It's about TIME

Proposal of standard conventions for describing TIME

version 2.3

Met Ocean DWG

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March 2011

Aim

Agree a standard way to:

describe the different time perspectives of meteorologists in a way that can be readily understood across thematic domains

[CHANGE LOG v2.2 (Feb 2011)]

Removal of discussion concerning how coverages are used as the result of an Observation event

Removal of discussion concerning 'convenience packaging' of coverages

Updates to proposal about modelling Analyses following feedback from Bryan Lawrence et al [http://home.badc.rl.ac.uk/lawrence/blog/2011/01/07]

[CHANGE LOG V2.3 (Mar 2011)]

Modification to terminology used to describe the assimilation window; removal of terms initialisation time and datum time

Proposal outline

1. Introduction to problem space, common terminology
2. Mapping to ISO 19156 Observations and Measurements

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1. Introduction to problem space, common terminology
2. Mapping to ISO 19156 Observations and Measurements

Terminology

Meteorologists use complex numerical models to simulate the behaviour of the atmosphere. A weather forecast is based on the output of a numerical **simulation**.

The **result** of each simulation will describe the variation of many geo-physical **properties** within a spatio-temporal domain (i.e. **coverages**).

In the majority of cases, meteorologists are interested in predicting the future state of the weather. This is a **forecast**.

The simulation used to create the forecast is a **forecast model run**.

In operational meteorology, new forecasts are created on a regular cycle incorporating new weather observations from deployed instruments. The collective term for a sequence of these simulations is a **forecast model run collection**.

Meteorologists also re-run simulations of recent and historical events, incorporating additional observations or new computational algorithms. These **re-analyses** are normally used to improve accuracy of the simulation results, or to quantify improvements from such changes.

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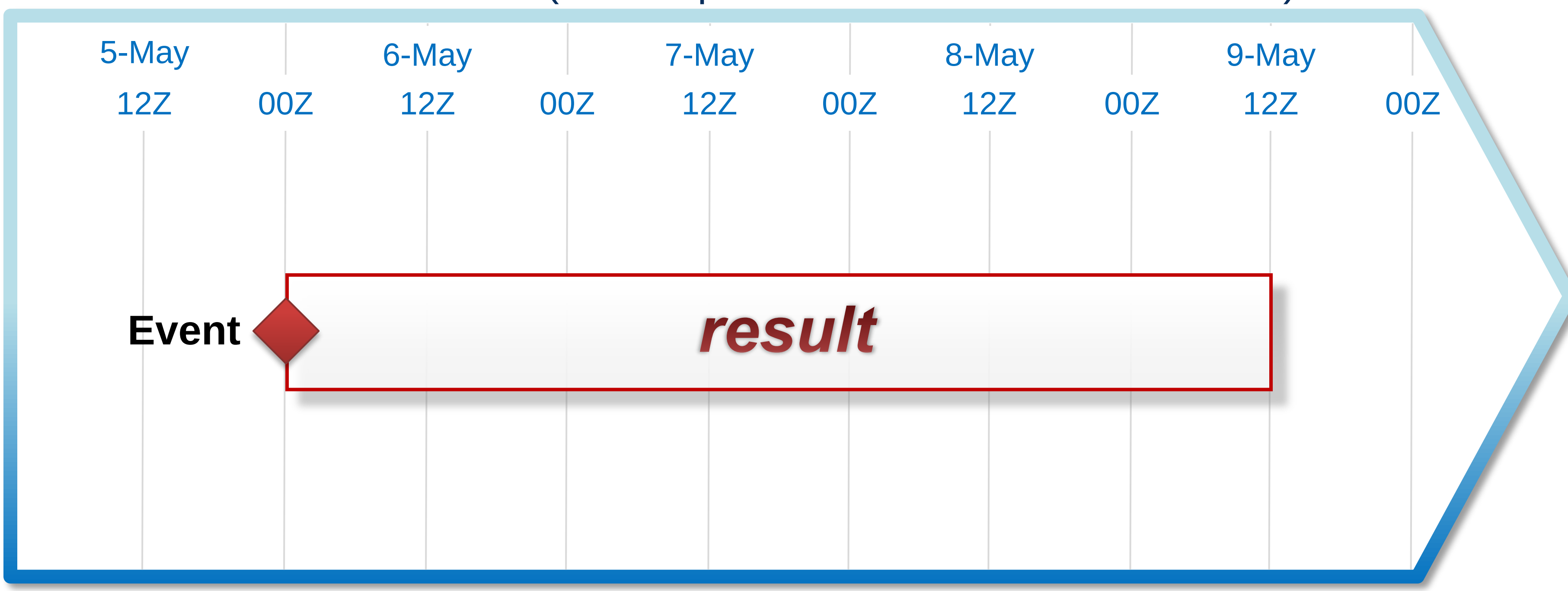
Forecast Model Run

Forecast model run (FMR) example from operational meteorology context:

- A forecast model computation (the simulation **event**) starts once all the weather observations that provide initial conditions have been collected – notionally this is 2010-05-06T00:00
- The simulation describes the future weather conditions for an 84-hour period from 2010-05-06T00:00 (the temporal extent of simulation **result**)



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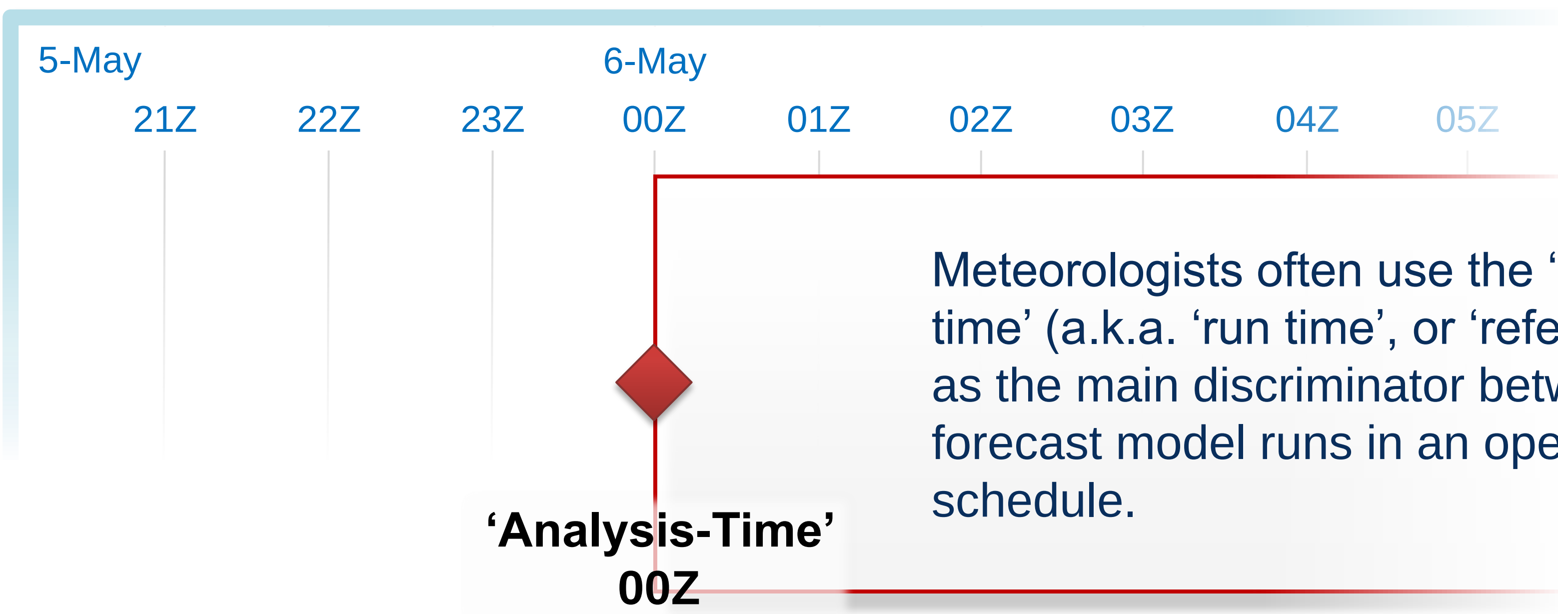
Initialising the Forecast Model Run

Like many computational processes, numerical weather prediction simulations require a set of initial conditions from which the simulation will evolve.

Meteorologists refer to these initial conditions as the **analysis**.

The analysis provides the best estimate of the state of the atmosphere and related geophysical components at particular instance in time – referred to as the **analysis time**.



Meteorologists often use the ‘analysis time’ (a.k.a. ‘run time’, or ‘reference time’) as the main discriminator between forecast model runs in an operational schedule.

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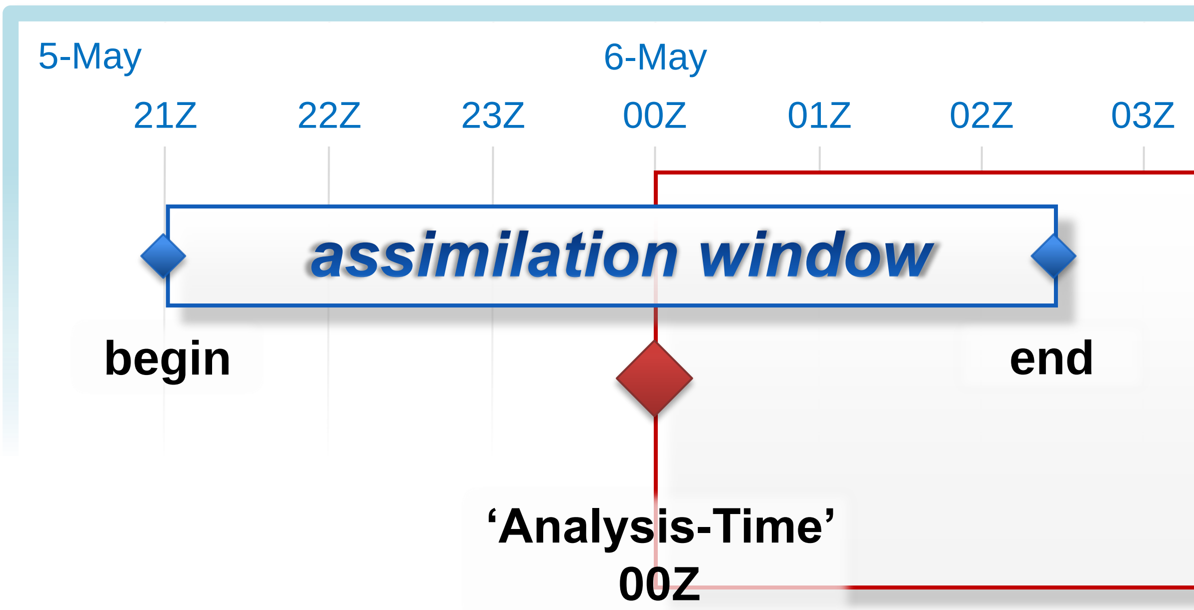
Assimilation: creating the initial conditions

The **analysis** – a best estimate of the state of the atmosphere at a given time-instant – is derived from a (large) set of observations from a number of sources including (but not limited to) weather stations, buoys, radio sondes, wind profilers, weather radars and satellites etc. Details of these input observations is beyond the scope of this discussion.

The process of converting these input observations into an analysis is known as **assimilation**.

The time-period from which observations are selected is known as the **assimilation window**.

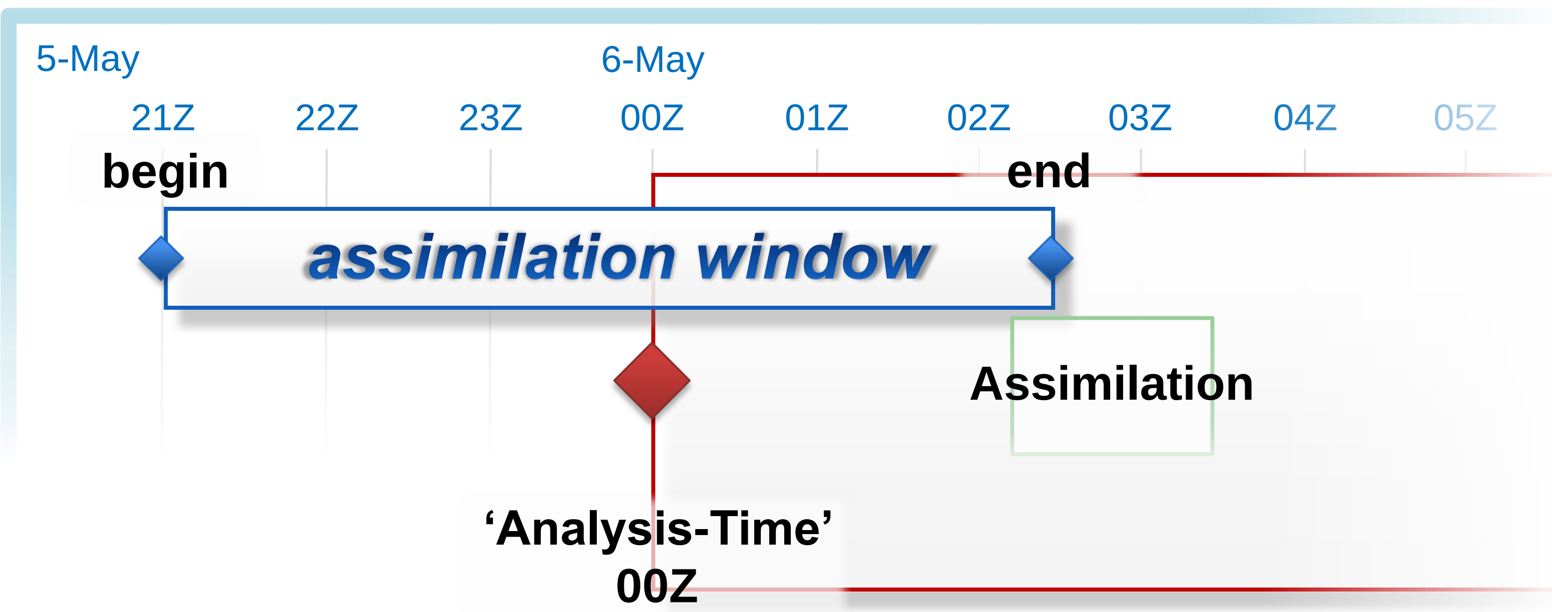


Observations are used as input to the assimilation only if they are taken within the duration of the assimilation window. Depending on the assimilation scheme used, the analysis time does not necessarily occur at the end of the assimilation window.

