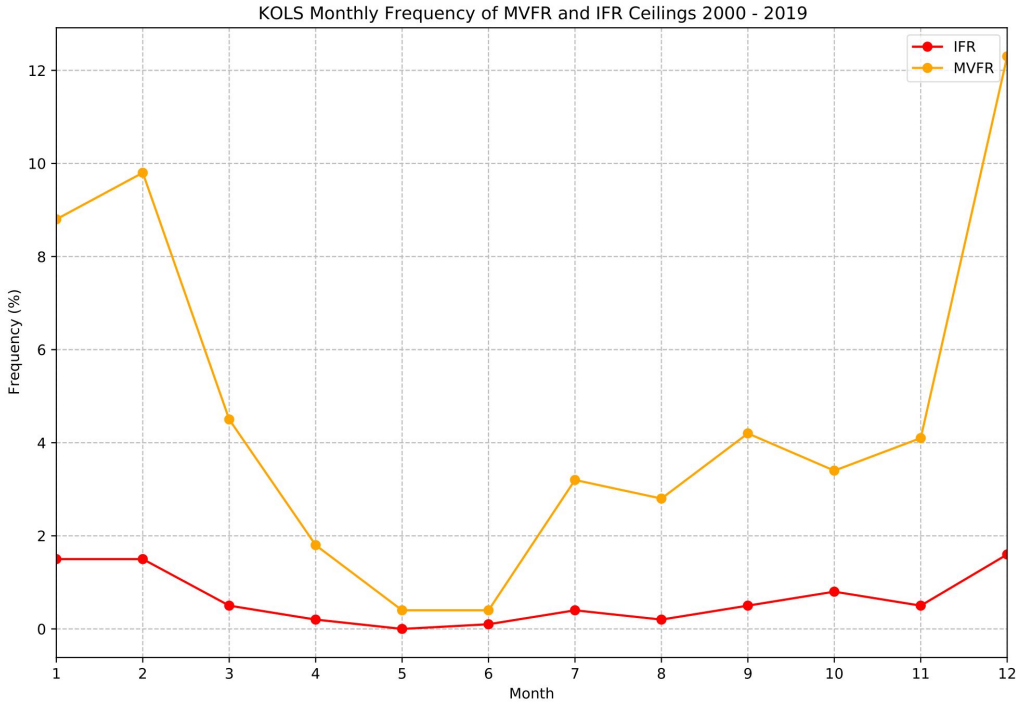


- Lowest cloud base in Dec, highest in June
- Nogales has lowest average cloud bases
- Sharp decline in cloud bases as monsoonal moisture moves in.

Monthly Frequency of MVFR IFR Ceilings

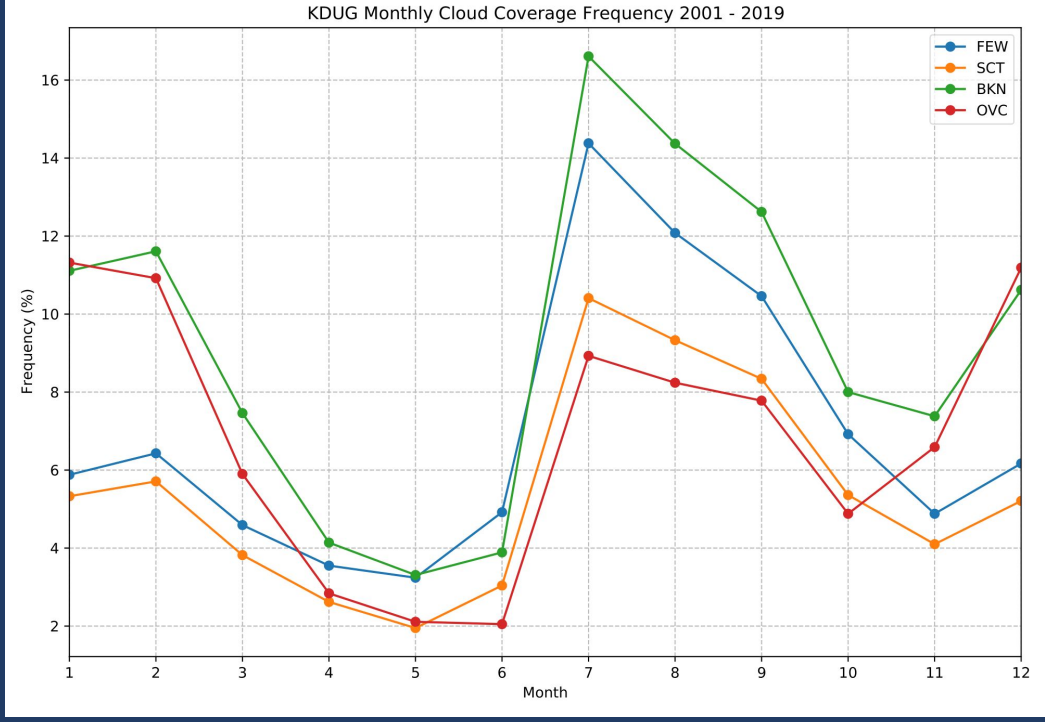


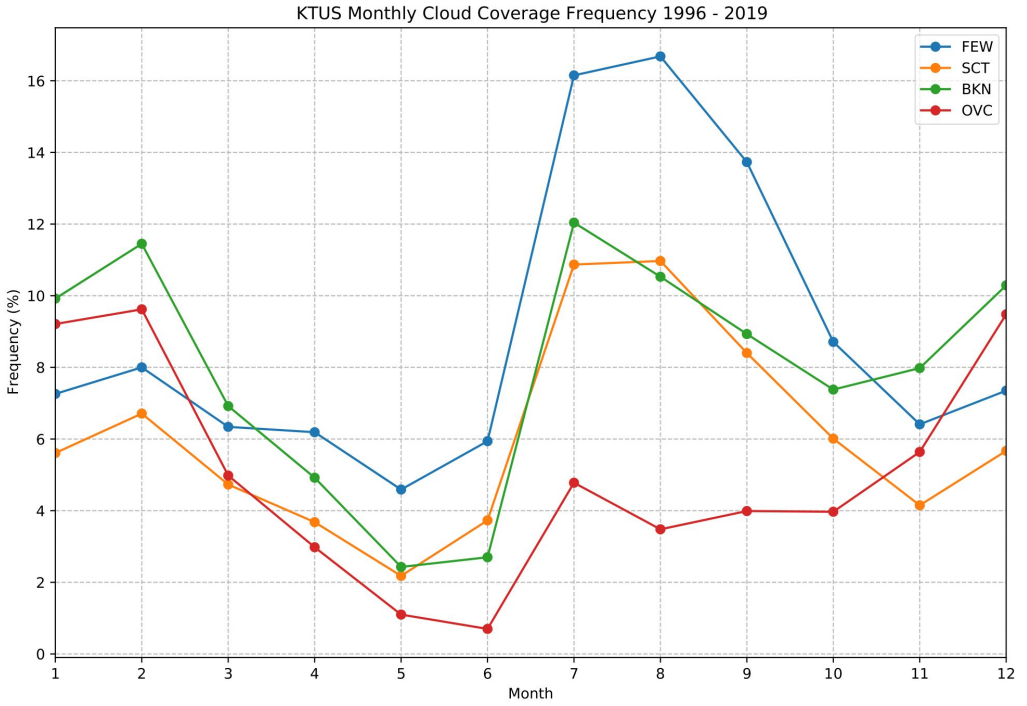


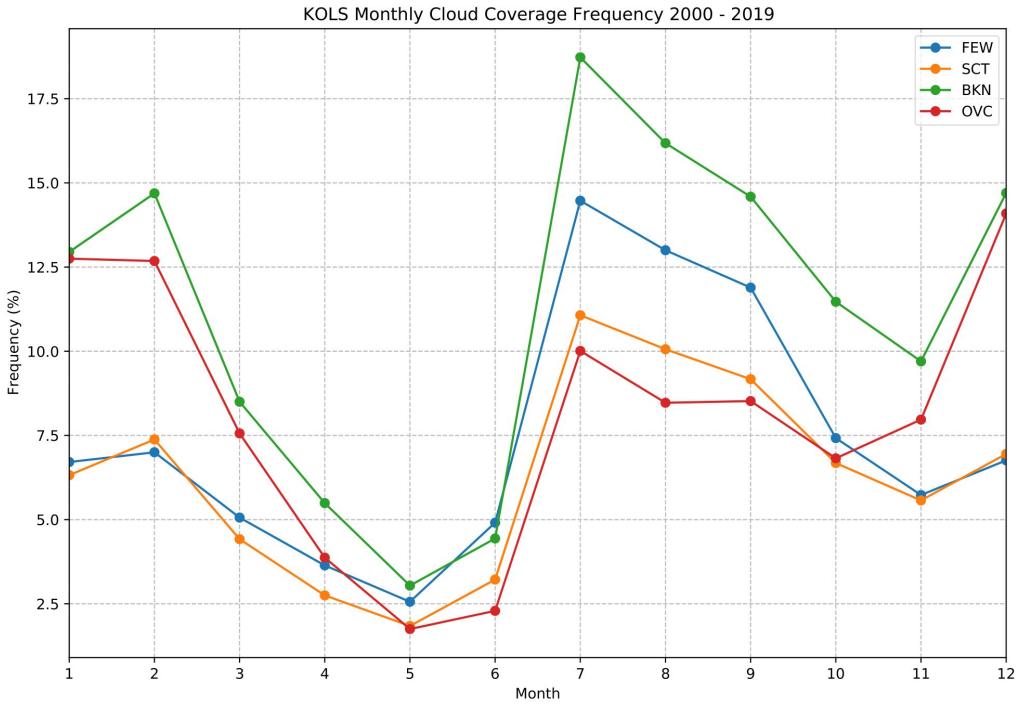


- IFR/MVFR cigs most common during winter months with secondary max during monsoon.
- Outside of winter September is month with highest frequency of low clouds and non-VFR.
- Overall non-VFR conditions are rare.

