DANISH METEOROLOGICAL INSTITUTE

——— SCIENTIFIC REPORT ———

00-14

Use of GPS observations in an optimum interpolation based data assimilation system

Bjarne Amstrup
Kristian S. Mogensen
Xiang-Yu Huang

COPENHAGEN 2000

ISSN-Nr. 0905-3263 (printed)
ISSN Nr. 1399-1949 (online)
ISBN-Nr. 87-7478-422-6

Use of GPS observations in an optimum interpolation based data assimilation system

Bjarne Amstrup, Kristian S. Mogensen and Xiang-Yu Huang

Danish Meteorological Institute

Abstract

An Optimum Interpolation (OI) based data assimilation system is further developed to include geopotential profiles retrieved from Global Positioning System (GPS) occultation measurements. The error statistics of the profiles are estimated, and then used in the system. Important differences in the definition of geopotential height used in the GPS retrieval algorithm and that used in the Numerical Weather Prediction (NWP) models are addressed. An example of the impact on an analysis from the new data is also given.

The impact of the geopotential profiles retrieved from GPS/MET occultations on the data assimilation system is investigated. A 16-day period is chosen to run parallel experiments with or without the additional data included. Simple statistics are used to quantify the impact. The impact turns out to be neutral averaged over the whole period, but varies on daily basis.

1 Introduction

Atmospheric profiling using the radio occultation technique provides an additional data source for climate monitoring and numerical weather forecasting (see Høeg *et al.*, 1995 and references therein). As high quality conventional profile data are still inadequate for determining the three dimensional atmospheric state, especially over the oceans and in the southern hemisphere, the GPS profile data may become one of the most important future observing systems. Simulated occultation data have been assimilated into NWP models indicating a great potential of the new data (Eyre, 1994; Zou *et al.*, 1995).

In this study we intend to explore the possibility of using real data in an operational NWP system which is based on the OI analysis method. The real data are the retrieved geopotential profiles from the GPS/MET occultation measurements (Syndergaard *et al.*, 2000). The operational NWP system used in this study is the HIgh Resolution Limited-Area Modelling (HIRLAM) system implemented at the Danish Meteorological Institute (DMI) (Sass *et al.*, 1999).

Using the real data, one has to face and attack, among other things, the problems related to data error statistics. Quality control procedures are

necessary for removing erroneous data. Interpolation of the data in space is part of the OI scheme, but a strategy is needed for the interpolation in time. When using the operational NWP system, one has to keep the basic setup and only include the new component as a small addition. The impact of the new data could be small simply because they are few.

This report gives a brief overview of the DMI I M section , presents the approach we took in estimating the data error statistics sec tion , and shows an e ample of the impact from the new data on an analysis section . ection describes the observation system e periment O setup, section de nes the veri cation measures and section gives some results from a few of the e periments.

The data assimilation system used for the e periments is the operational I M forecasting system at DMI. The system has been developed in a collaborative research pro ect between the national meteorological institutes of Denmark, inland, rance, Iceland, Ireland, the Netherlands, Norway, pain, and weden see e.g. Machenhauer, ustafsson, ynch , . It is an intermittent data assimilation system including an OI analysis scheme and a forecast model. The system at DMI is documented in ass and further details concerning the I M OI analysis scheme can be found in allen and nden .

The I M OI is a limited area version of the MW OI scheme onnberg and haw, . The rst guess eld is the h forecast based on the previous data assimilation cycle. Three dimensional multi variate statistical interpolation is used for the wind, geopotential, and surface pres sure. Three dimensional univariate statistical interpolation is used for rela tive humidity. The observation window covers a h span around the time for the analysis , , and T . standard observation set is used, including synoptic observations, ship observations, drifting and moored buoys, pilot balloons, radiosonde data and aircraft data. or ra diosondes the OI system uses geopotential height, wind and humidity at a ed number of pressure levels. ere we would like to point out that no satellite observations have been included e cept P pro les.