4DVAR: example assimilation scheme

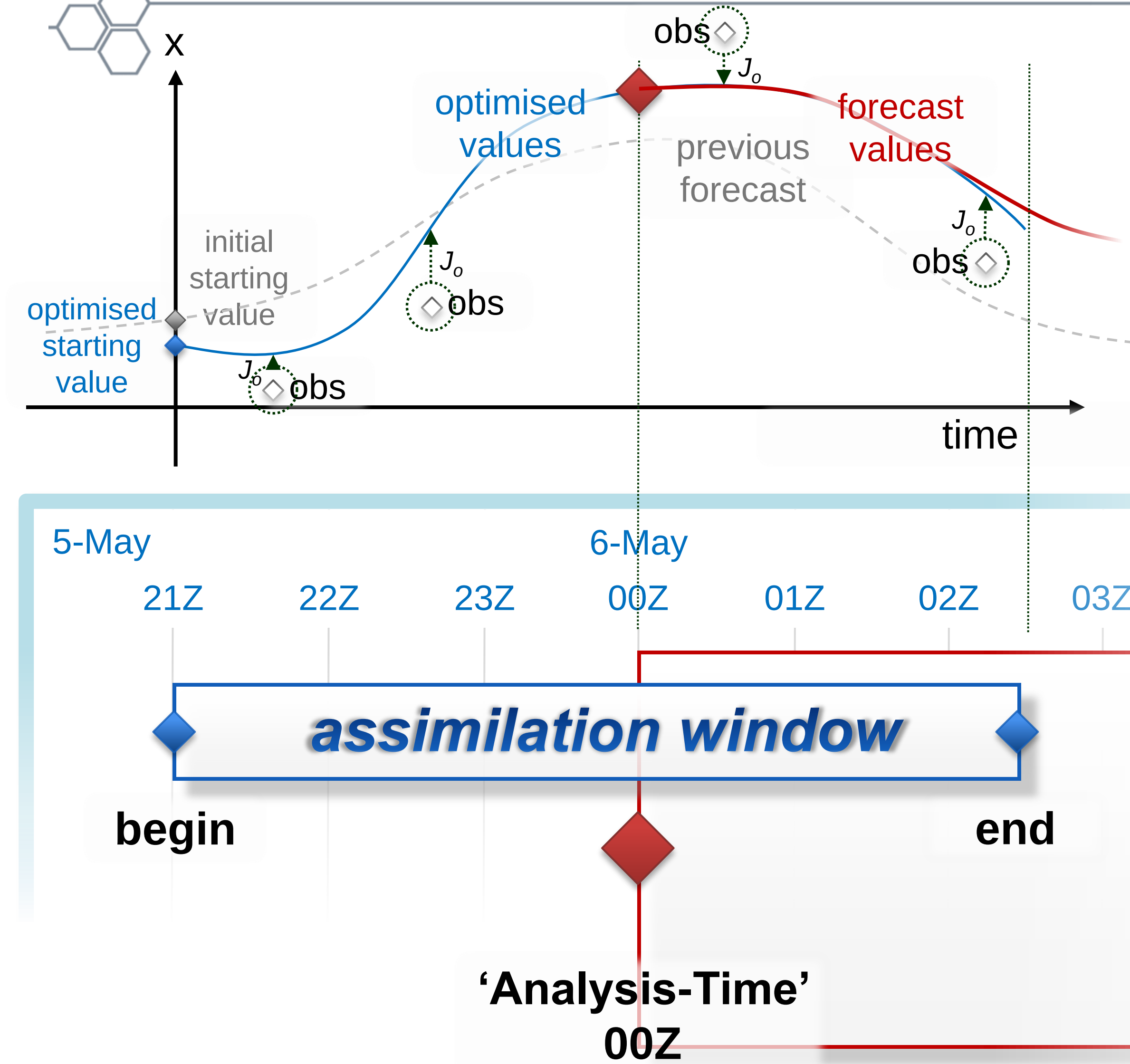
With four-dimensional variational analysis (4DVAR) the influence of an observation in both space AND time is controlled by the model dynamics – thus increasing the realism and (by implication) accuracy of the resulting analysis.

The execution of the 4DVAR assimilation scheme can only begin once all the observations have been collected. However, the assimilation will often begin prior to the datum time in order to pre-process the observations into the correct form for the assimilation scheme.



Note that the green box represents the time during which the assimilation process executes

4DVAR: example assimilation scheme



The illustration shows a how a single parameter (x) may vary through time at a given location.

Using a set of initial conditions – perhaps from a previous forecast – 4DVAR employs a simplified model to estimate how the geophysical parameters may vary throughout the assimilation window. A 'penalty function' (J) for the entire domain of the model is then calculated that describes the error between observations and the estimate. Next, an adjoint model is used to minimise that penalty function across the entire spatio-temporal domain of the assimilation, resulting in a new (slightly more realistic) starting value (here shown at 21Z).

This process iterates, using the model dynamics to re-estimate the variation of geophysical parameters, until the penalty function reaches some specified criteria, at which point, the assimilation is considered to be optimised across the spatio-temporal domain.

The analysis 'snapshot' is chosen from a time-instant toward the middle of the assimilation window where the model state is considered to be more realistic.

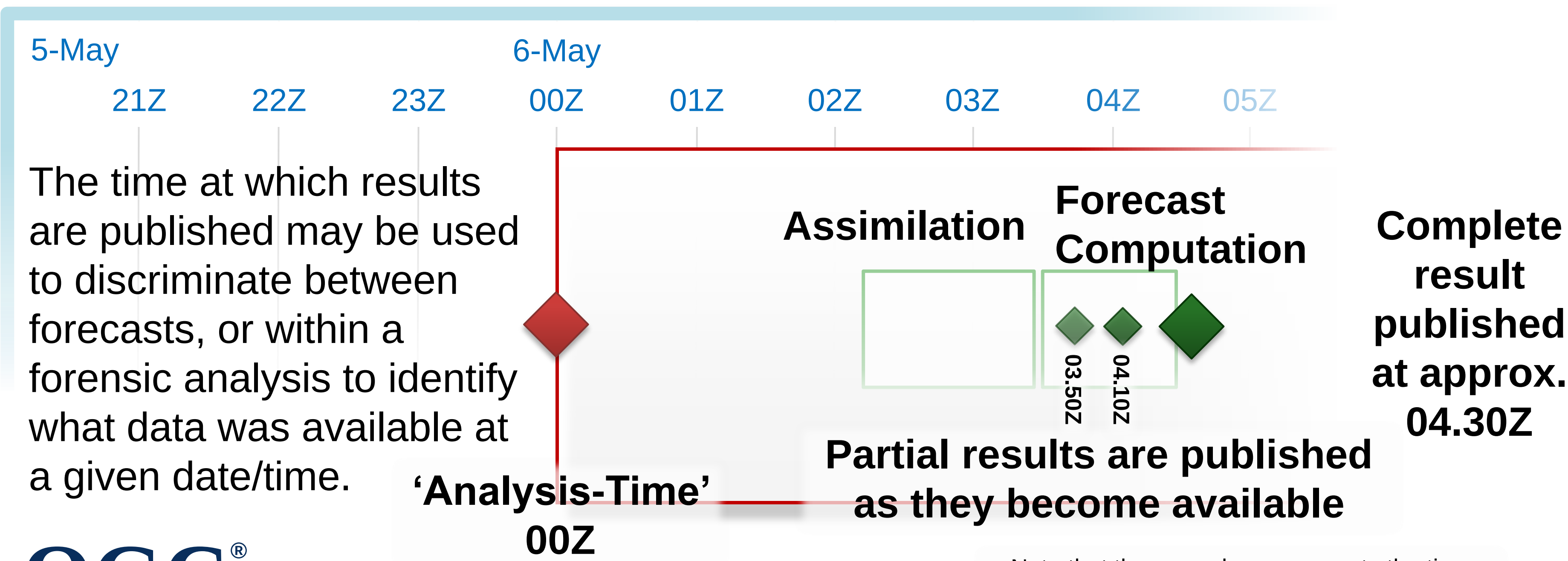
This analysis field is then used to drive the forecast model – noting that minor deviations from the assimilation estimate are to be expected.

When does a forecast simulation finish?

Forecasts are not created instantaneously: the **simulation event** – comprising of assimilation and forecast computation elements – has DURATION.

In this example, the simulation is complete at 2010-05-06T04:30Z

Also note that in many operational forecasting schedules, partial results are released as they become available to enable earlier dissemination of derived products; in this example the first 36-hours of the forecast are released at 03:50Z, with the subsequent 24-hours released 20-minutes later.



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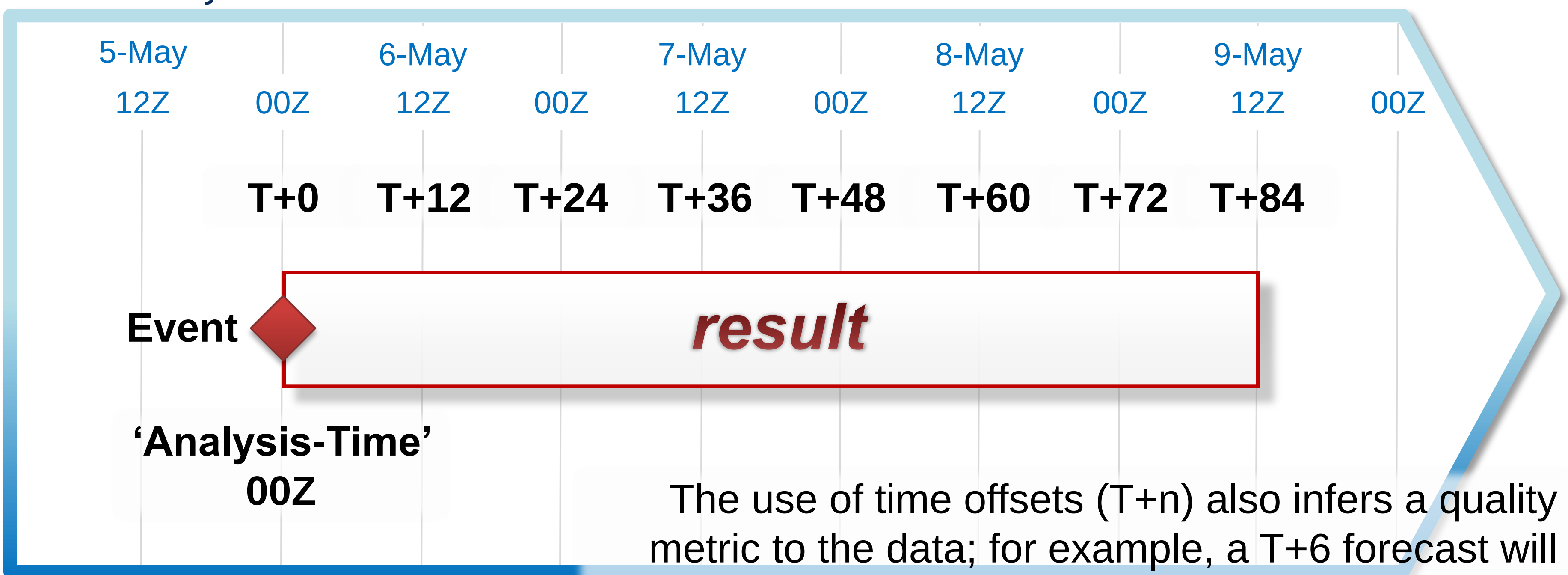
Validity time and use of time offsets

Meteorologists often refer to instants within the time domain of the simulation result as **validity time**; i.e. an *instant of interest* in the simulation result.

Given that the analysis time is used as the main discriminator between forecast model runs, meteorologists often specify **validity time** using offsets from the analysis time; e.g. T+6, T+12 etc.

The analysis time is often referred to as T+0.