Monthly Cloud Coverage Frequency

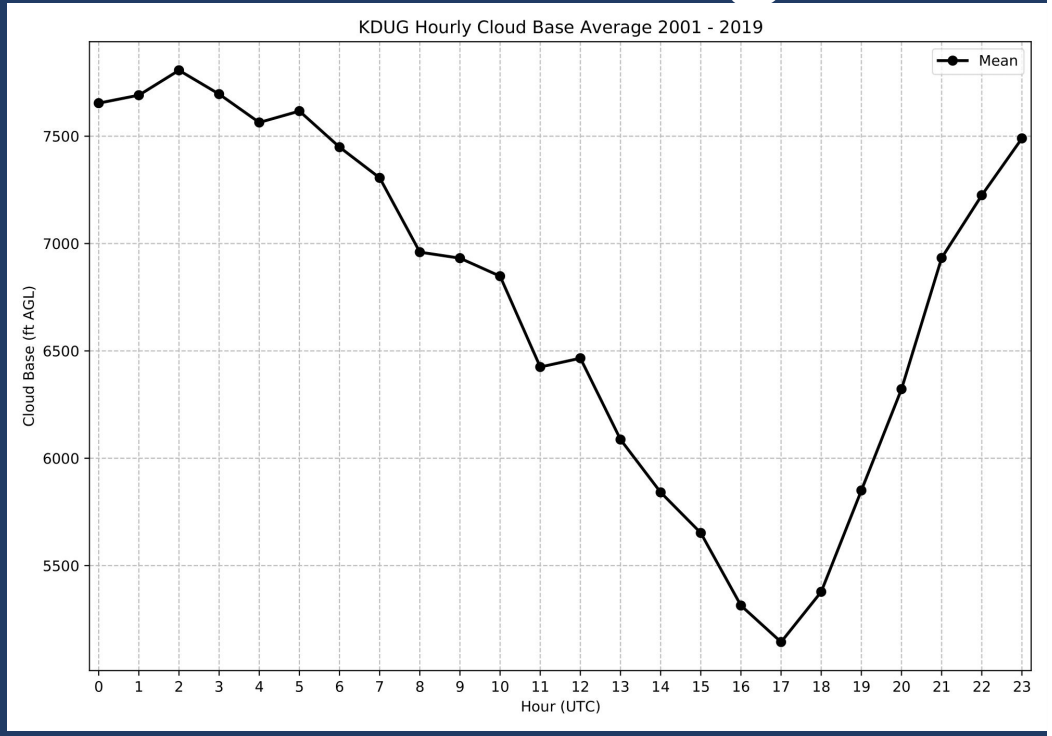


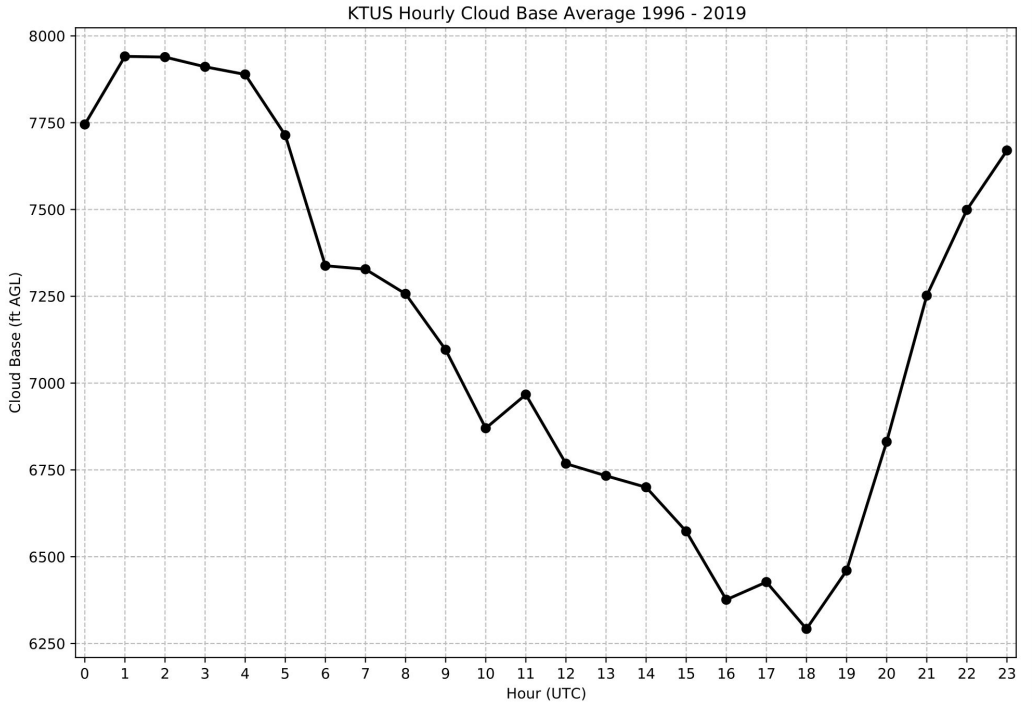


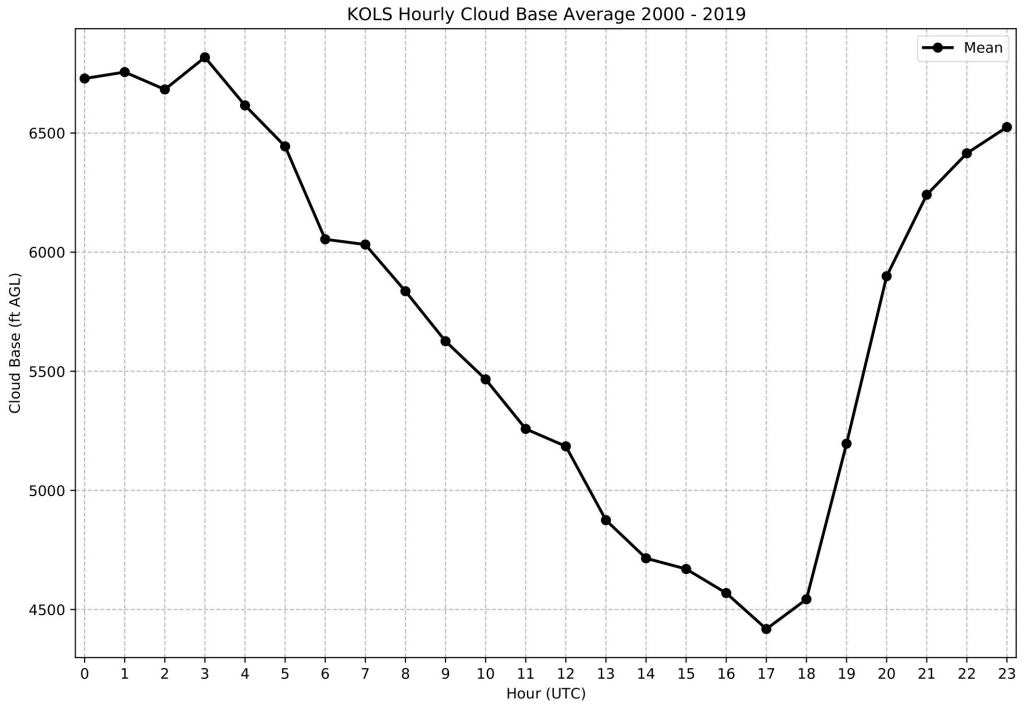


- Seasonality of cloud coverage. Max during the monsoon with secondary max in Winter.
- Generally BKN is most common coverage with exception of Tucson.

