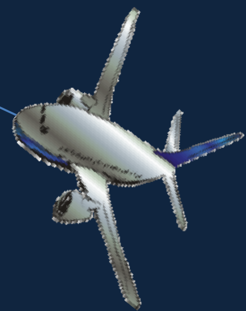
DIGITAL METEOROLOGICAL SERVICE FOR SIMULATING FUTURE AIR TRAFFIC MANAGEMENT AUTOMATION



WETICE-COMETS Paris, 2011

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Summary

Who	Partners
Why	Motivation
What	Technical objetives & Definition
How	Technical Approach
Where we are	Progress to date & Key developments
AOB	Conclussions and Next Steps

...and Questions

...Introduction & something about us

DMET development → Research efforts based on a Collaboration Agreement between University and Company

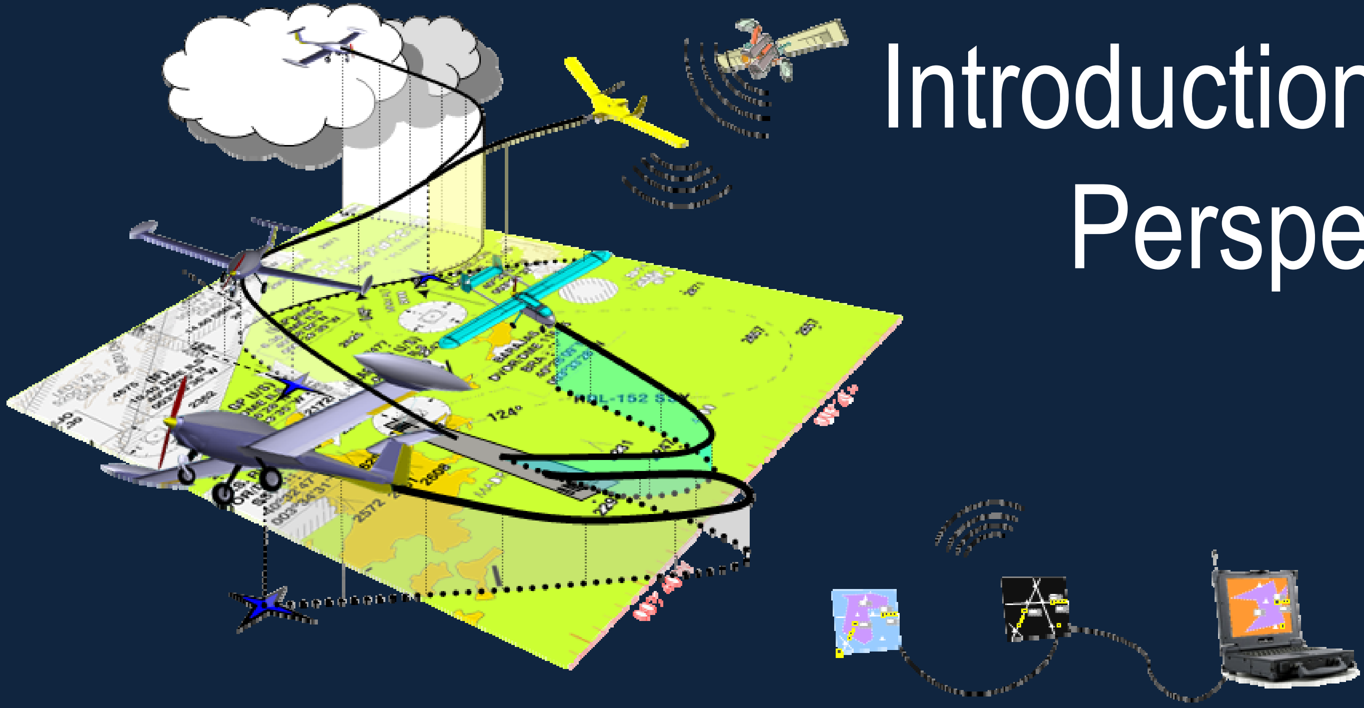
- ✓ University of Leon, (Located in the North of Spain)
- ✓ School of Aerospace Engineering: Aerospace Engineering Lab
- ✓ UAVs, Meteorology
- ✓ Supercomputing Center

INSA
INGENIERIA Y SERVICIOS AEROESPACIALES, S.A.

