Recent advances in the use of satellite data in the French NWP models

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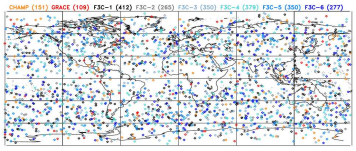
Summary: The use of satellite data in the French NWP models at global (ARPEGE) and regional (ALADIN) scales is described.
In the last year, a lot of effort had been dedicated to the assimilation of data from the MetOp satellite (ATOVS, ASCAT and IASI). The operational assimilation of ATOVS and ASCAT has been performed. 50 IASI channels are taken into account in the current E-suite. Another major milestone has been the operational use of GPS radio-occultation data from the COSMIC, CHAMP and GRACE satellites mid-2007. METEOSAT CSR data are also being introduced in the global model (in the regional model ALADIN, a fine resolution radiance product provided by the CMS in Lannion is used instead).
In terms of algorithmic development, an improved parametrisation of microwave emissivity allows a better use of these data over land, as investigated in particular over Africa during the AMMA field experiment period. Another major development was the introduction of a variational bias correction algorithm for radiances based on the one developed at ECMWF.

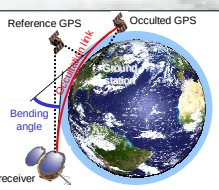
20 stratospheric AIRS channels SSM/I F13 and F15 — **2007** — **GPS-RO, ATOVS on MetOp (AMSU-A, MHS), ERS** — **2008** — **VarBC for radiances ASCAT** — **June: IASI, HIRS on Metop, SSM/I F14 Emissivity param. over land for microwave, Meteosat-9 SEVIRI CSR**

GPS Radio-occultation :

- **Assimilation of bending angles from COSMIC/CHAMP/GRACE between 1 and 18 km**
- **Ad hoc quality control** to discard data reporting abnormal propagation conditions (e.g. super-refraction) *(Pauli et al., 2008)*
- **Observation operator from ECMWF**



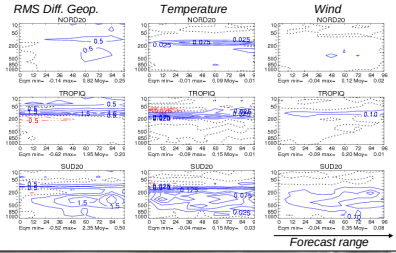
GPS-RO from CHAMP/GRACE/COSMIC over one day (20070301)



How does it work? *The atmosphere affects the propagation of radio signals by bending their path and introducing a delay. These effects depend primarily on the vertical gradients of atmospheric density and water vapor. With the help of a precise knowledge of the positions and velocities of the occulted GPS and receiver satellites, the time derivative of the atmospheric delay (Doppler shift) can be retrieved. From this information, the atmospheric bending angle can be inferred using radio-optics principles.*

Impact on forecasts:
Scores vs. RS
41days, March-April 2007

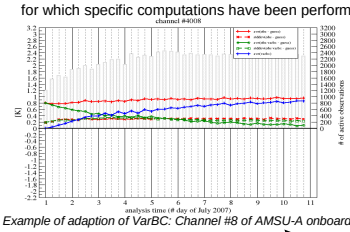
BLUE = GPSRO better
RED = GPSRO worse



⇒ **Improvement at all forecast ranges**
⇒ **included in ARPEGE & ALADIN oper**

Variational Bias correction (VarBC)

- **VarBC operational in ARPEGE 4DVar** since February 2008 for radiances
- ALADIN 3DVar uses the coefficients computed for ARPEGE, except for SEVIRI radiances at high resolution for which specific computations have been performed

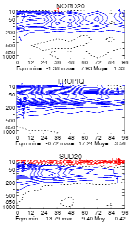


VarBC main principles:

- *Satellite radiance data have systematic biases that have to be removed before the assimilation*
- *These biases can depend on the scan angle and on the flow. They can be explained by predictors such as powers of the scan angle, layer thicknesses, skin temperature, etc., by a mulitple linear regression*
- *In the VarBC scheme, coefficients of the regression are dynamically adapted at each analysis time. They are included in the control variable of the assimilation, and they use other "conventional" data (like radiosondes or aircraft data) as anchors.*

(see Dee (2005), Auligné et al (2007))

Example of adaption of VarBC: Channel #8 of AMSU-A onboard MetOp-A



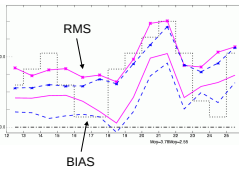
RMS Diff. Geop.