Hourly Cloud Base Average

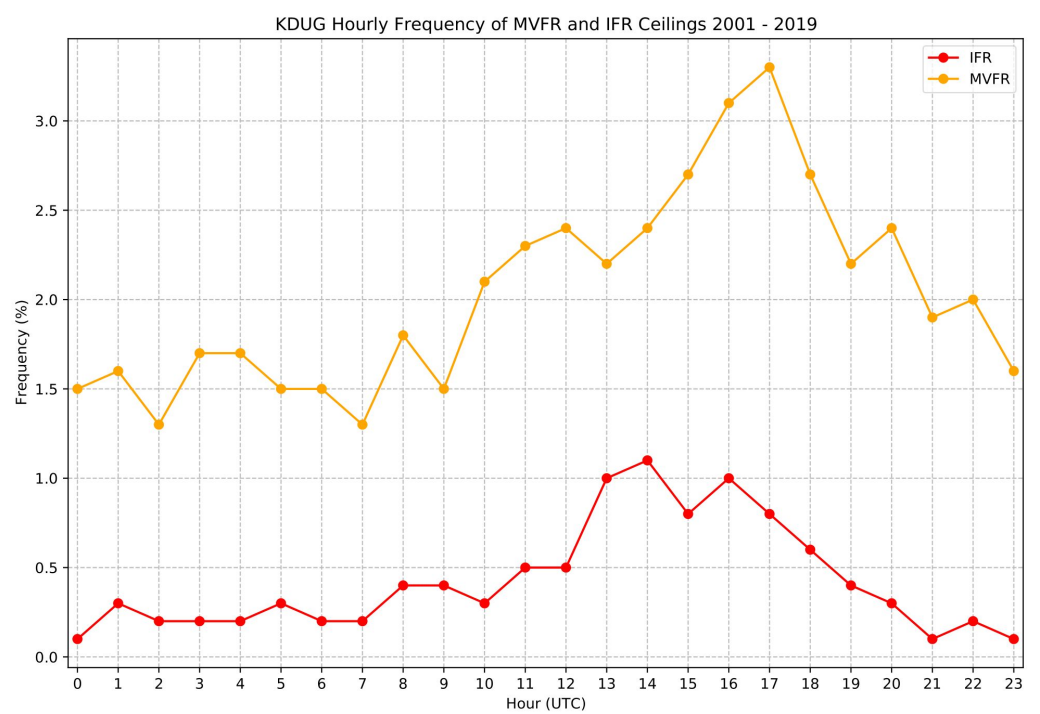


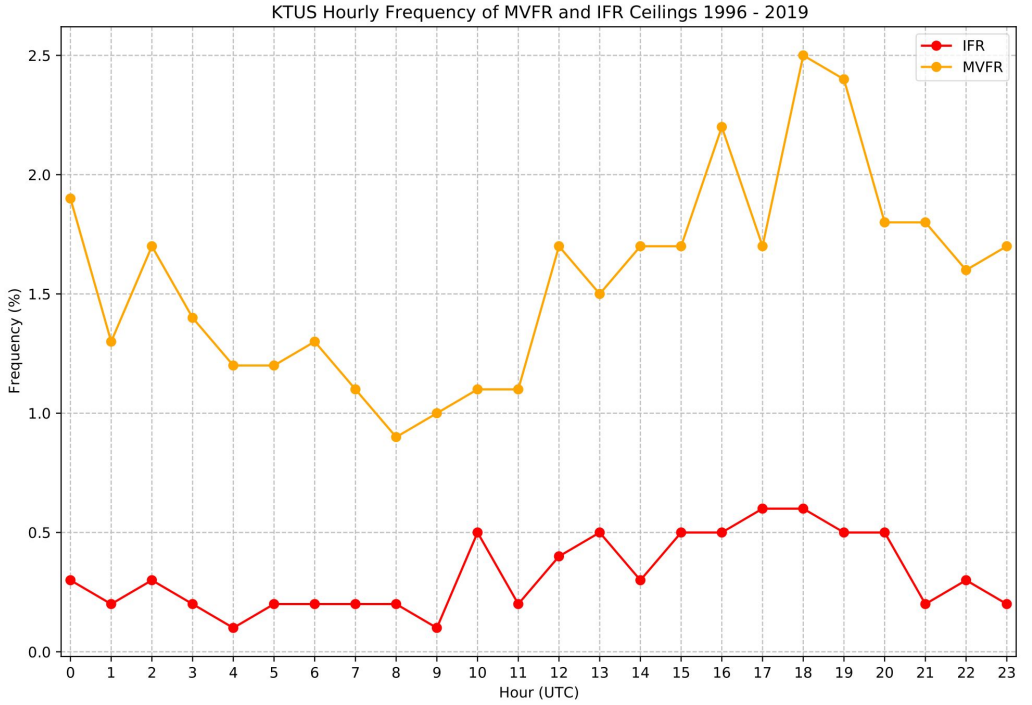


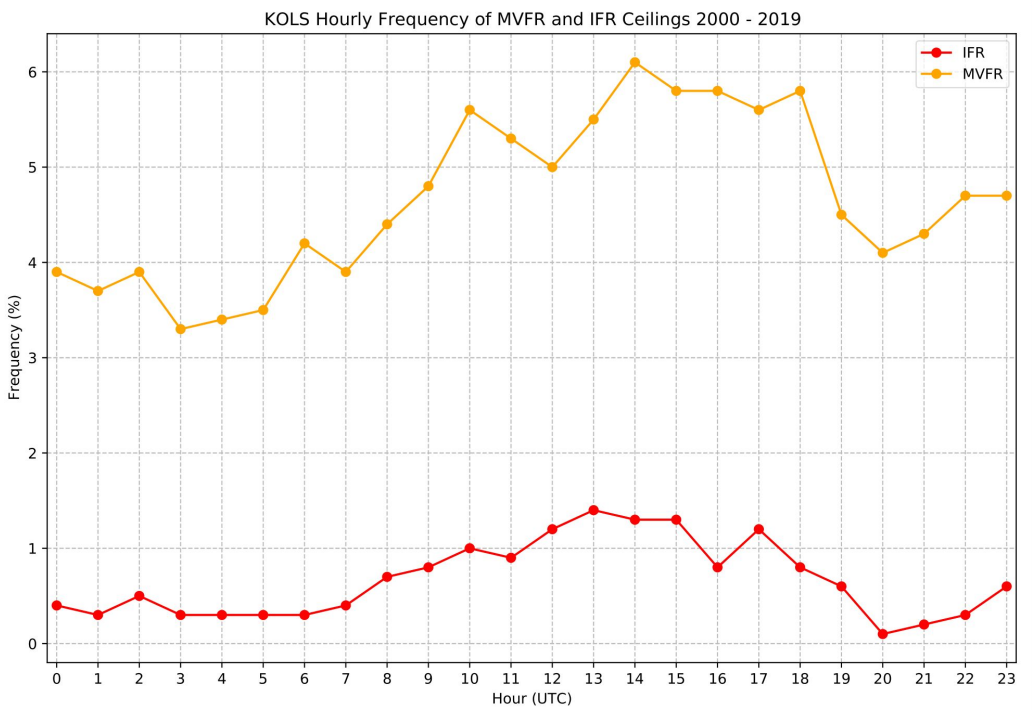


- Diurnal variability of about 2500 feet.
- Generally lowest cloud bases occur 14Z – 19Z (morning to noon).
- Max in the 23Z – 4Z timeframe (4pm-9pm)
- Slight differences in timeframe of lowest clouds between winter and monsoon.

