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GRACE GRAVITY MODEL: ASSESSMENT IN TERMS OF DEEP OCEAN CURRENTS FROM HYDROGRAPHY AND FROM THE ECCO OCEAN MODEL.

V. Zlotnicki (1), D. Stammer (2), I. Fukumori (1).
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The horizontal slope of the difference between a Mean Sea Surface (MSS) and a Geoid model, in principle, yields the absolute geostrophic current at the ocean surface. If that same current is computed from the vertical integration of the specific volume of seawater 'relative' to a certain depth, one incurs an error by disregarding the current at this 'level of no motion'. Until now, however, global geoid models have been less accurate than the small error incurred by the 'level of no motion' assumption. Thus, one way to view the error of a geoid model for oceanographic applications is to ask 'for which depth is the error of this geoid model comparable to the error of a 'no motion' assumption ?'. Conversely, this is the ability of a geoid model to see deep currents.
Here we assess the new generation of gravity models, derived from GRACE data. The differences between a global geoid model (one from GRACE data and one the well-known EGM-96), minus a Mean Sea Surface derived from over a decade of altimetric data (Wang, 2001; Hernandez, 2001) are compared to hydrographic data from the Levitus compilation and to the ECCO numerical ocean model, which assimilates altimetry and other data. The new (GRACE) gravity models are sufficiently accurate to retrieve time-averaged currents at depth: a preliminary version dubbed GRACE 21 (dated November 2002), can accurately retrieve dynamic height and currents at least to 1000m in the Atlantic and Pacific, and to at least 3000m in the Antarctic Circumpolar Current region, which cannot be done with the older EGM-96 geoid. The geoid also provides new information to the ocean models, so assimilating its data can improve the model. We expect the reprocessed GRACE data to be available in early 2003 to improve upon these early results.

DATA & PROCESSING

DATA:

- 1. GEOID: **GRACE21** or **EGM96** to n=120, 70, 40
- 2. MSS: **Wang 2001** MSS (2'), minus MEAN TIDE. 4' lon shift
- 3. HYDRO: **Levitus Atlas 2002** T,S =>Dynamic Height above 3km,4km,5km, 1 deg

MSS: Pre-smoothing and Subsampling

- 1.5 deg ave, two pass (in lon, /cos(lat)), then subsampled to 0.5 deg

Smoothing MSS-GEOID:

- (5 or 9 deg ave), two-pass (in lon, /cos(lat)

Smoothing Levitus:

