FORECAST IMPACT STUDIES
OF ZENITH TOTAL DELAY DATA
FROM EUROPEAN GPS STATION NETWORKS
IN METEO-FRANCE 4DVAR

P. POLI * (1), P. MOLL (1), F.-Z. EL GUELAI (2), S.B. HEALY (3), E. ANDERSSON (3)

(1) METEO FRANCE CENTRE NATIONAL DE RECHERCHES METEOROLOGIQUES
(2) DIRECTION DE LA METEOROLOGIE NATIONALE DU MAROC
(3) EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS
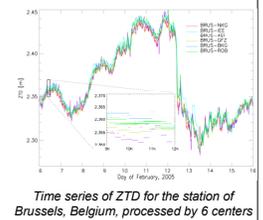* Corresponding author: paul.poli@meteo.fr

ABSTRACT

The Zenith Total Delay (ZTD) data collected by various European networks of ground-based Global Positioning System (GPS) stations have been made available to the operational meteorological centers in near-real time since 2004, thanks in particular to the efforts of the Targeting Optimal Use of GPS Humidity measurements in meteorology (TOUGH) project. This poster presents the use of the ZTD data received at Meteo France. A specific pre-processing has been implemented to accommodate these data in the Four-Dimensional Variational assimilation (4DVAR) in operational use at Meteo France. Forecast impact trials are conducted for two one-month long experiments. The Numerical Weather Prediction (NWP) forecasts issued with the addition of ZTD data are then compared with regular forecasts, using in situ measurements as a validation reference. The impact of the ZTD data shows favorably on the circulation thanks to an improvement in the prediction of the surface pressure. Visual comparisons of the predicted precipitation patterns with rain gauge measurements suggest an improved skill when ZTD data are assimilated as compared to the regular forecasts.

1. GPS ZTD DATA

• Data received in real time in BUFR format via the Global Telecommunication System (GTS)

• Data archived in the Meteorological DataBase

• Processing centers release data valid at different times and with different averaging time periods

Map of the European GPS stations color-coded by processing center

Time series of ZTD for the station of Brussels, Belgium, processed by 6 centers
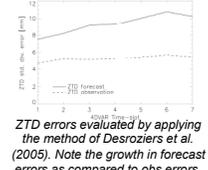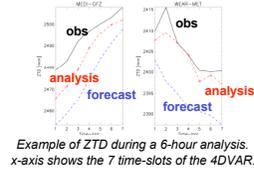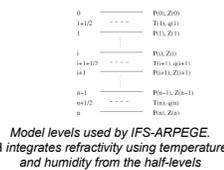
2. ASSIMILATION METHODOLOGY

• 4DVAR assimilation attempts to determine the 'best' initial conditions for issuing the next weather forecast, using prior information (short-term forecast) and observations.

• Minimization of a cost function: $J(x) = J_b(x) + J_0(x) + J_c(x)$ where
$J_b(x) = (x - x_b)^T R^{-1} (x - x_b)$
$J_0(x) = (H(x) - y^0)^T R^{-1} (H(x) - y^0)$ $(y^0 - H(x_b))$: called 'first-guess difference'
$J_c(x)$ includes additional constraints.

• Assumptions: non-biased Gaussian errors for prior and observations, uncorrelated observation errors, no correlation between prior information and observations, observation operators close to linearity.
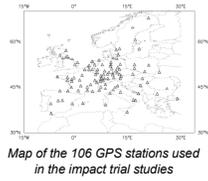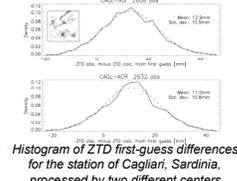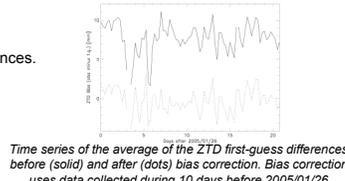
• Config.: IFS-ARPEGE T358L41, CY29T1, 7 time-slots per 6-hour 4DVAR assim. window

• H : observation operator which simulates the observations y^0, given an estimate of the atmospheric state x. Prior information is x_b (also called first-guess).
• B (R) : error covariance matrix of the prior informations (observations, respectively)
• H: integrates the refractivity at the vertical of the station. Code provided by ECMWF.
• Coded analytical H' (tangent linear model, TL) and H* (adjoint of the tangent linear model, AD)

Model levels used by IFS-ARPEGE. H integrates refractivity using temperature and humidity from the half-levels

Example of ZTD during a 6-hour analysis. x-axis shows the 7 time-slots of the 4DVAR.