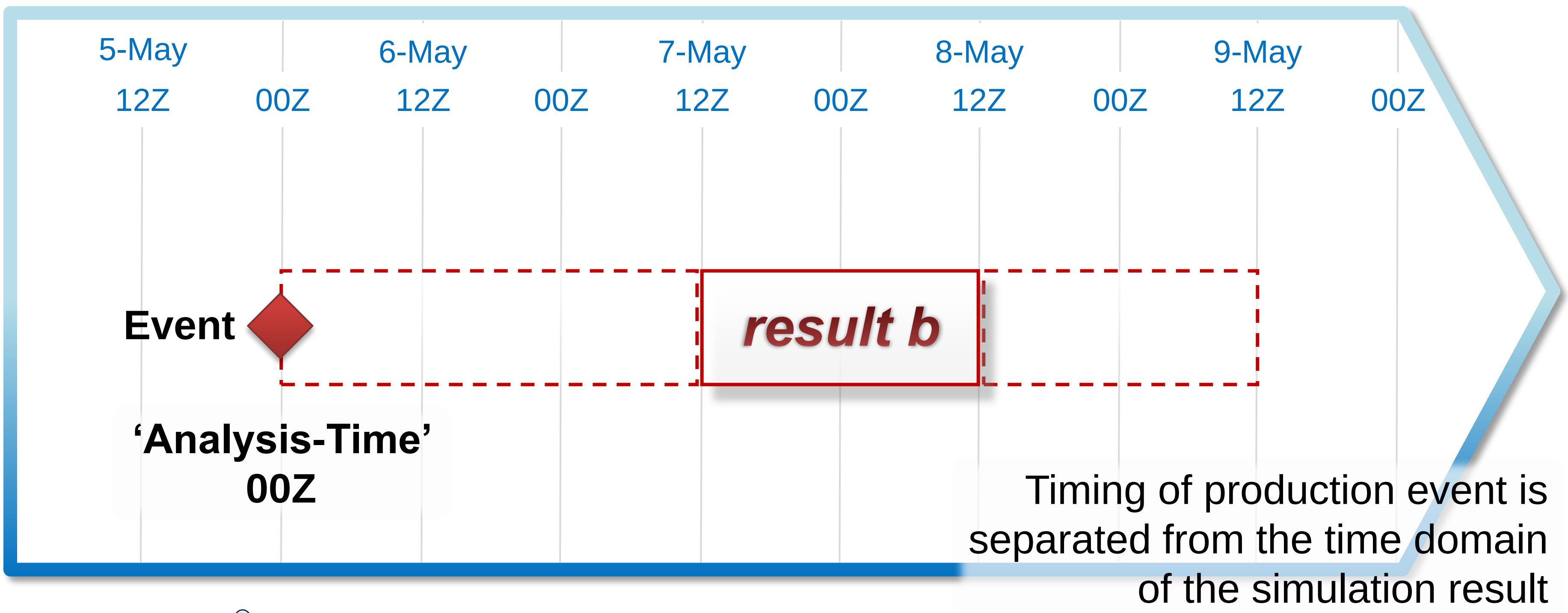


The use of time offsets (T+n) also infers a quality metric to the data; for example, a T+6 forecast will almost always be more accurate than T+60.

Partial Forecasts

There are many instances where a segment of a forecast is released as a separate entity; such as the previous example where forecast hours T+36 to T+60 were released early (labelled below as ‘*result b*’).

In such cases, the time-domain of the result no longer correlates with the **analysis time**.



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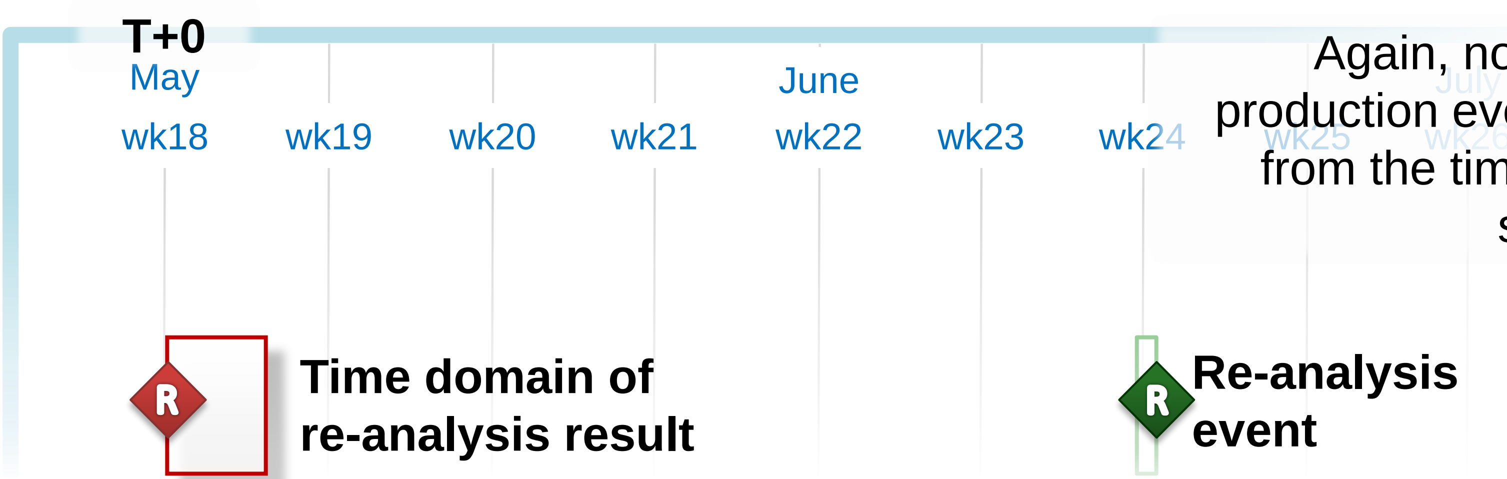
Re-analyses

For re-analyses, where meteorologists re-run simulations of recent or historical events to improve accuracy with the addition of new observations or to test the utility of a new algorithm, there is no correlation between the **analysis time** and the time (or date!) that the re-analysis is executed (i.e. the simulation **event**).



Again, note that timing of production event is separated from the time domain of the simulation result

note: the term ‘re-analysis’ is typically used only to describe the running of numerical simulations to build long-duration climatologies – this example uses the term in a more general sense

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Sequential simulations in operational forecasting

In operational meteorology, numerical weather prediction simulations are executed on regular schedules as new weather observations become available. The temporal extent of each simulation will usually overlap with that of previous and subsequent simulations.

Operational meteorologists routinely compare the results of a sequence of simulations. For example, a meteorologist will ‘verify’ a forecast against observed weather conditions to identify systematic errors in earlier forecasts, or to evaluate the ‘forecast evolution’ from one forecast model run to the next. Alternatively, the (lack of) variation from one forecast to the next of predicted weather conditions at a specific point in space and time can be used to infer a level of confidence in the accuracy of a forecast.

For these reasons, operational meteorologists tend to retain the results of sequential simulations (‘forecast model runs’) for comparison. The term for this aggregated dataset is ‘**forecast model run collection**’.

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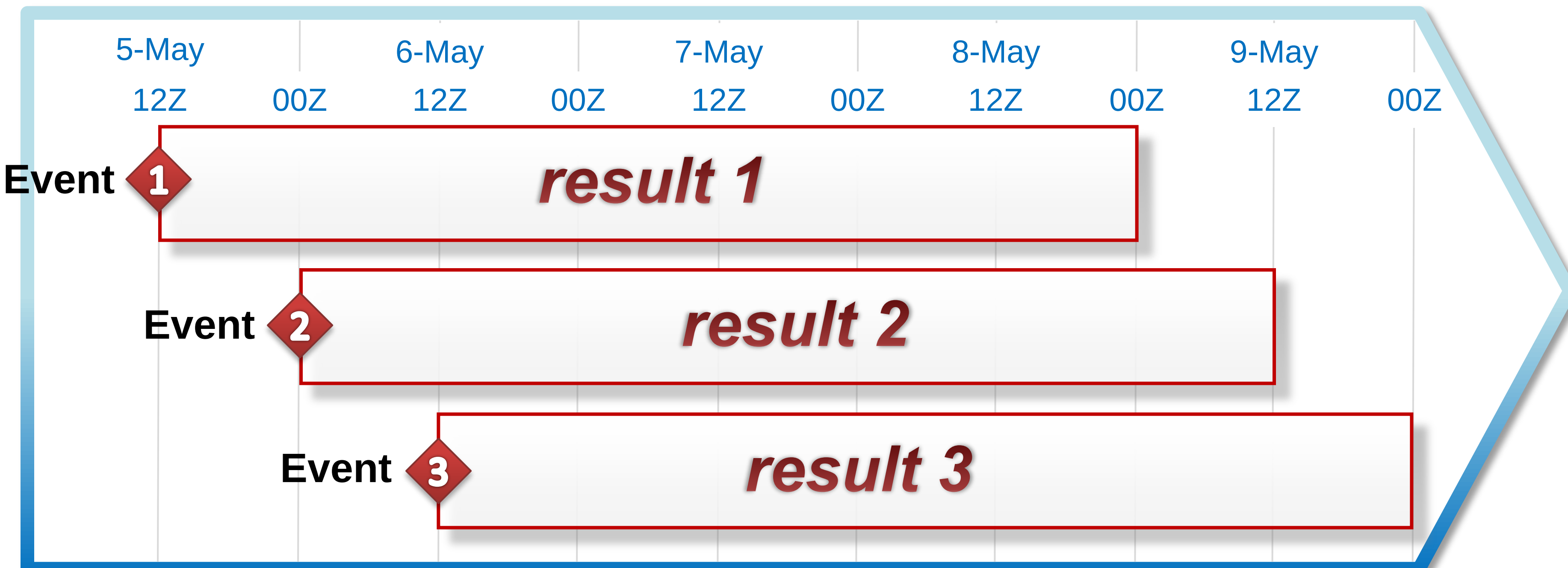
Forecast Model Run Collection

Forecast model run collection (FMRC) example:

- A forecast model is repeatedly executed at 12-hour intervals
- Each simulation describes the future weather conditions for an 84-hour period
- The time domains of each simulation result overlap

Each simulation **result** is coupled to a specific simulation **event** (i.e. observation instance)



FMRC: overlapping results

For our example forecast model, let us assume that:

- the **result** is a gridded coverage (ISO 19123 CV_DiscreteGridPointCoverage)
- the **featureOfInterest** is the atmosphere within the North Atlantic European region
- the **observedProperty** is Temperature, measured in ^{o}K (Kelvin)

The situation of overlapping coverage domains of the **result** objects from a forecast model run collection is analogous to having different coverage datasets derived from multiple observing instruments – such as a radar mosaic.

The crucial point is that **both** cases should relate each coverage dataset explicitly to the ***observation* event** that they derive from – noting that OM_Observation, as we have seen, appropriate for describing forecasts too.

Each **forecast model run** relates to specific OM_Observation and CV_DiscreteGridPointCoverage objects. Our example would require THREE instances of **OM_Observation*** and, consequently, THREE distinct **coverage results**.

* assuming the Analyses are not modelled explicitly – see later

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1. Introduction to problem space, common terminology
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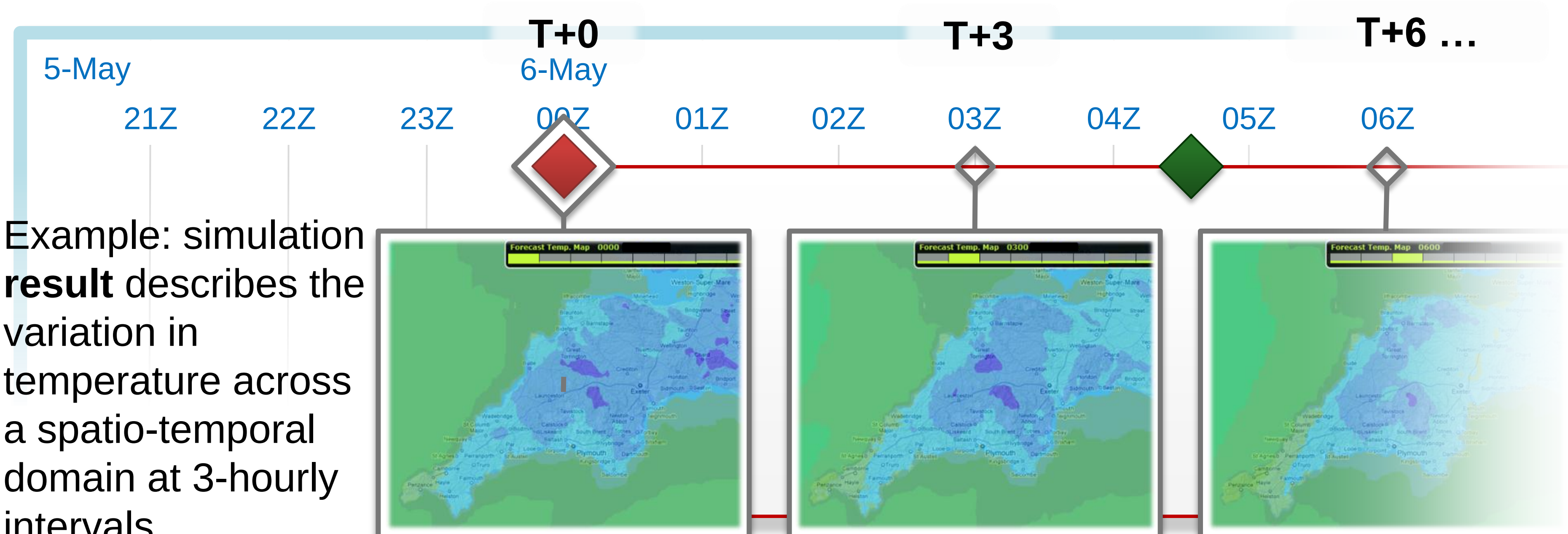
Simulation: metadata & results

Clearly, the **result** of the simulation provides the data required for analysis; in the case of our example (below) this is a temperature coverage.

