A new approach for near-real-time monitoring of atmospheric stability, atmospheric water vapor and liquid water

https://www.eumetsat.int/

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Motivation

“Seamless Prediction” = nowcasting + short-term

Where will severe convection occur in the next hours?

Where is there a high threat for ground fog?

→ **Monitor atmospheric stability**

Stability Indices (STI)

Index	threshold	
$KI=(T_{850}-T_{500})+Td_{850}-(T_{700}-Td_{700})$	$>21\,K$	Thunderstorms
$KO=\frac{1}{2}((\Theta_{e500}+\Theta_{e700})-(\Theta_{e850}+\Theta_{e1000}))$	$<1.9\,K$	Thunderstorms
$TT=T_{850}+Td_{850}-2T_{500}$	$>46.7\,K$	Thunderstorms
$LI=T_{500}-T_{sfc\rightarrow 500}$	$<1.6\,K$	Thunderstorms
$SI=T_{500}-T_{850\rightarrow 500}$	$<4.2\,K$	Thunderstorms
$CAPE=-R_d \int_{sfc}^{el} (Tv_p-Tv_e)d(\ln p)$	$>168\,\frac{J}{kg}$	Thunderstorms
$FT=\Theta_{wb850}-FP$ Fog Threat	$<3\,K$	Radiation Fog

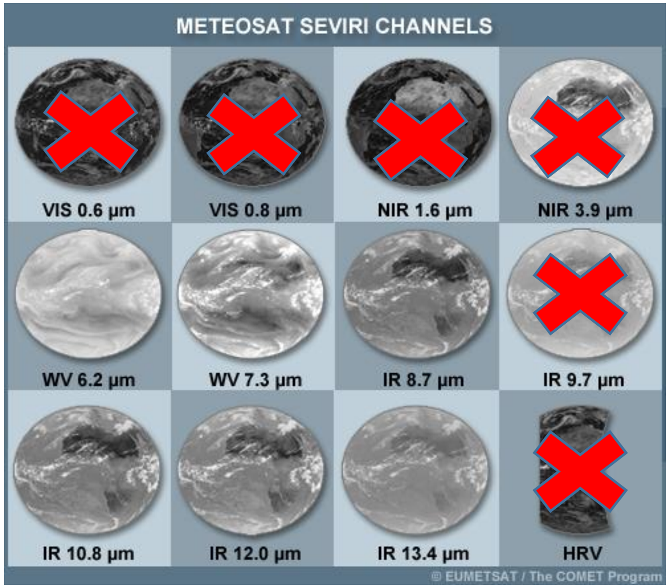
Monitoring of Atmospheric Stability

Demands

- Accurate → ABL information
- Temporally continuous & good spatial coverage
- Clear & cloudy sky
- Day / night
- Over different land surfaces

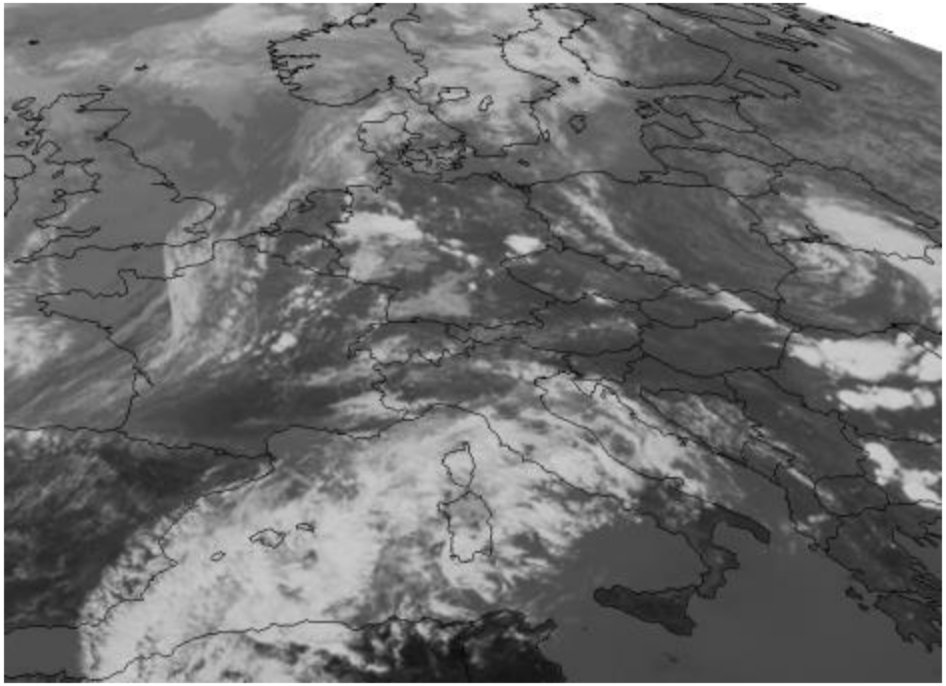
SEVIRI (MSG, current):

- 6 channels
- geostationary, „always“ available
- ~3 km horiz. Resolution
- very limited vertical resolution

