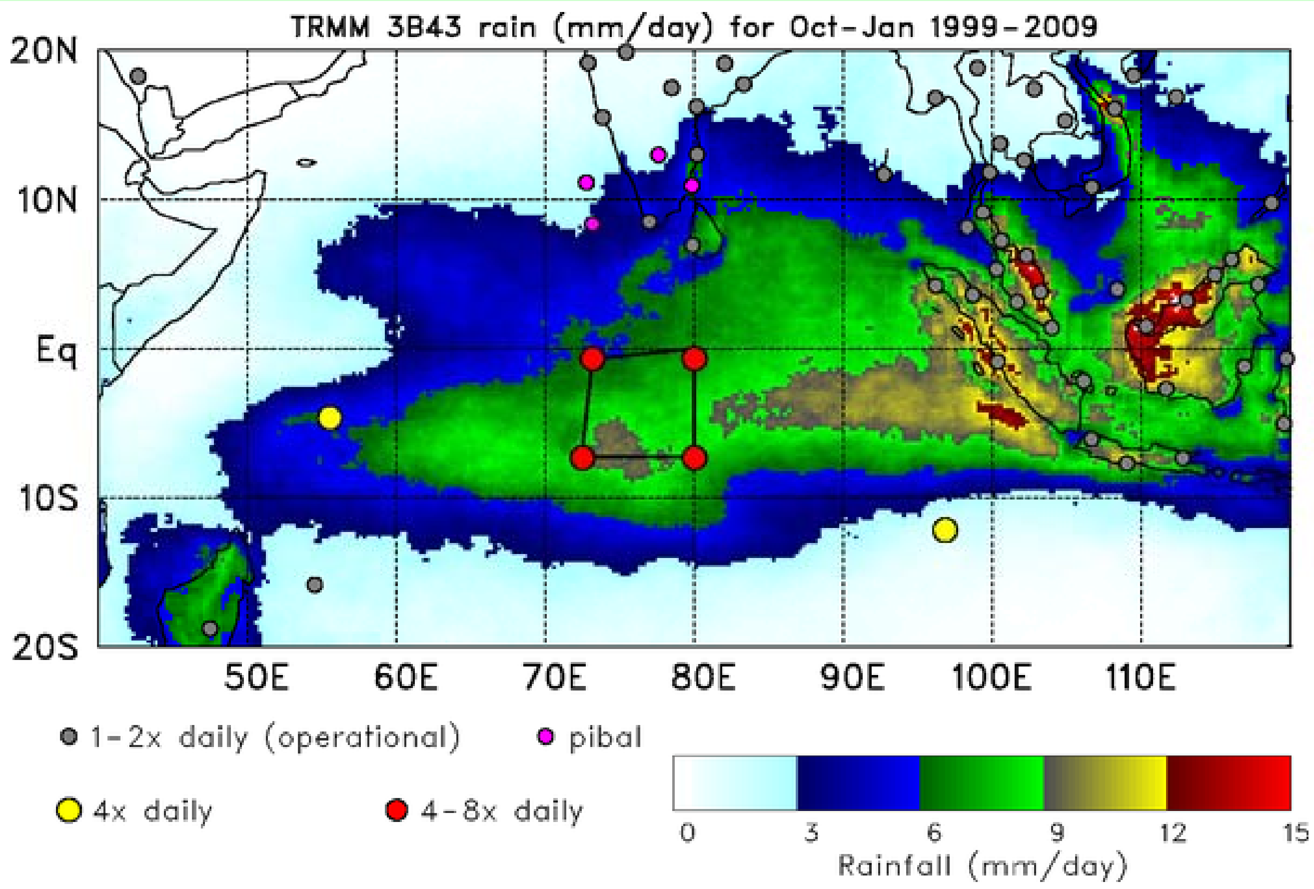
Error analyses for large-scale budgets in DYNAMO/CINDY

or

The search for an optimal sounding array configuration

P. Ciesielski, D. Johnson and M. Katsumata

TRMM rain map for October-January with proposed sounding network



What is the best sounding configuration *for estimating large-scale budgets* when only one ship is available?

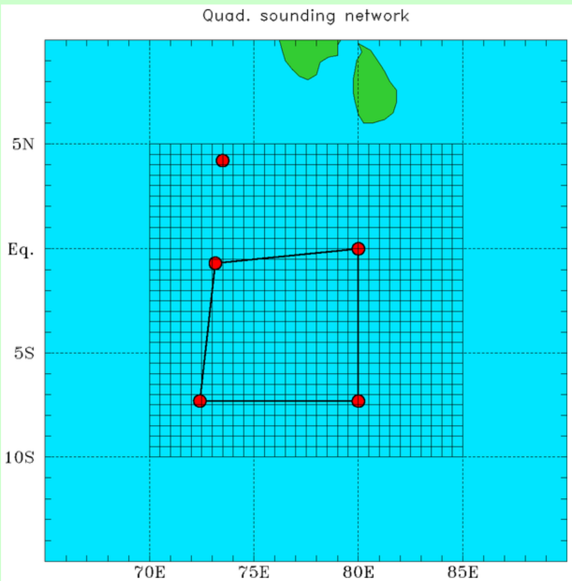
Procedure: use high resolution (hires) ECMWF reanalysis from Year of Tropical Convection (YOTC) dataset to compute budgets for different array configurations.

•Create simulated soundings by sampling YOTC analysis at discrete sounding locations.

•Analyze simulated soundings (just as we would actual soundings) by interpolating the data onto a uniform grid, then compute budgets on this grid.

•Average budgets within sounding array with both hires YOTC analysis and simulated sounding analysis.

•Then compare two analyses.



Apparent heat source/moisture sink:

(Yanai et al. 1973)

$$Q_1 \equiv c_p[(\partial\bar{T}/\partial t + \bar{\mathbf{v}}\cdot\nabla\bar{T} + (p/p_0)^{\kappa}\bar{\omega}\partial\bar{\theta}/\partial p)]$$

$$Q_2 \equiv -L(\partial\bar{q}/\partial t + \bar{\mathbf{v}}\cdot\nabla\bar{q} + \bar{\omega}\partial\bar{q}/\partial p)$$

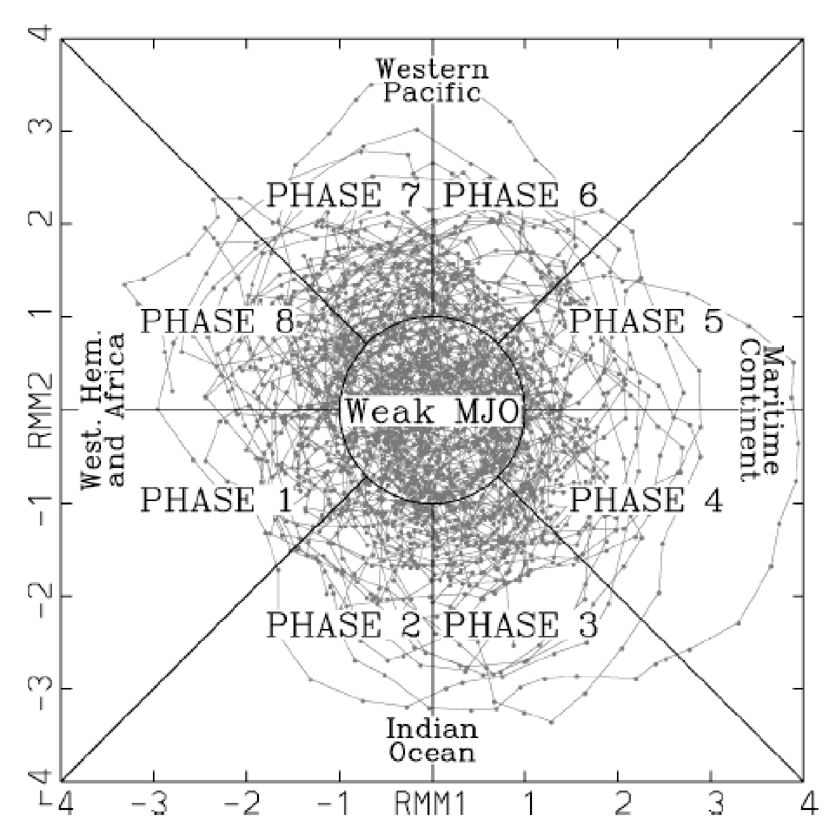
YOTC ANALYSES

- used ECMWF 4-D variational data assimilation system
- Input assimilated datasets include 3 hr TRMM 3B42 rainfall
- resolution is 0.22 near equator, 91 vertical levels, every 6 hours
- reanalyses are available from May 2008 to April 2010
- large suite of reanalysis fields.
- reanalyses can be obtained from: http://data-portal.ecmwf.int/data/d/yotc_od/

In this study YOTC data over the DYNAMO/CINDY region for Oct-Jan period for 08-09 and 09-10 is used.

An important, yet unproven, assumption is that the YOTC analysis is good representation of the true conditions (e.g., does it contain a realistic spectrum of equatorial waves).

