# Ch. 11 天氣預報 (5 hr)

## 天氣預報方法：

- 持續法：預報未來（如明天）天氣與今天相同
- 統計法：類比法，迴歸法，時間延遲迴歸分析，多變數分析法(CCA, 判別分析…)…等
- 數值天氣預報（**NWP)**（正壓、準地轉、**PE**模式**)**
- **MOS (model output statistics)**
- **Ensemble forecast** （系集預報）

## 天氣預報流程：

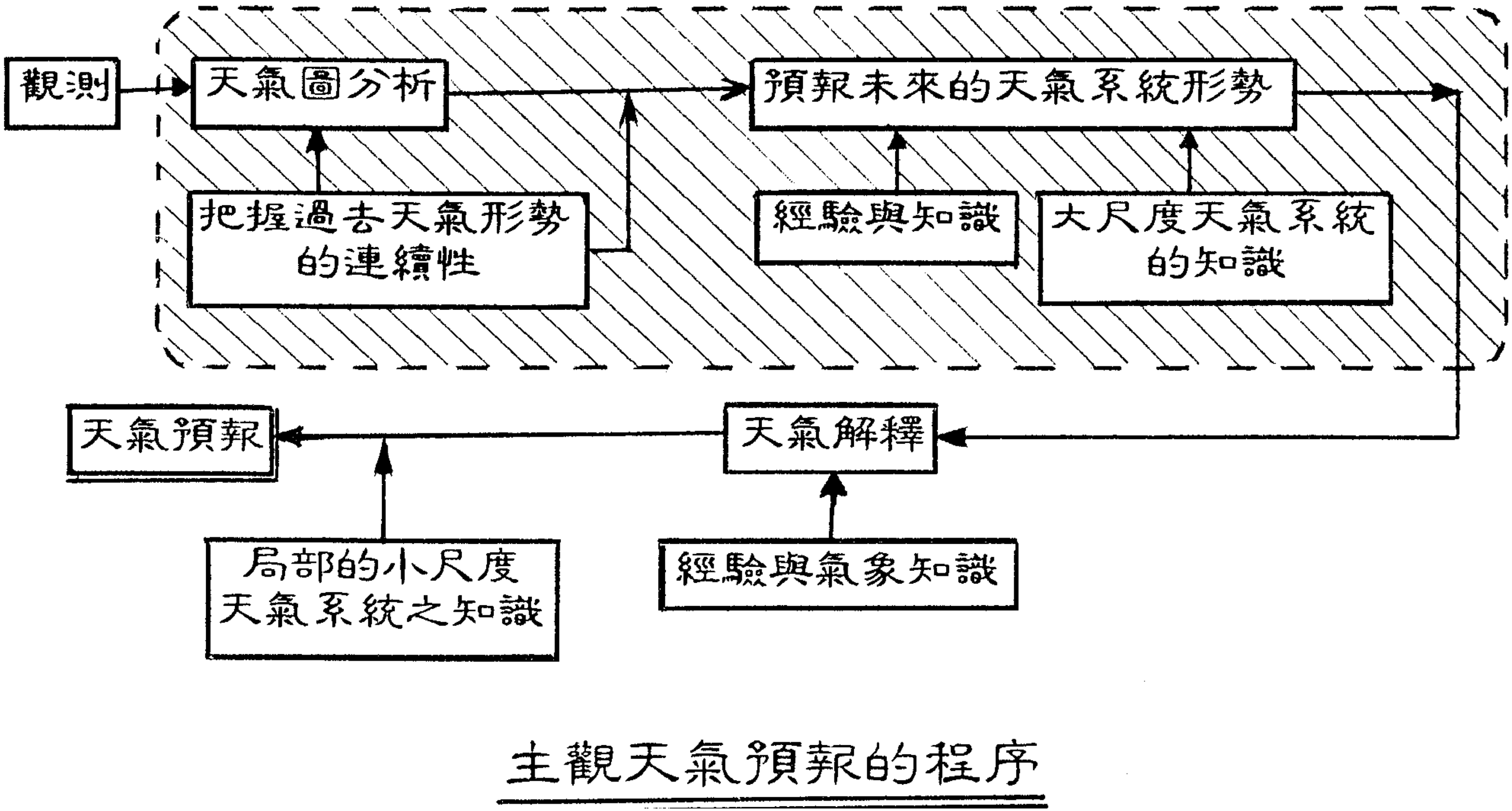
- 觀測 → 客觀分析
- 數值天氣預報（**NWP)**，預報討論（多數決等）
- **Forecasting and warning**
- 機率預報（如下雨的機率有多大，颱風路徑扇形圖等）