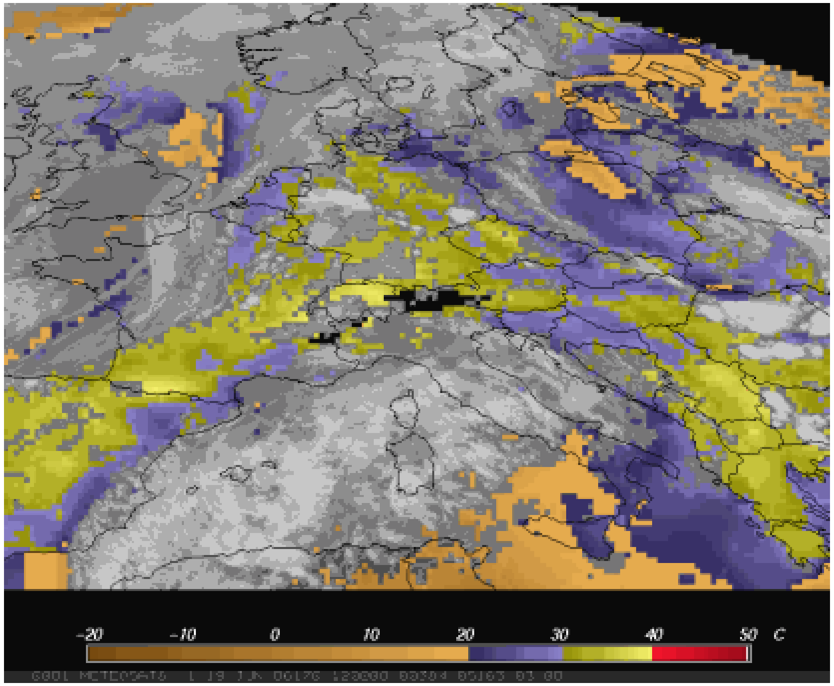


SEVIRI GII: Global Instability Index

SEVIRI IR Image

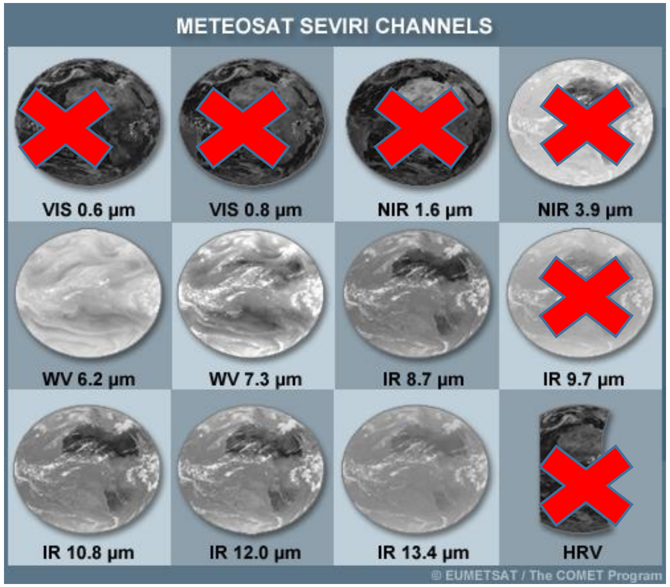


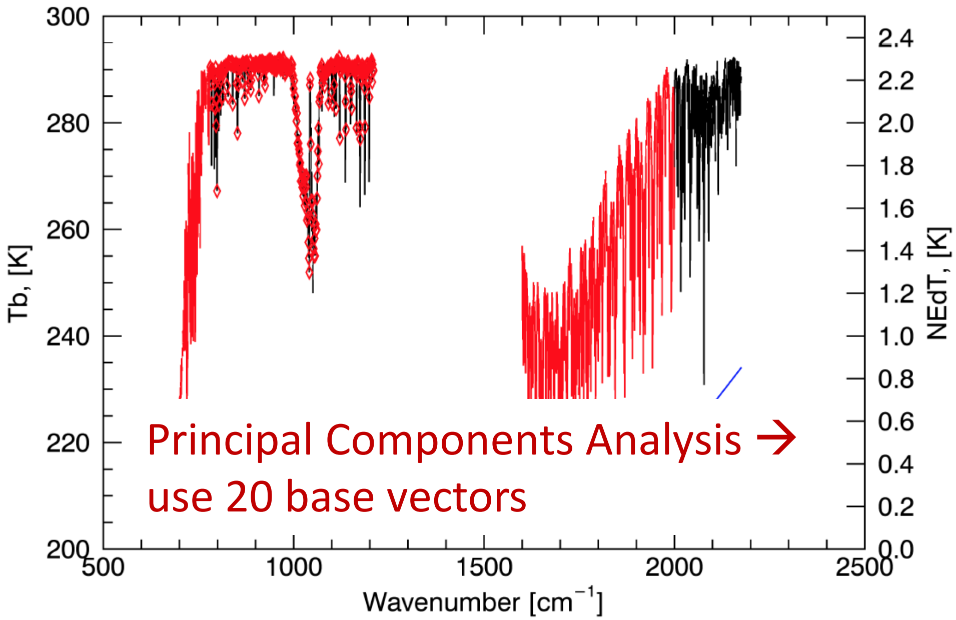
K-Index



Indices: KI, KO, Max. Buoyancy, Precip. Water
(limited accuracy, only in clear sky conditions)

Expected Improvement with MTG





SEVIRI (MSG, current):

- 6 channels
- geostationary, „always" available
- ~3 km horiz. res. (nadir)
- very limited vertical resolution

IRS (MTG, from 2021):

- 1738 channels with 0.5-0.625 cm^{-1} resolution
- geostationary, „always" available
- ~4 km horiz. res. (nadir)
- **Use 770 channels: CO_2 , H_2O absorption and surface sensitive**

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Further Improvement: Ground-based remote-sensing

Point measurements, but network-suitable instruments

24/7 unattended, automatic all-weather operation

Microwave profiler

- 14 Channels, 5 elevation angles
- High accuracy IWV, LWP
- low resolution profiles of T (ABL!) and humidity

→ Evolving network (i.e. E-PROFILE – business case)

