Origins of Extreme Climate States during the 1982–83 ENSO Winter

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ABSTRACT

The origin of extreme climate states during the exceptional 1982–83 El Niño event has continued to be a source of controversy and debate. On the one hand, empirical analyses of extratropical climate patterns during past El Niño events suggest the observed anomalies during 1982–83 were consistent with tropical forcing. On the other hand, the large amplitude of those anomalies have not been replicated in atmospheric general circulation model (AGCM) simulations for that period performed as part of the Atmospheric Model Intercomparison Project (AMIP).

It has recently become apparent, however, that the sea surface boundary conditions used to drive the multitude of AMIP simulations were deficient, in that at least 30% of available tropical Pacific SST observations were discarded in the analysis cycle due to excessive trimming constraints. It is shown from a reanalysis of the sea surface temperatures that the observed east equatorial Pacific waters were 1.5°C warmer than original estimates.

In order to address the extent to which simulations of the extratropical climate of 1982–83 are sensitive to different SST analyses of that period, a parallel suite of AGCM simulations using two SST prescriptions is performed. One set is based on the blended satellite–in situ data used also in the AMIP runs, whereas the other is based on the optimum interpolation (OI) reanalysis. A nine-member ensemble of such simulations is performed, and this is compared with observations. The model response using the original blended SSTs is shown to severely underestimate the tropical rainfall anomalies, and this contributes to the simulation of a weak extratropical response as reported earlier in the AMIP experiments. A larger, more realistic response during 1982–83 is shown to occur in an identical set of runs based on the OI SST boundary conditions, and most aspects of the observed pattern and strength of the Pacific–North American climate anomalies during that winter are reproduced in the model’s ensemble mean response.

Further analysis of the models’ intersample variability are performed to ascertain the extent to which the observed anomalies may have been influenced by atmospheric initial conditions. It is shown from the OI runs that the observed tropical Pacific rainfall anomalies and the Southern Oscillation index were phenomena causally determined by the El Niño. Even over the Pacific–North American region, the spatial pattern of the anomalies in individual runs was highly reproducible, and several members of the OI runs achieved climate anomalies exceeding in amplitude those observed. The findings strongly indicate the important role of El Niño in determining the climate state over the Pacific–North American region during 1982–83, and various competing hypotheses are critiqued in light of these new model results.

1. Introduction

Whether the unusual extratropical climate state of 1982–83 was a manifestation of tropical Pacific SST forcing associated with the extreme El Niño of that year is a question of fundamental scientific and practical importance. The existence of extreme extratropical climate states during El Niño need not imply a causal link, especially when considering the large natural atmospheric variability in the extratropics and the fact that climate anomalies resembling El Niño composites (e.g., Ropelewski and Halpert 1986; Kiladis and Diaz 1989) can occur in the absence of tropical SST anomalies. One can argue that a definitive answer may never emerge, since a single observed sample of the extratropical climate during 1982–83 is insufficient to uniquely identify the signal associated with that event’s anomalous tropical SSTs.

An approach to determining the climate signal associated with anomalous tropical SSTs is to impose such forcing as an external boundary condition in an atmospheric general circulation model (AGCM). Multiple integrations of the model using the same SSTs but different atmospheric initial states are required in order to separate the climate signal from the climate noise.
eral such studies for 1982–83 have been reported in the literature (e.g., Boer 1985; Fennessy et al. 1985), though the results from these have been inconclusive because of the small number of members in the ensemble.

As part of the Atmospheric Model Intercomparison Project (AMIP; Gates 1992), 30 different AGCMs were forced with identical SST anomalies of the 1979–88 period based on the blend of satellite and in situ observations (Reynolds 1988). Comparison of these simulations against observations for 1982–83 reveals an inability to reproduce the extreme character of the observed extratropical climate anomalies (Robock 1996). Though results from any single AGCM are not sufficient to separate the climate signal from the noise, the fact that the aggregate of 30 models in the AMIP fails to simulate the strength of extratropical anomalies lends support to the suggestion that processes and mechanisms other than El Niño might have been important during 1982–83.

