Monitoring of Atmospheric Profiles (& Cloud Properties) using InfraRed Sounders

(TOVS, AIRS, IASI)

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Atmospheric Radiation Analysis (ARA) team

Atmosphere Biosphere Climate per remote sensing ABC(t)

IPSL - Laboratoire de Météorologie Dynamique, France

- ❖**Sounder observations: TOVS, ATOVS, AIRS, IASI**
- ❖**Retrieval of T, H_2O profiles** ***(emphasis on LMD-3I inversion)***
- ❖**ARSA (Analyzed RadioSounding Archive) data base**
- ❖**Evaluation with radiosondes**
- ❖**Conclusions & outlook for monitoring**

International activities:

❖**DWD-LMD federated activity (CM-SAF) on potential climate data records from sounding instruments for CDOP II**

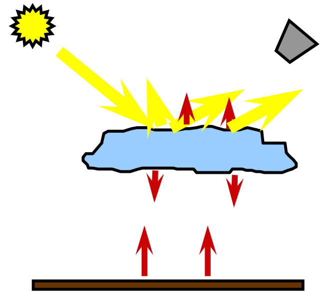
❖**ESA GlobVapour project**

❖**GEWEX Water Vapour Assessment**

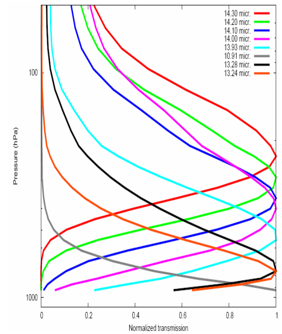
Application:

❖**Synergy of RH / cloud properties from Sounders** ***(contrails)***

Atmospheric properties from space:



good spatial coverage



__Vertical Sounder T, H_2O, cloud retrieval__

multi-spectral cloud detection

cloud clearing ← *cloud property retrieval*

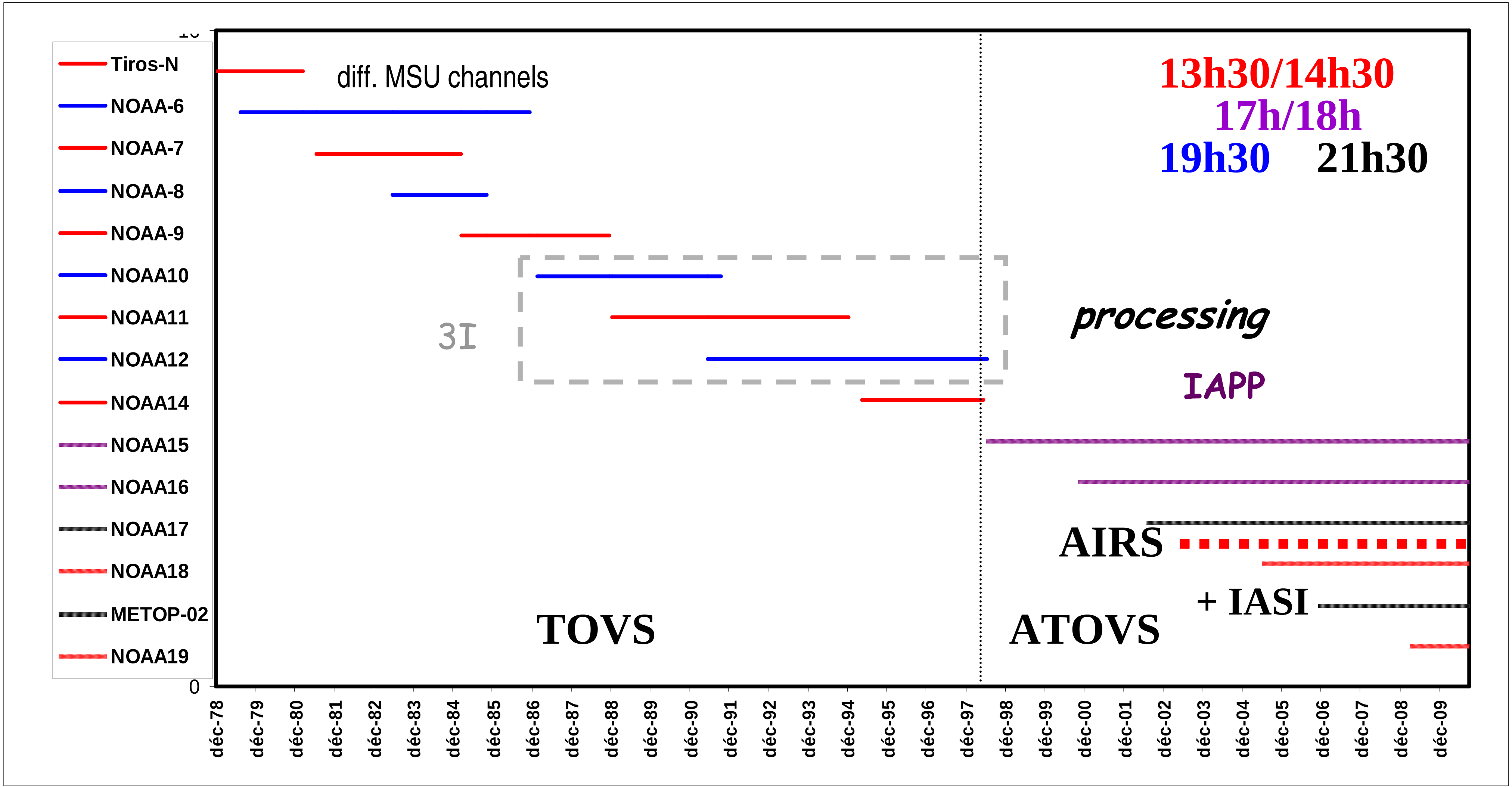
T/H_2O inversion

vertical sounders :

