Forecast Verification at The Weather Company

Joseph Koval, Lauriana Gaudet, John Williams, Peter Neilley, and Tom Hamill

The Weather Company

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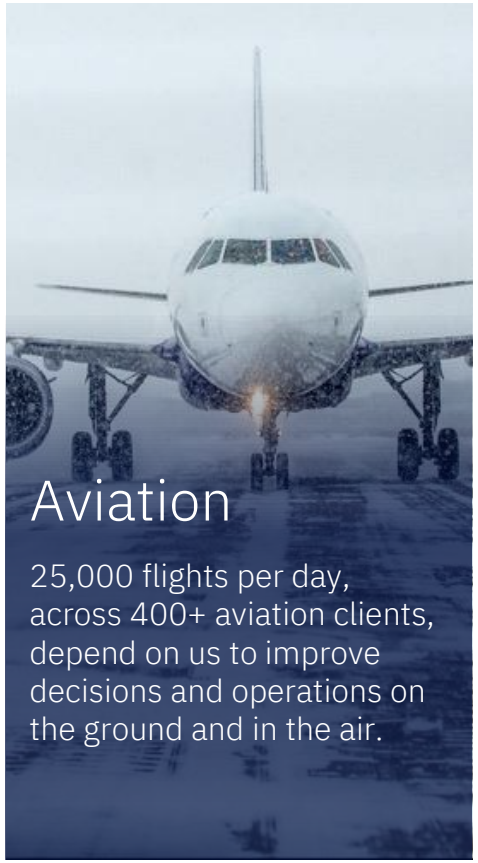
The Weather Company overview

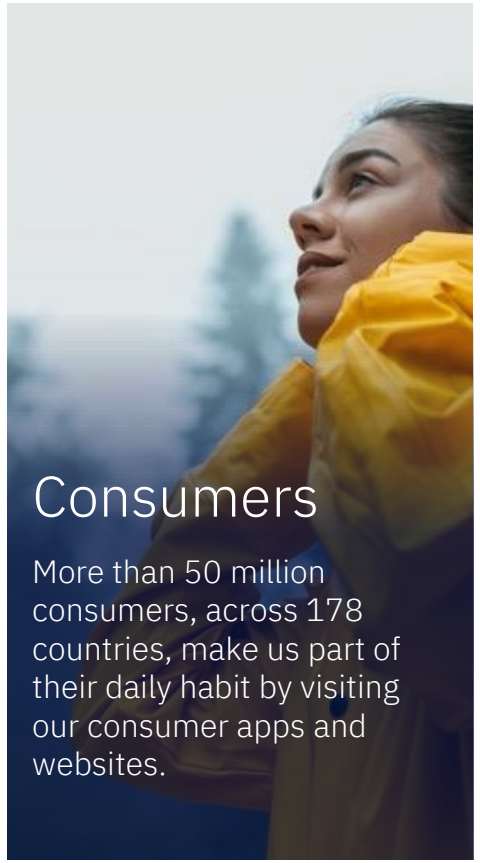
Advertising

275+ premium brands and marketers leverage our predictive and privacy-forward weather solutions to drive engagement and growth.



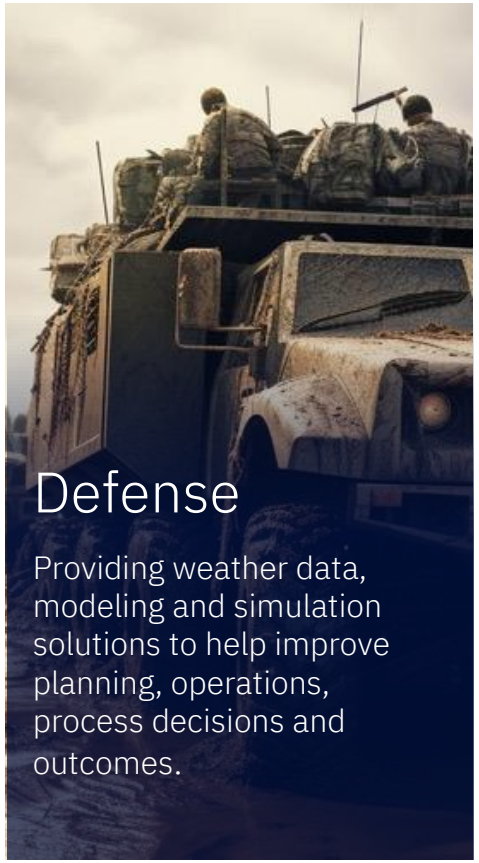
Aviation

25,000 flights per day, across 400+ aviation clients, depend on us to improve decisions and operations on the ground and in the air.



Consumers

More than 50 million consumers, across 178 countries, make us part of their daily habit by visiting our consumer apps and websites.



Defense

Providing weather data, modeling and simulation solutions to help improve planning, operations, process decisions and outcomes.

Media

750+ global broadcasters use our data and visualizations to engage their audiences.

Why verify forecasts?

- **To *monitor* forecast quality** - how accurate are the forecasts and are they improving over time?
- **To *improve* forecast quality** - the first step toward getting better is discovering what you're doing wrong
- **To *compare* the quality of different forecast systems or providers** - to what extent does one forecast system give better forecasts than another, and in what ways is that system better?
- **To *enable* decision making** - use verification of past weather events to understand how to make decisions in future events

Adapted from https://www.cawcr.gov.au/projects/verification/#Why_verify

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Verification is at the heart of our forecasting process

- At TWC, creating the World's Best Weather is our mission
- Verification informs every change or enhancement to our systems
- But, we realize that it is challenging to verify forecasts in a way that's tailored to every use case
- Our wide range of use cases require a verification infrastructure that's sustainable, extensible and configurable

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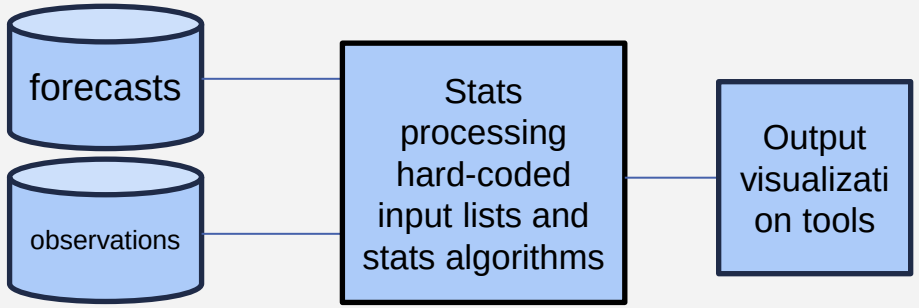
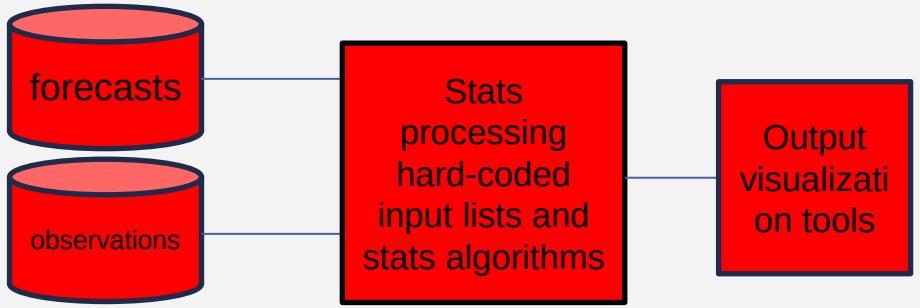
TWC Forecast Verification System Genealogy – Legacy system architecture