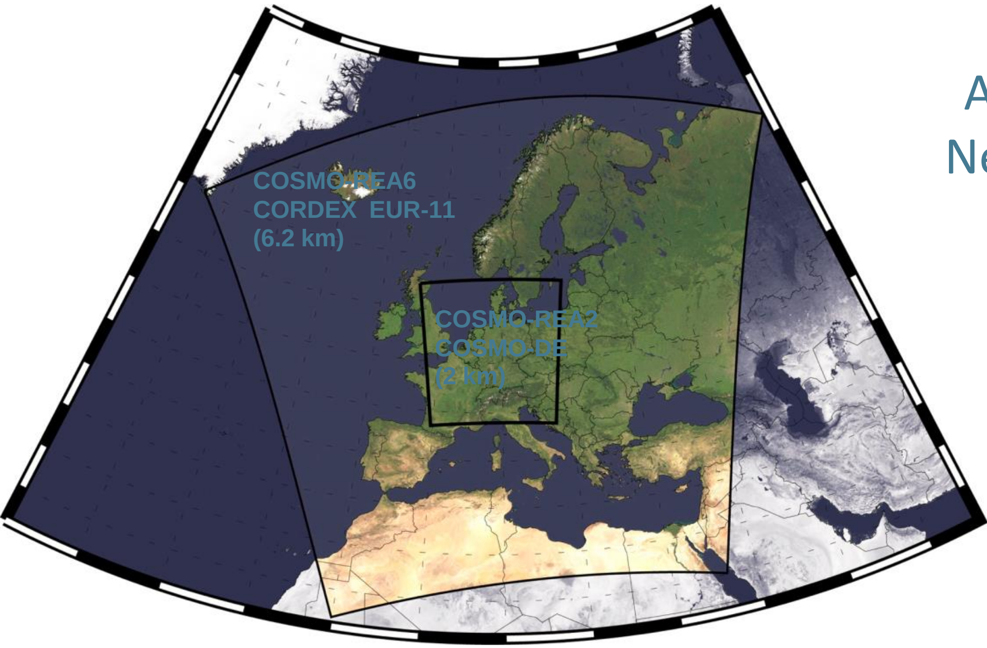
How to combine with satellites?

The prototype Vaisala **DIAL** system:

- Consider 10 humidity levels between 100 and 1900 m
- Assumption on absolute humidity uncertainty: 10 %

→ Potential future network

ARON



A virtual Remote sensing Observation Network for continuous, near-real-time monitoring of atmospheric stability (DWD-Extramurale Forschung)

High resolution regional reanalysis for Europe and Germany (Bollmeyer et al., 2015)

IRS not flying yet, ground-based remote sensing network not yet estbalished

Simulation by using multi-year reanalyses based on COSMO model (COSMO-REA2)

STI-Retrieval for COSMO-REA2 Reanalysis

COSMO-REA2
1D, clear & cloudy sky , T, p, q & hydrometeor profiles

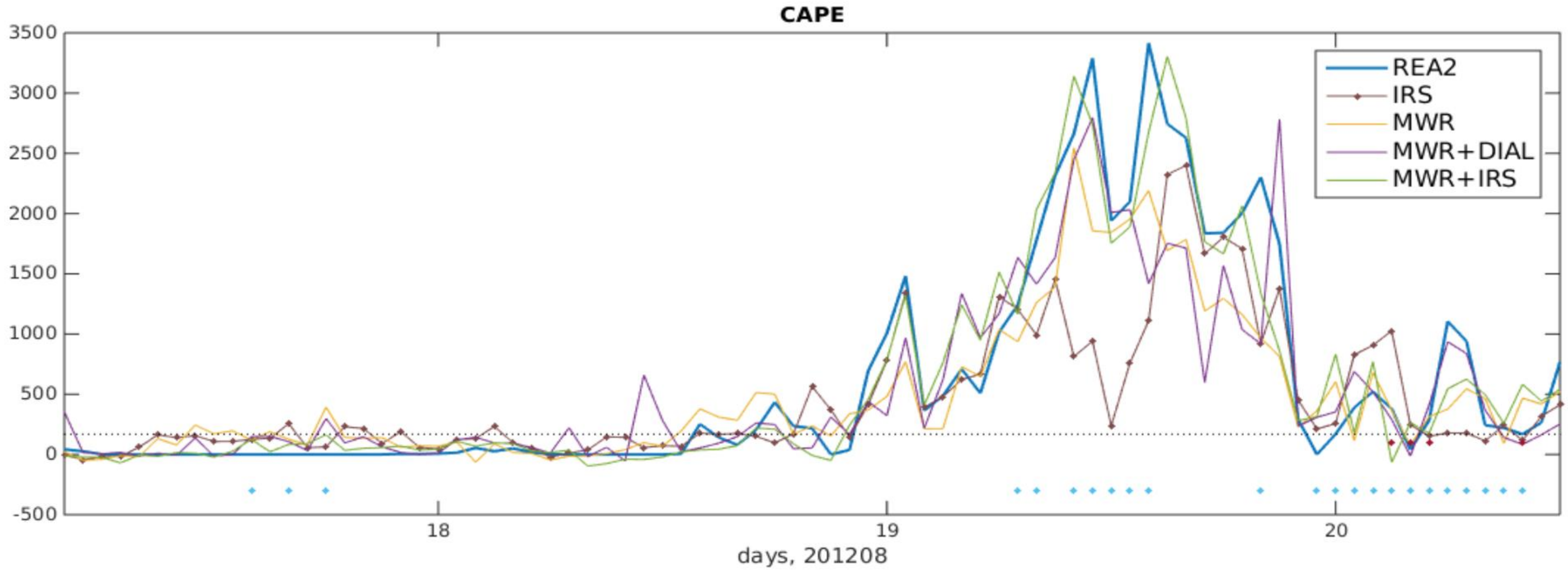
RTTOV-gb, RTTOV

Ground-based observations
MWR (Tb)
DIAL (q-profile)