- Both unsmoothed and with same smoothing as MSS-GEOID

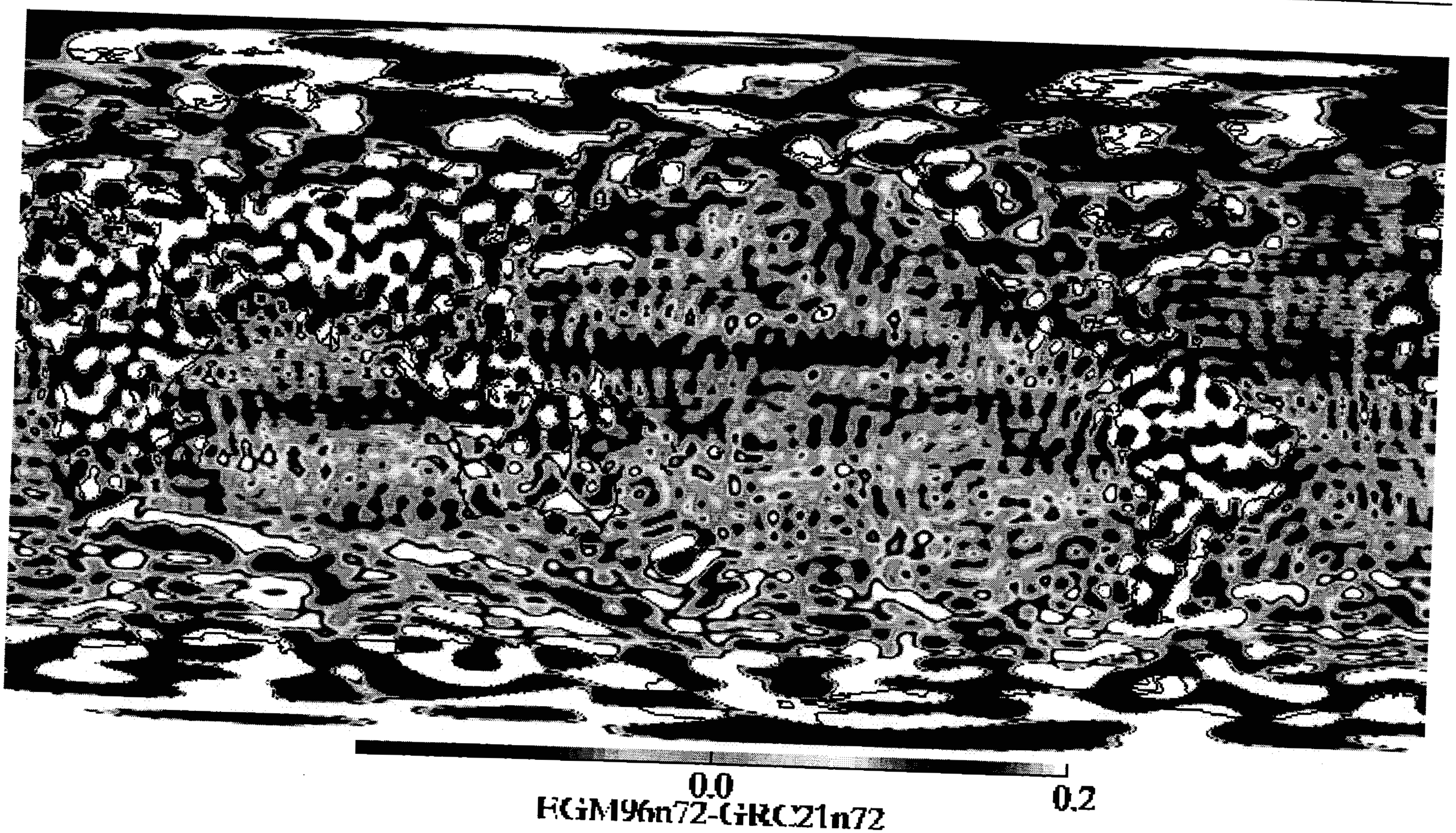
Geoid

- Used Brun's formula, then subtracted a correction field to yield iterative solution. (from (Brun (GRC21n70) -IterGeoid(GRC21n70)), D. Chambers)
- GRACE21 is in ZERO TIDE system. EGM-96 is in NON-TIDE system

