



WCS2.0 Met-Ocean

MetGis Frankfurt

Peter Trevelyan 28th October 2014

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The Main Messages(1)

- To incorporate actionable advice within their applications, DST (Decision Support Tools) developers require functionality that can:
 - Convert 'raw weather data' (e.g., winds, rain, and clouds) into 'actionable information';
 - Retrieve, manage, analyze, and display weather data/rules;
 - Facilitate efficient machine to machine exchange.
- Such service by definition will need to be interoperable.



The Main Messages(2)

- The challenge is to move from a “data centric” approach to one that is “service centric”
 - To do this the data must be accessible to any function/service via commodity interface.
 - Bulk data transfer is no longer viable due to data volumes; therefore data must be tailored at source to fit the use of the use
 - Data may be in the form of images, features (e.g. lines/contours, or cut out grids.
- Services may be “chained” to increase functionality.



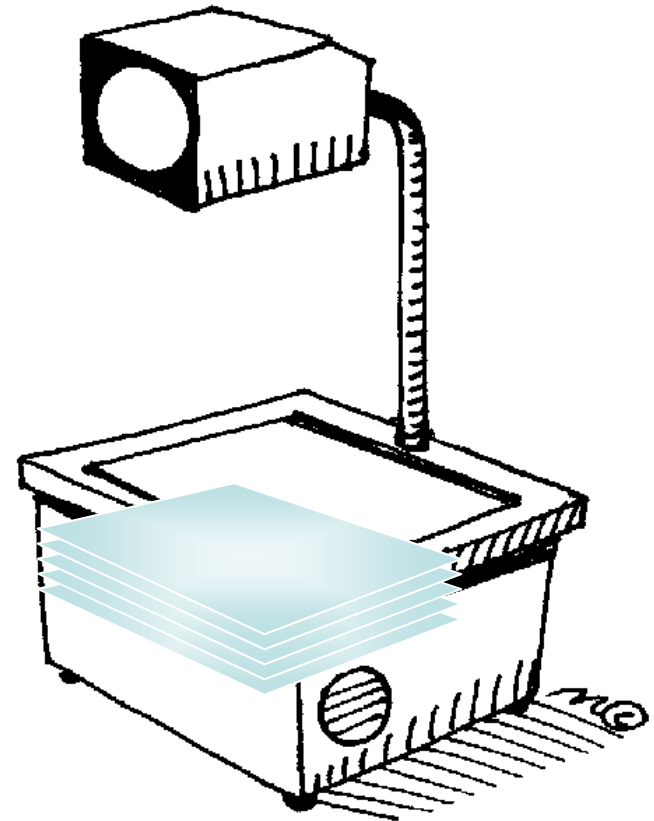
Opportunities:-

“Weather information must be designed to integrate with, and support, decision-oriented products with automation capabilities that enhance user safety and efficient operations. Many decisions are based on threshold conditions”.

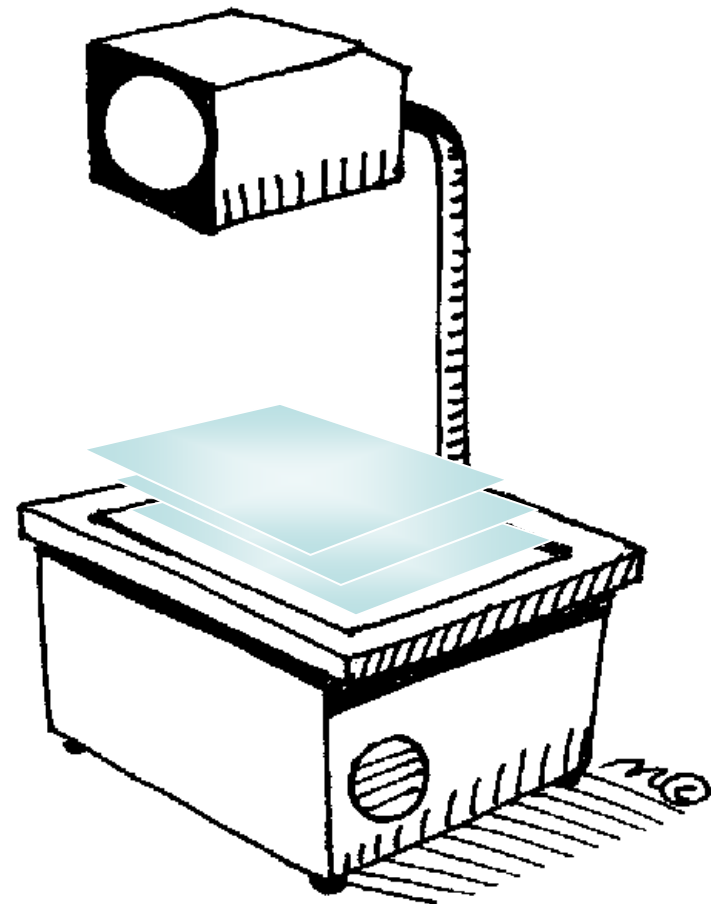
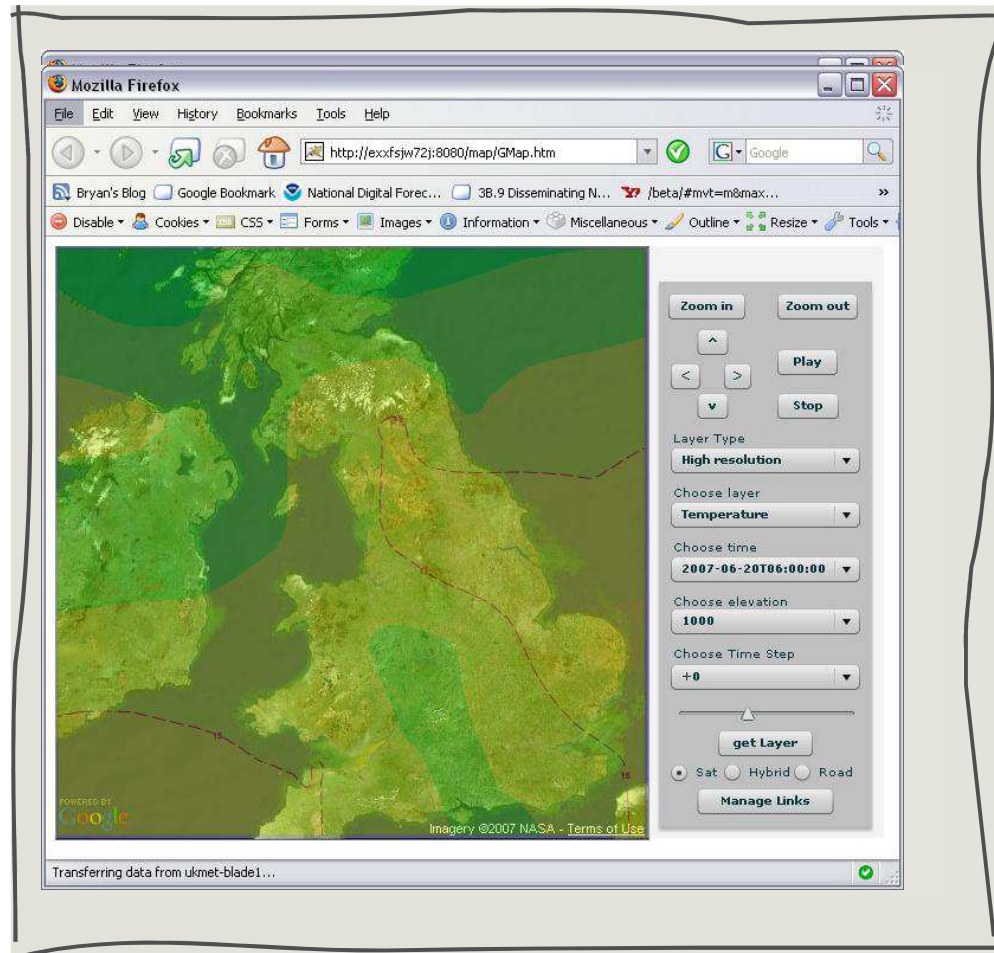
The Story so far:

Overhead projector (metaphor for WMS) ...

- Historically when developing visualisation systems we've developed a complete 'stove-pipe' ... all the transparencies and a new overhead projector every time!
- Now we can develop the projector once (e.g. a web-client) and build up a catalogue of reusable transparencies ...
- We can sell 'off-catalogue' & build 'bespoke' layers to specification.



The Current Approach:





What has changed with the weather?

- NWP (Numerical Weather Prediction) has evolved such that:
 - High spatial resolution (2KM for limited area) is now common and will soon be down to 1KM;
 - The update frequency of weather information is now commensurate with the need to respond to rapidly changing circumstances;
 - Weather capabilities allow rapid notification (automation-to-automation) of changing weather situations to strategic and tactical decision makers; update rate now every 15 minutes, soon to be 5 minutes.
 - Probabilistic weather forecast elements are better suited for risk based decisions and greatly increase the amount of data needed to be processed.



The Paradigm shift:

- The "weather forecast" paradigm shift in the next era is that, while stand-alone graphical displays of weather readily convey more information than text, they are no longer adequate.
- Required is the merging of more accurate probabilistic weather forecasts in gridded format with expected asset e.g. aircraft, ships, traffic positions etc enabling DST (Decision Support Tools) algorithms to determine optimal 'throughput' in and around forecast weather.



What kind of hazards:-

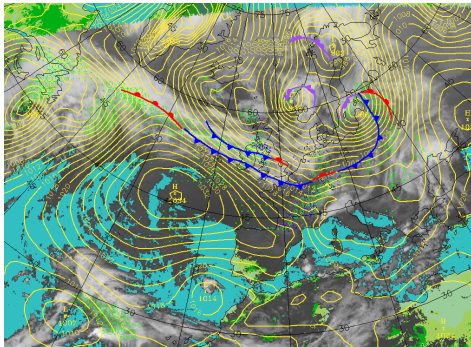
- Low-level wind shear and gusty surface winds:
- Large hail:
- Moderate or greater in-flight icing:
- Meso-cyclones, tornadoes, funnel clouds, and waterspouts:
- Lightning:
- Low visibility and ceiling due to heavy precipitation:



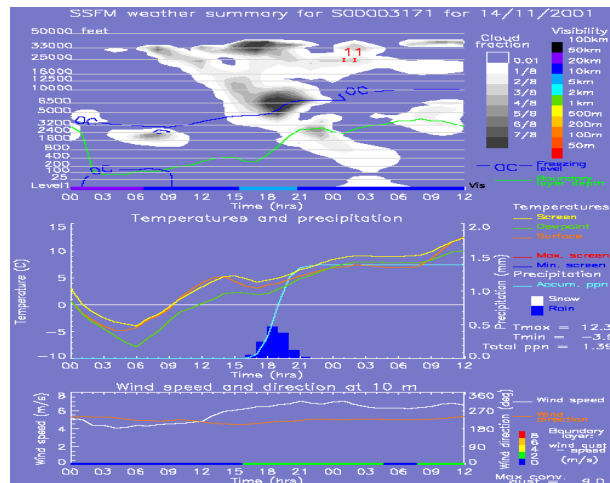
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The Data Problem:

- Most of our data is structured to meet one requirement i.e. creating contoured charts and this causes real issues e.g.



The data to create this are stored in layers and created by sampling **604X481** grid points.



The data to create this are stored in layers and created by sampling **784,414,800** grid points! If the data had been optimally for this request the amount of data would have been: **2,700!**



The Shape of things to come:

(Welcome to the world of coverages)

- What is important is the impact of weather, not the weather itself.
- The execution of business rules on raw data should be done upstream and only data relevant to a business process passed to the consumer.
- The extraction of relevant information from large data holdings is key to solving the data overload experienced by many of today's decision support tools.



The “shape” of the data is critical to its use.

- For example; if you want to find out how many times the temperature will fall below zero for a site you do not need the complete 4D grid for the UK, only a time series of temperature for the selected site.
- Better still you may only want the hours, if any, for which the temperature is below zero.



What kind of shapes:-

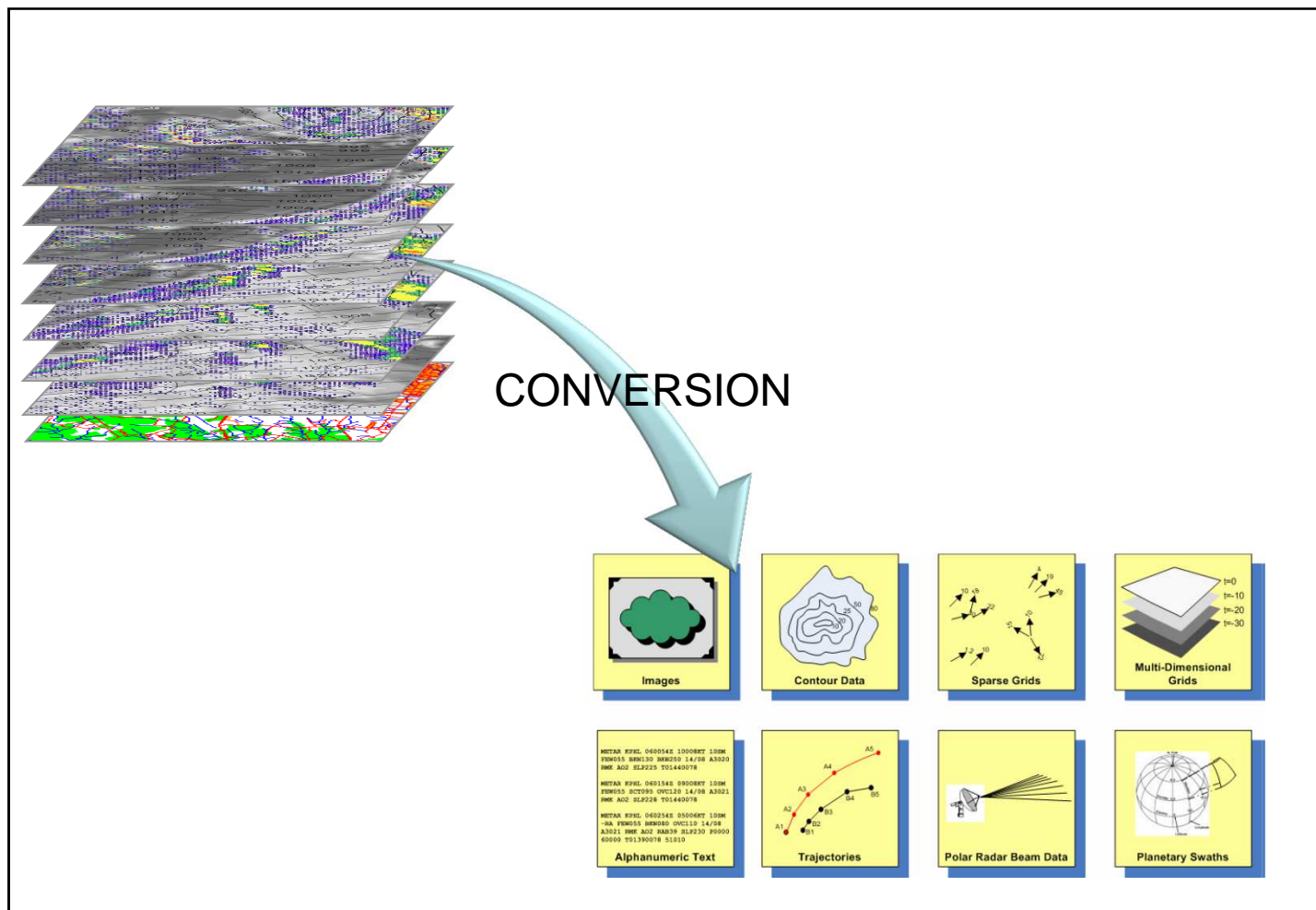
- A number of use cases have been examined and the following “data shapes” have been identified.
 - GRIDS:
 - Time Series:
 - Cross sections:
 - Point collections (e.g. observations):
 - Vertical profiles (e.g. ascents):
 - Trajectories:



Flexibility of Digital Data:

- Two main uses of digital data:
 - As input into DST (decision support tool)
 - Respond to interrogation e.g. give me a value at a certain point.
- We will look at each in turn starting with the DST and some case studies:-

The Goal is to:



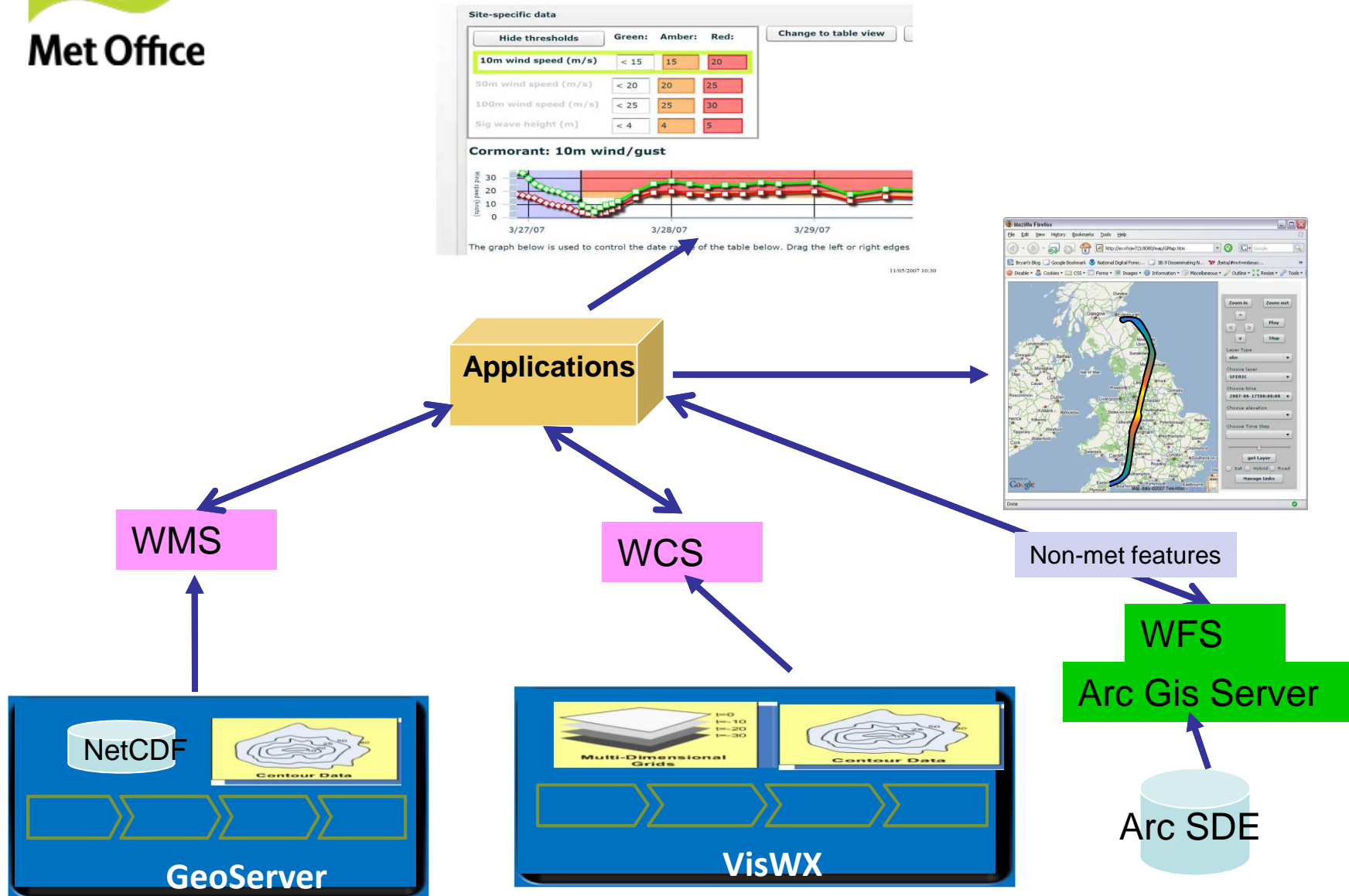


Welcome to the world of geospatial data and the OGC:

- The OGC (Open Geospatial Consortium) is a grouping of interested parties.
- The OGC sponsors interoperability through the use of geospatial standards.
- The term “Feature” and “Feature Type” are used to describe real world objects.
- Data shapes identified for use within meteorology map into the world of Features and Feature Type.
- We can therefore use OGC services and definitions.



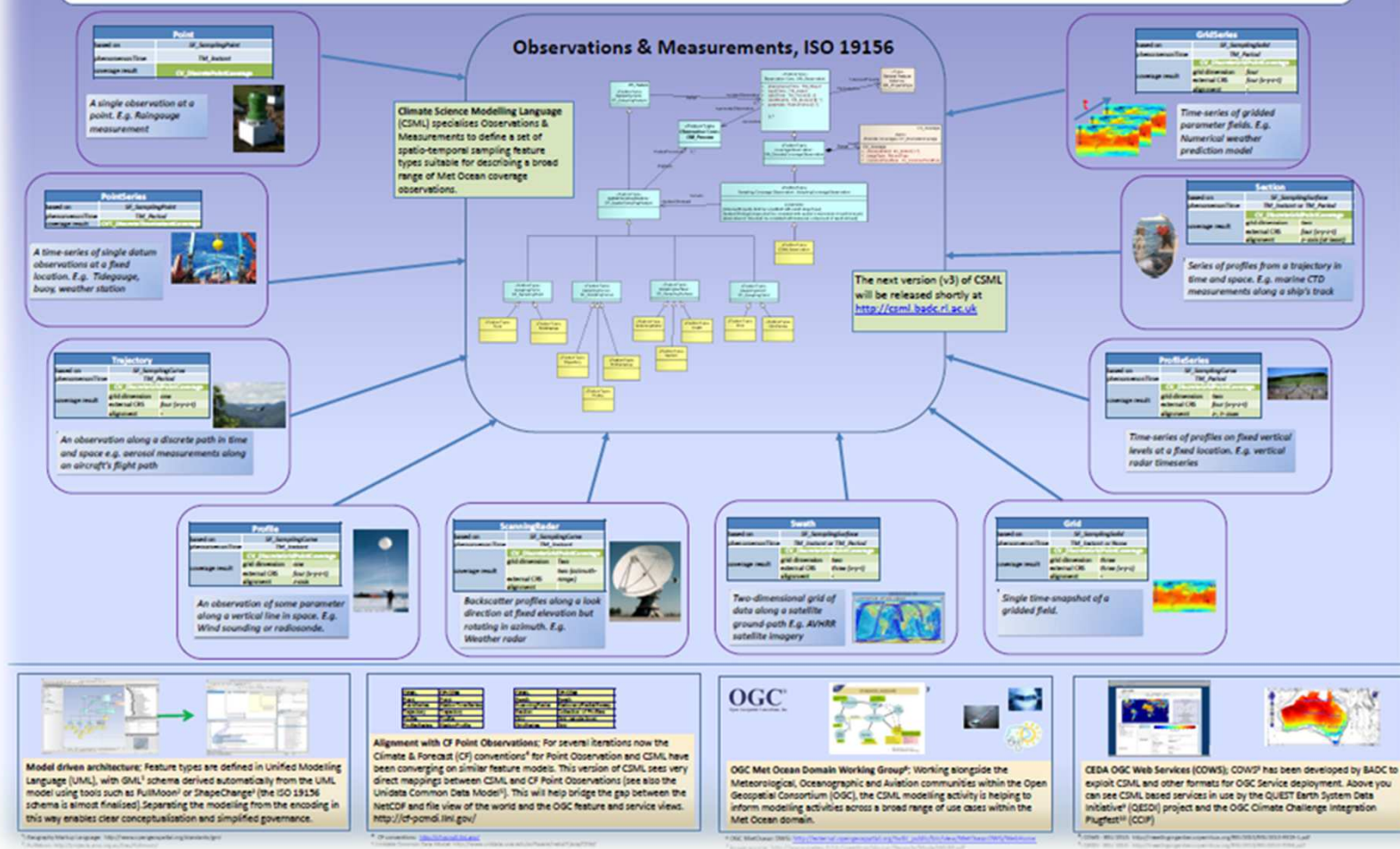
An Integrated World



Coverages used in Met-Ocean

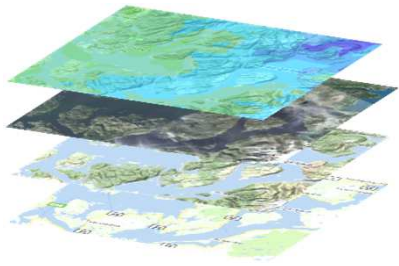
Evolution of Climate Science Modelling Language within international standards frameworks

Lowe, Dominic & Woolf, Andrew: Science and Technology Facilities Council, UK. dominic.lowe@stfc.ac.uk, andrew.woolf@stfc.ac.uk



What kind of coverages?

1. Assess foundation data



MetOc
imagery
DEM
topography/
bathymetry

2. UAV Mission Planning



deterministic &
probabilistic
weather f/c with
'confidence'
quality mask

3. Data capture (UAV & sensors) – integrate with predictive models



temp/pressure/ wind/precip time-series (deployed met-sensors)
temp soundings (deployed sono-bouys)
geo-rectified hi-res imagery / hi-res TIN coverage DEM

4. Assess overland trafficability for route plan



DEM
land-usage
terrain type
soil moisture
precipitation

5. Assess optimal coastal landing point and time



bathymetry
SCAT-winds
ocean-currents
sea-state
Tideline variation



So what are Coverages?

- A “coverage” is a special kind of geographic feature, with the distinguishing characteristics that whilst other features have one particular value associated a coverage typically conveys different values at different locations.
- A “coverage” is represented by its "domain" (the universe of extent) and a range of values representing the Coverage's value at each defined location.
- A “coverage” can be multi-dimensional, such as a 4-D x/y/z/t for climate, weather and ocean data.



Coverage = Field





Why WCS and Why OGC?:

- “The OGC Web Coverage Service (WCS) supports **electronic retrieval of geospatial data** as “coverages” – that is, digital geospatial information **representing space/time-varying phenomena.**”
- “A GetCoverage request prompts a WCS service to process a particular coverage selected from the service’s offering and **return a derived coverage.** The WCS Core standard defines the domain sub-setting operation which delivers all data from a coverage inside a **specified request envelope** (“bounding box”), relative to the coverage’s envelope – more precisely, the intersection of the request envelope with the coverage envelope. “



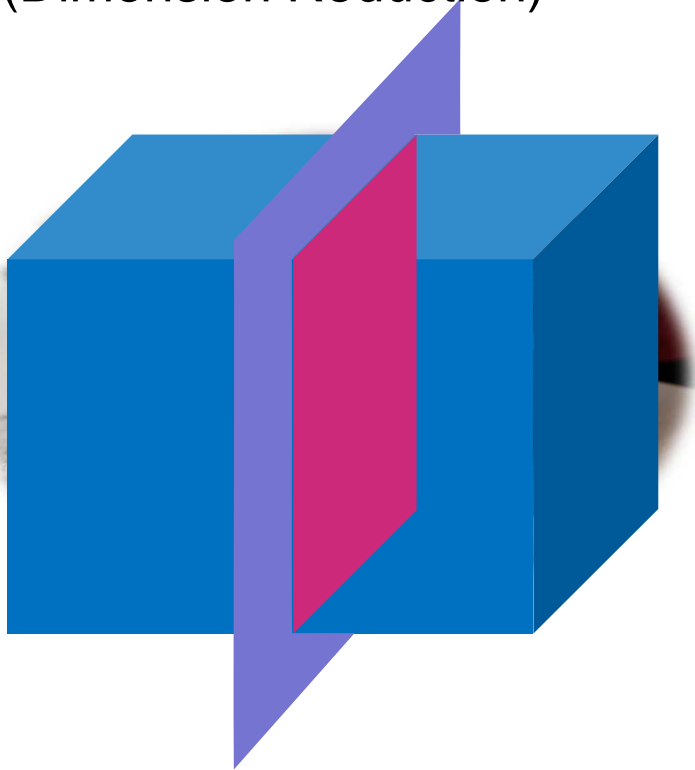
Core of the WCS 2.0 Core Standard

- Reasonably sized (?) 49 pages, closely coupled with GML.
 - 3 main types of requests (procedures):
 - GetCapabilities – lists all coverages.
 - DescribeCoverage – describes coverage metadata.
 - GetCoverage with “Slice” and “Trim” operations.
- Designed to be extensible:
- By default the WCS requests are passed via HTTP XML POST requests

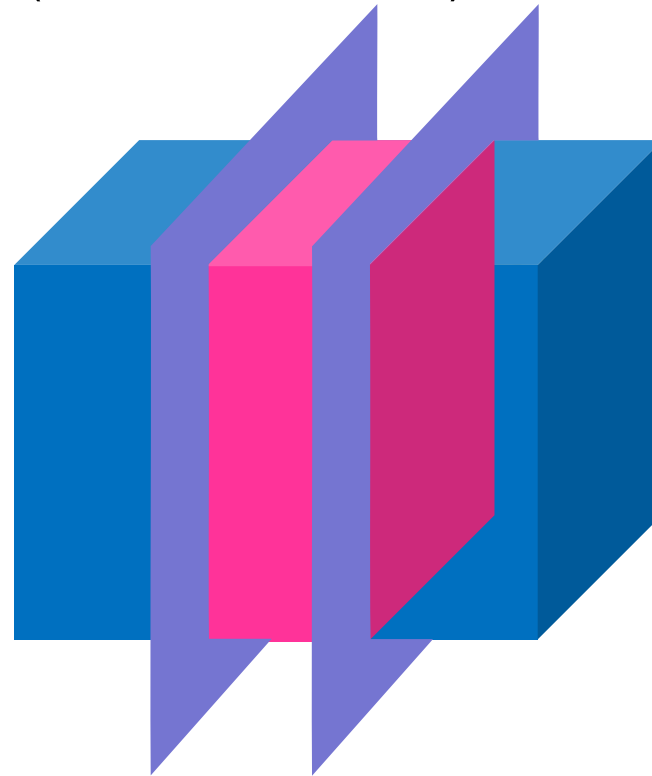


WCS 2.0 Core GetCoverage Operation

Slice Operation
(Dimension Reduction)



Trim Operation
(Extent Reduction)



Courtesy Jozef Matula IBL



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Start with an example:

- Source coverage data is potentially N dimensional – just like variables in NetCDF. Can have X, Y, Z (vertical level), Time.
- “Slice” operation reduces dimensions e.g. from 3D to 2D.
 - Sounds promising for vertical profile extraction.
- “Trim” operation implements dimension range filtering, if typically applied to both X and Y.
 - Sounds promising for geospatial data “BBOX” extraction.
- “Slice” and “Trim” can be requested in other coordinate reference systems (CRS) than the CRS of the source data (re-projection)

