Thoughts on Research-to-Operations (R2O... and O2R2O)

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TSgt Paige Crafter and SE Team (16 WS)

Flavors of Research-to-Operations (R2O)

- **Long-term Programs**
  - Requirement Vetting
  - Formal Program of Record
- **Research & Development**
  - Formal R&D Program
    - Successful R&D ➡ Transition to Lifecycle Management Program of Record work
- **Operational Changes at "Building Level"**
  - GALWEM deterministic NWP model (contractor maintains baseline)
- **Operational Changes at "Local Level"**
  - Air Force Weather Ensemble Prediction Suite (AFWEPS; 16 WS maintenance)

R2O: Not Just Systems and "Things"...

- **#1 R2O Success Story: Forecasting Mentality *Paradigm Shift***
- **Movement from Deterministic to Probabilistic Thinking**
  - Fully incorporating Operational Risk Management - ORM
  - The move from YES/NO …and Red-Yellow-Green ...to probability-based
  - It's not over. It's an *ongoing learning process* for users and developers
- **Research --**
  - Leveraged ensemble research that was taking place at NCAR, Universities (and we continue to do so)
- **Development --**
  - In the beginning we had to be the developers and the salespersons
  - *Local development* ultimately resulted in AFWEPS

Why Should We Run Ensembles?

- Running a deterministic weather model produces one possible outcome...
  - ...but it is wrong! What do you mean it's wrong?
    - Models simply can't start with a perfect initial analysis; they're "flawed from the start"!
    - Various physics equations are applied to estimate multiple intricate and complex processes in the atmosphere (physics parameterizations)
      - They're all estimates and they're all not perfect
  - One model run may do well in certain areas, for certain variables/times, but not all
- One solution? Run the model many times to produce probability of outcomes
  - Use slightly perturbed analyses, different boundary conditions, and/or model physics
  - Each different "ensemble member" produces a different solution.
- Running multiple ensemble members for mult. solutions; probabilities calculated
  - Increased solution spread increases chance what will occur is sampled
  - Repeatability of a solution (higher probability) => gives higher forecaster confidence

R2O: Global-Scale Ensemble - GEPS

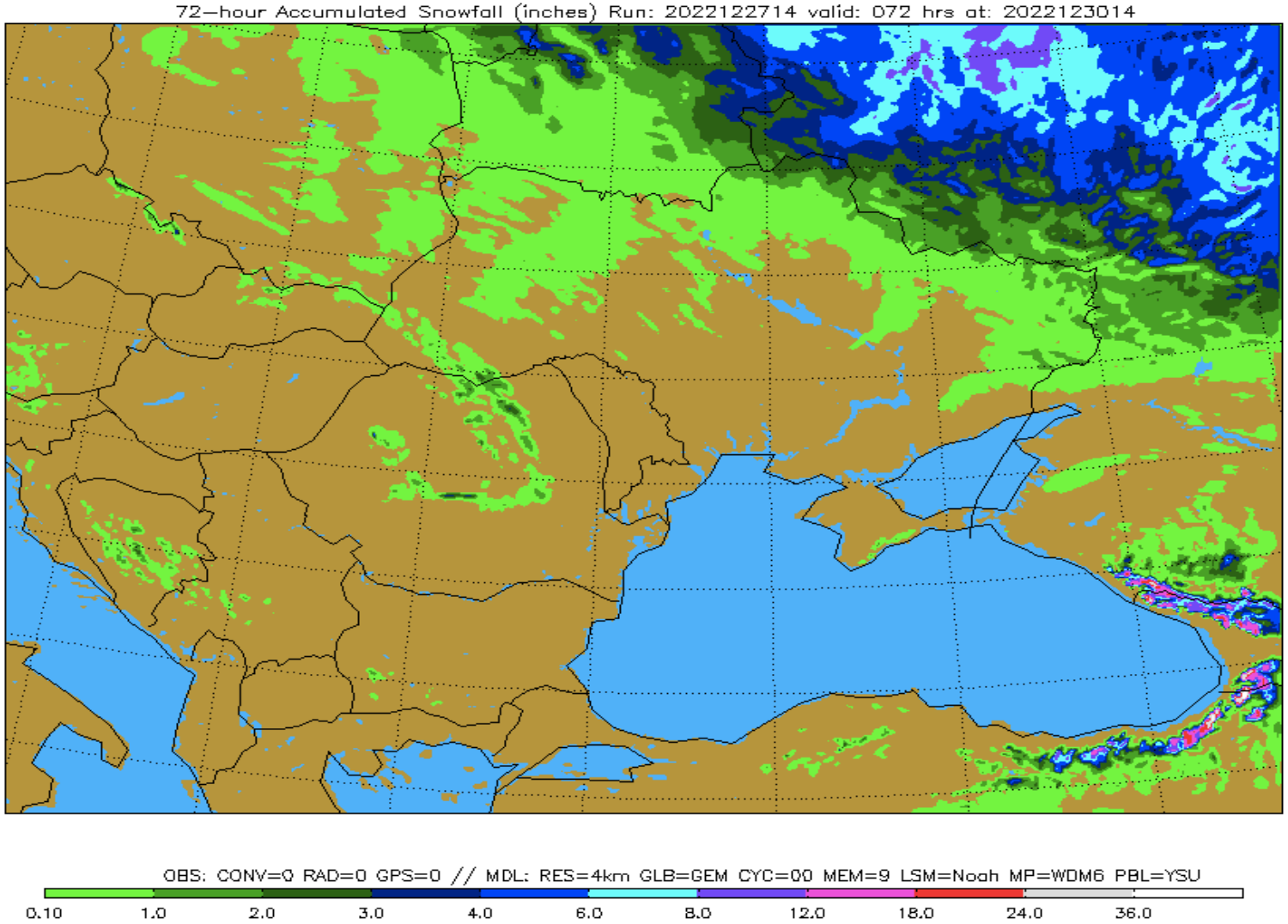
- 16 WS runs the Air Force Weather Ensemble Prediction Suite (AFWEPS)
  - AFWEPS produces global and mesoscale ensemble products
- The Global Ensemble Prediction System (GEPS)
  - GEPS derives probability products from 63 global ensemble forecast solutions
    - 21 global ensemble solutions (called members) from 3 centers: (1) U.S. National Center for Environmental Prediction (NCEP), (2) the U.S. Navy (FNMOC), and (3) Environment Canada
  - GEPS Probability products are available out to 10 days, 6-hr temporal resolution
  - GEPS Four-Panel products show deterministic GALWEM, GFS from NCEP, NAVGEM from FNMOC, and GEM from EC in one product
    - 4-panel products go out 7 days with 3-hr temporal resolution
  - Point Ensemble Probability (PEP) products display probability for 20+ parameters and thresholds in a convenient table for the entire forecast projection at a selected point
    - Data in GEPS PEPs goes out 15 days with 6hr temporal resolution