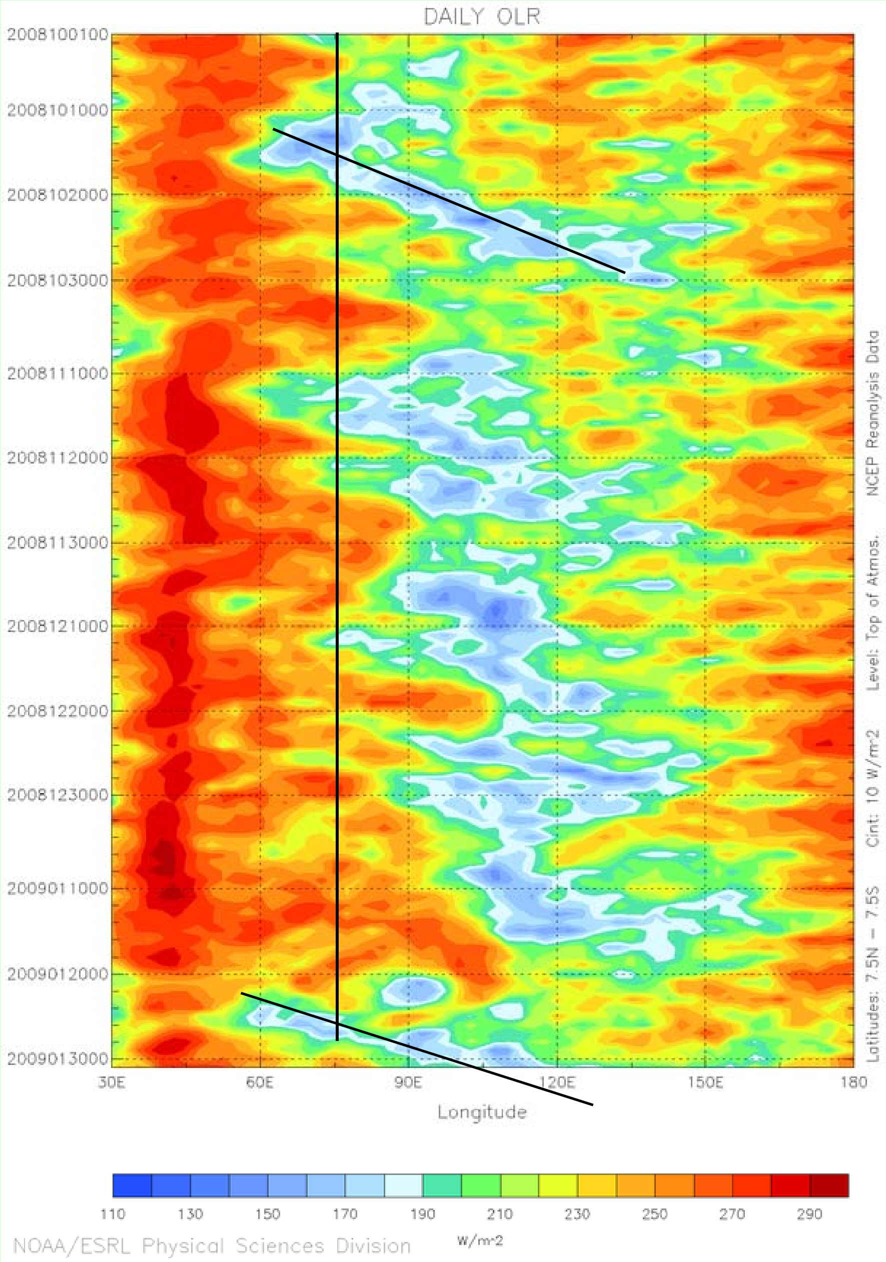
Wheeler-Hendon MJO index

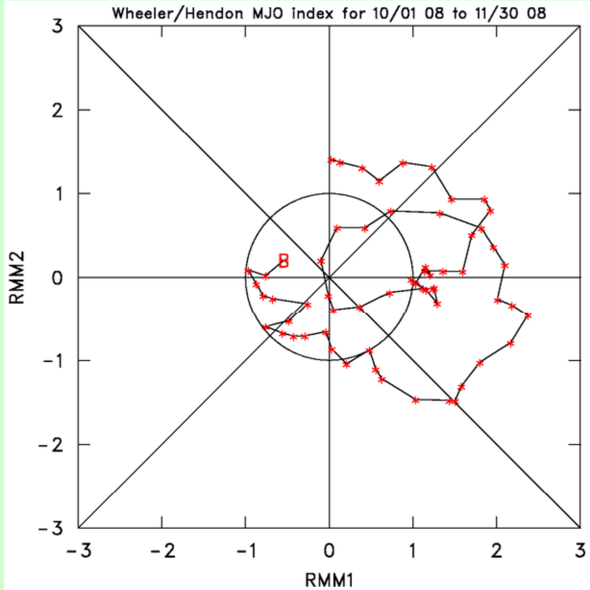


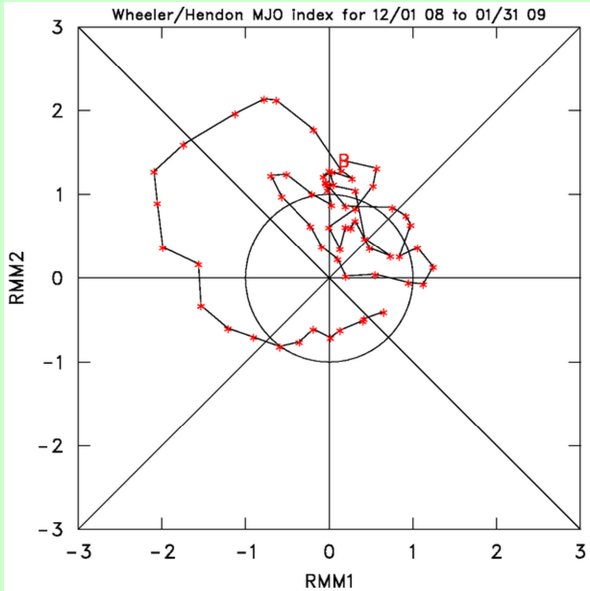
- To examine MJO activity during the YOTC years it's instructive to examine the behavior of the W-H MJO index.
- This index is based on a pair of EOFs of combined fields of 850 and 200 hPa winds and OLR.
- The EOF pair represents the spatially propagating signal of the MJO.
- The daily state of MJO activity is indicated by a point in the 2D phase space of these EOF pairs.

- Large-amplitude anticlockwise circles indicate strong MJO activity
- Weak MJO activity appears as rather random motions near the origin.
- Point in phase 2 and 3 indicate activity in the Indian Ocean

OLR (7.5N – 7.5S) 10/2008 – 01/2009

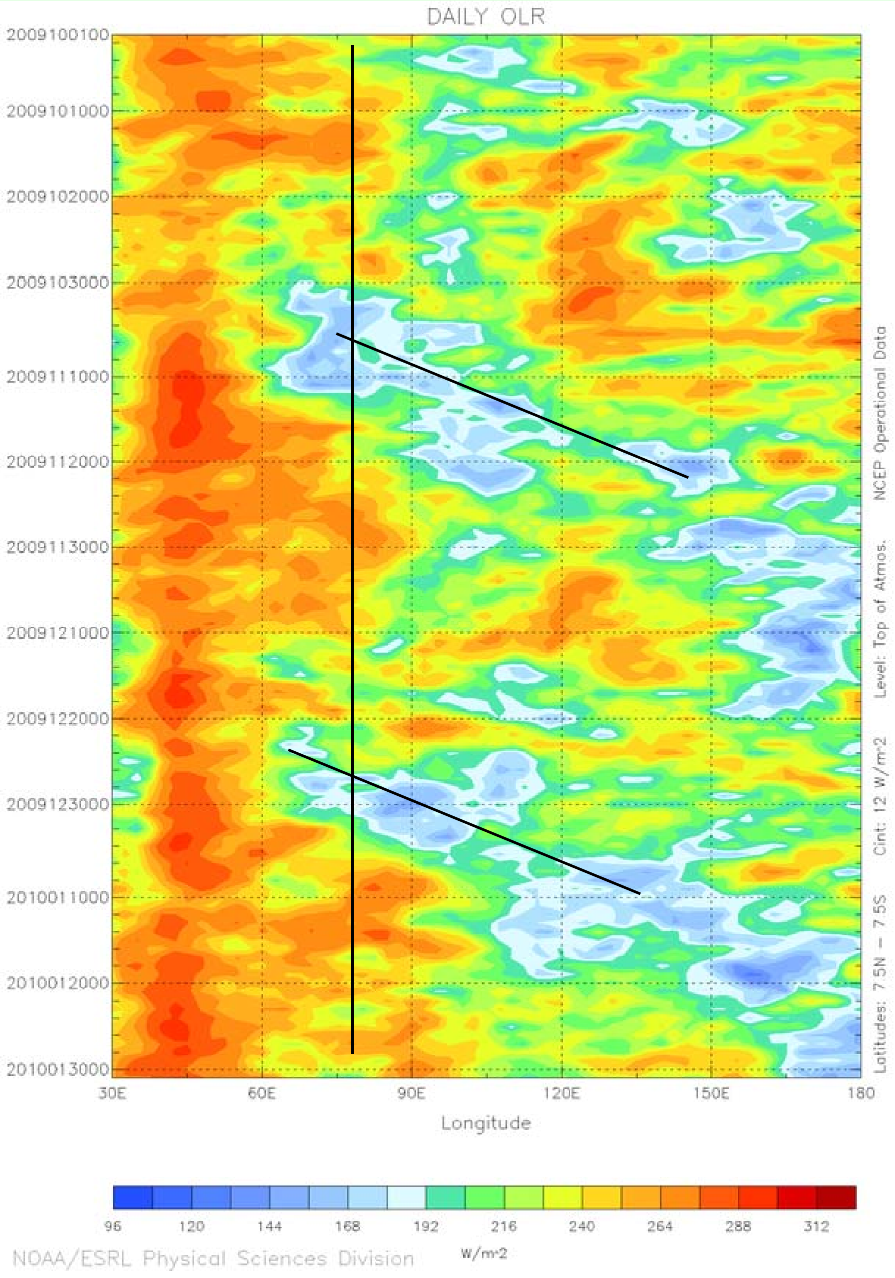


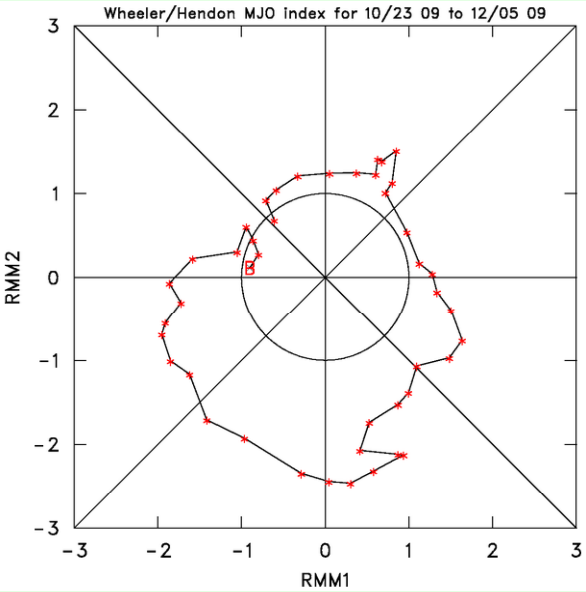


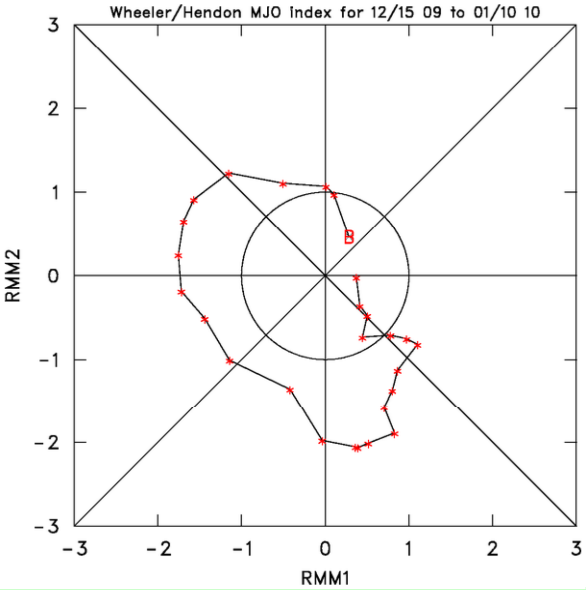


Two weak MJOs occurred over IO in 08-09 season.

OLR (7.5N – 7.5S) 10/2008 – 01/2009

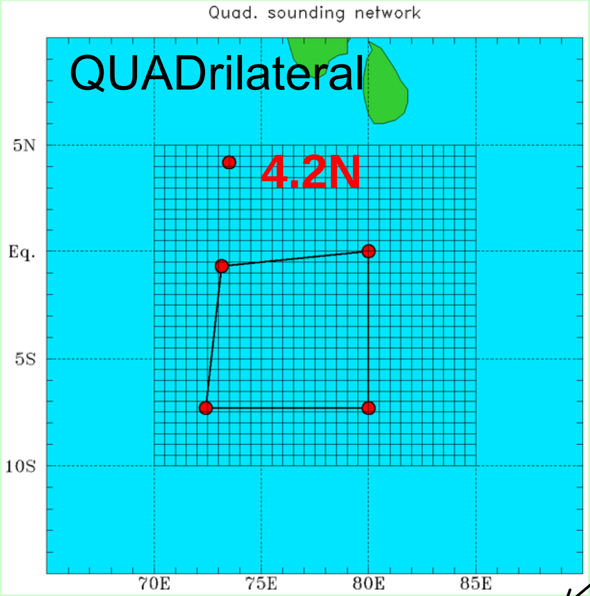




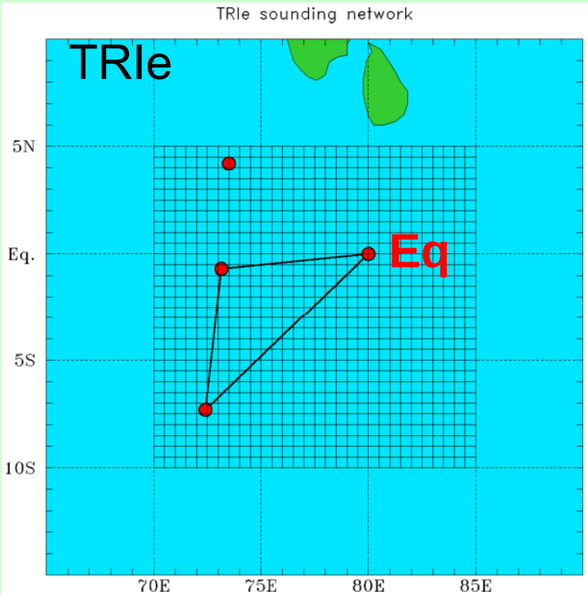


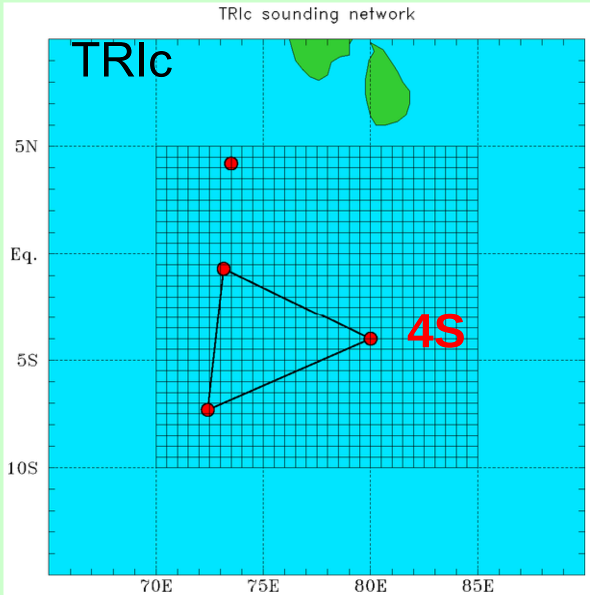
Two strong MJO occurred over IO in 09-10

