## **List of Figures**

2.1 Atmospheric transmission of a mid-latitude standard summer at	tmo-
sphere around the $\rho\sigma\tau$ -water vapour absorption band. The blue	and
red boxes indicate the spectral location of the MERIS and MO	DIS
channels used for the retrieval of atmospheric water vapour cor	ntent
and the appropriate channel numbers as given in Tables 2.1 and	12.2. 5
2.2 Optical depth scaling factors $f$ determined from observed and	cal-
culated integrated intensities over $100 \text{ cm}^{-1}$ wide spectral inter	rvals
for four different databases. The spectral range of the MERIS	and
MODIS water vapour absorption channels 14 and 19, respective	vely,
are indicated.	12
2.3 Two dimensional histograms of the relative difference between	cal-
culated and observed optical depths for the a) HITRAN 2000, b)	) ESA-WVR,
c) HITRAN 99 and d) HITRAN 96 database for a spectral in	nter-
val around 940 nm (10638 cm $^{-1}$ ). The white crosses repre	esent
the mean values of the distribution at increments of 0.05 in o	opti-
cal depth. The dashed horizontal lines indicate the extremes re-	sult-
ing from the estimated $\pm$ 6% uncertainty on the water vapour	total
column	14
2.4 Sensitivity of the measured signal for varying columnar water va	apour
content above land. The signal is the logarithm of the radiance	ratio
of one absorption and one window channel. Value are calcul	lated
for padir viewing direction and sup zenith angle of $25^{\circ}$	16

2.5	Estimated relative error in columnar water vapour content due to	
	sensor noise. Values are calculated for nadir viewing direction and	
	sun zenith angle of $35^{\circ}$	17
2.6	Theoretical regression error for water vapour above land based on	
	the inversion of simulated radiances. Results are shown as a func-	
	tion of sun and viewing geometry for MERIS (left panel) and MODIS	
	(right panel). Inversions were performed for 20.000 randomly cho-	
	sen simulations with sun zenith angles between $12^\circ$ and $70^\circ$ and	
	viewing zenith angles of $0^{\circ}$ and $50^{\circ}$	20
2.7	Theoretical regression error for water vapour above clouds based	
	on the inversion of simulated radiances. Results are shown as a	
	function of sun and viewing geometry for MERIS (left panel) and	
	MODIS (right panel). Inversions were performed for 20.000 ran-	
	domly chosen simulations with sun zenith angles between $12^\circ$ and	
	70°, viewing zenith angles of 0° and 50° and surfaces reflectivities	
	$\leq 0.3.$	21
2.8	True colour image created from MERIS full resolution measure-	
	ments taken 12.08.2003	22
2.9	Subset of the MERIS scene shown above (left), derived columnar	
	water vapour (middle) and surface height from a digital elevation	
	map (right)	22
2.10	MERIS reduced resolution scene taken the 3rd of August 2002 over	
	Sicily. Shown are a true colour image (upper left), the derived in-	
	tegrated water vapour (upper right), the surface height (lower left)	
	and a transection of surface height and water vapour along $15^\circ E$	
	(lower right).	23
2.11	MERIS reduced resolution scene taken the 12th of December 2002	
	over eastern Germany and Poland. Shown are a true colour im-	
	age (upper left), the derived integrated water vapour above clouds	
	(upper right), the derived cloud top pressure (lower left) and a tran-	
	section of cloud top pressure and water vapour along 18°E (lower	
	right)	24

2.12	NCEP reanalysis of 850 hPa temperature for 12. 10. 2002, 00 UTC.	
	Figure taken from http://www.wetterzentrale.de/topkarten	25
2.13	True colour image and retrieved water vapour from a MODIS scene	
	taken the 6th of August 2003	26
2.14	Columnar water vapour from radio soundings and MODIS for the	
	radiosonde station indicated in figure 2.13	26
3.1	Flowchart of the near-real-time processing system used at the Insti-	
	tut für Weltraumwissenschaften for the automated retrieval of atmo-	
	spheric water vapour and cloud properties from MODIS data and	
	the display of results on the Internet	28
3.2	Time delay between begin of MODIS daytime overpasses and start	
	of ftp-transfer of level 1b data for two satellite receiving stations.	
	The dots show values for individual overpasses, the lines indicate	
	monthly mean values. Overpasses with a time delay larger than 3	
	hours were omitted	29
3.3	Histogram of the time-delays shown in figure 3.2	30
3.4	Number of days per month for which no MODIS daytime over-	
	passes were transmitted within 3 hours from the two receiving sta-	
	tions of Figure 3.2.	31
3.5	Mosaic of true colour images from four daytime MODIS overpasses	
	on $6^{th}$ August, 2003	32
4.1	The Microwave Water at the ARM-SGP site. Image courtesy of the	
	ARM program.	34

