Adrian's contribution to data assimilation

Florence Rabier, ECMWF

December 11, 2017

Adrian's early involvement in Data Assimilation

When head of Numerical and Dynamical Aspects section and then head of Model division (1978-1995)

This article appeared in the Meteorology section of ECMWF Newsletter No. 141 – Autumn 2014, pp. 22–30.

Twenty-five years of IFS/ARPEGE

Jean Pailleux, Jean-François Geleyn, Mats Hamrud, Philippe Courtier, Jean-Noël Thépaut, Florence Rabier, Erik Andersson, David Burridge, Adrian Simmons, Deborah Salmond, Ryad El Khatib, Claude Fischer

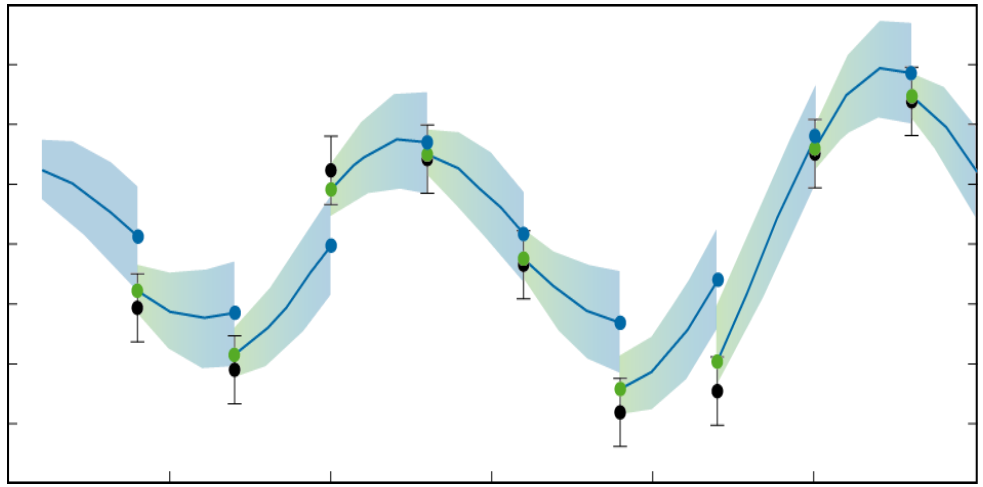
The coding of the first version of the IFS/ARPEGE model was initiated by Philippe Courtier and Mats Hamrud at ECMWF in 1987 as a project involving ECMWF and Météo-France – IFS: Integrated Forecasting System and ARPEGE: Action de Recherche Petites Echelles Grandes Echelles. Many scientific projects, sub-projects, and operational and research options have been built around this initial code since then, both on data assimilation and forecasting aspects.

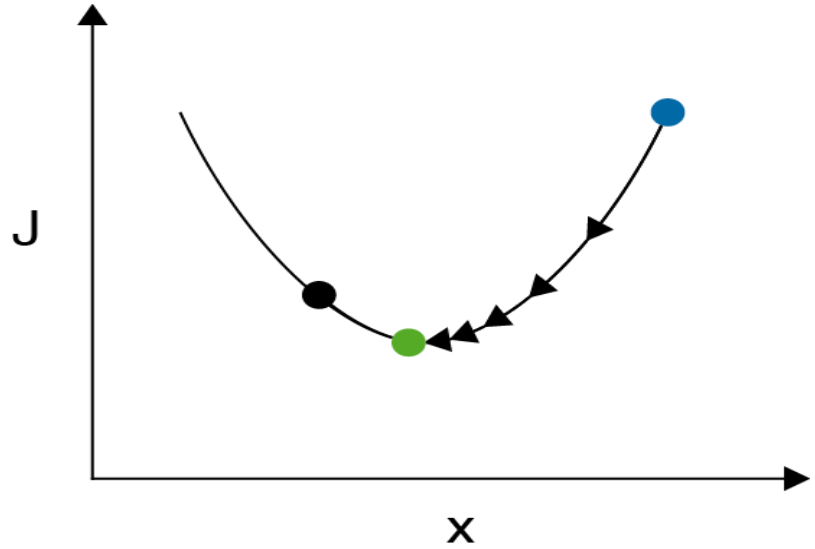
Adrian’s early involvement in Data Assimilation

Main scientific rationale was development of variational data assimilation

Benefits: use of satellite data, analysis of large scale flow, consistency of initial conditions with model dynamics and physics

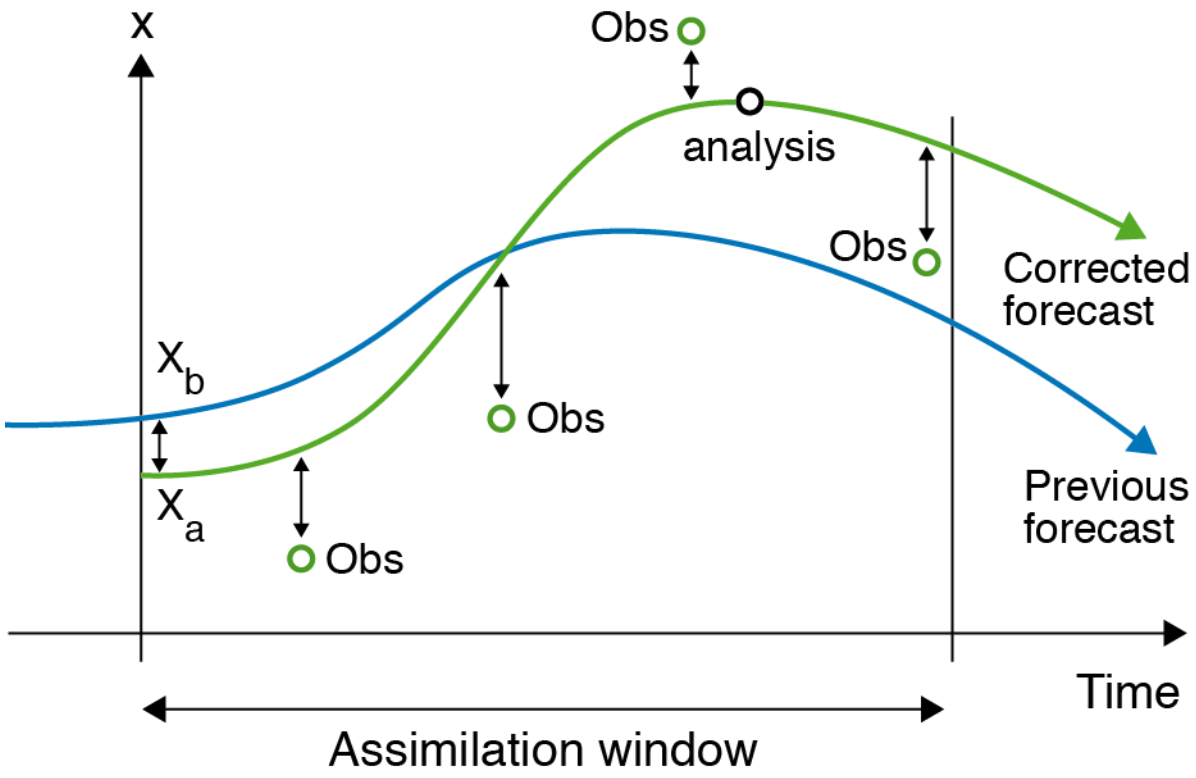
Link between model development and data assimilation through coding TL/AD