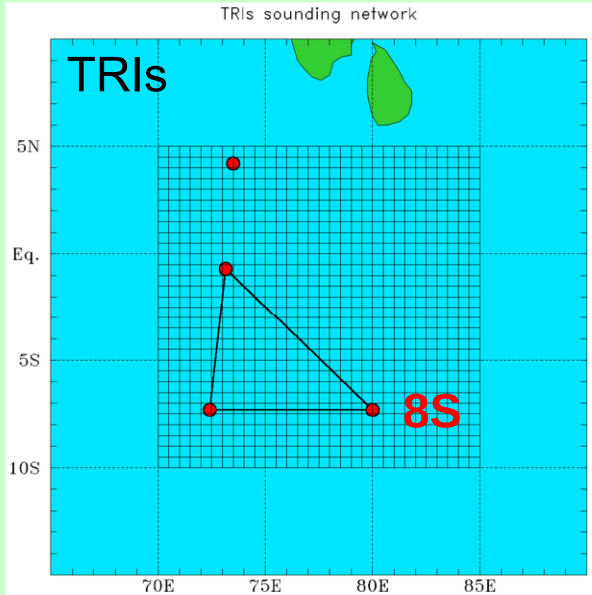
ARRAY CONFIGURATIONS EXAMINED



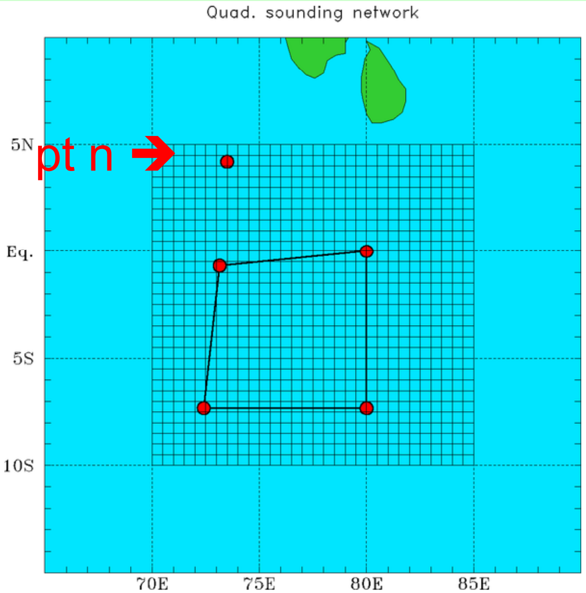
When only one ship is present which TRIangular array provides the smallest budget errors?

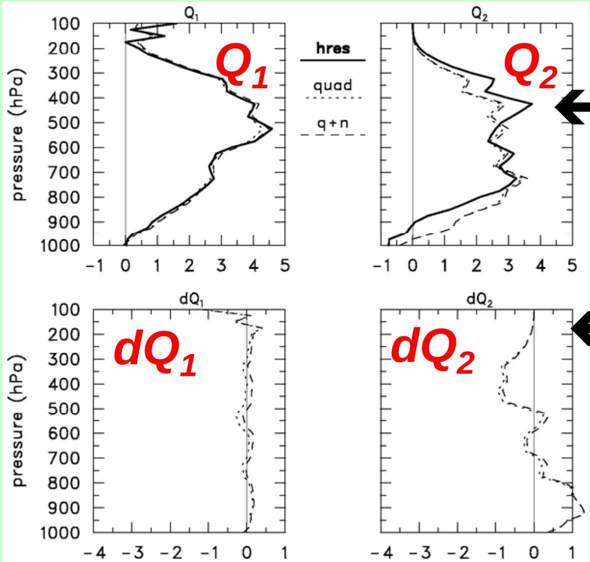






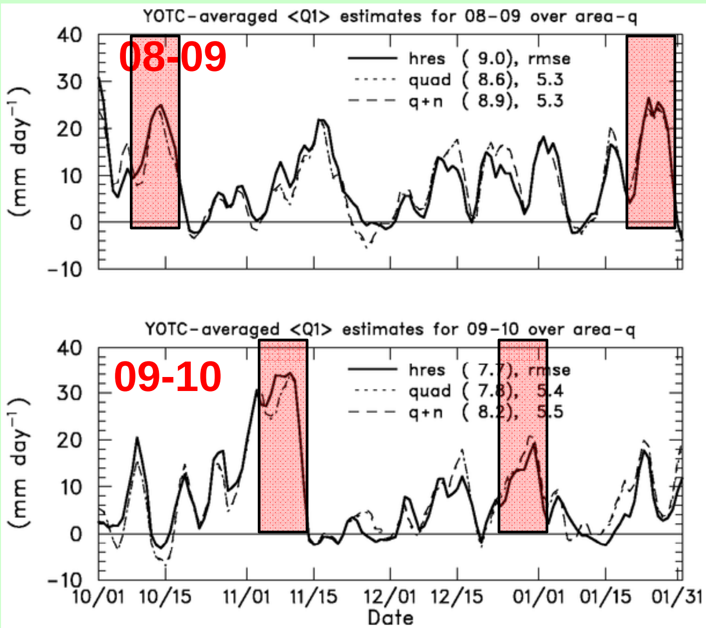
Analysis for QUAD





← Mean vertical profiles averaged over both years

← Difference profiles
$dQ_1 = Q_1$ (hires) – Q_1(sim)

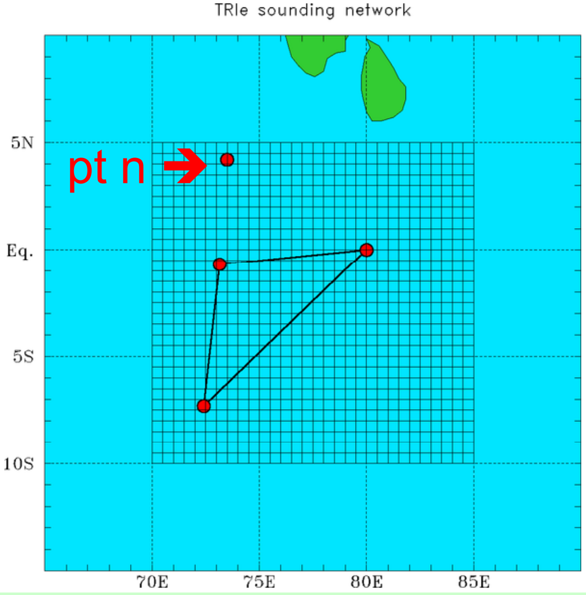


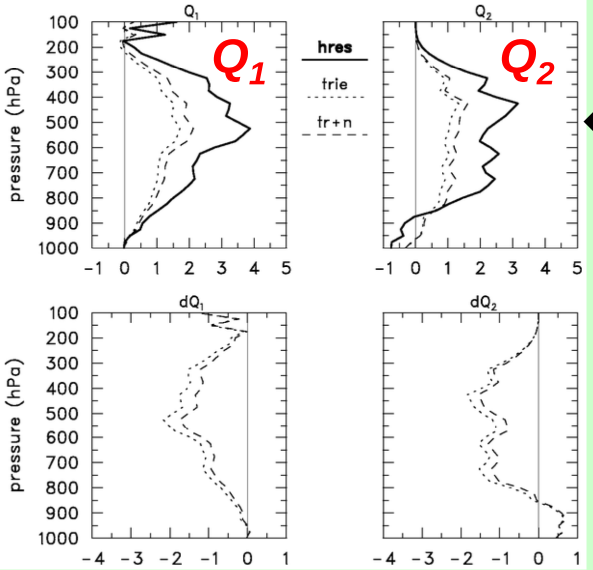
← Time series of vertically integrated <Q1>, where $\langle Q_1 \rangle \approx$ LP

( ) – 4 month mean
rmse = | $\langle Q_1 \rangle$ (hires) – $\langle Q_1 \rangle$(sim)|

- Errors in mean budget profiles from stimulated QUAD network are on order of a few percent.
- Errors in Q_2 are somewhat larger than Q_1 due to greater spatial variability in the moisture field.
- Simulated QUAD captures all significant rain events; the addition pt n makes little difference

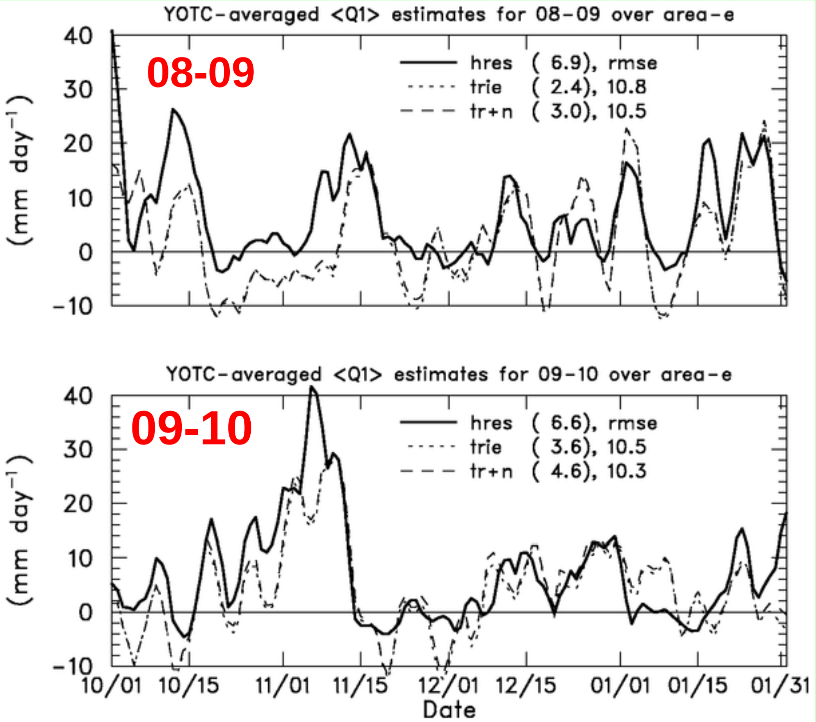
Analysis for TRIe





← Mean vertical profiles averaged over both years

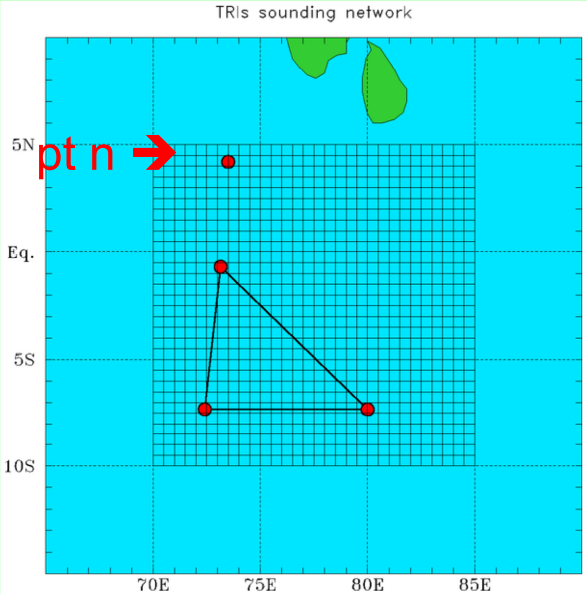
← Difference profiles $dQ_1 = Q_1$ (hires) – Q_1(sim)

