ESA CONTRACT REPORT

European Space Agency Contract Report

Extension of the OSSE Data Base to Scatterometer and ATOVS Data

Final Report Part II:

The European Centre for Medium-Range Weather Forecasts (ECMWF) Synthetic Observation Production Suite

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October 1995

CONTENTS

1. Introduction: OSSE project: preparation of a data base 1
2. Contents of the OSSE data base 3
3. How the OSSE data base was created 4
   - 3.1 The orbit simulator 4
   - 3.2 The observation preprocessor 5
   - 3.3 The nature run truth 5
   - 3.4 The postprocessor 6
   - 3.5 The error model 8
   - 3.6 The OSSE data base access routines 8
4. Validation tasks 9
   - 4.1 Orbit simulator 9
   - 4.2 Observation preprocessor 9
   - 4.3 Nature run truth 9
   - 4.4 Postprocessor 9
   - 4.5 Final data bases 10
5. Conclusion 11
6. References 11
7. Appendix A: BuFR Templates 13

Extension of the Observation System Simulation Experiment (OSSE) data base to scatterometer and ATOVS data
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Abstract

To produce a synthetic data base of conventional observations and future satellite systems over a period of 30 days, we used the ECMWF forecast model as a physically sound basis to simulate the atmosphere. The resulting wind, temperature, humidity and cloud fields were then used to simulate both conventional and remotely sensed observations. In a postprocessing step, a mix of realistic Gaussian and Gross observation errors were applied to the observations. Five Doppler Wind Lidar (DWL) scenarios, Tiros Operational Vertical Sounder (TOVS), Advanced Tiros Operational Vertical Sounder (ATOVS), Advanced Scatterometer (ASCAT) and all conventional observation types have been successfully simulated. This data base was created to study the impact of DWL data on Numerical Weather Prediction (NWP) in Observation System Simulation Experiments (OSSE).

1 Introduction: OSSE project: preparation of a data base

The accuracy of a forecast from a Numerical Weather Prediction (NWP) system depends on a realistic computer model of the atmosphere, but also on a very accurate description of the initial state of the atmosphere, from which the subsequent forecast evolves. The accuracy of the analysis of the initial state is highly dependent on the observation coverage, spatial and temporal resolution, and accuracy. Over oceans, which cover most of the earth's surface, the coverage of "conventional" observations (i.e. from surface stations/platforms, from balloons and from aircraft) is very sparse. Space-based systems offer the only realistic hope of meeting the requirements of operational meteorology for a global coverage of observations with adequate spatial and temporal resolution. The main variables that must be observed in order to specify the initial state of the atmosphere are the three-dimensional fields of temperature, humidity and wind. For an adequate description of the atmosphere on scales represented by most of the present global NWP models, observations are needed at a 50-100 km resolution in the horizontal, 1 km in the vertical, from the surface to about 30 km altitude. In the mid and high latitudes, the temperature and wind fields are coupled through the dynamical equations governing the atmospheric motion. However, there is a significant component of the flow on small horizontal scales which is not coupled, making measurements of wind useful and important, even in the presence of temperature observations. In the tropics the coupling is much weaker and the wind field cannot be inferred, even approximately, from the temperature field. Thus direct observations of wind are even more important here.

One of the most promising future instruments is a space-borne Doppler Wind Lidar (DWL), measuring the wind component along line-of-sight of a conical scanning laser beam, deduced from doppler shift of refracted signal due to moving aerosol and cloud particles. An instrument like that could be profiling the atmosphere from 20 km height to the surface with a vertical resolution of about 300 m. At the European Space Agency (ESA) a group called the Aladin scientific advisory group is working on the assessment of such an instrument. Following their recommendations and in close colaboration, a comprehensive and consistent data base was created for a period of 30 days, allowing the potential of a future observing system for NWP through Observation System Simulation Experiments (OSSEs) to be assessed. ECMWF has completed a first ESA study contract, "Theoretical studies of the impact of Doppler Wind Lidar (DWL) data. Preparation of a data base". This covers the simulation of the following data sets with realistic coverage and error characteristics :

- Conventional observations
  - surface observations (SYNOP)
  - ship observations (SHIP)
  - observations from drifting and moored buoys (DRIBU)
  - radiosonde observations (TEMP)
  - pilot balloon observations (PILOT)
  - surface pressure observations derived from imagery and ancillery information (PAOB)
  - aircraft observations (AIREP)
  - satellite cloud-tracked winds (SATOB)
- TOVS clear-column brightness temperatures,
- DWL line-of-sight wind profiles. Measurement of wind component along line-of sight of a conical scanning laser beam, deduced from doppler shift of refracted signal due to moving aerosol and cloud. Profiling the atmosphere from 20 km height to the surface with a vertical resolution of ca. 300 m.

The main purpose of this data base is to allow the potential DWL impact on NWP to be assessed. However, a rigorous assessment of DWL impact should take into account the availability of other systems expected to be operational at the time when DWL could be flown (i.e. the next century). Consequently, we have simulated observations from the following new satellite systems, which will be available at that time :

- Advanced SCATterometer (ASCAT), a double swath scatterometer which will be very similar to the single swath ones flown by ERS-1 and ERS-2, and will be part of the payload of the European meteorological polar satellites (METOP).
- Advanced TOVS (ATOVS), which will replace TOVS on the National Oceanic and Atmospheric Administration of the USA (NOAA) operational polar-orbiters from 1996, and is planned to continue as the operational sounder on the American and European polar systems which follow the NOAA series.

The observations from these new systems (OSSE2) have been simulated fully consistently with the ones of the first project (OSSE1). They have been produced on the same 30-days period, using the same version of the Integrated Forecasting System (IFS)(Courtier et. al.,1991, Temperton et.al., 1995), and starting from the same operational ECMWF analysis.

This memorandum has been written to fill in the gaps between using the simulated data on the one hand and creating new simulated data on the other. It shall give some kind of manual, which answers questions regarding the technical implications of the creation of this comprehensive data set. The contents of the OSSE data base is described in section 2. A brief description of the major functionality of the production suite and where to find more information, on how the OSSE data base was created is given in section 3. In section 4, a brief description of validation tasks and some of the results will be presented. It should be read together with the two final reports and previously published memoranda.

2 Contents of the OSSE data base

The OSSE data base contains the following simulated observations over a 30-day period:

Observation	pp	dd	ff	T	rH	T_{dew}	T_{bright}	Z	HLOS	σ_0	Level:
SYNOP	x	x	x	x	x	x					surface
SHIP	x	x	x	x	x	x					surface
AIREP	x	x	x	x	x	x					flight level
SATOB	x	x	x	x							cloud top
DRIBU	x	x	x	x	x	x					surface
TEMP	x	x	x	x		x		x			31 levels
PILOT	x	x	x								31 levels
TOVS							x				25 channels
PAOB	x										surface
DWL									x		0-20 km
ATOVS							x				38 channels
ASCAT										x	seasurface

And it contains the following nature run values, which represent the "true" observations before the error generation at each observation point:

Observation	pp	u	v	T	rH	TCC	T_{bright}	CLW	CC	σ_0	Level:
SYNOP	x	x	x	x	x						surface
SHIP	x	x	x	x	x						surface
AIREP	x	x	x	x	x						flight level
SATOB	x	x	x	x	x						cloud top
DRIBU	x	x	x	x	x						surface
TEMP	x	x	x	x							31 levels
PILOT	x	x	x								31 levels
TOVS						x	x				25 channels
PAOB	x										surface
DWL		x	x		x			x	x		0-20 km
ATOVS						x	x				38 channels
ASCAT										x	seasurface

The abbreviations are pp for pressure, dd and ff for wind direction and speed, u and v for wind vector components, T for temperature. rH for relative humidity, T_{dew} for dew point temperature, T_{bright} for brightness temperature, Z for geopotential, HLOS for Horizontal Line-Of-Sight wind, σ_0 for radar backscatter measurement, TCC for total cloud cover, CC for fractional cloud cover per grid volume and CLW for cloud water content.

TOVS brightness temperatures are provided for HIRS channels 1-8 and 10-19, SSU channels 1-3 and MSU channels 1-4. ATOVS brightness temperatures are provided for HIRS channels 1-8 and 10-19, AMSU-A channels 1-15 and AMSU-B channels 16-20. The 31 TEMP and PILOT pressure level are the standard pressure levels and additional levels close to the forecast model's vertical nodes. They are 10, 30, 50, 70, 90, 100, 125, 150, 175, 200, 250, 300, 335, 370, 400, 450, 500, 540, 580, 620, 660, 700, 730, 770, 810, 850, 900, 935, 970, 1000 and 1010 hPa. An example for the DWL vertical resolution is given in Figure 14. Each of these simulated observation has an appendix, describing the history of the simulated datum. It contains the true data and the applied error characteristics as described in section 3.5. The five DWL instrument scenarios are: two scenarios with a 800 km orbit, two scenarios with a 525 km orbit, with 5 J and 10 J transmitted energy each, with a 0.95 Hz horizontal resolution and a vertical resolution of about 950 m, and one high resolution case study with a high horizontal resolution of 9.5 Hz and a vertical resolution of about 270 m for a period of one day in the North Atlantic.

3 How the OSSE data base was created

The choice of using a numerical atmospheric model to conduct this task is based on the fact, that it provides a consistent evolution in space and time for parameters which are not analysed by a data assimilation system, like for example cloud information. In most current assimilation systems, an analysis is available only every 6 hours which would leave us with considerable difficulties to simulate contiguous observations with a temporal resolution of the order of seconds. The observation systems have been simulated from the 5. of February 1993 to the 6. of March 1993, starting from the operational ECMWF analysis. We decided to use the original data coverage from conventional observations, but employ orbit simulators for the DWL, ASCAT, ATOVS and TOVS instruments for the whole period. We could have used existing TOVS data coverage from National Environmental Satellite, Data and Information Service (NESDIS), but to be independent from technical problems in the TOVS data reception over this rather long period in time and to be consistent with the treatment of the other orbiting satellite platforms, we chose the orbit simulator. The governing script scheduling the synthetic observation production suite runs the following main tasks in batches of 24 hours. (To be found in the file ~ stb/suite/st_cycle)

- adoption of the Laboratoire de Météorologie Dynamique's (LMD) orbit simulator for conical and crosstrack scanning satellites.
- observation preprocessor as an enhanced version of observation preprocessing system PREOB.
- ECMWF Integrated Forecasting System (IFS) in observation comparison mode.
- archive job for nature run observation Central Memory Array (CMA) files.
- observation verification in framework of the observation preprocessing system PREOB.
- observation plotting
  - data coverage plots
  - Root Mean Square (RMS) statistics
- observation postprocessor in framework of PREOB to
  - apply an error model to the simulated data
  - apply a neutral postprocessor
  - bufferize all observations
  - calculate statistics
- archive job for simulated observation CMA files.

The major tasks are described as follows:

3.1 The orbit simulator

LMD provided a program to calculate the positions of Fields Of View (FOVs) of a conical scanning instrument on a satellite platform in polar orbit with given inclination and altitude for a prescribed period in time (P. Flammant, personal communication). The observation preprocessor requires a contiguous orbit written to different files in batches of 6 hours providing vertical resolution or channel numbers for TOVS/ATOVS, the number of shots per scan unit, time and position plus node number for ASCAT. The scan unit for the DWL instrument is two mirror cycles of the conical scanning instrument with an odd number of shots (19) to provide a uniform ground coverage. Compare Figure 2 left with 19, right with 20 shots per two mirror cycles (20 seconds). For TOVS and ATOVS, the scan unit is one swath cross track. We simulate the 125 km resolution NESDIS product. That is boxes of three by three FOVs, 18 across track, randomly thinned by 50 %. Roughly the same code was adopted to cater for the different scanning and orbit geometries of the other satellite instruments. For the DWL orbit simulator to behave like TOVS, the azimuth angle was restricted, to allow only crosstrack variation of the incidence angle as seen from the satellite. Compare TOVS orbit simulator (~ stb/prog/tov212.f) with the DWL orbit simulator(~ stb/prog/dwl8.f)). For ASCAT, each FOV is simulated as seen under its individual (node dependent) incidence angle on either side of the satellite track (~ stb/prog/orbit/ers1.f). FOVs over land or ice are discarded. Continuity of the orbits is achieved by saving the last equator crossing time and -longitude in the simulation period to a file, to pick this information up as a starting point for the next days simulation. The along-track error is smaller than the distance between two scan units.

3.2 The observation preprocessor

This is an enhanced version of PREOB_002. It is faster and can be split in two parts for more efficient memory use. It translates the orbit simulator outputs of 2 DWL and 2 TOVS satellites over a timeperiod of 24 hours and merges this with one day's conventional data from Comprehensive Observation File (COF) to Central Memory Array (CMA) in 750 seconds. The simulated COF files are about 850 Mbytes per six hour period. Diskspace requirements are about 7 Gbytes and 31 Mw of Memory are needed. One hours CMA file is 18.5 Mw in size and every day around 330000 observations are simulated. It is the tool to set up the CMA-files which finally communicate with the forecast model. See the slightly outdated ECMWF technical memorandum 164 (J. Pailleux and Per Undén, 1989) for further details. The source can be found in clearcase branch sts_v001_a001 logged into hugin under sts. The latest working version however resides under ~ stb/prog/preob/cycle38/.

The exact time in the CMA header has got a new format. The word ncmetm now expresses time of the measurement accurate to the second, which was necessary, to be able to reestablish the orbits of the satellites which were destroyed by the sorting in latitude rows in PREOB. Ncmetm contains the exact time as HHMMSS. (This is true at least for the OSSE2 data base, ATOVS and ASCAT)

Because of the huge number of simulated data, there were considerable technical problems to surmount. The interface of the orbit simulator output into PREOB is in the COF domain, meaning, that first, the location, time and vertical and channel information is converted into COF reports, sorted, boxed and written out to disk. For OSSE1 these files were of 830Mb in size per six hour period. In a second step, these files are read back in and merged with the conventional observations from the operational COF data base to create CMA files. The original measurement values are overwritten with 0, say, the CMA files were stripped down to skeletons, providing only characteristic data coverage by time, location and observation type. The quality control measures before merging had therefore to be changed. Profiling instruments TEMPs and PILOTs were modified in so far, that at each such station, a 31 level profile on standard pressures and some additional levels close to the model's vertical nodes was provided. Out comes a set of hourly CMA files, containing the observation skeletons with 0 replaced for the original observations, sorted and boxed by observation type, latitude row and time.

This set of files is then compared with the simulated truth from the forecast fields in the IFS at every hour, and the departure value from the previously set (0) observation is stored at ncmomn in the CMA body. This number is -1∗ nature run value.

3.3 The nature run truth

The IFS cycle12 is run from an initialized analysis in normal forecast mode, with resolution T213, 31 levels in the vertical and the observation-comparison facility switched on (LSIMUL=true). This resolution is equivalent to a 80 km gridpoint spacing. Every 4 timesteps, that is every full hour, the corresponding CMA file is compared to the nature run truth at observation position and the departure from the preset value in CMA (0) is stored. These values are postulated as to be the true atmospheric state. No information on model errors will be given. Radiation and cloud physics are called every 3 hours, except at the beginning of the production, where it is called every hour for the first quarter of the day to suppress spin up problems in the cloud-physics. The obs comparison module for cloud information takes the closest model cloud. Postprocessing and archiving of the model fields to the Meteorological Archive and Retrieval System (MARS), including 3-d cloudcover and cloudliquid water content, is executed every 6 hours. Restart files are saved every 96 timesteps to run the 30 days production in batches of 24 hours. These restart files reside on ecfile, directory /stb/restart/indat$DATE$XID_1, 2, 3. Study ~ stb/xmaster/aw9/aw9_bigjob to see, how it all falls into place. Memory requirements for the first OSSE project were 72Mw plus 84 Mw SDS if run using six cpus for about 2 hours elapsed time and 18200 seconds user CPU plus about 520 seconds system CPU time. The second project needed only 43 Mw plus 84 Mw SDS for about 45 minutes elapsed time and 6820 seconds user CPU plus about 130 seconds system CPU time, as the total data volume was only one fifth of that in OSSE1. The experiment id is m2ab, the scripts are to be found in ~ stb/xmaster/aw9/aw9_bigjob and atovs_bigjob. Any changes to the standard cycle12 code are to be found in clearcase, branchname is ifs_stb_CY12_SFC when logged into hugin as stb. The unicos scripts were initially set up by PREPIFS, but needed to be changed to allow the batching of the production run. All action is user controllable, as all used modules are started from the testjob level (See PREPIFS documentation). The TOVS and ATOVS brightness temperatures are calculated using the fast radiativ transfer model RTTOV (Eyre, 1991). It is an integrate part of the ECMWF forecasting system. Temperature is interpolated above the 7 hPa highest model level for the realistic forecast of brightness temperatures of the TOVS and ATOVS stratospheric channels, using a linear regression scheme.

$$T(0.1-5hPa) = (\sum_{P=7hPa}^{400hPa} T(P) * coef(P)) + T_{offset}(0.1-5hPa)$$

The regression coefficients are to be found on ecfile -p /daa/unicos/ifs/excf72p1. This (in some cases inadequate) scheme has meanwhile been replaced by an interpolation of SSU data to specify the stratospheric temperatures (Tony McNally, private communication).

(delays in the project occured due to the constantly changing configuration of the IFS under development. We had to follow all stages of bugfixes and new releases from cycle 10 to cycle 12.) However, and although the CMA files are not a deliverable of the projects, they were stored under the ecfile directory /stb/t213/cmas. Filenames and contents are:

cNXID$DATE	nature run CMA files	Size [Mbytes]
c$N2ab$DATE	DWL, TOVS and conventional nature run observations	145
c$N2aa930306	DWL, high resolution nature run observations	145
c$N1aa$DATE	ASCAT and ATOVS nature run observations	28

$N = 01 to 25, $DATE = 930205 to 930306

3.4 The postprocessor

The postprocessor was developed in the same framework as the observation preprocessor to get a full handle on the observations in CMA format. It can be run to calculate statistics, apply an active or a neutral postprocessing and it includes the step to convert the observations into BuFR. In the production suite, it is switched to apply the active error model, calculate statistics and carry out bufferization. For TOVS and ATOVS data, the postprocessor includes the decision on the cloud-clearing route, on which different error characteristics are applied in the error model.

For DWL data, we simulated both detection error, which is dependent on instrument and atmosphere optical properties, and representativeness error. Detection error was derived from a universal profile of clear sky backscatter and transmission computed from nature run relative humidity, cloud cover, cloud water/ice content and a climatological temperature profile, providing a Signal-to-Noise Ratio (SNR) which is linked to the LOS wind error by the so called Zrnic equation. The detection error and representativeness error have been squared and added, and the square root has been taken to give the final standard deviaition of error for the Horizontal Line-Of-Sight wind (HLOS). See Stoffelen et. al. (1994) for more details.

ASCAT data are simulated from the 10m nature run wind after application of a gaussian error with a standard deviation of 1.6 m/s as described above, which is then transposed into σ_0 space using the transfer function CMOD4 (Stoffelen and Anderson, 1994) where a further wind speed dependent error and a constant representativeness error are applied (Roquet et. al., 1995).

For the other observation types, the statistics applied in the error model are deduced from experience in data assimilation (Andrew Lorenc, personal communication). Neutral postprocessing is a mere multiplication of the stored departure value from the preset 0 value with -1 and to change the position of this value at ncmomn to the position of the observed value at ncmvar, to allow for an inner consistency check of the nature run production. Rerunning neutral postprocessed CMA files through the same forecast period must supply a 0 cost value. This check was carried out and was successfull. Active postprocessing is the application of the error model to all observations.

Here is a brief description of the contents of a CMA body, after postprocessing.

1	ncmvnm	variable number
2	ncmppp	pressure, channel number for TOVS
3	ncmprl	azimuth angle against north, useless in non DWL case
4	ncmpob	gross error flag 1 for Gross error, 0 for Gauss error applied
5	ncmvar	value of variable
6	ncmomf	gross error range
7	ncmoma	standard deviation
8	ncmomi	probability of gross error
9	ncmomn	applied error
10	- 17	unchanged

The contents of a CMA body for ASCAT is slightly different:

1	ncmvnm	variable number = 200
2	ncmppp	pressure
3	ncmprl	missing indicator
4	ncmpob	gross error flag 1 for Gross error, 0 for Gauss error applied
5	ncmvar	Wind ff
6	ncmomf	nature run σ_0 fore beam (σ_0 from u/v + gaussian error of 1.6 m/s standard deviation)
7	ncmoma	simulated σ_0 fore beam
8	ncmomi	applied error
9	ncmomn	theoretical error = $\sigma_0 * \sqrt{(zkp^2 + .05^2)}$, zkp=.000644*(ff - 16.)^2
10	ncmoer	nature run σ_0 mid beam (σ_0 from u/v + gaussian error of 1.6 m/s standard deviation)
11	ncmrer	simulated σ_0 mid beam
12	ncmfge	applied error
13	ncmper	theoretical error = $\sigma_0 * \sqrt{(zkp^2 + .05^2)}$
15		nature run σ_0 aft beam (σ_0 from u/v + gaussian error of 1.6 m/s standard deviation)
16		simulated σ_0 aft beam
17		applied error
18		theoretical error = $\sigma_0 * \sqrt{(zkp^2 + .05^2)}$

Zkp is the geophysical error depending on wind speed as given in this empirical relation (Stoffelen and Anderson, 1995). However, and although the CMA files are not a deliverable of the projects, they were stored under the ecfile directory /stb/t213/cmas. Filenames and contents are:

pNXID$DATE	post processed CMA files,	Size [Mbytes]
pone$N2ab$DATE	DWL scenario I, TOVS and conv. observations	145
ptwo$N2ab$DATE	DWL scenario II, TOVS and conv. observations	145
p$N2aa930306	DWL scenario III high resolution observations	145
pers$N1aa$DATE	ASCAT and ATOVS observations	28

$N = 01 to 25, $DATE = 930205 to 930306

RMS statistics are computed and the provision for plotting is made. The plotting itself is carried out by slave jobs, submitted from the postprocessor.

Converting the data into BuFR allows an efficient way to store and retrieve huge data files. We achieved a compression rate of 1/40 and better, depending on data type. That is comparing CMA/BuFR. The workfield size for the bufferization is 40000 words. Data is collected by observation type, until this margin is reached, and then the lot is bufferized in one go. Fortunately, the reports of synthetic data always have the same length and contents per observation type (See appendix A).

3.5 The error model

The error $\mathcal{E}$ to each datum is determined by a standard deviation σ, a probability of gross error Pg and a gross error range Rg. Depending on a random number rand compared to Pg a random gaussian error with the mentioned standard deviation or a random value within the range Rg is added to the nature run value.

$$\mathcal{E} = \begin{cases} \mathcal{G} \quad * \ \sigma & ; \text{rand} \leq \text{PG} \\ Rg \quad *rand & ; \text{otherwise} \end{cases}$$

$\mathcal{G}$ is a function providing a random number from a gaussian distribution with a mean of zero and a standard deviation of one.

3.6 The OSSE data base access routines

The whole of the OSSE data base resides on ecfile,
/rdx/esa/dwl_osse/bufr$TYPE$DATE where $TYPE can be synop, tovs, atovs, dwl1, dwl2 and scatt. $DATE may be any date in the form YYMMDD from 930205 to 930306. Individual files can be requested for a particular date or the whole period.

file	contents	size [Mbytes]
bufrsynop*	SYNOP, AIREP, SATOB, DRIBU, TEMP, PILOT and PAOB	3
bufrtovs*	HIRS 1-8 and 10-19, SSU 1-3 and MSU 1-4	7
bufratovs*	HIRS 1-8 and 10-19, AMSU-A 1-15 and AMSU-B 1-5	9
bufrscatt*	ASCAT double swath σ_0	5
buf1dwl1*	high orbit, high energy DWL	18
buf1dwl2*	low orbit, high energy DWL	18
buf2dwl1*	high orbit, low energy DWL	18
buf2dwl2*	low orbit, low energy DWL	18
buf3dwl1930206	high resolution, high orbit DWL	8

The original BuFR tables can be found in the same directory. The total volume of this data base is ca. 2.888 Gbytes, split across 241 files. Each BuFR report contains the simulated data, the nature run values, the standard deviation of error σ, the probability of a gross error Pg, the gross error range Rg and a gross error tag. Access to the data base is granted by ESA. Applications should be sent to:

ESA/ESTEC
Director of the Earth Science Division
Dr. C. J. Readings
Postbus 299
NL-2200 AG Nordwijk
The Netherlands

BuFR decoding routines are needed and these can be provided, if necessary.

For our convenience, we put some effort into the development of an access interface to the buffered product. This interface allows you to request any particular data from any sort of bufr message, sort in time and write out to distinct files by observation type.
To prepare the OSSE data base to be used in the ECMWF assimilation system PREPAN:
The unicos script st_chopso, the subroutines buchopso.f and separex.f are to be found on ~ stb/prog-/bufr/.. In st_chopso, a namelist is set to address the time, area and kind of data requested. In buchopso.f, this data is expanded and screened, where separex.f allows to preset bufr descriptors for items to be selected from the bufr reports. Note, that preset values must exist in the data, there is no provision to take the next closest, or values from a range. (pages 36 ff., BUFR User guide and reference manual, Milan Dragosavac, 1994) Data that complies with the set selection rules, is

written out expanded to random access files to allow sorting. Currently sorting is in time, but that can easily be changed by choosing appropriate keyvalues. After sorting, new BuFR messages are created, complying with the set rules. Currently 52 reports per TOVS BuFR message, no quality control and only simulated data plus quality control are chosen for input to mkaof, the ECMWF translator from BuFR to COF. These messages are written out blocked and unblocked to have high flexibility on later data usage. Prepan expects the blocked file format.

The nature run model fields are stored in MARS as one 30-day forecast, starting 93020500, including all model fields every 6 hours over the whole period. When access is granted, contact R. Saunders at ECMWF (rsaunders@ecmwf.int) for further details of the data distribution procedures. A description of the nature run model fields stored in MARS is given in Stoffelen et.al. (1994).

4 Validation tasks

There are several aspects of the validation of this data set. They are briefly outlined below.

4.1 Orbit simulator

The simulated orbits are plotted and compared with true coverage plots if they exist. Figures 2 to 4 show examples of three scan patterns.

4.2 Observation preprocessor

Data coverage plots validate again the integrity of the simulated orbits and comparison with operational data coverage plots from COF and from CMA give further evidence in case of omitting data etc. These figures would appear very similar to Figures 37 and 38. Data counts plotted as time series as in Figure 5 allow monitoring of the continuity of the CMA production.

4.3 Nature run truth

After one day forecast and neutral postprocessing, the same set of CMA files underwent an identical forecast and the cost function for all observation types was 0. Standard deviation and mean plotted as profiles on standard pressure levels or per channel as in Figures 6 to 14 allow simple monitoring of the nature run. The solid line shows the standard deviation of simulated natural variability, the dotted line shows the mean over the domain, which is the Northern hemisphere on the left, the Tropics in the middle and the Southern hemisphere on the right hand side. The number on the right hand side of the individual graphs indicate the data count per level/channel/wind speed bin. The first 27 ATOVS channels are identical to the whole of the TOVS instrument channels. Hence, only ATOVS results are beeing presented. The figures refer to all data in a period of one day.

