MET 3502 Synoptic Meteorology

Lecture 5: Forecasting Temperatures

Forecasting Temperatures

Considerations

- Humidity (specific heat of water vapor is much larger than specific heat of dry air)
- Surface characteristics (vegetation, elevation, etc.)
- Length of Day
- Advection
- Wind speed
- Latent heat
- Precipitation
- Local effects

(city island, fire, etc.)

- Air mass changes
- Measurements

Temperature tendency equation

$$\frac{\partial T}{\partial t} = -\mathbf{V} \bullet \nabla_p T - \omega \frac{T}{\theta} \frac{\partial \theta}{\partial p} + \frac{1}{C_p} \frac{DQ}{Dt}$$

Local rate of change of temperature

Horizontal advection

Vertical Advection (turbulence)

Diabatic heating/ cooling

- To **forecast future temperature**, you'll start with current temperature. Then add on the local rate of change of temperature. In order to estimate the local rate of change of temperature, you need to estimate horizontal temperature/thermal advection, vertical thermal advection, and diabatic heating/cooling. **In fact, the horizontal temperature advection is more important than the other two terms.**

Major Factors for Temperature Forecasting

1. Horizontal thermal advection (remember thermal advection is a function of the thermal gradient, the wind speed through the thermal gradient, and the angle the wind is through the temperature gradient)

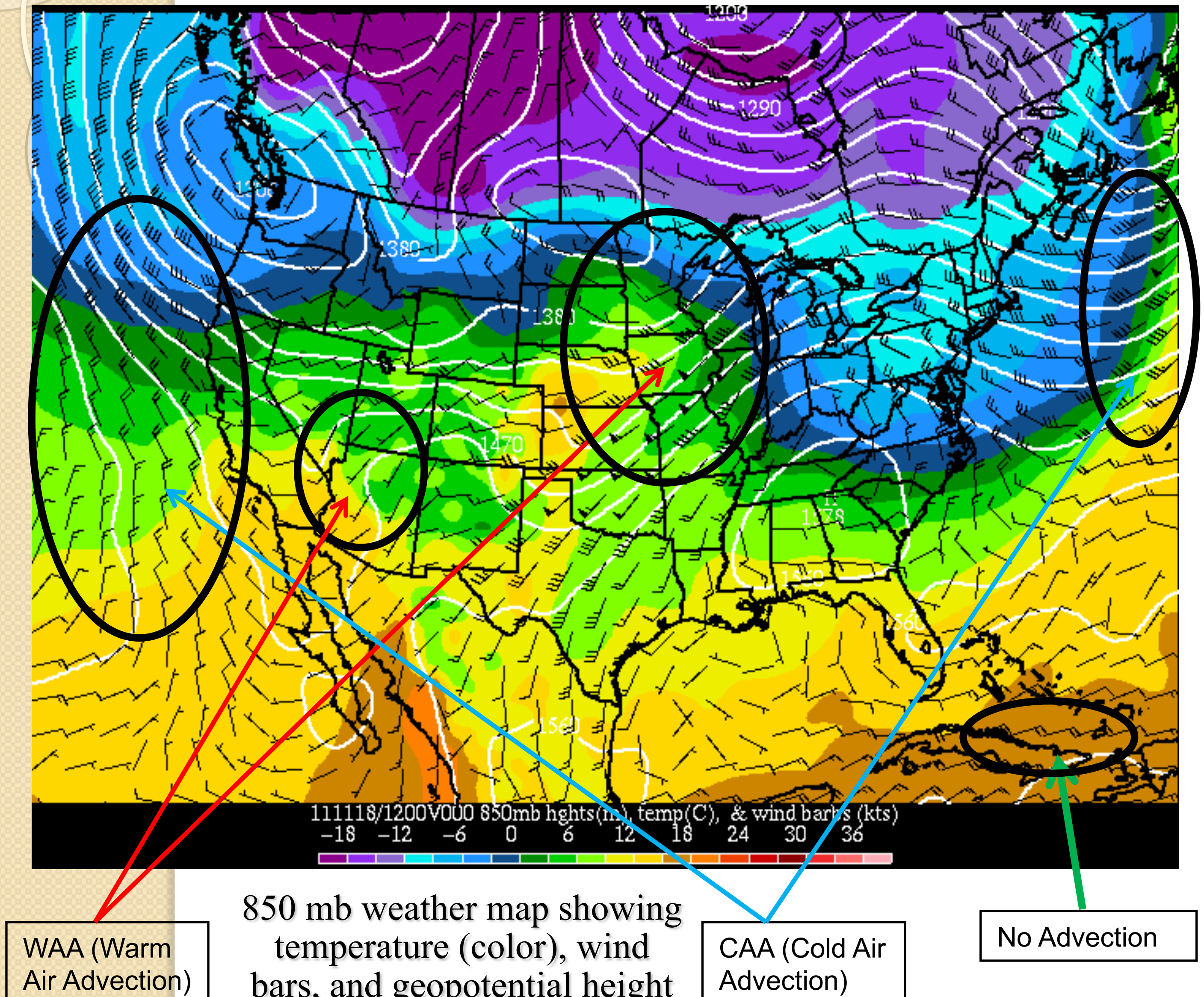
2. Keep in mind the soil temperatures, cloud cover / lack of cloud cover and snow cover. These three parameters will modify air temperature as an air mass advects.

