

暴潮模式應用之推廣

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摘要

中國海域為世界三大大陸棚之一，面積遼闊，水理複雜。海域水理之動力因素，包括天文潮、氣象潮、風浪、海流及密度流等。由於各力之間產生非線性之交互作用，更因柯氏力及摩擦效應和潮流之淺水化，故極為複雜。又因中國及台灣海域的地理形態三面臨海，為求取得模式所需的邊界條件及不同的解析度，中央氣象局目前執行的『台灣海域三度空間天文潮與氣象潮數值預報模式研究計畫』乃採用行政院科技顧組所建立的中國海域三度空間數值模式（Liu, 1982、1988）加以修改，以供台海地區天文潮及氣象潮數值預報之用。其涵蓋範圍，請見圖1。

數值預報模式採用橢圓球面座標，內含動量、連續、鹽、溫、次格點紊流、污染質濃度、冰及垂直紊流與波浪間的動力組合計算。其中數值解之概要請參閱 Liu (1986)。邊界點大洋深水潮及其他種類之邊界處理方法請參閱表一及圖2。在國內使用方面，包括天文潮的推算、大台北防洪計畫邊界條件、港灣設計、電廠放水、外海探油、岸區開發、堤防及公路定線等等。

由於暴潮模式中含有海象測報方面所涉及的基本物理參數，如鹽、溫、污染物濃度、冰、浪、水位、流速、海流等，故其應用範圍頗廣。本文就其中一二提出討論。

一、模式率定及計算，操作程序之改進

海域數值模式在進入作業階段之後，不斷在下列幾方面修正，以增進預報確度。

- (一)、海底地形及水深資料之修定。
- (二)、模式邊界條件之增修及放射性條件之處理方法。
- (三)、模式起始條件如鹽溫資料之增修。
- (四)、增加模式之解析度。
- (五)、改進與颱風路徑、強度預報組合運算間之作業程序。
- (六)、修正模式內所含之其他物理參數如大氣天文潮等之計算。

(七)、在天文潮的預報方面，目前的精確度大約如圖 3 所示。在暴潮方面大約如圖 4 所示。在週邊軟體的發展方面，目前列為工作重點。圖 5 及圖 6 為即時顯示作圖系統所做，有颱風及無颱風兩種情況下，台灣海域水位及流速之分佈圖例。圖 7 為暴潮模式流程及即時預報系統所採用的指引圖。暴潮資料庫中存有約兩千個不同強度及路徑所引起的暴潮分佈。

二、近岸及河口淺水區紊流與波浪之動力組合計算

數值模式在從事紊流封閉性計算時，次格點動能在垂直方向的界面處理方法如圖 8。在淺水地區及潮流強，底床摩擦力大的河口海灣。波浪的增減和擴方向受水位、流向與底床摩擦的影響（圖 9）。沿岸地區的折射和風向改變後的湧浪分佈（圖 10、11）。

三、暴潮模式與台北防洪模式組合運算

大台北地區之河川系統為感潮河段，暴潮對下瀉洪水產生頂托作用，抬高洪位，加重災害。河口之海峽水位為河系內洪波計算時之下游邊界條件。如需改進洪水預報之精確度，台北防洪活動變格點模式（圖 12 及 13）必需與暴潮模式組合運算。

四、太平洋地區長波及津浪預報

太平洋沿岸有衆多地震帶（圖 14），地震所引起的津浪（Tsunami，或稱海嘯）傳播方向及到達各岸區時間可由海域模式計算。不同地區地震所產之海嘯到達台灣之時間，可以列表方式，提供海象預報之參考。

五、海域水溫計算及漁場預報

三度空間數值模式可用於計算風所引起之上湧流。在海洋生態之『食物環』中，微生物所遺留之養份，沈於海底，如無上昇流帶至表層光合區，魚場即無法產生。因此海域數值模式可與數值天氣預報模式組合應用，預報漁場地點。