4.4 Postprocessor

To check the correct application of gaussian and gross errors in the error model for all observation types, the Root Mean Square (RMS) of the simulated errors are plotted against the standard deviations applied. Plots such as in Figures 15 to 31 are kept and archived for all observation types and each day of production and postprocessing. The number plotted on the right hand side of the individual graphs indicate the data count per pressure level/channel/wind speed bin, which are plotted on the left hand side of the graphs. The figures refer to all data in a period of one day in the Northern Hemisphere (left), the Tropics (middle) and the Southern Hemisphere (right). Solid lines are the RMSs, the dotted lines are their means, calculated as follows:

$$\text{RMS} = \sqrt{\sum x_i^2/N}$$
$$\text{mean} = \sum x_i/N$$

whereby x_i is successively the theoretical error standard deviations and the applied error and N is the data count per level/channel/wind speed bin in Figures 15 to 23.

The expectation is, that as long as the theoretical standard deviation of error applied in the error model is constant with atmospheric state, the RMS of the applied error is identical. The mean of the applied error shall always be zero.

Note, that the match between the solid lines is the better, the higher the data count, and that the mean of the applied gaussian error is very close to zero.

In Figure 17 the The SNR for the DWL varies with the optical properties of the penetrated column. As a consequence, the standard deviation of the theoretical error is not constant , but varies with the varying cloud and moisture field, throughout the troposphere. Above 170 hPa the match between the minimum theoretical error and the applied error is good, as due to the lack of backscattering cloud particles the SNR is always low (the amount of aerosol particles is constant at each vertical level). An exact match between the theoretical and applied errors is found after decomposition by SNR bins.

Figure 23 shows RMS statistics of gaussian error of brightness temperature in K, plotted over channel numbers (on the left hand side of the individual graphs) for ATOVS over land (top) and sea (bottom) for clear (left), partly cloudy (middle) and overcast (right) cases. Figure 21 shows RMS statistics in σ_0 space plotted over wind speed bins in m/s (left hand axis). Note, that the curve depicts nicely the applied error function $= \sigma_0 * \sqrt{(zkp^2 + .05^2)}$, zkp=.000644*(ff - 16.)^2 with the minimum at $\sigma_0 = 0.05$ and 16 m/s.

Figures 24 to 31 show statistics on the applied gross error. The notation is the same as for the applied gaussian error. The right hand dotted line indicates the gross error range, the dotted line arround 0 indicates the mean of the applied error and the solid lines are the RMS of the theoretical and of the applied gross error. The theoretical gross error RMS is the integral over the square of the applied error in the interval [-Rg/2, Rg/2] equal to Rg $*1/(2 * \sqrt{3})$. The observation count allows also a check on the correct application of the gross error probability, since adding up the observation counts of both errors does match the nature run data count for each pressure level or channel and cloud-clearing route. Note the very high gross error rate in Figure 26 for DWL in the stratosphere and upper troposphere due to the lack of backscattering particles, and the decreasing measurement error towards the lower troposphere. The accuracy of the DWL is about 2.5 times smaller than for TEMP. But if the availability of many measurements providing global coverage and high vertical resolution but with low accuracy is of less benefit for data assimilation than fewer accurate observations, only extended OSSEs can tell. A quick test assimilation of DWL data has proven beneficial over data void areas (Jean-Noel Thepaut, personal communication).

Simulated σ_0 plotted by wind speed bin and node number shows the correct variation of σ_0 with node number and hence incidence angle (Figure 32). Furthermore, you see, that the theoretical crosswind σ_0 as an upper and the theoretical downwind σ_0 as a lower margin frame the nature run σ_0, and that the simulated σ_0 are all inside or very close (closer than the applied error) to the framed area.

4.5 Final data base

Time series of single observation stations reveal the behavior of the nature run and the simulated value. Figure 35 shows surface pressure in Sule Skerry at 59.05 N and 4.24 W. The smooth line depicts the nature run and the spiky line depicts the simulated surface pressure. Long spikes indicate the application of gross errors.

The simulation of the TOVS and the ATOVS instrument allows an intercomparison of channels with similar weighting functions to be compared with single model level temperatures (Figure 33 and Figure 34), to develop a feeling for the gross patterns to be correct. The simulated ASCAT data were processed by the ERS1 retrieval module developed at ECMWF. A comparison of retrieved and input wind vectors to the CMOD4 transfer function validates the assumptions made on the ASCAT σ_0 error (Figure 36). This check was run on every day of ASCAT data to recognize any changes in the overall statistics over the period of the production.

A 6 hour time window around 6 UT, on the 5th of February 1993 was chosen from the BuFR product for an assimilation experiment. The simulated data from the original BuFR templates for observation types SYNOP, AIREP, SATOB, DRIBU, TEMP, PILOT and TOVS were extracted from the data base. Specially developed selection and sorting tools using explicitly BuFR software were applied to cut out only the wanted data, resort and chop in batches required to input the selected data into PRE(pare)SAT(ellite data) and MKAOF, for running the current ECMWF assimilation. Mkaof needed to be modernized to allow the new, faster C based I/O routines for unblocked (machine independent!) bitstream (BuFR) files to be used. The latest chop-and-sorting program creates input directly understood by the standard mkaof as implemented in prepan too (job ~ stb/prog/bufr/st_chopso). PRESAT needed to be changed slightly, because the instrument type codes in the simulated TOVS and ATOVS data are set to be 15 and 16 for the two different orbits and PRESAT expects these numbers to be 201 and 202 and to provide the satellite pressure levels to address the layers, PRESAT calculates the virtual layer temperatures for. This is usually provided by NESDIS deliverables.

The result of the first assimilation of the simulated data was the revelation of incorrect storage of the surface pressure for SYNOPs and the pressure of AIREPs. The omission of the BuFR quality control tag in TOVs and DWL BuFR data also caused some headache at the chop-and-sorting level. Here the assimilation of the simulated data has proven really fruitfull, because these deficiencies were not trackable in the validation applied to the CMA files. After improving on the conversion software from CMA to BuFR, the assimilation experiment was rerun. Hence the provision of the final BuFR templates in appendix A is necessary. They replace the BuFR templates given in the first final report. Two assimilations have been run using model cycle 12r1 and T106 resolution (Note! These are different from the nature run). Experiment ai4r assimilated 6 hours of original data from COF. Experiment ai4s assimilated 6 hours of simulated data from the OSSE data base. Now the result of the assimilation of the simulated data is to a very high degree similar to the assimilation of the original data from COF (Figures 37 to 41). These validation tasks increase our confidence, that the production of the OSSE data base has been conducted successfully. The data can be used for OSSE experiments and supply a nice training field for anyone developing data handling or assimilation systems.

5 Conclusion

For the first time, a comprehensive and complete data base for Observation System Simulation Experiments has been completed. This effort has not only provided data sets for three future satellite instruments and all conventional data with realistic data coverage and error characteristics, but also developed tools to make feasibility studies of other future satellite instruments possible. Any data assimilation centre can conduct the final impact assessments on DWL, ASCAT and ATOVS measurements using these data sets. Also, this coherent data set allows developers of assimilation- or data handling systems to check their schemes for internal consistency, so that they can detect developing systematic analysis errors during assimilation or other data processing.

Acknowledgement

This work was carried out under ESA contract numbers AO/1-2345/90/HGE-1 and 10921/94/NL/CN. Numerous people at ECMWF got envolved in this demanding task and we want to express our special gratitude to Per Undén, Draško Vasiljević and Jan Hassler to bring us closer to understanding the operating assimilation system, Graeme Kelly, Erik Anderson and Tony McNally for their support in TOVS data usage techniques, Milan Dragosavac for his aid in BuFR and not least Graham Holt to provide us with the necessary computing power.

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7 APPENDIX A: BuFR Templates

LAND SYNOP

1	001001	WMO BLOCK NUMBER	NUMERIC
2	001002	WMO STATION NUMBER	NUMERIC
3	002001	TYPE OF STATION	CODE TABLE
4	004001	YEAR	YEAR
5	004002	MONTH	MONTH
6	004003	DAY	DAY
7	004004	HOUR	HOUR
8	004005	MINUTE	MINUTE
9	005001	LATITUDE (HIGH ACCURACY)	DEGREE
10	006001	LONGITUDE (HIGH ACCURACY)	DEGREE
11	007001	HEIGHT OF STATION	M
12	010004	PRESSURE	PA
13	010051	PRESSURE REDUCED TO MEAN SEA LEVEL	PA
14	010061	3 HOUR PRESSURE CHANGE	PA
15	010063	CHARACTERISTIC OF PRESSURE TENDENCY	CODE TABLE
16	011011	WIND DIRECTION AT 10 M	DEGREE TRU
17	011012	WIND SPEED AT 10 M	M/S
18	012004	DRY BULB TEMPERATURE AT 2M	K
19	012006	DEW POINT TEMPERATURE AT 2M	K
20	013003	RELATIVE HUMIDITY	%
21	020001	HORIZONTAL VISIBILITY	M
22	020003	PRESENT WEATHER	CODE TABLE
23	020004	PAST WEATHER (1)	CODE TABLE
24	020005	PAST WEATHER (2)	CODE TABLE
25	020010	CLOUD COVER (TOTAL)	%
26	008002	VERTICAL SIGNIFICANCE (SURFACE OBSERVATI	CODE TABLE
27	020011	CLOUD AMOUNT	CODE TABLE
28	020013	HEIGHT OF BASE OF CLOUD	M
29	020012	CLOUD TYPE	CODE TABLE
30	020012	CLOUD TYPE	CODE TABLE
31	020012	CLOUD TYPE	CODE TABLE
32	008002	VERTICAL SIGNIFICANCE (SURFACE OBSERVATI	CODE TABLE
33	020011	CLOUD AMOUNT	CODE TABLE
34	020012	CLOUD TYPE	CODE TABLE
35	020013	HEIGHT OF BASE OF CLOUD	M
36	008002	VERTICAL SIGNIFICANCE (SURFACE OBSERVATI	CODE TABLE
37	020011	CLOUD AMOUNT	CODE TABLE
38	020012	CLOUD TYPE	CODE TABLE
39	020013	HEIGHT OF BASE OF CLOUD	M
40	008002	VERTICAL SIGNIFICANCE (SURFACE OBSERVATI	CODE TABLE
41	020011	CLOUD AMOUNT	CODE TABLE
42	020012	CLOUD TYPE	CODE TABLE
43	020013	HEIGHT OF BASE OF CLOUD	M
44	008002	VERTICAL SIGNIFICANCE (SURFACE OBSERVATI	CODE TABLE
45	020011	CLOUD AMOUNT	CODE TABLE
46	020012	CLOUD TYPE	CODE TABLE
47	020013	HEIGHT OF BASE OF CLOUD	M
48	013023	TOTAL PRECIPITATION PAST 24 HOURS	KG/M**2
49	013013	TOTAL SNOW DEPTH	M
50	222000	QUALITY INFORMATION FOLLOW	
51	031031	DATA PRESENT INDICATOR	NUMERIC

100	001031	GENERATING CENTRE	CODE TABLE
101	001201	GENERATING APPLICATION	CODE TABLE
102	033007	% CONFIDENCE	NUMERIC
151	235000	CANCEL BACKWARD DATA REFERENCE	
152	001031	GENERATING CENTRE	CODE TABLE
153	001201	GENERATING APPLICATION	CODE TABLE
154	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
155	010004	PRESSURE	PA
156	010051	PRESSURE REDUCED TO MEAN SEA LEVEL	PA
157	011192	U - COMPONENT AT 10 M	M/S
158	011193	V - COMPONENT AT 10 M	M/S
159	012004	DRY BULB TEMPERATURE AT 2M	K
160	013003	RELATIVE HUMIDITY	%
161	224000	FIRST ORDER STATISTICS FOLLOW	
162	236000	BACKWARD REFERENCE BIT MAP	
163	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
164	031031	DATA PRESENT INDICATOR	NUMERIC
170	001031	GENERATING CENTRE	CODE TABLE
171	001201	GENERATING APPLICATION	CODE TABLE
172	008023	FIRST ORDER STATISTICS (STD)	CODE TABLE
173	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
174	224255	FIRST ORDER STATISTICS VALUE MARKER	
180	224000	FIRST ORDER STATISTICS FOLLOW	
181	237000	USE PREVIOUSLY DEFINED BIT MAP	
182	001031	GENERATING CENTRE	CODE TABLE
183	001201	GENERATING APPLICATION	CODE TABLE
184	008023	FIRST ORDER STATISTICS (RG)	CODE TABLE
185	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
186	224255	FIRST ORDER STATISTICS VALUE MARKER	
192	222000	QUALITY INFORMATION FOLLOW	
193	237000	USE PREVIOUSLY DEFINED BIT MAP	
194	001031	GENERATING CENTRE	CODE TABLE
195	001201	GENERATING APPLICATION	CODE TABLE
196	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
197	033241	GROSS ERROR PROBABILITY	NUMERIC
203	222000	QUALITY INFORMATION FOLLOW	
204	237000	USE PREVIOUSLY DEFINED BIT MAP	
205	001031	GENERATING CENTRE	CODE TABLE
206	001201	GENERATING APPLICATION	CODE TABLE
207	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
208	033242	GROSS ERROR INDICATOR	CODE TABLE

		SHIP SYNOP	
1	001011	SHIP'S CALL SIGN	CCITTIA5
2	001012	DIRECTION OF MOTION OF MOVING OBSERVING	DEGREE TRU
3	001013	SPEED OF MOTION OF MOVING OBSERVING PLAT	M/S
4	002001	TYPE OF STATION	CODE TABLE
5	004001	YEAR	YEAR
6	004002	MONTH	MONTH
7	004003	DAY	DAY
8	004004	HOUR	HOUR
9	004005	MINUTE	MINUTE
10	005002	LATITUDE (COARSE ACCURACY)	DEGREE
11	006002	LONGITUDE (COARSE ACCURACY)	DEGREE
12	010004	PRESSURE	PA
13	010051	PRESSURE REDUCED TO MEAN SEA LEVEL	PA
14	010061	3 HOUR PRESSURE CHANGE	PA
15	010063	CHARACTERISTIC OF PRESSURE TENDENCY	CODE TABLE
16	011011	WIND DIRECTION AT 10 M	DEGREE TRU
17	011012	WIND SPEED AT 10 M	M/S
18	012004	DRY BULB TEMPERATURE AT 2M	K
19	012006	DEW POINT TEMPERATURE AT 2M	K
20	013003	RELATIVE HUMIDITY	%
21	020001	HORIZONTAL VISIBILITY	M
22	020003	PRESENT WEATHER	CODE TABLE
23	020004	PAST WEATHER (1)	CODE TABLE
24	020005	PAST WEATHER (2)	CODE TABLE
25	020010	CLOUD COVER (TOTAL)	%
26	008002	VERTICAL SIGNIFICANCE (SURFACE OBSERVATI	CODE TABLE
27	020011	CLOUD AMOUNT	CODE TABLE
28	020013	HEIGHT OF BASE OF CLOUD	M
29	020012	CLOUD TYPE	CODE TABLE
30	020012	CLOUD TYPE	CODE TABLE
31	020012	CLOUD TYPE	CODE TABLE
32	022042	SEA TEMPERATURE	K
33	012005	WET BULB TEMPERATURE AT 2M	K
34	222000	QUALITY INFORMATION FOLLOW	
35	031031	DATA PRESENT INDICATOR	NUMERIC
68	001031	GENERATING CENTRE	CODE TABLE
69	001201	GENERATING APPLICATION	CODE TABLE
70	033007	% CONFIDENCE	NUMERIC
103	235000	CANCEL BACKWARD DATA REFERENCE	
104	001031	GENERATING CENTRE	CODE TABLE
105	001201	GENERATING APPLICATION	CODE TABLE
106	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
107	010004	PRESSURE	PA
108	011192	U - COMPONENT AT 10 M	M/S
109	011193	V - COMPONENT AT 10 M	M/S
110	012004	DRY BULB TEMPERATURE AT 2M	K
111	013003	RELATIVE HUMIDITY	%
112	224000	FIRST ORDER STATISTICS FOLLOW	
113	236000	BACKWARD REFERENCE BIT MAP	
114	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
115	031031	DATA PRESENT INDICATOR	NUMERIC
120	001031	GENERATING CENTRE	CODE TABLE
121	001201	GENERATING APPLICATION	CODE TABLE

122	008023	FIRST ORDER STATISTICS	CODE TABLE
123	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
124	224255	FIRST ORDER STATISTICS VALUE MARKER	
129	224000	FIRST ORDER STATISTICS FOLLOW	
130	237000	USE PREVIOUSLY DEFINED BIT MAP	
131	001031	GENERATING CENTRE	CODE TABLE
132	001201	GENERATING APPLICATION	CODE TABLE
133	008023	FIRST ORDER STATISTICS	CODE TABLE
134	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
135	224255	FIRST ORDER STATISTICS VALUE MARKER	
140	222000	QUALITY INFORMATION FOLLOW	
141	237000	USE PREVIOUSLY DEFINED BIT MAP	
142	001031	GENERATING CENTRE	CODE TABLE
143	001201	GENERATING APPLICATION	CODE TABLE
144	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
145	033241	GROSS ERROR PROBABILITY	NUMERIC
150	222000	QUALITY INFORMATION FOLLOW	
151	237000	USE PREVIOUSLY DEFINED BIT MAP	
152	001031	GENERATING CENTRE	CODE TABLE
153	001201	GENERATING APPLICATION	CODE TABLE
154	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
155	033242	GROSS ERROR INDICATOR	CODE TABLE

AIREP

1	001006	AIRCRAFT IDENTIFIER	CCITTIA5
2	001008	AIRCRAFT REGISTRATION NUMBER	CCITTIA5
3	002061	AIRCRAFT NAVIGATIONAL SYSTEM	CODE TABLE
4	002062	TYPE OF AIRCRAFT DATA RELAY SYSTEM	CODE TABLE
5	002002	TYPE OF INSTRUMENTATION FOR WIND MEASUREMENT	CODE TABLE
6	002005	PRECISION OF TEMPERATURE OBSERVATION	CODE TABLE
7	002070	ORIGINAL SPECIFICATION OF LAT/LON	CODE TABLE
8	002063	AIRCRAFT ROLL ANGLE	CODE TABLE
9	002001	TYPE OF STATION	CODE TABLE
10	004001	YEAR	YEAR
11	004002	MONTH	MONTH
12	004003	DAY	DAY
13	004004	HOUR	HOUR
14	004005	MINUTE	MINUTE
15	005001	LATITUDE (COARSE ACCURACY)	DEGREE
16	006001	LONGITUDE (COARSE ACCURACY)	DEGREE
17	008004	PHASE OF AIRCRAFT FLIGHT	CODE TABLE
18	007004	PRESSURE	HPA
19	008021	TIME SIGNIFICANCE	HPA
20	011001	WIND DIRECTION	DEGREE TRU
21	011002	WIND SPEED	M/S
22	011031	DEGREE OF TURBULENCE	CODE TABLE
23	011034	VERTICAL GUST VELOCITY	M
24	011035	VERTICAL GUST ACCELERATION	M
25	012001	TEMPERATURE/DRY BULB TEMPERATURE	K
26	012003	DEW POINT TEMPERATURE	K
27	013003	RELATIVE HUMIDITY	%
28	020041	AIRFRAME ICING	CODE TABLE
29	222000	QUALITY INFORMATION FOLLOW	
30	031031	DATA PRESENT INDICATOR	NUMERIC

58	001031	GENERATING CENTRE	CODE TABLE
59	001201	GENERATING APPLICATION	CODE TABLE
60	033007	% CONFIDENCE	NUMERIC
88	235000	CANCEL BACKWARD DATA REFERENCE	
89	001031	GENERATING CENTRE	CODE TABLE
90	001201	GENERATING APPLICATION	CODE TABLE
91	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
92	007004	PRESSURE	PA
93	011003	U-COMPONENT	M/S
94	011004	V-COMPONENT	M/S
95	012001	TEMPERATURE/DRY BULB TEMPERATURE	K
96	013003	RELATIVE HUMIDITY	%
97	224000	FIRST ORDER STATISTICS FOLLOW	
98	236000	BACKWARD REFERENCE BIT MAP	
99	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
100	031031	DATA PRESENT INDICATOR	NUMERIC
105	001031	GENERATING CENTRE	CODE TABLE
106	001201	GENERATING APPLICATION	CODE TABLE
107	008023	FIRST ORDER STATISTICS	CODE TABLE
108	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
109	224255	FIRST ORDER STATISTICS VALUE MARKER	
114	224000	FIRST ORDER STATISTICS FOLLOW	
115	237000	USE PREVIOUSLY DEFINED BIT MAP	
116	001031	GENERATING CENTRE	CODE TABLE
117	001201	GENERATING APPLICATION	CODE TABLE
118	008023	FIRST ORDER STATISTICS	CODE TABLE
119	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
120	224255	FIRST ORDER STATISTICS VALUE MARKER	
125	222000	QUALITY INFORMATION FOLLOW	
126	237000	USE PREVIOUSLY DEFINED BIT MAP	
127	001031	GENERATING CENTRE	CODE TABLE
128	001201	GENERATING APPLICATION	CODE TABLE
129	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
130	033241	GROSS ERROR PROBABILITY	NUMERIC
135	222000	QUALITY INFORMATION FOLLOW	
136	237000	USE PREVIOUSLY DEFINED BIT MAP	
137	001031	GENERATING CENTRE	CODE TABLE
138	001201	GENERATING APPLICATION	CODE TABLE
139	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
140	033242	GROSS ERROR INDICATOR	CODE TABLE

SATOB

1	001007	SATELLITE IDENTIFIER	CODE TABLE
2	002023	CLOUD MOTION COMPUTATIONAL METHOD	CODE TABLE
3	004001	YEAR	YEAR
4	004002	MONTH	MONTH
5	004003	DAY	DAY
6	004004	HOUR	HOUR
7	004005	MINUTE	MINUTE
8	004006	SECOND	SECOND

9	005001	LATITUDE (HIGH ACCURACY)	DEGREE
10	006001	LONGITUDE (HIGH ACCURACY)	DEGREE
11	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
12	010004	PRESSURE	PA
13	012001	TEMPERATURE/DRY BULB TEMPERATURE	K
14	011001	WIND DIRECTION	DEGREE TRU
15	011002	WIND SPEED	M/S
16	222000	QUALITY INFORMATION FOLLOW	
17	031031	DATA PRESENT INDICATOR	NUMERIC
32	001031	GENERATING CENTRE	CODE TABLE
33	001201	GENERATING APPLICATION	CODE TABLE
34	033007	% CONFIDENCE	NUMERIC
49	235000	CANCEL BACKWARD DATA REFERENCE	
50	001031	GENERATING CENTRE	CODE TABLE
51	001201	GENERATING APPLICATION	CODE TABLE
52	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
53	011003	U-COMPONENT	M/S
54	011004	V-COMPONENT	M/S
55	010004	PRESSURE	PA
56	012001	TEMPERATURE/DRY BULB TEMPERATURE	K
57	224000	FIRST ORDER STATISTICS FOLLOW	
58	236000	BACKWARD REFERENCE BIT MAP	
59	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
60	031031	DATA PRESENT INDICATOR	NUMERIC
64	001031	GENERATING CENTRE	CODE TABLE
65	001201	GENERATING APPLICATION	CODE TABLE
66	008023	FIRST ORDER STATISTICS	CODE TABLE
67	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
68	224255	FIRST ORDER STATISTICS VALUE MARKER	
72	224000	FIRST ORDER STATISTICS FOLLOW	
73	237000	USE PREVIOUSLY DEFINED BIT MAP	
74	001031	GENERATING CENTRE	CODE TABLE
75	001201	GENERATING APPLICATION	CODE TABLE
76	008023	FIRST ORDER STATISTICS	CODE TABLE
77	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
78	224255	FIRST ORDER STATISTICS VALUE MARKER	
82	222000	QUALITY INFORMATION FOLLOW	
83	237000	USE PREVIOUSLY DEFINED BIT MAP	
84	001031	GENERATING CENTRE	CODE TABLE
85	001201	GENERATING APPLICATION	CODE TABLE
86	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
87	033241	GROSS ERROR PROBABILITY	NUMERIC
91	222000	QUALITY INFORMATION FOLLOW	
92	237000	USE PREVIOUSLY DEFINED BIT MAP	
93	001031	GENERATING CENTRE	CODE TABLE
94	001201	GENERATING APPLICATION	CODE TABLE
95	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
96	033242	GROSS ERROR INDICATOR	CODE TABLE

		DRIBU	
1	001005	BUOY/PLATFORM IDENTIFIER	NUMERIC
2	001012	DIRECTION OF MOTION OF MOVING OBSERVING	DEGREE TRU
3	001013	SPEED OF MOTION OF MOVING OBSERVING PLAT	M/S
4	002001	TYPE OF STATION	CODE TABLE
5	004001	YEAR	YEAR
6	004002	MONTH	MONTH
7	004003	DAY	DAY
8	004004	HOUR	HOUR
9	004005	MINUTE	MINUTE
10	005002	LATITUDE (COARSE ACCURACY)	DEGREE
11	006002	LONGITUDE (COARSE ACCURACY)	DEGREE
12	010004	PRESSURE	PA
13	010051	PRESSURE REDUCED TO MEAN SEA LEVEL	PA
14	010061	3 HOUR PRESSURE CHANGE	PA
15	010063	CHARACTERISTIC OF PRESSURE TENDENCY	CODE TABLE
16	011011	WIND DIRECTION AT 10 M	DEGREE TRU
17	011012	WIND SPEED AT 10 M	M/S
18	012004	DRY BULB TEMPERATURE AT 2M	K
19	012006	DEW POINT TEMPERATURE AT 2M	K
20	013003	RELATIVE HUMIDITY	%
21	020001	HORIZONTAL VISIBILITY	M
22	020003	PRESENT WEATHER	CODE TABLE
23	020004	PAST WEATHER (1)	CODE TABLE
24	020005	PAST WEATHER (2)	CODE TABLE
25	020010	CLOUD COVER (TOTAL)	%
26	008002	VERTICAL SIGNIFICANCE (SURFACE OBSERVATI	CODE TABLE
27	020011	CLOUD AMOUNT	CODE TABLE
28	020013	HEIGHT OF BASE OF CLOUD	M
29	020012	CLOUD TYPE	CODE TABLE
30	020012	CLOUD TYPE	CODE TABLE
31	020012	CLOUD TYPE	CODE TABLE
32	022042	SEA TEMPERATURE	K
33	222000	QUALITY INFORMATION FOLLOW	
34	031031	DATA PRESENT INDICATOR	NUMERIC
66	001031	GENERATING CENTRE	CODE TABLE
67	001201	GENERATING APPLICATION	CODE TABLE
68	033007	% CONFIDENCE	NUMERIC
100	235000	CANCEL BACKWARD DATA REFERENCE	
101	001031	GENERATING CENTRE	CODE TABLE
102	001201	GENERATING APPLICATION	CODE TABLE
103	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
104	010004	PRESSURE	PA
105	011192	U - COMPONENT AT 10 M	M/S
106	011193	V - COMPONENT AT 10 M	M/S
107	012004	DRY BULB TEMPERATURE AT 2M	K
108	013003	RELATIVE HUMIDITY	%
109	224000	FIRST ORDER STATISTICS FOLLOW	
110	236000	BACKWARD REFERENCE BIT MAP	
111	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
112	031031	DATA PRESENT INDICATOR	NUMERIC
117	001031	GENERATING CENTRE	CODE TABLE
118	001201	GENERATING APPLICATION	CODE TABLE
119	008023	FIRST ORDER STATISTICS	CODE TABLE
120	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
121	224255	FIRST ORDER STATISTICS VALUE MARKER	