R2O: Mesocale Ensemble - MEPS

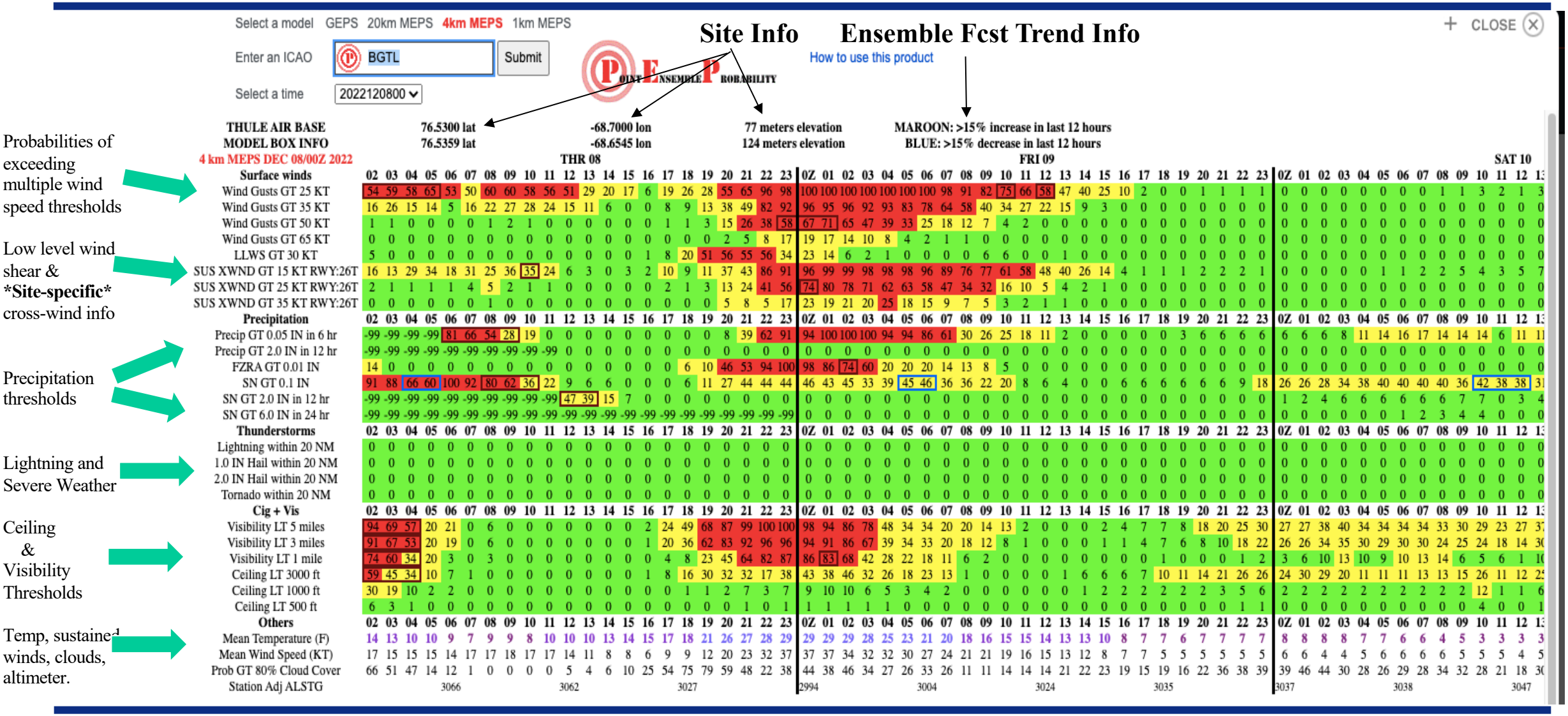
- The Mesoscale Ensemble Prediction System (MEPS)
  - The Weather Research Forecast Model - Advanced Research WRF (WRF-ARW) is the base model for MEPS, and is run by the 16th Weather Squadron
  - 16 members with diverse initial conditions and varied physics packages are cycled, with a distinct run every 2 hours.
  - Macroscale - Synoptic Scale: 20 km resolution; 144hr fcst, 2hr time step
    - Currently 20 domains covering much of the world (and almost all land area)
  - Mesoscale - Microscale: 4 km resolution; 72hr fcst, 1hr time step
    - Currently 7 domains plus 8 relocatable theaters, created for specific users/requirements
  - Small, localized 1 km resolution MEPS for significant local terrain challenges
    - Currently 6 theaters, 30hr forecast, 1hr time step; computationally expensive
    - Developed for user requirements to better resolve local convection, wind, marine lyrs
- PEPs are produced for 20km, 4km, and 1km ensemble data (28 parameters)

