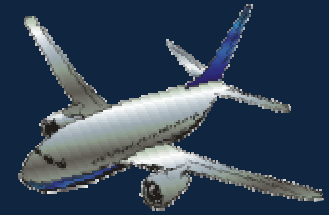


SESAR Innovation Days - 1th Dec 2011 - Toulouse (France)



Advances in Digital Meteorological Services (DMET) for ATM

Aviation Meteorology in support of air Traffic Optimization and
Automation



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Summary

INTRODUCTION Motivation, State of the Art

OBJETIVES Definition & Concept of Operation

METHOD Service Architecture

DMET in the Future Information
Managemet System

RESULTS Performance Estimations

Towards the ATM Automation Support:
Trajectory Optimization

NEXT STEPS Conclusions & Next Steps

Introduction: Motivation & State of the Art

Air Traffic Operations

ANNUAL COST OF WEATHER DELAYS IN COMMERCIAL AVIATION
~ €900M (EUROCONTROL)

The ATM System

OBJECTIVE: ATM AUTOMATION: NEED TO OPERATE MUCH MORE
EFFICIENTLY . DEVELOPMENT OF ATM AUTOMATION TOOLS

Aviation Meteorology State of the Art

FUTURE DIGITAL MET SERVICES: SATISFY DEMANDING
REQUIREMENTS: 4D PREDICTION OF ATMOSPHERIC VARIABLES

ATM & MET Services

MAJOR CHALLENGE NOWADAYS: REPLACING EXISTING MET
SERVICES – ACCURATE PREDICTIONS OF ATMOSPHERIC
ASPECTS BY MODERN COMPUTATIONAL RESOURCES

D-MET Definition & Concept of Operation

What is D-MET



Digital Meteorological Service for the future
ATM Support (Operational)

Analysis & Sim  Operational
NOW **IN THE FUTURE**

DMET ConOp

- ✓ Change the operational concept, single global scenario
- ✓ Cooperation, data sharing and compatible technologies
- ✓ Fully digital environment
- ✓ SESAR Operational Concept
- ✓ ATM Master Plan, information exchange methods, standardization of ATM Information

D-MET Definition & Concept of Operation

Requirements for future Weather Services

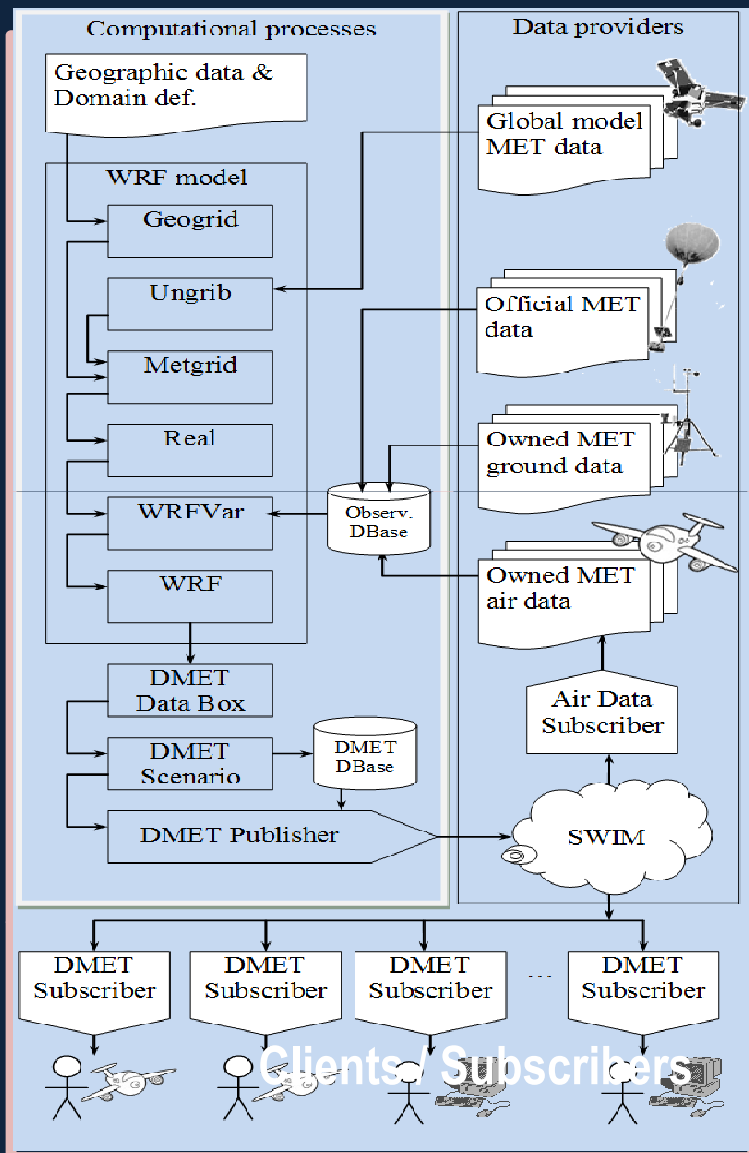
- Global access to existing meteo data & compatibility
- CDM and common situational awareness
- Real Time updating