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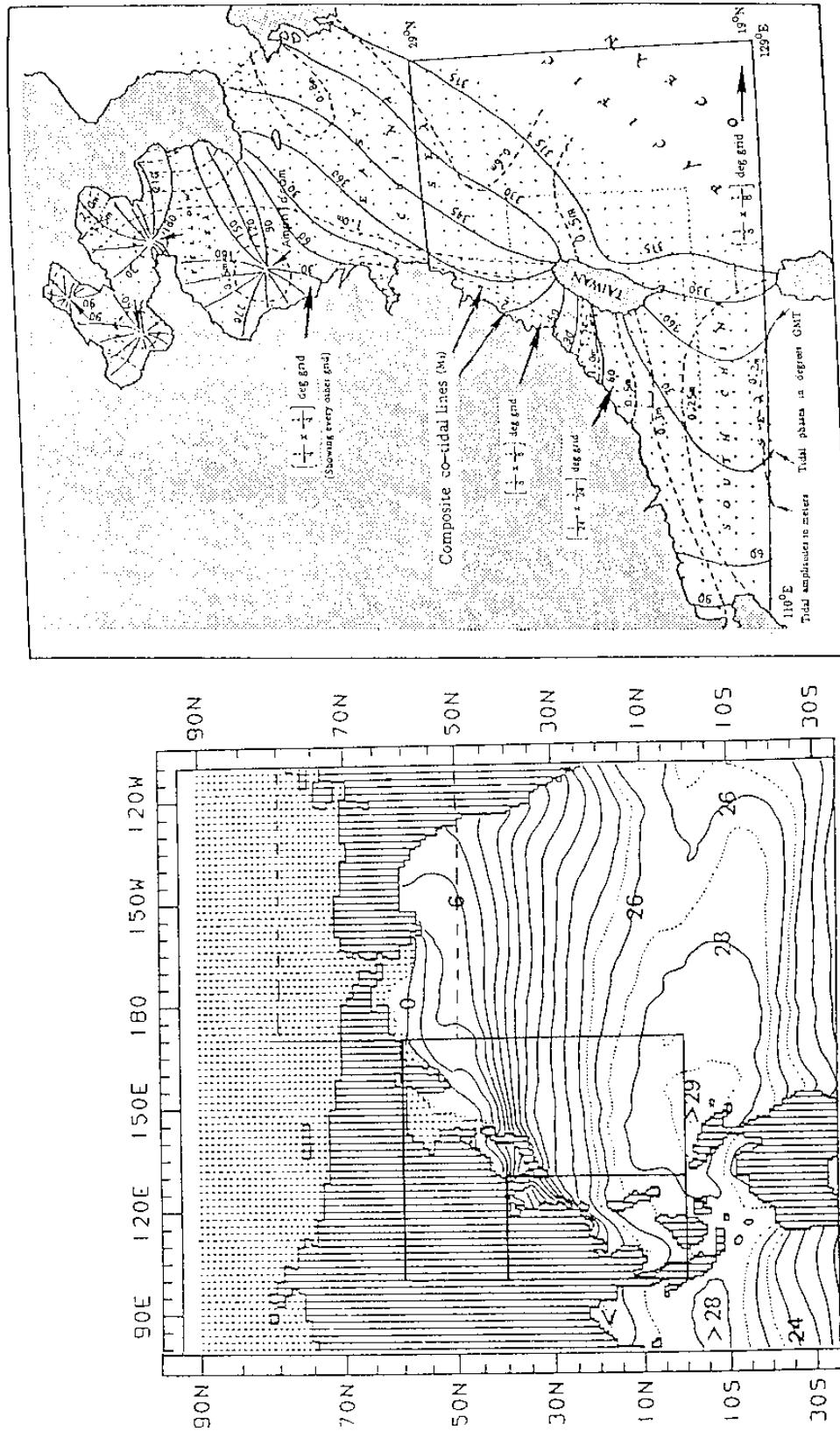


圖 1 西太平洋及中國海域數值模式之計算格點與地球之橢圓面座標吻合，故易於接納
全球性的衛星資料及連接其他國際性的數值模式計算結果及預報。

Table 1
MAJOR TIDAL POTENTIAL CONSTITUENTS APPLIED AT
MÖDÉL'S OPEN BOUNDARIES

Name	Symbol	Period (yr)	Amplitude (m)***
Principal lunar (1/19)*	M_1^2	12.421**	0.2422340
Principal solar (1/15)	S_1^2	12.300	0.1128410
Larger lunar elliptic (1/19)	S_1^2	12.653	0.0463980
Unisolar semi-diurnal (1/8)	K_1^2	11.967	0.0307040
Larger solar elliptic (1/7)	T_1^2	12.019	0.0056153
Smaller lunar elliptic (1/16)	L_1^2	12.190	0.0063501
Lunar elliptic 2nd order (1/14)	$2N_1^2$	12.910	0.0061403
Larger lunar evctional	ν_1^2	12.630	0.0080879
Smaller lunar evctional	λ_1^2	12.220	0.0017879
Variational	μ_1^2	12.870	0.0074105
Unisolar diurnal (1/24)	A_1^2	23.935	0.1415650
Principal lunar diurnal (1/6)	O_1^1	25.319	0.1005140
Principal solar diurnal (1/9)	P_1^1	24.066	0.0468430
Larger lunar elliptic (1/6)	Q_1^1	26.868	0.0192560
Smaller lunar elliptic (1/20)	M_1^1	24.860	0.0079095
Small lunar elliptic (1/17)	J_1^1	23.100	0.0079095
Lunar fortnightly (1/22)	M_1^1	327.364	0.0411420
Lunar monthly (1/20)	M_{12}^1	661.300	0.0220260
Solar semi-annual (1/16)	S_{52}^1	4382.904	0.0194775
Annual		8765.813	0.0318088
18.61 year		16131.785	0.0174842

* Representative of a group, e.g., $\{1/16\}$ means one out of a group of 16.
Bousson (1921) carried out the tide-generating potential into 380 internationally accepted expansion terms.

