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Uncertainties in Climate Data Sets

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Climate diagnostics are constructed from either analysed fields or from observational data sets. Those that have been commonly used are normally considered ground truth. However, in most of these collections, errors and uncertainties exist which are generally ignored due to the consistency of usage over time. Examples of uncertainties and errors are described in NMC and ECMWF analyses and in satellite observational sets--OLR, TOVS and SMMR. It is suggested that these errors can be large, systematic and not negligible in climate analysis.

Analysed moisture fields. Because of the importance of greenhouse warming and many research initiatives, the climate drift of water vapor has become an important issue. Fig. 1 intercompares an instantaneous NMC analysis of upper tropospheric relative humidity with the 48 h forecast relative humidity over the tropical Pacific. Although the analysis represents the approximate state of the art in assessing moisture distribution, the 48-h prog appears to be a more realistic view of the synoptic distribution, better fitting the observed infrared and vapor satellite images and better defining a single synoptic system. It appears that the forecast model describes a better evolution of the moisture field, but this view is being overridden by "observations", in this case subjectively determined bogus moisture profiles.

Operational analysis uncertainty. One simple way of assessing uncertainty in operational analysis is by intercomparing operational analysis from two centers--ECMWF and NMC. Without deciding which analysis is superior, the degree to which they do not agree provides a *lower limit* to the uncertainty of our knowledge of atmospheric structure. Fig. 2 presents the difference fields between ECMWF and NMC analyses of 200 mb wind, temperature and geopotential for a random day in March 1984. These panels show synoptic scale difference patterns (or uncertainies) with magnitudes exceeding 20 m/s, 4 K and 30 m; these maximum amplitudes are typical of most days. Monthly means (not shown) describe systematic biases (net climate drift) of 6 m/s, 2.5 K and 10 m, with meaningful spatial patterns. The amplitudes and patterns are somewhat sensitve to climatic state (ENSO warm and cold phases). Generally, about half of the uncertainty is due to climate drift and about half to synoptic scale variability.

OLR/TOVS errors. Given 15 y of daily analysis and usage of OLR and TOVS sounding products (used operationally), it was anticipated that these observation sets would be error free. Fig. 3 displays a large tropical region centered on Central America. The associated time series shows the mean daily perturbation OLR averaged over that domain for part of 1984. Apparent are the spikes occurring every 7 d (on Sunday) throughout that time series. The analysis on the map shows the differences in the OLR field between the day before that spike and the day of the spike for one event. Difference fields for each of the spikes looks similar, whereas difference fields between days before and days after the spikes look more like typical synoptic variation. What appears to be happening is that a spurious field is being inserted once a week, with larger OLR values over normal convective regions. This behavior has not been fully documented yet. Secondly, within the TOVS observation set, we have identified unrectified limb brightening and darkening effects in most of the channels. This feature appears as a 2800 km zonal wave moving eastward at 1.28 m/s. It is largest in the subtropics (where it may be 25% of the signal), becoming nearly insignificant near the equator and north of 30 N. It probably is reflected in operational analysis through retrieved soundings.

SMMR precipitable water. It is generally assumed that the best estimator of column precipitable water over the oceans is through microwave measurements, such as SMMR or SSM/I. Fig. 4 shows high resolution estimates from SMMR during January 1983. However, the black circles denote observations which are impossible large (greater than 8.5 cm) or small (less than 0) in regions that should be uncontaminated by "physical effects". Correlation of SMMR to Raob estimated precipitable water over the tropical Pacific for January 1983 and 1984, even when unrealistic values are purged and account is taken of "island-contaminated" SMMR estimates, do not exceed 0.76 with standard errors not less than 0.84 cm (23%). Well controlled calibration estimates by numerous investigators all claim errors less than 0.5 cm (10%). It seems that, for undetermined reasons, operational use of the SMMR algorithms, even in 1983, does not live up to the calibration estimates. It is pointed out that precipitable water estimates from TOVS, stratified by OLR range, can correlate with raobs at over 0.9 with rms errors of $\pm$1.2 cm (32%).