3. Wind speed/ direction, location of source air masses

4. Pressure pattern

Keep in mind that the other processes in the temperature equation (vertical motion, diabatic effects) may modify the magnitude of the horizontal advection term locally!

How to identify/estimate cold/warm advection on a weather map?



850 mb weather map showing temperature (color), wind bars, and geopotential height contours at 850-mb pressure surface

1) In the location you are interested in, identify the wind direction and the temperature contours (different colors)
2) If the wind direction is parallel with the contours, no advection.
3) If not parallel, determine how the wind is blowing the cold or warm air mass.
If the wind is blowing cold (warm) air to your location of interest, then it's cold (warm) advection.
3) Temperature advection is large if the angle between wind direction and temperature contours is nearly 90 degree, or wind speed is large, or the temperature gradient is large (contours are very close to each other).
4) Temperature advection is zero if no temperature gradient (all same color in an area) or if the wind speed is zero.

Forecasting Temperatures (major considerations)

High and low temperatures are a primary function of thermal advection, wind speed, cloud cover, dewpoint and the number of daylight hours.

*Highs can be less than expected due to Cold Air Advection (CAA), high wind speed, increased cloud cover, higher dewpoint and shorter daylength.

*Highs can be greater than expected due to Warm Air Advection (WAA), low wind speed, decreased cloud cover, lower dewpoint and longer daylength.

*Lows can be less than expected due to CAA, low wind speed, decreased cloud cover, lower dewpoint and longer nights.

*Lows can be greater than expected due to WAA, high wind speed, increased cloud cover, higher dewpoint and shorter nights.

Forecasting Temperatures (other factors)

- Mesoscale effects:
  - such as urban heat islands, differential vegetation, topography, nearby lakes / rivers / oceans and altitude must also be taken into consideration

- Effects of wind speed on temperature
  - Low wind speed on sunny days will result in warmer temperatures than if the winds were stronger. With light winds, heat can build right at the surface without being significantly mixed with cooler air aloft. This can form what is known as the superadiabatic lapse rate. This is the opposite case on a clear night.
  - Light wind at night – cooler, because it does not allow radiationally cooled air at surface to mix with warmer air aloft.

Fronts

- Fronts may cause highs and lows to occur at untraditional times during the day. In association with a strong cold front, the high will occur before frontal passage and the low will usually occur at midnight on the second night
- The timing of the front is critical in determining what the high will be before the front passes

Terrain

- Sloped terrain produces downsloping and upsloping wind especially when the wind direction is perpendicular to the slope of the terrain.
- A wind direction forecast is critical in determining how much adiabatic warming or cooling will occur along the slope.
- Upslope cooling in the cool season can produce adiabatic cooling and snow while downslope flow produces adiabatic warming and a chinook wind (A warm, dry wind that descends from the eastern slopes of the Rocky Mountains).

Precipitation

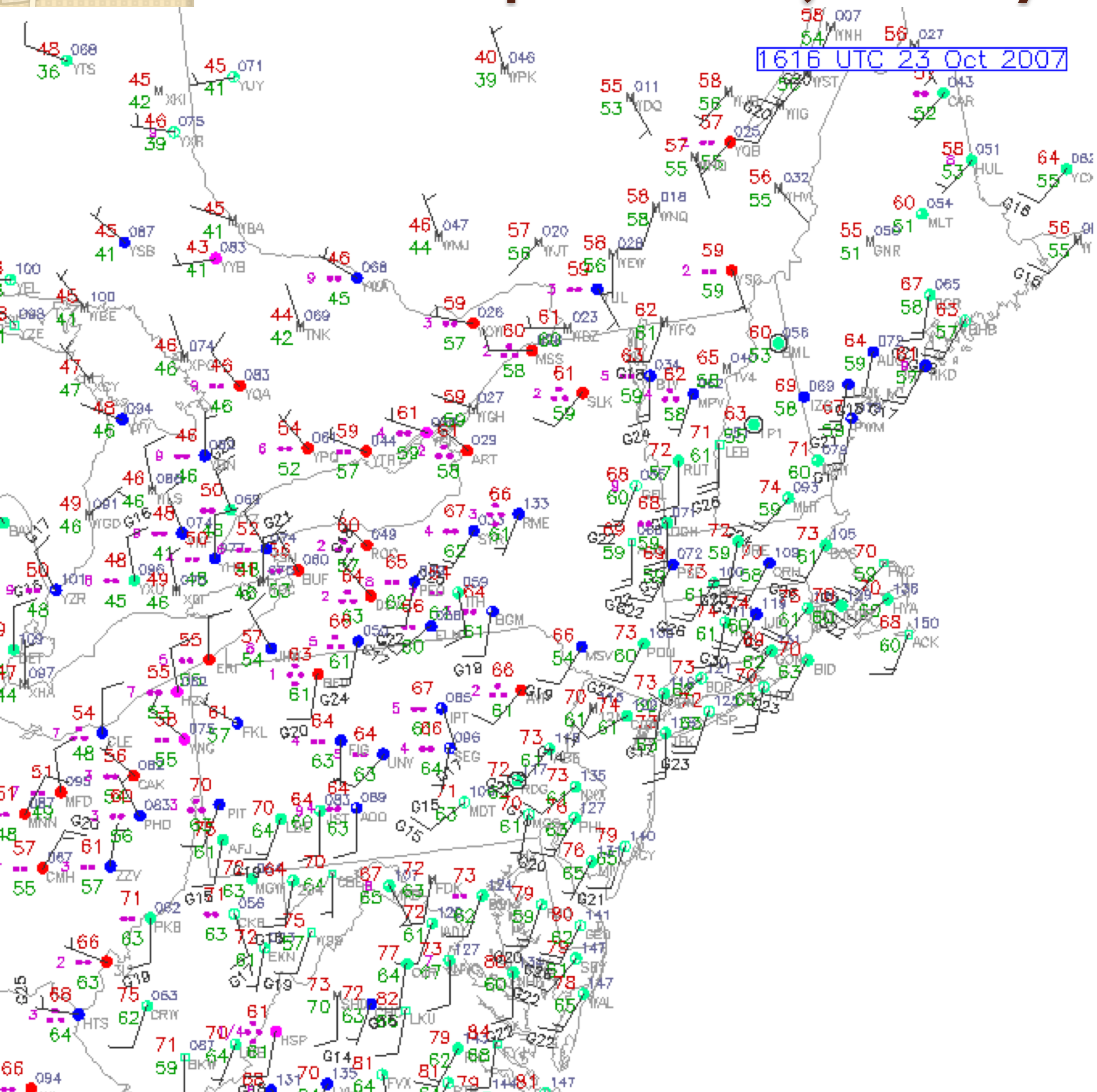
- *Wet-bulb cooling* will occur over regions precipitation occurs. If the precipitation forecast is incorrect, odds are the temperature forecast will suffer also.
- Heavy rain will tend to cool the atmosphere to the wet-bulb temperature in 1 hour, light to moderate rain in 2-3 hours
- Afternoon thunderstorms can cause the high temperature to be cooler than predicted. Any rain during any time of the day will cause evaporational cooling at the surface. The low level dewpoint depression (dewpoint depression=T-Td) determines how much surface temperatures will cool. A high dewpoint depression will result in a greater evaporational cooling.
- Convective thunderstorms also transport air from higher in the atmosphere to the surface. This will alter surface temperatures greatly in these downdraft regions.