## 天氣預報價值：

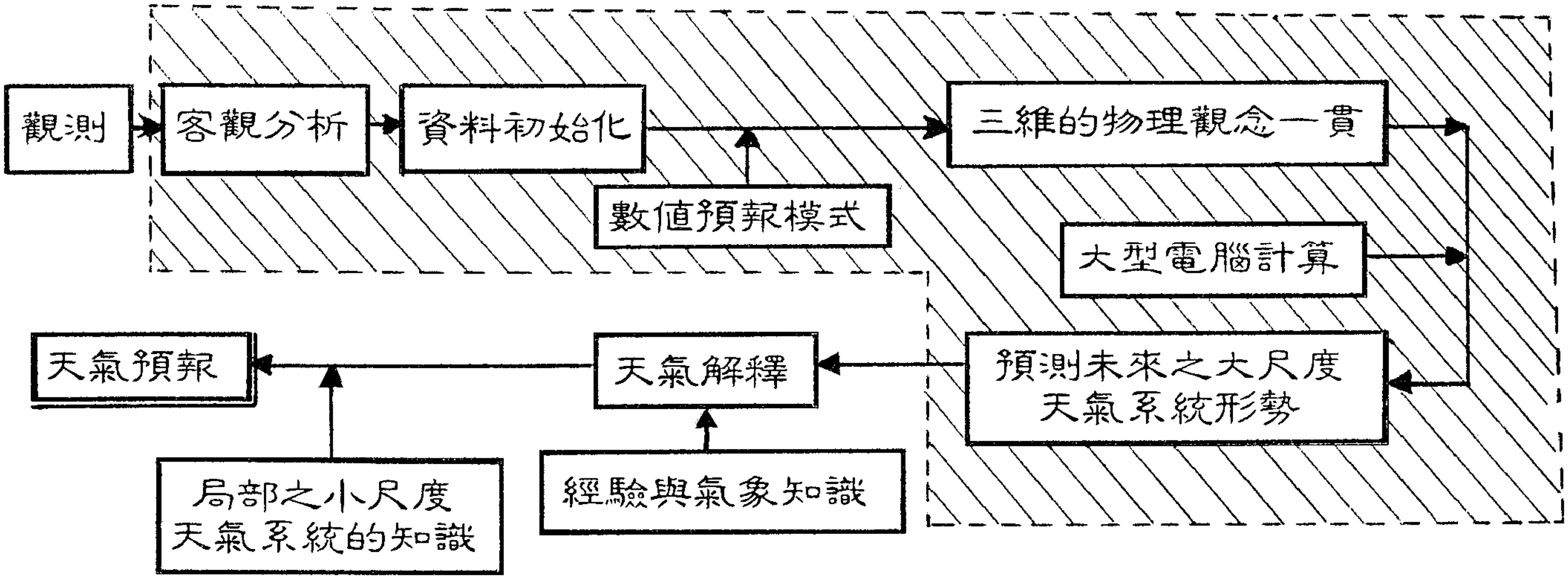
## 天氣預報方法：

- 持續法：預報明天之天氣與今天相同；或下個月之擾動與本月相同。
- 類比法：要先對過去之天氣現象（如颱風路徑）做分類（如主觀分類，或**cluster analysis**等**)**；再對發生之現象做歸類（主觀判別**or**判別分析），然後依照判別出之類別去做類似天氣之預報。（如判別出颱風之路徑為西北颱後，可用過去西北颱在台灣各地降水的分佈來做預報。
- 迴歸法：包括單元迴歸（$y = a + bx$)，再用**least-square fit**求**a, b**；多元迴歸($Y = a_0+a_1X_1+a_2X_2+\ldots+a_kX_k$)，要先找出有意義之因子來（包含時間之延遲），再求出各因子之係數；及
  自我迴歸：利用時間延遲**(time lag)**，求出同一變數之準週期性變化；
  多變數分析法：如正準相關分析（**CCA**），**EOF, SVD, …**等
- 數值天氣預報（**NWP)**：正壓模式、準地轉模式、**PE**模式等；區域模式、全球大氣模式、全球海氣耦合模式

# 主觀天氣預報流程圖


觀測
天氣圖分析
預報未來的天氣系統形勢
把握過去天氣形勢的連續性
經驗與知識
大尺度天氣系統的知識
天氣預報
天氣解釋
局部的小尺度天氣系統之知識
經驗與氣象知識
主觀天氣預報的程序

# 數值天氣預報流程圖




數值天氣預報的程序

# Problems in NWP

1. Richardson (1922) thought that his failure was due primarily to the poor initial data available – especially the absence of upper-air soundings. However, it is now know that there were other even more serious problems with Richardson's scheme.

