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VERIFICATION OF REGIONAL CLIMATES OF GISS GCM- Part 2: SUMMER

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Foreword

The GCM used for climate studies at GISS is now second generation (model II). It was described in the Monthly Weather Review in 1983 in a 53-page article by Hansen, Russell, Rind, Stone, Lacis, Lebedeff, Ruedy and Travis. This benchmark publication discussed the computational schemes as well as the research that created model II from its predecessor and characteristics of the model climate. Regional details of the simulated climate for fine and medium resolutions (4°lat x 5°long and 8°lat x 10°long) were beyond its scope.

Model climatology for December-January-February averages at both resolutions was documented and verified in the Part I of this study: Druyan and Rind (1988) NASA Tech. Memo. 100695. Here, we repeat the foreword of Part I which is equally relevant to the present verification of the model June-July-August climatology.

Since models computed at grid resolutions no finer than 4° x 5° do not resolve many synoptic weather features very well, one must be cautious about interpreting their results for specific geographic locations. Time and space averaging of model output can certainly make it more meaningful. Still, a seemingly successful verification of zonal mean fields may mask very serious deficiencies, such as when errors of opposite sign cancel each other. When the errors derive from computational instabilities or small displacements of features (that may result from the limitations of the spatial resolution), then the smoothing accomplished by zonal averaging is desireable. When, however, the errors derive from a poor simulation of the characteristics of major circulation features, then the emphasis on accurate profiles of a zonal mean quantity is misleading. (Consider, for example, that if a maritime high and a continental low at the same latitude were both simulated to be too shallow, it would not show up in the zonal mean of the sea-level pressure.) Moreover, one cannot ignore the components of monsoonal circulations in favor of tropical or subtropical zonal means, nor should one overlook the blurring of southwestern deserts with southeastern humid zones because the zonal mean precipitation rate verifies well. Naturally, verifiable model success in depicting regional climates generates confidence that the larger-scale features are realistic for the right reasons.

A number of interesting and useful model applications relate to regional climates and they require a complete understanding of the unperturbed models' faithfulness to the actual climate of the zone under study. A model prediction of the double-CO_2 climate of Europe is more believable when the model has been shown to simulate today's European climate realistically.

Sea-level pressure fields and precipitation rates are compared to analyses of observed data published by Dennis Shea in his Climatological Atlas (NCAR, 1986). The data cover the years 1950-79.

The components of the wind aloft and the surface wind are verified against analyses by Abraham Oort in his Global Atmospheric Circulation Statistics (NOAA, 1983). These data cover the period 1963-1973. Qualitative comparison of surface flow is made with analyses of the gradient wind by Atkinson and Sadler (US Air Force, 1970) and a streamflow analysis over North America made by NAVAIR (1966) but published by Bryson and Hare in their Climates of North America (Elsevier, 1974).

Two versions of model II have been chosen for the present verification study. The fine grid, for which computations are made at a horizontal resolution of 4° latitude by 5° longitude, was run for five consecutive model years as 848F9. It used prescribed, climatological sea-surface temperatures, time-interpolated to each day of the year. The discussion in this presentation relates to the mean fields for the five years.

The medium grid version is computed at the spatial resolution of 8° latitude by 10° longitude. It was run for 37 model years as 882M9, but the fields shown in this presentation represent the means for the ten model years 26-35. This version computes the sea-surface temperature as a by-product of the air/sea energy exchange based on prescribed, seasonally varying values of heat transport within the ocean. Mean monthly and seasonal sea-surface temperatures generated by this interactive ocean formulation have been shown to be climatologically realistic.

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VERIFICATION OF REGIONAL CLIMATES OF GISS GCM-
PART 2: SUMMER (JUNE-JULY-AUGUST)

1.1 SLP: North America, North Pacific, North Atlantic

Fine Grid: The Pacific anticyclone is represented, but maximum sea-level pressures (SLP) are about 4mb too low and do not extend far enough westward. The circulation over the subtropical Pacific is a good representation of the actual trades, but the observed band of westerlies north of the high pressure cell is not developed by the model. The juxtapositions of the high center and a SLP minimum over the southwestern United States creates a northerly flow that simulates the actual circulation, although the pressure gradient is somewhat too strong in the vicinity of California. SLP over the United States and Mexico are too low, especially along the Atlantic coast where the error reaches about 7mb. The Atlantic high is also about 4mb too shallow and is slightly too far north, making the area of westerlies over northern portions too narrow and too weak; the model's subtropical Atlantic easterly trades are more realistic. SLP over Greenland are about 8mb too high.

Medium Grid: The center of the Pacific high pressure is about 10° latitude too far north and its central pressure is about 4mb too shallow. The underestimate of pressure is rather systematic over the southern half of the Pacific, so that the gradients (which determine the stregnth of the circulation) south of the high are quite reasonable. North of the high, however, the pressures should also decrease by some 8-12mb and the model's failure to do this means that the wide band of westerlies over the North Pacific is missing in the simulation.

The heat low over Mexico is about 4mb too deep but is otherwise reasonable. Troughing over the eastern United States in the model is much different from the observed pattern of weak southerlies that are caused by the gradual increases in pressure from the Mexican low eastward to the Bermuda high. The model does show small increases from North America to the Atlantic, but its center of anticyclonic circulation is at 50°N northwest of the observed position at 35°N. The diffuse gradient over most of the Atlantic indicates a weak easterly flow instead of the observed bands of stronger easterlies 10°N-30°N and westerlies 40°N-55°N. Pressures over the southeastern United States and the subtropical North Atlantic are some 10mb too low while they are almost that much higher than observations over southern Greenland and the adjacent ocean areas.

1.2 Precipitation: North America, North Pacific, North Atlantic

Fine Grid: The excessive rainfall over the central Pacific along 20°-30°N may be associated with the model's not extending the subtropical ridge westward along 30°N. The model gives an excellent representation of the summertime dry season over the southeastern United States and the adjacent eastern Pacific Ocean. Rainfall rates correctly increase toward Texas, but a minimum appears along the Texas Gulf coast that does not verify and the simulated rates do not reach the 4mm/day over the Gulf of Mexico that is observed creating a model error of - 2 to -3mm/day. (Tropical storms contribute about 15% of the summer rainfall along the Gulf coast, so the absence of these distubances in the model meteorology could account for about 0.5mm/day of the error.) The model minimum over the great Lakes also creates another model spurious dry area, although here the errors are only about -1mm/day. The simulated precipitation along the east coast of the United States verifies well, but the maximum over Canada's maritime provinces is 2-3mm/day too much. The model does not show the observed rainfall maximum south of Greenland, but does show realistic isohyets for most of the North Atlantic Ocean. The trend of increasing precipitation from north Africa accross the tropical Atlantic and toward the Caribbean Sea is depicted by the model climatology, but the southwestern North Atlantic is too wet by about 3mm/day.

Medium Grid: The summertime rainfall minimum of the eastern Pacific and California coast is fairly well depicted by the model climatology. The precipitation rate correctly increases eastward, but the maximum over the Mexico-Texas Gulf coast is not accurate. The rainfall over Florida verifies well but it is too high elsewhere along the east coast of the United States and Canada. The simulated maximum over Mexico and Texas does not correspond to any distinctive synoptic pressure feature, so the explanation is probably related to moist convection initiated by excessive ground heating. The high rates along the east coast of North America, on the other hand, reflect the unstable flow of moist Atlantic air reaching the continent from the southeast. The model brings these rains too far north because it does not simulate the "nose" of high pressure that often keeps this area dry in summer.

Table 1.1 Verification summary, North America, N. Pacific and Atlantic

	Fine Grid (848F9)	Medium Grid (882m9)
Pacific anticyclone	4mb too shallow, no westward elongation	4mb too shallow, 10° lat too far north
Pacific westerlies	much too weak	not represented at all
Pacific trades	reasonable	10° lat too far north
SW USA heat low	4mb too deep	6mb too deep
High SLP E. USA	troughing, 7mb error	troughing, 10mb error
Atlantic anticyclone	4mb too shallow	5mb too shallow, 15° lat too far north
Atlantic westerlies	too weak	not represented at all
Atlantic trades	reasonable	diffuse, too far north
West coast precip min	excellent simulation	slightly worse than fine rainy over Nevada
Gulf of Mex US coast	spurious dry spot	excessive rain Texas, too dry lower Missippi
Eastern Canada	2-3 mm/d too rainy	2-3 mm/d too rainy
South of Greenland	rain max missing	min instead of max
SW North Atlantic	3mm/day too rainy	like fine grid

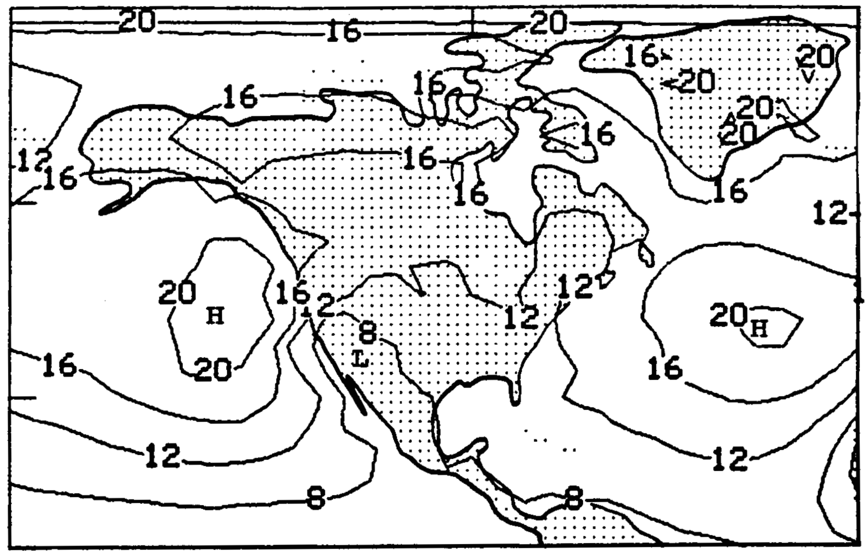


Fig. 1.1 Sea-level pressure (mb-1000), Fine Grid, Summer (JJA)

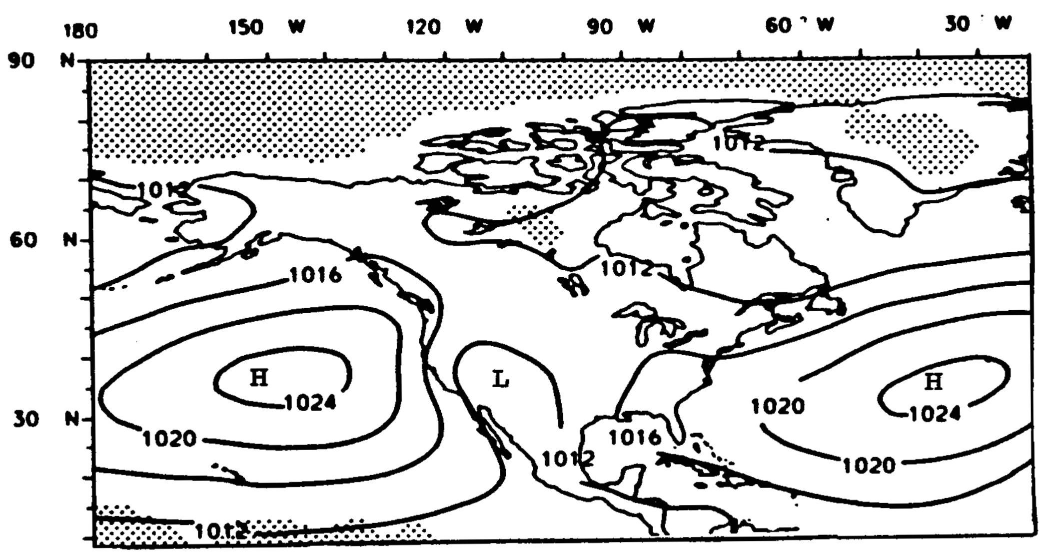


Fig. 1.2 Sea-level pressure (mb), Observed, Summer (JJA)

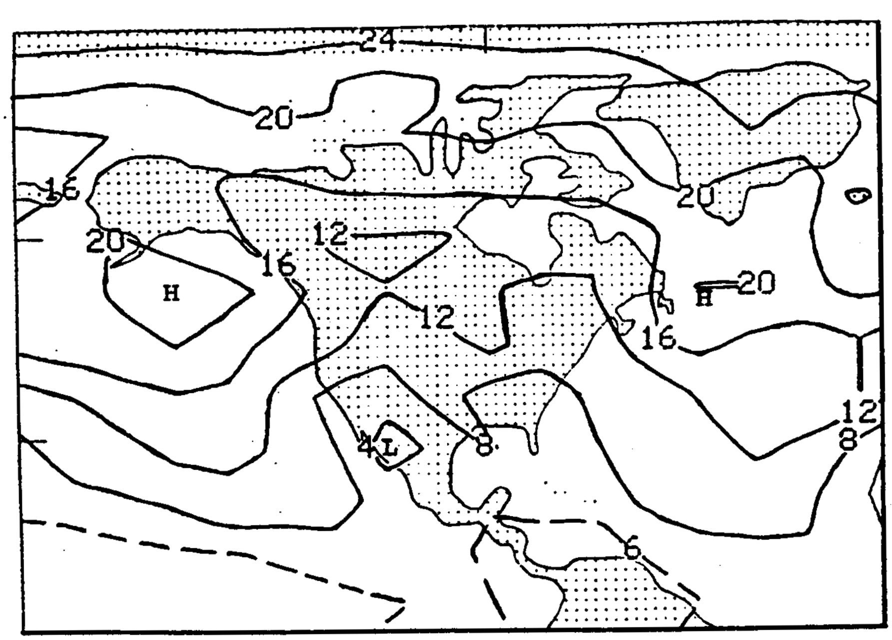
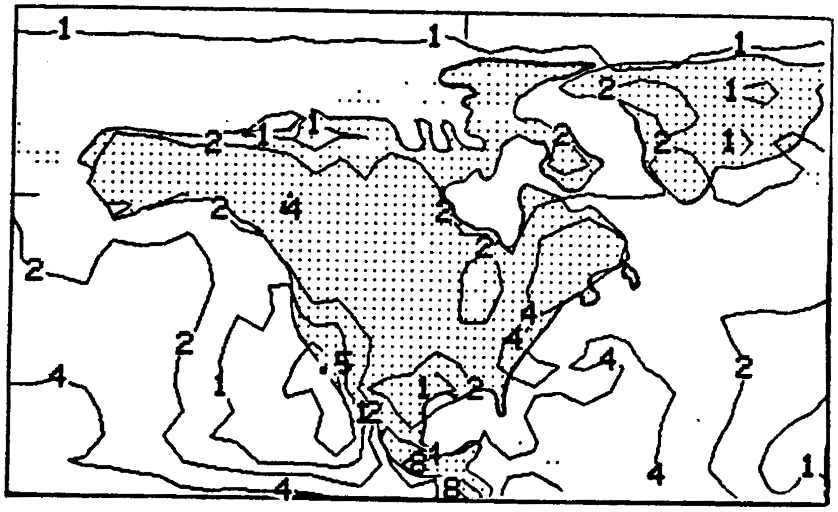