Indeed, alternative explanations for the origins for the observed 1982–83 atmospheric anomalies have been proposed. One argument holds that El Niño was of secondary importance in determining the amplitude of the extratropical anomalies during 1982–83. Instead, the effect of the El Chichon volcanic eruption is claimed to have been dominant (Mao and Robock 1995; Robock 1996; Mao and Robock 1997). Their argument relies on the fact that the aerosol anomaly associated with El Chichon was not included in the AMIP simulations, and the GCMs’ failure is presumed to stem from omission of this external forcing. Another argument holds that the observed global anomalies during 1982–83 were a unique outcome of the particular initial atmospheric state, while anomalous boundary conditions played a less significant role (Smith 1995). This claim relies on the fact that seasonal anomalies, especially in the extratropics, are only modestly constrained by tropical SST forcing. For example, considerable case-to-case variability of climate anomalies between the various observed El Niño events exists, a behavior that is consistent with the low signal-to-noise ratio in the extratropics (Kumar and Hoerling 1997).

An important consideration in interpreting the AMIP simulations is new evidence that the SST anomalies during 1982–83 were appreciably larger than originally suggested in the blended SST analyses upon which those simulations were based. Due to excessive trimming constraints, one-third of the SST observations over the central Pacific during the 1982–83 winter were originally discarded (Wolter 1997). Wolter (1997) shows that more reasonable trimming constraints enhance the quality of the SST analysis during extreme events like 1982–83, and his results reveal that the central equatorial Pacific SST anomalies during February 1983 were 1.5°C warmer than previously suggested. Given that the strength of the extratropical signal increases quasi-linearly with the amplitude of tropical Pacific SST anomalies (Kumar and Hoerling 1997), the possibility exists for a quasi-deterministic extratropical response for sufficiently large SST forcing, and a reassessment of El Niño’s role during 1982–83 is in order.

It is suggested here that shortcomings in prescribed SST forcing may themselves account for the failure of AMIP experiments in simulating the atmospheric events of 1982–83. The purpose of the current study is to demonstrate, with a suite of AGCM simulations employing different estimates of the SST boundary conditions, that several key aspects of the observed 1982–83 extreme climate states were indeed consistent with the tropical Pacific SST forcing. Two SST analyses, the original blended data used in the AMIP experiments and a reanalyzed SST dataset with relaxed trimming constraints, are described and intercompared in section 2. Section 3 compares the climate response of a nine-member AGCM ensemble using each of these SST states against the observed anomalies. The response using the AMIP SST data is too weak compared to observations, consistent with the numerous AMIP experiments. A larger, more realistic response occurs in an identical set of runs that differ only in their use of the reanalyzed SSTs. Various measures of that response are analyzed, including the simulated Southern Oscillation Index, tropical rainfall, North American surface temperature, and global atmospheric conditions in the upper troposphere. Some aspects of the initial condition sensitivity of the AGCM simulations for the 1982–83 winter are presented section 4. Section 5 presents a discussion and concluding remarks.

2. Data and methods

a. SST analyses

The blended SST analysis of Reynolds (1988) has been widely used in the scientific community and possesses the attribute of combining the ground truth of ship and buoy data with the greater spatial coverage and sampling frequency of satellite measurements. This inherent characteristic of the dataset is preserved in the National Centers for Environmental Prediction’s (NCEP) reanalysis of global SSTs for the 1982–94 period, with further improvement resulting from satellite bias correction and the use of the optimum interpolation (OI) technique (Reynolds and Smith 1994).

Most relevant for this study of the 1982–83 period, however, is the change in the OI SST analysis that results from new quality control procedures for the in situ data analysis (R. Reynolds and D. Stokes 1996, personal communication). In the original blended analysis, an important trimming test on the veracity of in situ observations was the size of the SST anomaly, and all observations were discarded if their SST anomaly exceeded 3.5 times the climatological standard deviation (σ). An identical constraint was imposed in constructing the trimmed monthly SST summaries in the so-called “standard” Comprehensive Ocean–Atmosphere Data
Set (COADS) release versions 1 and 1a (Woodruff et al. 1987; Wolter 1992; Woodruff et al. 1993). Based on such a limit, however, too many in situ observations in the tropical Pacific were eliminated during the 1982–83 El Niño. The climatological standard deviation in the cold tongue region is typically 1°C. These normal limits were not adequate for this period. The erroneous elimination of observations, which totaled about one-third of the available in situ data during the winter of 1982–83, has been referred to as a statistical Type 1 error (e.g., Wolter et al. 1989; Wolter 1997), as opposed to the intended purpose of trimming constraints to remove truly bogus data.

