Spatial sampling requirements for tropospheric temperature and humidity

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Workshop to define climate requirements for upper-air observations

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Introduction

Purposes of the GUAN:

- Establish national commitments for the preservation of a minimum set of upper-air stations for the foreseeable future.
- To build a collection of validated data from these stations.
- To provide these data to the global community with no formal restriction.

Data requirements:

- Homogeneous distribution of stations.
- Freely available historical data records of reasonable length.
- High quality observations.

Introduction

GUAN acts as a reference network for upper-air climate research.

Data requirements:

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- Freely available historical data records of reasonable length.
- High quality observations.

What are the station density requirements for a reference network to monitor large-scale changes in temperature and humidity?

Spatial Sampling Error

RMS errors decrease with altitude with respect to the total inter-annual variance (Santer et al. 1999). Lower troposphere RMS for Angell and HadRT networks estimates range from 0.07 to 0.12^{o}C.

Sampling errors in trend estimates are not related to the total number of stations, and reanalysis data may not be a quantitative guide to their magnitude (Free and Seidel 2005) .

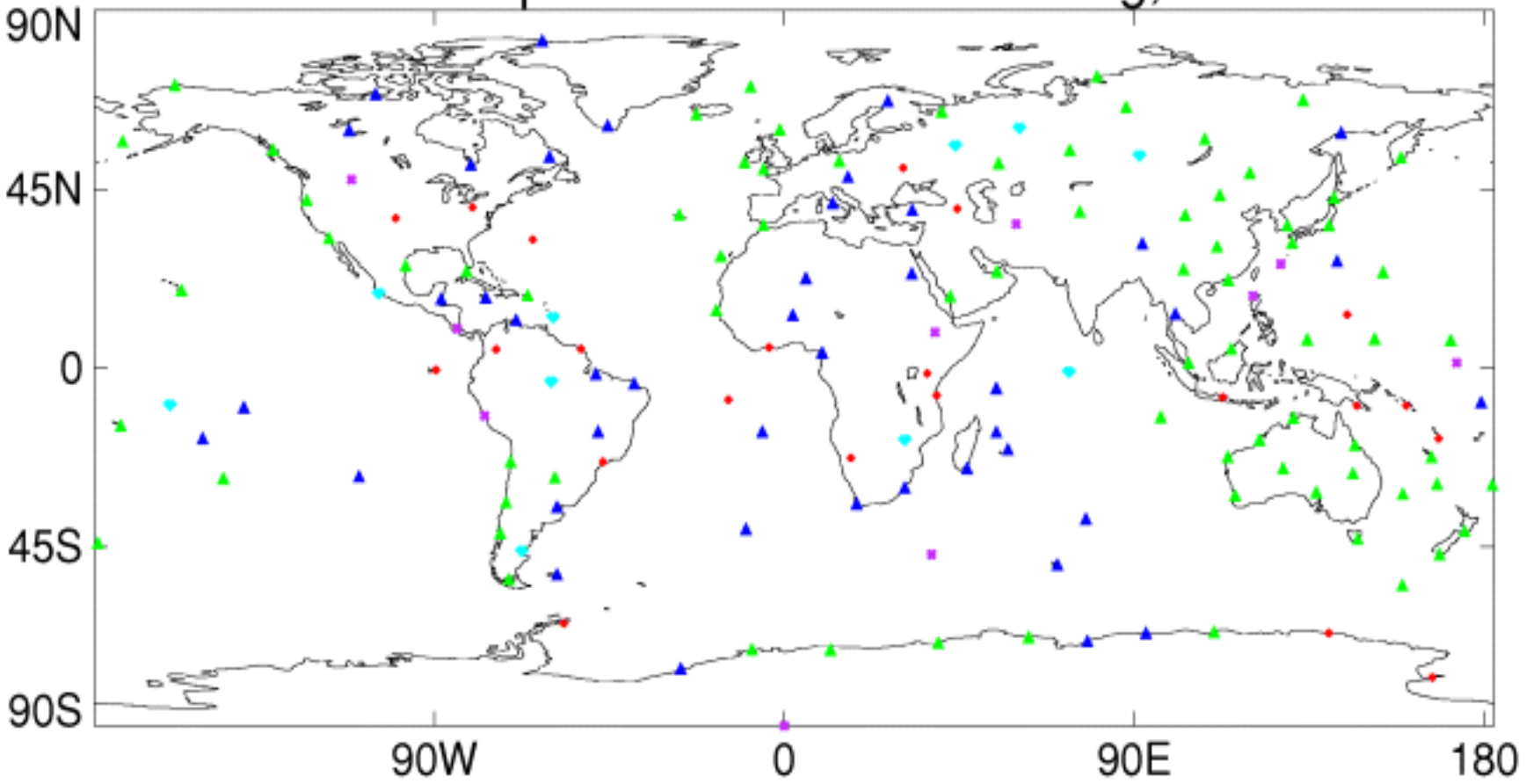
Network design

GUAN originally designed by Paul Julian on contract to GCOS. The current network comprises 161 stations. LKS network is 87 stations.

Trevor Wallis (1998) also designed a network of 188 stations based upon data availability and representative areas.

Region	No. GUAN stations	No. LKS stations	Mean GUAN separation (Km)	Mean LKS separation (Km)
60-90N	14	14	1072	1171
30-60N	38	23	1021	1537
0-30N	36	18	1102	1699
0-30S	42	15	1159	2113
30-60S	19	11	1128	1783
60-90S	12	6	944	1084

% of GUAN reports for 12 months ending, Nov 2004



- 90–100% reports received, (76)
- 50–90% reports received, (43)
- 25–50% reports received, (10)
- 1–25% reports received, (10)
- 0–1% reports received, (22)