4.2	Upper panel: True colour image derived from a MODIS overpass	
	over the ARM-SGP site / Oklahoma; USA, 14th August 2002. The	
	left image shows a global overview, the right image is zoomed, the	
	grey cross indicates the location of the ARM site. Lower panel:	
	the left image shows the integrated water vapour over cloud free	
	areas derived from the same MODIS scene, the right image shows	
	the diurnal cycle of water vapour measurements from the MWR	
	instrument. The red diamond indicates the MODIS measurements	
	closest to the ARM site	35
4.3	Scatter plots of integrated columnar water vapour from the Mi-	
	crowave Water Radiometer at the ARM-SGP site and from MERIS	
	(left) and MODIS (right) measurements using the retrieval algo-	
	rithms described in this work	36
4.4	Integrated columnar water vapour from the Microwave water ra-	
	diometer at the ARM-SGP site and from MODIS MOD05 (Version	
	3)	37
4.5	Scatter plots of integrated columnar water vapour from ground based	
	GPS and from MERIS (left) and MODIS (right) measurements us-	
	ing the retrieval algorithms described in this work	38
4.6	Scatter plots of integrated columnar water vapour from radio sound-	
	ings and from MERIS (left) and MODIS (right) measurements us-	
	ing the retrieval algorithms described in this work	40
4.7	Left: Scatter plot of integrated columnar water vapour above clouds	
	from radio soundings and from MERIS; right: scatter plot of cloud	
	top pressure from radio soundings and from MERIS	42
4.8	Absolute and relative deviations of measurements of columnar wa-	
	ter vapour above land from MERIS and MODIS compared to mi-	
	crowave radiometer measurements, ground-based GPS data and ra-	
	dio soundings. The dashed areas indicate the range given by the $5\%$	
	and 95% percentiles.	45

5.1	Integrated water vapour derived from MODIS measurements and	
	averaged over HIRLAM grid boxes for 01. 07. 2002, 06 UTC (left	
	panel) and 12 UTC (right panel)	52
5.2	Frequency of occurrence of deviations between MODIS and MWR	
	(left panel) and GPS (right panel) water vapour measurements. The	
	red lines shows Gaussians around the mean differences	53
5.3	Ground-based GPS stations used for the calculation of the spatial	
	correlation of MODIS water vapour observation errors	54
5.4	Spatial correlation of MODIS water vapour observation errors as	
	a function of distance. The results are based on comparisons with	
	ground-based GPS measurements. For details see text	55
5.5	MODIS scene and HIRLAM forecast at 01. 07.2002, 06 UTC	56
5.6	MODIS scene and HIRLAM forecast at 01. 07.2002, 06 UTC	57
5.7	Difference histogram between MODIS observed integrated water	
	vapour and the HIRLAM 6 hour forecast from the example showed	
	in figures 5.5 and 5.6	58
5.8	Mean precipitable water for the first two weeks in July:	60
5.9	Mean precipitable water calculated from radio soundings for the	
	assimilation experiment period. The crosses indicate the location	
	of the radiosonde stations.	61
5.10	HIRLAM Humidity profiles of two grid boxes from analyses for the	
	$2^n d$ of July, 12 UTC. The analysis from the reference run is plotted	
	in a solid black line, the analysis from the MODIS run is plotted	
	in grey. The dashed line shows the difference between both. The	
	left panel shows a MODIS observation larger, the right panel an	
	observation smaller than the 6 hours forecast	63
5.11	Mean humidity profile and standard deviation of analysis incre-	
	ments for all assimilation cycles and all MODIS observations	63
5.12	Differences in integrated water vapour between the MODIS and the	
	reference run, the individual rows are for the 02. to 05. 07, the left	
	panel always shows the difference at 00 UTC, the right panel at 12	
	UTC	65

5.13	Like figure 5.12, but for the area of MODIS observations	66
5.14	Like figure 5.12, but for 09. to 12. 07	67
5.15	Like figure 5.13, but for the 09. to 12. 07	68
5.16	Total precipitation from $1^{st}$ to $15^{th}$ of July 2002	70
5.17	Total precipitation from $1^{st}$ to $15^{th}$ of July 2002	71
5.18	Histograms of absolute differences of total precipitation and of F(dB).	
	For details see text.	72