Temperature Forecasting Methods

Trajectory method

- Examine surface trajectories to find the origin of air parcels that will be in the forecast area during the forecast period
- Correct for changes in elevation (rising air cools at 5.5F/1000ft if unsaturated, 3.3F/1000ft if saturated, warms at 5.5F/1000ft if sinking)
- Factor in modification of air for changes in surface type, cloud cover, wind, and precipitation

A Surface Map for Trajectory Method Example

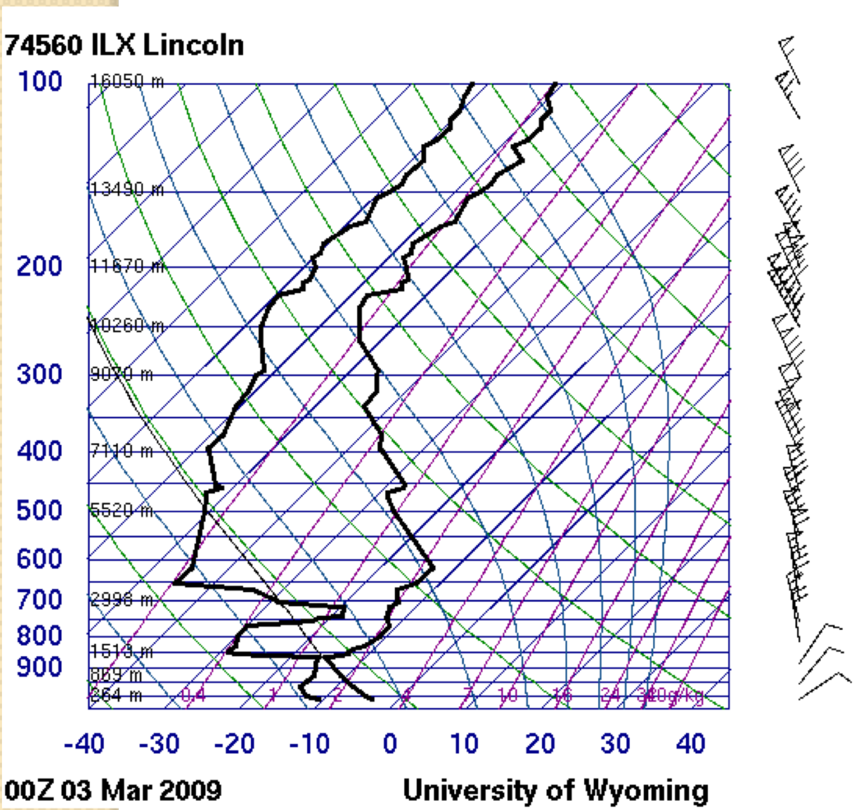


- Winds are from southwest in the east coast regions.
- The next day, the temperature in the north along the east coast will be warmer than the current due to warm air being blowed by the winds from South to the North

