4.7 Development of a Link From the 4-D cube to the Derived Sensible Weather Elements

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ABSTRACT

Beyond meeting Initial Operating Capability (IOC) goals, the most important task facing the IFPS/GFE team at WFO Anchorage is the development of an objective forecast framework within IFPS/GFE. A major obstacle to the formulation of a systematic methodology is the disconnect between the sensible weather elements in the IFPS "forecast" database and the atmosphere. Stated differently, once a set of sensible weather elements is manipulated, it ceases to be physically associated with a 4-dimensional representation of the atmosphere (the 4-D Cube). This disassociation renders the systematic use of NWP output in subsequent calculations problematic.

Further complicating the IFPS process is the fact that the forecaster is modifying sensible weather elements based on a conceptual model that often diverges from any NWP (best model of the day) 4-D Cube. The result can lead to an incoherent, or inconsistent "forecast" database. This is especially evident as one tracks the evolution of a time-slice of sensible weather elements from Day 7 through Day 1.

This paper is an attempt to provide a framework for future IFPS/GFE development. The framework would allow the forecaster to create a suite of sensible weather element grids that is physically consistent with the 4-D Cube from which it is derived.

This paper attempts to provide a direction and justification for a framework for future IFPS/GFE development.

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DISCUSSION

IFPS/GFE initialization is a deterministic, and one-way process (Figure 1) such that:

1. An identical 4-D cube of model data should always produce an identical set of sensible weather elements.

2. The state of the atmosphere cannot be derived (back-engineered) from a given set of sensible weather elements.

3. Once a set of sensible weather elements is modified those sensible weather elements cease to be connected to the 4-D cube of model data from which they were derived.

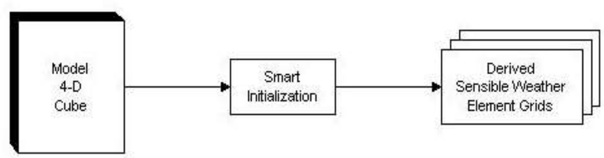

Figure 1. Deterministic, One-Way IFPS/GFE Initialization Process

Points two and three are particularly relevant to the issue of "science" within the IFPS/GFE process. The fundamental question is this: "What is the consequence of modifying a sensible weather element grid?" The answer is likely two-fold. First, the forecaster (hopefully) obtains a sensible weather element grid that is closer to reality for a particular time-slice. The second effect is unanticipated, but important: the sensible weather element grid modified by any of the numerous mathematical tools (called Smart Tools) is now permanently disassociated from the state of the atmosphere from which it was derived (Figure 2).

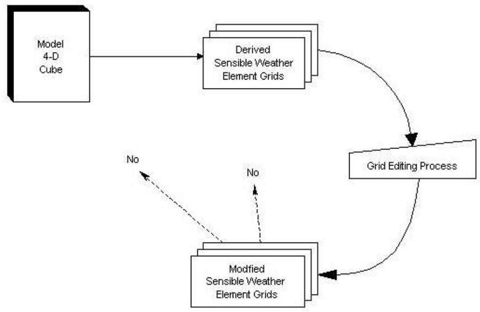

Figure 2. Disconnect Between the Modified Sensible Weather Element Grids and the Model 4-D Cube

The absence of a link between the modified grids and any representation of the atmosphere from which they were derived is critically important, and has broad implications. Forecaster methodology, how a forecaster selects a conceptual model and applies that model to "correct" the NWP model of the day is inextricably tied to the business of product creation. Prior to IFPS/GFE the onus was on the meteorologist to maintain spatial, temporal, and internal consistency of the product suite. Fortunately subjective textual products were sufficiently vague as to blur all but the more glaring discrepancies.

However, GFE/IFPS is inherently, and inexorably objective. SmartTools obey formal rules of programming and logic. A forecaster executing a tool, or procedure (a series of SmartTools executed serially) that employs "raw" model data will necessarily be incoherent, since the modified weather element-to-atmosphere connection does not exist within the IFPS/GFE system. For example Figure 3 represents a temperature field derived from the MesoEta Model via the IFPS/GFE initialization.