- ***good spectral resolution -> esp. reliable Ci properties (day & night)***
- ***atmospheric T, H_20 profiles (RH) + clouds + aerosols***

- **vert. resolution depends on weighting fcts of channels**
- **dry bias in presence of clouds**
- **properties of uppermost cloud layers**

Sounder observations : 1979- now



Climate monitoring:

calibration, instrument changes, drift of satellites

Retrieval of atmospheric T & water vapour profiles

TOVS,
Scott et al. 1999
3I, LMD

ATOVS,
Li et al. 1999
IAPP, Uni Wisconsin

AIRS
Susskind et al. 2003
NASA

stored at DWD

1) Forward model & bias adjustment
(using radiosondes)

2) Cloud detection / cloud clearing
(multispectral, IR-μwave; 3 x 3 FOV's)

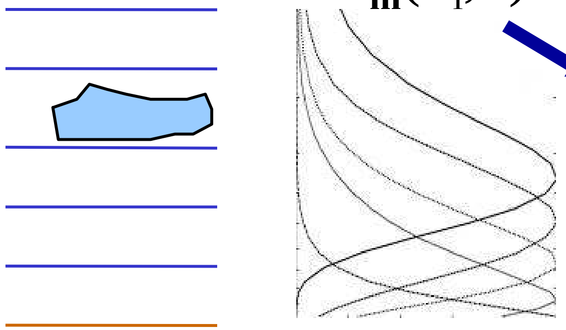
3) First guess
(from radiosondes, reanalysis or forecast)

4) Inversion
nonlinear iterative procedure to solve RTE
neural network trained on TIGR

TOVS Path-B climatology:…, 1987- 1995, …

Scott et al., BAMS, 1999

MSU+HIRS $\mathbf{R}_{\mathbf{m}}(\lambda_i,\theta)$ along H_2O, CO_2 absorption bands



3I Inversion *(Chédin, Scott 1985)*

- atmospheric temperature (9 layers, ≥10hPa), water vapor (5 layers, ≥100hPa)
- surface skin temperature, microwave emissivity
- cloud pressure (≥ 100 hPa), effective emissivity *(Stubenrauch et al.1999, 2006)*

based on: *controlled use of a priori information*

GEISA spectroscopic data base
\+
radiative transfer
(http://www.noveltis.fr/4AOP)

$T(p_k)$, $H_2O(p_k)$, T_s *from* radiosondes

$R_{clr}(\lambda_i,\theta)$, $R_{cld}(\lambda_i,p_k,\theta)$ *per airmass (5), land – sea*

TIGR dataset
Thermodynamic Initial Guess Retrieval

Forward model & bias adjustment

use radiosonde data to remove systematic biases

(due to radiative transfer model, instrument, unexpected events)

- ✓colocation of TOVS / ATOVS with radiosondes (3h, 100km)
- ✓identify clear sky scenes
- ✓4A computation of **bias corrections** $\Delta = TB_{obs}(\lambda_i) - TB_{sim}(\lambda_i)$

NOAA-NASA Pathfinder TOVS Path-B (1987-1995):
NOAA/NESDIS colocated radiosonde-satellite data: **DSD5** *(clear sky identified)*
(Uddstrom, Mcmillin 1995)

ARSA (Analyzed RadioSoundings Archive) : 1989 - 2009

N. A. Scott, A. Chédin, et al. ARA-LMD

from WMO radiosondes, ERA-Interim, ACE-FTS
validation : 4A simulation of IASI spectrum

available at : http://www.ara.lmd.polytechnique.fr

The ARSA (Analyzed RadioSounding Archive) Database

Scott, Chédin et al., to be published

- start with radiosonde reports of ECMWF archive
- require measurements: for T min up to 30 hPa, for H_2O min up to 350 hPa
- use TIGR to remove values deviating too much from respective air-mass average
- extrapolate T, H_2O to upper atmosphere (use ERA Interim up to 0.1 hPa & ACE/Scisat L2 products uo to 0.0026 hPa)
- complete with O_3 profiles from ERA Interim
- auxiliary surface information (e.g. T) from surface station archive of ECMWF

Validation: investigate TB_{obs}-TB_{sim} residuals.

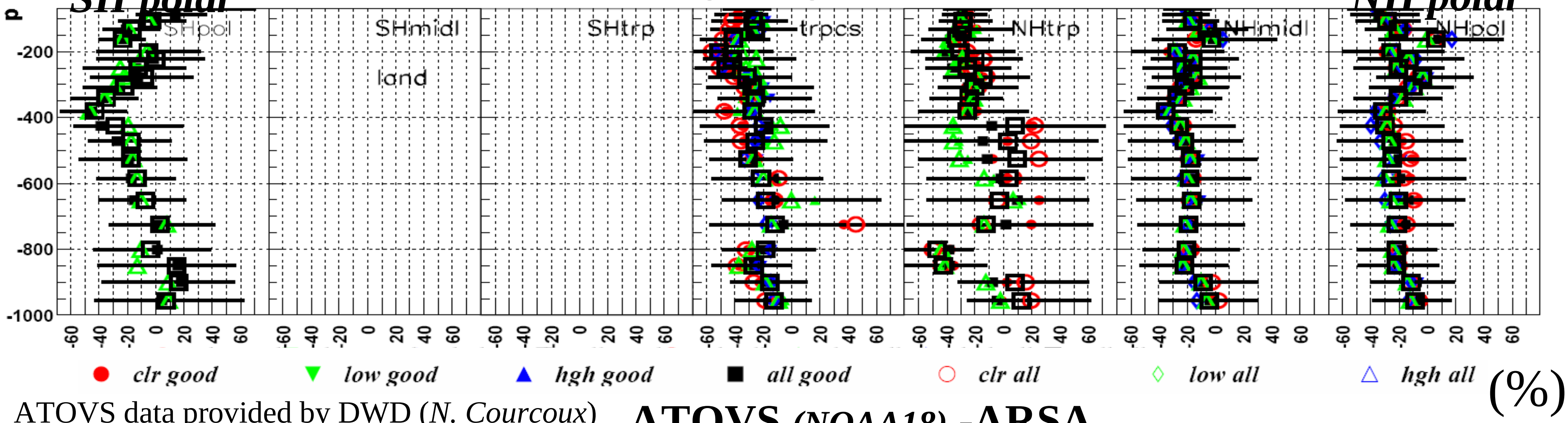
IASI/AMSU/MHSMetop-A (2007-2009), ATOVS/NOAA15 (2001-2004), IIR/Calipso , Seviri/MSG, Modis/Aqua (2006-2010)

