ZONAL-MEAN WINDS AND MOMENTUM BUDGETS

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The global scale temperature field is rather simply related to the energy balance and can rather easily be reproduced, at least in the troposphere, by a wide variety of models. Transfer of momentum between latitude belts is more difficult to understand and to model satisfactorily. Divergence of momentum flux is associated with surface stress and so more-or-less directly with the surface wind. (The connection is not unique for the mechanism for the transfer of momentum to the surface probably depends on pressure drag on a variety of scales: the motion on successively larger scales being influenced by the conditions over successively greater depths of the atmosphere.) We will study the surface wind under the impression that it is relevant to the transfer of momentum between latitude belts. The gradient of mean sea level pressure is related to the surface wind and is often reported as a diagnostic of model runs. Fig.1 shows the January mean m.s.l. geostrophic wind calculated from various models and observed.

1. POLE-EQUATOR PRESSURE DIFFERENCE

All models get the m.s.l. pressure in low latitudes correct. Table 1 shows the m.s.l. pressure at the poles predicted by different models. M30 is GFDL spectral, 500 is GFDL gridpoint, 11ℓ is British M.O., data from GARP, No.22.

TABLE 1.

	N.Jan.	S.Jan.	N.July	S.July
M15	1013	1002	1017	1035
M21	994	1001	1008	1016
M30	1008	990	1008	1016
500 km	1046			
250 km	1028			
ANMRC	1002	1016		
AES	995	pass		
11 ℓ	1013	1030	1031	1010
11 ℓ	1023	1030	1022	1025
MGO, 5 ℓ	1036			
Climate	1016	997	1014	995
FGGE	1025	1004	1013	993

Viewed as a statistical set, the 11 models predict 1018 ± 18 mb for the N.polar January mean sea-level pressure. If this is a prediction of the climatic value 1016 mb, then the scatter between models is rather large.

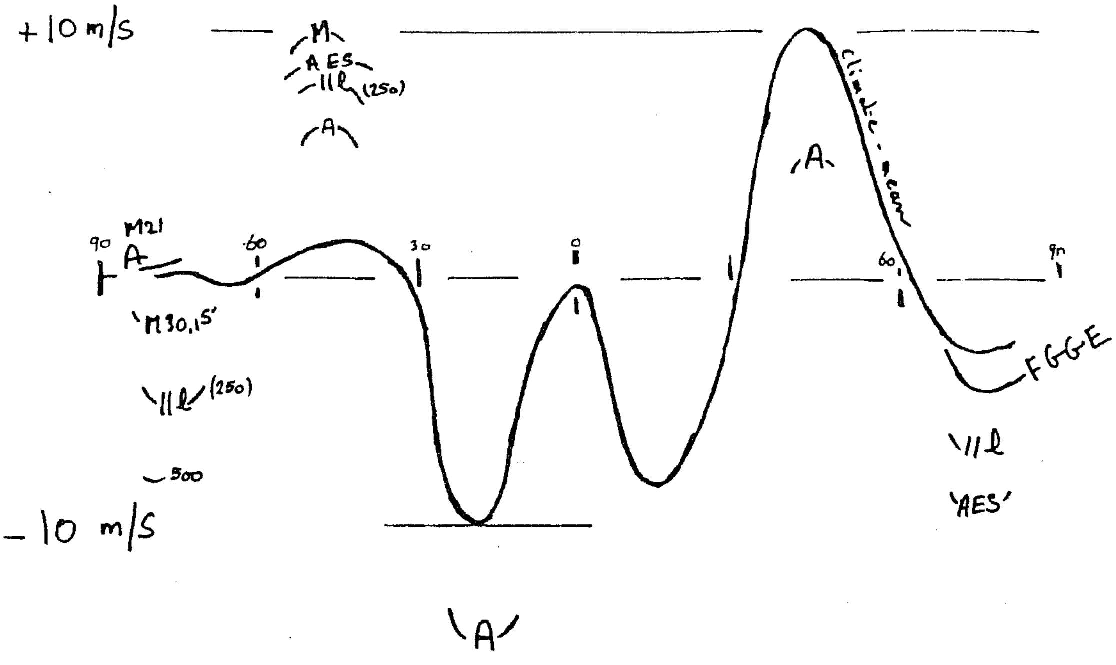
If it is a prediction of some January mean value, then the scatter is consistent with the difference between the FGGE and climate-January. It is not clear to me that different models *should* predict different years. The 11 ℓ experiment shows that the initial conditions are important.

2. <u>MEAN-SEA LEVEL GEOSTROPHIC WINDS</u>

Systematic differences between the models and climate and FGGE data can be seen in Fig.1. All the models predict tropical winds well. January, N.hemisphere mid-latitude winds are too strong by factors of 4 to 6. They are comparable with those observed (at all seasons) in the S.hemisphere middle latitudes. The Australian model is, in this respect, one of the worst for the S.hemisphere but one of the best for the N.hemisphere.