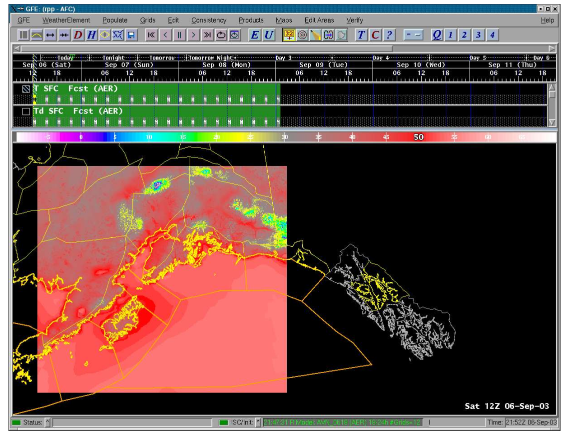

Figure 3 Surface Temperature Field Derived Via GFE Smart Init Process

Figure 4 is the result of using the Assign_Value SmartTool to adjust the Temperature value within the domain. Now all grid points within the domain whose elevation are 50 ft or less have the value of 25F. This example is absurd, of course, but it does serve the purpose of illustrating the issue. Without going into detail regarding the IFPS/GFE initialization process, suffice it to say that a number of model boundary layer fields are used to derive the surface temperature field. However, as Figure 5 simplistically shows, the sounding at any grid point thus adjusted bears little resemblance to the real atmosphere.

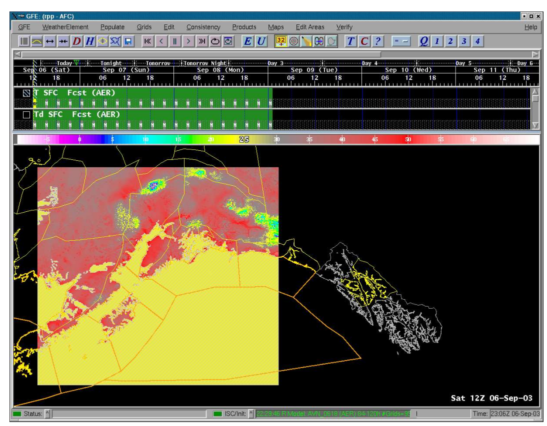

Figure 4 Surface TemperatureFieldModified with a Simple SmartTool

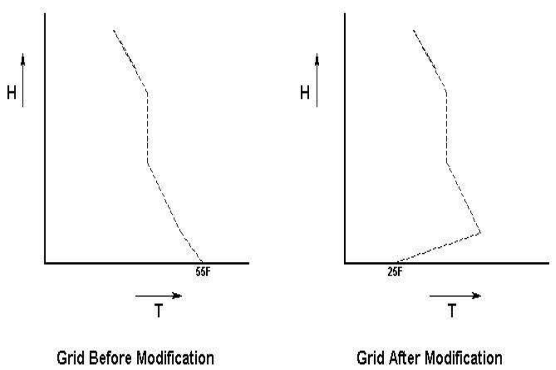

Figure 5 Illustrative, Raw Model Soundings associated with the Surface Temperature Field (Before and After Modification)

The question now is, "How does a forecaster systematically incorporate data from the model of the day to derive additional fields, or products?" The answer is highly problematic for critical decisions (e.g., freezing v. frozen v. liquid precipitation, ventilation factor, etc.). In addition there is no consistent means of objectively relating various sensible weather element fields (e.g., Surface Wind v. Dew Point Temperature, or QPF v. virtually any other field).

In the NWP world, internal, physical consistency among all variables is maintained through the governing equations. For example a change in initial conditions will almost certainly lead to a different NWP solution. This is loosely analogous to the type of "connectivity" that should be organic in the IFPS/GFE system of software (Figure 6).In other words, it is proposed that any modification in the sensible weather elements should be physically related to changes in the 4-D representation of the atmosphere from which those elements were derived.It is difficult to envision a scenario within the current IFPS/GFE architecture that would allow for the sort of feedback loop indicated in Figure 6. As described earlier, there is a design-disconnect between the sensible weather elements and the 4-D cube. The IFPS/GFE software system was never intended to provide the link, and to unite the them would likely require an re-engineering effort.