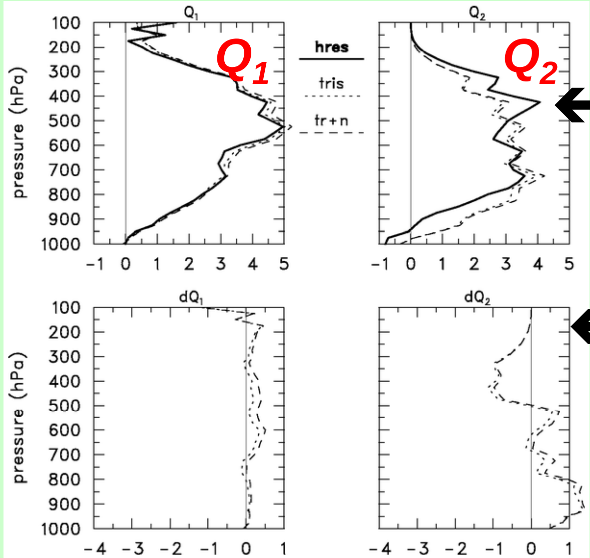


← Time series of vertically integrated <Q1>, where $\langle Q_1 \rangle \approx$ LP

- significant errors (on order of 50%) in mean budget profilers
- slight improvement by adding pt n (pt n is at Hulhule 4.2° N, 73.5° E)

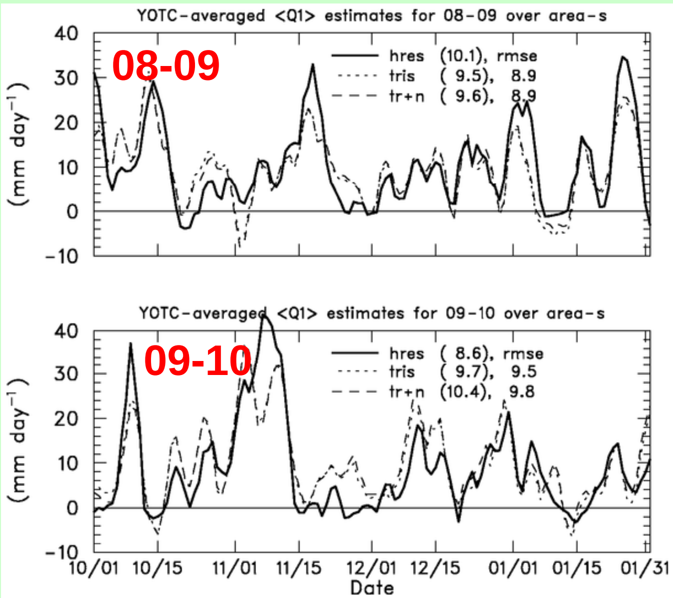
Analysis for TRIs





🡐 Mean vertical profiles averaged over both years

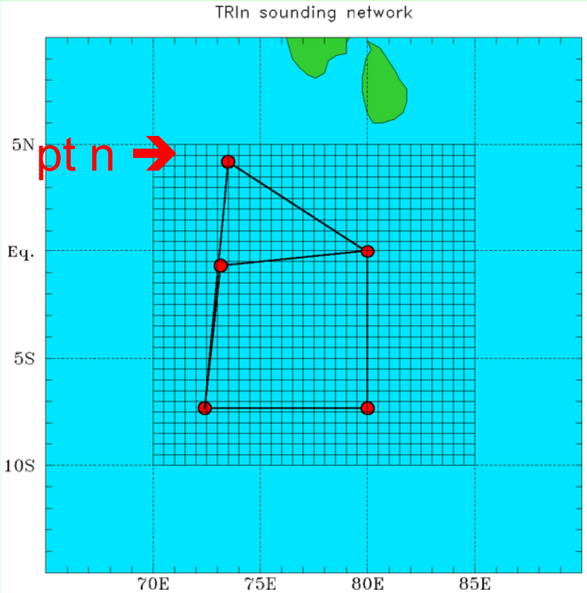
🡐 Difference profiles
$dQ_1 = Q_1$ (hires) – Q_1(sim)

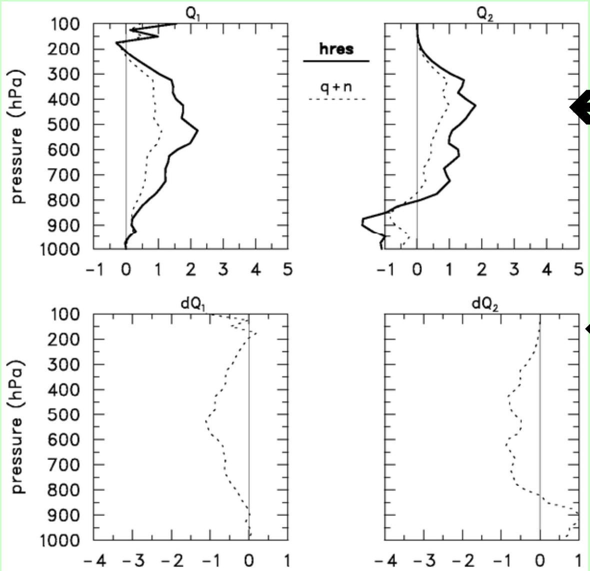


🡐 Time series of vertically integrated <Q1>, where <Q_1> ≈ LP

- Magnitude of Q_1 and Q_2 is largest for this region due to its proximity to core of ITCZ convection.
- Simulated TRIs network does a good job of representing mean budget profiles (with errors comparable to QUAD array)
- Significant rainfall events are well captured.

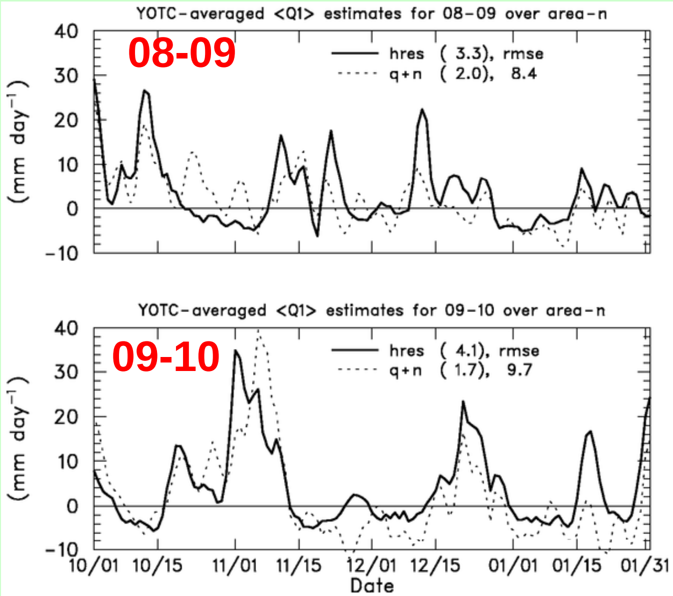
Analysis for TRIn





← Mean vertical profiles averaged over both years

← Difference profiles $dQ_1 = Q_1$ (hires) – Q_1(sim)



← Time series of vertically integrated <Q1>, where $\langle Q_1 \rangle \approx$ LP

- heating peaks over TRIn have about half the amplitude of southern arrays
- largest heating peaks occur in Oct. and Nov. period when ITCZ convection is still strong in NH.

Summary Tables

area	True $\langle Q_1 \rangle$	Sim. Area $\langle Q_1 \rangle$	Sim. area + pt n $\langle Q_1 \rangle$
QUAD	8.7	8.5 (2%)	8.6 (1%)
TRIe	6.7	3.0 (55%)	3.8 (43%)
TRIc	8.5	3.1 (63%)	3.8 (55%)
TRIs	9.4	9.6 (3%)	10. (6%)
TRIn	3.7	-	1.8 (51%)

Mean heating magnitude

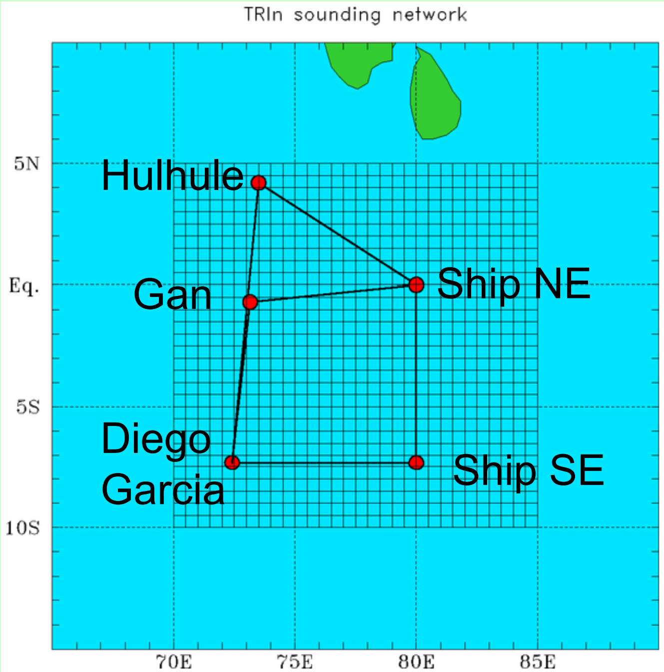
- QUAD array does an excellent job of capturing magnitude of mean heating.
- TRIs array yields next best results followed by TRIe
- TRIc array shows poorest performance
- Heating in TRIn is about half the magnitude of other arrays.
- Pt n reduces errors in all but TRIs networks.

area	Sim. Area	Sim. Area + pt n
QUAD	5.4	5.4
TRIe	10.7	10.4
TRIc	10.7	10.4
TRIs	9.2	9.4
TRIn	-	9.0

$\langle Q_1 \rangle$ RMS errors

- QUAD array does a good job of capturing individual rain events; RMS errors are nearly double in other networks
- Additional pt n helps reduce errors in TRIe and TRIc networks.

