NextGEN

Meteorological Algorithm

FAA

Federal Aviation
Administration

INTRODUCTION

- Meteorological Data Description
- Flight Level Height Estimation
- Flight Level Height Implementation for the Calculation of Altimetry System Error (ASE)

Meteorological Data Description (Data Source is NOAA)

- To determine flight level height for the calculation of ASE, the FAA uses meteorological data from NOAA / NWS / NCEP / EMC (National Oceanic and Atmospheric Administration / National Weather Service / National Centers for Environmental Prediction / Environmental Modeling Center)
- The EMC is one of nine National Centers for Environmental Prediction
- The FAA uses the WAFS (Wide Area Forecast System) meteorological data file
- The WAFS file is derived from the NCEP GFS (Global Forecast System)
- The atmospheric forecast model the GFS uses is the GSM (Global Spectral Model) with spherical harmonic basis functions
- The initial conditions the GSM uses is from the NCEP GDAS (Global Data Assimilation System)
- The GDAS uses all satellite, conventional, and radar observations within a plus or minus 3 hour window of the analysis time
- The NCEP Unified Post Processor (UPP) compares and verifies all model output

Meteorological Data Description
(Data File is WAFS)

- The WAFS file the FAA uses is in Gridded Binary 1 (GRIB 1) format on a 1.25 x 1.25 degree world grid comprised of 8 octants
- Each data file contains 2 time periods or 2 cycles
- The first time period is analysis data and the second time period is forecast data
- Two data files comprise one day of data where the first file contains time periods 00Z (analysis) and 06Z (forecast) and the second file contains time periods 12Z (analysis) and 18Z (forecast)
- For each grid point [1.25 x 1.25] degrees, at each time period [00,06,12,18]Z, the FAA degribs the WAFS data and extracts height in geopotential meters (gpm) above MSL and temperature in degrees Kelvin for mb levels [1000, 800, 750, 600, 500, 400, 300, 200, 150, 100]
- Based on these meteorological data variables (height, temperature), RVSM flight level heights [290 – 410] are estimated as a function of location and time

FAA

NextGEN

Flight Level Height Estimation
(Flight Levels Are Pressure Surfaces)

- Aircraft fly and maintain altitudes by measuring meteorological pressure levels defined by the Standard Atmosphere
- For each RVSM flight level [290 – 410] there is a corresponding mb level (pressure surface) that is defined by the Standard Atmosphere
- For example, when an aircraft is assigned fl 290 (29,000 feet), the aircraft avionics / pitot static system will try to measure a mb level of 314.94911 as defined by the Standard Atmosphere
- Because the meteorological data does not report the exact height of the pressure level at 314.84911 mb (29,000 ft), the FAA uses the hydrostatic equation and ratios to calculate the exact height of the pressure level at 314.84911 mb.
- The hydrostatic equation relates pressure, temperature and height
- To maintain an assigned flight level of 290 (29,000 feet), the aircraft must continuously measure through pressure sensors a pressure level of 314.84911 mb
- The continuous sensing of pressure level 314.84911 mb is referred to as flying the pressure surface

Flight Level Height Estimation

let $p1_i$ = standard atmosphere mb levels
= {400, 300, 250, 200, 150, 100}, i= 1,…,6
$h1_i$ = standard atmosphere geopotential heights (feet) at mb levels $p1_i$
= {23574.2, 30065.4, 33999.1, 38661.3, 44646.8, 53082.8}
$h2_j$ = standard atmosphere geopotential flight levels heights
= {29000, 310000,…,45000}, j=1,…,9
$p2_j$ = standard atmosphere mb levels at $h2_j$ flight level heights
= {314.84911, 287.44595, 262.00689, 238.42236, 216.62475, 196.77083, 178.73656, 162.35514, 147.47510}

← Standard Atmosphere Pressure and Height

$h3_i$ = WAFS geopotential heights at mb levels $p1_i$ (input variable)
t_i = WAFS temperatures at mb levels $p1_i$ (input variable)
$\bar{t}$ = mean WAFS temperatures between mb levels (estimated variable)
$\bar{t}1$ = mean WAFS temperatures between mb levels and flight level (estimated variable)
$\tilde{h}$ = geopotential flight level height (estimated variable)