≥ 3,102,000 profiles: 870,000 tropics / 1,966,000 midlatitudes / 267,000 polar

unique data base for many applications **(LMD participates in GSICS)**

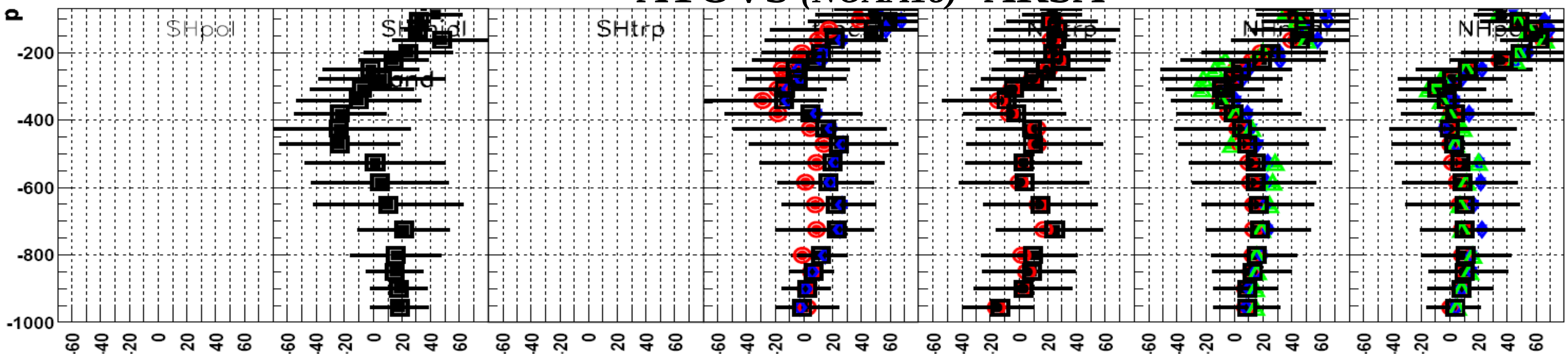
H_2O profile comparisons : land *(July 2008)*

SH polar — AIRS-ARSA — NH polar



ATOVS data provided by DWD (*N. Courcoux*)

ATOVS *(NOAA18)* -ARSA



differences probably linked to weighting functions
AIRS in general dryer than ARSA ;
ATOVS good agreement in lower atmosphere (AMSU-A/B)
(slightly more humid than ARSA)

H_2O profile comparisons

TOVS Path-B – DSD5 radiosondes

Chaboureau et al. 1998

globe:
-1.9% +- 20.2%

Watervapour [%]	Tropics Bias	Tropics std	Midlatitude Bias	Midlatitude std	Polar Bias	Polar std
Surf-300 hPa	**0.4**	**17.5**	**-5.4**	**24.6**	**-15.1**	**26.9**
surf-850 hPa	**-7.1**	**20.0**	**-8.0**	**23.9**	**-20.4**	**33.5**
850-700 hPa	**2.4**	**25.0**	**-8.2**	**31.9**	**-17.5**	**31.7**
700-500 hPa	**15.1**	**36.2**	**-2.8**	**34.8**	**-9.0**	**30.0**
500-300 hPa	**-0.9**	**34.8**	**14.6**	**45.8**	**12.4**	**51.6**

global good agreement
TOVS dryer near surface; radiosonde dryer in upper troposphere

Global averages of atm. water vapour

(Raschke & Stubenrauch, LB, Springer 2005)