Geostationary satellite observations
SEVIRI (MSG, 6 channels)
IRS (MTG, 20 PCs)

Retrieval for STI
via Neural Networks

CAPE Times Series in August 2012



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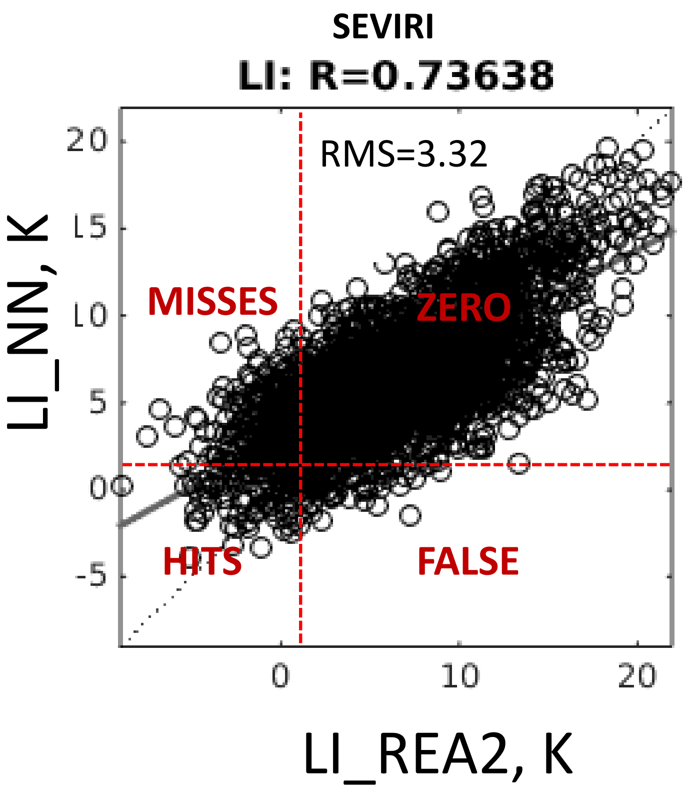
Contingency Tables, Verfication Parameters



	Observed		
Forecast	Yes	No	Total
Yes	h	f	h+f
No	m	z	m+z
Total	h+m	f+z	N

$\mathrm{POD}=\frac{h}{h+m}$ probability of detection

$\mathrm{FAR}=\frac{f}{h+f}$ false alarm ratio

$\mathrm{HSS}=\frac{2(hz-fm)}{(h+m)(m+z)+(h+f)(f+z)}$ Heidke skill score

HSS – fractional improvement over "chance" forecast; appropriate in case of rare events forecast, when correct forecasts of non-events dominate

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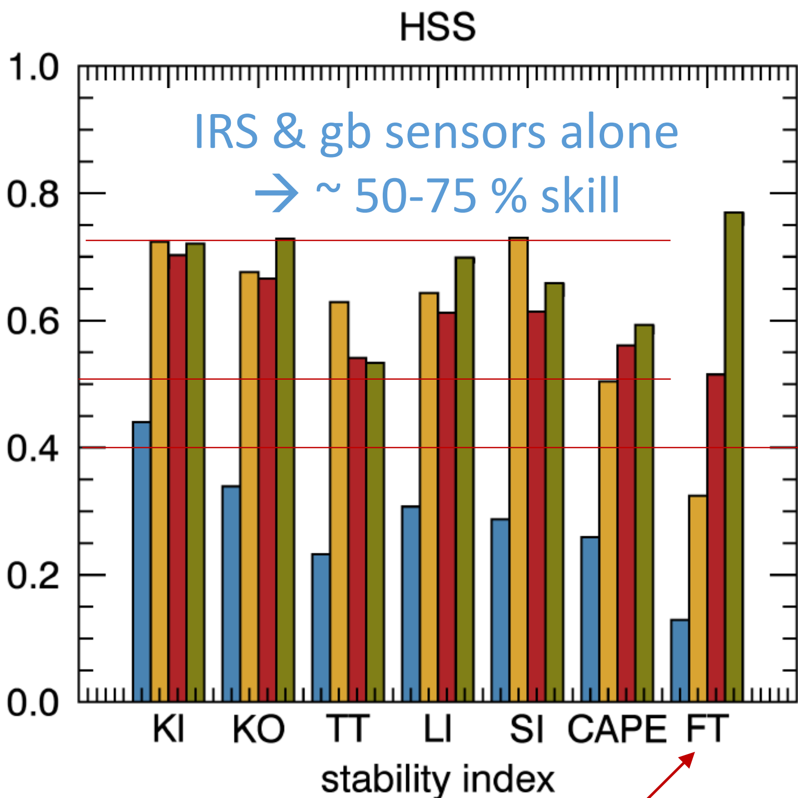
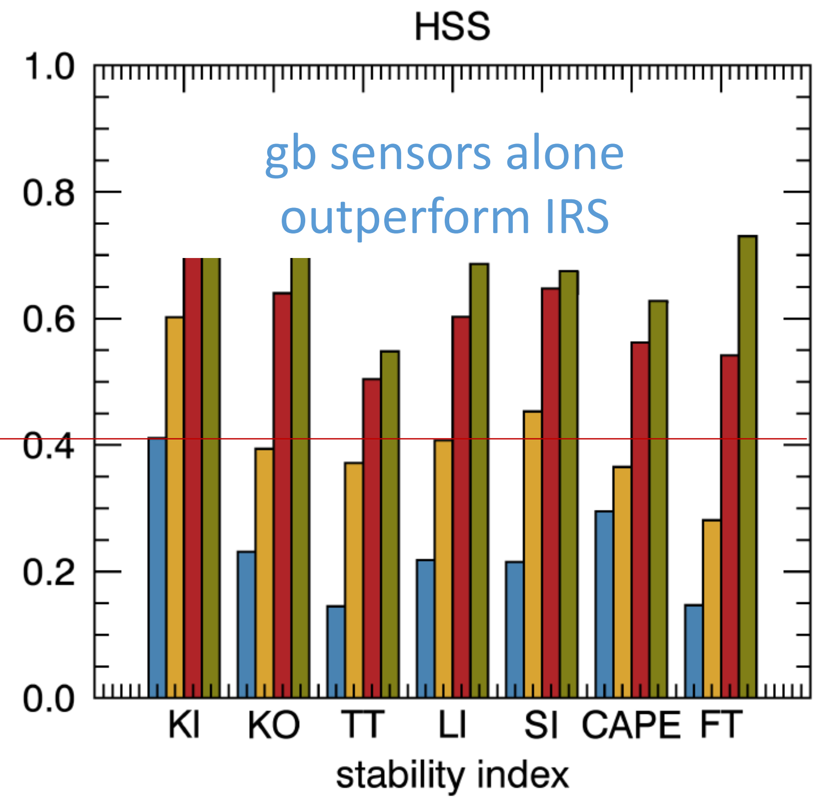
Performance of Single Systems