4D-Var

Find the model trajectory that best fits the available observations



Adrian's early involvement in Data Assimilation

Adrian in jury of PhD on variational assimilation in the context of baroclinic waves (1992)

Used Simmons
and Hoskins 1978,
life cycle of a
baroclinic wave

Simulated observations

24-hour 4D-Var

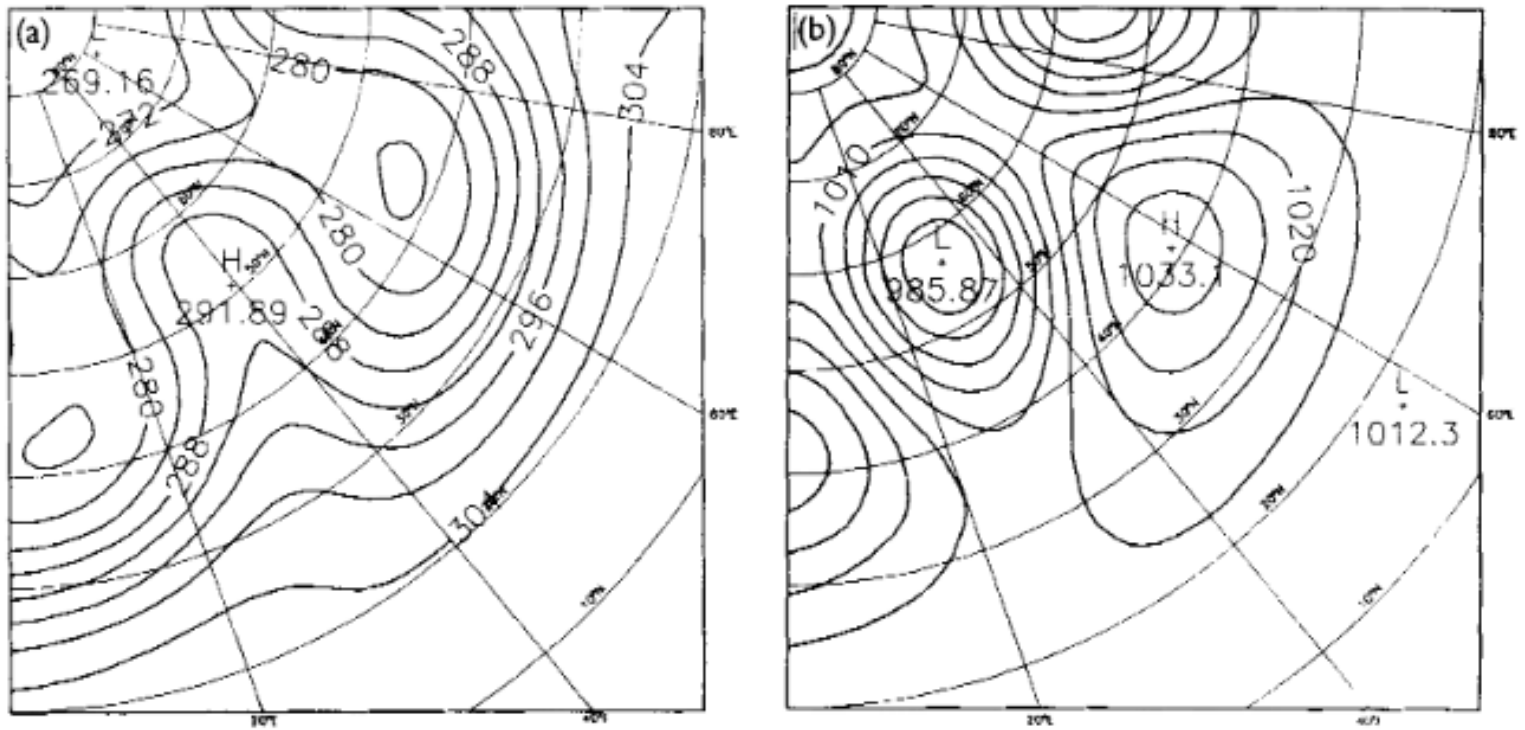


Figure 3. (a) Temperature (K) at the lowest level and (b) surface pressure (hPa) at day 7.

Adrian's early involvement in Data Assimilation

Link between atmospheric dynamics and data assimilation

Current operational assimilation methods have revealed deficiencies in cases of strong baroclinic development. Baroclinic conditions are therefore appropriate for evaluating the potential for improvement which could be achieved through the implementation of a fully four-dimensional data assimilation. In this paper the behaviour of a variational scheme is investigated for a typical baroclinic instability problem, where a wave develops and retroacts on to the basic zonal flow. The tangent-linear model is shown to lead to a good approximation of the time evolution of the wave over a range of 48 hours, even at the most intense cyclogenesis period. For the assimilation experiments the twin experiment approach is applied. Only part of the flow evolution is observed, either the zonal component or the eddy component. In either case the method proves successful in reconstructing the unobserved part of the flow, taking advantage of the nonlinear coupling that exists between those components. However, nonlinearities can lead to difficulties when the range of validity of the tangent-linear model is exceeded or when the cost function exhibits multiple minima.

