Five decades in Science and Mathematics: Celebrating the Career of prof. Ionel Michael Navon

Inverse Problems and Data Assimilation minisymposium
SIAM CSE 2015, Salt Lake City, Utah

Ionel Michael Navon
Florida State University

- After five decades in science and mathematics, Professor Ionel Michael Navon is retiring.
- Fields of interest: applied mathematics, physics, computational math, meteorology, geophysics, astrology.
- Publications: 5 Books and co-authored more then 250 scientific articles.
- Navon has always been a scholar, a researcher, an investigator and has spent his life and career in learning and scholarship.
- Along the way, he has worked for universities, meteorological institutes, and science and space powerhouses around the world.
- He has collaborated and created global alliances

A bit of history

- Navon is a native of Romania, and lived there with his family until 1950. Following World War II, the political climate changed and became unfavorable for them, as Russian influence gave rise to imposed communism.
- Concerned for their security; Navon's father moved the family to Israel.
- Between the ages of 10 and 14 he had to learn Hebrew. *"I didn't know a word of Hebrew, but I learned it in a few months*".
- He finished elementary school, and went to high school at the age of 14, in Paris, France. The family sent him there where his father's sister lived, to get a better education there. *"So I had to learn French within few a months"*.
- After high school, he tried to go to university, but he couldn't pursue his studies since being an Israeli citizen he was called to serve **2** and**1/2** years in the army.

After being discharged from the army, he studied for and received the B.S. in Mathematics and Physics (Hebrew Univ. of Jerusalem, 1967)

Soon after graduation, Michael married, and completed his M.S. diploma in Meteorology (Hebrew Univ. of Jerusalem, 1971)

In 1974 Michael joined the Council of Scientific and Industrial Research, Pretoria. His accomplishments in reflected in South African press: 1983, 1985

MEET MIKE NAVON

DR MIKE NAVON of the Department of Mathematics and Dynamic Meterology at NRIMS is the only CSIR staff member known to have been invited to spend almost a year at NASA. In the past, Mike had been involved in an investigation programme of NASA and was invited to spend a year of specialization as a visiting scientist (Senior research associate) at the Goddard Space Flight Centre in Maryland.

Dr Mike Navon

Mike told SCIENDABA that the laboratory of atmospheric sciences was very large and its Global Modeling and Simulation Branch of the Laboratory for Atmospheric Sciences, where Mike was housed, is engaged in general circulation modeling studies related to global atmospheric and oceanographic research. The research activities are organized into global weather/observing systems and climate/open-air interactions.

Mike worked directly with Dr E Kalnay, who is head of the branch, and is regarded as one of the most outstanding scientists in the field of global modeling and simulation. Mike was instrumental in finishing the determination of the three-dimensional modes of the priliutive equations of the atmosphere and completed almost single handedly two important research projects. He discovered that computational modes should not be nonlinearly but linearly initialized and developed a simple method to determine these modes objectively. He also developed a new method for high latitude filtering in global finite differences models which is optimum because it does not introduce any of the distortion on the Rossby waves that other filtering methods do. This project will soon be submitted for publication. He also completed several other experimental studies and developed the methodology to implement variational constraints in dynamic initialization of numerical models. He has also completed a review paper on the performance of several state-of-the-art algorithms for nonlinear minimization.

In a report Dr Kalnay mentions that Mike's knowledge of and experience in weather prediction is vast and deep and compared favourably with the best in the field.

Mike told us that NRIMS is hoping to establish collaboration

southern hemisphere. This project will be similar to work done before. This special operational project (FGGE) involved intensive collecting of data involving weather satellites, ships and airplanes and will not be repeated soon.

The CDC-205 Vectorial computer used at NASA impressed Mike very much as it can store up to ten million words, and is one of the fastest in the world. He misses these super computers but says that his present office accommodation is much better than that which he worked in at NASA. He told us that the NASA/GSFC computer centre is busy seven days a week and twentyfour hours a day! Such frenetic activity can be very stimulating. Mike and other contractors had to justify themselves and work under stressful situations. He even lost a lot of weight while working there.