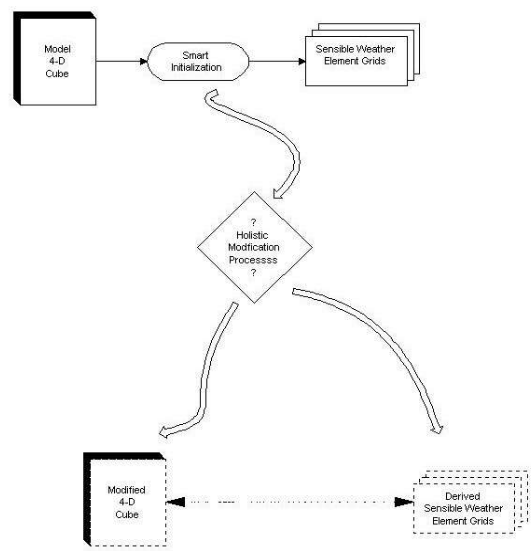

Figure 6 Idealized IFPS/GFE Connectivity

PROPOSED ARCHITECTURE

To improve the design of a next-generation system one should examine how a meteorologist approaches the job of forecasting. There are any number of authors who have discussed this issue (Doswell, 1986) at length. A simplistic, updated flowchart of the forecast process can be seen in Figure 7. The diagram is not submitted to illicit discussion of the forecast process, but to provide a framework for understanding how a meteorologist approaches the job, and how technology might better fit into that process.

It goes without saying that diagnosis-prognosis is a continuum, and a well designed software system will provide the forecaster the opportunity to easily move between the various functions described in the flowchart (Figure 7). For this discussion we are focused on prognosis, and specifically at the decision point diamond "4-D formulation". At this juncture it is assumed that the forecaster has applied a conceptual model to information gleaned during the analysis stage, and is now ready to look critically at NWP. The forecaster must decide, based upon NWP information, whether to move forward, making adjustments to the model-of-the-day, or loop back through the analysis phase again and re-evaluate.

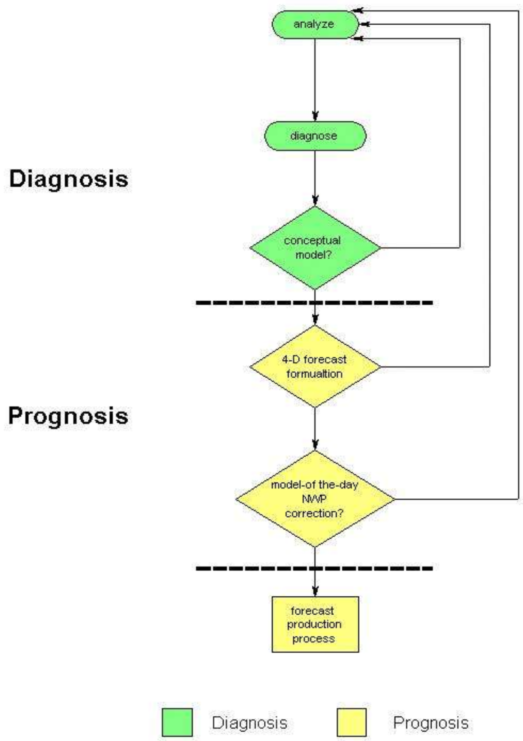

Figure 7 Simplified Flowchart of the Forecast Process

Unfortunately it is at this point that the current IFPS/GFE paradigm breaks down. Because there is no 4-D representation of the atmosphere available to objectively adjust, the forecaster is forced to skip the next decision point diamond (model of the day, NWP correction?) and proceed directly to forecast production. The meteorologist is now responsible for applying mental corrections to a 4-D Cube (the cause) and the sensible weather elements (effects) in a single step. This result places the forecaster in the unenviable mode of adjusting "the effects" to match a hypothetical "cause". It is proposed that a better design would be one that places the meteorologist in the position of applying systematic correction directly to a 4-D representation of the atmosphere (the cause) before proceeding to the business of working with sensible weather elements (the effects).

Figure 8 is a simplistic depiction of the prognosis step shown in Figure 7. The forecaster is focused on the current state of the "living" 4-D Cube with the goal of systematically "adding value" through the use of deterministic NWP, ensembles, and insight gained during the analysis step. There are software systems available that provide the sort of functionality required in this critically important phase (Carroll, 1997 and Grahame, 2000). The overriding concern for the forecaster is to maintain a 4-dimensionally consistent state of the atmosphere from which to generate sensible weather elements. After the meteorologist is satisfied with the 4-D representation of the atmosphere, he is then ready to proceed to the forecast production process.

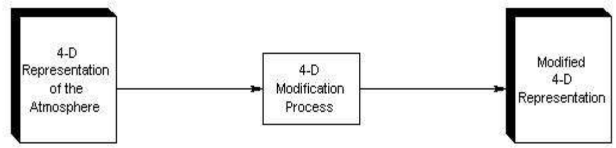

Figure 8 Simplified Depiction of Forecaster InterventionWithin Prognosis

The first step in the forecast production process (the last box in Figure 6) is the initialization of the sensible weather element grids from the "living" 4-D Cube. It can not be over emphasized that within this new paradigm the day to day continuity and integrity of the forecast lay in the 4-D Cube, not the sensible weather elements. An unexpected benefit to this approach is that it allows for finer control of the sensible weather element generation during initialization. This may be demonstrated in the following illustration.