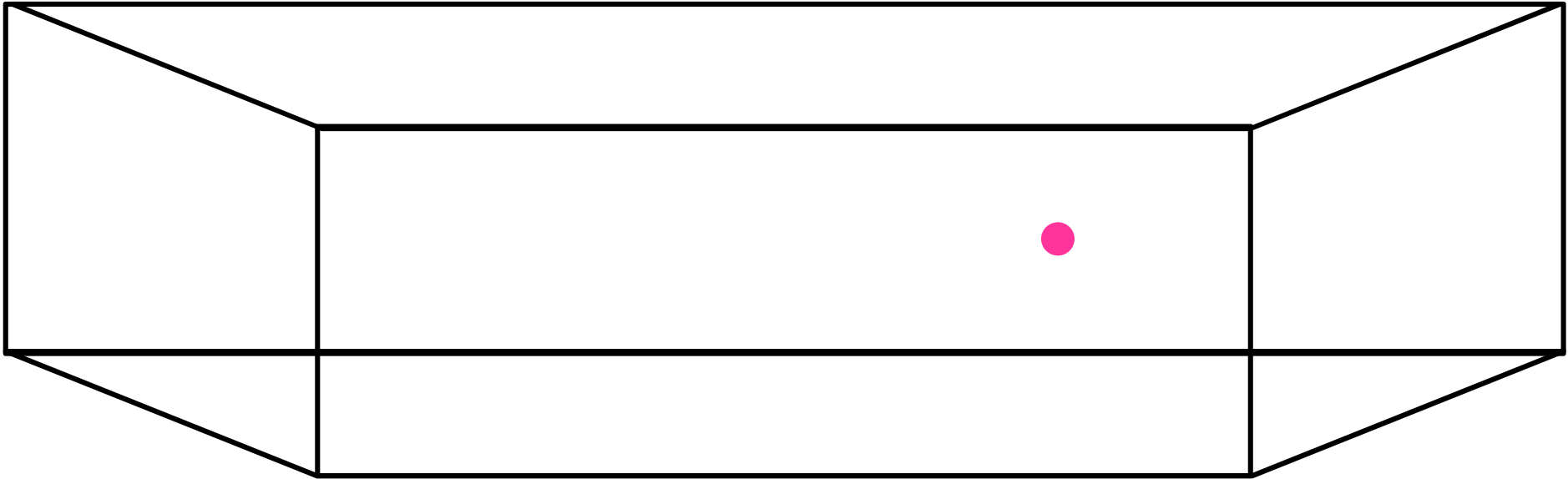


Meteorological Data Extraction Patterns





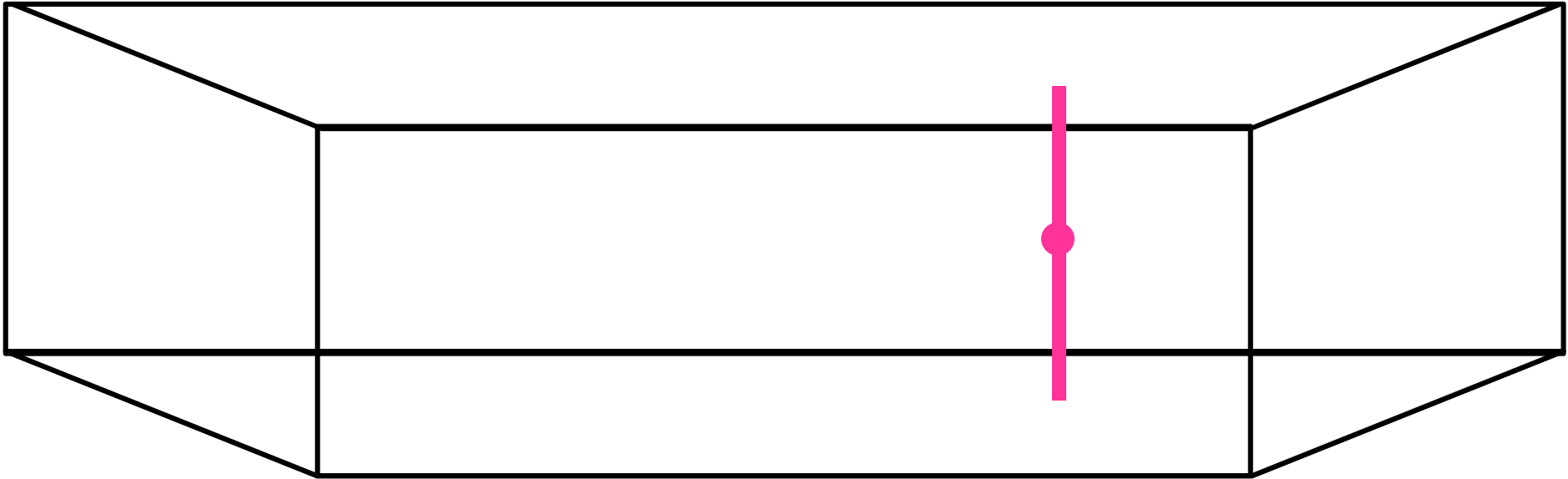
Meteorological Data Extraction Patterns



- Extracting data for a point = Slice X, Slice Y, Slice Z



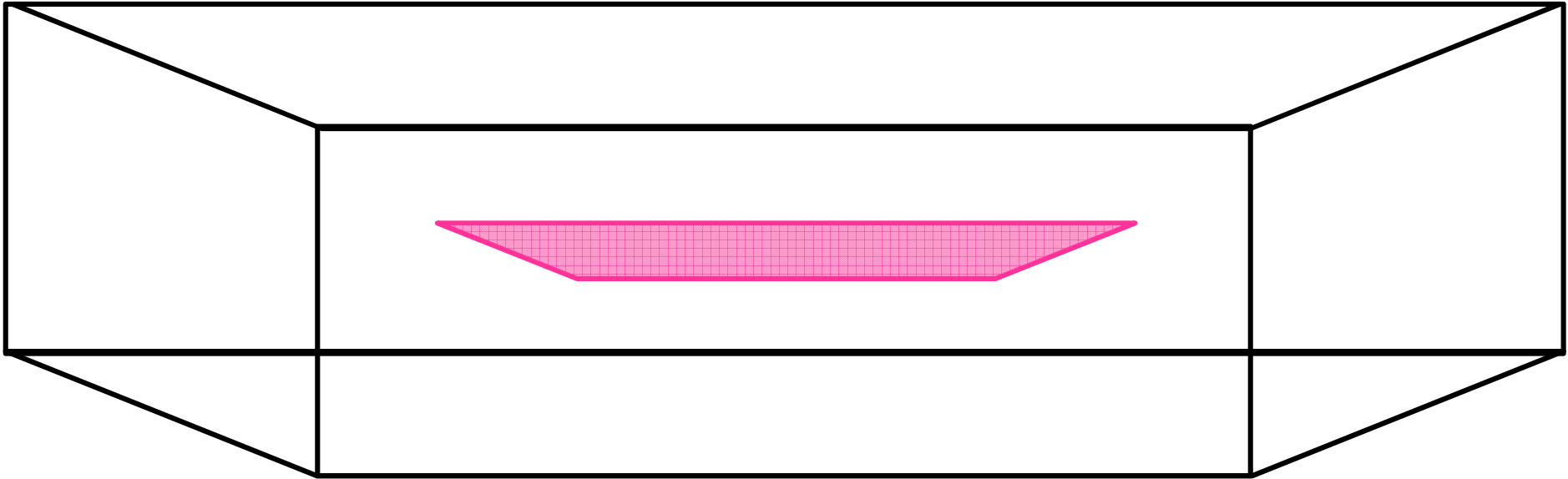
Meteorological Data Extraction Patterns



- Extracting vertical profile data for a point = Slice X, Slice Y
- With vertical range = Slice X, Slice Y, Trim Z



Meteorological Data Extraction Patterns



- Extracting data for 2D geospatial domain for a single vertical level = Trim X, Trim Y, Slice Z

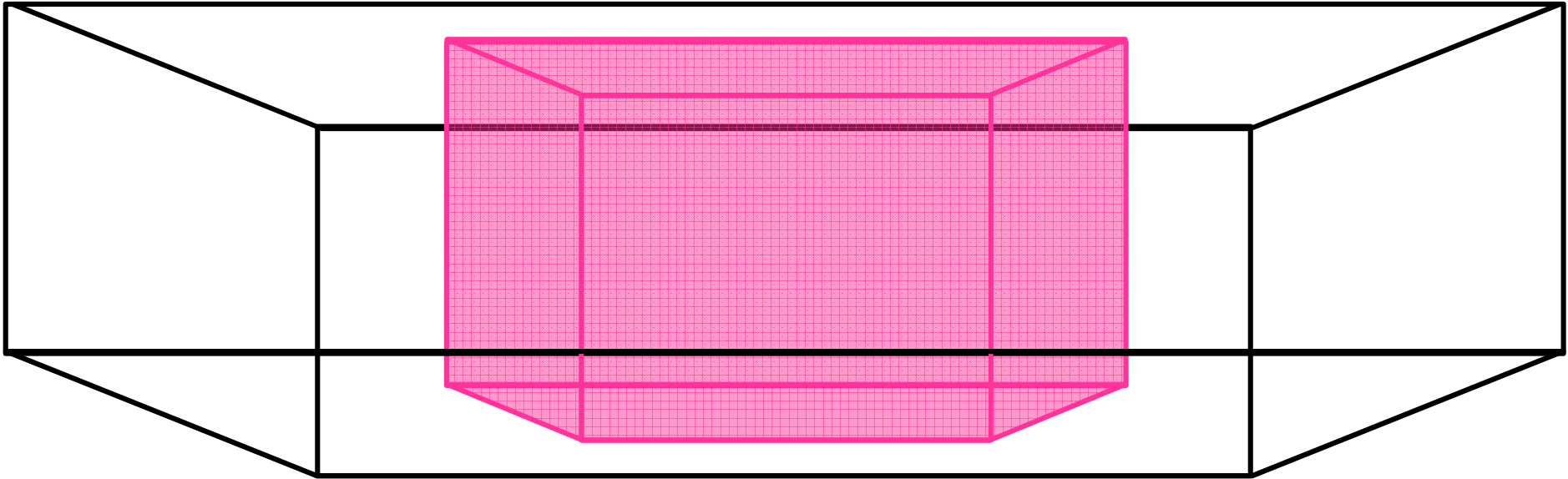


Met-Ocean Data Extraction.

- All mentioned patterns were purely geospatial and height related.
- Is the time is just yet another 4th dimension?
- We need to take into account: – Forecast validity time.
 - Model run reference time. –
 - Ensemble member dimension.
- This potentially creates a 6D coverage?!
- Not to be forgotten too - “sampling” and “interpolation.”



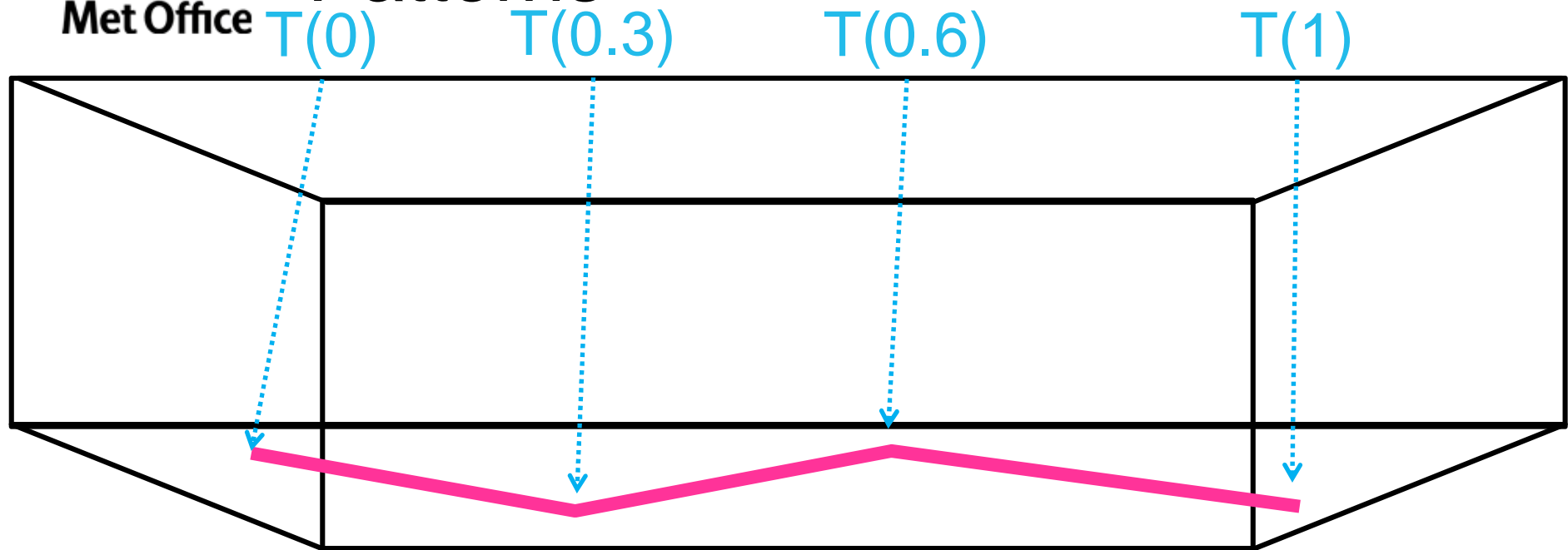
Meteorological Data Extraction Patterns



- Extracting vertical profile data for 2D geospatial domain = Trim X, Trim Y, Trim Z



Meteorological Data Extraction Patterns

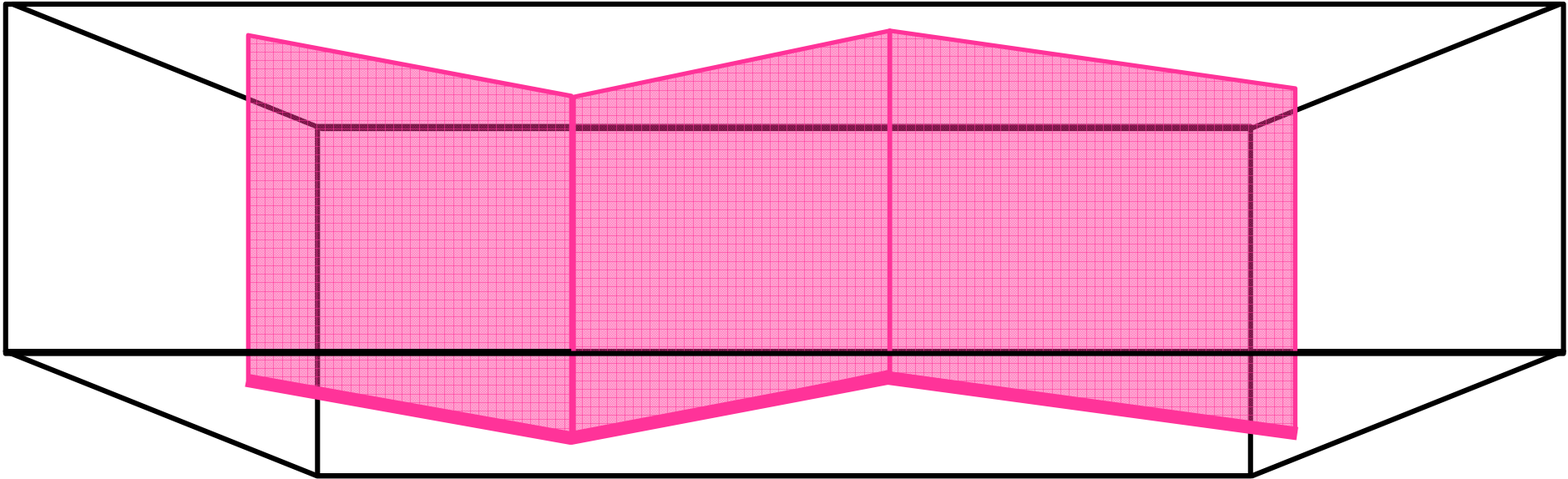


- Extracting data for a trajectory (for example road) = Trim in Trajectory CRS + Slice in Z.
- Trajectory CRS is 1 dimensional function $T(q)$ for q in $<0;1>$ mapping q to actual X, Y coordinates!

Courtesy Jozef Matula IBL



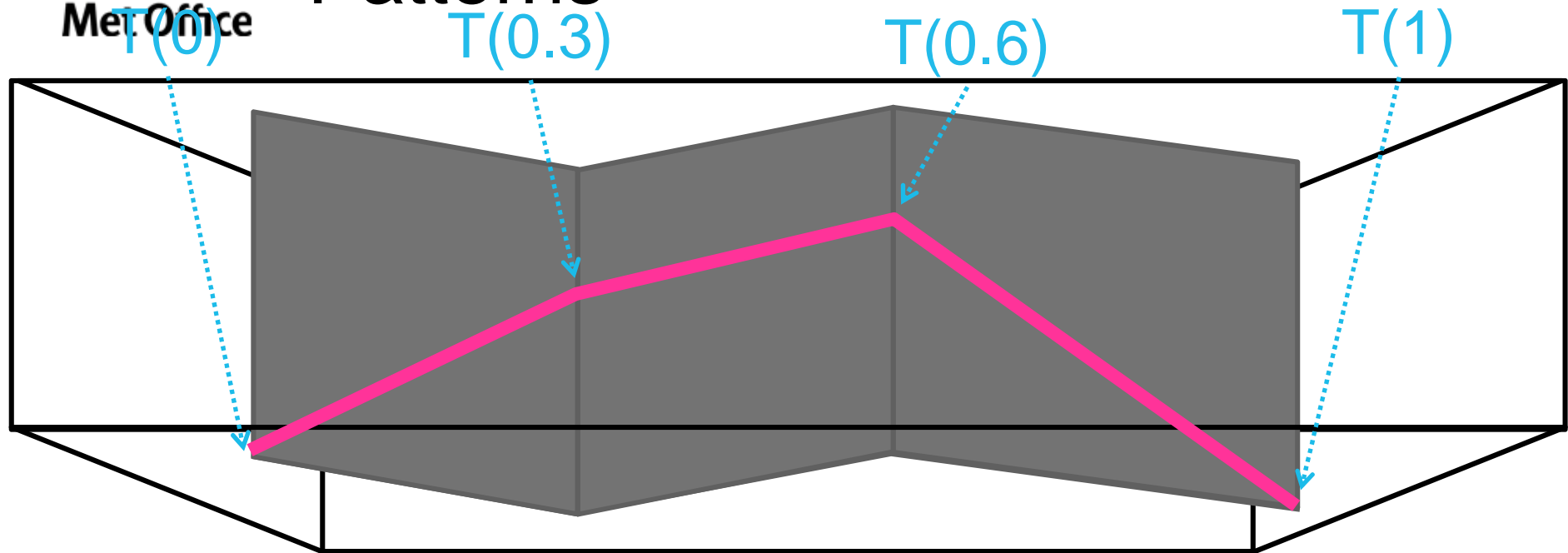
Meteorological Data Extraction Patterns



- Extracting vertical profile data for a trajectory =
Trim in Trajectory CRS



Meteorological Data Extraction Patterns



- Extracting data for a 3D trajectory (airplane flight) = Trim in 3D Trajectory CRS
- 3D Trajectory CRS is 1 dimensional function $T(q)$ for q in $[0;1]$ mapping q to real X,Y,Z coordinates.



Extending the WCS2.0 Core:

- WCS 2.0 Core Spec: “The specification contained in this WCS Core is not sufficient for a fully functioning WCS implementation.”
- No guidance on how to advertise validity times for which coverage data is available!
- Vertical level type of a coverage must be uniform (same as in WMS)
- Definition of “trajectory CRS” is strange quite hard to extend (time, corridor extents, interpolation types, etc.).
- How do you encode a “sparse coverage”?