A different verification system (and owner) for each use case

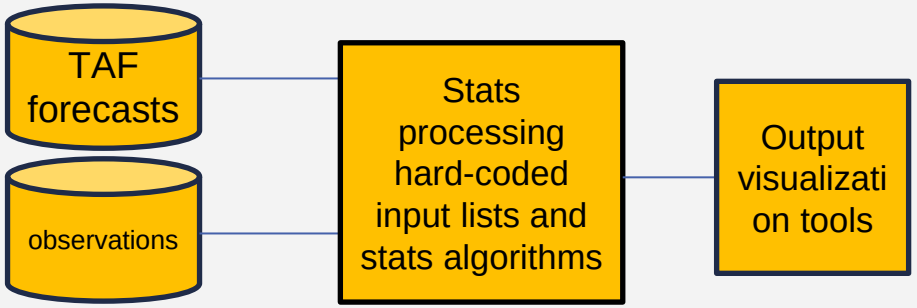
Consumer (public) weather forecast verification system



NWP (GRAF) weather forecast verification system



Aviation (TAF) weather forecast verification system



- Bespoke verification systems for each use case and even for different data types for a given use case (verif of continuous [temperature] vs. discrete [precipitation] public weather forecasts)
- Parameters of the verification (sites, meteorological parameters, gen/valid times, statistical measures) all hard coded in compiled software
- Very inflexible and difficult to maintain/extend

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TWC Forecast Verification System Philosophy

“Any member of our science staff can bring their forecast and obs data in a predefined format and use configuration files to quickly drive verification results for R & D and production system monitoring purposes”

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TWC Forecast Verification System Genealogy – Legacy system architecture

The challenges of the legacy verification architecture and the capabilities of the new

Old

- Inflexible, hardcoded configuration
- Difficult to include new data sources
- Required a software engineer to perform a new verification analysis
- Output format static HTML tables only – no chart, maps
- No debugging/auditing capability
- Old, inefficient hardware

New

- Analysis configuration driven
- Easy to add new data sources – use standardized format
- Config files make new analyses easy to add
- Specify multiple output types easily in config file
- Robust debugging/auditing capabilities
- Modern HPC hardware

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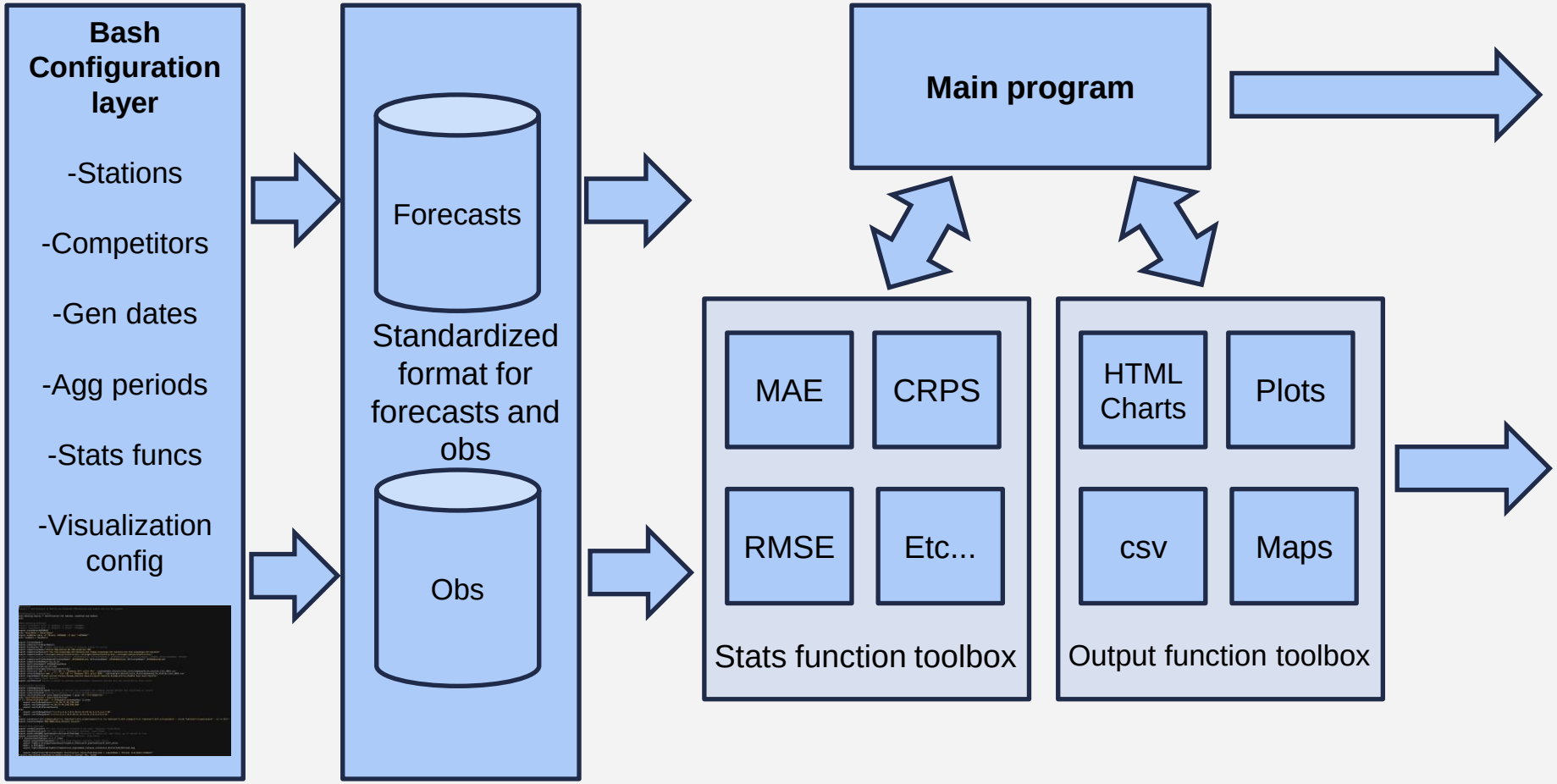
Modern TWC Forecast Verification System