The P geopotential pro les have been included in the analysis scheme in the same way as for radiosondes, but with modi ed vertical correlations and observation errors. While the providers of P derived atmospheric pro les used W World eodetic ystem geometric heights, the geopotential heights widely used in NWP modeling are not referred to the W ellipsoid but to the M arth ravitational Model geoid. Therefore, we made a conversion of W geometric heights to NWP model I M geopotential heights as described in edel .

on. CEC AIR Programme. Contract No. AIR3 - CT92-0652

No. 96-9
Rashpal S. Gill and Hans H. Valeur
Evaluation of the radarsat imagery for the operational mapping of sea ice around Greenland

No. 96-10
Jens Hesselbjerg Christensen, Bennert Machenhauer, Richard G. Jones, Christoph Schär, Paolo Michele Ruti, Manuel Castro and Guido Visconti: Validation of present-day regional climate simulations over Europe: LAM simulations with observed boundary conditions

No. 96-11
Niels Larsen, Bjørn Knudsen, Paul Eriksen, Ib Steen Mikkelsen, Signe Bech Andersen and Torben Stockflet Jørgensen European Stratospheric Monitoring Stations in the Artic: An European contribution to the Network for Detection of Stratospheric Change (NDSC): CEC Environment Programme Contract EV5V-CT93-0333: DMI contribution to the final report

No. 96-12
Niels Larsen: Effects of heterogeneous chemistry on the composition of the stratosphere: CEC Environment Programme Contract EV5V-CT93-0349: DMI contribution to the final report

No. 97-1
E. Friis Christensen og C. Skøtt: Contributions from the International Science Team. The Ørsted Mission - a pre-launch compendium

No. 97-2
Alix Rasmussen, Sissi Kiilsholm, Jens Havskov Sørensen, Ib Steen Mikkelsen: Analysis of tropospheric ozone measurements in Greenland: Contract No. EV5V-CT93-0318 (DG 12 DTEE): DMI's contribution to CEC Final Report Arctic Trophospheric Ozone Chemistry ARCTOC

No. 97-3
Peter Thejll: A search for effects of external events on terrestrial atmospheric pressure: cosmic rays

No. 97-4
Peter Thejll: A search for effects of external events on terrestrial atmospheric pressure: sector boundary crossings

No. 97-5
Knud Lassen: Twentieth century retreat of sea-ice in the Greenland Sea

No. 98-1
Niels Woetman Nielsen, Bjarne Amstrup, Jess U. Jørgensen:
HIRLAM 2.5 parallel tests at DMI: sensitivity to type of schemes for turbulence, moist processes and advection

No. 98-2
Per Høeg, Georg Bergeton Larsen, Hans-Henrik Benzon, Stig Syndergaard, Mette Dahl Mortensen: The GPSOS project
Algorithm functional design and analysis of ionosphere, stratosphere and troposphere observations

No. 98-3
Mette Dahl Mortensen, Per Høeg:
Satellite atmosphere profiling retrieval in a nonlinear troposphere
Previously entitled: Limitations induced by Multipath

No. 98-4
Mette Dahl Mortensen, Per Høeg:
Resolution properties in atmospheric profiling with GPS

No. 98-5
R.S. Gill and M. K. Rosengren
Evaluation of the Radarsat imagery for the operational mapping of sea ice around Greenland in 1997

No. 98-6
R.S. Gill, H.H. Valeur, P. Nielsen and K.Q. Hansen: Using ERS SAR images in the operational mapping of sea ice in the Greenland waters: final report for ESA-ESRIN's: pilot projekt no. PP2.PP2.DK2 and 2nd announcement of opportunity for the exploitation of ERS data projekt No. AO2..DK 102

No. 98-7
Per Høeg et al.: GPS Atmosphere profiling methods and error assessments

No. 98-8
H. Svensmark, N. Woetmann Nielsen and A.M. Sempreviva: Large scale soft and hard turbulent states of the atmosphere

No. 98-9
Philippe Lopez, Eigil Kaas and Annette Guldberg: The full particle-in-cell advection scheme in spherical geometry

No. 98-10
H. Svensmark: Influence of cosmic rays on earth's climate

No. 98-11
Peter Thejll and Henrik Svensmark: Notes on the method of normalized multivariate regression