126	224000	FIRST ORDER STATISTICS FOLLOW	
127	237000	USE PREVIOUSLY DEFINED BIT MAP	
128	001031	GENERATING CENTRE	CODE TABLE
129	001201	GENERATING APPLICATION	CODE TABLE
130	008023	FIRST ORDER STATISTICS	CODE TABLE
135	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
136	224255	FIRST ORDER STATISTICS VALUE MARKER	
137	222000	QUALITY INFORMATION FOLLOW	
138	237000	USE PREVIOUSLY DEFINED BIT MAP	
139	001031	GENERATING CENTRE	CODE TABLE
140	001201	GENERATING APPLICATION	CODE TABLE
141	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
142	033241	GROSS ERROR PROBABILITY	NUMERIC
147	222000	QUALITY INFORMATION FOLLOW	
148	237000	USE PREVIOUSLY DEFINED BIT MAP	
149	001031	GENERATING CENTRE	CODE TABLE
150	001201	GENERATING APPLICATION	CODE TABLE
151	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
152	033242	GROSS ERROR INDICATOR	CODE TABLE

TEMP

1	001001	WMO BLOCK NUMBER	NUMERIC
2	001002	WMO STATION NUMBER	NUMERIC
3	002011	RADIOSONDE TYPE	CODE TABLE
4	002012	RADIOSONDE COMPUTATIONAL METHOD	CODE TABLE
5	004001	YEAR	YEAR
6	004002	MONTH	MONTH
7	004003	DAY	DAY
8	004004	HOUR	HOUR
9	004005	MINUTE	MINUTE
10	005001	LATITUDE (HIGH ACCURACY)	DEGREE
11	006001	LONGITUDE (HIGH ACCURACY)	DEGREE
12	007001	HEIGHT OF STATION	M
13	020010	CLOUD COVER (TOTAL)	%
14	008002	VERTICAL SIGNIFICANCE (SURFACE OBSERVATI	CODE TABLE
15	020011	CLOUD AMOUNT	CODE TABLE
16	020013	HEIGHT OF BASE OF CLOUD	M
17	020012	CLOUD TYPE	CODE TABLE
18	020012	CLOUD TYPE	CODE TABLE
19	020012	CLOUD TYPE	CODE TABLE
20	031001	DELAYED DESCRIPTOR REPLICATION FACTOR	NUMERIC
21	007004	PRESSURE	PA
22	008001	VERTICAL SOUNDING SIGNIFICANCE	FLAG TABLE
23	010003	GEOPOTENTIAL	M**2/S**2
24	012001	TEMPERATURE/DRY BULB TEMPERATURE	K
25	012003	DEW POINT TEMPERATURE	K
26	011001	WIND DIRECTION	DEGREE TRU
27	011002	WIND SPEED	M/S
238	222000	QUALITY INFORMATION FOLLOW	
239	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
240	031031	DATA PRESENT INDICATOR	NUMERIC
477	001201	GENERATING CENTRE	CODE TABLE
478	001201	GENERATING APPLICATION	CODE TABLE
479	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
480	033007	% CONFIDENCE	NUMERIC

717	235000	CANCEL BACKWARD DATA REFERENCE	
718	001031	GENERATING CENTRE	CODE TABLE
719	001201	GENERATING APPLICATION	CODE TABLE
720	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
721	007004	PRESSURE	PA
722	010003	GEOPOTENTIAL	M**2/S**2
723	012001	TEMPERATURE/DRY BULB TEMPERATURE	K
724	013003	RELATIVE HUMIDITY	%
725	011003	U-COMPONENT	M/S
726	011004	V-COMPONENT	M/S
907	224000	FIRST ORDER STATISTICS FOLLOW	
908	236000	BACKWARD REFERENCE BIT MAP	
909	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
910	031031	DATA PRESENT INDICATOR	NUMERIC
1096	001031	GENERATING CENTRE	CODE TABLE
1097	001201	GENERATING APPLICATION	CODE TABLE
1098	008023	FIRST ORDER STATISTICS	CODE TABLE
1099	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
1100	224255	FIRST ORDER STATISTICS VALUE MARKER	
1286	224000	FIRST ORDER STATISTICS FOLLOW	
1287	237000	USE PREVIOUSLY DEFINED BIT MAP	
1288	001031	GENERATING CENTRE	CODE TABLE
1289	001201	GENERATING APPLICATION	CODE TABLE
1290	008023	FIRST ORDER STATISTICS	CODE TABLE
1291	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
1292	224255	FIRST ORDER STATISTICS VALUE MARKER	
1478	222000	QUALITY INFORMATION FOLLOW	
1479	237000	USE PREVIOUSLY DEFINED BIT MAP	
1480	001031	GENERATING CENTRE	CODE TABLE
1481	001201	GENERATING APPLICATION	CODE TABLE
1482	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
1483	033241	GROSS ERROR PROBABILITY	NUMERIC
1669	222000	QUALITY INFORMATION FOLLOW	
1670	237000	USE PREVIOUSLY DEFINED BIT MAP	
1671	001031	GENERATING CENTRE	CODE TABLE
1672	001201	GENERATING APPLICATION	CODE TABLE
1673	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
1674	033242	GROSS ERROR INDICATOR	CODE TABLE

PILOT

1	001001	WMO BLOCK NUMBER	NUMERIC
2	001002	WMO STATION NUMBER	NUMERIC
3	002011	RADIOSONDE TYPE	CODE TABLE
4	002012	RADIOSONDE COMPUTATIONAL METHOD	CODE TABLE
5	004001	YEAR	YEAR
6	004002	MONTH	MONTH
7	004003	DAY	DAY
8	004004	HOUR	HOUR
9	004005	MINUTE	MINUTE
10	005001	LATITUDE (HIGH ACCURACY)	DEGREE
11	006001	LONGITUDE (HIGH ACCURACY)	DEGREE
12	007001	HEIGHT OF STATION	M
13	031001	DELAYED DESCRIPTOR REPLICATION FACTOR	NUMERIC
14	007004	PRESSURE	PA
15	008001	VERTICAL SOUNDING SIGNIFICANCE	FLAG TABLE

16	010003	GEOPOTENTIAL	M**2/S**2
17	011001	WIND DIRECTION	DEGREE TRU
18	011002	WIND SPEED	M/S
169	222000	QUALITY INFORMATION FOLLOW	
170	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
171	031031	DATA PRESENT INDICATOR	NUMERIC
339	001031	GENERATING CENTRE	CODE TABLE
340	001201	GENERATING APPLICATION	CODE TABLE
341	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
342	033007	% CONFIDENCE	NUMERIC
510	235000	CANCEL BACKWARD DATA REFERENCE	
511	001031	GENERATING CENTRE	CODE TABLE
512	001201	GENERATING APPLICATION	CODE TABLE
513	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
514	007004	PRESSURE	PA
515	011003	U-COMPONENT	M/S
516	011004	V-COMPONENT	M/S
607	224000	FIRST ORDER STATISTICS FOLLOW	
608	236000	BACKWARD REFERENCE BIT MAP	
609	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
610	031031	DATA PRESENT INDICATOR	NUMERIC
703	001031	GENERATING CENTRE	CODE TABLE
704	001201	GENERATING APPLICATION	CODE TABLE
705	008023	FIRST ORDER STATISTICS	CODE TABLE
706	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
707	224255	FIRST ORDER STATISTICS VALUE MARKER	
800	224000	FIRST ORDER STATISTICS FOLLOW	
801	237000	USE PREVIOUSLY DEFINED BIT MAP	
802	001031	GENERATING CENTRE	CODE TABLE
803	001201	GENERATING APPLICATION	CODE TABLE
804	008023	FIRST ORDER STATISTICS	CODE TABLE
805	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
806	224255	FIRST ORDER STATISTICS VALUE MARKER	
899	222000	QUALITY INFORMATION FOLLOW	
900	237000	USE PREVIOUSLY DEFINED BIT MAP	
901	001031	GENERATING CENTRE	CODE TABLE
902	001201	GENERATING APPLICATION	CODE TABLE
903	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
904	033241	GROSS ERROR PROBABILITY	NUMERIC
997	222000	QUALITY INFORMATION FOLLOW	
998	237000	USE PREVIOUSLY DEFINED BIT MAP	
999	001031	GENERATING CENTRE	CODE TABLE
1000	001201	GENERATING APPLICATION	CODE TABLE
1001	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
1002	033242	GROSS ERROR INDICATOR	CODE TABLE

TOVS/ATOVS

1	001007	SATELLITE IDENTIFIER	CODE TABLE
2	004001	YEAR	YEAR
3	004002	MONTH	MONTH
4	004003	DAY	DAY
5	004004	HOUR	HOUR
6	004005	MINUTE	MINUTE
7	004006	SECOND	SECOND
8	005002	LATITUDE (COARSE ACCURACY)	DEGREE
9	006002	LONGITUDE (COARSE ACCURACY)	DEGREE
10	007022	SOLAR ELEVATION	DEGREE
11	002025	SATELLITE CHANNEL(S) USED IN COMPUTATION	FLAG TABLE
12	002022	SATELLITE DATA PROCESSING TECHNIQUE USED	FLAG TABLE
13	027020	SATELLITE LOCATION COUNTER	NUMERIC
14	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
15	015001	OZON	DOBSON
16	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
17	010004	PRESSURE	PA
18	020010	CLOUD COVER (TOTAL)	%
19	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
20	008012	LAND/SEA QUALIFIER	CODE TABLE
21	010001	HEIGHT OF LAND SURFACE	M
22	012061	SKIN TEMPERATURE	K
23	010004	PRESSURE	PA
24	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
25	007004	PRESSURE	PA
26	007004	PRESSURE	PA
27	012007	VIRTUAL TEMPERATURE	K
70	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
71	007004	PRESSURE	PA
72	007004	PRESSURE	PA
73	013016	PRECIPITABLE WATER	KG/M**2
80	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
81	012062	EQUIVALENT BLACK BODY TEMPERATURE	K
108	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
109	010004	PRESSURE	PA
110	012001	TEMPERATURE/DRY BULB TEMPERATURE	K
111	222000	QUALITY INFORMATION FOLLOW	
112	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
113	031031	DATA PRESENT INDICATOR	NUMERIC
222	001031	GENERATING CENTRE	CODE TABLE
223	001201	GENERATING APPLICATION	CODE TABLE
224	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
225	033007	% CONFIDENCE	NUMERIC
335	235000	CANCEL BACKWARD DATA REFERENCE	
336	001031	GENERATING CENTRE	CODE TABLE
337	001201	GENERATING APPLICATION	CODE TABLE
338	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
339	012062	EQUIVALENT BLACK BODY TEMPERATURE	K
366	224000	FIRST ORDER STATISTICS FOLLOW	
367	236000	BACKWARD REFERENCE BIT MAP	
368	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
369	031031	DATA PRESENT INDICATOR	NUMERIC
396	001031	GENERATING CENTRE	CODE TABLE
397	001201	GENERATING APPLICATION	CODE TABLE
398	008023	FIRST ORDER STATISTICS	CODE TABLE

399	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
400	224255	FIRST ORDER STATISTICS VALUE MARKER	
428	237000	USE PREVIOUSLY DEFINED BIT MAP	
429	001031	GENERATING CENTRE	CODE TABLE
430	001201	GENERATING APPLICATION	CODE TABLE
431	008023	FIRST ORDER STATISTICS	CODE TABLE
432	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
433	224255	FIRST ORDER STATISTICS VALUE MARKER	
460	222000	QUALITY INFORMATION FOLLOW	
461	237000	USE PREVIOUSLY DEFINED BIT MAP	
462	001031	GENERATING CENTRE	CODE TABLE
463	001201	GENERATING APPLICATION	CODE TABLE
464	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
465	033241	GROSS ERROR PROBABILITY	NUMERIC
492	222000	QUALITY INFORMATION FOLLOW	
493	237000	USE PREVIOUSLY DEFINED BIT MAP	
494	001031	GENERATING CENTRE	CODE TABLE
495	001201	GENERATING APPLICATION	CODE TABLE
496	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
497	033242	GROSS ERROR INDICATOR	CODE TABLE

PAOBS

1	004001	YEAR	YEAR
2	004002	MONTH	MONTH
3	004003	DAY	DAY
4	004004	HOUR	HOUR
5	004005	MINUTE	MINUTE
6	005001	LATITUDE (HIGH ACCURACY)	DEGREE
7	006001	LONGITUDE (HIGH ACCURACY)	DEGREE
8	010051	PRESSURE REDUCED TO MEAN SEA LEVEL	PA
9	010004	PRESSURE	PA
10	010004	PRESSURE	PA
11	012007	VIRTUAL TEMPERATURE	K
12	222000	QUALITY INFORMATION FOLLOW	
13	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
14	031031	DATA PRESENT INDICATOR	NUMERIC
25	001031	GENERATING CENTRE	CODE TABLE
26	001201	GENERATING APPLICATION	CODE TABLE
27	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
28	033007	% CONFIDENCE	NUMERIC
39	235000	CANCEL BACKWARD DATA REFERENCE	
40	001031	GENERATING CENTRE	CODE TABLE
41	001201	GENERATING APPLICATION	CODE TABLE
42	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
43	010004	PRESSURE	PA
44	012001	TEMPERATURE/DRY BULB TEMPERATURE	K
45	224000	FIRST ORDER STATISTICS FOLLOW	
46	236000	BACKWARD REFERENCE BIT MAP	
47	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
48	031031	DATA PRESENT INDICATOR	NUMERIC
50	001031	GENERATING CENTRE	CODE TABLE
51	001201	GENERATING APPLICATION	CODE TABLE
52	008023	FIRST ORDER STATISTICS	CODE TABLE
53	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
54	224255	FIRST ORDER STATISTICS VALUE MARKER	

56	224000	FIRST ORDER STATISTICS FOLLOW	
57	237000	USE PREVIOUSLY DEFINED BIT MAP	
58	001031	GENERATING CENTRE	CODE TABLE
59	001201	GENERATING APPLICATION	CODE TABLE
60	008023	FIRST ORDER STATISTICS	CODE TABLE
61	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
62	224255	FIRST ORDER STATISTICS VALUE MARKER	
64	222000	QUALITY INFORMATION FOLLOW	
65	237000	USE PREVIOUSLY DEFINED BIT MAP	
66	001031	GENERATING CENTRE	CODE TABLE
67	001201	GENERATING APPLICATION	CODE TABLE
68	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
69	033241	GROSS ERROR PROBABILITY	NUMERIC
71	222000	QUALITY INFORMATION FOLLOW	
72	237000	USE PREVIOUSLY DEFINED BIT MAP	
73	001031	GENERATING CENTRE	CODE TABLE
74	001201	GENERATING APPLICATION	CODE TABLE
75	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
76	033242	GROSS ERROR INDICATOR	CODE TABLE

DWL

1	001205	SATELLITE IDENTIFIER	CODE TABLE
2	002201	SIMULATED SATELLITE INSTRUMENT	FLAG TABLE
3	002022	SATELLITE DATA PROCESSING TECHNIQUE USED	FLAG TABLE
4	004001	YEAR	YEAR
5	004002	MONTH	MONTH
6	004003	DAY	DAY
7	004004	HOUR	HOUR
8	004005	MINUTE	MINUTE
9	004006	SECOND	SECOND
10	005002	LATITUDE (COARSE ACCURACY)	DEGREE
11	006002	LONGITUDE (COARSE ACCURACY)	DEGREE
12	007021	ELEVATION	DEGREE
13	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
14	007004	PRESSURE	PA
15	005021	BEARING OR AZIMUTH	DEGREE TRU
16	011201	HORIZONTAL LINE OF SIGHT COMPONENT	M/S
86	222000	QUALITY INFORMATION FOLLOW	
87	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
88	031031	DATA PRESENT INDICATOR	NUMERIC
172	001031	GENERATING CENTRE	CODE TABLE
173	001201	GENERATING APPLICATION	CODE TABLE
174	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
175	033007	% CONFIDENCE	NUMERIC
259	235000	CANCEL BACKWARD DATA REFERENCE	
260	001031	GENERATING CENTRE	CODE TABLE
261	001201	GENERATING APPLICATION	CODE TABLE
262	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
263	007004	PRESSURE	PA
264	011201	HORIZONTAL LINE OF SIGHT COMPONENT	M/S
265	013001	SPECIFIC HUMIDITY	KG/KG
266	013201	CLOUD LIQUID WATER	KG/KG
267	020010	CLOUD COVER (TOTAL)	%
383	224000	FIRST ORDER STATISTICS FOLLOW	
384	236000	BACKWARD REFERENCE BIT MAP	

385	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
386	031031	DATA PRESENT INDICATOR	NUMERIC
506	001031	GENERATING CENTRE	CODE TABLE
507	001201	GENERATING APPLICATION	CODE TABLE
508	008023	FIRST ORDER STATISTICS	CODE TABLE
509	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
510	224255	FIRST ORDER STATISTICS VALUE MARKER	
630	224000	FIRST ORDER STATISTICS FOLLOW	
631	237000	USE PREVIOUSLY DEFINED BIT MAP	
632	001031	GENERATING CENTRE	CODE TABLE
633	001201	GENERATING APPLICATION	CODE TABLE
634	008023	FIRST ORDER STATISTICS	CODE TABLE
635	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
636	224255	FIRST ORDER STATISTICS VALUE MARKER	
756	222000	QUALITY INFORMATION FOLLOW	
757	237000	USE PREVIOUSLY DEFINED BIT MAP	
758	001031	GENERATING CENTRE	CODE TABLE
759	001201	GENERATING APPLICATION	CODE TABLE
760	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
761	033241	GROSS ERROR PROBABILITY	NUMERIC
881	222000	QUALITY INFORMATION FOLLOW	
882	237000	USE PREVIOUSLY DEFINED BIT MAP	
883	001031	GENERATING CENTRE	CODE TABLE
884	001201	GENERATING APPLICATION	CODE TABLE
885	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
886	033242	GROSS ERROR INDICATOR	CODE TABLE

ASCAT

1	001007	SATELLITE IDENTIFIER	CODE TABLE
2	001012	DIRECTION OF MOTION OF MOVING OBSERVING	DEGREE TRU
3	002021	SATELLITE INSTRUMENT DATA USED IN PROCES	FLAG TABLE
4	004001	YEAR	YEAR
5	004002	MONTH	MONTH
6	004003	DAY	DAY
7	004004	HOUR	HOUR
8	004005	MINUTE	MINUTE
9	004006	SECOND	SECOND
10	005002	LATITUDE (COARSE ACCURACY)	DEGREE
11	006002	LONGITUDE (COARSE ACCURACY)	DEGREE
12	002111	RADAR INCIDENCE ANGLE	DEGREE
13	002112	RADAR LOOK ANGLE	DEGREE
14	021192	RADAR BACK SCATTER	DB
15	021193	NOISE FIGURE	%
16	021195	MISSING PACKET COUNTER	NUMERIC
17	002111	RADAR INCIDENCE ANGLE	DEGREE
18	002112	RADAR LOOK ANGLE	DEGREE
19	021192	RADAR BACK SCATTER	DB
20	021193	NOISE FIGURE	%
21	021195	MISSING PACKET COUNTER	NUMERIC
22	002111	RADAR INCIDENCE ANGLE	DEGREE
23	002112	RADAR LOOK ANGLE	DEGREE
24	021192	RADAR BACK SCATTER	DB
25	021193	NOISE FIGURE	%
26	021195	MISSING PACKET COUNTER	NUMERIC
27	011012	WIND SPEED AT 10 M	M/S
28	011011	WIND DIRECTION AT 10 M	DEGREE TRU

29	021197	UWI PRODUCT CONFIDENCE	FLAG TABLE
30	222000	QUALITY INFORMATION FOLLOW	
31	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
32	031031	DATA PRESENT INDICATOR	NUMERIC
61	001031	GENERATING CENTRE	CODE TABLE
62	001201	GENERATING APPLICATION	CODE TABLE
63	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
64	033007	% CONFIDENCE	NUMERIC
93	235000	CANCEL BACKWARD DATA REFERENCE	
94	001031	GENERATING CENTRE	CODE TABLE
95	001201	GENERATING APPLICATION	CODE TABLE
96	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
97	002111	RADAR INCIDENCE ANGLE	DEGREE
98	002112	RADAR LOOK ANGLE	DEGREE
99	021192	RADAR BACK SCATTER	DB
100	021193	NOISE FIGURE	%
101	021195	MISSING PACKET COUNTER	NUMERIC
102	002111	RADAR INCIDENCE ANGLE	DEGREE
103	002112	RADAR LOOK ANGLE	DEGREE
104	021192	RADAR BACK SCATTER	DB
105	021193	NOISE FIGURE	%
106	021195	MISSING PACKET COUNTER	NUMERIC
107	002111	RADAR INCIDENCE ANGLE	DEGREE
108	002112	RADAR LOOK ANGLE	DEGREE
109	021192	RADAR BACK SCATTER	DB
110	021193	NOISE FIGURE	%
111	021195	MISSING PACKET COUNTER	NUMERIC
112	224000	FIRST ORDER STATISTICS FOLLOW	
113	236000	BACKWARD REFERENCE BIT MAP	
114	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
115	031031	DATA PRESENT INDICATOR	NUMERIC
130	001031	GENERATING CENTRE	CODE TABLE
131	001201	GENERATING APPLICATION	CODE TABLE
132	008023	FIRST ORDER STATISTICS	CODE TABLE
133	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
134	224255	FIRST ORDER STATISTICS VALUE MARKER	

ATOV

1	001007	SATELLITE IDENTIFIER	CODE TABLE
2	004001	YEAR	YEAR
3	004002	MONTH	MONTH
4	004003	DAY	DAY
5	004004	HOUR	HOUR
6	004005	MINUTE	MINUTE
7	004006	SECOND	SECOND
8	005002	LATITUDE (COARSE ACCURACY)	DEGREE
9	006002	LONGITUDE (COARSE ACCURACY)	DEGREE
10	007022	SOLAR ELEVATION	DEGREE
11	002025	SATELLITE CHANNEL(S) USED IN COMPUTATION	FLAG TABLE
12	002022	SATELLITE DATA PROCESSING TECHNIQUE USED	FLAG TABLE
13	027020	SATELLITE LOCATION COUNTER	NUMERIC
14	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
15	015001	OZON	DOBSON
16	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
17	010004	PRESSURE	PA
18	020010	CLOUD COVER (TOTAL)	%
19	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE

20	008012	LAND/SEA QUALIFIER	CODE TABLE
21	010001	HEIGHT OF LAND SURFACE	M
22	012061	SKIN TEMPERATURE	K
23	010004	PRESSURE	PA
24	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
25	007004	PRESSURE	PA
26	007004	PRESSURE	PA
27	012007	VIRTUAL TEMPERATURE	K
70	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
71	007004	PRESSURE	PA
72	007004	PRESSURE	PA
73	013016	PRECIPITABLE WATER	KG/M**2
80	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
81	012062	EQUIVALENT BLACK BODY TEMPERATURE	K
121	008003	VERTICAL SIGNIFICANCE (SATELLITE OBSERVA	CODE TABLE
122	010004	PRESSURE	PA
123	012001	TEMPERATURE/DRY BULB TEMPERATURE	K
124	222000	QUALITY INFORMATION FOLLOW	
125	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
126	031031	DATA PRESENT INDICATOR	NUMERIC
249	001031	GENERATING CENTRE	CODE TABLE
250	001201	GENERATING APPLICATION	CODE TABLE
251	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
252	033007	% CONFIDENCE	NUMERIC
375	235000	CANCEL BACKWARD DATA REFERENCE	
376	001031	GENERATING CENTRE	CODE TABLE
377	001201	GENERATING APPLICATION	CODE TABLE
378	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
379	012062	EQUIVALENT BLACK BODY TEMPERATURE	K
419	224000	FIRST ORDER STATISTICS FOLLOW	
420	236000	BACKWARD REFERENCE BIT MAP	
421	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
422	031031	DATA PRESENT INDICATOR	NUMERIC
462	001031	GENERATING CENTRE	CODE TABLE
463	001201	GENERATING APPLICATION	CODE TABLE
464	008023	FIRST ORDER STATISTICS	CODE TABLE
465	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
466	224255	FIRST ORDER STATISTICS VALUE MARKER	
507	237000	USE PREVIOUSLY DEFINED BIT MAP	
508	001031	GENERATING CENTRE	CODE TABLE
509	001201	GENERATING APPLICATION	CODE TABLE
510	008023	FIRST ORDER STATISTICS	CODE TABLE
511	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
512	224255	FIRST ORDER STATISTICS VALUE MARKER	
552	222000	QUALITY INFORMATION FOLLOW	
553	237000	USE PREVIOUSLY DEFINED BIT MAP	
554	001031	GENERATING CENTRE	CODE TABLE
555	001201	GENERATING APPLICATION	CODE TABLE
556	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
557	033241	GROSS ERROR PROBABILITY	NUMERIC
597	222000	QUALITY INFORMATION FOLLOW	
598	237000	USE PREVIOUSLY DEFINED BIT MAP	
599	001031	GENERATING CENTRE	CODE TABLE
600	001201	GENERATING APPLICATION	CODE TABLE
601	031002	EXTENDED DELAYED DESCRIPTOR REPLICATION	NUMERIC
602	033242	GROSS ERROR INDICATOR	CODE TABLE