Hourly Frequency of MVFR/IFR Ceilings

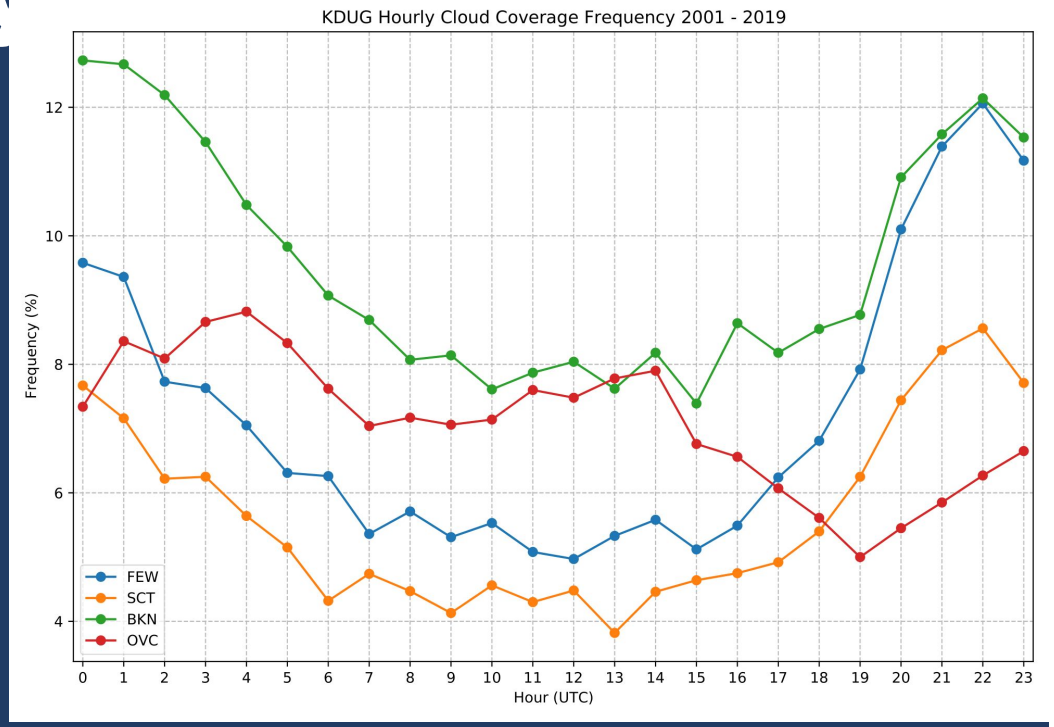


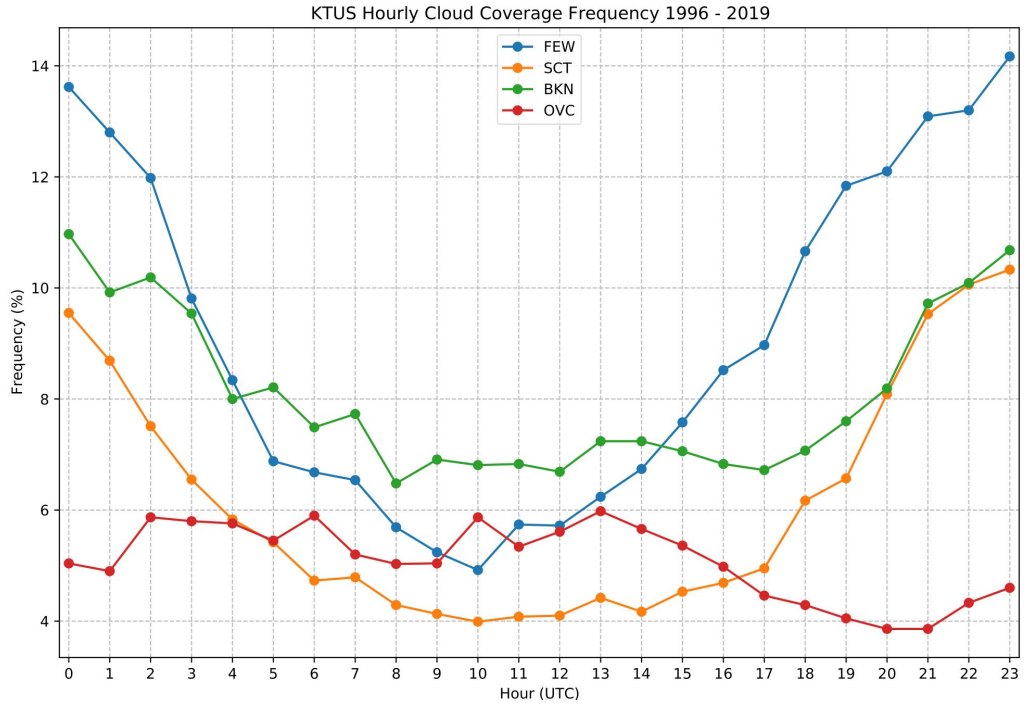


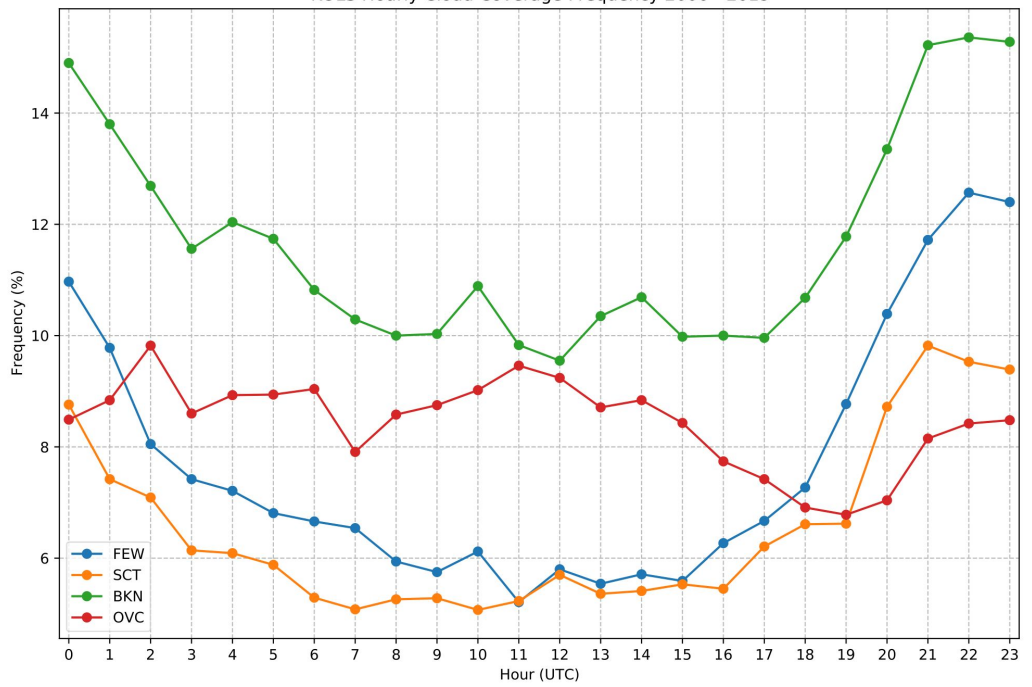


- Smaller diurnal trend than cloud bases.
- Most likely to have low clouds/non VFR cigs 14Z-19Z (7am – 12pm).
- Overall frequencies are very low at each site, the highest 6.1% 13Z KOLS.

Hourly Cloud Coverage Frequency

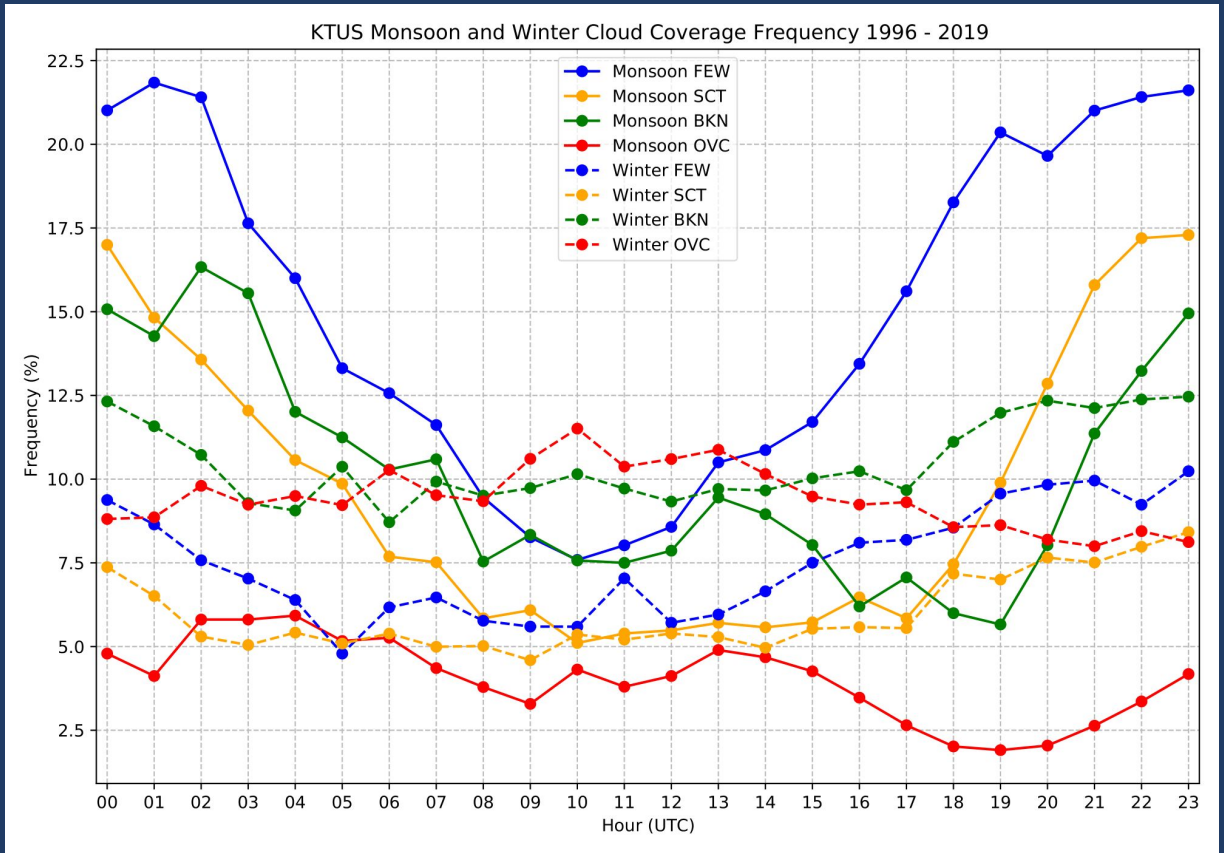


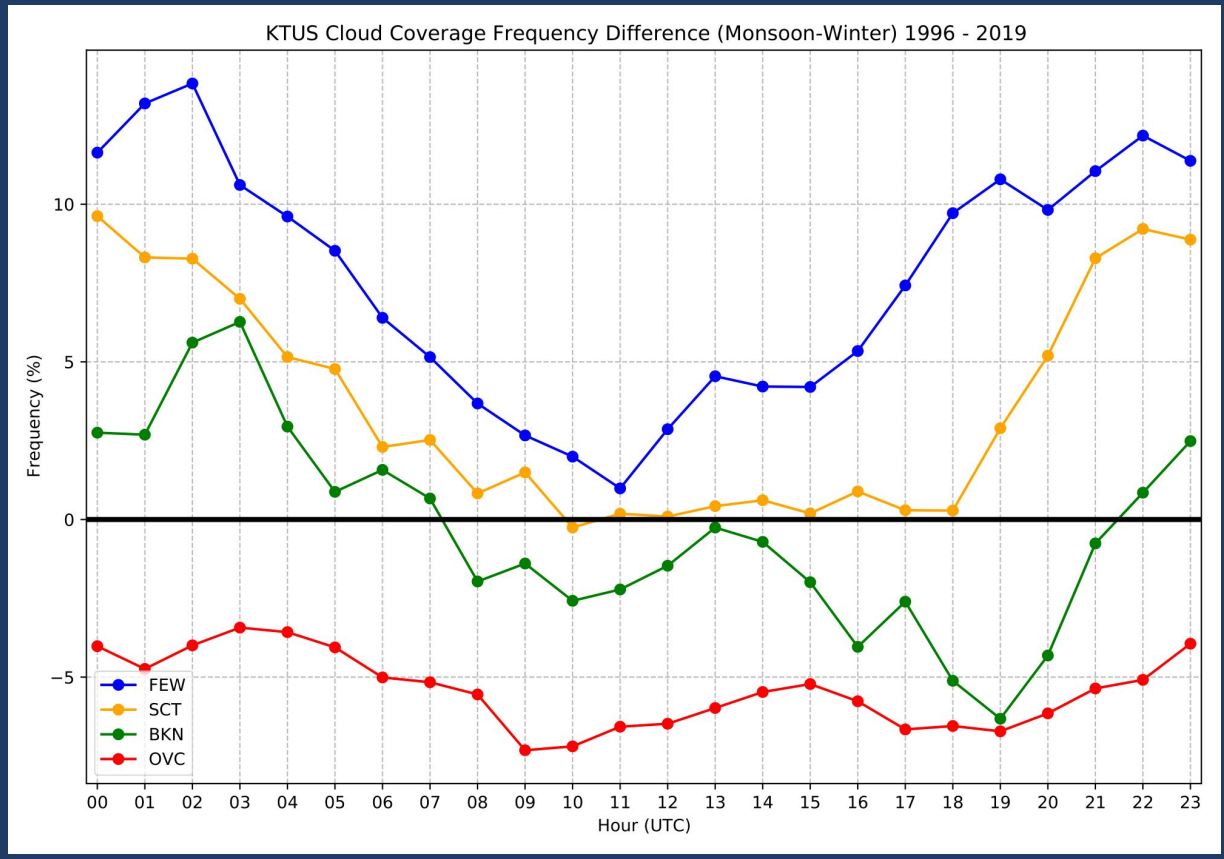




- Max during afternoon/evening and minimum after midnight into early morning.
- BKN highest occurrence at KDUG and KOLS. FEW and BKN have highest occurrence at KTUS.
- OVC does not have as much of a diurnal trend.