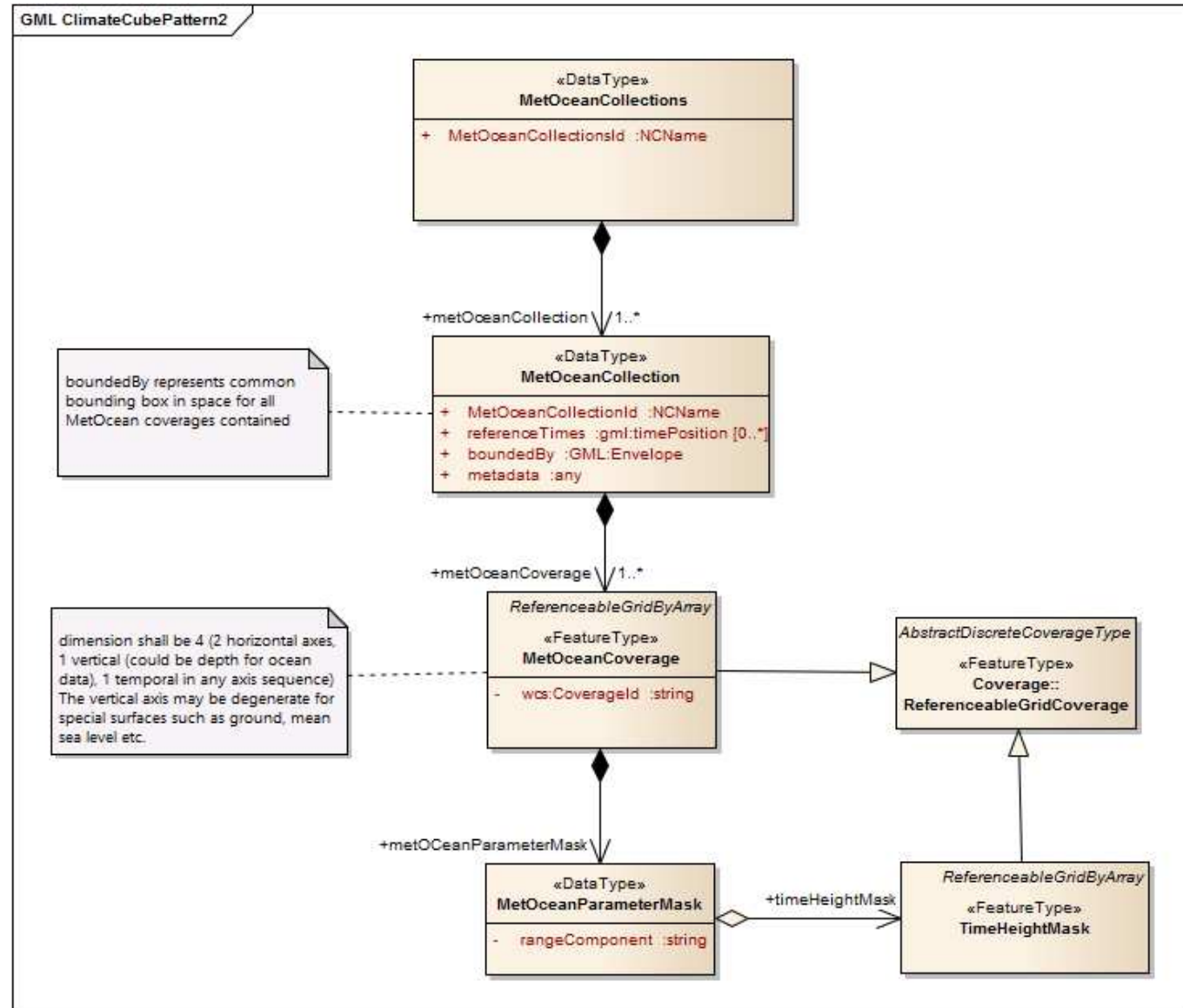
Extending the WCS2.0 Core:

- Developed a prototype with IBL to test concepts:
- Working with Prof Baumann (the author of WCS2.0 core) to create a MetOcean interface standard.
- The document is currently out for discussion:
- Will be voted on using the 60 day rule.
- How do you encode a “sparse coverage”?

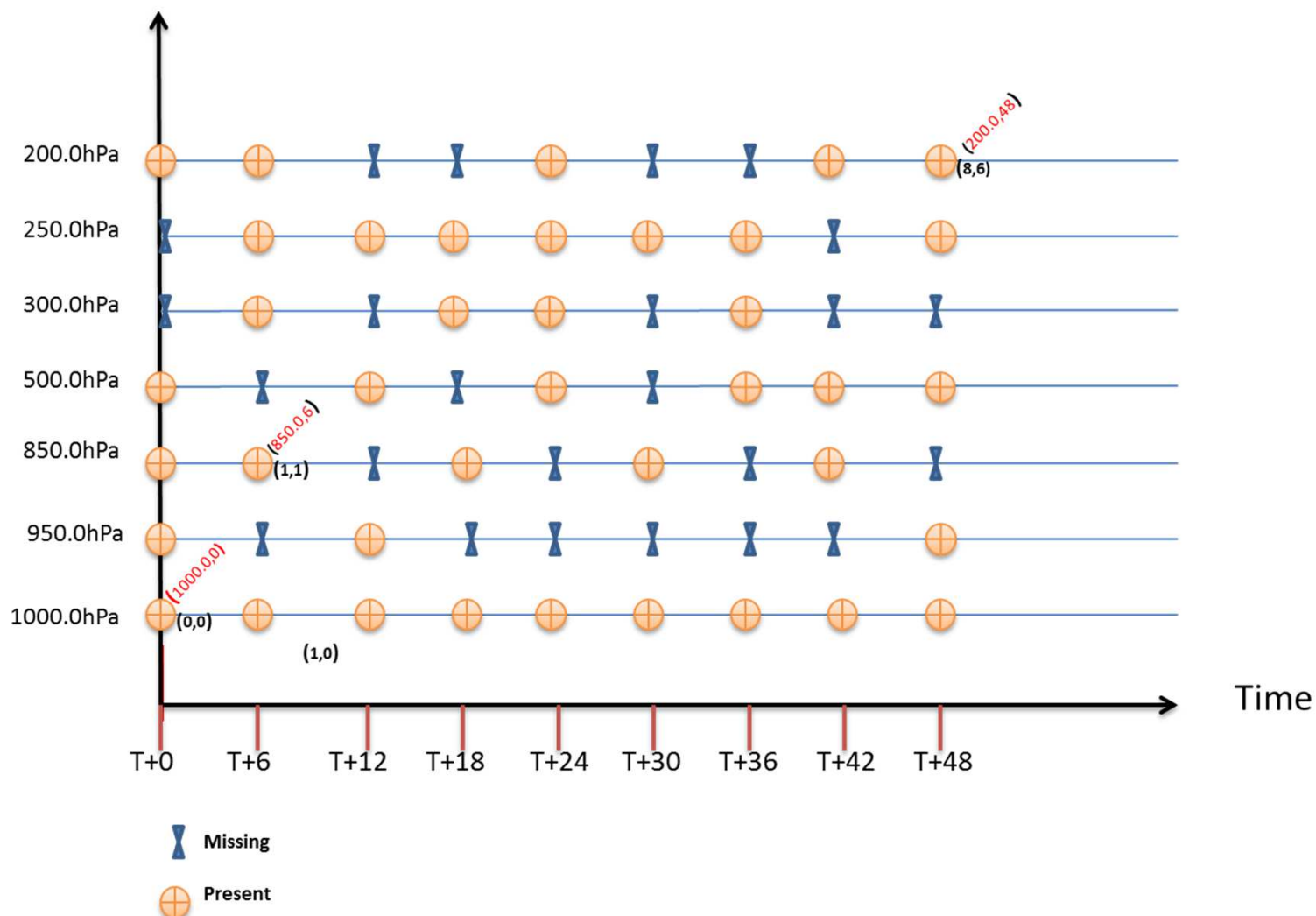


New Met-Ocean Patterns:-

- Create a true 4D coverage from a sparse coverage



The data mask for a sparse coverage.





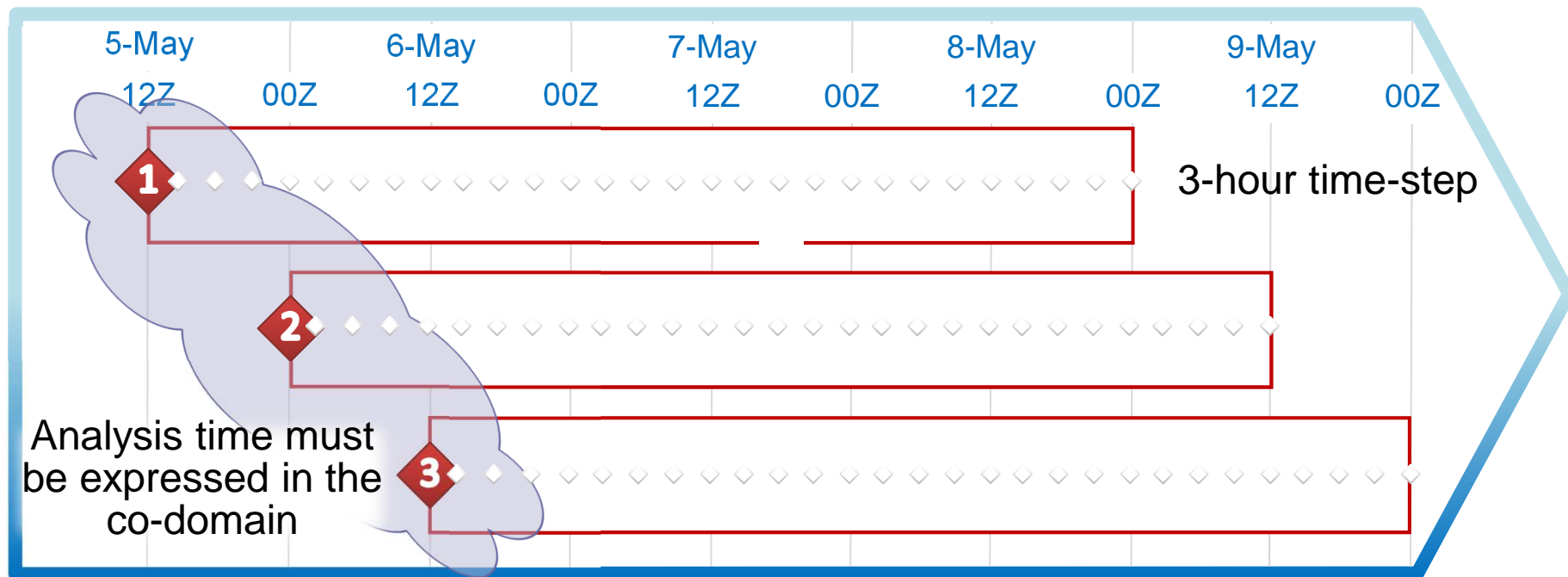
New Met-Ocean Patterns (2):-

- A “MetOcean Coverage” is a type of coverage, but extended by the use of a mask.
- This mask enables the sparse coverage (typical of normal NWP output) to be treated as true 4D coverage.
- The time and vertical axes are enumerated:
- The mask itself is a coverage:



Querying a Forecast Model Run Collection coverage

... there is often a requirement to compare values from different simulations. This slide shows an example Web Coverage Service (WCS) requests for a service exposing **forecast model run collection** as a single coverage offering ...

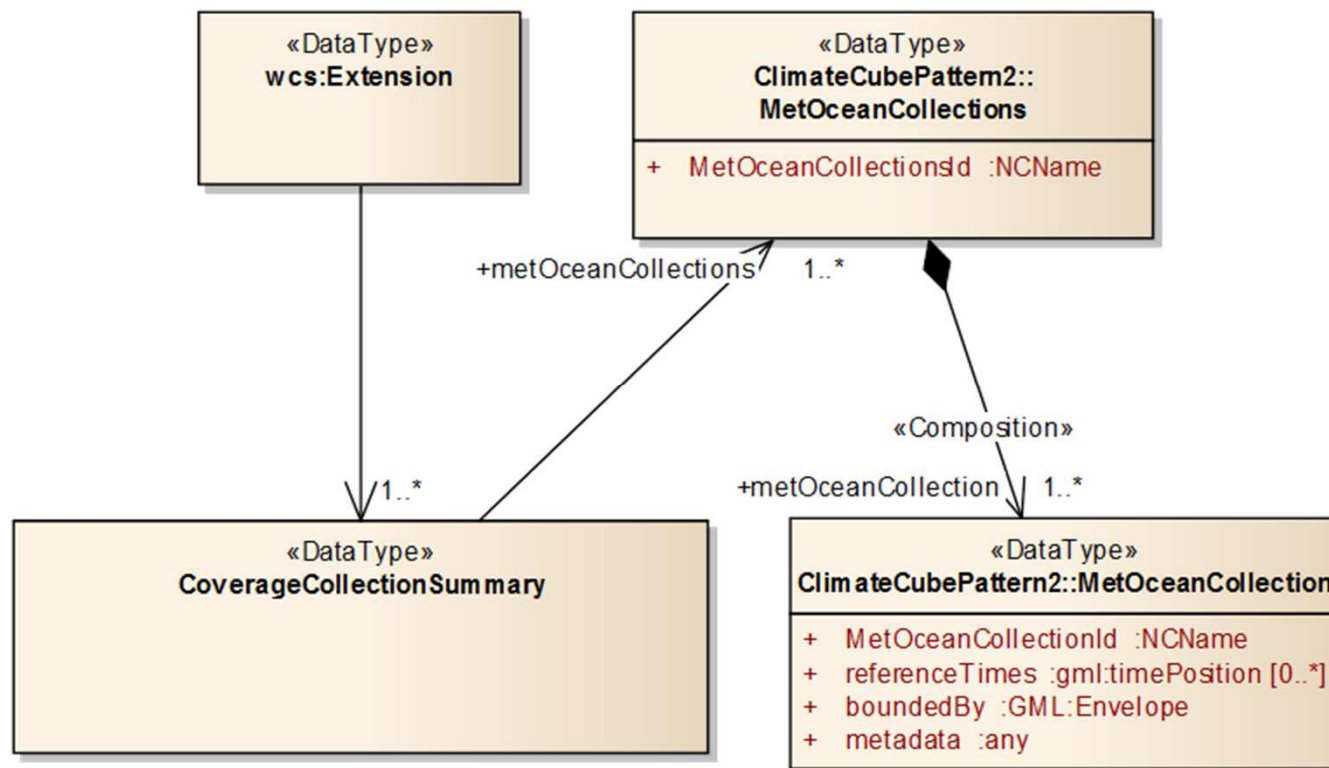


full details of WCS requests omitted for brevity



MetOcean Collection:-

A MetOcean collection as advertised in the GetCapabilities response.



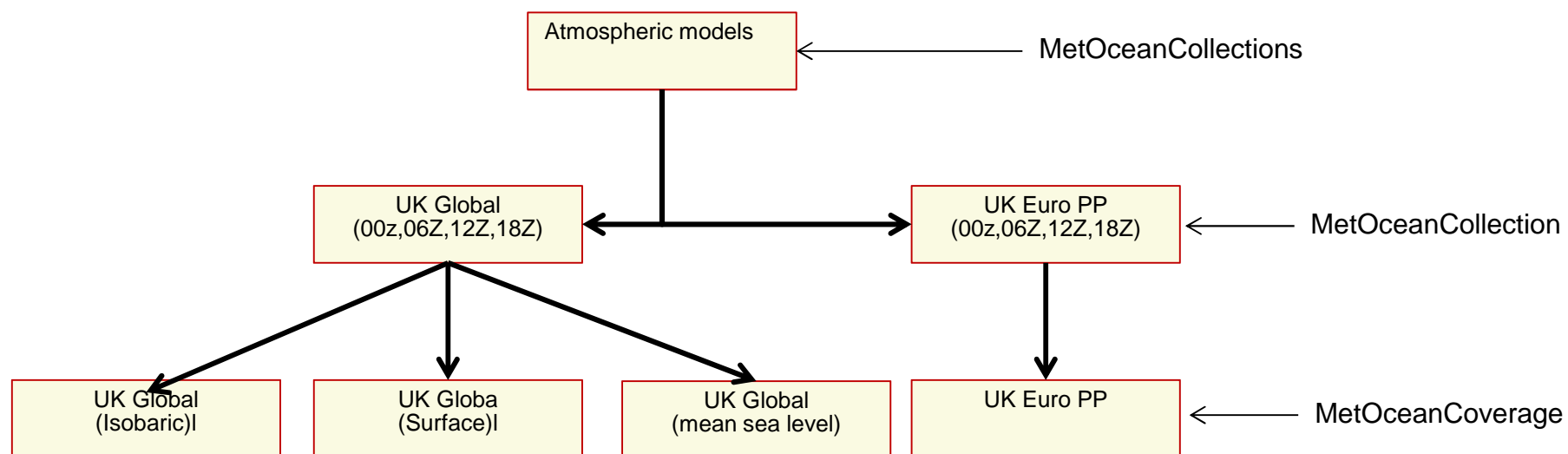


Collections:-

- The concept of collections is very powerful as it allows coverages to be grouped together.
- An individual model run is, in its own right, a collection of coverages, each with a different vertical coordinate reference system.
- There is often a requirement to compare values from different simulations. The “reference times” (aka model run times) are considered to be a property of the coverage collection.