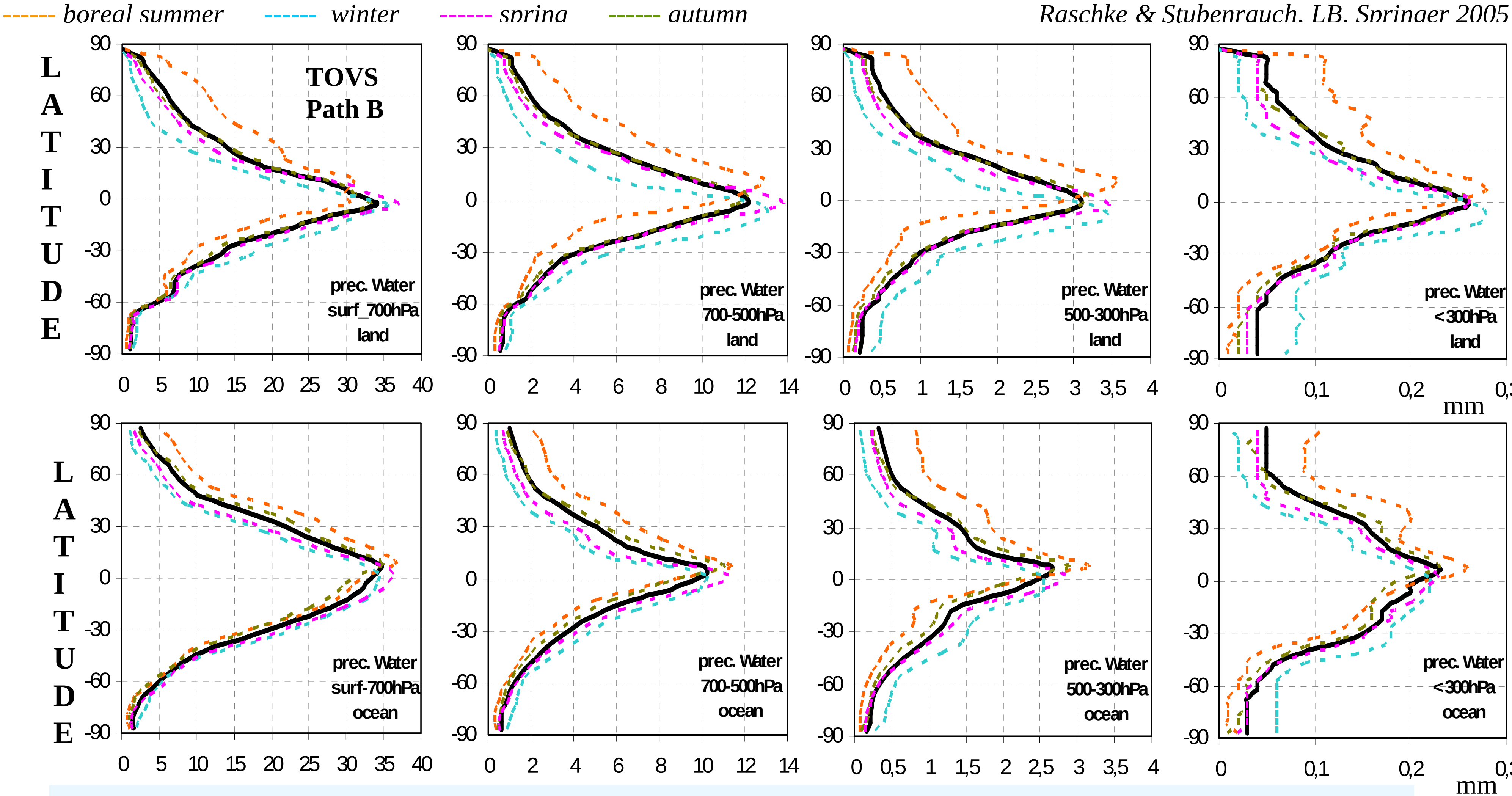
Watervapour [mm]	globe	ocean	land
total column	28 25 24	28 26 26	28 22 20
surf-700 hPa	21 19	21 20	21 15
700-500 hPa	5 5.0	5 4.8	5 5.5
500-300 hPa	1.8 1.3	1.8 1.3	1.8 1.4
300-100 hPa	0.14	0.14	0.13

NVAP: 1991-1995 **TOVS-B:** 1991-1995 **AIRS-L2:** 2003-2009

NVAP: NASA Water Vapor Project ***(Randel et al. BAMS 1996)***
merged radiosondes, TOVS, SSM\I

TOVS 10% (ocean) and 20% (land) dryer than NVAP,
because TOVS retrieval only in not too cloudy conditions
AIRS slightly lower over land

