Use of satellite radiances in the 4D-VAR ECMWF system

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Contributions from

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Assimilation changes

Four Dimensional variational data assimilation (4D-Var)
Conceptual difference between 3D-Var and 4D-Var

Analysis resolution at $t_0$ --- $J_b$ is determined for a set of ensemble assimilations, and the statistics are not flow dependant and filter. Horizontal scales less than $\sim 120$km
The Early Delivery From 29 June 2004 System

Delayed cut-off
4D-Var (12 h)

Early Delivery Analysis
4D-Var (6 h)

Early Delivery System gains from:
- using 00 and 12UTC data earlier in window of 12h 4D-Var
- using slightly more data in 12h 4D-Var

Early Delivery System loses from
- using less data in 6h 4D-Var
Anomaly correlation of 500hPa height forecasts

- Northern hemisphere
- Southern hemisphere

Year: 81 to 06

- Day 3
- Day 5
- Day 7
Northern hemisphere observation impact in Early Delivery System

March 2004

Anomaly correlation of 500hPa height forecasts

Early delivery system

Control
No satellite data
No radiosondes/profilers

Previous system
Increase in model and analysis resolution

Anomaly correlation of 500hPa height forecasts,
9 August – 13 November 2004

N Hem

S Hem

Pressure (hPa)

Level number

Forecast Day
Comparison other centres
April & May 2005
The numbers refer to all data items received over a 24 hour period on 5 July 2004 (without AIRS)
Number of observational data used in the ECMWF assimilation system (with AIRS)

- 3.6 millions

- 6h 3D
- 6h 4D
- 12h 4D
- 25r4/26r1
- AIRS
September 2004

- Use data from EUMETSAT ATOVS Retransmission System
- Improved AIRS bias correction and cloud detection
- Assimilation of Meteosat Second Generation (Meteosat-8) water vapour radiances (in place of Meteosat-7 radiances)
- New version of fast radiative transfer model: RTTOV8
- Corrected use of AMSU-B over land
- Use of total ozone retrievals from SCIAMACHY on ENVISAT
- Improved use of TEMP and SYNOP humidity observations
- Small revisions to surface, convection and cloud schemes
- Radiation frequency reduced from three hourly to hourly
- Better vertical diffusion in the first minimization of 4D-Var
EUMETSAT ATOVS Retransmission Service (EARS)

STATISTICS FOR RADIANCES (EARS) FROM NOAA-15 / AMSU-A - 07
MEAN OBSERVATION (USED)
DATA PERIOD = 2004120100 - 2004122506, HOUR = ALL
EXP = 0001
Min: 202.9   Max: 229.75   Mean: 219.74
April 2005

• Blacklist ten AIRS channels with long tails in humidity weighting functions in the stratosphere

• MODIS winds from AQUA as well as TERRA, plus reduced observation error

• Updates for simulated GEO imagery (Met-8 channels)

• 1D-Var analysis of rain-affected radiances active in the screening, including an upgraded version of RTTOV-8

• Monitoring of ground-based GPS
April 2005 (continued)

• Wavelet Jb, with statistics based on new DA-ensemble for ozone
• Surface pressure bias correction and reduced observation errors for automatic stations
• Activate METAR, stop using PAOBS

• New moist boundary layer scheme
• Bugfix to first timestep of semi-Lagrangian physics
• Modification to tile coupling of snow cover
• Bugfix to QNEGAT
• New dissipation source function for wave model
ECMWF operations since September 2004

- AQUA AIRS
- 3xAMSUA (NOAA-15/16/17) + AQUA AMSUA
- 3 SSMI (F-13/14/15)
- 2xHIRS (NOAA-14/17)
- 2xAMSU-B (NOAA-16/17)
- Radiances from 5xGEOS (Met-5/7 GOES-9/10/12)
- Winds from 5xGEOS (Met-5/7 GOES-9/10/12) and MODIS/TERRA
- SeaWinds from QuiKSCAT
- ERS-2 Altimeter / SAR (limited coverage)
- SBUV (NOAA 16)
- ENVISAT OZONE (MIPAS+SCIAMACHY)

28 satellite data sources
Typical distribution of observations

In situ observations
synop-ship:
buoy:
temp:
pilot:
aircraft:

Geostationary satellites
Grad, Satob

Polar-orbiting satellites
ATOVS, AIRS, SCAT, SSMI, Ozone

14/03/2004 00UTC
ERA-40
(www.ecmwf.int/research/era)

• A re-analysis from September 1957 to August 2002 based on operational code (June 2001)

• Six-hourly 3D-Var analysis T159 horizontal resolution (~125km grid) ops T511 (~39km grid)

