Section 5: Statistical down-scaling for Wind, Tmax and Tmin

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Statistical down-scaling method has been applied to NCEP global ensemble from 1.0 degree to National Digital Guidance Database (NDGD-5km for CONUS region) resolution. There are four variables (2-meter temperature, surface pressure, 10-meter u and v) for this application in current CONUS operation. Statistical down-scaling method in general has been formularized in Section 4. In this section, down-scaling wind speed (*Ws*), wind direction (*Wd*), maximum temperature (*Tmax*) and minimum temperature (*Tmin*) will be introduced separately.

1. Wind speed and direction: Based on 1*1 degree bias corrected *U* and *V* at 10 meters, wind speed (*Ws*) and wind direction (*Wd*) have been generated according to following formula:

$$W_s = \sqrt{u^2 + v^2} \quad \text{and}$$

$$W_d = sign(u \cdot v) \cdot \arctan\left|\frac{u}{v}\right| + d_p \quad \text{where} \quad d_p = \begin{cases} 0, if\_u \le 0, v < 0 \\ 180, if\_u < 0, v \ge 0 \\ 180, if\_u \ge 0, v > 0 \\ 360, if\_u > 0, v \le 0(?) \end{cases}$$

Down-scaling vector could be generated by using the same method as in Section 4, except for *DV(Wd)* which needs considering the angle 0-180 and -180-0 instead of 0-360 standing. This angle needs to be transfer back to 0-360 range after adding *DV*.

The details of probabilistic wind direction (*Wd*) calculation:

1) Divide (0,360) into many small units (current 6 units, each unit is 60 degrees, see schematic figure 1 in the end of the documentation), choose the closed 2 units where wind direction data fall most.

2) Rearrange the date, to allow 2 units (step 1)) in the middle of the distribution.

3) Calculate the average wind direction using the 2 units (step 1)) data only.

4) Calculate the direction probability 10%, 50% and 90%, mode and spread by using full ensemble data (not 2 units).

5) Adjust wind direction phase in [0,360]: if(angle(ij).lt.0.) angle(ij)=360.0+angle(ij); if(angle(ij).ge.360.) angle(ij)=angle(ij)-360.0

6) Example of map (figure 2) to demonstrate the mean wind direction to compare the wind vectors directly from *u* and *v* (ensemble mean)

The details of wind direction (*Wd*) downscaling vector calculation:

1) Read in gdas fnl u & v components and calculate wind speed & direction in phase [0,360)

2) Read in rtma wind speed and direction in phase [0,360)

3) Adjust gdas & rtma wind direction to (-180,180], then calculate their difference

4) Adjust prior wind direction downscaling vector to (-180,180] for bias accumulation

5) Bias accumulation is based on phase (-180,180]

6) Adjust bias accumulation to phase (-180,180] in case any value is out of range

7) Change bias accumulation to phase [0,360)

2. *Tmax* and *Tmin* for Alaska region: Based on 1*1 degree 6-hour bias corrected maximum and minimum temperature at 2 meters and down-scaling vectors for temperature at each 6-hour cycle, approximated *Tmax* and *Tmin* could be created from following steps:

1) Definition of *Tmax* and *Tmin* for Alaska region (asked):

Tmax period: 15UTC(7am-local) – 04UTC(8pm-local) – daylight time
Tmin period: 03UTC(7pm-local) – 17UTC(9am-local) – daylight time

2) Required 6-hour time range *Tmax/Tmin* in UTC for giving any initial cycle (00, 06, 12, 18UTC) forecasts to present *Tmax/Tmin* period in a) (see figure 4). For example:

00UTC initial forecast:

First *Tmax* period is: 12-18h, 18-24h, 24-30h, (30-36h) forecasts
Second Tmax period is: 36-42h, 42-48h, 48-54h, (54-60h) forecasts
……
First *Tmin* period is: 00-06h, 06-12h, 12-18h, (18-24h) forecasts
Second *Tmin* period: 24-30h, 30-36h, 36-40h, (40-48h) forecasts
……