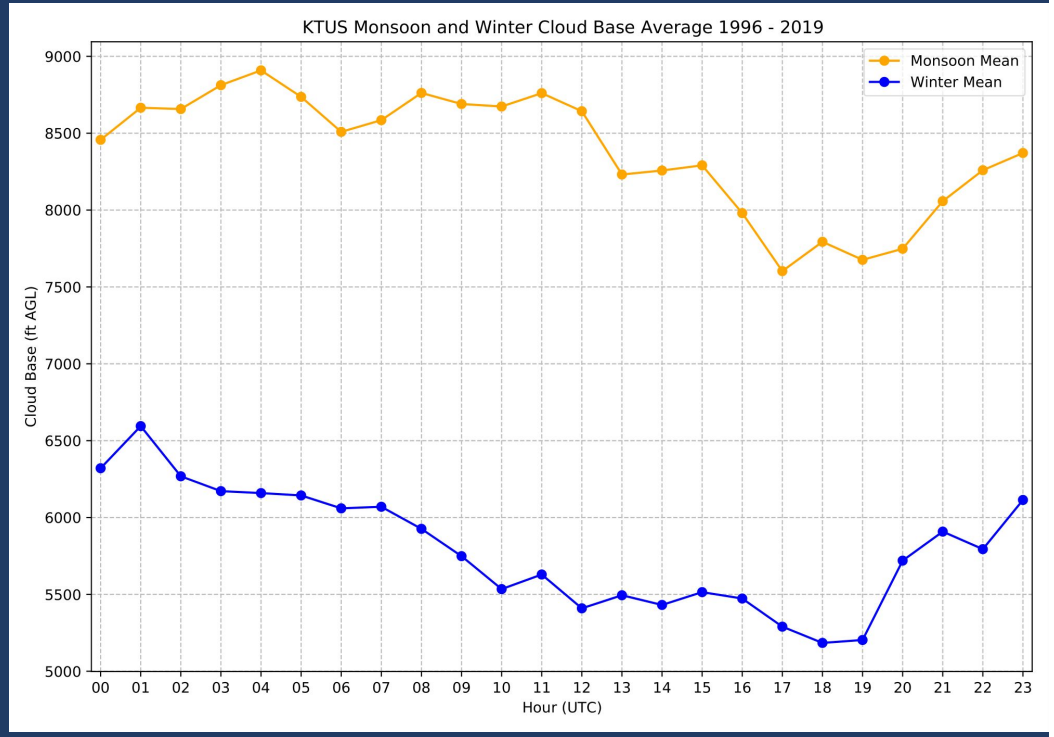
Monsoon and Winter Comparison KTUS

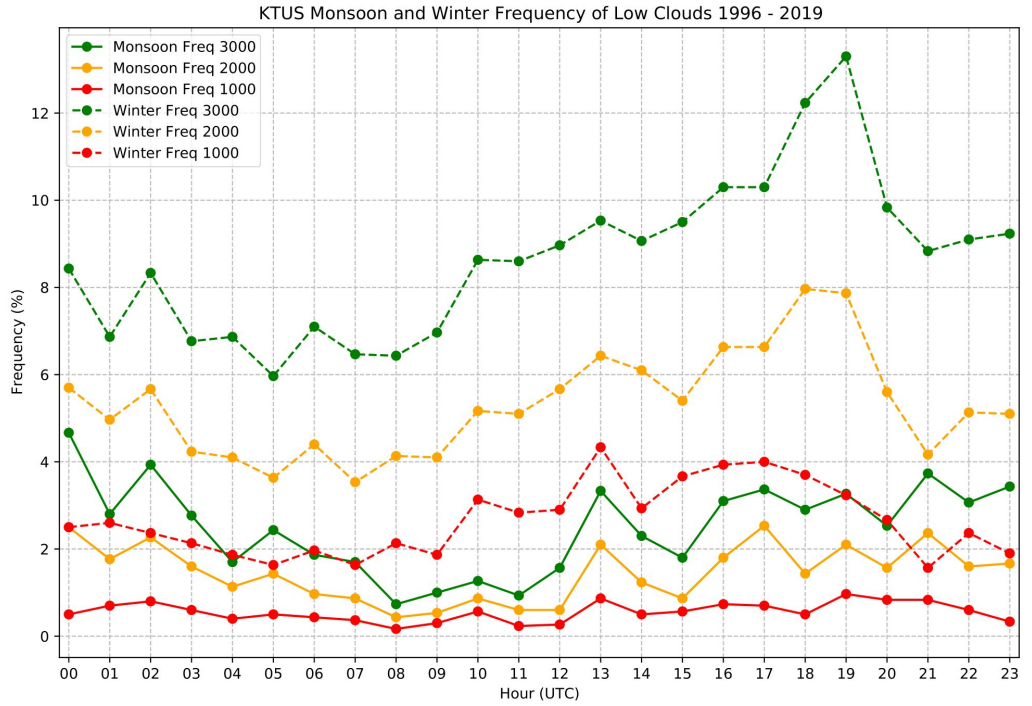


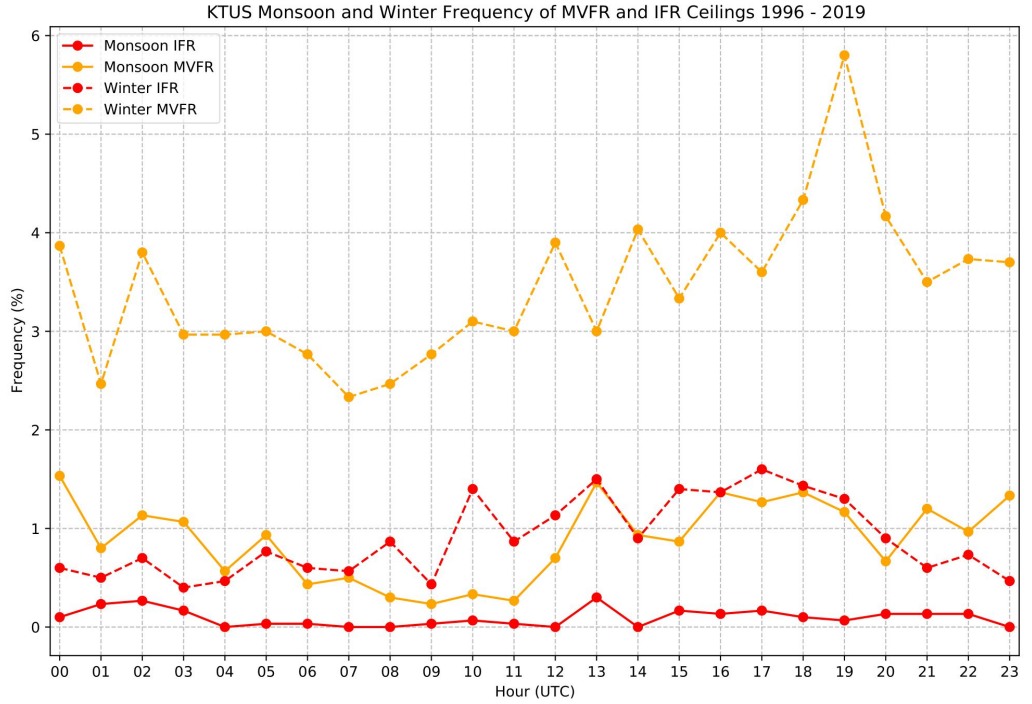


- Frequency of OVC coverage higher in winter for every hour, FEW higher for all hours during the monsoon.
- Monsoon has higher overall cloud coverage in afternoon/evening than winter.
- During nighttime and early morning hours (6Z-14Z) in winter BKN/OVC ~5% higher than FEW/SCT. May be more stratiform clouds during that time frame (An et al 2017).

Monsoon and Winter Comparison KTUS







- Cloud bases generally 2000-2500 ft lower during winter than monsoon.
- Max of non-VFR and low clouds in late afternoon during monsoon.
- During winter most likely to have low clouds in the morning through noon.