** Approximate. One year = 365.242219907 days

*** Equilibrium amplitude η (or tide-generating potential $G\eta$)

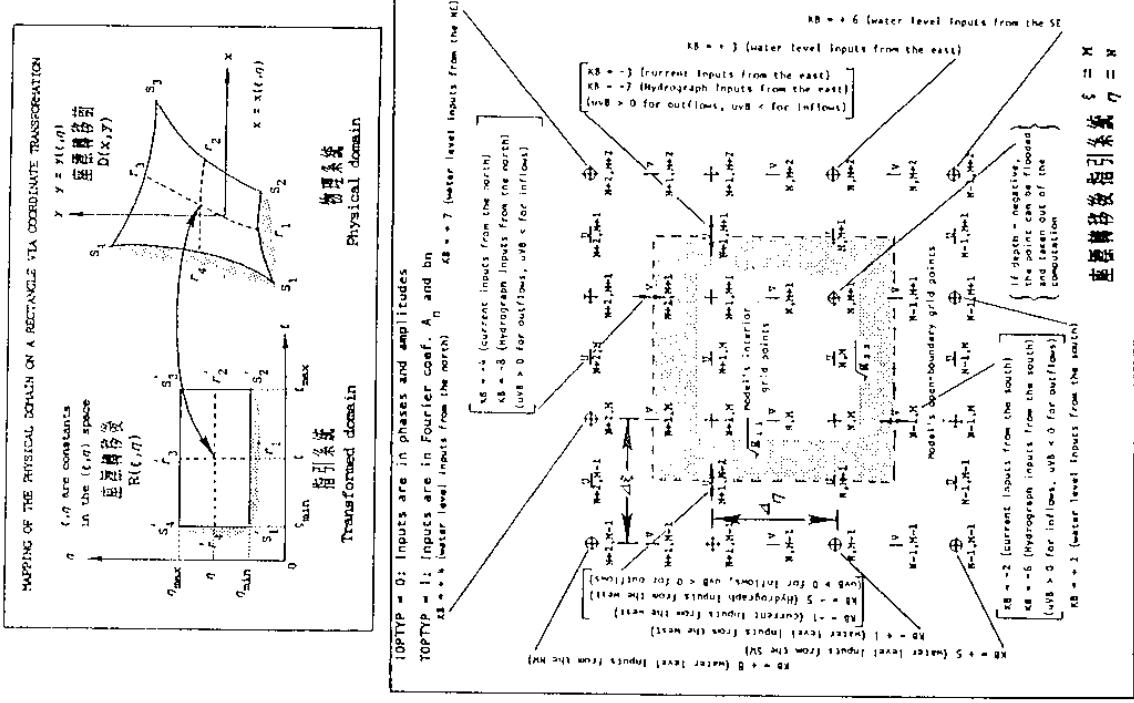


Fig. 2 Schematic diagram showing model grid transformation and numerical treatment of various open boundary conditions

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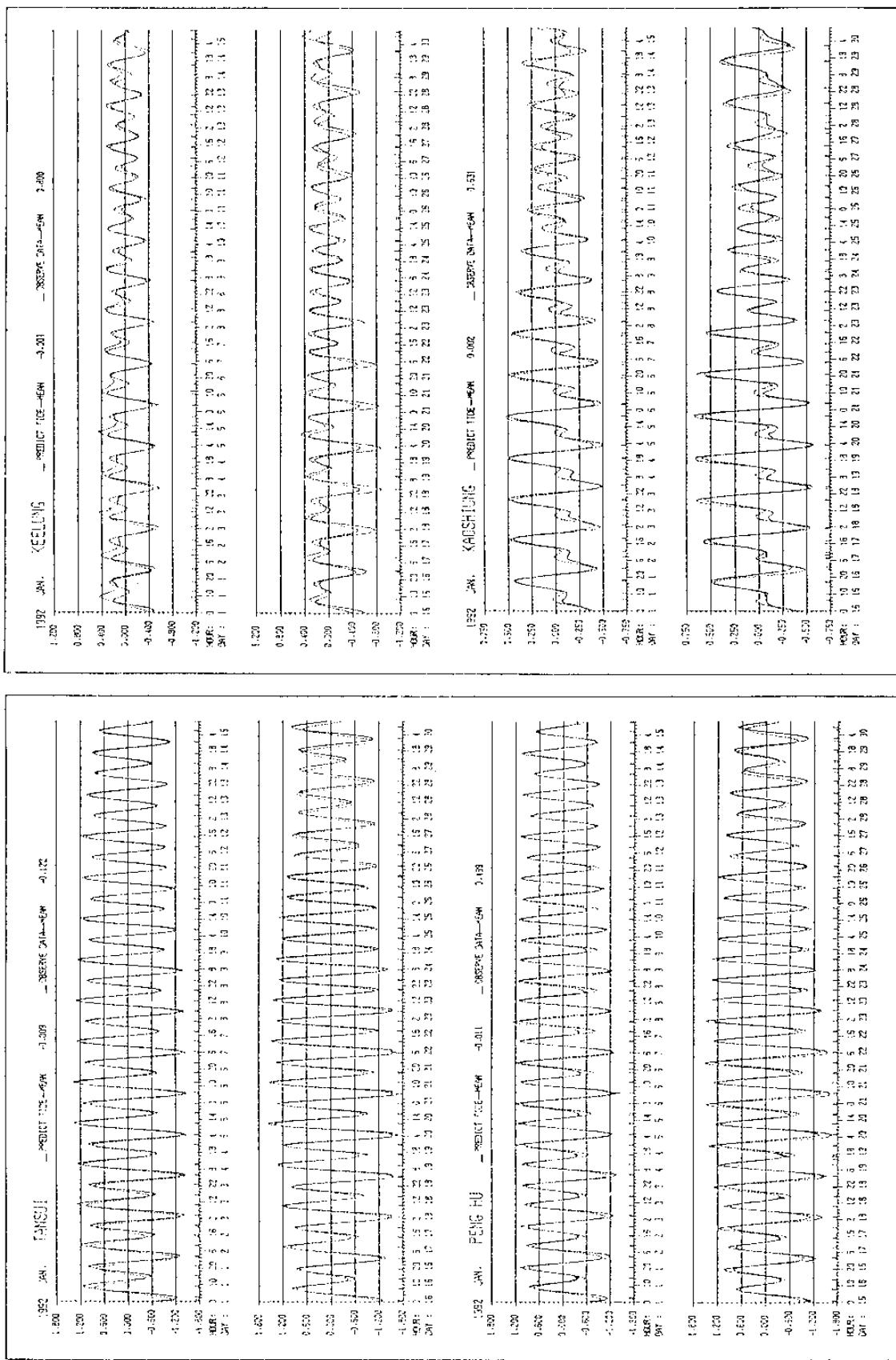
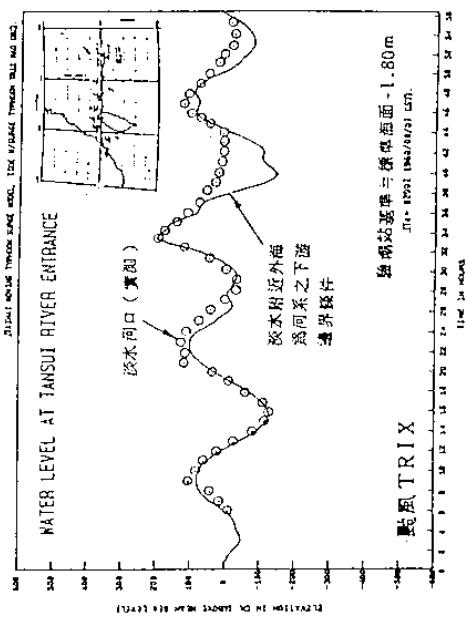


