Analysis of total water vapour content from GPS data, radiosondes and numerical weather prediction models in West Africa

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1. Introduction

- **Context and objectives**
  - The water cycle is governed by interactions between the ocean, the atmosphere and land. Many processes take place at various spatial and temporal scales. AMMA will provide intensive observations for the study and modelling of these processes.
  - We focus on the humidity component of the atmospheric water budget and related atmospheric processes (advection and convection) at regional and mesoscale.
- **Methodology**
  - Assess accuracy of various observational humidity data sources over land: ground-based (GPS, radiosondes, sun photometers) and space-borne (MODIS, AIRS…).
  - Assess accuracy of NWP models and climatologies (NCEP and ECMWF reanalyses, mesoscale models).
  - Improve observational products and NWP models through assimilation of new data and validation/improvement of parameterisations related to the water cycle.

2. Comparison of IWV observations

2.1. Description of data set

GPS: ▲

10 IGS stations

1999-2005

Radiosondes: ■

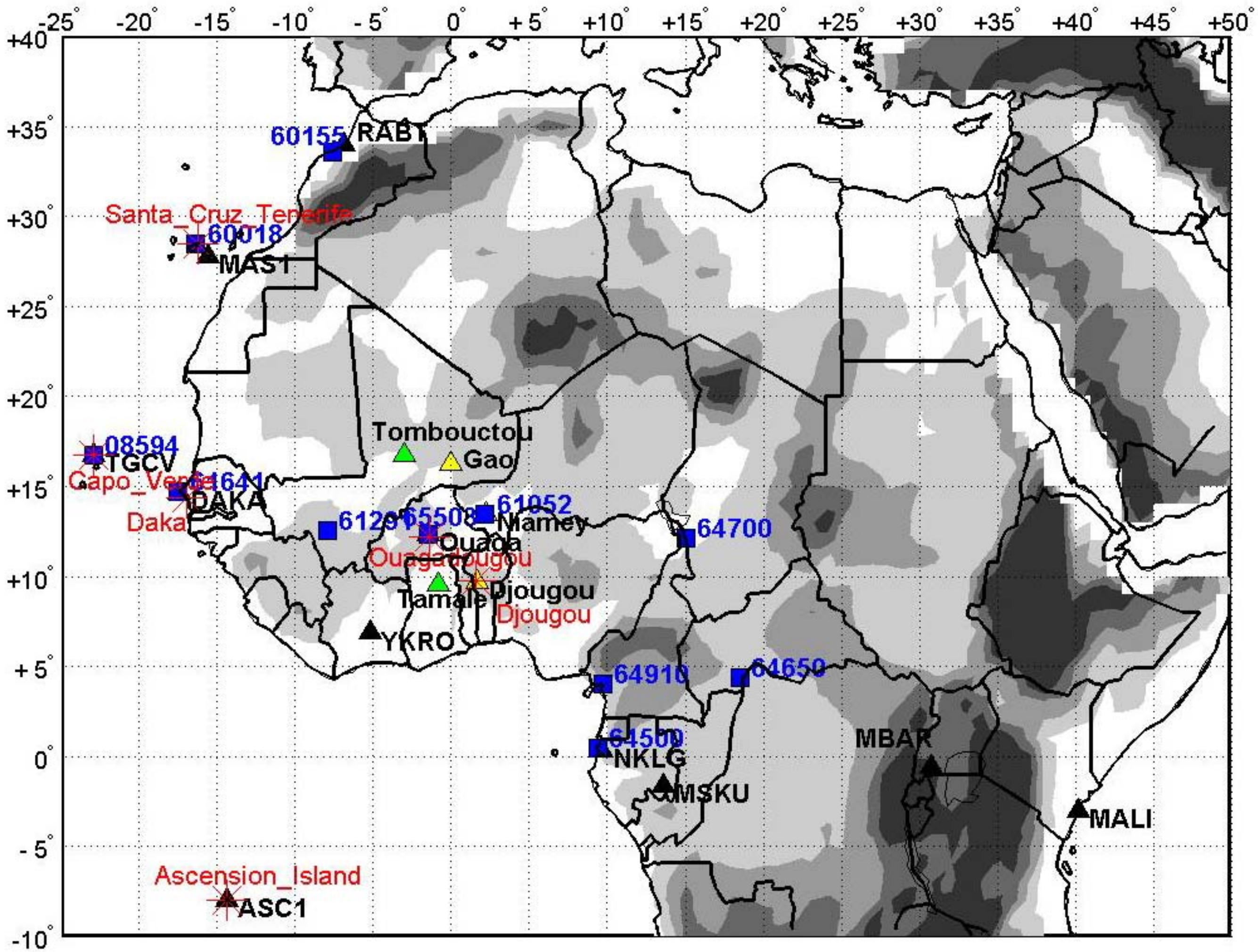
11 stations,

1999-2005

AERONET: *

6 stations,

1999-2005



AMMA GPS stations:

EOP: Gao, Niamey, Djougou △

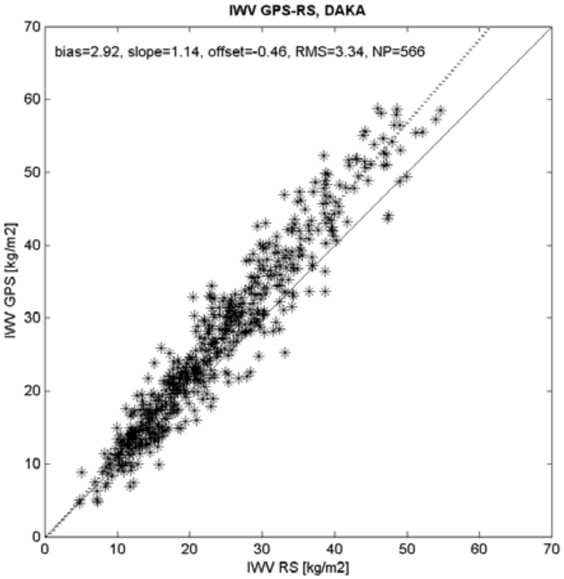
SOP: Tombouctou, Ouagadougou, Tamale △

2. Comparison of IWV observations

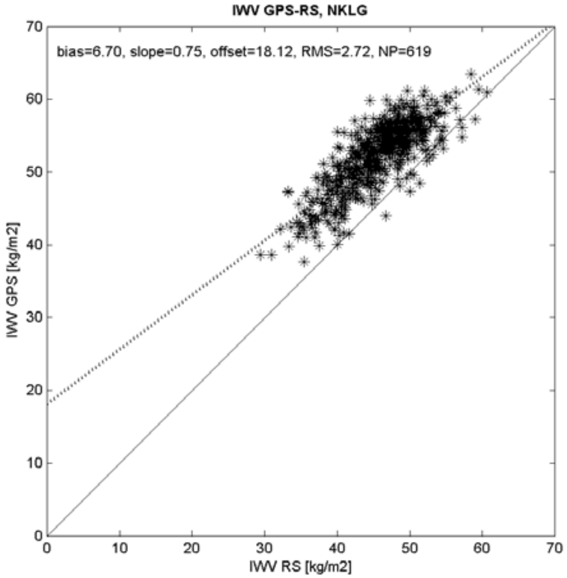
2.2. GPS compared to radiosondes

Station	ΔH [m]	PWV [kg/m2]	BIAS [kg/m2]	STD [kg/m2]	BIAS [%]	STD [%]	Correlation	slope	offset [kg/m2]	RMS [kg/m2]	NP
DAKA	-8	23.6	2.9	3.6	12	15	0.96	1.14	-0.5	3.3	566
MAS1	51	17.1	1.2	2.8	7	16	0.90	0.97	1.8	2.7	1545
NKLG	7	45.6	6.6	3.0	15	7	0.81	0.76	17.6	2.8	623
RABT	-23	17.9	2.3	2.4	13	14	0.94	1.06	1.2	2.4	925
TGCV	2	35.6	0.6	3.4	2	9	0.95	1.04	-0.9	3.3	33

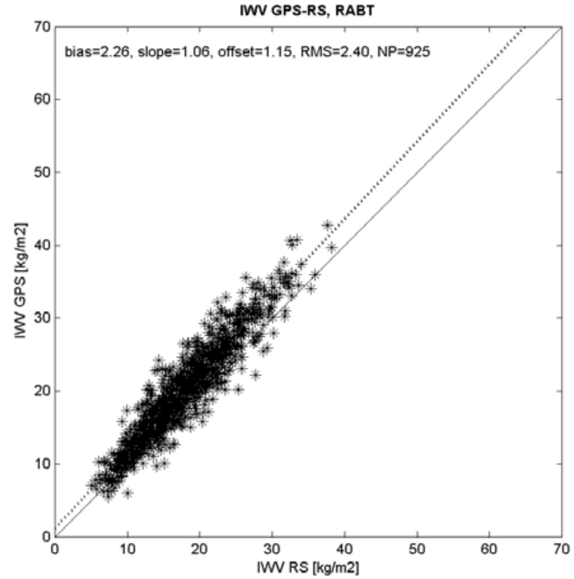
Dakar



Libreville



Rabat



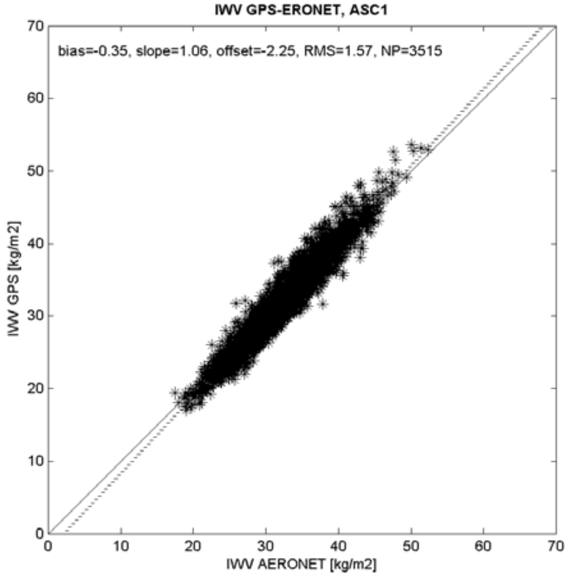
GPS

RS **RS** **RS**

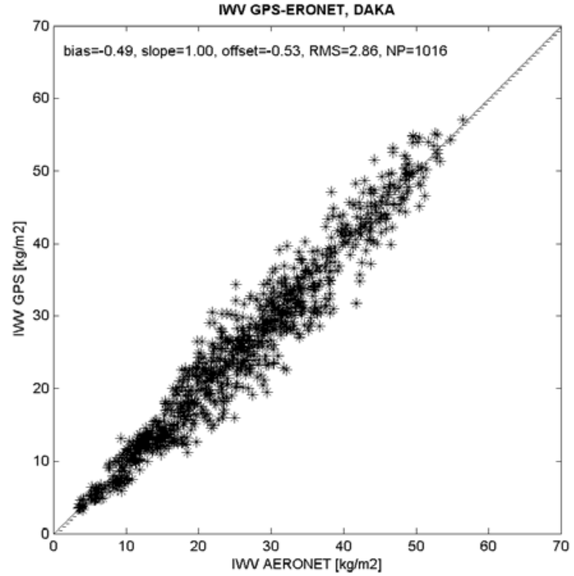
2.3 GPS compared to AERONET sun photometers