- ✓ Consultancy Services and Engineering , Aerospace Sector
- ✓ Commercial firm 100% Property of the National Institute for Aerospace Technique (INTA), a body of the Spanish Ministry of Defence
- ✓ Research and Development activities

Why ?

DMET motivation



Introduction and Perspective

DMET Perspective

Air Traffic Operations

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

The ATM System

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

Aviation Meteorology State of the Art

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

ATM & MET Services

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

What ?

Technical Objetives and Definition

DMET Definition & Objetives

«DMET def»

NOW

The Digital Meteorological Model for ANALYSIS purposes in support of Air Traffic management Automation (simulation)

FUTURE

Digital Meteorological Model for OPERATIONAL purpouses

OBJETIVES

REQUIREMENTS

OVERALL OBJETIVE

To support aircraft operations providing the best possible accuracy of atmospheric parameters in support of trajectory prediction

How ?

Technical Approach

Model Foundamentals: Structure, Architecture and Data Flow

DMET Fundamentals & Model Structure

Prediction Origin

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

Basic Model Structure

4D Grid of spatial temporal cells.

Size of cells = f (propagation stamp & acceptable accuracy)

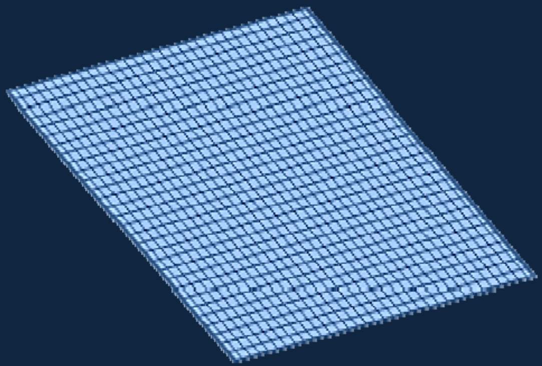
Elements

The structure of 4D Grid for a particular weather scenario («t or several t ») is based on the following elements:

LAYER → BOX → OBJECT → SCENARIO

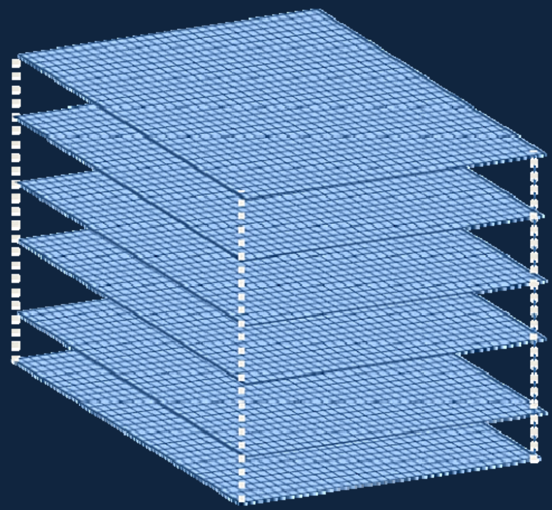
DMET Model Structure

The Layer



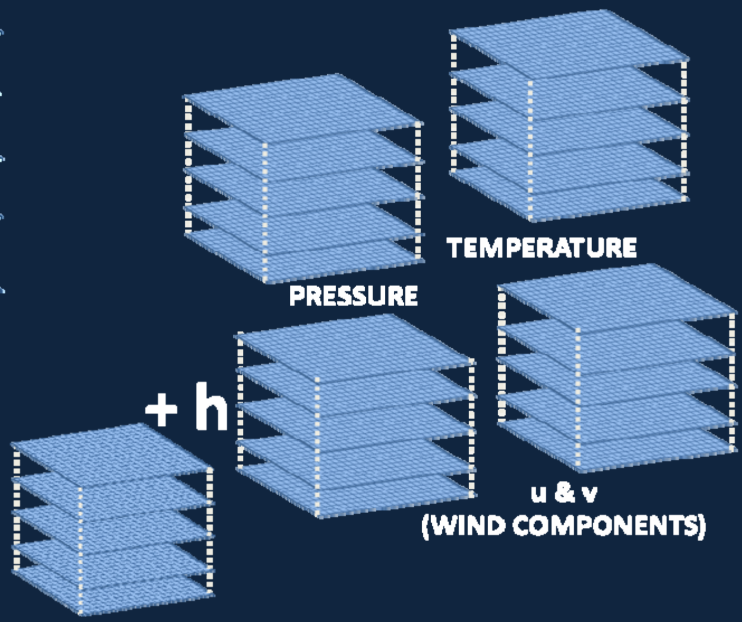
Bidimensional element corrresponding to a grid.
Tailored according with the required domain.
One layer per pressure level