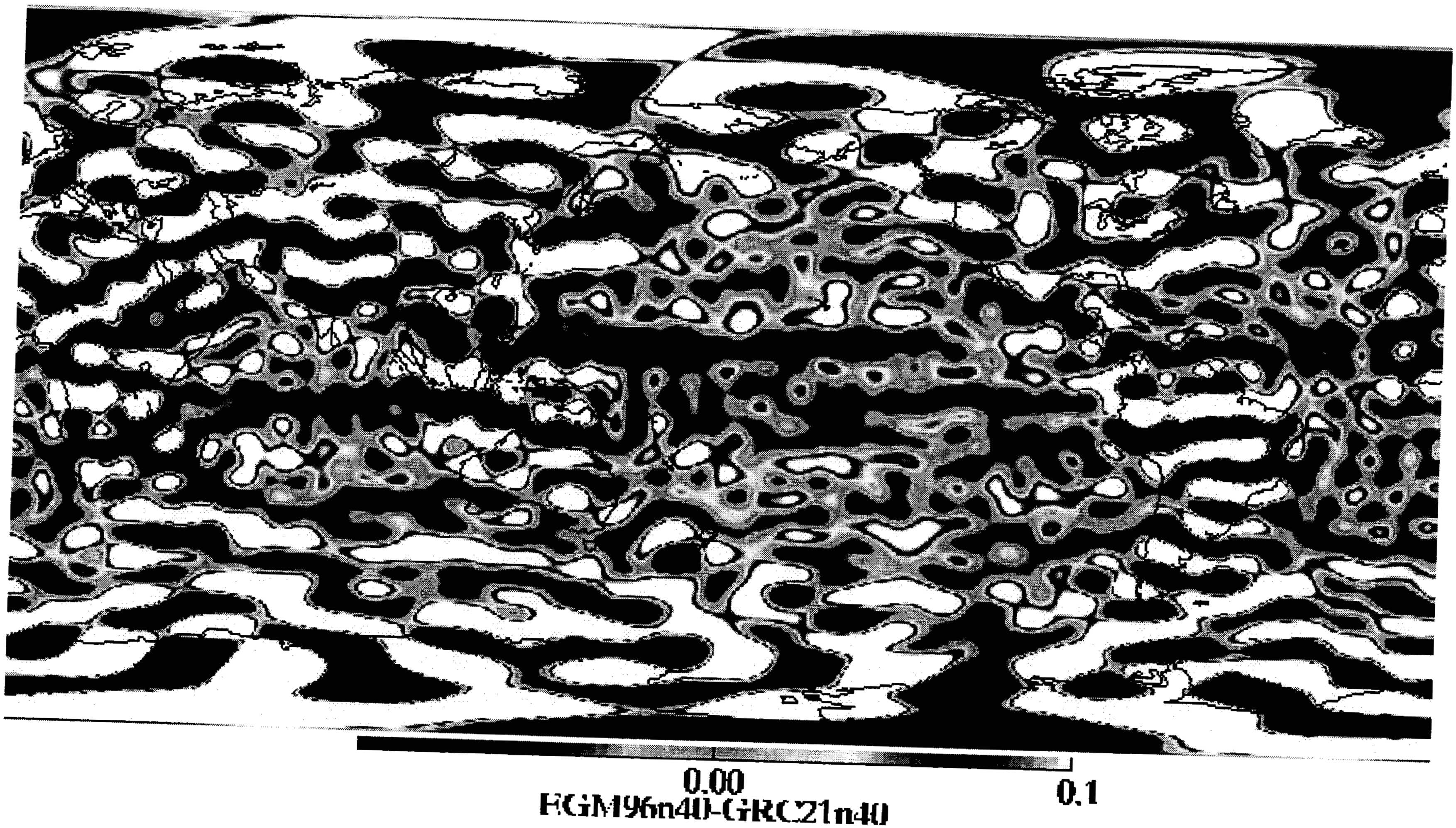
GRACE21–EGM96

- The diff between the two geoids, GRACE21–EGM96, shows very different patterns over land and ocean
- The Gulf Stream, Kuroshio, Equatorial Currents, Antarctic Circumpolar Curr., all appear in GRACE 21-EGM96 even to n=40 (1000km wavelength).
- As will be shown below, these features are in EGM96, not in GRACE21.
- EGM96 used 1° grav anomalies. Over the oceans, these were derived from altimetric MSS, including time-averaged ocean signal.

