Manual of Weachart

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Forewords

Weachart is a tool that generates multi-element weather charts from GFS data. It updates twice a day (around 09Z and 21Z) and covered a period of 16 days since the data initializing time.

Weachart is a product of 7Timer!.

Explanation and legend

☑ Temperature

The "temperature" batch is consists of

⊕ 2-m above ground temperature

The average 2-m above ground temperature within 3 hours.

⊕ Surface temperature

The average surface temperature within 3 hours.

⊕ Temperature at 1000hPa, 925hPa, 850hPa, 700hPa, 500hPa, 300hPa and 200hPa

The average temperature at a given geopotential height within 3 hours.

⊕ 0-10cm, 10-40cm, 40-100cm and 100-200cm underground temperature

The average temperature of 10-40cm underground within 3 hours.

⊕ 2-m above ground maximum and minimum temperature

The maximum and minimum 2-m above ground temperature within 3 hours.

⊕ Felt-air temperature

Felt air temperature (or apparent air temperature) is the air temperature perceived by the body, which may differ from the actual temperature. It's combined by Heat Index (for temperature above 20C) and Wind Chill (for temperature below 10C). Heat Index can be calculated by

$$HI = \begin{bmatrix} 1 & T & T^2 & T^3 \end{bmatrix} \begin{bmatrix} 16.923 & 5.37941 & 7.28898\times10^{-3} & 2.91583\times10^{-5} \\ 1.85212\times10^{-1} & -1.00254\times10^{-1} & -8.14971\times10^{-4} & 1.97483\times10^{-7} \\ 9.41695\times10^{-3} & 3.45372\times10^{-4} & 1.02102\times10^{-5} & 8.43296\times10^{-10} \\ -3.8646\times10^{-5} & 1.42721\times10^{-6} & -2.18429\times10^{-8} & -4.81975\times10^{-11} \end{bmatrix} \begin{bmatrix} 1 \\ R \\ R^2 \\ R^3 \end{bmatrix}$$

where T is temperature in Fahrenheit and R is relative humidity. On the other hand, Wind Chill can be calculated by

$$T_{wc} = 13.12 + 0.6215T_a - 11.37V^{0.16} + 0.3965T_aV^{0.16}$$

where T_a is air temperature in Celsius and V is wind speed in KPH.

The elements above share the same legend, shown as below:

0C to 5C	5C to 10C	10C to 15C	15C to 20C	20C to 25C	25C to 30C	30C to 35C	35C to 40C	40C to 45C	45C to 50C	50C to 55C	55C to 60C	>60C

<-75C	-75C to -70C	-70C to -65C	-65C to -60C	-60C to -55C	-55C to -50C	-50C to -45C	-45C to -40C	-40C to -35C	-35C to -30C	-30C to -25C	-25C to -20C	-20C to -15C	-15C to -10C	-10C to -5C	-5C to 0C

Or, in Fahrenheit,

32F to 41F	41F to 50F	50F to 59F	59F to 68F	68F to 77F	77F to 86F	86F to 95F	95F to 104F	104F to 113F	113F to 122F	122F to 131F	131F to 140F	>140F

<-103F	-103F to -94F	-94F to -85F	-85F to -76F	-76F to -67F	-67F to -58F	-58F to -49F	-49F to -40F	-40F to -31F	-31F to -22F	-22F to -13F	-13F to -4F	-4F to 5F	5F to 14F	14F to 23F	23F to 32F

Celsius and Fahrenheit can be converted from/to each other by

$$[°F] = [°C] \times {}^{9}\!/_{5} + 32$$

$$[°C] = ([°F] - 32) \times {}^{5}\!/_{9}$$

☑ Geopotential height

Geopotential height is a vertical coordinate referenced to Earth's mean sea level — an adjustment to geometric height (elevation above mean sea level) using the variation of gravity with latitude and elevation. It is defined as

$$Z_g = \frac{\Phi}{g_0},$$

where g_0 is the standard gravity at mean sea level, and Geopotential Φ is defined as

$$\Phi = \int_0^h g(\phi, z)\, dz,$$

where $g(\varphi,z)$ is the acceleration due to gravity, φ is latitude, and z is the geometric elevation. The batch is consists of

⊕ Surface geopotential height (elevation)

With legend scaled as below:

<0m	0m to 100m	100m to 200m	200m to 1000m	1000m to 2000m	2000m to 3000m	3000m to 5000m	>5000m

⊕ Geopotential height of 1000hPa, 925hPa, 850hPa, 700hPa, 500hPa, 300hPa and 200hPa

⊕ 500hPa 5-wave geopotential height and anomaly

⊕ Highest tropospheric freezing level geopotential height

⊕ 0C isotherm level geopotential height

⊕ Tropopause geopotential height

⊕ Surface Planetary boundary layer height

PBL is the lowest part of atmosphere with a variable depth. Generally a tropical PBL could be as deep as 2000-m, a nocturnal PBL in mid-latitude area is typically 300-m, and a PBL in Arctic area could be as shallow as 50-m.