Fig. 1.3 Sea-level pressure (mb-1000), Medium Grid, Summer (JJA)

Fig. 1.4 Precipitation rate (mm/day), Fine Grid, Summer (JJA)



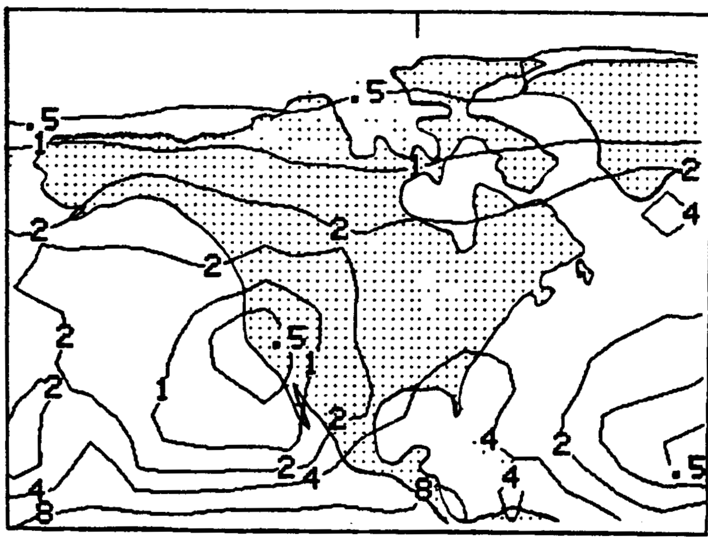


Fig. 1.5 Observed Summer Precipitation

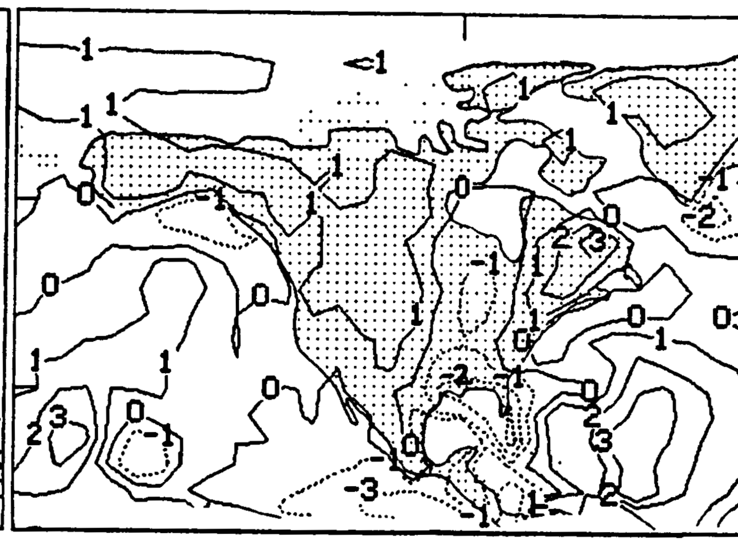


Fig. 1.6 Fine Grid Precip errors (mm/day)

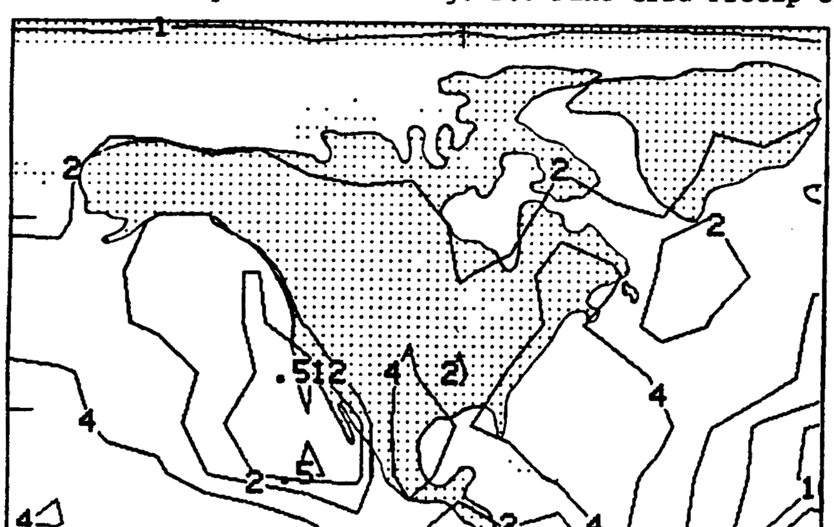


Fig. 1.7 Precipitation rate (mm/day), Medium Grid, Summer (June-July-August)

2.1 SLP: Europe, Mediterranean, Africa and S. Atlantic

Fine Grid: SLP are about 3mb too low over western Europe. The simulated northeasterly circulation over the Mediterranean and north Africa verifies. Ridging is correctly depicted over the Gulf of Sidra although the SLP remain about 3mb too low. The ITCZ trough over north Africa lies along 24°N in the model climatology with SLP minima of 1002mb. The observations confirm the trough latitude but minima should be only about 1007mb. The trough correctly extends toward the southwest over the tropical Atlantic. SLP increase southward to near correct values over South Africa with a fairly strong gradient correctly located between 10°S-30°S, although model values over the equator are about 4mb too low. The South Atlantic anticyclone is at the correct latitude but it is too shallow by about 2mb.

Medium Grid: The pattern of increasing SLP northward over Europe is not realistic and the model high near Iceland is spurious. Values of SLP are about 6mb too low over the Mediterranean, but the circulation pattern is similar to what is observed. The ITCZ trough axis is well placed over north Africa, but is about 8mb too deep. The SLP gradients that depict the easterly circulation north of the ITCZ and the westerly circulation south of the ITCZ are a good representation of the actual climate. Realistic increases in SLP from the tropics to South Africa depict the observed westerly circulation, but the maximum at 30°S is 4mb too low as are the pressure maxima of the South Atlantic anticyclone.

2.2 Precipitation: Europe, Mediterranean and Africa

Fine Grid: The precipitation maxima over central Europe and over Scandanavia do not verify, giving excesses of as much as 3mm/day. The model shows the summer dryness of the Mediterranean and north Africa, but parts of the sub-Sahara are 1-2mm/day too rainy. The observed maximum over Guinea is grossly underestimated although the monsoon maxima over subtropical Africa north of the equator are simulated well. The model does not show the observed dryness over the southern Arabian Peninsula and the Horn of Africa giving excesses of 3-5mm/day. There is, however, a correct depiction of minimum values over the southwestern Arabian Sea. The June-August dryness of southern Africa is represented but not extensively enough, giving excesses of 3-5mm/day over Angola and 3mm/day over Tanzania.

Medium Grid: The same unrealistic maximum is depicted over Europe as in the fine grid. The Sahara and Sahel are slightly too rainy, especially between 0°-10°E, and the Guinea maximum is here also grossly underestimated although the model does show a maximum in precisely the correct location. The subtropics north of the equator are correctly rainy except for the Horn and the southern Arabian Peninsula that should not be receiving any rain in this season. The same mistakes as in the fine grid are made here over the southern half of Africa: Angola and Tanzania are too rainy although the desert area of southwest Africa is properly rainless.

Table 2.1 Verification summary, Europe, Mediterranean, Africa & S. Atl.

	Fine Grid (848F9)	Medium Grid (882M9)
Europe	not enough ridging of SLP	spurious high to NW, unrealistic NE flow
	spurious precip maxima	same as fine grid
Mediterranean	realistic NE flow & ridge	same as fine grid
	realistically dry	too rainy W half
Sahara	most, realistically dry	slightly rainier 0°-10°E
Sahel	ITCZ trough at proper latitude but SLP too low	ITCZ trough at proper latitude, but even deeper
	1-2mm/day too rainy	similar to fine grid
Guinea	precip max underestimated	similar to fine grid
S. Atlantic	High position OK, 2mb low	similar to fine grid
Horn of Africa Saudi Arabia	too rainy, 3-5mm/d excess	rainier over S. Arabia
SW Africa	rainless desert depicted	same as fine grid
S. Africa	too rainy Angola, Tanzania	same as fine grid

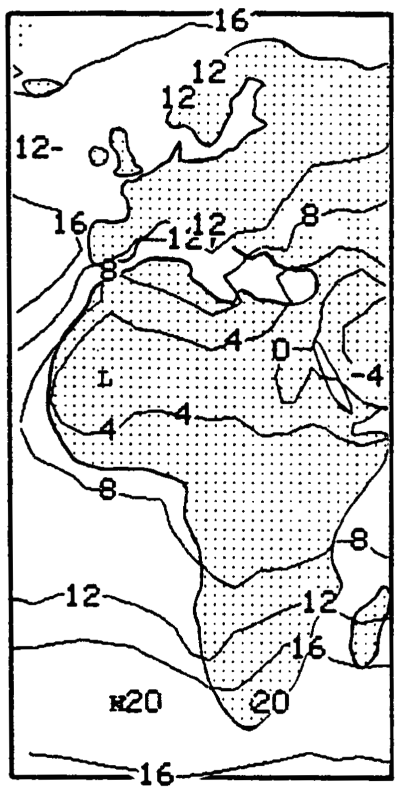


Fig. 2.1 SLP (mb-1000), Fine Grid, Summer

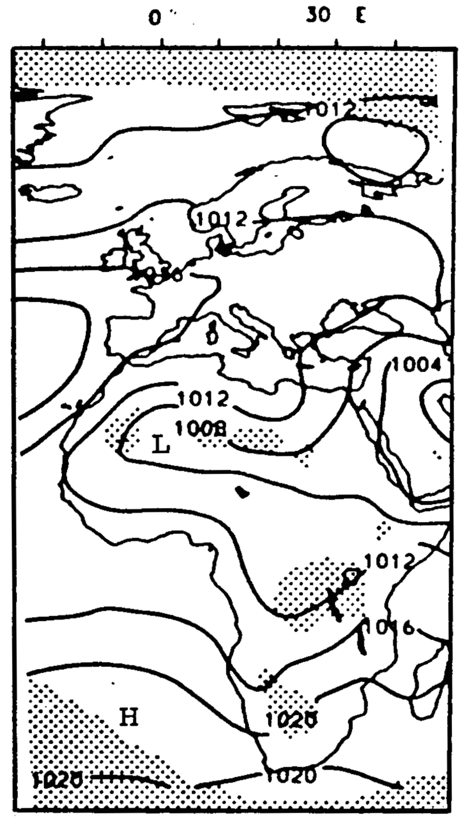


Fig. 2.2 SLP (mb), Observed, Summer

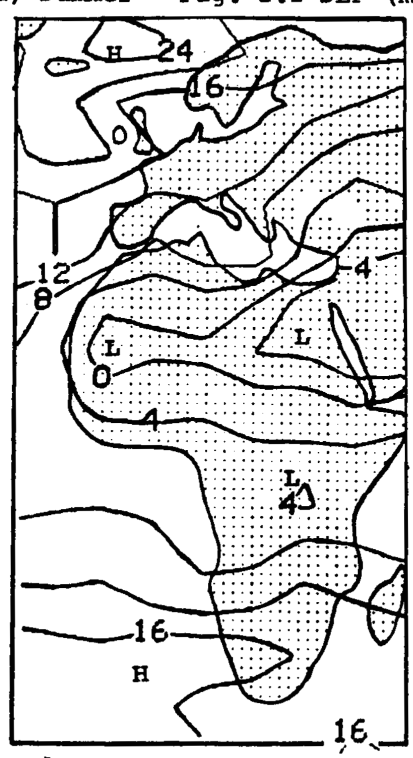


Fig. 2.3 SLP (mb-1000), Medium Grid, Summer

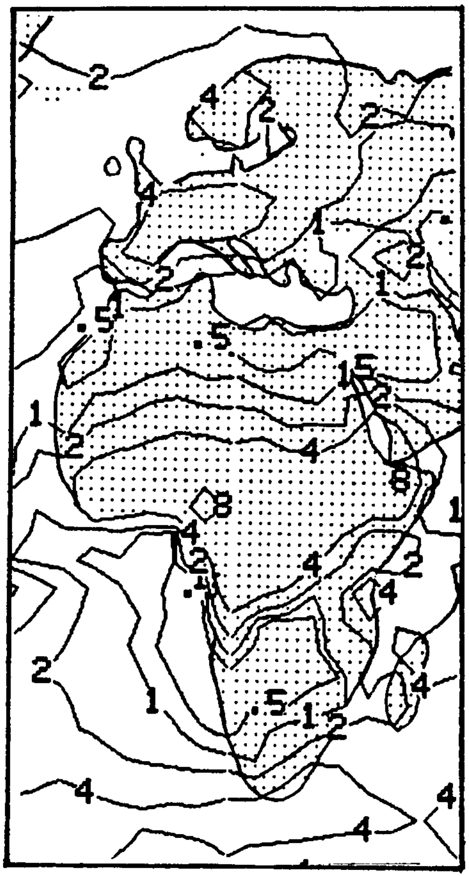


Fig. 2.4 Precipitation rate (mm/day)
Fine Grid, Summer (JJA)

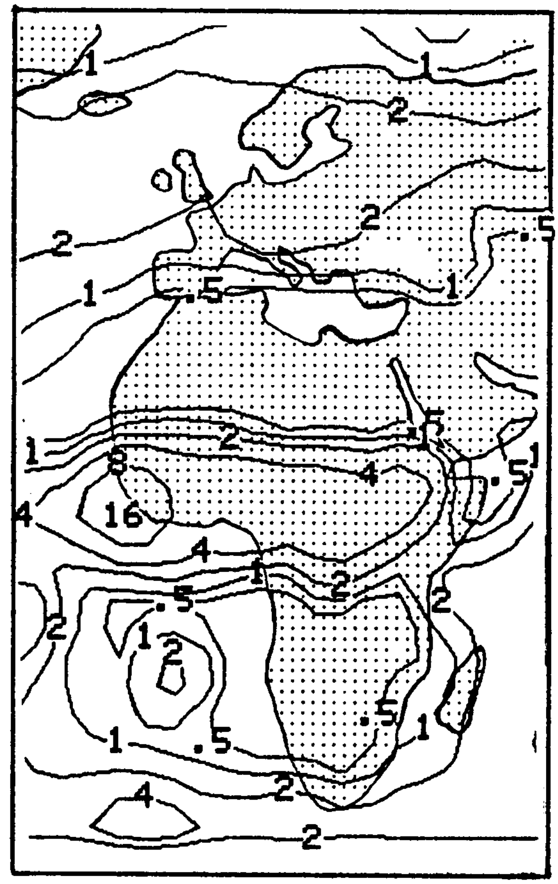


Fig. 2.5 Observed precip rate (mm/d)