latitudinal & seasonal variation of H2O per atmospheric layer



atm water vapour decreases polewards

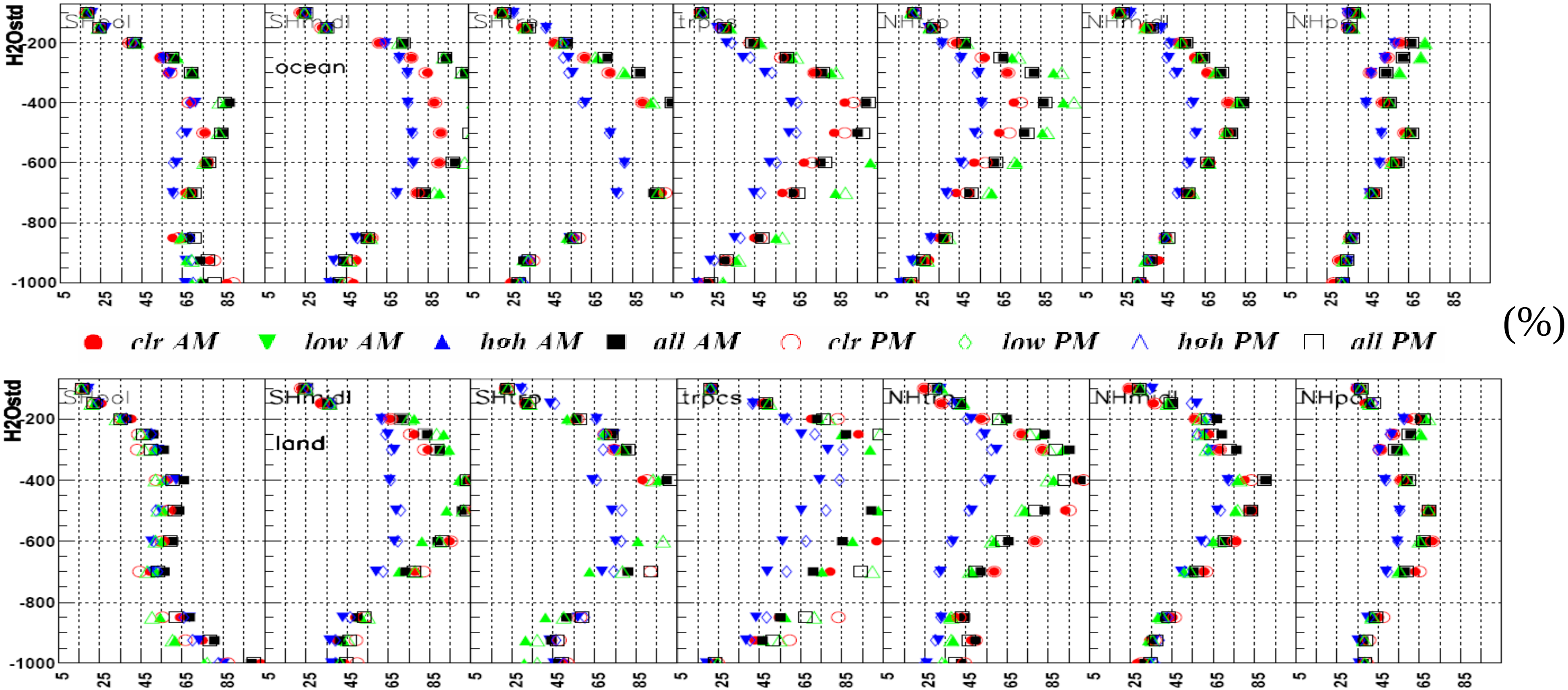
more water vapour in summer hemisphere

lower troposphere: seasonal effect stronger over land (evapotranspiration)

upper troposphere: shift of ITCZ towards summer hemisphere

H2O profile variability *(July 2008)*

AIRS-L2



rel variability largest around 400 hPa in tropics
smaller in the case of high clouds (because more humid)

- **in general total H_2O from sounders agrees quite well with radiosondes,**
- **slightly dryer in lower troposphere,**
- **however, radiosondes have slightly low bias in higher troposphere**
- **ATOVS provides improved H_2O retrieval due to AMSU-A/-B**

CM-SAF atmospheric profile monitoring (CDOP-II) :

- **check time series TOVS(3I) – ATOVS(IAPP)**

-> process ATOVS with 3I ?

(adaptations necessary: new neural network training, create ATOVS-TIGR base, etc)

GEWEX Water Vapour Assessment *(co-chair: M. Schröder, DWD)*

1rst meeting: 8 -11 March 2011

ESA GlobVapour project (2010 –2011, www.globvapour.info) :

❖3 tot column data sets (ocean + land):

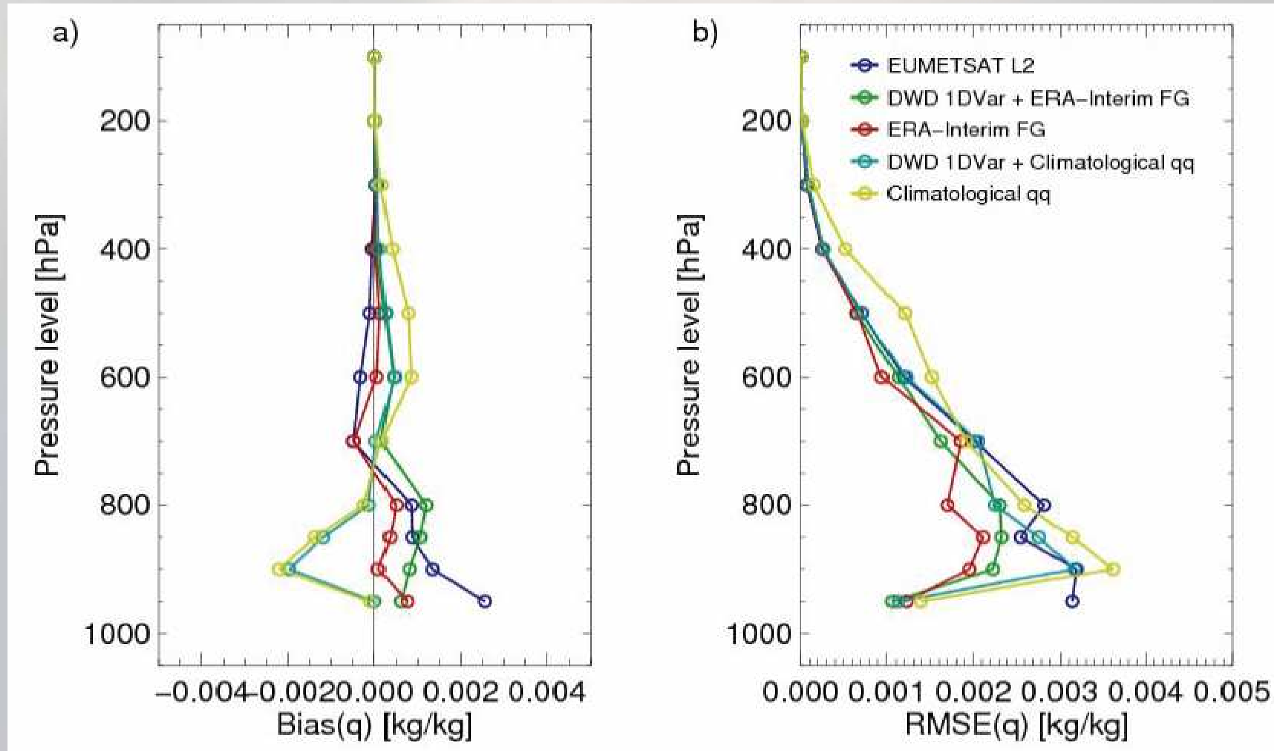
SSM\I-MERIS	2003-2008	(DWD,FUB)
GOME/SCIA/GOME-2	1996-2008	(DLR, MPI)
ATSR-2	1996-2008	(DWD)

❖1 profile data set (surf-850 hPa, 850 – 500, 500 – 200 hPa):

