The impact of airborne wind and water vapour lidar measurements on ECMWF analyses and forecasts

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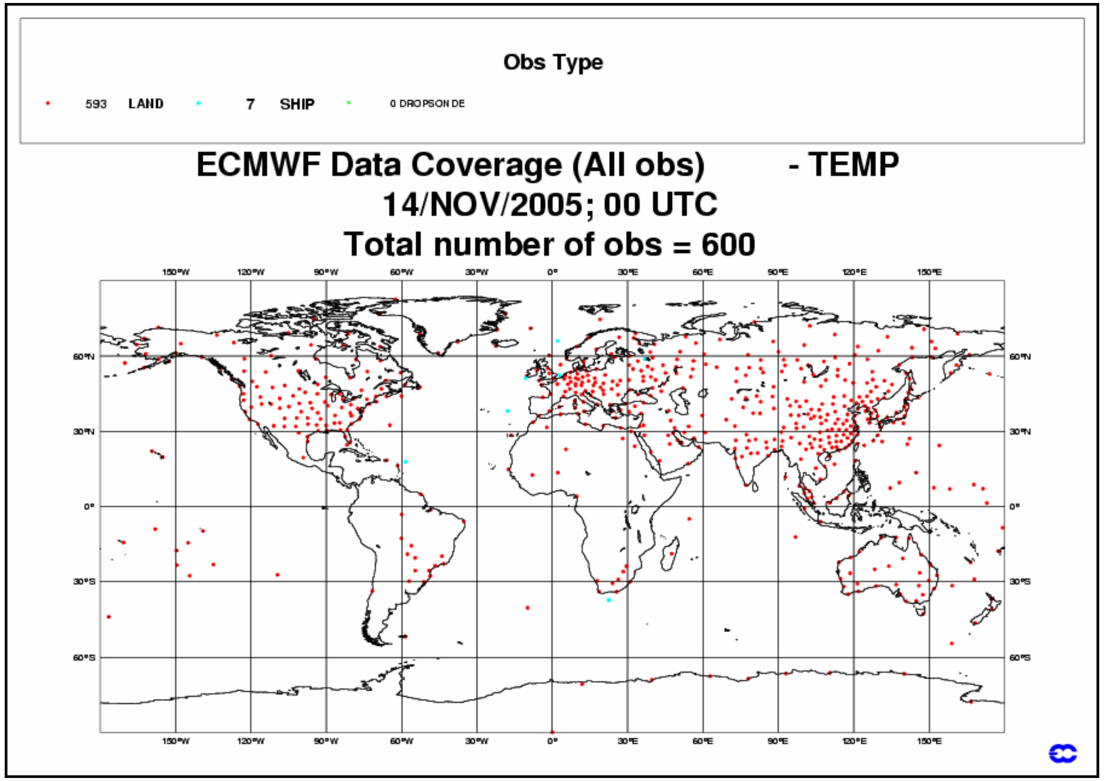
Motivation

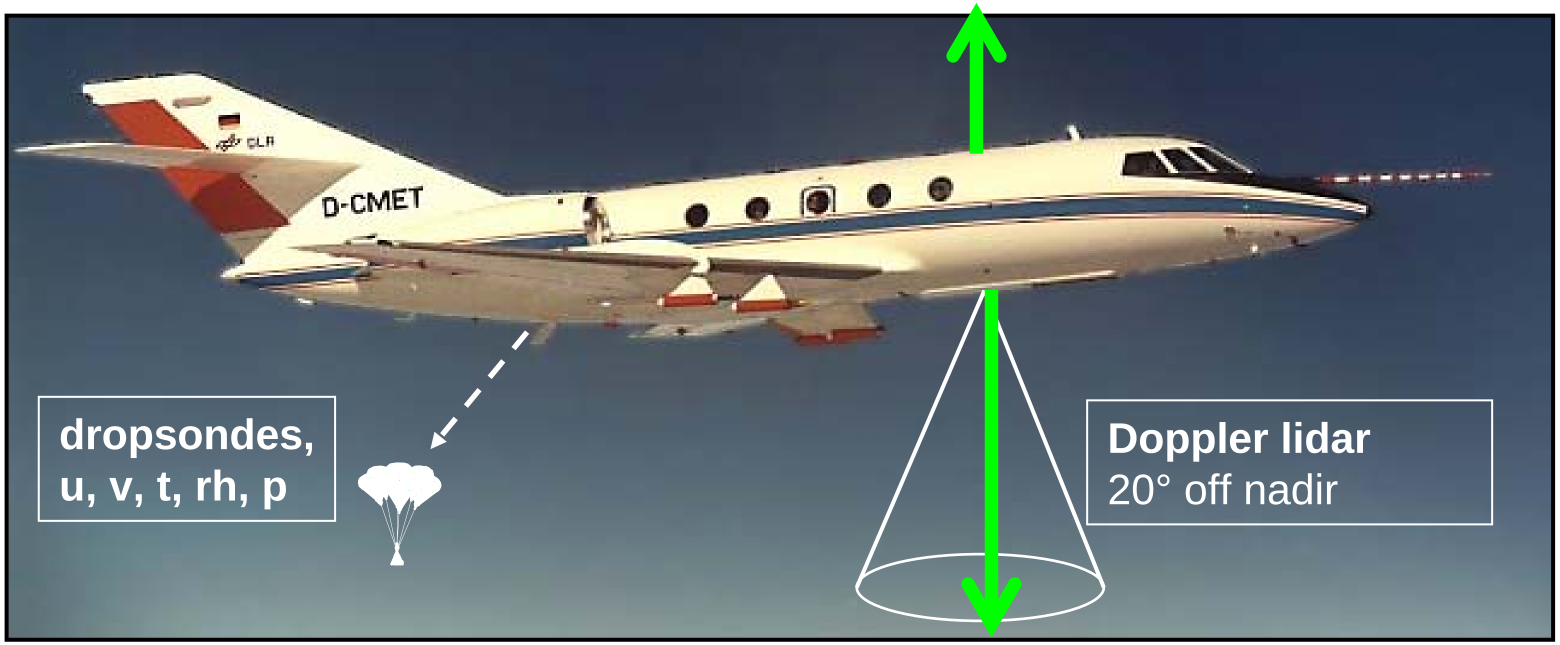


above oceans:
hardly any radiosondes
aircraft at cruise level
low accuracy of passive instruments
low resolution and height errors

lidars can measure various atmospheric quantities in remote regions with high accuracy and high resolution either from satellites or aircraft

goal: estimate benefit with impact studies

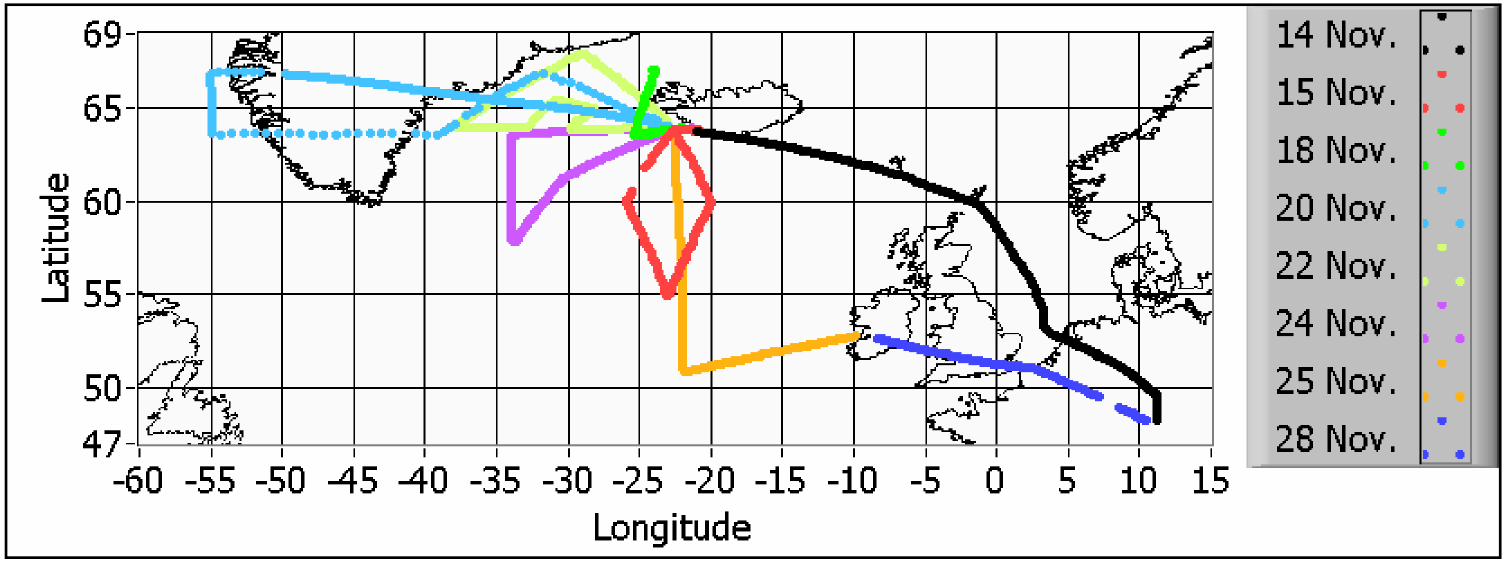
DLR lidar instruments



Differential Absorption Lidar (DIAL)
λ~920-945 nm, 100 Hz, 2 W
parameter: water vapour molecule number
nadir or zenith pointing
horiz. resolution: 2 - 40 km
vert. resolution: 500 - 2000 m

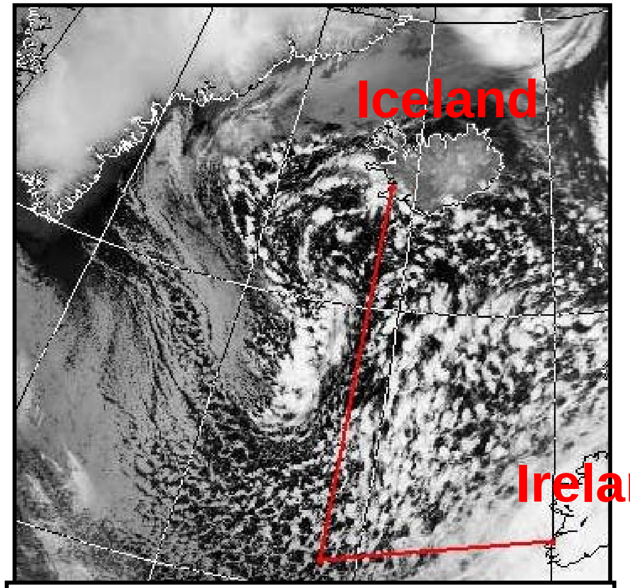
scanning coherent 2 µm Doppler lidar:
conical scans with 24 positions
→ 24 LOS observations (~30/54 s)
→ vertical profile of 3-D wind vector
horiz. resolution 5 - 40 km
vert. resolution 100 m
range: 0.5-12 km

Wind data - Atlantic THORPEX Regional Campaign (A-TReC)
14 - 28 November 2003

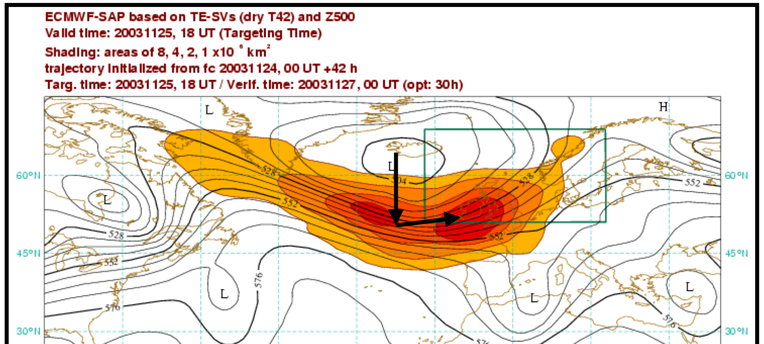


4 flights in "sensitive areas" (targeting)
1 flight for Greenland Tip Jet
1 flight for intercomparison ASAR and lidar
2 transfer flights
=====================================
8 flights, 1600 wind profiles, 40 000 lidar measurements, 49 dropsondes