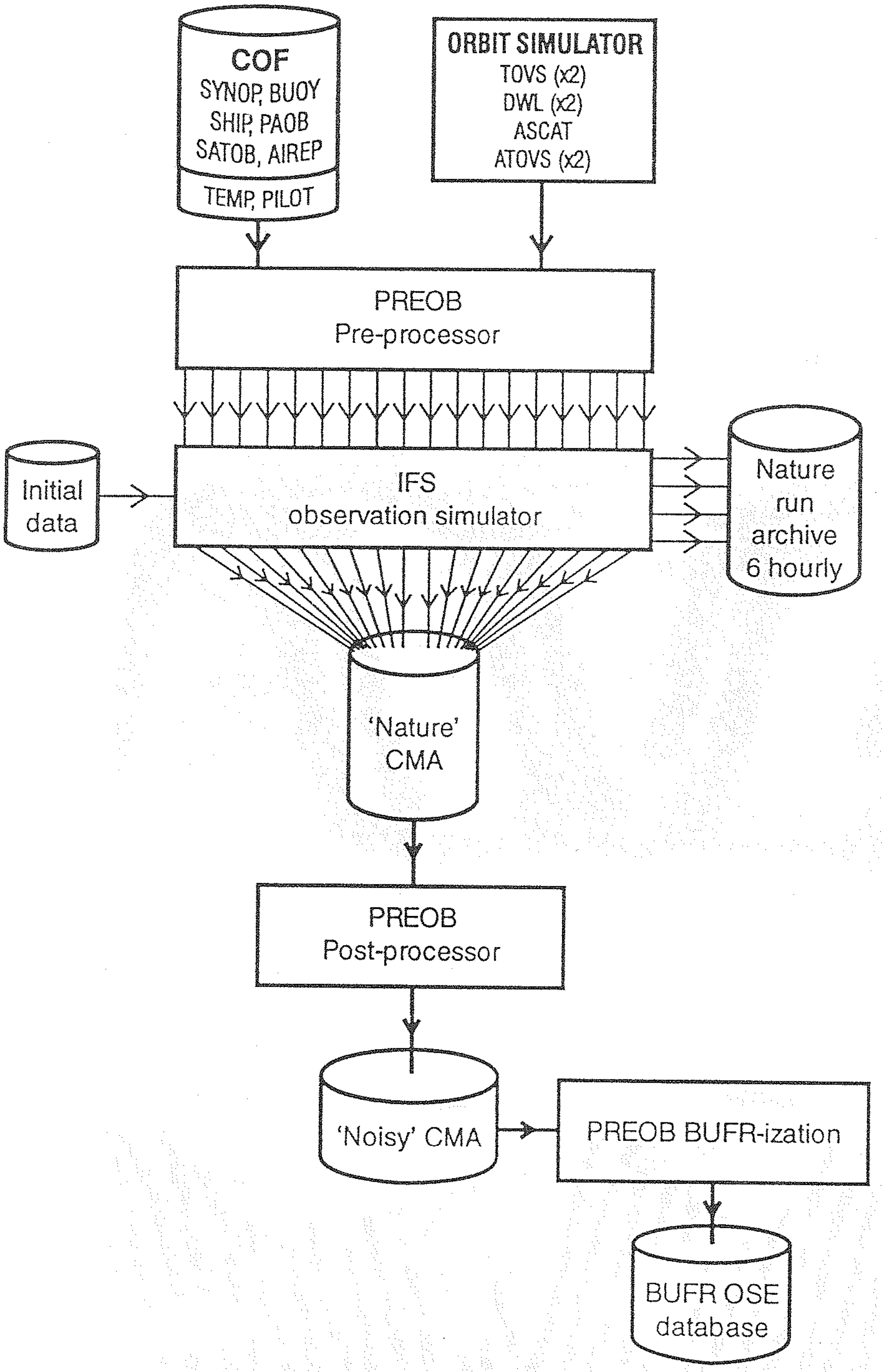


Figure 1: Schematic of the observation simulation system

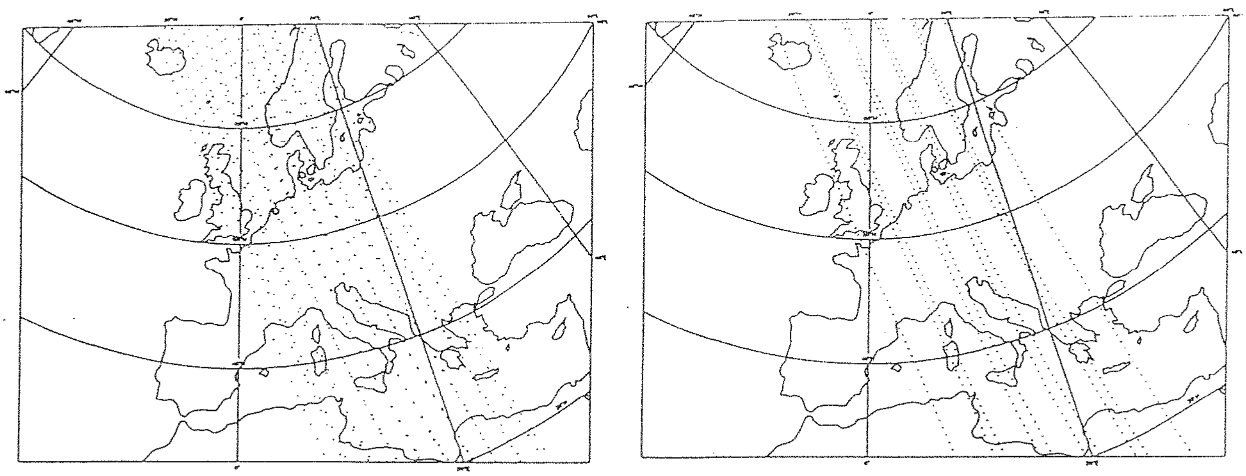


Figure 2: DWL conical scan pattern with 19/20 shots per double mirror cycle

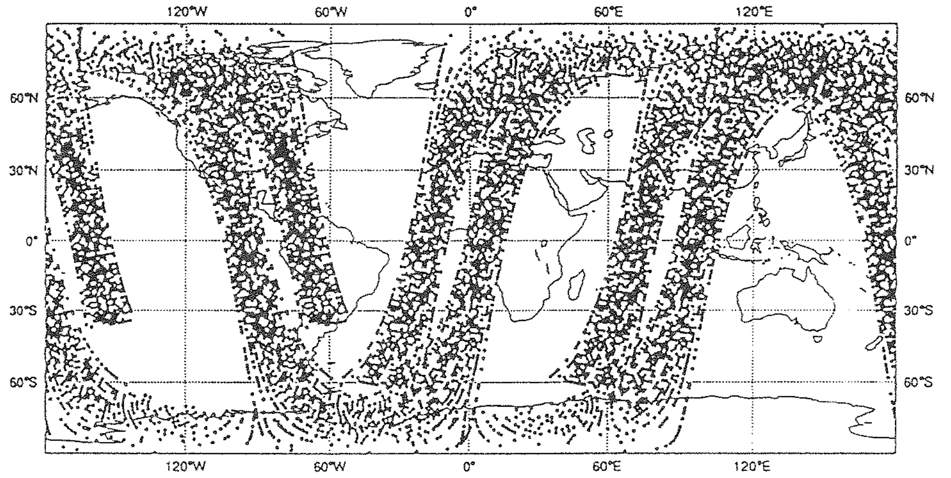


Figure 3: TOVS and ATOVS cross track scan pattern with 50% thinning applied

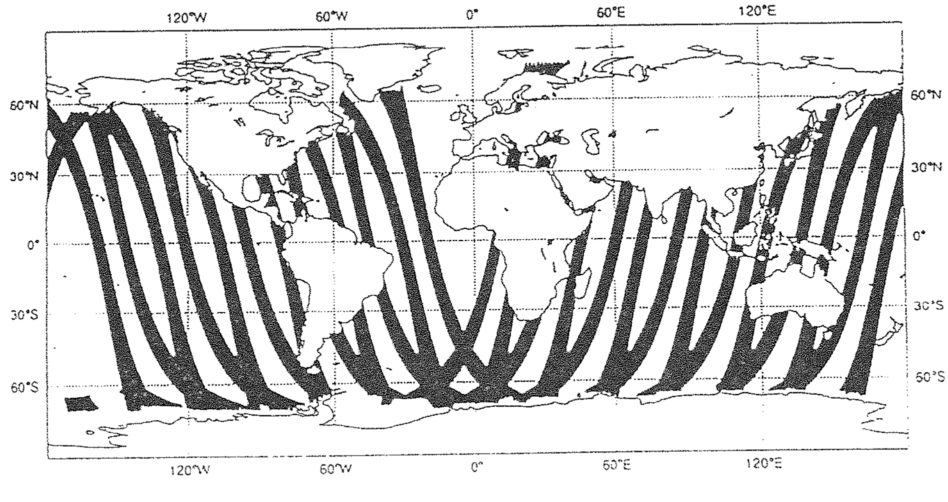


Figure 4: 12 hour coverage of the double sided ASCAT scan pattern

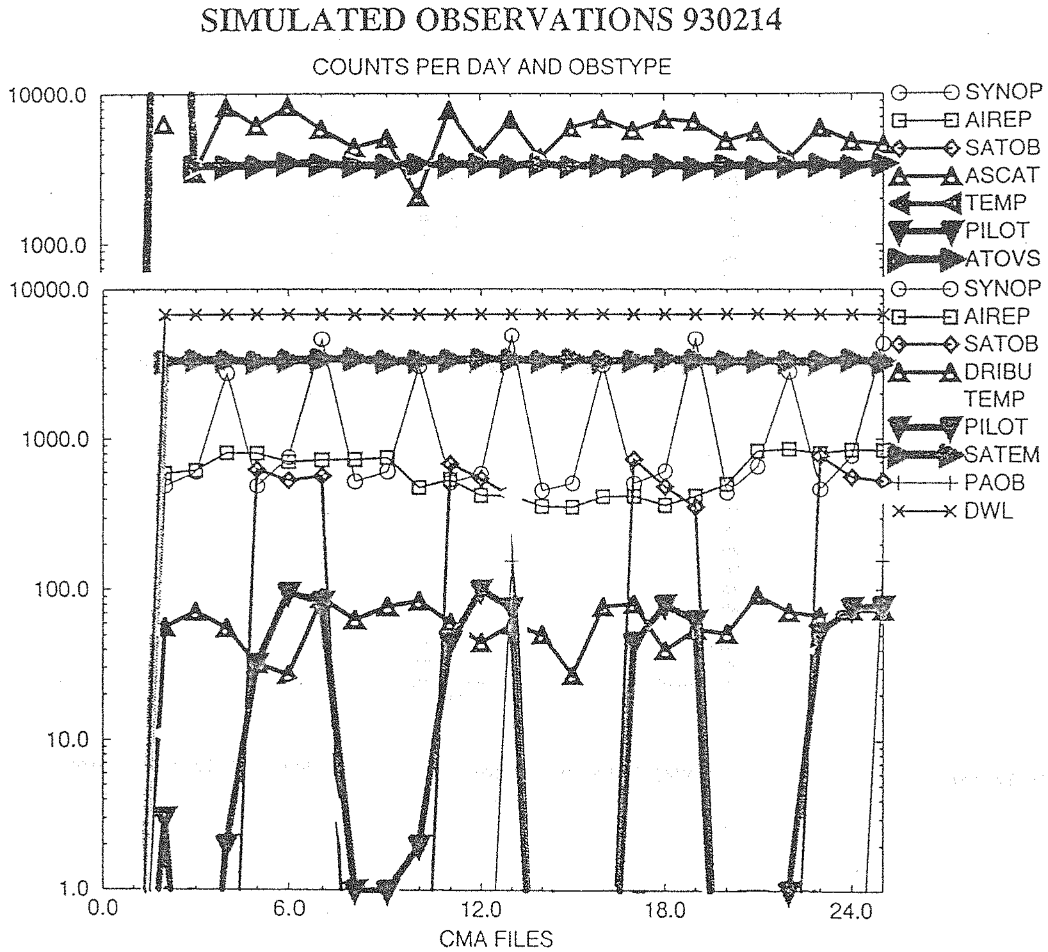


Figure 5: Observation counts per type and hour

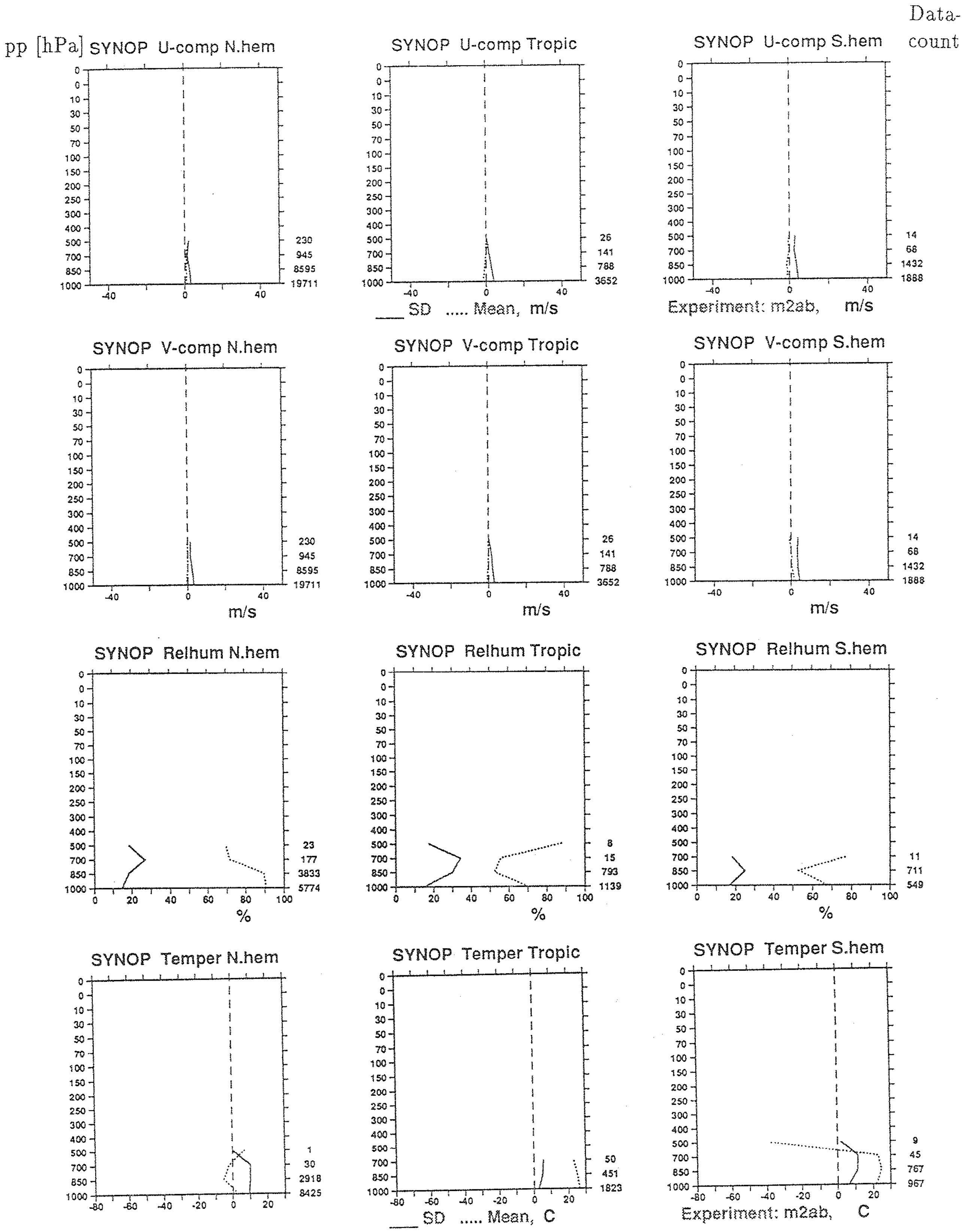


Figure 6: Standard deviation and mean of nature run SYNOPs. Solid: σ, dotted: Mean value

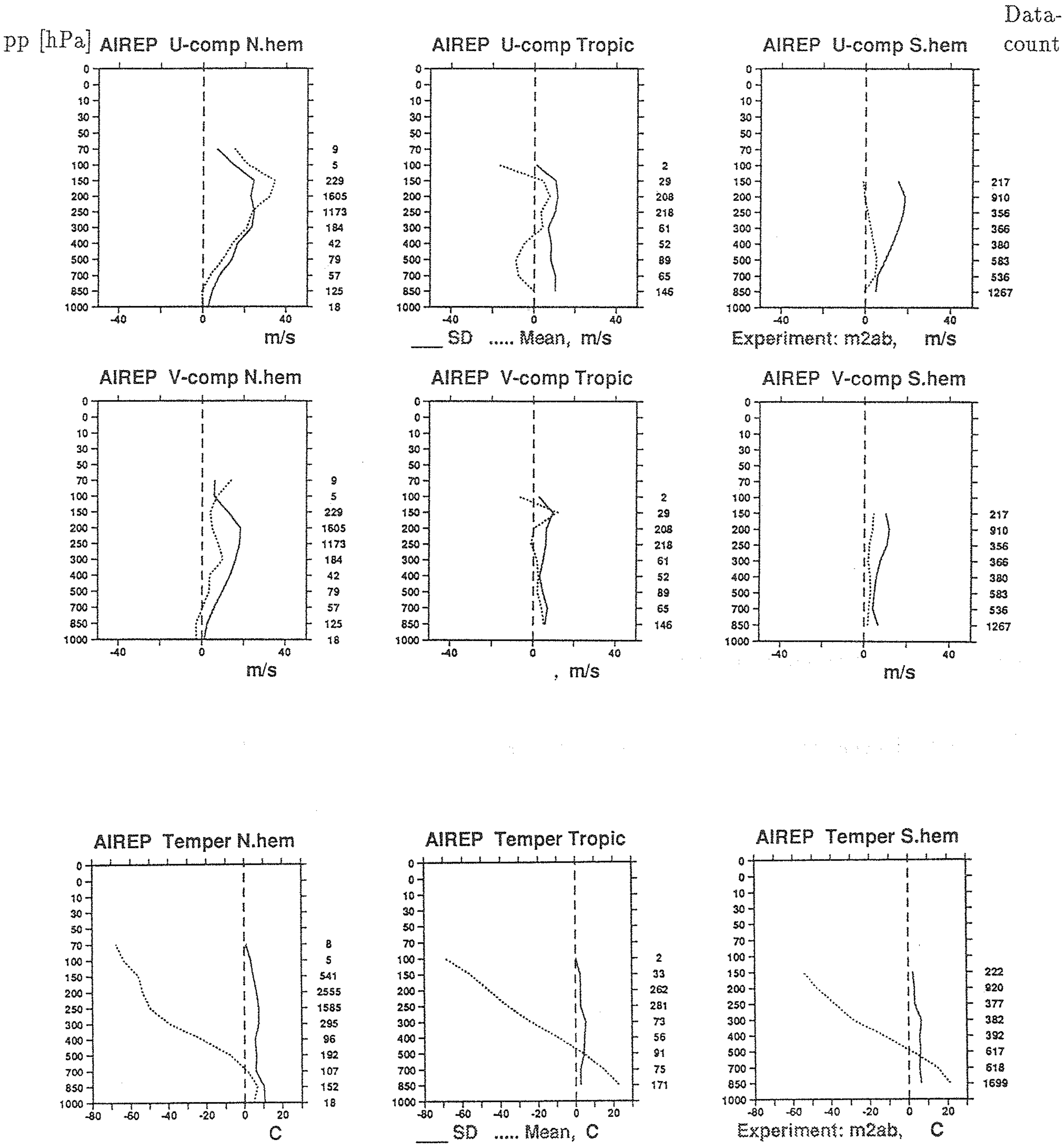


Figure 7: Standard deviation and mean of nature run AIREPs. Solid: σ, dotted: Mean value

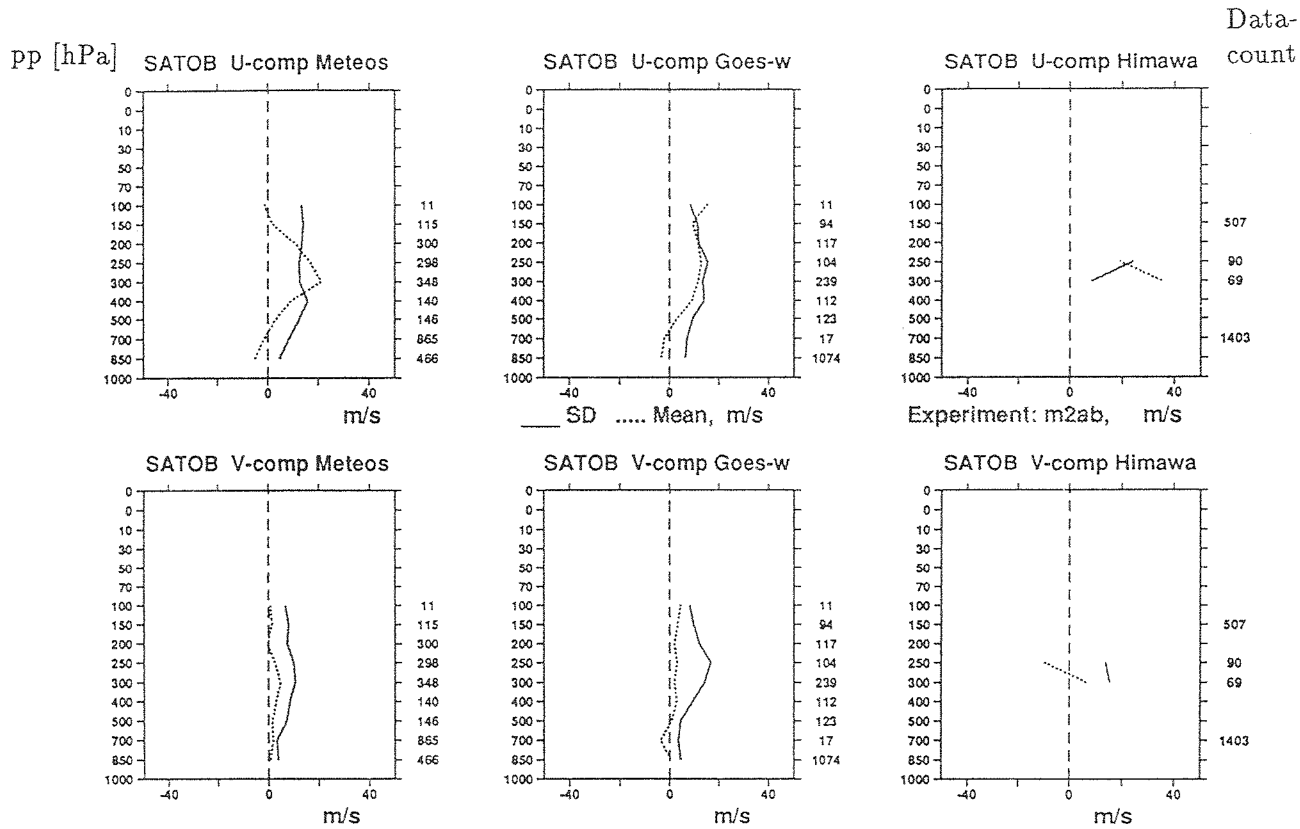


Figure 8: Standard deviation and mean of nature run SATOBs. Solid: σ, dotted: Mean value

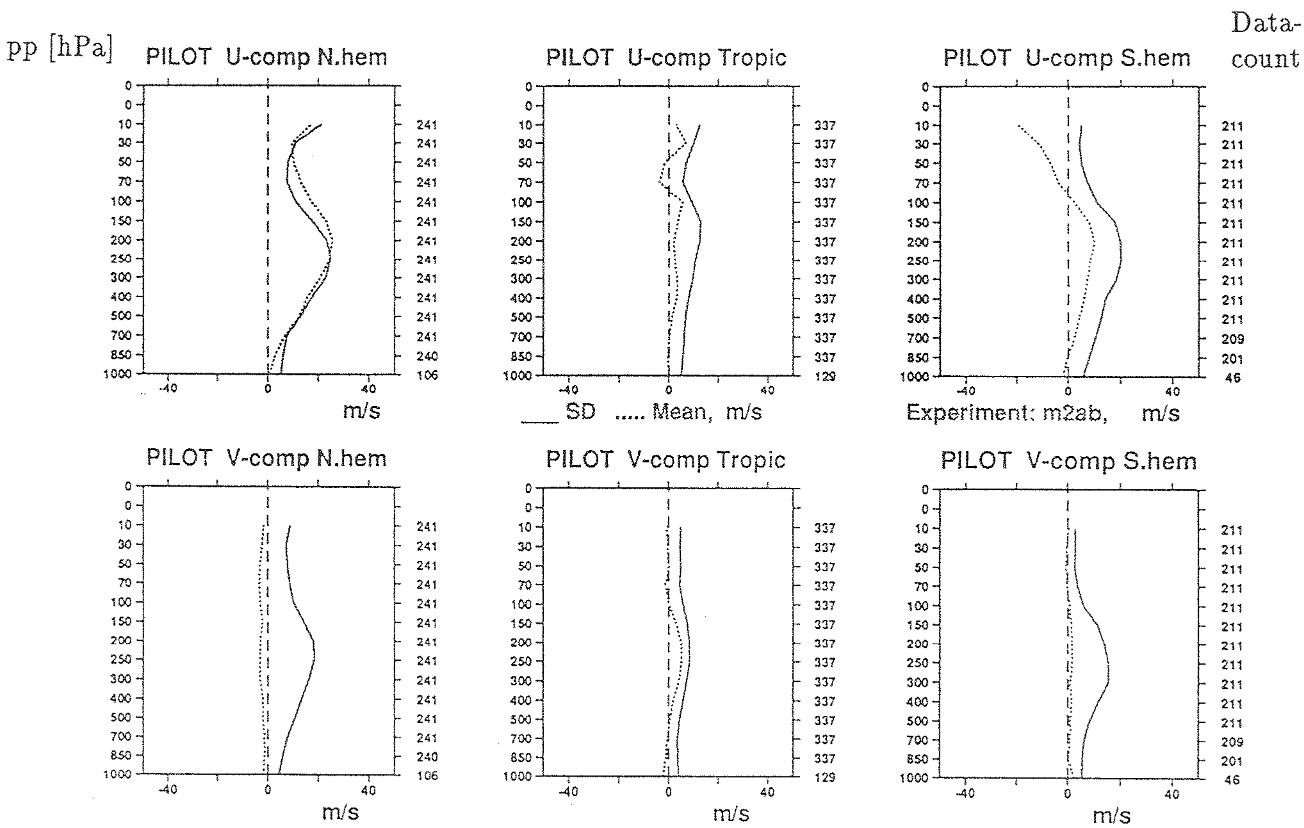


Figure 9: Standard deviation and mean of nature run PILOTs. Solid: σ, dotted: Mean value

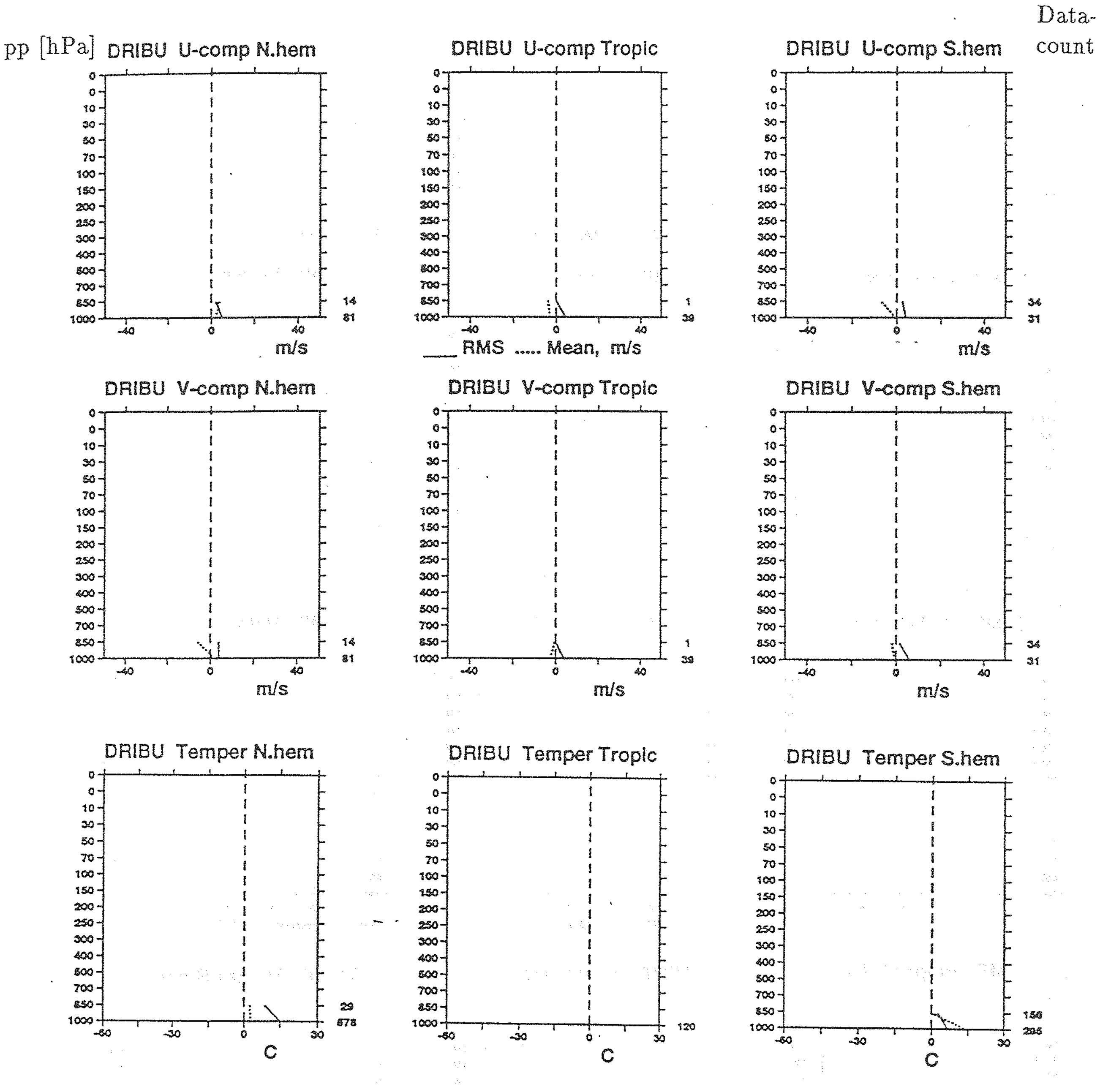


Figure 10: Standard deviation and mean of nature run DRIBUs. Solid: σ, dotted: Mean value

