Evaluation of Model Operational Analyses during DYNAMO

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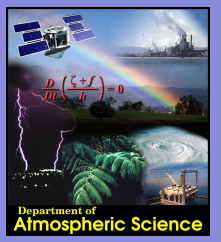
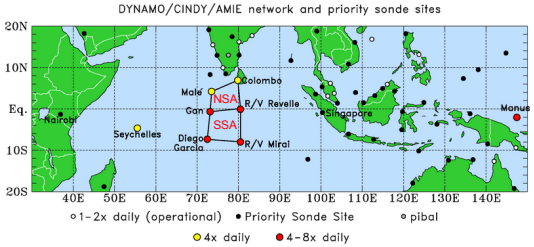


Introduction: A primary component of the observing system in the DYNAMO/CINDY2011/AMIE field campaign was an enhanced sounding network comprised of two sounding quadrilateral arrays, one north and one south of the equator over the Central Indian Ocean (IO). During the experiment a major effort was undertaken to ensure the real-time transmission of these data onto to the GTS for dissemination to the operational NWP centers (ECMWF, NCEP, etc). Preliminary estimates indicate that ~95% of the soundings from this network were successfully transmitted and used in their data assimilation systems.



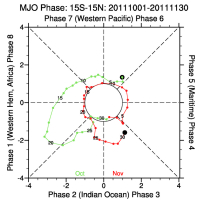
Map showing Northern Sounding Array (NSA) and Southern Sounding Array (SSA) for experiment.

Objective: Because of the wide use of operational and reanalysis products (e.g., in process studies, initializing numerical simulations, construction of large-scale forcing dataset for CRMs, etc.), their validity is examined by comparing a variety of basic and diagnosed fields from these products to similar analyses based solely on sounding data. Particular attention is given to the vertical structures of diabatic heating from the Operational Analyses (OA), which are strongly influenced by cumulus parameterizations, a source of model infidelity.

Analyses Used in this Study:

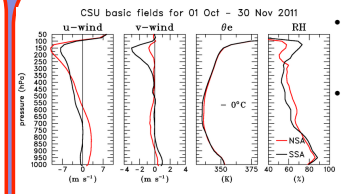
- **CSU** gridded analyses (1°, 25-hPa, 6-hr resolution) computed with multiquadric interpolation and based on a combination of high vertical resolution and GTS-resolution upper-air soundings.
- **ECMWF** OA (0.25°, 18 vertical levels from sfc to 50 hPa, 6-hr resolution)
- NCEP **GFS** OA (1°, 30 vertical levels from sfc to 50 hPa, 6-hr resolution)

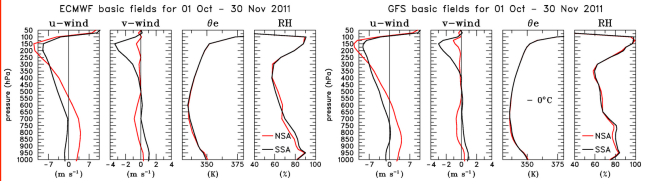
These analyses are examined for the Special Observing Period (SOP from 1 October - 30 November 2011) when the enhanced network was most complete. During this period, two MJOs were captured by the sonde network.



- **Wheeler-Hendon MJO index indicating two signficant MJO events over the Indian Ocean during the SOP.**

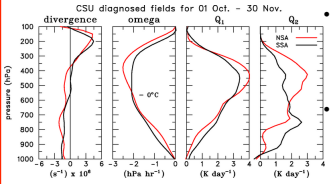
Comparison of SOP-Mean Basic Fields

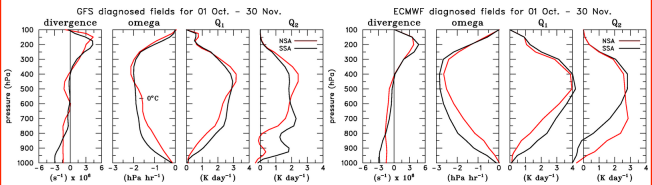




- Small differences exist among three analyses in mean wind and temperature profiles.
- Large differences in mean RH profiles at upper-levels with ECMWF and GFS values near saturation; GFS is drier at surface but its low-level moist layer extends deeper.
- Drier conditions at upper-levels in CSU analysis are due, in part, to using uncorrected RHs at some sites. Work is underway to correct these data.