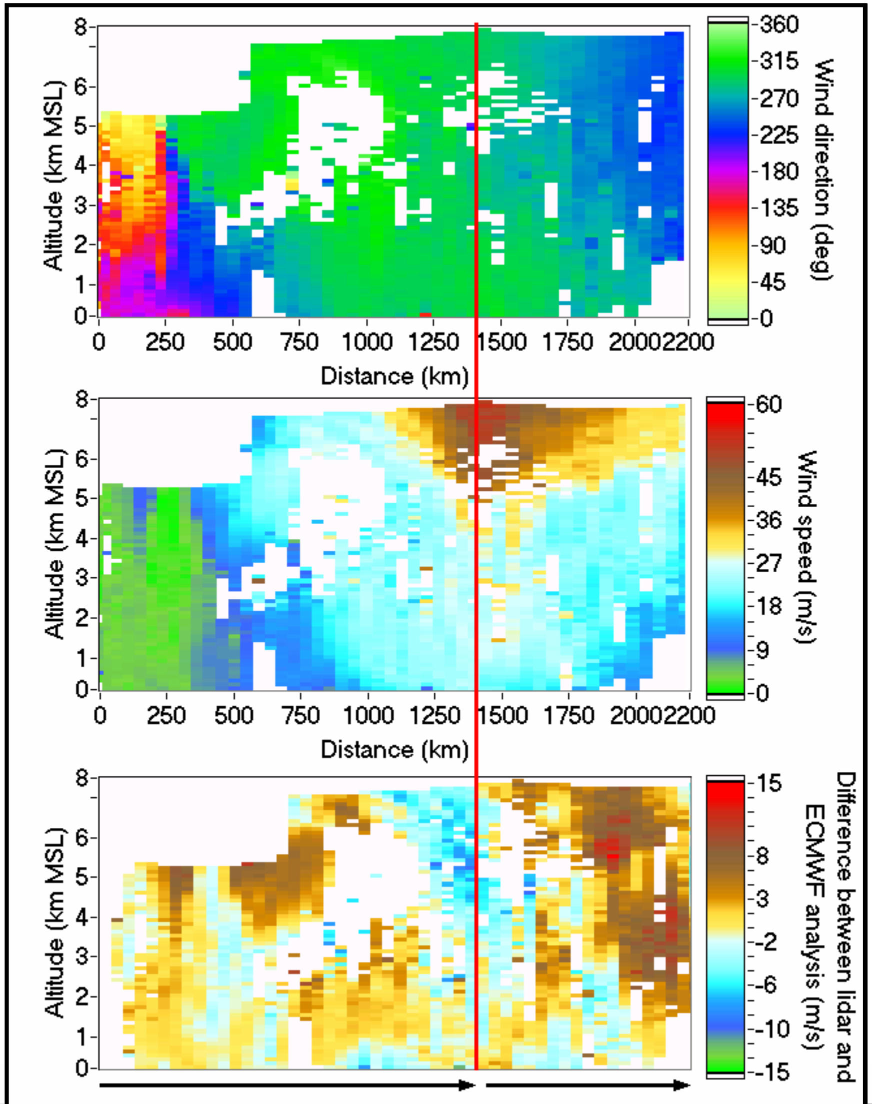
Observations on 25 November 2003



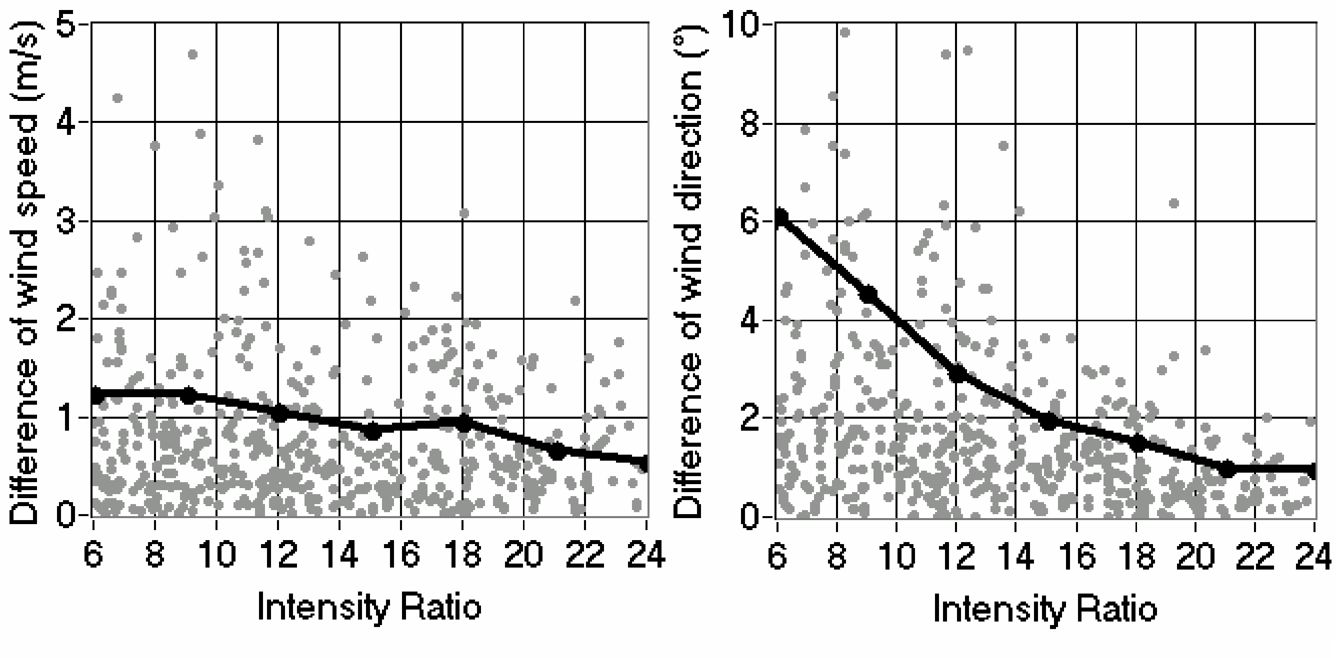
http://www.sat.dundee.ac.uk/



ECMWF sensitivity plot and 500 hPa



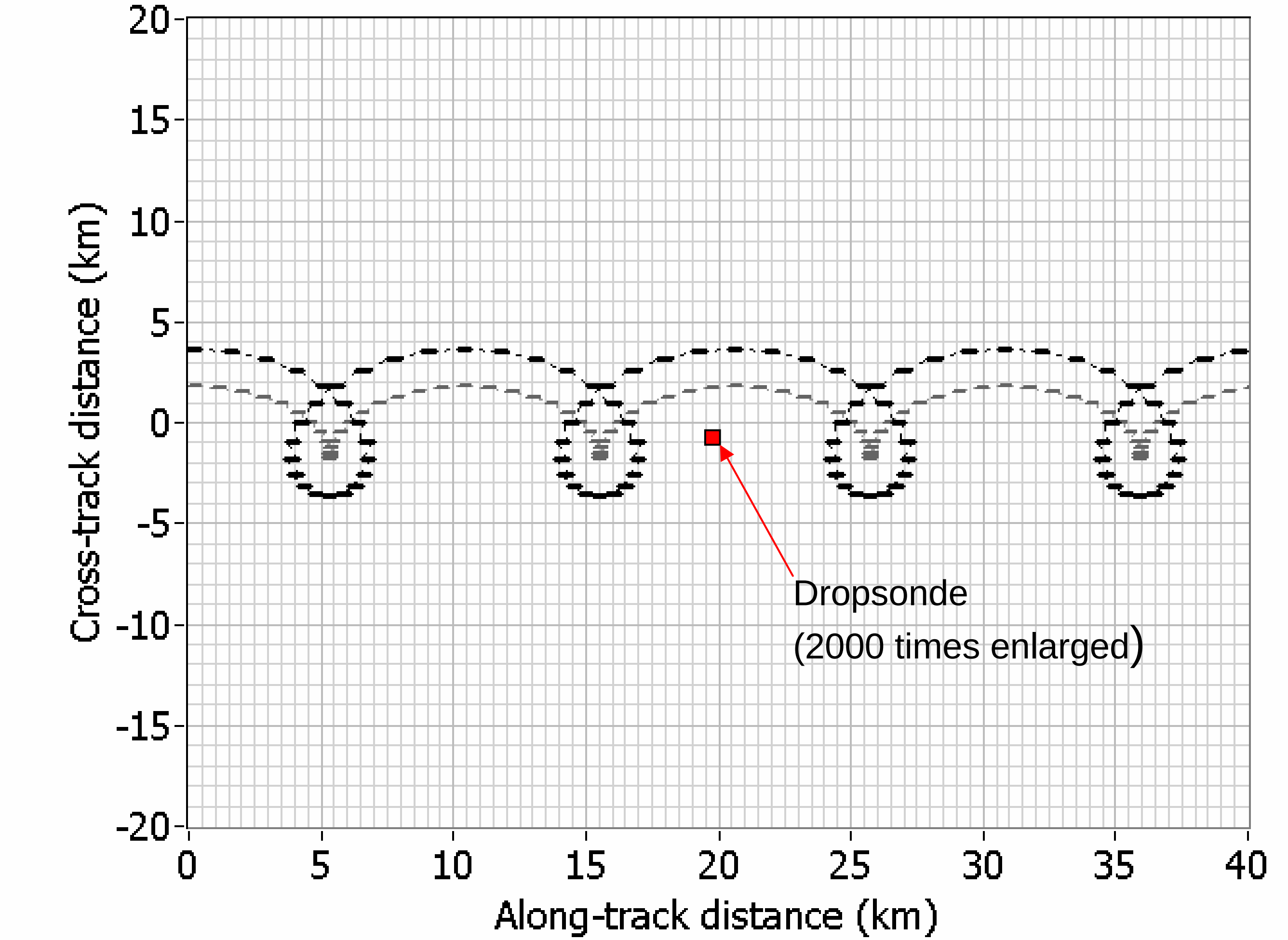
Statistical intercomparison of lidar and dropsonde winds



Comparison: 33 Wind profiles
> 500 Measurements

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

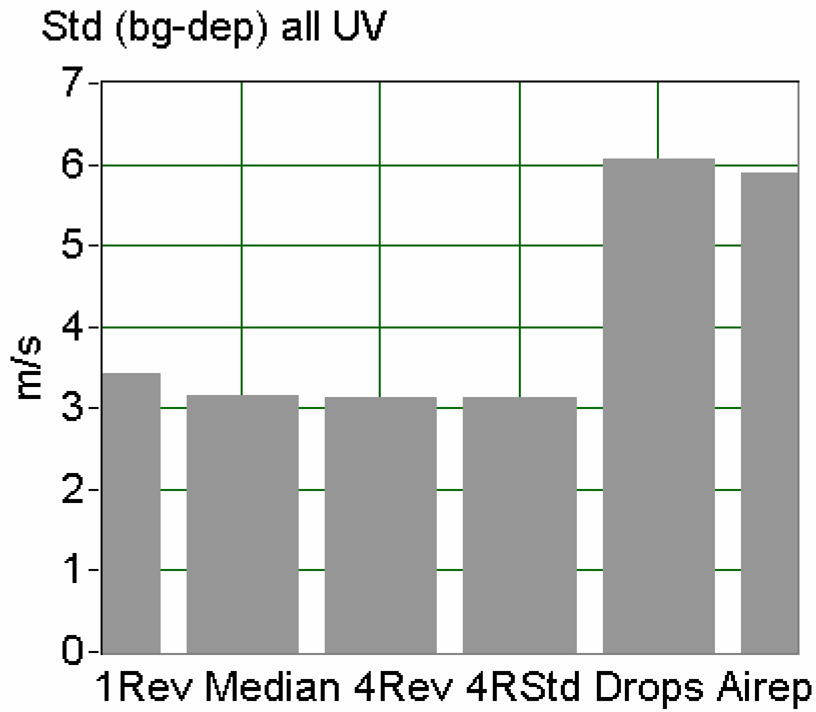
Experiments with ECMWF T511 global model