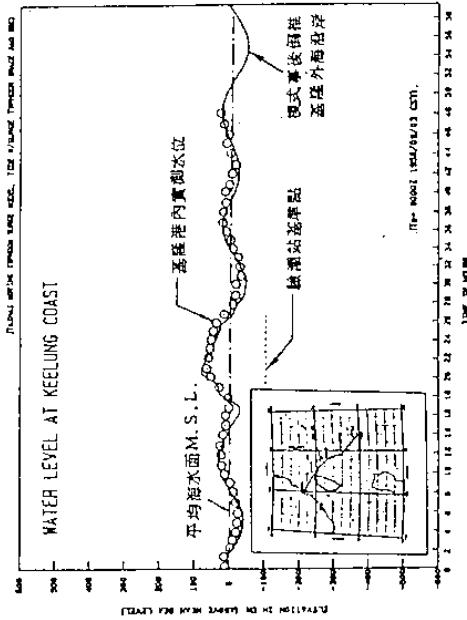
Fig. 3 Comparison between the observed and the predicted water level at several coastal stations around Taiwan

典型「北部」颱風的比較分析

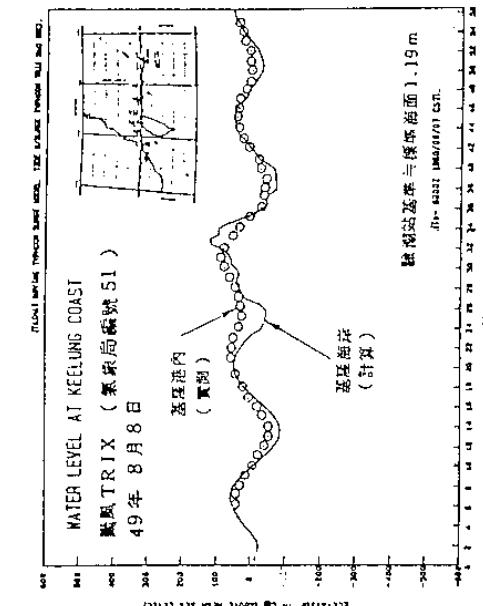


模式所計算基準水外海水位及實際淡水河口的比較，颱風
麥台期間海水位稍高，過境後之廿二小時內淡水河系
的還仍然存在，以低潮時最高為顯著。

典型「西北颱」的比較分析



颱風GRACE（氣象局編號42）47年9月3日侵台
模式所計算基隆岸區的水位與當時基隆港內實測的水位比較
。實測水位為底盤量測深底盤測量基準點。



模式所計算基隆岸區的水位與當時基隆港內實測的水位
比較。

圖4-4 Comparison between the observed and the computed water level under typhoon conditions at several locations.