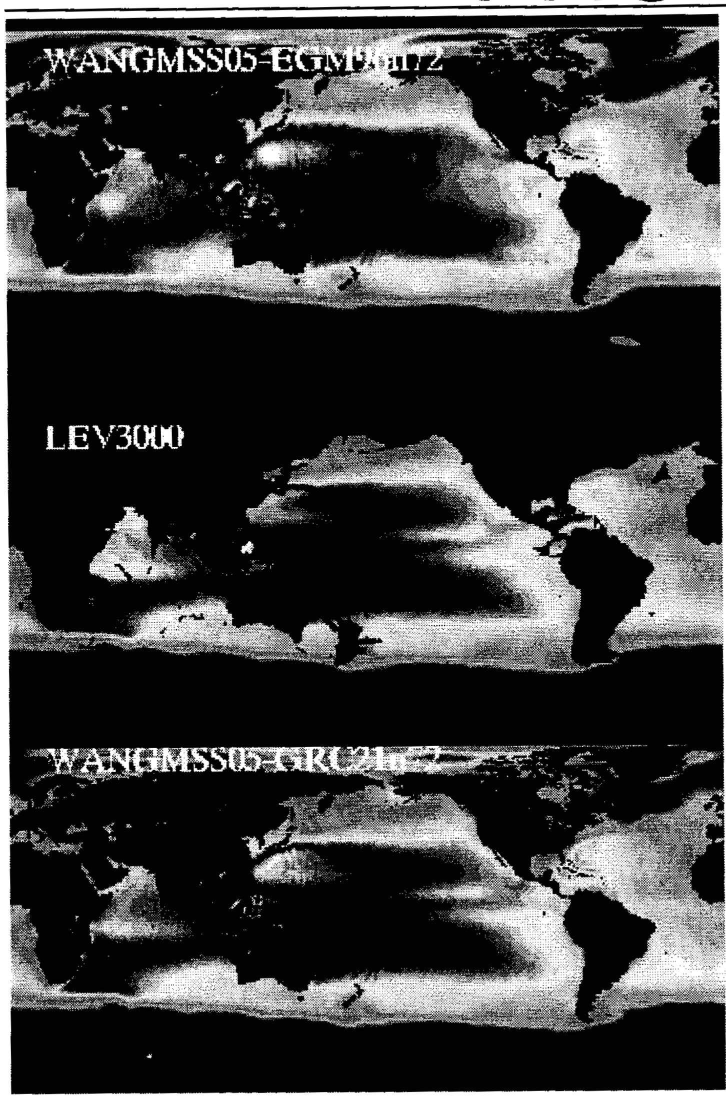
GRACE21–EGM96 to n=72



GRACE21–EGM96 to n=40



MSS-GEOIDS, DYNAMIC TOPO FROM LEVITUS



TOP: MSS-EGM96
MID: Levitus Dyn. Height
wrt 3000m ('Lev3k')
BOTT:MSS-GRACE21

To first order, either MSS-GEOID surface 'looks' plausible by comparison with the ocean climatology.

The following set of figures will focus on the nature of the **differences** between MSS-GEOID-Lev3k.

MSS-GEOID-LEV3k

The two figures below show MSS-GEOID-LEV3k.

Upper : MSS-EGM96-LEV3k
Lower: MSS-GRACE21-LEV3k

Left set: LEV3k unsmoothed
Right set: LEV3k smoothed.

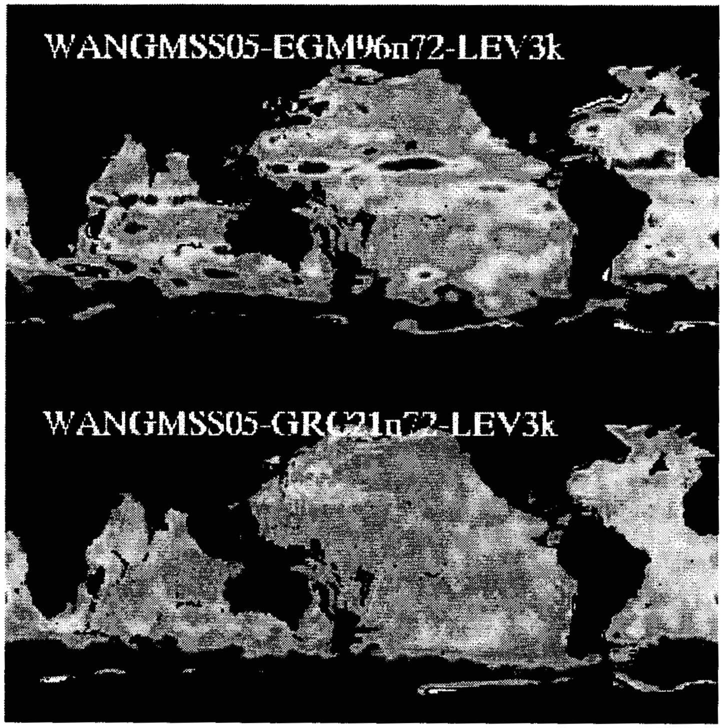
Color bar: in all cases goes from -30 cm to + 30 cm.

Focus on the left panels: the upper panel (EGM96) is 'busier', and shows the Gulf Stream, Kuroshio, N. Atlantic gyre, and especially equatorial patterns. It also shows the ACC.

The lower panel (GRACE21) is 'cleaner', with only the ACC as a major oceanographic feature.

The right panels (smoothed) show the same behaviour.

MSS-GEOID-LEV3k



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-0.3 0.3
MTS

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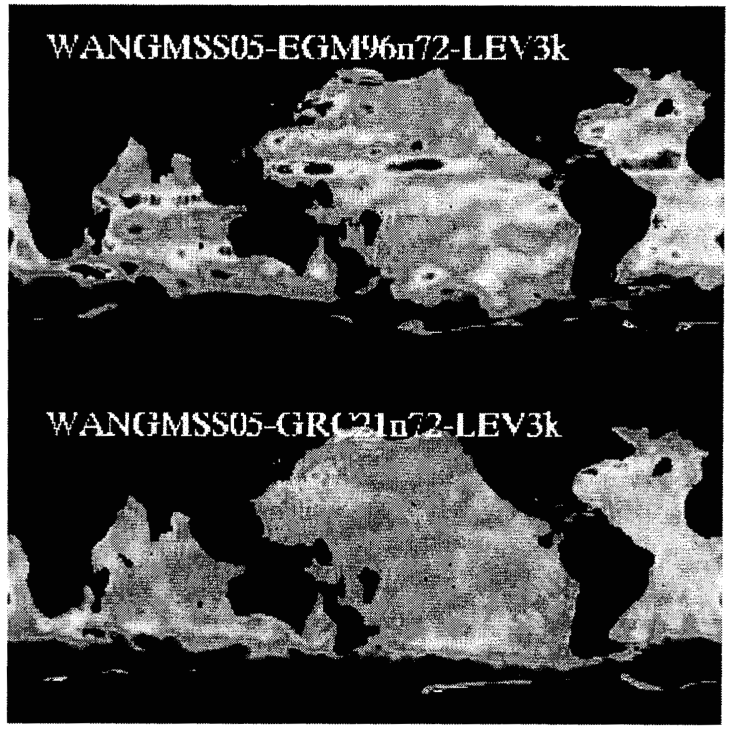