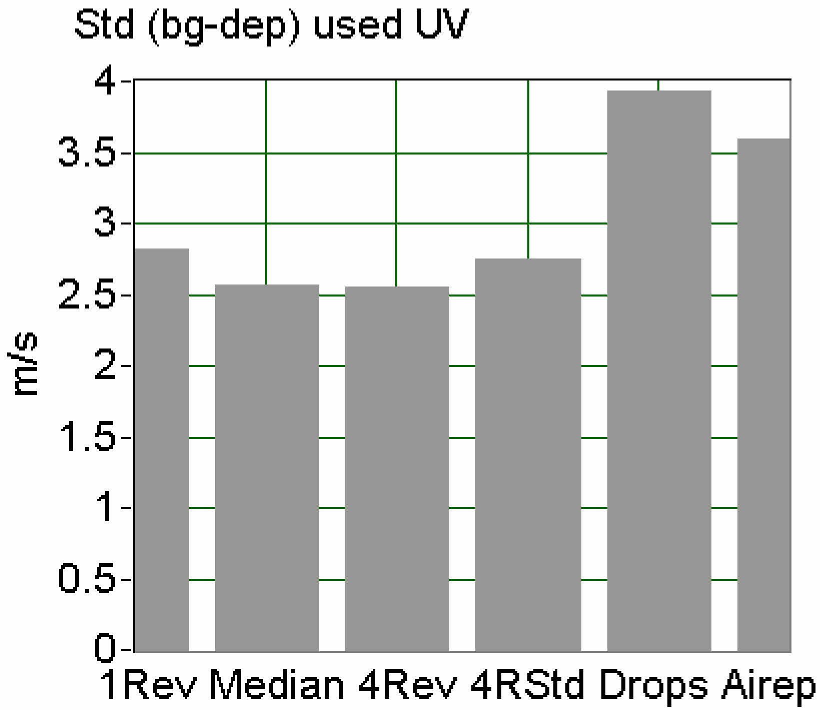
6 experiments 14-30 November 2003
- lidar, ~10 km, Std = 1 m/s
- lidar, ~40 km (2 averaging types), Std = 1 m/s
- lidar, ~40 km, Std =1.5 m/s
- ~100 dropsondes (from 10 flights)
- control run

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

4 un-cyled experiments to investigate targeted observations (forecast sensitivity)

Background departures

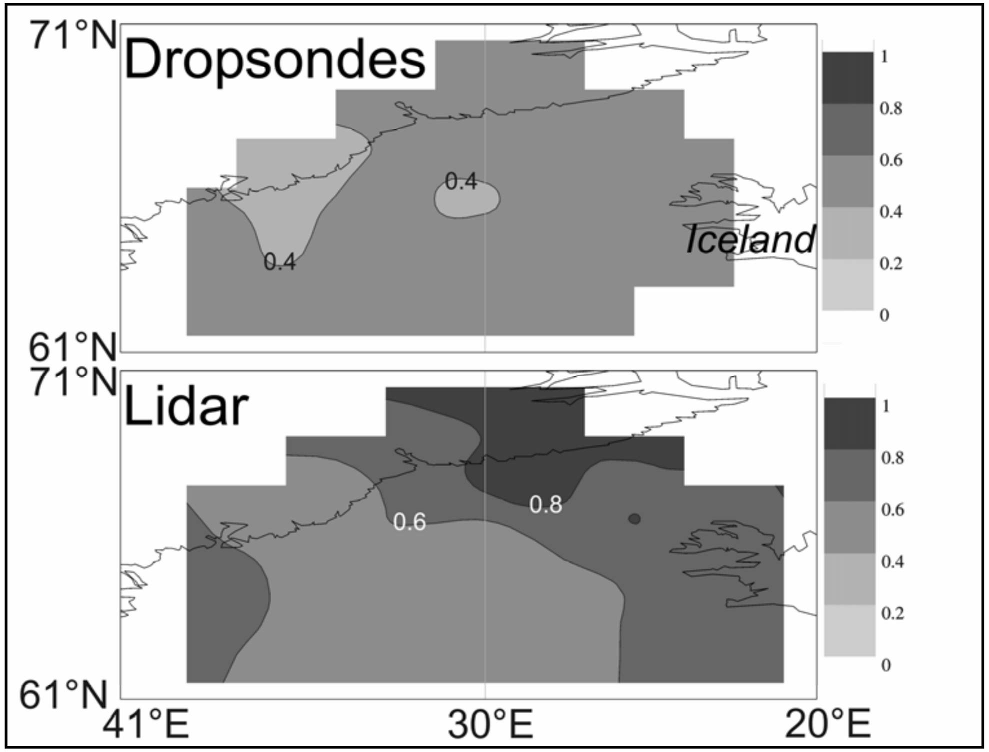




Background departure = difference background and observation

$(Std(bg\text{-}dep))^2 = (Stdo_{bs})^2 + (Std_{bg})^2$

Observation influence (22 November 2003)



	Lidar u, v	Dropsonde u, v
Observation influence	0.63	0.45
Number of observations	758	388
Information content	477.5	174.6

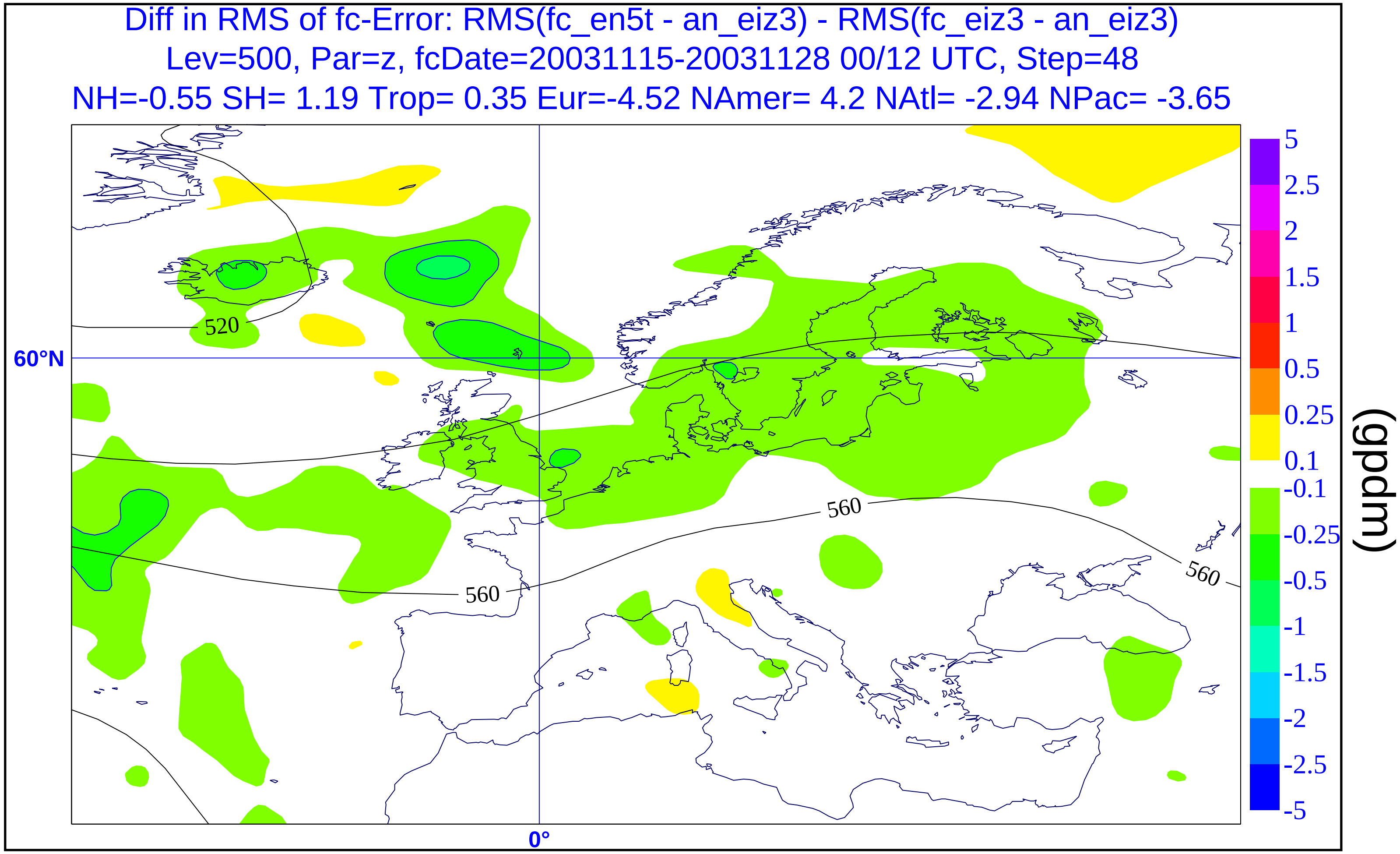
observation influence (Cardinali et al. 2004):