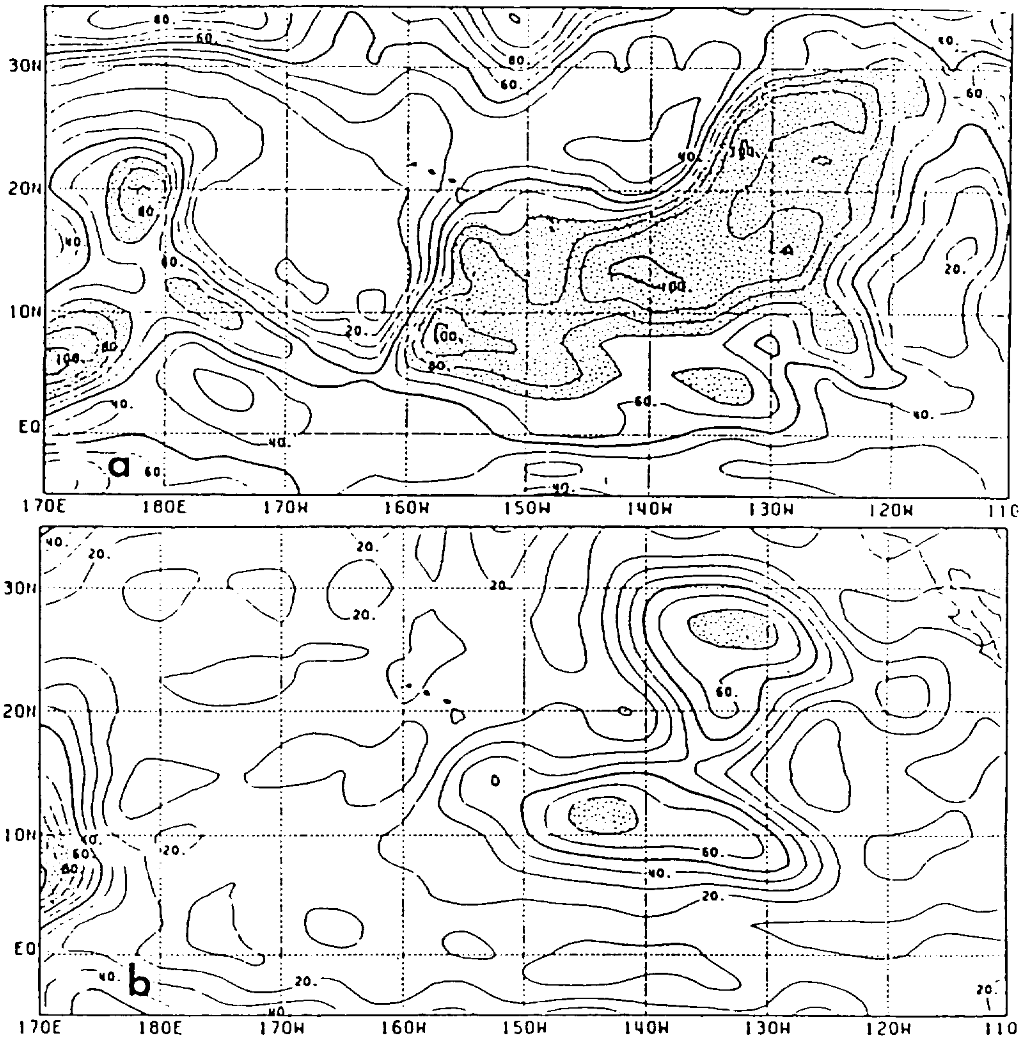

Fig. 1. a) 48-h NMC 300 mb relative humidity forecast from the global spectral model valid at 00GMT 18 January 1989; b) verifying NMC historical analysis valid at the same time. Relative humidity greataer than 70% is shaded. Although the forecast resembles the GOES vapor imagery closely, the analysis displays several unrealistic synoptic features.