Recommendations

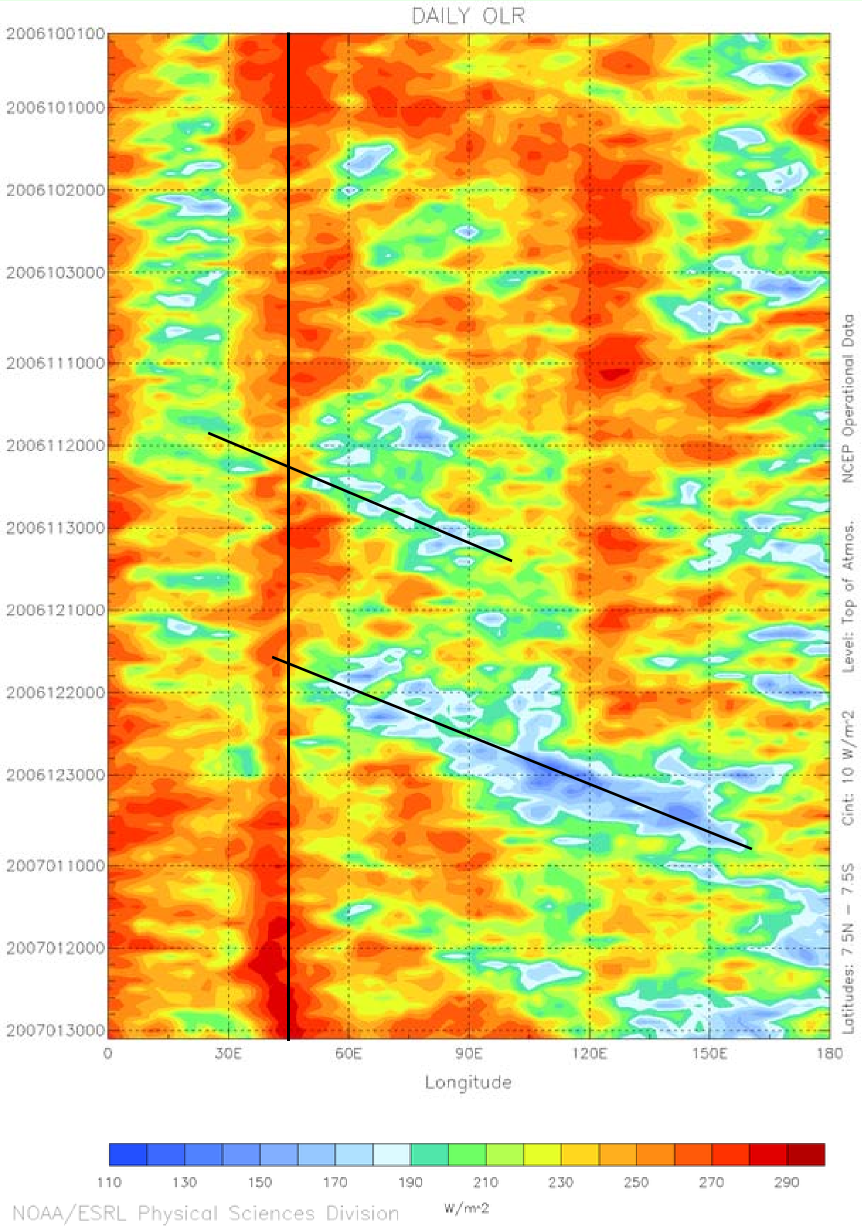


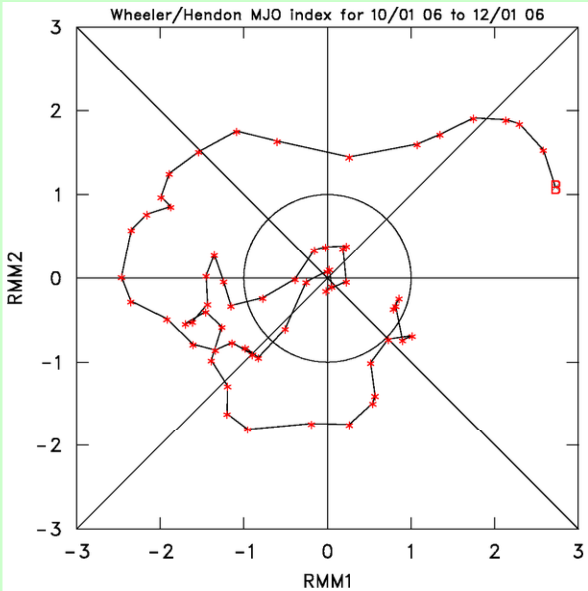
- **QUAD or QUAD+pt n** networks should provide excellent estimates of mean heating profile.
- **QUAD + pt n** would allow us to capture heating north of the equator particularly in the early months of the experiment.
- Errors in mean heating profiles are on order of a few percent with **QUAD** network but increase rapidly to ~50% when ship is at Eq. or 4° S.
- If budget errors were the only consideration, this analysis suggests that **TRIs** configuration would provide the best budget estimates when only 1 ship is present*.
- Additional sounding at pt n would help analysis particularly in **TRIe** configuration (i.e., ship on the equator).

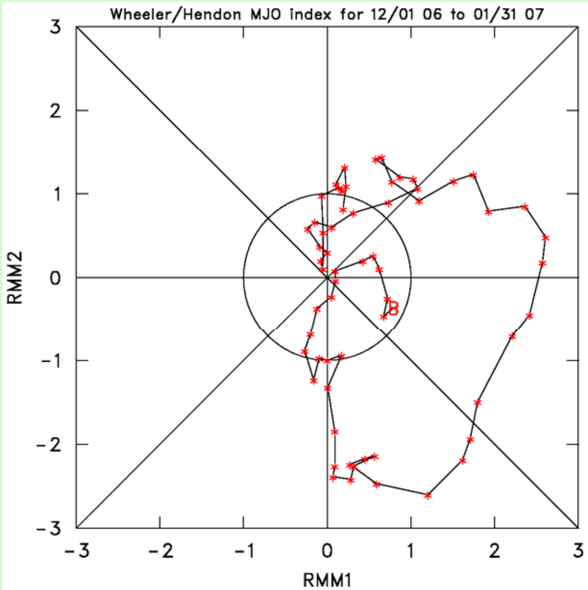
*These recommendations are based on the *unproved* assumption that the YOTC analyses is a good representation of reality in the DYNAMO region.