Weather Service Objectives

- 4D Weather Scenario Forecast
- Web based, net centric Service
- Real Time, short Term predictions: Support of Tactical Operations
- Trajectory Optimization

DMET is the prototype of a web based net-centric Aeronautical Digital Service and Meteorological Model focused to support future air traffic operations, based on the 4D Concept and the future ATM requirements

Service Architecture & Data Flow



Result of a full-physic atmospheric model (focused on specific geo domains) running in fast-time simulation and computing live observations at given time instants.

Fundamentals

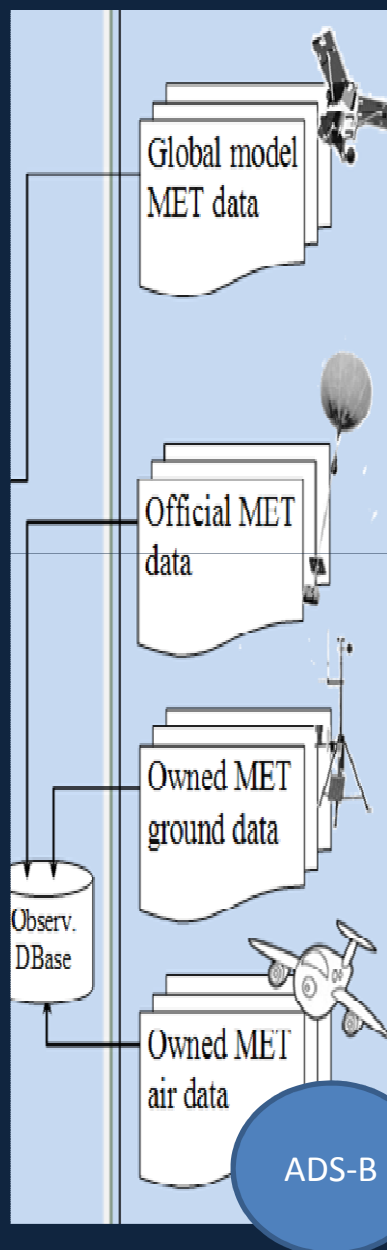
- Running of WRF (Weather Reference Forecast)
- Mesoscale propagators
- Baseline data:

Geographical

Meteorological

- ❖ Access to external Data Sources and Support to Service delivery: SWIM middleware
- ❖ Model outputs are routinely updated as soon as external data is received from several sources of information

Weather Data Types



Global data for the development of the initial model (NCEP-NOAA)

- ✓ Publicly delivered
- ✓ Refresh time: 6 horas
- ✓ Resolution 0.5 °
- Spatial and temporal resolutions insufficient for ATM applications
- Starting point for mesoscale and regional models

Local data and observations (ground and altitude) for the accuracy improvements & customizability

OFICIAL DATA: Spanish Meteorological Agency (AEMET)

- Real Time Observations (MetSt)
- RT: 10 MINUTES
- Balloons (parameters in altitude)
- HIRLAM MODEL