A unified, configurable, extensible forecast verification system



VISIBILITY Verification: hourly | Global | Period: Mar 09-Mar 26

Lead	Competitor	percent correct			bias			equitable threat score		
		1	3	5	1	3	5	1	3	5
1-24	TWC Forecast 1	0.974	0.899	0.838	0.874	1.351	1.245	0.152	0.185	0.2
	TWC Forecast 2	0.974	0.9	0.838	0.869	1.35	1.246	0.152	0.185	0.2
	TWC Forecast 3	0.975	0.898	0.835	0.761	1.258	1.195	0.148	0.161	0.182
	ECMWF	0.977	0.917	0.852	0.353	0.758	0.956	0.053	0.145	0.189
	GFS	0.97	0.892	0.814	0.723	1.298	1.361	0.045	0.141	0.155
	UKMO	0.951	0.891	0.819	2.192	1.497	1.479	0.104	0.172	0.19
	GEM	0.98	0.911	0.84	0.053	0.878	1.153	0.02	0.142	0.189
24-48	TWC Forecast 1	0.977	0.903	0.838	0.658	1.261	1.263	0.127	0.172	0.194
	TWC Forecast 2	0.977	0.903	0.838	0.655	1.259	1.263	0.127	0.172	0.193
	TWC Forecast 3	0.978	0.902	0.835	0.569	1.171	1.217	0.126	0.146	0.177
	ECMWF	0.977	0.917	0.852	0.377	0.767	0.954	0.053	0.135	0.175
	GFS	0.971	0.892	0.813	0.74	1.303	1.347	0.039	0.125	0.139
	UKMO	0.951	0.889	0.815	2.2	1.505	1.48	0.081	0.149	0.17
	GEM	0.981	0.909	0.833	0.062	0.92	1.205	0.018	0.128	0.168
48-72	TWC Forecast 1	0.978	0.905	0.839	0.564	1.155	1.175	0.108	0.148	0.174
	TWC Forecast 2	0.977	0.905	0.839	0.561	1.153	1.175	0.107	0.149	0.174
	TWC Forecast 3	0.978	0.904	0.836	0.493	1.063	1.124	0.107	0.122	0.156
	ECMWF	0.977	0.916	0.847	0.381	0.769	0.955	0.043	0.117	0.156
	GFS	0.97	0.889	0.807	0.794	1.326	1.359	0.035	0.107	0.122
	UKMO	0.952	0.887	0.811	2.099	1.468	1.445	0.062	0.125	0.148
	GEM	0.981	0.906	0.824	0.062	0.949	1.247	0.015	0.107	0.145
72-96	TWC Forecast 1	0.978	0.904	0.842	0.526	1.113	1.06	0.09	0.124	0.154
	TWC Forecast 2	0.978	0.904	0.842	0.523	1.109	1.062	0.09	0.124	0.154
	TWC Forecast 3	0.979	0.903	0.839	0.444	1.02	1.009	0.087	0.097	0.134
	ECMWF	0.978	0.916	0.846	0.331	0.732	0.911	0.034	0.099	0.135
	GFS	0.971	0.887	0.801	0.759	1.329	1.368	0.03	0.088	0.1
	UKMO	0.951	0.883	0.805	2.143	1.49	1.436	0.051	0.101	0.123
	GEM	0.982	0.904	0.819	0.059	0.99	1.266	0.014	0.094	0.127

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Modern TWC Forecast Verification System - Configuration

Configuration files drive the system's capabilities

Data Sourcing Settings Section

-Forecast generation date range

-Meteorological parameter name

-Generation cycle, e.g. 12UTC

-Names of forecast providers

-Paths to forecasts and obs datasets

-Temporal aggregation (hourly, 24 hour, etc)

-Station list / geographic aggregation

```
#!/bin/bash
#Hourly T verification configuration

#Configuration Information:
echo Running Hourly T Verification
echo

#Data Sourcing Settings
export startDate=`date -d "${date} -1 month" "+%Y%m01"`
echo "startDate = $startDate"
export endDate=`date -d "${date +%Y%m%d) -2 day" "+%Y%m%d"`
echo "endDate = $endDate"
export fcstVarName=T
export isCollectionStartDate=1
export fcstCycle='22' #comma separated string of forecast cycles to verify
export competitorName='TWC Forecast 1,TWC Forecast 2,TWC Forecast 3'
export competitorDataset='twc-fod-longrange-1hr-backend,twc-fodqa-longrange-1hr-backend,twc-fod-longrange-1hr-backend'
export competitorDir='/storage/library/archive/rec/,/storage/library/archive/rec/,/storage/library/archive/rec/'
export competitorFileVarName=${fcstVarName}'.SFC@2m@edited,'${fcstVarName}'.SFC@2m@edited,'${fcstVarName}'.SFC@2m@unedited'
export competitorNumDays='16,16,16'
export obsFileVarName=T.SFC@2m@TopofHour
export obsDataset=twc-qc-sfc-obs
export obsDir=/storage/library/archive/rec/
export siteList=`awk -F "," '{if ($1 != "Skybase ID") print $1}' ~/github/gfs-r2o/etc/site_lists/skybaseId_fw_station_list_2021.csv`
export siteListRegion=`awk -F "," '{if ($1 != "Skybase ID") print $18}' ~/github/gfs-r2o/etc/site_lists/skybaseId_fw_station_list_2021.csv`
export regionName='Global,United States,Canada,Central America,South America,Europe,Africa,Middle East,Asia Pacific'
export verifUnits=F #units in which to perform verification: forecasts and obs will be converted to these units.
```

Verification Settings Section

-Specify number of bins to use for calculating reliability

-How data should be aggregated, e.g. hours 1-24 or Days 1-3

-Desired statistical measures (e.g. MAE, RMSE, CRPS, etc)

-Contingency table thresholds

```
#Verification Settings
export isHomogeneous=1
export isVerifyValidTime=0 #boolean on whether the startDate and endDate period defines the validTimes to verify
export isVerifyProb=0 #boolean on whether to include probabilistic verification
export verifyStrPeriod=`echo $obsFileVarName | grep -oP '(?<=\@2m@)\w+'`
echo "verifyStrPeriod = $verifyStrPeriod"
if [[ "${verifyStrPeriod}" != @(daypart|calendarDay) ]];then
    export verifyRangeStart='1,24,48,72,96,120,240'
    export verifyRangeEnd='24,48,72,96,120,240,360'
    export verifyStrPeriod=hourly
else
    export verifyRangeStart='1,2,3,4,5,6,7,8,9,10,11,12,13,14,1,1,3,4,6,7,10'
    export verifyRangeEnd='1,2,3,4,5,6,7,8,9,10,11,12,13,14,3,5,5,6,9,9,14'
fi
export statsFunc='@(f,o)mean(abs(f-o),"omitnan");@(f,o)sqrt(mean((f-o).^2,"omitnan"));@(f,o)mean((f-o),"omitnan");@(f,o)(sum(abs(f - o)<=3,"omitnan")/(sum(isnan(f - o) == 0)))'
export statsFuncName='MAE,RMSE,Bias,Percent Correct'
```

Output Data Settings Section

-Boolean flag on outputting diagnostic info

-Type of output desired (HTML table, charts, csv)

-Output path

-Labels for output data (statistics names, etc)

```
#Output Data Settings
export saveCollocate=1 #To save collocated forecast & obs data  (options: 1=yes,0=no)
export saveStatistics=1 #To save output statistics (options: 1=yes,0=no)
export outDir=${HOME}/github/gfs-r2o/verif/fod/tmp/ #Location of where all .mat files, go if option is True
export outputHtmlTables=1 #to save html tables (options: 1=yes,0=no)
if [ ${outputHtmlTables} == 1 ] ;then
    export outputHtmlFigures=1 #to save html figures (options: 1=yes, 0=no)
    export figDir=/storage/home/maverif/public_html/verif_platform/verif_diff_plots
    mkdir -p ${figDir}
    export figFileName=${figDir}/temperature_regionName_release_validation_${verifyStrPeriod}.png
    export tableTitle="${fcstVarName} Verification: ${verifyStrPeriod} | regionName | Period: startDate-endDate"
    export tableDir=/storage/home/maverif/public_html/verif_platform/table/hourlytwithmodels
    mkdir -p ${tableDir}
    export tableFileName=${tableDir}/temperature_regionName_release_validation_${verifyStrPeriod}.html
    export tableStatsList='MAE,RMSE,Bias,Percent Correct'
fi
```


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The Weather Company Forecast Verification Platform Use Cases

- Use verification to validate each forecasting system upgrade/release (release must improve / do no harm)
- Identify areas of poor performance
- Assess the skill of human-driven forecast edits through our HOTL paradigm