Supplementary material

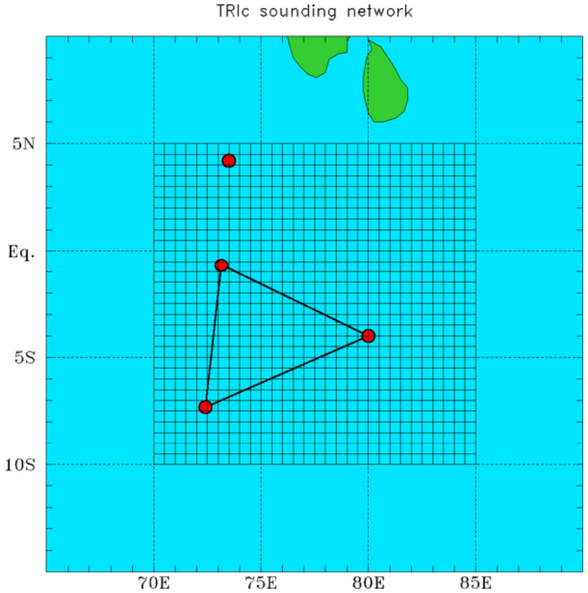
OLR (7.5N – 7.5S) 10/2006 – 01/2007

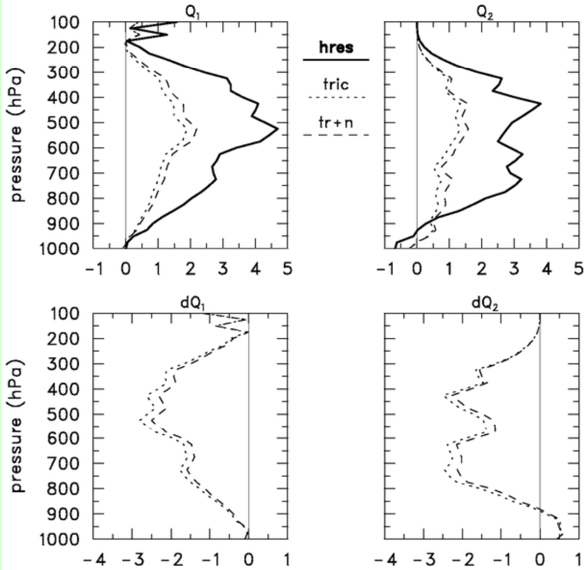


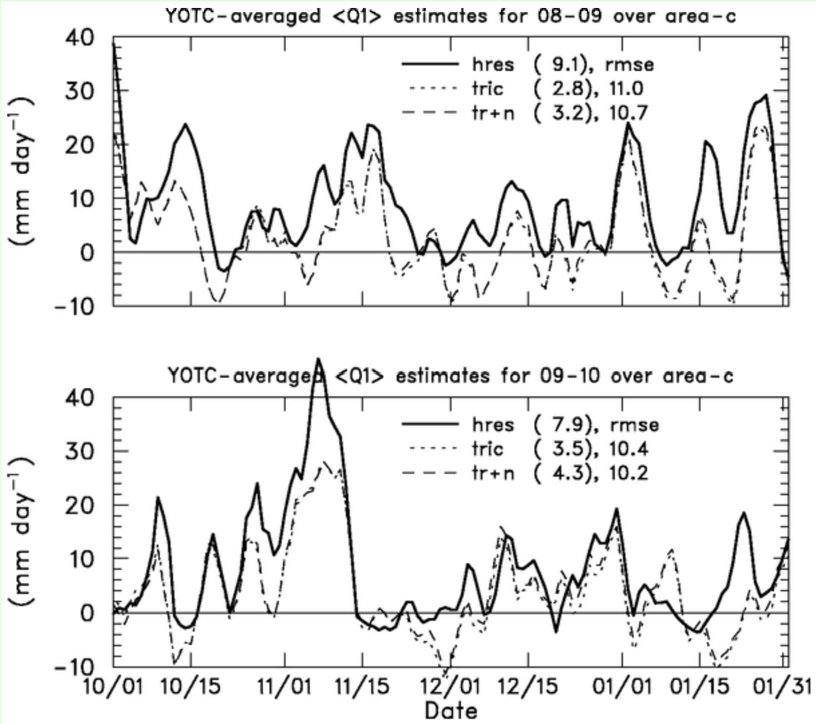




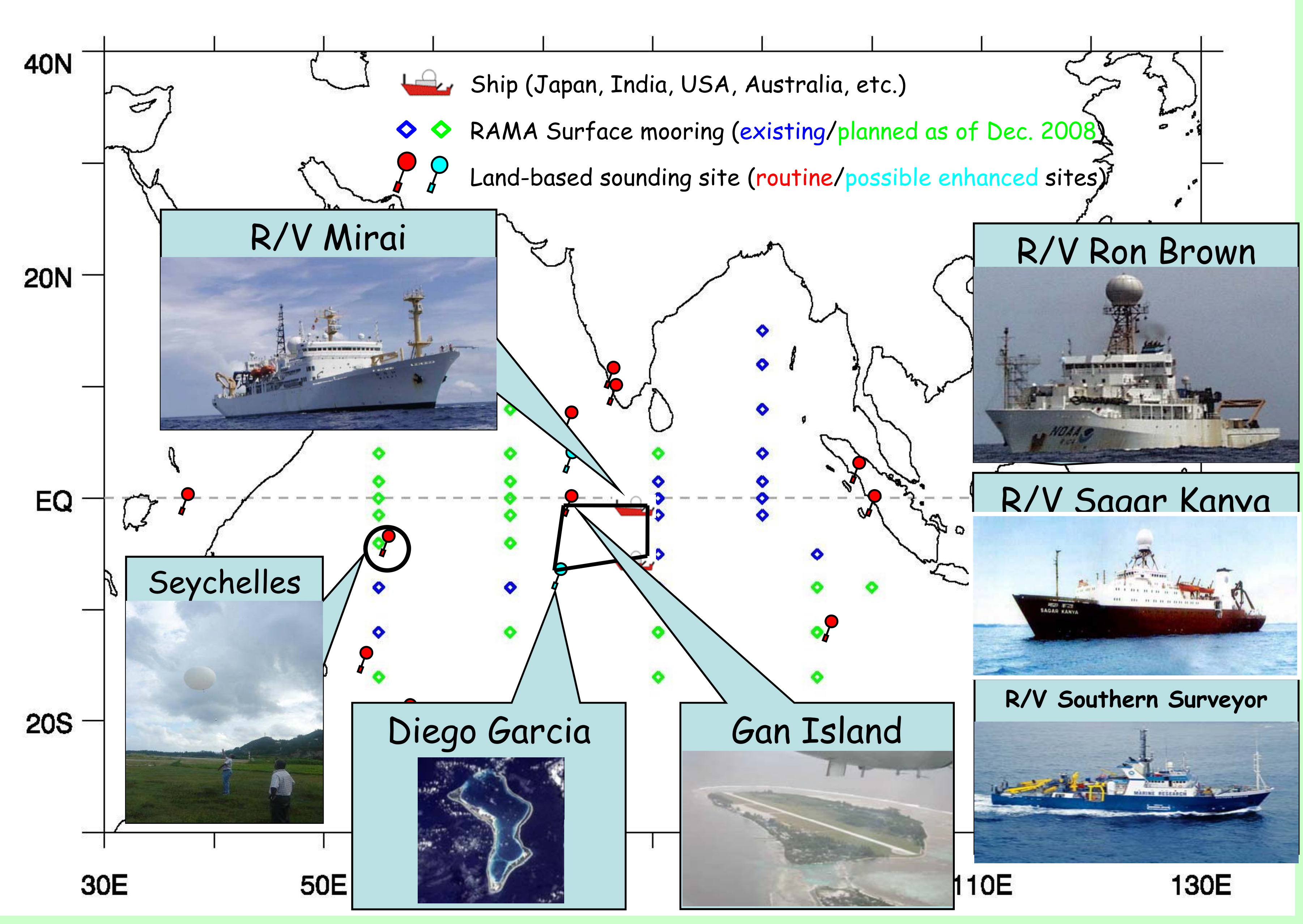
Analysis for TRIc



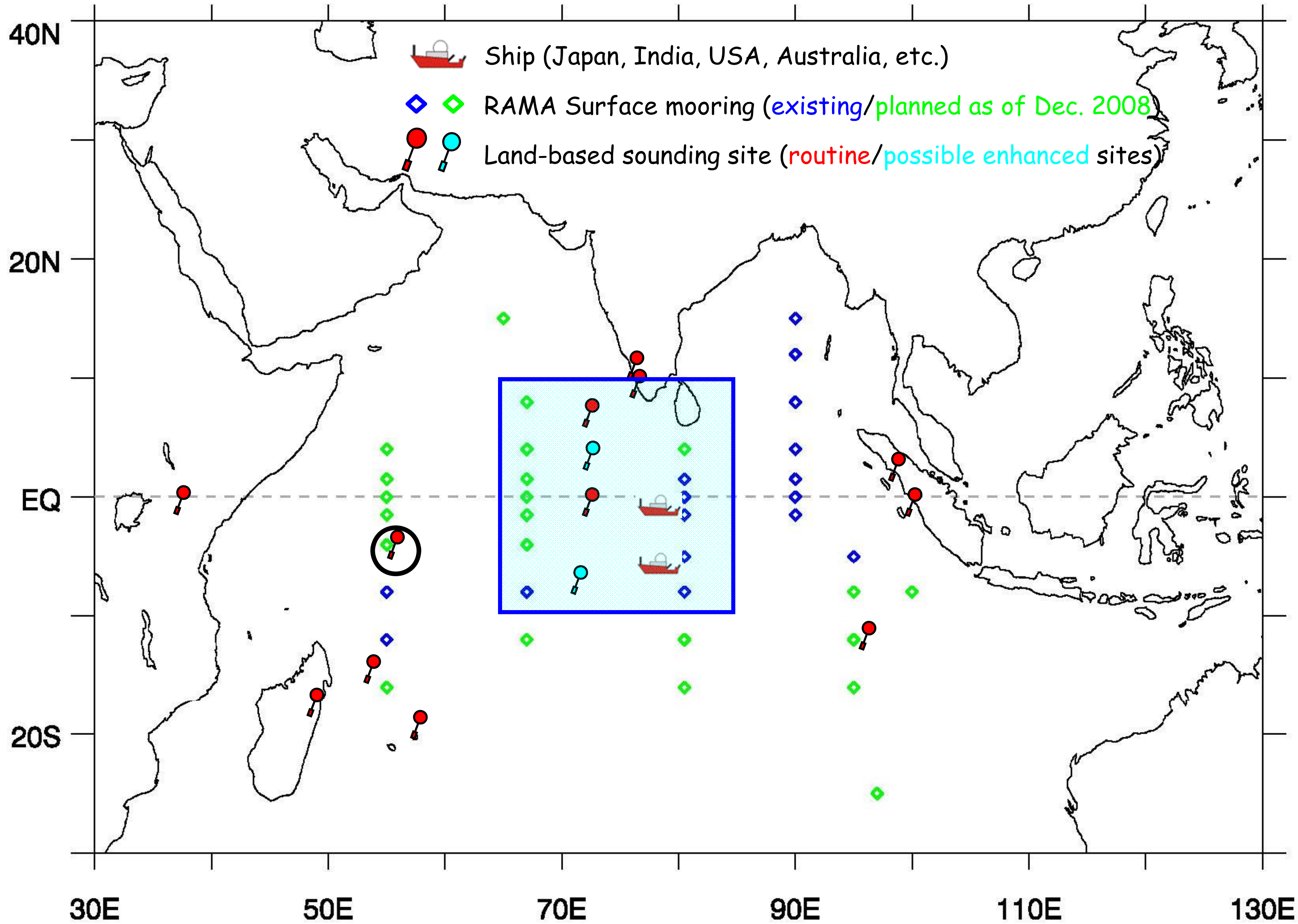




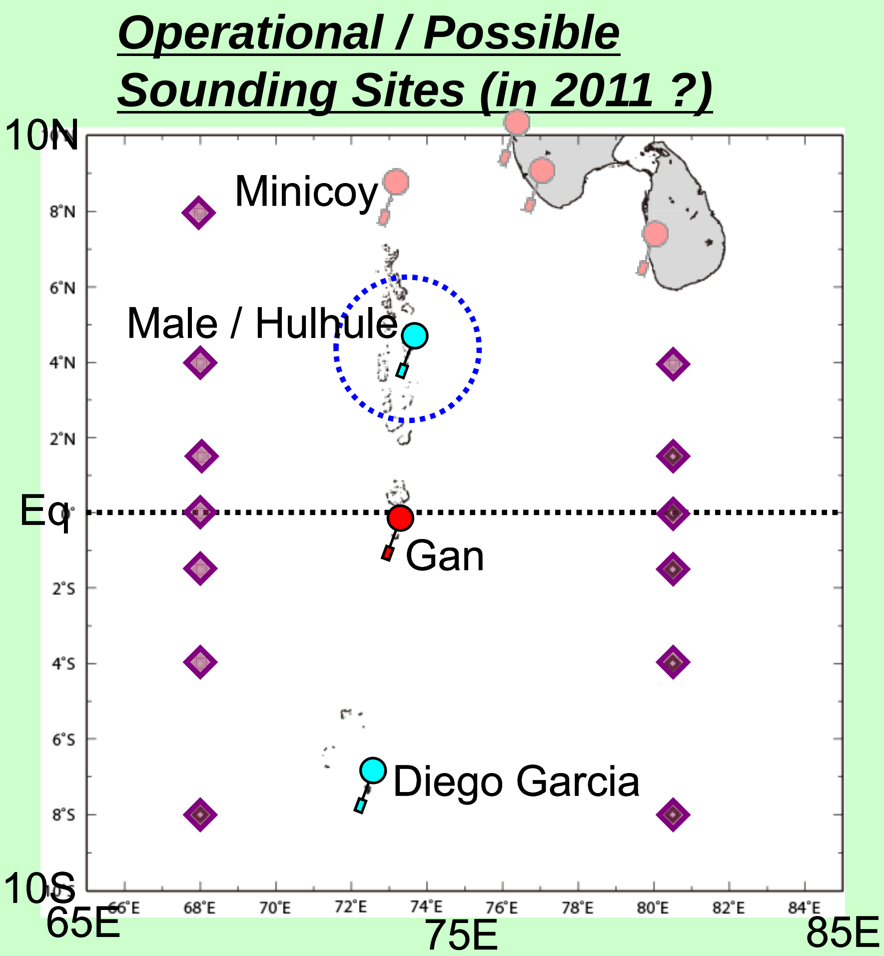
Large-area map for Indian Ocean

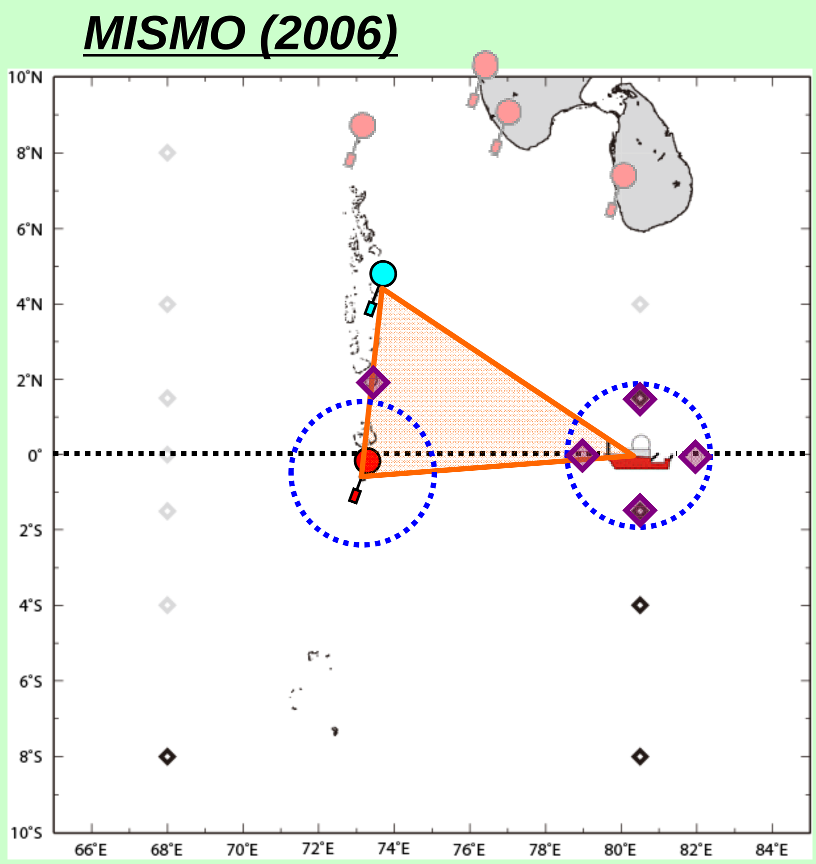


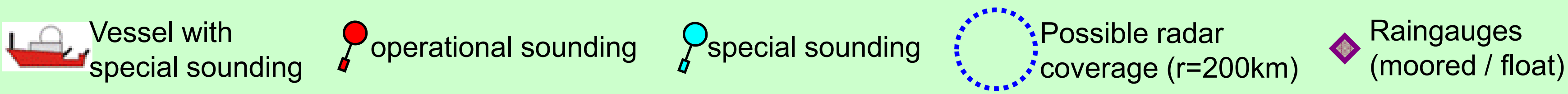
Large-area map for Indian Ocean



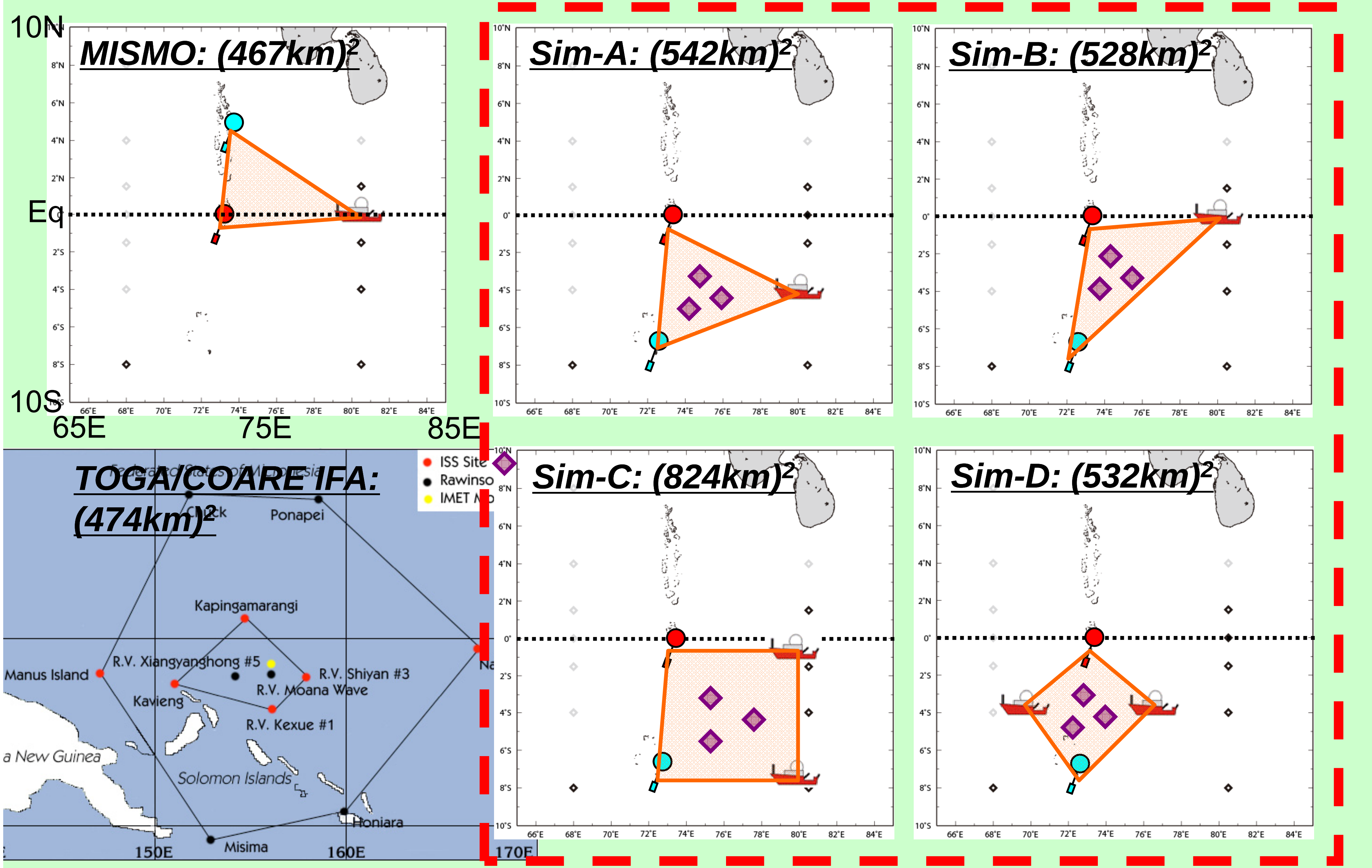