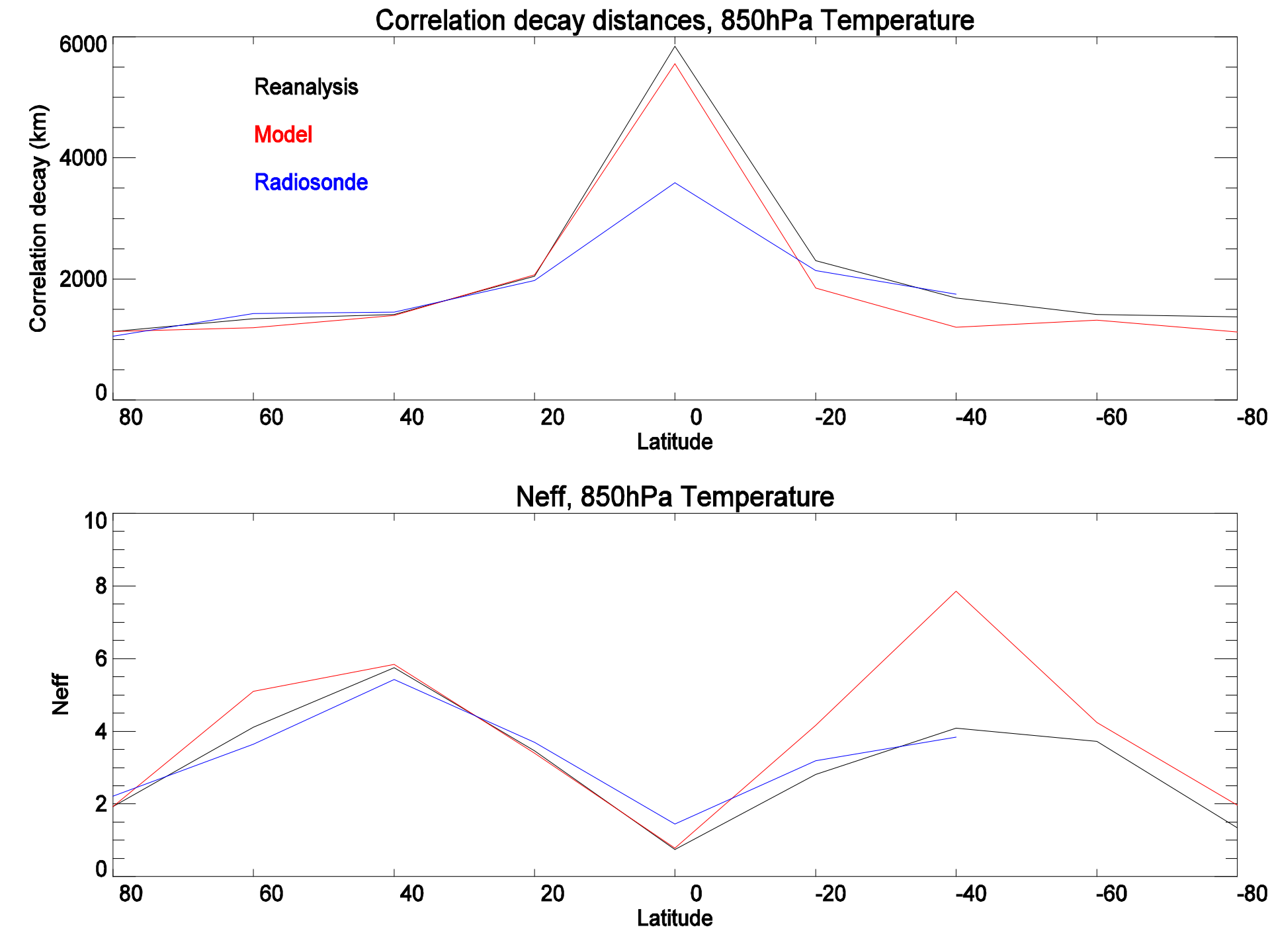
Representative areas

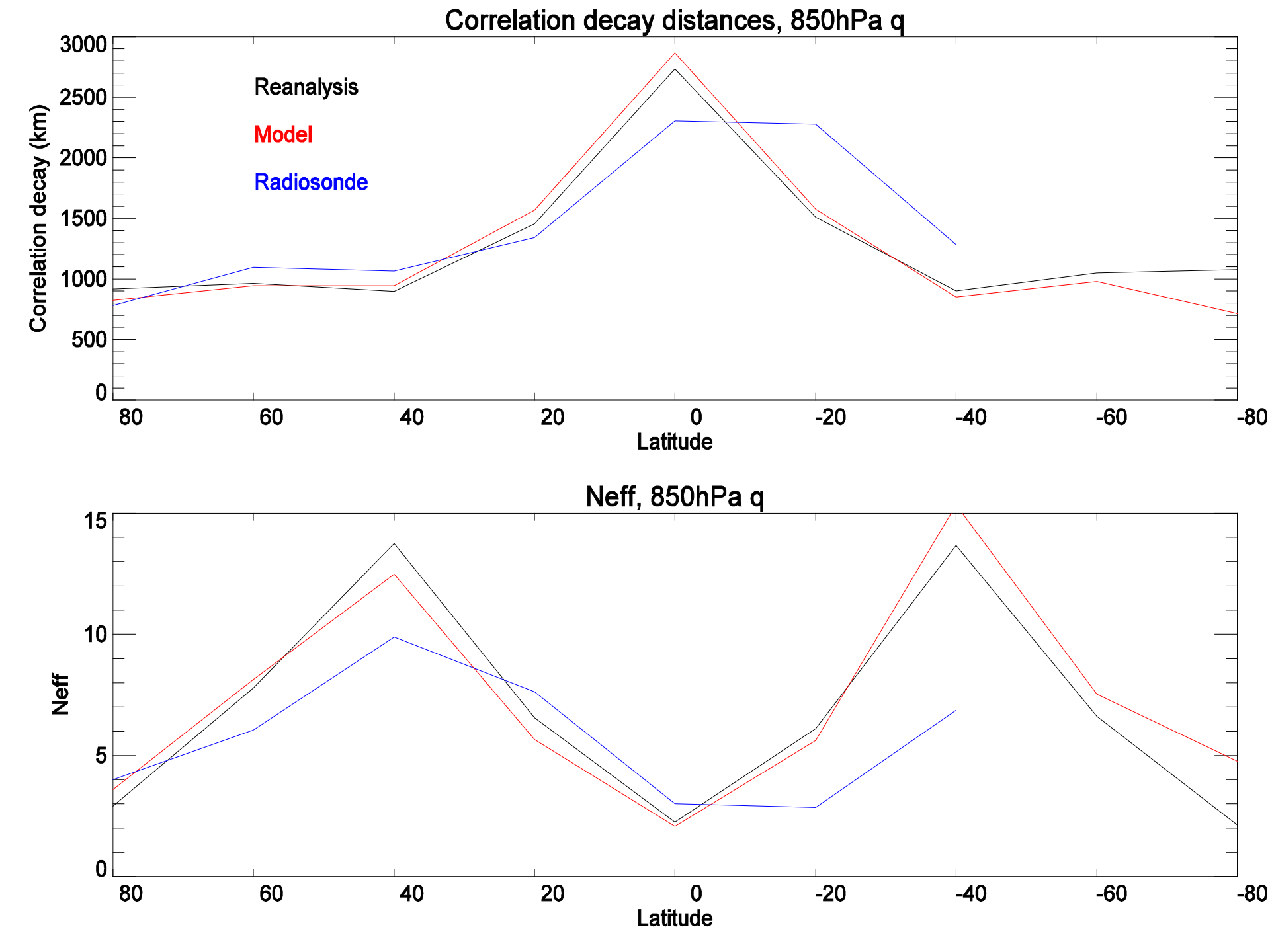
Jones et al. (1997) define correlation decay length (x_0):

$$r=EXP(-x/x_0)$$

Where r is correlation coefficient and x is the separation between two points.