The Box



All layers containing specific atmospheric variable data at differentent altitudes levels (pressure levels)

The Object

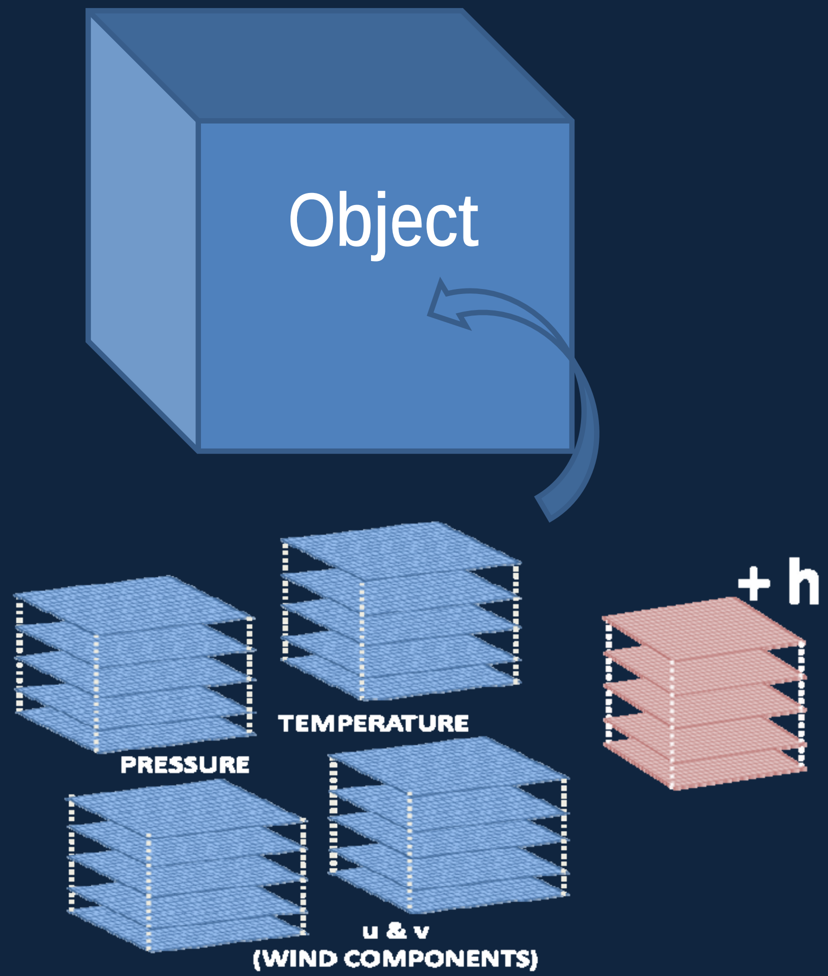


DMET Model Structure

The Object

Each specific time instant of the forecast is associated with an Object (five boxes)