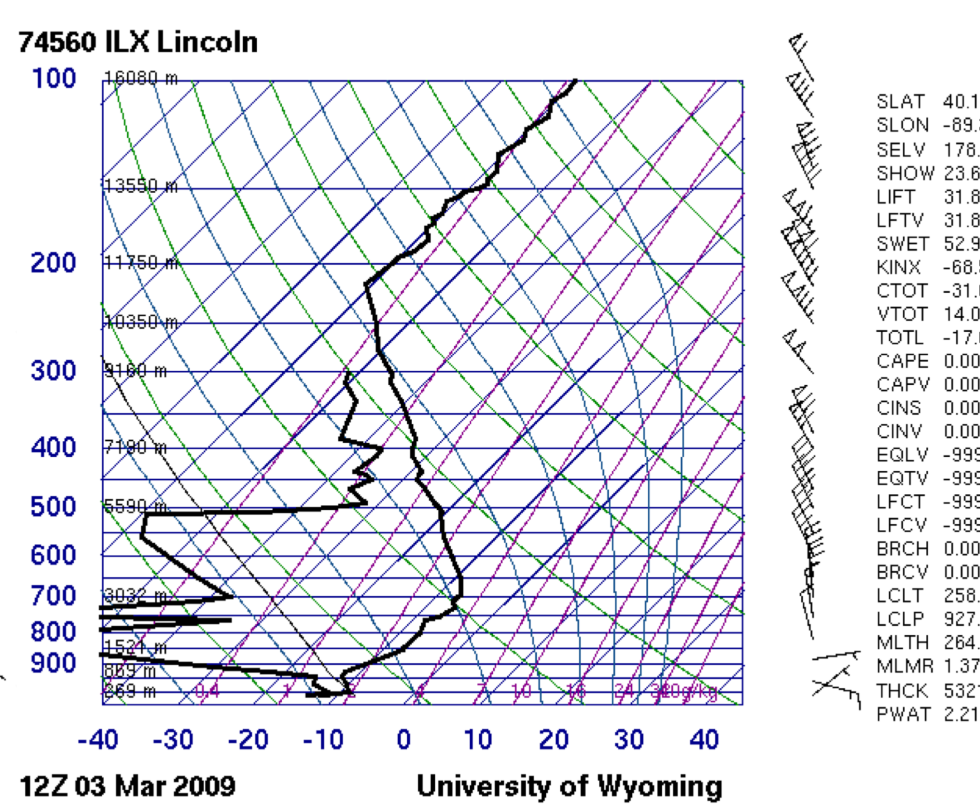
Minimum Temperature

- **Basic sounding method** : 1) At 850 hPa (700 hPa if the sfc is above 850 hPa), find T_d; 2) Extend line moist-adiabatically to surface. 3) Read temperature scale. 4) If airmass changes are expected, use a forecast sounding.
- Sounding on the left is used to determine Tmin=-15 deg C; Sounding on the right is used to verify that the next morning's surface T is about -15 deg C.

19pm (00 Z)