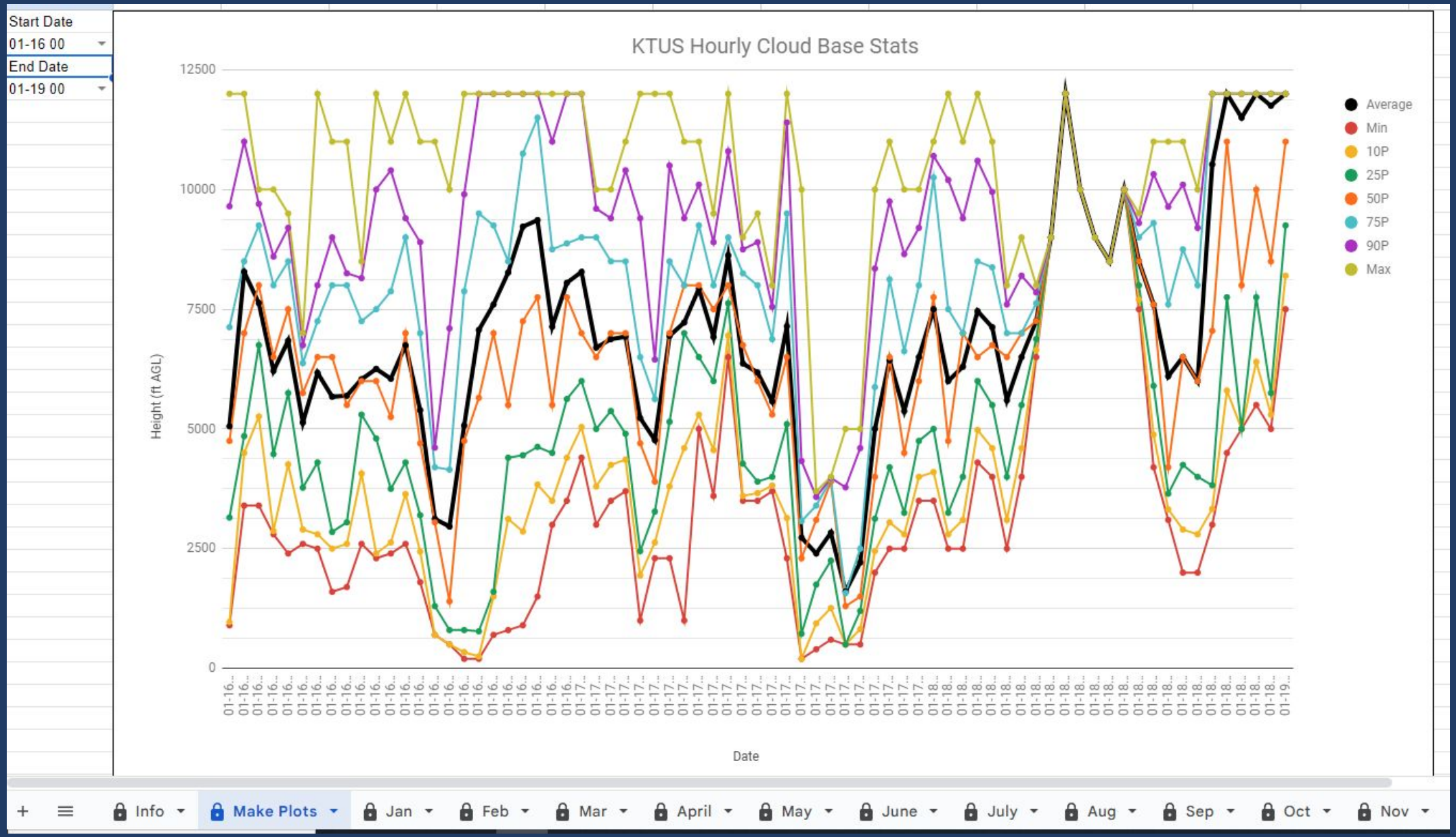
General Findings

- IFR ceilings have never occurred in May or June for KTUS, in May for KOLS, and April-June for KDUG.
- Generally cloud bases are lowest in the early morning to mid-morning regardless of the time of year.
- KOLS has a higher frequency of MVFR ceilings than KDUG and KTUS, especially in the winter months.
- During the monsoon cloud coverage is at a maximum during the afternoon and early evening, and during winter at a maximum in the early morning.

Google Spreadsheet

- Each spreadsheet has daily and hourly averaged data. The spreadsheets can be used to put cloud bases used for Digital Aviation Services (DAS) from model output in a climatological perspective when needed.
- Can be found on our office's Google Sites Aviation Page.

Sample Plot Created



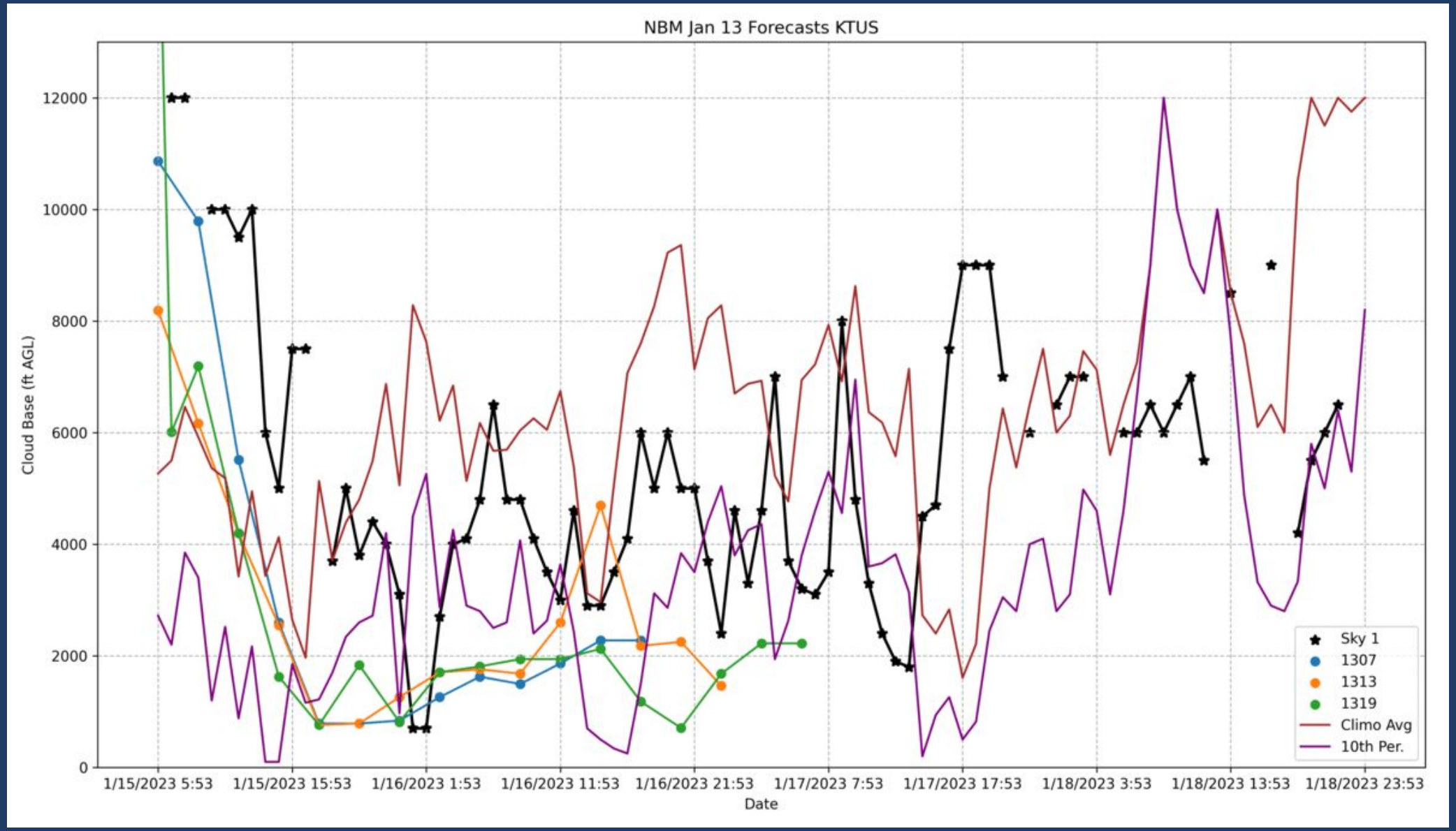
Daily Data

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Date	Average CB (ft)	Min (ft)	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Max	% Less 3000	% Less 2000	% Less 1000	% FEW	% SCT	% BKN	% OVC	Avg FEW CB (ft)	Avg SCT CB (ft)	Avg BKN CB (ft)	Avg OVC CB (ft)	% IFR	%MVFR	%VFR
01-01	4446	200	700	1800	4700	6000	8200	12000	15.8	13.6	7.8	9.22	6.48	12.1	13.54	4795	3873	4611	4335	4.2	5.8	90
01-02	4413	400	1500	2300	4000	6000	7500	12000	9	5.8	1.8	4	4.15	6	8.15	4762	4248	4536	4236	0.5	5.5	94
01-03	6520	400	3740	4800	6000	8000	10000	12000	0.9	0.2	0.2	5.57	4.1	5.41	3.44	6397	7284	6030	6581	0	0.3	99.7
01-04	6829	1900	4000	4900	6500	8000	11000	12000	1.5	0.5	0	6.99	5.02	11.7	10.64	7298	6579	6421	7087	0	0.7	99.3
01-05	5424	300	2300	3600	5500	7000	9000	12000	6.5	2.4	0.9	7.68	4.43	8.27	9.9	4723	5540	5088	6197	0	2	98
01-06	5413	200	1310	3000	5500	7625	9500	12000	12.5	8.1	3.9	8.03	8.03	10.85	14.23	5200	4763	4878	6308	1.5	6.2	92.3
01-07	4772	0	420	1900	3800	8000	10000	12000	11.7	7.6	5.2	6.85	3.35	6.24	8.37	4229	4627	4295	5976	1.4	4.2	94.4
01-08	6250	500	1680	3600	6500	9000	11000	12000	6.8	3.9	1.5	5.47	4.71	8.36	10.18	5361	6242	5818	7087	0	3.7	96.3
01-09	6291	200	2300	3750	6500	8000	11000	12000	4.4	2.7	1	6.12	3.88	8.36	7.16	4451	6608	6396	7567	0.2	1	98.8
01-10	7640	900	4000	5500	7500	10000	12000	12000	1.4	1	0.3	8.88	5.14	8.26	5.76	7065	8055	7662	8124	0	0.5	99.5
01-11	7555	500	3500	5000	8000	10000	11000	12000	2.8	1.2	0.5	7.38	5.18	9.26	8.16	7170	7273	7678	7944	0	0.7	99.3
01-12	6078	300	1240	2900	6000	8500	11000	20000	7.5	5.5	2.4	6.78	4.16	7.55	6.93	5507	5137	6067	7211	0.5	3.2	96.3
01-13	5916	300	3000	4000	5500	6500	10000	20000	4.7	1.2	0.7	7.59	6.86	11.39	8.91	4771	5794	5836	7089	0	1.4	98.6
01-14	5736	100	500	3900	5500	8000	9500	12000	5.9	4.3	4.2	5.81	4.74	9.33	8.87	5887	5845	6461	5581	2.2	0.5	97.3
01-15	5141	100	2100	2900	4200	7000	10000	12000	10.3	3.3	1.4	5.58	4.07	8.3	11.76	5462	3959	4649	5809	0.2	5.7	94.1
01-16	6072	200	1350	3025	5500	8000	11000	25000	12	8.2	4.3	6.42	6.56	14.48	11.61	4815	4840	6422	7027	0.7	5	94.3
01-17	5435	200	1300	2975	5000	8000	10000	15000	7	4.4	2.4	6.67	5.58	7.6	4.34	4623	5900	4990	6864	0.2	2.2	97.6
01-18	8354	2000	3420	4500	7000	10000	12000	25000	1	0.3	0	4.24	2.55	2.55	2.38	7172	9107	9167	8786	0	0	100
01-19	8574	100	3650	6000	7500	10750	12000	25000	1.2	0.5	0.3	1.99	2.16	4.98	5.14	8733	11985	7890	7745	0	0.5	99.5
01-20	6880	700	2580	4600	7000	9000	11000	18000	4.6	1.9	0.5	6.8	4.68	9.67	10.42	6147	6800	7273	7029	0	1.7	98.3
01-21	7019	800	3720	4800	6500	8500	10000	25000	4.3	2.4	0.5	9.85	9.14	14.91	12.94	5937	8971	6606	6939	0	2.4	97.6
01-22	5768	100	400	1500	5000	8000	11000	25000	21.4	17.6	13.5	9.27	8.9	15.16	13.16	4955	5949	6155	6312	5.2	5.2	89.6
01-23	8029	900	3400	5000	7000	9500	12000	25000	3.6	1.2	0.3	7.2	7.34	15.27	9.99	6329	7532	8902	8285	0	0.9	99.1
01-24	6728	100	3060	4775	6000	8000	10000	25000	4.3	2.4	1.9	8.57	7.52	11.88	8.72	5193	7944	6848	7024	0.3	0.9	98.8
01-25	9663	2400	4800	6000	8000	10000	20000	30000	0.4	0	0	5.28	3.8	5.78	7.92	8991	11713	8697	9833	0	0	100
01-26	6967	1600	3210	4150	6000	9000	12000	25000	3.6	1.4	0	9.37	6.95	8.76	8.46	5542	6372	7503	8479	0	0.7	99.3
01-27	6006	300	2500	4100	6000	8000	9200	12000	6.9	2.4	0.5	9.93	6.13	11.97	10.95	5178	5657	5807	7169	0	3.1	96.9
01-28	5865	600	1900	3100	4950	7000	9150	25000	11.9	5.8	2.2	9.2	7.69	11.95	10.71	5576	6332	5202	6515	0.2	6	93.8
01-29	7645	2100	3230	4300	7000	9000	14000	30000	2.4	0	0	8.42	5.36	9.95	7.5	6393	8620	7931	7976	0	1.4	98.6
01-30	4924	200	700	2100	4850	7000	9000	18000	14.1	11.1	7.3	6.86	5.76	13.99	10.97	3964	4957	4534	6004	2.8	6.1	91.1
01-31	5047	200	800	1800	5000	7500	10000	12000	17.2	13.7	6.2	10.51	6.87	11.73	9.84	4700	5259	4836	5523	0.7	7.9	91.4