R2O -- AFWEPS:

Black Sea Theater, 72-hr Snowfall Accumulation



Example of 4km MEPS PEP



Probabilities of exceeding multiple wind speed thresholds

Low level wind shear & ***Site-specific*** cross-wind info

Precipitation thresholds

Lightning and Severe Weather

Ceiling & Visibility Thresholds

Temp, sustained winds, clouds, altimeter.

"O2R2O": Add Crosswind Thresholds

Select a model GEPS 20km MEPS **4km MEPS** 1km MEPS

\+ CLOSE ⓧ

Enter an ICAO BGTL Submit

POINT ENSEMBLE PROBABILITY

How to use this product

Select a time 2022120800

THULE AIR BASE — 76.5300 lat — -68.7000 lon — 77 meters elevation — MAROON: >15% increase in last 12 hours

MODEL BOX INFO — 76.5359 lat — -68.6545 lon — 124 meters elevation — BLUE: >15% decrease in last 12 hours

4 km MEPS DEC 08/00Z 2022

Sustained Crosswinds {

THR 08

Surface winds	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Wind Gusts GT 25 KT	54	59	58	65	53	50	60	60	58	56	51	29	20	17	6	19	26	28	55	65	96	98
Wind Gusts GT 35 KT	16	26	15	14	5	16	22	27	28	24	15	11	6	0	0	8	9	13	38	49	82	92
Wind Gusts GT 50 KT	1	1	0	0	0	0	1	2	1	0	0	0	0	0	0	1	1	3	15	26	38	58
Wind Gusts GT 65 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	8	17
LLWS GT 30 KT	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	20	51	56	55	56	34
SUS XWND GT 15 KT RWY:26T	16	13	29	34	18	31	25	36	35	24	6	3	0	3	2	10	9	11	37	43	86	91
SUS XWND GT 25 KT RWY:26T	2	1	1	1	1	4	5	2	1	1	0	0	0	0	0	2	1	3	13	24	41	56
SUS XWND GT 35 KT RWY:26T	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5	8	5	17
Precipitation	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Precip GT 0.05 IN in 6 hr	-99	-99	-99	-99	81	66	54	28	19	0	0	0	0	0	0	0	0	0	8	39	62	91
Precip GT 2.0 IN in 12 hr	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	0	0	0	0	0	0	0	0	0	0	0	0
FZRA GT 0.01 IN	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	10	46	53	94	100
SN GT 0.1 IN	91	88	66	60	100	92	80	62	36	22	9	6	6	0	0	0	6	11	27	44	44	44
SN GT 2.0 IN in 12 hr	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	47	39	15	7	0	0	0	0	0	0	0	0
SN GT 6.0 IN in 24 hr	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Thunderstorms	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lightning within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tornado within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cig + Vis	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Visibility LT 5 miles	94	69	57	20	21	0	6	0	0	0	0	0	0	0	2	24	49	68	87	99	100	100
Visibility LT 3 miles	91	67	53	20	19	0	6	0	0	0	0	0	0	0	1	20	36	62	83	92	96	96
Visibility LT 1 mile	74	60	34	20	3	0	3	0	0	0	0	0	0	0	0	4	8	23	45	64	82	87
Ceiling LT 3000 ft	59	45	34	10	7	1	0	0	0	0	0	0	0	0	1	8	16	30	32	32	17	38
Ceiling LT 1000 ft	30	19	10	2	2	0	0	0	0	0	0	0	0	0	0	0	1	1	2	7	3	7
Ceiling LT 500 ft	6	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Others	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Mean Temperature (F)	14	13	10	10	9	7	9	9	8	10	10	10	13	14	15	17	18	21	26	27	28	29
Mean Wind Speed (KT)	17	15	15	15	14	17	17	18	17	17	14	11	8	8	6	9	9	12	20	23	32	37
Prob GT 80% Cloud Cover	66	51	47	14	12	1	0	0	0	0	5	4	6	10	25	54	75	79	59	48	22	38
Station Adj ALSTG					3066						3062						3027					