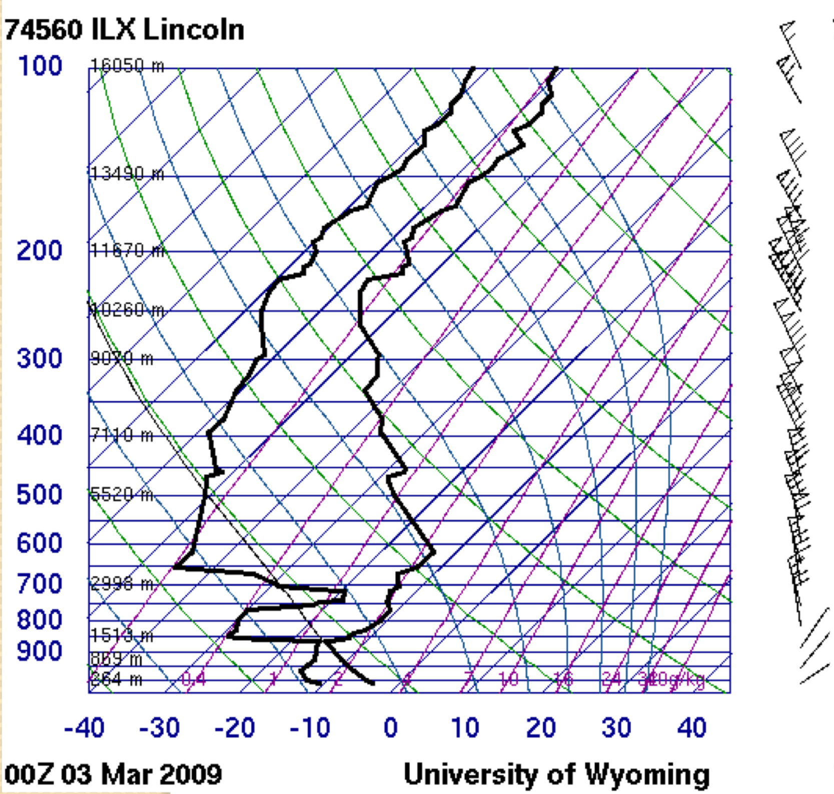
7am (12 Z) next day



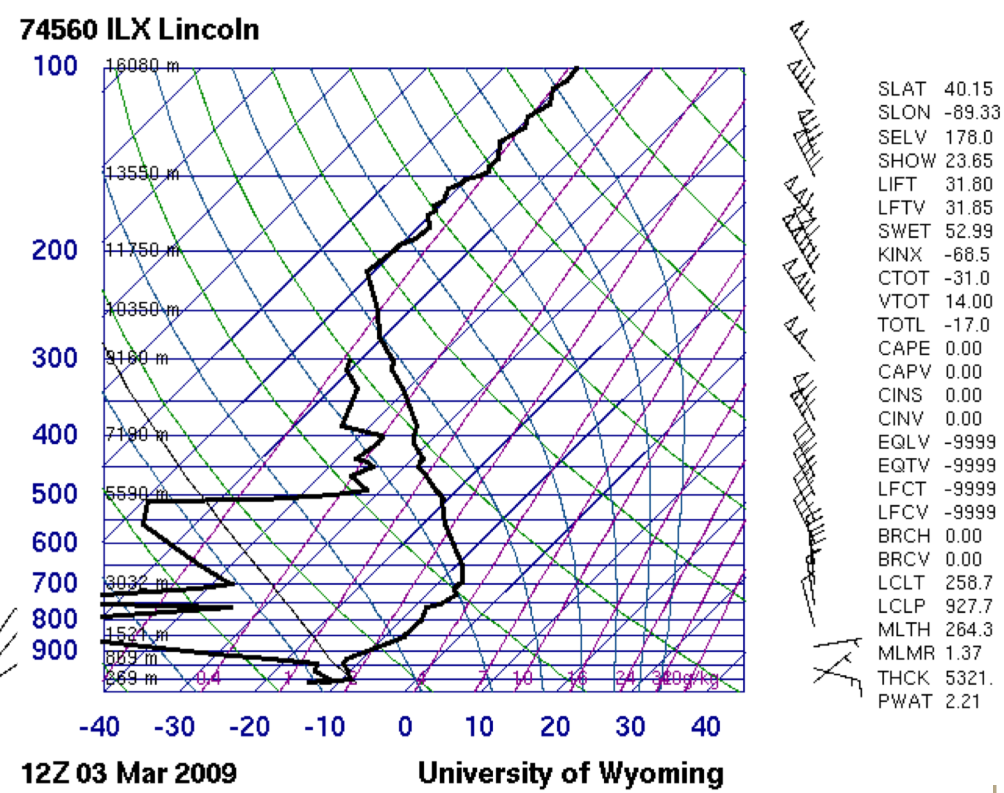
Minimum Temperature

- **Dewpoint method** 1) Find max temp in the day 2) read T_d; T_d will be following morning's min T; 3) Most accurate with clear/scattered sky and light and variable wind; 4) During non-summer periods on flat terrain, or in valleys, subtract 4 to 7 degrees.
- The 19pm sounding on the left is used to determine Tmin=-10 deg C; Sounding on the right is used to verify that the next morning's surface T is about -15 deg C. This is a bit off because the max temperature should be around 14 pm, not 19pm.

19pm (00 Z)



7am (12 Z) next day



Minimum Temperature

- **Craddock-Lowe method**

$$T_{min} = 0.32T + 0.55T_d + 2.12 + C$$

Early afternoon readings of T, Td

If winds are < 10 kt	If winds are > 10 kt
C=-3 if cloud cover is 0-2 oktas	C=0, except
C=-2 for 3 oktas (3/8 cloud cover)	C=-1 for 0-2 oktas
C=-1 for 4-5 oktas	C=+1 for 6-8 oktas (6/8 to 8/8)
C=0 for 6-8 oktas	

Maximum Temperature

- **Simple sounding method** (using a morning sounding) 1**) At 850 mb, find T. 2) In a clear/scattered sky, or when a warm front is approaching, extend line dry-adiabatically to surface; In broken or overcast skies, use** the moist adiabat, extend line moist-adiabatically to surface. 3) Read temperature scale.
- Alternate method (if clear, scattered clouds and if there is an inversion present with top between 4000 and 6000 ft Above Ground Level):
  1) Find T at warmest point in inversion. 2) Extend a line dry-adiabatically to surface. 3) Read temperature scale. (works best in warm season)