Station	ΔH [m]	PWV [kg/m2]	BIAS [kg/m2]	STD [kg/m2]	BIAS [%]	STD [%]	Correlation	slope	offset [kg/m2]	RMS [kg/m2]	NP
ASC1	61	32.2	-0.4	1.6	-1	5	0.96	1.06	-2.3	1.6	3515
DAKA	16	25.8	-0.5	2.9	-2	11	0.97	1.00	-0.5	2.9	1016
MAS1	104	25.9	0.3	3.7	1	14	0.66	0.45	14.4	2.5	63
TGCV	-54	34.0	1.6	3.3	5	10	0.93	1.05	0.0	3.3	279

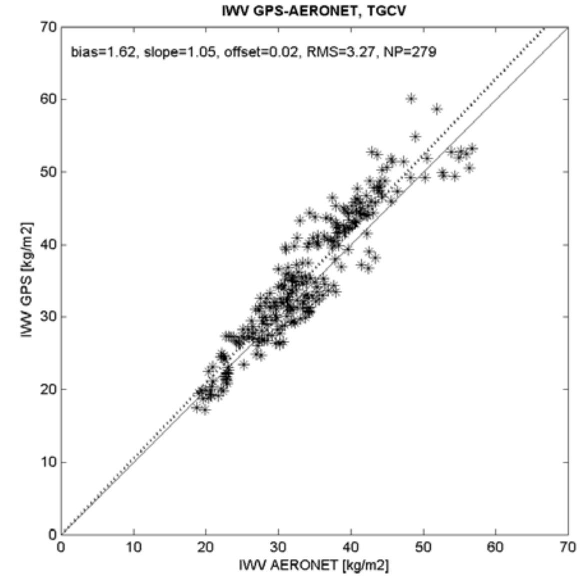
Ascension



Dakar



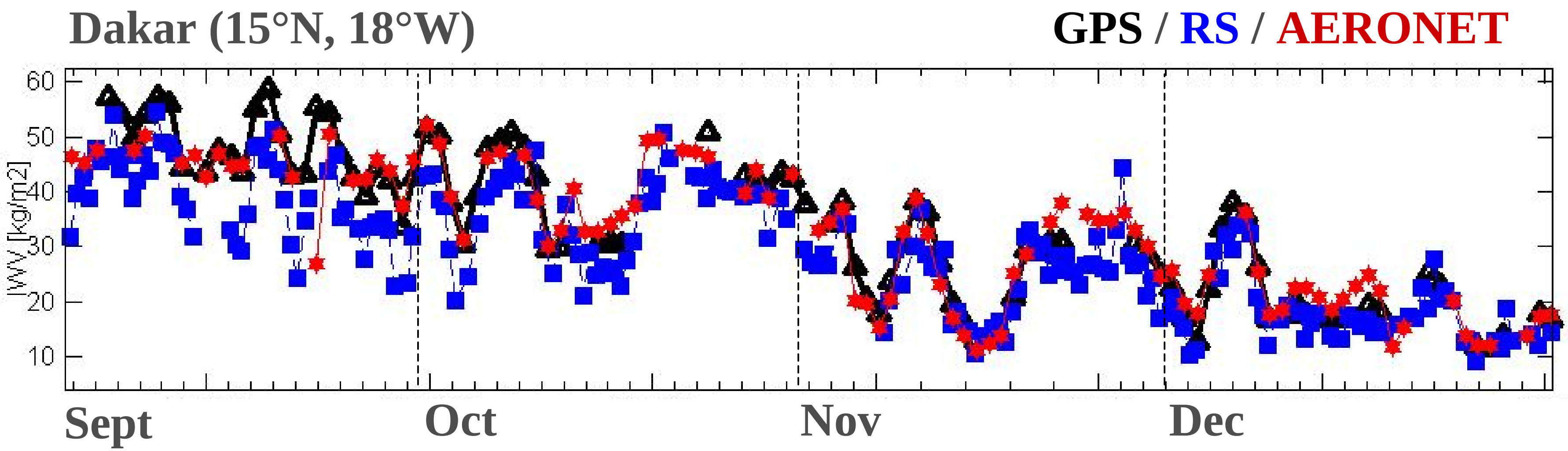
Sal



GPS

AERONET AERONET AERONET

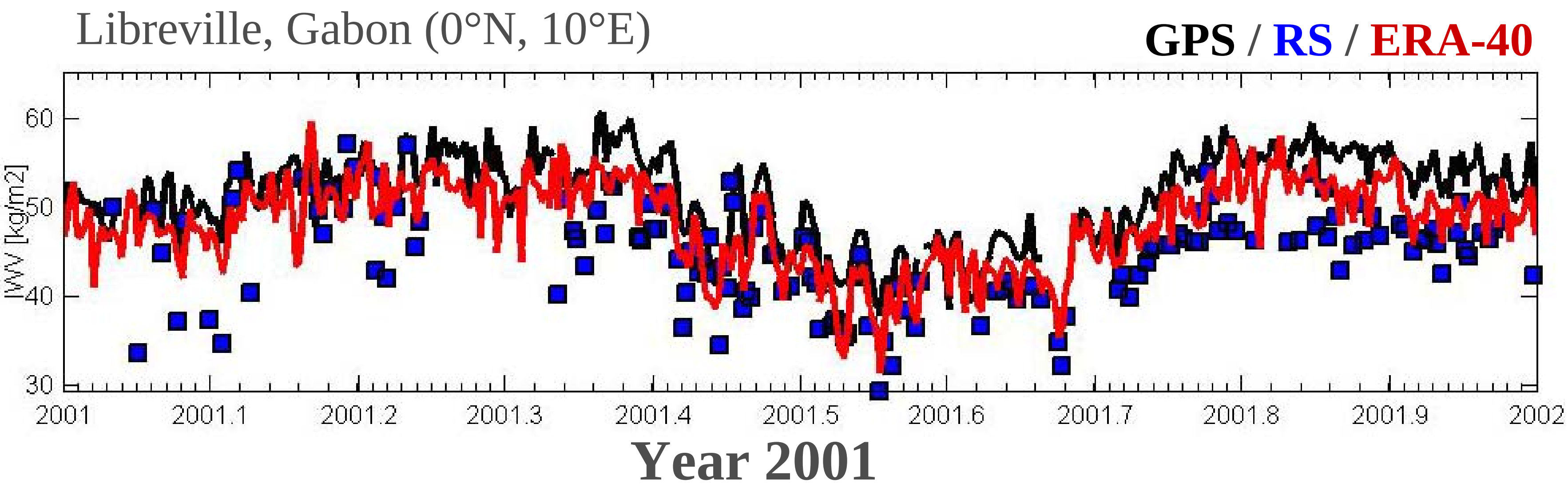
2.4 Focus on Dakar, Sept - Dec 2003



	GPS - RS				GPS - AERONET			
month	Sept	Oct	Nov	Dec	Sept	Oct	Nov	Dec
bias	9.1	6.9	2.6	2.1	-0.19	-0.51	-0.35	-2.4
std	3.1	3.5	3.1	2.6	3.3	4.1	3.7	2.5
corr	0.93	0.90	0.92	0.95	0.82	0.87	0.92	0.85
NP	40	31	40	35	62	79	110	88

=> large bias in radiosonde humidity data at Dakar for Sept. and Oct. 2003.

2.5 Focus on Libreville, 2001



=> Large bias in radiosonde humidity data at Libreville (constant over the period 2000 - 2004).

3. Model compared to GPS

3.1 ERA-40 compared to GPS

Domain: 9 IGS GPS stations (10°S - 35°N)

Period: 1999 - 2002

Model resolution: 1.125°

	Station	ΔH [m]	PWV [kg/m2]	BIAS [kg/m2]	STD [kg/m2]	BIAS [%]	STD [%]	Correlation	slope	offset [kg/m2]	RMS [kg/m2]	NP
SH	ASC1	91	35.0	-2.9	2.5	-8	7	0.92	0.86	2.1	2.3	3190