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CONCLUSIONS (1)

- ONLY A PRELIMINARY GRAVITY MODEL DERIVED FROM GRACE WAS ASSESSED HERE: **GRACE21**. IT WAS BASED ON LESS THAN 1 MONTH'S TRACKING DATA. **A NEWER MODEL**, BASED ON OVER TWO MONTHS OF GRACE TRACKING DATA (INTERNALLY CALLED GRACE29) ALREADY EXISTS. THE WORK HERE PLACES UPPER BOUNDS ON THE ACCURACY OF GRACE 21, SURELY LESS ACCURATE THAN GRACE29.

- THE DIFFERENCES EGM96-GRACE21 OVER THE OCEANS ARE DOMINATED BY WELL KNOWN CURRENTS: THE GULF STREAM, KUROSHIO, EQUSATORIAL CURRENTS AND ANTARCTIC CIRCUMPOLAR. THIS WAS TRACED BACK TO THE CONSTRUCTION OF EGM96, WHICH USED A MEAN SEA SURFACE OVER THE OCEANS TO STABILIZE THE SOLUTION.

CONCLUSIONS (2)

- OVER THE DEEP OCEANS, AND EXCLUDING THE ANTARCTIC CIRCUMPOLAR REGION, THE UPPER BOUND ON THE GEOID ERROR IN **EGM96** IS 6.8CM RMS. THIS IS MUCH LOWER THAN THE OFTEN-MENTIONED VALUE OF 10CM, WHICH IS A GLOBAL AVERAGE, DOMINATED BY LAND ERRORS.
- OVER THE DEEP OCEANS, AND EXCLUDING THE ANTARCTIC CIRCUMPOLAR REGION, THE UPPER BOUND ON THE GEOID ERROR IN **GRACE21** IS 4.1CM RMS. THIS IS A REDUCTION IN VARIANCE OF $\sim(6.8^2-4.1^2) = (5.4\text{CM})^2$ OVER EGM.
- THESE 4.1 CM PLACE AN UPPER BOUND ON THE ERROR OF GRACE21, SINCE ERRORS IN THE MSS AND THE LEV3K CALCULATION ARE INCLUDED.
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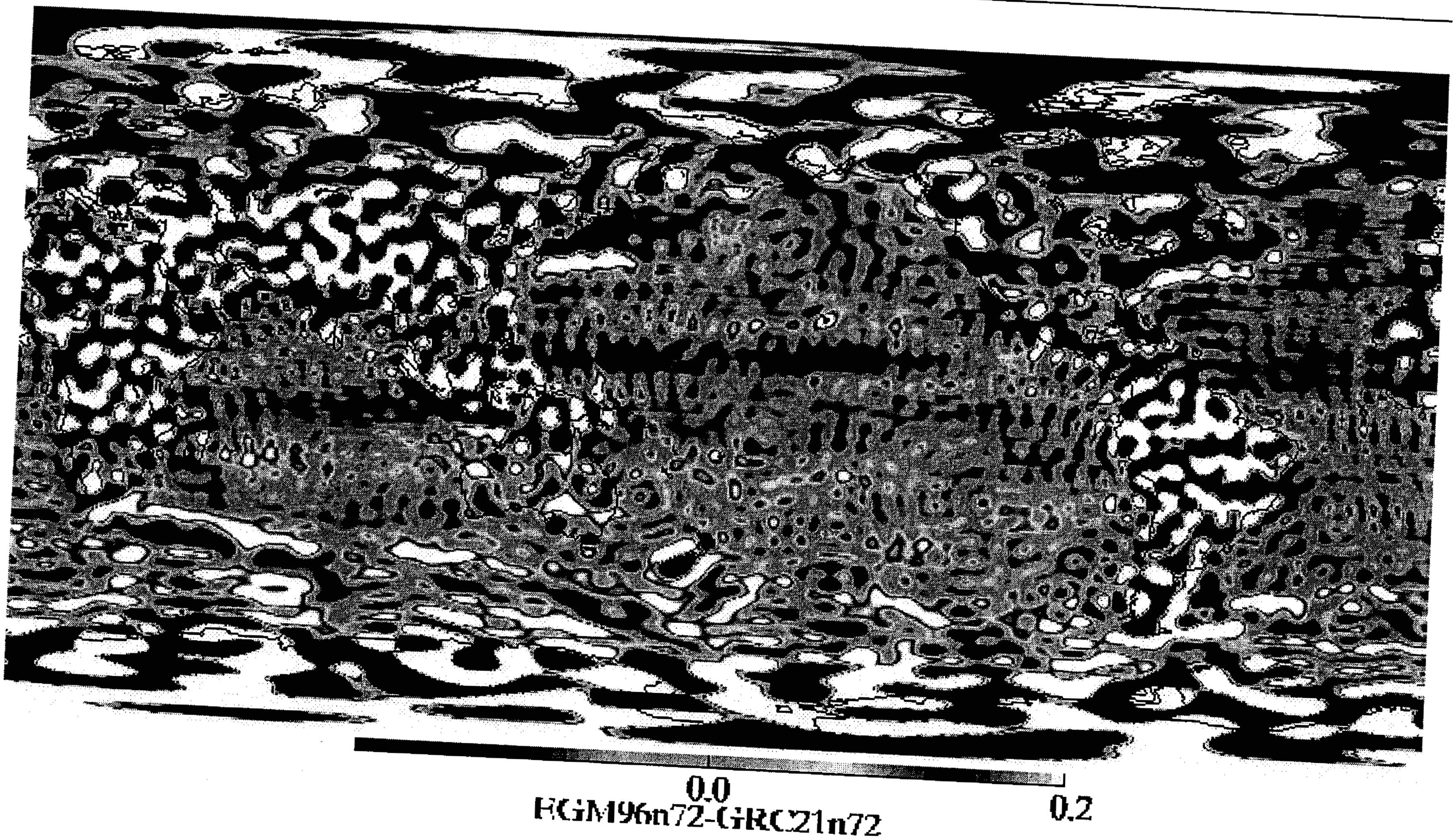