In meantime, coding of TL and AD ongoing

Adrian’s full involvement in data assimilation

Head of Data division from 1995 to 2007

Implementation of 3D then 4D-Var

Took major leading role in both implementations

Lots of hard technical work, major focus on a common goal

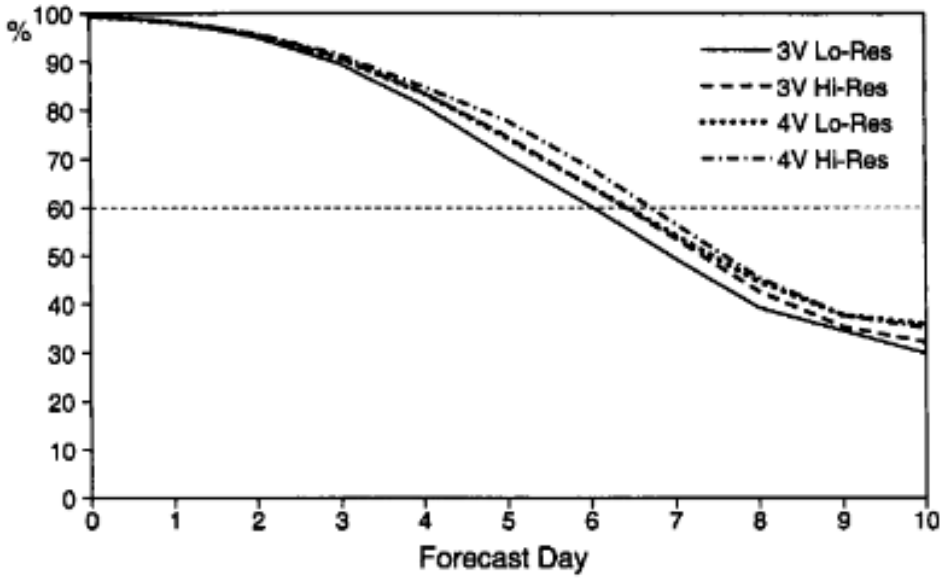
Focus on 4D-Var implementation

Initial results

With

6-Hour period

4 outer-loops of 4D-Var



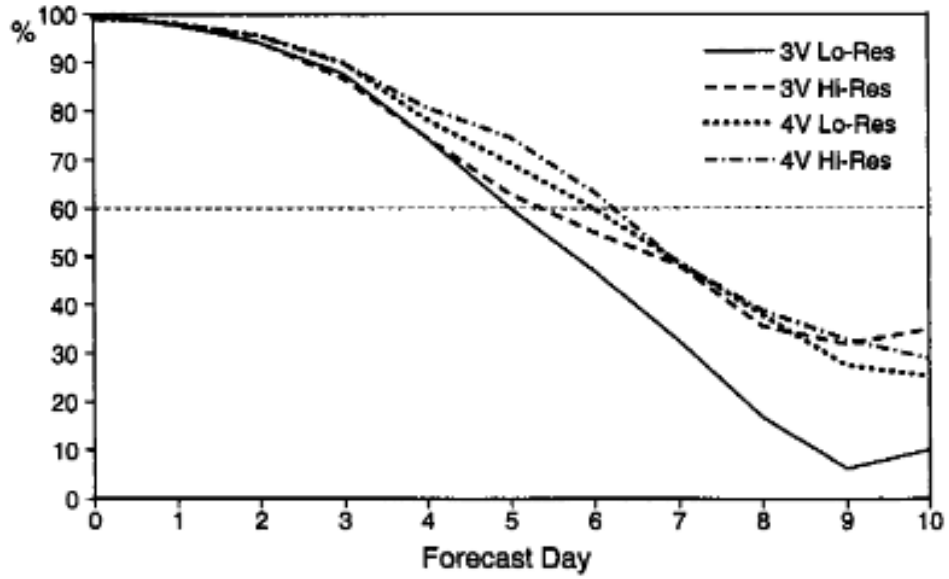


Figure 1. Anomaly correlation scores for 3D-Var (3V) and 4D-Var (4V) at T106L31 (Lo-Res) and at T213L31 (Hi-Res), using the same amount of observations, for the northern hemisphere (top panel) and North Pacific (bottom panel) for two weeks in January 1996. See text for discussion.