0 --> no influence of observations

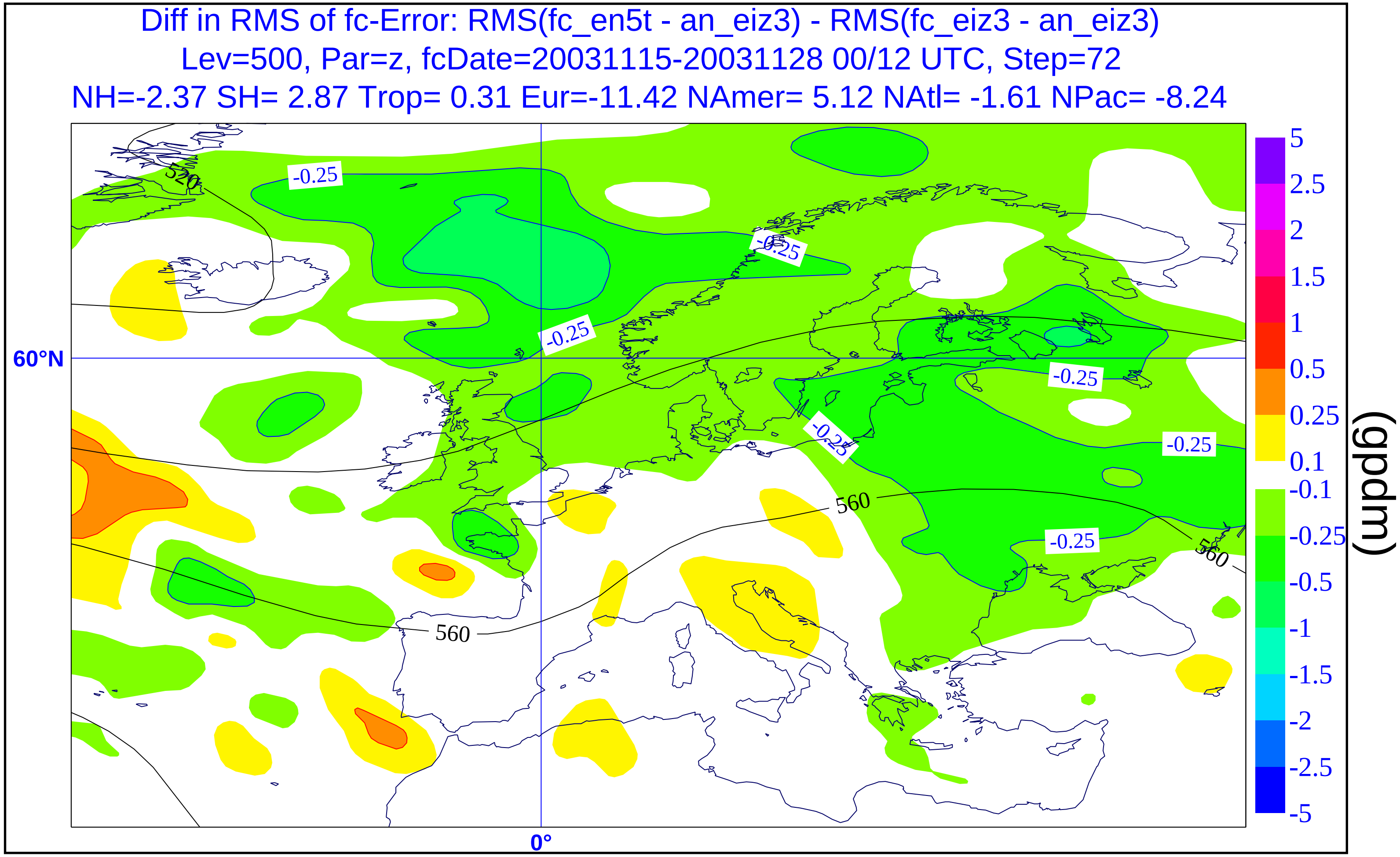
1 --> no influence of background

mean global observation influence = 0.15

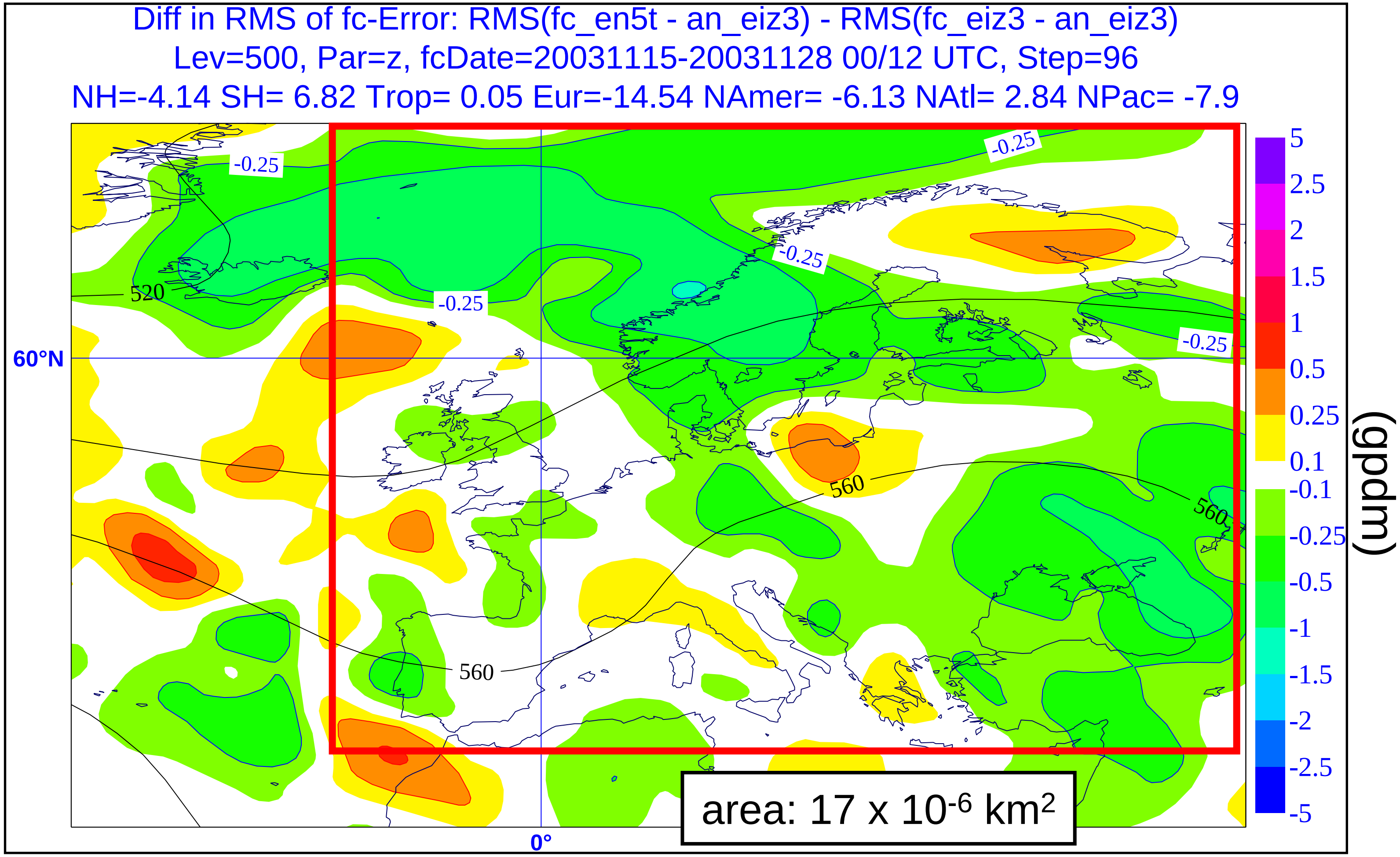
Reduction of forecast error at 500 hPa - 48 h



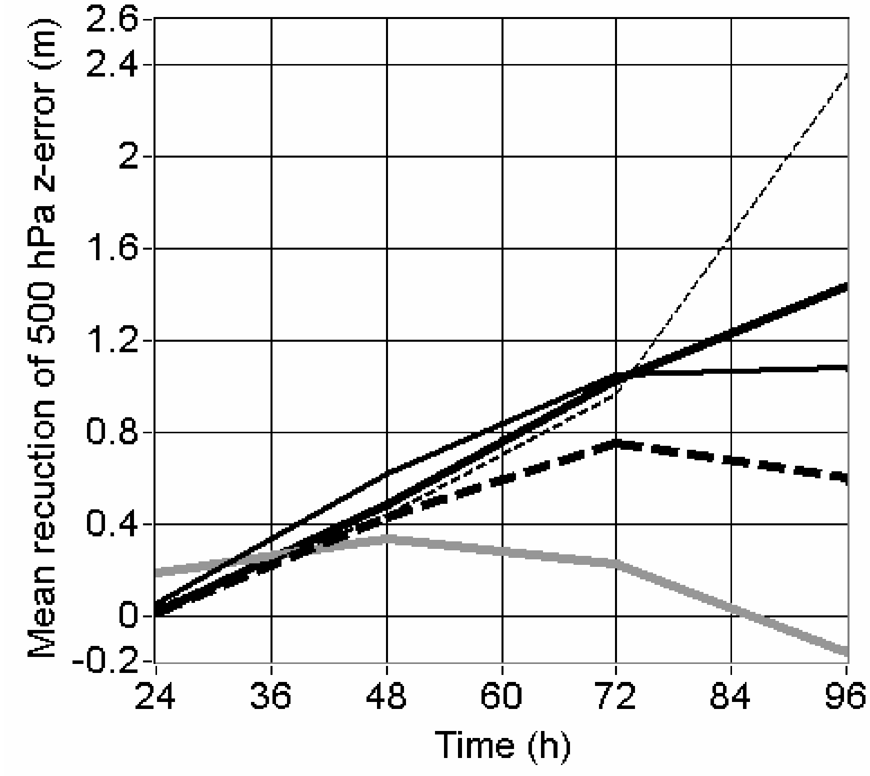
Reduction of forecast error at 500 hPa - 72 h

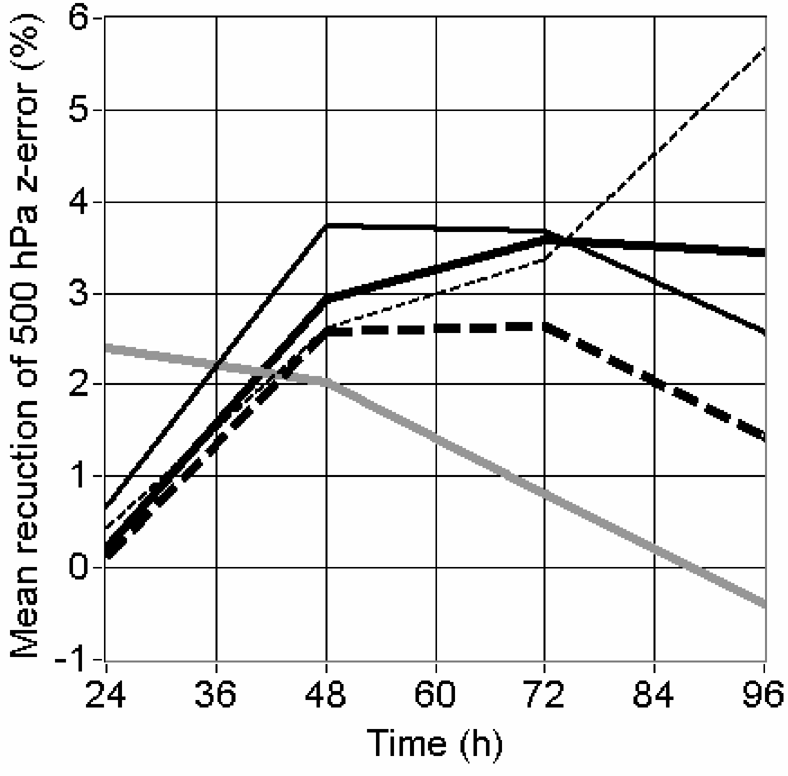


Reduction of forecast error at 500 hPa - 96 h



Reduction of forecast error - 500 hPa

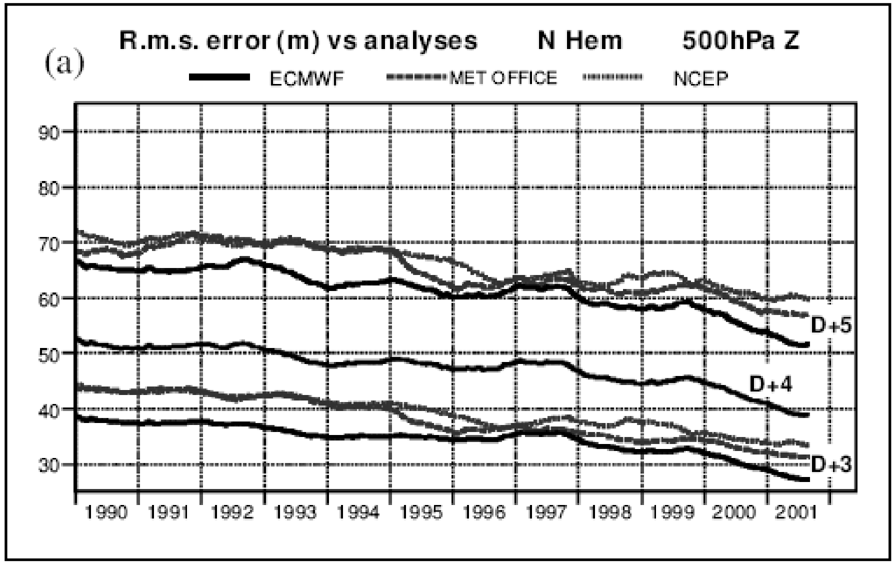




Mean reduction over Europe, averaged over 29 forecasts (2 weeks)
black: experiments with lidar, gray: experiment with 100 dropsondes