OWN LOCAL DATA: GROUND METEOROLOGICAL STATIONS IN DOMAIN

- Network of Met St deployed on the scene (tailored according to domain size)
- Geo-referenced observations
- Measuring rate: 10 min

LOCAL AIRBORNE OBSERVATIONS: Aircrafts in domain

- Measurement of interesting parameters along the aircraft flight path
- Enhance the accuracy at different altitude levels

DMET Computational Process

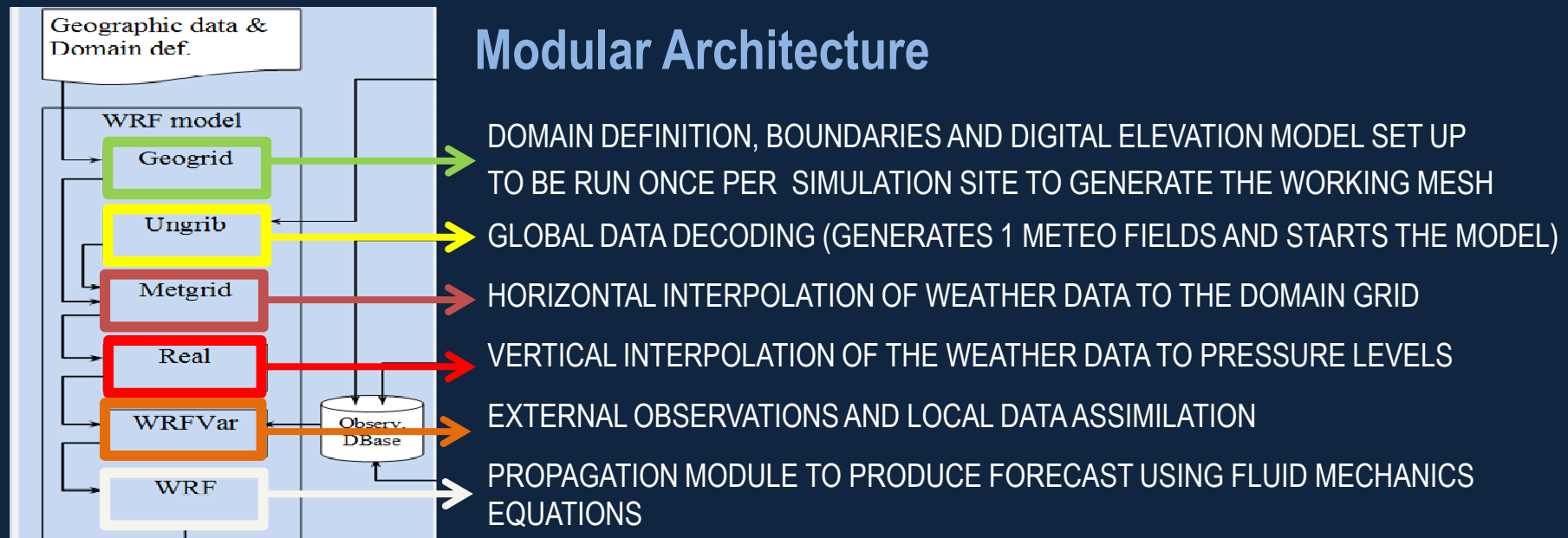
Based on the WRF model execution

WRF,
Weather Research and
Forecasting

Fluids Computational dynamics code for atmospheric simulation and weather prediction. Full-physic non-hydrostatic equation model.