Mike's wife Lily and two daughters adapted readily to the new surroundings even though Lily, who is a structural professional en-

Forthcoming

Mei 4:
Die Beeld van die Aangenome Kind in die gemeenskap soos weerspieël in die massamedia. Skakel met mev Kersten by tel 574353.
May 10:
Modern Measurement Techniques. Enquiries Mrs Taylor. Tel (011) 8322177.
May 15:
Search Strategy Design. Enquiries Jane Castle X2050.
May 17:
Seminar on Lake Le Roux. Enquiries Mrs C du Plessis X3634.
May 22-25:
Road Infrastructure Course. Enquiries Isabel Hooyberg X2997.

Honour for Dr Navon

Dr I M (Mike) Navon of the NRIMS has been invited to chair one of the six sessions of the forthcoming International Symposium on Variational Methods in Geosciences to be held in Oklahoma, USA.

The objective of the symposium is to provide an international high-level forum for the exchange of ideas in the study of theoretical and practical aspects of variational and identification methods in geophysical problems.

The symposium will consist of six sessions and internationally renowned participants include Prof J L Lions (France, College de France), Prof O C Zienknewicz (University of Wales), Prof J T Oden (University of Texas), Prof N A Phillips (Nat. Meteorological Centre), Prof E Isaacson (Courant Institute), Dr A N Staniforth (Head, Meteorological Numerical Prediction, Canada) amongst others.

Dr Mike Navon

It is an honour for South Africa to have a member of the CSIR, Mike Navon, chair the session on Meteorology and Oceanography. He will introduce the keynote speakers, Drs R Daley and O Talagrand, for that session as well as making the final selection of papers to be presented. Dr Mike Navon invites scientists particularly in the fields of geophysics, seismic analysis, atmospherics, meteorology and oceanography to contact him at x 4300 if they are interested in this symposium which takes place from 14-17 October 1985.

Michael received his Ph.D. in Applied Mathematics (University of the Witwatersrand, Johannesburg, South Africa, 1979)

MICHAEL IONEL NAVON was recently awarded his PhD in Mathematics from the University of the Witwatersrand for work on 'Numerical methods for the Solution of the Shallow-water equation in Meteorology'.

This impressive sounding title has to do with numerical weather forecasting in South Africa. At present Michael is involved in a project undertaken jointly by NASA and the CSIR in which the impact of satellite data on numerical weather forecast is looked at.

His promotor was Prof A M Starfield and his advisor Prof David Jacobson of NRIMS.

Michael, who is an Israeli name Navon can be found in the Book of Kings in the Bible) was born in Rumania, completed his schooling in France, and did his military training and BSc and MSc in Israel and finally his PhD in South Africa.

He is married to Lily, who is one of the few women Civil Engineers in the country. They speak Rumanian to each other and their little daughters, Daria and Livia, are adept in English and Afrikaans as well.

Michael has been working at the CSIR since 1975 and although he came on contract, likes it here so much that he has decided to stay permanently.

Well done, Michael!

Dr. Michael Navon

KEEP

IT

Michael joined FSU in 1985 and immediately started to make an impact

Reiser

Navon

Zou

• **I.M. Navon**, associate professor of mathematics and research associate with the Supercomputer Computations Research Institute, was named to a three-year term as editor of the American Meteorological Society Monthly Weather Review. He and **James J. O'Brien** received a National Science Foundation travel grant for a cooperative program between U.S. and French scientists studying optimal control-methods applications in meteorology. Navon co-wrote a paper with **Xiaolei Zou**, a SCRI postdoctoral research scientist, "Variational Data Assimilation Experiments at NMC," in the 1991 Proceedings of the Australian Bureau of Meteorological Research. Navon co-wrote a paper in Computers and Geosciences.