	MALI	42	41.4	2.7	3.9	7	9	0.85	0.81	10.7	3.6	4600
	MSKU	-146	41.9	3.7	4.0	9	10	0.61	0.68	17.1	3.8	1473
EQ	MBAR	127	28.0	3.4	3.5	12	12	0.71	0.72	11.4	3.2	1068
	NKLG	-170	48.5	2.8	4.0	6	8	0.73	0.66	19.5	3.5	3129
WA	YKRO	47	41.5	-0.9	4.6	-2	11	0.88	0.81	7.1	4.2	182
	TGCV	6	42.8	-1.8	4.2	-4	10	0.86	0.88	3.5	4.1	105
NH	MAS1	-161	20.1	-1.7	2.6	-8	13	0.92	0.94	-0.4	2.6	4145
	RABT	-426	19.2	-5.2	3.7	-27	19	0.84	0.76	-0.5	3.3	1409

=> Overall good agreement between ERA40 and GPS

3.2 NCEP2 compared to GPS

Domain: 10 IGS GPS stations (10°S - 35°N)

Period: 2001 - 2004

Model resolution: 2.5°

	Station	ΔH [m]	PWV [kg/m2]	BIAS [kg/m2]	STD [kg/m2]	BIAS [%]	STD [%]	Correlation	slope	offset [kg/m2]	RMS [kg/m2]	NP
SH	ASC1	90	36,0	-4,1	5,9	-12	16	0,54	0,55	12,1	5,2	3556
EQ	MALI	-195	35,6	8,7	7,2	24	20	0,48	0,50	26,5	6,3	4955
	MSKU	26	42,8	3,8	5,8	9	14	0,56	0,40	29,6	4,1	2280
	MBAR	138	29,6	0,5	5,3	2	18	0,51	0,40	18,1	4,0	2150
	NKLG	-159	46,1	6,6	5,2	14	11	0,52	0,43	32,8	4,0	5274
WA	YKRO	-12	48,4	-0,9	6,8	-2	14	0,09	0,06	44,7	3,7	407
	TGCV	0	32,9	3,0	4,5	9	14	0,88	1,04	1,6	4,5	201
	DAKA	27	27,6	0,1	5,4	0	19	0,93	1,22	-5,9	4,9	970
NH	MAS1	99	20,1	-1,2	3,3	-6	16	0,87	0,98	-0,8	3,3	5637
	RABT	-245,5	17,9	2,9	3,6	16	20	0,85	1,04	2,2	3,6	4494

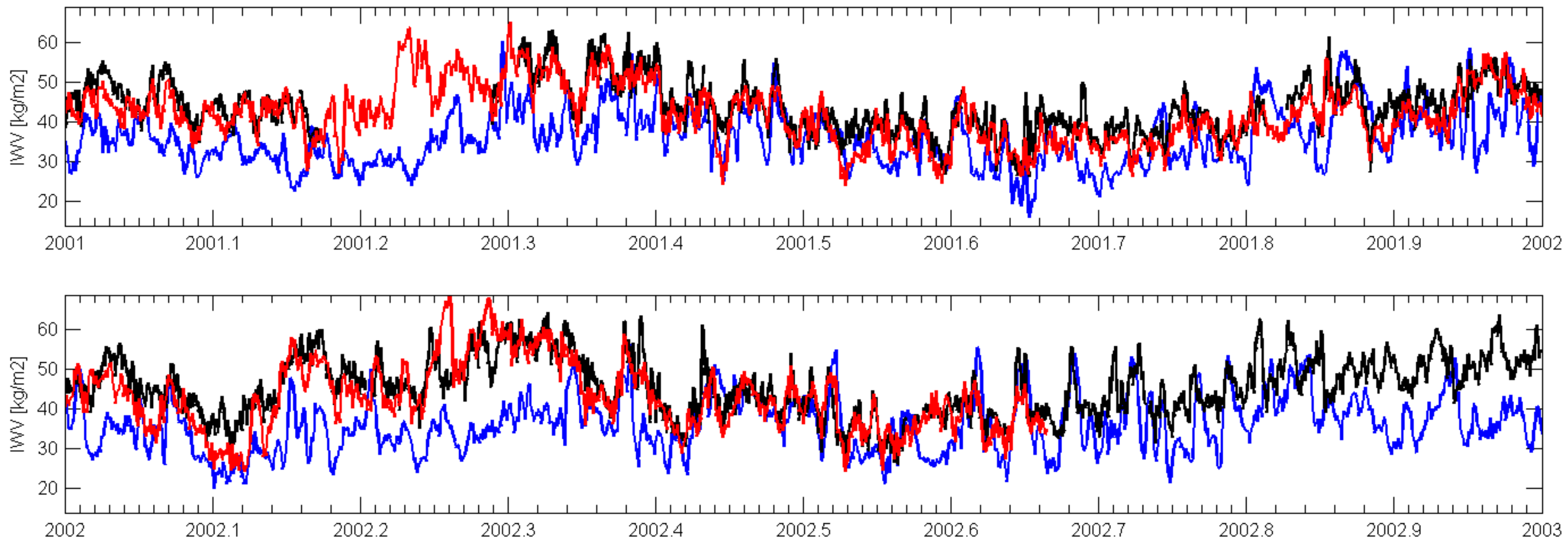
NCEP2: Bias= 6%, STD=16%, correlation=62%