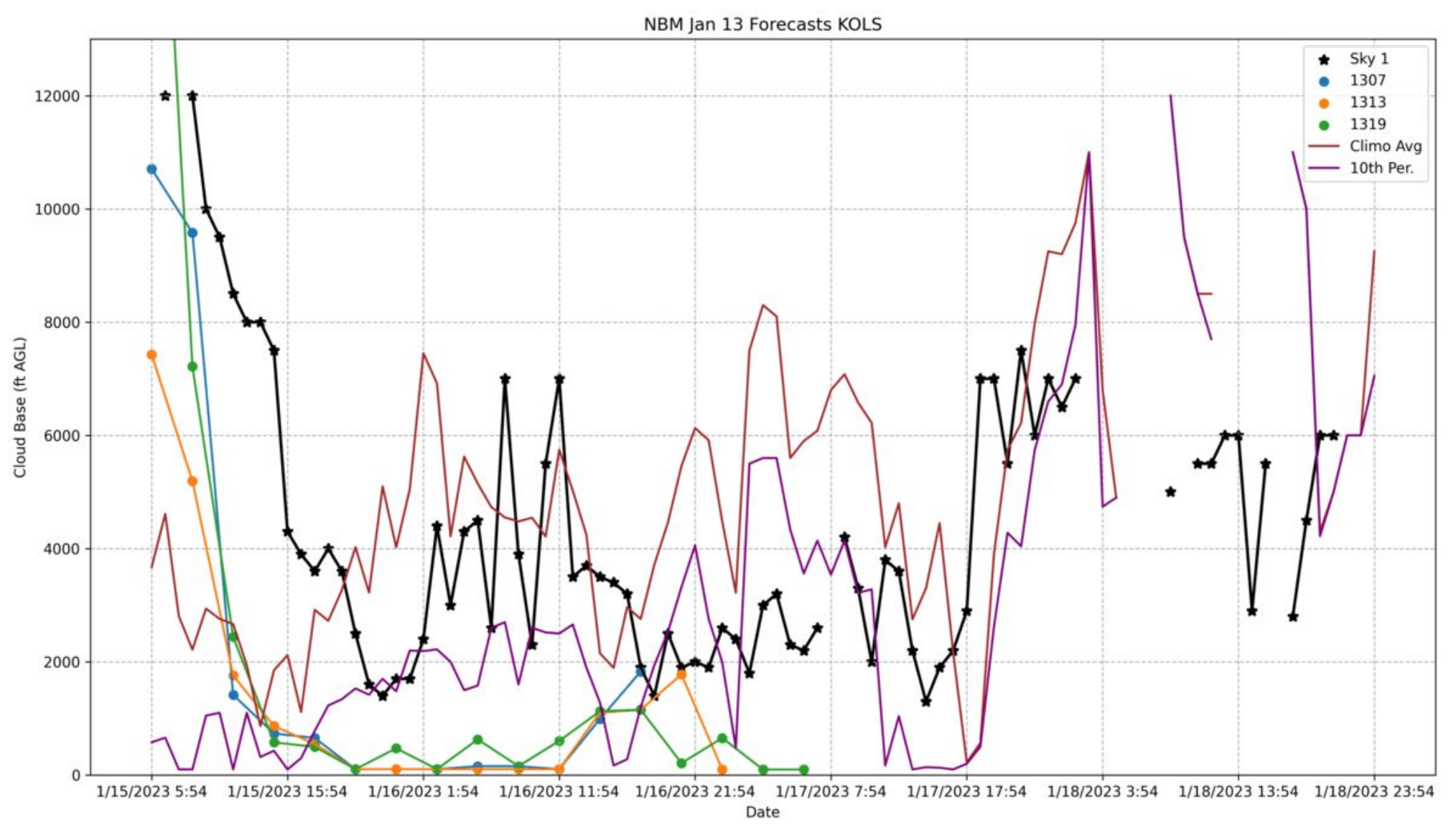
Case Study: January 15-18, 2023

- Used hourly ASOS data from all three TAF sites.
- Downloaded NBM V4.1 cloud base data from the NBM 1D Viewer for each TAF site. Forecast initializations run from 0113 07Z – 0117 19Z.
- Compared the NBM output to the observations from each TAF site and also calculated Mean Absolute Error.
- The time period analyzed was during the passage of a winter storm.
- “Low” cloud bases started around 1/15 16Z.