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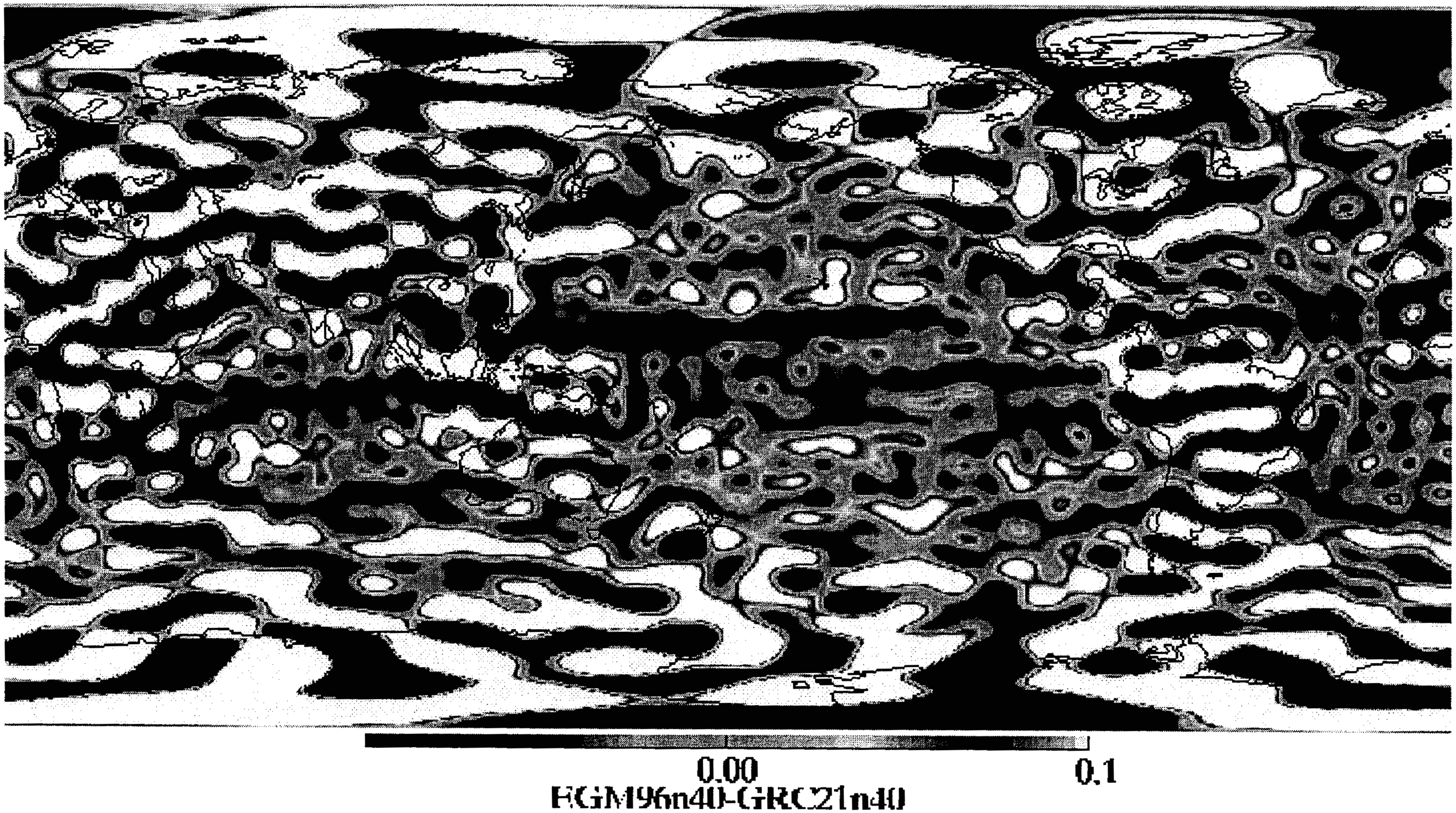