JOAN（氣象局編號45）48年8月30日由中南部通過
模式所計算基隆海岸水位與當時基隆港內實測水位之比較。

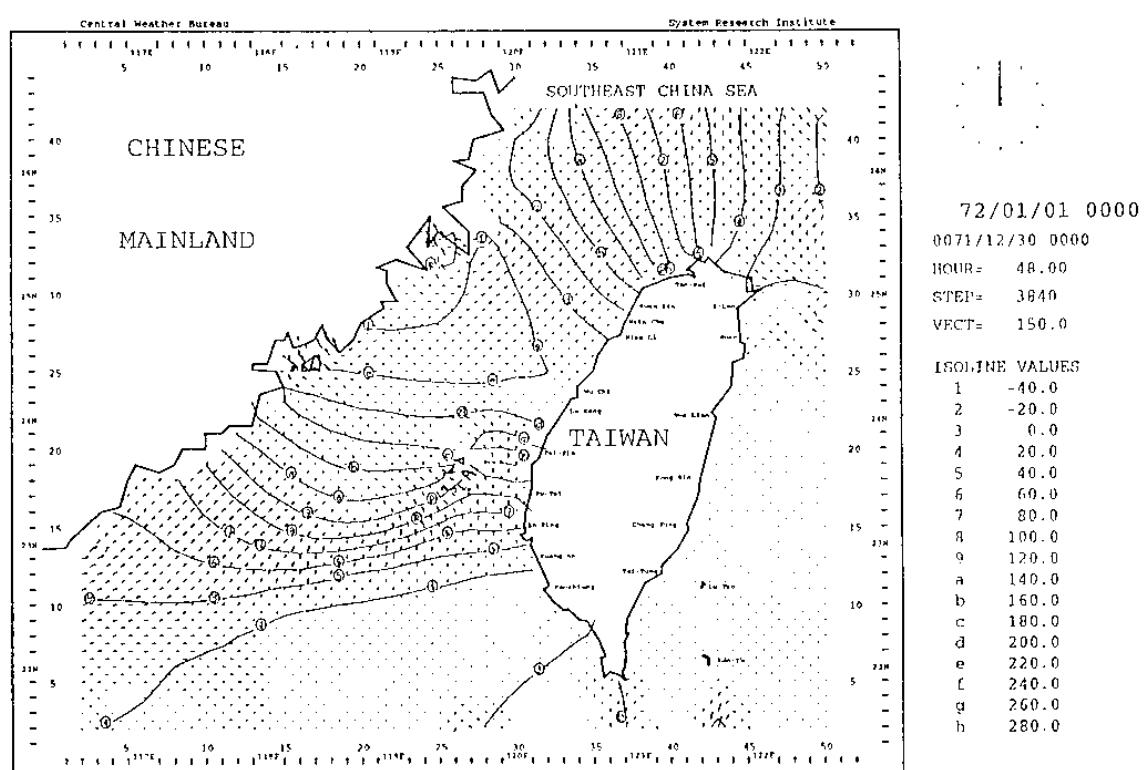


图5 水位和表层流速分布(无台风)

