A review of DSSs developed at NURC and future trends

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What are Decision Support Systems?

- Decision Support Systems (DSSs) are those systems aimed at helping a human decision maker in making decisions
  - a DSS has to bias towards better decisions
  - but a DSS can be wrong, i.e., it is not supposed 100% reliable (this is why human intervention is required)
- They are very different from Automatic Decision Making Systems (ADMSs), where the human aid is not required
  - In particular, in ADMSs there no need to fuse information coming from heterogeneous sources, like machines and human beings
  - thus there no need to take care of human factors

When a DSS fails?

- Any DSS can:
  - **bias towards worse decisions**
    - (the reasons for this are application dependent)
  - **add too much cognitive workload** to the decision maker/decision authority (DA) because
    - a graphical user interface (GUI) has not been provided
    - the GUI is provided but it is too complex
    - It conveys the right information, but it is difficult to find where the information has been put on the GUI
  - **become distrusted** by the DA because of
    - the too many false alarms generated
    - the too poor options/advises generated
    - the too many obvious errors produced

In these cases, the DSS becomes under-utilized/switched off in the mid/long term

How to avoid pitfalls when designing DSSs?

- By using a well-understood/well-recognized **cause-effect chain, i.e., deep reasons explaining why even a mediocre DSS is likely to succeed** on the specific application
- Examples:
  - a DSS which improves the alertness of the decision maker
  - a DSS which ranks options, in case the DA has no time to evaluate all of them
  - a DSS which reduces the cognitive workload required to analyze the scenario as a whole
- If a well-assessed cause-effect chain exists, an accurate DSS should be preferred to a mediocre one
- **But if it does not exist, even a very good DSS is prone to failure (distrusting, under-utilization, etc)**

How to avoid pitfalls when designing DSSs? (cont)

- By improving man-machine interfaces
  - Reducing the cognitive workload
  - producing more intuitive results (spatial maps, …)
  - Helping the DA when he feels tired or when he/she is sleeping
  - assists the DA when he has no sufficient time to evaluate all the alternatives
- By improving man-machine interfaces, the human performance will improve as well (of course good training is still required, but we can’t relay on training only)