However, it is metadata about the simulation **event** that enables an analyst to distinguish *between* results.

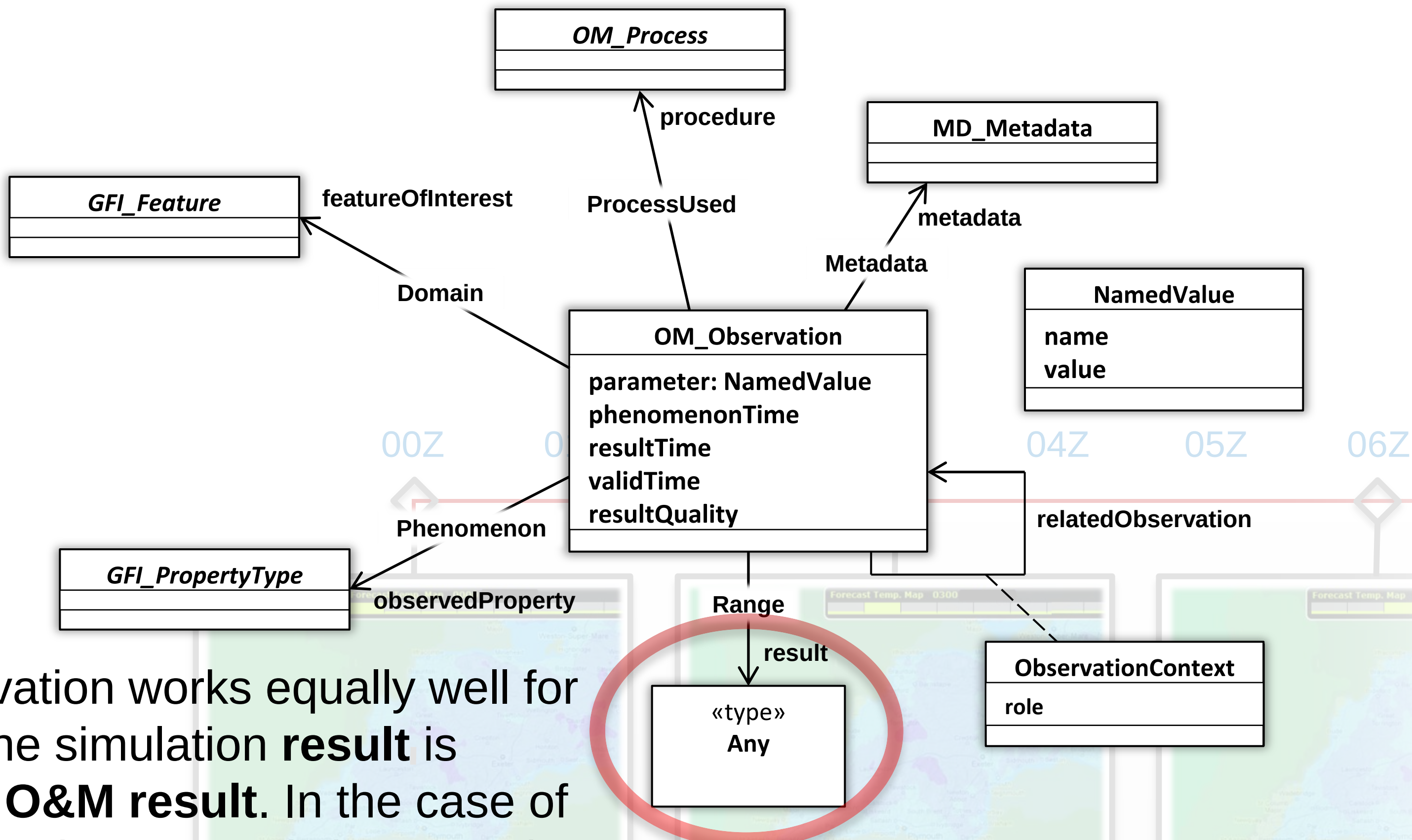
ISO 19156 Observations and Measurements provides a standard mechanism to describe the metadata for a simulation event …



Example: simulation **result** describes the variation in temperature across a spatio-temporal domain at 3-hourly intervals

ISO 19156 Observations and Measurements

An Observation is an **EVENT** whose Result is an estimate of the value of some Property of the Feature-of-interest, obtained using a specified Procedure



OM_Observation works equally well for forecasts; the simulation **result** is captured in **O&M result**. In the case of our example, the result will be a spatio-temporal temperature coverage

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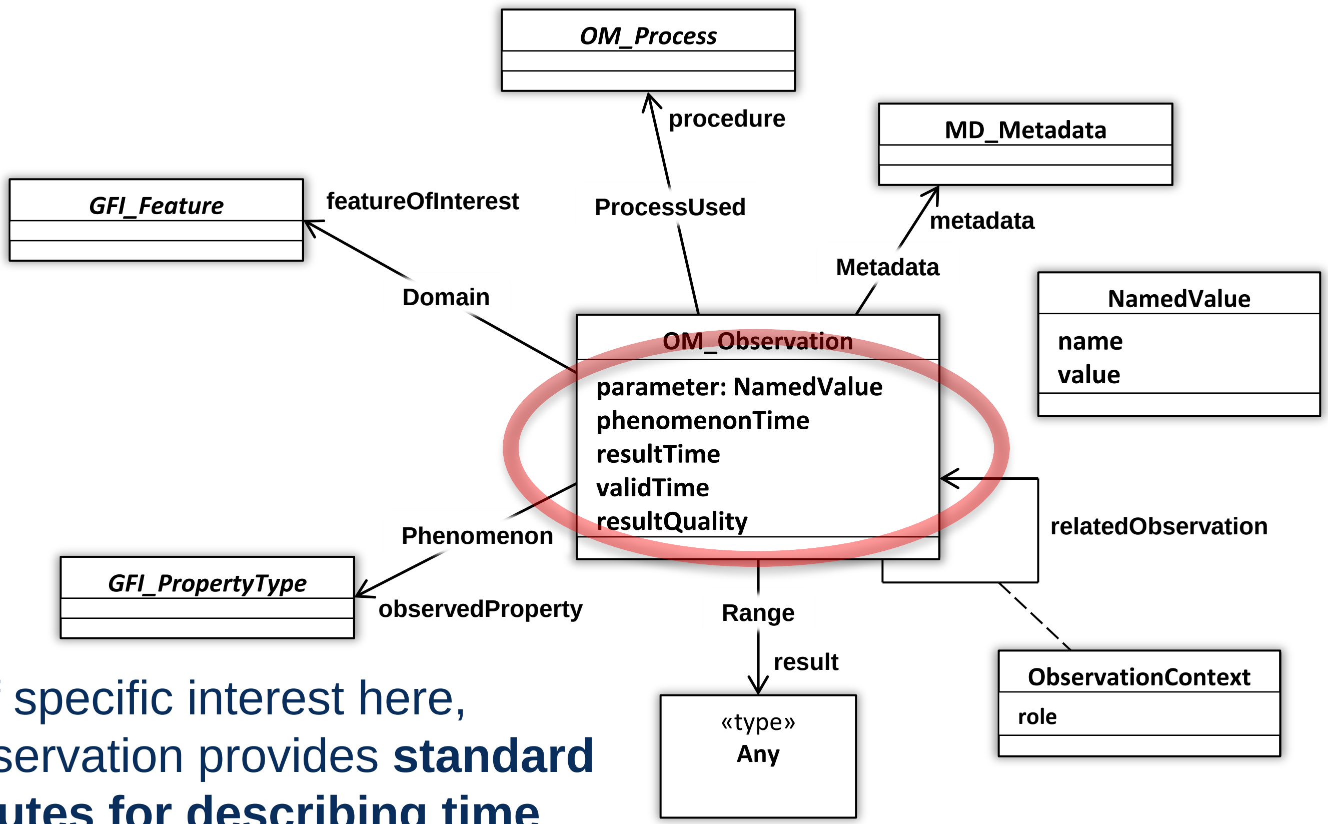
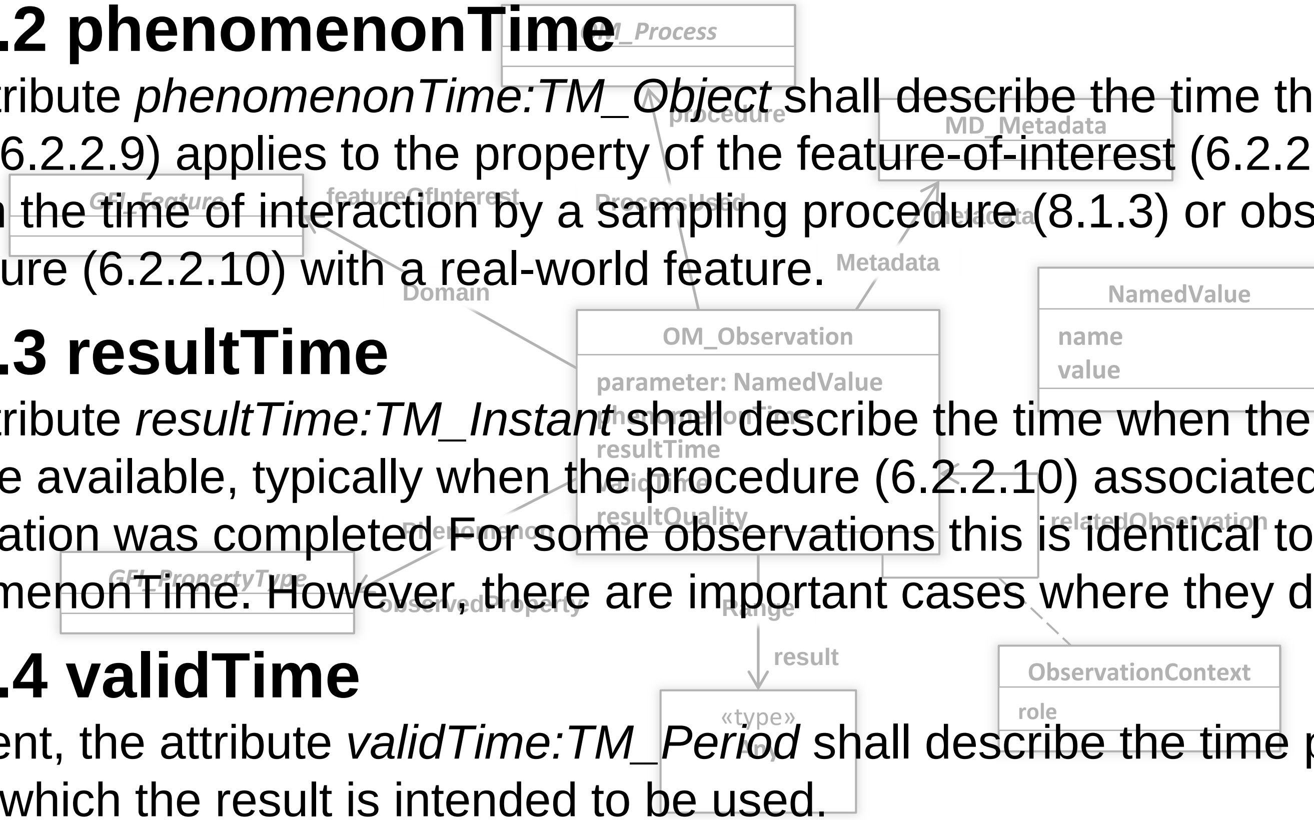
ISO 19156 Observations and Measurements

The Observations and Measurements *pattern* provides a standard mechanism to capture the metadata associated with an observation event.



Of specific interest here, OM_Observation provides **standard attributes for describing time entities** associated with the meteorological domain …

ISO 19156 Observations and Measurements



6.2.2.2 phenomenonTime

The attribute *phenomenonTime:TM_Object* shall describe the time that the result (6.2.2.9) applies to the property of the feature-of-interest (6.2.2.7). This is often the time of interaction by a sampling procedure (8.1.3) or observation procedure (6.2.2.10) with a real-world feature.

6.2.2.3 resultTime

The attribute *resultTime:TM_Instant* shall describe the time when the result became available, typically when the procedure (6.2.2.10) associated with the observation was completed. For some observations this is identical to the phenomenonTime. However, there are important cases where they differ.