Verification main page

Region	Calendar Day Precip	Daypart Precip	Hourly Precip	Hourly QPF	Daypart MaxT	Daypart MinT	Hrly Temp w/wxmix models	Calendar Day POP	Daypart POP	Hourly POP	Calendar Day Wind	Daypart Wind	Hourly Wind	Hourly Ceiling	Hourly Visibility
Global	Calendar Day Precip	Daypart Precip	Hourly Precip	N/A	Daypart Max T	Daypart Min T	Hourly T	Calendar Day POP	Daypart POP	Hourly POP	Calendar Day Wind Speed	Daypart Wind Speed	Hourly Wind Speed	Hourly Ceiling	Hourly Visibility
United States (.01" precip threshold)	Calendar Day Precip	Daypart Precip	Hourly Precip	Hourly QPF	Daypart Max T	Daypart Min T	Hourly T	Calendar Day POP	Daypart POP	Hourly POP	Calendar Day Wind Speed	Daypart Wind Speed	Hourly Wind Speed	Hourly Ceiling	Hourly Visibility
Asia Pacific	Calendar Day Precip	Daypart Precip	Hourly Precip	N/A	Daypart Max T	Daypart Min T	Hourly T	Calendar Day POP	Daypart POP	Hourly POP	Calendar Day Wind Speed	Daypart Wind Speed	Hourly Wind Speed	Hourly Ceiling	Hourly Visibility
Europe	Calendar Day Precip	Daypart Precip	Hourly Precip	N/A	Daypart Max T	Daypart Min T	Hourly T	Calendar Day POP	Daypart POP	Hourly POP	Calendar Day Wind Speed	Daypart Wind Speed	Hourly Wind Speed	Hourly Ceiling	Hourly Visibility
South America	Calendar Day Precip	Daypart Precip	Hourly Precip	N/A	Daypart Max T	Daypart Min T	Hourly T	Calendar Day POP	Daypart POP	Hourly POP	Calendar Day Wind Speed	Daypart Wind Speed	Hourly Wind Speed	Hourly Ceiling	Hourly Visibility
Canada	Calendar Day Precip	Daypart Precip	Hourly Precip	N/A	Daypart Max T	Daypart Min T	Hourly T	Calendar Day POP	Daypart POP	Hourly POP	Calendar Day Wind Speed	Daypart Wind Speed	Hourly Wind Speed	Hourly Ceiling	Hourly Visibility
Middle East	Calendar Day Precip	Daypart Precip	Hourly Precip	N/A	Daypart Max T	Daypart Min T	Hourly T	Calendar Day POP	Daypart POP	Hourly POP	Calendar Day Wind Speed	Daypart Wind Speed	Hourly Wind Speed	Hourly Ceiling	Hourly Visibility
Africa	Calendar Day Precip	Daypart Precip	Hourly Precip	N/A	Daypart Max T	Daypart Min T	Hourly T	Calendar Day POP	Daypart POP	Hourly POP	Calendar Day Wind Speed	Daypart Wind Speed	Hourly Wind Speed	Hourly Ceiling	Hourly Visibility
Central America	Calendar Day Precip	Daypart Precip	Hourly Precip	N/A	Daypart Max T	Daypart Min T	Hourly T	Calendar Day POP	Daypart POP	Hourly POP	Calendar Day Wind Speed	Daypart Wind Speed	Hourly Wind Speed	Hourly Ceiling	Hourly Visibility

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Some example Verification Platform products

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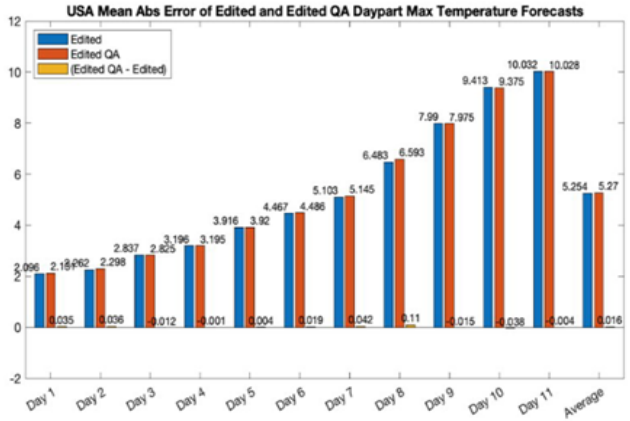
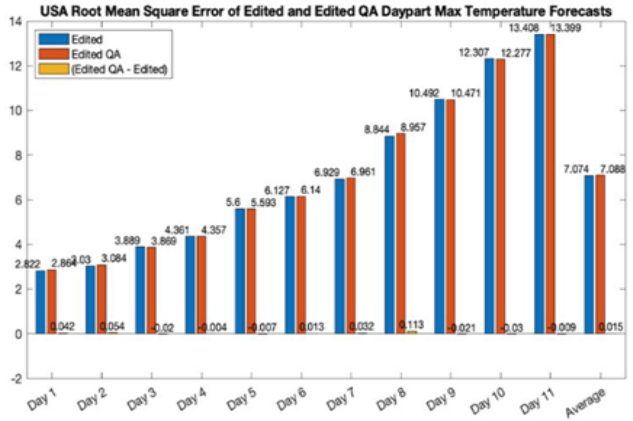
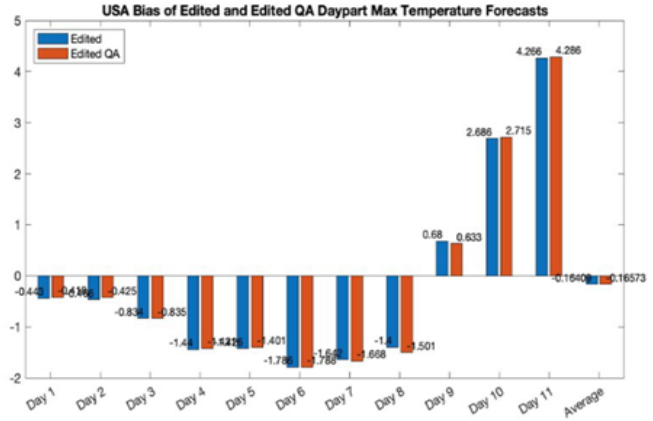
Figures Enhance Interpretability of Tabular Data When Evaluating Efficacy of a New Capability

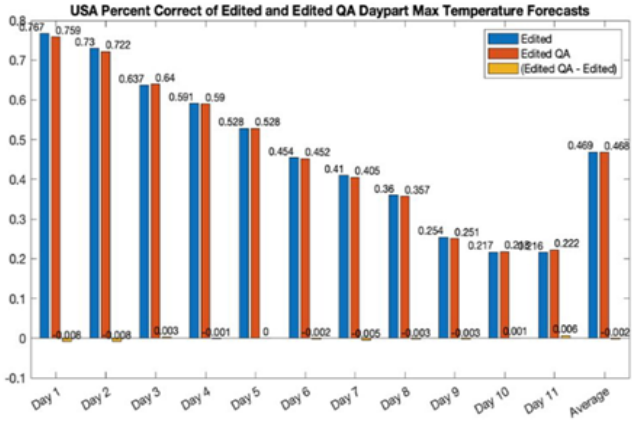
WETBOOL Verification: calendarDay | Global | Period: Jan 19-Feb 03

Lead	Competitor	percent correct	bias	equitable threat score
1	Edited FOD	0.815	0.759	0.458
	Edited QA FOD	0.814	0.757	0.456
	Unedited FOD	0.785	0.664	0.398
2	Edited FOD	0.777	0.675	0.384
	Edited QA FOD	0.777	0.674	0.384
	Unedited FOD	0.739	0.564	0.315
3	Edited FOD	0.774	0.7	0.376
	Edited QA FOD	0.774	0.699	0.376
	Unedited FOD	0.735	0.578	0.307
4	Edited FOD	0.744	0.67	0.324
	Edited QA FOD	0.743	0.667	0.322
	Unedited FOD	0.702	0.526	0.255
5	Edited FOD	0.727	0.7	0.297
	Edited QA FOD	0.727	0.698	0.296
	Unedited FOD	0.688	0.547	0.237
6	Edited FOD	0.71	0.734	0.271
	Edited QA FOD	0.711	0.732	0.272
	Unedited FOD	0.677	0.597	0.224
7	Edited FOD	0.692	0.761	0.241
	Edited QA FOD	0.691	0.759	0.239
	Unedited FOD	0.659	0.626	0.195
8	Edited FOD	0.682	0.809	0.224
	Edited QA FOD	0.682	0.808	0.224
	Unedited FOD	0.659	0.671	0.192
9	Edited FOD	0.655	0.765	0.186
	Edited QA FOD	0.655	0.765	0.187
	Unedited FOD	0.647	0.735	0.175