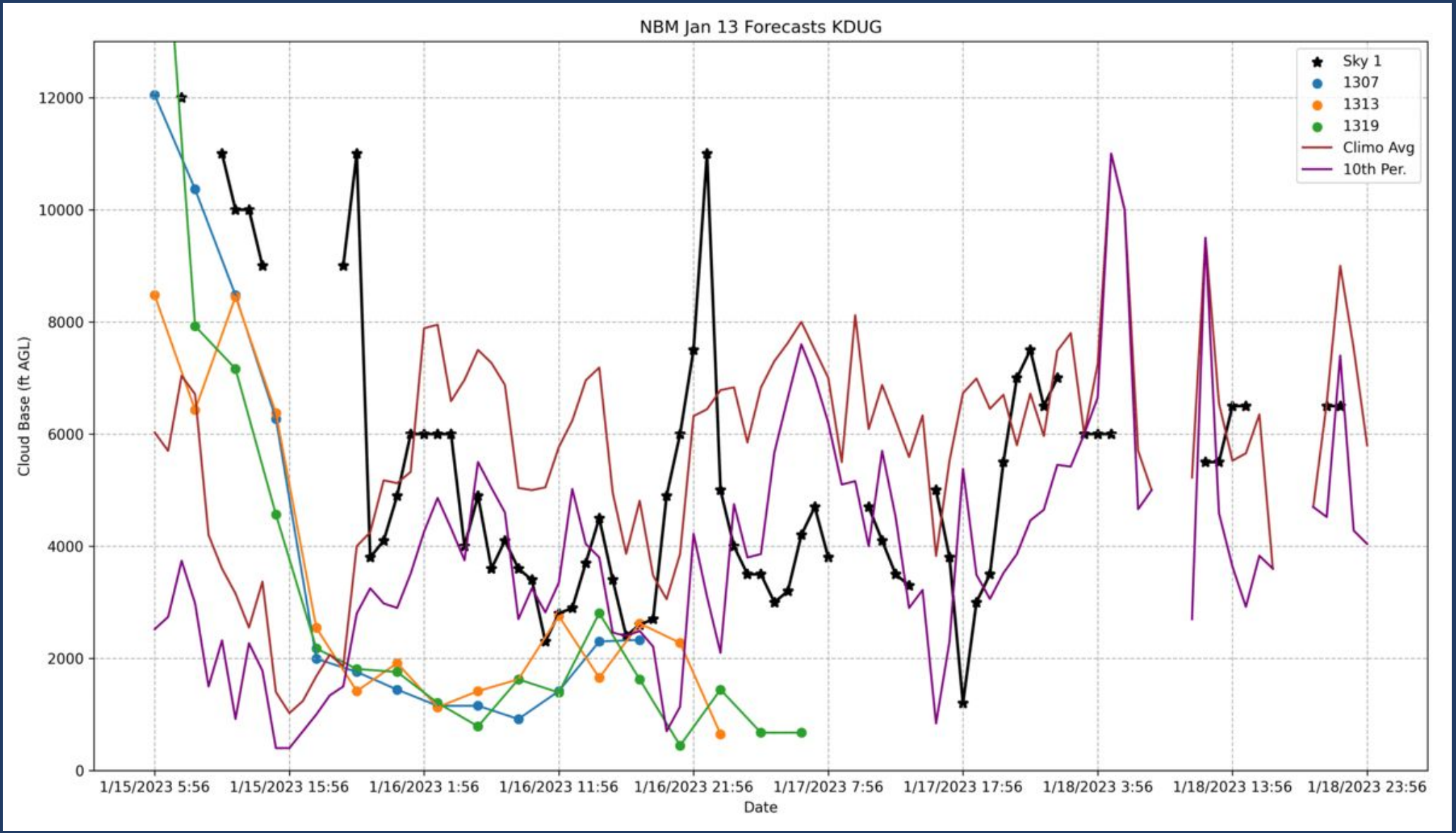
NBM Forecast Comparison KTUS



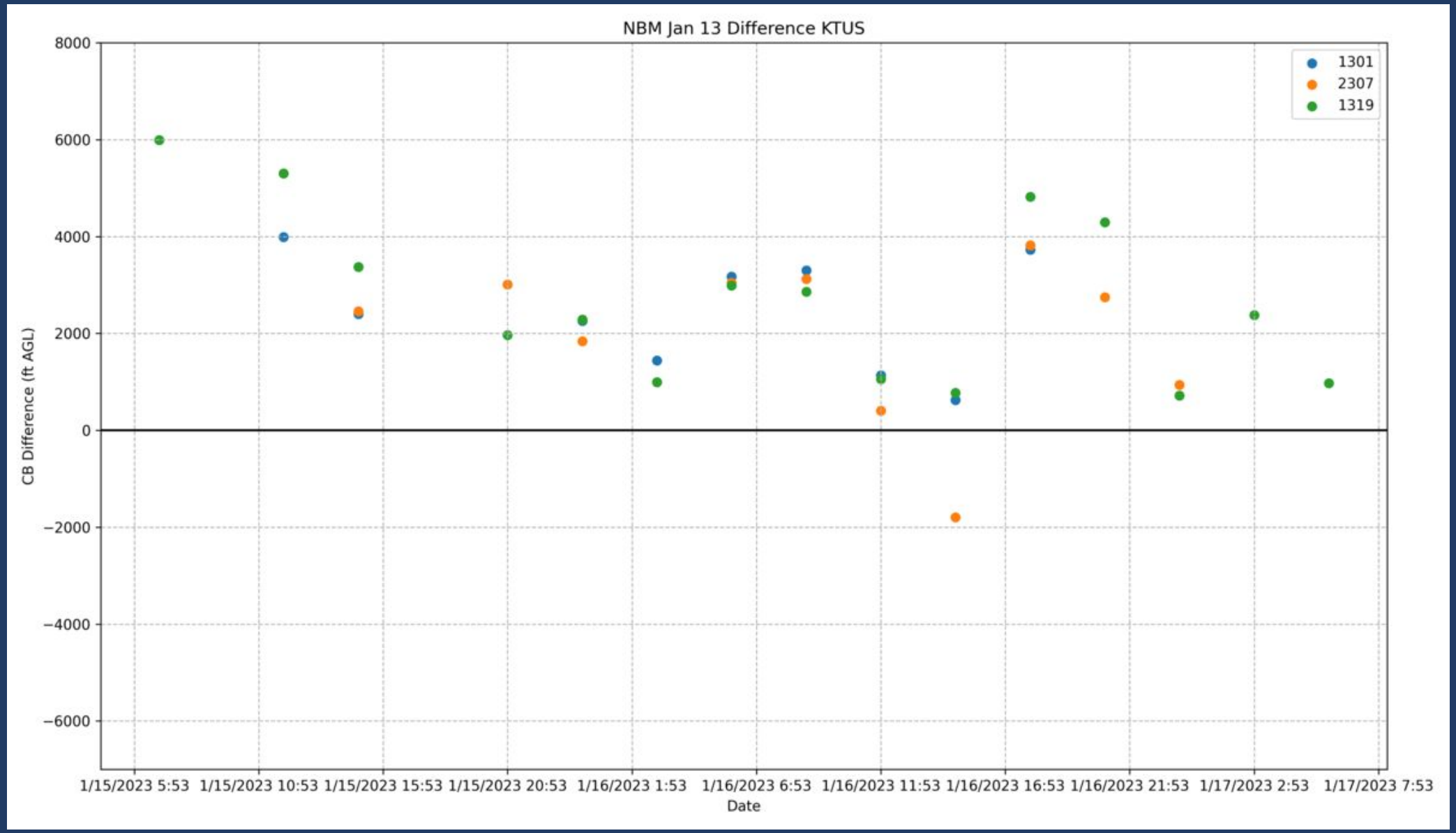
NBM Forecast Comparison KOLS



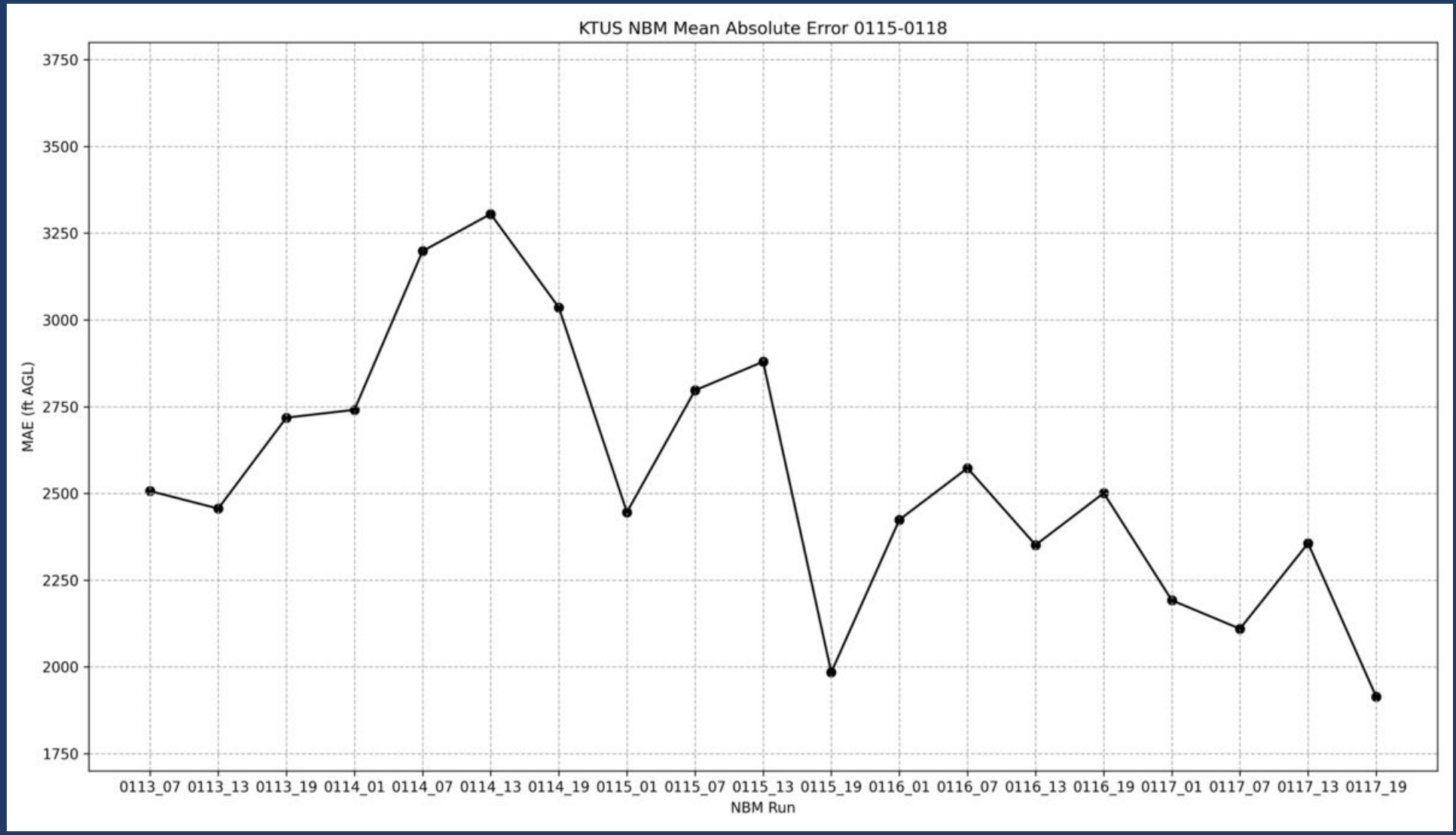
NBM Forecast Comparison KDUG



Forecast Differences KTUS (Obs – NBM)



Mean Absolute Error



KTUS: 2552 ft

KOLS: 2795 ft

KDUG: 2903 ft

Summary of NBM Comparison

- Most of the time the NBM forecast cloud bases are too low.
- But they do follow the trend and do ok with timing when the lower cloud bases will begin and end.
- For this particular case the NBM had the least amount of error at KTUS and most at KDUG.

Future Work

- Add in 2020-2023 data into cloud base climatology.
- Perform more case studies comparing NBM to observations during winter and monsoon.
- Is the NBM more accurate at one particular airport?
- Could aviation partners have a use for the climatology data?