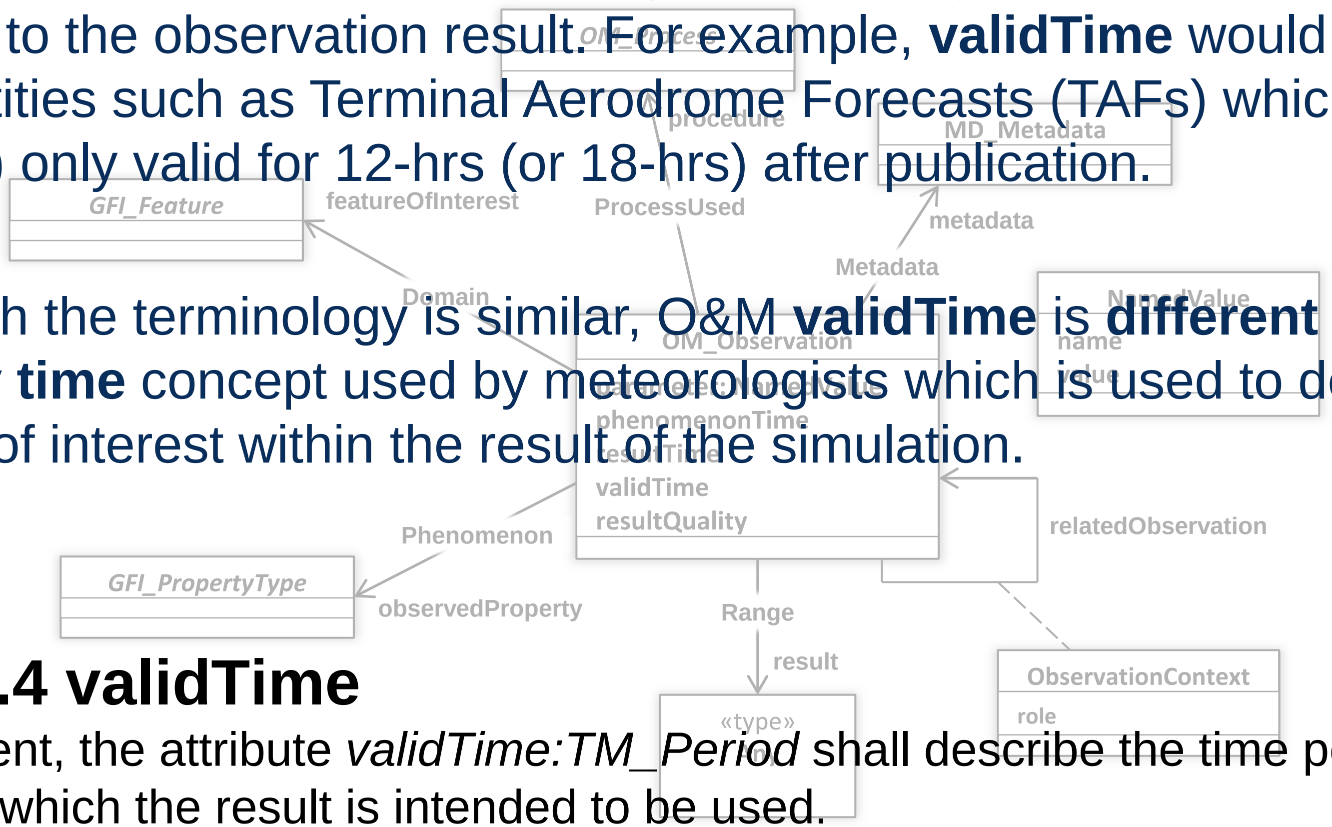
6.2.2.4 validTime

If present, the attribute *validTime:TM_Period* shall describe the time period during which the result is intended to be used.

O&M validTime

O&M **validTime** describes legal or practical usage constraints that are applied to the observation result. For example, **validTime** would be used with entities such as Terminal Aerodrome Forecasts (TAFs) which are (legally) only valid for 12-hrs (or 18-hrs) after publication.

Although the terminology is similar, O&M **validTime** is **different** to the **validity time** concept used by meteorologists which is used to describe an instant of interest within the result of the simulation.



6.2.2.4 validTime

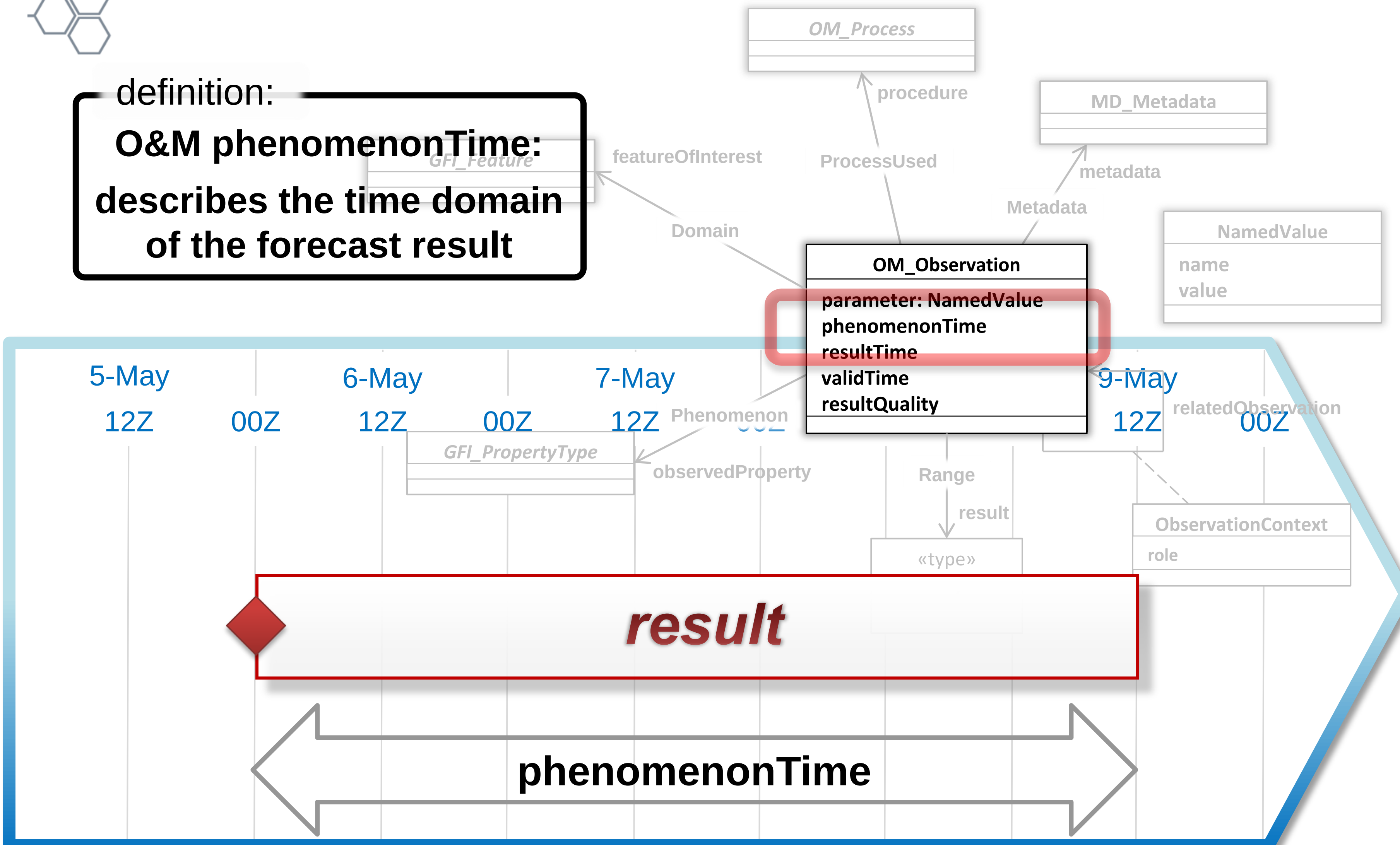
If present, the attribute *validTime:TM_Period* shall describe the time period during which the result is intended to be used.

O&M phenomenonTime

definition:

O&M phenomenonTime:

describes the time domain of the forecast result

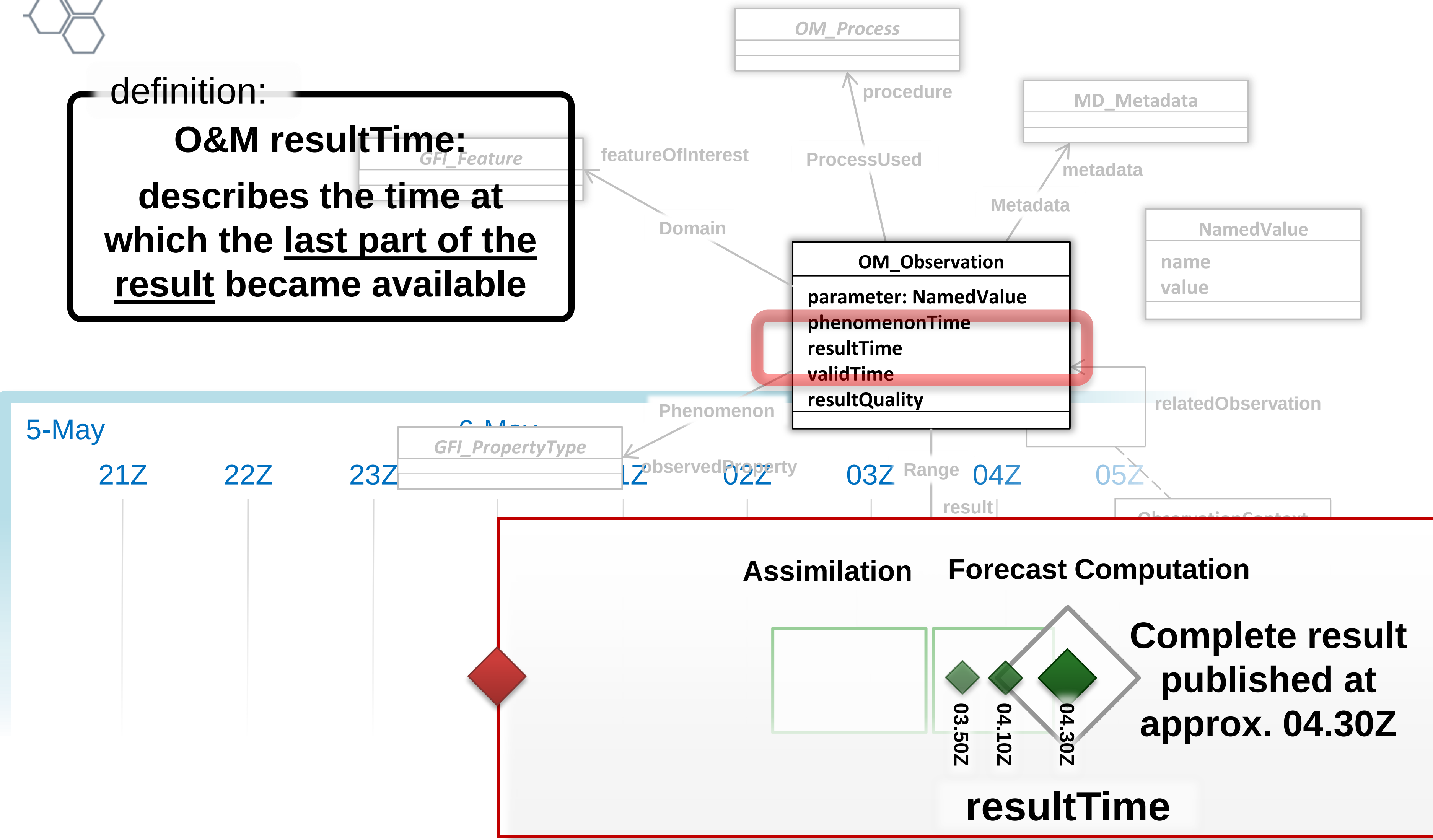


O&M resultTime

definition:

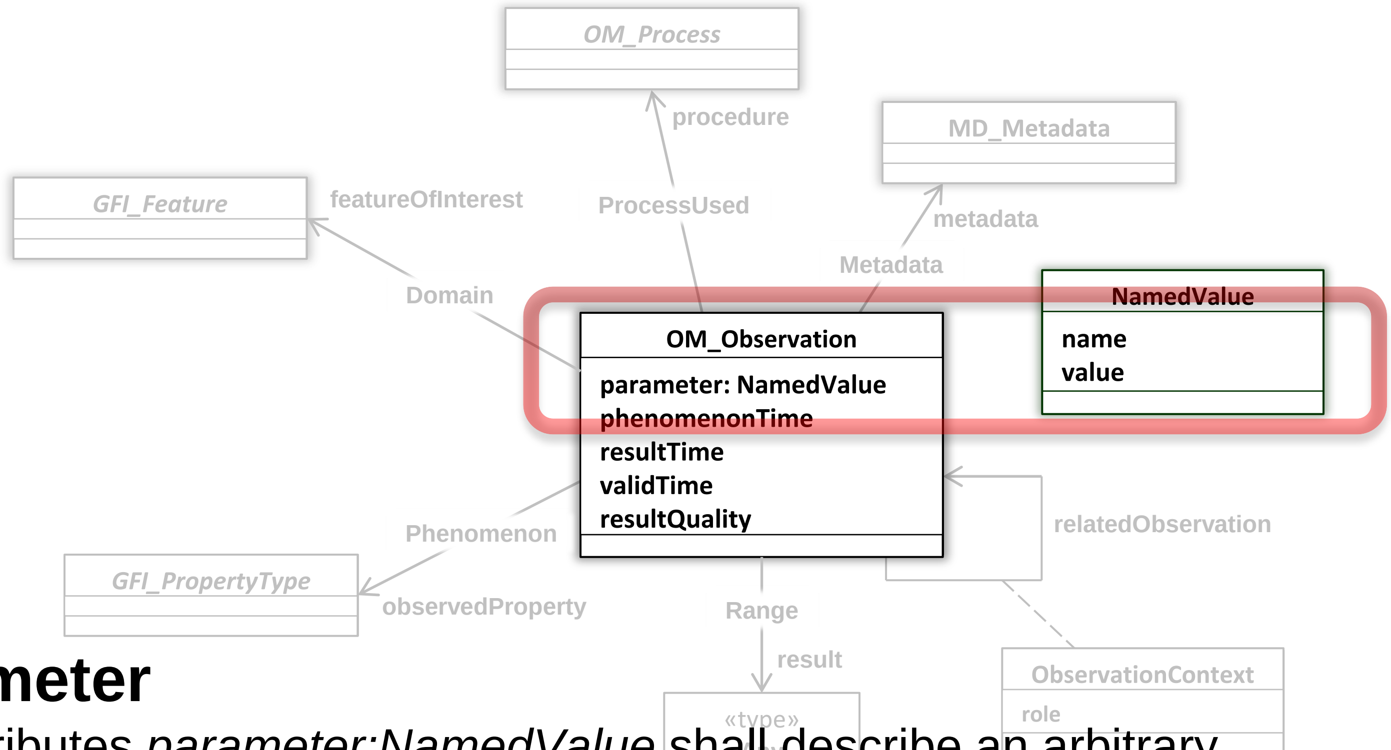
O&M resultTime:

describes the time at which the last part of the result became available



Note that the green box represents the time during which the simulation process executes

O&M parameter



6.2.2.5 parameter

If present, the attributes *parameter:NamedValue* shall describe an arbitrary event-specific parameter. This might be an environmental parameter, an instrument setting or input, or an event-specific sampling parameter that is not tightly bound to either the feature-of-interest (6.2.2.7) or to the observation procedure (6.2.2.10). To avoid ambiguity, there shall be no more than one parameter with the same name.