06UTC initial forecast:

First *Tmax* period is: 06-12h, 12-18h, 18-24h, (24-30h) forecasts
Second *Tmax* period is: 30-36h, 36-42h, 42-48h (48-54h) forecasts
……
First *Tmin* period is: 18-24h, 24-30h, 30-36h, (36-42h) forecasts
Second *Tmin* period: 42-48h, 48-54h, 54-60h, (60-66h) forecasts
……

3) To get mean down-scaled vector of temperature for each 6-hour period by taking average of two instantaneous vectors (need to discuss?)

4) Interpolating bias corrected 6-hourly *Tmax*, *Tmin* from 1 by 1 degree to 6km NDGD grid for Alaska region.

5) Appling mean down-scaled vectors to each grid point, each ensemble member, and each 6-hour lead-time period, to produce down-scaled *Tmax* and *Tmin* for each 6-hour lead-time period, then to find out highest *Tmax* and lowest *Tmin* for approximated period for *Tmax* and *Tmin* (step b defined) at 6km resolution. Therefore, for different grid points, different ensemble members, highest *Tmax* could be in different 6-hour period, it is the same for lowest *Tmin*. Finally, there is only one down-scaled *Tmax* and *Tmin* for every 24-hour forecast, up to 384 hours.

6) To calculate the mean, spread, mode, 10%, 50% and 90% based on step e.