Clear-only



Cloudy-only



FT very sensitive to near-surface humidity gradient

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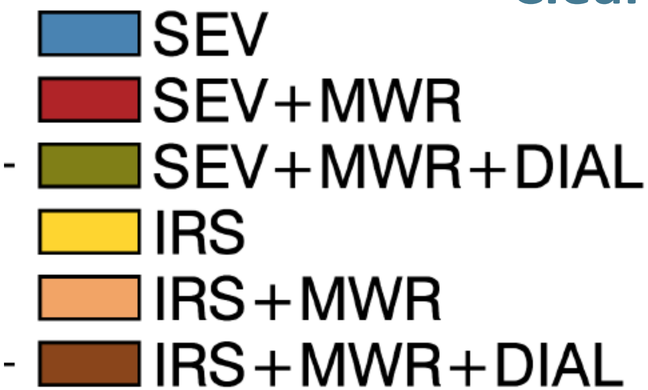
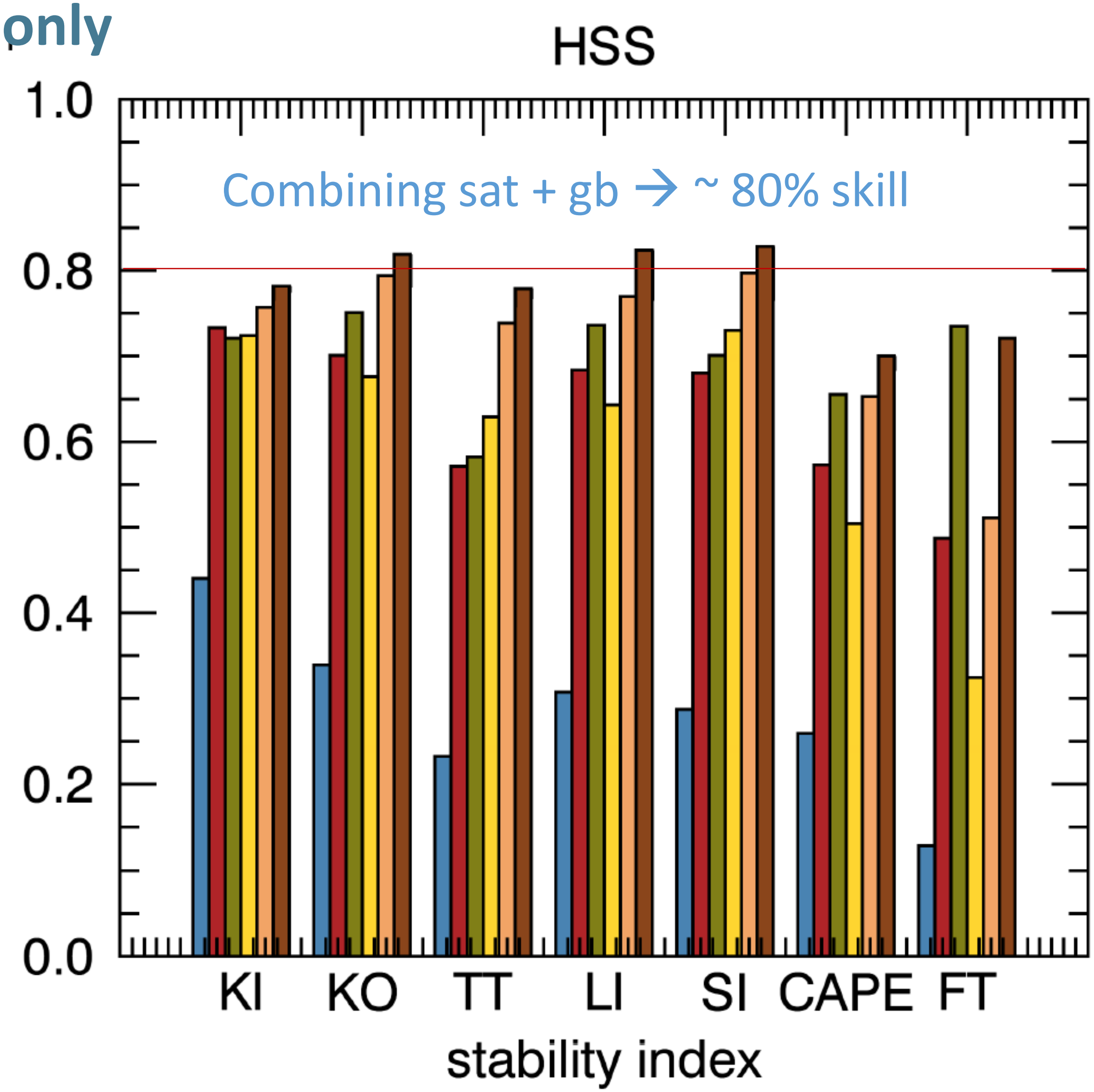
Performance of Systems in Synergy