Focus on 4D-Var implementation

Initialisation issues

and

tropical performance

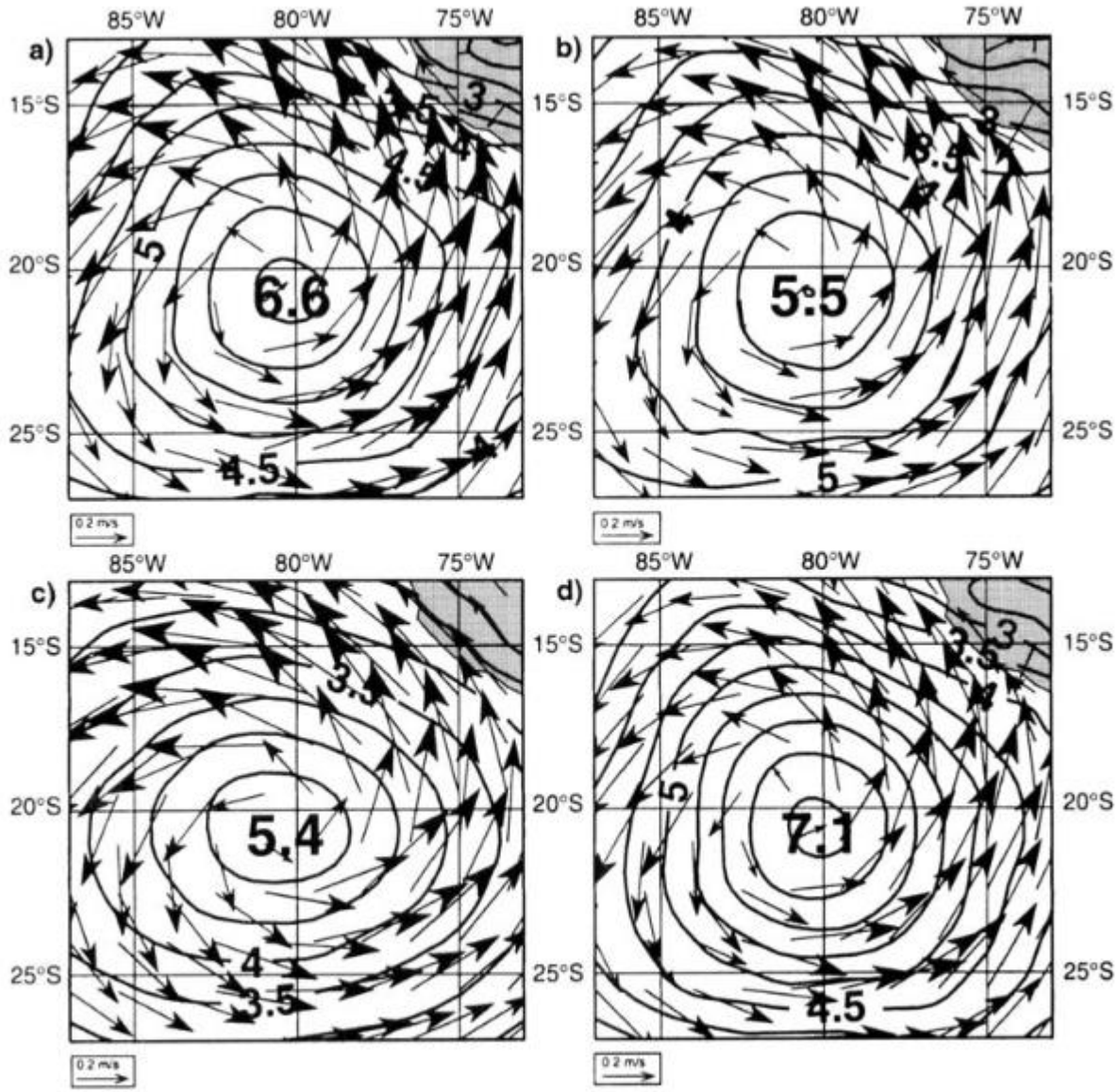


Figure 4. Mass and wind increments from an isolated mass observation at 850 hPa. (a) 4D-Var with 4 outer-loo and initialization; (b) 4D-Var with 1 outer-loop and initialization; (c) 3D-Var with initialization; and (d) 4D- with 1 outer-loop and without initialization. Contour intervals are 0.5 geopotential metres.

Focus on 4D-Var implementation

Initialisation issues

and

tropical performance

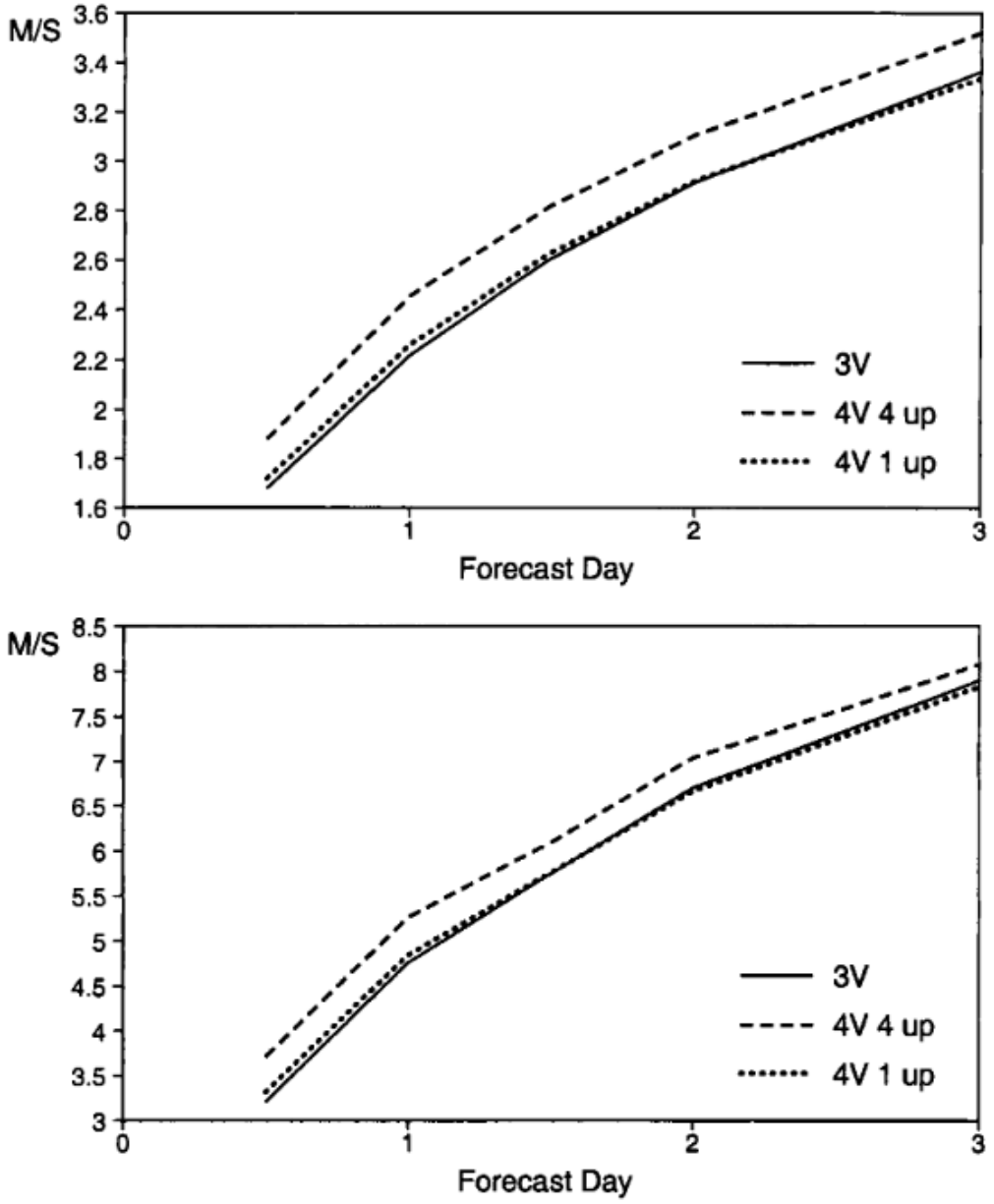


Figure 5. Tropical wind scores (root-mean-square errors in m s^{-1}) verified against own analysis at 850 (top) and 200 hPa (bottom). 3D-Var is shown as a solid line, 4D-Var with 4 outer-loops as a dashed line, and 4D-Var with one outer-loop as a dotted line.