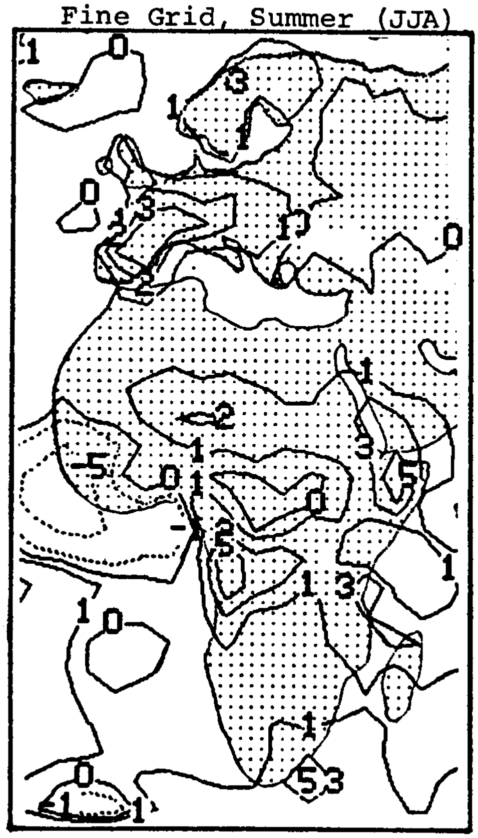


Fig. 2.6 Fine Grid precip errors (mm/d)

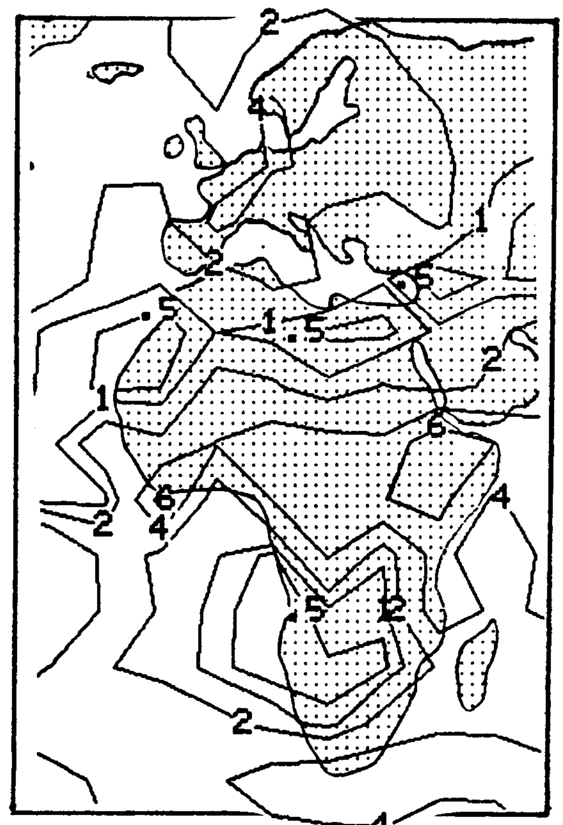


Fig. 2.7 Precipitation rate (mm/day)
Medium Grid, Summer (JJA)

3.1 SLP: Asia, Australia, Indian Ocean, W. Pacific

Fine Grid: The model's lowest SLP are those reduced from surface pressures over the high Himalayan plateau, and they are much too low. The monsoon trough correctly extends along 25°N but the SLP are about 4-8mb too low from the Bay of Bengal, accross India and westward to Saudi Arabia. The gradient driving the southwest circulation over southern Asia is reasonable over India and the Arabian Sea, but it is slightly too strong over the Bay of Bengal. SLP over the Indian Ocean are consistently 4mb too low, including the ridge along 30S, but the general pattern and the the gradients are quite realistic. Over the western Pacific Ocean the model's anticyclonic circulation is slightly too strong and the center of curvature is some 15° latitude too far north.

Medium Grid: The low over the Himalayas is even deeper than in the fine grid. The monsoon trough is correctly oriented, but SLP are about 4mb too low within the trough over India becoming as much as 8mb too low to the west, over the Arabian Peninsula. The SLP gradients within the southwest monsoon circulation are quite realistic over southern India and most of the Indian Ocean. The South Indian Ocean ridge is weaker and less realistic than for the fine grid, however, and it is aligned along 45°S, some 15° latitude south of the observed position. The anticyclonic circulation of the western Pacific is even stronger here than for the fine grid, and it too is displaced about 15° north of its verified location.

3.2 Precipitation: Asia, Australia, Indian Ocean, W. Pacific

Fine Grid: The model's precipitation maximum over northeast Bangladesh would be more realistic if it extended southward along the Burma coast to join the second maximum over the Bay of Bengal. The orographic maximum observed along the Ghats Mountains of southwest India has not been resolved by the model, nor has the rain shadow over Siri Lanka. North central India is too dry with simulated rainfall of less than 1mm/day over regions that receive summer monsoon rains at rates closer to 5mm/day. Errors over most of India are therefore in excess of 5mm/day. Model rainfall maxima over Indonesia, Borneo and New Guinea are not realistic because observations show this to be a transition zone between dry conditions over Australia and the heavy rainfall over the South China Sea north of Borneo and the equatorial Pacific Ocean. The simulated precipitation pattern over Australia shows a remarkably close resemblance to the observed pattern. Thus the model depicts the seasonal dryness over northern Australia, the desert dryness over western Australia and the winter raininess of the southern parts of the continent with errors that are almost everywhere less than 1mm/day.

Medium Grid: Many aspects of the medium grid depiction of summer rainfall over southern Asia are more realistic than the fine grid distribution of rainfall rates. Southern India registers more than 8mm/day as part of a swath of heavy rainfall that extends eastward to southeast Asia. Although this pattern ignores the orographic rain shadow over southeast India, it does cover the observed maxima of southern India and the Burma coast. Here, however, Bangladesh rainfall is too low, and this indicates that the medium grid does not produce orographic rainfall along the southern slopes of the Himalayas which the fine grid exaggerates. Northern India is not quite rainy enough, but it still verifies within 2-3mm/day unlike the fine grid that was desert-like over this area of summer monsoon precipitation. This version of the model does not create a maximum over Indonesia and Borneo like the fine grid does, and shows only small errors in this region. The precipitation minimum over Australia here is, however, less pronounced, and much of the continent that should be rainless is showered with rates of 1-2mm/day.

Table 3.1 Verification summary, Asia, Australia, Indian Ocean, W. Pac.

	Fine Grid (848F9)	Medium Grid (882M9)
Monsoon trough S. Asia	10-15mb too low	more than 25mb too low
Trough over Arabia	4mb too low	8mb too low
SLP gradient SW flow	realistic	realistic
S. Indian Oc. ridge	2mb too shallow, good position	5mb too shallow, 15° too far south
W. Pacific anticyclonic	15°too far north	similar to fine grid
Precipitation, India	gross underestimate	better than fine grid, -3mm/d over north
Precipitation, Bangladesh	large max too broad	maximum missing
Precipitation, Burma coast	erroneously minimized	realistic maximum
Precip-Indonesia/Borneo	erroneously maximized	realistic minimum
Precipitation, Australia	accurately dry	1-2mm/d too rainy

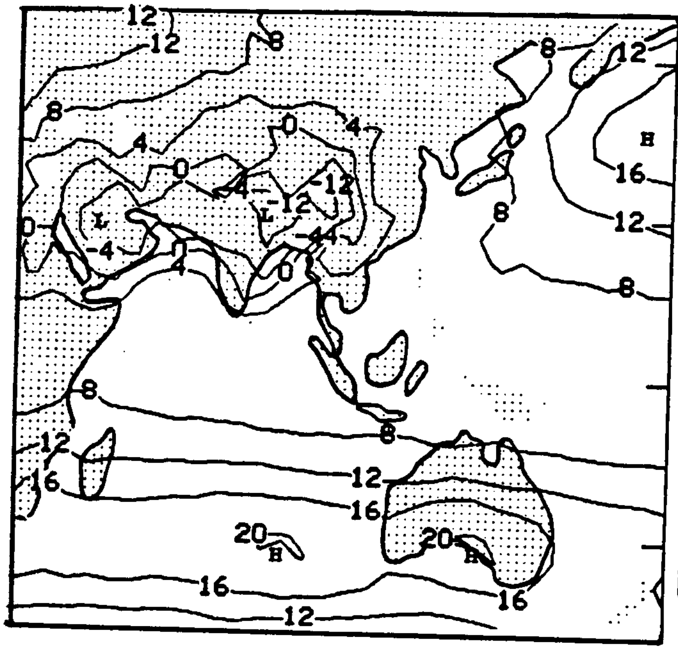


Fig. 3.1 Sea-level pressure (mb-1000), Fine Grid
Summer (June-July-August)

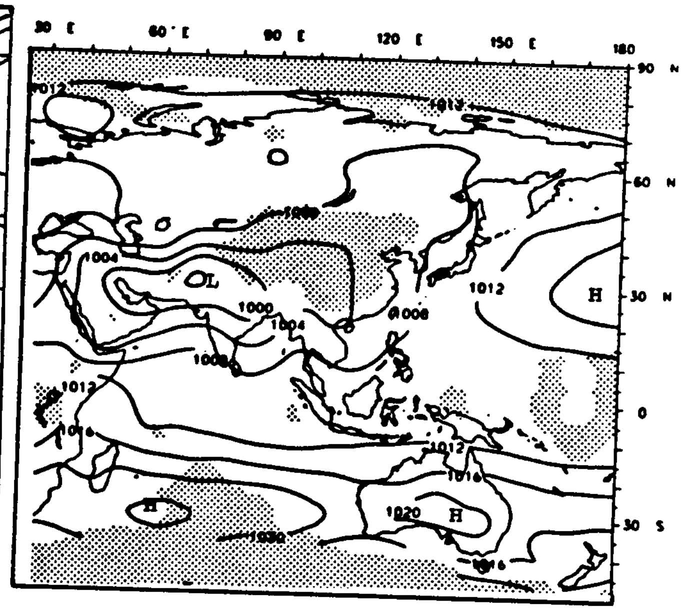


Fig. 3.2 Sea-level pressure (mb), Observed
Summer (June-July-August)

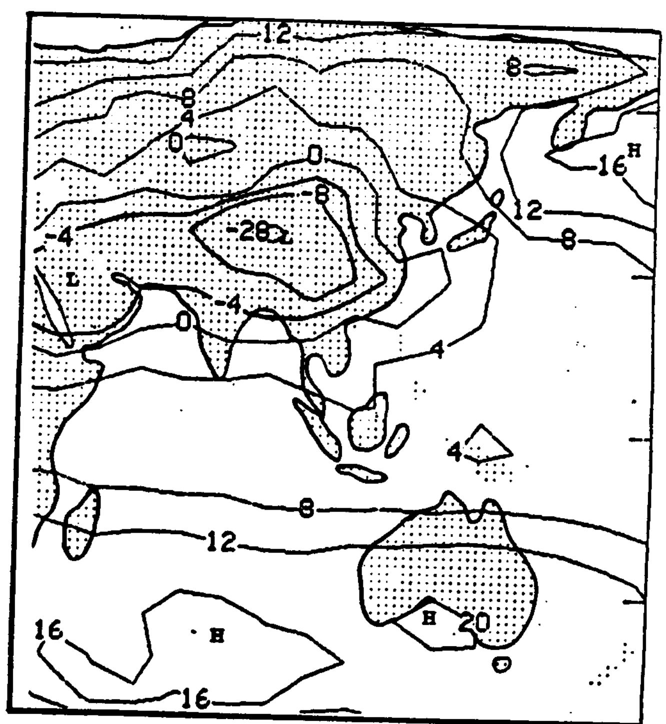


Fig. 3.3 Sea-level pressure (mb-1000), Medium Grid
Summer (June-July-August)

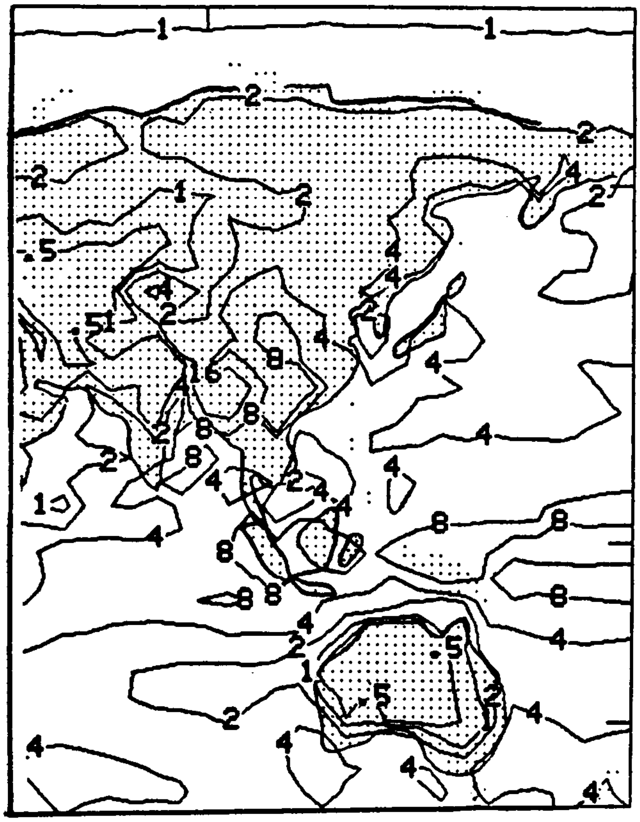


Fig. 3.4 Precipitation rate (mm/day)
Fine Grid, Summer (JJA)

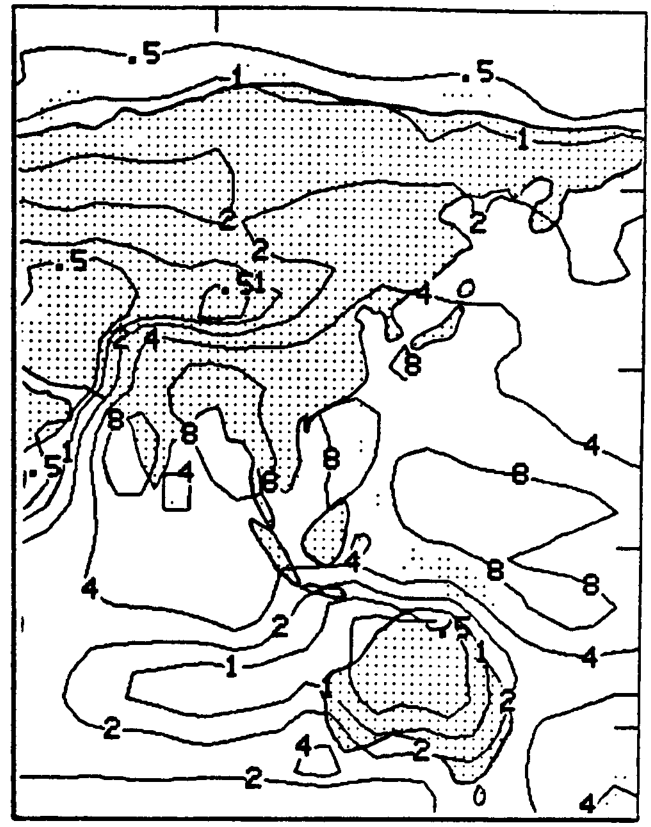


Fig. 3.5 Precipitation rate (mm/day)
Observed, Summer (JJA)

