The impact of targeted observations from 2011 Winter Storms Reconnaissance on deterministic forecast accuracy

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Previously (~10 years ago) there were many optimistic assessments on the impact of mid-latitude targeted observations.

Example: results from 1998. Over many cases, where either extra cloud-drift wind measurements or dropsonde data were assimilated in pre-defined sensitive regions, there was a reduction in error in the target verification area.

From Langland et al. July 1999 BAMS article on NORPEX-98 expt.
Targeted observation concept

Figure 1. Times involved in the decision making process. Based on an ensemble initialized at time(s) $t_i$, a decision is made at time $t_d$ to deploy adaptive observational resources at the future analysis time $t_a$, to improve a forecast (initiated at $t_a$) valid within a verification region at time $t_f$. 
Will mid-latitude dropwindsonde targeting have the same effect in the 2010’s?

• More observations, especially satellite, so fewer “gaps” in the global observing system.
• Better models.
• Better data assimilation systems.
ECMWF: conventional observations used

SYNOP/METAR/SHIP:
- MSL Pressure, 10m-wind, 2m-Rel. Hum.

Radiosonde balloons (TEMP):
- Wind, Temperature, Spec. Humidity

Aircraft:
- Wind, Temperature

DRIBU:
- MSL Pressure, Wind-10m

PILOT/Profilers:
- Wind
Satellite data sources used in the operational ECMWF analysis

13 Sounders: NOAA AMSU-A/B, HIRS, AIRS, IASI, MHS

5 imagers: 3xSSM/I, AMSR-E, TMI

3 Scatterometer sea winds: ERS, ASCAT, QuikSCAT

Geostationary, 4 IR and 5 winds

2 Polar, winds: MODIS

4 ozone

6 GPS radio occultation
Satellite data usage at ECMWF, past, present and near future

Millions of observations assimilated per 24h period

- POES
- ENVISAT
- Suomi-NPP
- COSMIC
- DMSP
- METOP
- ERS-1/2
- GCOM-W/C
- TRMM
- COSMIC-2
- CNOFS
- GRACE
- GMS/MTSAT
- QuikSCAT
- Megha Tropiques
- AURORA
- FY-3A/B
- JASON-1/2/3
- Oceansat
- METEOSAT AMV
- GMS/MTSAT Rad
- GOES AMV
- FY-2C/D AMV
- GOSAT
- Cryosat
- GOES Rad
- TERRA/AQUA AMV
- Sentinel 1
- GMS/MTSAT AMV
- SMOS
- EarthCARE
- ADM Aeolus
- Sentinel 3
...though it’s probably more the improved assimilation techniques and models that have improved skill.
Are targeted observations still valuable enough to merit expensive plane flights (and staff time to run targeted observation program)?
NOAA’s Winter Storms Reconnaissance Program

- Each winter day, NOAA forecasters ID systems that may impact US during the next week.
- Forecasters consider automated guidance (ensemble transform Kalman filter, or “ETKF”) to identify regions of longer-range forecast uncertainty and what uncertainty in earlier forecast features were primarily responsible.
- Examine ETKF’s estimates of potential reduction of analysis/forecast errors were observations taken in a given constellation.
- Determine approximately optimal flight path to reduce analysis errors the most.
- Assign subjective importance to case (low/med/high), determine a target verification region where high-impact forecasts are expected, and suggest reconnaissance mission to pilots.
- Pilots fly the mission and take targeted observations (typically dropwindsondes).
- Extra observations are assimilated alongside the normal observations.
What hasn’t been done over the past decade.

• Parallel assimilations and forecasts, with and without the targeted observations, using ...

• A modern data assimilation method (e.g., 4D-Var, ensemble Kalman filter, or hybrid), and ...

• A modern generation, higher-resolution global forecast model.

• A systematic comparison of forecast errors with and without targeted observations.
2011 WSR Impact Study

- 22 high, 62 medium, 14 low-priority cases, and 776 dropwindsondes deployed.
- Target verification times from +12 to +120 h.
Impact study design

• Assimilate with ECMWF 4D-Var (version 37r2 of IFS; T511L91 outer loop, linearized T159, T159, and T255 inner loops).
• Parallel assimilation and forecast cycles without (“NODROP”) and with (“CONTROL”).
• Deterministic forecasts to +5 days lead, T511L91
• Verification in ~ total energy norm in 20x20-degree target verification region, and over PNA region. Verification against CONTROL analysis.
• Also: verification of precipitation forecasts over CONUS.
(Approximate) total-energy norm

\[
E = \sqrt[1/2]{\frac{1}{2} \int_A \left[ \frac{1}{4} \left( u_{250}^2 + v_{250}^2 + \frac{c_p}{T_r} t_{250}^2 \right) + \frac{1}{4} \left( u_{500}^2 + v_{500}^2 + \frac{c_p}{T_r} t_{500}^2 \right) + \frac{1}{4} \left( u_{850}^2 + v_{850}^2 + \frac{c_p}{T_r} t_{850}^2 \right) + \frac{1}{4} \left( u_{10m}^2 + v_{10m}^2 + \frac{c_p}{T_r} t_{2m}^2 \right) + R_r T_r \left( \frac{p}{P_r} \right)^2 \right]} }
\]
Results over target verification region

(a) Energy Norm, NODROP v.s. CONTROL, over 20x20-deg Boxes

(b) Energy Norm Difference over 20x20-deg Boxes, NODROP − CONTROL
Results over broader PNA region

(a) Energy Norm, NODROP v.s. CONTROL, over PNA

(b) Energy Norm Difference over PNA, NODROP – CONTROL
24-48 h precipitation forecast skill


Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests
+48-72 h precipitation forecast skill


Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests
Conclusions

• No significant positive forecast impact from assimilation of 2011 WSR data in ECMWF system.

• Possible reasons:
  – Incomplete targeting of sometime relatively large initial sensitive regions.
  – Better forecast and assimilation systems.
  – More observations

• What next?
  – Targeted observations more focused on increased use of satellite data (cloud-drift winds, radiances, etc.).
Significant increase in number of observations assimilated

Conventional and satellite data assimilated at ECMWF 1996-2010

Unit is millions of data values assimilated per 24 hour period

from tinyurl.com/ecmwf-satreport