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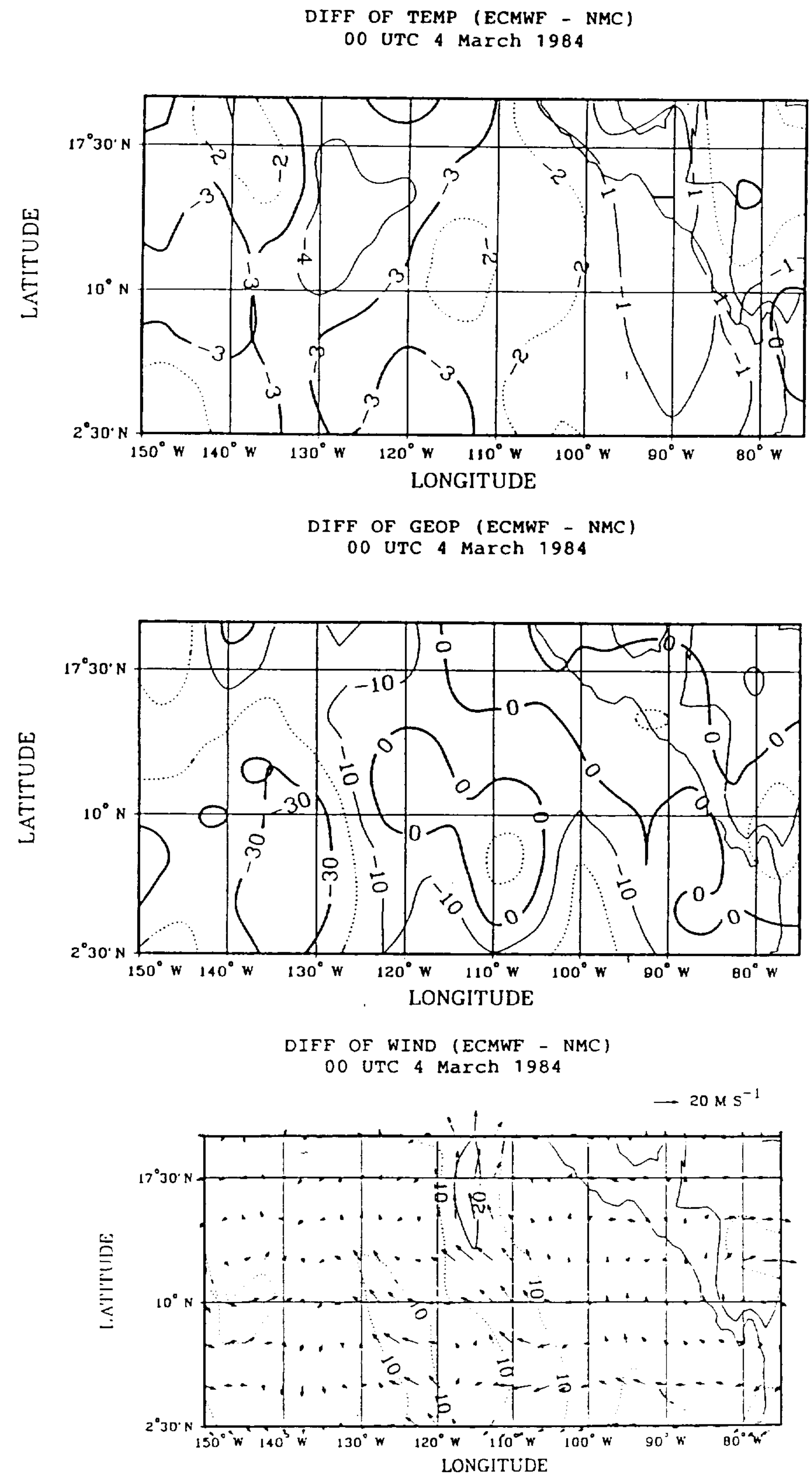

Fig. 2. 200-mb synoptic difference fields between the ECMWF and NMC analyses for 4 March 1984 for a) temperature (K); b) geopotential (m); and, c) winds and isotachs (m/s). The differences provide a lower bound for our uncertainty of the synoptic scale features over the tropical Pacific. Note especially the wind differences in excess of 20 m/s which are common on many days.