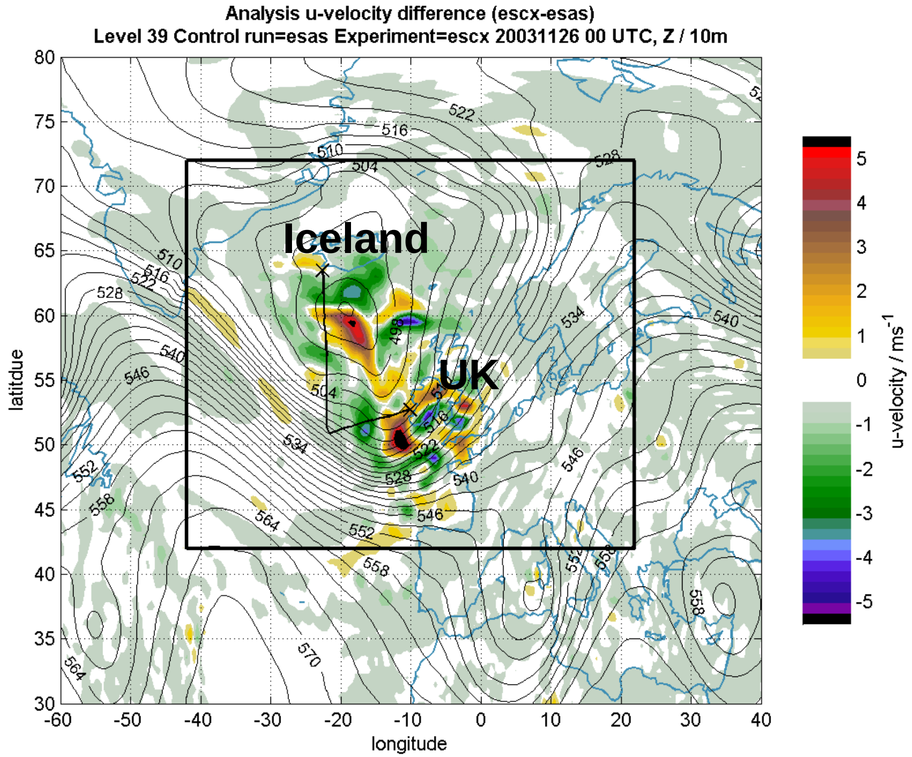
Comparison to mean reduction of NWP error

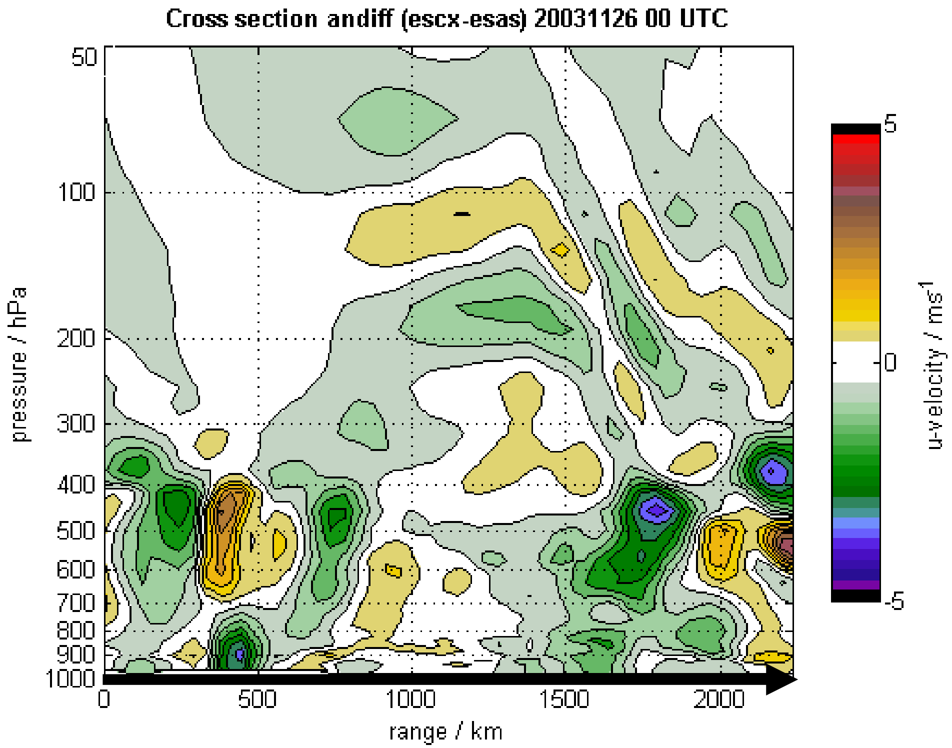
Reduction of forecast error of 500 hPa geopotential height:
Lidar 72 h: ~ 1 m (3.5%)



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

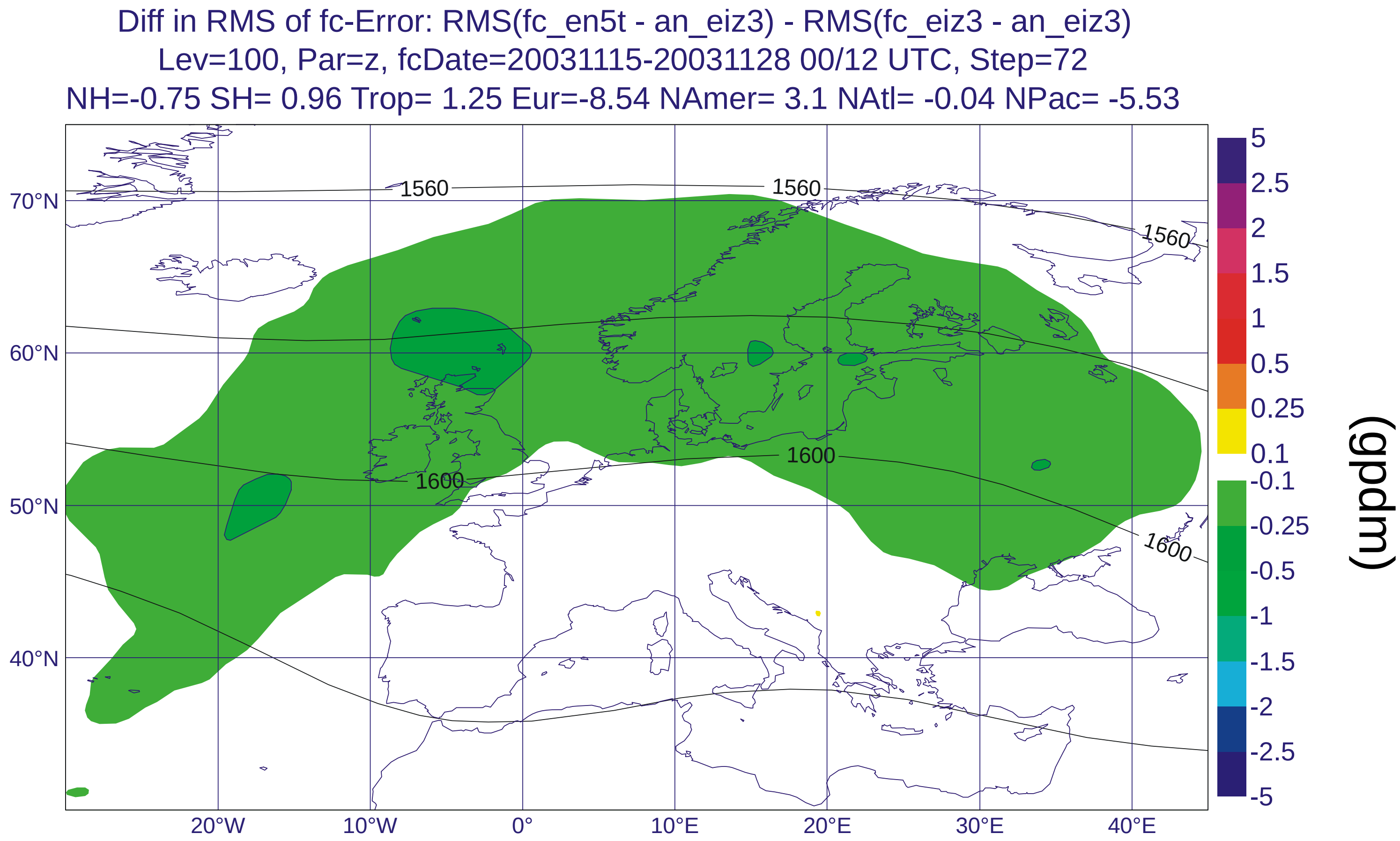
Analysis influence of lidar data





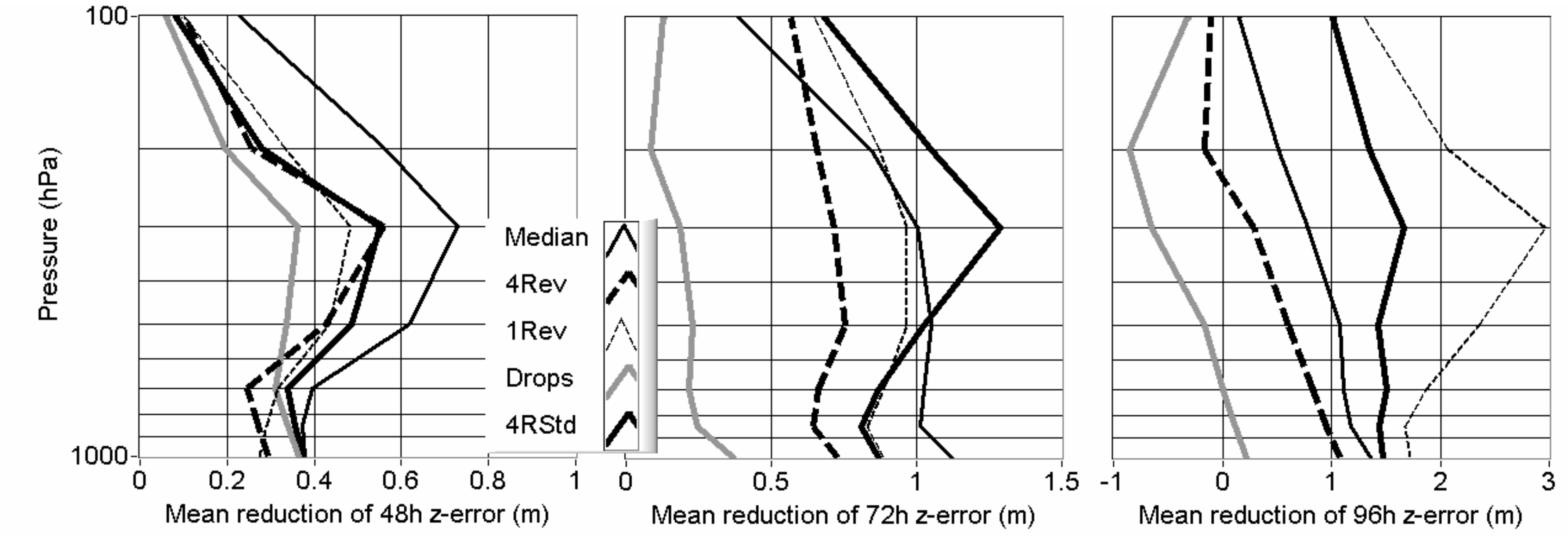
Analysis difference of lidar experiment and control run
26 November 2003, 00 UTC