Polewards of 60° latitude the models generally have much stronger polar easterlies than those found in the N.hemisphere, again comparable with those found in the S.hemisphere. This is serious for heat-transfer, ocean mixing and ice-movement calculations that are critical according to simple climate models. In July, observed and predicted N.hemisphere sea-level geostrophic winds are weak and erratic, predicted S.hemisphere polar easterlies are too strong.

FIG.1. January zonal mean, zonal component, sea-level geostrophic wind.



3. PRESSURE DIFFERENCE ACROSS WIND BELTS

Most models generate three fairly well-defined belts of zonal mean-zonal surface winds. Table 2 shows some values of the m.s.l. pressure differences, measured in mb, over these belts for N.H. January. In comparison, the S.H. values are consistently close to those observed.

TABLE 2.	90°N		60°N		30°N		0
M30		-11		27		-10	
ANMRC		+ 1½		21		-15	
AES		0		29		-11	
11 ℓ		-27		23		-11	
11 ℓ		-16		27		-12	
5 ℓ		-38		17		- 8	
MGO		-23		9		-12	
OSU		-23		13		- 8	
500		-39		5		- 6	
250		-24		14		-10	
Obs.climate		- 2		5		- 9	
FGGE		-12		5		- 9	

Viewed as a statistical set, the 10 models predict -20 ± 14, 19 ± 8, -10 ± 2.5 for the three wind belts.

4. MOMENTUM TRANSFER

Momentum transfer is 20% too strong, particularly in high latitudes where it is practically all done by the eddies. Eddy K.E. is 30% too small so the eddies are 1.2/0.7 = 1.71 times too efficient at transferrers of momentum. Transient eddies are of particularly small amplitude, stationary eddies too intense.

5. CONCLUSIONS

N.hemisphere January extra-tropical surface winds are too strong. Looking at a variety of models and explanations and hemispheres one concludes that it is the N.hemisphere observations that are anomalous; can we understand them better? How biassed are observations taken at standard sites? We at I.C. have thought that perhaps the largest obstacle met in 1 km run of wind determines the frictional stress over land. If so, then standard land sites near airfields or seaside are unrepresentative. Reduction of pressure to mean sea level is arbitrary and unsatisfactory and should be abandoned, but then what should be analysed on the surface chart in the presence of significant orography? Presumably a near surface wind, a dynamical quantity like $\phi + R\overline{T}\,\ln\,p_s$, where $\overline{T} = \overline{T}^{xy}(\sigma = 1)$, and a thermodynamic quantity like potential temperature.

Do we really ignore the difference between the static pressure measured by a stationary barometer and the dynamic pressure that appears in the equations of motion? Is smoothed orography permissible?

6. WINDS AT UPPER LEVELS

The horizontal distribution of zonal-mean temperature in the troposphere is determined by the mechanics of baroclinic disturbances. The vertical distribution is determined by combined convective and radiative transfer usually represented in a parametric form and closely related to the state of the real atmosphere. Conditions in the lower stratosphere are more difficult to model. It is likely that momentum transfer from the troposphere forces a meridional circulation in which air is forced to descend in the polar stratosphere. Adiabatic warming (*sic*) results in a warm polar stratosphere and ensures that the mid-latitude jet decreases above the tropopause. This is, like the horizontal transfer of momentum, an indirect process and (therefore?) difficult to model. Some models do not attempt to represent this layer at all and replace the upper atmosphere by a layer topped by a lid. Table 3 shows (1) the minimum zonal-mean zonal component of the velocity where it exists, then the 12 to 14 km turning-point values for the (2) NH (3) equator (4) S.H. in January, *i.e.* the jet velocities and equatorial upper easterly minimum, all measured in m s^{-1}.

TABLE 3.

	(1)	(2)	(3)	(4)
M30	27	40	-5	35
NCAR	30	40	7	30
GLAS	50	40	-2	30
5 ℓ		40	-1	28
ANMRC	70	30	-5	20
AES	50	47	-8	35
Observed	19	35	-2	20

Viewed as a statistical set, these models give 45 ± 17 for the minimum zonal velocity above the jet, 40 ± 5, -2 ± 5, 30 ± 6 for the other turning points.

6. CONCLUSIONS

Shutts and Green believe that the long stationary waves lose energy not by friction but by radiating wave energy into the lower stratosphere. Misrepresentation of this process would be expected to allow tropospheric long waves to attain too large amplitude, which would result in blocking of the resonant long-wave type, rather than (say) the Green transient-eddy supported type, and to fail to force warming of the polar stratosphere.