Objective

Build the next generation mesoscale model (DMET) and provide the necessary architecture for the data assimilation

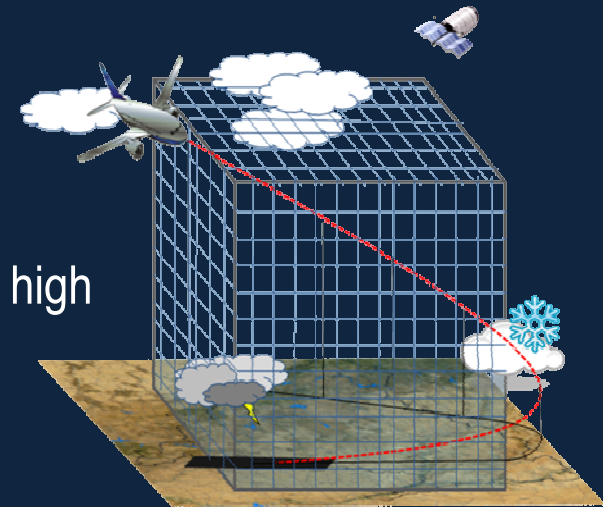


Computational Process & Model Features

- Process repeats each hour (managed by timestamps & control identifiers)
- In a single run the model produces enough 4D predictions to support aircraft trajectory during TMA operation

Domain Size

- 150*150*20 KM domain
- Contained in a 100*100*27 cell grid
- Compatible with TMAs of tests airports
- Vertical dimm: ground/sea level to 20km high
- Computed by pressure levels or layers
- Resolution 27 layers



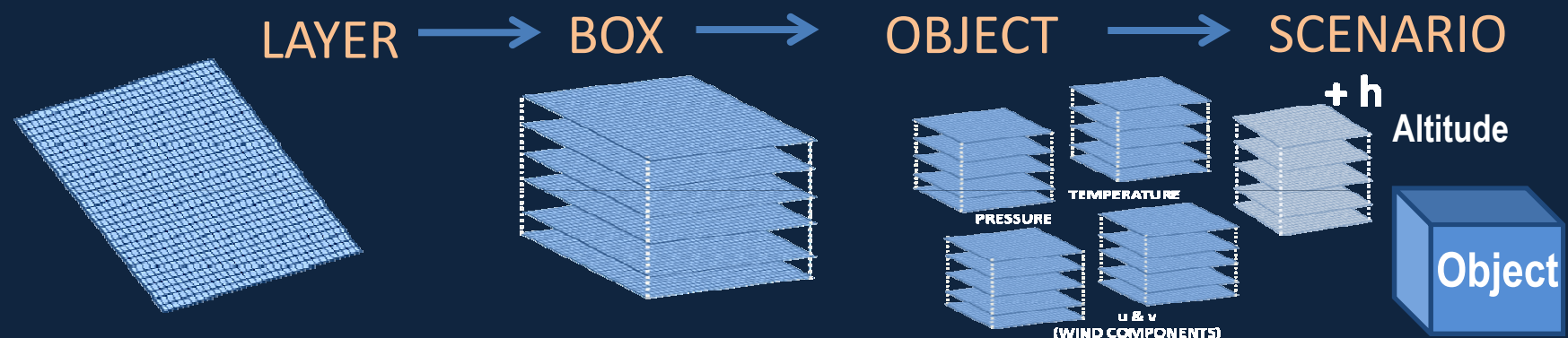
Forecast time

In current implementation: 2,5 h forecast per each computing process.
Forecast is discretised at intervals of 10min (15 files are produced per simulation)

DMET Model Structure

Basic Model Structure 4D grid of spatial temporal cells

Elements The structure for a particular weather scenario is based on following elements



- ONE LAYER PER PRESSURE LEVEL
- BIDIMENSIONAL ELEMENT CORRESPONDING TO A GRID, TAILORED ACCORDING TO THE DOMAIN
- IT CONTAINS DATA POINTS ABOUT A SPECIFIC ATMOSPHERIC VARIABLE