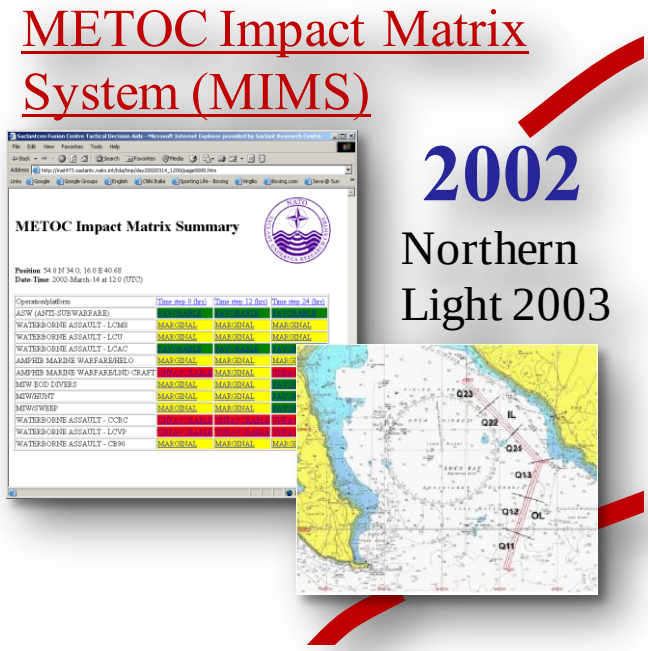
DSSs developed at NURC so far

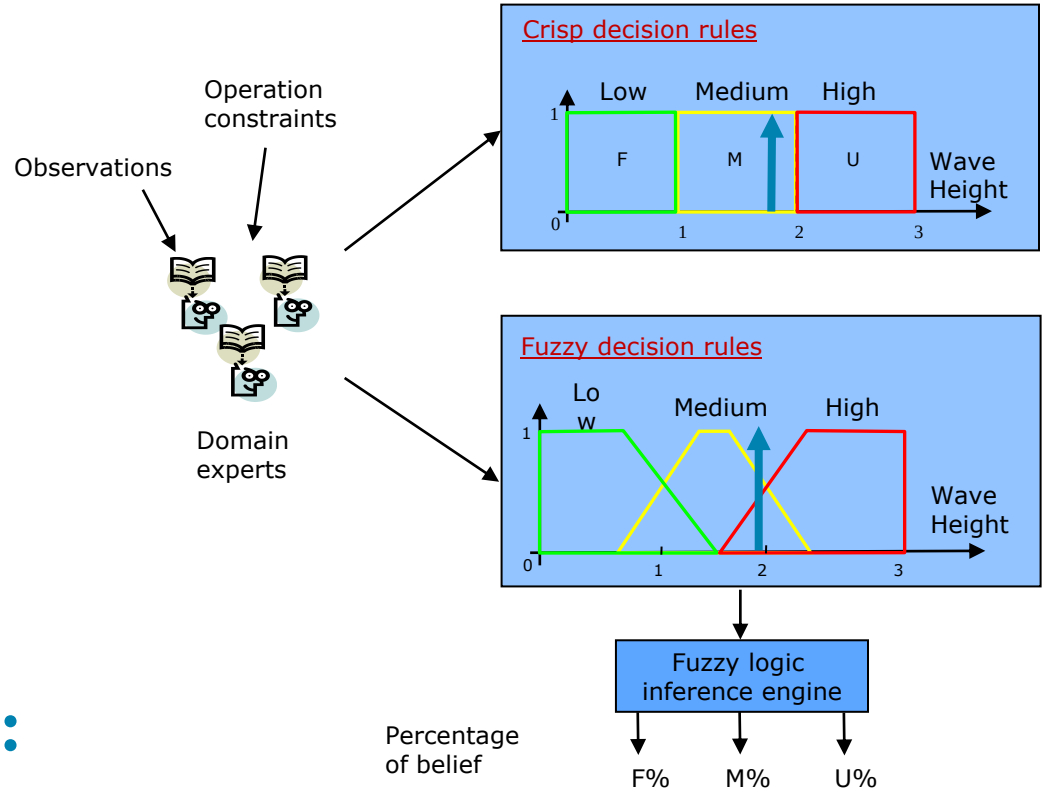
- Aimed at being as much generic as possible, in order to aid in any kind of maritime operations
- Based on METOC data, both measured and forecasted
- Able to generate risk maps and traffic light maps (like *go/no go* maps)
- Able to rank hypothesis and to suggest the course of actions

From crisp logic (2002) to Fuzzy Logic (2005)

2002: crisp rules

2005: fuzzy rules

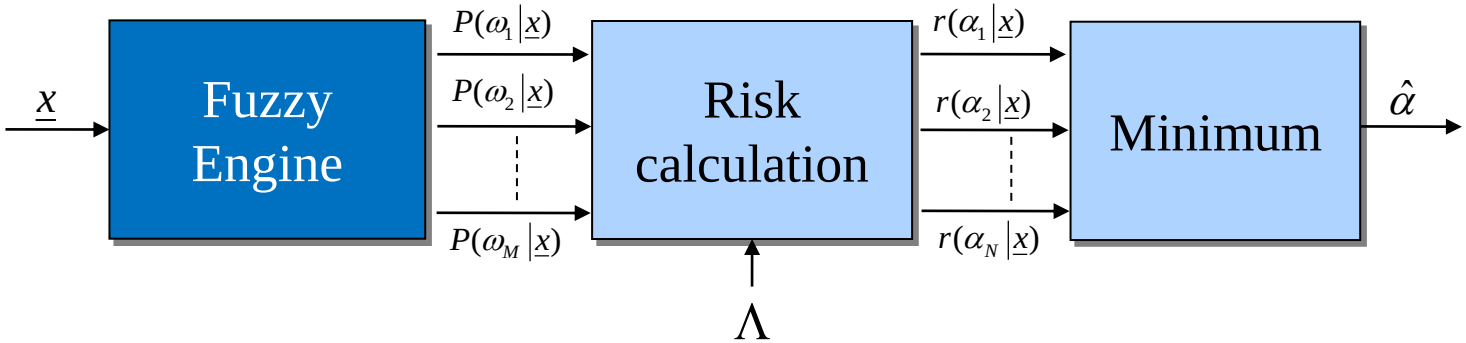




The improvements were:

- greater expressiveness
- fewer rules required → greater interpretability

Hybrid fuzzy/Bayesian risk model (2008)



$\Omega \equiv \{\omega_1, \ldots, \omega_M\}$ Environmental classes

$A \equiv \{\alpha_1, \ldots, \alpha_N\}$ Action set

Assess mission cost and decide course of action

Conditional cost matrix

$$\Lambda = \begin{bmatrix} \lambda(\alpha_1|\omega_1) & \lambda(\alpha_1|\omega_2) & \ldots & \lambda(\alpha_1|\omega_M) \\ \lambda(\alpha_2|\omega_1) & \lambda(\alpha_2|\omega_2) & \ldots & \lambda(\alpha_2|\omega_M) \\ \vdots & \vdots & \ldots & \vdots \\ \lambda(\alpha_N|\omega_1) & \lambda(\alpha_N|\omega_2) & \ldots & \lambda(\alpha_N|\omega_M) \end{bmatrix}$$

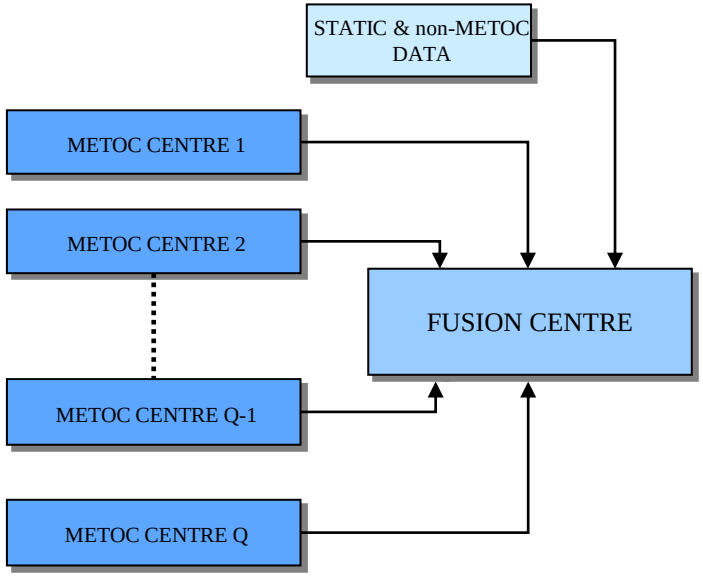
Action conditional risk

$$r(\alpha_n|\underline{x}) = \sum_{\omega_m \in \Omega} \lambda(\alpha_n|\omega_m) \cdot P(\omega_m|\underline{x})$$

Minimum risk decision rule

$$\hat{\alpha} = \arg\min_{\alpha_n}([r(\alpha_1|\underline{x}), \ldots, r(\alpha_N|\underline{x})]^T)$$

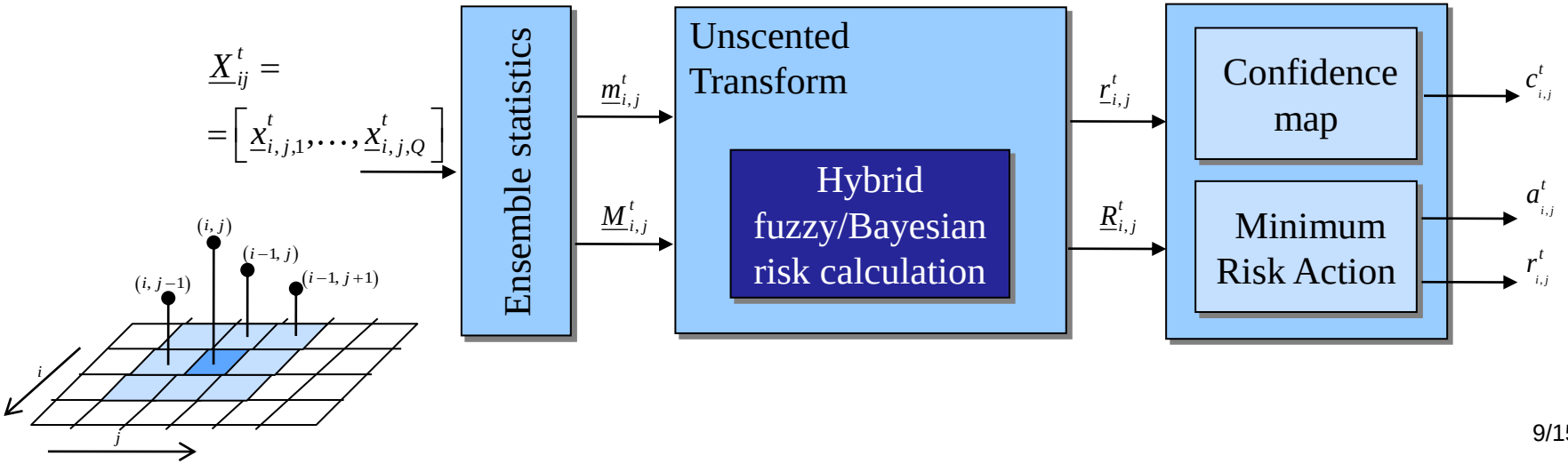
Multiple METOC centres and uncertainty propagation on the risk maps (2009-10)



