B-11.1 Prediction of Hydrological cycle change in a river catchment scale by the coupling of meteorological and hydrological models

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Abstract

Purpose of the study is to predict hydrological cycle changes due to greenhouse-induced climate change. The prediction is, however, for more uncertain than prediction of climate change, because any climate models do not yield regional climate changes such as precipitation and evapotranspiration changes over a river catchment in the interest of rough resolution of the climate models. The best method to solve the problem is the utilization of hydrologic model with mesoscale atmospheric model. We were developing the coupling models can describe interrelationship between the land surface and the atmosphere, e.g., regional precipitation and evapotranspiration. We could get the good estimation from this latest model about winter simulation.

Key Words Hydrological cycle, Meteorological model, Catchment scale, Prediction of Precipitation, Land surface process

1. Introduction

Weather and climate are among the foremost factors which determine how a society develops in a geographical region. Daily fluctuations of the atmosphere are called weather while the long-term averages (usually 30 years or more) of the atmospheric fluctuations define a region's climate.

The social, economical and physical infrastructure of a geographical region (such as Japan) has evolved from the adaptation of that region's society to the prevailing climate and to the hydrological conditions brought about by that climate over decades or, as in the case of Japan, over centuries. The frequency of occurrence and magnitudes of such phenomena as typhoons, floods and droughts have a profound influence on the habitability of a region and on the social and economical activities of that region's population which tries to moderate the stresses bought about by those climatic/hydrological extreme events.

During the last decade two by-products of men's industrial and agricultural activities were recognized as potential causes for climate change in the form of global warming. These by-products are the gases released into atmosphere.

An analysis of the future usage of fossil fuels predicts that the CO_2 concentration will reach twice the pre industrial value by the year 2100. Since an earth surface temperature of 0.5 °C has followed a 19% increase in atmospheric CO2 content, a 100% increase in the CO2 content by the year 2100 may have serious ramification on the earth surface temperature.

2. Research Objectives

This research aim is to develop a mesoscale atmospheric model for Japan in order to translate reliably the climatic findings of GCM global change studies to the potential impacts on the water resources of the mesoscale region of Japan. Since a GCM grid size is typically around 300km, it is not possible to translate its generally coarse climate findings to the micro and small mesoscale sub regions of geographical regions with rough terrain. This is the case in Japan where mountain ranges dominate the topography and strongly influence the climate.

Within the above framework the overall objective of the research is to develop a methodology for the quantitative assessment of the atmospheric and hydrologic changes over the mesoscale region of Japan which may be brought about by climatic changes due to the greenhouse effect.

3. Research Method

3.1. Research scheme

This research is collaborative study with University of California, Davis. The schedule is as follows;

FY 1990	Research for basic structure of model, Basic experiment for land surface process
FY 1991	Developing the model (first version), Test simulation in small area
FY 1992	Modifying the model for adapting it to whole Japanese area, Inserting sub model for land surface process, Simulation for precipitation of winter season in whole Japan

3.2. Basic Model Structure

A set of primitive equations with a terrain-following sigma coordinate system are used in the model. The model employs an ordinary Cartesian coordinate system in the horizontal directions with variables' x and y. The σ-coordinate, where σ=p/p_{sfc}, is used as the vertical coordinate in order to deal with the problems generated by topography. Here p denotes description of the σ-coordinate system is provided in Fig1. In the σ-coordinate framework the model equations are as follows:

Conservation of horizontal momentum in x and y directions:

$$\frac{Du}{Dt}=\left[f-v\frac{\partial m}{\partial x}+u\frac{\partial m}{\partial y}\right]v-\dot{\sigma}\frac{\partial u}{\partial \sigma}-\left[m\frac{\partial \Phi}{\partial x}+mc_p\theta\frac{\partial \Pi}{\partial x}\right]+F_{u\sigma}$$

$$\frac{Dv}{Dt}=\left[f-v\frac{\partial m}{\partial x}+u\frac{\partial m}{\partial y}\right]v-\dot{\sigma}\frac{\partial v}{\partial \sigma}-\left[m\frac{\partial \Phi}{\partial y}+mc_p\theta\frac{\partial \Pi}{\partial y}\right]+F_{v\sigma}$$