To minimize such trimming errors, the upper limit for SST data retention was increased to 4.5σ within the region 30°S to 10°N and 180° to 65°W, for the period 1 November 1982 to 31 August 1983. This was the only screening change to the 3.5σ limit for the entire reanalysis period and made the percentage of discarded anomalies more uniform during that period (R. Reynolds and D. Stokes 1996, personal communication). Wolter (1997) has recently shown that an increase of the trimming limits from 3.5 to 4.5σ is the most efficient means for minimizing Type 1 errors in the enhanced COADS dataset, and he has shown the impact of such changes on SST analyses for the period 1872–1992. Figure 1 compares the blended and OI SST analyses over the tropical Pacific for the 1982–83 period. The time series shows the evolution of SST anomalies averaged 5°N–5°S, 160°–120°W for the two datasets (Fig. 1a), and the largest differences occur during the winter season when El Niño was at its peak. The spatial pattern of the OI minus blended SSTs for the December 1982–March 1983 period (Fig. 1b) shows differences over 1°C, covering large portions of the Niño 3 and Niño 4 index regions.

b. AGCM experiments

GCM simulations of the atmospheric response to the observed monthly mean SSTs from February 1982–November 1993 are performed. A suite of parallel runs are made that use the two estimates of that SST evolution described above, and a nine-member ensemble of AGCM simulations is performed for both the blended and OI SST boundary conditions. These two experiments will be subsequently referred to as the blended and OI SST runs, respectively.

Anomalous sea surface temperature variations are retained only over the tropical Pacific Ocean between 20°N–20°S, whereas SSTs over the remainder of the global ocean are assigned climatological values that repeat each year of the model integration. For each SST boundary condition, individual ensemble members are begun from different atmospheric initial conditions, but subjected to identically evolving boundary conditions. The initial conditions are derived from consecutive February states of a multiyear control integration of the AGCM that uses repeating climatological SSTs.

The AGCM is a climate version of NCEP’s Medium Range Forecast model (referred to as MRF9 in Kumar and Hoerling 1995 and Kumar et al. 1996), and a detailed description of that model appears in Kumar et al. (1996). Horizontal scales are spectrally represented with triangular truncation at wavenumber 40 (T40), yielding a spatial resolution of approximately 2.8° latitude–longitude. A sigma coordinate system having 18 unequally spaced levels that sample the troposphere and lower stratosphere is used. Deep convection is parameterized using a Kuo scheme. The details of the implementation of the Kuo scheme also appear in Kumar et al. (1996), in addition to an analysis of the model’s sensitivity to different treatments of the radiative effects of deep convection.

Simulated anomalies for the 1982–83 period are computed with respect to their respective model climatologies, which is defined to be the nine-member ensemble average for the 1982–93 base period.

c. Observed atmospheric data

Several variables are analyzed in order to define the state of the observed tropical atmosphere during 1982–
The Southern Oscillation index (SOI) is used as a measure of the tropical-wide mass redistribution and is calculated from the unnormalized monthly averaged Tahiti–Darwin surface pressure anomalies. Precipitation anomalies are estimated from two satellite datasets. One is based on the polar orbiting measurements of outgoing longwave radiation (OLR), and we use the globally complete OLR dataset described in Liebmann and Smith (1996). A second estimate is derived from the same polar orbiting satellite platform but is derived from the microwave sounding unit (MSU). The method of estimating precipitation from MSU measurements is described in Spencer (1993). Rainfall estimates based on both these datasets are available on a regular 2.5° grid, with the exception that the MSU data is undefined over land areas. Monthly mean land surface temperature data, based on the station network, are used to define the climate anomalies in the extratropics. These data are available on a 5° latitude–longitude grid. Finally, the NCEP monthly mean 500-mb global height analyses available on a regular 2.5° grid are used to diagnose the midtropospheric stationary wave patterns.

For all variables, observed anomalies are computed relative to a 1982–93 climatological base period so as to facilitate direct comparison with the AGCM anomalies.