ERA40: Bias=-2%, STD=11%, correlation=81%

3.3 Time evolutions

Malindi, Kenya (3°S, 40°E)

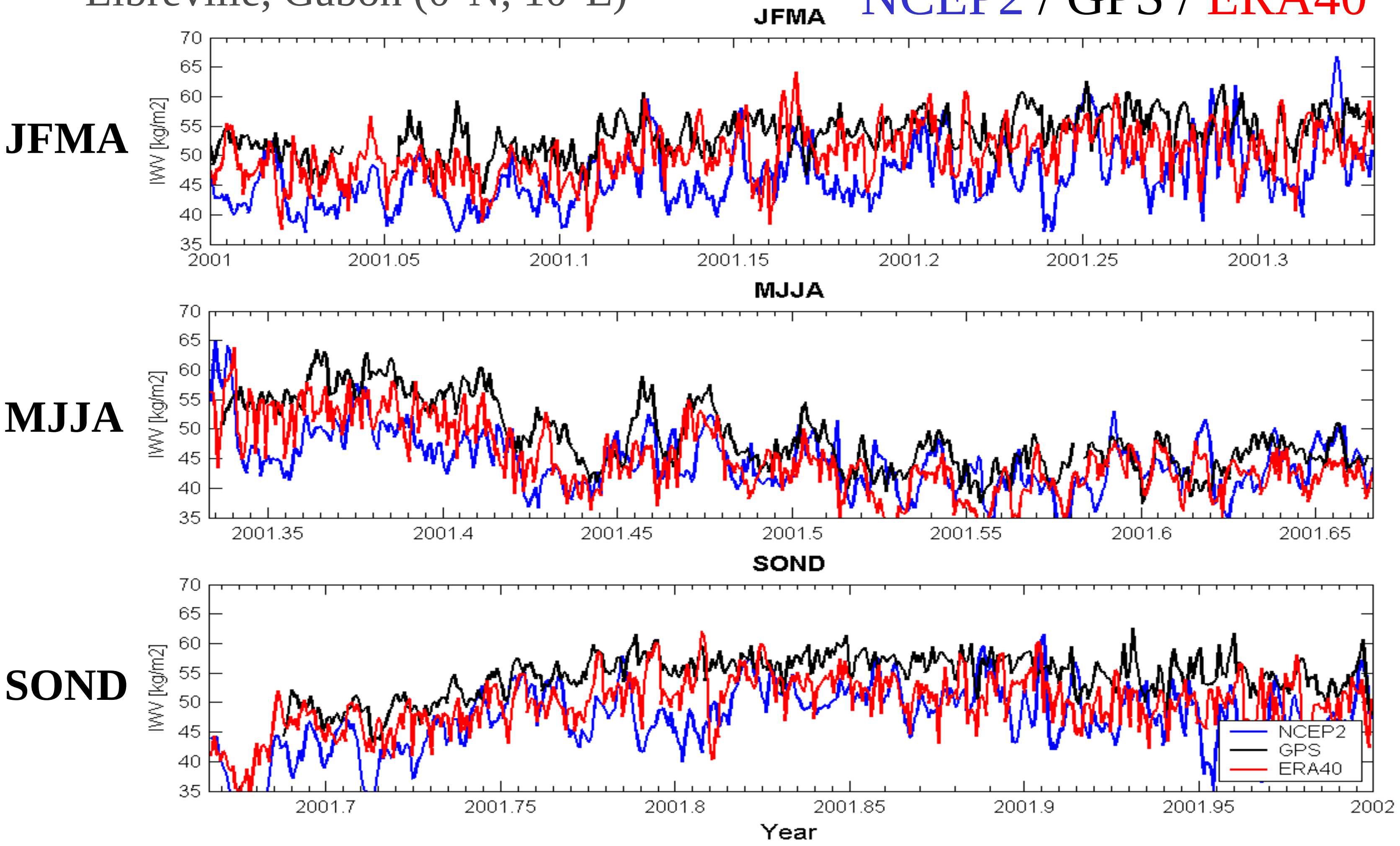
NCEP2 / GPS / ERA40



=> Problems with seasonal cycle in NCEP2

Libreville, Gabon (0°N, 10°E)

