PREDICTABILITY OF MONTHLY MEAN CIRCULATION AND RAINFALL:
PART I: CLASSICAL DYNAMICAL PREDICTABILITY EXPERIMENTS
PART II: INFLUENCE OF 1982-83 AND 1986-87 EL NINO SST ANOMALIES.

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SUMMARY (an expanded abstract)

In Part I we present the results of classical predictability experiments in which model integrations are performed with randomly (or nonrandomly) perturbed initial conditions, and the growth of error is examined for the space and time averaged model circulation. These results are examined for a two layer GCM by Schubert and Suarez (1988), a GFDL model (Miyakoda et al., 1986), a GLAS model (Shukla and Fennessy, 1988) and a NCAR community climate model (Tribbia and Baumhefner, 1988). In the GFDL and the GLAS models the random perturbations were superimposed on observed initial conditions, whereas, in the NCAR GCM and the two layer model of Schubert and Suarez, the random perturbations were superimposed on initial states obtained from long integrations of the respective models with perpetual winter boundary conditions. For the latter two models with long integrations, error among random perturbation integrations was compared with the models' variance to define the limit of predictability for time averages.

If the predictability limit is defined as the time period for which the error variance for random perturbations equals the

model variance (or the mean square difference between twin experiments is half of the model variance), both models suggest that the monthly means are dynamically predictable. However, the degree of predictability of both models is quite different. For example, for the Schubert and Suarez model, the error variance for the first 30-day average is a very small fraction of the model variance and 30-day averages even for days 21-50 are found to be highly predictable; whereas for the NCAR GCM the rms error between twin model runs for the first 30-day average is already comparable to the model variance. This is in spite of the fact that for Schubert and Suarez model, the rms error on day 1 is 9 meters, whereas for the NCAR GCM, the rms error on day 1 is only 1.2 meters for 500 mb height. This suggests that the growth characteristics of the initial random errors and error among 30-day averages are quite different in the two models. The most important difference in the two models is found in the nature of low-frequency variability which is far higher than the observed variability (about 150%) for the Schubert and Suarez model whereas far lower (about 67%) than the observed variability for the NCAR GCM. For the other two models (GFDL and GLAS) for which an estimate of model variance based on a long model integration does not exist, error among random perturbations is compared with the actual forecast error.

For both models it is found that the root mean square differences between twin model integrations with random perturbations for 10- and 30-day averages is smaller than the model forecast error as well as the persistence error.

Results from the four different models collectively suggest that 30-day averages are dynamically predictable, however, the degree of predictability differs considerably and depends upon the nature of low frequency variability of the model.

We have also examined the performance of various models in predicting 30 and 60 day average circulation, (300 mb geopotential height) by making forecasts with the observed initial conditions and verifying against actual observations. We present here some results for the region 20N - 76N. We have examined the following cases and models:

1. NMC-DERF model: 108 cases covering the period 14 December 1986 through 1 April 1987 (see the accompanying paper by Tracton and Kalnay). Forecast errors were examined for days 1-10, 11-20, 21-30, and 1-30.
2. NMC-COLA model: 3 cases (Jan. 1, 2, 3, 1987), with and without Pacific SST anomaly.
3. GLAS model: 6 cases (Jan. 1, 2, 3, 1987, Dec. 15, 16, 17, 1982), with and without Pacific SST anomalies and 5 cases (Jan. 1 for years 1979, 1980, 1981, 1982, 1984) with climatological SST.

The main results can be summarized as follows:

1.1 The NMC model has a large systematic 30-day mean forecast error. The error begins to develop immediately (but is not too large for days 1-10) and increases up to day 30. The zonal mean component of the error is so large for days 11-20 that the forecast error becomes larger than the persistence error for days 11-20. However, if only the zonally asymmetric part of the forecast field is compared with the corresponding observations, the average score for days 11-20 is better than persistance.

1.2 If the 108 case ensemble is broken into subensembles of 30 cases each, and systematic error is recalculated for each subensemble, the zonally asymetric part of the error shows large differences from one subensemble to the other; the zonally symmetric part also has some variability but not as large. These results suggest that generally it would not be possible to correct future forecast error using past forecast errors.

1.3 Based on the large error (larger than persistence error) in the zonally symmetric part of the flow, it is proposed to modify the forecast as follows:

Total forecast field = Zonally symmetric field based on persistence plus model predicted zonally asymmetic field.

The above modification of the forecast improves (see Table 1) the 108 case average forecast rms error (anomaly correlation) from 85 m (.69) to 80 m (.70) for days 1-10, 164 m (.16) to 132 m (.20) for days 11-20, and 190 m (.11) to 148 m (.13) for days 21-30. If the ten days preceding the initial day are used as the persistence forecast, the persistence forecast rms errors (anomaly correlations) are 121 m (.31) for days 1-10, 136 m (.16) for days 11-20, and 141 m (.20) for days 21-30.

1.4 If the 10-day average forecast for days 1-10 obtained by the above modification is scaled by the ratio of standard deviations of 30-day and 10-day averages and is used as a proxy for the 30-day mean forecast, the forecast rms error (anomaly correlation) is found to be 84 m (.49). This suggests that dynamical forecasts for 10 days can provide useful guidance for monthly mean forecasts.