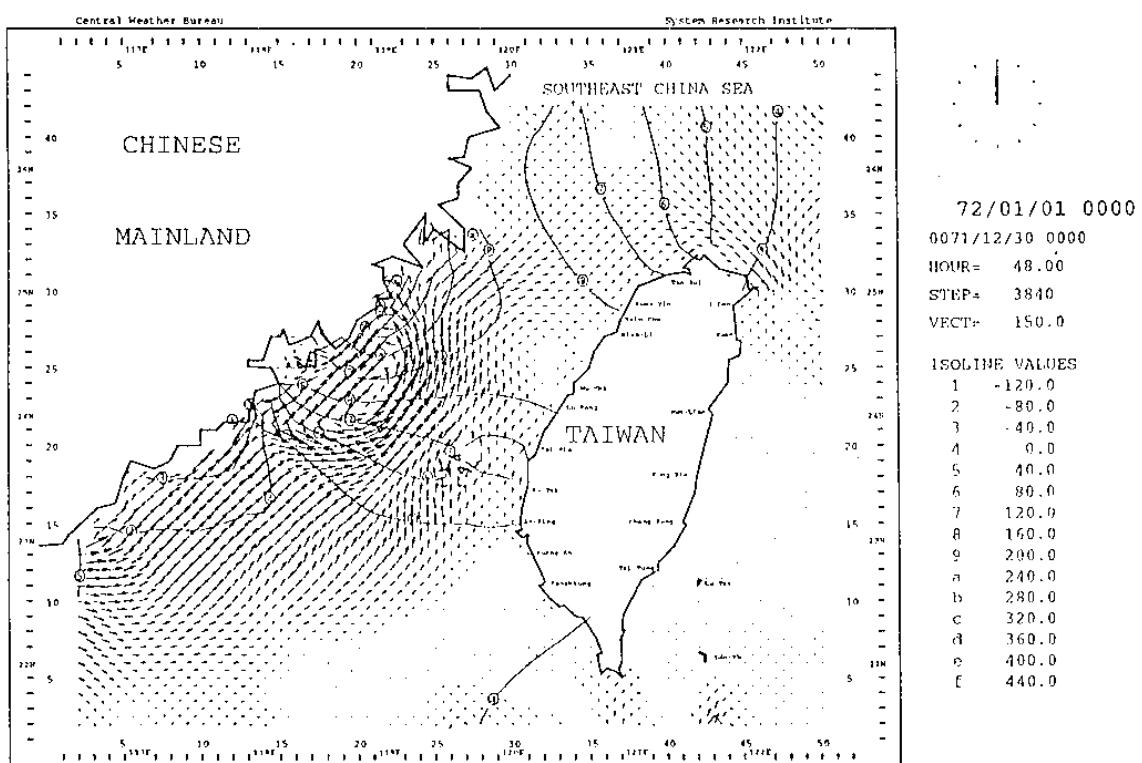
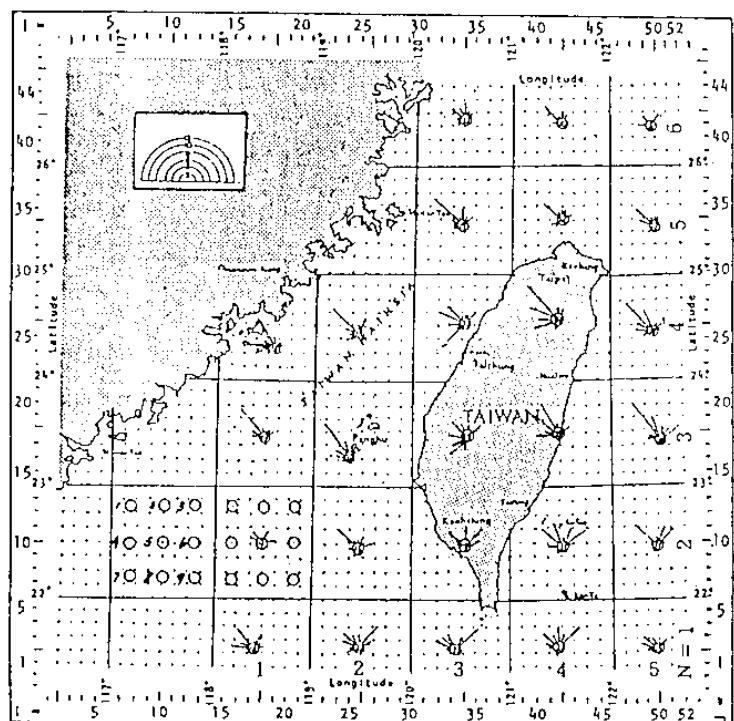
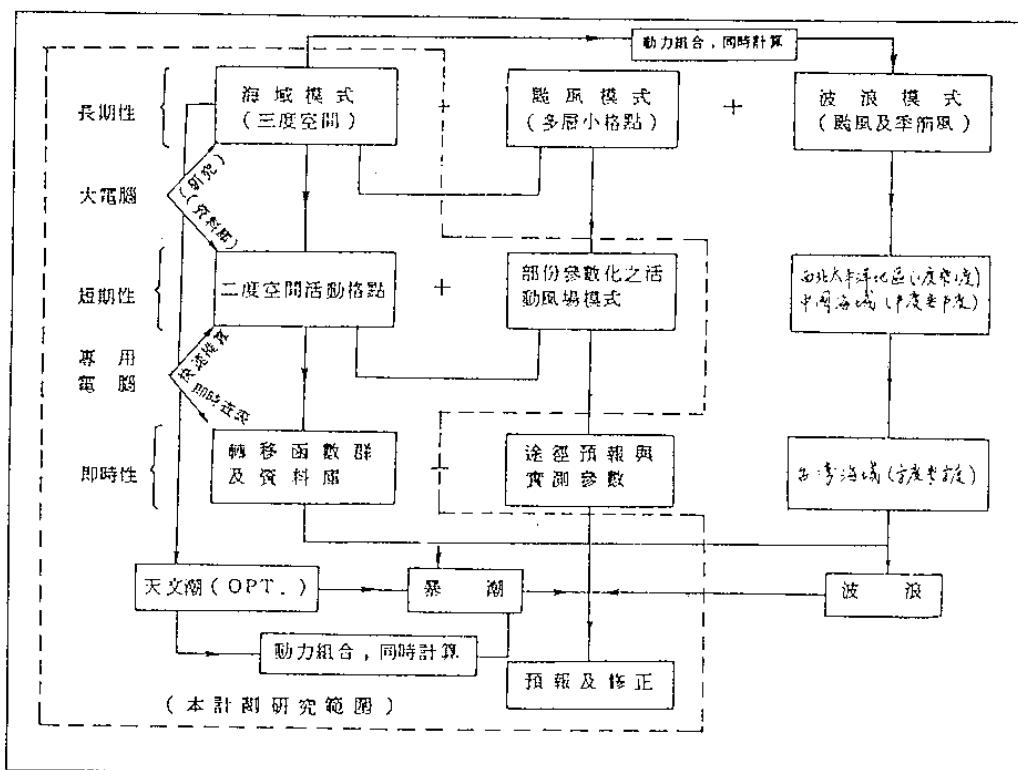