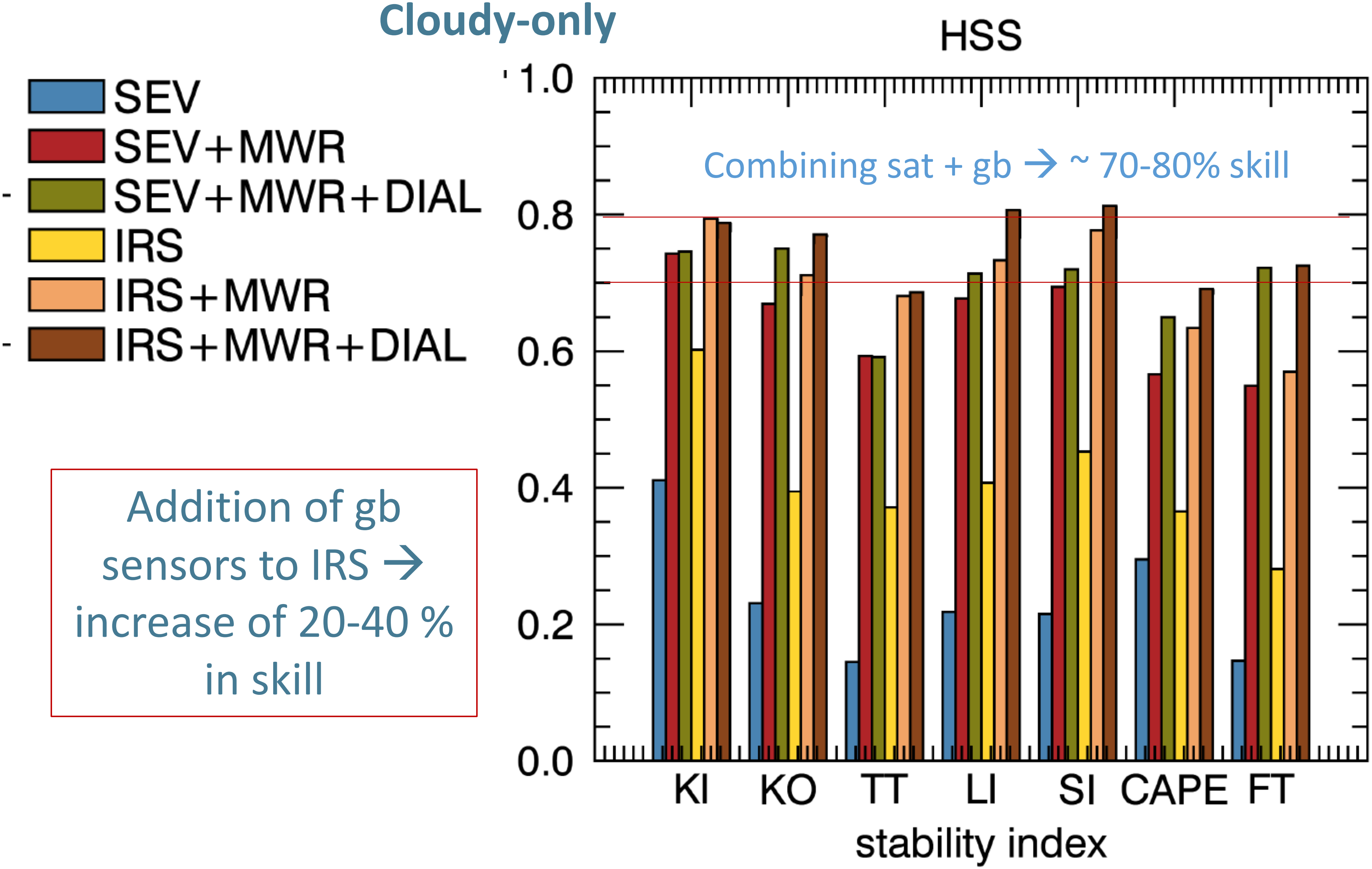
Clear-only



Addition of gb sensors to IRS → increase of 5-20 % in skill, FT +40%

Performance of Systems in Synergy

Cloudy-only



Addition of gb sensors to IRS → increase of 20-40 % in skill

Summary & Outlook

- As expected, IRS significantly better than SEVIRI for stability monitoring
- Ground-based profilers important for stability monitoring in cloudy cases
- IRS can be complemented with ground-based profilers; increased forecast skill 5-40 %