FRI 09

Surface winds	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Wind Gusts GT 25 KT	100	100	100	100	100	100	100	98	91	82	75	66	58	47	40	25	10	2	0	0	1	1	1	1
Wind Gusts GT 35 KT	96	95	96	92	93	83	78	64	58	40	34	27	22	15	9	3	0	0	0	0	0	0	0	0
Wind Gusts GT 50 KT	67	71	65	47	39	33	25	18	12	7	4	2	0	0	0	0	0	0	0	0	0	0	0	0
Wind Gusts GT 65 KT	19	17	14	10	8	4	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LLWS GT 30 KT	23	14	6	2	1	0	0	0	0	6	6	0	0	1	0	0	0	0	0	0	0	0	0	0
SUS XWND GT 15 KT RWY:26T	96	99	99	98	98	98	96	89	76	77	61	58	48	40	26	14	4	1	1	1	2	2	2	1
SUS XWND GT 25 KT RWY:26T	74	80	78	71	62	63	58	47	34	32	16	10	5	4	2	1	0	0	0	0	0	0	0	0
SUS XWND GT 35 KT RWY:26T	23	19	21	20	25	18	15	9	7	5	3	2	1	1	0	0	0	0	0	0	0	0	0	0
Precipitation	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Precip GT 0.05 IN in 6 hr	94	100	100	100	94	94	86	61	30	26	25	18	11	2	0	0	0	0	0	3	6	6	6	6
Precip GT 2.0 IN in 12 hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FZRA GT 0.01 IN	98	86	74	60	20	20	20	14	13	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0
SN GT 0.1 IN	46	43	45	33	39	45	46	36	36	22	20	8	6	4	0	0	6	6	6	6	6	6	9	18
SN GT 2.0 IN in 12 hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SN GT 6.0 IN in 24 hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thunderstorms	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lightning within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tornado within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cig + Vis	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Visibility LT 5 miles	98	94	86	78	48	34	34	20	20	14	13	2	0	0	0	2	4	7	7	8	18	20	25	30
Visibility LT 3 miles	94	91	86	67	39	34	33	20	18	12	8	1	0	0	0	1	1	4	7	6	8	10	18	22
Visibility LT 1 mile	86	83	68	42	28	22	18	11	6	2	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Ceiling LT 3000 ft	43	38	46	32	26	18	23	13	1	0	0	0	0	1	6	6	6	7	10	11	14	21	26	26
Ceiling LT 1000 ft	9	10	10	6	5	3	4	2	0	0	0	0	0	0	1	2	2	2	2	2	2	3	5	6
Ceiling LT 500 ft	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Others	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Mean Temperature (F)	29	29	29	28	25	23	21	20	18	16	15	15	14	13	13	10	8	7	7	6	7	7	7	7
Mean Wind Speed (KT)	37	37	34	32	32	30	27	24	21	21	19	16	15	13	12	8	7	7	5	5	5	5	5	5
Prob GT 80% Cloud Cover	44	38	46	34	27	26	33	26	11	11	14	14	14	21	22	23	19	15	19	16	22	36	38	39
Station Adj ALSTG	2994						3004						3024						3035					

SAT 10

Surface winds	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13
Wind Gusts GT 25 KT	0	0	0	0	0	0	0	0	1	1	3	2	1	3
Wind Gusts GT 35 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind Gusts GT 50 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind Gusts GT 65 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LLWS GT 30 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUS XWND GT 15 KT RWY:26T	0	0	0	0	0	1	1	2	2	5	4	3	5	7
SUS XWND GT 25 KT RWY:26T	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUS XWND GT 35 KT RWY:26T	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Precipitation	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13
Precip GT 0.05 IN in 6 hr	6	6	6	8	11	14	16	17	14	14	14	6	11	11
Precip GT 2.0 IN in 12 hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FZRA GT 0.01 IN	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SN GT 0.1 IN	26	26	28	34	38	40	40	40	40	36	42	38	38	31
SN GT 2.0 IN in 12 hr	1	2	4	6	6	6	6	6	6	7	7	0	3	4
SN GT 6.0 IN in 24 hr	0	0	0	0	0	0	1	2	3	4	4	0	0	0
Thunderstorms	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13
Lightning within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tornado within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cig + Vis	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13
Visibility LT 5 miles	27	27	38	40	34	34	34	34	33	30	29	23	27	37
Visibility LT 3 miles	26	26	34	35	30	29	30	30	24	25	24	18	14	30
Visibility LT 1 mile	3	6	10	13	10	9	10	13	14	6	5	6	1	10
Ceiling LT 3000 ft	24	30	29	20	11	11	11	13	13	15	26	11	12	25
Ceiling LT 1000 ft	2	2	2	2	2	2	2	2	2	2	12	1	1	6
Ceiling LT 500 ft	0	0	0	0	0	0	0	0	0	0	4	0	0	1
Others	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13
Mean Temperature (F)	8	8	8	8	7	7	6	6	4	5	3	3	3	3
Mean Wind Speed (KT)	6	6	4	4	5	6	6	6	6	5	5	5	4	5
Prob GT 80% Cloud Cover	39	46	44	30	28	26	29	28	34	32	28	21	18	30
Station Adj ALSTG	3037						3038						3047	

O2R2O: RYG Thresholds

All parameter probabilities have Red, Yellow, Green thresholds.