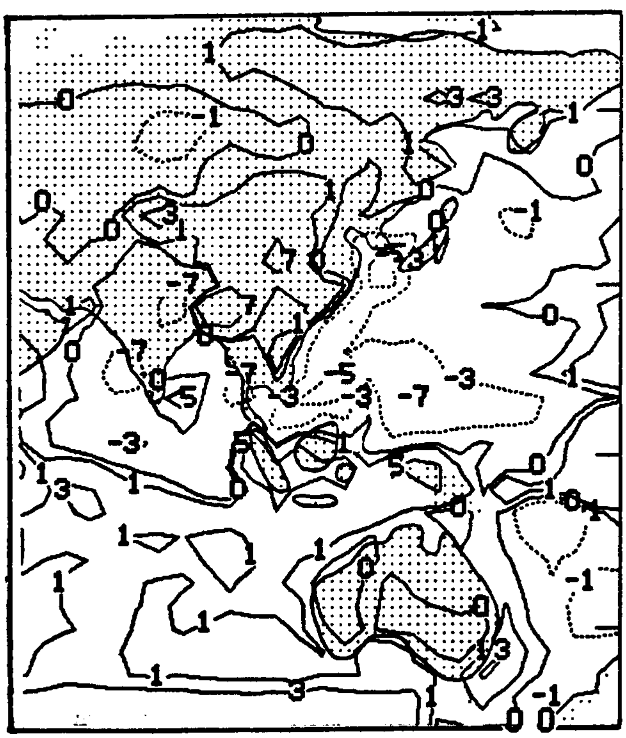


Fig. 3.6 Precipitation errors (mm/day)
Fine Grid - Observed, Summer

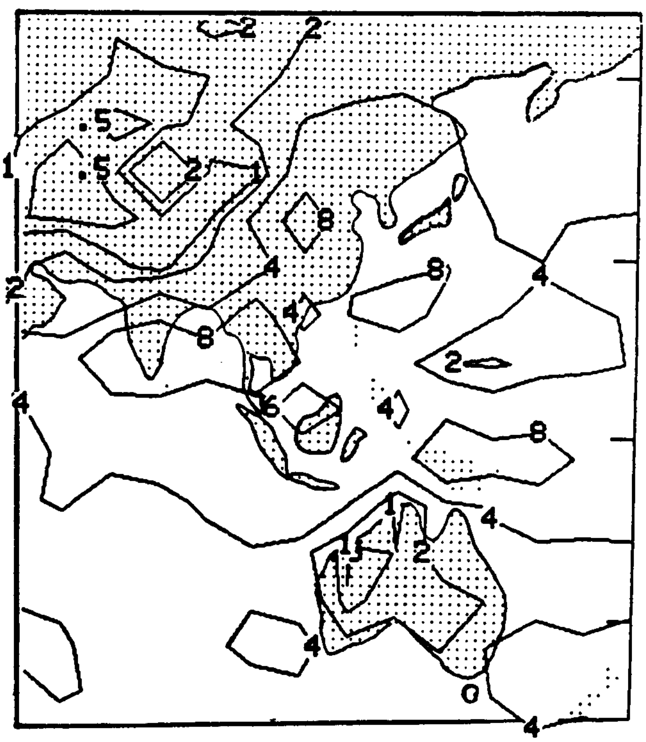


Fig. 3.7 Precipitation rate (mm/day)
Medium Grid, Summer (JJA)

4.1 SLP: South America and tropical and South Pacific Ocean

Fine Grid: The continental low that is correctly depicted over the equator is perhaps 6mb too deep, but its intensity is realistic because the model's background pressures are too low by about 4mb in the equatorial region. Pressures increase southward over the continent somewhat too steeply, but the high pressure ridge along 30°S is well-placed and the maximum pressure verifies well. The SLP should increase from Argentine westward to the eastern South Pacific, presumably because the water is cooler than the land. The decrease registered by the model produces a subtropical high pressure center that is about 4mb too shallow. Altogether, the pattern over the South Pacific is quite realistic because the 4mb deficit is systematic. Thus the SLP gradient responsible for the southeasterly trade winds verifies well, although the northerlies over mid-ocean west of the high are probably too strong. The equatorial trough is nicely resolved, but the ridge over the central parts is too broad, shifting the band of observed westerlies from 35°S to 60°S.

Medium Grid: SLP over the tropics are lower yet than in the fine grid by about 2mb. The gradient over South America generating southeasterlies is thus grossly exaggerated. The oceanic subtropical high verifies better than in the fine grid solution, although the ridge extention to the southwest encroaches on regions of observed westerlies over the central Pacific Ocean. The trade wind circulation may be slightly too strong owing to equatorial SLP that are 4-6mb too low. The orientation of the isobars does, however, delineate the trough and the trades quite realistically.

4.2 Precipitation: South America, tropical and South Pacific Ocean

Fine Grid: The largest continental errors in precipitation rate are a more than 4mm/day excess over Brazil and a deficit of 2mm/day over northern Argentine. The dry area along the western coast is quite realistic as is the rainy zone to the south although the transition in the model climate occurs too far to the south, giving rise to errors of -3mm/day adjacent to Chile. The narrow band of ITCZ precipitation along 5°N over the Pacific is clearly shown in the model climatology and is geographically as close to the observed pattern as the model resolution allows. Unfortunately, the simulated rates are too large by more than 5mm/day. Moreover, the model does not extend this maximum eastward to Panama where deficits of 3mm/day are in evidence. It does, however, show the secondary area of precipitation at 10°S over mid-ocean, but it too is exaggerated by at least 5mm/day. The dry wedge between the two rainfall maxima is resolved quite well.

Medium Grid: The dry area correctly covers more of the central continental region than in the fine grid, but the model climatology is still too rainy over eastern Brazil and also along the southeastern coast. The isohyetal gradient is too diffuse along the southwestern coast because of not enough rainfall over southern Chile and too much over northern Chile. This version shows an even larger deficit over Panama and the eastern tropical Pacific. The ITCZ rainfall is shared by grid boxes along 4°N and 4°S over mid-Pacific Ocean, compared with its observed orientation along 5°N.

Table 4.1 Verification summary, South America, tropical and S. Pacific

	Fine Grid (848F9)	Medium Grid (882M9)
Tropical and sub-tropical SLP	generally 4mb too low	generally 6mb too low
Continental N-S SLP gradient	too steep	even steeper than fine
Sub-tropical high	4mb too shallow	only 2mb too shallow
SLP gradient in southeast trades	realistic orientation and strength	realistic orientation, somewhat too strong
Central S. Pacific	high pressure instead of westerlies 30°-55°S	similar to fine grid
Brazil dry season	2-4mm/d instead of rainless	similar, but continental interior drier
S. America west coast dryness	very realistic	1-2 mm/d N. Chile
SW coast S. America	very realistic 4mm/d	no max, only 2-4mm/d
Pacific 5°N ITCZ rainfall maximum	perfect orientation, maximum >5mm/d too rainy	no max over eastern third, max crosses obs dry wedge along 5°S
E. Pacific dry wedge	resolved nicely	does not extend to central Pacific at 4°S

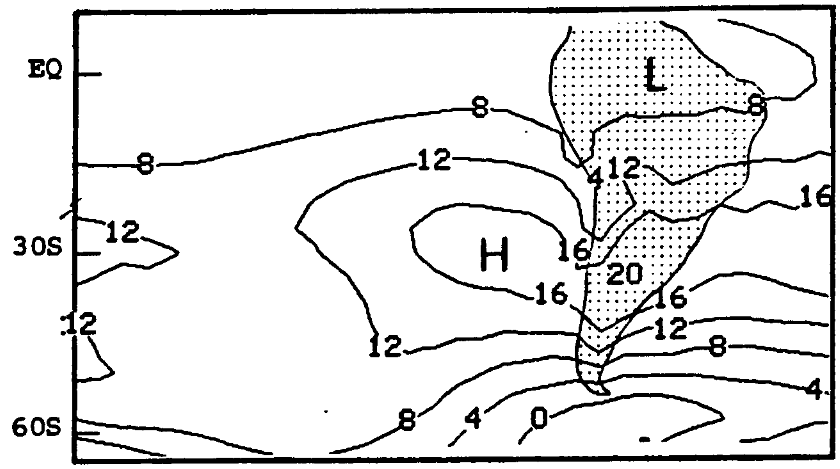


Fig. 4.1 Sea-level pressure (mb-1000), fine grid
June-July-Aug

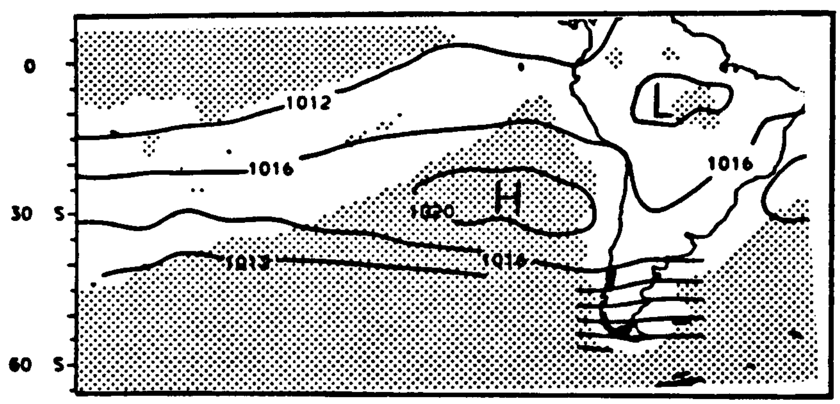


Fig. 4.2 Sea level pressure (mb), observed
June-July-Aug

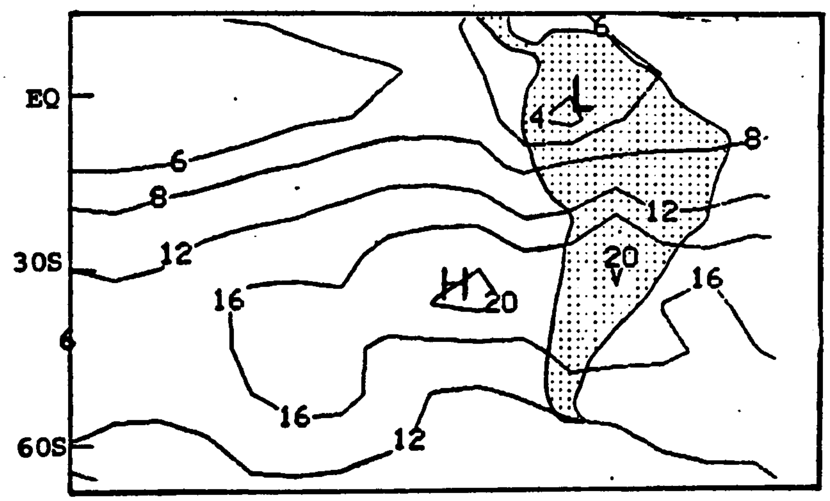


Fig. 4.3 Sea level pressure (mb-1000), medium grid
June-July-Aug

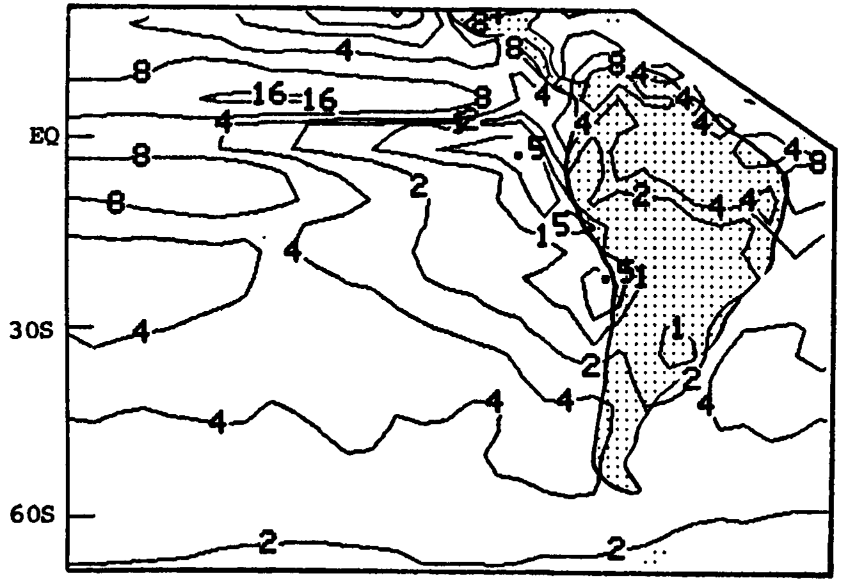


Fig. 4.4 Precipitation rate (mm/day), Fine Grid
June-July-Aug

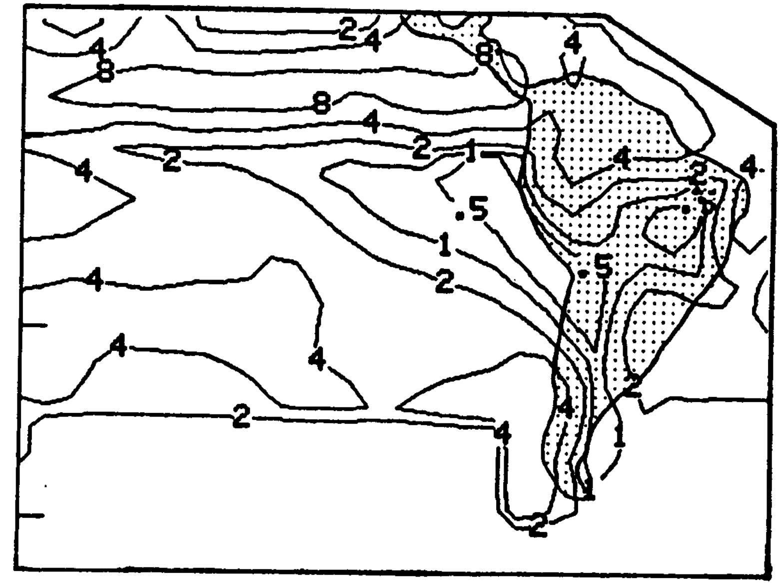


Fig. 4.5 Precipitation rate (mm/day), observed
June-July-Aug

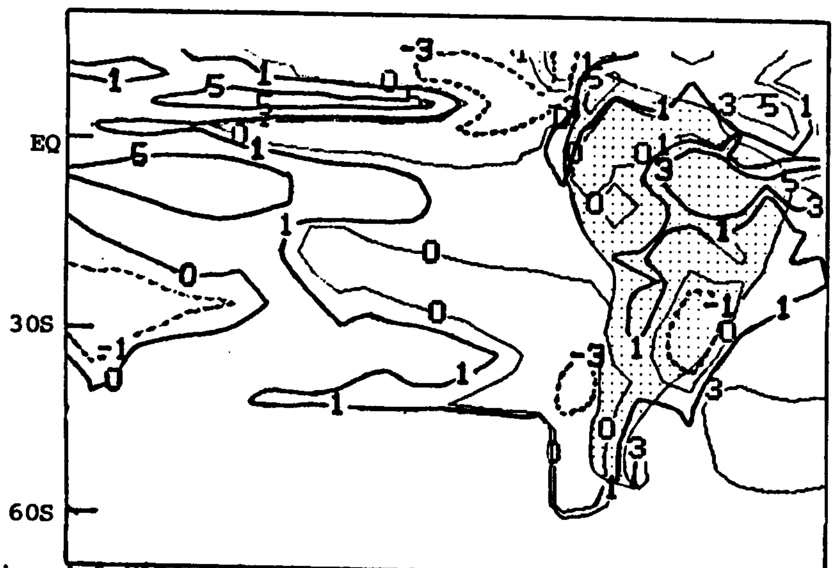


Fig. 4.6 Fine Grid precip errors (mm/d)

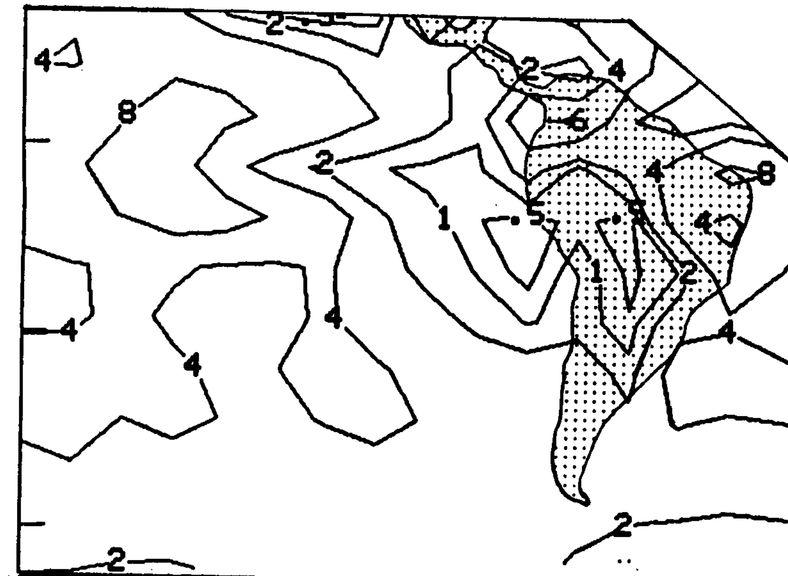


Fig. 4.7 Precip rate (mm/d), medium grid (JJA)

5. U-Component of the 7th-layer wind: June-July-Aug

The only winds aloft saved for model climatologies are at this level. For the mean global surface pressure, the 7th-layer corresponds to approximately 200mb. At this level, the u-component represents most of the total wind vector. The analyses of wind component observations are reproduced from Global Atmospheric Circulation Statistics by A. Oort (NOAA, 1983) and represent means from 1963-1973.