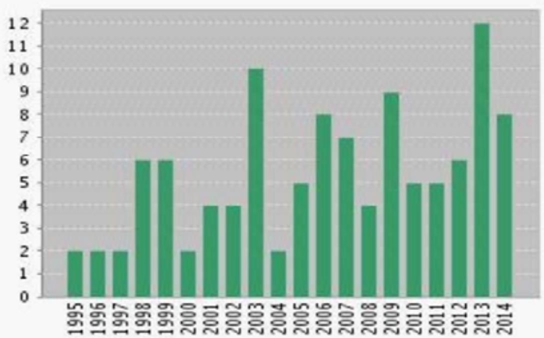
Tallahassee Democrat, Mon. Apr. 29, 1991

Michael joined Dept. of Mathematics in 1987 and Scientific Computing in 2006, where he happily remained until his retirement

(1998)

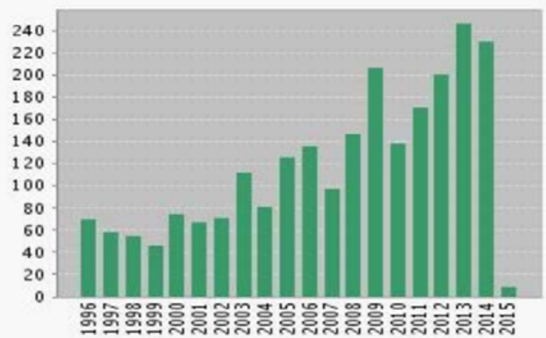
Michael is one of the most influential leaders in the field of variational data assimilation
Web of Science Report (1st page)

Published Items in Each Year



The latest 20 years are displayed.
View a graph with all years.

Citations in Each Year



The latest 20 years are displayed.
View a graph with all years.

Results found:	150
Sum of the Times Cited [?] :	2628
Sum of Times Cited without self-citations [?] :	2157
Citing Articles [?] :	1619
Citing Articles without self-citations [?] :	1493
Average Citations per Item [?] :	17.52
h-index [?] :	26

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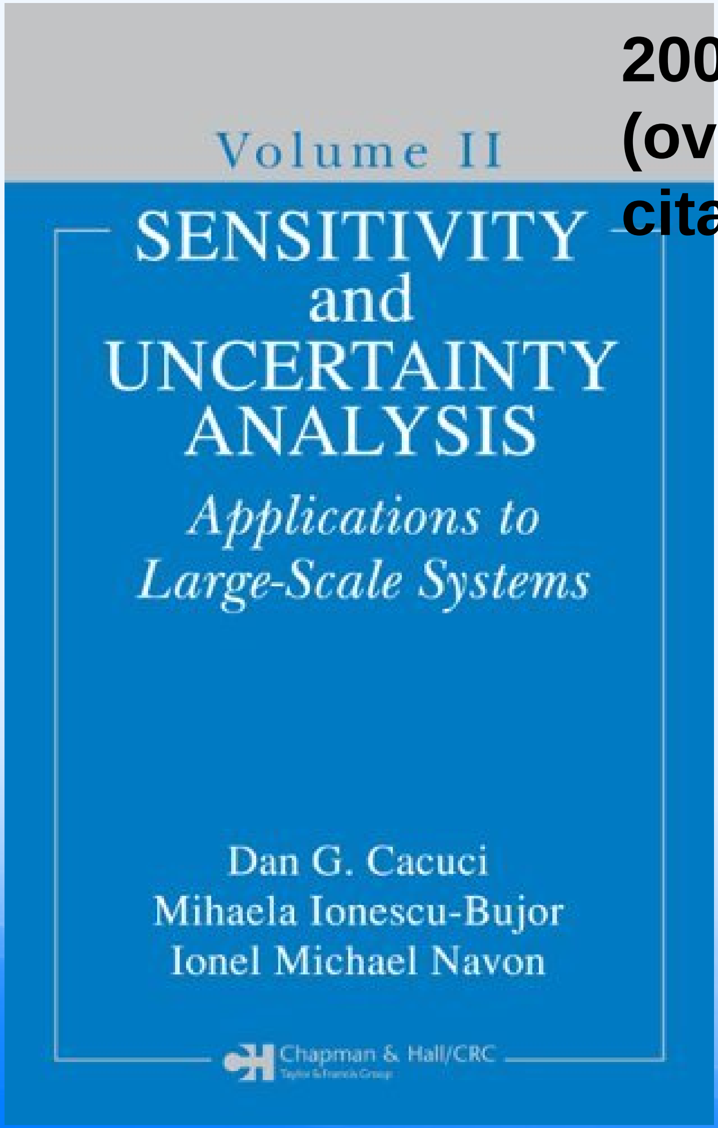
	2011	2012	2013	2014	2015	Total	Average Citations per Year
Use the checkboxes to remove individual items from this Citation Report or restrict to items published between 1... and 2... Go	171	201	247	231	9	2628	71.03
1. EN **VARIATIONAL DATA ASSIMILATION WITH AN ADIABATIC VERSION OF THE NMC SPECTRAL MODEL** By: NAVON, IM; ZOU, X; DERBER, J; et al. MONTHLY WEATHER REVIEW Volume: 120 Issue: 7 Pages: 1433-1446 Published: JUL 1992	4	8	10	8	0	199	8.29
2. EN **CONJUGATE-GRADIENT METHODS FOR LARGE-SCALE MINIMIZATION IN METEOROLOGY** By: NAVON, IM; LEGLER, DM MONTHLY WEATHER REVIEW Volume: 115 Issue: 8 Pages: 1479-1502 Published: AUG 1987	2	1	4	2	0	129	4.45