Supposed core area for CINDY2011

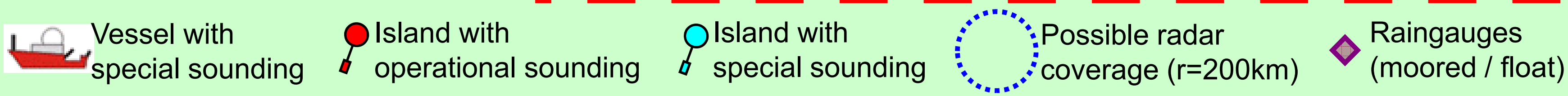






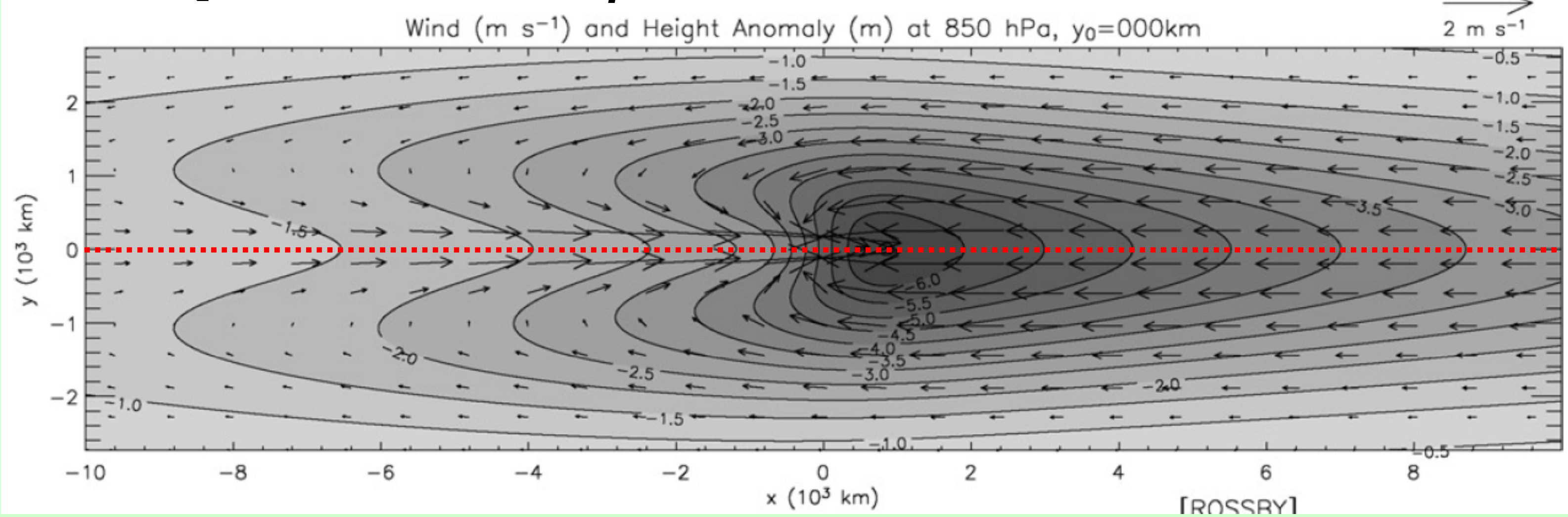
Simulated sounding array



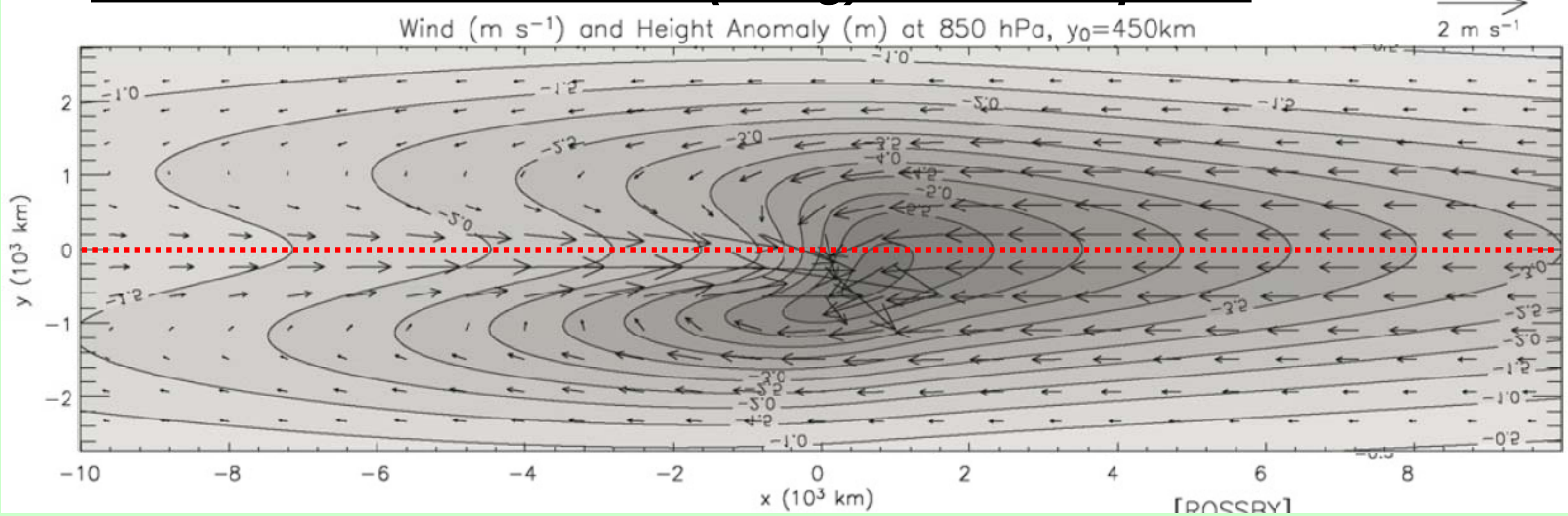


Given wind field (at 850hPa)

H-EQ: Heat source at ***Equator***

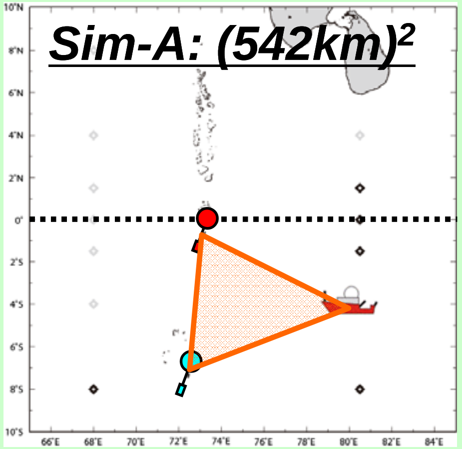


H-4S: Heat source at ***450km (4 deg) south of equator***

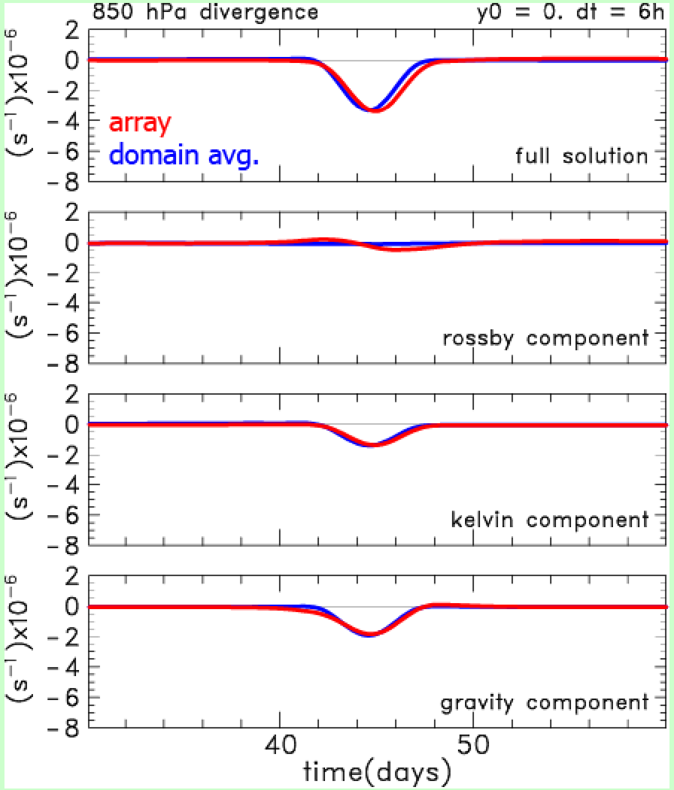


Schubert and Masarik (2006)

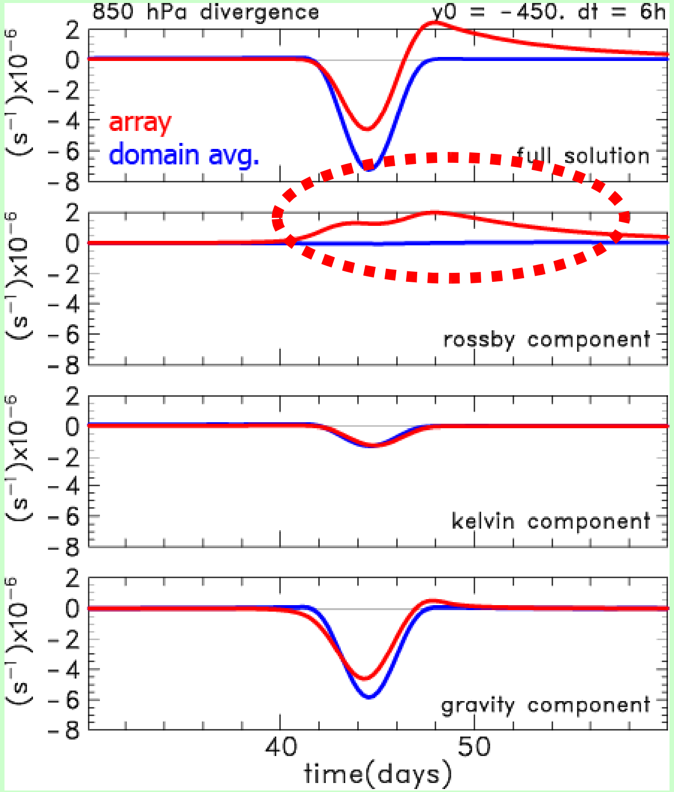
Simulation for Pattern-A [Triangle with (4S, 80E)]