图6 水位和表层流速分布(有920mb台风)

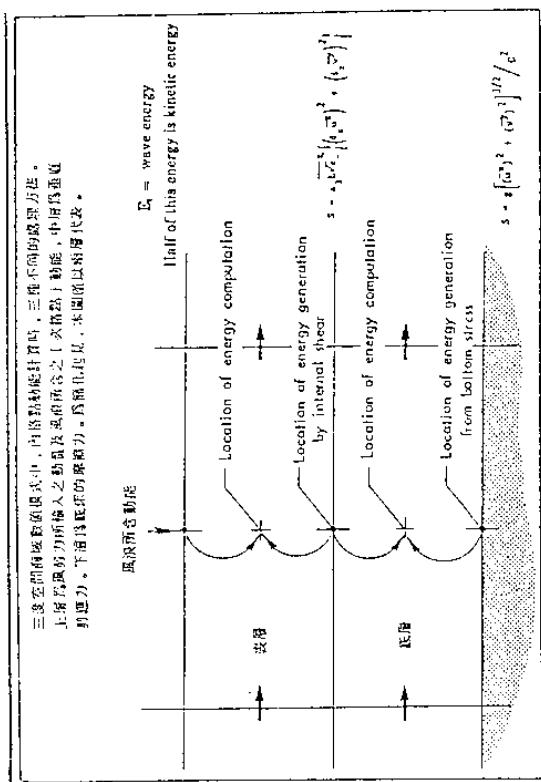


颱風暴雨即時預報系統數值計算所採用的指引圖

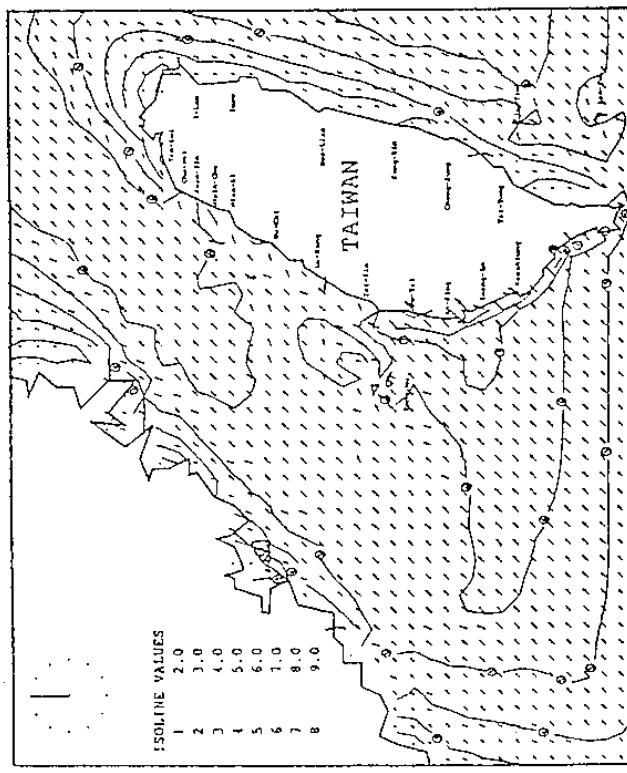


暴潮模式流程圖

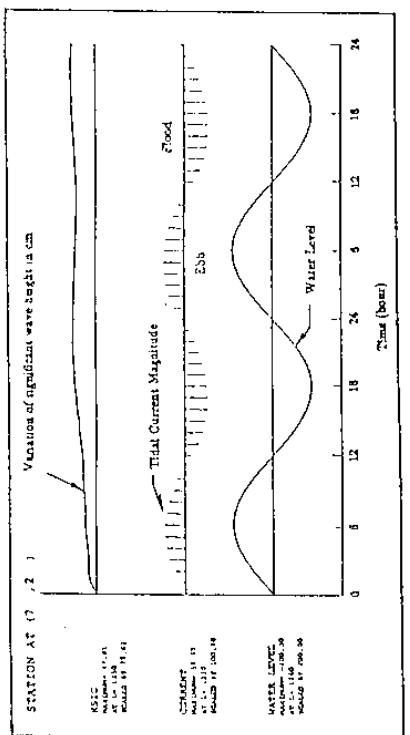
圖7



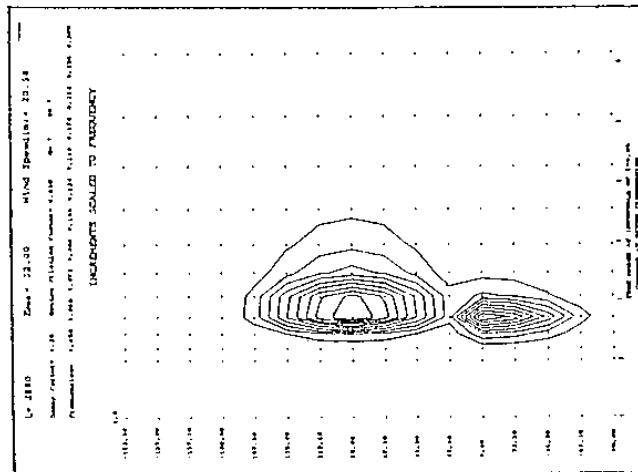
8 Numerical treatment of vertical boundary conditions for SGS energy computation



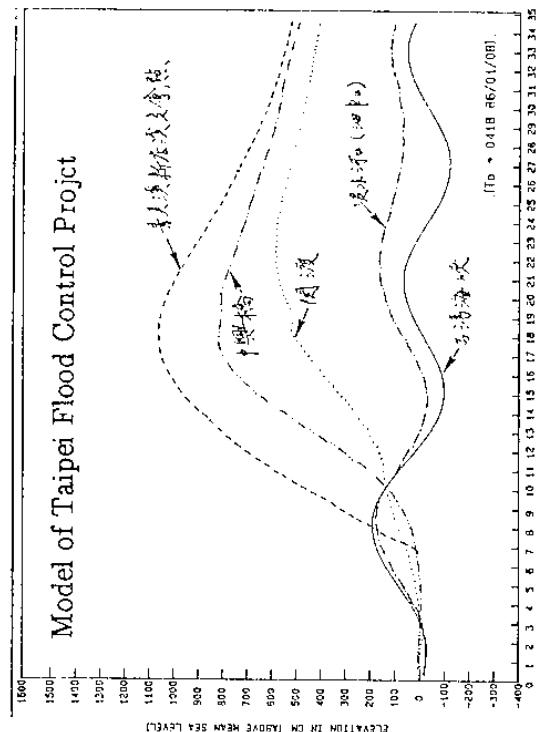
10 Spatial distribution of significant wave heights under SW monsoon at 20m/s