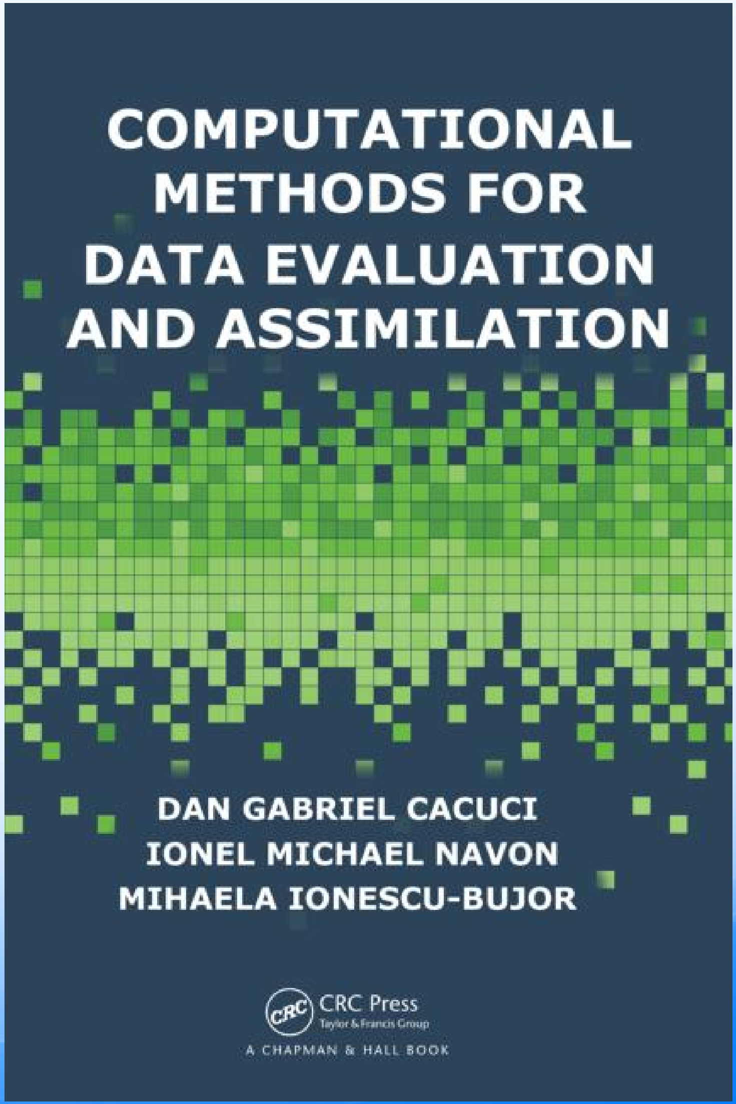
Michael’s work has defined and shaped the field of variational data assimilation
Google Scholar Report (1st page)