Multiple METOC forecasting centres have been used in order to increase reliability

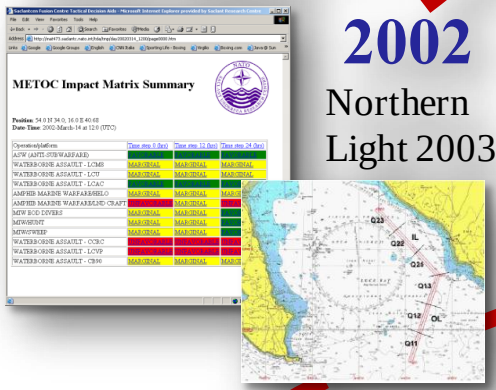
This introduces a inter-centres uncertainty (due to disagreement)

This uncertainty on the input is propagated to the output risk maps (using the Unscented Transform), to give more insights to the DA



DSSs evolution since 2002

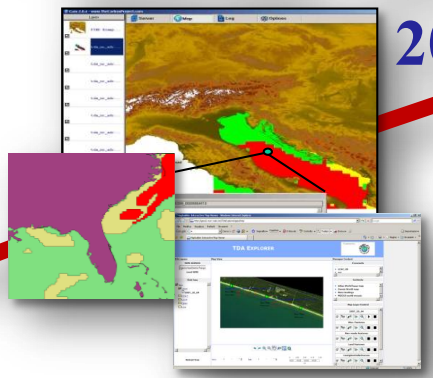
METOC Impact Matrix System (MIMS)



2002

Northern Light 2003

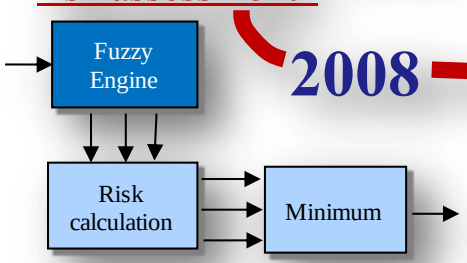
Fuzzy logic based decision making engine + OGC Web GIS



2005

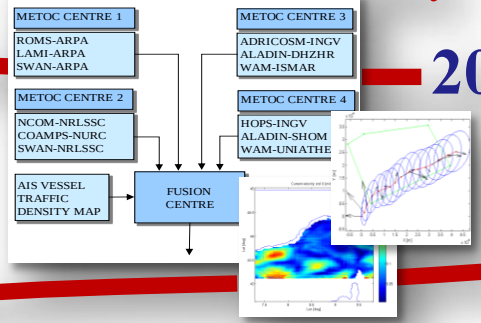
CWID 2005
Steadfast Jaguar 2006
DART 2006