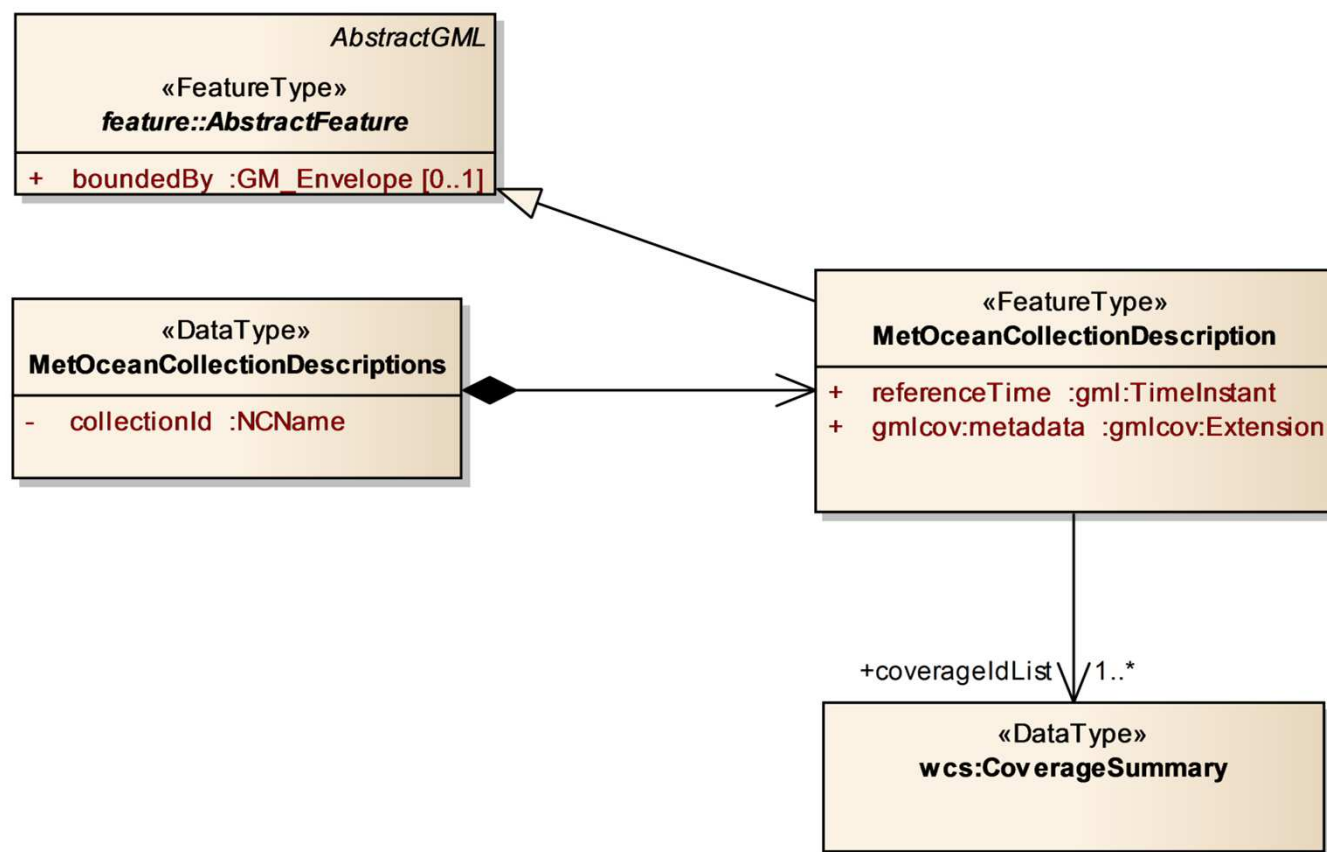


MetOceanCollections





A MetOcean Collection:-

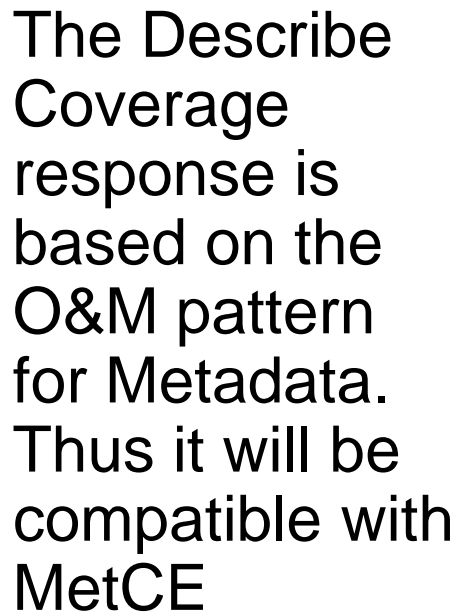




A MetOcean Coverage Summary

- Each coverage within the collection is listed with an identifier.
- The DescribeCoverage operation will further describe each coverage.
- The collection adds an extra level of description that may include a link the service serving the coverage.

```
<wcs:CoverageSummary>  
  <wcs:CoverageId>UK_GLOBAL_2012-05-15T12.00.00Z_Thickness</wcs:CoverageId>  
  <wcs:CoverageSubtype>NamedRange</wcs:CoverageSubtype>  
    <ows:Metadata xlink:href="www.codes.wmo.int/GRIB2/table4.5/Thickness"  
      <metocean:coverageDescription coverageDescription="Thickness"  
    </ows:Metadata>  
</wcs:CoverageSummary>
```

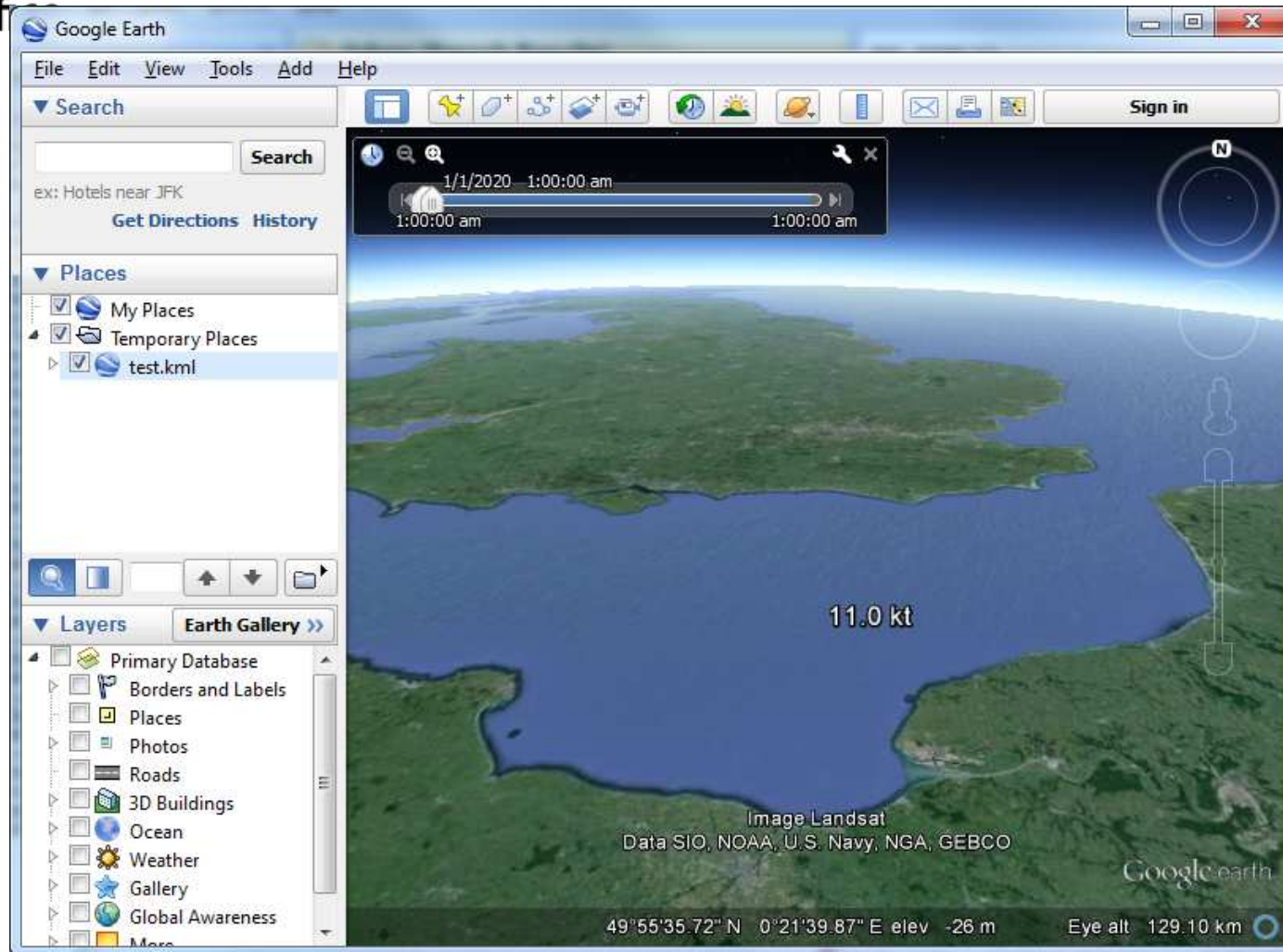


Describe Coverage:-



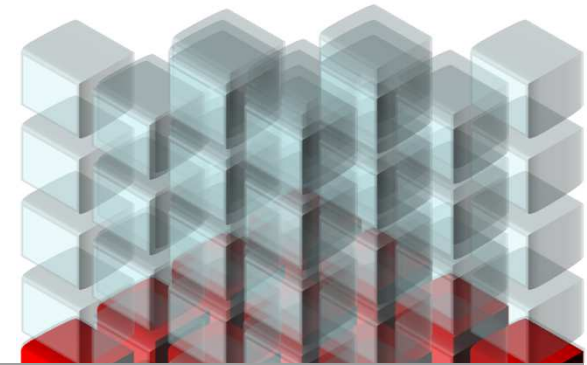


Visualisation





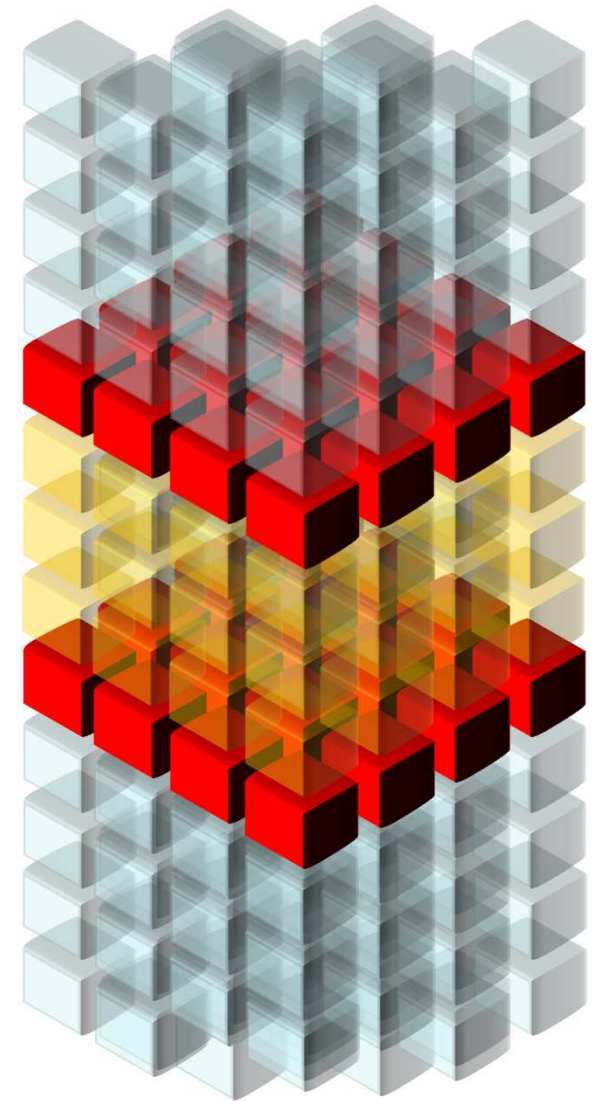
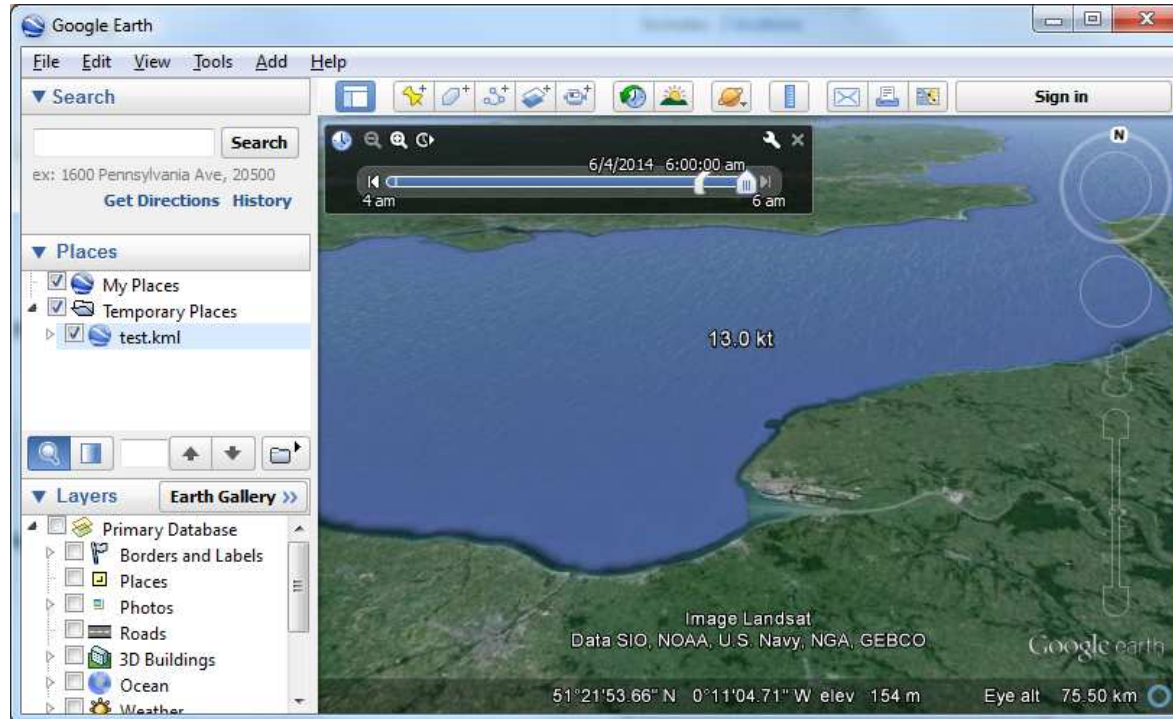
Trim Request



```
<?xml version="1.0" encoding="UTF-8"?>
<wcs:GetCoverage xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:wcs="http://www.opengis.net/wcs/2.0"
  xmlns:wcsCRS="http://www.opengis.net/wcs_service-extension_crs/1.0"
  xmlns:int="http://www.opengis.net/WCS_service-extension_interpolation/1.0"
  xmlns:rsub="http://www.opengis.net/wcs/range-subsetting/1.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:metocean="http://def.wmo.int/metce/2013/metocean"
  service="WCS" version="2.0.0">
  <wcs:Extension>
    <rsub:rangeSubset>
      <rsub:rangeComponent>UKPPNOW_
10m_Max_Gust_Speed_KT</rsub:rangeComponent>
    </rsub:rangeSubset>
```