Michael published five books



2005 (over 450 citations)

2013



1987: Michael introduces NLCG methods to variational data assimilation in NWP

Conjugate-Gradient Methods for Large-Scale Minimization in Meteorology

I. M. NAVON

Supercomputer Computations Research Institute, Florida State University, Tallahassee, FL 32306

DAVID M. LEGLER

Mesoscale Air–Sea Interaction Group, Department of Meteorology, Florida State University, Tallahassee, FL 32306

(Manuscript received 5 May 1986, in final form 31 October 1986)

ABSTRACT

During the last few years new meteorological variational analysis methods have evolved, requiring large-scale minimization of a nonlinear objective function described in terms of discrete variables. The conjugate-gradient method was found to represent a good compromise in convergence rates and computer memory requirements between simpler and more complex methods of nonlinear optimization. In this study different available conjugate-gradient algorithms are presented with the aim of assessing their use in large-scale typical minimization problems in meteorology. Computational efficiency and accuracy are our principal criteria.

Four different conjugate-gradient methods, representative of up-to-date available scientific software, were compared by applying them to two different meteorological problems of interest using criteria of computational economy and accuracy. Conclusions are presented as to the adequacy of the different conjugate-gradient algorithms for large-scale minimization problems in different meteorological applications.

1989

VOLUME 117 MONTHLY WEATHER REVIEW APRIL 1989

Objective Analysis of Pseudostress over the Indian Ocean Using a Direct-Minimization Approach

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I. M. NAVON

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(Manuscript received 25 April 1988, in final form 9 September 1988)

ABSTRACT

A variational approach is used to develop an objective analysis technique which produces monthly average 1-deg pseudostress vector fields over the Indian Ocean. A cost functional is constructed which consists of five terms, each expressing a lack of fit to prescribed conditions. The first expresses the proximity to the input (first-guess) field. The second deals with the closeness of fit to the climatological value for that month. The third is a measure of data roughness, and the fourth and fifth are kinematic constraints on agreement of the curl and divergence of the results to the curl and divergence of the climatology. Each term also has a coefficient (weight) which determines how closely the minimization fits each lack of fit. These weights are determined by comparing the results using various weight combinations to an independent subjective analysis of the same dataset. The cost functional is minimized using the conjugate-gradient method.

Results from various weight combinations are presented for the months of January and July 1984 and the results examined in terms of these selections. Quantitative and qualitative comparisons to the subjective analysis are made to find which weight combination provides the best results. It was found that the weight on the second term balances the influence of the original (first-guess) field and climatology. The smoothing term weight determines how wide an area deviations of the first guess from climatology is affected. The weights on the kinematic terms are fine-tuning parameters.

1992: Michael introduces second order adjoint analysis

Meteorol. Atmos. Phys. 50, 3–20 (1992)

Meteorology and Atmospheric Physics

551.509.3

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The Second Order Adjoint Analysis: Theory and Applications

Zhi Wang[1], I. M. Navon[1], F. X. Le Dimet[2], and X. Zou[3]

With 17 Figures

Received January 30, 1992
Revised May 26, 1992

Summary

The adjoint method application in variational data assimilation provides a way of obtaining the exact gradient of the cost function J with respect to the control variables. Additional information may be obtained by using second order information. This paper presents a second order adjoint model (SOA) for a shallow-water equation model on a limited-area domain. One integration of such a model yields a value of the Hessian (the matrix of second partial derivatives, $\nabla^2 J$) multiplied by a vector or a column of the Hessian of the cost function with respect to the initial conditions. The SOA model was then used to conduct a sensitivity analysis of the cost function with respect to distributed observations and to study the evolution of the condition number (the ratio of the largest to smallest eigenvalues) of the Hessian during the course of the minimization. The condition number is strongly related to the convergence rate of the minimization. It is proved that the Hessian is positive definite during the process of the minimization, which in turn proves the uniqueness of the optimal solution for the test problem.