5.1 Northwest Quarter

Fine Grid: The maxima define the average position of the jet stream, or some combination of the polar and subtropical jets. The seasonal maximum over North America is somewhat stronger than 20m/s, the axis being along about 45°N over the US, but closer to 50°N over the western Atlantic Ocean. The model shows very good agreement with the observations except for westerly maxima that are slightly too strong over the western third of the US. The transition to easterlies is correctly simulated along 15°N, but they become about 5m/s too strong near the equator.

Medium Grid: The westerly jet is a few m/s too weak over the US, although it is depicted at the observed latitude over the eastern two-thirds. A secondary maximum along 60° over Canada generated by the model is not verified by the observations. The core of westerlies over the eastern Pacific Ocean has been made too strong by more than 5m/s and the equatorial easterlies are missing over the Pacific near 110°W although they appear quite realistic over the central Pacific and over northern South America.

Table 5.1 Verification summary, 7th-layer winds, Northwest Quarter

	Fine Grid (848F9)	Medium Grid (882M9)
Jet core over US	good latitude and strength agreement	good latitude agreement 3-5 m/s too weak
Canada	very realistic	secondary maximum, 60°N
Equatorial easterlies	realistic transition in subtropics, 5 m/s too strong near 0°	missing near 110°W, realistic over central Pacific & S.Amer.at 0°

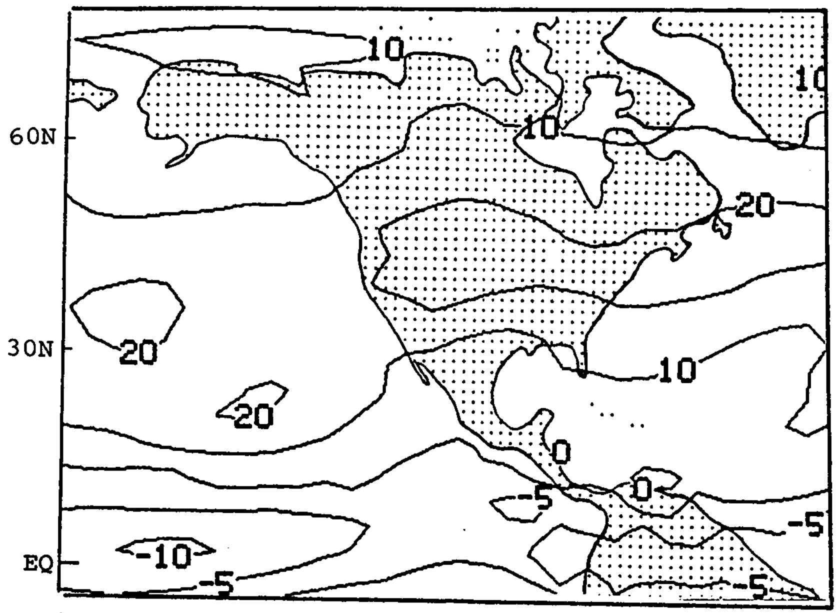


Fig. 5.1 U-Component 7th-layer wind, fine grid
Summer (June-July-Aug)
(m/s)

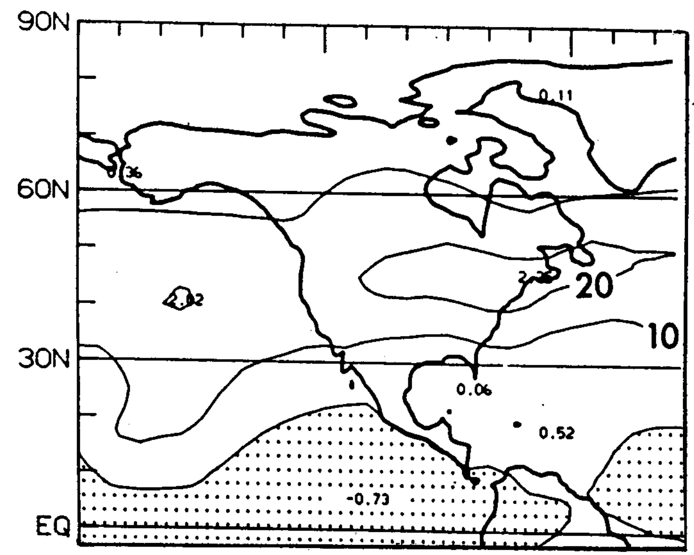


Fig. 5.2 U-Component 200mb wind, observed
JJA (m/s)

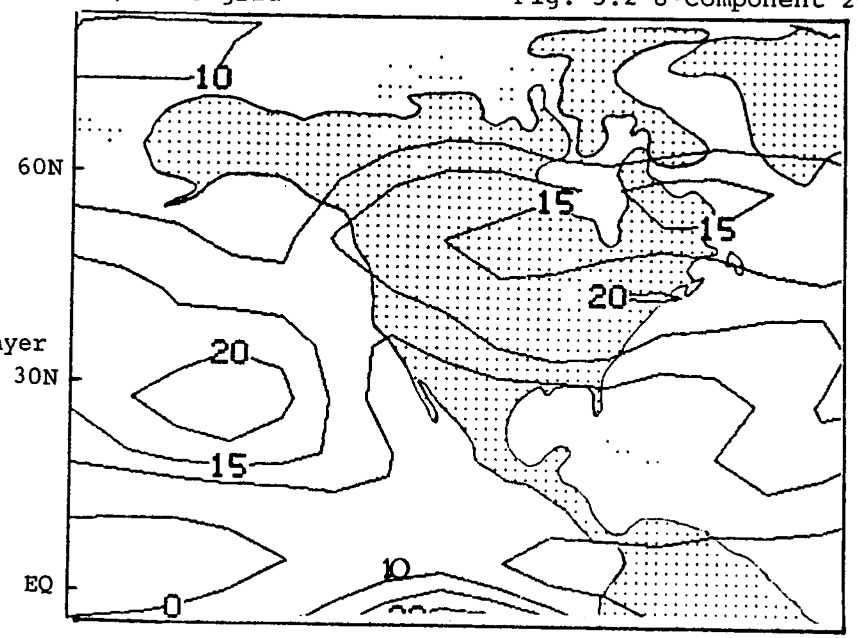


Fig. 5.3 U-Component 7th-layer wind, medium grid
JJA (m/s)

5.2 Eastern Hemisphere

Fine Grid: The core of westerlies from the eastern Mediterranean Sea eastward to the Caspian Sea is realistic, but instead of continuing along 40°N over Asia it is deflected southward to 30°N over northern India. The model separates this segment from the maximum over central Asia that is almost 10° too far north and about 5 m/s too weak. In general, computed speeds are somewhat too weak over eastern Europe and Asia north of 30°N compared with climatology.

The transition to easterlies occurs about 5° too far south so that the computed easterlies are not strong enough over southern Asia, including India. The core of the easterly jet is also about 5° too far south over the Indian Ocean and too weak by about 10 m/s. Over Africa, easterlies are only about 5 m/s too weak. The boundary between the tropical easterlies and the southern hemisphere westerlies is depicted realistically as is the latitude of the southern hemisphere westerly jet, although maximum speeds are as much as 10 m/s too strong.

Medium Grid: The core of westerlies is about 8° too far north over southeastern Europe and speeds are too weak over the Middle East. The axis of the westerly jet is also deflected to the south in this model resolution giving rise to very strong westerlies north of India at 35°N, similar to the fine grid solution. The speeds of westerlies over Europe are reasonable but over central Asia along 40°N, winds are much too weak.

Weak easterlies computed over India and Bangladesh at 28°N are realistic but otherwise the swath of easterlies is too narrow by about 5°. The model does not generate the northern flank of the Tropical Easterly Jet from 12°-20°N all across southern Asia and northeast Africa. The latitude of maximum easterlies, however, verifies as well as model resolution allows and peak winds are about 5m/s too weak, verifying better than the fine grid model.

The core of the southern hemisphere westerly jet is 10° too far north ranging from South Africa across the Indian Ocean and Australia to the western Pacific Ocean. Maximum westerly speeds over Australia verify well but the jet is more than 15m/s too strong over the Indian Ocean and South Africa.

Table 5.2 Verification summary, 7th-layer winds, Eastern Hemisphere

	Fine Grid (848F9)	Medium Grid (882M9)
NH Westerly Jet	displaced to south over Asia	similar to fine grid
Tropical E. Jet	too far south and max speeds too weak	too narrow, but core latitude and max speed better than fine grid
SH Westerly Jet	Good over Australia, too strong over Indian Oc. & S. Africa	Too far north, otherwise similar to fine grid

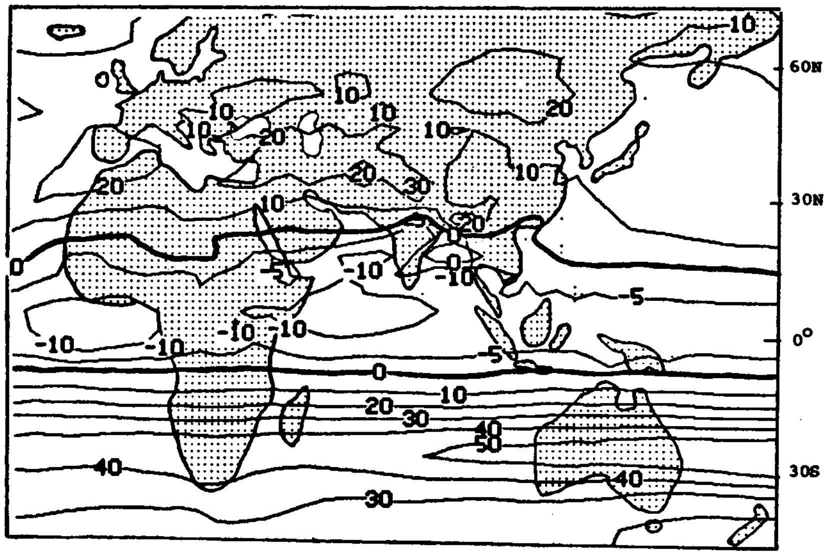


Fig. 5.4 U-Component 7th-layer wind, fine grid
Summer (June-July-Aug) (m/s)

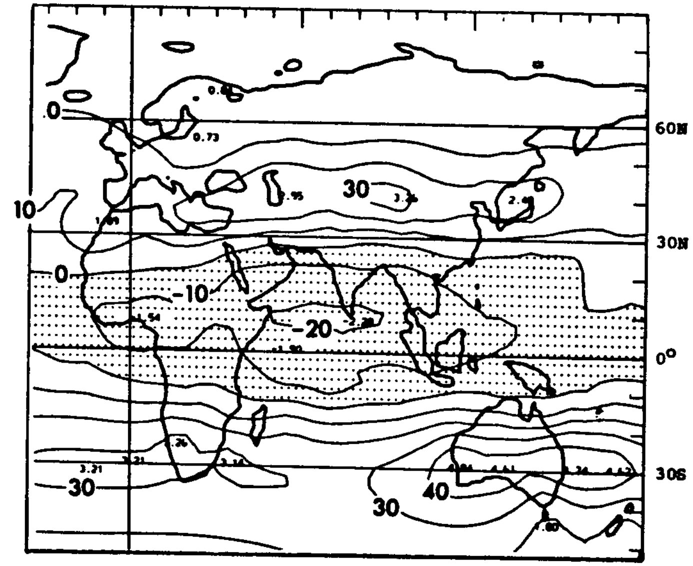


Fig. 5.5 U-Component 200mb wind, observed
Summer (June-July-Aug) (m/s)

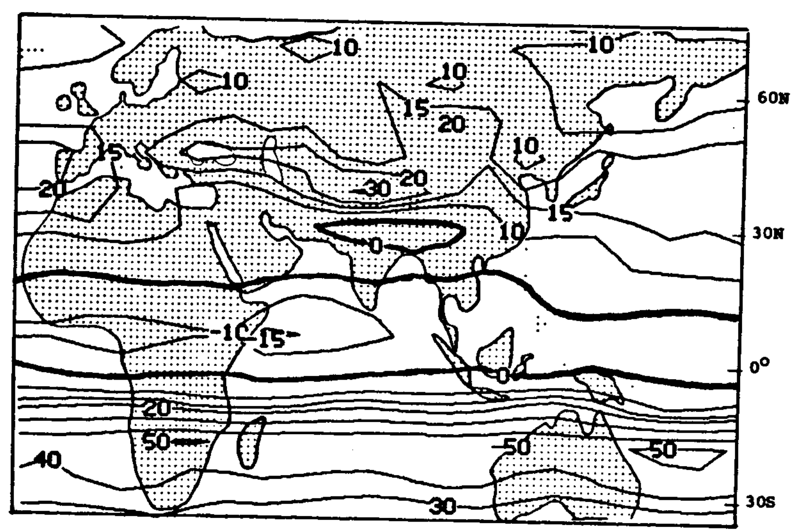


Fig. 5.6
U-Component
7th-layer wind,
medium grid
Summer (JJA) (m/s)

6. Resultant surface wind

The model's resultant surface winds for the three summer months are represented by vectors plotted at each grid box center. These charts show the simulated flow patterns at a glance and they can be compared qualitatively to the streamflow analyses for the observed gradient level wind (tropical latitudes: Atkinson and Sadler, 1970) and to the analysis of surface flow over North America and adjacent oceans (Climates of North America, Bryson and Hare, 1974). A more quantitative verification that relates to the mean zonal and meridional components of the surface wind follows.