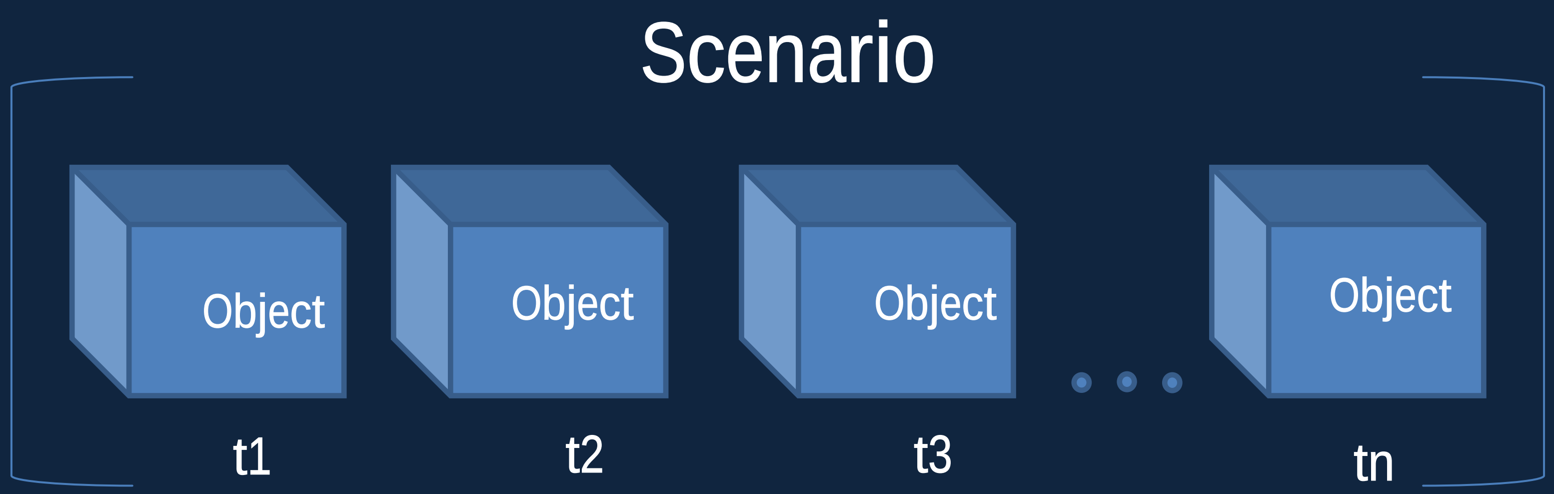
- Pressure
- Temperature
- The two horizontal wind components
- Geopotential altitude