The six groups of elements above draw in contour mode.

☑ Cloud Cover

Cloud cover (also known as cloudiness, cloudage or cloud amount) refers to the fraction of the sky obscured by clouds when observed from a particular location. The "cloud cover" batch is consists of

⊕ Total cloud cover of entire atmosphere

Average total cloud cover of atmospheric column within 3 hours.

⊕ Total cloud cover of planetary boundary layer

Average total cloud cover of planetary boundary layer (PBL) within 3 hours. PBL is the lowest part of atmosphere with a variable depth. Generally a tropical PBL could be as deep as 2000-m, a nocturnal PBL in mid-latitude area is typically 300-m, and a PBL in Arctic area could be as shallow as 50-m.

⊕ Total cloud cover of low, mid and high cloud level

Average total cloud cover of different cloud level within 3 hours. Generally low cloud level refers to 0-km to 2-km above ground, mid cloud level refers to 2-km to 6-km, and high cloud level refers to the layer above 6-km.

⊕ Total cloud cover of free convective layer

Average total cloud cover of free convective layer within 3 hours. Free convective layer (FCL) is the layer of conditional or potential instability in the troposphere, clouds in FCL indicates there are significant convections in this area.

The elements above share the same legend, shown as below:

Overcast	90%	80%	70%	60%	50%	40%	30%	20%	10%	Clear

☑ Cloud work function (CWF)

The cloud work function (CWF) is an integrated measure of the difference between the moist static energy in the cloud and that in the environment. Generally speaking, it can be viewed as an indicator that if the cloud is likely to grow.

<0	0-25	25-50	50-100	100-200	200-300	300-500	>500

(Unit: J/kg)

☑ Convective available potential energy (CAPE) and Convective inhibition (CIN)

The batch is consists of

⊕ Surface and 0-180mb CAPE

Convective available potential energy (CAPE) is the amount of energy a parcel of air would have if lifted a certain distance vertically through the atmosphere. CAPE is effectively the positive buoyancy of an air parcel and is an indicator of atmospheric instability, it is calculated by integrating vertically the local buoyancy of a parcel from the level of free convection (LFC) to the equilibrium level (EL):

$$CAPE = \int_{z_f}^{z_n} g \left(\frac{Tv_{parcel} - Tv_{env}}{Tv_{env}} \right) dz$$

Where z_f and z_n are, respectively, the heights of the levels of free convection and equilibrium (neutral buoyancy), Tv_{parcel} is the virtual temperature of the specific parcel, Tv_{env} is the virtual temperature of the environment, and g is the acceleration of gravity.

In the chart, it is scaled as

<0	0-100	100-250	250-500	500-1000	1000-1500	1500-2500	>2500
			Positive			Large	Extreme

(Unit: J/kg)

⊕ Surface and 0-180mb CIN

Convective inhibition (CIN or CINH) is a numerical measure in meteorology that indicates the amount of energy that will prevent an air parcel from rising from the surface to the level of free convection. CIN is defined as

$$CIN = \int_{z_{bottom}}^{z_{top}} g \left(\frac{Tv_{parcel} - Tv_{env}}{Tv_{env}} \right) dz$$

The z-bottom and z-top limits of integration in the equation represent the bottom and top altitudes (in meters) of a single CIN layer, Tv_{parcel} is the virtual temperature of the specific parcel and Tv_{env} is the virtual temperature of the environment. In many cases, the z-bottom value is the ground and the z-top value is the LFC. CIN is expressed as a negative energy value. CIN values greater than 200 J/kg are sufficient enough to prevent convection in the atmosphere. In the chart, it is scaled as

>0	0 to -25	-25 to -50	-50 to -100	-100 to -200	-200 to -300	-300 to -500	<-500

(Unit: J/kg)

☑ Lifted Index

The lifted index (LI) is the temperature difference between an air parcel lifted adiabatically Tp(p) and the temperature of the environment Te(p) at a given pressure height in the troposphere (lowest layer where most weather occurs) of the atmosphere, usually 500 hPa (mb). When the value is positive, the atmosphere (at the respective height) is stable and when the value is negative, the atmosphere is unstable. The lifted index can be used in thunderstorm forecasting, however, convective available potential energy (CAPE) is considered by most as a superior measurement of instability and is preferred by many meteorologists for convection forecasting.