← WAFS Input Height and Temperature

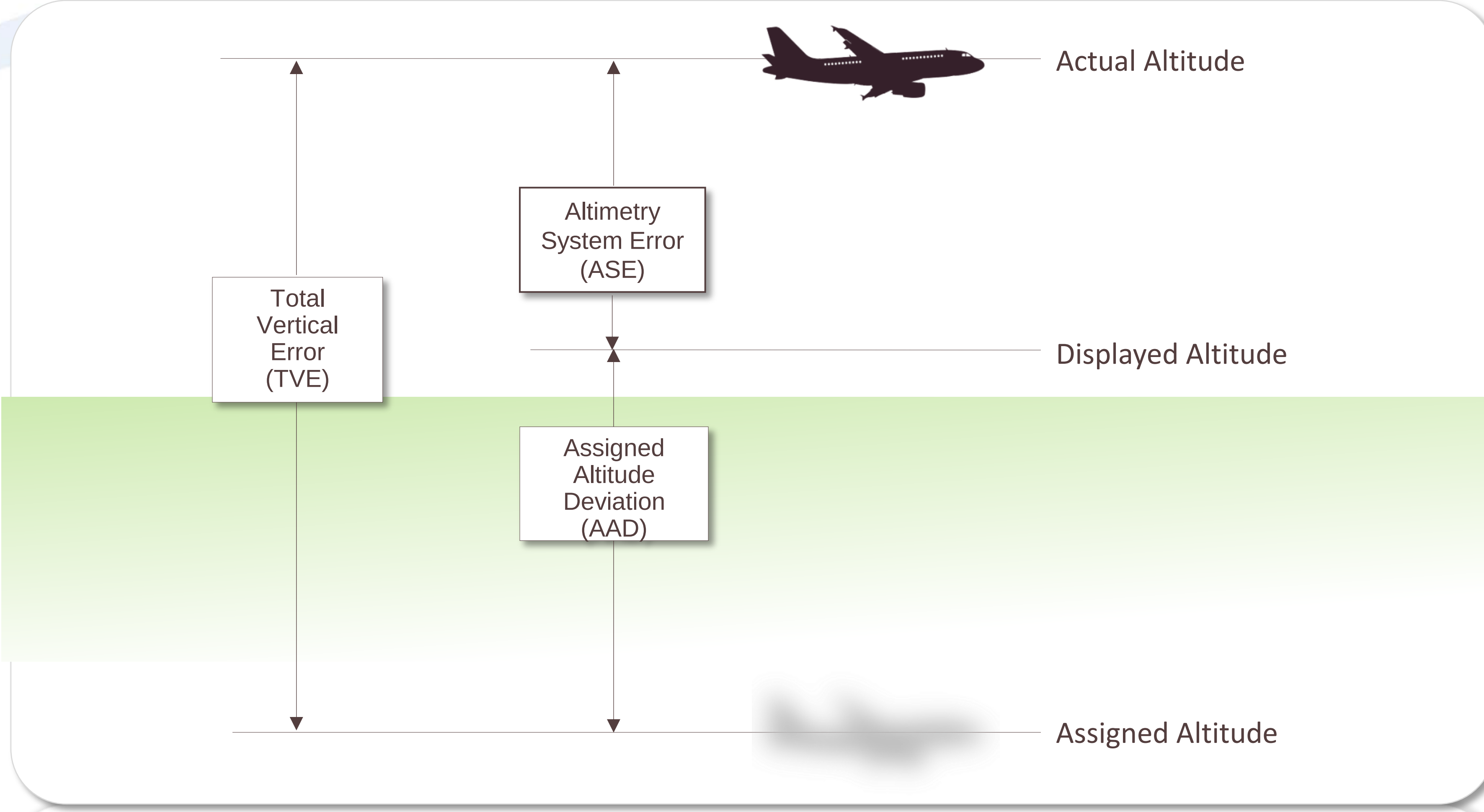
let d = $(t_{i+1} - t_i) / (h1_{i+1} - h1_i)$
$\bar{t}1 = t_i + (d/2)(h2_j - h1_i)$
$r = \ln(p1_i/p2_j) / \ln(p1_i/p1_{i+1})$
$d1 = (\bar{t}1 / \bar{t})\, r$
then
$\tilde{h} = h3_i + d1\,(h3_{i+1} - h3_i)$

← Equations Flight Level Height Estimation

Flight Level Height Implementation for the Calculation of Altimetry System Error (ASE Defined)

- ASE = TVE - AAD where TVE is the aircraft's Total Vertical Error and AAD is the aircraft's Assigned Altitude Deviation
- TVE = (Geometric Height of the Aircraft) - (Geometric Height of the Flight Level)
- AAD = (Aircraft Mode S Height) – (Assigned Flight Level Height)
- If we assume AAD = 0 for this presentation, then the implementation of flight level height estimation for the calculation of ASE becomes a matter of defining the pressure surface height as a function of the aircraft's track (latitude, longitude, time) and getting the height units, the earth model reference, and time units all the same so the subtraction TVE = (Geometric Height of the Aircraft) - (Geometric Height of the Flight Level) is valid
- For purposes of calculating ASE, an aircraft's track is defined when: (1) the aircraft is flying straight and level, (2) the aircraft maintains the same flight level, (3) there are no large time gaps caused by the aircraft landing and taking off again on the same day

Flight Level Height Implementation for the Calculation of Altimetry System Error (Elements of Total Vertical Error)



Flight Level Height Implementation for the Calculation of Altimetry System Error (Flight Level Height as a Function of Aircraft Position)

- Convert NOAA mb level heights from geopotential meters to geopotential feet to geometric feet
- Convert NOAA mb level height reference from MSL (HAG) to WGS84 (HAE)
- Convert GPS time to Z (start of day in seconds)
- To model the pressure surface, the FAA uses the method described in the Junkins paper "A Weighting Function Approach to Modeling of Irregular Surfaces", Junkins, Miller, Jancaitis, Journal of Geophysical Research, April 10, 1973, vol 78, NO 11
- For one aircraft track, define the modeled pressure surface coverage area to be a box that contains the aircraft track plus 5 degrees on all sides of the box
- For all four time periods, model the pressure surface according to Junkins and then spatially and temporally interpolate the pressure surface heights according to aircraft position (latitude, longitude, time)

Flight Level Height Implementation for the Calculation of Altimetry System Error
(Flight Level Height as a Function of Aircraft Position)

- Convert pressure surface heights (units geopotential feet) above HAG to HAE (geometric feet) using a table look-up and the bi-linear interpolation method as described in document DMAAC/GGAD, June 23, 1991 titled "Geoid Height Bi-Linear Interpolation Method"
- Convert GPS time to Z
- For each second, calculate TVE = (Geometric Height of the Aircraft) - (Geometric Height of the Flight Level)
- For each second, calculate AAD = Aircraft Mode S Height - Assigned Flight Level Height
- Check synchronization between TVE and AAD
- For each second, calculate ASE = TVE – AAD
- The mean ASE of the aircraft's track segment is one independent sample of the aircraft's ASE

FAA NextGEN

Pressure Surface Over Cleveland AGHME