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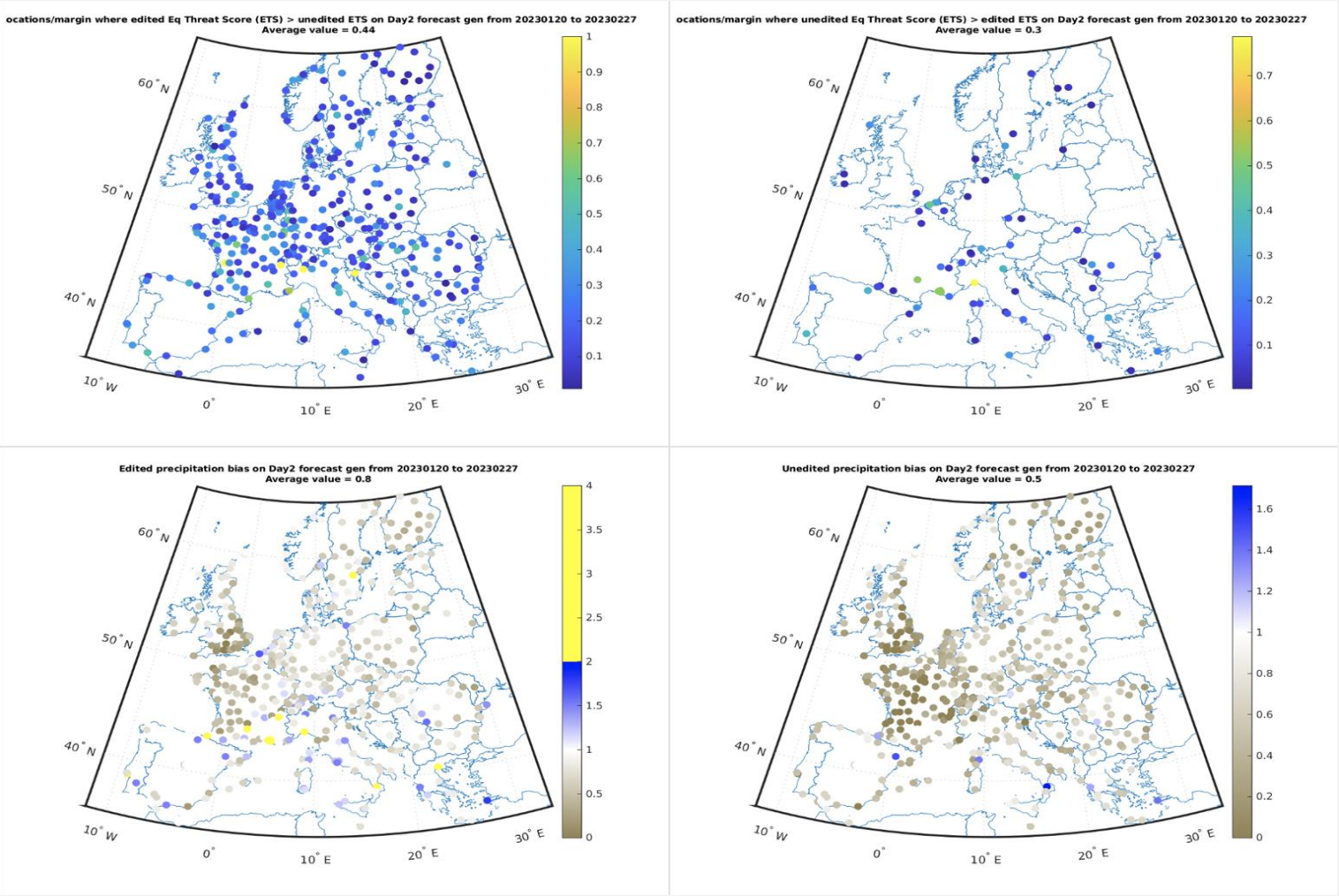
Map-based Results Reveal Where Human Forecaster Edits Add Value



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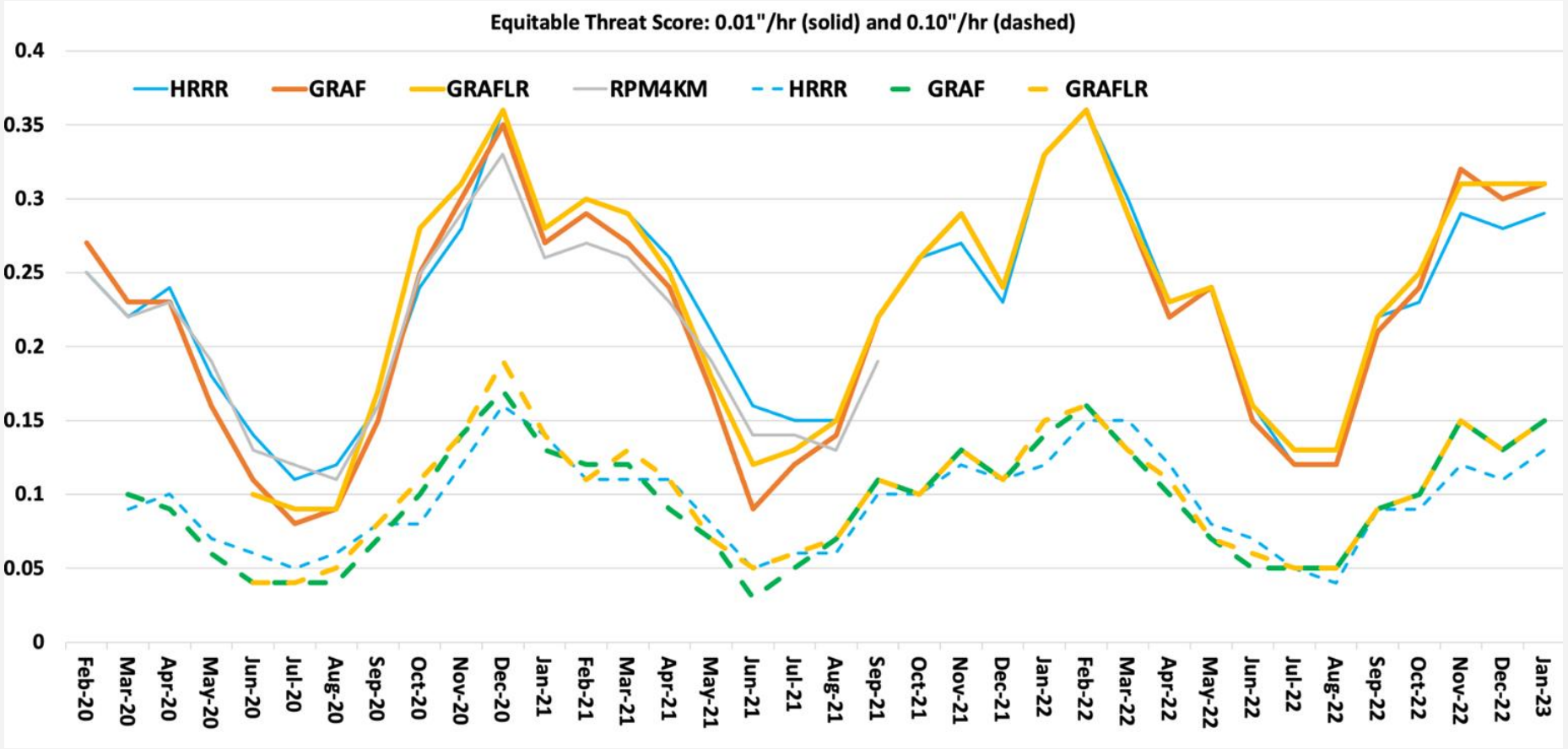
TWC GRAF NWP Precipitation Verification