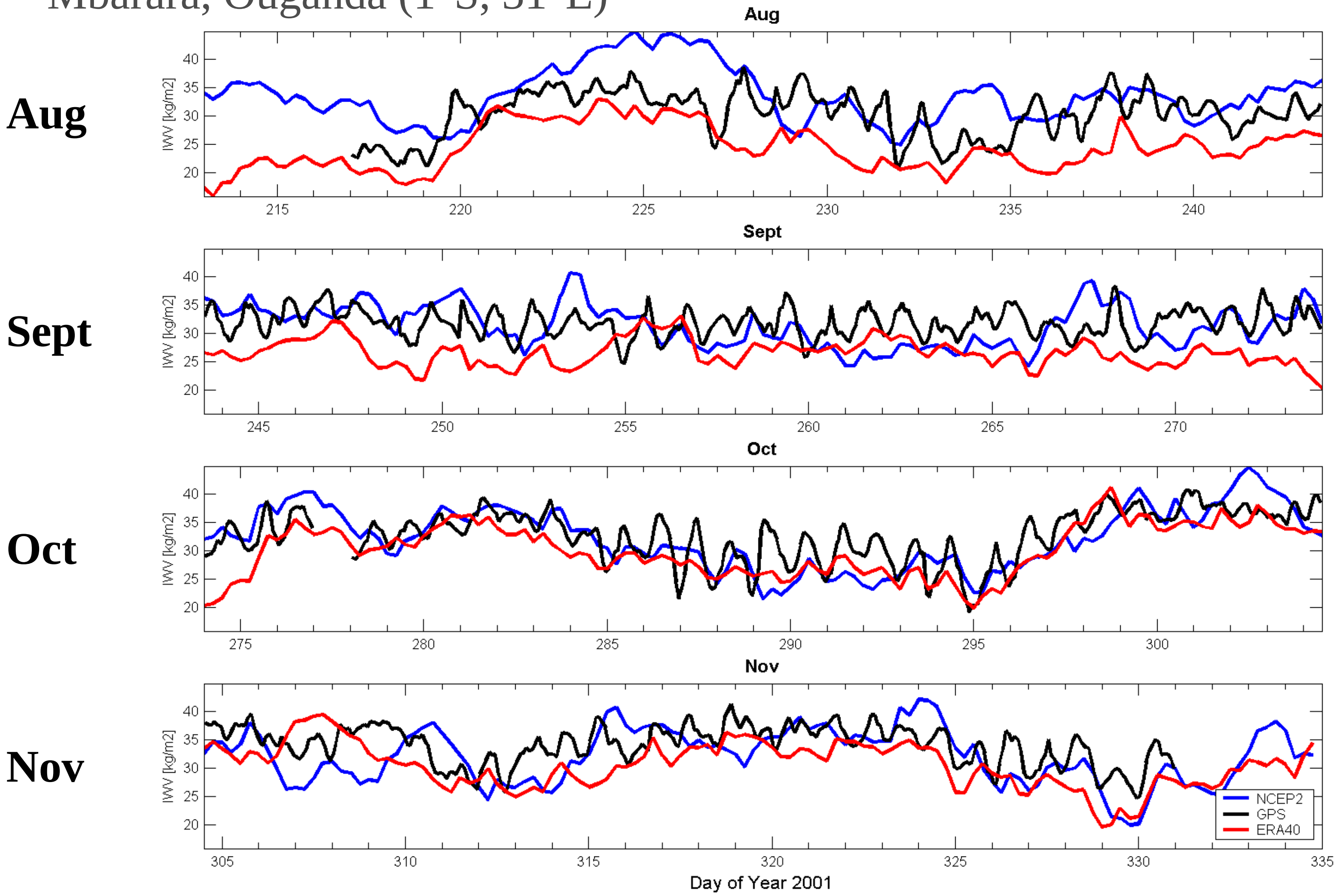
NCEP2 / GPS / ERA40



=> Problems at synoptic scale in both models

NCEP2 / GPS / ERA40

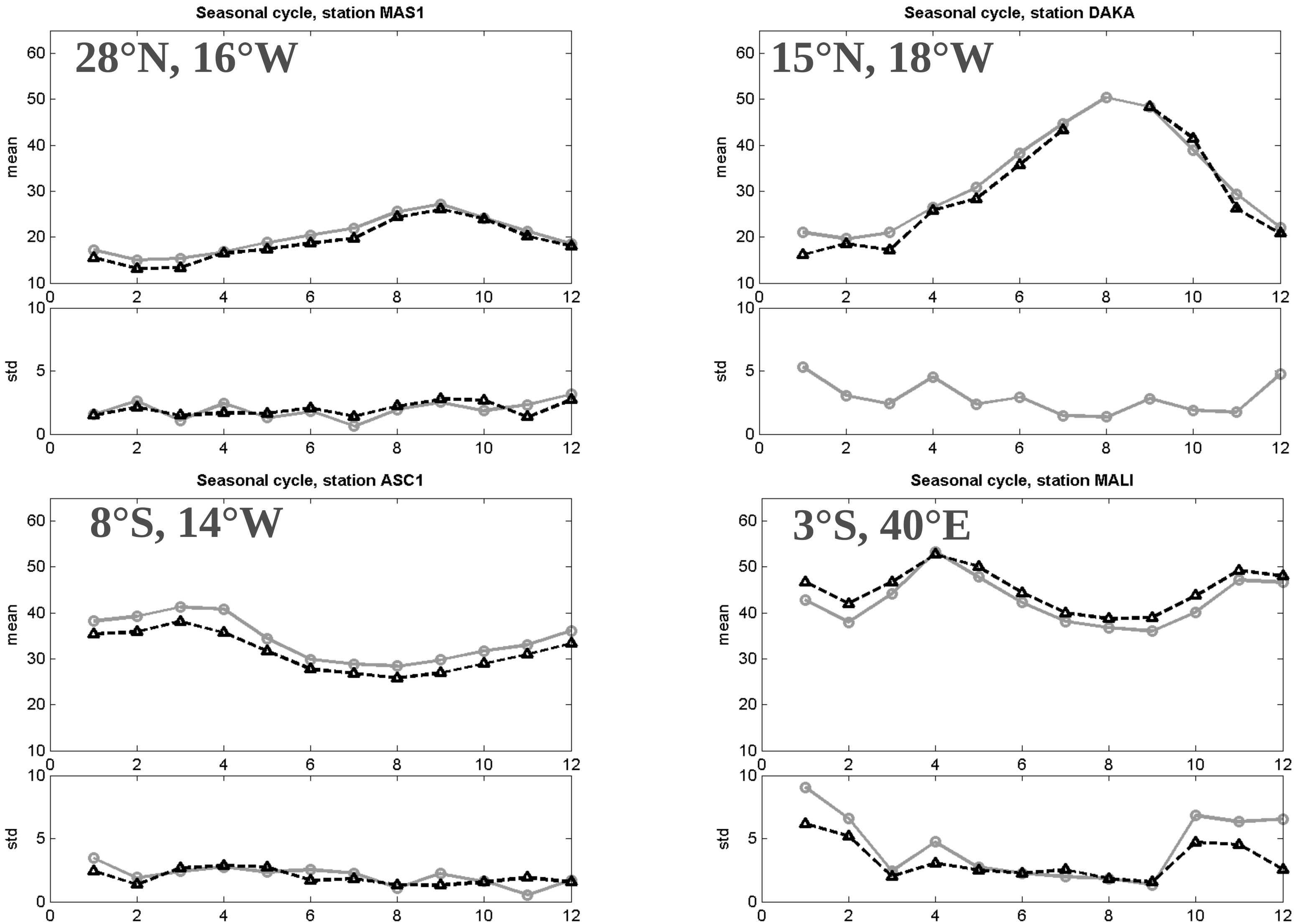
Mbarara, Ouganda (1°S, 31°E)