2. J.G. Charney (1948) showed how the dynamical equations could be simplified by systematic introduction of the geostrophic and hydrostatic assumption so that the sound and gravity oscillation were filtered out. （Charney 的另一貢獻：the scale analysis）

3. Problem in NWP
   - Filtering of high frequency waves:
     Sound wave: hydrostatic approx. ( vertical) ，但在nonhydrostatic model (e.q. MM5, WRF) 中，則無法消去。另外採用time-split的方式來處理
     Lamb wave (horizontal) : let w=0 | at sfc.
     Internal gravity wave: $\partial\delta/\partial t = 0$
   - Numerical schemes: truncation, computational instibility
   - Requirements in numerical methods: accuracy, stability, convergence ( to exact solution)
   - I.C. problem : using gradient wind balance

**MOS: JAM(1972), 1203-1211**

## The Use of Model Output Statistics (MOS) in Objective Weather Forecasting

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(Manuscript received 16 March 1972, in revised form 27 July 1972)

Model Output Statistics (MOS) is an objective weather forecasting technique which consists of determining a statistical relationship between a predictand and variables forecast by a numerical model at some projection time(s). It is, in effect, the determination of the "weather related" statistics of a numerical model. This technique, together with screening regression, has been applied to the prediction of surface wind, probability of precipitation, maximum temperature, cloud amount, and conditional probability of frozen precipitation. Predictors used include surface observations at initial time and predictions from the Subsynoptic Advection Model (SAM) and the Primitive Equation model used operationally by the National Weather Service. Verification scores have been computed, and, where possible, compared to scores for fore-

$$\hat{Y}=a_0+a_1X_1+a_2X_2+\cdots+a_kX_k.$$

$$\sum_{j=1}^{n}(y_j-\hat{y}_j)^2=\text{minimum}.$$

**1.對多元迴歸方程，尋找適當的因子**

**2.利用least square fit求出各項係數$a_0,a_1,\ldots$**

Sample equations for St. Louis are shown below:

$$\hat{U}^{12}=0.482+0.185U_0^{12}-0.333V_0^{12}+0.276V^{07}$$

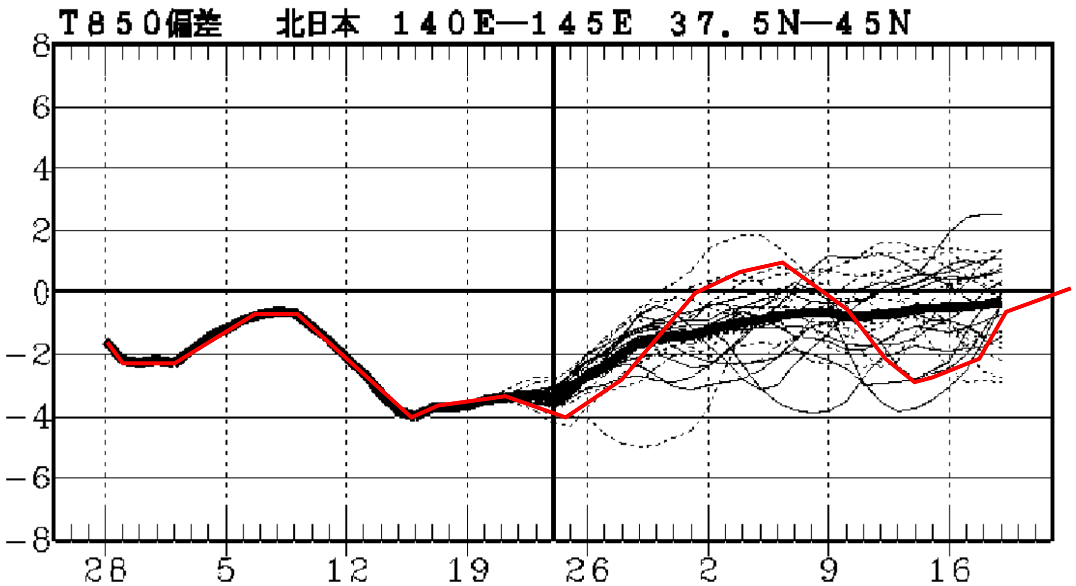
$$\hat{V}^{12}=0.194+0.164U_0^{12}+0.175V_0^{12}-0.005U^{07}+0.170V^{07}$$

