Dynamical aspects of atmospheric data assimilation in the tropics

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Reduction of uncertainties in the atmospheric analysis fields in the tropics
Definition

Observations $(V, T, p, q)$

Mass field

A priori information (model)

Analysis

Weather forecast

Climate simulations
Ingredients of the analysis

Observations:

24 hour summary of observations received at ECMWF, 18 March 2000

ERS-2
415,511

Geo-stationary satellites

Cloud motion vector
SATOB
412,455

Polar-orbiting satellites

ATOVS
SSMI
3,828,846
52,680

AIREP
21,872

AMDA
45,814

ACAR
15,145

Buoys – drifting
8,495
moored
287

Profiler
390

SYNOP – Ship 5064

SYNOP – Land 49,440

TEMP –
Land
1135
Ship
17
Pilot
878
Smagorinsky (1969): "... First of all, not all data are equal in their information-yielding capacity. Some are more equal than others..."
About the ingredients ...

- Observations:
  Imbalance between the mass- and wind-field information in the present Global Observing System

- A priori information:
  Physical laws governing the atmospheric flow

- Balance properties:
  Different in the tropics than in the mid-latitudes
Improvements

- New wind observing systems
- Improvements of data assimilation procedures
- Improvements of the models’s parameterizations and resolution
  
Subject of the thesis work

Balance relationships in the tropics

Thesis assumes the model is excellent
New wind data

New wind observing systems

Atmospheric Dynamic Mission

Peculiarity of ADM

line-of-sight (LOS) winds
Assimilation procedure

\[ J = J_o + J_b \], minimal

\[ J_o \] - distance to observations

\[ J_b \] - distance to the background

3D-Var
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Assimilation procedure

\[ J = J_o + J_b, \text{ minimal} \]

\( J_o \) - distance to observations
\( J_b \) - distance to the background

\[ J = J_o + J_b, \text{ minimal} \]

4D-Var

\( J_o \) - distance to observations
\( J_b \) - distance to the background

Time scale

\( t_1 \) to \( t_2 \)
Observations and a priori information are combined according to their error characteristics.

$$J(x) = J_o + J_b = \frac{1}{2} (x - y)^T R^{-1} (x - y) + \frac{1}{2} (x - x^b)^T B^{-1} (x - x^b)$$

**B - I M P O R T A N T**
Why is the B matrix important?

Observations are too few

Observed information needs to be spread to nearby points and levels in a dynamically consistent way
Information spreading

To the same variable

Univariate analysis
Also to other variables

Information spreading

Multivariate analysis
Also to other variables in the tropics
Methodology

General philosophy: to simplify
Multivariate tropical analysis

- **Mid-latitudes:** Rossby waves
- **Tropics:** Rossby, Kelvin, mixed Rossby-gravity and inertio-gravity waves
- Mid-latitudes: Rossby waves
- Tropics: Rossby, Kelvin, mixed Rossby-gravity and inertio-gravity waves

Mid-latitude approach
Multivariate tropical analysis

- Mid-latitudes: Rossby waves
- Tropics: Rossby, Kelvin, mixed Rossby–gravity and inertio–gravity waves

Mid-latitude approach

A new modelling approach
Impact of ADM winds

"Truth": equatorial Rossby wave
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"Truth": equatorial Rossby wave

Height data

Impact of ADM winds
Impact of ADM winds

"Truth": equatorial Rossby wave

Height data

Height & ADM winds
Question: How does the new methodology work in the "real" (numerical weather prediction) framework?
How does it work?

In average about 60–70%
What have I achieved?

- Developed an approach to multivariate analysis in the tropics based on equatorial waves coupled to convection.
- Applied it for studying the impact of new wind observations.
- Found that the same wave structures are present in an NWP system.
What remains to be done?

- Solving the methodology extention into the global NWP domain
- Representing the unexplained part of the variance field and remaining variables
- Taking into consideration discrepancy between theoretical assumptions and "real" forecast error patterns