>11K	8K~11K	4K~8K	0K~4K	-3K~0K	-5K~-3K	-7K~-5K	<-7K

LI can be scaled as followed:

Range (K)	Amount of Instability	Thunderstorm Probability
more than 11	Extremely stable conditions	Thunderstorms unlikely
8 to 11	Very stable conditions	Thunderstorms unlikely
4 to 7	Stable conditions	Thunderstorms unlikely
0 to 3	Mostly stable conditions	Thunderstorm unlikely
-3 to -1	Slightly unstable	Thunderstorms possible
-5 to -4	Unstable	Thunderstorms probable
-7 to -6	Highly unstable	Severe thunderstorms possible
less than -7	Extremely unstable	Violent thunderstorms, tornadoes possible

☑ Atmospheric pressure

Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of air above that surface at any given point in the Earth's atmosphere. The “pressure” batch is consists of

⊕ Surface pressure

Average surface atmospheric pressure within 3 hours.

⊕ MSL pressure

Mean sea level pressure (MSLP) is the pressure at sea level or (when measured at a given elevation on land) the station pressure reduced to sea level assuming an isothermal layer at the station temperature. MSL pressure is reduced by Barometric formula from surface pressure, and it makes the normal range of fluctuations in pressure is the same for anywhere. Barometric formula could be written as

$$P = P_b \cdot \left[\frac{T_b}{T_b + L_b \cdot (h - h_b)} \right]^{\frac{g_0 \cdot M}{R^* \cdot L_b}}$$

where

P = Static pressure (pascals)

T = Standard temperature (Kelvin)

L = Standard temperature lapse rate (Kelvin per m)

h = Height above sea level (meters)

R^* = 8.31432×10^3 N·m / (kmol·K)

g_0 = 9.80665 m/s^2

M = 28.9644 g/mol

☑ Relative Humidity

Relative humidity (RH) is a term used to describe the amount of water vapor that exists in a gaseous mixture of air and water. It is defined as the ratio of the partial pressure of water vapor in the mixture to the saturated vapor pressure of water at a prescribed temperature. Relative humidity is normally expressed as a percentage and is defined in the following manner:

$$RH = \frac{p_{(H_2O)}}{p^*_{(H_2O)}} \times 100\%$$

where $p_{(H_2O)}$ is the partial pressure of water vapor in the mixture; and is the partial pressure of water vapor in the mixture; and $p^*_{(H_2O)}$ is the saturated vapor pressureof water at the temperature of the mixture.

The batch is consists of

⊕ 2-m above ground relative humidity

The average 2-m above ground relative humidity within 3 hours.

⊕ Relative humidity at 1000hPa, 925hPa, 850hPa, 700hPa, 500hPa, 300hPa and 200hPa

The average relative humidity at a given geopotential height within 3 hours.

The elements above share the same legend, shown as below:

<29%	30%-35 %	35%-40%	40%-45%	45%-50%	50%-55%	55%-60%	60%-65%	65%-70%	70%-75%	75%-80%	80%-85%	85%-90%	90%-95%	95%-99%	100%

☑ Seeing

The astronomical seeing conditions on a given night at a given location describe how much the Earth's atmosphere perturbs the images of stars as seen through a telescope. The seeing here is a reference to the best possible angular resolution which can be achieved by an optical telescope.

To start with, we defined

$$C_N^2 = C_T^2 \left(\frac{7.9\times10^{-5}P}{T^2}\right)^2$$

Where P is the pressure in hPa, T is the temperature in K, and the temperature structure coefficient C_T^2 is defined as

$$C_T^2 = \frac{(T(x)-T(x+r))^2}{r^{\frac{2}{3}}}$$

Where r is the separation vector and T is temperature. Seeing quality is therefore related to high-frequency temperature fluctuations associated with atmospheric turbulence.