6.1 U- component of the surface wind: Northwest Quarter

Fine Grid: The mean zonal surface wind is correctly depicted as light westerlies of 0-2 m/s over most of North America. Areas of westerlies stronger than 2 m/s are realistically situated over the North Atlantic Ocean and off the coast of California. The simulated values are, however, slightly too weak over the western third of the US. The transition to easterlies is realistically made along 35°N over the southeast US and the eastern Atlantic Ocean, but the model easterlies encroach on an area of observed westerlies over the mid Atlantic. The core of the easterly Trade Winds is modelled in the tropical Atlantic and Pacific Oceans, but with peak speeds about 2 m/s too weak. Easterlies are correctly shown over southern Greenland and Iceland, but not over northern Canada and Alaska.

Medium Grid: The poor simulation of the Atlantic anticyclone is reflected by a rather misleading representation of the surface zonal circulation over the North Atlantic Ocean in which the westerlies are completely lacking over the mid-latitudes, except for a narrow band along 55°N. The easterly Trade Winds are, however, evident, although the tropical maxima are 3-4 m/s too weak. This model also shows a wedge of weak westerlies along the west coast of North America, underestimating the observations by about 2 m/s over Califoria.

6.2 U- component of the surface wind: Eastern Hemisphere

Fine Grid: Europe is realistically shown under positive zonal flow of 0-2 m/s. Very weak easterlies are correctly depicted over northwest Africa, as is the transition to westerlies over the Middle East. The location of the core of strongest westerlies along 4°N over Africa is also verified by the actual climatology. The westerly component of summer monsoon winds over the Arabian Sea is a prominent feature on both model and observed fields, although the latter gives a maximum that is twice as strong. The zonal flow becomes easterly over Africa and the Indian Ocean along the equator and reaches a maximum at 15°S. The simulated climatology is realistic in this respect, but its peak easterlies are only about 3 m/s instead of the observed 7.5 m/s over the Indian Ocean.

Medium Grid: The computed zonal wind is easterly over too broad an area from Spain to the Middle East, verifying well only over central and western north Africa. The simulated band of westerlies along 4°N over Africa is reasonable. Near India, the maximum of westerly speeds parallels nature, but like the fine grid solution, it underestimates the peak climatological values of these summer monsoon winds. Easterlies are correctly indicated south of the equator over the Indian Ocean, Africa and the South Atlantic, but the modelled maritime wind speeds are generally too weak, as in the fine grid solution.

6.3 V- component of the surface wind: Northwest Quarter

Fine Grid: The western flank of the North Atlantic anticyclonic gyre spreads a rather strong southerly circulation to the Gulf of Mexico and the eastern US that is not well simulated by the model. Instead, the simulation confines these surface southerlies to the western Atlantic Ocean where they are slightly weaker than the observed seasonal means. The return flow of northerlies on the east side of the gyre are depicted quite realistically, including the maximum of more than 4 m/s near northwest Africa. The corresponding feature over the eastern North Pacific is similarly represented southwest of California.

Medium Grid: As in the fine grid, this version of the model also fails to generate the southerly flow over the eastern US and Gulf of Mexico, confining it instead to the western Atlantic Ocean. Northerlies are correctly generated on the eastern sides of the Pacific and Atlantic Oceans, but the maxima are about 2 m/s too weak. Moreover, the spatial extent of these maxima are not as well placed as in the fine grid climatology: the Pacific maximum is too far west and the Atlantic maximum extends too far to the north.

6.4 V- component of the surface wind: Eastern Hemisphere

Fine Grid: The interruption of the northerly component modelled along 5°-10°E over northern Africa and southern Europe corresponds to a minimum in the strength of the surface northerlies according to the verification analysis. The model correctly maximizes the northerly wind over the eastern Mediterranean, and maximizes the southerlies over the South Atlantic, but the latter are weaker in the simulation than they should be, especially over the Gulf of Guinea. The strong southerly winds that characterize the summer monsoon over the western Indian Ocean are underestimated, but the southerlies over the Bay of Bengal are not. The meridional component of the surface wind is realistically minimized over the Indian sub-continent. Modelled southerly winds over the South Indian Ocean, eastern China and the east coast of Australia generally correspond to observed southerlies of greater magnitude.

Medium Grid: The model at this grid resolution also correctly maximizes the northerly component over the eastern Mediterranean, and it even maintains negative values over northwest Africa. The southerly maxima of the Arabian Sea and the Bay of Bengal are too weak and diffuse, but the strength of the southerlies over eastern China and coastal waters to the southeast verifies well. As in the fine grid model, the southerly surface winds are too weak over the Gulf of Guinea, the South Atlantic and the South Indian Ocean.

Table 6.1 Verification summary, zonal component of surface wind

	Fine Grid (848F9)	Medium Grid (882M9)
Atlantic mid-latitude westerlies	realistic, except for E comp encroachment from the tropics	westerlies absent, except near 55°N
NE Trades, Atlantic and Pacific	realistic, but peak speeds weak by 2 m/s	speeds 3-4 m/s too weak
Monsoon westerlies, Africa and S. Asia	Realistic over Africa Much too weak over Arabian Sea	Performance similar to fine grid
Easterlies over South Indian Ocean	Realistic, except max is 3-4 m/s too weak	Similar to fine grid

Table 6.2 Verification summary, meridional component of surface wind

	Fine Grid (848F9)	Medium Grid (882M9)
Southerlies, Gulf of Mex./SE US	Confined to western Atlantic, do not penetrate continent	Similar to fine grid
Northerlies, Eastern Atlantic & Eastern Pacific	Quite realistic	Maxima: 2 m/s too weak. In Atlantic, extends too far north; in Pacific, max is too far west
Convergence of meridional winds over Africa	Reasonable location, somewhat too weak; interrupted at 0° longitude	Similar to fine grid, except continuous accross Africa
Southerlies over Gulf of Guinea & E South Atlantic	Everywhere too weak	Similar to fine grid
Southerly max over W Indian Ocean	Underestimated	Underestimated and more diffuse than fine grid
Southerly max over Bay of Bengal	Quite realistic	Underestimated