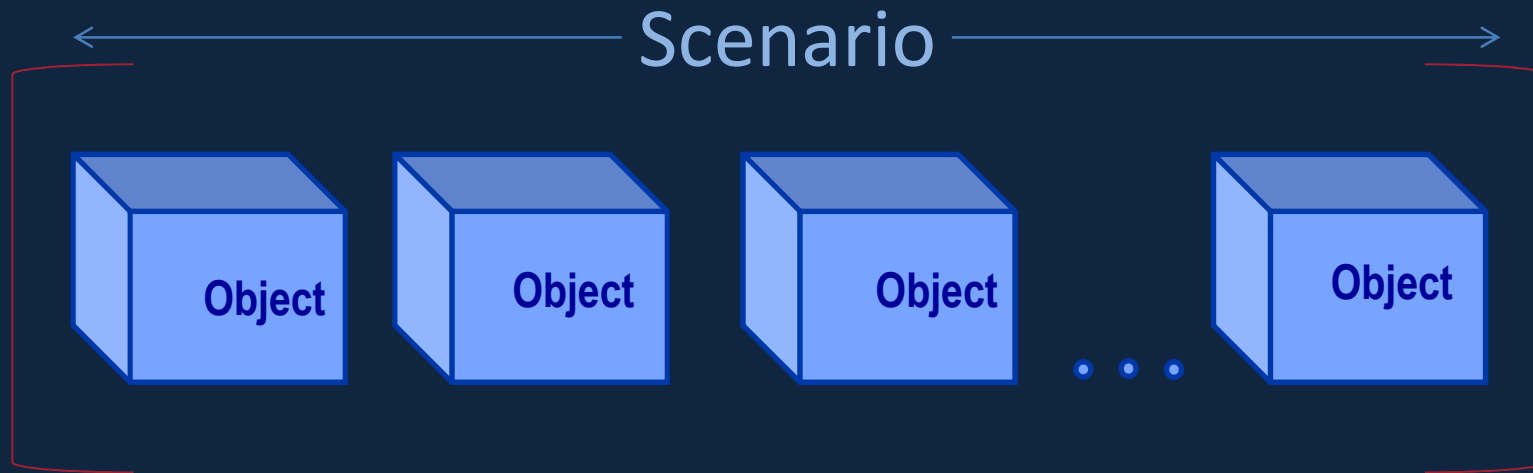
- 1 BOX PER SPECIFIC ATMOSPHERIC VARIABLE
- 3D ELEMENT CORRESPONDING TO A DOMAIN VOLUME
- IT CONTAINS ALL LEVEL-LAYERS OF A SPECIFIC VARIABLE.

- 1 OBJECT PER FORECAST TIME (EACH SPECIFIC TIME INSTANT OF THE FORECAST IS ASSOCIATED WITH AN OBJECT)
- THE OBJECT IS THE GROUP OF 5 BOXES (1*VARIABLE) FOR A SPECIFIC TIME: P, T, WIND COMPONENTS and GEOPOTENTIAL ALTITUDE

DMET Model Structure

The Weather Scenario

The weather Scenario is a series of time-spaced objects covering a certain time span



DMET in the Future Information Management System

Dissemination of Atmospheric 4D Models



Context

Operation in future
ATM

SERVICE ORIENTED
ARCHITECTURE

...GET THE «AVIATION
INTRANET CONCEPT»

The objective is the
provision of air traffic
services living in a
middleware

Standardized
management
system

Data
distribution in
a common
digital format

SOLUTION

**SERVICE-ORIENTED
CONCEPT
SWIM**

(System Wide Information
Management)

Publish/Subscribe
Paradigm

Technology :OMG Data Distribution Service for Real
Time Systems (DDS)

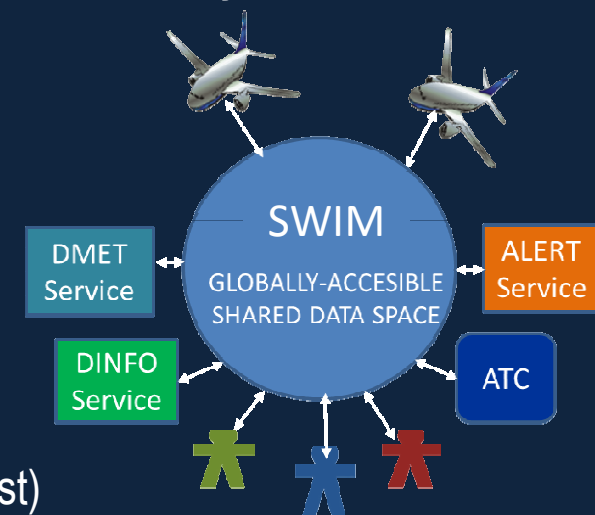
Communication and Dissemination

Objective Adapt the outputs to fit the dissemination standard

DataPackages Requirements

- Multiple User support
- Regular and Real Time updating
- Compliance with DDS Technology
- Acceptable bandwidth usage
- Provision of user understandable data or decoding support