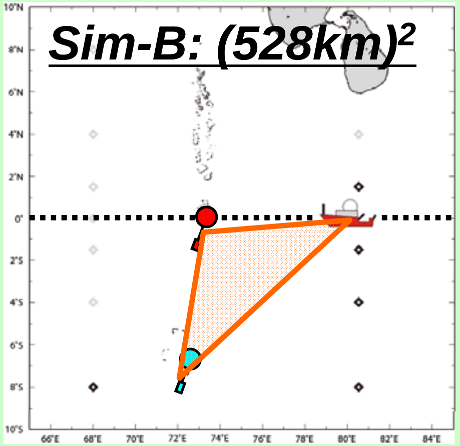
H-EQ



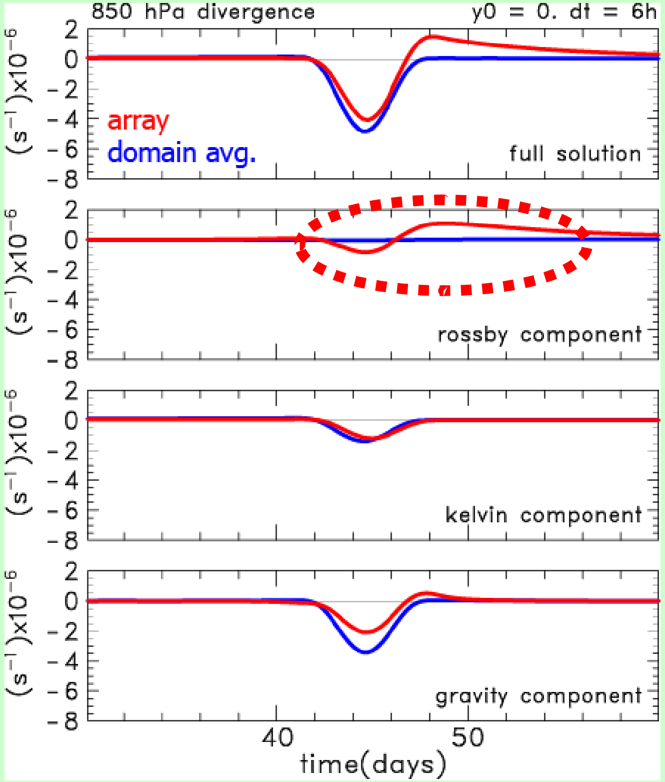
H-4S



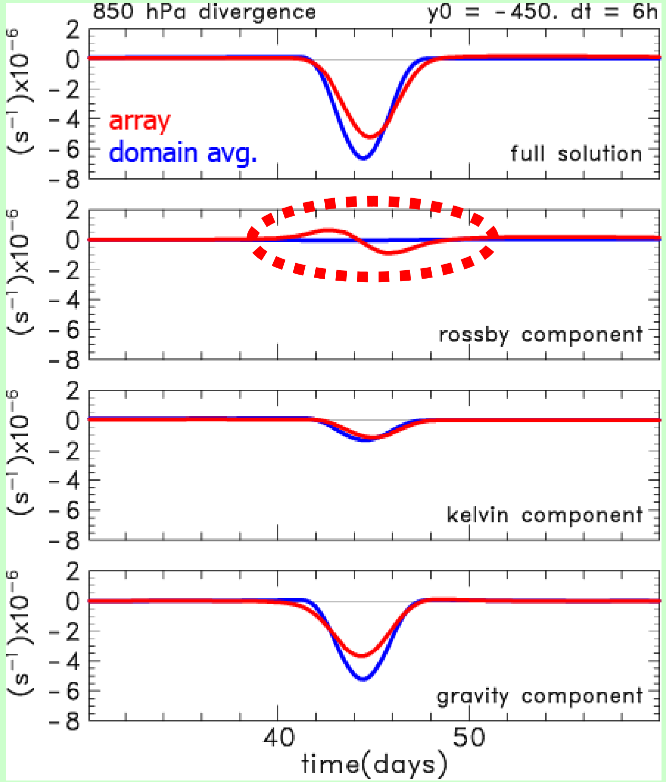
Simulation for Pattern-B [Triangle with (Eq,80E)]



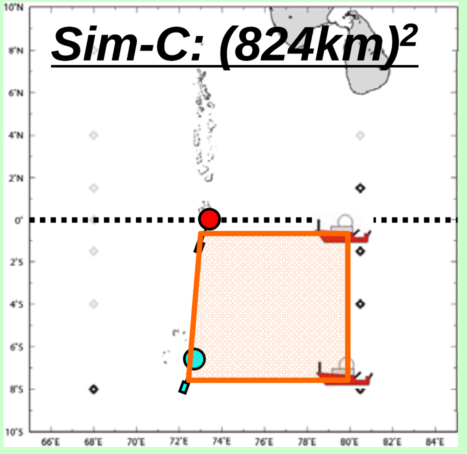
H-EQ



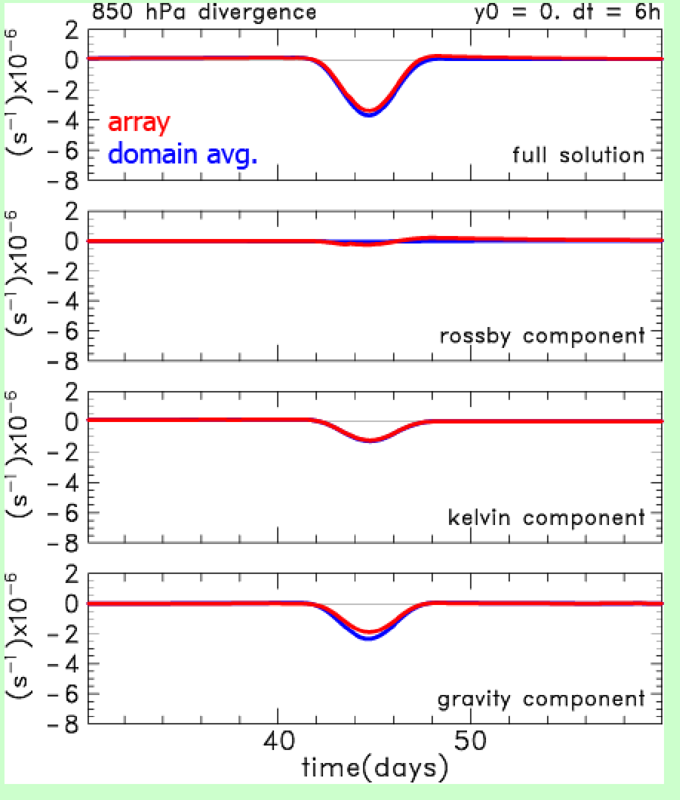
H-4S



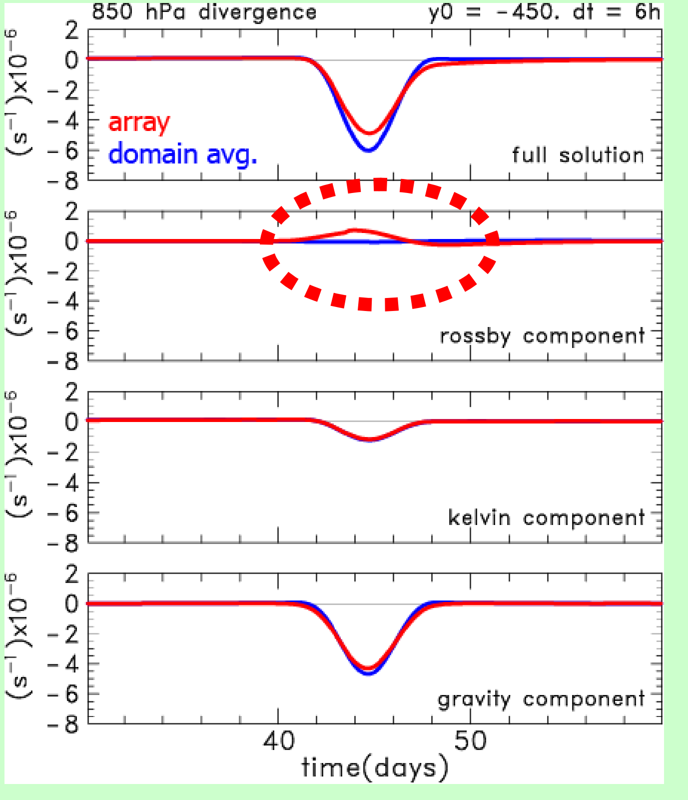
Simulation for Pattern-C [Rectangular]



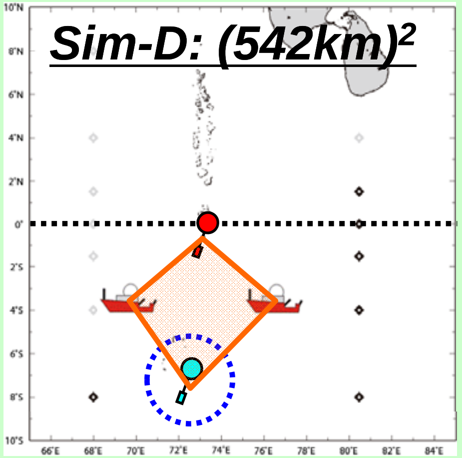
H-EQ



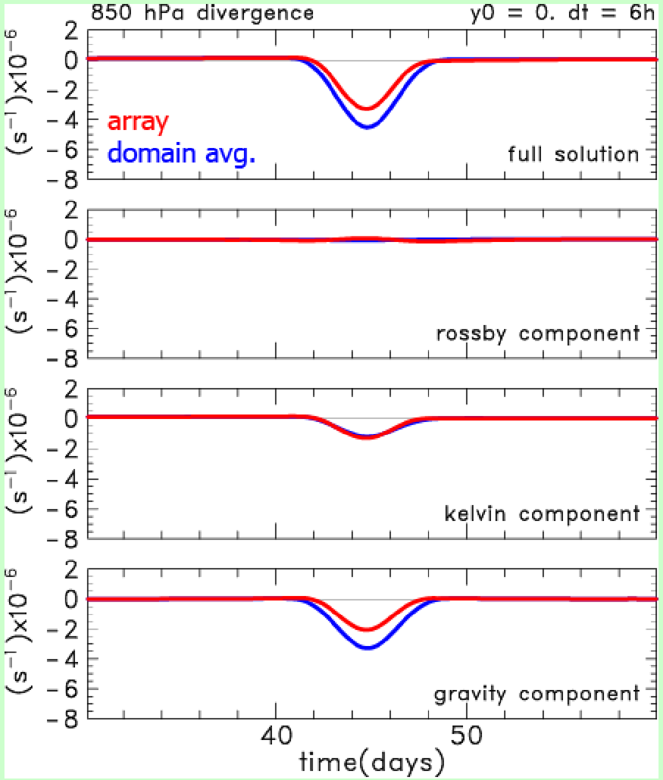
H-4S



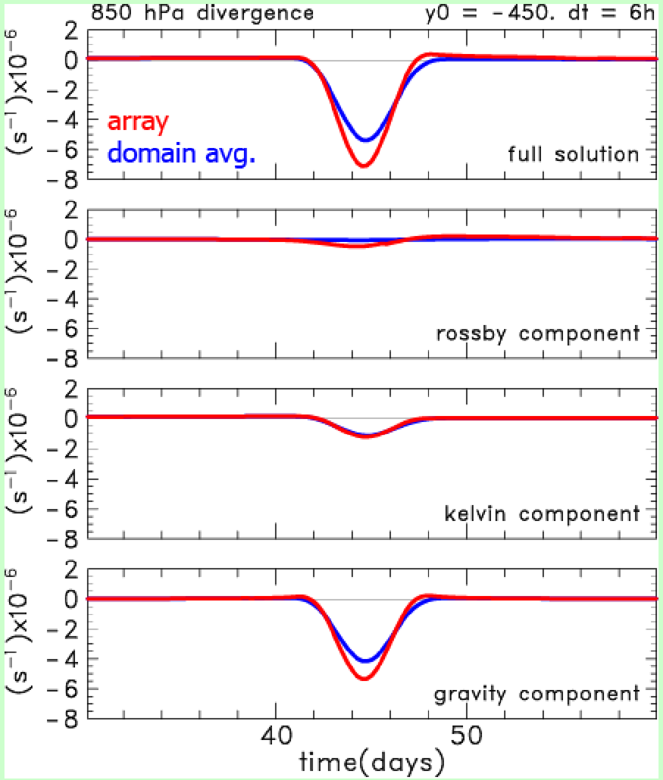
Simulation for Pattern-D [Diamond]



H-EQ

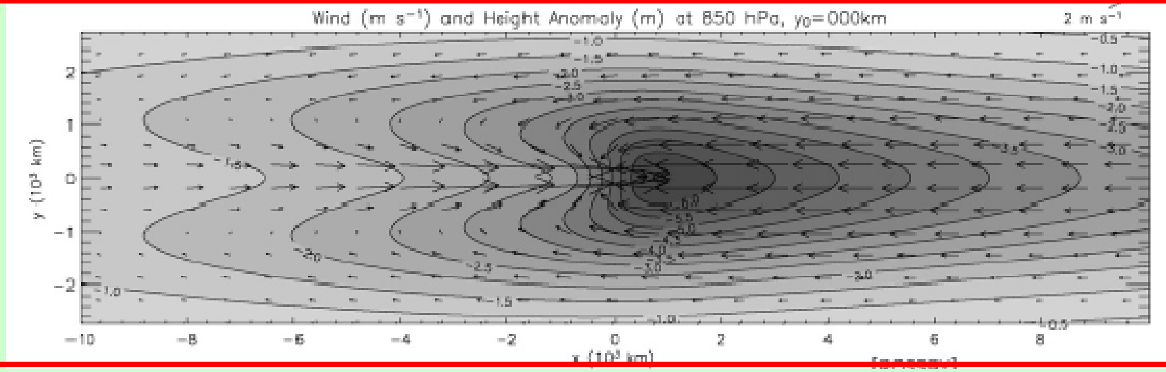


H-4S



Simulating budget analyses

Theoretical Wind Field
with TOGA/COARE-like heating
(Schubert and Masarik 2006)



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