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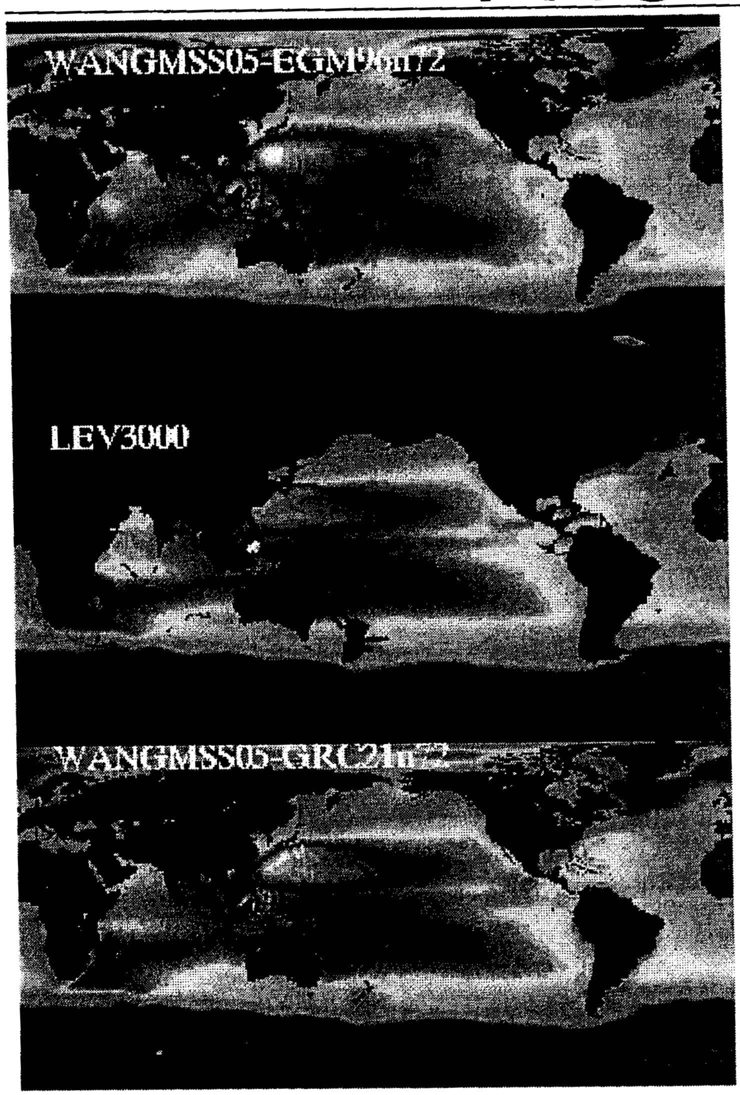