$$\hat{S}^{12}=1.576+0.239S_0^{12}+0.175S^{07}-0.040V_0^{18}+0.027U_0^{12}$$

where $U$, $V$ and $S$ are the $U$- and $V$-wind components, and the wind speed, respectively (knots); the subscript 0 indicates 1000-mb geostrophic values predicted by SAM; and the superscript indicates the valid time in GMT.

- **Ensemble forecast （系集預報）**

**Multiple predictions from an ensemble of slightly different initial conditions and/or various versions of models. The objectives are to improve the accuracy of the forecast through averaging the various forecasts, which eliminates non-predictable components, and to provide reliable information on forecast uncertainties from the diversity amongst ensemble members. Forecasters use this tool to measure the likelihood of a forecast.（http://www.weather.gov/glossary/glossary.php ）**



- **Ensemble forecast （系集預報）**

  **Since the atmosphere is a chaotic dynamical system, any small error in the initial condition will lead to growing errors in the forecast, eventually leading to a total loss of any predictive information. This is so even if our models were perfect (Lorenz, 1969). The rate of this error growth and hence the lead time at which predictability is lost depends on factors such as the circulation regime, season, and geographical domain. It is possible to obtain information on the inherent predictability of a given case by running the model from a number of initial conditions that lie within the estimated cloud of uncertainty that surrounds the control analysis (which is our best estimate of the true state of the atmosphere).**

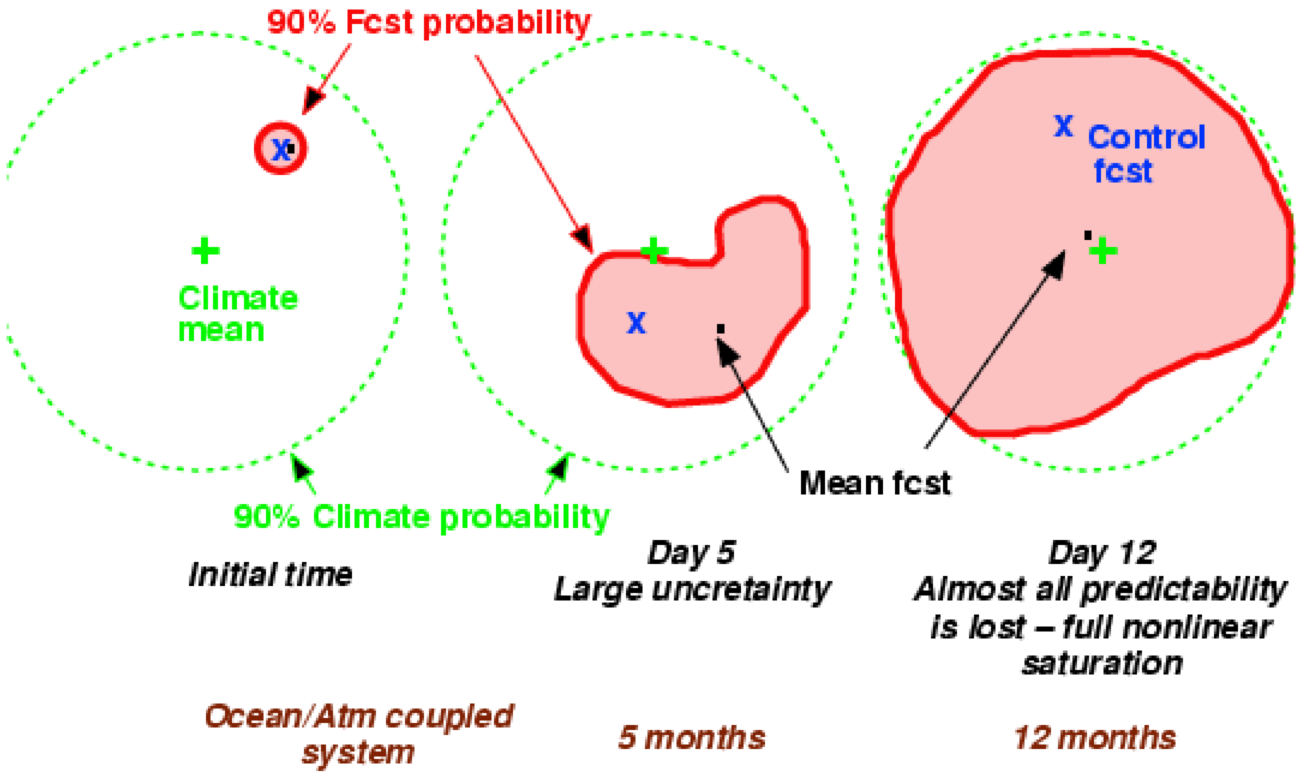
# SCIENTIFIC NEEDS - DESCRIBE FORECAST UNCERTAINTY ARISING DUE TO CHAOS (Zoltan Toth, 2003)