Numerical results show that the sensitivity of the response increases with time and that the sensitivity to the geopotential field is larger by an order of magnitude than that to the u and v components of the velocity field. Experiments using data from an ECMWF analysis of the First Global Geophysical Experiment (FGGE) show that the cost function J is more sensitive to observations at points where meteorologically intensive events occur. Using the second order adjoint shows that most changes in the value of the condition number of the Hessian occur during the first few iterations of the minimization and are strongly correlated to major large-scale changes in the reconstructed initial conditions fields.

1. Introduction

The complete description of the initial atmospheric state in a numerical weather prediction method constitutes an important issue. The four-dimensional variational data assimilation (VDA) method offers a promising way to achieve such a description of the atmosphere. It consists of finding the assimilating model solution which minimizes a properly chosen objective function measuring the distance between model solution and available observations distributed in space and time. The control variables are either the initial conditions or the initial conditions plus the boundary conditions. The boundary conditions have to be specified so that the problem is well posed in the sense of Hadamard. In most of the unconstrained minimization algorithms associated with the VDA approach, the gradient of the objective function with respect to the control variables plays an essential role. This gradient is obtained through one direct integration of the model equations followed by a backwards integration in time of the linear adjoint system of the direct model.

1992: Michael demonstrates that 4D-Var can be used with real life NWP models

Variational Data Assimilation with an Adiabatic Version of the NMC Spectral Model*

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X. ZOU

Supercomputer Computations Research Institute, Florida State University, Tallahassee, Florida

J. DERBER AND J. SELA

National Oceanic and Atmospheric Administration, National Meteorological Center, World Weather Building, Washington, D.C.

(Manuscript received 29 July 1991, in final form 10 October 1991)

ABSTRACT

Variational four-dimensional (4D) data assimilation is performed using an adiabatic version of the National Meteorological Center (NMC) baroclinic spectral primitive equation model with operationally analyzed fields as well as simulated datasets. Two limited-memory quasi-Newton minimization techniques were used to iteratively find the minimum of a cost function, with the NMC forecast as a constraint. The cost function consists of a weighted square sum of the differences between the model forecast and observations over a time interval. In all the experiments described in this paper, observations are available for all degrees of freedom of the model. The derivation of the adjoint of the discretized adiabatic NMC spectral model is presented. The creation of this adjoint model allows the gradient of the cost function with respect to the initial conditions to be computed using a single backward-in-time integration of the adjoint equations.

As an initial evaluation of the variational data-assimilation procedure, an assimilation system with a low-resolution version of the NMC spectral model was tested using fields from a Rossby–Haurwitz-wave solution as observations. The results were encouraging, with a significant reduction in the magnitudes of both the cost function and the norm of its gradient during the minimization process. In particular, the high-frequency noise exhibited in the rms of the divergence field, produced by random perturbation in the initial conditions, is largely eliminated after the variational data assimilation.

The performance of the assimilation scheme was examined in a more realistic configuration using the adiabatic NMC spectral model truncated at T40. Both operationally analyzed observations, consisting of vorticity, divergence, temperature, surface pressure and moisture fields (distributed at two time levels separated by a 6-h time interval), and model-generated data were variationally assimilated. The effect of the number of observation fields in time on the convergence rate of the minimization and the impacts due to the inclusion of the horizontal diffusion and the surface drag in the model and its adjoint on the convergence rate and the accuracy of the retrieval are addressed.