Predefined for now, in the future there will be option for these to be *locally determined* and applied.

Select a model GEPS 20km MEPS **4km MEPS** 1km MEPS

Enter an ICAO BGTL Submit

Select a time 2022120800

POINT ENSEMBLE PROBABILITY

How to use this product

CLOSE

THULE AIR BASE 76.5300 lat -68.7000 lon 77 meters elevation

MODEL BOX INFO 76.5359 lat -68.6545 lon 124 meters elevation

4 km MEPS DEC 08/00Z 2022

MAROON: >15% increase in last 12 hours

BLUE: >15% decrease in last 12 hours

THR 08

Surface winds	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Wind Gusts GT 25 KT	54	59	58	65	53	50	60	60	58	56	51	29	20	17	6	19	26	28	55	65	96	98
Wind Gusts GT 35 KT	16	26	15	14	5	16	22	27	28	24	15	11	6	0	0	8	9	13	38	49	82	92
Wind Gusts GT 50 KT	1	1	0	0	0	0	1	2	1	0	0	0	0	0	0	1	1	3	15	26	38	58
Wind Gusts GT 65 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	8	17
LLWS GT 30 KT	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	20	51	56	55	56	34
SUS XWND GT 15 KT RWY:26T	16	13	29	34	18	31	25	36	35	24	6	3	0	3	2	10	9	11	37	43	86	91
SUS XWND GT 25 KT RWY:26T	2	1	1	1	1	4	5	2	1	1	0	0	0	0	0	2	1	3	13	24	41	56
SUS XWND GT 35 KT RWY:26T	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5	8	5	17
Precipitation	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Precip GT 0.05 IN in 6 hr	-99	-99	-99	-99	81	66	54	28	19	0	0	0	0	0	0	0	0	0	8	39	62	91
Precip GT 2.0 IN in 12 hr	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	0	0	0	0	0	0	0	0	0	0	0	0
FZRA GT 0.01 IN	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	10	46	53	94	100
SN GT 0.1 IN	91	88	66	60	100	92	80	62	36	22	9	6	6	0	0	0	6	11	27	44	44	44
SN GT 2.0 IN in 12 hr	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	47	39	15	7	0	0	0	0	0	0	0	0
SN GT 6.0 IN in 24 hr	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Thunderstorms	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lightning within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tornado within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cig + Vis	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Visibility LT 5 miles	94	69	57	20	21	0	6	0	0	0	0	0	0	0	2	24	49	68	87	99	100	100
Visibility LT 3 miles	91	67	53	20	19	0	6	0	0	0	0	0	0	0	1	20	36	62	83	92	96	96
Visibility LT 1 mile	74	60	34	20	3	0	3	0	0	0	0	0	0	0	0	4	8	23	45	64	82	87
Ceiling LT 3000 ft	59	45	34	10	7	1	0	0	0	0	0	0	0	0	1	8	16	30	32	32	17	38
Ceiling LT 1000 ft	30	19	10	2	2	0	0	0	0	0	0	0	0	0	0	0	1	1	2	7	3	7
Ceiling LT 500 ft	6	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Others	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Mean Temperature (F)	14	13	10	10	9	7	9	9	8	10	10	10	13	14	15	17	18	21	26	27	28	29
Mean Wind Speed (KT)	17	15	15	15	14	17	17	18	17	17	14	11	8	8	6	9	9	12	20	23	32	37
Prob GT 80% Cloud Cover	66	51	47	14	12	1	0	0	0	0	5	4	6	10	25	54	75	79	59	48	22	38
Station Adj ALSTG					3066						3062						3027					