Focus on 4D-Var implementation

Compromises in

- assimilation length,
- resolution,
- number of updates,
- physics…

and positive scores

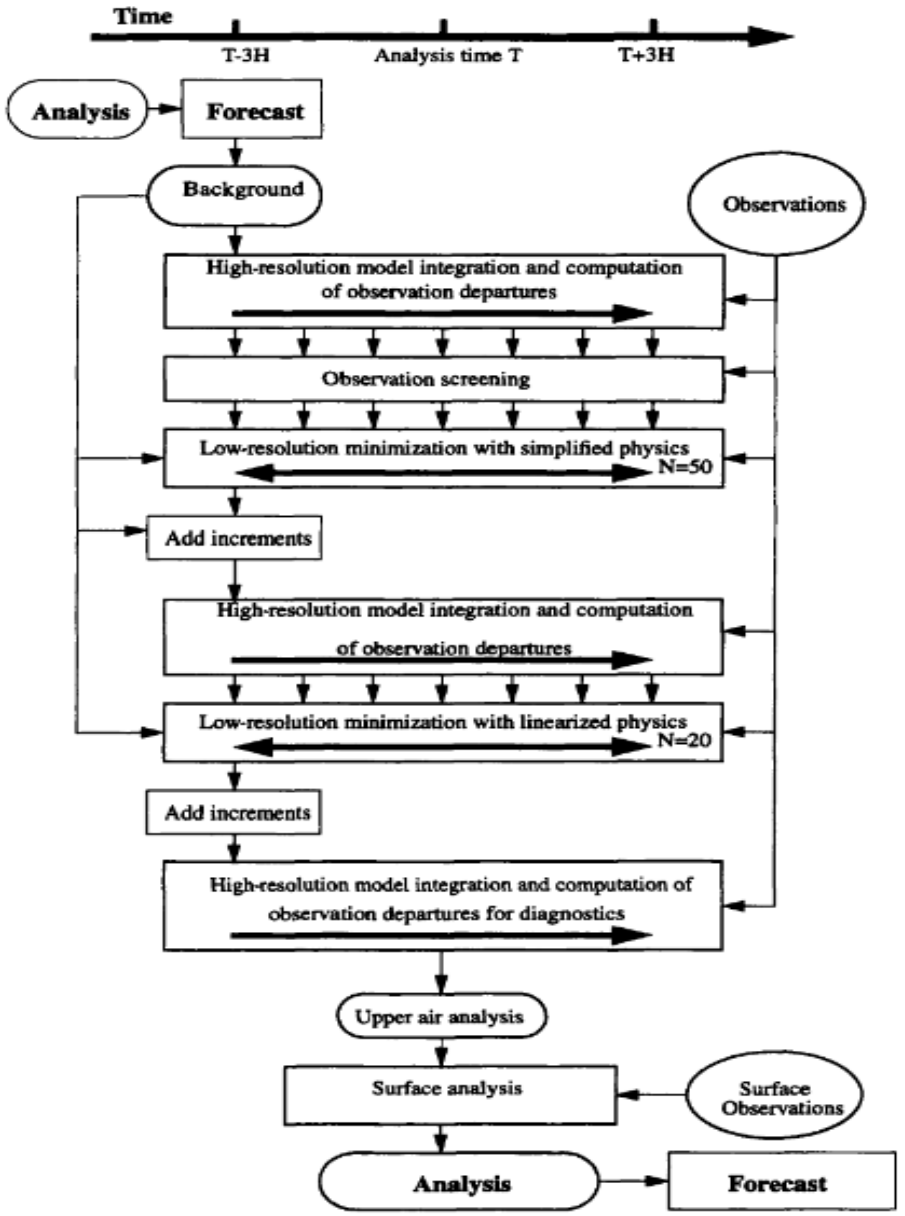


Figure 1. Flow diagram for one cycle of the 4D-Var Analysis system. See text for discussion.

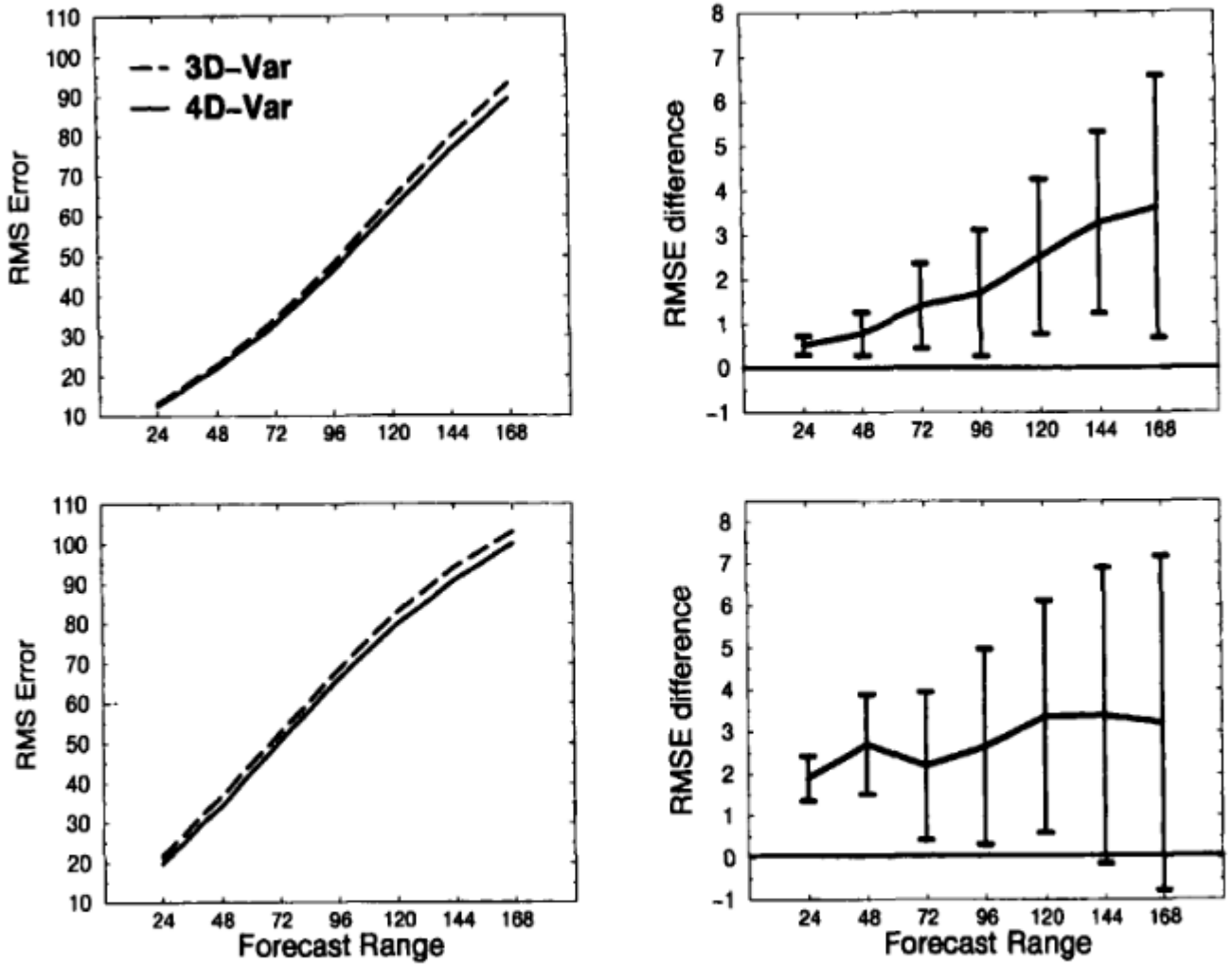


Figure 4. Root-mean-square (RMS) of 500 hPa geopotential height (m) forecast errors in the northern hemisphere (top-left panel) and the southern hemisphere (bottom-left panel) for 40 days of the 4D-Var and 3D-Var operational suites running in parallel. 4D-Var is represented by a solid line, and 3D-Var by a dashed line. Differences in RMS of forecast errors in the northern hemisphere (top-right panel) and the southern hemisphere (bottom-right panel) with error bars at 90% confidence level. See text for details.