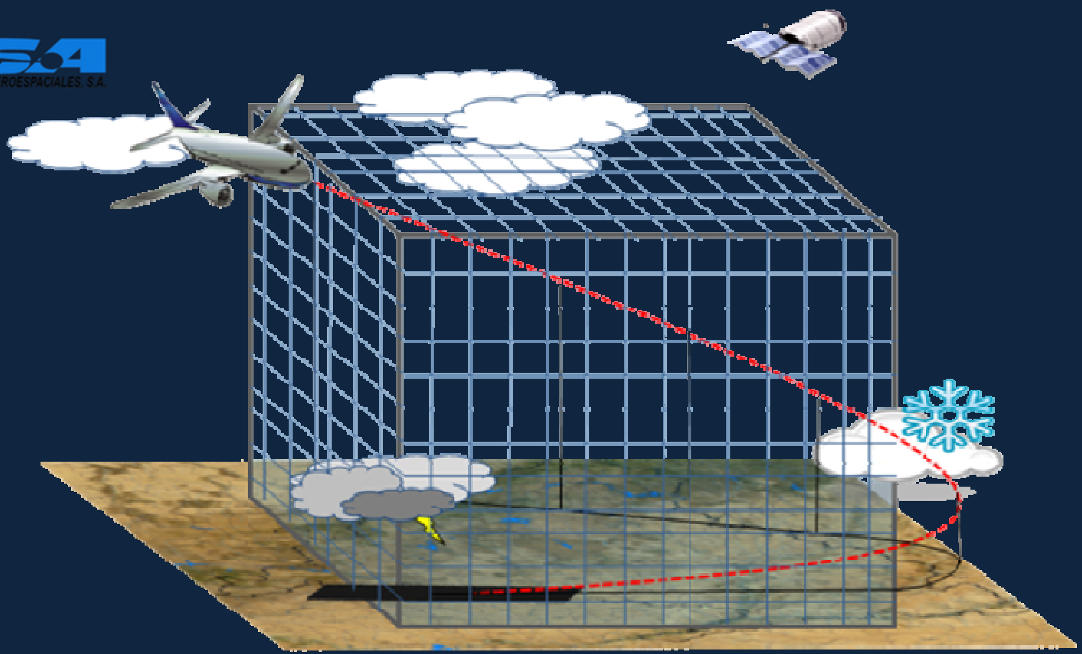


DMET Model Structure

The Weather Scenario

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



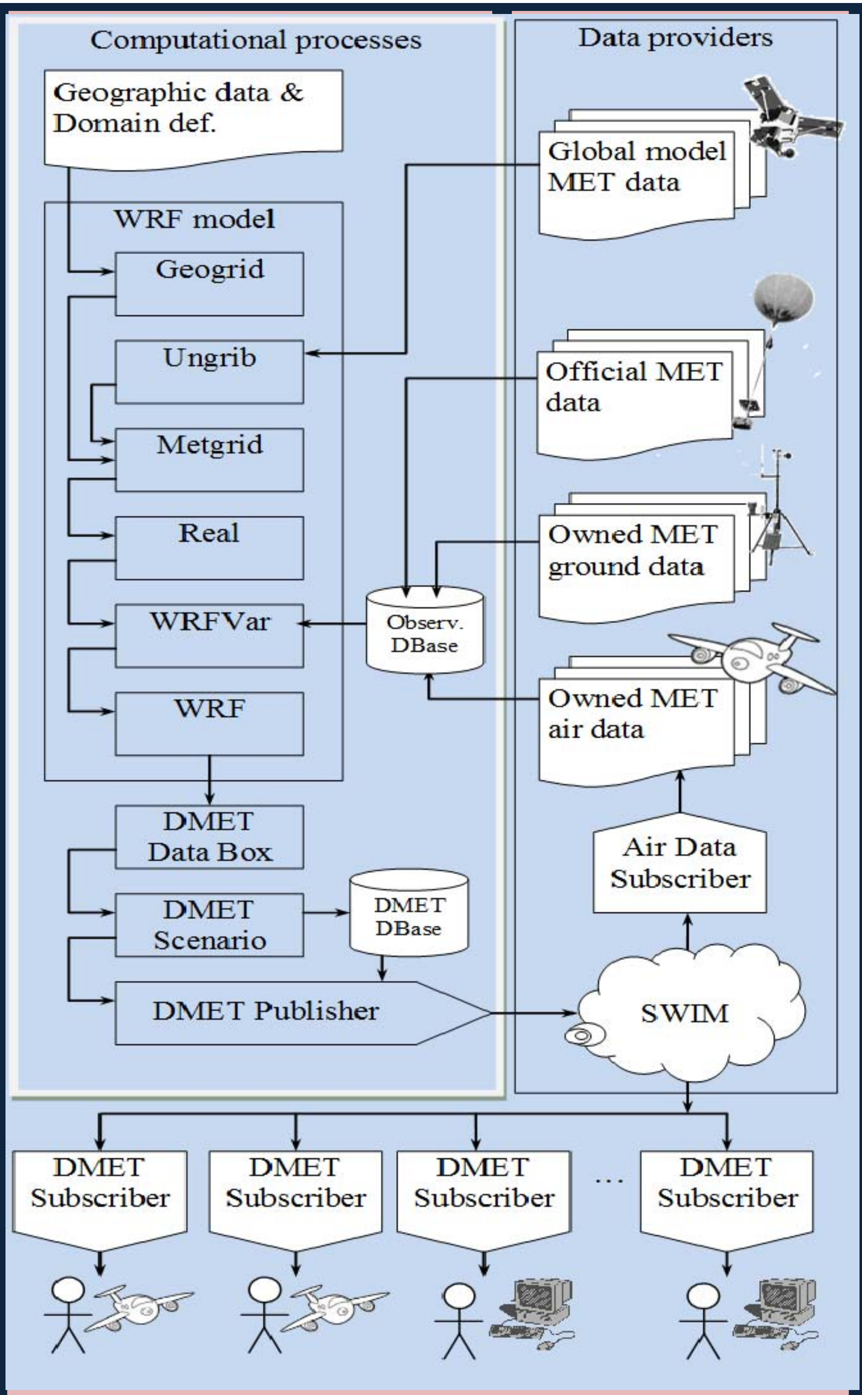


DMET Model
Features

Domain Size 150*150*20 KM domain successfully contained in a 100 * 100 * 27 cell grid

Forecast time Time domain is discretised in 10 min forecast time steps (15 files are produced per simulation: Time of Forecast: 2,5h

Hardware Requirements Detailed domain can be run in a dedicated cluster of 5 computers, 4 cores each (20 cores) / emmbedded in a supercomputing center



DMET Model Architecture

Data Flow

Fundamentals:

•Running of WRF(Weather Reference Forecast)

•Weather Local data and satellite information

•Mesoscale propagators

Access to external Data Souces and Support to Service delivery is performed through a SWIM middelware