Further questions

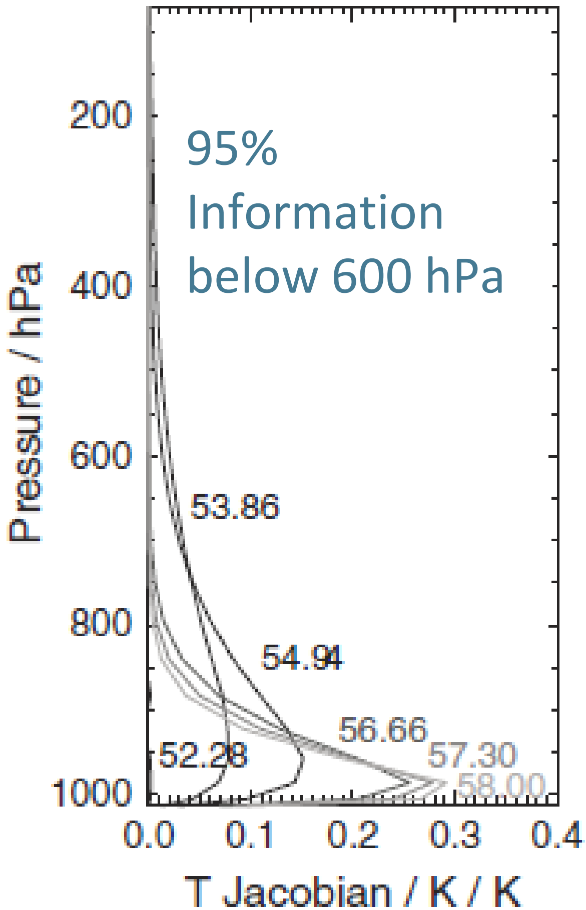
- Representativeness of ground-based observations?
- Required network density to reach which overall accuracy?
- Ground-based network vs. even denser near-surface observations?

Thank you for your attention!

This work was performed within the DWD Extramurale Forschung (EMF) project "A virtual Remote sensing Observation Network for continuous, near-real-time monitoring of atmospheric stability"