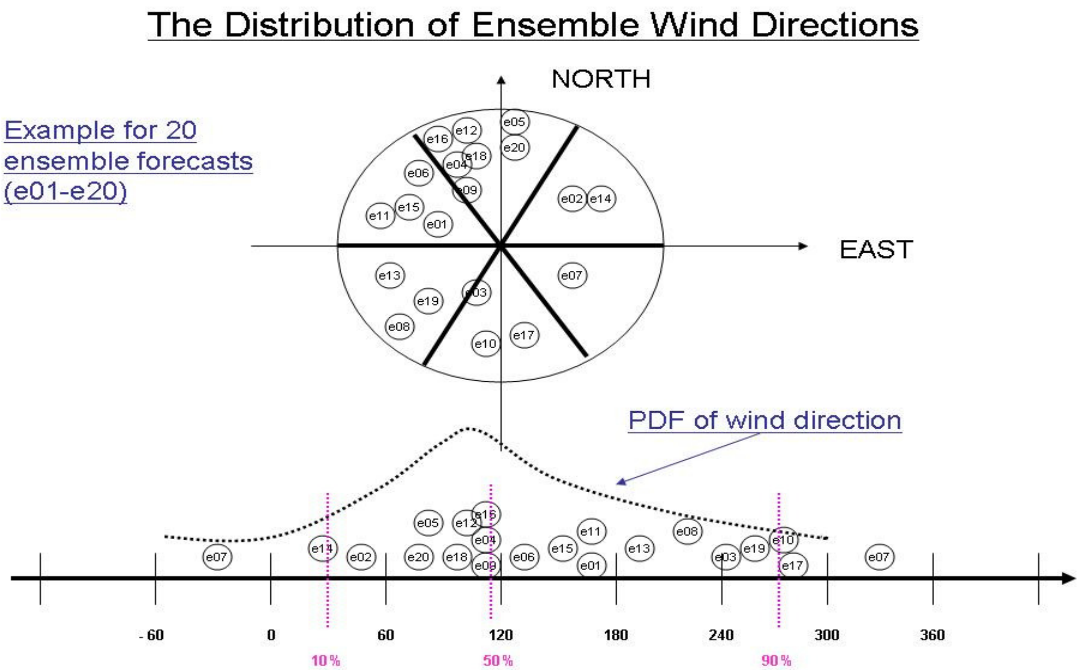

Figure 1: Schematic diagram for re-distribution of ensemble wind direction

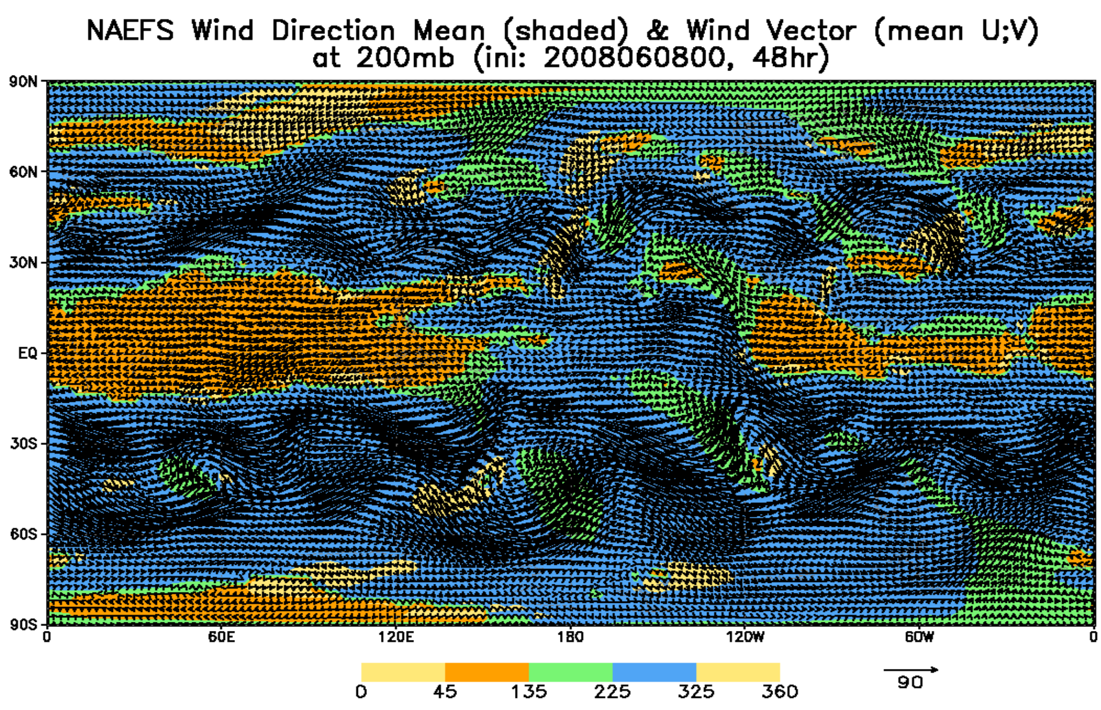

Figure 2: The example of mean wind direction from ensemble wind direction distribution to compare the wind vector (or direction) from ensemble mean *u* and *v*. Please note the East wind is 90 degree (shaded), and West wind is 270 degree.