The learning period typically lasts between 5 and 15 days

ARPEGE *Average/areas 43 days, Summer 2007* ← ***Impact on forecasts Scores vs. RS*** → ***ALADIN*** *Humidity at 500 hPa 12h forecast 13 days, Feb. 2008*

BLUE = VarBC for AMSU-A/B, MHS, SSM/I, HIRS & AIRS better
RED = Static bias correction better

---- VarBC for SEVIRI
···· Static bias correction for SEVIRI

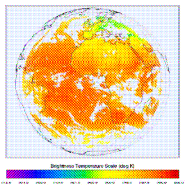


⇒ **Impressive improvement at all forecast ranges!**

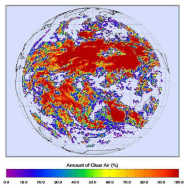
Meteosat 8-9 SEVIRI Clear Sky Radiances :

- Hourly 16x16 pixels super observation that includes a percentage of cloud
- Assimilation in ARPEGE 4DVar of 2 WV channels with a thinning of 250 km
- Only data that are cloud free over 70% are considered

⇒ **Positive impact on precipitation forecast, mainly over Africa**



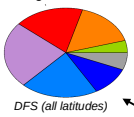
CSR (10.8 μ)



Associate %tage of cloud free

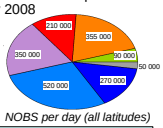
Impact of observations in analyses for ARPEGE

To quantify the relative influence of each type of observation on analyses, **the DFS** (Degrees of Freedom for Signal) has been computed for the next E-suite configuration for one day in january 2008



DFS (all latitudes)

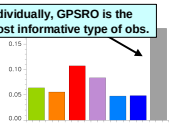
Radios. & Prof
Aircraft
Surface
GPSRO
AIRS, IASI
Bright. Temp
SATWIND



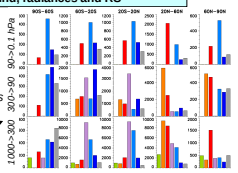
NOBS per day (all latitudes)

The analyses are mainly controlled by Satwind, radiances and RS

Individually, GPSRO is the most informative type of obs.



DFS/p (all latitudes)



But: important variations depending on latitudes and altitude

Emissivity parameterization over land

Position of the problem:

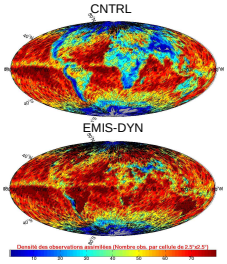
- **Over the ocean:** The emissivity (ε) is around 0.5. Since the sea surface contribution to the signal is lower than the land contribution, emissivity models are good enough to meet the NWP requirements
- **Over land:** High emissivities (~1.0). Large uncertainties on ε and skin temperature (T_s) estimation due to difficulties to describe variations in time and space for different surface types, roughness and moisture contents.

⇒ Only channels that are the least sensitive to the surface are currently assimilated

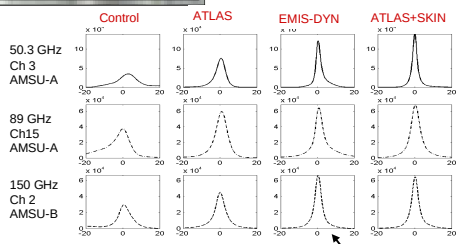
Studies on emissivity parameterization at Météo-France

- **Basic assumption:** *Emissivities retrieved for AMSU/SSM/I window channels could be used as a good approximation to simulate T_b at sounding channels*
- In order to take into account more satellite microwave observations from AMSU and SSM/I, **three land surface parameterizations based on statistical and/or dynamical approaches** have been tested (*Karbou et al., 2006*):

More data are taken into account
(+22%, 32%, 35 % for AMSUA chs 5, 6, 7 resp.)