IASI-SEVIRI	2007-2008	(DWD)

IASI assessment example:
M. Stengel, DWD
comparison to ARM profiles at SGP

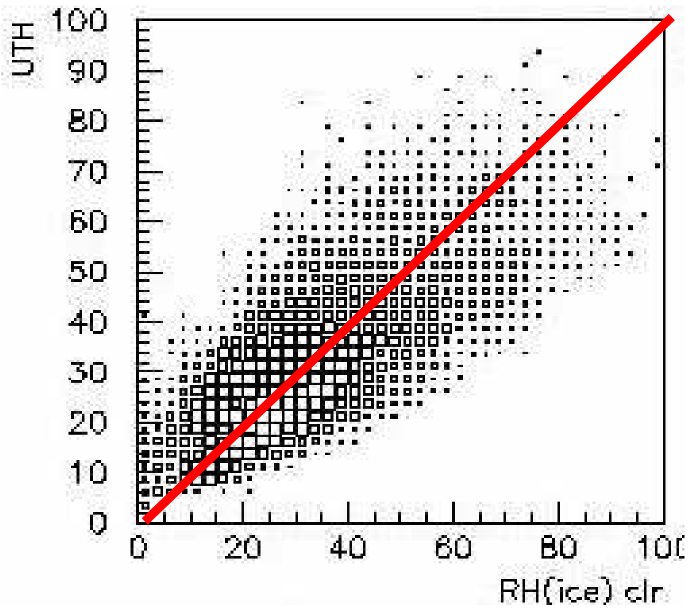
from presentation by M. Schröder at CM SAF User workshop, Sep 2010



3I RH (300-500hPa) - UTH

$$UTH = \frac{\exp(a_1 + a_2 T_{HIRS12})}{a_3 + a_4 T_{HIRS6}}$$

(Jackson & Bates, 2001)



$$RH_{ice} = g\rho\, W / \int q_{sat}^{ice}(p)dp$$

comparison of 3I RH, Meteosat UTH & JB UTH

Escoffier et al., 2001

- **very good spatial& temporal correlations (0.9 / 0.85)**
- **UTH layer limits depend on T, q & θv (weighting function)**

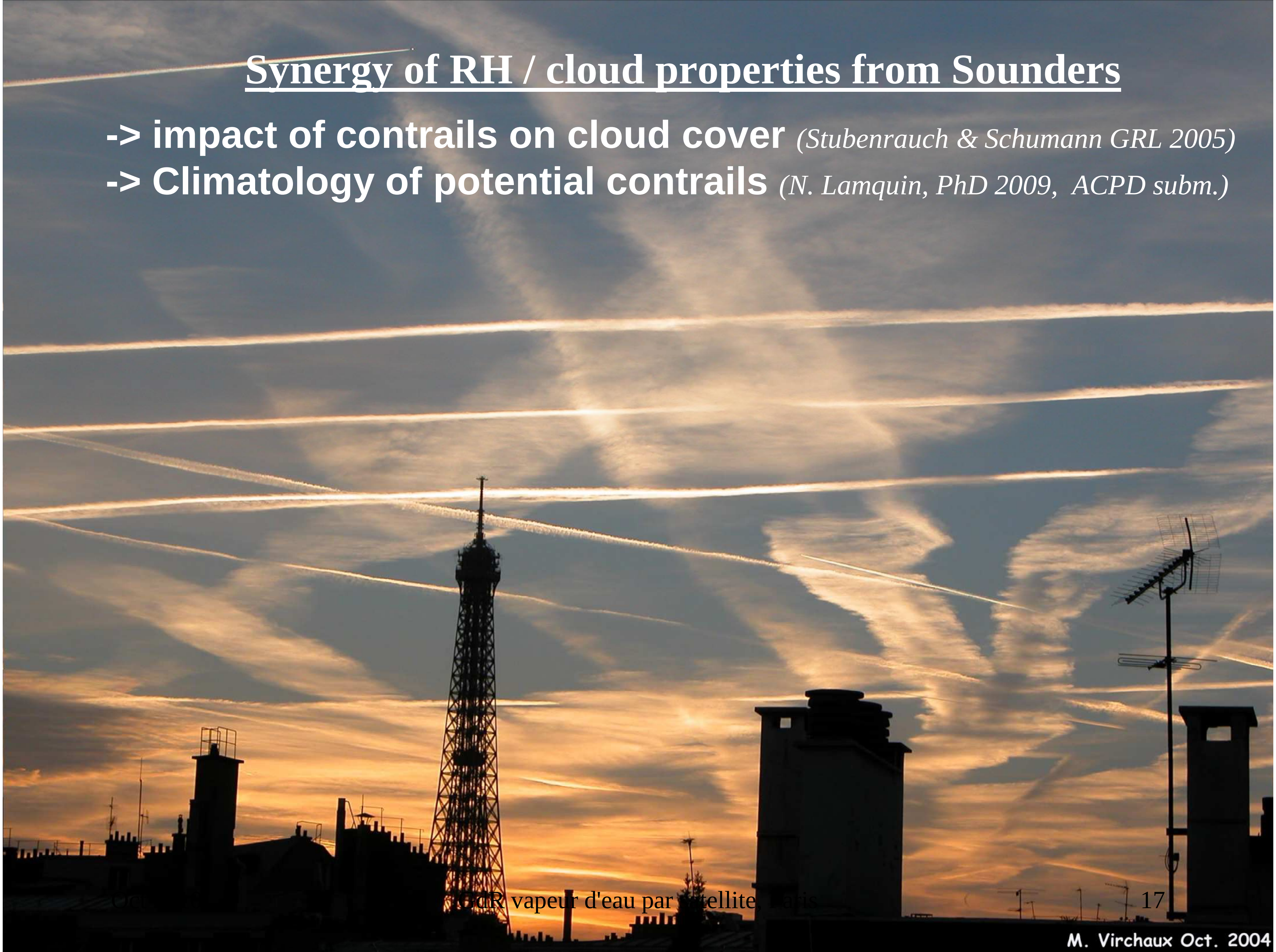
=> 3I RH – UTH ≤ 20% in convective & UTH – 3I RH ≤ 7% in arid regions