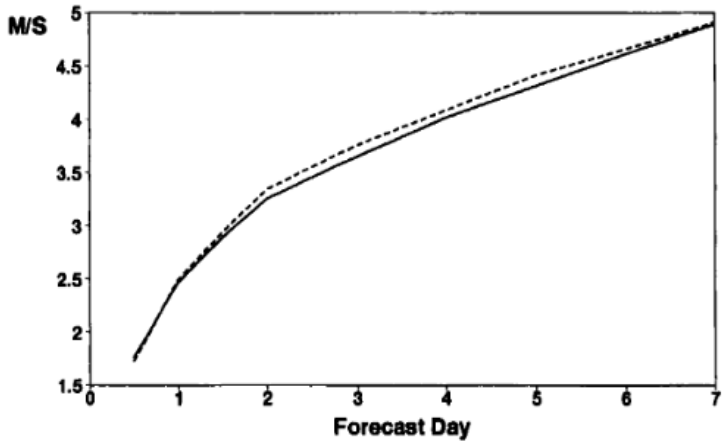


Figure 18. Root-mean-square errors of forecast wind (vector components) in the Tropics (20°N–20°S) for 40 days of the parallel operational suites. 4D-Var is represented by a solid line, and 3D-Var by a dashed line. The abscissa is forecast time in days and the ordinate refers to wind errors in m s^{-1}.

Focus on 4D Var implementation

The untold story…

Problem with bias correction for satellite data

Bad couple of weeks for scores over Europe

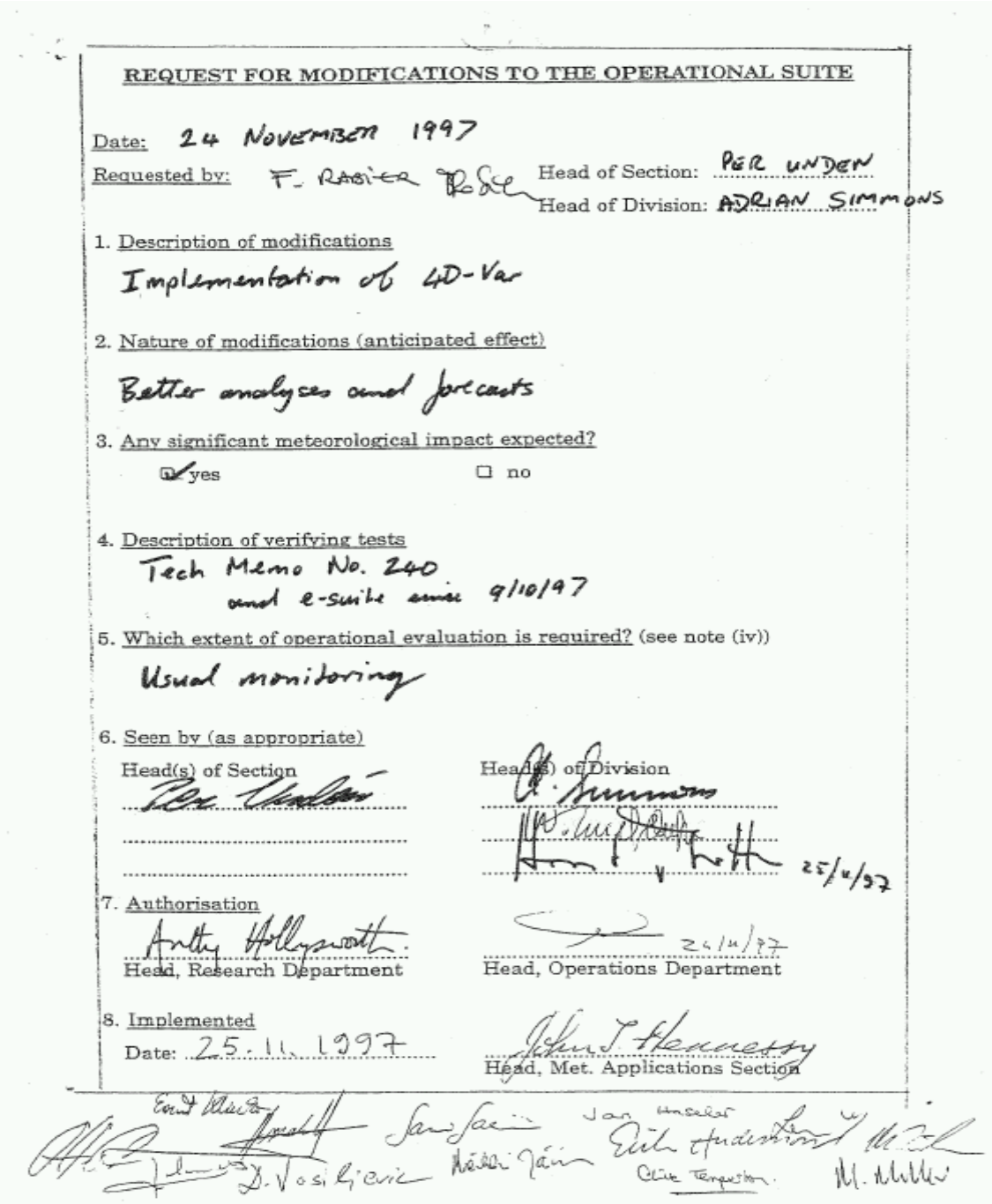
SAC: maybe we should delay implementation

And Adrian, always calm and supportive

4D-Var implemented 25 November 1997

Who officially signed?