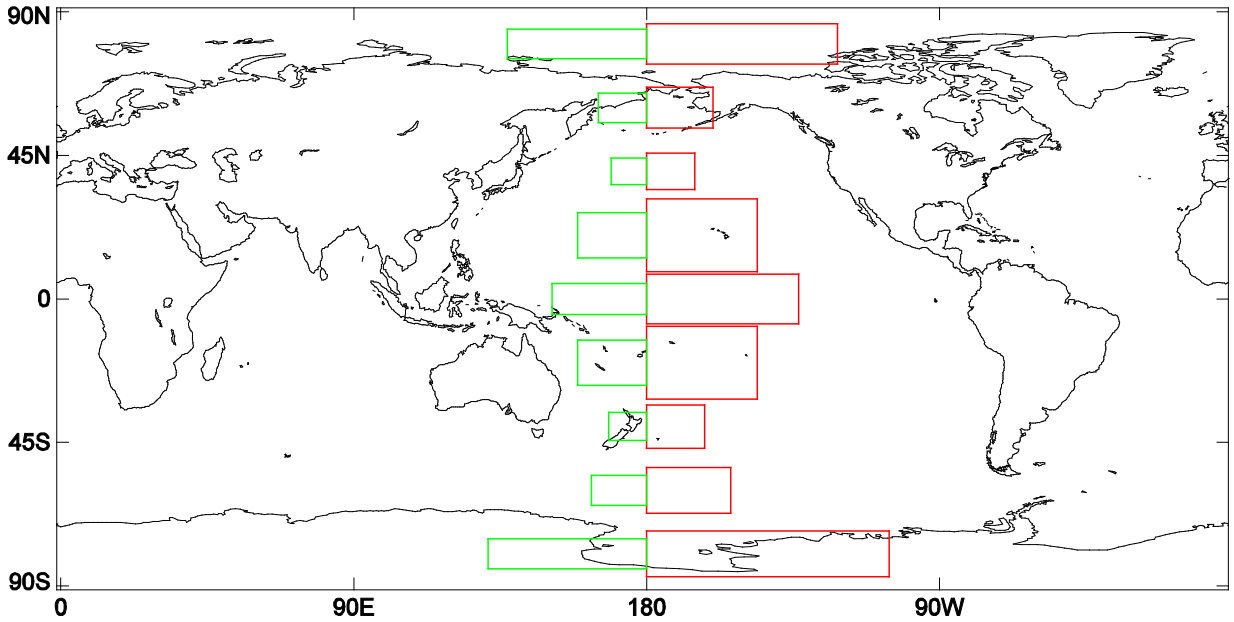
We estimate x_0 and the number of effective degrees of freedom (N_{eff}) from model (HadAM3 1979-1998), reanalysis (NCEP/NCAR 1948-2004) and radiosondes (1958-2002), for temperature and humidity.


Correlation decay distances, 850hPa Temperature
Reanalysis
Model
Radiosonde
Correlation decay (km)
6000
4000
2000
0
80
60
40
20
0
-20
-40
-60
-80
Latitude
Neff, 850hPa Temperature
Neff
10
8
6
4
2
0
80
60
40
20
0
-20
-40
-60
-80
Latitude


Correlation decay distances, 850hPa q
Reanalysis
Model
Radiosonde
Correlation decay (km)
3000
2500
2000
1500
1000
500
0
80
60
40
20
0
-20
-40
-60
-80
Latitude
Neff, 850hPa q
Neff
15
10
5
0
80
60
40
20
0
-20
-40
-60
-80
Latitude

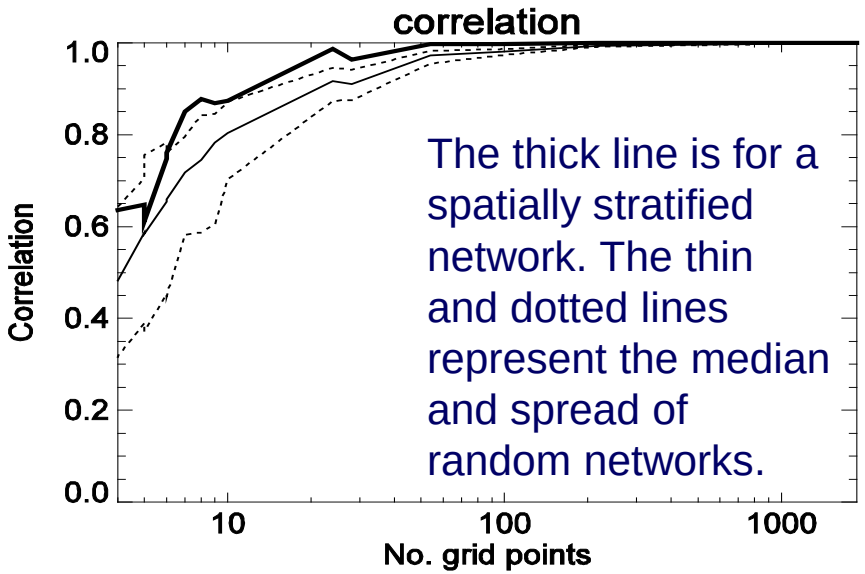
Representative areas:

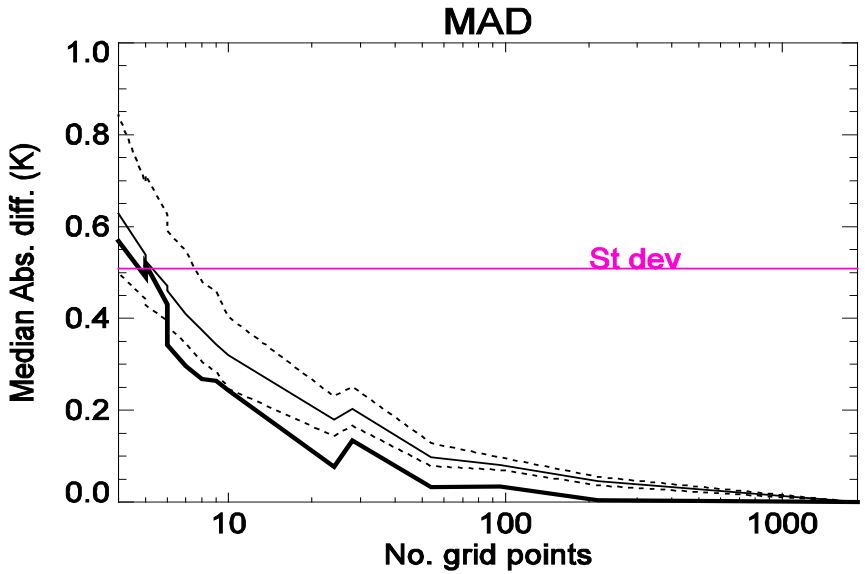
Humidity Temperature

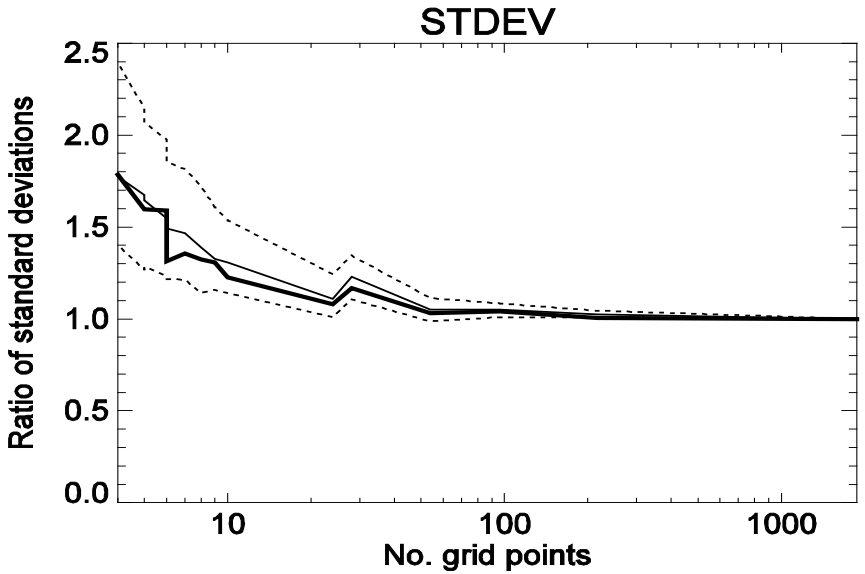


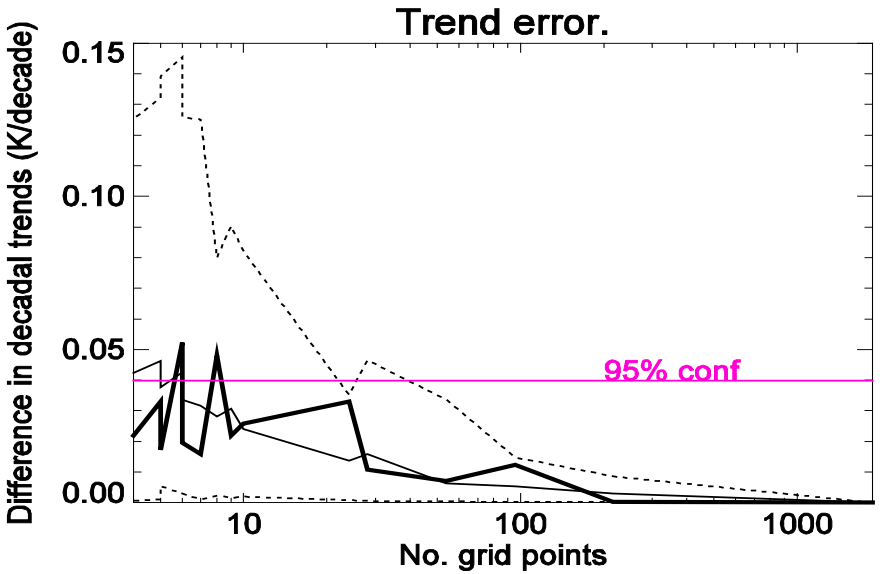
To fill this map requires approximately 150 stations for temperature, or 360 stations for humidity. In both cases greatest station density is between 30 and 60^{o} latitude in either hemisphere.

Reanalysis 30-60N, sub network performance.

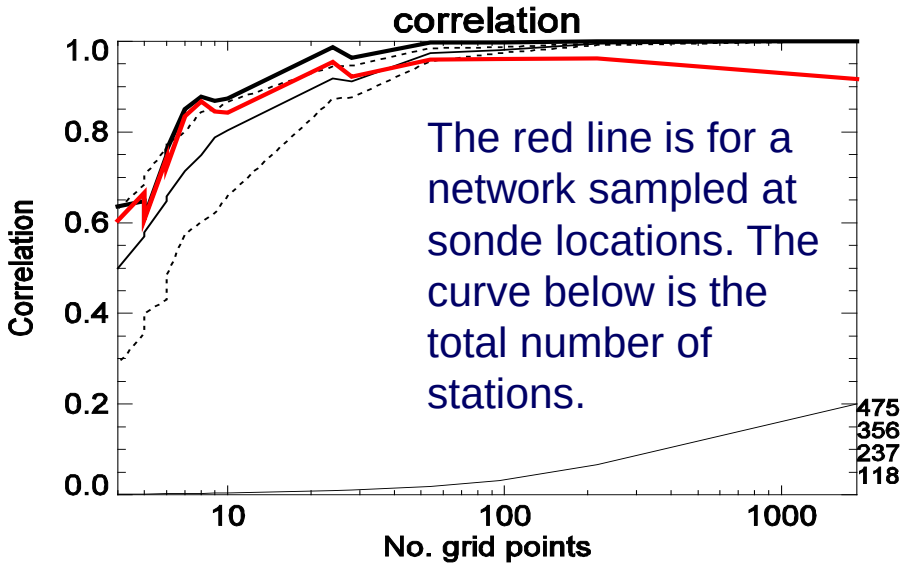


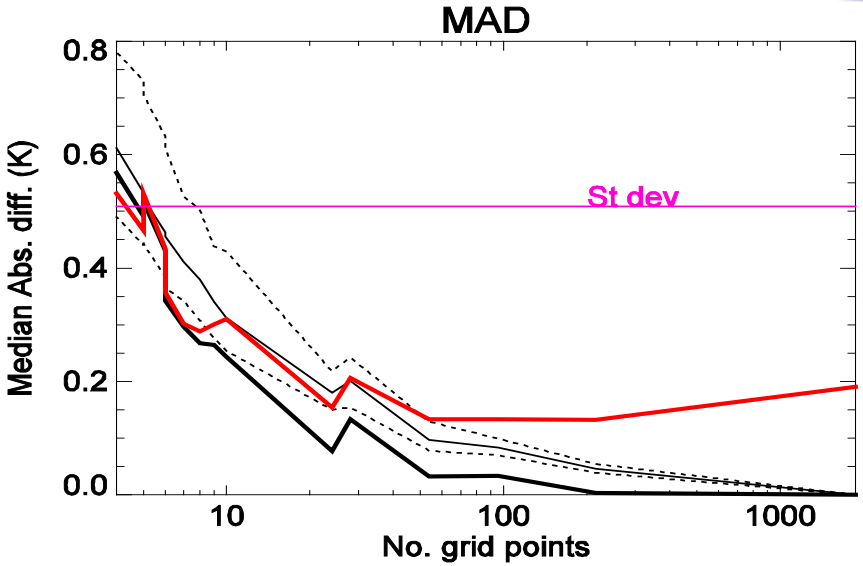


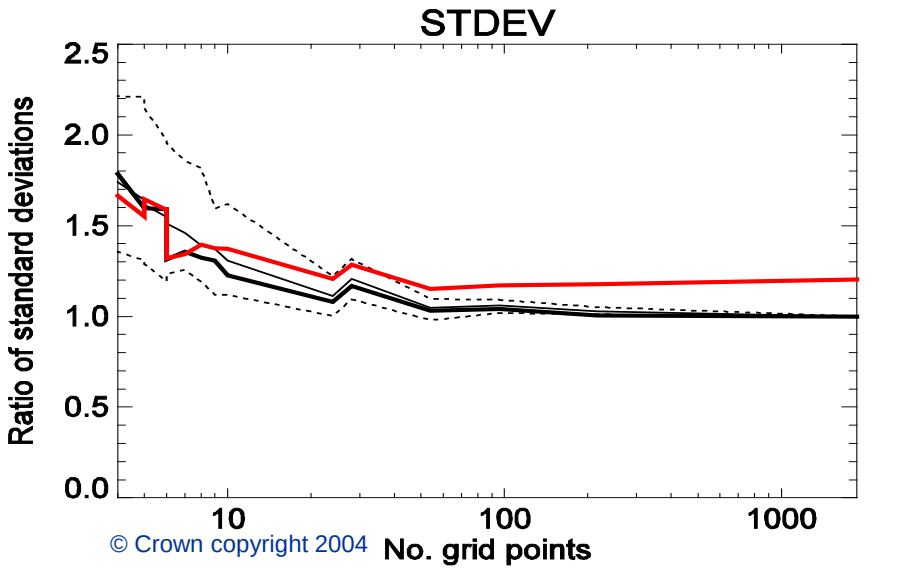


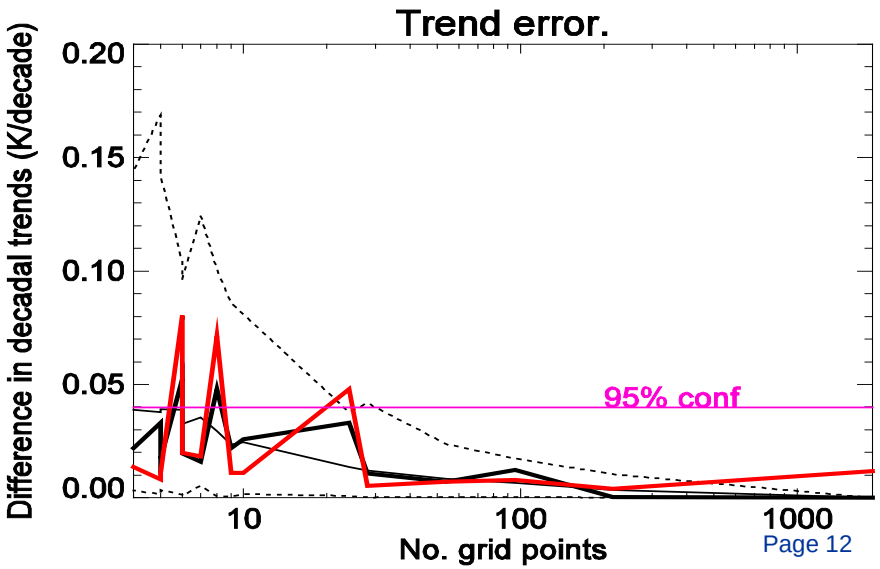


Reanalysis 30-60N, Sub-sampled sondes.