Using Models To Predict Temperature

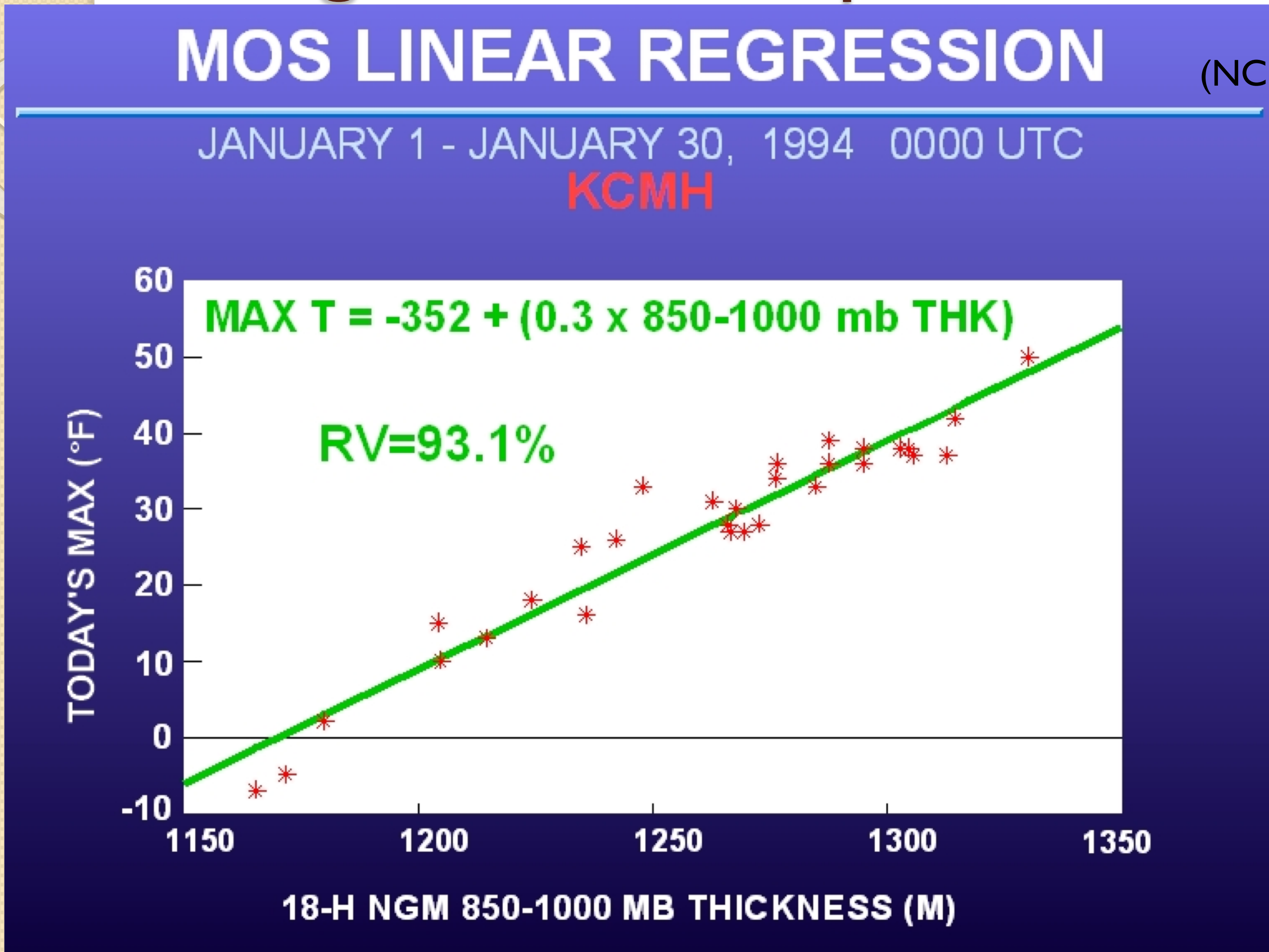
- You can use model output directly to forecast temperature (e.g. in IDV, GARP, or on the web)
- What level is the model output for?
- Large errors can be introduced if:
  - the model initialization is poor
  - physical processes are incorrectly parameterized (e.g. radiation, clouds, precipitation, boundary layer turbulence)
  - phenomena occur on scales smaller than are resolved by the model
  - numerical or other errors

Forecaster's aide: Model Output Statistics (MOS)

- Regression equations are fit to past forecasts compared with verification and climatology in an attempt to reduce systematic and random errors associated with the prediction of forecast variables
- Variables which are found to be statistically related to a forecast variable are used to predict a variable in MOS (use variables that are better predicted by models to help reduce biases in variables that are poorly predicted)
- Predict what the model doesn't (i.e. probability of precipitation)
- Produce site specific forecasts

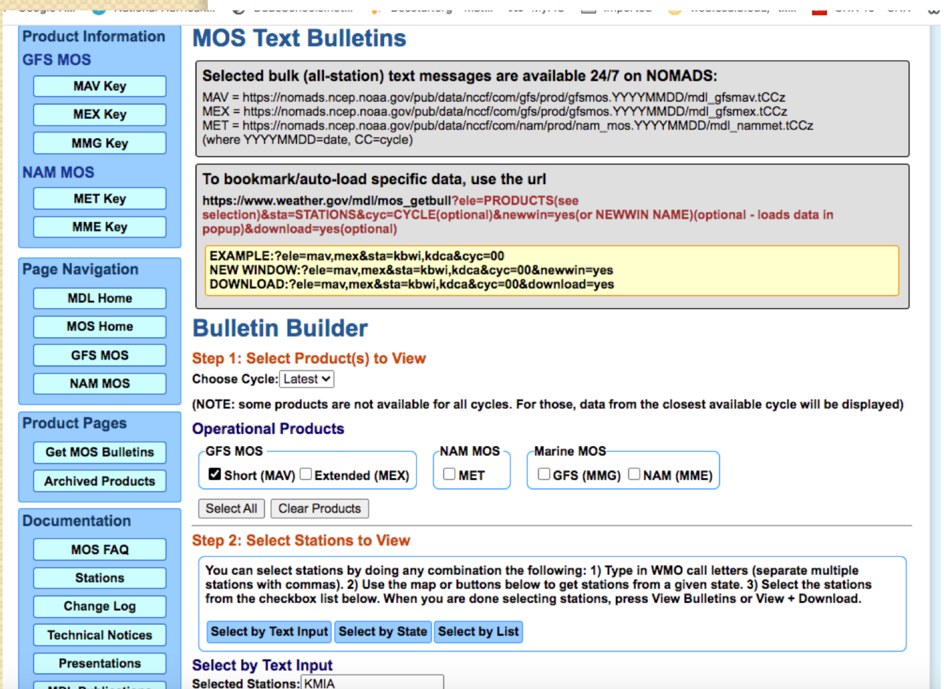
MOS regression example

(NCEP)



