TECHNICAL MEMORANDUM

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The ECMWF humidity analysis

S. Tibaldi

Research Department

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European Centre for Medium-Range Weather Forecasts
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1. Introduction

The purpose of this Technical Memorandum is to describe the Humidity Analysis package, as it is presently incorporated in the operational-to-be 6-hours data assimilation cycle. The overall structure of the package is the same as for the Mass and Wind (M&W) analysis, and here I will describe in some detail only the parts that are different.

The analysis variable is a form of precipitable water content (PWC) of layers (called analysis layers) enclosed between successive analysis levels up to 300 mb:

$$PWC_{1-2} = \frac{1}{g\rho_w} \int_{p_1}^{p_2} q_{(p)} d_p = \tag{1.1}$$

$$= \frac{1}{g\rho_w} [Q]_1^2 = \frac{1}{g\rho_w} \Delta Q_{1-2} \tag{1.2}$$

where $g \equiv$ gravity acceleration and ρ_w = density of liquid water.

For convenience, the actual analysis variable is not PWC but ΔQ, that numerically corresponds almost exactly to tenths of millimeter of precipitable water.

I will, from now on, refer to ΔQ as the precipitable water content, even if this is not strictly correct. δA will always indicate the error on any variable A.

As for the M&W, the analysis is performed on p-surfaces or, rather, layers, and therefore the need of interpolating the model humidity field (r, mixing ratio ≃ q, specific humidity) from σ to p and the analysed field (or the correction field) from p to σ is present.

This is accomplished in both ways fitting a spline to the values of Q for the known levels and deriving from it values for the required levels. Being Q proportional to the integrated PWC, this ensures that the total amount of water present in the column is conserved with substantial accuracy (within 0.5% of the global PWC, being the difference of random sign). This operation is repeated for every analysis grid point.

The process is divided in three major steps: preanalysis, analysis and postanalysis.

2. Preanalysis: PREGAP

The preanalysis is performed by the program PREGAP (UPDATE Library PRG) in humidity mode (MODE=2). Its task, as for the M&W analysis is to:

a) extract the relevant information from observation reports,

b) transform this information into the analysis variable (ΔQ) at the appropriate analysis level,

c) compute the associated error ($\delta\Delta Q$),

d) subtract the first guess from the observed value so to obtain a "deviation",

e) normalize both deviation and error with respect to the first guess error,

f) flag as unreliable excessive deviations,

g) write deviation, error and flags to a random-access work file.

Points a), b) and c) differentiate amongst information coming, in different form, from different observation types. At present three observation types are used:

i) TEMPS &TEMPSHIPS(radiosondes)

ii) SYNOPS&SHIPS (surface obs)

iii) SATEMS (satellite soundings)

I will now briefly describe how each observation type is processed.

i) Radiosondes provide pressure and T_D (dew point temperature) at a number of levels, some of which can be standard and some of which can be special. All these levels are sorted in order of decreasing pressure. At each level where T_D is reported HMR (humidity mixing ratio) is computed. δHMR is also computed, using the Clausius-Clapeyron relationship and an estimate for δT_D. The estimate on δT_D is made assuming δT_D varying linearly with lnp from 0.5 ^oK at 1000 mb and 1.0 ^oK at 300 mb. Then ΔQ and $\delta\Delta Q$ for each layer enclosed by two successive levels are computed (and stored in two arrays at a position corresponding to the highest (of the two) levels; this causes the lowermost value to be undefined).

This is done using the relation

$$\Delta Q = \bar{q}\ \Delta p \tag{2.1}$$

$$\delta\Delta Q = \delta\bar{q}\ \Delta p \tag{2.2}$$

where

$$\bar{q} = \frac{q_{up} + q_{down}}{2} \tag{2.3}$$

$$\delta\bar{q} = \frac{\delta q_{up} + \delta q_{down}}{2} \tag{2.4}$$

Data up to 100 mb are used in this procedure and if two consecutive levels are separated by more than 200 mb the sounding is interrupted.

The ΔQ (and $\delta\Delta Q$) sounding so obtained is therefore partitioned amongst the analysis layers.

ii) Surface observations provide T, T_D, cloud amount and types and current weather. This information is used to derive an estimate or $\overline{RH}$ (average relative humidity) in four layers (a "bogus" low-resolution RH vertical sounding). The four layers are enclosed by five levels so defined:

$$p_1 = p_* \quad \text{(analyzed model surface pressure at observation position)}$$

$$\begin{aligned} p_2 &= p_1 - 50 \text{ mb} \\ p_3 &= p_2 - \frac{p_2 - 300 \text{ mb}}{3} \\ p_4 &= p_3 - \frac{p_2 - 300 \text{ mb}}{3} \\ p_5 &= 300 \text{ mb} \end{aligned} \tag{2.5}$$

The lowermost layer (layer 2; layer 1 is undefined) is a 50 mb-deep PBL, and the other three (layers 3,4, and 5) are three equi-deep layers, vaguely corresponding to the classification for low, middle and high clouds.