Conservation of thermal energy:

$$\frac{D\theta}{Dt}=-\dot{\sigma}\frac{\partial \theta}{\partial \sigma}+\frac{\theta}{c_pT}H+F_{\theta\sigma}$$

Conservation of water vapor:

$$\frac{Dq}{Dt}=-\dot{\sigma}\frac{\partial q}{\partial \sigma}+M+F_{q\sigma}$$

Conservation of mass:

$$\frac{D\ln P_{sfc}}{Dt}=-\nabla_\sigma\bullet\overline{V}-\frac{\partial \dot{\sigma}}{\partial \sigma}$$

Hydrostatic equation:

$$\frac{\partial \Phi}{\partial \sigma}=-\frac{RT}{\sigma}=-c_p\theta\frac{\partial \Pi}{\partial \sigma}$$

Where, D/Dt = horizontal substantive derivative of time = $\frac{\partial}{\partial t}+\vec{v}\bullet\nabla$, f = Coriolis parameter = $2\Omega\sin\phi$, Ω= Earth's angular velocity;ϕ=latitude, u,v = x and y direction horizontal velocities, $\dot{\sigma}$= dσ/dt = w = vertical velocity in sigma coordinates, Φ= geopotential height; dΦ(z)=gdz, Cp= specific heat of air at constant temperature 1004JKg-1K-1, T= temperature, θ= potential temperature, π = dimensionless pressure T/θ = $(P/1000)^{0.286}$, m = map factor for polar stereographic projection = $(1+\sin\phi_0)/(1+\sin\phi)$, ϕ_0= to 60°N, $F_{u\sigma}$, $F_{v\sigma}$ = vertical turbulent flux divergence, respectively of x-direction and y-direction momenta, H = rate of heating/cooling, $F_{\theta\sigma}$ = vertical turbulent flux divergence of hear, q = mixing ratio, M = change in mixing ratio due to convection, $F_{q\sigma}$ = vertical turbulent flux divergence of moisture, psfc = surface pressure, R = gas content of dry air

A quasi-Lagrangian advective scheme is used to integrate the model. Unlike most other prediction schemes which are based on an Eulerian framework, a second-order accurate scheme in a quasi-Lagrangian framework is employed.

Latest version of this model have two size which is large domain model(60km*60km, 10layers) and small domain model(20km*20km, 12layers) nested by large one (See Fig.2).

3.3. Inserting boundary layer and land surface parameterization

We could not get good result from simulation of FY1991 because the wind, temperature and moisture distributions within the lowest 100 meters of the atmosphere, adjacent to the land surface, could not be modeled appropriately. Therefore we developed a boundary layer and land surface parameterization and combined the these parameterization with our model.

4. Result

We did simulation of winter season of whole Japan area(1988 Dec - 1989 Feb). We made the initial field and boundary condition from NMC(US National Meteorological Center) and COADS(Comprehensive Ocean-Atmosphere Data set) .

We can get the better estimation of precipitation by means of modified model than old version according to Fig. 3a and 3b.

5. Discussion

We have to do the simulation of summer and to develop the nesting method with GCM (General Circulation Model).