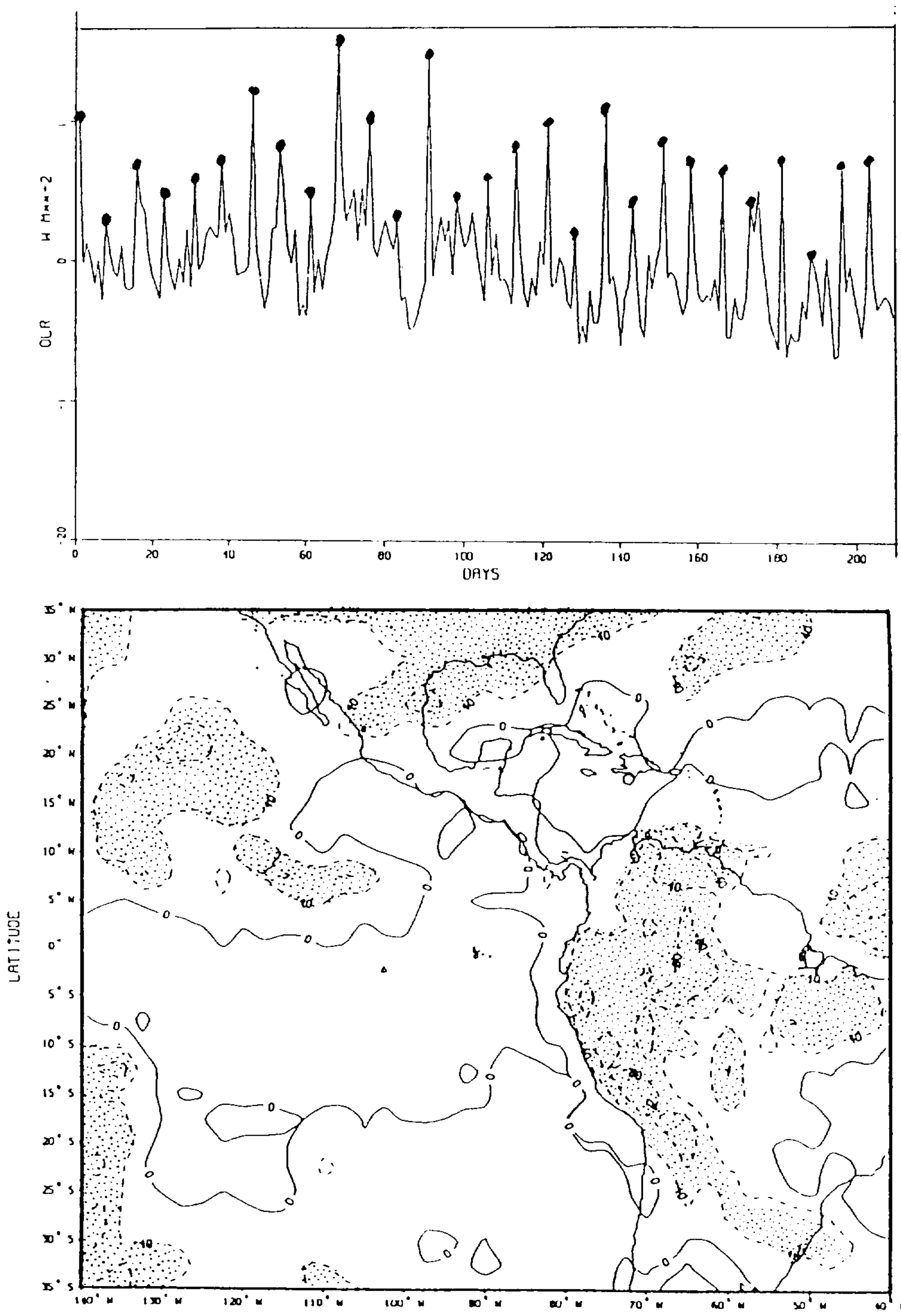

Fig. 3. Time series of the mean daily OLR anomaly over the domain of the map for the first 210 days of 1984. Highlighted are spikes occurring every 7 days. Also displayed is the difference map between 16 and 17 January highlighting the typical pattern of the 7-day "anomaly" field. Shaded areas greater than 4 W/m^2. Note that nearly no positive values exist.