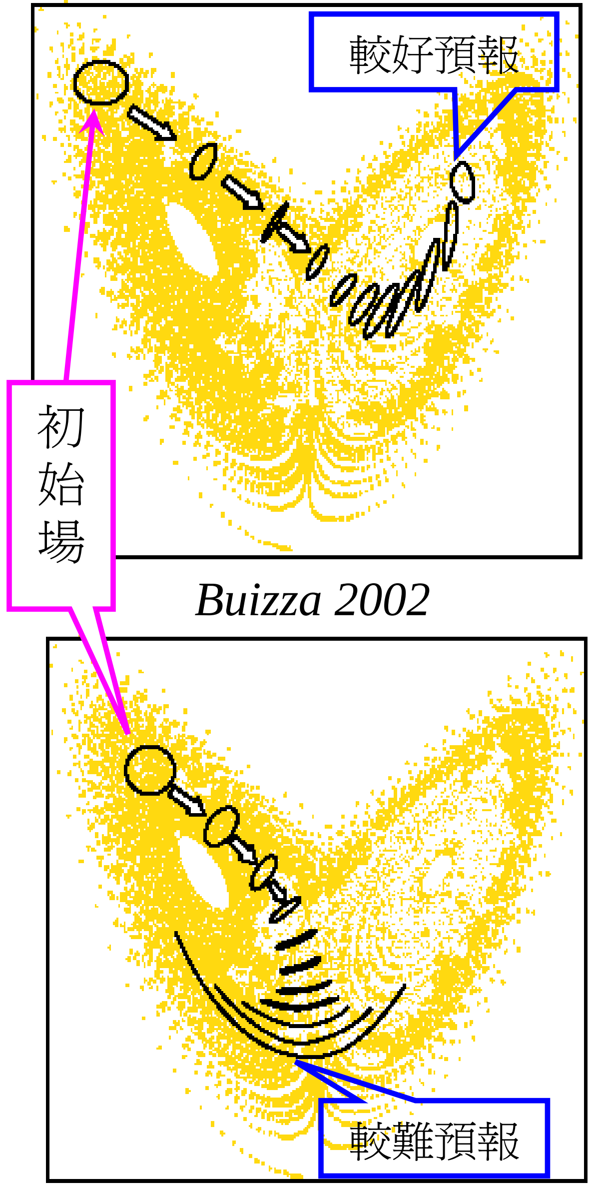
## ORIGIN OF FORECAST UNCERTAINTY

1) The atmosphere is a **deterministic system** *AND* has at least one direction in which **perturbations grow**

2) **Initial** state (and model) has **error** in it ==>

***Chaotic system + Initial error =(Loss of) Predictability***



## ☆ 列聯表(contingency table)

| 預報 \ 實情 | 有災害 | 無災害 | 合計 |
|---|---|---|---|
| 災害發生 | M | m | M+m |
| 災害未發生 | n | N | n+N |
| 合計 | M+n | m+N | M+N+m+n |