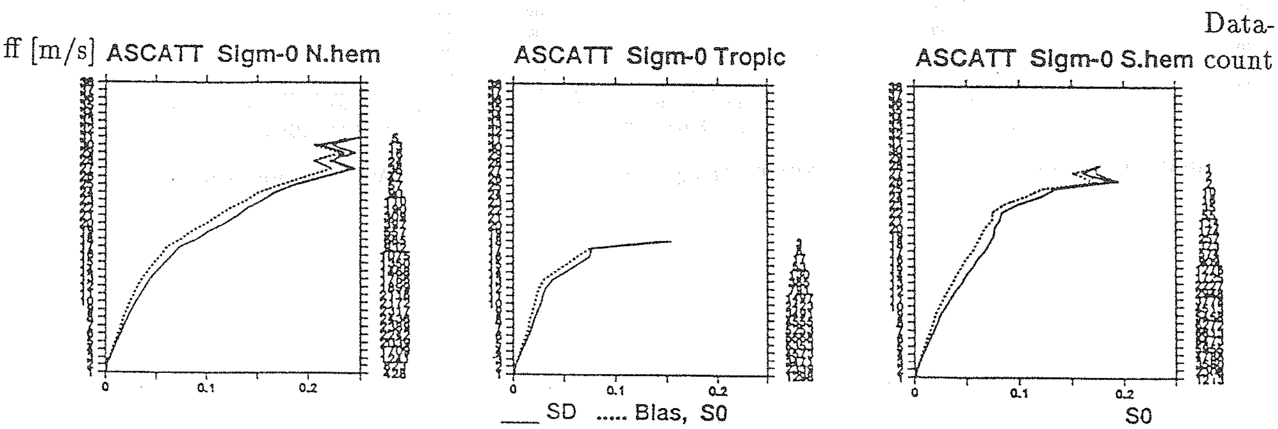


Figure 11: Standard deviation and mean of nature run ASCATs in bins of ff in [m/s]. Solid: σ, dotted: Mean value

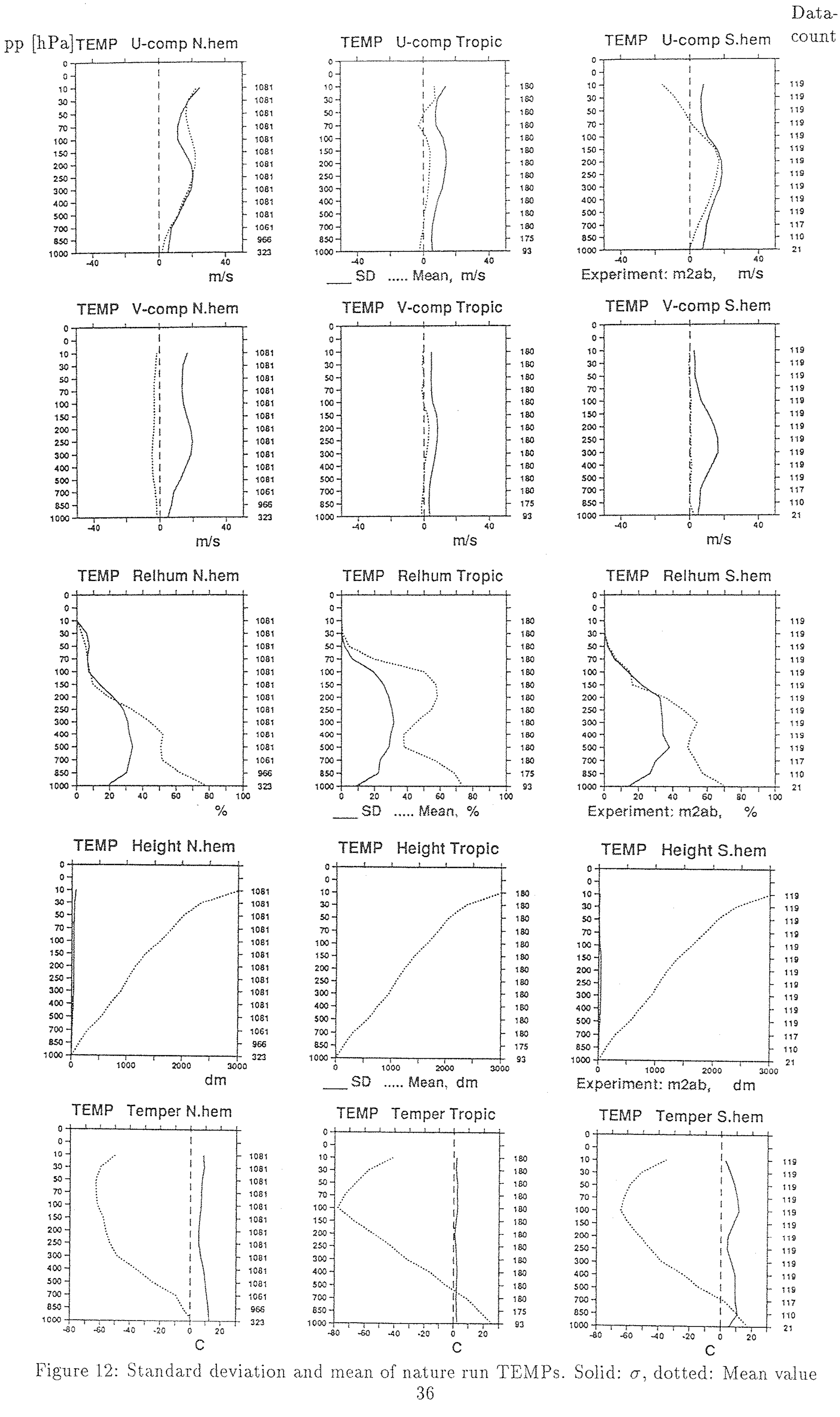


Figure 12: Standard deviation and mean of nature run TEMPs. Solid: σ, dotted: Mean value

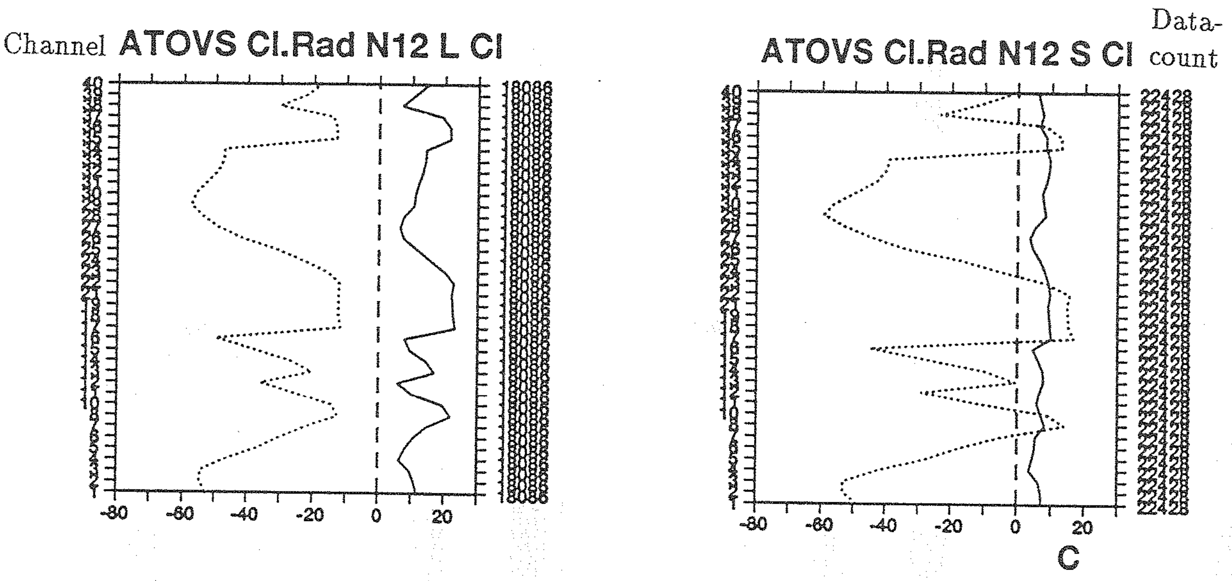


Figure 13: Standard deviation and mean of nature run ATOVS. Solid: σ, dotted: Mean value per channel. L, S indicates over land or over sea

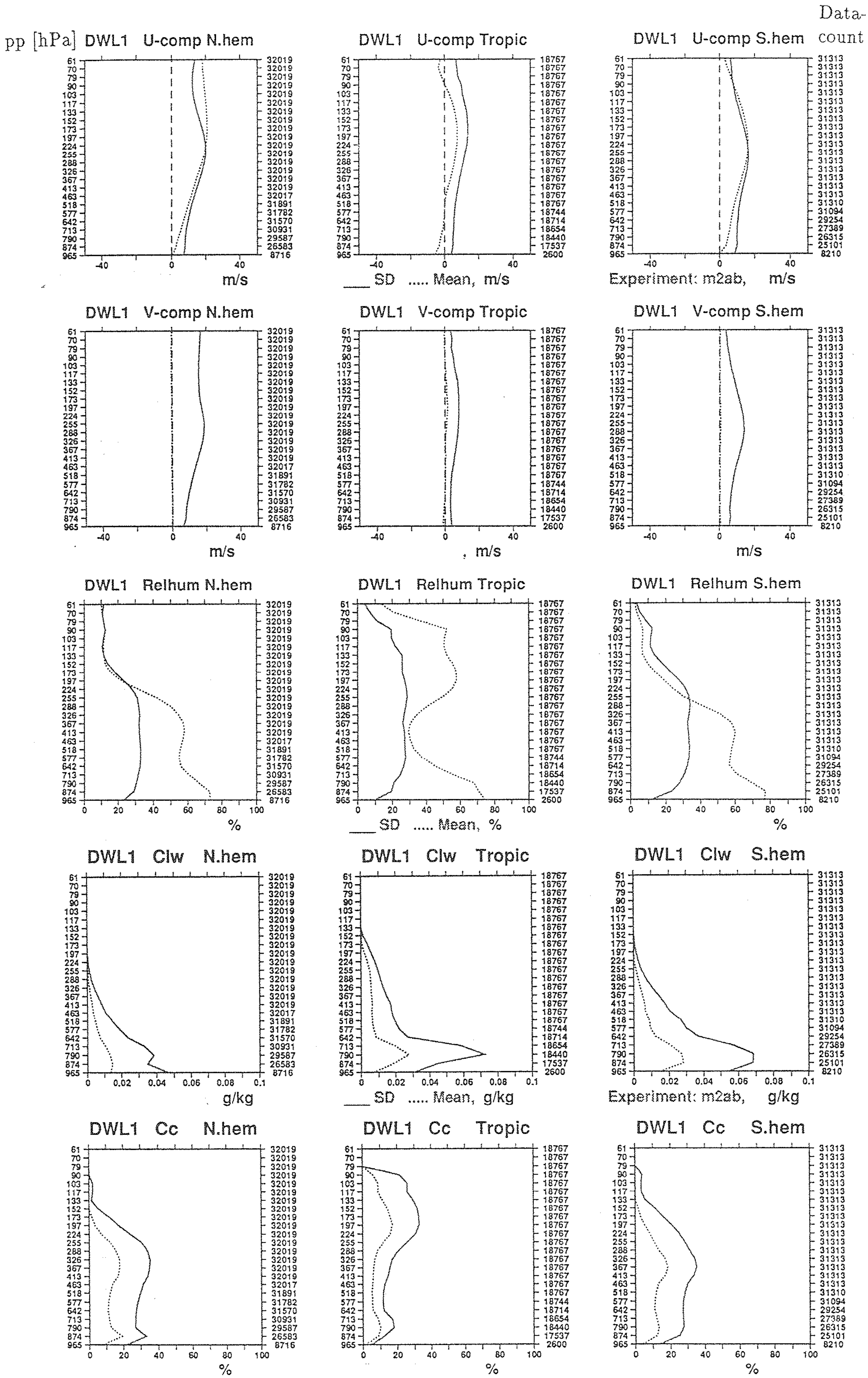


Figure 14: Standard deviation and mean of nature run DWLs. Solid: σ, dotted: Mean value

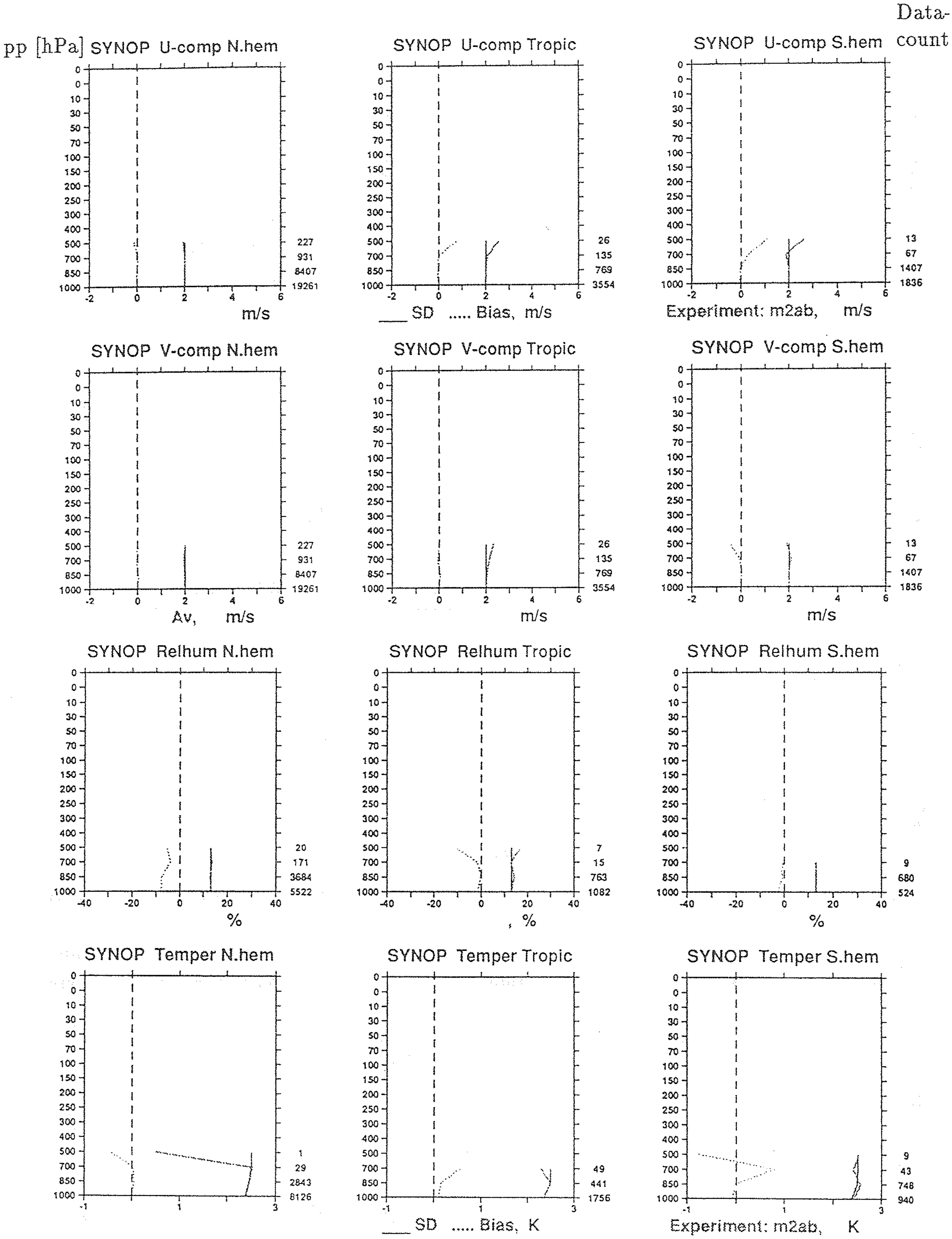


Figure 15: RMS statistics of gaussian error of the simulated SYNOPs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

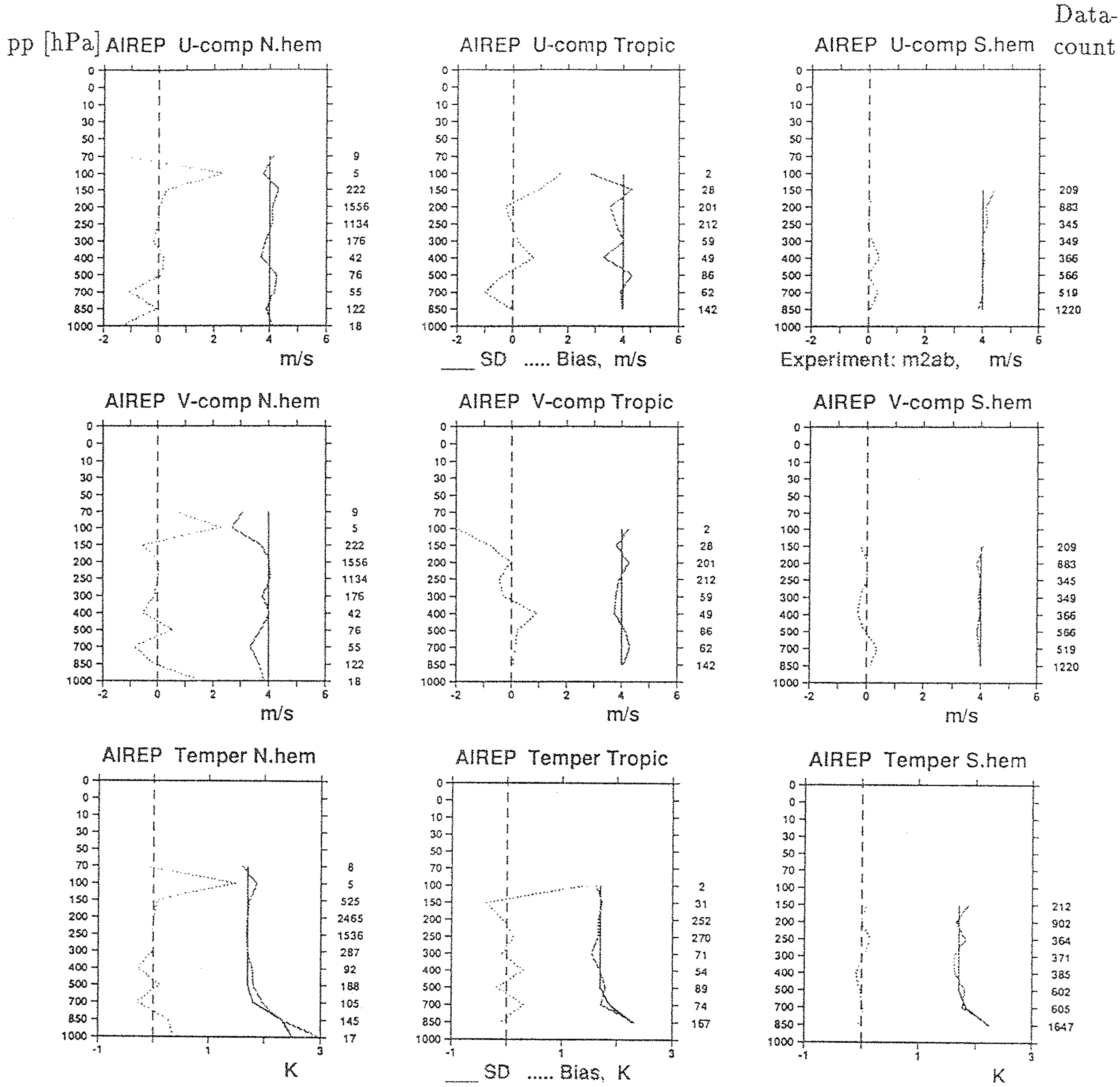


Figure 16: RMS statistics of gaussian error of the simulated AIREPs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

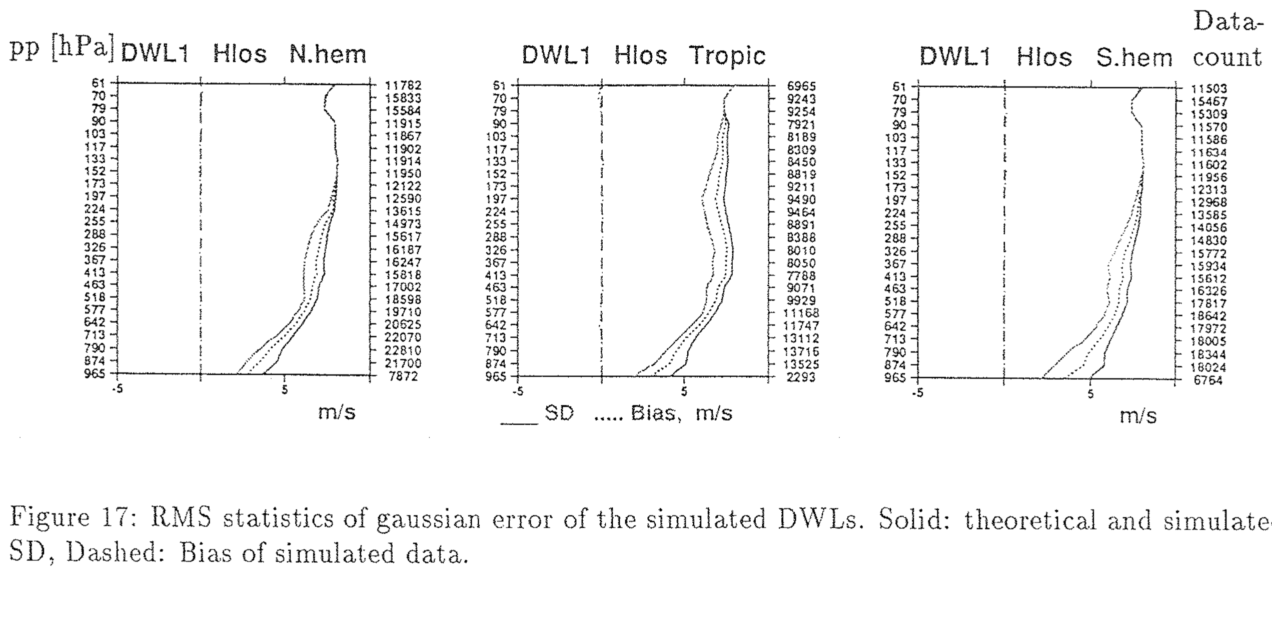


Figure 17: RMS statistics of gaussian error of the simulated DWLs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

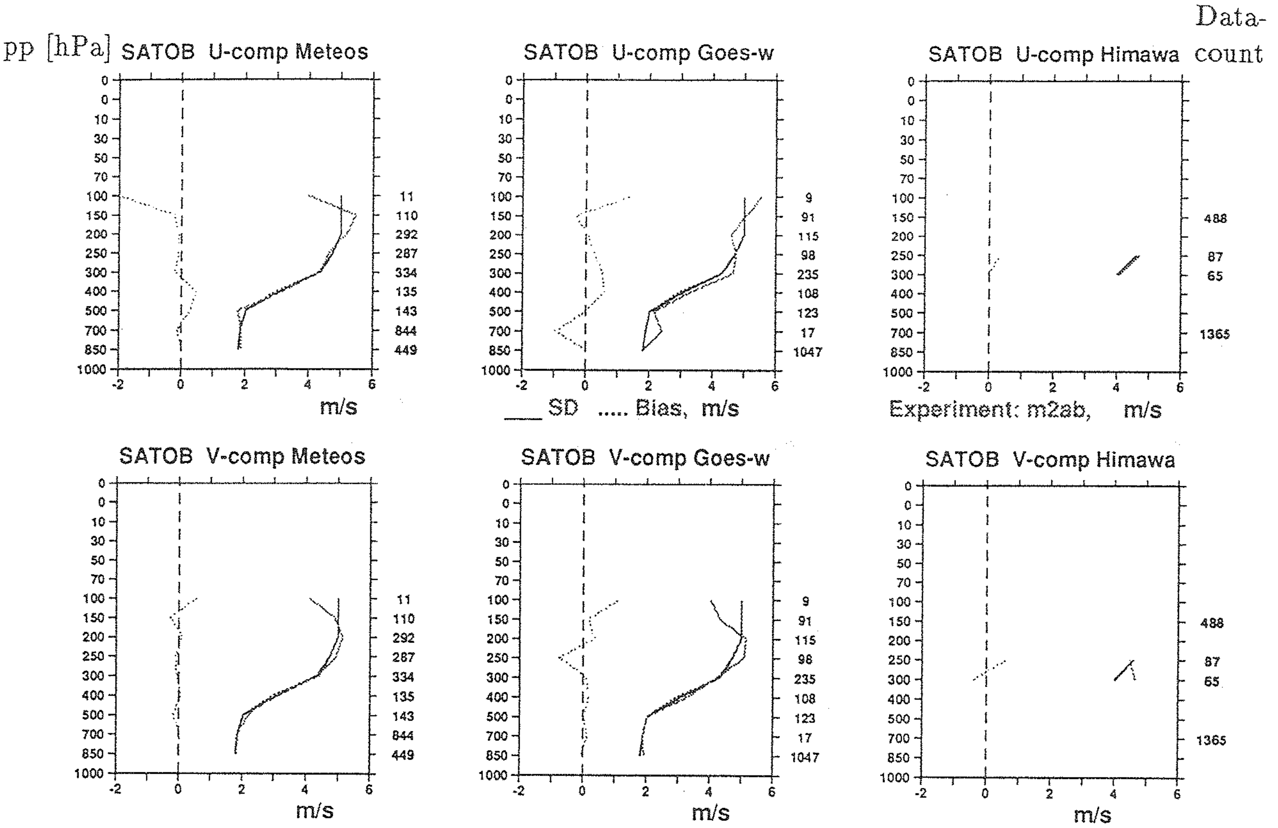


Figure 18: RMS statistics of gaussian error of the simulated SATOBs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