1.5 The forecast rms errors (anomaly correlation) for the zonally asymmetric conponent of the flow averaged for 108 cases are 124 m (.17) for days 11-20 and 132 m (.11) for days 21-30. Corresponding values for the persistence forecast are 128 m (.11) for days 11-20 and 125 m (.17) for days 21-30. This suggests that, on the average, the model's prediction of zonal asymmetries is no worse than persistence even for days 11-20. However, the forecast error is highly variable from case to case. One of the most important unresolved questions concerning DERF is the relative contribution of deficiencies in the model (climate drift and its interaction with the transients), errors in the initial data, and the inherent dynamical instability of the large scale flow.

It is our conjecture that model physics is a primary cause of the rapid degradation of the zonal mean fields. We recognize the dynamical role of eddies in maintaining the zonal mean flow, however, we consider it less likely that within a few days an incorrect prediction of eddies will produce such a large error in the zonal mean. On the other hand, it is more likely that the treatment of radiation, convection and mountains produces a large error in zonal mean. This conjecture is supported by the high persistence of zonal means in actual observations.

2.1 We have also used a modified version of the NMC model (Kinter et al., 1988) and GLAS model (Shukla and Fennessy, 1988) to make 30-day forecasts for the initial conditions of 1, 2, 3 January, 1987. Table 2 gives the forecast verfication for all the three models. It is seen that forecasts using the high resolution spectral models (NMC and NMC/COLA) are clearly superior to the low resolution (4° x 5°) GLAS model.

In Part II we review the results of 30- and 60-day prediction experiments with and without the Pacific Ocean SST anomalies observed during the El Nino events of 1982-83 and 1986-87 (see the accompanying paper by Fennessy).

Table 3 gives the rms errors and anomaly correlations for 10- and 30-day average geopotential height at 300 mb. The main results are:

1. There is a significant improvement in prediction of tropical rainfall and circulation when the observed SST anomalies are included in the boundary conditions. There is very small variability due to changes in the initial conditions.
2. There is also some improvement in the mid-latitude circulation forecasts, but the variability among forecasts with different initial conditions is not small.
3. The impact of SST anomalies is found to be largest if the verification area is confined to the Pacific-N. American sector.
4. SST anomalies produce about equal improvement in the prediction of the zonal mean and the zonal asymmetries.
5. If the 60-day mean circulation anomaly produced by the SST anomaly is subtracted from the daily values and then 10- or 30-day averages of the residual anomaly are compared with the observations, there is no impact of SST anomalies on the departures from the 60-day mean. This suggests that SST anomalies enhance only the time mean prediction.
6. Identical SST anomalies were used to carry out 30- and 60-day prediction experiments with GLAS model and the NMC/COLA model using the initial conditions of 1, 2, 3 January 1987. Table 2 gives the results for rms and anomaly correlation.

We found a rather ambigious result that the GLAS model which has lower resolution and a clearly inferior predictions for control integrations (without SST anomaly) produces larger and positive impacts on predictions with SST anomalies. On the other hand, for the NMC/COLA model there is no (or some negative) impact of SST anomalies. We propose to investigate this in the future.

7. We have also carried out forecast experiments with the GLAS model (which has a large zonal mean drift) in which an artificial momentum source was introduced in the zonal momentum equation such that the zonal mean zonal wind had no error at all (12 hourly observations were used to correct every time step). This procedure almost completely removed the error in the forecast of the zonal mean height field, however, there was no change in the forecast error for the zonally asymmetric height field. We are still investigating this counter-intuitive result.

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Table 1: Average of 108 cases for Root Mean Square (RMS) error in meters and anomaly correlation for 10-day and 30-day average forecast for 300 mb height for the region 20N - 76N.

RMS ERRORS (Meters)

	Days 1-10	Days 11-20	Days 21-30	Days 1-30
Total Forecast error	85	164	190	120
Total Persistence error	121	136	141	95
Zonal mean Forecast error	45	107	137	94
Zonal Mean Persistence error	34	46	65	56
Zonal Deviation Forecast error	72	124	132	74
Zonal Deviation Persistence error	116	128	125	77
Total Adjusted Forecast error	80	132	148	84
Total Persistence error	121	136	141	95

ANOMALY CORRELATIONS

	Days 1-10	Days 11-20	Days 21-30	Days 1-30
Total Forecast error	.69	.16	.11	.31
Total Persistence error	.31	.16	.20	.30
Zonal mean Forecast	.60	.29	.21	.35
Zonal mean Persistence	.52	.45	.33	.56
Zonal deviation Forecast	.72	.17	.11	.39
Zonal deviation Persistence	.28	.11	.17	.29
Total adjusted Forecast	.70	.20	.13	.49
Total Persistence	.31	.16	.20	.30

Table 2: Northern hemisphere verification for zonally asymmetric height at 300 mb. Ensemble mean of 1, 2, 3 January 1987 cases.

ANOMALY CORRELATION

Model	Days 1-10	11-20	21-30	1-30
NMC-DERF	.82	.30	.47	.53
NMC-COLA	.87	.46	.36	.70
GLAS	.62	.09	.37	.32
NMC-COLA with SSTA	.86	.37	.41	.65
GLAS with SSTA	.65	.15	.56	.37

ROOT MEAN SQUARE ERROR (Meters)

Model	Days 1-10	11-20	21-30	1-30
NMC-DERF	60	107	119	63
NMC-COLA	53	98	126	56
GLAS	85	142	124	83
NMC-COLA with SSTA	53	109	120	62
GLAS with SSTA	81	144	107	83

analysis and Brian Doty carried out the predictability calculations for the GFDL model. Jim Kinter was always available for dicussions and criticism of the results.

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