災害發生之氣候值（機率）

$$P_0 = \frac{M+n}{M+N+m+n}$$

發佈警報之經費 + 防災措施經費 **(protection cost) = c** 元

發佈警報仍發生災害之損失 **(protection loss) = a** 元

沒發警報而發生災害之損失 **(unprotection loss) = A** 元

警報所期待之利益（**G**）**=** (因預報正確而保護到的財產總和 **–** 每次預報加防災的成本總和）***/***（預報有災害的次數）

$$G=\frac{M(A-a)-c(M+m)}{M+m}=(A-a-c)\frac{M}{M+m}-c\frac{m}{M+m}$$

故警報發佈命中率 **P**（預報的成績）

$$\mathrm{P}=\frac{\mathrm{M}}{\mathrm{M}+m}\ ,\qquad 1-P=\frac{m}{M+m}$$

則 **G = (A – a – c) P – c (1 – P) = (A – a) P – c > 0** 預報才有價值

所以須要 $P>\frac{c}{A-a}$ 才值得

例如：一艘船**2000**萬元（**A**），船滯留一天**20**萬元，五天**100**萬元（**a**）

預報經費**500**萬元。則 $P>\frac{500}{2000-100}=26\%$

# — Example

| 觀測 / 預報 | 下雨 | 不下雨 | 合計 |
|---|---|---|---|
| 下雨 | M=50 | m=20 | c1=M+m=70 |
| 不下雨 | n=15 | N=100 | c2=n+N=115 |
| 合計 | R1=M+n=65 | R2=m+N=120 | T=M+N+m+n =185 |

預報準確度

$$f = \frac{M+N}{T} = \frac{50+100}{185} = 81.08\%$$

**氣候之：下雨機率 = R1/T = 65/185 = 35.4%**

**沒下雨的機率 = R2/T = 120/185 = 64.86%**

預報 **c1** 次下雨，預報 **c2** 次不下雨

假設亂報：

猜中下雨一次之機率爲：**R1/T = 35.4%**

猜中不下雨一次之機率：**R2/T = 64.86%**

所以氣候學中的命中率爲 $D = \frac{c1R1 + c2R2}{T} = 99.12$ 次

實際預報命中數 **F = M + N = 150**

**Heidke Skill Score**之技術得分：$S = \frac{F - D}{T - D} X100 = \frac{150 - 99}{185 - 99} = 59.3\%$

則 **f – S = 81.1% – 59.3% = 21.8%**

有時氣候命中率太高，**D**大，用**D**就可以預報，但對民眾沒有預報價值。

例如：台南十月只有一天下雨，不用特別做預報，天天報晴天，就有 **f = 97%**，但沒意義。

# A Social and Economic Benefits of Meteorological and Hydrological Services

- agriculture, water resources, and the natural environment;
- human health;
- tourism and human welfare;
- energy, transportation and communications;
- urban settlement and sustainable development; and
- economics and financial services.

# The role of NMHS (the national meteorological and hydrological service)

- To provide the information and services that enable governments and other stakeholders to minimize the costs of natural disasters, protect and strengthen the weather-, climate- and water-sensitive sectors of the economy and contribute to the health, welfare and quality of life of the population.

- To provide a wide range of information and advisory services, including: historical climate data and products; current information (weather, climate, air quality, streamflow, etc.); weather, climate, air quality, river and ocean forecasts; warning services (for all forms of meteorological, hydrological and oceanographic hazards); projections and scenarios of future human-induced climate change; scientific advice and investigations.

- To draw to the attention of decision-makers everywhere, the large and growing impact of weather, climate and water influences on community safety and well-being around the world, and the enormous potential benefits to be gained from improved and enhanced use of meteorological and hydrological services in decision-making in virtually every social and economic sector and every country.

Ref. Morss, R. E., J. K. Lazo, B. G. Brown, H. E. Brooks, P. T. Ganderton, and B. N. Mills, 2008: Societal and Economic Research and Applications For Weather Forecasts: Priorities for the North American THORPEX Program. *Bull. Amer. Meteor. Soc.*, 89, 335-346.

作業：分組（每組**4**人）將上文翻譯，並做一份心得報告（**5**頁）。包含心得及

1. **CWB**該如何向民眾解釋其預報之價值？
2. 你是天氣預報公司的一員，你如何向客戶解釋（推銷）你的預報價值？

**PRIORITIES FOR RESEARCH AND APPLICATIONS.**

- understanding the use of forecast information in decision making;
- communicating weather forecast uncertainty;
- developing user-relevant verification methods;
- estimating the economic value of weather forecasts; and
- developing decision-support systems and tools.