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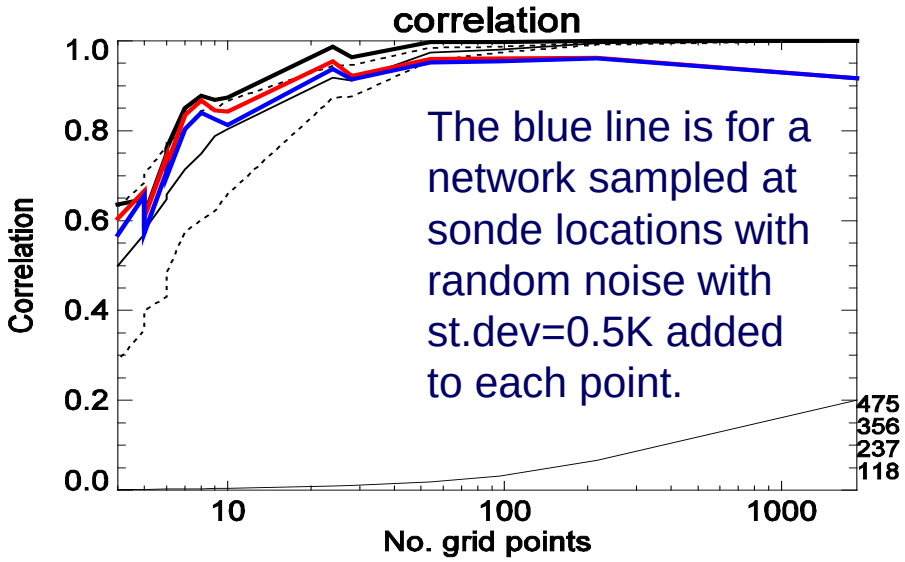
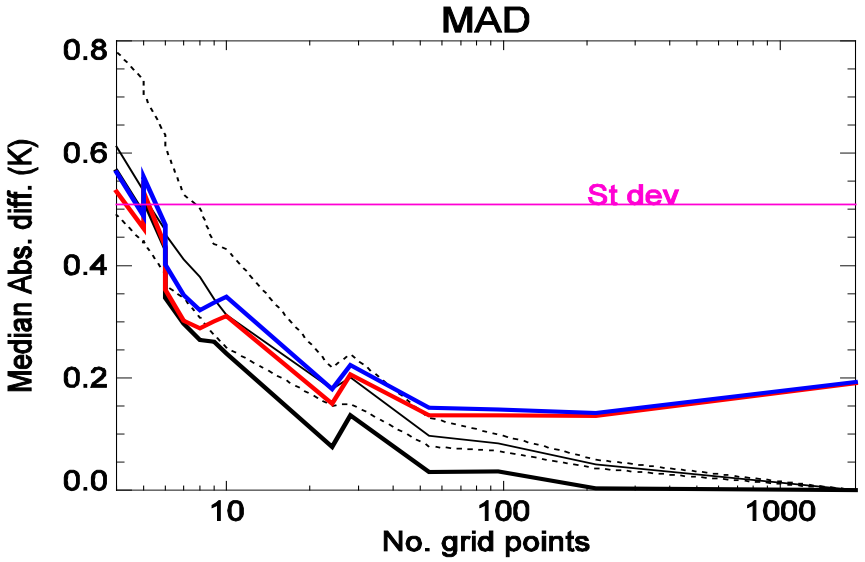
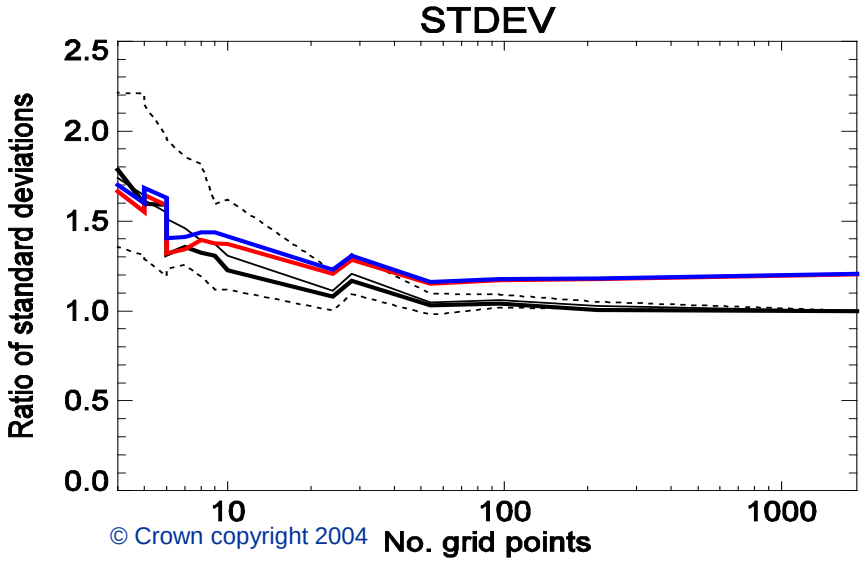
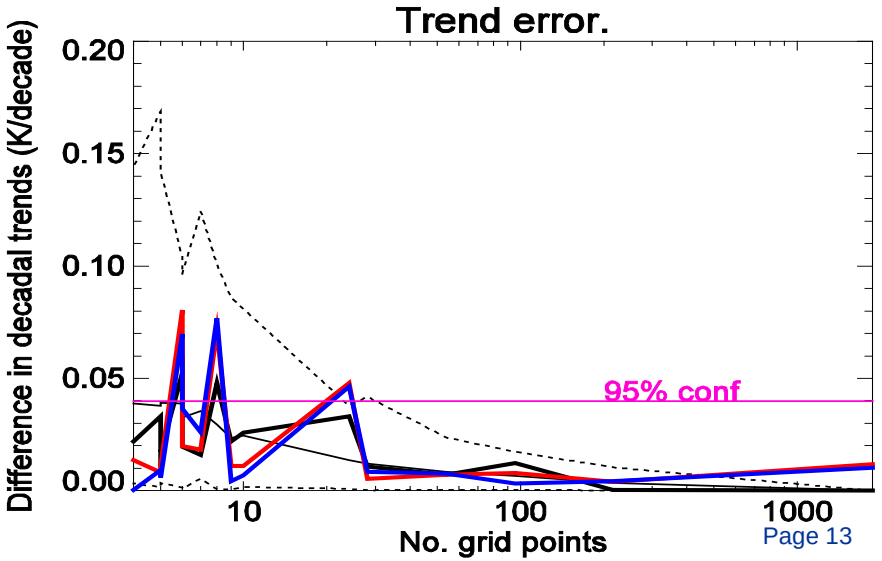
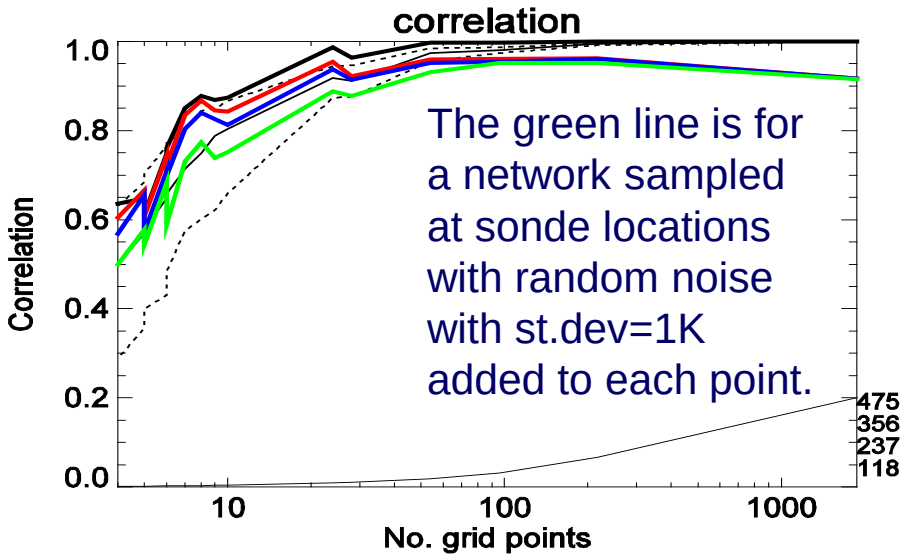