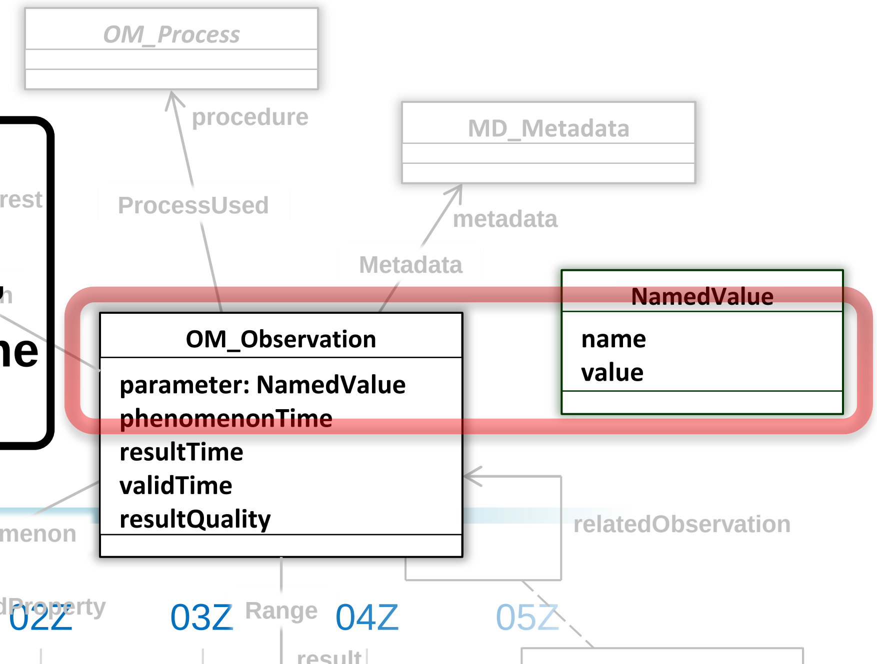
O&M parameter: analysisTime

definition:

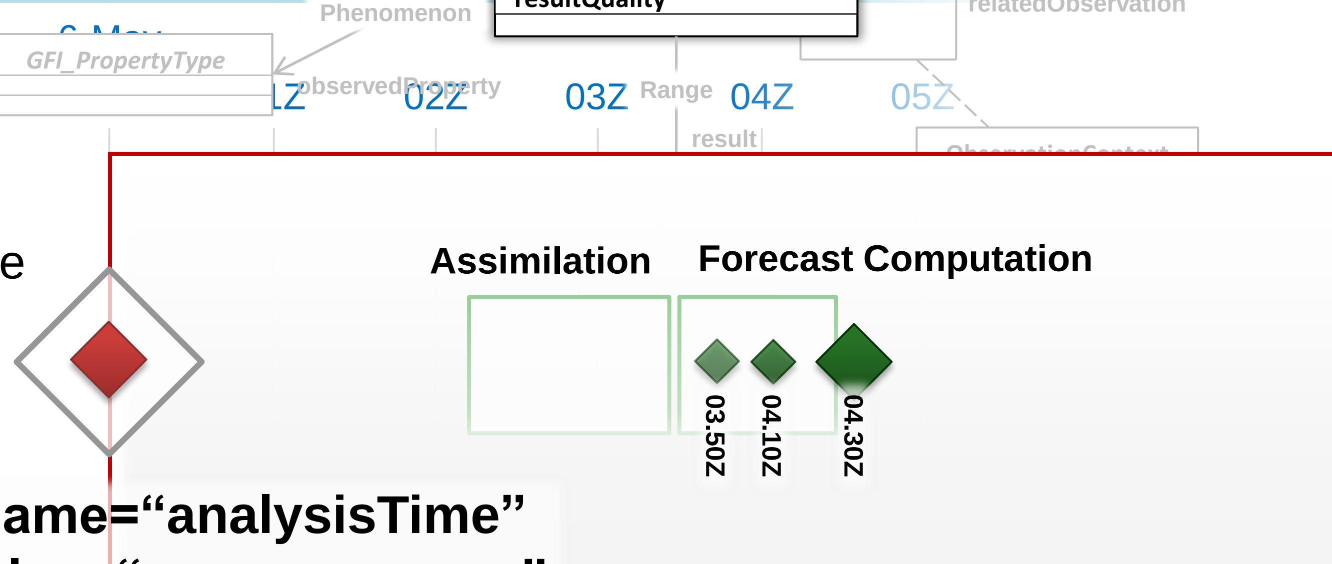
O&M parameter:

where parameter.name = "analysisTime",

parameter.value describes the analysis time



parameter is used to express the analysis time as an "arbitrary event-specific parameter"



parameter.name="analysisTime"
parameter.value="2010-05-06T00:00Z"

Note that the green box represents the time during which the simulation process executes

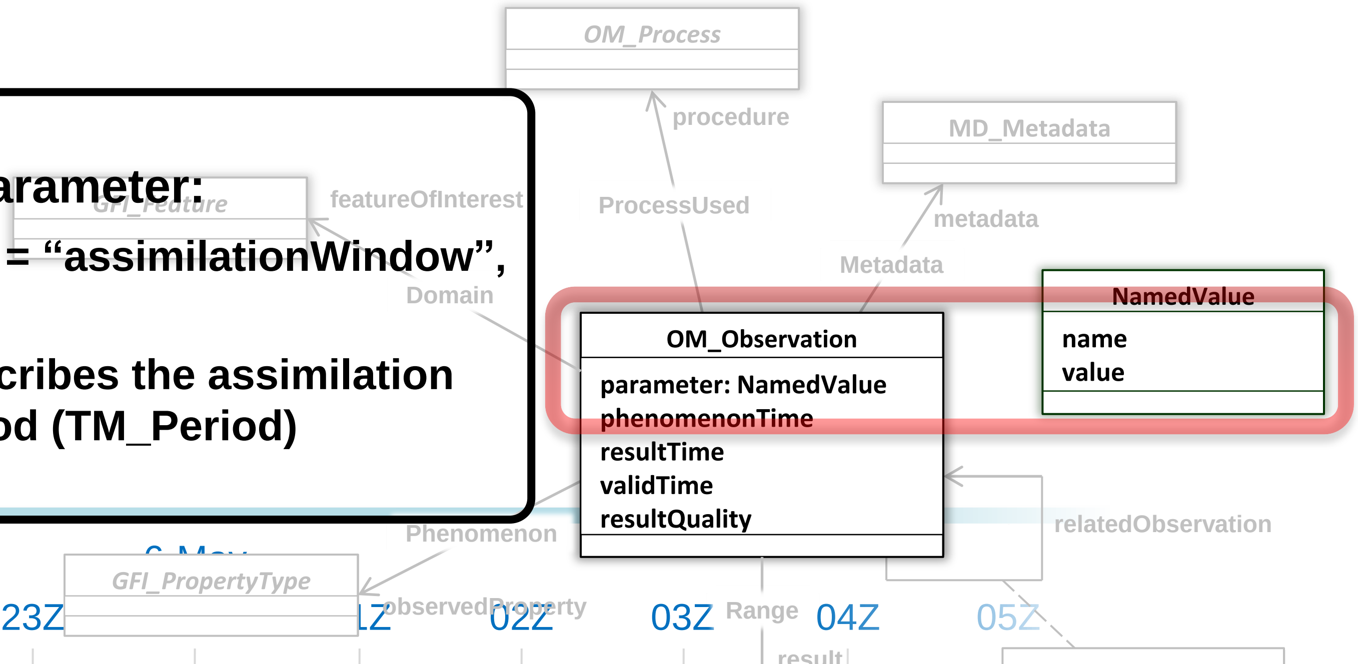
O&M parameter: assimilationWindow

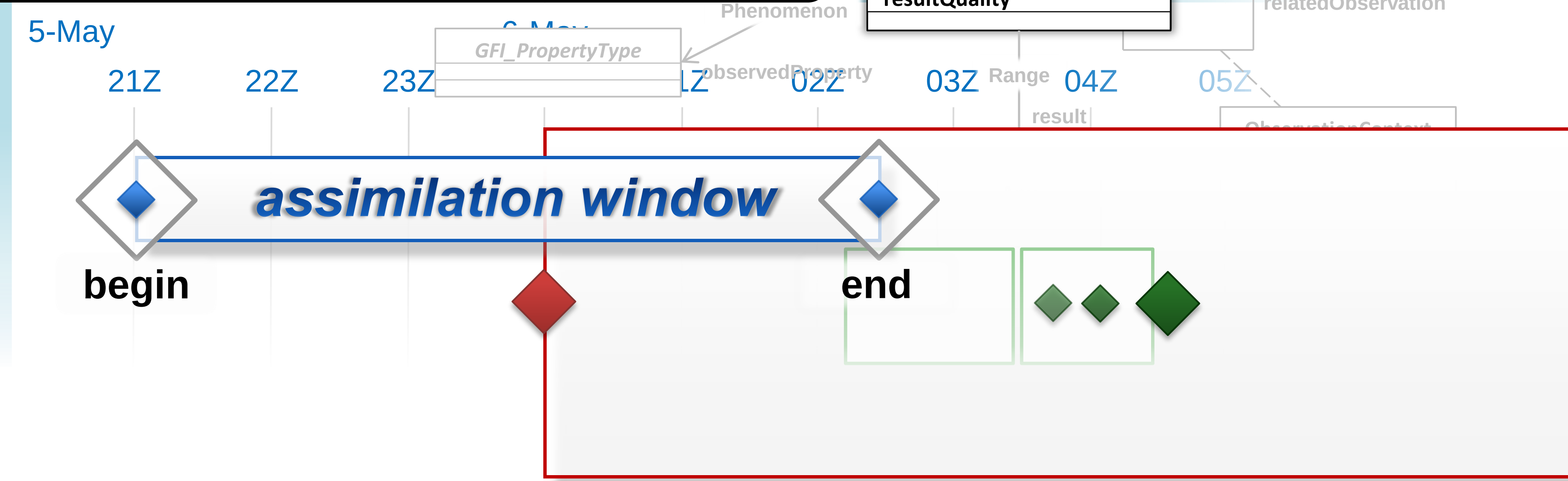
definition:

O&M parameter:

where parameter.name = "assimilationWindow",

parameter.value describes the assimilation window period (TM_Period)





Note that the green box represents the time during which the simulation process executes

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Example OM_Observation object

Using the example from previous slides:

- A numerical weather model simulation starts at 2010-05-06T00:00Z
- This simulation will describe the future weather conditions over the subsequent 84-hour period until 2010-05-09T12:00Z
- Observations are assimilated into the numerical model until 2010-05-06T03:00Z
- The ‘analysis’ of weather conditions at 2010-05-06T00:00Z (i.e. the input conditions for the forecast computation) completes at 2010-05-06T03:35Z
- The simulation then predicts the future atmospheric state (i.e. the forecast), producing interim results for the first 36-hours at 03:50Z and the next 24-hours (T+36 to T+60) at 04:10Z
- The simulation finally completes at 04:30Z with the publication of the final 24-hour segment of the result (T+60 to T+84)