Hybrid Fuzzy/Bayesian risk assessment



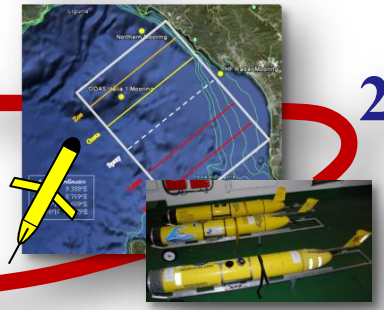
2008

Multi-source METOC fusion & data uncertainty



2009

REP10



2010

Dealing with uncertainty associated with METOC forecasts

- Uncertainty is originated

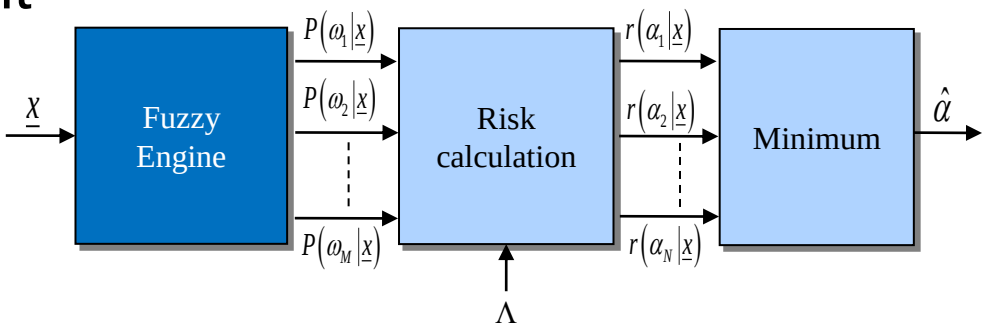
1. by forecast errors introduced by each METOC centre (*intra-centre uncertainty*)
2. by disagreement between METOC forecasts (*inter-centre uncertainty*)

- By "handling" at NURC we mean:
  - understanding the sources of uncertainties
  - reduce uncertainties (e.g., by using super-ensemble, adaptive sampling, etc.)
  - exploit uncertainties

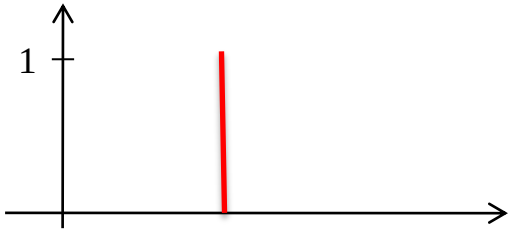
How **uncertainty handling** is meant at NURC

Improve uncertainty handling

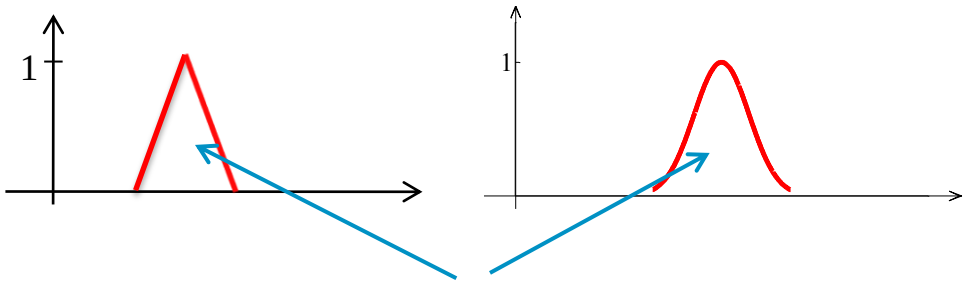
This year we started to exploit METOC uncertainties by Using non-exact METOC input on the hybrid fuzzy-Bayesian system



In the past



Today



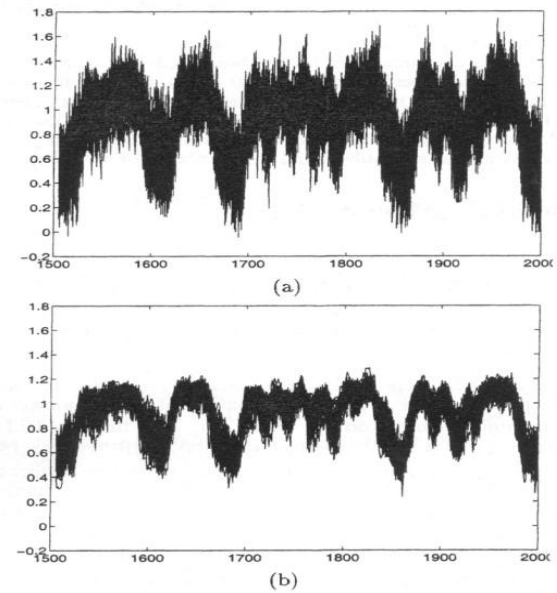
The standard deviation will be made proportional to the METOC uncertainty
(it can be computed by the super-ensemble)