STEPWISE MULTIPLE REGRESSION
SMMR PRECIPITABLE WATER ONTO
RAOB & TOVS PRECIPITABLE WATER

	# of obs	R^2	mean	sigma	radius/ year
RAOB/TOVS	1,001	0.71	3.32	1.15	
SMMR/TOVS	11,994	0.31	3.73	1.72	83
SMMR/TOVS	5,787	0.52	3.01	0.88	84
SMMR/RAOB	963	0.52	3.63	1.31	1.0-0.0
SMMR/RAOB	509	0.58	3.69	1.38	1.0-0.25
SMMR/RAOB	195	0.48	3.93	1.08*	1.0-0.5

- **SMMR correlates poorly with Raobs**
- **Island effect only partially responsible**
- **"Impossible" SMMR estimates noted below**

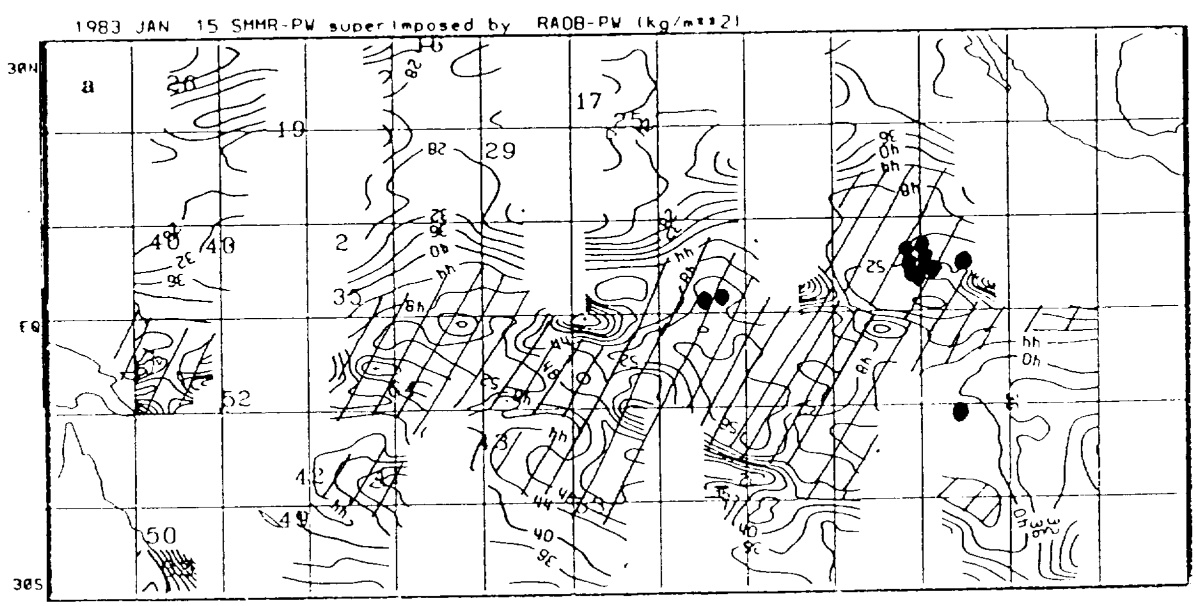

Fig. 4. Typical precipitable water estimates from SMMR for 15 January 1983. Spots denote impossibly large values (>10 cm). Table summarizes several regressions of satellite observations and raob precipitable water. The SMMR/raob correlations are much poorer than infrared TOVS/raob correlations, even when SMMR is corrected for island effects.