- **3I RH larger variability**

Synergy of RH / cloud properties from Sounders

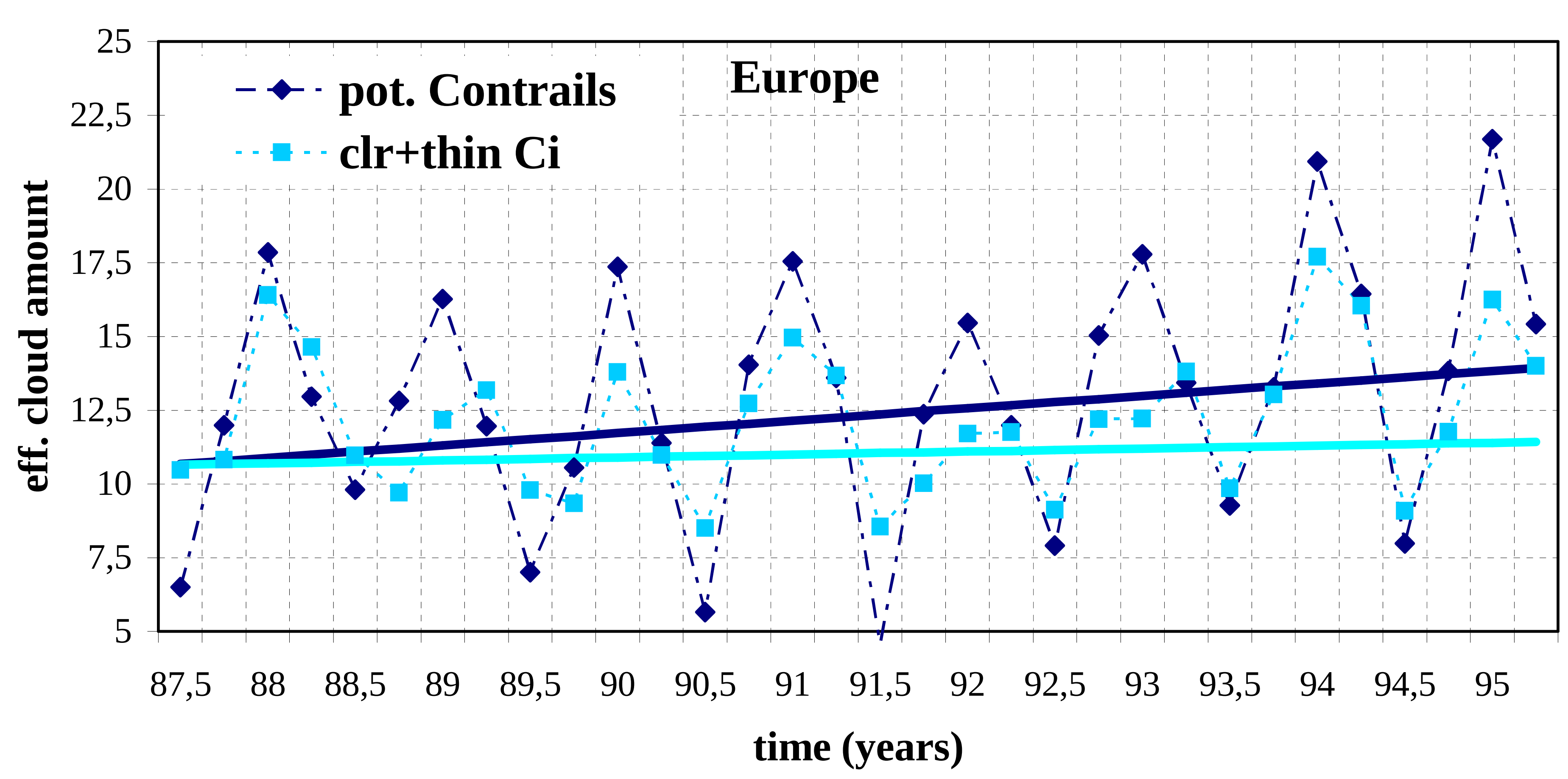
-> impact of contrails on cloud cover *(Stubenrauch & Schumann GRL 2005)*

-> Climatology of potential contrails *(N. Lamquin, PhD 2009, ACPD subm.)*



Contrails form in cold & humid air

Stubenrauch & Schumann GRL 2005



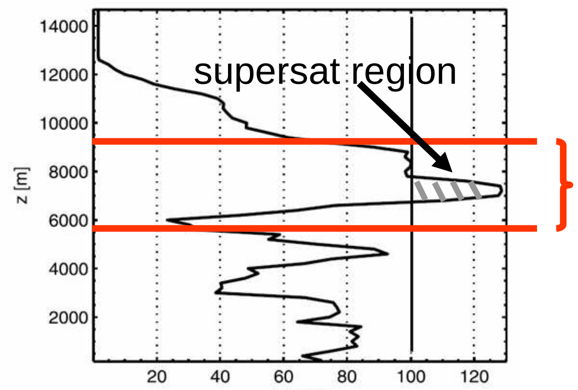
❖stronger ECA increase for potential contrail situations than for all situations:

2.8-3.5% (±1.5%) per decade

❖However: Occurrence of pot. contrail situations is small: 5 - 10%
=> Overall effect over Europe ~0.19% - 0.25% per decade