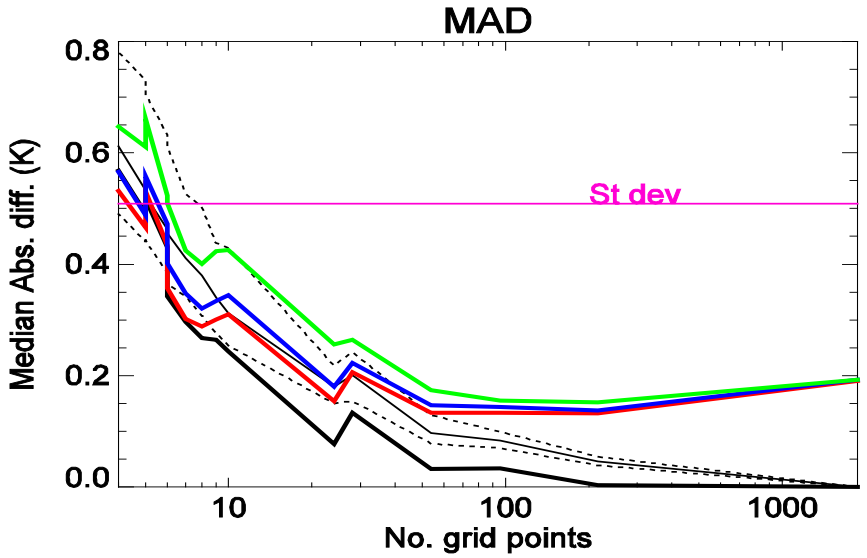


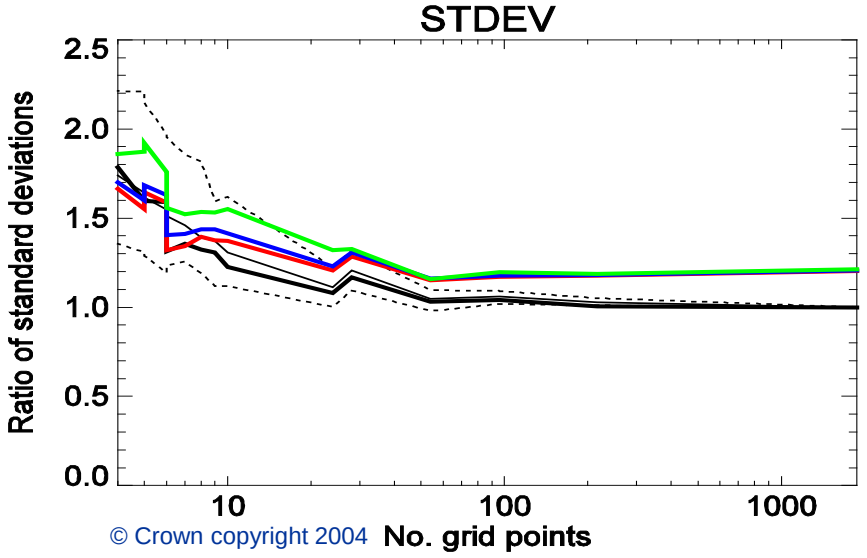


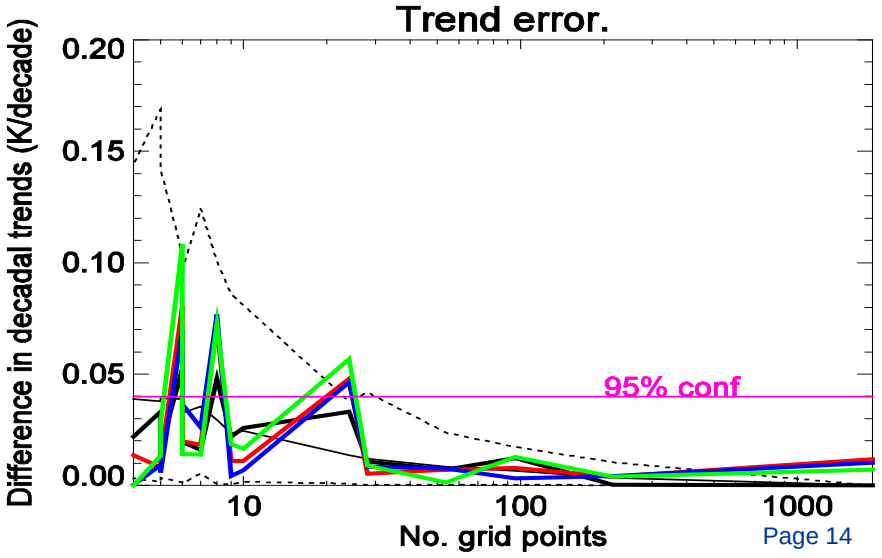


Reanalysis 30-60N, Sub-sampled sondes.









30-60N network performance.