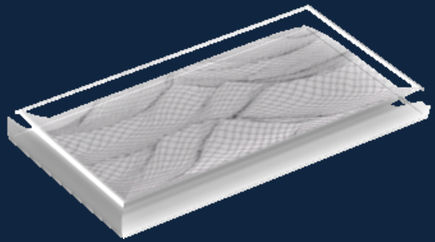
Model outputs are routinely updated as soon as external data is received from several sources of information

DMET Model Architecture

Data Sources

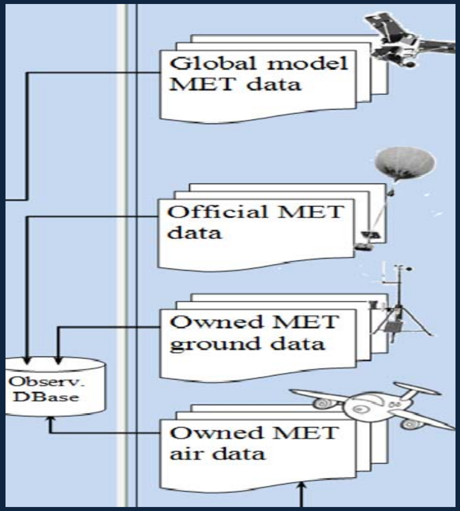
Based on two groups of Data:

•<u>Geographical Data</u>:



GROUND LAYER GENERATION-
Geographical Data, Digital Elevation Models
NOAA, resolution: 0.5º

•<u>Meteorological Data</u>

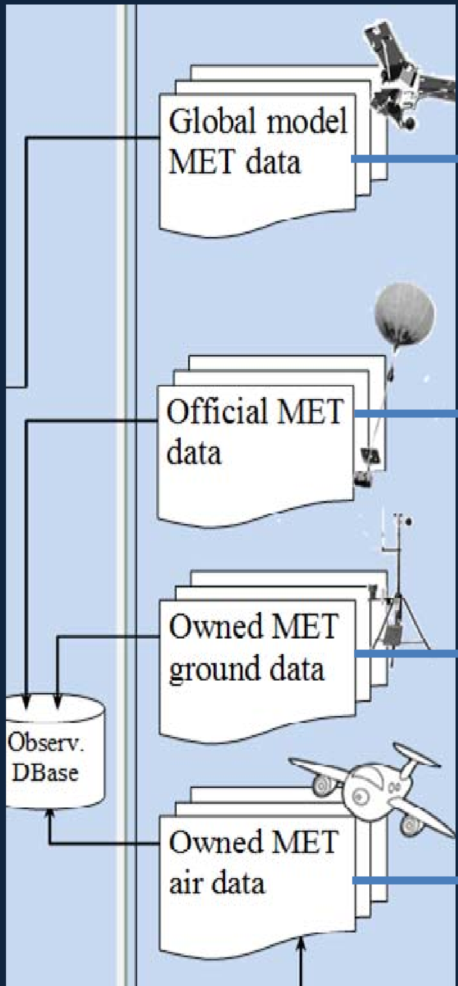


Global data for the development of the initial model – NCEP-NOAA

Local data and observations (ground and altittude) for the accuracy improvements and customiizability

DMET Model Architecture

Data Providers



METEOROLOGICAL INITIAL DATA : Global Forecast System (GFS):

- ✓Publicly delivered
- ✓Refresh time: 6 horas
- ✓Resolution 0.5 º

- Spatial and temporal resolutions are insufficient for ATM applications
- Startig point for mesoscale and regional models

OFICIAL DATA: Spanish Meteorological Agency (AEMET)

- •Real Time Observations
  - RT: 10 MINUTES
  - Met Stations in domain
- Balloons (parameters in altittude)
- HIRLAM MODEL

OWN LOCAL DATA: Ground Meteorological Stations in Domain

•Network of Met Stations deployed on the scene (tailored according to scenario characteristics)