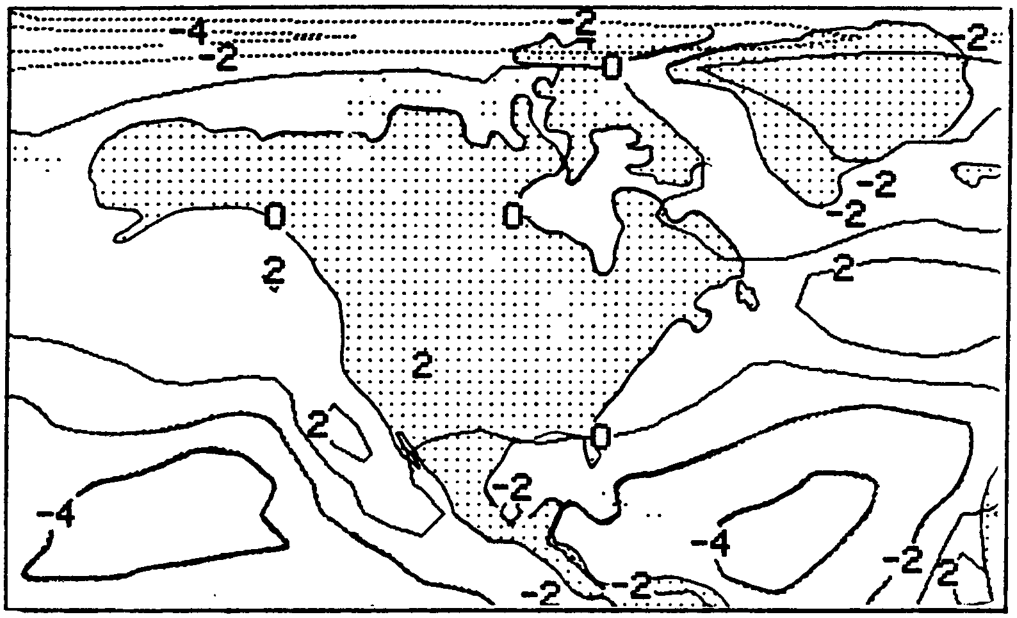


Fig. 6.1 U- component of surface wind (m/s), Fine Grid, June-July-Aug

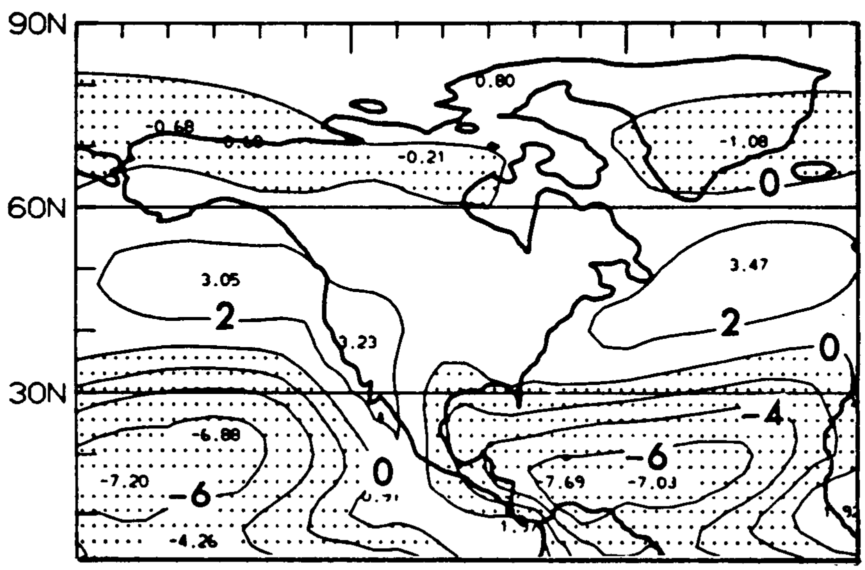


Fig. 6.2 U- component of surface wind (m/s), Observed, June-July-Aug

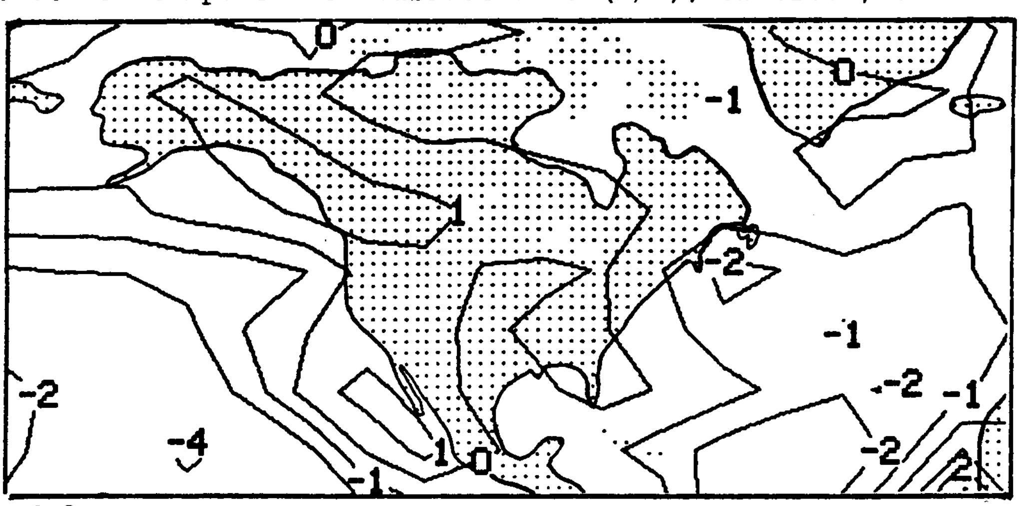


Fig. 6.3 U- component of surface wind (m/s), Medium Grid, JJA

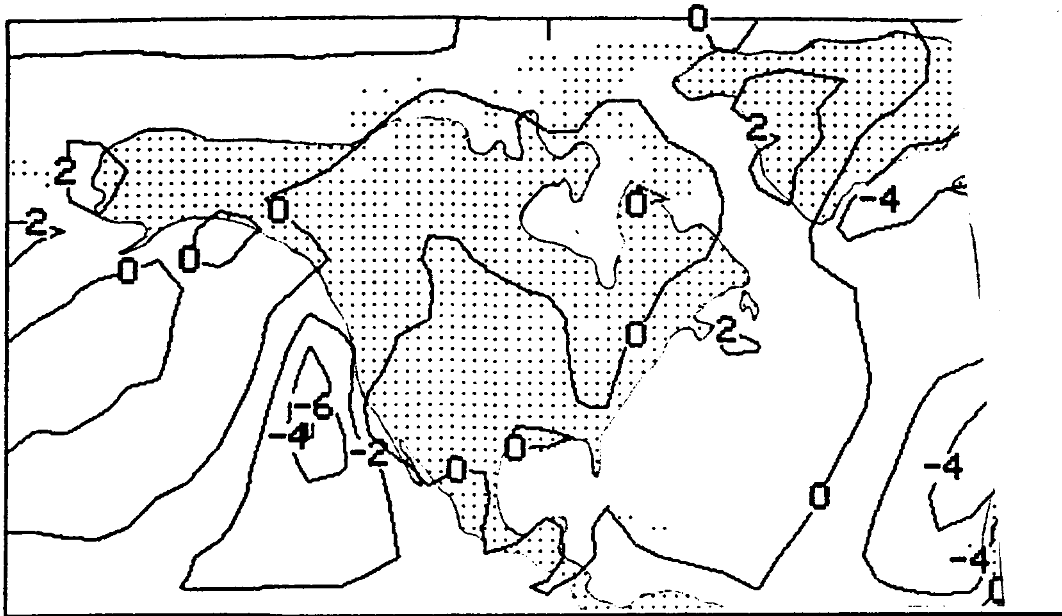


Fig. 6.4 V- component of surface wind (m/s), Fine Grid, June-July-Aug

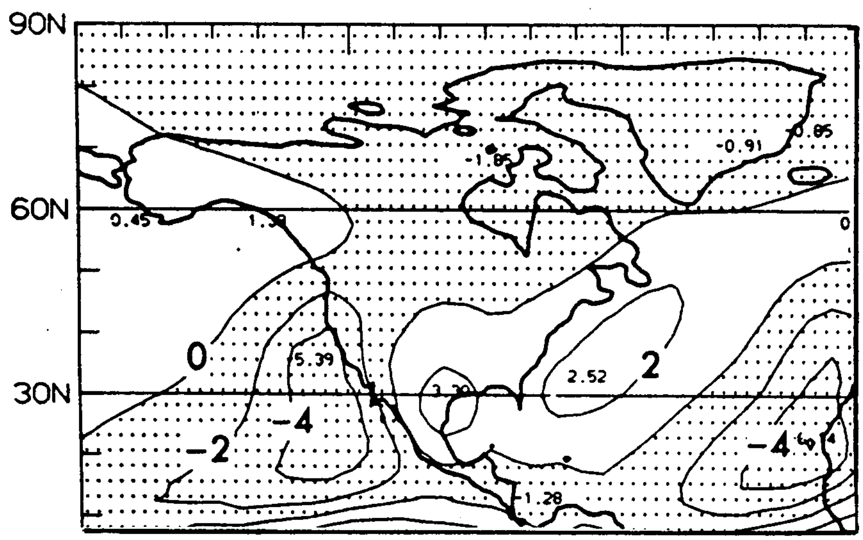


Fig. 6.5 V- component of surface wind (m/s), Observed, JJA

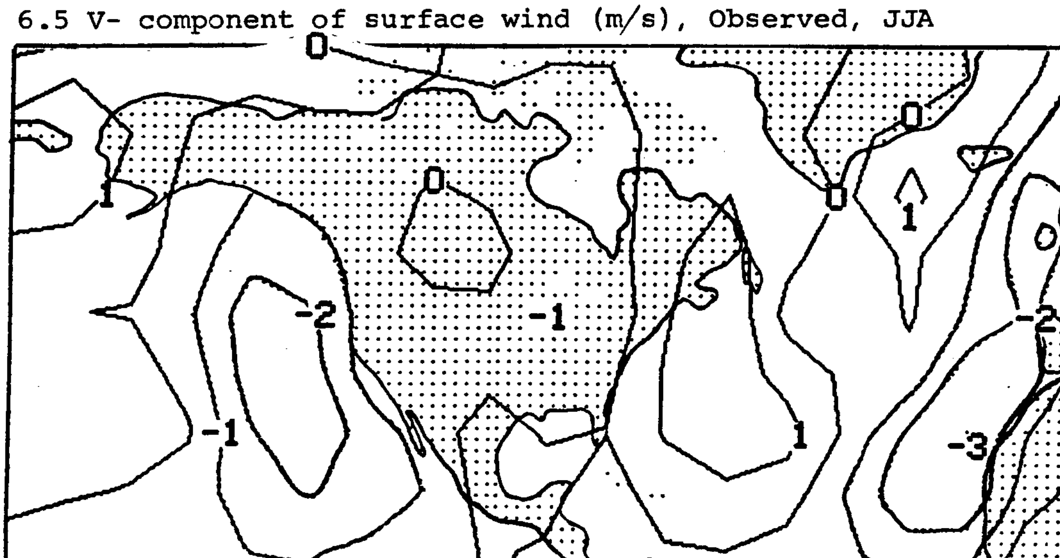


Fig. 6.6 V- component of surface wind (m/s), Medium Grid, JJA

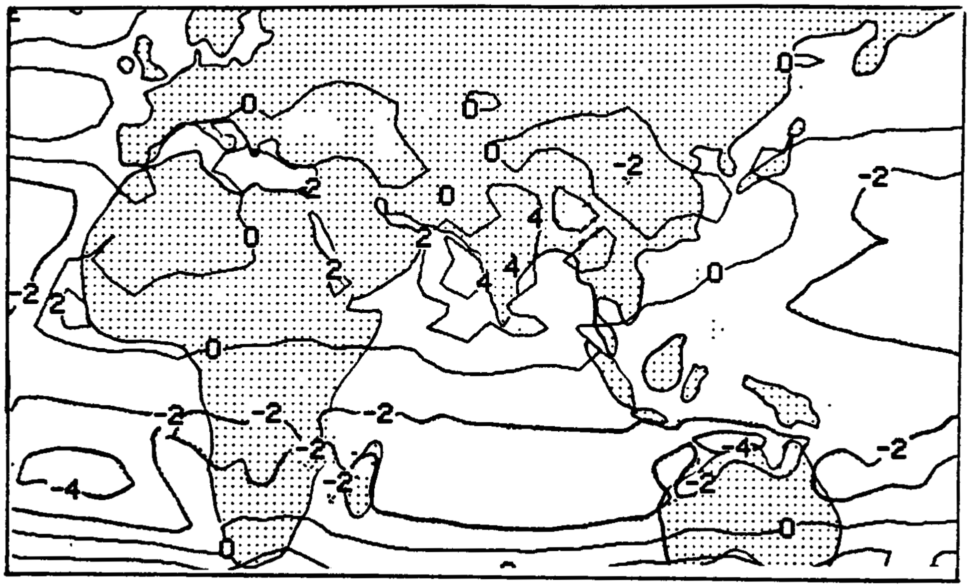


Fig. 6.7 U- component of surface wind (m/s), Fine Grid, June-July-Aug

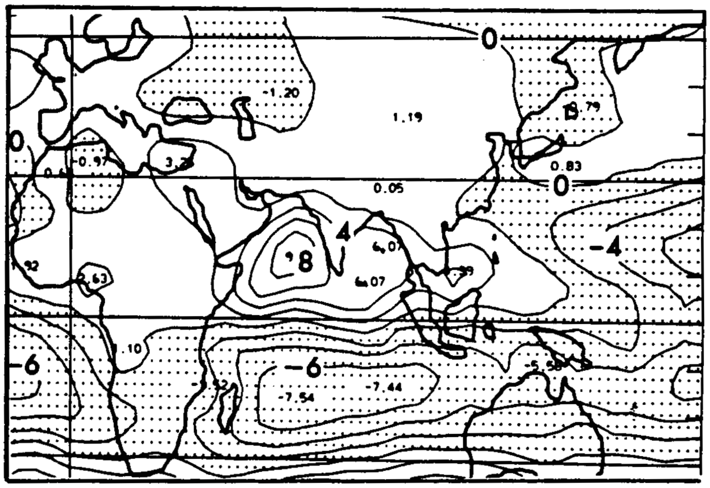


Fig. 6.8 U- component of surface wind (m/s), Observed, JJA

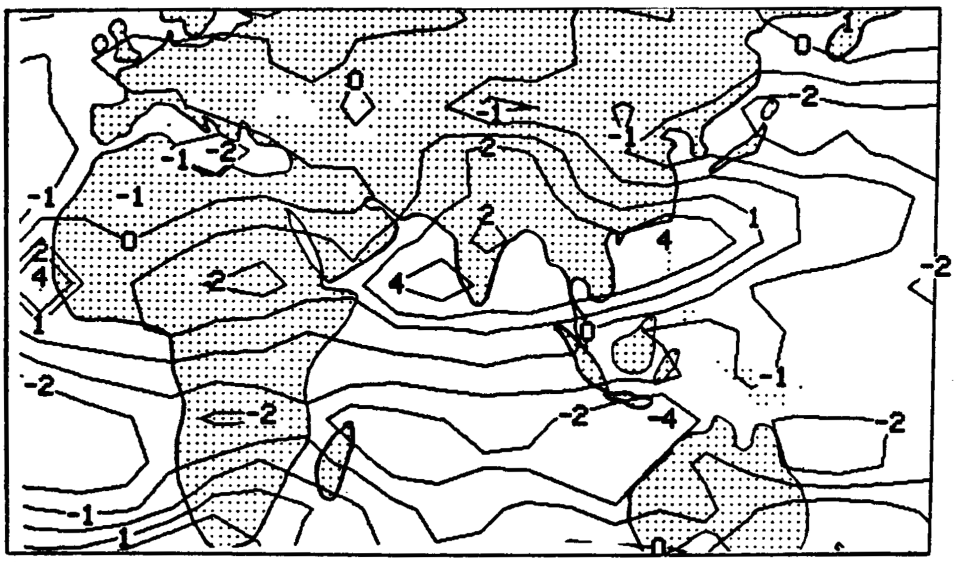


Fig. 6.9 U- component of surface wind (m/s), Medium Grid, June-July-Aug

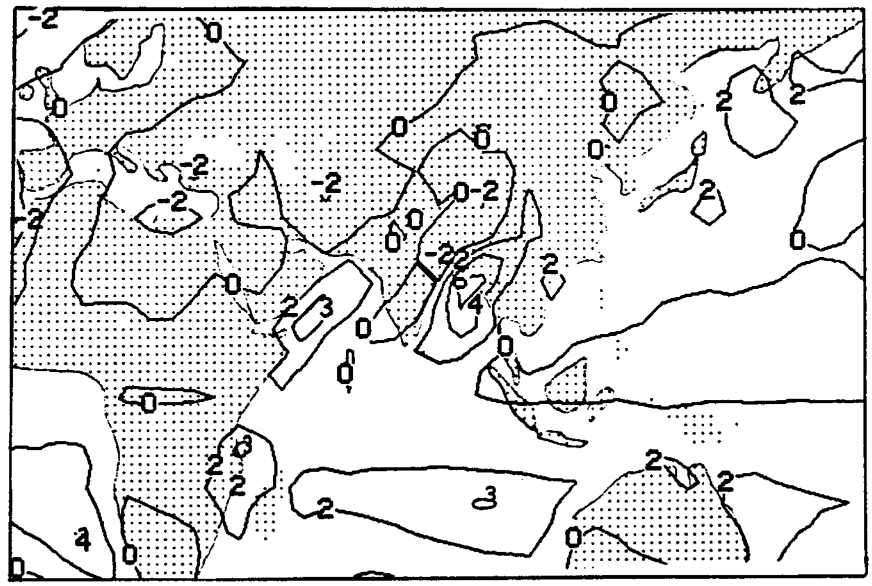


Fig. 6.10 V- component of surface wind (m/s), Fine Grid, June-July-Aug

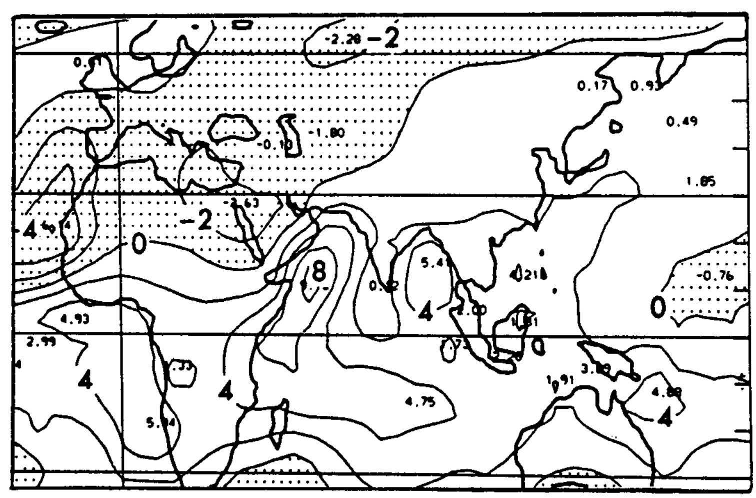


Fig. 6.11 V- component of surface wind (m/s), Observed, JJA

Fig. 6.12 V- component of surface wind (m/s), Medium Grid, JJA

Fig. 6.13 **RESULTANT SFC WND** **JJA** (Fine grid) **RUN 848 F9**

10m/s reference: ——

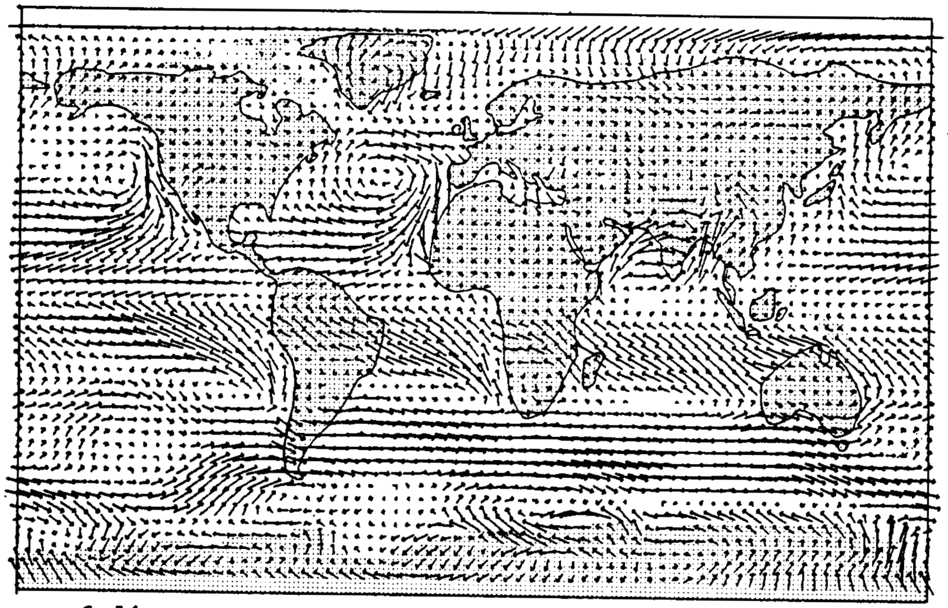


Fig. 6.14 a

Observed **RESULTANT GRADIENT LEVEL WIND - JULY**

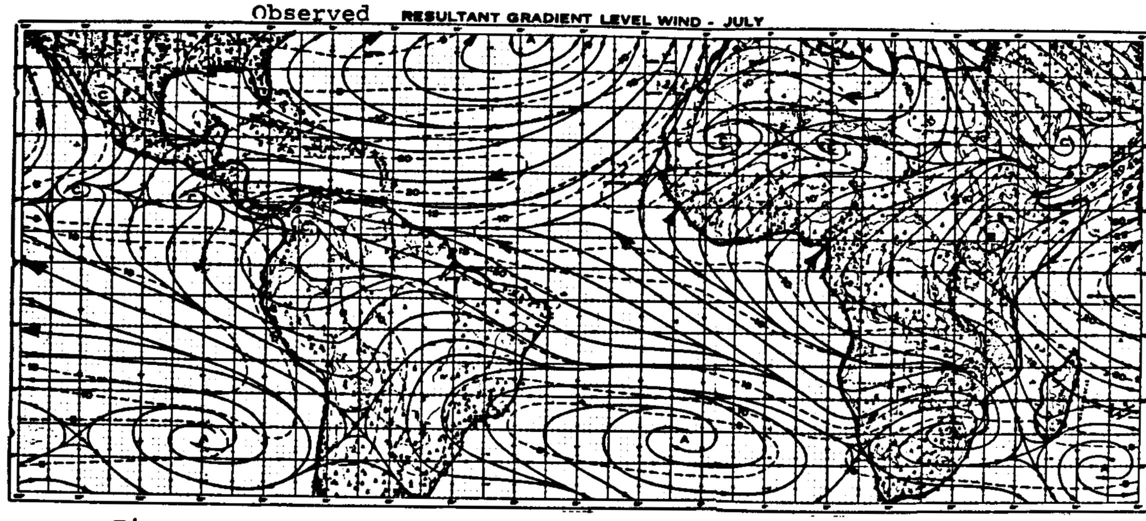
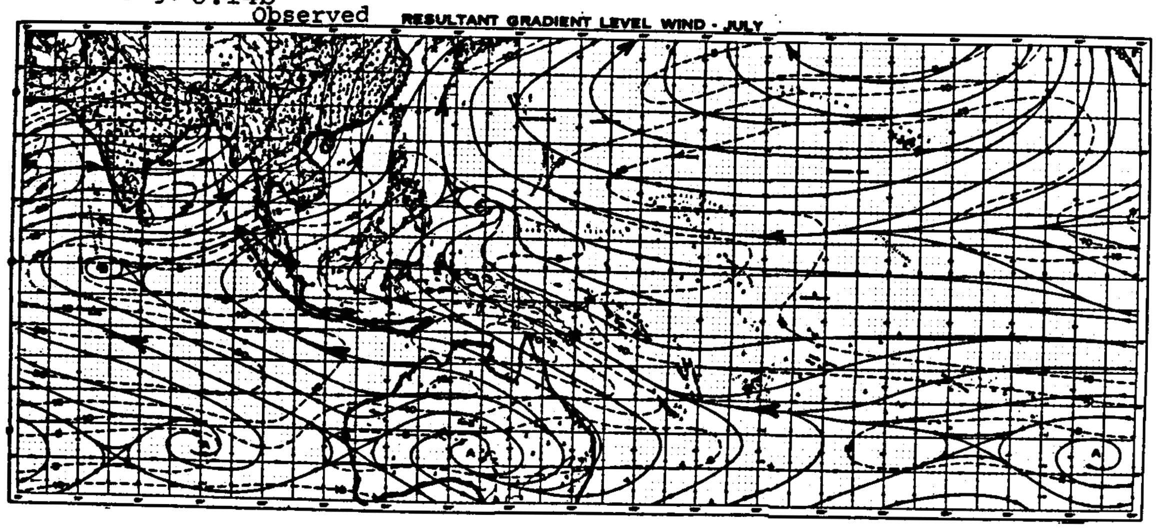