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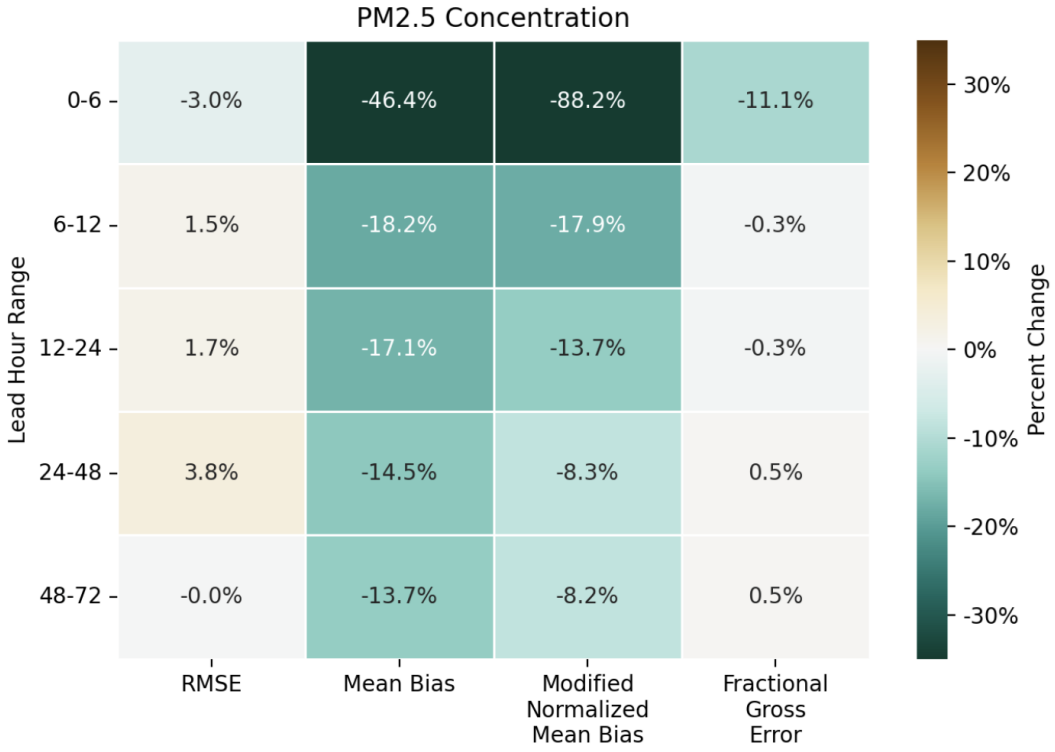
TWC Air Quality Forecast Verification



PM25_epa_aqicat Verification: hourly | United States | Period: Apr 28-May 12 | airnow-airquality-fcst

Forecast (rows), Observation (cols)	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy	Hazardous
Good	332972 (96.35%)	12206 (3.53%)	218 (0.06%)	185 (0.05%)	7 (0%)	0 (0%)
Moderate	44414 (75.52%)	13342 (22.69%)	815 (1.39%)	238 (0.4%)	5 (0.01%)	0 (0%)
Unhealthy for Sensitive Groups	563 (20.98%)	1267 (47.21%)	624 (23.25%)	230 (8.57%)	0 (0%)	0 (0%)
Unhealthy	13 (26%)	5 (10%)	9 (18%)	23 (46%)	0 (0%)	0 (0%)
Very Unhealthy	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Hazardous	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

- Heat maps identify cases where TWC's air quality system forecast performs better than the background CAMS model forecast. A negative number indicates a more performant TWC forecast

- A confusion matrix identifies how forecasted air quality categories matched with observed categories. This view can aid in identifying forecast biases

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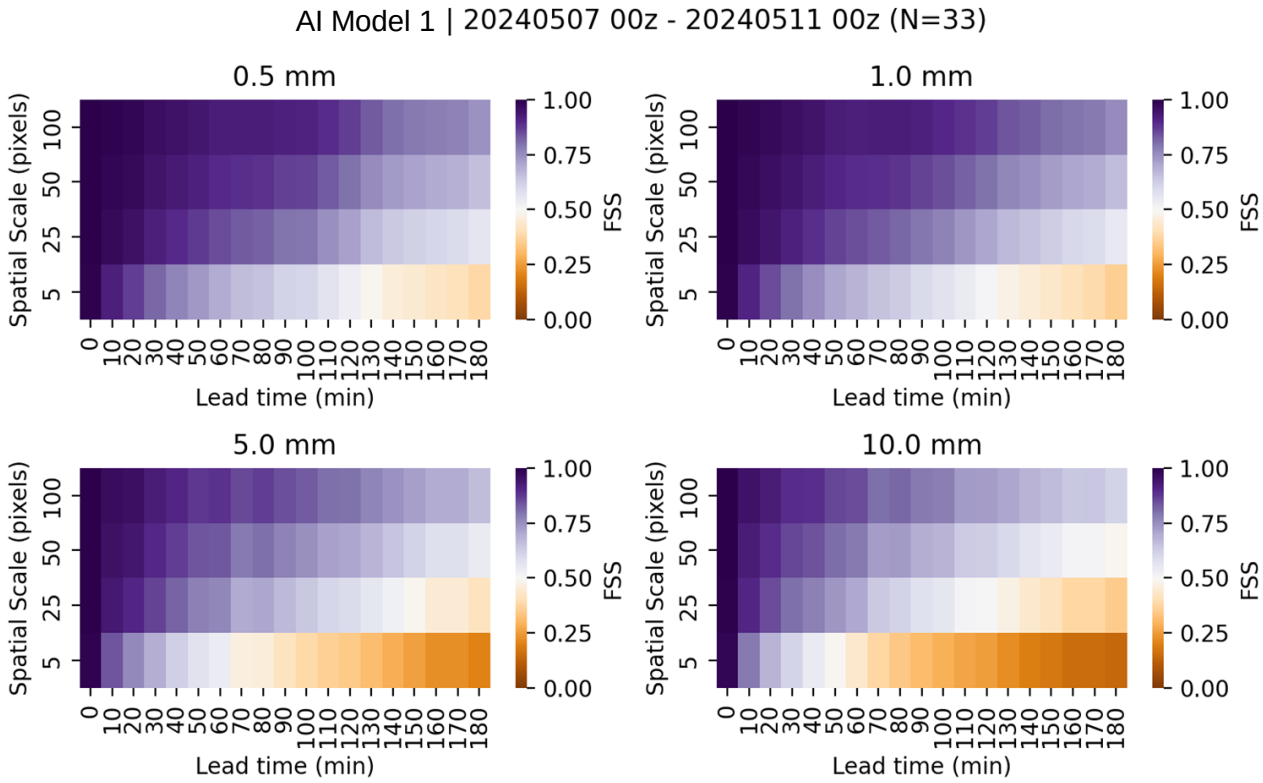
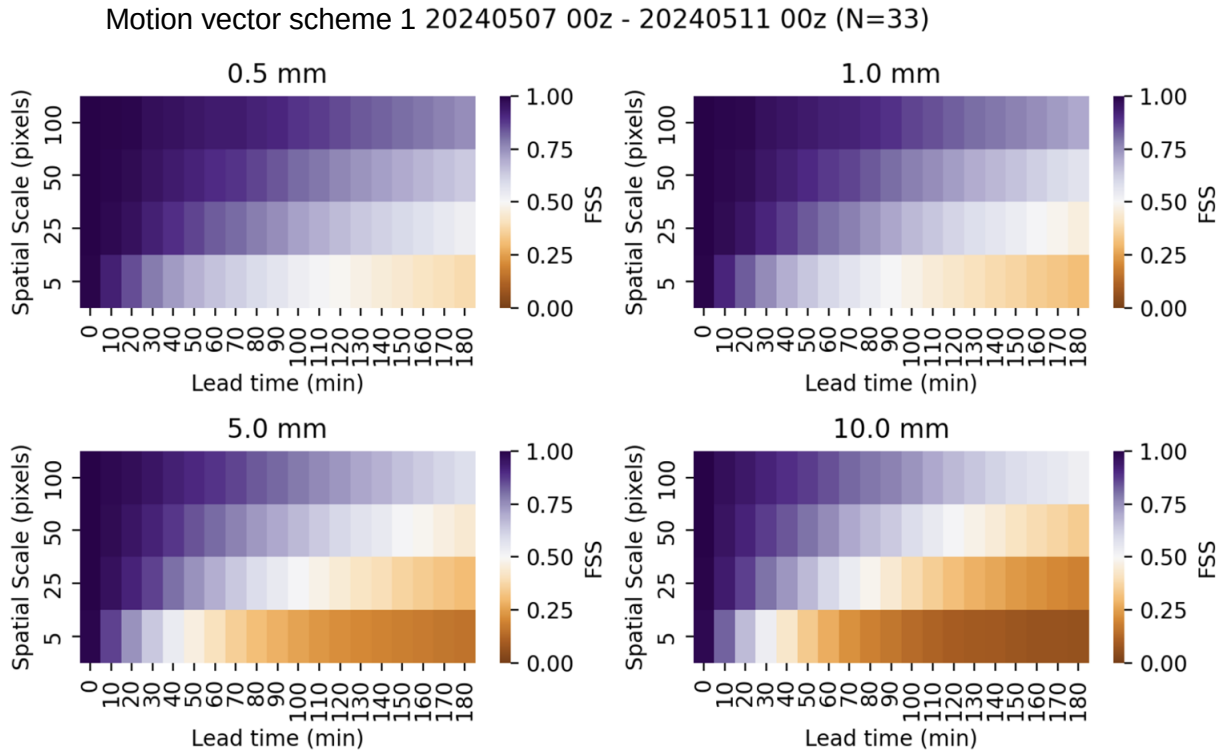
Fractions Skill Score