•Geo-referenced observations

•Measuring Rate: 10 minutes

LOCAL AIRBORNE OBSERVATIONS: Aircrafts in domain

•Measurement of interesting parameters along the aircraft flight path

•Enhance the accuracy at diferent altitude levels

DMET Model Architecture

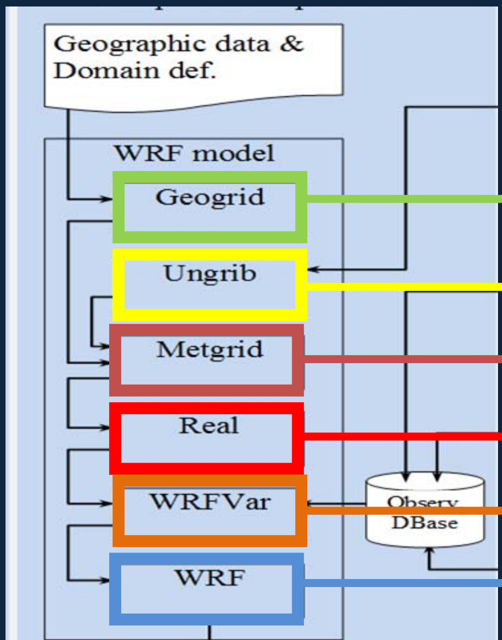
Computational Process: based on the WRF model execution

WRF,
Weather Research and Foecasting

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

Objetive

Build the next generation mesoscale model (DMET) and provide the neccessary architecture fot the data assimilation



Modular Architecture

- Domain definition, boundaries and digital elevation model set up
  To be run once per simulation site (domain)
- Global data decoding (generates the first meteorological fields)
- Horizontal interpolation of the meteorological data to the domain grid
- Vertical interpolation of the meteorological data to pressure levels
- Observations and Local Data assimilation
- Propagation module to produce forecast using fluid mechanics equations

DMET Model Data Publication (I/II)

Dissemination of Atmospheric 4D Models

Context

Operation in futur
ATM

Data distribution in a
common digital format

The objetive is the
provision of air traffic
services living in a
middelware

Standardized
management system

SERVICE-ORIENTED
CONCEPT
SWIM
(System Wide Information
Management)

Publish/Subscribe
Paradigm

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

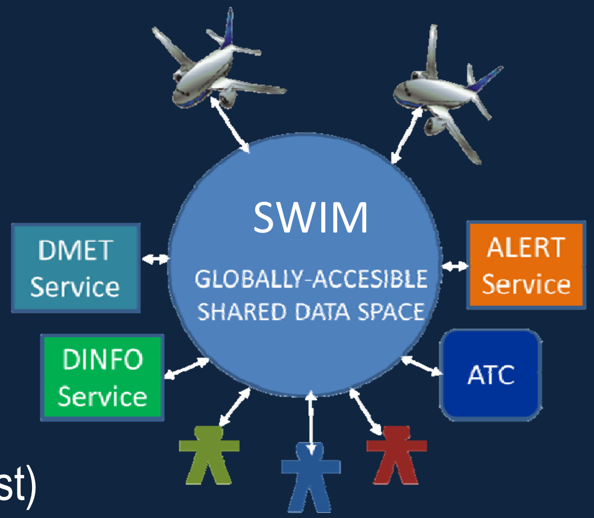
DMET Model Data Publication (II/II)

Objective Adapt the outputs to fit the dissemination standard

Data Packages Requirements

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

Addressed by DDS TECHNOLOGY



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

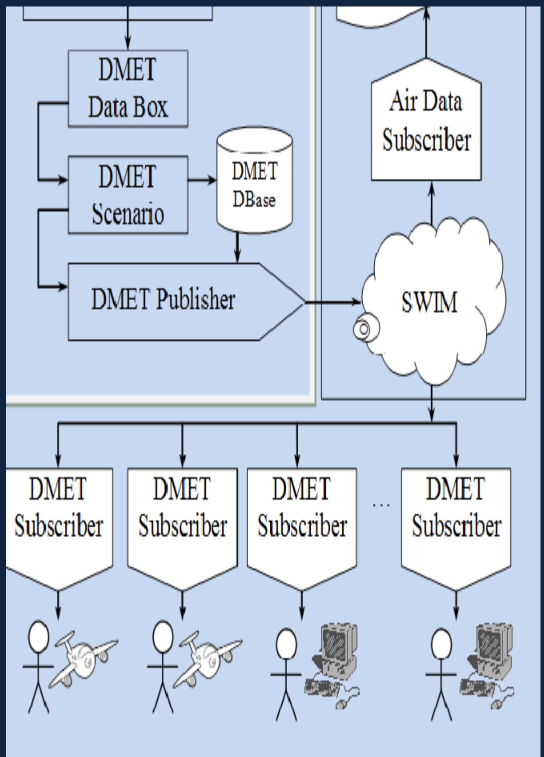
DMET Implementation

8 Computers:

- 7 Slave nodes / 1 master

HW & SW Homogeneus System

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



-Publisher activation: Every time and object is generated

(Time to publish a full box ≤ processing time for the next box)

-In a single run: enough predictions to support trajectory in TMA operation

-Process repeats one hour later (managed by timestamps and control identifiers). Each 1hour= 2,5 h forecast.