Fig. 6.14b

Observed **RESULTANT GRADIENT LEVEL WIND - JULY**



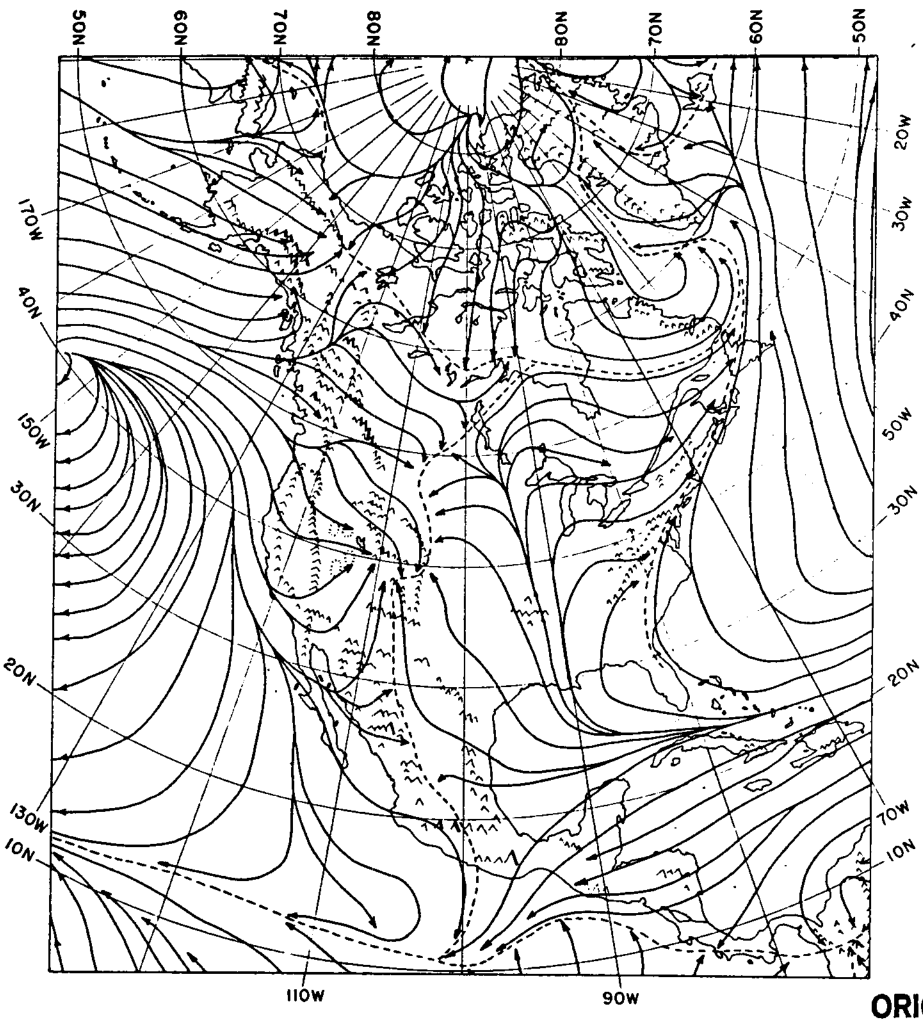


Fig.6.15 Resultant surface streamlines for July (after NAVAIR, 1966).

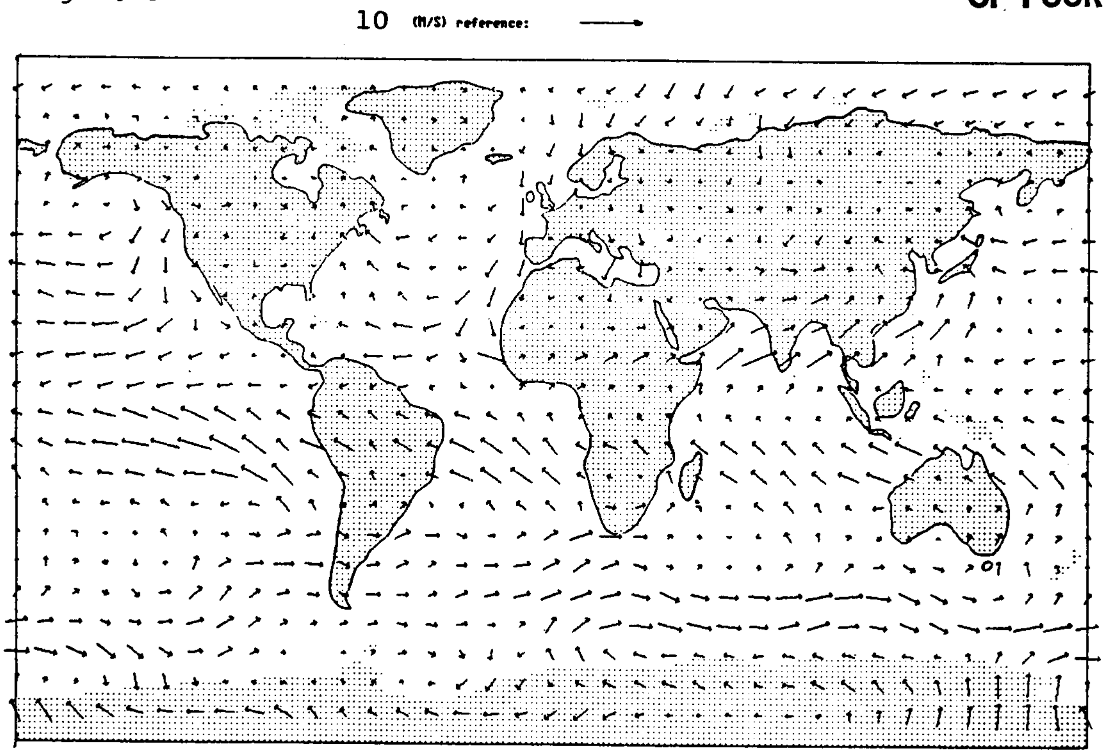


Fig. 6.16 Resultant surface wind, Medium Grid, JJA

7. Cross-equatorial flow, June-July-August

The seasonal mean V component of the surface wind is verified against the climatological observations of Oort (1983) which are means for 1963-1973.

Fine Grid: In the Pacific Ocean, 160°W to South America, the southeasterly trade winds cross the equator and V varies between +2 and +5 m/s. In the model, southerlies cross the equator only at 100°-110°W where the southerly component is weakly positive. The average V simulated in the stretch 160°W-South America is close to 0.0 m/s.

Over equatorial Brazil, observations show a southerly component of 2-4 m/s, while the model indicates slightly negative values (i.e., northerlies).

Over the Atlantic Ocean the southeasterly trades should also cross the equator to give positive values of V up to 5m/s. Again, the model shows near-zero cross equatorial flow, except over the Gulf of Guinea where V reaches +1 m/s.

The summer monsoon maximum of cross-equatorial flow along the Indian Ocean coast of Somalia exceeds 6 m/s. The maximum is indeed simulated although V in the model in this region averages little more than 2 m/s.

The climatology indicates weak southerlies of 0-2 m/s over the remainder of the Indian Ocean and the western Pacific. The component V is indicated by the model climatology realistically over the Indian Ocean, but the small northerly component of the surface winds over the western Pacific is not realistic. (It reflects a simulated ITCZ convergence that is too far south.)

Medium Grid: The differences between the model solution at this resolution and the fine grid solution include slightly stronger southerlies over the Gulf of Guinea and a more realistic southerly component of the surface winds over Indonesia and Borneo. On the other hand, the surface reflection of the Somali jet is slightly weaker at the equator than in the fine grid. Otherwise the June-July-August average cross-equatorial flow simulated by this version has the same deficiencies as noted above for the fine grid model.

Table 7.1 V-component of surface wind along the equator (m/s), JJA

	Fine Grid (848F9)	Medium Grid (882M9)	Observations (Oort, 1983)
E. Pacific	0.0	0.0	+2 to +5
S. America	-0.5	0.0	+1 to +2
E. Atlantic	+0.5	+1.0	+4 to +5
W. Indian Oc.	+2.0	+1.5	+6 to +7
Cent'l and E.Indian Oc.	+1.0	+1.0	+1 to +2
Indonesia	0.0	+0.5	+1 to +2
W. Pacific	-0.5	0.0	0 to +2

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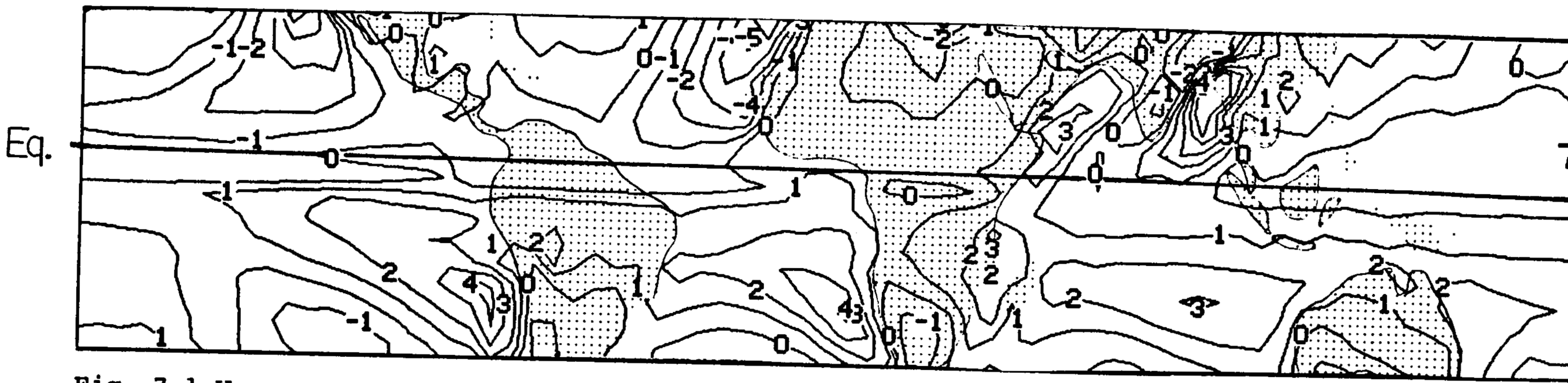

Fig. 7.1 V- component of surface wind (m/s) showing cross equatorial flow, Fine Grid, JJA

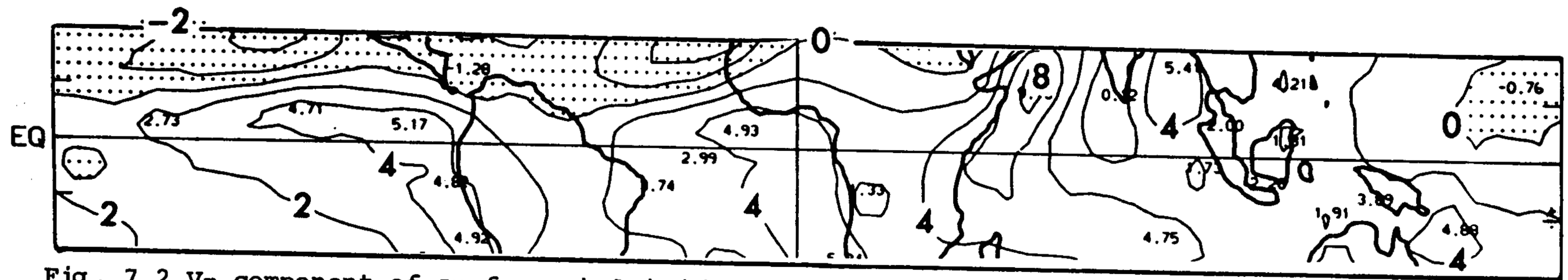

Fig. 7.2 V- component of surface wind (m/s), Observed, JJA

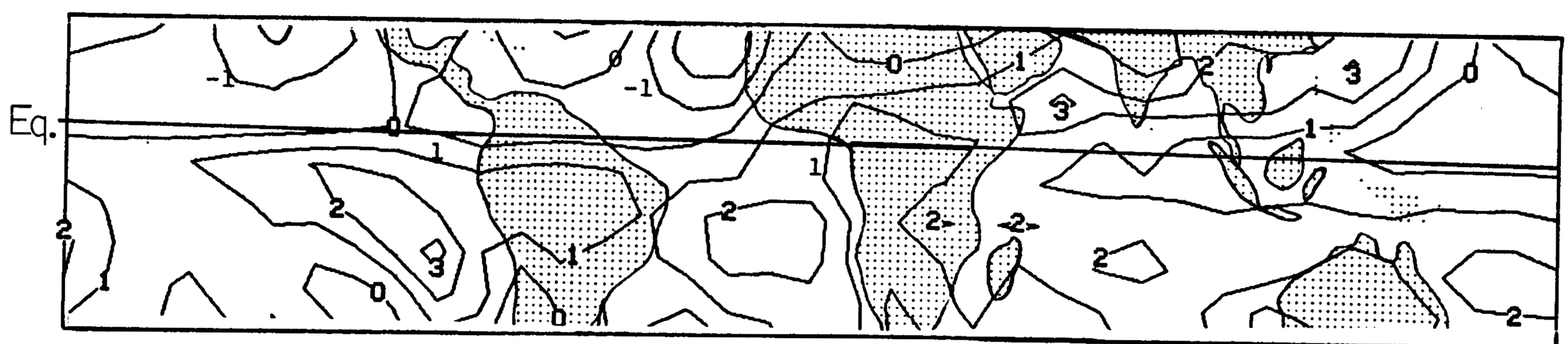

Fig. 7.3 V- component of surface wind (m/s), Medium Grid, JJA

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15. Supplementary Notes

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16. Abstract

Verification is made of the synoptic fields, sea-level pressure, precipitation rate, 200mb zonal wind and the surface resultant wind, generated by two versions of the GISS climate model. The models differ regarding the horizontal resolution of the computational grids and the specification of the sea-surface temperatures. Maps of the regional distributions of seasonal means of the model fields are shown alongside maps that show the observed distributions. Comparisons of the model results with observations are discussed and also summarized in tables according to geographic region.

17. Key Words (Selected by Author(s)) GCM verification model climate verification synoptic climatology simulations	18. Distribution Statement 47/ unclassified/unlimited

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