No. 98-12
K. Lassen: Extent of sea ice in the Greenland Sea 1877-1997: an extension of DMI Scientific Report 97-5

No. 98-13
Niels Larsen, Alberto Adriani and Guido Di-Donfrancesco: Microphysical analysis of polar stratospheric clouds observed by lidar at McMurdo, Antarctica

No.98-14
Mette Dahl Mortensen: The back-propagation method for inversion of radio occultation data

No. 98-15
Xiang-Yu Huang: Variational analysis using spatial filters

No. 99-1
Henrik Feddersen: Project on prediction of climate variations on seasonel to interannual timescales (PROVOST) EU contract ENVA4-CT95-0109: DMI contribution to the final report:Statistical analysis and post-processing of uncoupled PROVOST simulations

No. 99-2
Wilhelm May: A time-slice experiment with the ECHAM4 A-GCM at high resolution: the experimental design and the assessment of climate change as compared to a greenhouse gas experiment with ECHAM4/OPYC at low resolution

No. 99-3
Niels Larsen et al.: European stratospheric monitoring stations in the Artic II: CEC Environment and Climate Programme Contract ENV4-CT95-0136. DMI Contributions to the project

No. 99-4
Alexander Baklanov: Parameterisation of the deposition processes and radioactive decay: a review and some preliminary results with the DERMA model

No. 99-5
Mette Dahl Mortensen: Non-linear high resolution inversion of radio occultation data

No. 99-6
Stig Syndergaard: Retrieval analysis and methodologies in atmospheric limb sounding using the GNSS radio occultation technique

No. 99-7
Jun She, Jacob Woge Nielsen:Operational wave forecasts over the Baltic and North Sea

No. 99-8
Henrik Feddersen: Monthly temperature forecasts for Denmark - statistical or dynamical?

No. 99-9
P. Thejll, K. Lassen: Solar forcing of the Northern hemisphere air temperature: new data

No. 99-10
Torben Stockflet Jørgensen, Aksel Walløe Hansen: Comment on "Variation of cosmic ray flux and global coverage - a missing link in solar-climate relationships" by Henrik Svensmark and Eigil Friis-Christensen

No. 99-11
Mette Dahl Meincke: Inversion methods for atmospheric profiling with GPS occultations

No. 99-12
Benzon, Hans-Henrik; Olsen, Laust: Simulations of current density measurements with a Faraday Current Meter and a magnetometer

No. 00-01
Høeg, P.; Leppelmeier, G: ACE: Atmosphere Climate Experiment: proposers of the mission

No. 00-02
Høeg, P.:FACE-IT: Field-Aligned Current Experiment in the Ionosphere and Thermosphere

No. 00-03
Allan Gross: Surface ozone and tropospheric chemistry with applications to regional air quality modeling. PhD thesis

No. 00-04
Henrik Vedel: Conversion of WGS84 geometric heights to NWP model HIRLAM geopotential heights

No. 00-05
Jérôme Chenevez:Advection experiments with DMI-Hirlam-Tracer

No. 00-06
Niels Larsen: Polar stratospheric clouds microphysical and optical models

No. 00-07
Alix Rasmussen, Jens Havskov Sørensen, Niels Woetmann Nielsen and Bjarne Amstrup Uncertainty of meteorological parameters from DMI-HIRLAM, RODOS(WG2)TN(99)12, EU-Contract FI4P-CT95-0007

No. 00-08
A.L. Morozova: Solar activity and Earth's weather. Effect of the forced atmospheric transparency changes on the troposphere temperature profile studied with atmospheric models

No. 00-09
Niels Larsen, Bjørn M. Knudsen, Michael Gauss, Giovanni Pitari Effects from high-speed civil traffic aircraft emissions on polar stratospheric clouds

No. 00-10
Søren Andersen:Evaluation of SSM/I sea ice algorithms for use in the SAF on ocean and sea ice, July 2000
(In Press)

No. 00-11
Claus Petersen, Niels Woetmann Nielsen: Diagnosis of visibility in DMI-HIRLAM

No. 00-12
Erik Buch: A monograph on the physical oceanography of the Greenland waters
(In Press)