Visualisation





Polygon Use Case

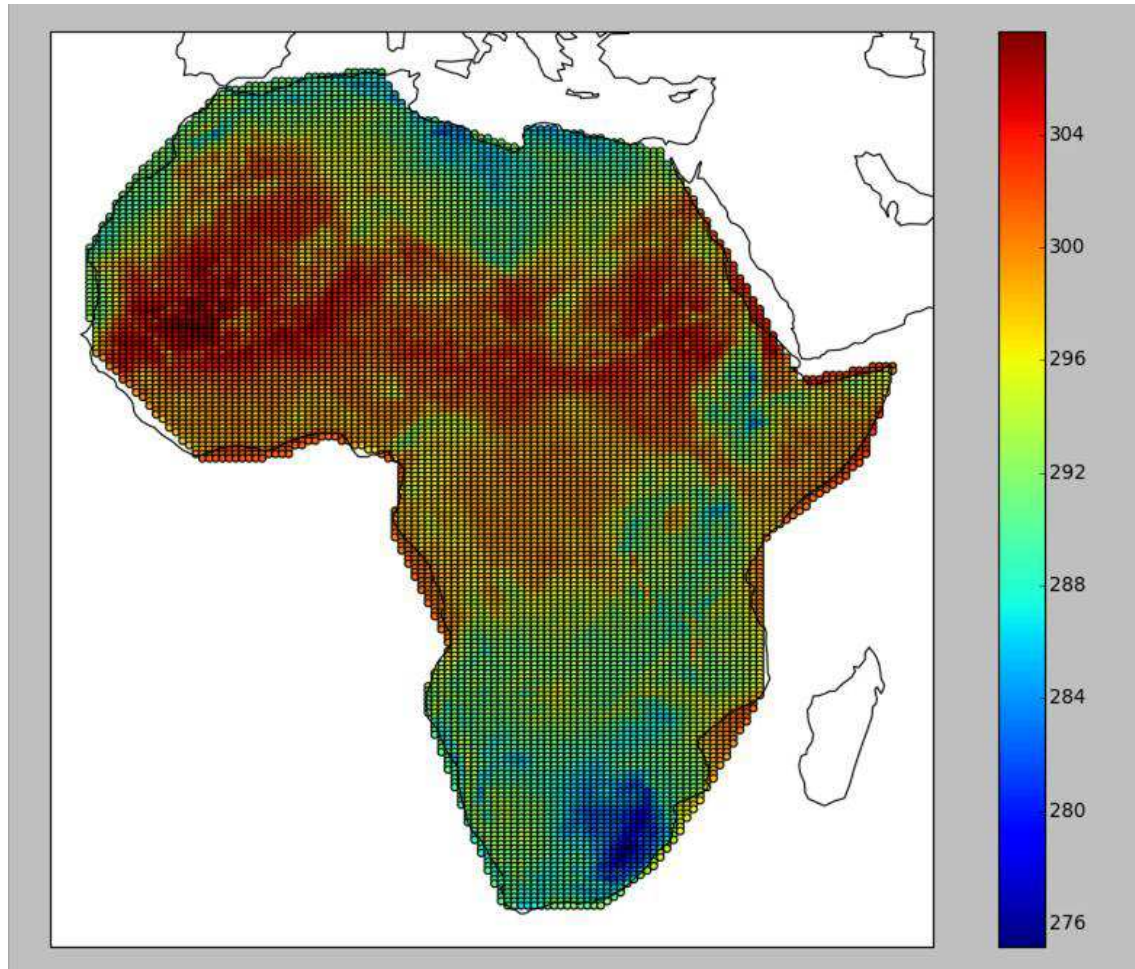




Polygon Request

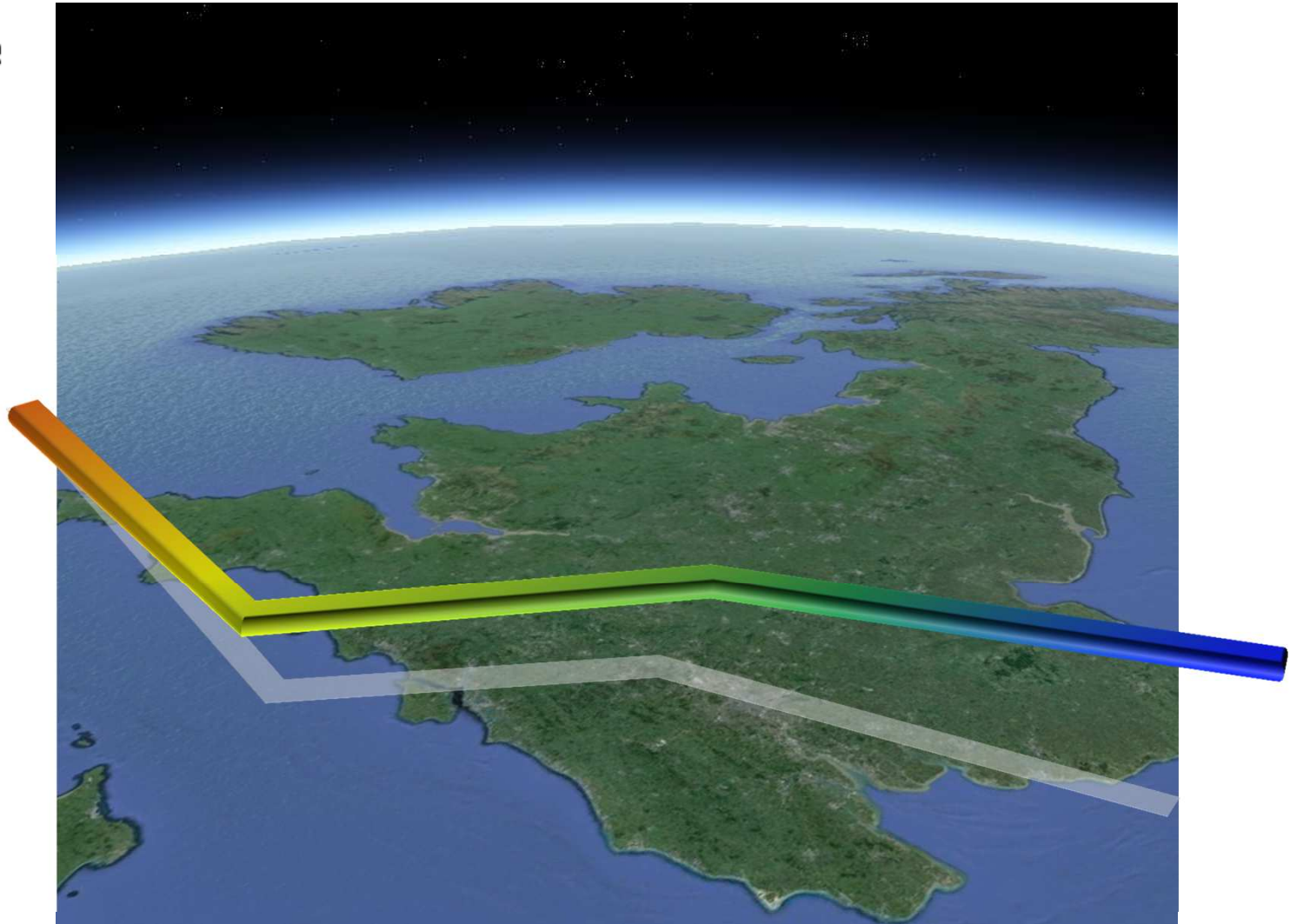
```
<?xml version="1.0" encoding="UTF-8"?>
<metocean:GetPolygonCoverage xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:wcs="http://www.opengis.net/wcs/2.0"
  xmlns:metocean="http://def.wmo.int/metce/2013/metocean"
  xmlns:wcsCRS="http://www.opengis.net/wcs_service-extension_crs/1.0"
  xmlns:int="http://www.opengis.net/WCS_service-extension_interpolation/1.0"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  xmlns:rsub="http://www.opengis.net/wcs/range-subsetting/1.0"
  xmlns:gmlrgrid="http://www.opengis.net/gml/3.3/rgrid"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  service="WCS" version="2.0.0"
  xsi:schemaLocation="http://www.opengis.net/wcs/2.0 http://schemas.opengis.net/
http://www.opengis.net/wcs/crs/1.0 https://raw.githubusercontent.com/EOxServer/schemas/
http://www.opengis.net/WCS_service-extension_interpolation/1.0 file:/C:/Users/f
http://def.wmo.int/metce/2013/metocean file:/C:/Users/Rocky/WCS/MOWCS3/sc
http://www.opengis.net/wcs/range-subsetting/1.0 file:/C:/Users/Rocky/WCS/MO
  <wcs:Extension>
    <rsub:rangeSubset>
      <rsub:rangeComponents>UKMO Global Temperature</rsub:rangeCom
```

Visualisation (IRIS)





Corridor Use Cases



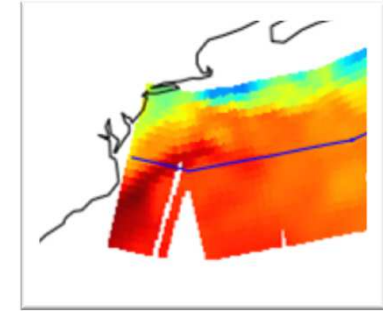


Planes, Trains and Automobiles





Ship Tracks Request



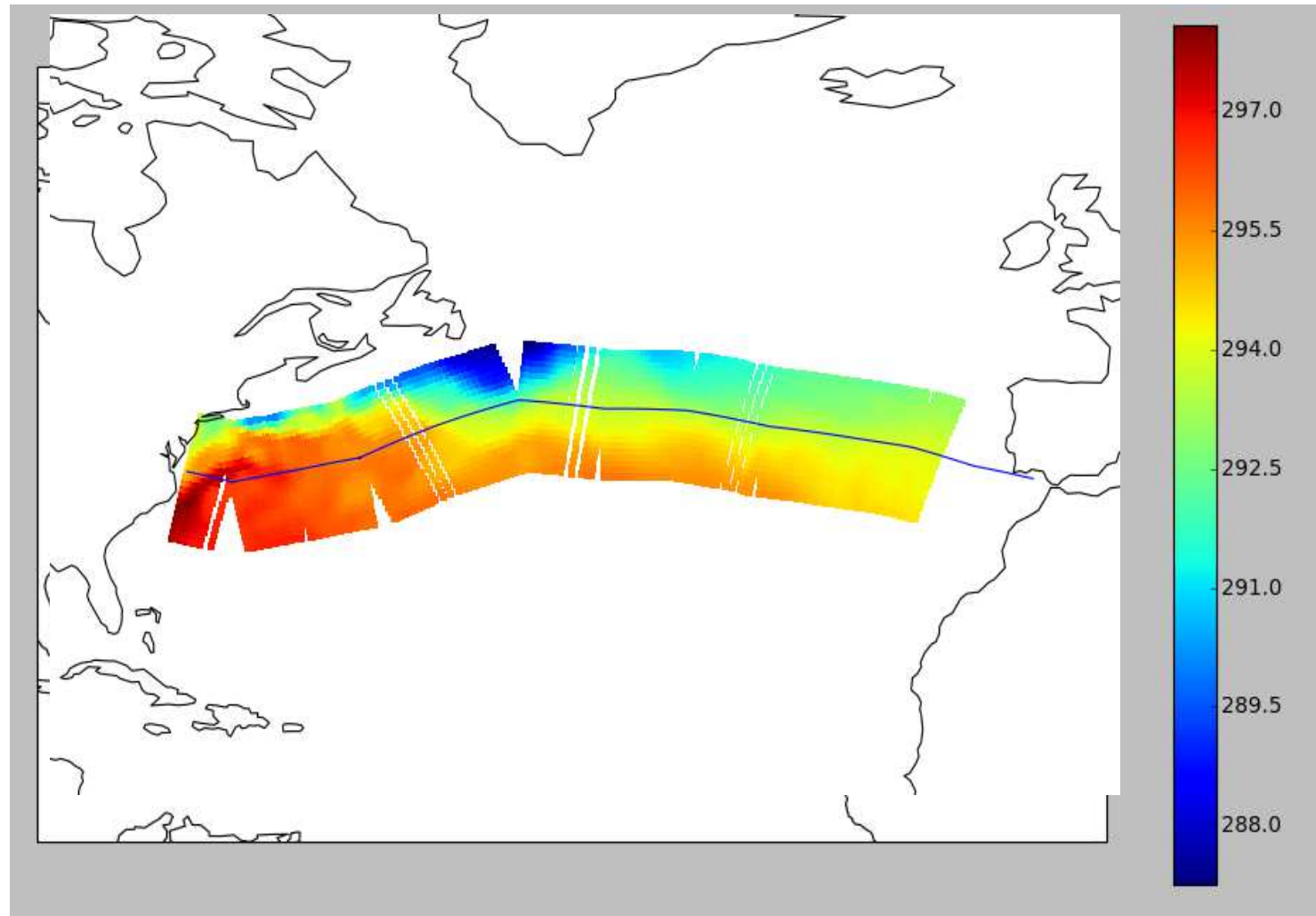
```
<?xml version="1.0" encoding="UTF-8"?>
<metocean:GetCorridorCoverage xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:wcs="http://www.opengis.net/wcs/2.0"
  xmlns:metocean="http://def.wmo.int/metce/2013/metocean"
  xmlns:wcsCRS="http://www.opengis.net/wcs_service-extension_crs/1.0"
  xmlns:int="http://www.opengis.net/WCS_service-extension_interpolation/1.0"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  xmlns:rsub="http://www.opengis.net/wcs/range-subsetting/1.0"
  xmlns:gmlrgrid="http://www.opengis.net/gml/3.3/rgrid"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  service="WCS" version="2.0.0"
  xsi:schemaLocation="http://www.opengis.net/wcs/2.0 http://schemas.opengis.net/wcs/2.0
http://def.wmo.int/metce/2013/metocean file:/C:/Users/Rocky/WCS/MOWCS3
http://www.opengis.net/wcs/crs/1.0 https://raw.githubusercontent.com/EOxServer/schemas
http://www.opengis.net/WCS_service-extension_interpolation/1.0 file:/C:/Users/Rocky/WCS
http://www.opengis.net/wcs/range-subsetting/1.0 https://raw.githubusercontent.com/EOxServer/schemas
<wcs:Extension>
```

```
-26.565,39.799,201401201800
-26.160,39.543,201401270000
-23.215,39.160,201401270222
-22.139,39.000,201401270600
-20.325,38.765,201401271200
-17.480,38.336,201401271501
```




Ship Tracks Data

Visualisation (IRIS)



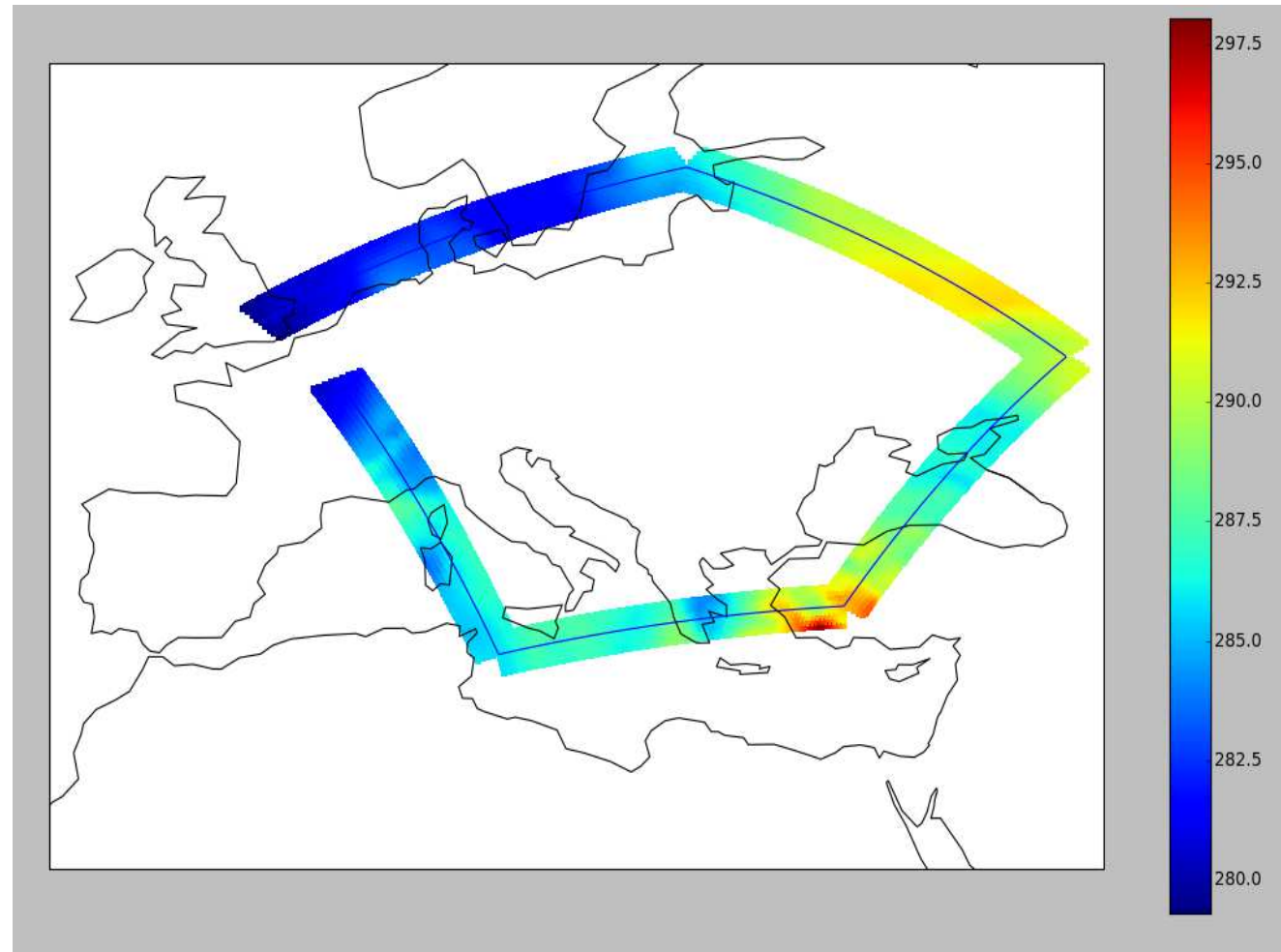
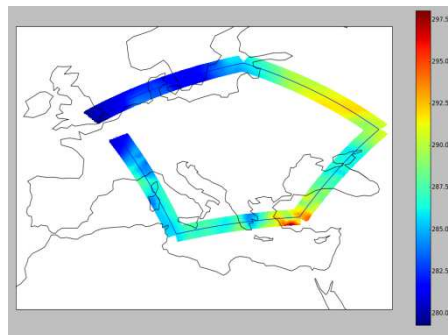
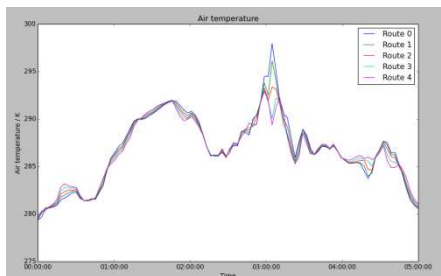
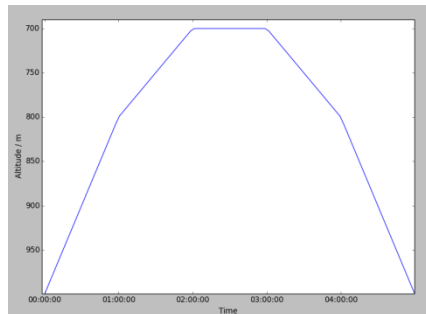
-22.139,39.000,201401270600
-20.325,38.765,201401271200
-17.480,38.336,201401271501

Aerial Trajectory





Visualisation (IRIS)



Route Planning

WCS 2 demo

labs.metoffice.gov.uk/map/journey/journey.html

Pick options

.....

UKPPBEST

List available data

Temperature

>

18.4


exeter

Journey start time:

10/09/2014 11:56

london

Get Route



Map data ©2014 Google Terms of Use Report a map error



Drag and Drop Shapefiles

WCS 2 MetOc ShapeFile query

labs.metoffice.gov.uk/map/shpjs/

HTML5 Shapefile reader

Select (or Drag and drop) a Shapefile (.shp), its dBASE table file (.dbf) and its Projection file (.prj)

DROP!