3. Comparison of observed anomalies with the AGCMs’ response to the 1982–83 El Niño

a. Tropics

Figure 2 shows the time series of 3-month running mean Tahiti–Darwin surface pressure anomalies during 1982–83 for observations and model simulations. The abrupt drop of the observed SOI has been previously emphasized, and the winter minimum of −5 mb was the lowest recorded value since 1935 (Quiroz 1983). The two model responses also capture the SOI’s rapid decline in spring 1982. They begin to diverge, however, by fall 1982, after which time the OI run exhibits a much steeper, and more realistic, decline of the SOI. A minimum value of −4.5 mb achieved in the OI run is nearly double that realized in the experiment using blended SSTs, and this value is close to the observed record minimum. A more negative SOI value is simulated in the OI run until late spring 1983, beyond which time the two model responses are again indistinguishable, consistent with near equality of the two SST analyses after April 1983 (see Fig. 1a).

The extreme swing of the SOI during 1982–83 was accompanied by a shift of precipitation from the normally active western Pacific to the arid regions of the equatorial east Pacific. Two satellite estimates of the observed rainfall anomalies within the 5°N–5°S band across the Pacific Ocean are shown in Fig. 3. These are in general agreement with each other, and indicate a gradual eastward shift and intensification of the rainfall anomaly during the course of the event. A maximum 12 mm day−1 rainfall anomaly was located at 140°W during December–February (DJF).

Simulated rainfall anomalies in the two GCM ensembles are much more different from each other, with the response based on the OI SSTs (Fig. 4a) containing the essential features of the observed rainfall anomalies. The model differences are well outside the range of observational uncertainty implied by Fig. 3, and these results give further evidence for appreciable degradation in quality of climate simulations resulting from trimming errors in the original blended SST analysis of 1982–83. The simulations using the weaker blended SST anomalies show a maximum rainfall anomaly during fall 1982, with amplitudes declining thereafter (Fig. 4b). By DJF the simulated rainfall anomaly is less than half that in the OI simulation and, likewise, half of the observed amplitude.

Figure 5 shows the spatial pattern of the observed and model simulated rainfall anomalies averaged for the December 1982–March 1983 period. The observed distributions (Figs. 5a, b) are realistically simulated only in experiments using the OI SSTs (Fig. 5c), which capture both the spatial detail of the basin-wide rainfall anomalies and the extreme positive anomalies near 140°W. It is in this region that the two SST analyses are most different (see Fig. 1b). Note also that the intensity of suppressed rainfall north of the equator and in the tropical western Pacific is more realistically simulated in Fig. 5c, although SST analyses in these regions are quite similar. The sharper contrast between wet and dry regions in the OI simulations is related to the stronger meridional and zonal overturning driven by the east equatorial Pacific heat source, a feature also implicit in the OI run’s more extreme Tahiti–Darwin surface pressure anomaly.
**Fig. 3.** Hovmoller diagrams of the observed equatorial Pacific monthly rainfall anomalies averaged for the 5°N–5°S band for the period September 1982–April 1983 based on analysis of (a) outgoing longwave radiation (OLR) measurements and (b) the microwave sounding unit. Contour interval is 2 mm day⁻¹, and the darkest shading highlights values greater than 10 mm day⁻¹. Rainfall estimates from the OLR data are derived from Arkin and Meisner’s (1987) empirical formula relating OLR and precipitation rates. Plots have been smoothed with a 3-month running average.

**Fig. 4.** Same as Fig. 3 except the nine-member ensemble average of AGCM simulations using (a) OI reanalysis SST and (b) original blended SST boundary conditions.

**b. Extratropics**

The temporal evolution of 200-mb geopotential height anomalies averaged between 40°–60°N for the Pacific–North American (PNA) sector is shown in Fig. 6. The dominant observed feature is the unusually strong negative anomaly centered at 150°W during winter, and Quiroz (1983) has pointed out that the February 1983 sea level pressure anomaly in the northeast Pacific was the second lowest since record keeping began in 1899. The wave characteristics of the circulation anomalies are evident with downstream positive anomalies located east of 90°W. An additional feature of note is that the springtime circulation anomalies were only slightly reduced from their wintertime peaks, and these were appreciably larger than their preceding fall counterparts.

Many aspects of the seasonality and intensity of the observed PNA sector response are captured in the ensemble mean response based on OI SST forcing (Fig. 6b). The peak amplitude of below-normal heights in the nine-member GCM average is ~100 m during winter, compared to the observed ~140 m minimum in February 1983. In contrast, the ensemble mean response based on the blended SST forcing (Fig. 6c) is only half that attained in the OI runs, and clearly much weaker than observed.