- Evaluating spatial skill at differing length scales





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December 12, 2022: BOS (Daily Avg Penalty = 0.09)

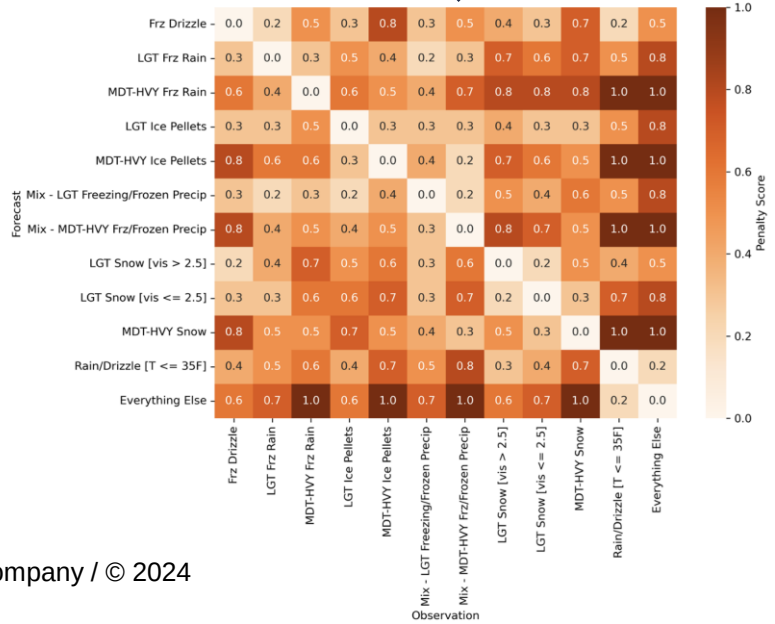
		KBOS Winter Event Dec 12 : Met Review																								
		12-Dec																								Average Penalty
		00z	01	02	03	04	05	06z	07	08	09	10	11	12z	13	14	15	16	17	18z	19	20	21	22	23	
Forecast Table	Total Snowfall/Icing	19L	20	21	22	23	00	01L	02	03	04	05	06	07L	08	09	10	11	12	13L	14	15	16	17	18	
12/09/2022 12:00Z	0.3																									
12/09/2022 18:00Z	0.1																									
12/10/2022 00:00Z	0.3																									
12/10/2022 06:00Z	0.3																									
12/10/2022 12:00Z	0.4																									
12/10/2022 18:00Z	0.5																									
12/11/2022 00:00Z	0.7																									
12/11/2022 06:00Z	0.4																									
12/11/2022 12:00Z	0.4																									
12/11/2022 18:00Z	0.7																									
12/12/2022 00:00Z	0.8																									
Observations	0																									
Verification		0.3	0.02	0.05	0.05	0.05	0.5	0.45	0.41	0.27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09
12/12/2022 00:00Z: Verification		0.7	0.2	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12
12/11/2022 18:00Z: Verification		0.3	0	0	0	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08
12/11/2022 12:00Z: Verification		0.2	0	0	0	0	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09
12/11/2022 06:00Z: Verification		0.2	0	0	0	0	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09
12/11/2022 00:00Z: Verification		0.2	0	0	0	0	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09
12/10/2022 18:00Z: Verification		0.2	0	0	0	0	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09
12/10/2022 12:00Z: Verification		0.2	0	0	0	0	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09
12/10/2022 06:00Z: Verification		0.2	0	0	0	0	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09
12/10/2022 00:00Z: Verification		0.2	0	0	0	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07
12/09/2022 18:00Z: Verification		0.2	0	0	0	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07
12/09/2022 12:00Z: Verification		0.7	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07

Precipitation Type / Intensity

- Freezing Drizzle
- LGT Freezing Rain
- MDT-HVY Freezing Rain
- LGT Ice Pellets
- MDT-HVY Ice Pellets
- Mix - LGT Freezing or Frozen Precipitation
- Mix - MDT-HVY Freezing or Frozen Precipitation
- LGT Snow [vis > 2.5 mi]
- LGT Snow [vis <= 2.5 mi]
- MDT-HVY Snow
- Rain/Drizzle [T <= 35 F]
- Everything Else

Aviation forecast winter weather scoring tables – impact-based verification

Sensible weather penalty matrix



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Convective TAF Verification Product

- Desire for single verification product to be both human- & machine-readable.
- Sheets are automatically generated and provided to airline partner on daily basis for multiple airport locations
- Verification product can be made available to other airline partners with their own or generic penalty table