Or Select

Service: UKPPBEST [List available data](#)

Coverage: Temperature

Start Time: Wed, 10 Sep 2014 09:00:00 GMT

End Time: Wed, 10 Sep 2014 09:00:00 GMT

[Calculate](#)

Temperature for Penrith and The Border Co Const

Maximum:	15.4	C
Minimum:	9.8	C
Average:	13.1	C

Penrith and The Border Co Const [View](#)

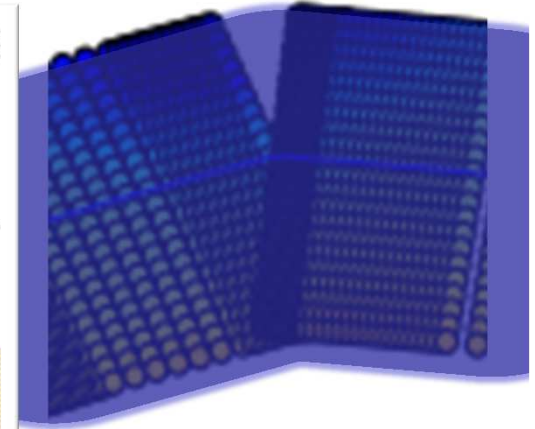
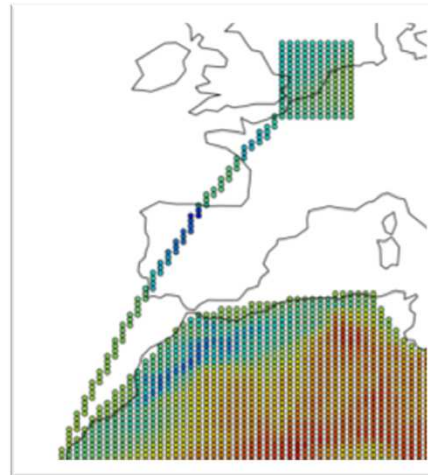
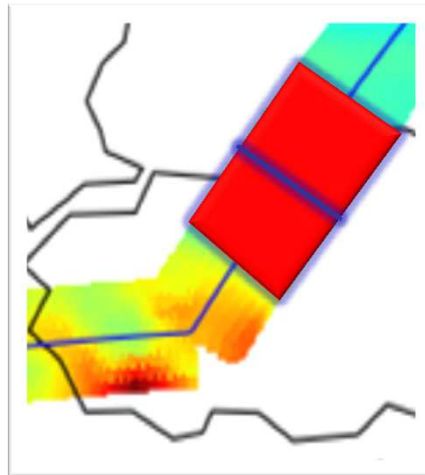
A map of the United Kingdom with a highlighted region in the north-west, corresponding to the "Penrith and The Border Co Const" area. The map shows major cities and roads across the country.

-5.84438, 51.88540



WCS2.0 MetOcean extensions – future changes

- Variable corridor height and width
- Time/segment length
- Multiple polygons in single request
- Perpendicular corridors - use locus instead



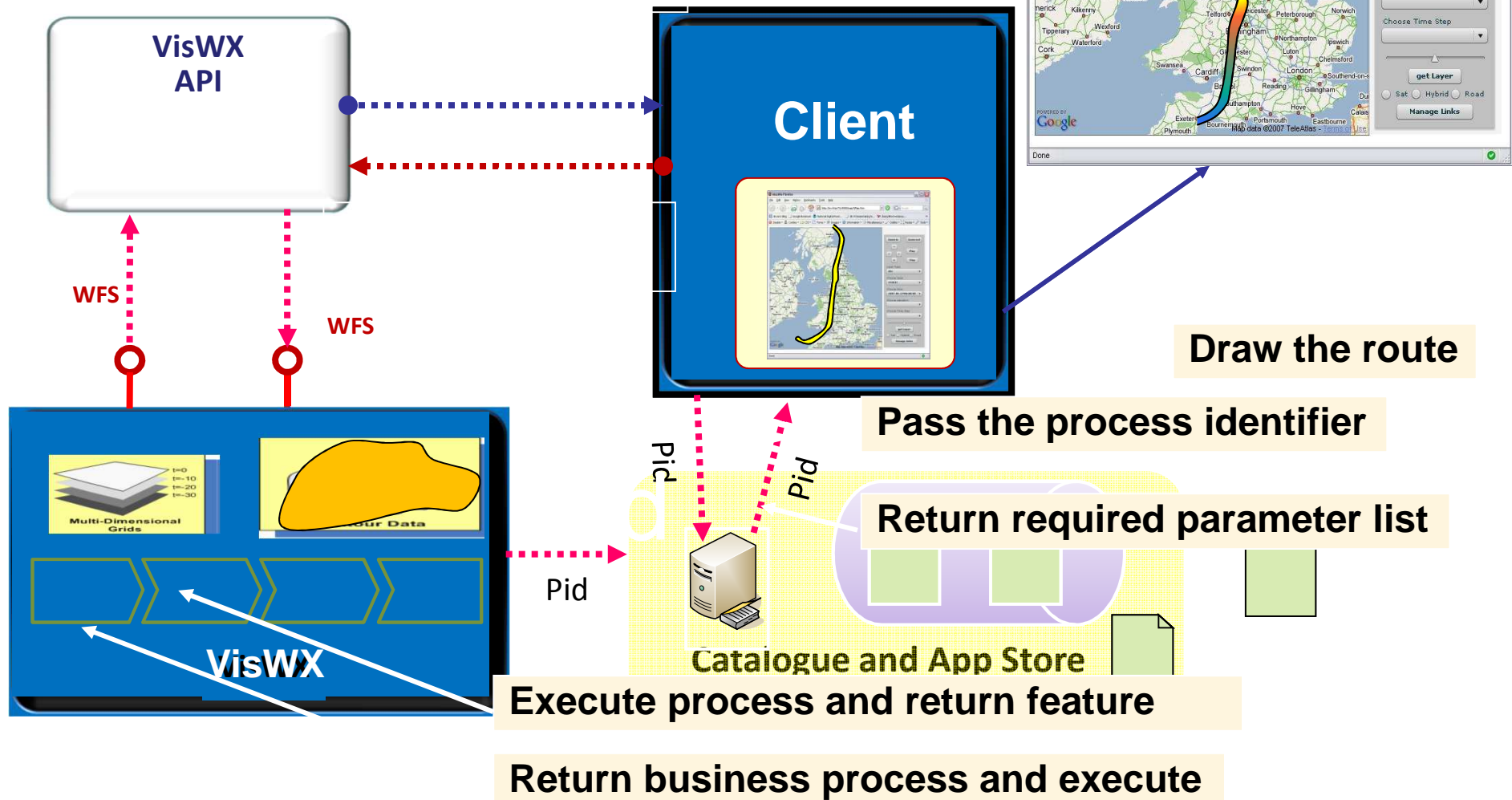


Questions & answers



Flow Diagram...

Re-Draw feature with new properties





Trajectory Based Operations:

- With the advent of Trajectory Based Operations (TBO), a paradigm shift is required in the way weather information is requested, accessed, depicted, and integrated into DSTs. To support the capabilities that will enable TBO, all digital weather elements are atmospheric values only and are user threshold independent.
- Their interpretation and ultimate impact is to be determined by the users' DSTs. Impacts, for example, may be in the form of re-routes or sections of airspace throughput based on traffic loads and performance characteristics.

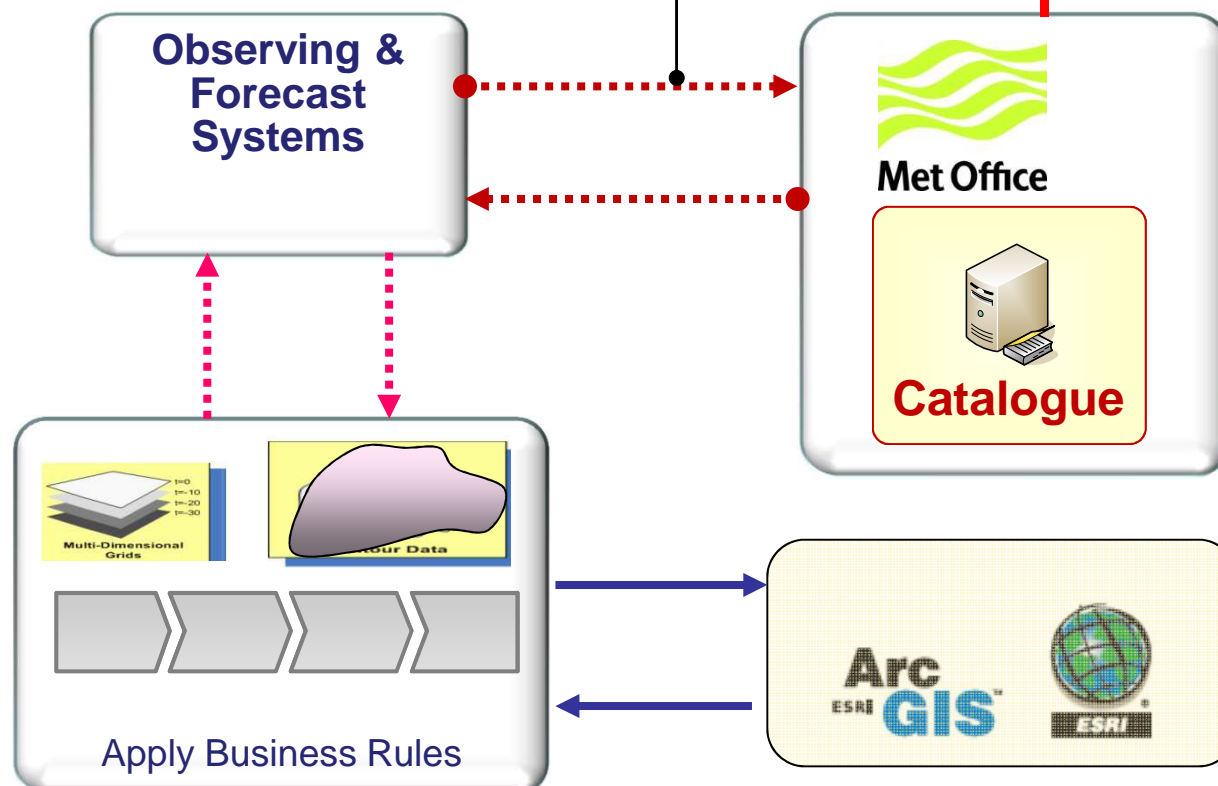
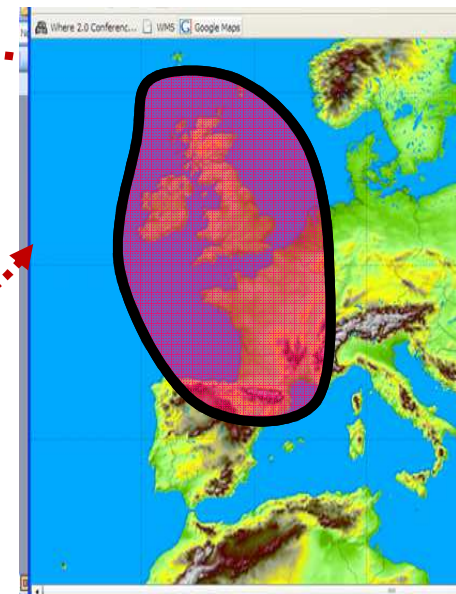


Setting the scene

...

Property of the feature

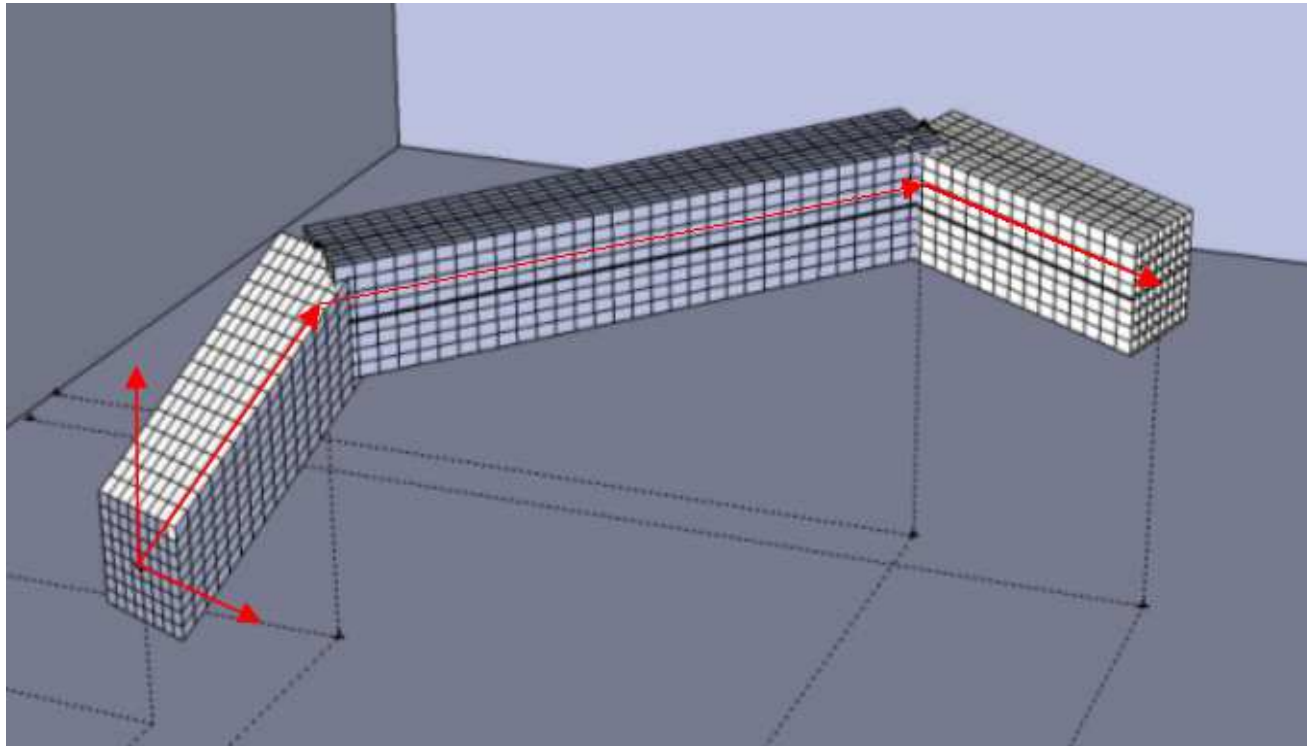
WFS



- Draw area of interest and specify query e.g. max probability of heavy rain
- Pass area to forecast system
- Evaluate probability of rain for a threshold.
- Colour code area by risk
- Pass area as GML feature back to client.



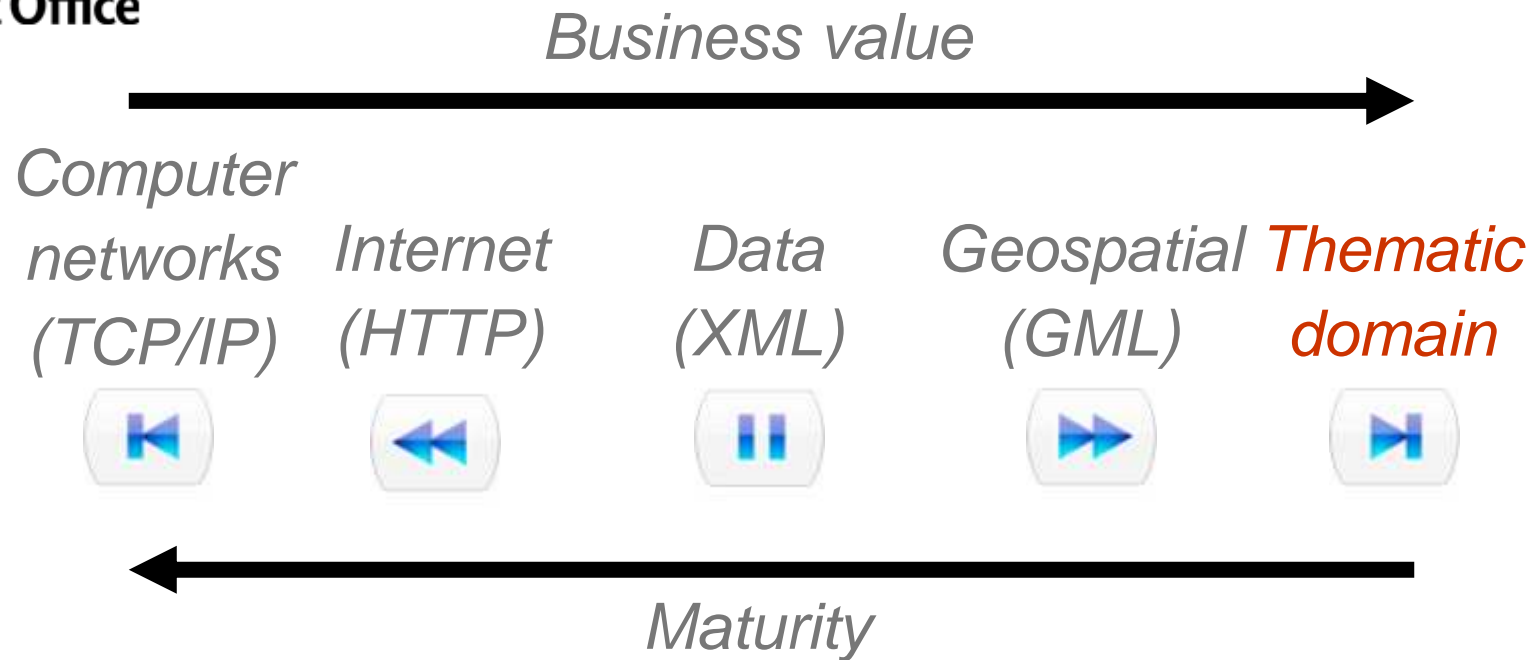
Trajectory sub-set of a trajectory in 4D