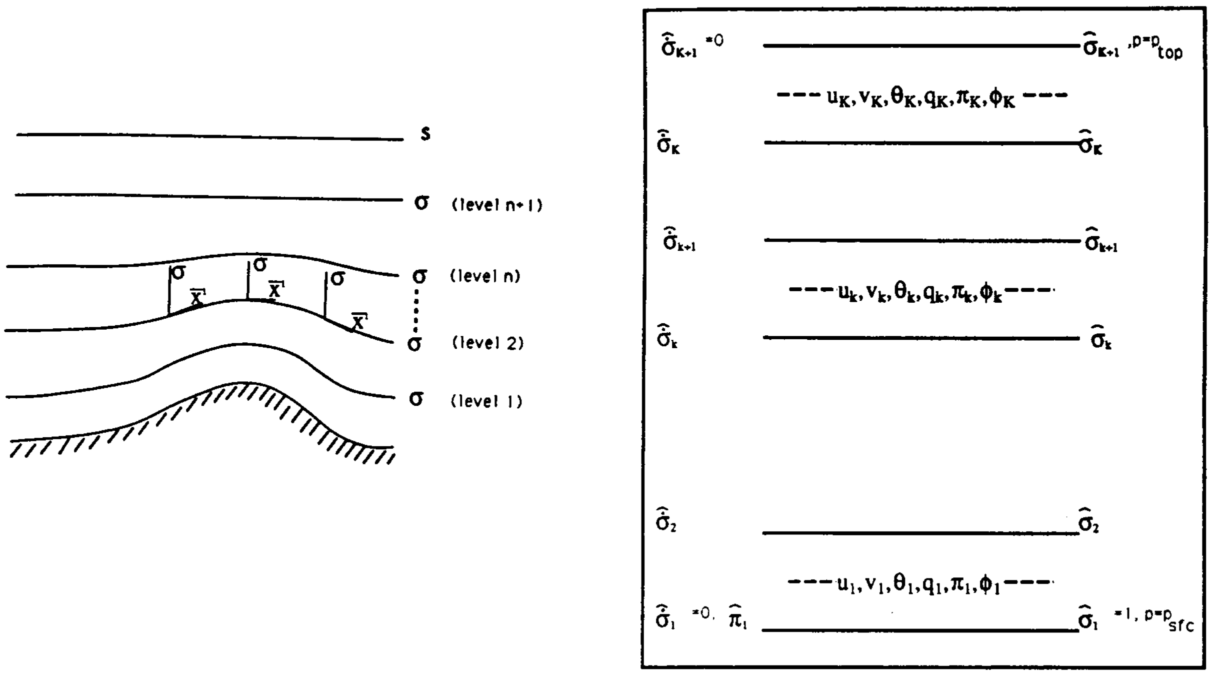


Fig.1 Vertical Coordinate

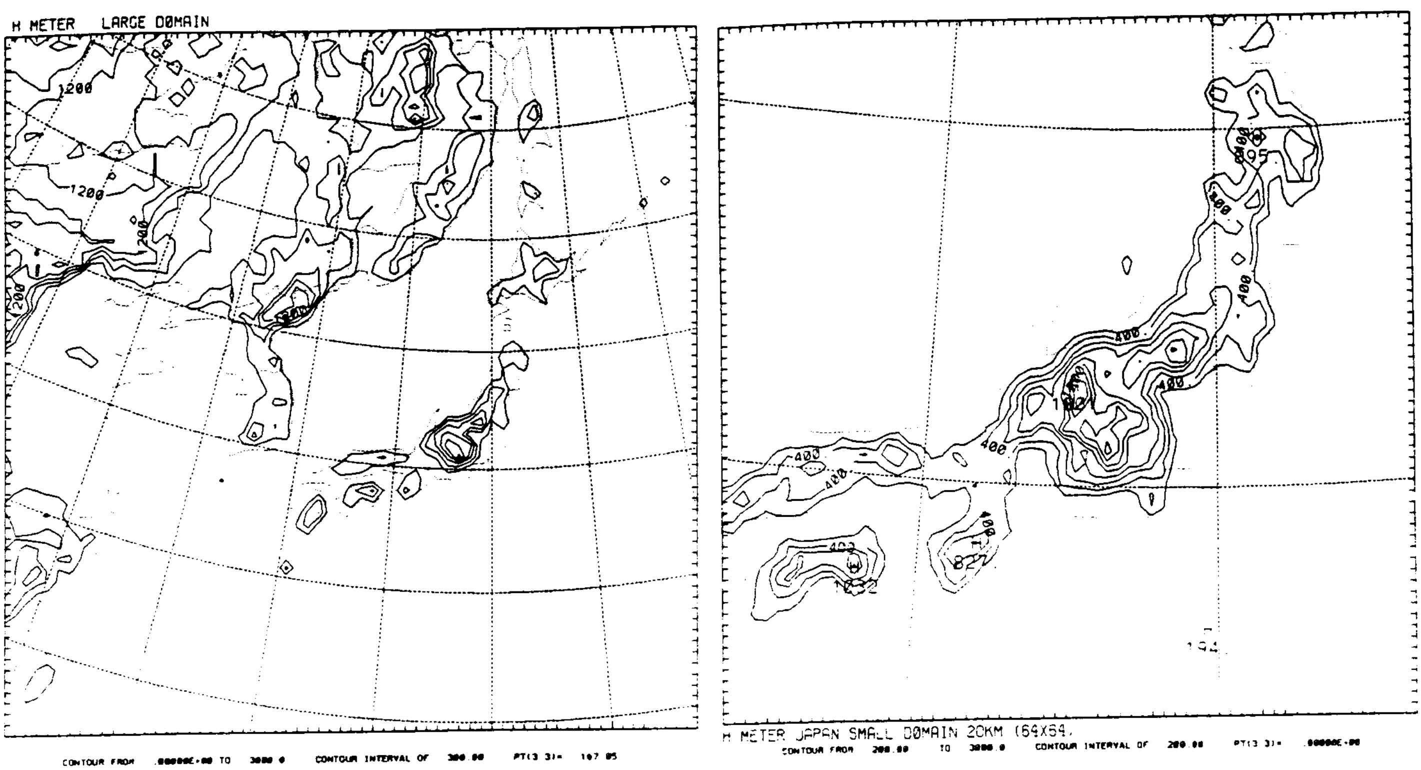