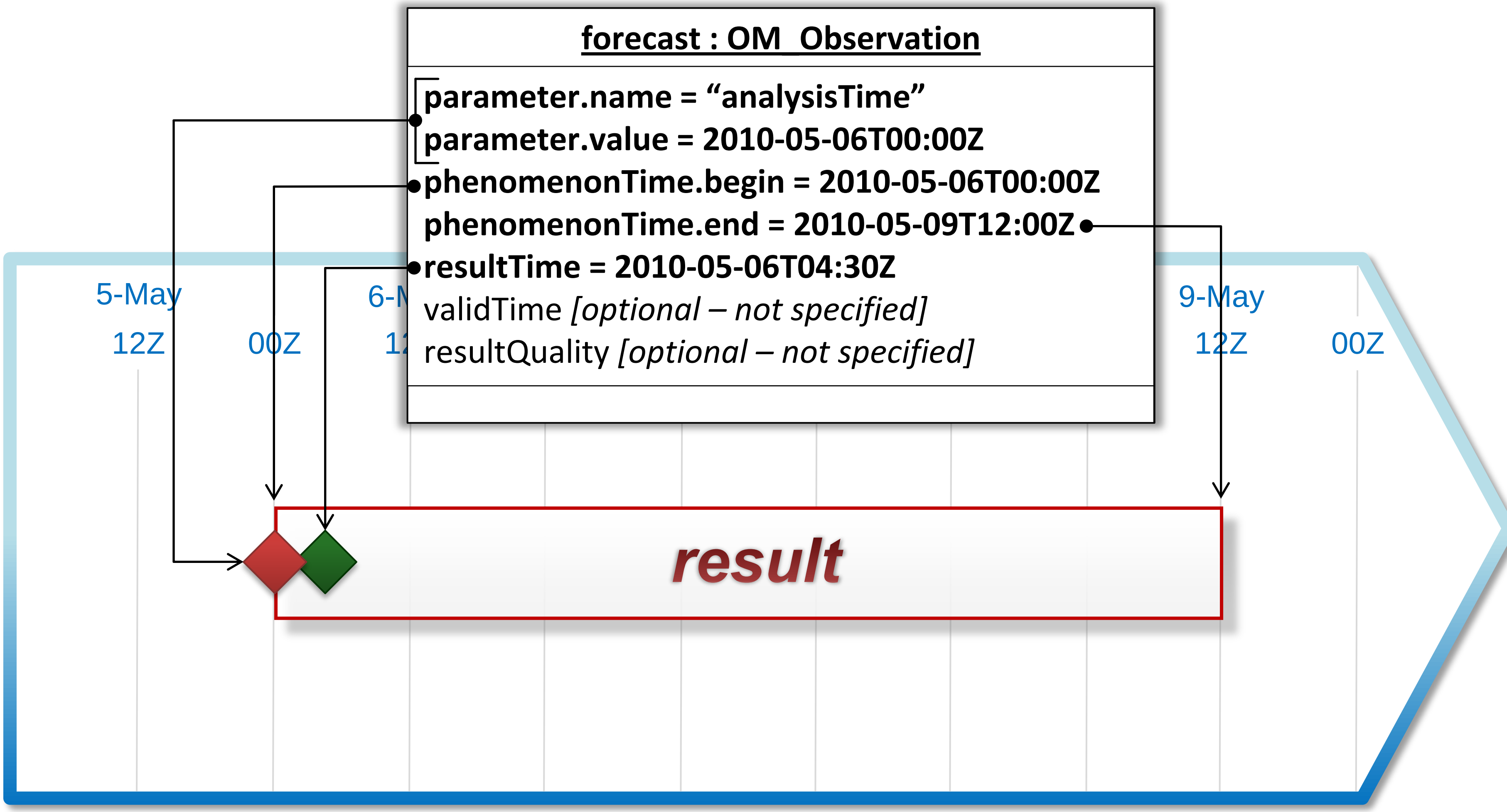
analysisTime = 2010-05-06T00:00Z

phenomenonTime.begin = 2010-05-06T00:00Z
phenomenonTime.end = 2010-05-09T12:00Z

resultTime = 2010-05-06T04:30Z

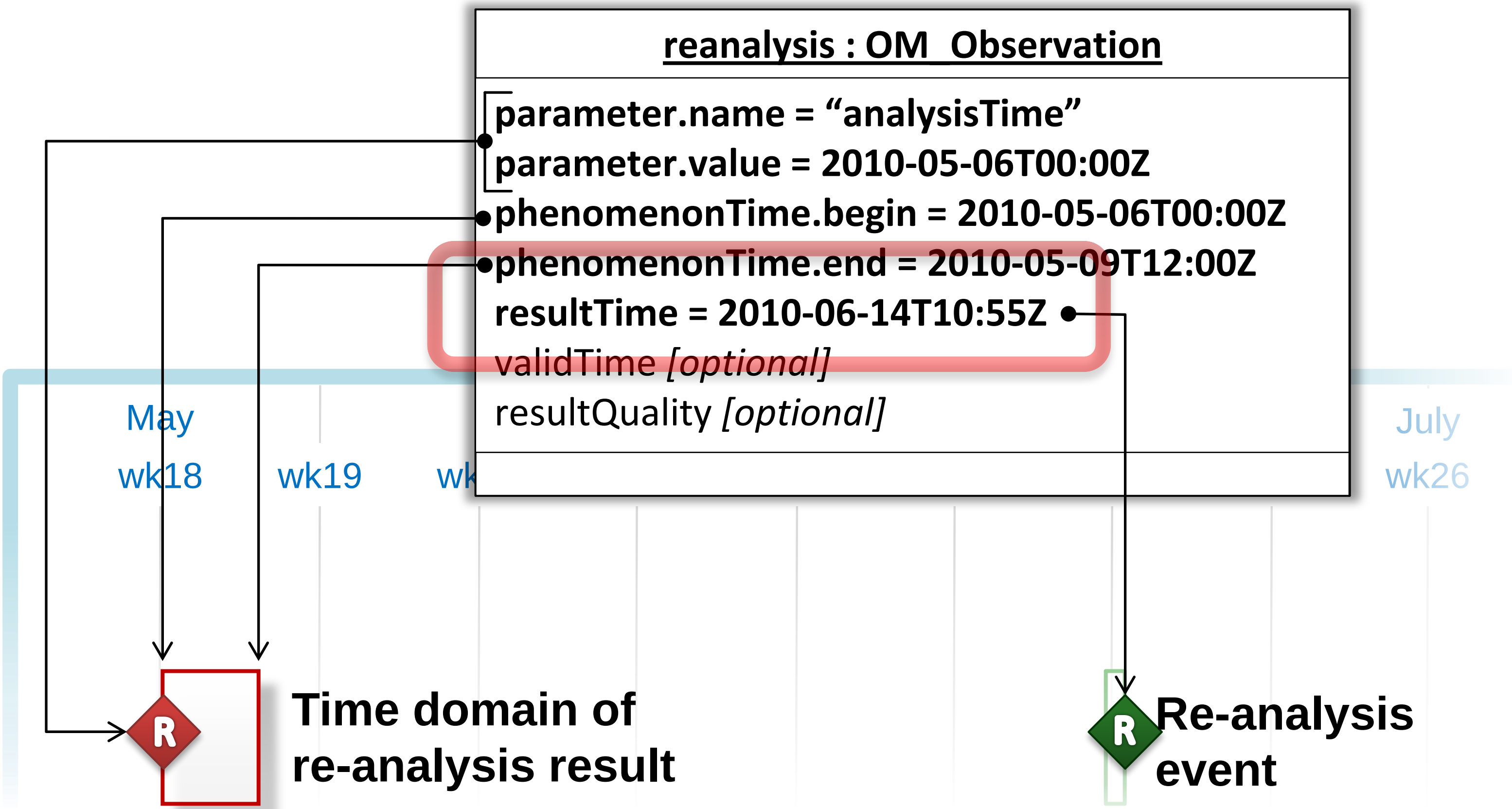
Example OM_Observation object: ‘normal’ forecast

associated objects are not shown to aid clarity



Example OM_Observation object: re-analysis

associated objects are not shown to aid clarity



note that only the resultTime has changed; thus enabling the original forecast event to be discriminated from the reanalysis event

Note that the green box represents the time during which the reanalysis process executes

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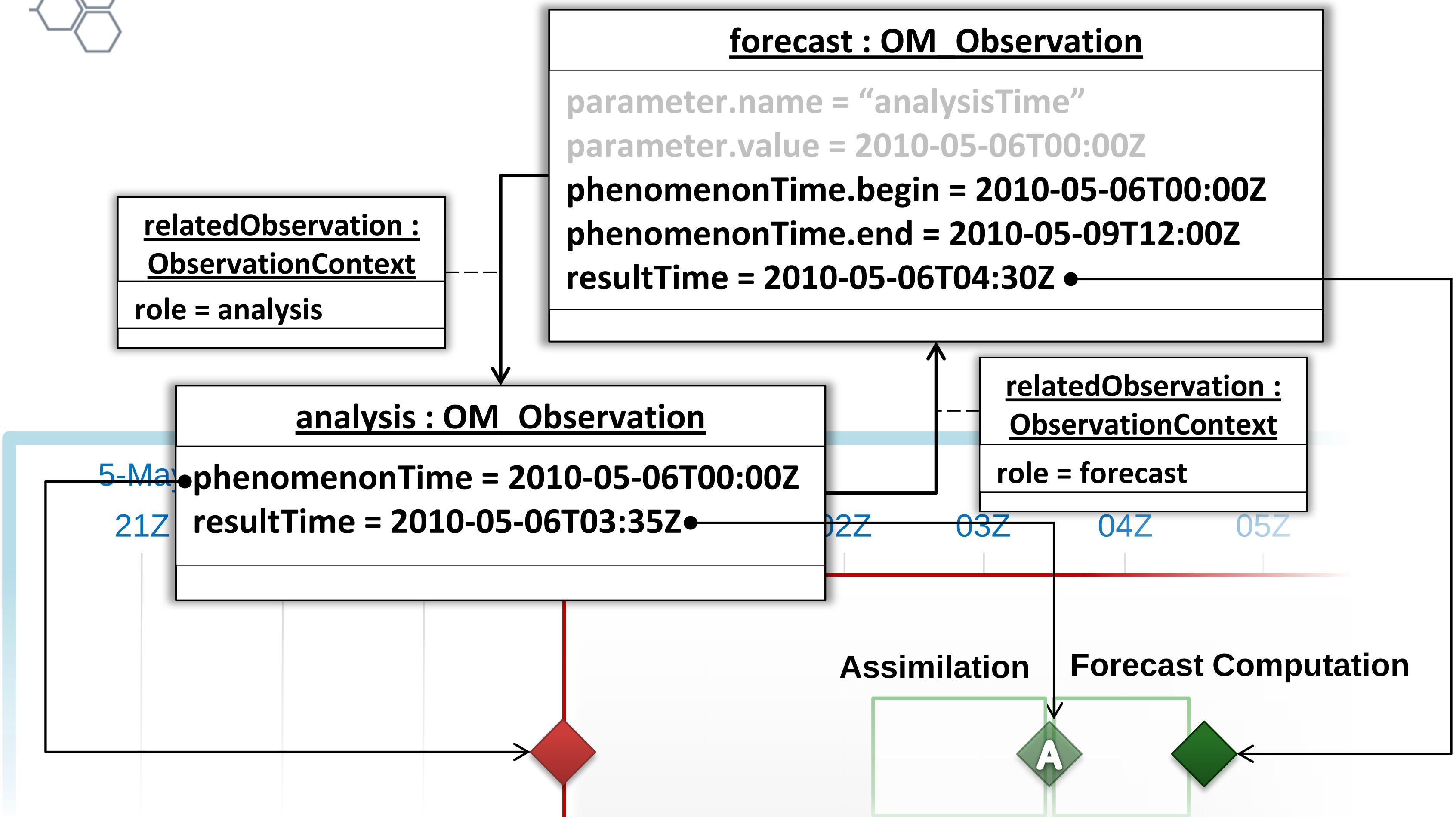
Explicit modelling of Analysis event



In some situations it may be desirable and/or necessary to explicitly model the analysis entity

Note that the green box represents the time during which the simulation process executes