1993: Michael introduces LBFGS and TN to variational DA

SIAM J. OPTIMIZATION
Vol. 3, No. 3, pp. 582–608, August 1993

NUMERICAL EXPERIENCE WITH LIMITED-MEMORY QUASI-NEWTON AND TRUNCATED NEWTON METHODS*

X. ZOU†, I. M. NAVON‡, M. BERGER§, K. H. PHUA¶,
T. SCHLICK‖, AND F. X. LE DIMET**

Abstract. Computational experience with several limited-memory quasi-Newton and truncated Newton methods for unconstrained nonlinear optimization is described. Comparative tests were conducted on a well-known test library [J. J. Moré, B. S. Garbow, and K. E. Hillstrom, *ACM Trans. Math. Software*, 7 (1981), pp. 17–41], on several synthetic problems allowing control of the clustering of eigenvalues in the Hessian spectrum, and on some large-scale problems in oceanography and meteorology. The results indicate that among the tested limited-memory quasi-Newton methods, the L-BFGS method [D. C. Liu and J. Nocedal, *Math. Programming*, 45 (1989), pp. 503–528] has the best overall performance for the problems examined. The numerical performance of two truncated Newton methods, differing in the inner-loop solution for the search vector, is competitive with that of L-BFGS.

Key words. limited-memory quasi-Newton methods, truncated Newton methods, synthetic cluster functions, large-scale unconstrained minimization

Michael at NATO Advanced Research Workshop, les Houches, France, 1993

1997: Michael establishes the use of 4D-Var for parameter estimation (in addition to state estimation)

ELSEVIER

Dynamics of Atmospheres and Oceans 27 (1997) 55–79

dynamics of atmospheres and oceans

Practical and theoretical aspects of adjoint parameter estimation and identifiability in meteorology and oceanography [1]

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Received 3 April 1996; revised 28 January 1997; accepted 29 January 1997

Abstract

The present paper has two aims. One is to survey briefly the state of the art of parameter estimation in meteorology and oceanography in view of applications of 4-D variational data assimilation techniques to inverse parameter estimation problems, which bear promise of serious positive impact on improving model prediction. The other aim is to present crucial aspects of identifiability and stability essential for validating results of optimal parameter estimation and which have not been addressed so far in either the meteorological or the oceanographic literature.

As noted by Yeh (1986, *Water Resour. Res.* 22, 95–108) in the context of ground water flow parameter estimation the inverse or parameter estimation problem is often ill-posed and beset by instability and nonuniqueness, particularly if one seeks parameters distributed in space-time domain. This approach will allow one to assess and rigorously validate results of parameter estimation, i.e. do they indeed represent a real identification of physical model parameters or just compensate model errors? A brief survey of other approaches for solving the problem of optimal parameter estimation in meteorology and oceanography is finally presented.

2001: Michael establishes fundamental equivalence properties between 4D-Var and KF

Q. J. R. Meteorol. Soc. (2001), **127**, pp. 661–683

Optimality of variational data assimilation and its relationship with the Kalman filter and smoother

By ZHIJIN LI and I. M. NAVON*
Florida State University, USA

(Received 23 June 1999; revised 25 August 2000)

SUMMARY

The known properties of equivalence between four-dimensional variational (4D-Var) data assimilation and the Kalman filter as well as the fixed-interval Kalman smoother point to particular optimal properties of 4D-Var. In the linear context, the 4D-Var solution is optimal, not only with respect to the model trajectory segment over the assimilation time interval, but also with respect to any model state at a single observation time level; in the batch processing (cycling 4D-Var) method, the information in 4D-Var is fully transferred from one batch to the next by the background term; 4D-Var allows the processing of observations in subsets, while the final solution is optimal as all observations are processed simultaneously. These properties hold even for models that are imperfect, as well as not invertible. Various properties of equivalence of 4D-Var to the Kalman filter and smoother result from these optimality properties of 4D-Var. Further, we show that the fixed-lag Kalman smoother may also be constructed in an optimal way using a multiple batch-processing 4D-Var approach. While error covariances are crucial for the equivalence, practical techniques for evaluating error covariances in the framework of cycling 4D-Var are discussed.