	A	B	C	N	O	P	Q	R	S	T	U	AR
1	TAF	Issue Time	Source	07/16 10Z	07/16 11Z	07/16 12Z	07/16 13Z	07/16 14Z	07/16 15Z	07/16 16Z	07/16 17Z	Total Weighted Penalty
2	20230716T0000	152326Z	NWS	VCTS	VCTS	VCTS	VCTS	VCTS				
3	20230716T0000	152313Z	WSI			VCTS	VCTS	VCTS	VCTS			
4	20230716T1500	161500Z	NWS						TEMPO	TEMPO	VCTS	
5	20230716T1500	161459Z	WSI						TEMPO	VCTS	VCTS	
6	Observations		METAR				VCTS 5-10		TSTM Field			
7	Observations		Radar	TSTM Gates	TSTM Gates	TSTM Gates	VCTS 10-25	TSTM Field	TSTM Field	VCTS 10-25	VCTS 10-25	
8	Observations		Lightning			TSTM Gates	VCTS 10-25	TSTM Field	TSTM Field	VCTS 10-25	VCTS 10-25	
9	Verification		LightningOnly									
10	20230716T1500	161459Z	WSI						0	0	0	0
11	20230716T1500	161500Z	NWS						0	0.4	0	0.4
12	20230716T0000	152313Z	WSI	0	0	0.18	0	0.36	0.36	0.36	0.36	1.62
13	20230716T0000	152326Z	NWS	0.4	0.4	0.18	0	0.36	0.6	0.36	0.36	2.66
14	Verification		RadarOnly									
15	20230716T1500	161459Z	WSI						0	0	0	1.8
16	20230716T1500	161500Z	NWS						0	0.4	0	2.2
17	20230716T0000	152313Z	WSI	0	0	0.18	0	0.36	0.36	0.36	0.36	2.34
18	20230716T0000	152326Z	NWS	0.24	0.24	0.18	0	0.36	0.6	0.36	0.36	3.06

	Observed
TSTM Field	
VCTS 5-10	
VCTS 10-25	
TSTM Gates	
No TSTMs	

	Forecast
TEMPO/FM	
PROB30	
VCTS	
No TSTMs	

Rows 2–5: TWC & NWS TAFs mapped to convective forecast categories for each valid hour

Rows 6–8: METAR, Radar, and Lightning observations mapped to convective observation categories

- *Future improvement:* blend radar & lightning data as a single source of observation truth

Rows 10–13, 15–18: Time-weighted penalty table values assigned to TWC & NWS TAFs using lightning, radar observations

Final column: Sum of penalty values across all valid hours to aid in comparisons between competitors and generation times

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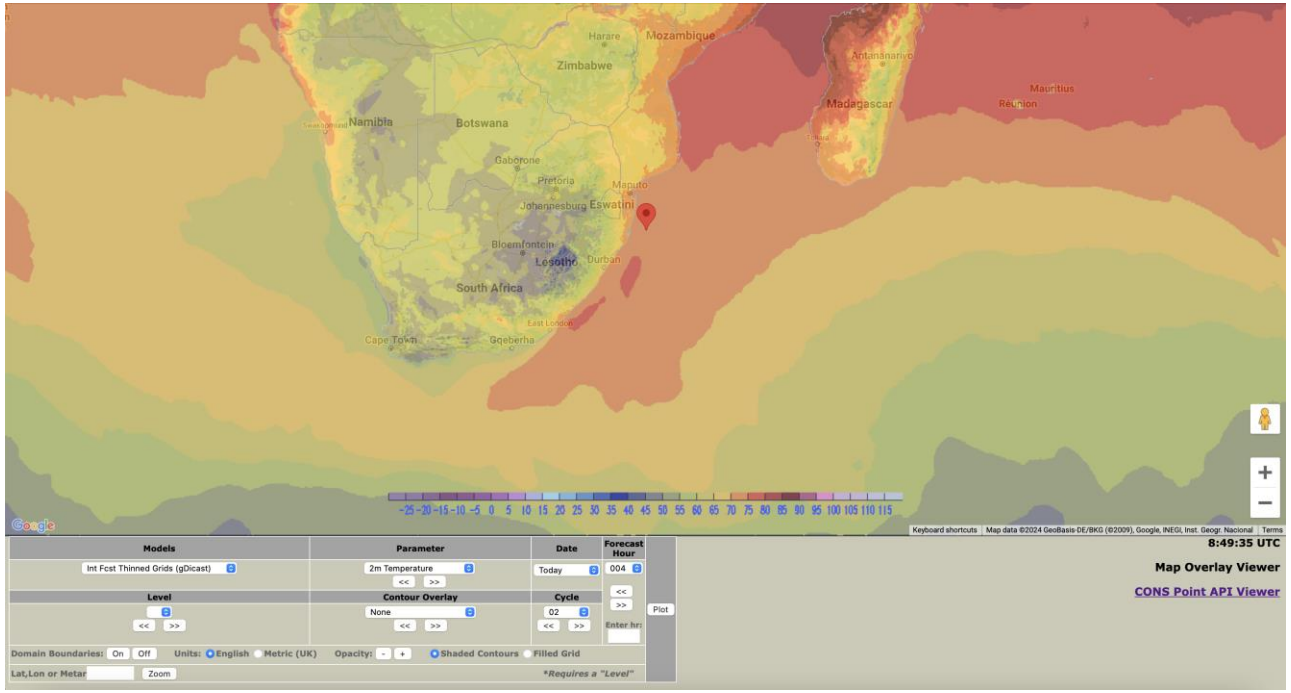
Subjective verification

- Sophisticated point and map viewer tools used to evaluate results for meteorological sensibility
- Particularly important as we integrate AI models into our consensus blend



CAPE TOWN, , SOUTH AFRICA

68816000 FACT -33.9670 18.6000 42m

Integration Process

/shared-data/csv_data/wxmix_full_sitelist/20240520/00/N000_S360/advanced/FACT.20240520T000000.N000_S360.csv

Day 1 - 11Z Temperature forecasts (F) - Produced 00Z May 20, 2024 (forecast hour 11)

Module Name	Forecast	Bias	Weight	Contribution
GFS[0] 20240519 18Z	72.88	0.90	0.000	0.000
GEFS_ENSMEAN[0] 20240519 12Z	71.88	0.15	0.000	0.000
FNV2[0] 20240519 12Z	68.39	-2.75	0.046	3.244
ECMWF_HOURLY[0] 20240519 12Z	71.81	0.83	0.165	11.711
ECMWF_AIFS[0] 20240519 12Z	65.77	-4.59	0.146	10.266
ECMWF_ENSMEAN[0] 20240519 12Z	70.16	0.62	0.136	9.480
NAM[0] 20240519 18Z	-9999	0.00	0.000	0.000
MAV_MOS[0] 20240519 18Z	-9999	0.00	0.000	0.000
ETA_MOS[0] 20240519 12Z	-9999	0.00	0.000	0.000
NBM[0] 20240519 18Z	-9999	0.00	0.000	0.000
GLMP[0] 20240519 23Z	-9999	0.00	0.000	0.000
GRAF_CONUS[0] 20240519 21Z	-9999	0.00	0.000	0.000
RPM_GLOBAL[0] 20240519 18Z	70.32	0.10	0.110	7.745
GEM[0] 20240519 12Z	68.81	-1.99	0.156	11.025
GEM_ENSMEAN[0] 20240519 12Z	66.17	-3.00	0.059	4.053
UKMO[0] 20240519 12Z	64.02	-2.78	0.117	7.808
UKMOSR[0] 20240519 18Z	62.73	-2.40	0.066	4.279
GRAF_EUROPE[0] 20240519 21Z	-9999	0.00	0.000	0.000
INTEGRATION	69.31	0.00	1.000	69.61

Summary

- Verification plays a crucial role in The Weather Company's forecasting process
- We had an inefficient, inflexible set of antiquated verification tools that did not support our needs to assess the skill our our forecast products across a number of business lines
- We have built a flexible, extensible and configuration-driven verification system to enable robust verification products to support a wide variety of use cases across our business
- Future enhancements include an emphasis on probabilistic verification and further verification products to support our aviation business

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The
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Company