Short-range GFS-Based MOS (MAV)

- The short-range GFS-Based MOS MAV guidance is generated from 0000, 0600, 1200, and 1800 UTC model output from NCEP's Global Forecast System (GFS). This guidance is valid for stations in the United States, Puerto Rico, and the U.S. Virgin Islands. Forecast elements are valid from 6 to 72 hours in advance.
- How to get real-time MEX: go to here and select the correct product (MAV) & enter the station key (KMIA for Miami): https://www.weather.gov/mdl/mos_getbull#top

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KMIA    GFS MOS GUIDANCE    1/22/2022  1200 UTC
DT /JAN  22/JAN  23                /JAN  24                 /JAN  25
HR   18 21 00 03 06 09 12 15 18 21 00 03 06 09 12 15 18 21 00 06 12
N/X                    60          75          52          69    58
TMP  74 73 70 67 64 62 61 66 73 74 69 63 57 54 52 60 67 69 64 60 61
DPT  65 63 63 60 59 58 57 58 56 54 53 50 47 45 43 42 42 42 45 53 56
CLD  OV OV OV OV OV OV OV BK BK BK SC FW FW SC FW CL CL CL CL SC SC
WDR  32 33 34 33 34 33 33 32 32 30 29 29 30 31 31 32 28 14 14 29 12
WSP  06 06 06 03 04 05 06 05 07 07 05 05 05 05 05 05 05 06 03 01 03
P06        53    44    23    12     3     6     2     5     1  4  8
P12                    44          15           6           5     8
Q06         1     1     0     0     0     0     0     0     0  0  0
Q12                     1           0           0           0     0
T06      6/ 3  1/ 0  1/ 0  1/ 0  0/ 4  1/ 3  0/ 6  0/ 4  0/ 0  0/ 0
T12            7/ 3        2/ 0        1/ 7        0/ 6     0/ 2
POZ   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
POS   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
TYP   R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R
CIG   5  4  4  4  5  5  5  6  6  8  8  8  8  8  8  8  8  8  8  8  8
VIS   7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7
OBV   N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N
```

Description of MAV

- General information: https://vlab.noaa.gov/web/mdl/mav-card
- Detailed Documentation about MAV:
  - 0000/1200 UTC forecast cycle: https://www.weather.gov/media/mdl/mdltpb05-03.pdf
  - 0060/1800 UTC forecast cycle: https://www.weather.gov/media/mdl/mdltpb05-04.pdf
- Simple parameter explanations below:

- **DT** = The day of the month, denoted by the standard three or four letter abbreviation
- **HR** = Hour of the day in UTC time. This is the hour at which the forecast is valid, or if the forecast is valid for a period, the end of the forecast period.
- **N/X** = nighttime minimum/daytime maximum surface temperatures.
- **TMP** = surface temperature valid at that hour.
- **DPT** = surface dewpoint valid at that hour.
- **CLD** = forecast categories of total sky cover valid at that hour.
- **WDR** = forecasts of the 10-meter wind direction at the hour, given in tens of degrees.
- **WSP** = forecasts of the 10-meter wind speed at the hour, given in knots.
- **P06** = probability of precipitation (PoP) during a 6-h period ending at that time.
- **P12** = PoP during a 12-h period ending at that time.
- **Q06** = quantitative precipitation forecast (QPF) category for liquid equivalent precipitation amount during a 6-h period ending at that time.
- **Q12** = QPF category for liquid equivalent precipitation amount during a 12-h period ending at the indicated time.
- **SNW** = snowfall categorical forecasts during a 24-h period ending at the indicated time.
- **T06** = probability of thunderstorms/conditional probability of severe thunderstorms during the 6-hr period ending at the indicated time.
- **T12** = probability of thunderstorms/conditional probability of severe thunderstorms during the 12-hr period ending at the indicated time.
- **POZ** = conditional probability of freezing pcp occurring at the hour.
- **POS** = conditional probability of snow occurring at the hour.
- **TYP** = conditional precipitation type at the hour.
- **CIG** = ceiling height categorical forecasts at the hour.
- **VIS** = visibility categorical forecasts at the hour.
- **OBV** = obstruction to vision categorical forecasts at the hour.

Another MAV Example for Miami

Miami FL:

KMIA GFS MOS GUIDANCE 8/29/2010 1800 UTC

DT	/AUG 30								/AUG 31								/SEPT 1				
HR	00	03	06	09	12	15	18	21	00	03	06	09	12	15	18	21	00	03	06	12	18
N/X					78				88				80				91			81	
TMP	83	82	81	80	81	85	85	85	83	82	82	81	82	87	91	90	85	84	83	84	90
DPT	75	75	75	75	75	74	73	73	73	73	73	73	73	72	72	72	73	74	74	74	72