This picture is courtesy:-
National Center for Atmospheric Research
MIT Lincoln Laboratory
National Oceanic and Atmospheric Administration/Global Systems Division



Levels of interoperability

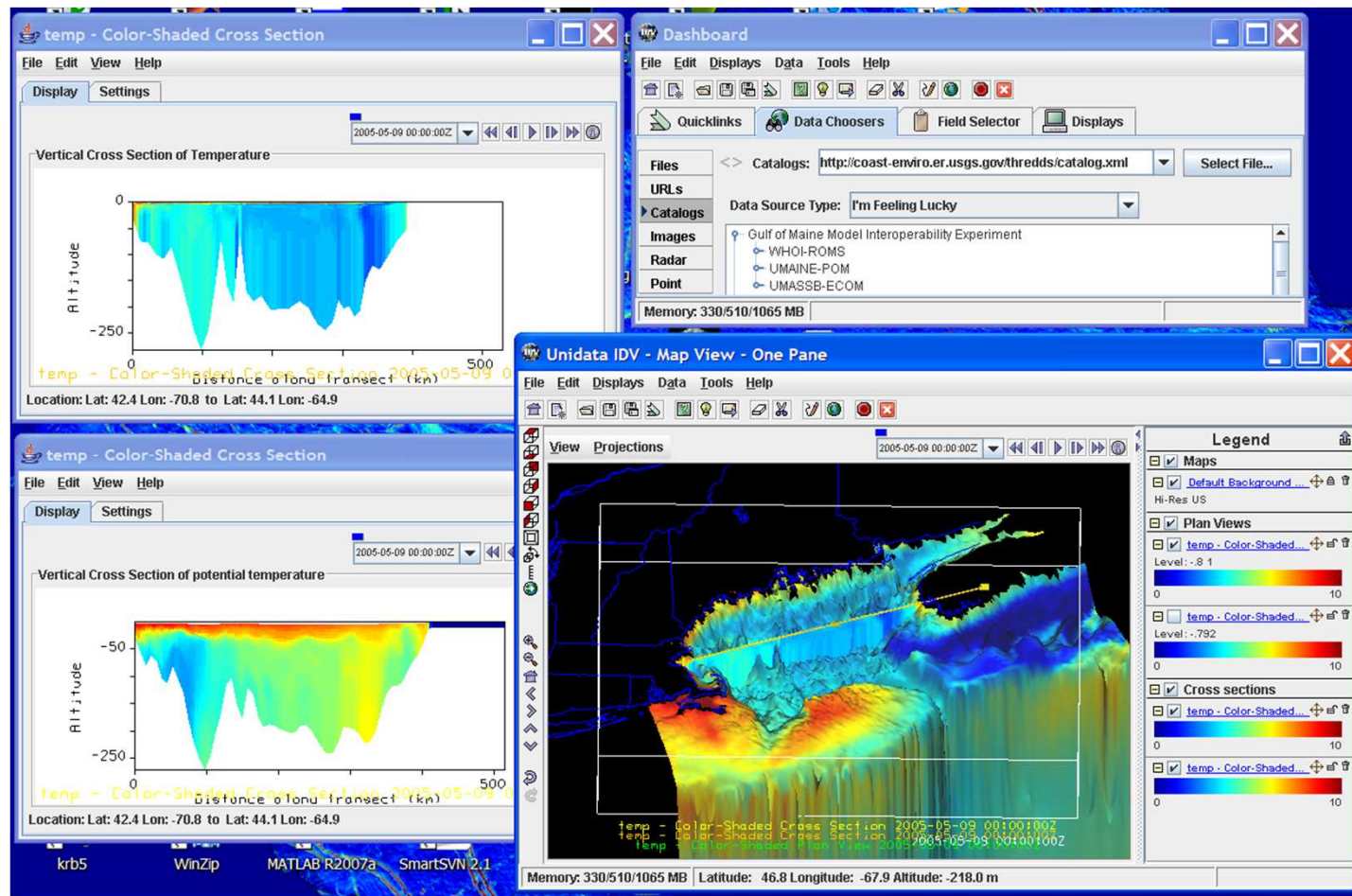


**Semantic interoperability
vs.
Syntactic interoperability**



Example 1: CF-netCDF

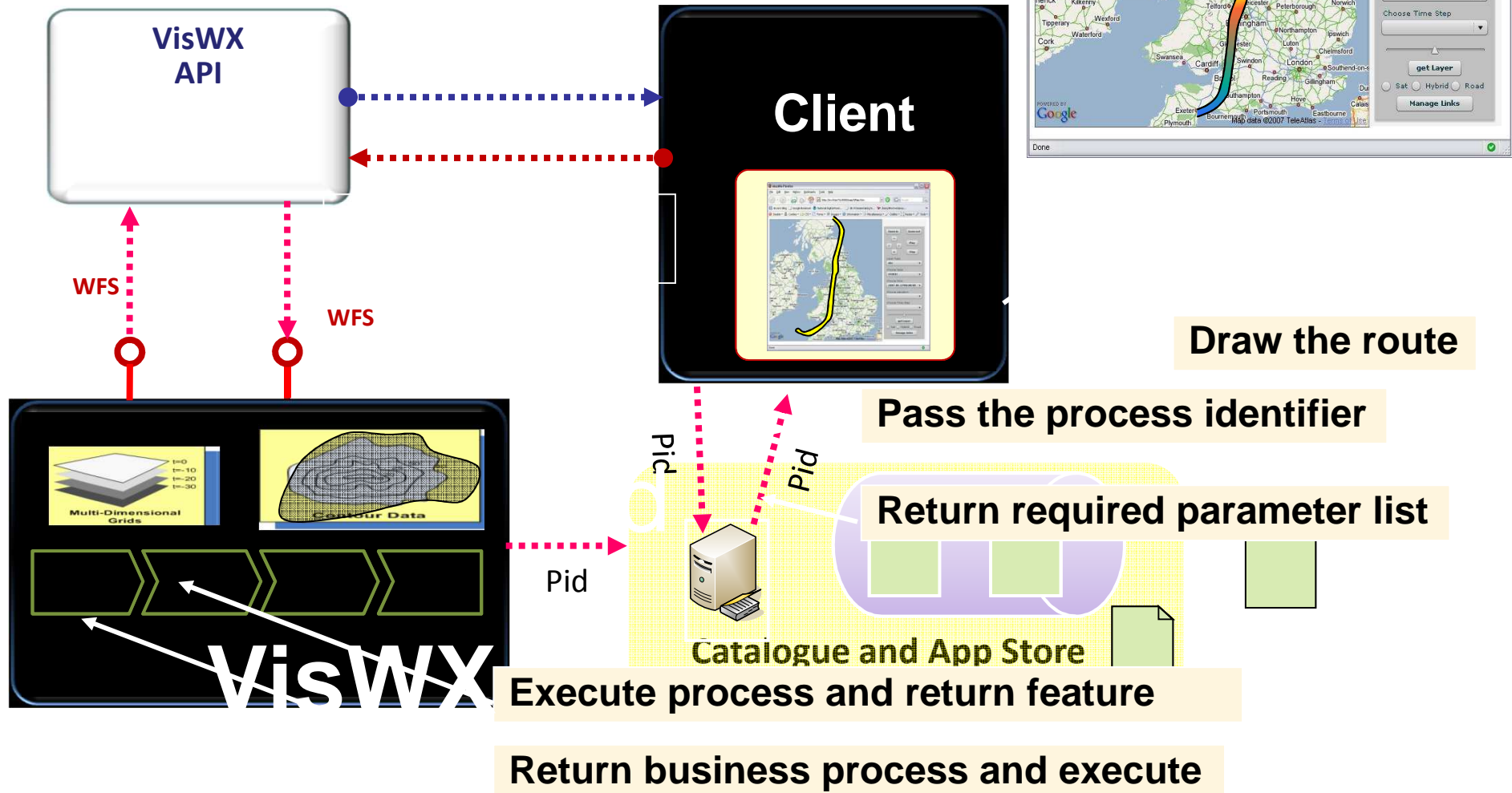
- De facto standard used by wider fluid earth sciences community (esp. research & academia)
- Adopted as standard by IPCC





Flow Diagram...

Re-Draw feature with new properties





Example 2: Keyhole Markup language (KML)

- Google have revolutionised access to geospatial information ...
- De facto standard now an open standard: OGC KML 2.2 (ref 07-147r2)
- Everyone* supports KML!



Rich ecosystem of collaborators within diverse community, simple semantics

- Why is KML successful?
- Semantics are limited to geometry / topology & representation; it does not try to explain WHAT the data is
- Applicable to an extremely diverse community – just enough semantics to share meaning
- OGC 'simple features profile' attempts to constrain full ISO general feature model to similar semantics

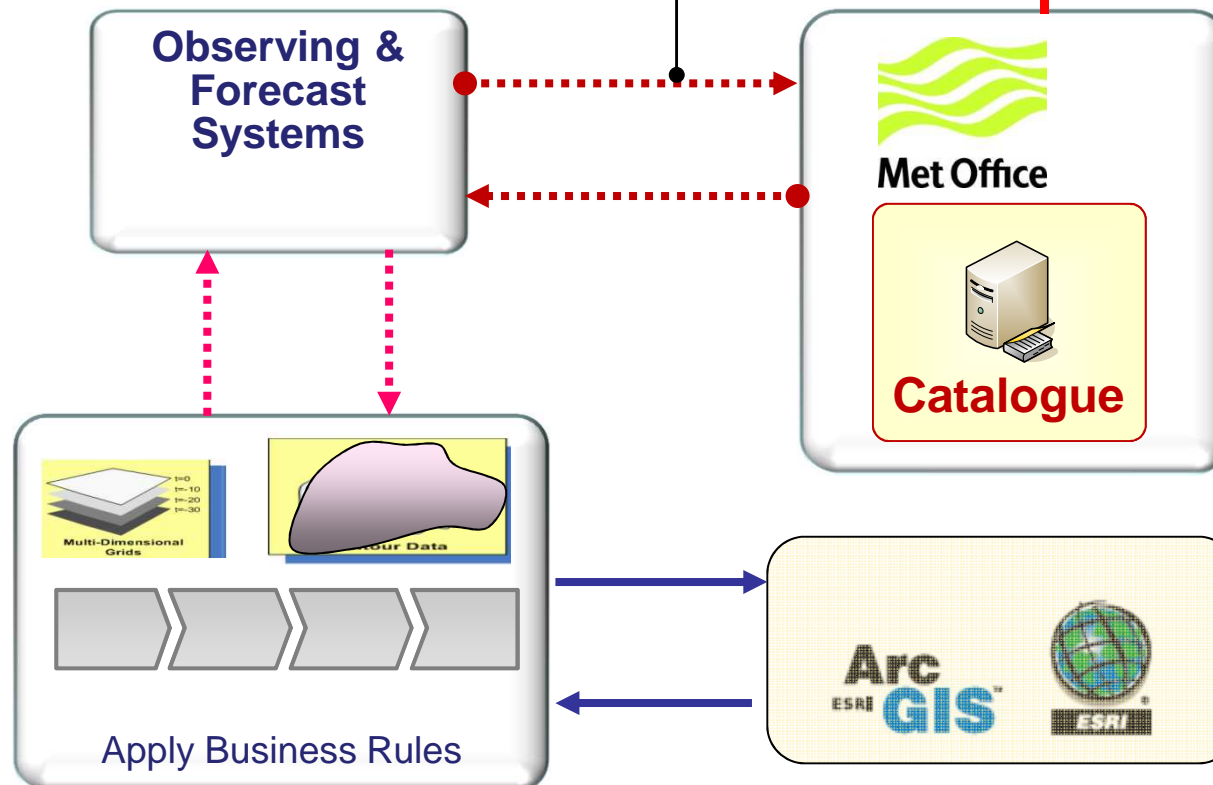
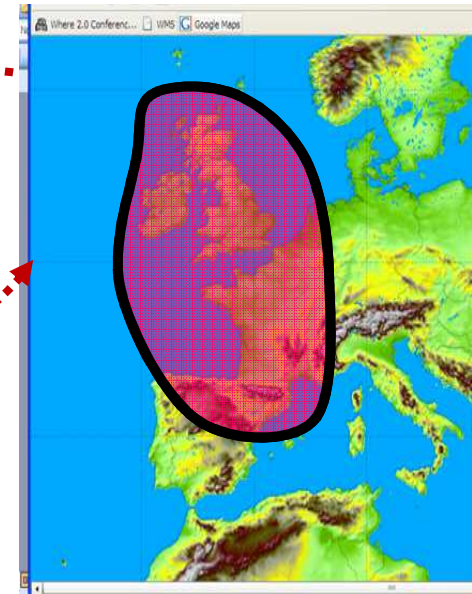


Setting the scene

...

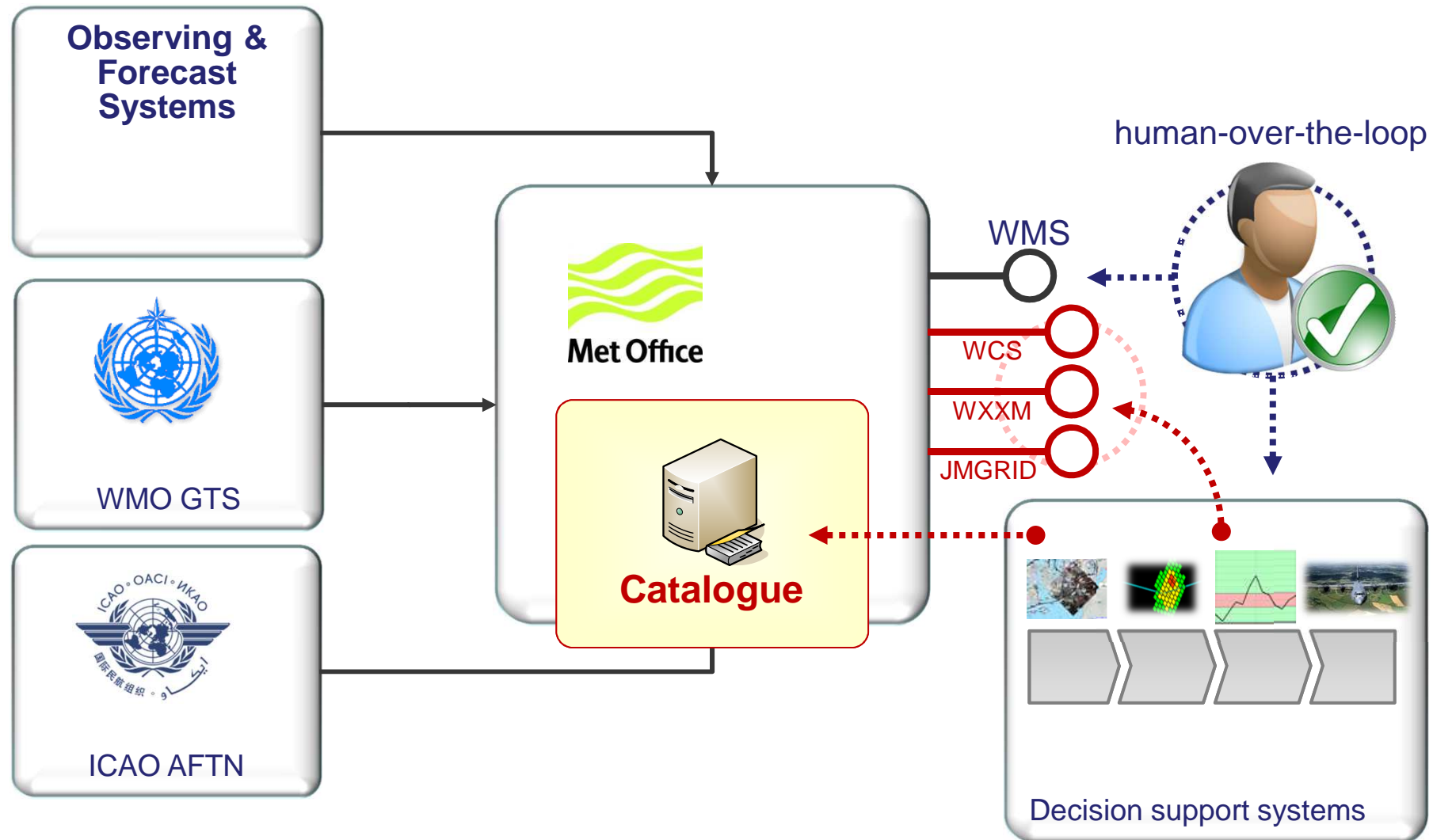
Property of the feature

WFS



- Draw area of interest and specify query e.g. max probability of heavy rain
- Pass area to forecast system
- Evaluate probability of rain for a threshold.
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Setting the scene ...





Met Support for decision makers; An example:

- Convective storms today, are often depicted using a 2D map of radar reflectivity to show a moving and shifting three-dimensional volume of convective weather hazards.
- Decision makers need to know where the hazards are expected to exceed operational thresholds associated with convection/thunderstorms, e.g., hail, icing, low-level wind shear, low ceiling/visibility, downdrafts, high wind gusts, etc.
- In addition, a three-dimensional (not two-dimensional) perspective of these hazards, or attributes, is needed so that so that avoidance planning can be undertaken.