Addressed by DDS TECHNOLOGY



- High size of 4D Meteo Models Instances (~5Mb / 2,5 h forecast)
- TOPICS: Basic units of information (datapackets). DDS is based on the reading and writing of these dataobjects

Solution Creation of 2 topics

MetaData

Data header (one instance per scenario) Info for the assembly of the updated model structure

DMETScenario

Meteo information following the compositional structure set by MetaData
One instance per layer /Multiple instances

D-MET Performance Estimations

Implementation

8 Computers:

- 7 Slave nodes / 1 master

HW & SW Homogeneous System

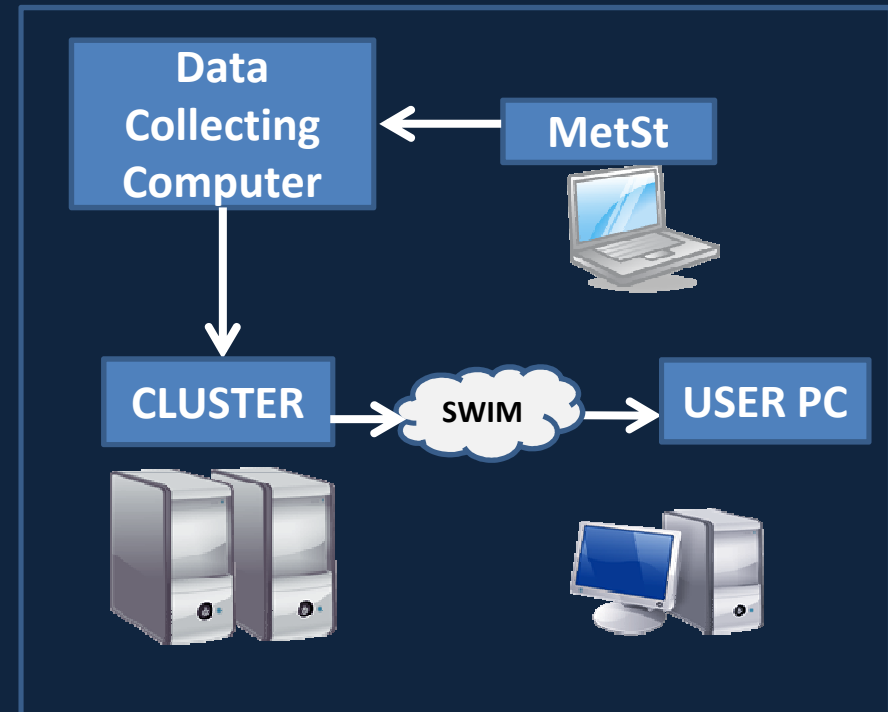
- Intel Core 2 Quad, CPU Q6600@2Ghz, 2GB RAM
- OpenSuse 11.2 O.S.

Performance

Objective: better resolution and shorter refreshing times

Improve every sim step in order to get outputs as fast as possible

PARALELL COMPUTING ; process division into smaller tasks, executed in different processor cores (in the machine or in the network)



D-MET Performance Estimations

- **Technologies**

- Open MP (Shared Memory): Shares the simulation data among all the processor cores of a single machine by means of a threading protocol.
- MPI (Distributed Memory): Partial tasks are executed in different computers in the same network

- **Time for the simulation:**

	20 Cores CLUSTER	32-8 Core Machines SUPERCOMPUTING CNTR
	21,33 ms/km²/h	2,13 ms/km²/h
	 20 min	 2 min
- **Transmission speed : 140 s /object** (fully compatible with the cluster performance)

Scaling with number of nodes has a limit, determined by the size of the chopped domains;
When larger domains are necessary, the scaling with size is almost lineal.