In our seeing model, we convert the coordinate system from z to p, thus,

$$C_T^2 = \frac{(T(p)-T(p+dp))^2}{(dp)^{\frac{2}{3}}}$$

From 1000hPa to 750hPa, the separation vector is 50hPa; and from 700hPa to 200hPa, the separation vector is 100hPa. Pressure reductions due to various height is considered.

When C_N^2 is deduced, seeing parameter r_0 (also called Fried parameter) can be calculated by

$$r_0 = \left(16.7\lambda^{-2}(\cos\gamma)^{-1}\int_0^\infty dh C_N^2(h)\right)^{-3/5}$$

Then we can convert r_0 to the well-known “seeing” in arcsec by

$$\mathrm{SI} = 0.98 \times \frac{\lambda}{r_0}$$

In the chart, seeing is scaled as followed:

<0.5"	0.5"-0.75"	0.75"-1"	1"-1.25"	1.25"-1.5"	1.5"-2"	2"-2.5"	>2.5"

Generally the actual seeing is slightly worse than the prediction, as of the contribution of the turbulence near the ground.

☑ Transparency

The transparency here is an integrated measure of the extinction of sky objects. The extinction is generally caused by the moisture of atmosphere. In this forecast, both moisture and ozone are taken into account, but no industrial pollutants or aerosols (although they are big contributors for starlight extinction as well), because they are hard to be measured and predicted across the global by far.
The transparency model can be expressed in the following manner:

$$\varepsilon = 0.1066e^{-\frac{9}{820}} + 0.12e^{-\frac{3}{50}} \times \left(\frac{0.68}{\lg(R/100)}\right)^{\frac{4}{3}} + 0.0001OZ + 0.031 \times 0.0094R \times e^{\frac{T}{15}} \times e^{-\frac{9}{820}}$$

Where R is the average 0-30mb (about a few hundred meters) above ground relative humidity, T is the average 0-30mb above ground temperature, and OZ is the ozone density in entire atmospheric column. The result is in V magnitude per air mass.

<0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.85	0.85-1	>1

(Unit: magnitude/air mass)

☑ Wind velocity and direction

The “wind” batch is consists of

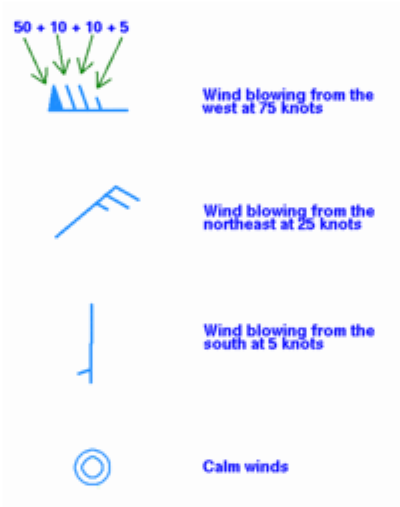
⊕ 10-m and 0-30mb above ground wind velocity and direction

Average 10-m and 0-30mb above ground wind speed and direction within 3 hours.

⊕ Wind velocity and direction at 1000hPa, 925hPa, 850hPa, 700hPa, 500hPa, 300hPa and 200hPa

Average wind speed and direction at a given geopotential height.

Wind barb is used in the chart. The wind barb shows the speed using "flags" on the end. Each half of a flag depicts five knots, each full flag depicts 10 knots, while each pennant (filled triangle) depicts 50 knots. Winds are depicted as blowing from the direction the flags are facing. Therefore, a northeast wind will be depicted with a line extending from the cloud circle to the northeast, with flags indicating wind speed on the northeast end of this line. The barb is illustrated with different color to indicate the wind speed as well as the flags.



Calm	Light	Moderate	Fresh	Strong	Gale	Storm	Hurricane

The conversion table of Beaufort Class and different wind speed units is shown below.