=> Problems with diurnal cycle in both models

4.1 Seasonal cycle

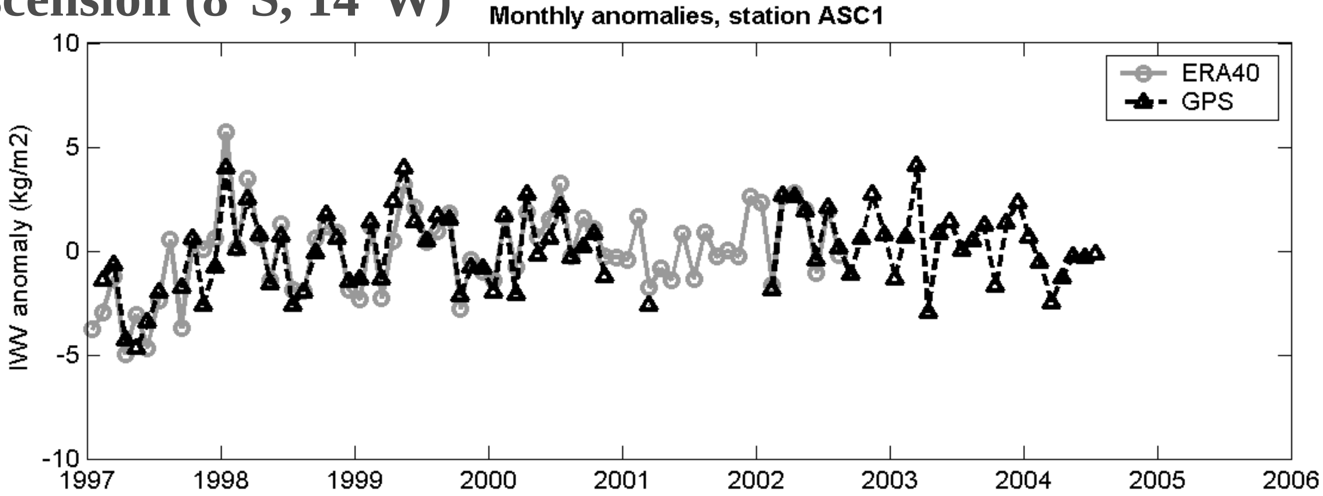
GPS (1997/04) and ERA40 (1997/02)



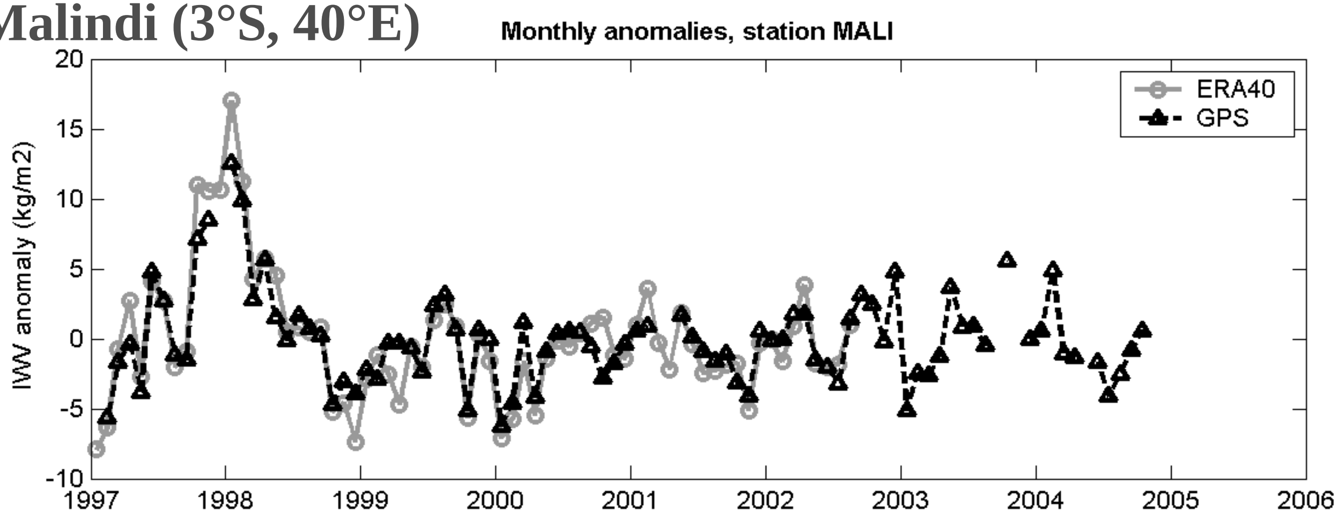
4.2 Monthly anomalies

GPS vs. ERA40

Ascension (8°S, 14°W)