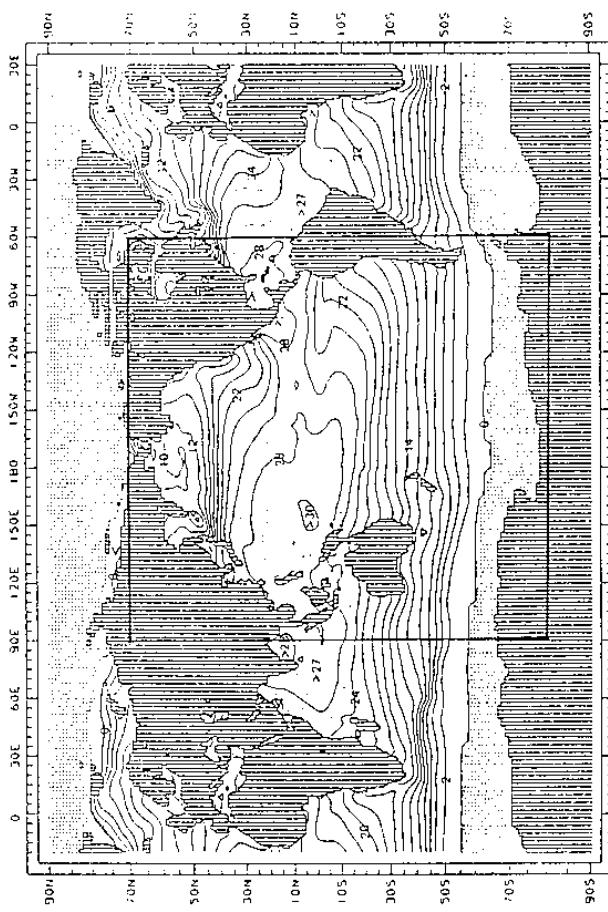
9 Time-varying distribution of significant wave height under various tidal-currents and water level in a tidal estuary.



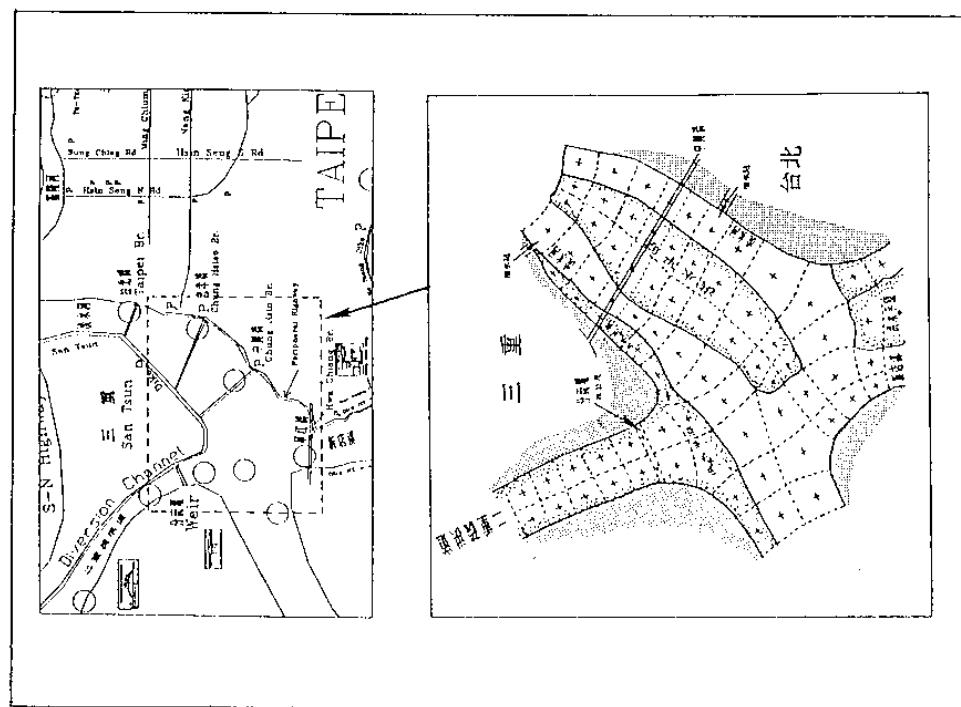
11 Directional spectral energy distribution after a sudden change of wind direction showing the propagation of swell train.



■13 Water level at various points under 200-yr flood



■14 Numerical tsunami prediction model of the Pacific Basin.



Linkage between typhoon surge model and the Taipei flood prediction model

Extensity of the Operational Typhoon Surge/Tidal Prediction Model

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Abstract

The dynamic effects of typhoon, when combined with tides, may create disastrous sea water level in the coastal areas. Along the coast of the SE China Sea and Taiwan, tidal range may reach 8 meters. To minimize the potential property damage and the loss of human lives, a numerical modeling system has been developed to predict water level and currents induced by typhoon and tidal forces. The model is based on the equations of motion, continuity, the balance of heat, salt, pollutant concentration, turbulent energy densities, and the directional spectral energy of wind waves, formulated over the universal ellipsoidal grid. To obtain proper boundary conditions, a cascade of nested models of various resolutions are adapted. The western Pacific model, which covers the area north of the equator and west of the 170 degree meridian, provides the boundary conditions for models covering the China Sea region. Models within the China Seas have resolutions range from 1/4 degree by 1/4 degree to 1/24 degree by 1/24 degree (Fig.1). Many engineering and economical issues (e.g., flood control, power plant design, dike heights, coastal land development, etc.) are related to the surge problem. In addition to providing coastal flood warnings, results from this modeling work can also be used for engineering design and other related purposes. This paper points out several such applications including the specification of boundary conditions for the near shore models. These models often have small, variable grid, formulated via coordinate transformation. The dynamic linkage between the typhoon surge model and the flood prediction model for the Taipei metropolitan area is used as an example in this paper.

The prediction of sea-state parameters (i.e., temperature, salinity, pollution concentrations, water level and currents) is also important to fishery, marine ecology, navigation, pollution control and coastal defense. Formulated to include those physical parameters in the operational model, the paper thus discusses the extensity to such applicaitons.