F. Rabier
P. Undén
A. Simmons
W. Zwieflhofer
H. Böttger
A. Hollingsworth
M. Capaldo
J. Hennessy



REQUEST FOR MODIFICATIONS TO THE OPERATIONAL SUITE

Date: 24 NOVEMBER 1997

Requested by: F. RABIER Head of Section: PER UNDEN

Head of Division: ADRIAN SIMMONS

1. Description of modifications
Implementation of 4D-Var

2. Nature of modifications (anticipated effect)
Better analyses and forecasts

3. Any significant meteorological impact expected?
☑ yes ☐ no

4. Description of verifying tests
Tech Memo No. 240
and e-suite since 9/10/97

5. Which extent of operational evaluation is required? (see note (iv))
Usual monitoring

6. Seen by (as appropriate)
Head(s) of Section
Head(s) of Division
25/11/97

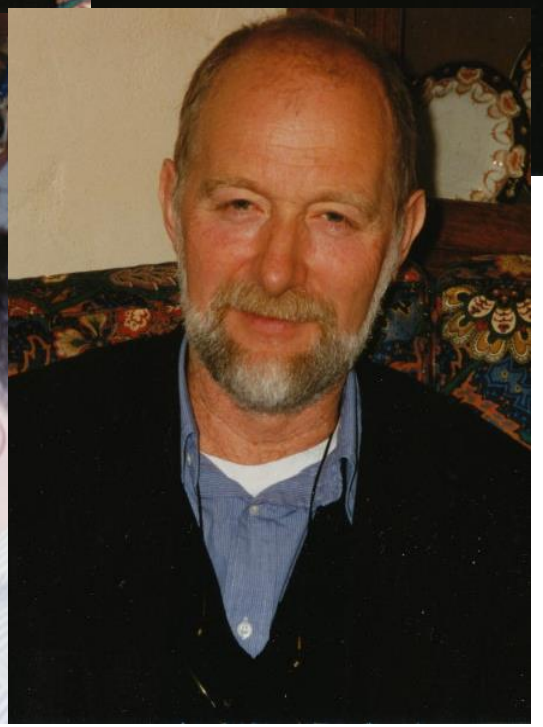
7. Authorisation
Head, Research Department
24/11/97
Head, Operations Department

8. Implemented
Date: 25.11.1997
Head, Met. Applications Section

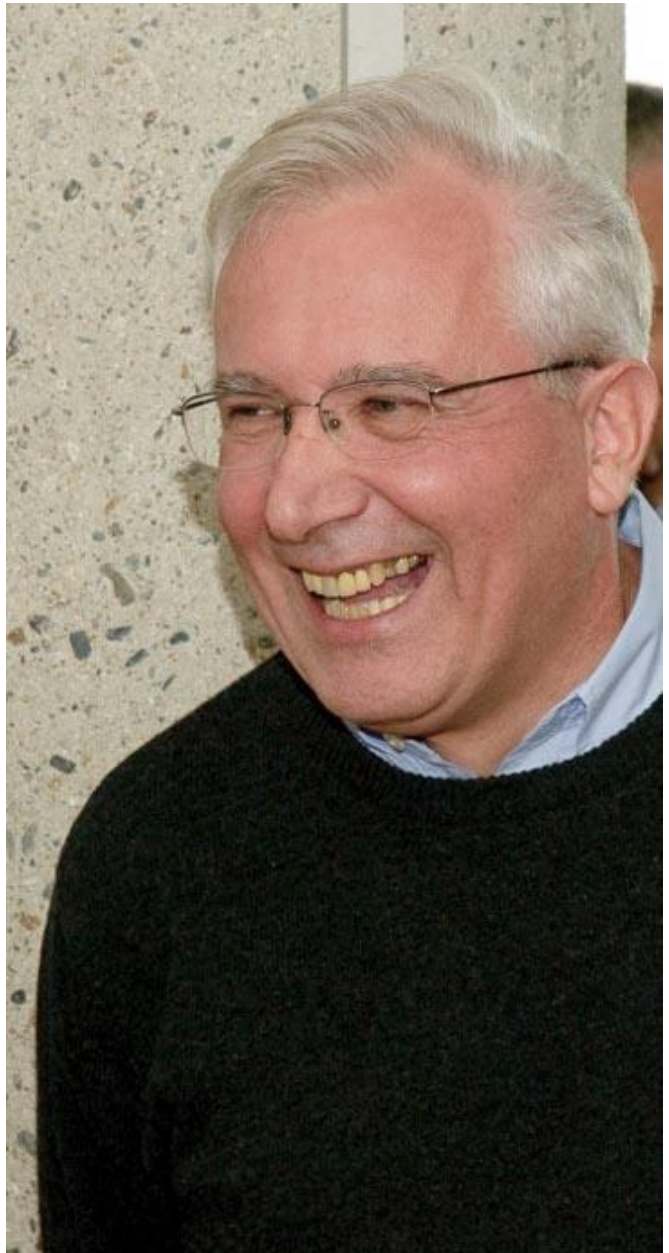
And many others!

P. Courtier
J-N. Thépaut
J. Pailleux
D. Burridge
J. Eyre
E. Andersson
M. Fisher
J. Haseler
M. Hamrud
L. Isaksen
H. Järvinen
E. Klinker
F. Lalaurette
J-F. Mahfouf
M. Miller
O. Pesonen
S. Saarinen
C. Temperton
D. Vasiljević
T. McNally
G. Kelly
F. Bouttier …

Main actors



It took 3 heads of Data Assimilation Section



And an impressive management chain

Many other improvements while head of data division

12 hour 4D-Var

Use of raw radiances

Wavelet Jb

Implementation of variational QC

First use of SSM/I data (from cloudy/rainy situations), a very early precursor to All-sky assimilation

First use of ODB .. Heavy investment in the development of a technical tool

First use of hyper-spectral IR (AIRS)

Other achievements

Fastest ever implementation of a new satellite..NOAA-16 operational at ECMWF 6 weeks after launch!

First adaptive VARBC bias correction

Adrian was personally involved in a fix to constrain humidity increments above the tropopause.