Reduction of forecast error at 100 hPa - 72 h

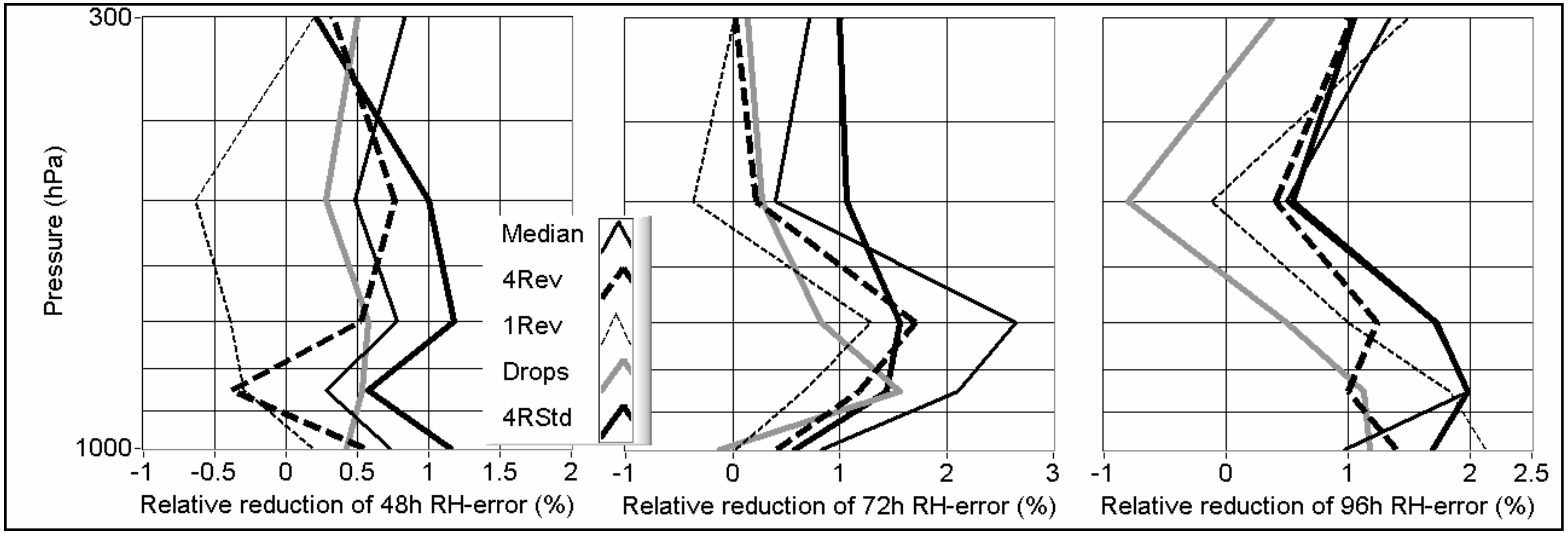


highest lidar observations at 250-300 hPa

Reduction of forecast error - 48, 72, 96 h



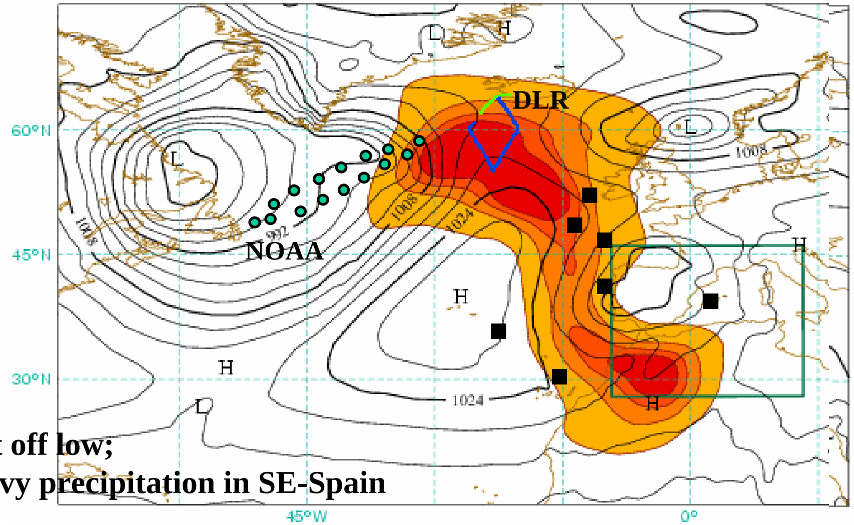
Relative reduction of RH forecast error - 48, 72, 96 h



→Reduction of u, v, z, rh, and t forecast errors

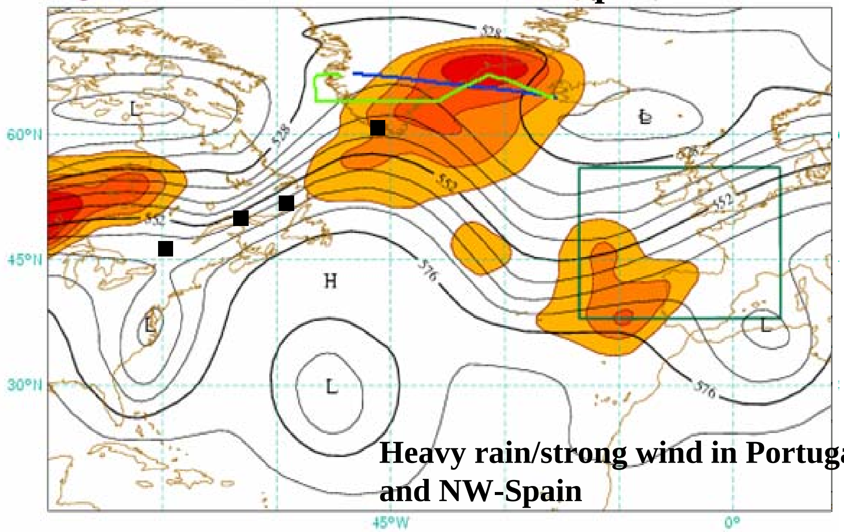
A-TReC targeting campaigns

20031115 at 18 Step42



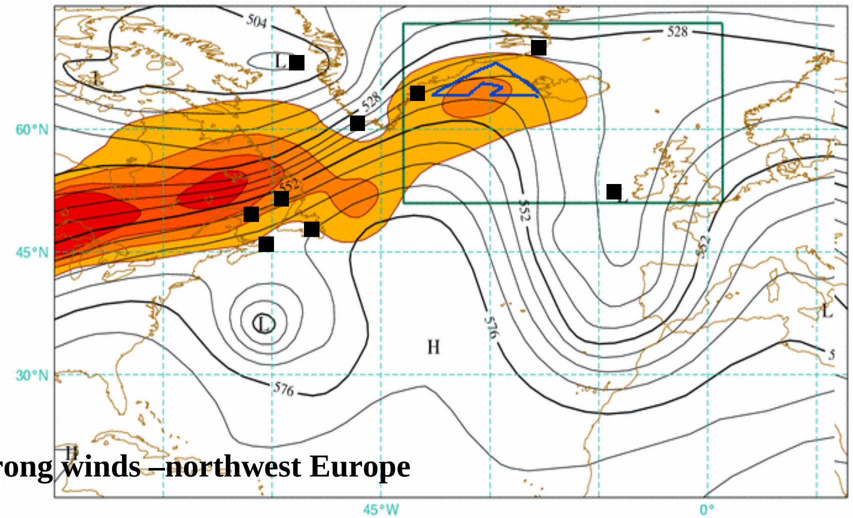
Cut off low; heavy precipitation in SE-Spain

20031120 at 18 Step54



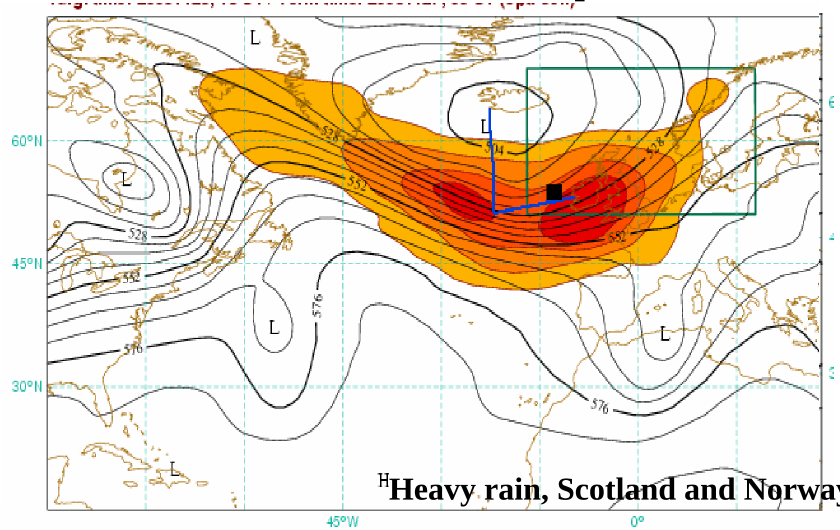
Heavy rain/strong wind in Portugal and NW-Spain

20031122 at 18 Step66



Strong winds –northwest Europe

20031125 at 18 Step30



Heavy rain, Scotland and Norway

The influence of targeted observations

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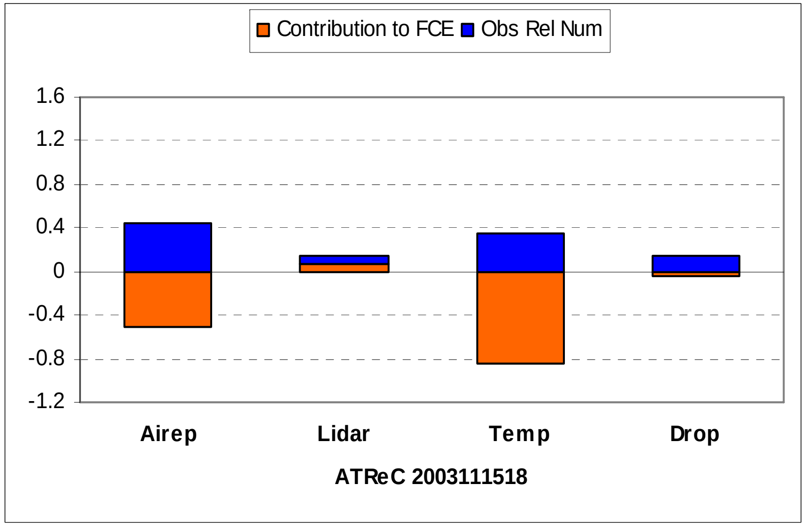

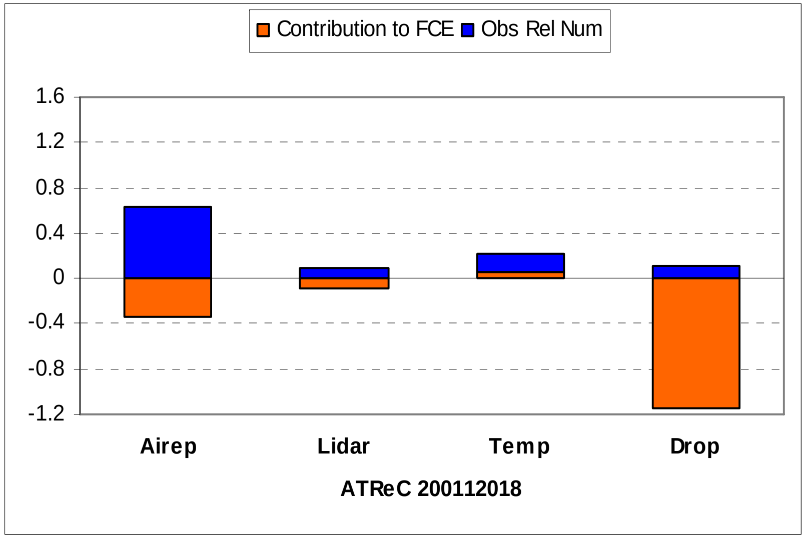

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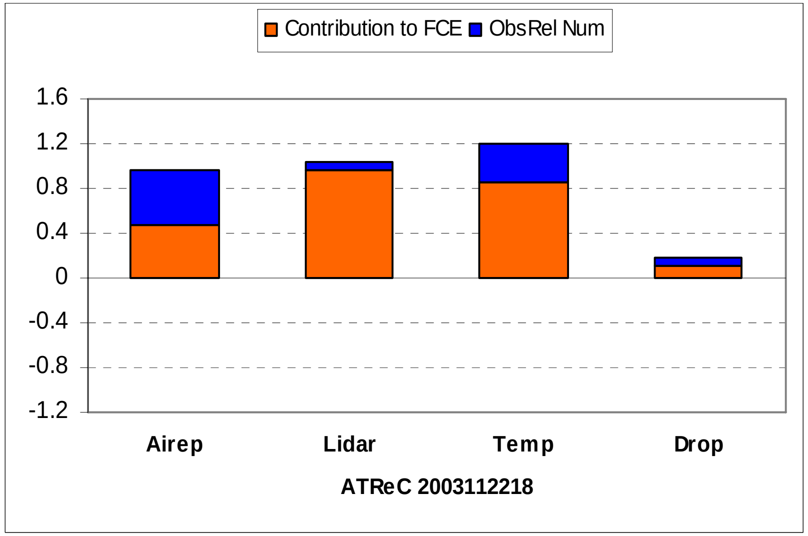