Improve uncertainty handling (cont)

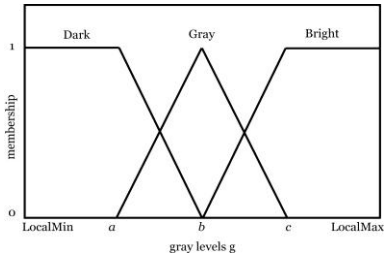
- Another new way to exploit uncertainties:

Use uncertain Knowledge Bases for the hybrid fuzzy-Bayesian system

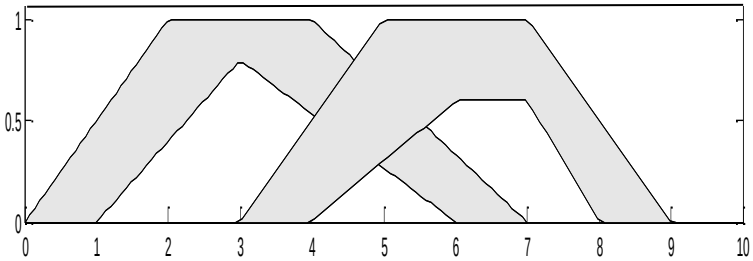
- An uncertain knowledge base is made of uncertain membership functions
- Uncertain membership functions are described by means of the so called type-2 fuzzy sets



An example of Type-1 fuzzy sets



An example of Type-2 fuzzy sets



Expected effect:
reduced variability on estimated risks

Support decision under time pressure, stress or fatigue

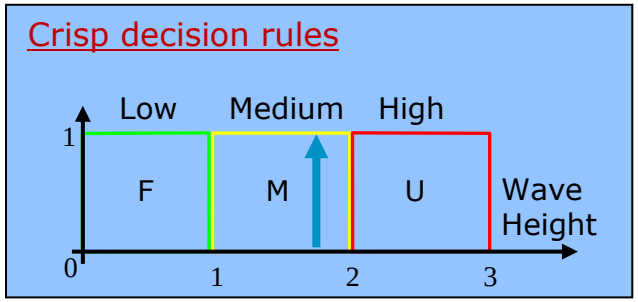
- In the future we want to support the decision authority in case of fatigue
  - For instance, we may generate alerts during the night while the DA is sleeping:

WARNING! The glider is going to exit the allowed area!

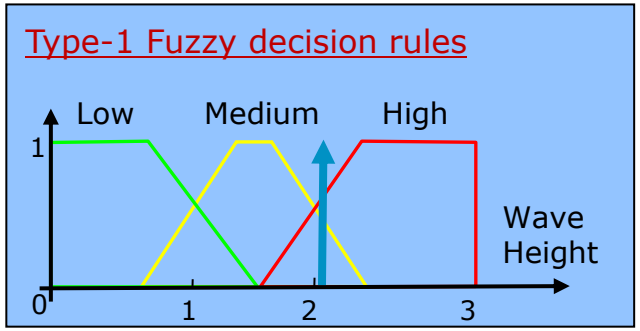
- Also, we want to start modeling the time pressure
  - For instance, we may use costs associated to the actions which increase with time

Conclusions

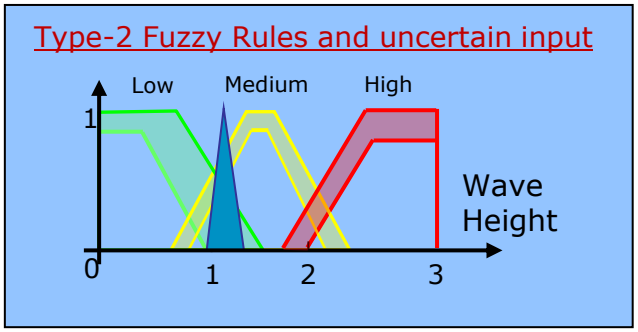
- We have reviewed past DSSs developed at NURC
- We have identified some general pitfalls to avoid
- We have highlighted some features to add to next DSSs



MIMS (2002)



Fuzzy-based DSS (2005)



Uncertain Fuzzy-Based DSS (2010)

Maritime Decision Support Systems: an ocean of challenges and opportunities!