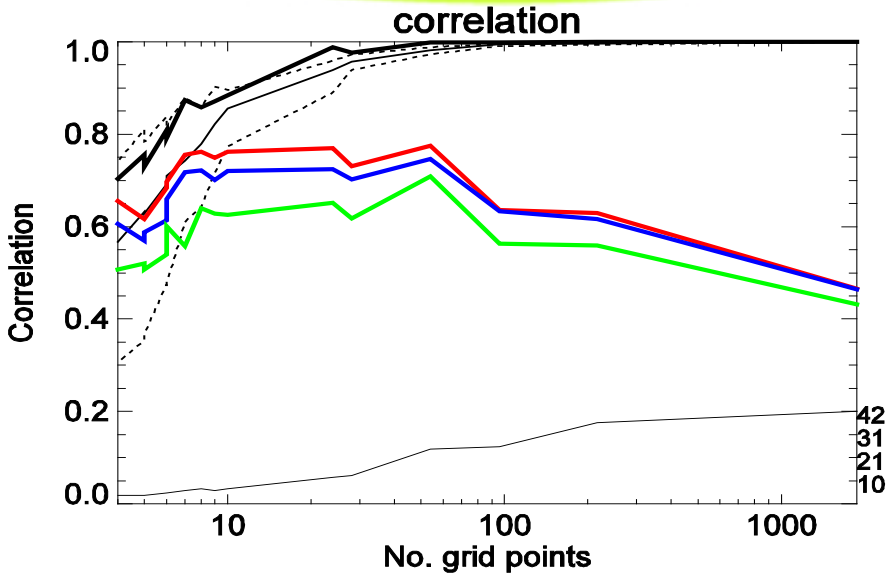
Drop in performance when number of stations falls below 54 points (10x20 lat-lon grid).

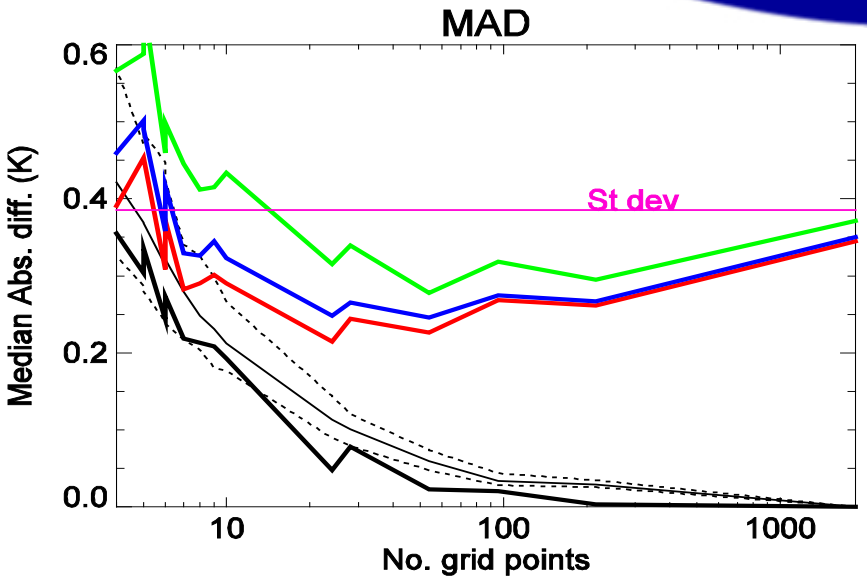
For a 54 point network 44 have at least one station located within grid box region. The sonde distribution increase MAD from 0.03K to 0.13K.

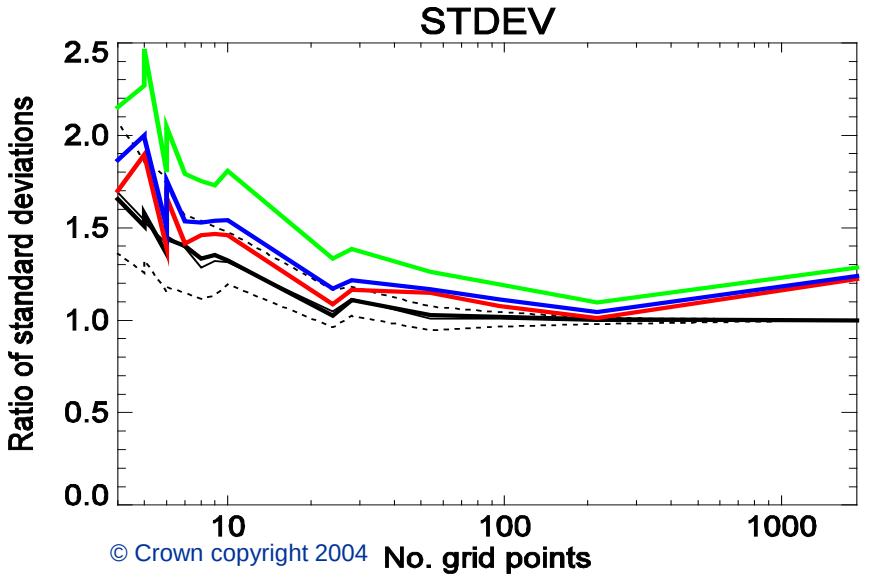
GUAN (38 stations) and Lanzante (23 stations) perform well compared to networks of similar size.

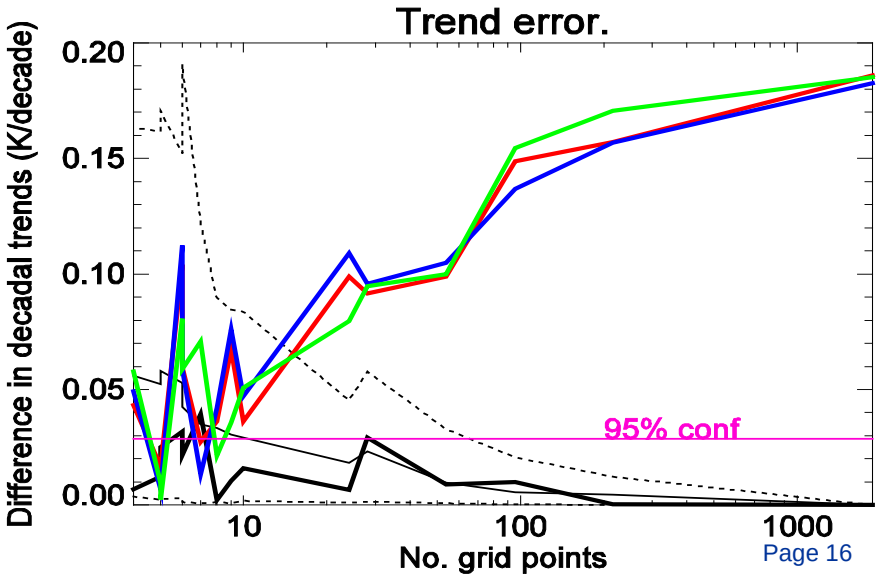
Random error at individual stations must be below 0.5K or small networks can be degraded.

Reanalysis 30-60S, Sub-sampled sondes.

