On Impact of Radiosondes' Shift into Objective Analysis[1]

Vladimir V.Bayev, Vladimir A.Gordin, *Hydrometeorological Center of Russia, Moscow, Russia*

The trajectories of a radiosonde ascend can be described by the following system:

$$\begin{cases} \dfrac{dx}{dt}(t) = U(x(t), y(t), \xi(t), t) \cdot b_x(y(t)), & x(0) = x_0 \\ \dfrac{dy}{dt}(t) = V(x(t), y(t), \xi(t), t) \cdot b_y, & y(0) = y_0 \\ \dfrac{d\xi}{dt}(t) = -\dfrac{\mu g \cdot (az_0 + b) \cdot e^{-a(t-t_0)}}{R \cdot T(x(t), y(t), \xi(t), t)}, & \xi(0) = \ln(p_0) \end{cases},$$

where x, y are latitude and longitude in minutes, $\xi = \log(p)$, p is pressure in hPa, t is time in minutes, U, V – fields of zonal and meridian wind's components in m/sec,

$b_y = \dfrac{60}{R_{\mathrm{E}} \cdot \pi / 10800}$, $b_x(y) = b_y / \cos(y \cdot \pi / 10800)$ are corresponded coefficients of conversion for units of measurements of horizontal velocity (R_{E} is Earth's radius),

μ is molar mass of air,
g – acceleration of free falling,
R is the universal gas constant,
T is a temperature in Kelvin,

$\left.\begin{matrix} a = 0.0058 \ \ \mathrm{min}^{-1} \\ b = 274 \ \ \mathrm{m/min} \end{matrix}\right\}$ – empirical constants for sonde's lifting: $\dfrac{dz}{dt} = az + b$, $z(t)$ is the sonde's height,

x_0, y_0, z_0, p_0 are latitude and longitude of a station, it's height over sea level and pressure in the sonde's launch moment t_0.

Table 1.

i	p_i,gPa	$\langle t_i \rangle$,min	$\langle t_i \rangle_2$,min	$\langle \Delta X_i \rangle$,km	$\langle \Delta Y_i \rangle$,km	$\langle d_i \rangle_2$,km	$d_i^{\max}$,km	q_i
1	1000	-38.10	42.09	-0.02	-0.01	0.13	0.54	8050
2	925	-37.71	41.74	-0.03	-0.04	0.84	3.12	13392
3	850	-35.75	40.02	0.06	-0.07	1.88	7.46	14758
4	700	-30.68	35.58	1.01	-0.11	4.65	20.03	15326
5	500	-22.11	28.50	4.85	-0.32	11.10	44.51	15470
6	400	-16.93	24.69	8.69	-0.50	16.94	62.83	15471
7	300	-10.79	20.97	14.85	-0.66	26.06	87.92	15471
8	250	-7.17	19.36	19.33	-0.70	32.51	103.36	15471
9	200	-2.93	18.22	25.11	-0.74	40.49	121.61	15471
10	150	2.29	18.13	32.27	-0.78	49.92	147.50	15471
11	100	9.27	20.21	40.29	-0.87	60.10	174.34	15471
12	70	15.13	23.47	45.13	-1.01	66.09	190.69	15471
13	50	20.49	27.24	48.15	-1.15	69.73	200.51	15471
14	30	28.41	33.61	51.26	-1.40	73.43	208.71	15471
15	20	34.56	38.96	53.74	-1.60	76.41	213.57	15471
16	10	44.73	48.22	59.32	-1.84	82.81	237.69	15471

By the way we can take into account the exact place and moment of any concrete measurement. The statistics of the deviations see in Table 1. Here d_i is the distance in kilometers, q_i is the number of measurements in the ensemble, $\langle s \rangle$ is the average value of s, and $\langle s \rangle_2 = \sqrt{\langle s^2 \rangle}$.

[1] *The work was partly supported by the grant 01-05-64748a;* vagordin@vagordin.mccme.ru

We can see the shift of the measurements is significant and really can make worse the objective analysis results, especially on higher levels.

Can we reduce the errors if localize the measurement's point more exactly. To answer on the question we compare a meteorological value A with 1) first guess of A for horizontal coordinates of the corresponding station; 2) first guess of A for horizontal coordinates of the corresponding sonde. We denote these values $\Delta A^{\text{current}}$ and ΔA^{lifted}.

We use the following experiment to understand the maximal impact of exact sonde's localization. We compute first guess in the true time-space point of the concrete observation and compare with the result of this observation. These results are our goal for future investigation of the following Lagrangian model.

If we assume some meteorological value A is conserved in any particle, we should integrate the ordinary differential system

$$\frac{dA}{dt} = 0, \quad \text{where } \frac{d}{dt} = \frac{\partial}{\partial t} + U\frac{\partial}{\partial x} + V\frac{\partial}{\partial y} + W\frac{\partial}{\partial z}, \tag{1}$$

along the particle trajectory. We start in the true observation moment and finish in the basic moment $t = 0$ in a "traced" point. We obtain the initial data for A by the way. The coefficients of the system $U, V, W,$ can be obtained from a forecast model.

If the value A is not conserved, e.g. it is a component of horizontal wind, then we should use in the right hand-side some fields from the forecast, too:

$$-\frac{du}{dt} = \frac{\partial \Phi}{\partial x} - lv \quad , \quad -\frac{dv}{dt} = \frac{\partial \Phi}{\partial y} + lu \, . \tag{2}$$

Here it is geopotential $\Phi = \Phi(x, y, p, t)$. The approach can be useful for assimilation of any asynchronic meteorological data, e.g., from satellites and aircrafts.

In the Table 2 we demonstrate some improvement of concordance[2] with 12-h forecast of temperature (similar results for wind's components were obtained):

Table 2

i	p_i ,gPa	$\langle \Delta T_i^{\text{current}} \rangle_2$, K	$\langle \Delta T_i^{\text{lifted}} \rangle_2$, K	$\langle \Delta T_i^{\text{lifted0}} \rangle_2$, K	$\langle \Delta T_i^{\text{traced}} \rangle_2$, K	q_i
3	850	1.516	1.526	1.516	1.528	10238
4	700	1.123	1.121	1.121	1.124	10701
5	500	1.046	1.037	1.042	1.044	10780
6	400	1.033	1.028	1.030	1.034	10700
7	300	1.239	1.240	1.241	1.250	10532
8	250	1.349	1.341	1.341	1.339	10354
9	200	1.433	1.410	1.412	1.413	10152
10	150	1.365	1.347	1.349	1.352	9825
11	100	1.523	1.516	1.520	1.521	9543
13	50	1.659	1.640	1.642	1.652	7111

Now only 65% of TEMP messages include information on exact start moment (with minutes). We appeal meteorologists to do it.

V.A.Gordin. *Meteorological Data Assimilation as a Subject of Applied Mathematics.* Proc. Hydrometeorological Center of Russia 334, pp.69-78, 1999 (Russian).

V.A.Gordin. *Mathematical Problems and Methods in Hydrodynamic Weather Forecasting.* Gordon & Breach, 2000.

Triphonov G.A. "Approximation of a dependence of radiosonde radiation error from the Sun elevation and height", Proc. Centr. Aerol. Observ., Russia, 1983, N 151, pp.8-13.

[2] *Model (1) with the simple transport of A should be exchanged on model (2).*