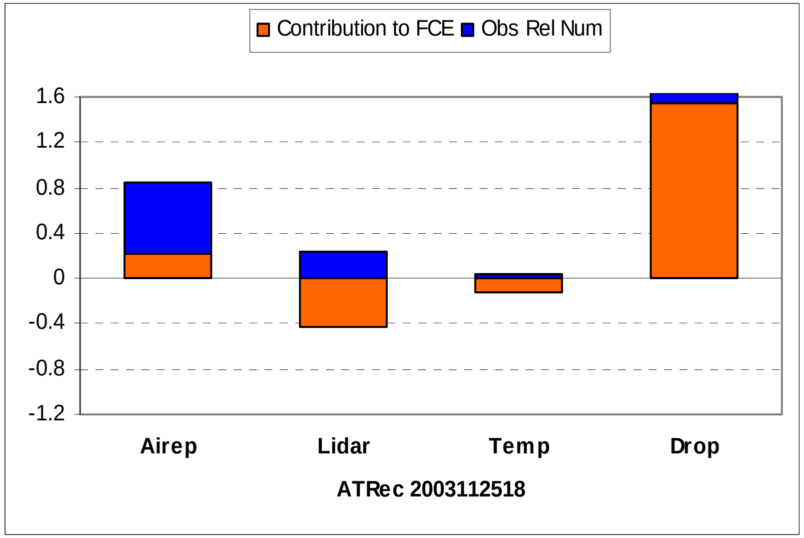

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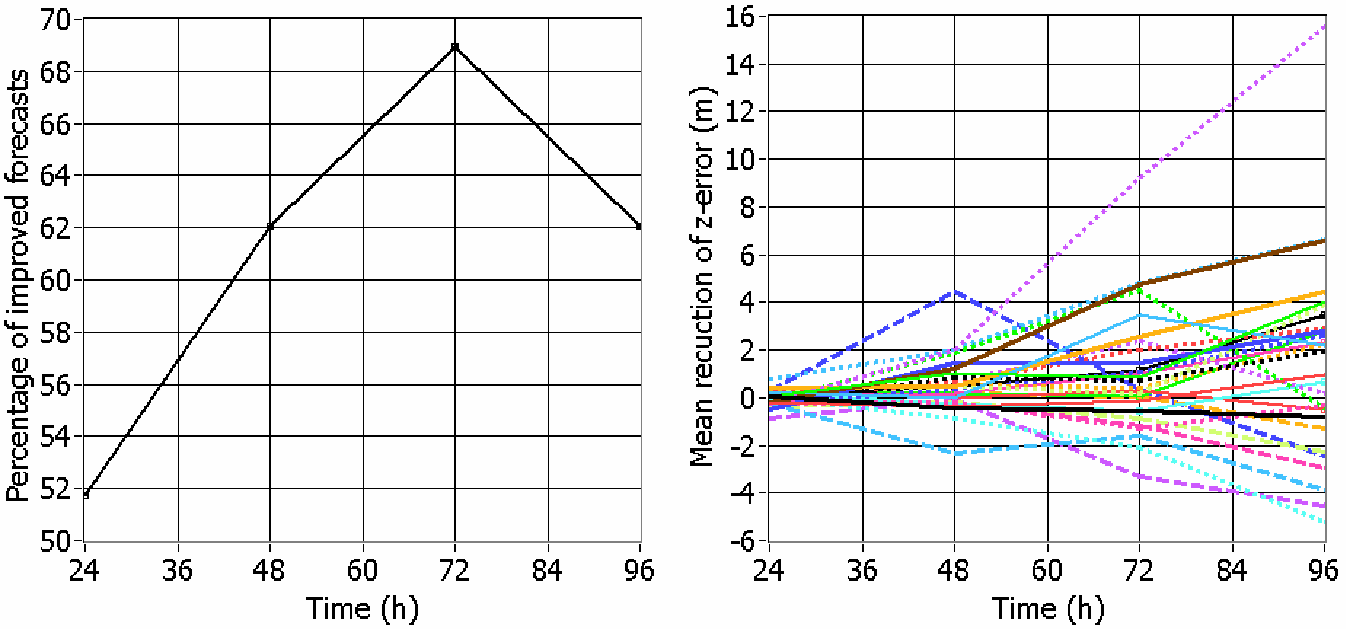
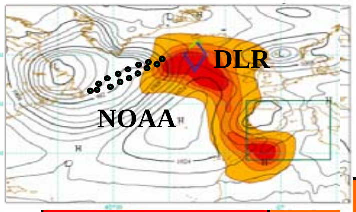
The problem of case studies ...