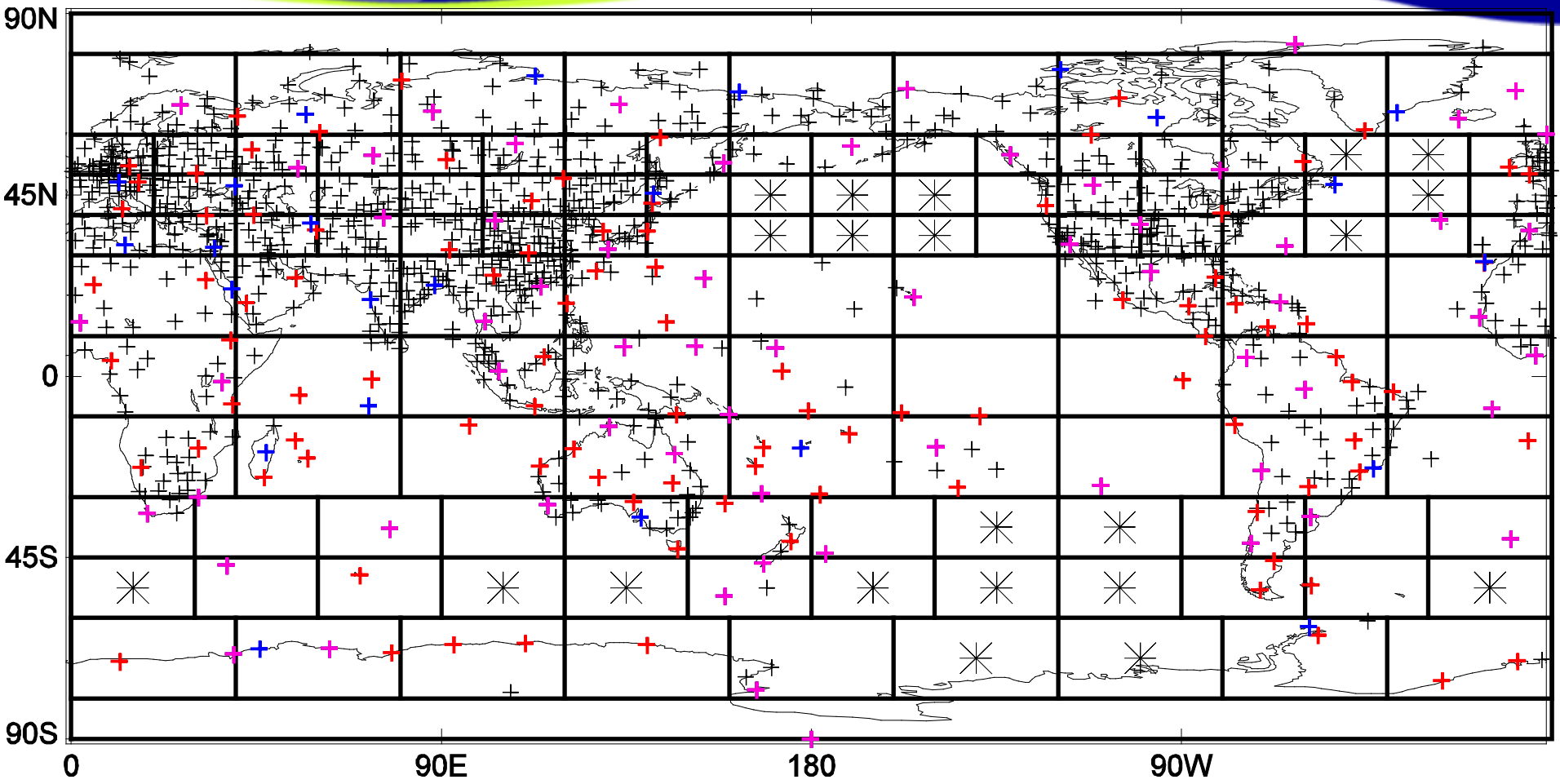




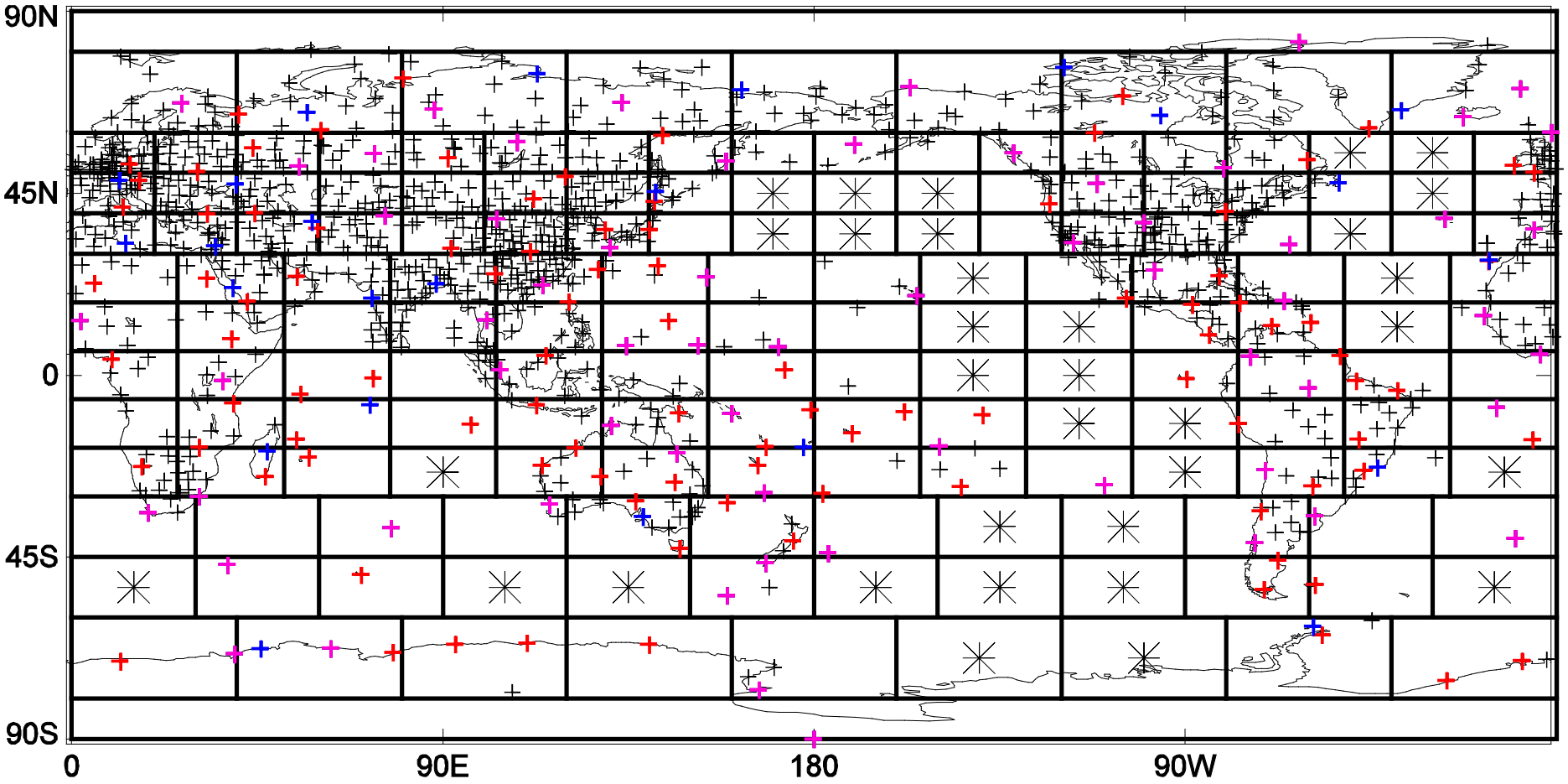




Example network - Temperature.



Example network - Humidity.



Recommendations:

- Horizontal resolution of order 1000km at mid to high latitudes and 2000km in the tropics.

- Keep random error in monthly means at individual locations to <0.5K for temperature and <3g/kg (~3σ) for humidity at 850hPa.

- Maintain a reference radiosonde network of a similar size to the current GUAN.

- Prioritize isolated radiosonde stations.

- Require improved sampling in the southern hemipshere than the radiosonde network can provide.

Discussion points.

These requirements are based upon monthly mean anomalies of model and reanalysis data of the lower troposphere, and the availability of all possible radiosonde site locations.

The degrees of freedom in the system on timescales of interest constrain the usefulness of additional observations. Any network of observations must reflect this in its sampling density.

How might we resolve the poor sampling of the southern oceans. Are there possible in-situ solutions? (workshop II?)