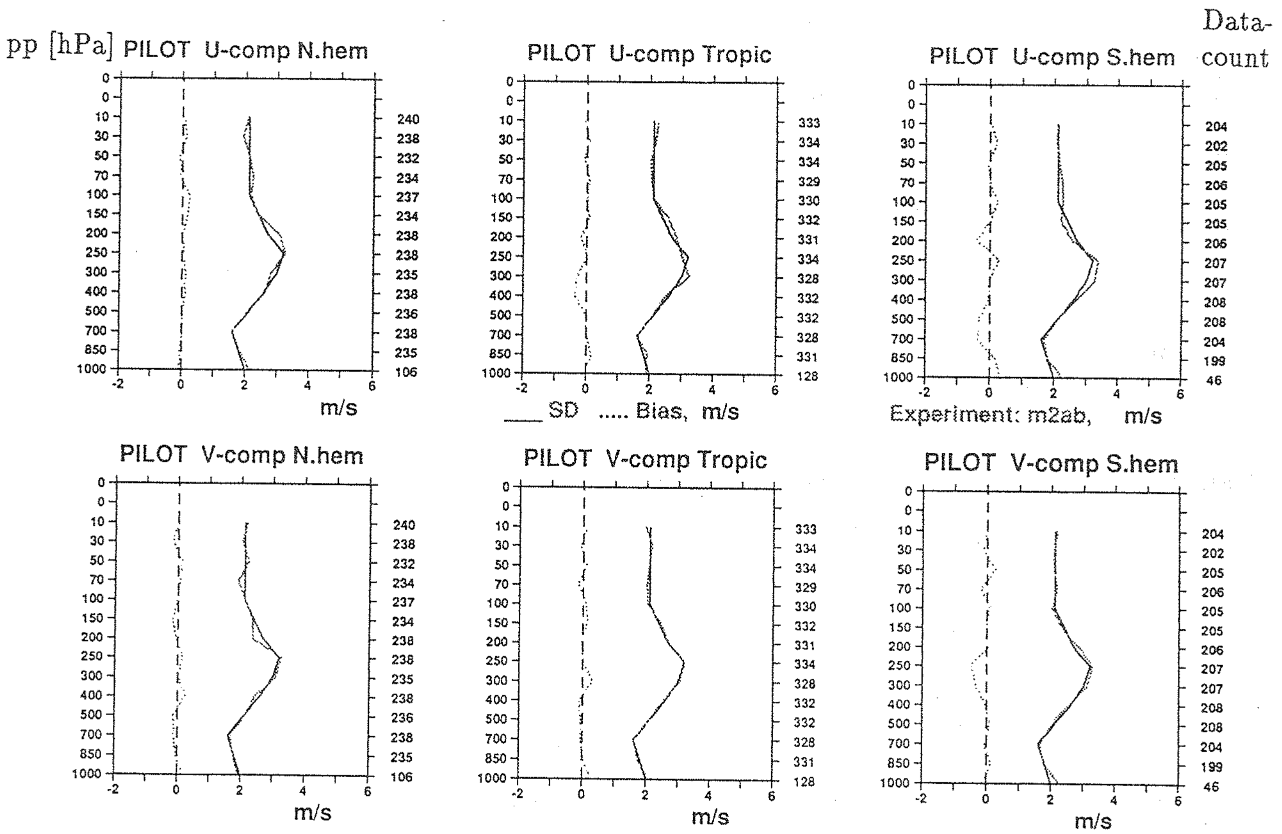


Figure 19: RMS statistics of gaussian error of the simulated PILOTs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

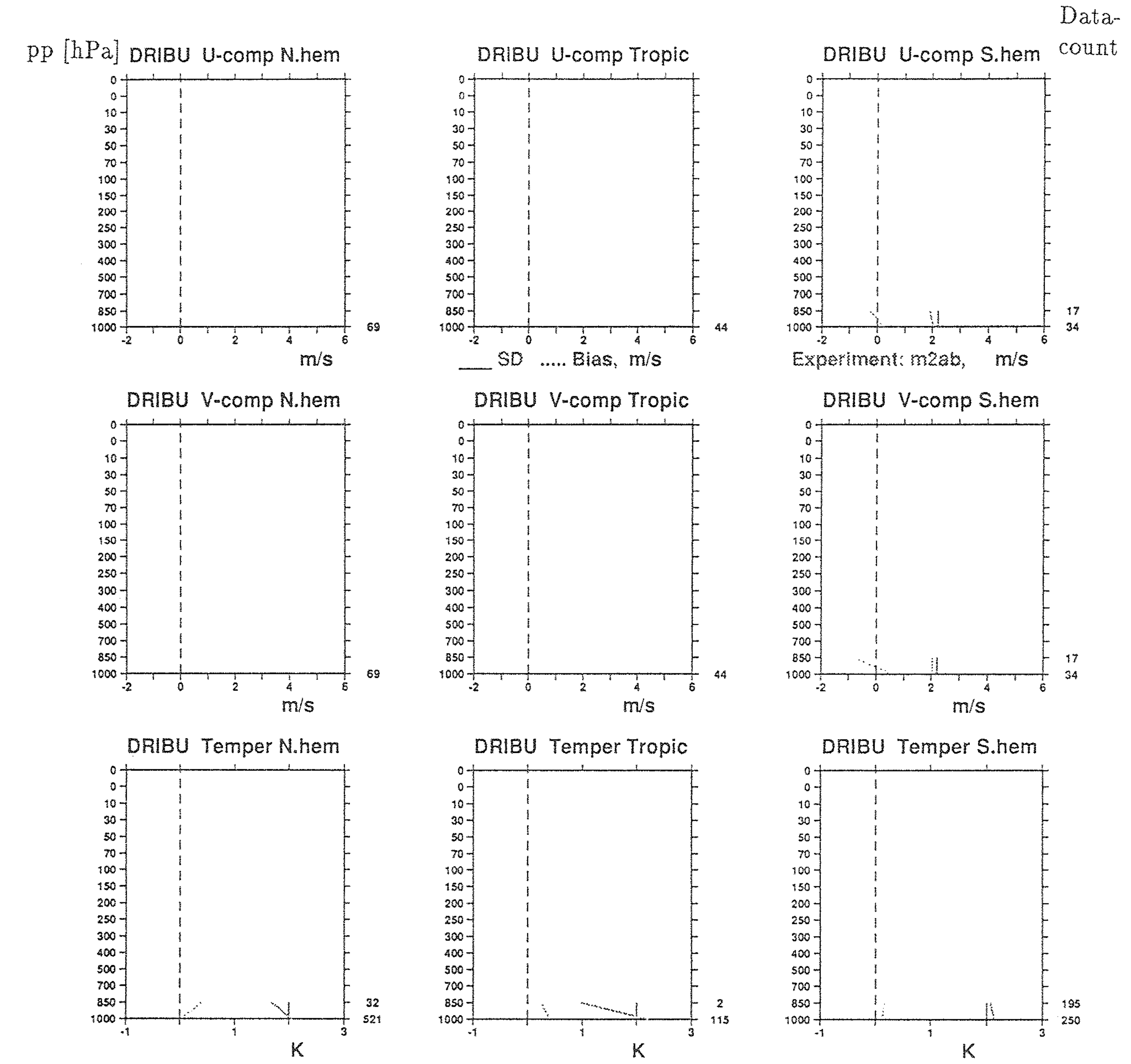


Figure 20: RMS statistics of gaussian error of the simulated DRIBUs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

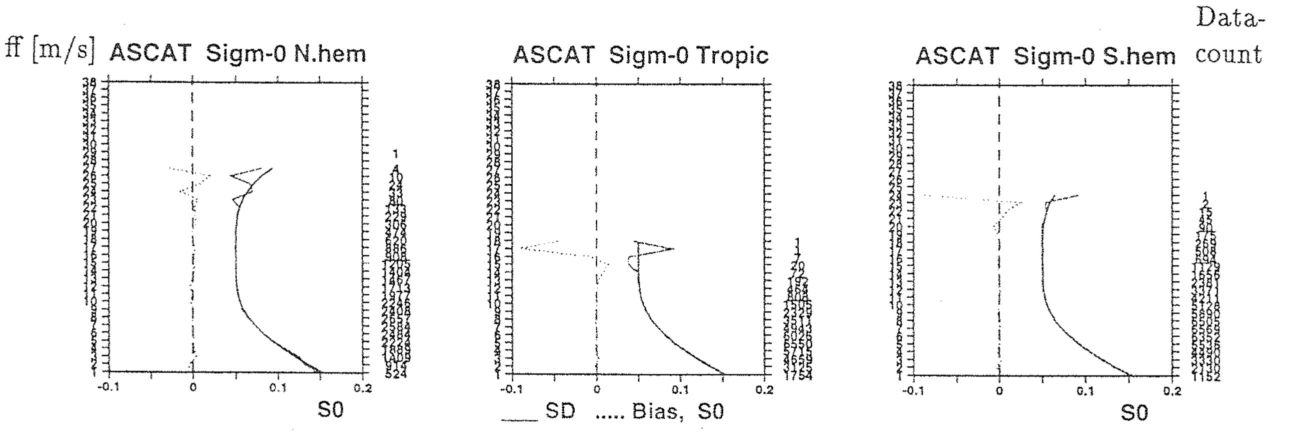


Figure 21: RMS statistics of the simulated ASCATs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data. in bins of ff in [m/s]

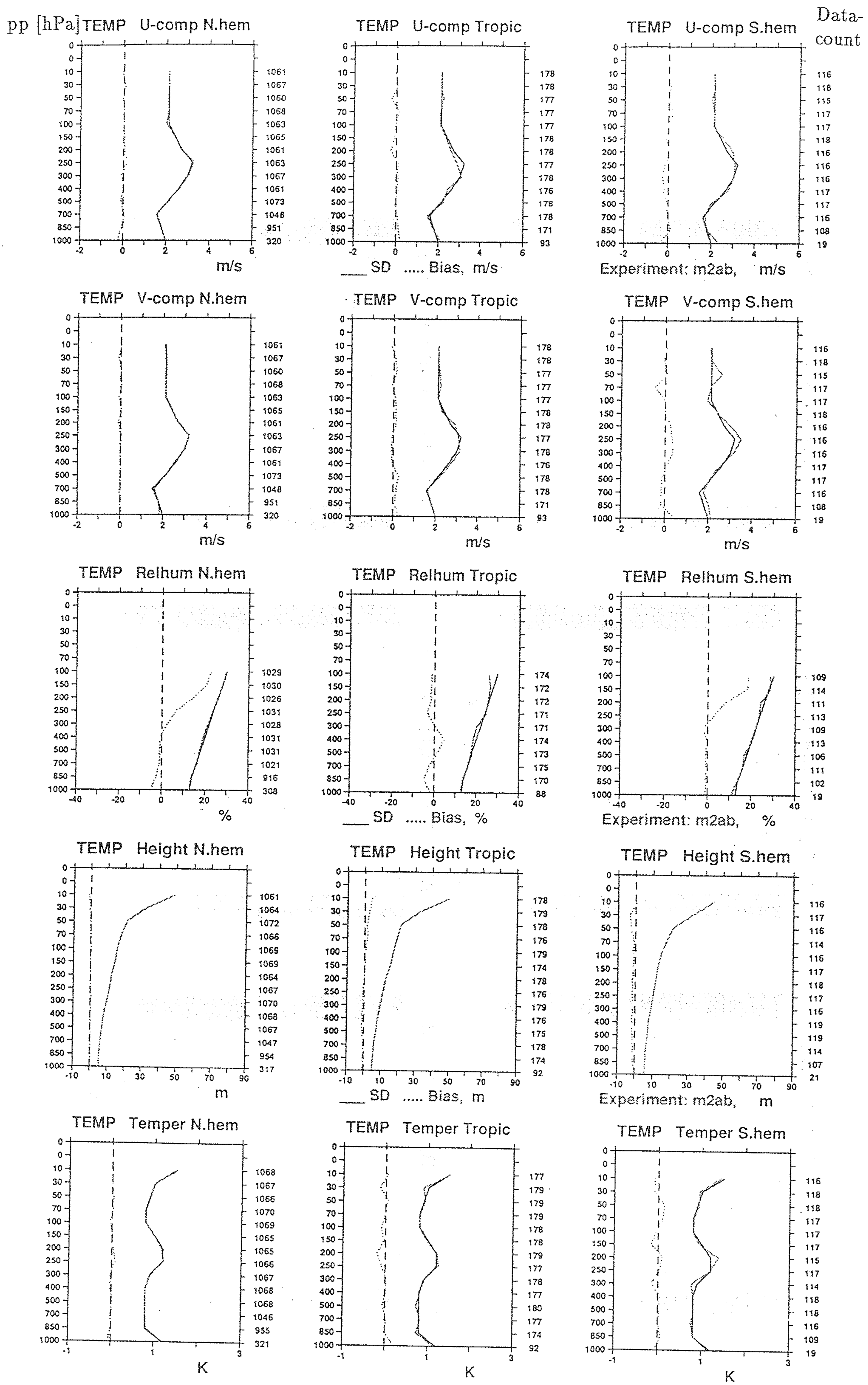


Figure 22: RMS statistics of gaussian error of the simulated TEMPs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

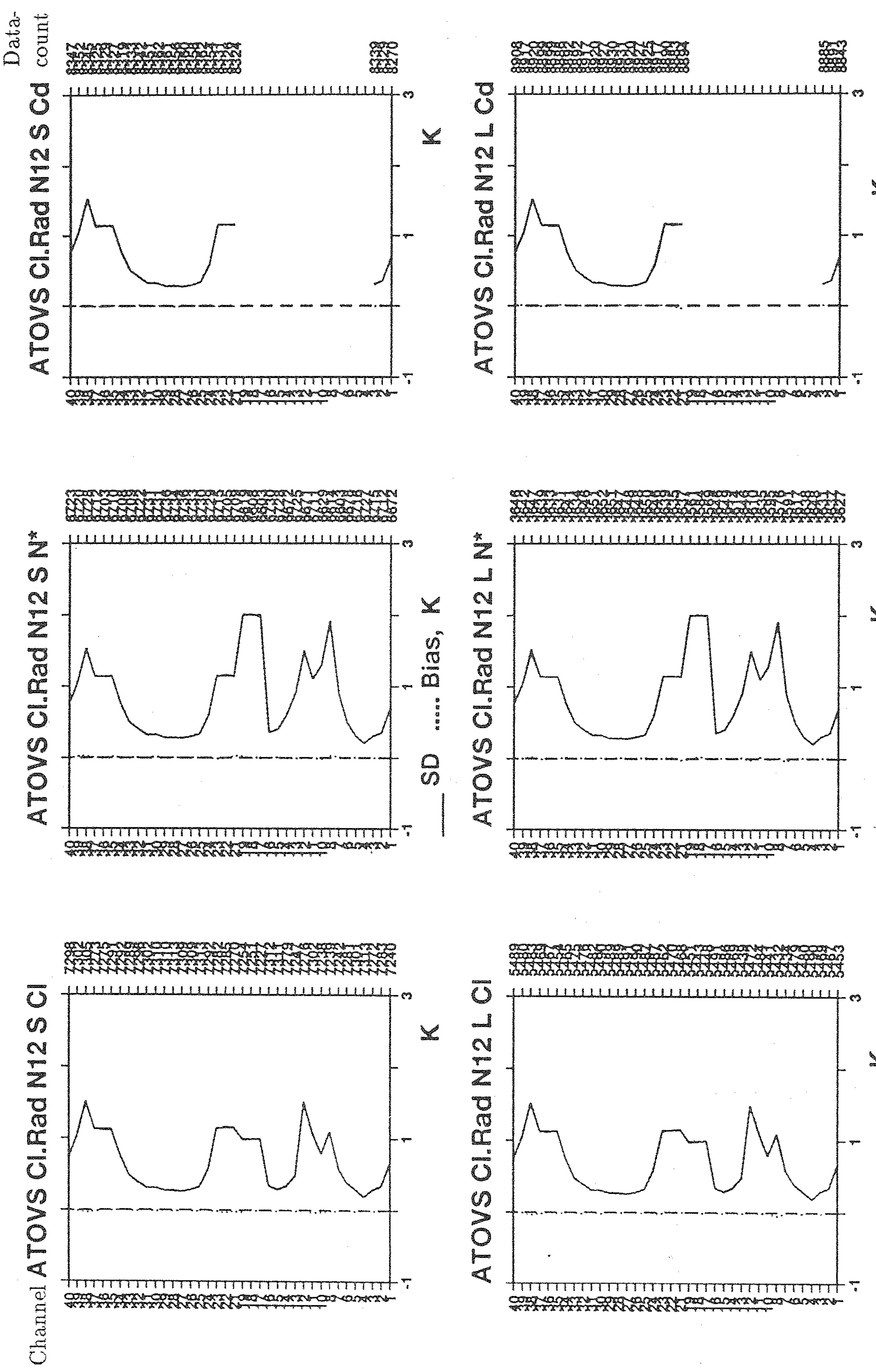


Figure 23: RMS statistics of gaussian error of the simulated ATOVS. Solid: theoretical and simulated SD, Dashed: Bias of simulation per channel. L, S indicates over land or over sea

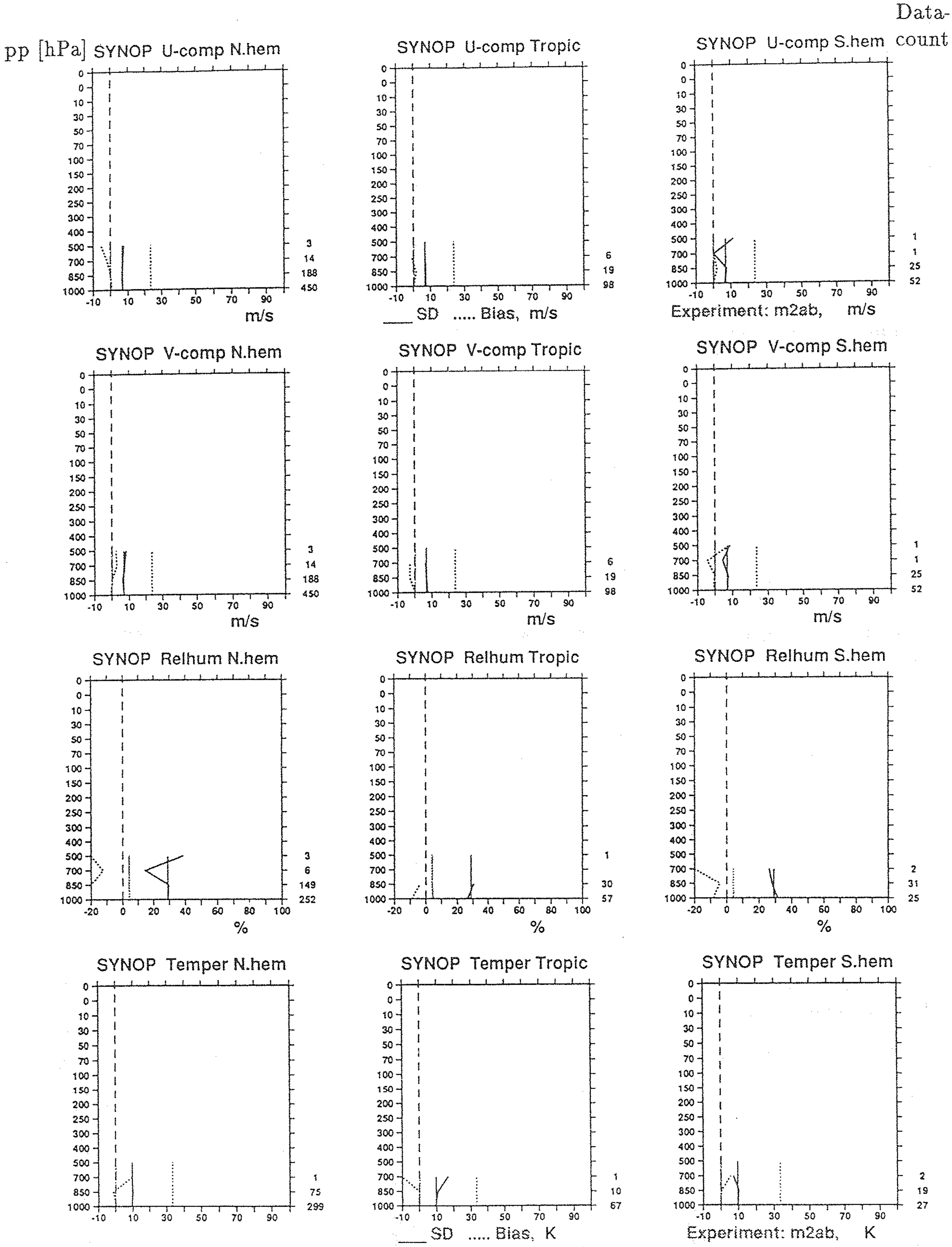


Figure 24: RMS statistics of gross error of the simulated SYNOPs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

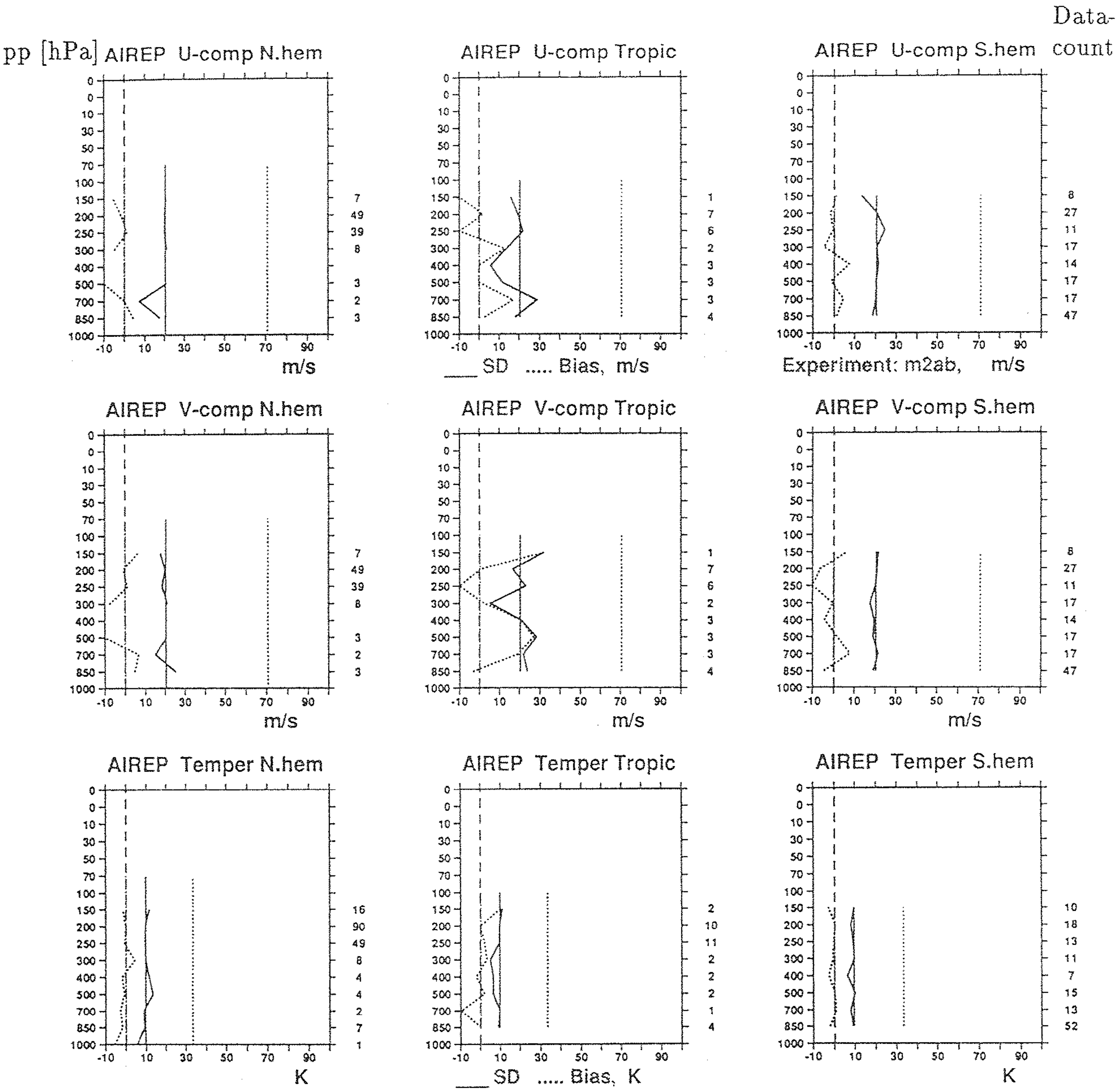


Figure 25: RMS statistics of gross error of the simulated AIREPs. Solid: theoretical and simulated SD. Dashed: Bias of simulated data.