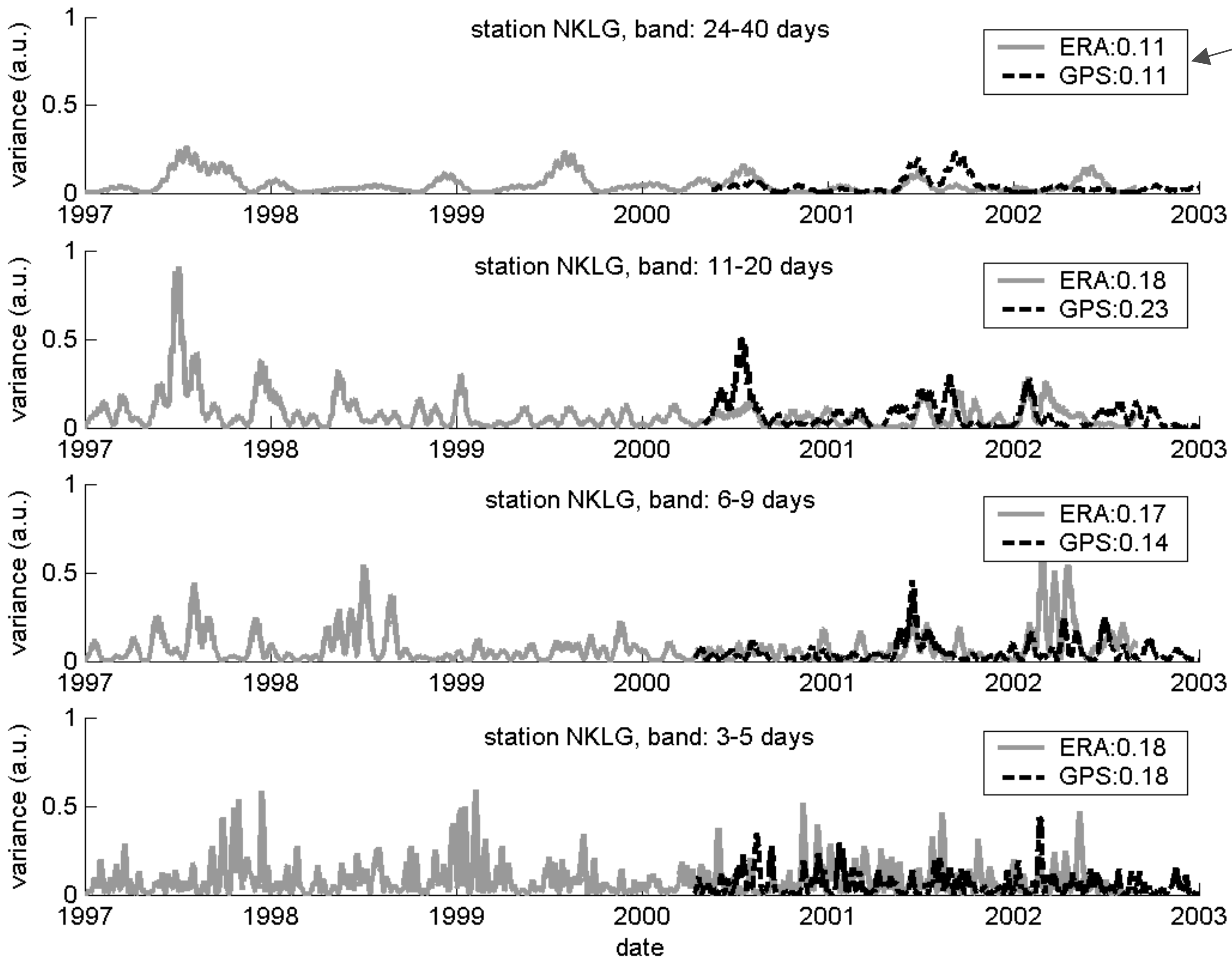


Malindi (3°S, 40°E)



4.3 Intraseasonal to synoptic scales

GPS vs. ERA40



Fraction of intra-seasonal variance (2-60 d.)

5.1 Conclusions

- **Comparison of IWV observations**

  => Good agreement between GPS and AERONET sun photometers

  => Biases in radiosonde data (Dakar, Libreville)

- **Comparison of NWP reanalyses to GPS**

  => Better performance of ERA40 over NCEP2

  => Some differences at synoptic scale and diurnal cycle compared to GPS

- **Multiscale analysis of IWV over Africa**

  => GPS provides a coherent description of the IWV climatology over the 1997 - 2005 period

5.2 Perspectives

- **GPS deployment during the AMMA project**
  - Six additional GPS stations from AMMA-Fr:

    EOP 2005 - 2007: Gao, Niamey, Djougou

    SOP April - Oct 2006: Tombouctou, Ouagadougou, Tamale
  - Possibly, two or more stations from IHY 2007 project (UN funded), see Poster from Basu et al. (Guinea, Nigeria)
- **Contribution of GPS data to AMMA**
  - At regional scale:

    Validation and improvement of humidity observations from satellites (MODIS, AIRS) and NWP models (parameterisations)

    => Improve understanding of diurnal cycle, intra-seasonal and inter-annual variability in convection and rainfall
  - At mesoscale:

    Assimilation into / validation of mesoscale atmospheric models

    => Process studies (convection) and mesoscale water budgets.