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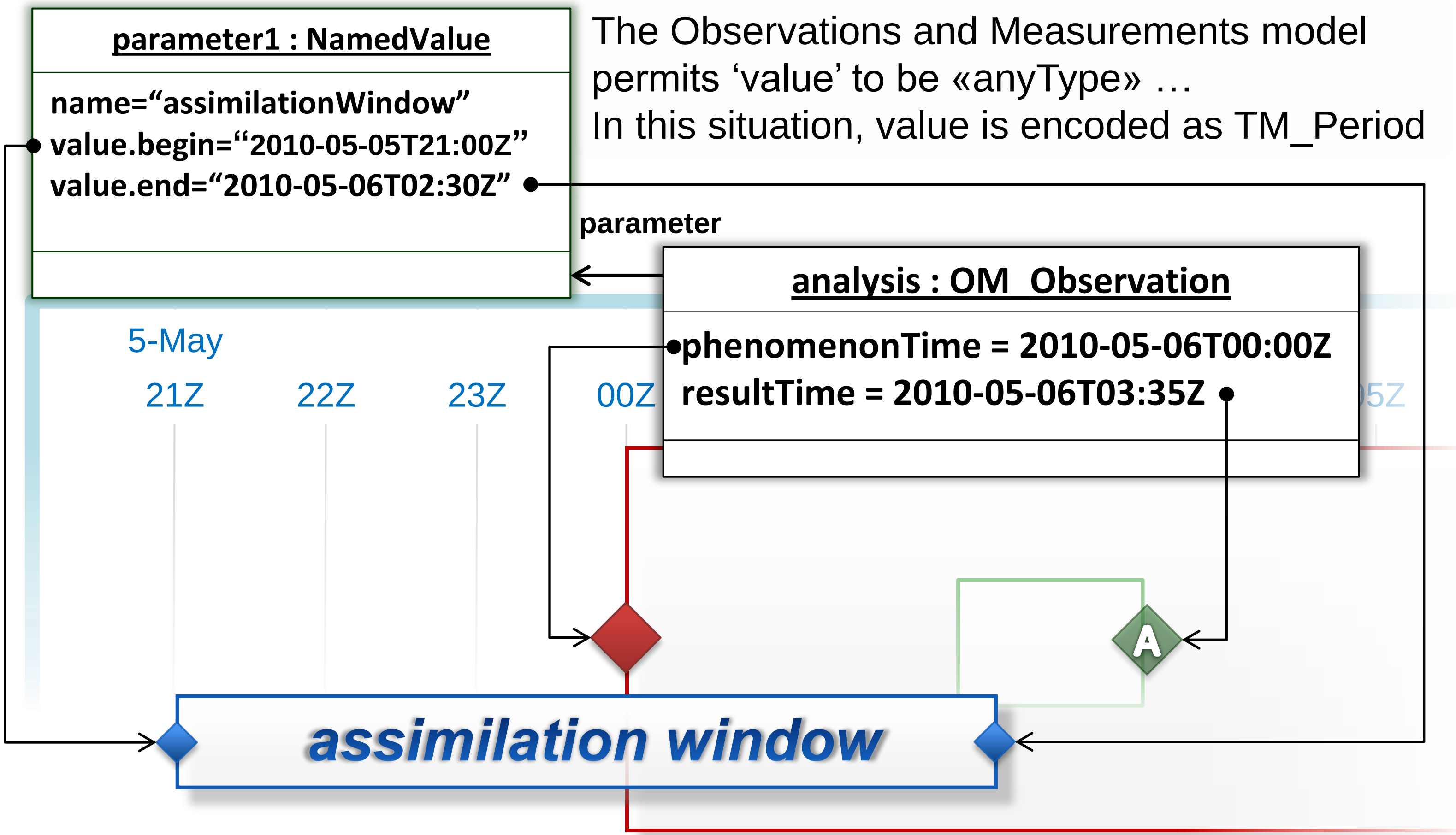
Explicit modelling of Assimilation Window

In some situations it may be desirable and/or necessary to explicitly model the assimilation window used in deriving the analysis entity

The Observations and Measurements model permits ‘value’ to be «anyType» …
In this situation, value is encoded as TM_Period



Note that the green box represents the time during which the assimilation process executes

Explicit modelling of *interim* forecast results

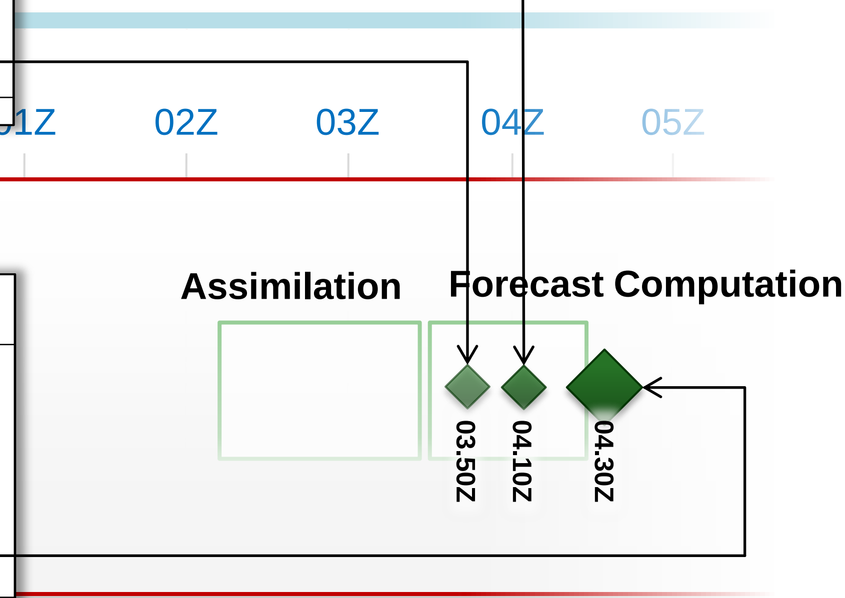
forecast-a: T+0 to T+36
forecast-b: T+36 to T+60
forecast-c: T+60 to T+84

forecast-b : OM_Observation

parameter.name = "analysisTime"
parameter.value = 2010-05-06T00:00Z
phenomenonTime.begin = 2010-05-07T12:00Z
phenomenonTime.end = 2010-05-08T12:00Z
resultTime = 2010-05-06T04:10Z

forecast-a : OM_Observation

parameter.name = "analysisTime"
parameter.value = 2010-05-06T00:00Z
phenomenonTime.begin = 2010-05-06T00:00Z
phenomenonTime.end = 2010-05-07T12:00Z
resultTime = 2010-05-06T03:50Z

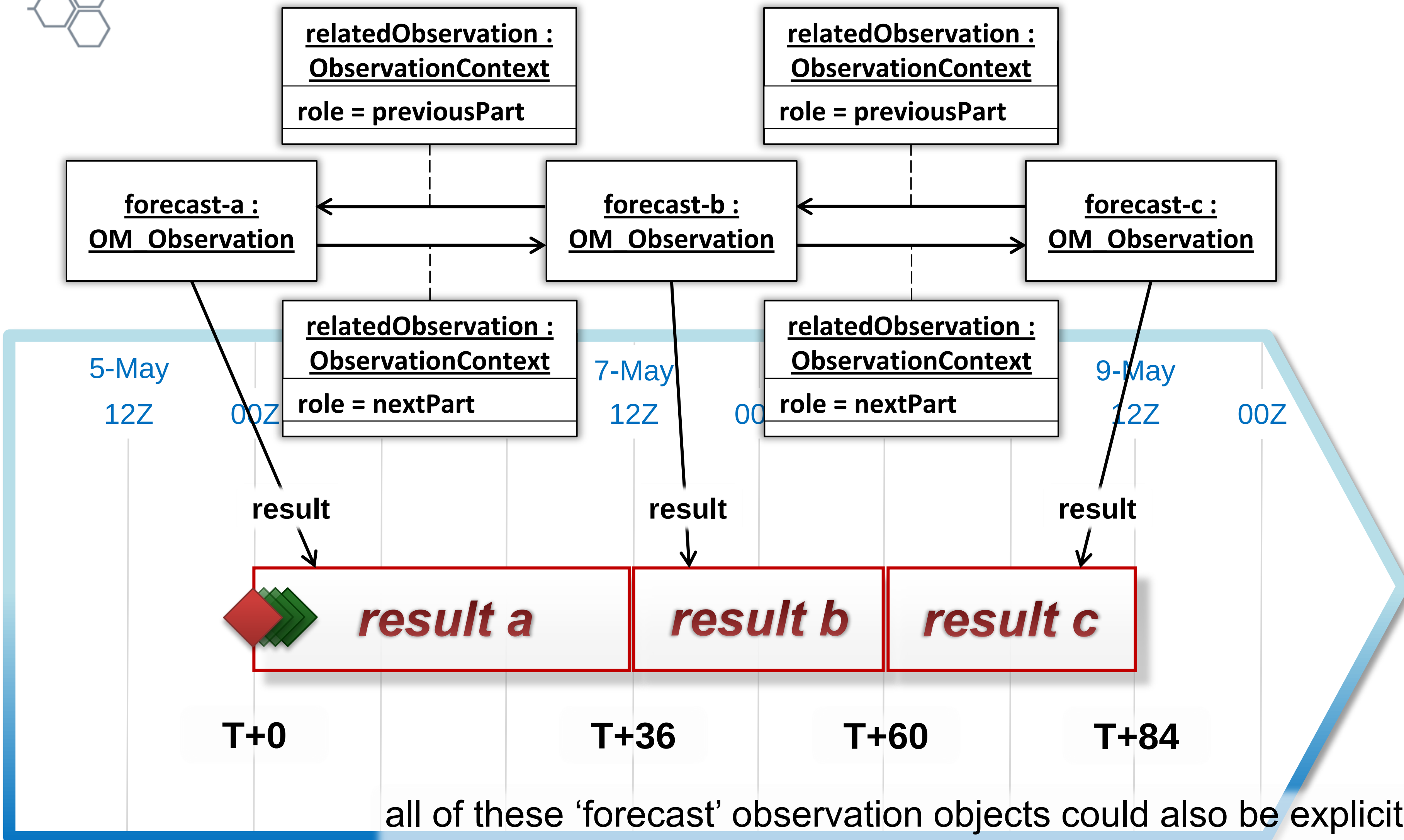


forecast-c : OM_Observation

parameter.name = "analysisTime"
parameter.value = 2010-05-06T00:00Z
phenomenonTime.begin = 2010-05-08T00:00Z
phenomenonTime.end = 2010-05-09T12:00Z
resultTime = 2010-05-06T04:30Z

Note that the green box represents the time during which the simulation process executes

Explicit modelling of *interim* forecast results



all of these ‘forecast’ observation objects could also be explicitly related to an ‘analysis’ observation object if deemed necessary

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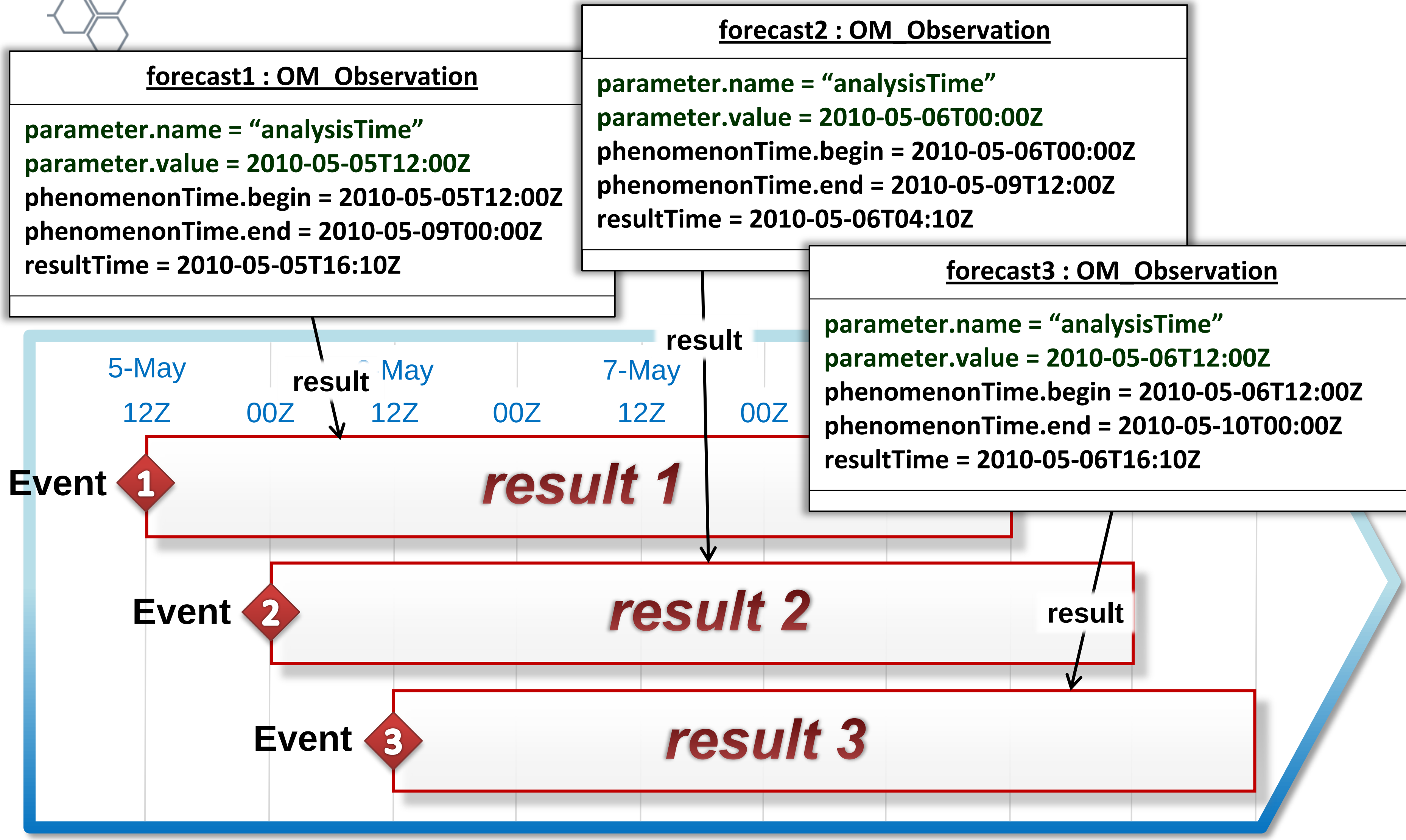
Explicit modelling of members of Forecast Model Run Collection



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