FRI 09

Surface winds	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Wind Gusts GT 25 KT	100	100	100	100	100	100	100	98	91	82	75	66	58	47	40	25	10	2	0	0	1	1	1	1
Wind Gusts GT 35 KT	96	95	96	92	93	83	78	64	58	40	34	27	22	15	9	3	0	0	0	0	0	0	0	0
Wind Gusts GT 50 KT	67	71	65	47	39	33	25	18	12	7	4	2	0	0	0	0	0	0	0	0	0	0	0	0
Wind Gusts GT 65 KT	19	17	14	10	8	4	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LLWS GT 30 KT	23	14	6	2	1	0	0	0	0	6	6	0	0	1	0	0	0	0	0	0	0	0	0	0
SUS XWND GT 15 KT RWY:26T	96	99	99	98	98	98	96	89	76	77	61	58	48	40	26	14	4	1	1	1	2	2	2	1
SUS XWND GT 25 KT RWY:26T	74	80	78	71	62	63	58	47	34	32	16	10	5	4	2	1	0	0	0	0	0	0	0	0
SUS XWND GT 35 KT RWY:26T	23	19	21	20	25	18	15	9	7	5	3	2	1	1	0	0	0	0	0	0	0	0	0	0
Precipitation	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Precip GT 0.05 IN in 6 hr	94	100	100	100	94	94	86	61	30	26	25	18	11	2	0	0	0	0	0	3	6	6	6	6
Precip GT 2.0 IN in 12 hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FZRA GT 0.01 IN	98	86	74	60	20	20	20	14	13	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0
SN GT 0.1 IN	46	43	45	33	39	45	46	36	36	22	20	8	6	4	0	0	6	6	6	6	6	6	9	18
SN GT 2.0 IN in 12 hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SN GT 6.0 IN in 24 hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thunderstorms	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lightning within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tornado within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cig + Vis	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Visibility LT 5 miles	98	94	86	78	48	34	34	20	20	14	13	2	0	0	0	2	4	7	7	8	18	20	25	30
Visibility LT 3 miles	94	91	86	67	39	34	33	20	18	12	8	1	0	0	0	1	1	4	7	6	8	10	18	22
Visibility LT 1 mile	86	83	68	42	28	22	18	11	6	2	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Ceiling LT 3000 ft	43	38	46	32	26	18	23	13	1	0	0	0	0	1	6	6	6	7	10	11	14	21	26	26
Ceiling LT 1000 ft	9	10	10	6	5	3	4	2	0	0	0	0	0	0	1	2	2	2	2	2	2	3	5	6
Ceiling LT 500 ft	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Others	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Mean Temperature (F)	29	29	29	28	25	23	21	20	18	16	15	15	14	13	13	10	8	7	7	6	7	7	7	7
Mean Wind Speed (KT)	37	37	34	32	32	30	27	24	21	21	19	16	15	13	12	8	7	7	5	5	5	5	5	5
Prob GT 80% Cloud Cover	44	38	46	34	27	26	33	26	11	11	14	14	14	21	22	23	19	15	19	16	22	36	38	39
Station Adj ALSTG	2994						3004						3024						3035					

SAT 10

Surface winds	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13
Wind Gusts GT 25 KT	0	0	0	0	0	0	0	0	1	1	3	2	1	3
Wind Gusts GT 35 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind Gusts GT 50 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind Gusts GT 65 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LLWS GT 30 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUS XWND GT 15 KT RWY:26T	0	0	0	0	0	1	1	2	2	5	4	3	5	7
SUS XWND GT 25 KT RWY:26T	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUS XWND GT 35 KT RWY:26T	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Precipitation	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13
Precip GT 0.05 IN in 6 hr	6	6	6	8	11	14	16	17	14	14	14	6	11	11
Precip GT 2.0 IN in 12 hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FZRA GT 0.01 IN	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SN GT 0.1 IN	26	26	28	34	38	40	40	40	40	36	42	38	38	31
SN GT 2.0 IN in 12 hr	1	2	4	6	6	6	6	6	6	7	7	0	3	4
SN GT 6.0 IN in 24 hr	0	0	0	0	0	0	1	2	3	4	4	0	0	0
Thunderstorms	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13
Lightning within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.0 IN Hail within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tornado within 20 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cig + Vis	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13
Visibility LT 5 miles	27	27	38	40	34	34	34	34	33	30	29	23	27	37
Visibility LT 3 miles	26	26	34	35	30	29	30	30	24	25	24	18	14	30
Visibility LT 1 mile	3	6	10	13	10	9	10	13	14	6	5	6	1	10
Ceiling LT 3000 ft	24	30	29	20	11	11	11	13	13	15	26	11	12	25
Ceiling LT 1000 ft	2	2	2	2	2	2	2	2	2	2	12	1	1	6
Ceiling LT 500 ft	0	0	0	0	0	0	0	0	0	0	4	0	0	1
Others	0Z	01	02	03	04	05	06	07	08	09	10	11	12	13
Mean Temperature (F)	8	8	8	8	7	7	6	6	4	5	3	3	3	3
Mean Wind Speed (KT)	6	6	4	4	5	6	6	6	6	5	5	5	4	5
Prob GT 80% Cloud Cover	39	46	44	30	28	26	29	28	34	32	28	21	18	30
Station Adj ALSTG	3037						3038						3047	

O2R2O: Addition of Trend Information

Probabilistic Forecast Trends in the last 12 hours:

>15% increase

>15% decrease

Select a model GEPS **20km MEPS** 4km MEPS 1km MEPS

Enter an ICAO KMCI Submit

Select a time Most recent

POINT ENSEMBLE PROBABILITY

How to use this product

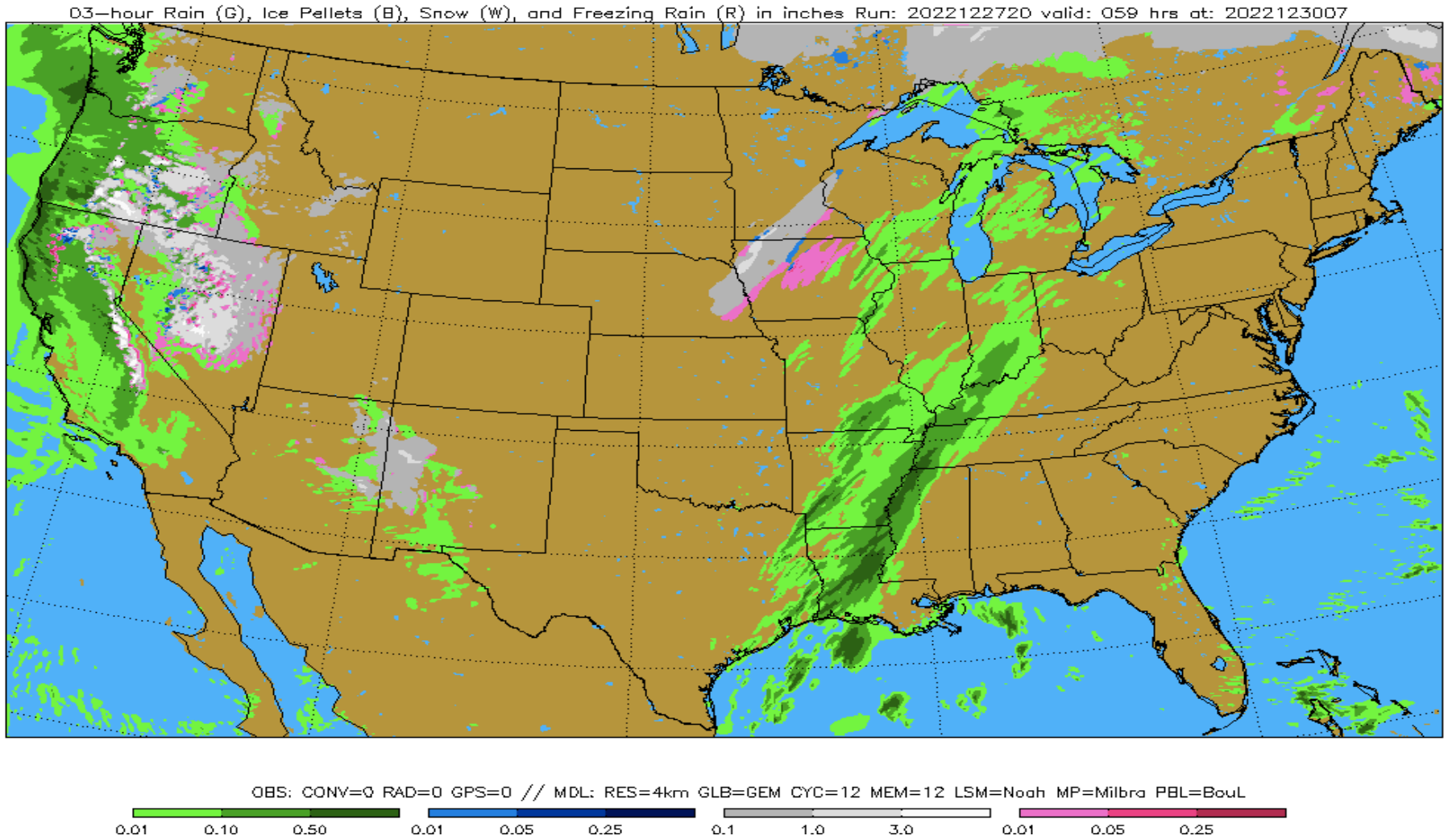
KANSAS CITY INTL 39.3000 lat -94.7100 lon 313 meters elevation
MODEL BOX INFO 39.2949 lat -94.8046 lon 274 meters elevation
20 km MEPS APR 25/22Z 2023