Figure 7 illustrates the spatial pattern of the 200-mb extratropical anomalies. The structure of the observed anomalies resembles the Tropical–Northern Hemisphere (TNH) teleconnection pattern of Barnston and Livezey (1987), and this is reproduced in both GCMs. Consistent with the Hovmoller diagrams, however, the response based on the blended SSTs (Fig. 7c) is significantly weaker than the observed anomalies, both in the vicinity of the subtropical Pacific high, and the centers of action over the North Pacific–North American region. A doubling in atmospheric response in the OI simulations (Fig. 7b) is entirely consistent with the stronger equatorial rainfall anomalies in those runs and is further consistent with the quasi-linear relation between tropical Pacific SST anomalies and the extratropical response noted in...
North American surface temperature anomalies for the December 1982–March 1983 period are shown in Fig. 8. The two model simulations are even more at variance here than previously indicated in the upper troposphere. A west–east band of greater than 1.5°F covers all of southern Canada and the northern United States in observations (Fig. 8a), and a similar amplitude warming is simulated in this region in the OI runs (Fig. 8b). In contrast, much more modest warming is simulated in the blended SST runs (Fig. 8c), consistent with Mao and Robock’s (1997) findings based on analysis of the various AMIP runs. The differences between the two GCM surface temperature signals are significant at the 95% confidence level over much of the northern and central United States (Fig. 8d). There are no significant differences in signals over northern Canada however, and the appreciable warming over the Canadian Arctic shown in both models is contrary to the observed below normal temperatures there.

It should be noted that the above analysis compares the nine-member ensemble AGCM responses with the observed anomalies, which can be a blend of a true SST-forced signal and atmospheric internal variability. The possibility cannot be dismissed that the correspondence between OI ensemble responses and observations is fortuitous, and that the observed patterns may actually have had different origins. Further clarification of this matter is given in section 4, based on analysis of the GCMs’ intersample variability.

4. Initial condition sensitivity of simulated atmospheric anomalies during the 1982–83 El Niño

A well-known fact is that the atmosphere, especially in extratropical latitudes, can exhibit a wide range of behavior even when subjected to the same boundary conditions. In other words, the individual AGCM simulations forced with identical SST anomalies can generate seasonal anomalies that differ from the ensemble mean. The extent to which the models’ ensemble mean response is reproducible within individual runs using different initial atmospheric conditions is an indication of the strength of the SST related signal (i.e., the ensemble mean response) relative to the climatic noise. Such analysis further points to the probability that the ensemble mean response can be the anomaly of any individual GCM realization.

Figure 9 shows the wintertime equatorial Pacific rainfall anomaly for each realization of the model based on OI SSTs (left-side panels) and blended SSTs (right-side panels). A feature of the model sensitivities is that the equatorial Pacific rainfall response averaged for the 1982–83 winter is a near-deterministic outcome of the imposed SST forcing, a behavior noted in other GCM studies (e.g., Dix and Hunt 1995). Importantly, no single run based on the blended SSTs achieves the amplitude of rain anomalies in the OI runs, and the two populations derived from the two different prescribed SST forcings are nonoverlapping for equatorial central Pacific rain.

The robustness of the tropical central-Pacific rainfall anomaly among the individual GCM realizations implies a high signal-to-noise ratio. To the extent that
the GCM is an analog for nature, the observed rainfall anomaly cross section (Fig. 10a) is likely a result of the tropical SST forcing as given by the OI analysis, with the influence of initial conditions playing a minor role.