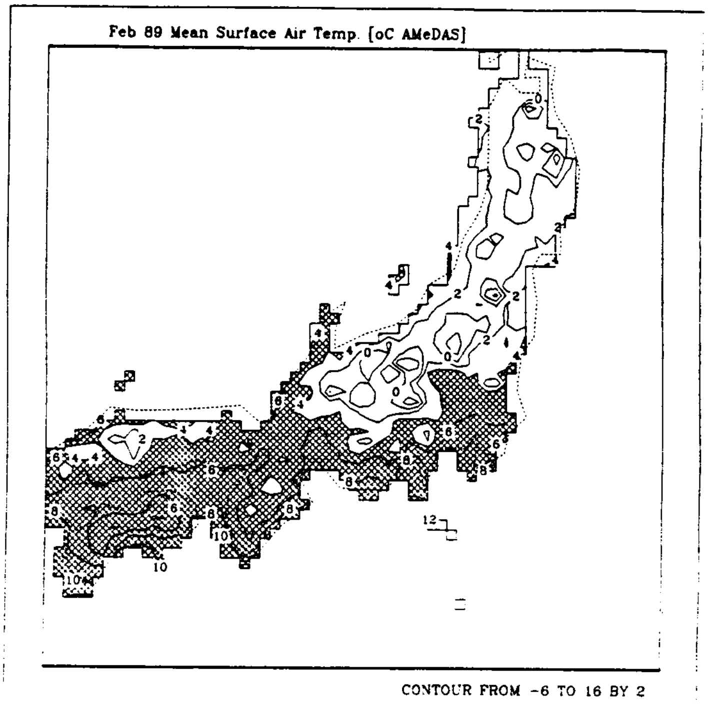
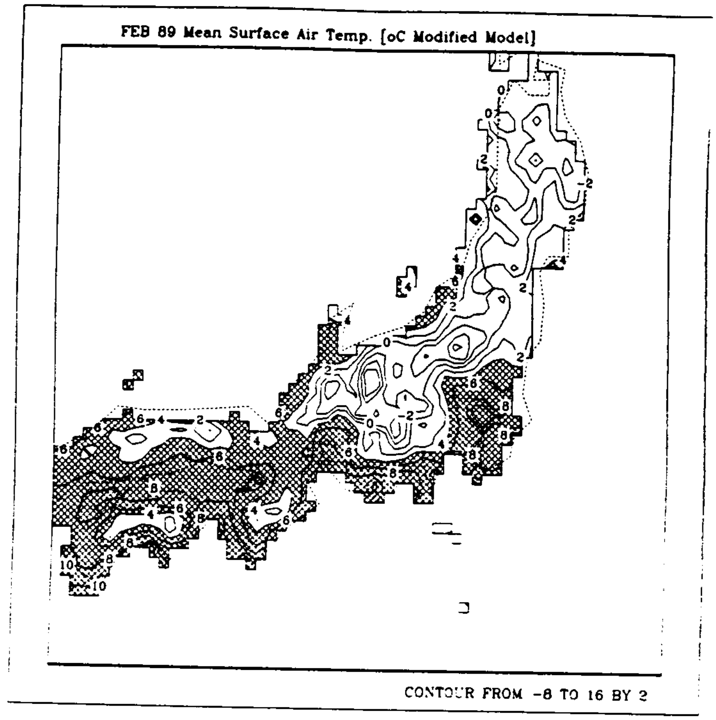