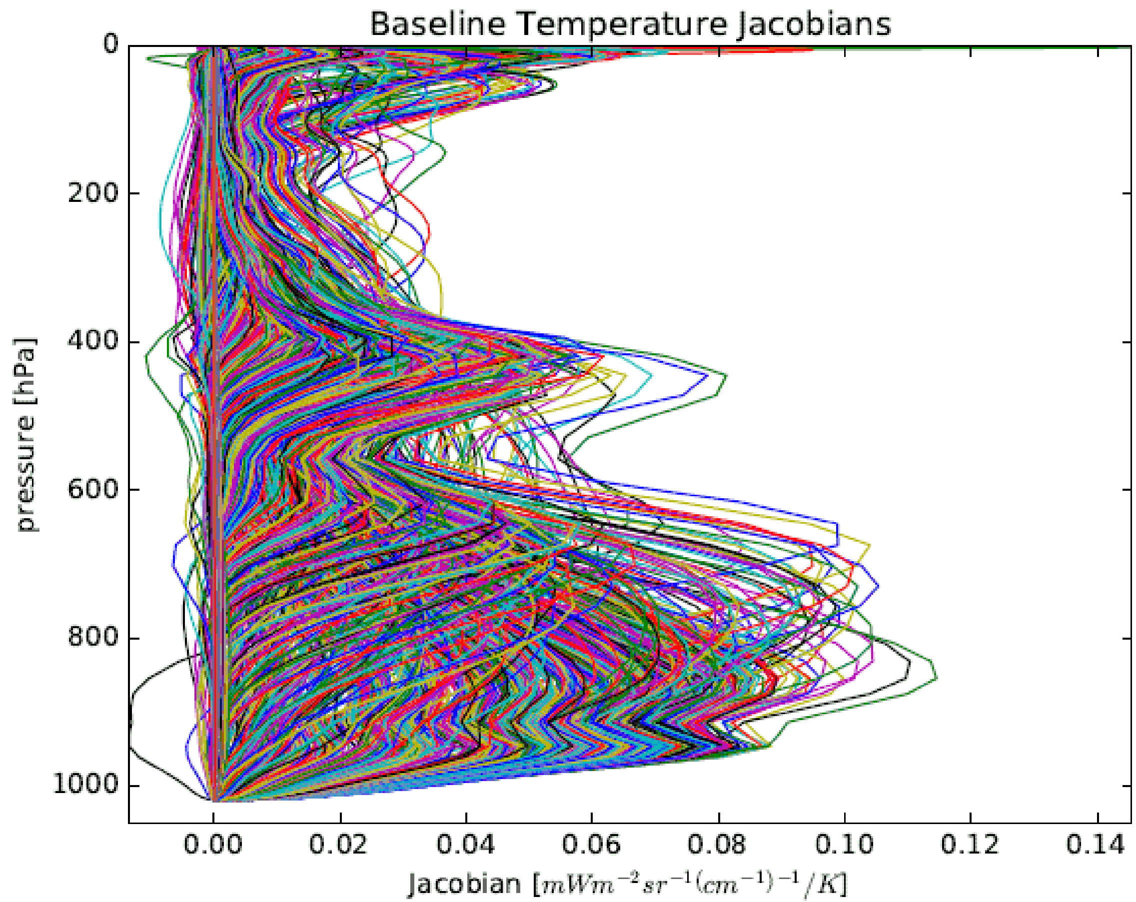
Complementary Weighting Functions

Ground-based MWR



Ebell et.al. 2013

MTG – IRS



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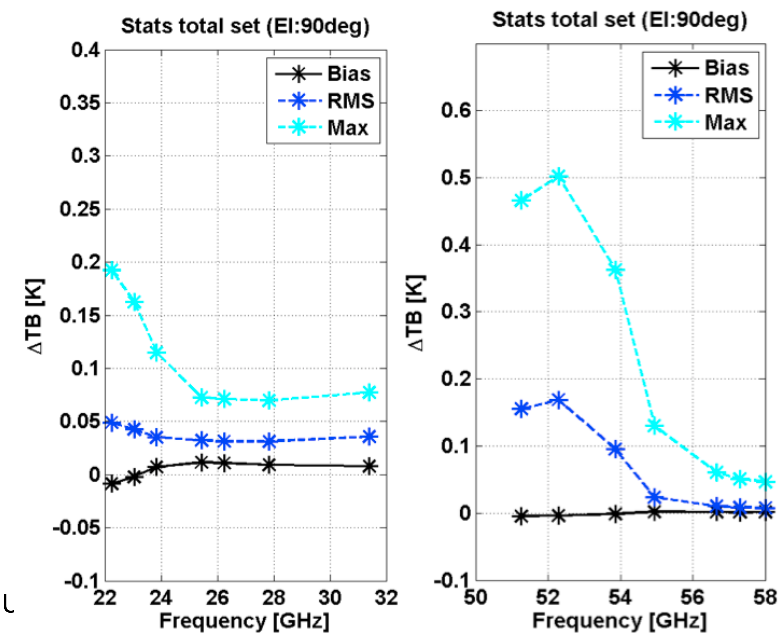
Forward model RTTOV-gb

- **RTTOV**: fast RT model developed within NWPSAF
- Widely used in the NWP community
- Computes brightness temperatures and Jacobians

RTTOV ground-based developed by DeAngelis et al. within COST Action TOPROF *(http://cetemps.aquila.infn.it/mwrnet/software.html)*

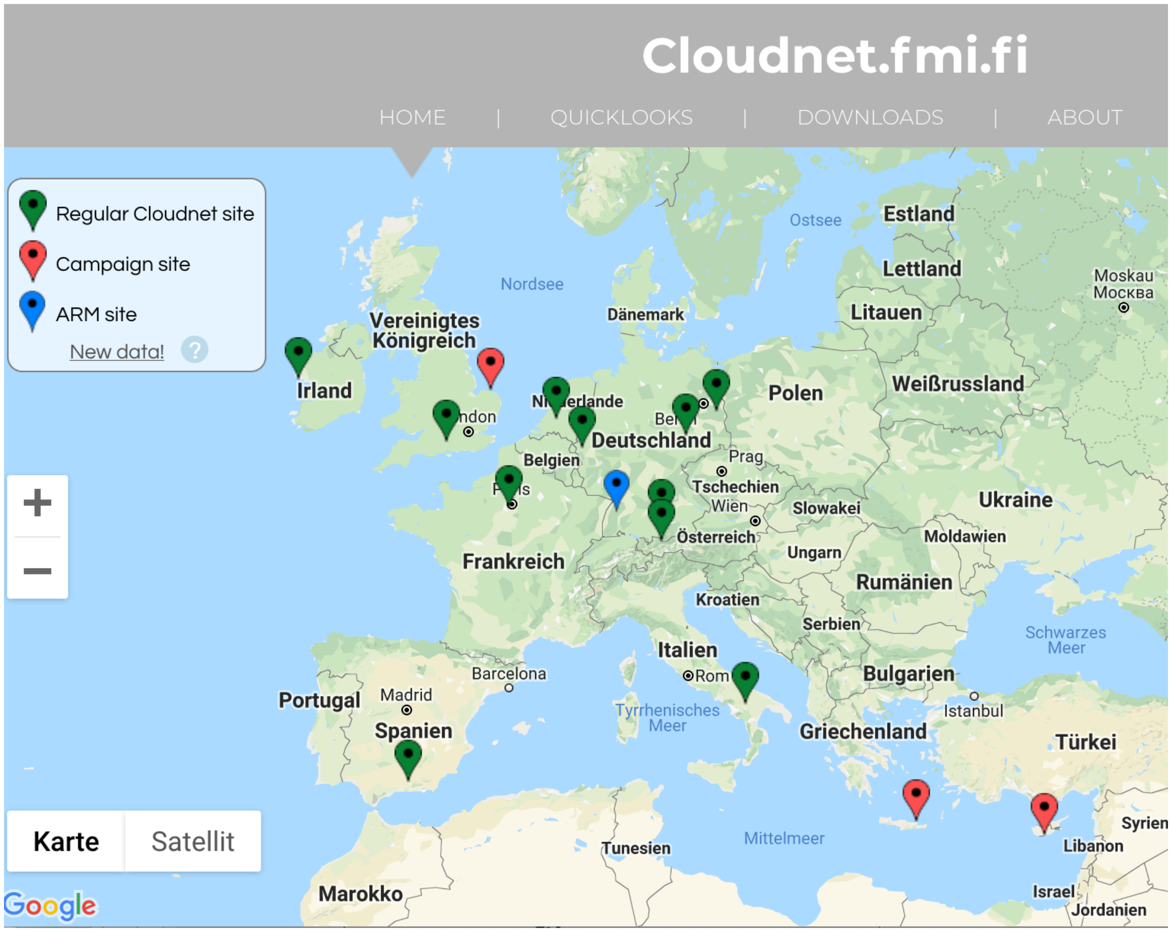
LBL vs. RTTOV-gb

De Angelis et al., 2016:- Adapting the fast radiative transfer model RTTOV for the assimilation of ground-based microwave radiometer observations, Geosci. Model Dev.



RTTOV-gb accuracies better than 0.2 K throughout at zenith observations

ACTRIS Cloudnet sites: all equipped with MWRs



- Liquid water path
- Radiances
- Temperature profiles BL
- Low-res. humidity profiles