The impact of airborne Doppler lidar measurements on ECMWF forecasts

Martin Weissmann, Andreas Dörnbrack, Stephan Rahm, Oliver Reitebuch
Institut für Physik der Atmosphäre, DLR Oberpfaffenhofen, Germany

Carla Cardinali
European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, UK
The Atlantic THORPEX Regional Campaign A-TReC
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Goals:
(1) investigate how much forecast errors over Europe and N-America can be reduced by additional observations above the N-Atlantic
(2) test observation targeting
(3) investigate the value of new observing systems
DLR participation: 14 - 28 November 2003

Conical scans: 1 scan = 24 LOS positions (~30/54s)
vertical profile of 3-D wind vector
horiz. resolution 5 - 40 km, vert. resolution 100 m
range: 0.5-12 km
4 flights in "sensitive areas" (targeting)
1 flight for Greenland Tip Jet
1 flight for intercomparison ASAR and lidar
2 transfer flights

8 flights, 1600 wind profiles, 40 000 lidar observations, 49 dropsondes
Observations on 25 November 2003

http://www.sat.dundee.ac.uk/
Statistical intercomparison of lidar and dropsondes

Comparison: 33 wind profiles
> 500 observations

Error lidar (u,v):
RMS = 0.75-1 m/s
Assigned errors

Error lidar: 0.75-1 m/s

Representativeness error (Frehlich & Sharman 2004) < 0.5 m/s

Total error lidar: 1-1.5 m/s

Total error Dropsonde/Radiosonde: 2-3 m/s

Total error AMV 2-5 m/s
Experiments with ECMWF T511 Global Model

6 experiments 14-30 November 2003
  lidar, ~10 km, Std = 1 m/s
  lidar, ~40 km (2 averaging types), Std = 1 m/s
  lidar, ~40 km, Std = 1.5 m/s
  ~100 dropsondes (from 10 flights)
  control run

thinning to grid points (40 x 40 km, 60 levels)
  ~ 80% not used
  ~ 3000 used observations
  5 million operational observations used per day
  lidar = 0.005% additional observations
Background departures

Background departure = difference background and observation

\[(\text{Std(bg-dep)})^2 = (\text{Std}_{\text{obs}})^2 + (\text{Std}_{\text{bg}})^2\]
Observation influence (22 November 2003)

<table>
<thead>
<tr>
<th></th>
<th>Lidar u, v</th>
<th>Dropsonde u, v</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation influence</td>
<td>0.63</td>
<td>0.45</td>
</tr>
<tr>
<td>Number of observations</td>
<td>758</td>
<td>388</td>
</tr>
<tr>
<td>Information content</td>
<td>477.5</td>
<td>174.6</td>
</tr>
</tbody>
</table>

observation influence (Cardinali et al. 2004):
- 0 --> no influence of observations
- 1 --> no influence of background

mean global observation influence = 0.15
Reduction of forecast error - 48 h

Diff in RMS of fc-Error: RMS(fc_en5t - an_eiz3) - RMS(fc_eiz3 - an_eiz3)
Lev=500, Par=z, fcDate=20031115-20031128 00/12 UTC, Step=48
NH=-0.55 SH= 1.19 Trop= 0.35 Eur=-4.52 NAmer= 4.2 NAtl= -2.94 NPac= -3.65

(gpdm)
Diff in RMS of fc-Error: RMS(fc_en5t - an_eiz3) - RMS(fc_eiz3 - an_eiz3)

Lev=500, Par=z, fcDate=20031115-20031128 00/12 UTC, Step=72

NH=-2.37 SH= 2.87 Trop= 0.31 Eur=-11.42 NAmer= 5.12 NAtl= -1.61 NPac= -8.24
Diff in RMS of fc-Error: RMS(fc_en5t - an_eiz3) - RMS(fc_eiz3 - an_eiz3)

Lev=500, Par=z, fcDate=20031115-20031128 00/12 UTC, Step=96
NH=-4.14 SH= 6.82 Trop= 0.05 Eur=-14.54 NAmer= -6.13 NAT= 2.84 NPac= -7.9

area: 17 x 10^-6 km^2
Reduction of forecast error - 500 hPa

Mean reduction over Europe, averaged over 29 forecasts (2 weeks)
black: experiments with lidar, gray: experiment with 100 dropsondes
Reduction of forecast error - 48, 72, 96 h

![Graphs showing the mean reduction of forecast error over different hours.](image-url)
Comparison to mean reduction of NWP error

Reduction of forecast error of 500 hPa geopotential height:
Lidar 72 h: ~ 1 m (3.5%)

Simmons and Hollingsworth 2002:
72 h: 10 m in 10 years
Conclusions

first assimilation of Doppler lidar observations in global NWP model

lidar measurements have a smaller error than all other wind operational observations
  --> analysis influence is 50% higher than that of dropsonde wind obs.
    information content is three times higher

lidar wind observations reduce the forecast error of u, v, z, rh, and t over Europe

average reduction of the 48 - 96 h forecast error over Europe ~3%

emphasizes the need for better observations and the potential airborne and spaceborne lidars