• Testing 4D-Var for INTERIM re-analysis at various resolutions

• T159/L60/L91 horizontal resolution (~125km grid) T511/L60/L91 horizontal resolution (~39km grid)
Comparison of 3/4DVAR T159 (4 months) 500 hPa rms error
Time series

FORECAST VERIFICATION 12UTC

500hPa GEOPOTENTIAL

ROOT MEAN SQUARE ERROR FORECAST

S. HEM LAT -90.000 TO -20.000 LON -180.000 TO 180.000

- Loss of NOAA 9 MSU ch3
- Blacklist of NOAA 6 MSU
T511/L60 Venice storm 1979 Dec
the 2\textsuperscript{nd} Highest tide since 1900

Five day forecast
OSE’s ECMWF (1997, 1999 and 2002)

A series of OSE's were run with the current operational version (at the time) of the ecmwf system

The 2002 OSE used:
(4dvar (TL511 40km) forecast model and (TL159/511 120km) 4dvar analysis).

The number of cases:
1997 OSE 34 days (Kelly 1998)
1999 OSE 43 days (Bouttier and kelly 2001)
2002 OSE 120 days (Kelly 2004)
Northern Hemispheric OSE’s (RMS 200hPa vector wind)
Tropical OSE’s (RMS 200hPa vector wind)

- 2002
- 1999
- 1997
Southern Hemispheric OSE’s (RMS 200hPa vector wind)
A new challenge: Assimilation of cloudy microwave radiances

1D+4D-Var approach to assimilate rain information from satellites (SSM/I – SSMIS)

TB's

Rainfall retrieval algorithm

BG (T,q) → 1D-Var → RT-model Cloud/Convection Minimizer

TCWV pseudo obs.

BG, OBS → 4D-Var → RT-model Minimizer
**Assimilation of Cloud/Precipitation Affected Microwave Radiances**

(P. Bauer)

**Important Features:**

- 1D-Var executed with model physics 1\(^{st}\) traj (15’ time step, full resolution, oceans only)
- Observations are interpolated to model grid
- 1\(^{st}\) time for moist physics and multiple scattering radiative transfer schemes in an observation operator
- Only satellite observations that are intentional assimilated in clouds and precipitation
- New load-balancing ensures code efficiency
FG Radiance Departures (03/08/2004 00 UTC)

SSM/I clear-sky radiance data coverage
DCDA: 70,000 observations/cycle
DA 50,000 observations/cycle

SSM/I precipitation TCWV data coverage
DCDA: 50,000 observations/cycle
DA 25,000 observations/cycle

SSM/I clear-sky FG radiance departure pdf

SSM/I precipitation FG radiance departure pdf

SSM/I Channels:
Impact on rain and cloud SSMI channels
GEMS tasks at ECMWF

• Greenhouse gases
  – Start on CO$_2$, then CH$_4$, N$_2$O and CO
  – Develop modelling and data assimilation, and use analyses to infer sources and sinks for CO$_2$ and CH$_4$

• Reactive gases
  – Couple main forecast model with global CTMs
  – Carry O$_3$, NO$_2$, CO, SO$_2$ and CH$_2$O in main model and develop data assimilation

• Aerosols
  – Add to model, based on existing parameterizations
  – Develop assimilation of retrievals, then radiances

• Integrate above components, and run past periods
• Provide boundary conditions and technical support for regional air-quality prediction
Total ozone
9 Sept 2004

Operations, no SCIAMACHY

Pre-operational test, including SCIAMACHY

TOMS
Monitoring of the CO$_2$

- Trace gases: CO$_2$, CH$_4$, CO, N$_2$O, ..
- Reactive gases: O$_3$, NO$_x$, ...
- Aerosols
- Exchanges between land/ocean/atmosphere
- Monitoring of the carbon cycle
CO$_2$ estimation

One year of AIRS radiances (Feb 03 to Mar 04) have now been analyzed inside the ECMWF 4DVAR and CO$_2$ estimates produced.

In general the agreement with the sparse validation data (JAL flight data) is quite good, although some periods need more study.

Zonal column estimates (ppmv)
Plans for 2005

• Higher vertical resolution
  ……L91 for 4D-Var and deterministic forecast
  ……L62 for EPS, seasonal and monthly forecasts
• T799 horizontal resolution in deterministic forecast and outer loops of 4D-Var with T255 inner loops (T319 for SVs?)
• Use of SSMIS and AMSR data
• Assimilation of cloudy/precipitation data (radiances through a 1D+4D approach)
• Preparation for METOP (IASI in particular) and better exploitation of AIRS
  – Channel selection, cloud detection, monitoring,…
  – Environment monitoring