Beaufort Number	Description	General Description	Wind Speed			
			knots	km/h	mph	m/s
0	Calm	Calm	0	0-1	0-1	0-0.2
1	Light	Light air	1-3	2-6	1-3	0.3-1.5
2		Light breeze	4-6	7-11	4-7	1.6-3.3
3	Moderate	Gentle breeze	7-10	12-19	8-12	3.4-5.4
4		Moderate breeze	11-15	20-29	13-18	5.5-7.9
5	Fresh	Fresh breeze	16-21	30-39	19-24	8.0-10.7
6	Strong	Strong breeze	22-27	40-50	25-31	10.8-13.8
7		Near gale	28-33	51-62	32-38	13.9-17.1
8	Gale	Gale	34-40	63-75	39-46	17.2-20.7
9		Severe gale	41-47	76-87	47-54	20.8-24.4
10	Storm	Storm	48-55	88-103	55-63	24.5-28.4
11		Violent storm	56-63	104-117	64-72	28.5-32.5
12	Hurricane	Hurricane	64+	118+	73+	32.6+

☑ Precipitation

Precipitation is any product of the condensation of atmospheric water vapor that is deposited on the earth's surface. It occurs when the atmosphere, a large gaseous solution, becomes saturated with water vapor and the water condenses and falls out of solution. The every element of "precipitation" batch, as well as their legends, is shown below:

⊕ Accumulated snow-depth

0cm	0-1cm	1-5cm	5-10cm	10-25cm	25-50cm	50-100cm	100-150cm	150-20cm	>250cm

⊕ Surface total precipitation

0mm	<0.25mm/hr	0.25-1mm/hr	1-4mm/hr	4-10mm/hr	10-16mm/hr	16-30mm/hr	30-50mm/hr	50-75mm/hr	>75mm/hr
No significant rainfall		Light rain	Moderate rain	Heavy rain		Very heavy rain		Extreme rain or Rainstorm	

⊕ Precipitation type

Snow	Rain	Freezing rain	Ice pellets

☑ Surface downward short-wave flux

The surface downward short-wave flux is related to, although not equivalently, the UV index.

<0	0-50	50-100	100-200	200-400	400-600	600-1000	>1000

(Unit: W/m^2)

☑ Atmospheric column total Ozone

Ozone (O_3) is a key constituent of the troposphere (it is also an important constituent of certain regions of the stratosphere commonly known as the Ozone layer). The chart here is draw in contour mode, measured in Dobson.

☑ Tropopause vertical wind shear

Vertical wind shear refers to the variation of wind over vertical distances. Low level wind shear can affect aircraft airspeed during take off and landing in disastrous ways. It is also a key factor in the creation of severe thunderstorms. The additional hazard of turbulence is often associated with wind shear.

<-0.025	-0.025 to -0.02	-0.02 to -0.015	-0.015 to -0.01	-0.01 to -0.005	-0.005 to 0	0 to 0.005	0.005 to 0.01	0.01 to 0.015	0.015 to 0.02	0.02 to 0.025	>0.025

(Unit: s^{-1})

☑ Vorticity for 1000hPa, 925hPa, 850hPa, 700hPa, 500hPa, 300hPa and 200hPa

Vorticity is the rotation of air around a vertical axis. Vorticity is a vector quantity and the direction of the vector is given by the right-hand rule with the fingers of the right hand indicating the direction and curvature of the wind. When the vorticity vector points upward into the atmosphere, vorticity is positive; when it points downward into the earth it is negative. Vorticity in the atmosphere is therefore positive for counter-clockwise rotation (looking down onto the earth's surface), and negative for clockwise rotation.

$$\zeta = \frac{\partial v_r}{\partial x} - \frac{\partial u_r}{\partial y}$$

Where u_r and v_r are the zonal and meridional components of wind velocity, respectively.

<-0.01	-0.01 to -0.008	-0.008 to -0.006	-0.006 to -0.004	-0.004 to -0.002	-0.002 to 0	0 to 0.002	0.002 to 0.004	0.004 to 0.006	0.006 to 0.008	0.008 to 0.01	>0.01

(Unit: s^{-1})

☑ Convergent/divergent property for 1000hPa, 925hPa, 850hPa, 700hPa, 500hPa, 300hPa and 200hPa

The convergent/divergent property of a region can be measured by the divergence, defined as

$$\nabla \cdot F = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

Where u and v are the zonal and meridional components of wind velocity. For a vector field that denotes the velocity of air expanding as it is heated, the divergence of the velocity field would have a positive value because the air expands, generally this will occur in a high pressure area. On the other hand, if the air cools and contracts, the divergence is negative, or call, “convergence”. A good example of convergence is the Intertropical Convergence Zone (ITCZ), a low pressure area which girdles the Earth at the Equator.

<-5	-5 to -4	-4 to -3	-3 to -2	-2 to -1	-1 to 0	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	>5

(Unit: $10^{-6}s^{-1}$)

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