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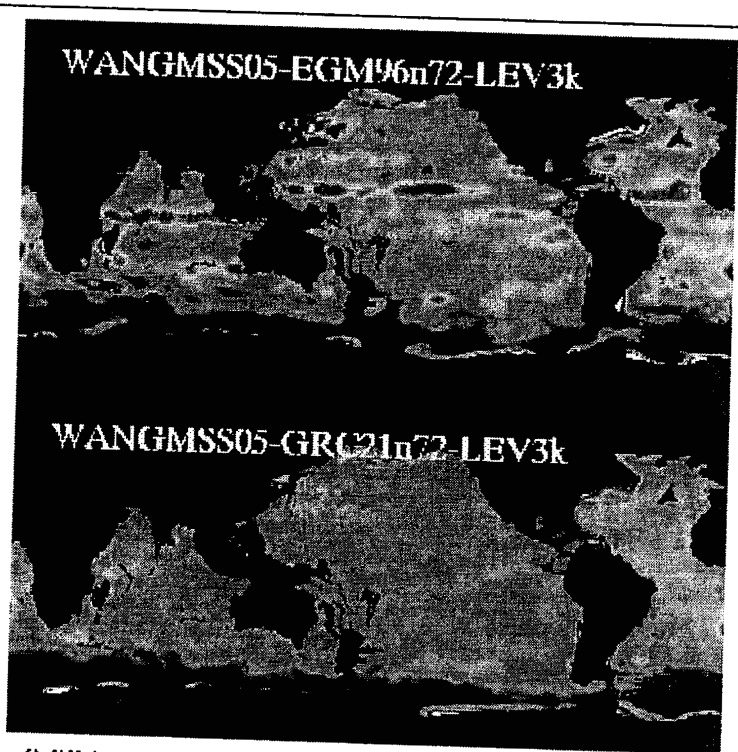

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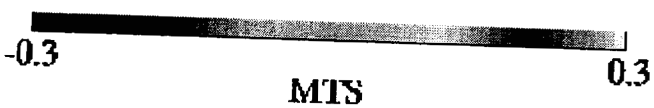

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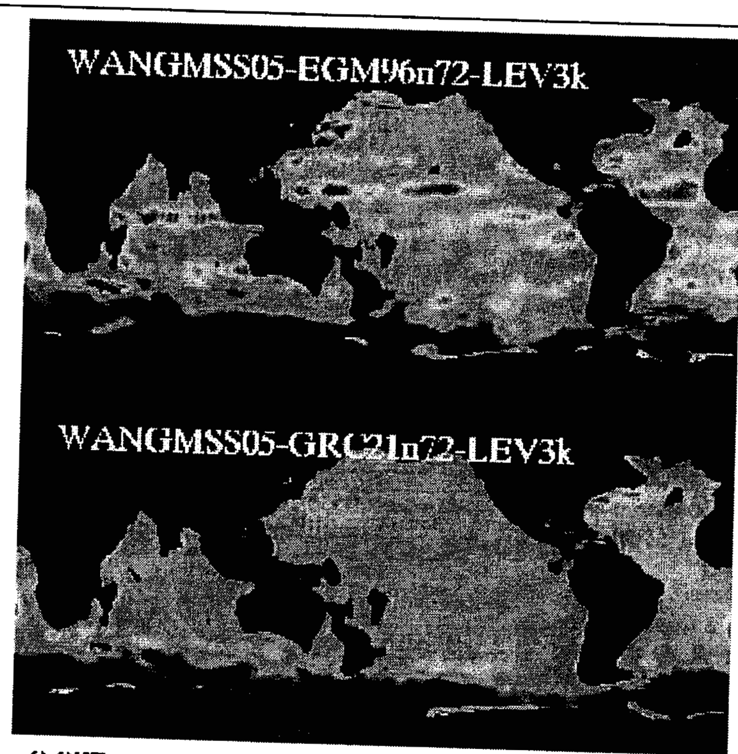

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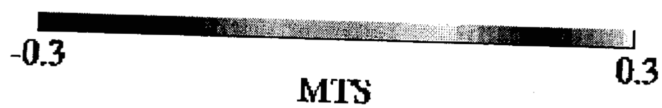

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