And of course re-analysis…

Adrian's legacy

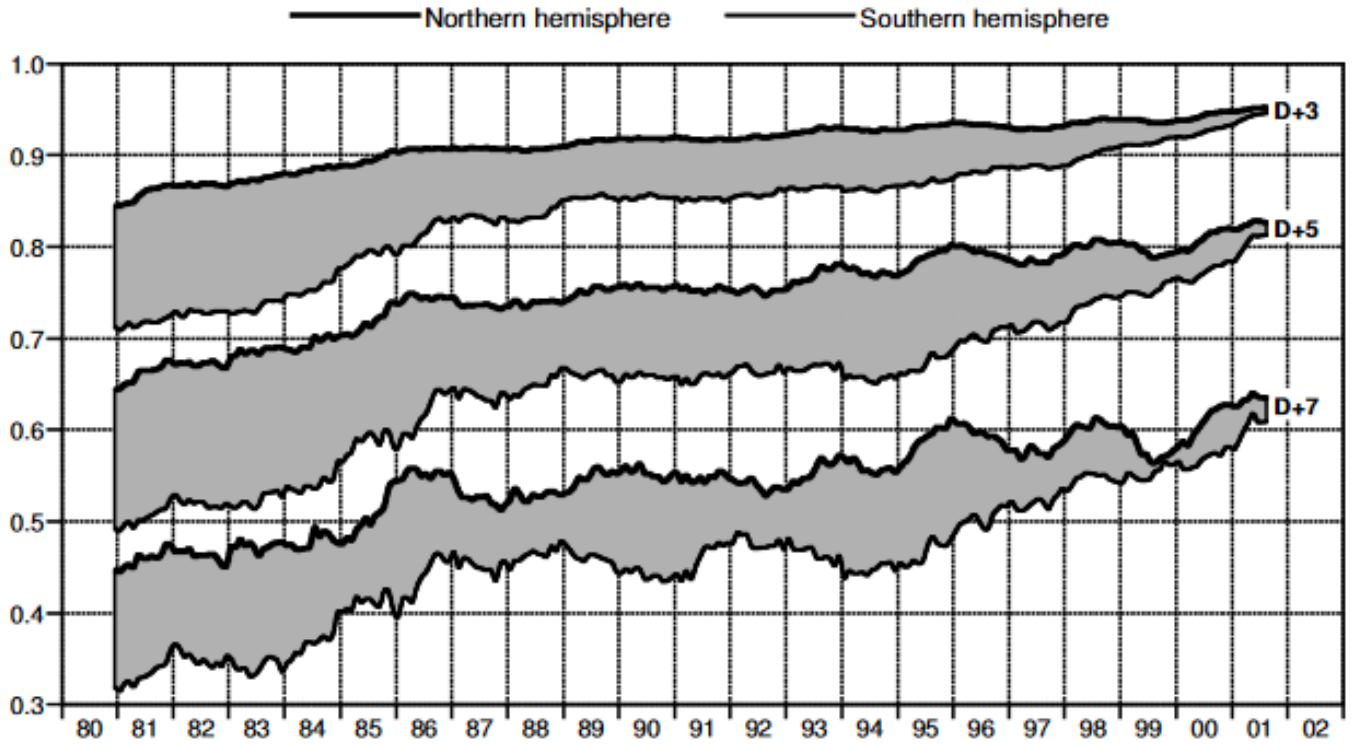
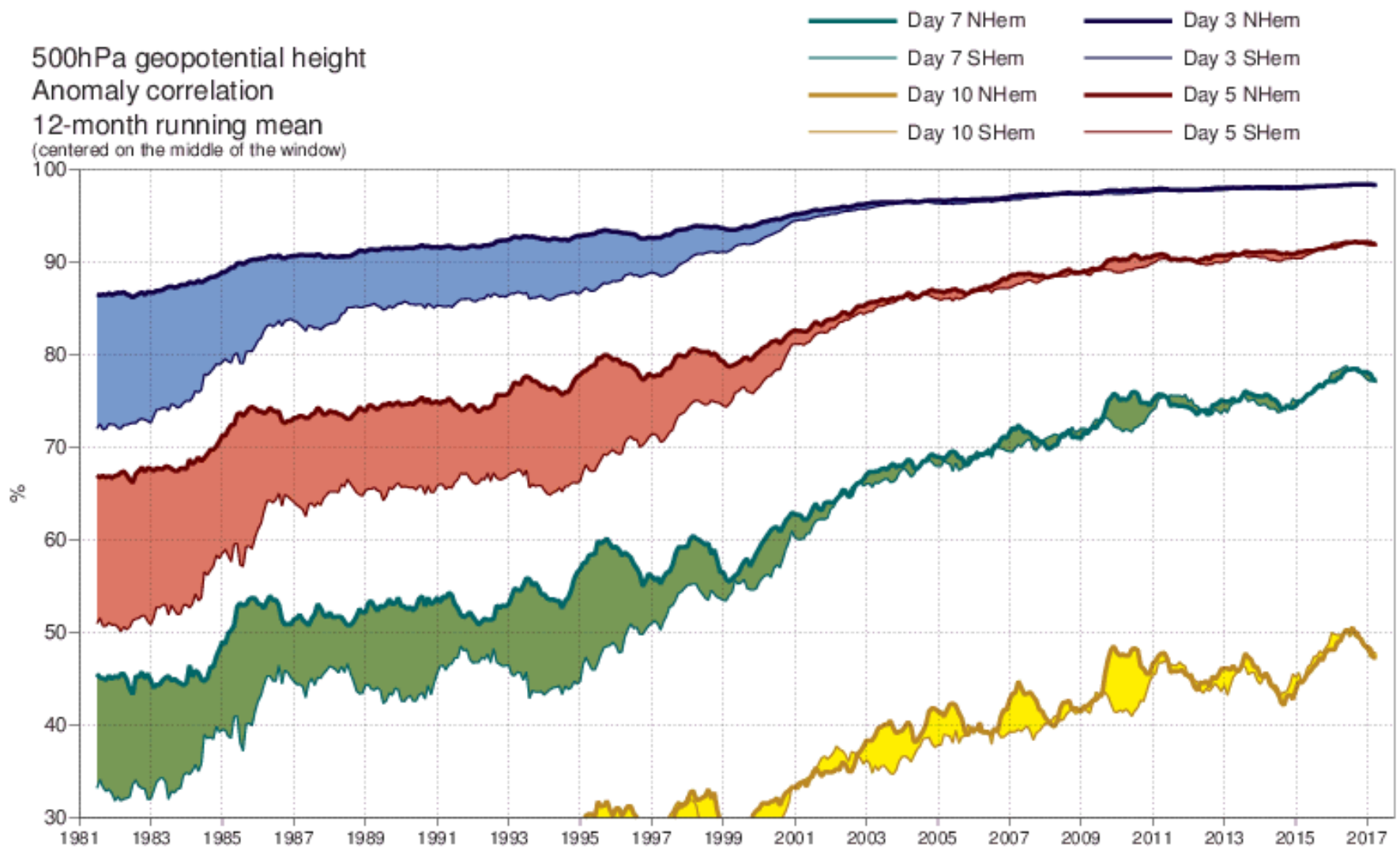


Figure 4. Anomaly correlation coefficients of 3-, 5- and 7-day ECMWF 500 hPa height forecasts for the extratropical northern and southern hemispheres, plotted in the form of annual running means of archived monthly-mean scores for the period from January 1980 to August 2001. Values plotted for a particular month are averages over that month and the 11 preceding months. The shading shows the differences in scores between the two hemispheres at the forecast ranges indicated.

He invented the famous figure (QJRMS, 2002)

Adrian's legacy



. . . and he made the curves go up!

And finally

Thank you for support and advice while implementing 4D-Var

On behalf of ECMWF,

thank you for everything


ECMWF