European whole coverage, 1500 m resolution, European supercomputers centers

...Better for large domains simulation

D-MET Performance Estimations

Validation Model has been tested for accuracy using two kind of official data (AEMET)

- Meteorological forecast service
- Atmospheric sounding data

August, 2010, Santander Airport (North Coast of Spain)

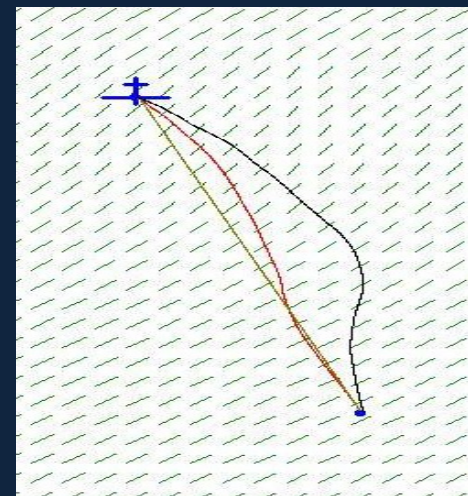
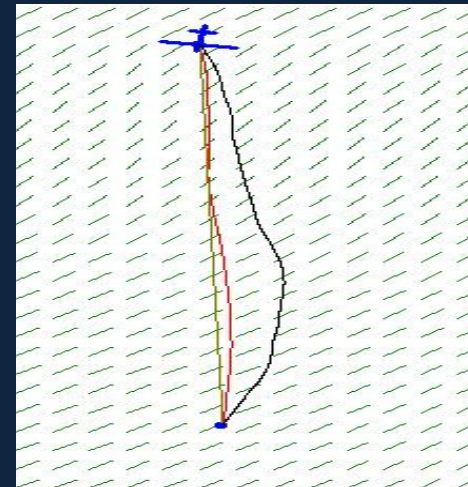
Test results

- ✓ Excellent matching with HIRLAM forecast (official model)
- ✓ Less than 10% mean error in wind speed modules (within the operational range below tropopause)

Larger time spam and different location tests must to be conducted to certify the acceptable QoS for future operational use.

...ATM Automation Support: DMET for the Optimization of Flight Trajectories

- Optimization of Flight Trajectories: one of the most relevant DMET applications
- Constrained programming and analytic methods designed and tested initially for cruise phase
- Pseudospectral algorithms are currently under assesment (wind speed components & their spatial derivatives in the resulting trajectory equations)
- Use of cinematic models for several cases of level flight.
- Most common cost functions:
 - **Minimun time**
 - Minimum consumption
- Next steps
 - To include dynamic aircraft models, ascending & descending paths and more complex optimization functions
 - Use of CFD (Computational Fluid Dynamics) computing



Conclusions

DMET, IS THE DEVELOPMENT OF A DIGITAL METEO MODEL THAT COMBINES ATMOSPHERIC DATA FROM SEVERAL SOURCES INTO A 4D PREDICTIVE SCENARIO, AVAILABLE TO SUBSCRIBERS BY PERIODIC UPDATES

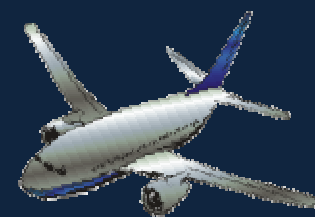
FINAL PRODUCT

4D GRID P, T, & WIND COMPONENTS
AIRSPACE CUBE 150*150*20km
TIME INTERVAL: 2.5 HOURS

Minimum time, minimum consumption and other interesting trajectories simulated to check the wind impact

NEXT STEPS

- Preliminary validation very encouraging, so more effort is currently being dedicated to allow optimal operational requirements
- **«DMET as long term support tool for ATM automation»**
Efforts should be allocated to the paradigm of management of meteorological maps in order to ensure all the actors involved in ATM perform operations using compatible data
- Looking for SESAR collaboration, participation....!!



**Acknowledgements to ATLANTIDA project and
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