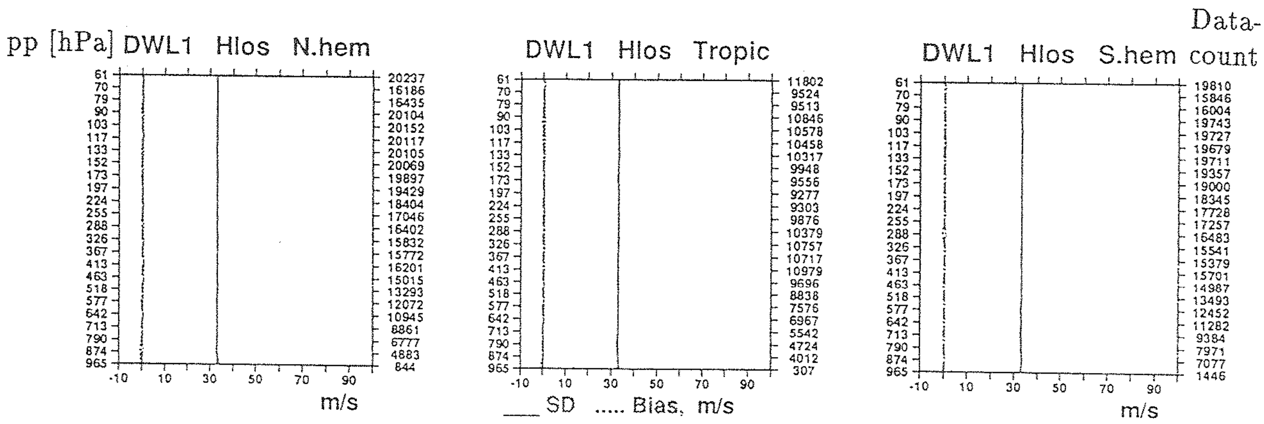


Figure 26: RMS statistics of gross error of the simulated DWLs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

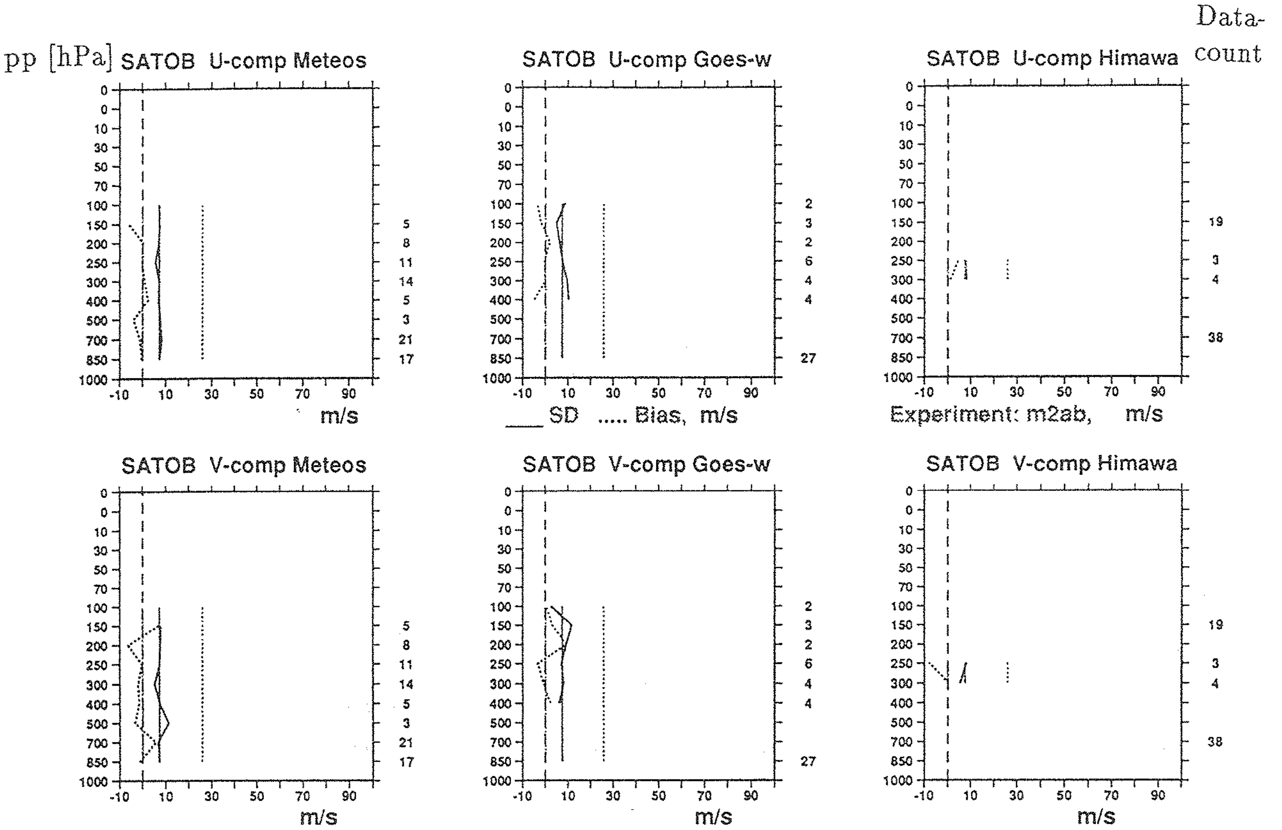


Figure 27: RMS statistics of gross error of the simulated SATOBs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

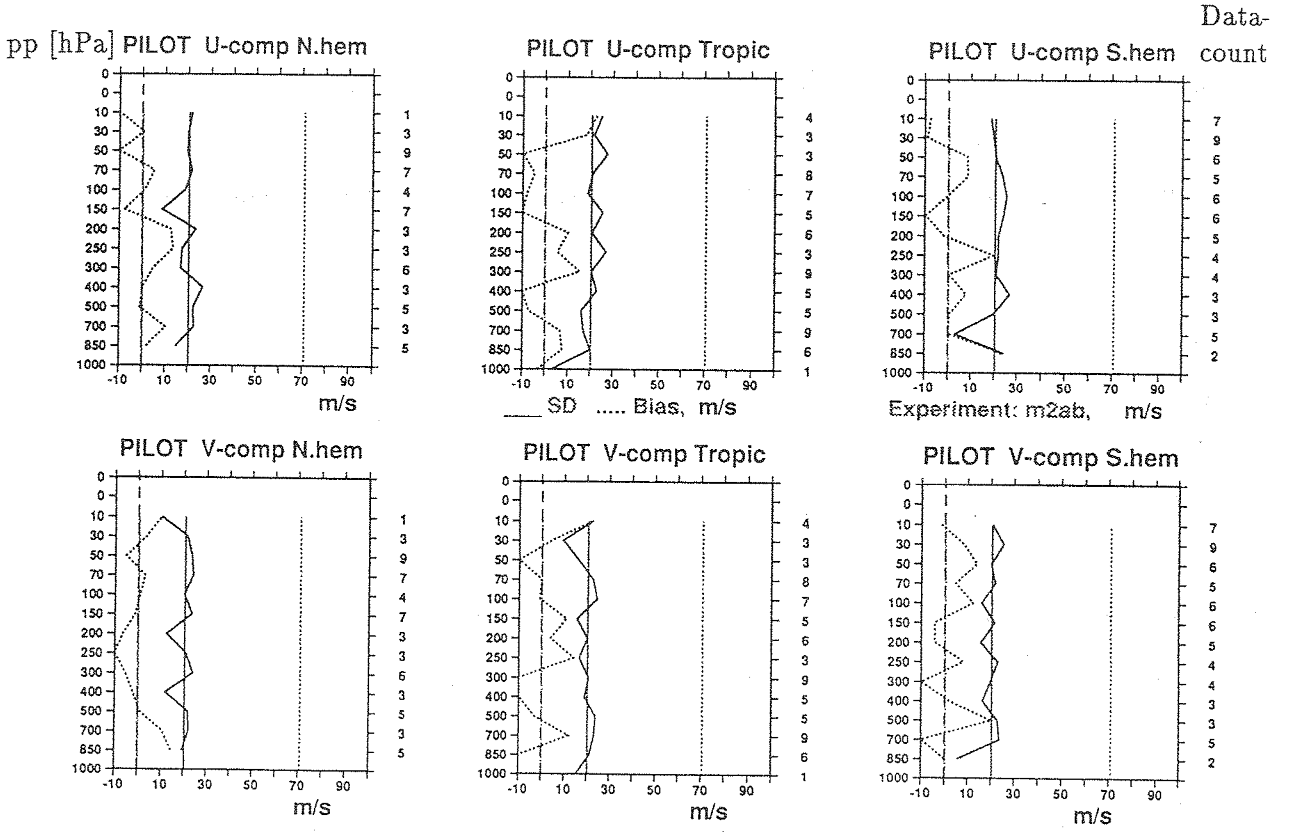


Figure 28: RMS statistics of gross error of the simulated PILOTs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

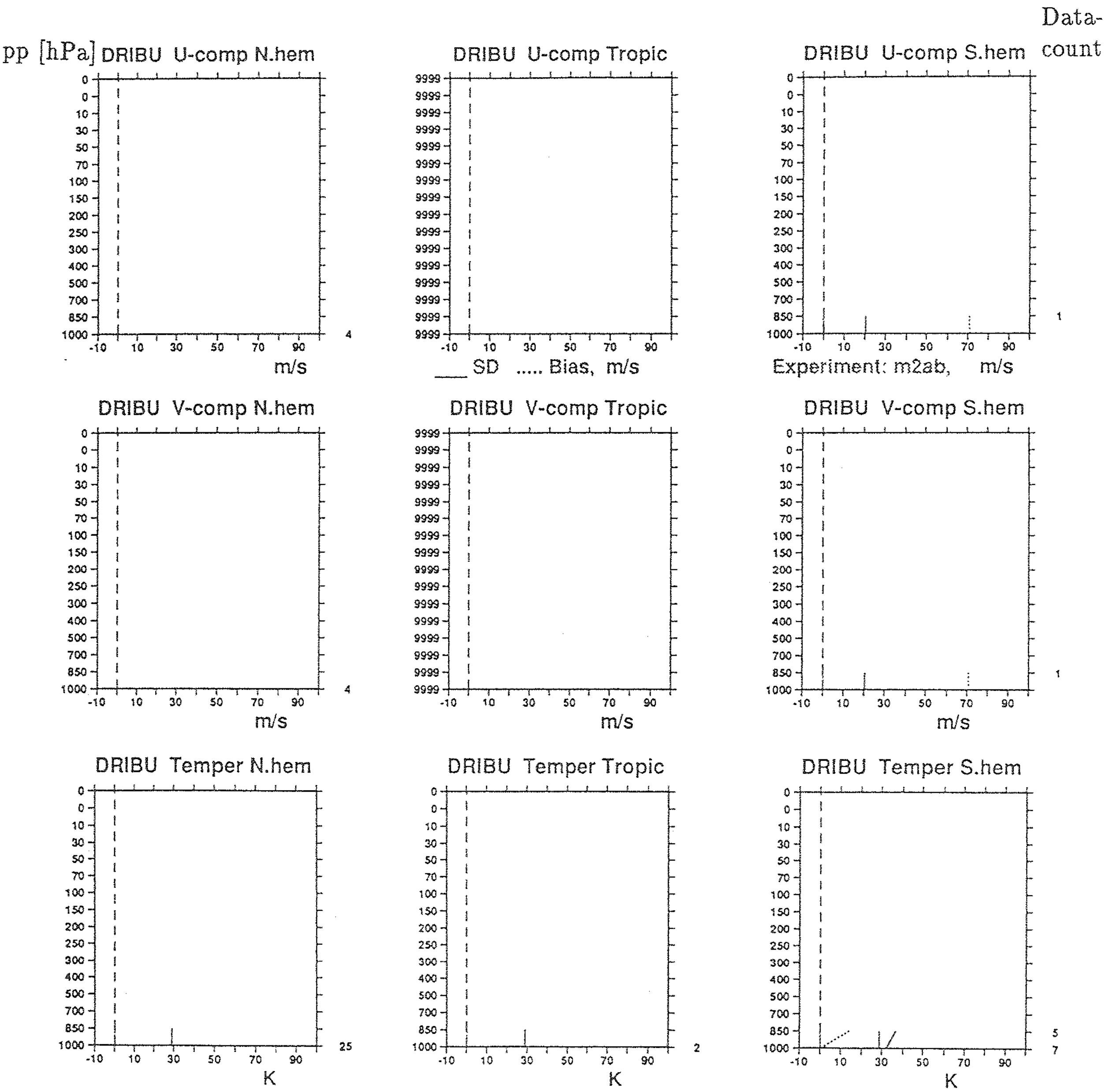


Figure 29: RMS statistics of gross error of the simulated DRIBUs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

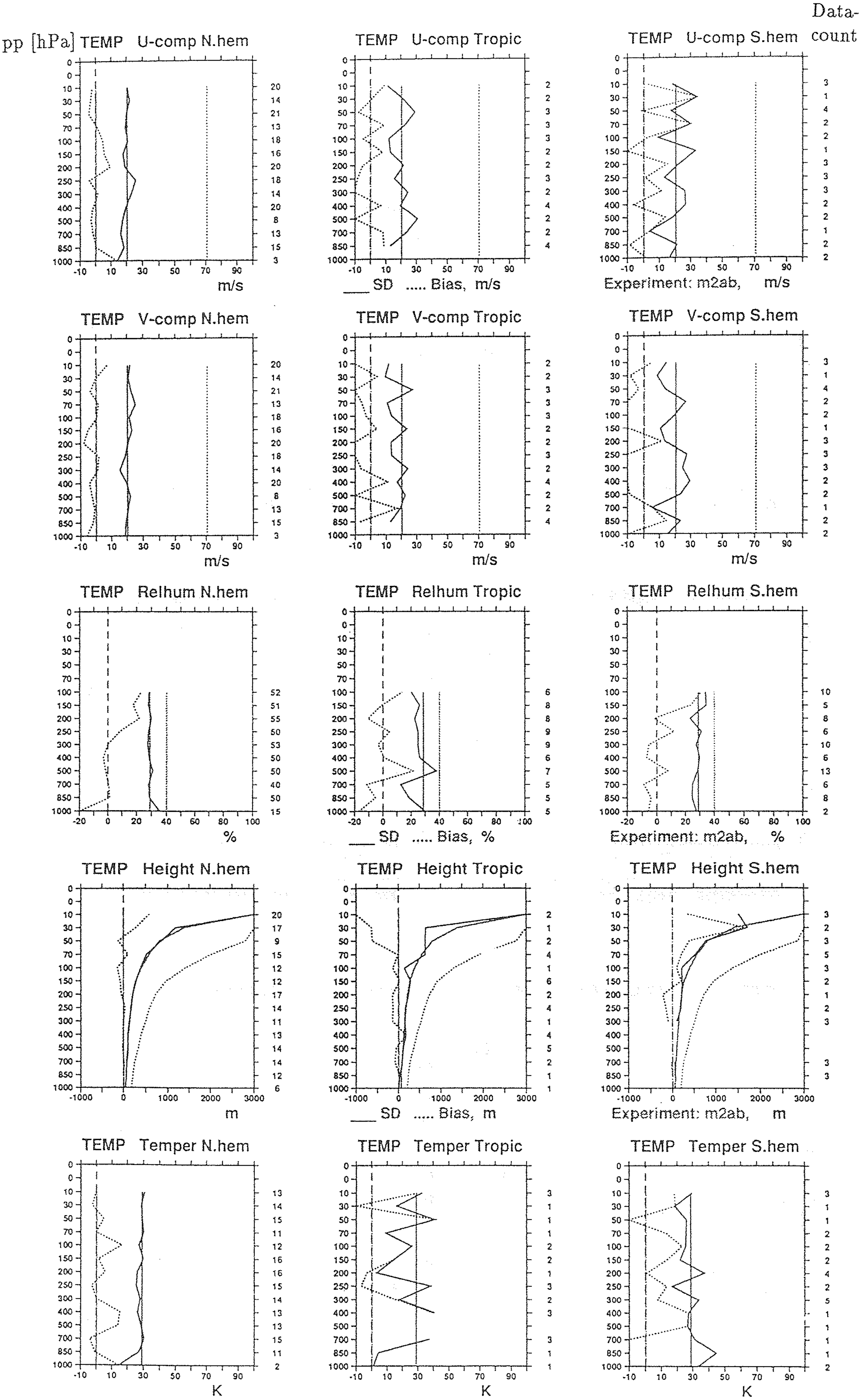


Figure 30: RMS statistics of gross error of the simulated TEMPs. Solid: theoretical and simulated SD, Dashed: Bias of simulated data.

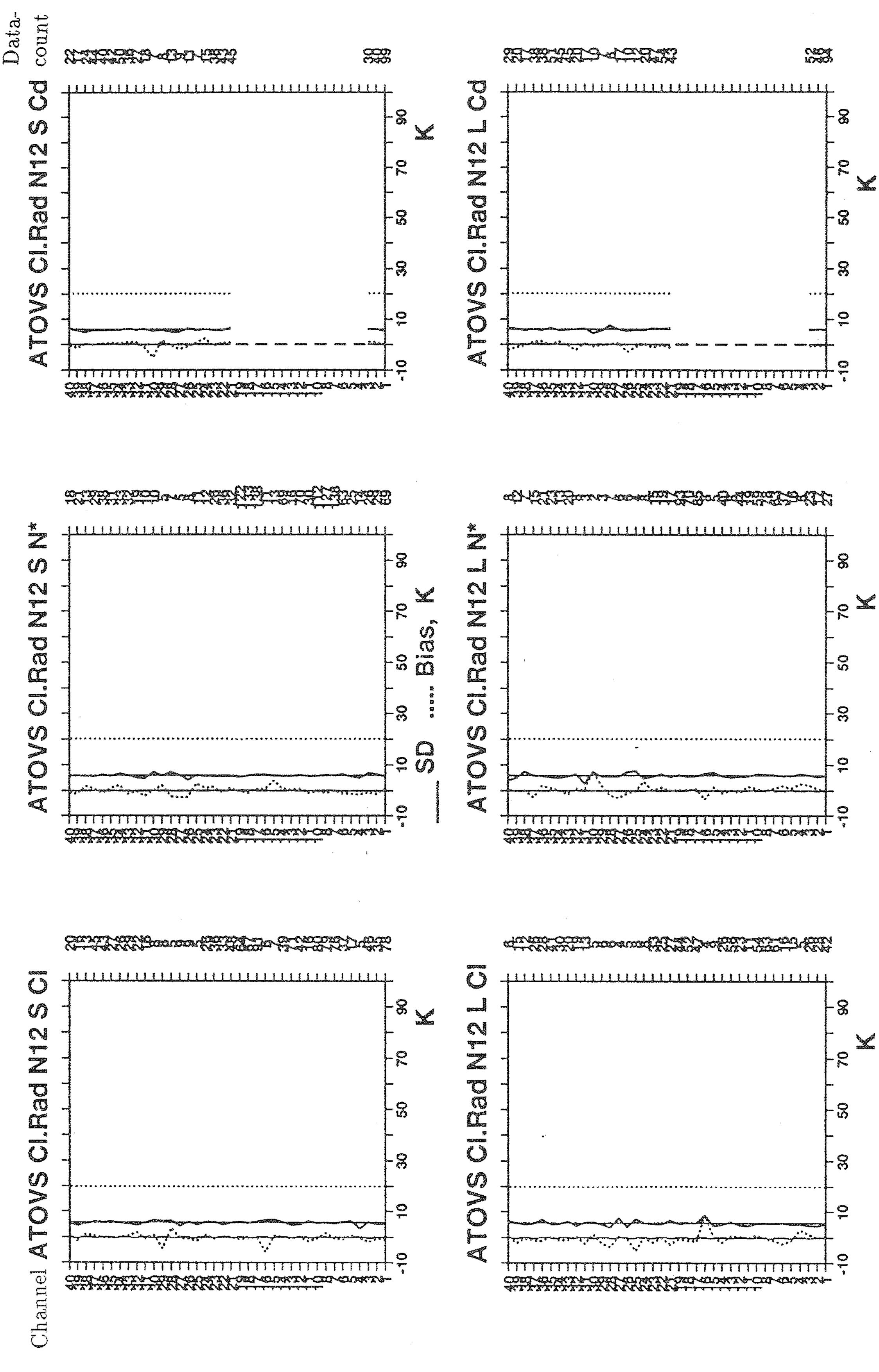


Figure 31: RMS statistics of gross error of the simulated ATOVS. Solid: theoretical and simulated SD, Dashed: Bias of simulation per channel. L, S indicates over land or over sea

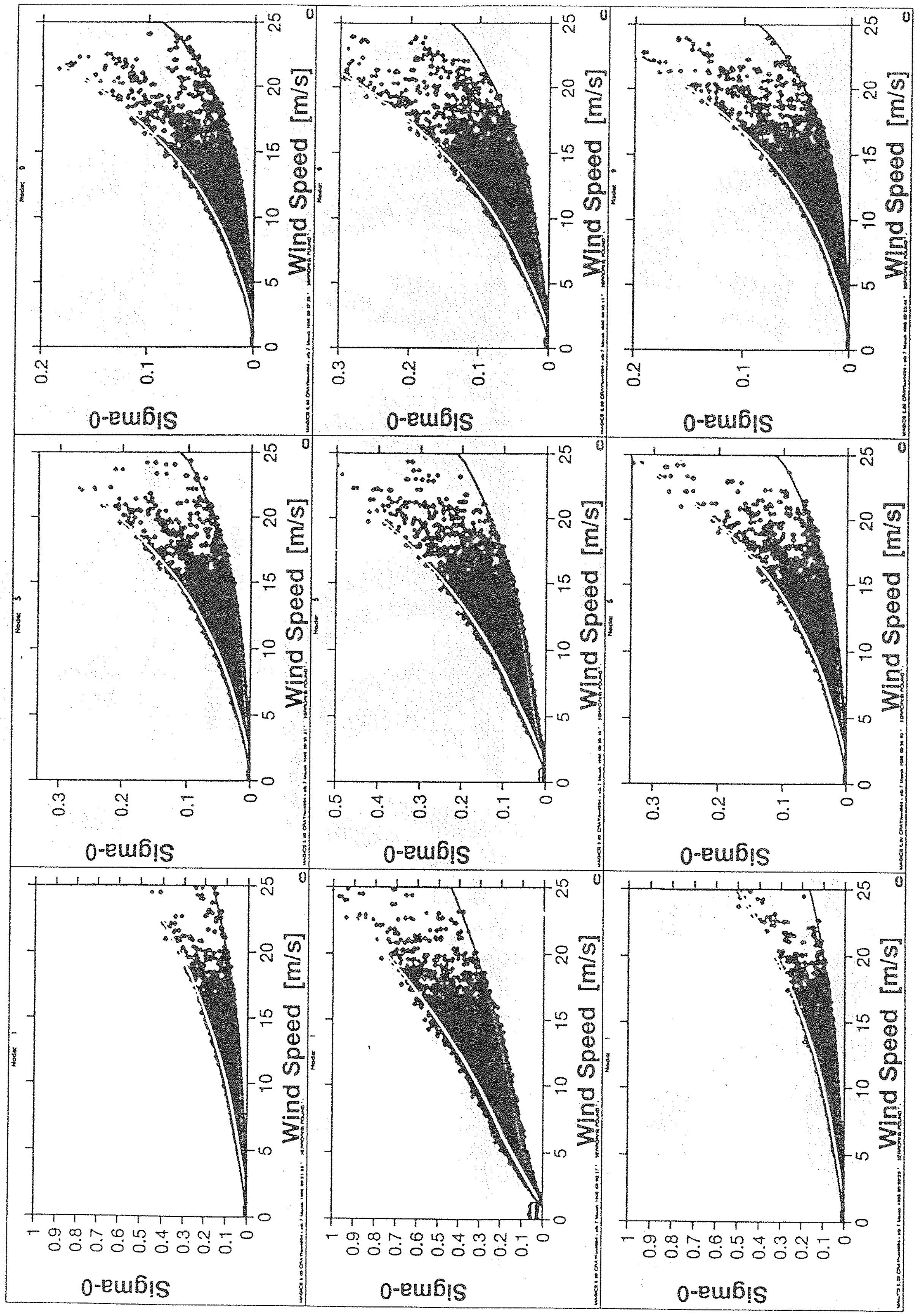


Figure 32: Simulated Sigma_0 per wind speed bin and node number 1, 5, 9, Forebeam on top, mid beam in the middle and aft beam below. Yellow: crosswind sigma_0, Red: downwind sigma_0, Green: nature run sigma_0, Blue: simulated sigma_0

Figure 33: comparison of HIRS channel 2 with AMSU channel 10 and the 50hPa Temperature, of HIRS channel 3 with MSU channel 4 and with AMSU channel 9 and the 100hPa Temperature and of MSU channel 3 with AMSU channel 7 and the 300hPa Temperature

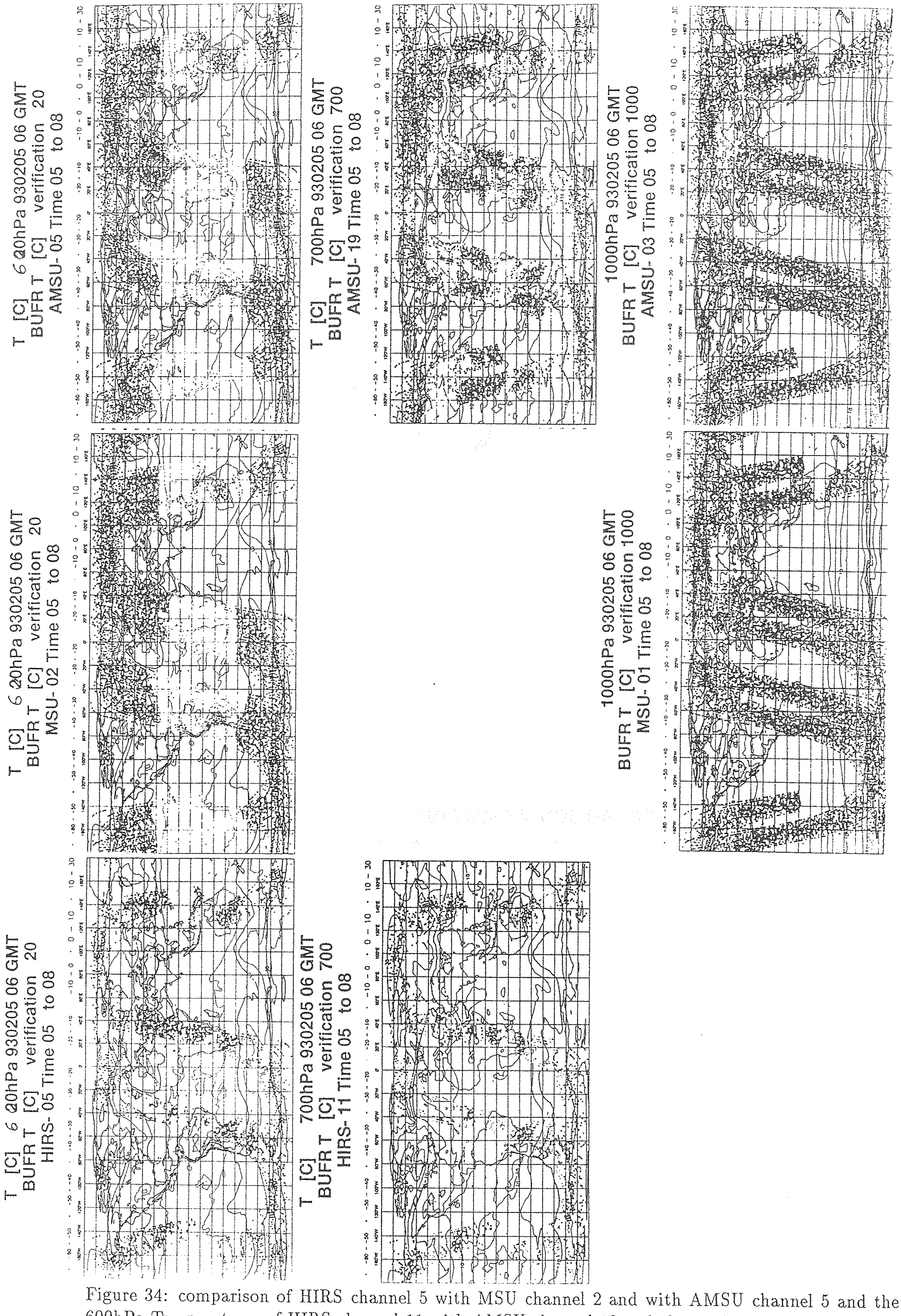


Figure 34: comparison of HIRS channel 5 with MSU channel 2 and with AMSU channel 5 and the 600hPa Temperature, of HIRS channel 11 with AMSU channel 19 and the 700hPa Temperature and of MSU channel 1 and with AMSU channel 3 and the 1000hPa Temperature