Where we are ?

Progress to date & Key developments

DMET First Validation Procedures

Validation

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

- Meteorological forecast service
- Atmospheric sounding data

Test

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

Results

✓Excellent matching with HIRLAM forecast (oficial 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.

DMET Model Performance (I/II)

Performance Critical Issue in MET simulations (processing time, high resolution, shorter refreshing times, longer forecast…)

Relevant Factors Nº of cores, processor architecture, available memory and network Technology

Objetive 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

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.

…Better for large domains simulation

- Low latency technology networks (Infiniband): very suitable for MPI applications

DMET Model Performance (II/II)

	20 Cores CLUSTER	32-8 Core Machines SUPERCOMPUTING CENTER
Time for the simulation :	21,33 ms/km²/h	2,13 ms/km²/h
	20 min	2 min

Transmission speed currently reaches 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.

DMET Simulation of Trajectories (I/II)

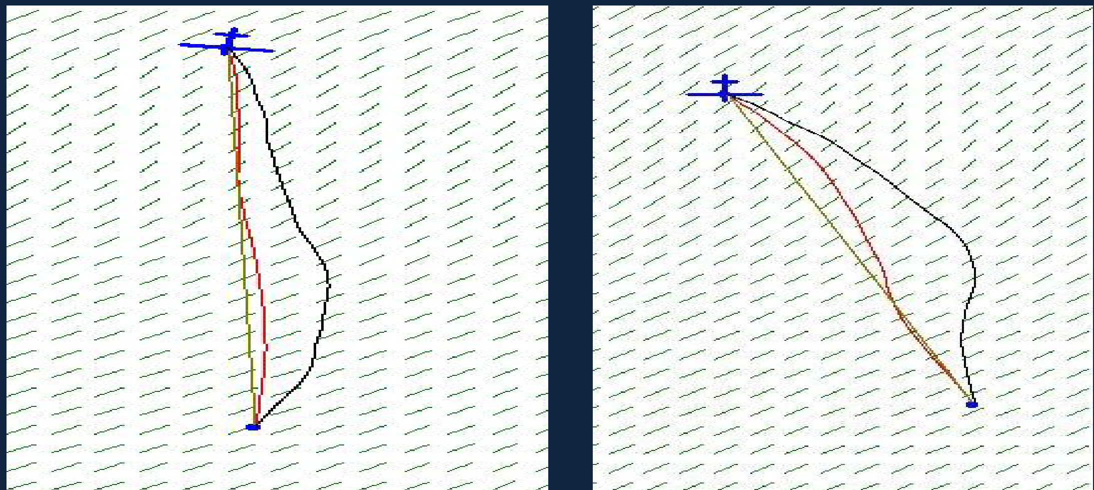
OPTIMIZATION OF FLIGHT TRAJECTORIES

- One of the most relevant DMET applications
- Based on future requirements for the ATM automatization and the meteorological influence over aircraft trajectory

- Numerical and analytic methods for aircraft trajectory optimization heve been designed and tested, initially for cruise phase:
- The development, allows a comparison between conventional trajectory prediction simulations and more sophisticated scheme in non-uniform atmospheric conditions
- Test , have included the utilization of cinematic models for several cases of flight level, flight in thermal ascending winds and obstacle negotiation.

DMET Simulation of Trajectories (II/II)

- The most common cost functions include minimum time and minimum consumption
- The importance of wind field knowledge is demostrated



- Next steps shall include dynamic aircraft models, ascending and descending paths and other more complex optimization functions.

DMET Conclusions

- Accurate estimation of atmospheric parameters = Key requirement for future automation of Air Traffic Management
- 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 consists of a 4D grid of pressure, temperature and wind data fields valid over an airspace cube of about 150*150*20 km, within a time interval of 2.5 hours.
- On top of the model, minimum time, minimum consumption and other interesting trajectories are simulated to check the wind impact.
- Preliminary validation is very encouraging, so more effort is currently being dedicated to allow optimal operational requirements.

Thank you!

...any question?