Fig.2 The topography of Large domain and Small domain model

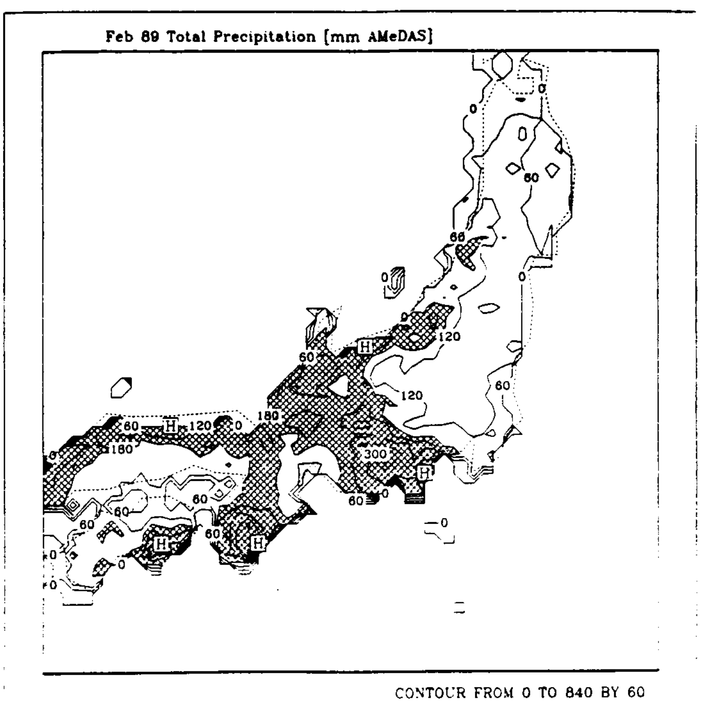


Observation

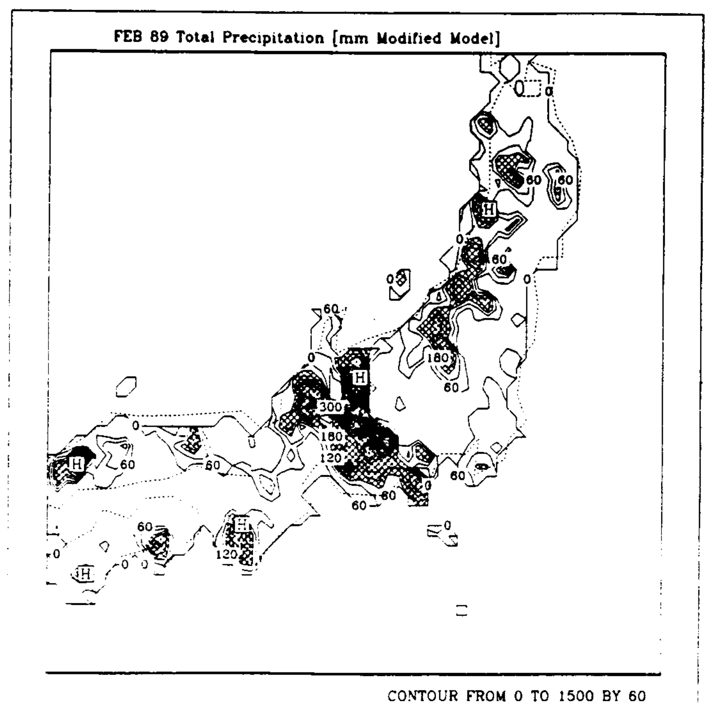


Calculation

a) Surface temperature



Observation



Calculation

b)Precipitation amount

Fig.3 Result of Small domain model (1989 Feb)