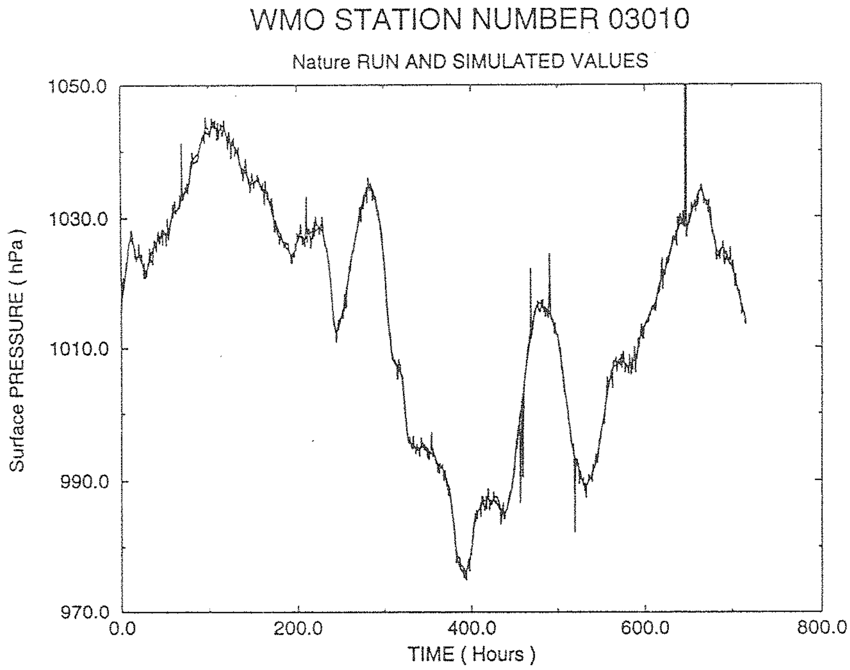


Figure 35: Surface pressure in Sule Skerry at 59.05 North and 4.24 West

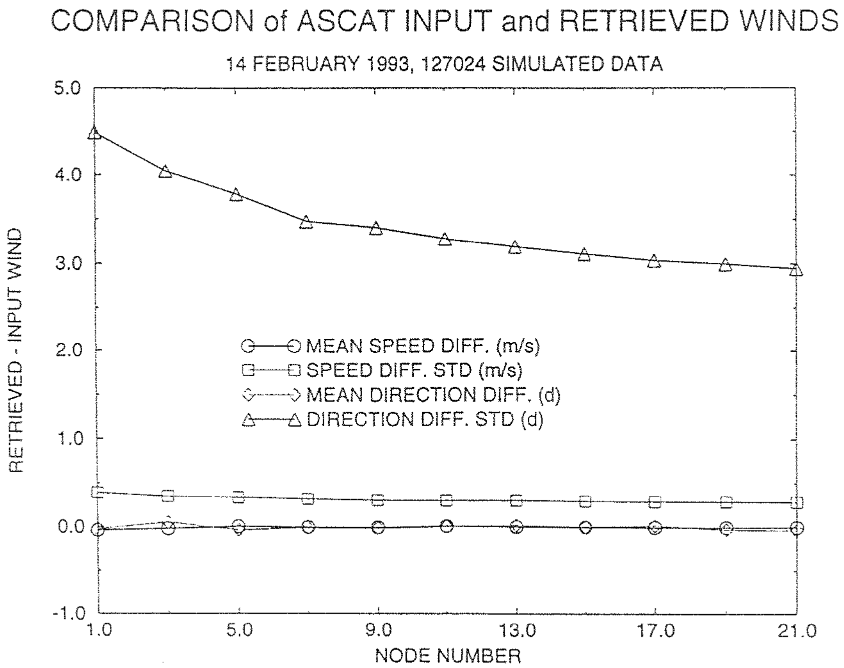


Figure 36: ASCAT: Retrieved and input wind vectors over node number

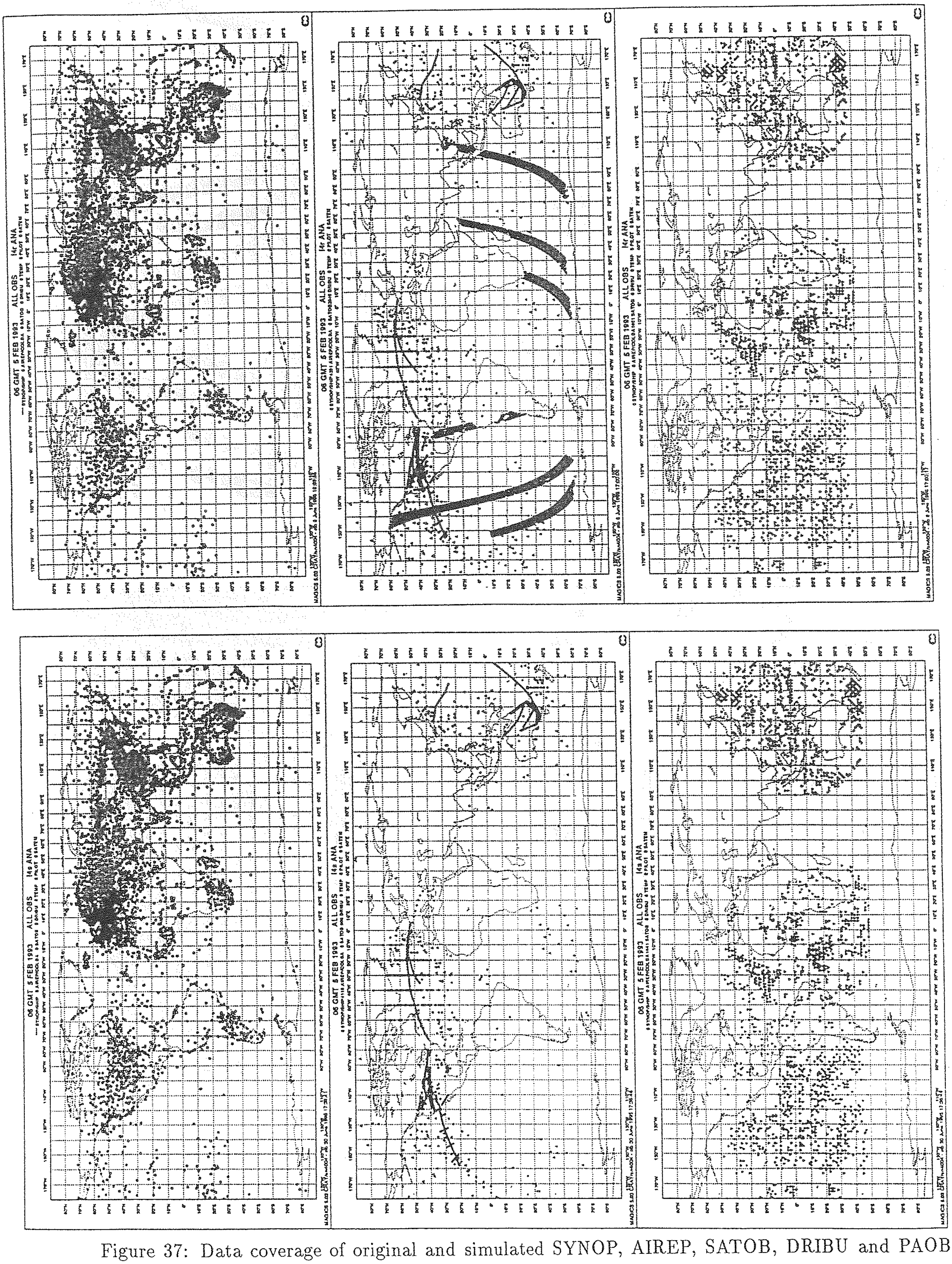


Figure 37: Data coverage of original and simulated SYNOP, AIREP, SATOB, DRIBU and PAOB observation data

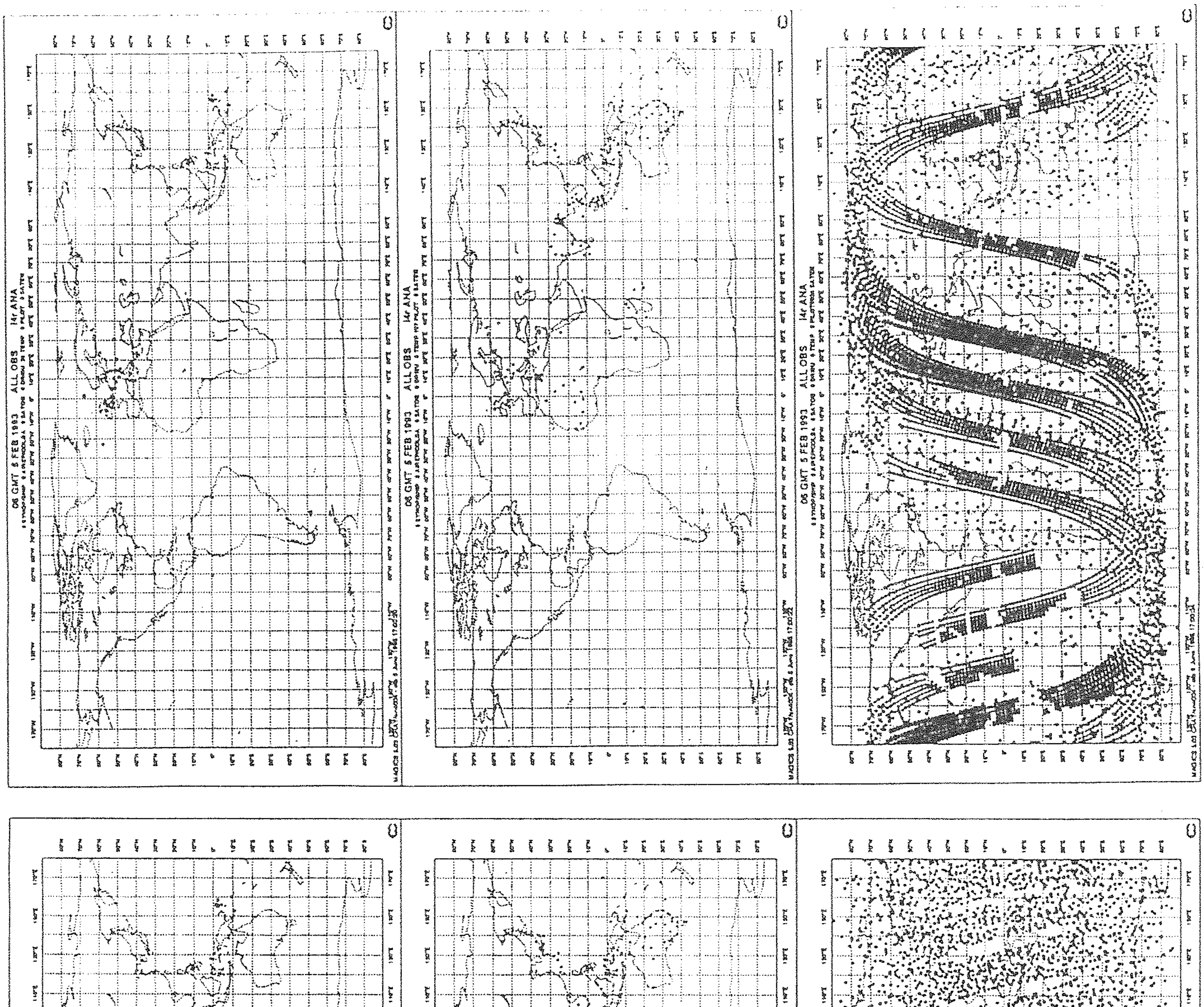
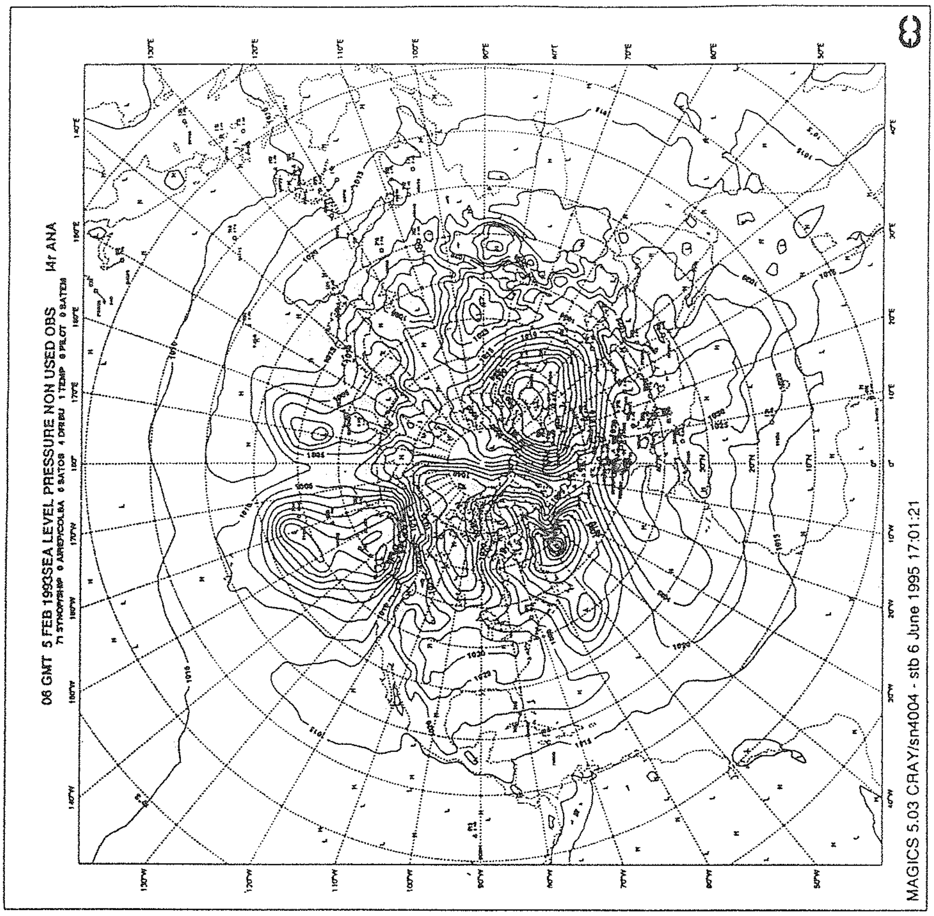


Figure 38: Data coverage of original and simulated TEMP, PILOT and TOVS observation data



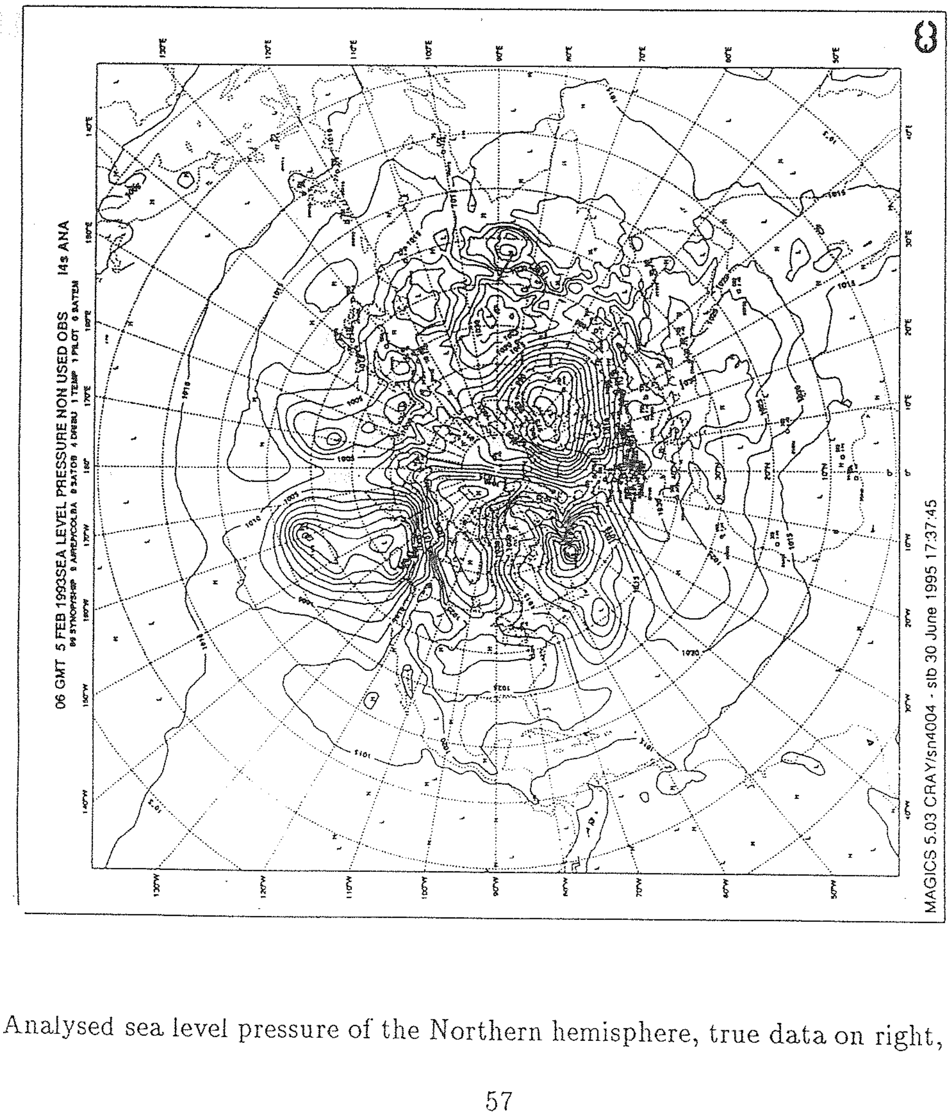
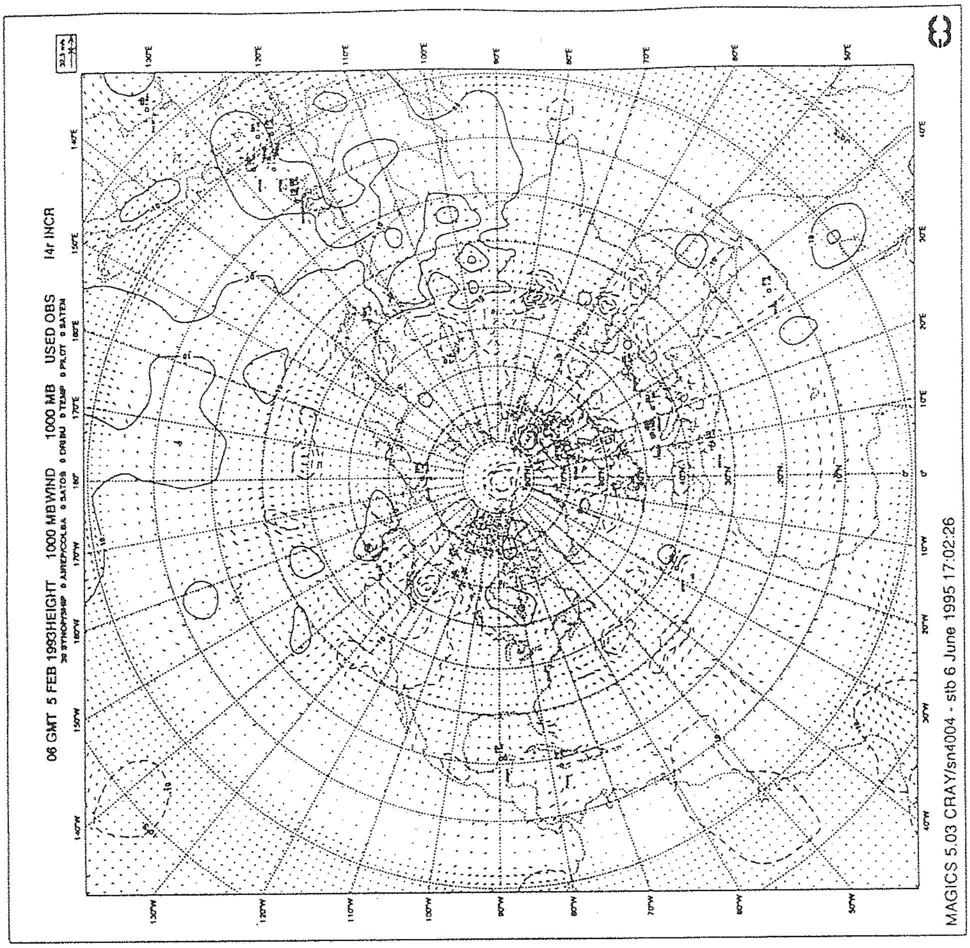


Figure 39: Analysed sea level pressure of the Northern hemisphere, true data on right, simulated data left



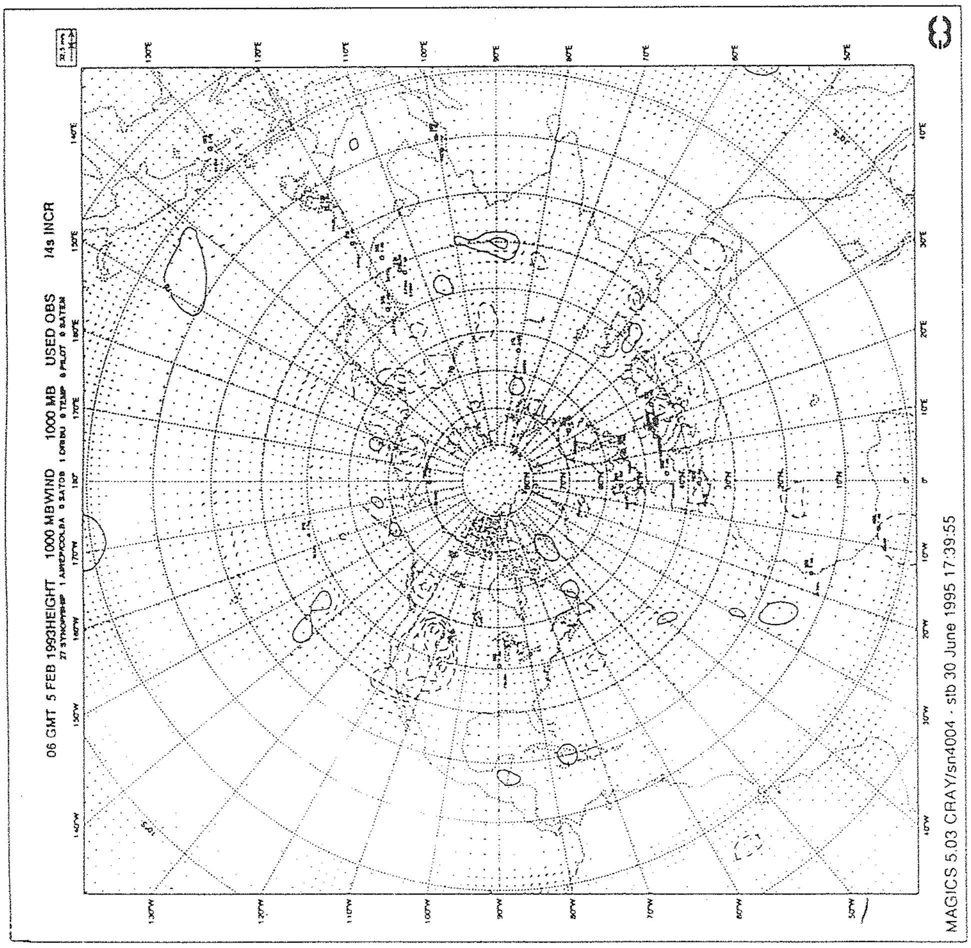
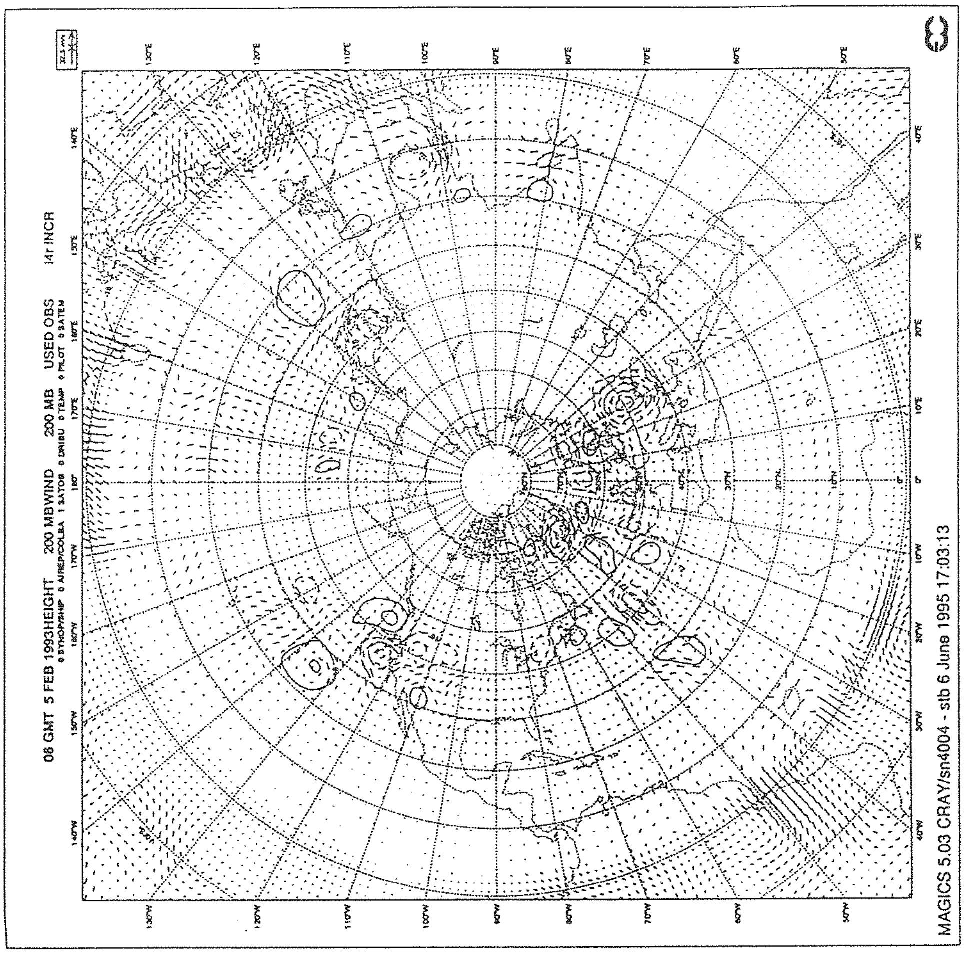


Figure 40: Increments of wind and height at 1000 hPa Northern hemisphere, true data on right, simulated data left



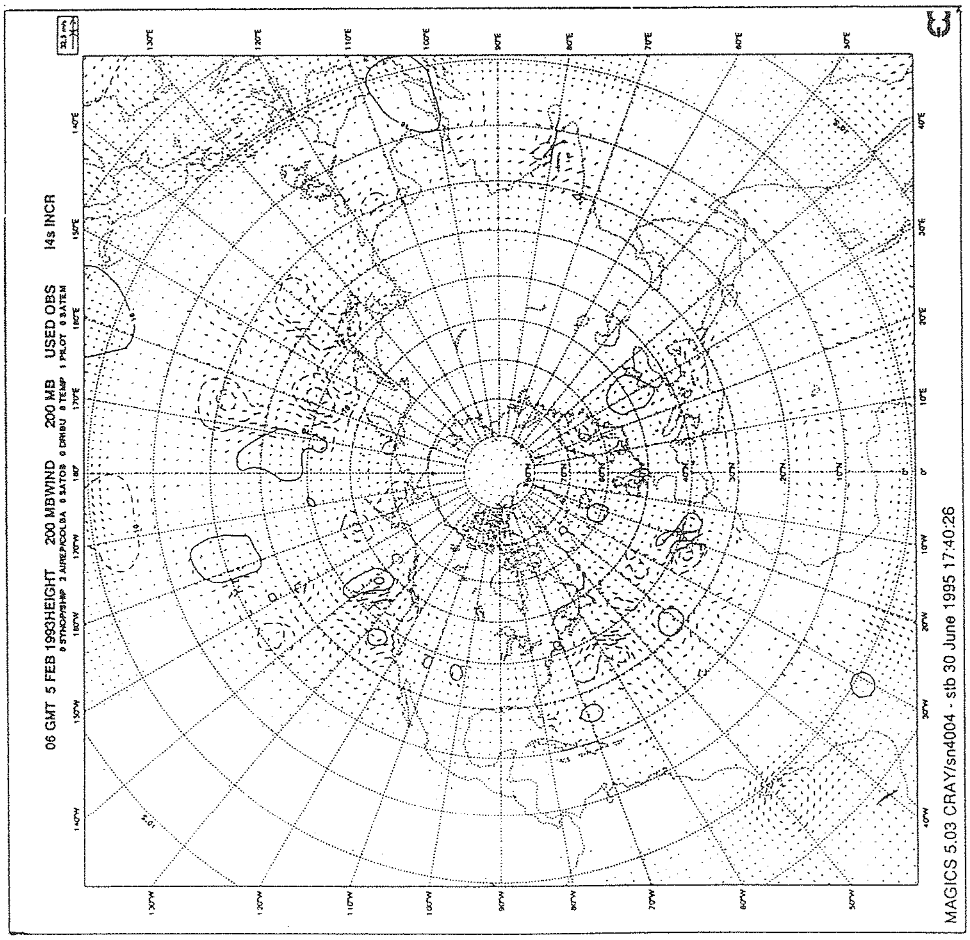


Figure 41: Increments of wind and height at 200 hPa Northern hemisphere, true data on right, simulated data left