Considerable intersample variability across the North Pacific–North American region is evident in the cross sections of 200-mb height anomalies averaged between 40°–60°N (Fig. 11). It is apparent that a variety of midlatitude circulation states can coexist with near-identical anomalies in tropical rainfall. However, the spatial pattern of the “climate signal” related to the 1982–83 El Niño, as given by the composite model responses in Figs. 6 and 7, is discernable in many of the individual model realizations. Thus, the majority of both model realizations exhibit below-normal heights over the North Pacific and downstream positive heights over North America. However, consistent with the larger amplitude of the ensemble-averaged signal in the OI experiments, reproducibility of the extratropical anomaly pattern is greater in those runs (Fig. 11, left side) than in the runs using the weaker blended SST forcing (Fig. 11, right side). Although the GCM results indicate that the simulated extratropical anomalies are not a deterministic result of the SST forcing, contrary to the case for equatorial Pacific rainfall, it is nonetheless interesting to note that several of the OI realizations reproduce the observed amplitude of the midlatitude circulation anomalies (Fig. 10b), whereas no single run based on blended SSTs achieves such extreme amplitudes. This result does not preclude the possibility that such states can never occur within a larger sample of runs using the blended SST anomalies (or perhaps even no SST anomalies). The key point is that such states are more likely to occur under the influence of the stronger OI SST forcing, and increases the likelihood that the observed circulation anomalies over the PNA region during 1982–83 were themselves strongly influenced by El Niño.
5. Discussion and conclusions

No period in the modern era of global observations has captured popular awareness and scientific interest so strongly as the winter of 1982–83. Many tropical regions experienced record-breaking rainfall anomalies, and adjacent areas were simultaneously plagued by prolonged drought or flood conditions with devastating socioeconomic effects (e.g., Quiroz 1983; Glantz et al. 1987). Equally memorable were events in the extratropics. These included record low surface pressure over the northeast Pacific, heavy rains and flooding along the Pacific Coast and the southeast United States, near-record warmth over southern Canada, the northern United States, and much of Eurasia (Quiroz 1983).

Over a decade ago, Rasmusson and Wallace (1983) raised the question of whether the meteorological events of 1982–83 could be linked to the extreme El Niño phenomena. The weight of empirical evidence regarding ENSO teleconnections that has emerged during the past decade (see Glantz et al. 1991) certainly favors the notion that the character of the PNA sector climate anomalies during 1982–83 were related to the unusually strong tropical SST forcing. The chorus of AGCM simulations, most notably the large suite of experiments performed recently as part of AMIP, have not, however, isolated the origin of the extreme character of the global climate anomalies. Indeed, those runs have led to the impression that El Niño was but a minor player in the extratropical climate of 1982–83, spurring alternate hypotheses on the origin of the extreme climate states.

Our analysis has shown that answers to such questions depend greatly on the particular SST boundary conditions used to drive the AGCM, and that errors in the original blended SST boundary conditions for 1982–83 used in the AMIP experiments led to an underestimate of El Niño’s role during that winter. The error, resulting from unrealistically large trimming constraints (e.g., Wolter 1997), is shown to have been corrected by using relaxed constraints in the reanalysis OI dataset. The AGCM results using both SST datasets further suggest that one need not invoke the hypothesis that aerosol forcing, associated with the El Chichon volcanic eruption, was a significant contributor to the North American climate anomalies during 1982–83. That proposition, put forth by Robock and collaborators (Robock 1995, 1996), was based on the weakness of the signal simulated in the original AMIP experiments for 1982–83, a failure that our results suggest originated not from ignoring the aerosol loading, but from discarding the largest amplitude tropical Pacific SST anomalies in the boundary forcing.

Parallel sets of ensemble AGCM simulations using both SST datasets revealed a striking contrast in climate signals during the winter of 1982–83. In particular, the record negative value of the observed SOI was simulated in the nine-member ensemble mean of GCM runs using the reanalyzed OI SSTs, whereas only half of the SOI swing was realized in the blended SST runs. Likewise, the observed equatorial Pacific rainfall anomalies during the winter of 1982–83 were shown to be a deterministic outcome of the SST forcing when that forcing was based on the OI SSTs, whereas less than half of the rainfall amplitude was captured in simulations using the original blended SSTs. At higher latitudes, the ensemble mean circulation response in the OI runs achieved 75% of the amplitude of the observed extreme negative height anomalies in the midtroposphere over the North Pacific, and the extreme warmth experienced throughout southern Canada and the northern United States.
States was entirely captured in the OI run’s ensemble mean response. In contrast, little surface warming occurred over southern Canada and the northern United States in the blended runs, consistent with the AMIP results, and no single run achieved the amplitude of the observed PNA-sector anomalies.