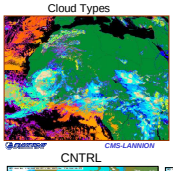


Number of assimilated data, AMSU-A channel 7, August 2006

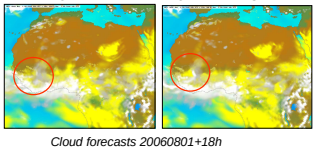


Innovation RMS error are reduced
(EMIS-DYN: AMSUA ch2 (-54%), ch3 (-29%), ch4 (-12%), ch5 (-2.5%)

Cloud Types



Improvements in Cloud cover forecasting



Cloud forecasts 20060801+18h

The three tested land surface parameterizations:

(1) Averaged emissivities (ATLAS): *using 2 weeks prior to the assimilation period,*
- *averaged ε for ch3 and ch16 are respectively affected to temperature and humidity channels*
- *T_s is taken from the model FG*

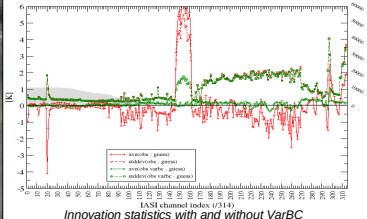
(2) Dynamically estimated emissivities (EMIS-DYN):
- *derived at each pixel using only one channel (or two) of each instrument*
- *T_s is taken from the model FG*

(3) Averaged emissivities + dynamically estimated T_S (ATLAS+SKIN):
- *T_s at each pixel using one (or two) channel of each instrument*

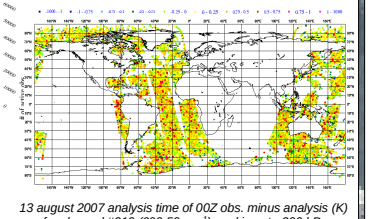
Solution (2) is running in the current ARPEGE's E-Suite, with AMSUA ch3 and AMSUB ch1 as reference channels.

IASI in ARPEGE

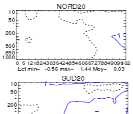
- Level 1C radiances are received *via* EumetCast in Toulouse(whole BUFR including 8461 channels)
- **A subset of 314 channels is retained** in the Operational Observational DataBase (commonly chosen with other NWP centres) **and monitored**
- **Radiances are bias corrected using VarBC**
- **Cloud detection for data selection** based on a channel ranking method from ECMWF *(McNally & Watts, 2003)*
- First-guess check, thinning distance of 250 km
- **50 channels are actively assimilated**, only over sea (peaking between 100 hPa and 620 hPa)



Innovation statistics with and without VarBC for the 22nd of october, 2007 analysis time of 18 UTC



13 august 2007 analysis time of 00Z obs. minus analysis (K) for channel #219 (699,50 cm^{-1}) peaking at ~200 hPa



Impact of the assimilation of 50 IASI channels on forecasts: Scores vs. ECMWF analyses 17 days, August 2007

BLUE = better with IASI
RED = better without IASI

RMS Diff. Geop

⇒ **Encouraging positive impact**

Perspectives:

- Extend the channel selection
- Extend the assimilation over sea ice
- Validate and improve the use of IASI over Antarctica (international Project Concordiasi)

Auligné, T., McNally, A. P., and D. Dee, 2007: Adaptive bias correction for satellite data in a numerical weather prediction system. QJRMS,133, 631-642.
Dee, D. P., 2005: Bias and data assimilation. QJRMS, 131, 3323-3343.
Karbou, F., Gérard, E, and Rabier, F, 2006: Microwave land emissivity and skin temperature for AMSU-A and -B assimilation over land. QJRMS, 132, 2333-2355.
McNally, A. P., and P. D. Watts, 2003: A cloud detection algorithm for high-spectral-resolution infrared sounders. QJRMS, 129, 3411-3423.
Poli, P., P. Moll, D. Puech, F. Rabier, and S.B. Healy, Quality control, error analysis, and impact assessment of FORMOSAT-3/COSMIC in numerical weather prediction, Terr. Atm. Ocean. Sci., in press

See also: Cloudy AIRS/IASI: Cloud detection (Polar areas, A. Bouchard, A23), **Assimilation of cloudy radiances** (T. Pangaud, A31), **SEVIRI used as images in the assimilation** (Y. Michel, 9.8), **Cloudy/rainy SSM/I data for tropical cyclones** (R. Montroty, 9.2), **Obs. operator adapted for fine-scale analysis** (F. Duffourg, A13)