CLD	OV	OV	OV	OV	OV	OV	OV	OV	OV	BK	OV	BK	BK	SC	SC	SC	SC	SC	BK	SC	BK
WDR	07	07	06	07	07	08	08	07	06	07	08	08	08	08	08	08	07	07	07	05	06
WSP	07	07	08	08	08	12	14	14	11	12	13	12	11	15	14	15	14	13	11	09	13
P06			26		16		34		50		27		16		7		7		6	3	4
P12					33				59				38				11			6	
Q06			0		0		1		1		0		0		0		0		0	0	0
Q12					1				2				1				0			0	
T06			31/ 0		16/ 0		59/ 0		70/ 0		34/ 1		20/ 0		16/ 0		27/ 1		12/ 1		5/ 0
T12							60/ 0				72/ 1				20/ 0				31/ 2		14/ 1
CIG	8	8	8	7	6	6	6	7	8	6	6	6	6	8	8	8	8	8	6	8	8
VIS	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
OBV	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

Extended-range (long-term) GFS-Based MOS (MEX)

- The extended-range GFS-Based MOS (MEX) guidance is generated from the 0000 and 1200 UTC cycles of NCEP's Global Forecast System (GFS) Model. This guidance is valid for stations in the United States, Puerto Rico, and the U.S. Virgin Islands. Forecast elements are valid from 24 to 192 hours in advance.
- How to get real-time MEX: go to here and select the correct product (MEX) & enter station key (KMIA): https://www.weather.gov/mdl/mos_getbull#top

MEX TEXT BULLETIN

KMIA GFSX MOS GUIDANCE 1/22/2022 1200 UTC

FHR	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192		
	SUN	23	MON	24	TUE	25	WED	26	THU	27	FRI	28	SAT	29	SUN	CLIMO	
N/X	60	75	52	69	58	77	69	81	62	77	64	78	66	76	50	57	76
TMP	61	69	52	64	61	73	71	73	63	71	66	73	67	67	51		
DPT	57	53	43	45	56	63	69	65	57	58	59	64	61	56	43		
CLD	OV	PC	PC	CL	PC	OV	OV	OV	PC	PC	OV	OV	OV	OV	OV		
WND	6	7	5	6	3	13	10	11	6	10	10	14	14	13	9		
P12	44	15	6	5	8	12	46	45	22	12	22	27	36	27	15	12	14
P24		44		11		12		58		24		28		57			22
Q12	1	0	0	0	0	0	1	1	0	0	0	0					
Q24		1		0		0		2		0		0					
T12	2	2	1	0	0	2	8	10	2	3	3	4	12	5	1		
T24			2		0		9		10		3		15		17		
PZP	0	0	0	0	0	0	2	1	1	1	1	0	3	0	1		
PSN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
PRS	0	0	0	0	1	0	0	1	0	1	0	1	2	2	1		
TYP	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R		

Description of MEX

- General information: https://vlab.noaa.gov/web/mdl/mex-card
- Detailed Documentation about MEX:
  - 0000/1200 UTC forecast cycle: https://www.weather.gov/media/mdl/mdltpb2010-01.pdf
- Simple parameter explanations below:

- **FHR** = Forecast hour, i.e. how many hours from the model run time
- **X/N** = daytime max/nightime min temperatures
- **TMP** = temperature valid at that hour
- **DPT** = dewpoint valid at that hour
- **CLD** = mean total sky cover over the 12-hr period ending at that time
- **WND** = maximum sustained surface wind (WND) during a 12-h period
- **P12** = 12-hr probability of precipitation (PoP) ending at that time
- **P24** = 24-hr PoP ending at that time
- **Q12** = 12-hr quantitative precipitation forecast (QPF) ending at that time
- **Q24** = 24-hr QPF ending at that time
- **T12** = 12-hr probability of thunderstorm ending at that time
- **T24** = 24-hr probability of thunderstorm for the 1200-1200 UTC time period ending at that time
- **PZP** = conditional probability of freezing pcp occurring for the 12-hr period ending at that time
- **PSN** = conditional probability of snow occurring for the 12-hr period ending at that time
- **PRS** = conditional probability of rain/snow mix occurring for the 12-hr period ending at that time
- **TYP** = conditional precipitation type for the 12-hr period ending at that time
- **SNW** = snow fall categorical forecasts during a 24-h period ending at the indicated time.

- **CLIMO** = Go here for more information on climatology

Another MEX Example for Miami

KMIA GFSX MOS GUIDANCE 8/29/2010 1200 UTC

FHR	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192		
	MON	30	TUE	31	WED	01	THU	02	FRI	03	SAT	04	SUN	05	MON	CLIMO	
N/X	78	89	79	92	81	91	79	92	78	93	79	92	79	92	78	75	90
TMP	80	84	82	86	84	84	82	85	81	85	81	85	82	85	81		
DPT	75	73	73	73	74	72	71	70	72	71	74	72	75	71	74		
WND	11	14	13	16	14	14	10	9	8	9	7	9	6	9	7		
P12	29	43	28	20	15	5	12	7	11	20	14	16	13	23	18	33	46
P24		58		41		15		16		27		22		30			59
Q12	0	1	0	0	0	0	0	0	0	0	0	0					
Q24		1		0		0		0		0		0					
T12	41	80	21	42	9	9	0	10	3	6	0	7	19	62	32		
T24			80		42		9		10		6		35		69		

So, why not use MOS all of the time?? (or, why do we still need human forecasters?)

- Models will produce results that statistics can’t correct for
- Statistics have uncertainties associated with them (i.e. was regression model appropriate?, scatter about regression line)
- MOS tends to be best in “mundane” weather, worst in extremes → need best forecast in extreme situations