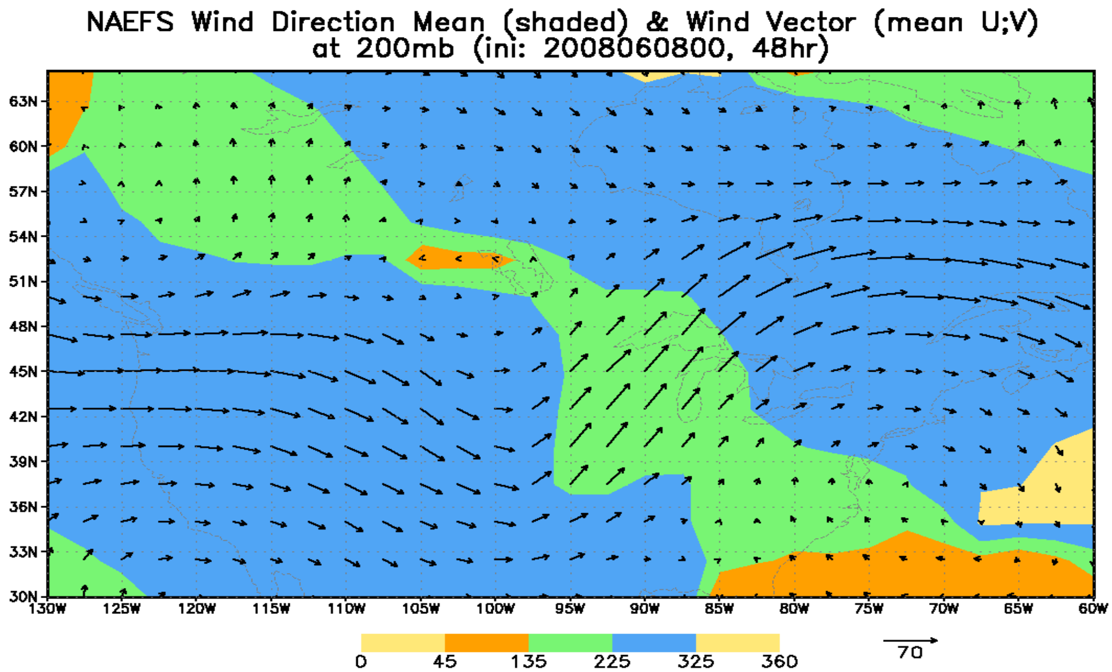

Figure 3: The same as figure 2, but for CONUS only.

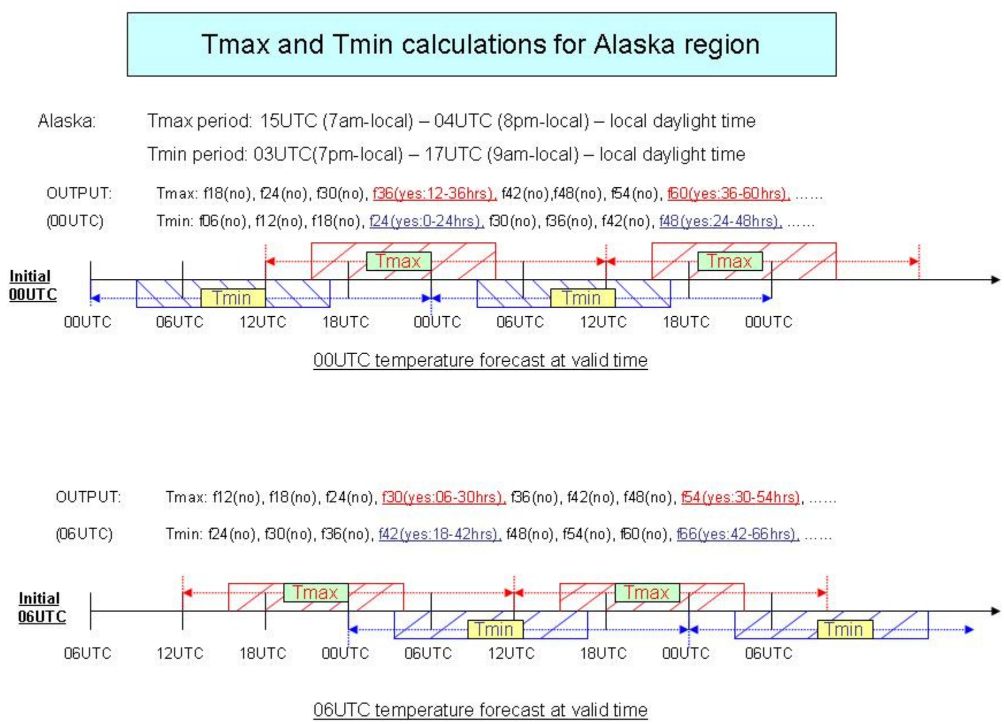

Figure 4: The schematic diagram for *Tmax, Tmin* calculation