KEYWORDS: Data assimilation Kalman filter Kalman smoother Optimality

2002: Michael starts the “modern age” of widely accepted SOA use in DA

2007: Michael pioneers the use of ROMs as surrogates in variational DA

INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN FLUIDS
Int. J. Numer. Meth. Fluids 2007; **53**:1571–1583
Published online 10 October 2006 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/fld.1365

A reduced-order approach to four-dimensional variational data assimilation using proper orthogonal decomposition

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[3] *College of Fundamental Sciences, North China University of Technology, Beijing 100041, China*

SUMMARY

Four-dimensional variational data assimilation (4DVAR) is a powerful tool for data assimilation in meteorology and oceanography. However, a major hurdle in use of 4DVAR for realistic general circulation models is the dimension of the control space (generally equal to the size of the model state variable and typically of order 10^7–10^8) and the high computational cost in computing the cost function and its gradient that require integration model and its adjoint model.

In this paper, we propose a 4DVAR approach based on proper orthogonal decomposition (POD). POD is an efficient way to carry out reduced order modelling by identifying the few most energetic modes in a sequence of snapshots from a time-dependent system, and providing a means of obtaining a low-dimensional description of the system's dynamics. The POD-based 4DVAR not only reduces the dimension of control space, but also reduces the size of dynamical model, both in dramatic ways. The novelty of our approach also consists in the inclusion of adaptability, applied when in the process of iterative control the new control variables depart significantly from the ones on which the POD model was based upon. In addition, these approaches also allow to conveniently constructing the adjoint model.

The proposed POD-based 4DVAR methods are tested and demonstrated using a reduced gravity wave ocean model in Pacific domain in the context of identical twin data assimilation experiments. A comparison with data assimilation experiments in the full model space shows that with an appropriate selection of the basis functions the optimization in the POD space is able to provide accurate results at a reduced computational cost. The POD-based 4DVAR methods have the potential to approximate the performance of full order 4DVAR with less than 1/100 computer time of the full order 4DVAR. The HFTN (Hessian-free truncated-Newton)algorithm benefits most from the order reduction (see (*Int. J. Numer. Meth. Fluids*, in press)) since computational savings are achieved both in the outer and inner iterations of this method.

Received 22 December 2005; Revised 5 July 2006; Accepted 6 July 2006

2015: Still going strong!

INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN FLUIDS
Int. J. Numer. Meth. Fluids 2014; **00**:1–25
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/fld

Comparison of optimized Dynamic Mode Decomposition vs POD for the shallow water equations model reduction with large-time-step observations

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[2] *Department of Scientific Computing, Florida State University, Tallahassee, FL, 32306-4120, USA*

SUMMARY

We propose a framework for dynamic mode decomposition of 2D flows, when numerical or experimental data snapshots are captured with large time steps. Such problems originate for instance from meteorology, when a large time step acts like a filter in obtaining the significant Koopman modes, therefore the classic dynamic mode decomposition method is not effective. This study is motivated by the need to further clarify the connection between Koopman modes and POD dynamic modes. We apply dynamic mode decomposition (DMD) and proper orthogonal decomposition (POD) to derive reduced-order models of Shallow Water Equations (SWE). A new algorithm for extracting the dominant Koopman modes of the flow field and a new criterion of selecting the optimal Koopman modes are proposed. A quantitative comparison of the spatial modes computed from the two decompositions is performed and a rigorous error analysis for the ROM models obtained by the classic POD and the optimized DMD is presented.

Fellow of the American Meteorological Society, 1998
Honorary Member of Romanian Academy of Science, 2013
(1998, with prof. Ying Hwa Kuo)

Professor Emeritus, Florida State, 2014

Florida State University

Tallahassee, Florida

In Recognition of Meritorious Service to the University,
And on Recommendation of the Faculty of the

College of Arts & Sciences

Hereby is Designated

I. Michael Navon

Professor Emeritus

Effective on the 30th day of August, 2014

Dean

Interim Provost and Executive Vice President

President

Let the celebrations begin!