ZTD errors evaluated by applying the method of Desroziers et al. (2005). Note the growth in forecast errors as compared to obs errors.
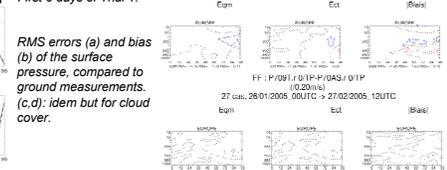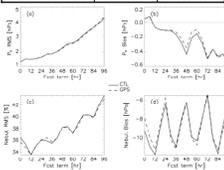
3. ZTD PRE-PROCESSING

• Station selection based on χ^2 tests. Retain stations with Gaussian first-guess differences.

• Time averaging of the ZTD observation consistent with the 4DVAR time-slots.

• Horizontal thinning (50 km). Discard stations with temporal coverage < 50%.

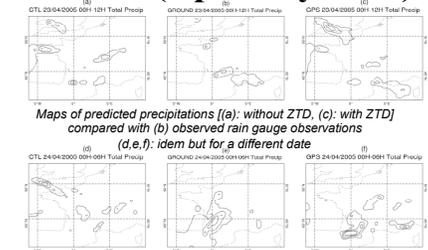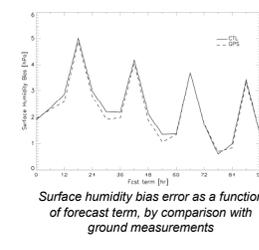• Bias correction: constant, station-dependent.

Time series of the average of the ZTD first-guess differences before (solid) and after (dots) bias correction. Bias correction uses data collected during 10 days before 2005/01/26

Histogram of ZTD first-guess differences for the station of Cagliari, Sardinia, processed by two different centers

Map of the 106 GPS stations used in the impact trial studies

4.1 RESULTS: TRIAL 1 (Jan-Feb 2005)

Quantity	$y^0 - H(x_b)$	$y^0 - H(x_a)$
Number	13251	13251
mean [mm]	0.5	0.5
std. dev. [mm]	6.1	4.3

Statistics of the fit to the ZTD observations before (middle column) and after assimilation (right column). First 6 days of Trial 1.

RMS errors (a) and bias (b) of the surface pressure, compared to ground measurements. (c,d): idem but for cloud cover.

Forecast scores by comparison with radiosondes Positive (negative) areas indicate improvements (degradations). X-axis: forecast term (hours)

4.2 RESULTS: TRIAL 2 (Apr-May 2005)

Surface humidity bias error as a function of forecast term, by comparison with ground measurements

Maps of predicted precipitations [(a): without ZTD, (c): with ZTD] compared with (b) observed rain gauge observations (d,e,f): idem but for a different date

CONCLUSIONS & FUTURE WORK

➤ **First assimilation study of the ZTD data in the 4DVAR assimilation at Meteo France**.
• Implemented an assimilation branch in the IFS-4DVAR, with obs. operator, TL/AD.
• Initiated ZTD obs. and background error evaluation following Desroziers et al. (2005)
• Developed a specific pre-processing for the ZTD data: Serves the following purposes: quality control, spatial and temporal data thinning, respect of the variational hypotheses.
➤ **Conducted two forecast trials**, each one month-long.
• Both indicate small but consistent positive impact on the prediction of the circulation (geopotential height, surface pressure, wind), and a neutral impact on temperature.
• The second trial with more precipitation cases indicates that the precipitation patterns predicted with assimilation of ZTD are better located than without assimilation of ZTD, when compared to rain gauge measurements.
• *Future work*: conduct experiments with ZTD data collected during Summer and Fall 2005; Refine error estimates ; investigate assimilation options in the Limited Area Model ALADIN.

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