Comparsion of SOP-Mean Derived Fields





- Larger vertical separation between Q_1 and Q_2 peaks over SSA suggest that convective eddies are stronger in this region than in NSA.
- Absence of low-level drying in NSA Q_2 mean is due to a period (1-14 Oct.) of moistening in this layer from shallow non-precipitating clouds.
- Shallower low-level convergence in GFS compared to ECMWF results in weaker mean upward motion and heating profiles in GFS.
- Weak mean drying below 800 hPa over NSA is present in GFS Q_2 profile, consistent with CSU, but is absent in ECMWF.
- Strong low-level drying over SSA in CSU and GFS Q_2 profiles is not present in ECMWF where moistening is observed below 800 hPa.

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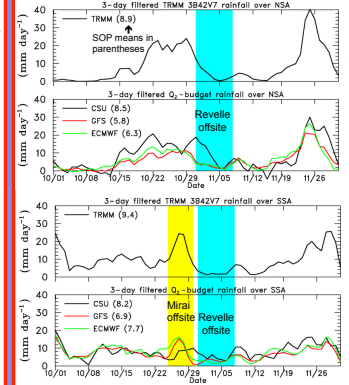
Comparison of Rainfall Time Series

- TRMM 3B42 V7 product (0.25°, 3-hr), used as an independent estimate for rainfall, compares well to surface gauge estimates over IO (not shown).
- Budget rainfall computed as $P_o = \langle Q_2 \rangle / L + E$, where $\langle\ \rangle$ is the vertical integral and E (surface evaporation rate) is from WHOI OAFlux product.



Rainfall over NSA shows strong modulation associated with MJOs.

- In both regions, budgets underestimate rainfall with CSU closest to TRMM mean but NWP OA products have higher temporal correlation with TRMM rainfall (see Table below).
- When Revelle is offsite, CSU estimate is higher than TRMM.

Rainfall over SSA impacted by fluctuations in ITCZ and MJO events.

- When Mirai is offsite, CSU estimate is much lower than TRMM.
- Over both regions GFS rainfall is lowest, consistent with its weaker vertical motion.

SOP-Mean Rainfall and Correlation (r) to TRMM 3B42 V7 Rainfall

Sounding Array	TRMM	CSU		ECMWF		GFS	
	Mean (mm/day)	Mean (mm/day)	r	Mean (mm/day)	r	Mean (mm/day)	r
NSA	8.9	8.5	0.88	6.3	0.92	5.8	0.94
SSA	9.4	8.2	0.68	7.7	0.88	6.9	0.86

Budget uncertainly analysis was conducted by using the full hi-res ECMWF dataset to determine the effects on budgets of discrete sonde sampling associated with various network configurations including changes to arrays due to the port calls of the R/Vs Revelle and Mirai. Budgets were computed using: (1) the full hi-res dataset and (2) by sampling this dataset at discrete sounding locations then objectively analyzing these stimulated soundings onto a 1° grid. Comparisons between budget analyses (1) and (2) were then made. Uncertainly analysis indicates:

- quadrilateral (QD) sampling of the NSA *overestimates* mean rainfall by ~1 mm/day. This overestimate doubles when the Revelle was offsite.
- QD sampling of the SSA *underestimates* mean rainfall in this region by 1.3 mm/day. This underestimate increases five-fold when the Mirai was offsite.
- Budget errors nearly double during the ship port calls.

Summary

- Approximately 95% of the enhanced upper-air sondes were used in producing the ECMWF and NCEP operational analyses (OA).
- In general, these OA products did a reasonable job at capturing the mean and temporal characteristics of convection during the DYNAMO SOP.
- Budget sampling errors nearly double when sonde networks collapsed from quadrilateral to triangular configurations due to ship port calls.