The RH estimate is made following the relationships:

$$\begin{aligned} RH_2 &= \frac{1}{3}(RHSF+RHWW+RHPBLC) \\ RH_3 &= RHLC \\ RH_4 &= RHMC \\ RH_5 &= RHHC \end{aligned} \tag{2.6}$$

Where RHSF is derived from reported surface T and T_D; RHWW is extracted from an NMC table giving RH estimates for every value of reported current weather; RHPBLC, RHLC, RHMC and RHHC are of the type

$$RHXC = M_x - A_x \cos\left(\frac{\pi}{8} OKTAS_x\right) \tag{2.7}$$

where $OKTAS_x$ is the cloud cover in eights (X=PBL, L,M,H for low, middle and high clouds) and M_x and A_x vary according to the table:

	LCBH ≤ 600 m		LCBH > 600 m	
	M_x	A_x	M_x	A_x
HIGH	55	10	55	10
MIDDLE	60	15	60	15
LOW	70	10	75	15
PBL	79	19	-	-

LCBH is the reported height of the base of the lowest cloud.

This RH estimate is then converted into ΔQ for the same four bogus layers. $\delta\Delta Q$ is also evaluated using the following procedure:

$$\delta\Delta Q = RE_J \cdot \Delta Q \tag{2.8}$$

where

$RE_2 = .2$ $\quad$ $RE_4 = .4$

$RE_3 = .3$ $\quad$ $RE_5 = .6$

ΔQ and $\delta\Delta Q$ are then partitioned amongst analysis layers.

iii) Satellite soundings provide PWC between a reference level and standard pressure levels. These are immediately converted into ΔQ between analysis levels. Errors are evaluated following a criterion similar to that used for SYNOPs (2.8) but RE $\equiv$ .8 has been temporarily assumed. This part has been coded but has not been implemented yet.

After having subtracted the first guess (interpolated at ob position) from the observation, PREGAP proceeds to normalize these observations "deviations" and the observation errors dividing them times the first guess error for that position. This is extracted from a climatological file.

The observation deviations are then flagged according to their magnitude:

flag 0 $\quad (OB-FG)^2 \leq 36\ (OBERR^2+FGERR^2)$

flag 1 $\quad (OB-FG)^2 \leq 64\ (OBERR^2+FGERR^2)$

flag 2 $\quad (OB-FG)^2 \leq 100\ (OBERR^2+FGERR^2)$

flag 3 $\quad (OB-FG)^2 > 100\ (OBERR^2+FGERR^2)$

Observations flagged 2 or more are not used by GAP (the analyses program) and observations flagged 3 are not even written into the workfile.

No super-observations are formed, at present, in humidity analysis, although the possibility is coded in.

3. Analysis: GAP

The analysis is performed by the program GAP (UPDATE library GAP, *DF HUM) in grid point analysis mode. Its task is to:

a) Read, for the current box, the non-dimensional observation corrections contained in the influence area (box and neighbours; one 2D layer only).

b) For each grid point in the current box compute all the weights relative to the observations contained in the influence area following the formulae:

$$W(J) = \frac{\{R(J)/E(J)\}}{1 + \Sigma_J \{R(J)/E(J)\}}$$

where

$$R(J) = e^{-\frac{r(J)}{r_o(JLEV)}}$$

and

$r_o(JLEV)$ is

500 km for JLEV = 2
650 km for JLEV = 3
800 km for JLEV = 4
900 km for JLEV = 5
1000 km for JLEV = 6

and

$$E(J) = 1 + OBER(J)^2 - R(J)^2$$

where

OBER(J) non dimensional observation error

r(J) distance between grid point and J^{th} observation

J = 1,2,...,NOBS

NOBS = no. of observations in the influence area

c) Again for each grid point compute the weighted average of the non-dimensional observation deviations following:

$$GPCORR = \frac{\Sigma_J\ W(J)*CORR(J)}{WFG(JLEV) + \Sigma_J\ W(J)}$$

where W(J) was defined above

and WFG(JLEV) (weight of the first guess) is

.2 for JLEV = 2
.5 for JLEV = 3
1.∅ for JLEV = 4
1.4 for JLEV = 5
2.∅ for JLEV = 6

4. Postanalysis: POSTGAP

The only difference between POSTGAP in Mass and Wind mode and in Humidity mode is that in the latter the program chops subzero and over 100% relative humidities, using the analysed height field to derive a mean layer temperature.