MAROON: >15% increase in last 12 hours
BLUE: >15% decrease in last 12 hours

	WED 26												THR 27												FRI 28												SAT 29						
Surface winds	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12
Wind Gusts GT 25 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	14	24	28	28	30	25	28	30	32	30	34
Wind Gusts GT 35 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	2	2	2	2	2	3	6	6	7
Wind Gusts GT 50 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind Gusts GT 65 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LLWS GT 30 KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1	0	0	0	0	7	22	22	22	21	15	17
SUS XWND GT 15 KT RWY:19L	0	0	0	1	0	0	1	1	1	1	2	1	0	0	0	0	-99	0	0	0	0	0	1	2	0	0	0	0	0	0	2	2	10	13	7	9	9	5	16	12	14	13	14
SUS XWND GT 25 KT RWY:19L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1
SUS XWND GT 35 KT RWY:19L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Precipitation	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12
Precip GT 0.05 IN in 6 hr	-99	-99	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	10	10	7	2	11	24	28	28	23	8	10	20	22	34	30	40	66	80	87	76	55	44	42	38
Precip GT 2.0 IN in 12 hr	-99	-99	-99	-99	-99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1
FZRA GT 0.01 IN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SN GT 0.1 IN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
SN GT 2.0 IN in 12 hr	-99	-99	-99	-99	-99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SN GT 6.0 IN in 24 hr	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thunderstorms	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12
Lightning within 10 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	3	3	2	1	0	0	0	0
Svr Wx within 25 NM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cig + Vis	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12
Visibility LT 5 miles	0	0	1	6	12	16	22	7	0	0	0	0	0	0	1	2	3	6	17	14	4	2	6	12	13	33	46	64	66	63	67	53	34	15	10	25	27	23	22	20	20	26	19
Visibility LT 3 miles	0	0	0	1	2	3	5	4	0	0	0	0	0	0	0	0	1	1	6	10	1	1	3	6	5	16	24	38	42	37	38	26	14	5	2	10	9	6	7	7	6	10	10
Visibility LT 1 mile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	1	2	3	5	6	4	2	2	0	0	0	0	1	1	1	0	0	4
Ceiling LT 3000 ft	3	5	3	2	0	2	7	19	4	0	2	2	0	4	9	10	3	0	18	21	26	35	41	30	34	45	35	46	38	59	69	77	79	79	67	78	64	74	72	71	63	62	49
Ceiling LT 1000 ft	0	0	0	0	0	2	7	15	4	0	0	0	0	0	1	1	0	0	2	6	9	8	10	18	20	32	27	40	34	46	55	66	70	48	38	47	32	33	32	27	29	22	14
Ceiling LT 500 ft	0	0	0	0	0	1	6	6	2	0	0	0	0	0	0	0	0	0	0	1	1	2	5	8	11	17	16	26	23	29	38	44	34	9	8	18	18	14	10	4	9	2	2
Others	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12	14	16	18	20	22	0Z	02	04	06	08	10	12
Mean Temperature (F)	59	54	50	49	46	44	42	48	55	60	62	62	59	53	50	48	46	44	44	50	56	60	61	60	58	52	50	49	49	48	47	49	52	52	53	50	49	46	45	44	43	42	40
Mean Wind Speed (KT)	5	4	5	8	8	8	7	8	7	7	8	8	5	5	5	4	3	3	4	4	4	5	7	7	7	5	5	5	5	4	5	7	8	10	12	13	12	11	12	12	13	13	13
Prob GT 80% Cloud Cover	47	45	41	23	8	17	22	32	43	51	66	58	46	37	25	34	26	30	34	34	43	61	62	64	57	54	47	62	70	83	86	78	80	80	73	92	94	90	87	89	82	62	59
Station Adj ALSTG	3005			3012			3017			3016			3009			3010			3005			2993			2979			2972			2973			2977			2981			2983			2982

Example of 4km MEPS:

CONUS Theater, Precipitation Type at T+59hr



R2O Process: Stakeholder Engagement

- These are examples of improvements directly from stakeholder engagement
- R2O should involve O back to the R...
  - Operators feedback to the Researchers, or "Users to the Developers"
- 16 WS proactively stood up SE Team to formalize this process - O2R
  - Began with surveys, over 100 organizations contacted now...
    - What do you use, where are shortcomings, what do you need?
  - Visits to bases and airfield OPS – in-person if possible, or via zoom as nec.
  - Get to true users at "pointy tip of the spear" -- weather and non-weather operators
- Process went beyond "what" is needed & into the "why" it is needed
    - Researchers and developers need to understand operations and wx impacts
      - Learn about use-cases and how forecast data applied
    - Operators may not know what to ask for, nor what we have the capability to provide

Continuous SE Feedback - O2R2O

- Researchers and developers receive a solid understanding of:
  - How we can help
  - How our products are used
  - Downfield Intel and use-cases; more complete case studies
- Users too gain a better understanding of:
  - What we and the models can provide
  - The current limitations of the model data
  - What the products they receive really mean
  - Guidance on how forecast data can be applied to their use-cases
- "O2R2O" -- user feedback > development > OPS loop – "continuous R2O"

R2O Evolution, Lessons Learned

- New AFWERX (SPACEWERX) agile innovation construct
  - Technology directorate of the AFRL, innovation arm of USAF
  - Teaming across academia, industry, interagency/int'l partners
    - Help w/ networking (SBIR/STTR), funding (STRATFI/TACFI), problem solving, transition
    - Foster collaboration & innovation for faster and affordable capability transition
    - 4 cores of AFWERX: AFVentures, Spark, Prime, SpaceWERX (learn more: https://afwerx.com)
- R2O Lessons Learned from various types of programs include...
  - Enable continuous feedback with users, keep progressing forward toward real need
    - Include weather piece and SME(s) right from the start
    - Consider weather impacts on mission success from very beginning of design
    - Test in adverse weather; Avoid expensive and/or difficult retrofitting
- O2R2O is a continuous process & needed to provide best actionable support

More Information

- Thank you for the opportunity to provide some thoughts from this middle and lower level perspective. We call it "grass roots" at times...

- Please contact me with any questions!

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