Even when employing the best available SST conditions, the OI simulations failed to capture important aspects of the climate anomalies over Eurasia. The observed warming over Eurasia during the winter of 1982–83 was actually greater than that witnessed over North America (Quiroz 1983), yet such a feature was not simulated in the current suite of GCM runs. This result is outwardly consistent with the statistical analysis of Hurrell (1996), in which surface temperature fluctuations over Eurasia are shown to be related largely to the North Atlantic Oscillation and not El Niño. However, due to the extreme nature of the 1982–83 event, it remains to be seen whether the Eurasian warming might have been due to tropical SSTs and perhaps our GCM’s failure is instead a reflection of model bias. It is also interesting to note that the winter-average surface temperature composite associated with volcanic eruptions exhibits a statistically significant Eurasian warming pattern (Robock and Mao 1995). A similar pattern of surface temperature anomalies has also been shown to be associated with extreme phases of the midlatitude tropospheric zonal mean zonal circulation (Ting et al. 1996) and with a particular phase of the stratospheric polar vortex (Perlwitz and Graf 1995). Further GCM experiments, that incorporate estimates of aerosol forcing would be of interest for understanding the impact of stratospheric aerosols on surface climate, and further clarify the role of the El Chichon eruption in the Eurasian anomalies during the 1982–83 winter.

Finally, this paper’s results on the intercomparison of GCM simulations, using two different SST analyses for 1982–83, have implications for large-scale modeling ef-

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**Fig. 8.** December 1982–March 1983 averaged land surface temperature anomalies over North America based on (a) observations, (b) the nine-member ensemble average of AGCM simulations using OI SSTs, (c) the nine-member ensemble average of AGCM simulations using blended SSTs, and (d) the difference field (b) minus (c). Contour interval is 0.5°F, and negative anomalies are dashed. In (a)–(c), the darkest shading highlights positive surface temperature anomalies greater than +3°F. In (d), the darkest (lightest) shading highlights differences between the two model responses significant at 95% (90%).
Fig. 9. Cross sections of the time-averaged December 1982–March 1983 equatorial Pacific rainfall anomalies averaged between 5°N–5°S for each individual realization of the AGCM simulations based on the OI reanalysis SSTs (left-side panels) and the original blended SSTs (right-side panels). Dark (light) shading indicates longitudes with above (below) normal rainfall. The cross sections cover the region 100°E–60°W.

Fig. 10. (a) Cross section of the time-averaged December 1982–March 1983 observed equatorial Pacific rainfall anomalies averaged 5°N–5°S based on the analysis of the outgoing longwave radiation. Dark (light) shading indicates longitudes with above (below) normal rainfall. The cross section covers 100°E–60°W. (b) Cross section of the time-averaged December 1982–March 1983 observed North Pacific–North American 200-mb height anomalies averaged 40°–60°N. Dark (light) shading indicates longitudes with above (below) normal heights. The cross section covers 150°E–60°W.
Fig. 11. Cross sections of the time-averaged December 1982–March 1983 North Pacific–North American 200-mb height anomalies averaged between 40°–60°N for each individual realization of the AGCM simulations based on the OI reanalysis SSTs (left-side panels), and the original blended SSTs (right-side panels). Dark (light) shading indicates longitudes with above (below) normal heights. The cross sections cover the region 150°E–60°W.

Forts to simulate the interannual climate variations throughout the twentieth century (e.g., Palmer and Anderson 1994). Sparsity of sea surface temperature data, especially in the Tropics prior to the International Geophysical Year of 1957, make reliable analyses problematic at best. Trimming issues become even more relevant, and Wolter (1997) shows the sensitivity of tropical SST analyses to trimming assumptions back to 1872. In the absence of remotely sensed data, constraints on the SST analyses are lacking, and various methods used to generate globally complete data, such as EOF reconstruction (Smith et al. 1996) and time–space interpolation methods, can yield quite different results. Complete gridded SST data are of course needed for GCMs, and it is evident from the results presented herein that inferences on the SST-forced atmospheric climate signal can be sensitive to the assumed SST boundary conditions. The differences discussed herein for 1982–83 were quite large, and an important question concerns the error tolerance of the SST analysis as it impacts the simulated climate response. For example, the results of Kumar and Hoerling (1997) suggest that precise knowl-
edge of the spatial details of SST warming during large-scale events may not be particularly important for simulations of the extratropical response, though a more thorough analysis of this problem is required.

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