Climatology of potential contrails

N. Lamquin, PhD 2009

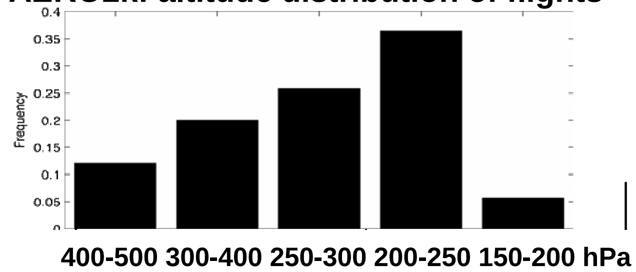


RHi (%), radiosondes

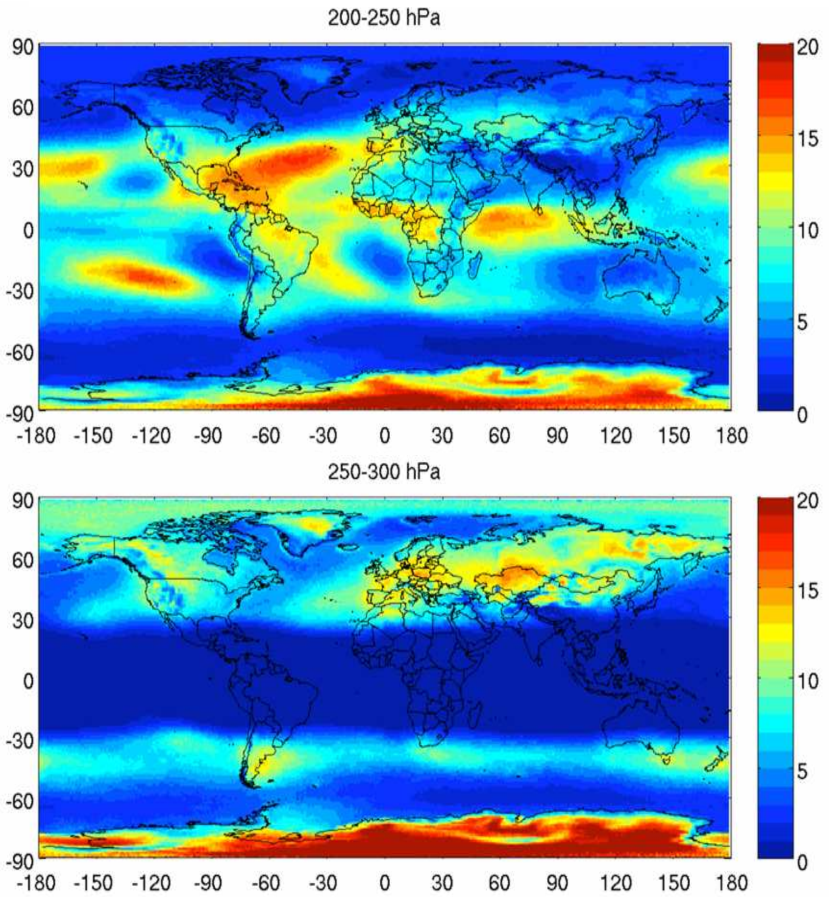
AIRS

calibrate with MOZAIC (air planes) : presence of sursaturation -> probability of supersaturation AIRS

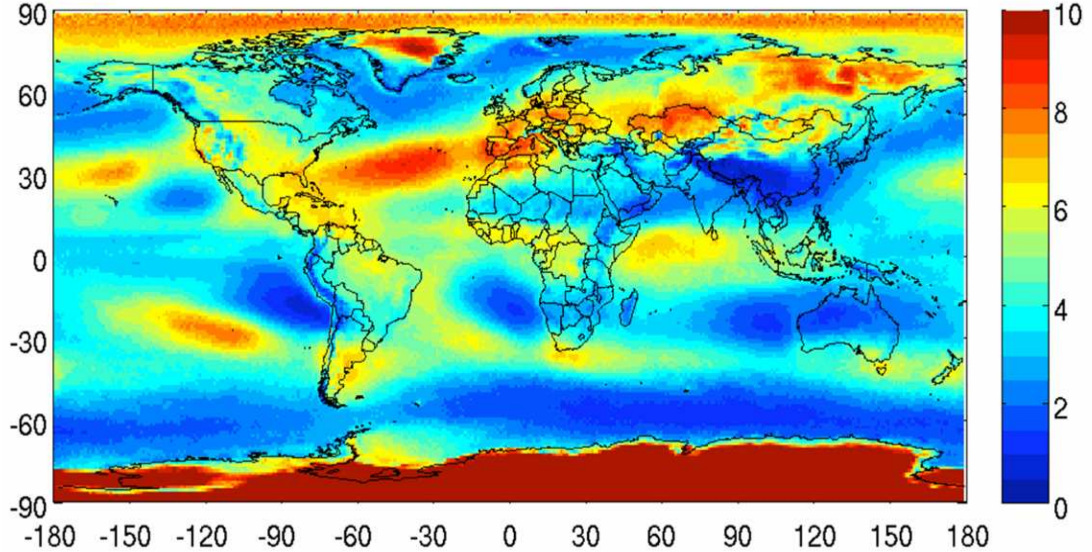
AERO2k: altitude distribution of flights



Ice supersaturation occurrence



Occurrence of potential contrails



could be continued with IASI

Our activities are supported by CNRS & CNES.

We also want to thank all Science teams

as well as the engineers & space agencies

for their efforts & cooperation in providing the data.

The development of the ARSA data base was possible thanks to the radiosonde archive, surface station archive & ERA-Interim data from ECMWF & data from ACE-FTS