As stated previously the sensible weather elements for any time slice ***T*** tend to be initialized only once, at Day ***T+7*** (See figure 9, in red). As time passes the grids for any time slice (***T+N***) progress forward in time, and the grids metamorphose via the numerous modification methods and tools. In other words the grids initialized from a model at time slice ***T+7*** are the same grids that show up at time slice ***T***, albeit highly altered. Objective input from current model information tends to mathematically blended into the grids to reflect significant divergence the model of the day and the current database.

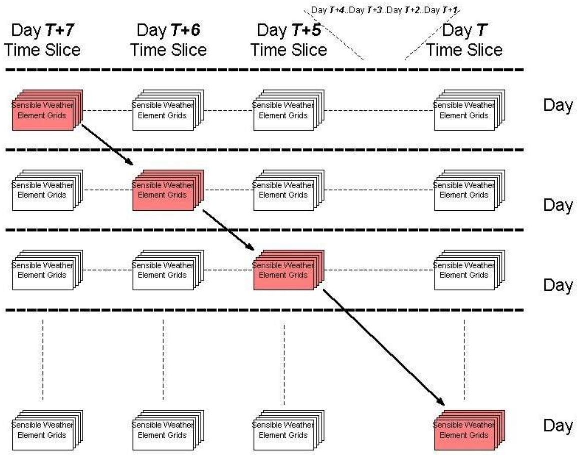

Figure 9 Simplified Depiction of the Progress of a Time Slice of Grids

With continuity now maintained in the 4-D representation of the atmosphere, the weather elements are no longer restricted to a single initialization. The proposed strategy opens the floodgate for the development of variational initialization strategies tailored to the season, or the weather pattern. More importantly each forecast office would be able to explore the use of initialization algorithms tuned to specific "edit areas". This would be especially helpful for offices in complex terrain, or with marine responsibility. With the emphasis now on the 4-D-Cube, and variational initialization of the sensible weather elements from the 4-D-Cube, less effort should be required manually editing the grids (figure 10).

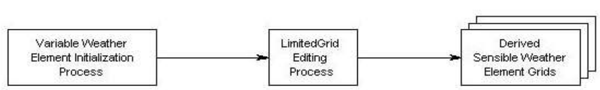

Figure 10. Proposed Forecast Production Process

SUMMARY

A more effective means of producing grids of sensible weather elements has been proposed, as shown if Figure 11. The fundamental difference between the current system and the proposed process is the 4-D Cube modification process.

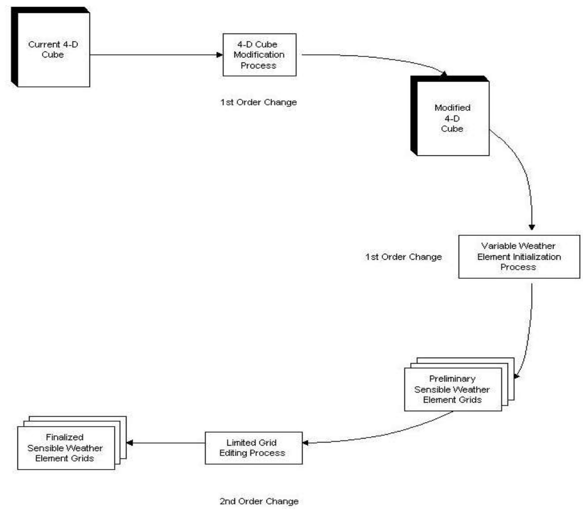

Figure 11. Proposed Sensible Weather Element Grid Production Process

Forecast continuity is maintained in the sensible weather element grids with the current system. Under the 4-D Cube modification process forecast continuity is maintained in the 4-Dimensional representation of the atmosphere.

To summarize the benefits of the proposed process:

- Provides a direct link between the atmosphere and the sensible weather element grids;
- Provides a more systematic approach to forecast production, with the sensible weather element grids rigorously connected to a 4-D representation of the atmosphere;
- Allows the forecaster to focus more on the cause (the atmosphere) as opposed to being totally focus on the effects (sensible weather elements).

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Doswell, C.A (1986) Paper 6.2 in Preprints, 11th Conf. on Weather Forecasting and Analysis, Kansas City, MO, American Meteorological Society, 177-182.

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