# *high-impact weather forecasts.*

*What are high-impact weather forecasts:*

1. Forecasts of extreme, low-probability, or hazardous weather events (e.g., hurricanes, floods, or heat waves)
2. Forecasts of weather conditions that historically have had a major impact on one or more segments of society (e.g., agriculture, energy, or transportation)
3. Weather forecasts that have a significant impact (positive or negative) on one or more segments of society.

*High-impact forecasts provide information that individuals or organizations can use in making decisions that may significantly mitigate costs or enhance benefits.*

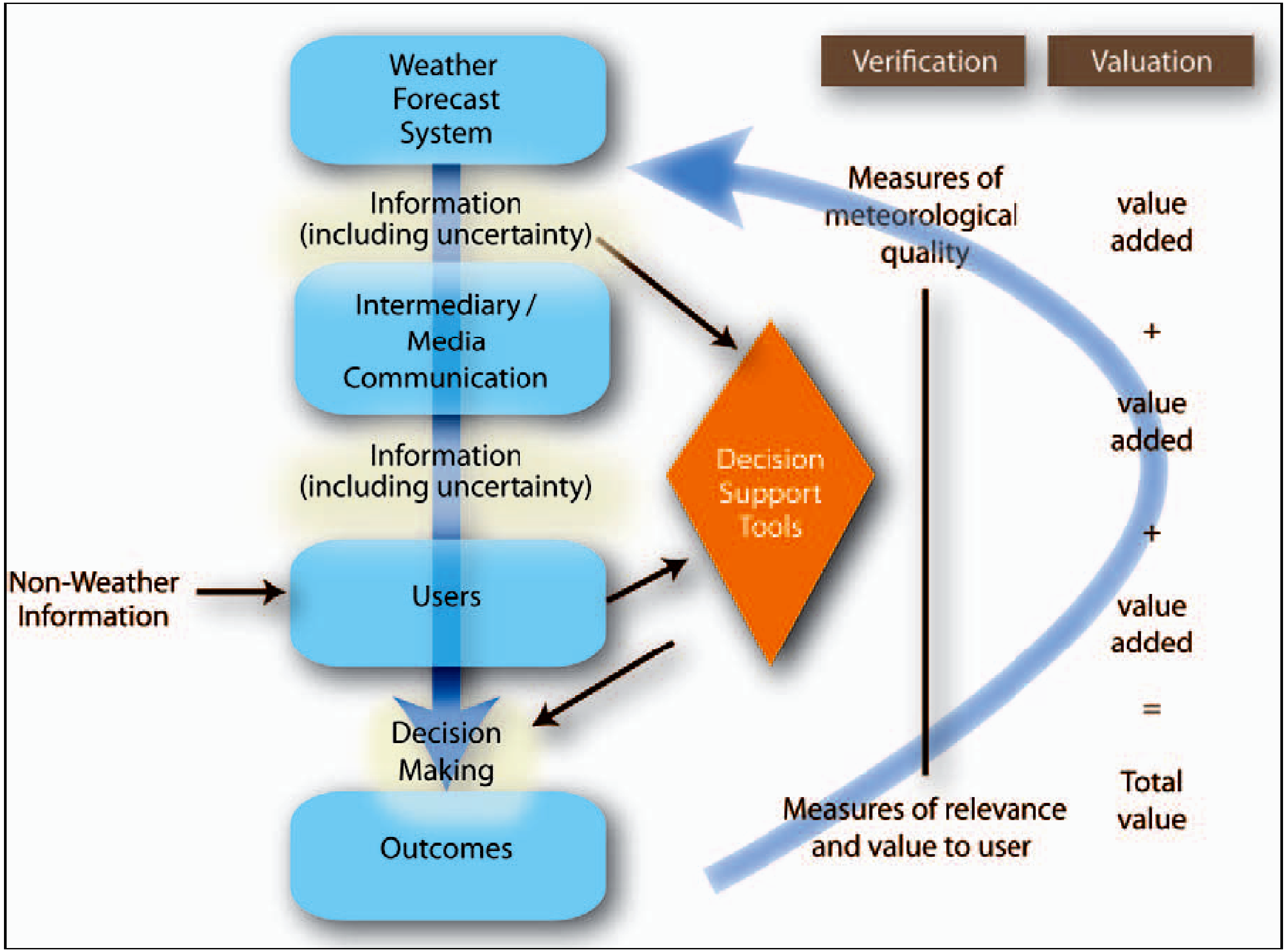



FIG. 1. Simplified model of the chain from forecast creation to value realization and the five SERA priority themes.