28 forecasts
14-28 November

statistical problem --> larger sample
practical restrictions --> better planning

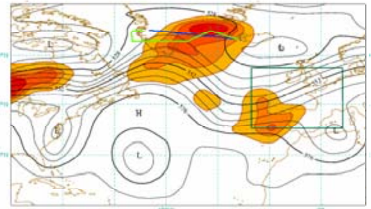
Impact outside the verification area



2003111518 Step42

28	20	15
7	14	4
3	7	2

2003112018 Step 54



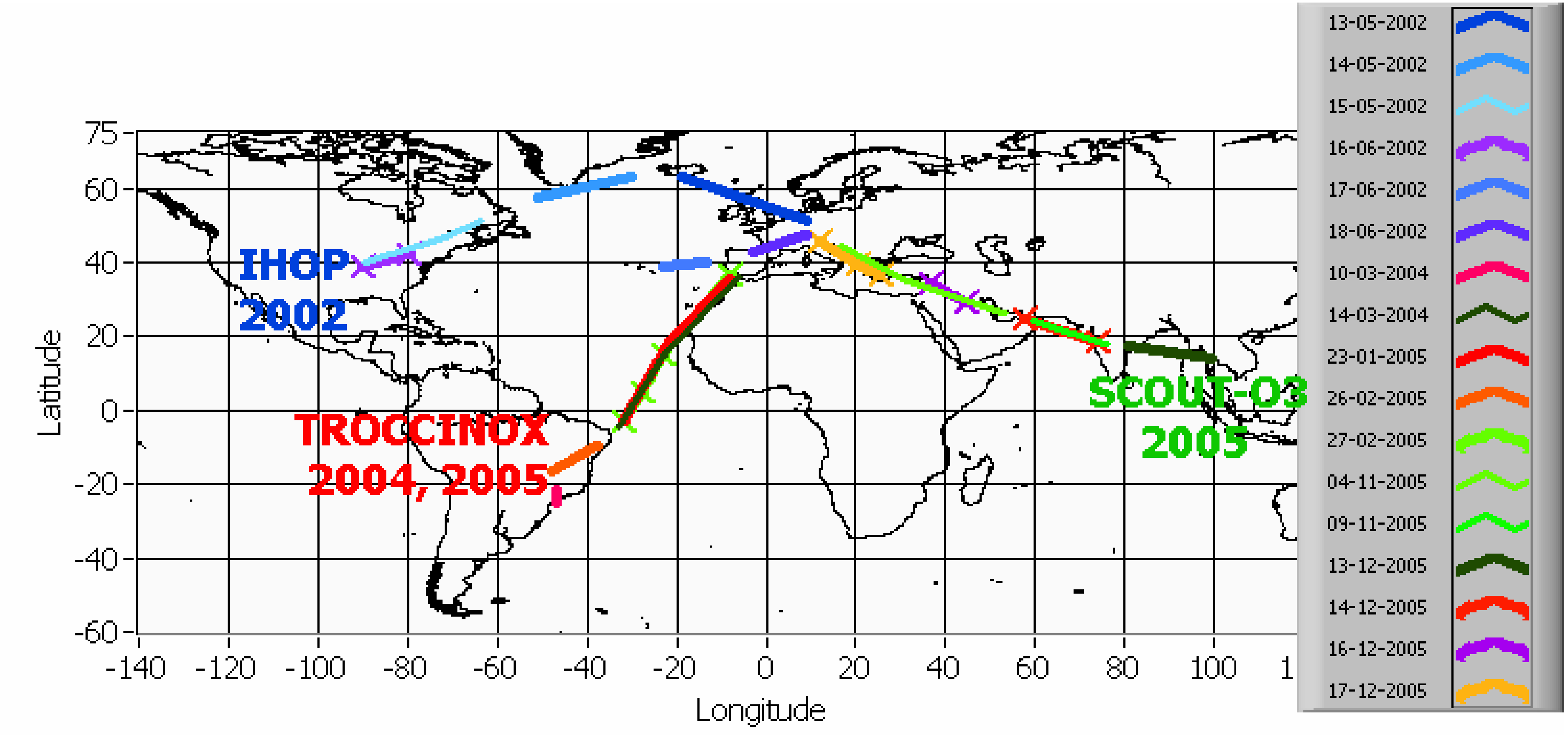
15	13	9
8	27	8
7	10	2

9	18	25
10	10	10

8	13	6
8	37	5

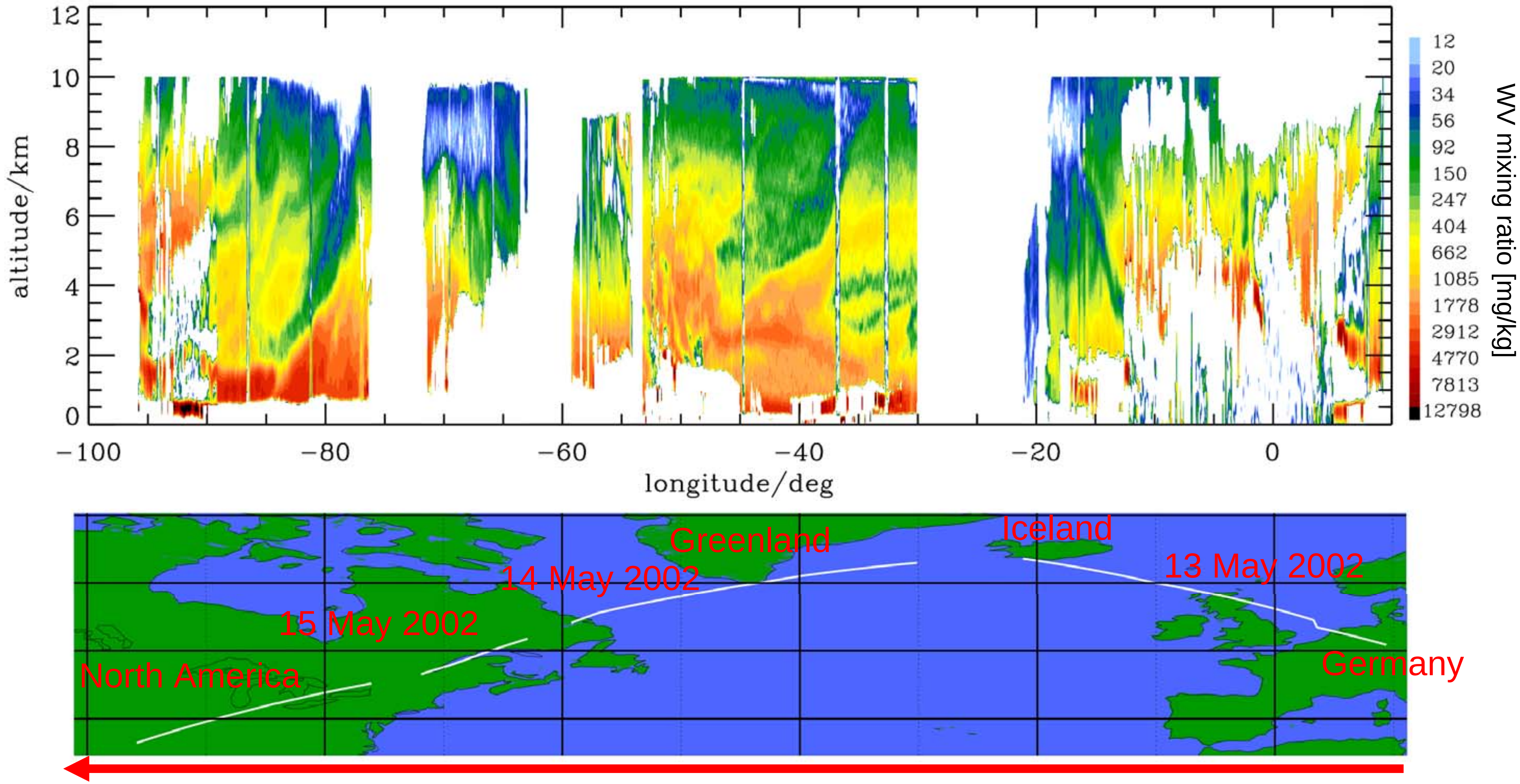
impact outside of verification area --> larger areas
improved sensitivity predictions - Kalman Filter
no compromise between sensitive areas calculated by different models

DIAL lidar water vapour observations



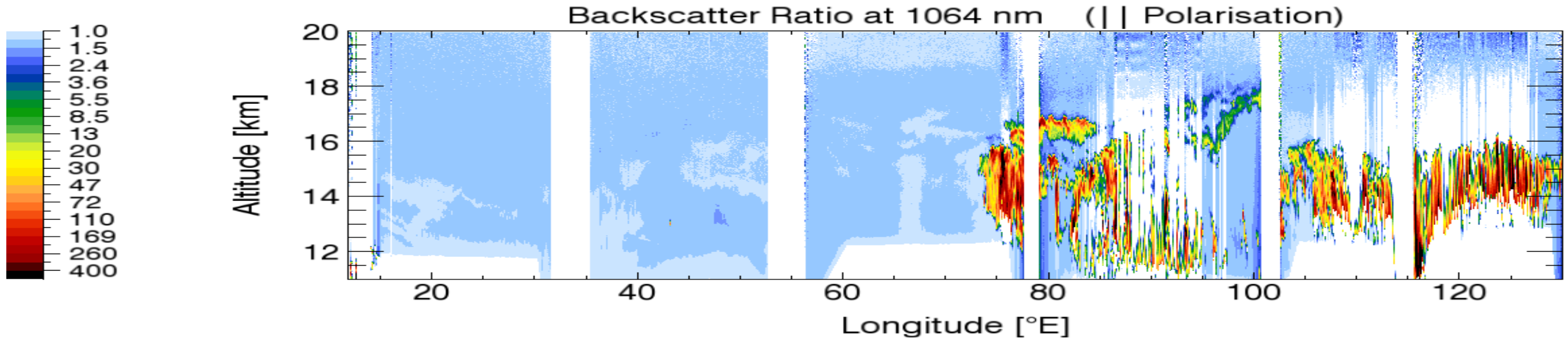
Transfer flights to 4 field campaigns during 2002 - 2005

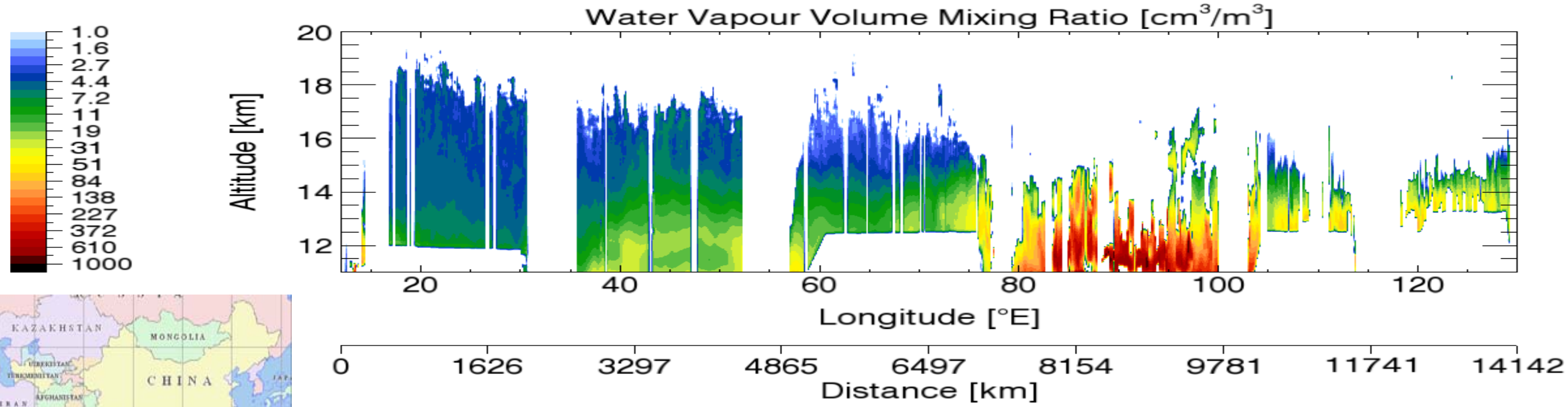
Transfer Germany --> Oklahoma, IHOP 2002



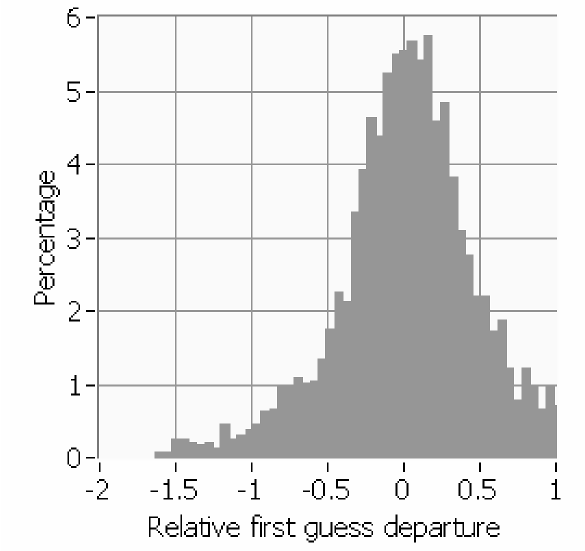
Flentje et al. 2005

Stratospheric DIAL observations





Impact of lidar H2O-observations (preliminary)

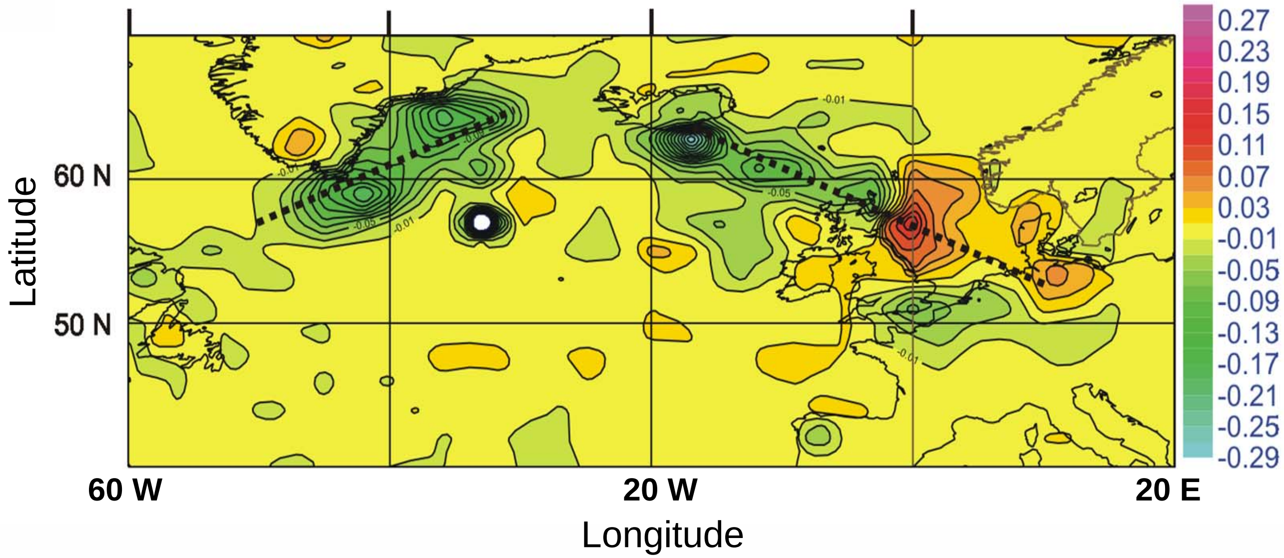


Assigned errors: 4 - 10%

Mean relative background departure:

- 2400 observations
- Std = 44%
- Bias < 1%

Reduction of TCWV first guess error (lidar - control)



Conclusions

first assimilation of "real" Doppler lidar measurements in global NWP model

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

lidar wind measurements reduce the average forecast error of u, v, z, rh, and t over Europe
average reduction of the 48 - 96h forecast error over Europe ~3%

propagation of the information into the lower stratosphere through 4D-Var

limitations of targeted observations
need for more cases, larger verification area, systematic decisions

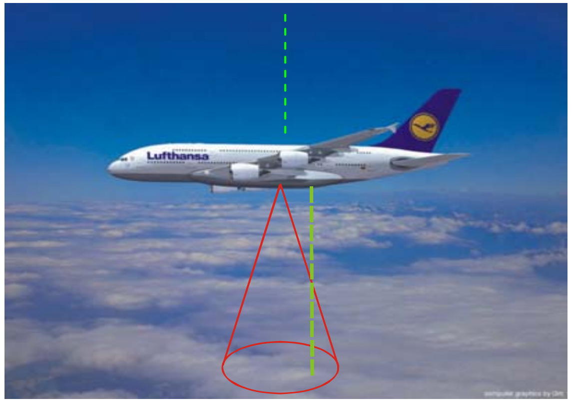
ongoing water vapour studies

emphasizes the potential airborne and spaceborne lidars (ADM-Aeolus, possible future water vapour DIAL satellite)

future campaigns: COPS 2007, IPY 2008, T-PARC 2008

Cost estimates

launch: 2009
300 Mio. Euros for 3 years
3000 LOS-profiles per day
100 Euros per LOS-profile
std 2-3 m/s
vert. resolution 500-1000 m
horiz. resolution 50/200 km
no modification after launch
stratospheric winds
regular spacing



10-20 Mio. Euros for >3 years
650 wind profiles per day
two wind components
15-30 Euros per LOS-profile
std 1-1.5 m/s
vert. resolution 100 m
horiz. res.: 50 km (up to 5 km)
no signal in very clear air
could be operated longer

radiosonde/drops.
500-1000 Euros
std 2-3 m/s
also T, q, p