EVALUATING ATMOSPHERIC INSTABILITY FROM HIGH SPECTRAL RESOLUTION IR SATELLITE OBSERVATIONS

P. Antonelli[1], A. Manzato[2], S. Puca[3], F. Zauli[4], R. Garcia[1], R. Stuhlmann[5], S. Tjemkes[5]

(1) Space Science Engineering Center, University of Wisconsin - Madison; (2) Osservatorio Meteorologico Regionale ARPA FVG; (3) Diaprtimento di Protezione Civile; (4) Centro Nazionale di Meteorologia e Climatologia Areonautica; (5) EUMETSAT

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This poster describes a procedure to derive instability predictors from IASI observations and from rawinsonde developed and tested over selected regions in Italy with the aim of showing their statistical links with the occurrence of convective activity as detected by lightnings. Statistical relationships were evaluated in different way as a first step in investigating and comparing the skills of individual predictors in deriving the probability of the occurrence of convection. Following in part the concept described in, three different approaches respectively based on linear regression, cross-entropy, and skill scores, were used. The results, which refer to individual indices skills, were found to be strongly dependent on the threshold used to map the number of lightning observed in the 10 hours following the satellite overpass into a boolean index for instability occurrence, and demonstrated the need for a statistical tool capable of combining all the indices to take advantage of their individual skills.

Procedure Development

IASI (METOP-A) observations were collected over 1 by 1 degree boxes centered in Udine, Milano, Cagliari, and Pratica di Mare, Italy for the time period April-October, and for the morning overtpasses. The observations, in clear sky conditions, were used to derive vertical profiles of temperature and water vapor and principal component scores. Vertical profiles, after spectral and environmental validation were used to derive 30 instability indices (table 1). Instability indices and principal component scores were then correlated to the occurrence of lightnings within 10 hours from satellite overpass.

Fig. 1, Example of selected areas.

Inversion of IASI data

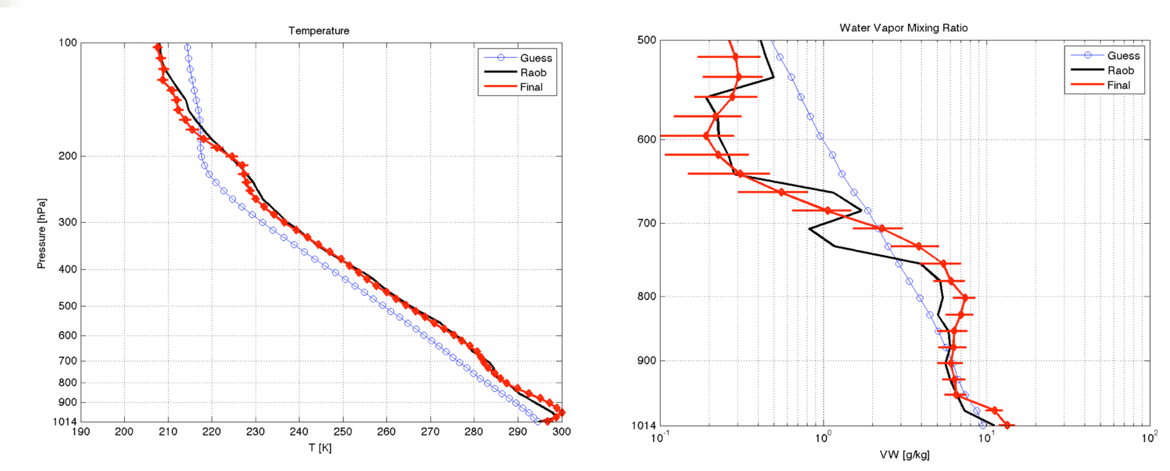
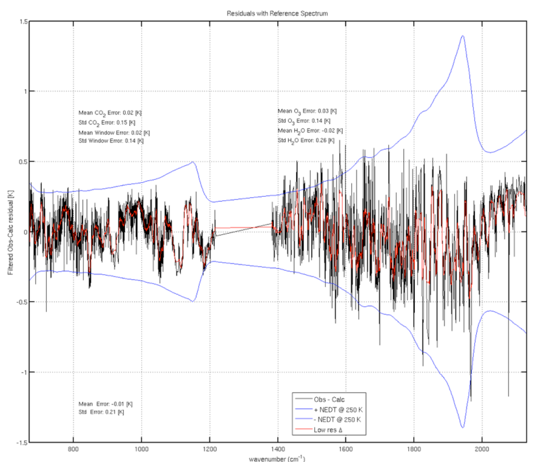


Fig. 2 and 3 Temperature and Water Vapor profiles

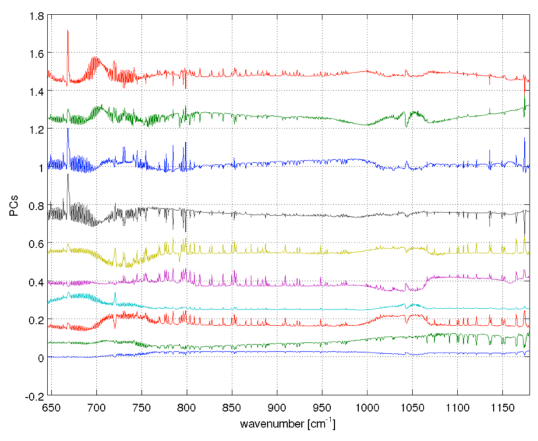
IASI data were inverted using UWPHYSRET an optimal estimation software package developed at the Space Science Engineering Center of the University of Wisconsin - Madsion. UWPHSYRET makes use of local climatology to characterize the a-priori information, and on the Levemberg-Marquardt approach to derive the solution. Figures 2 and 3 show example of temperature and water vapor retrievals obtained over one of the three selected areas (Pratica di Mare, Italy). Retrieved profiles were validated: 1) environmentally, by comparison with rawinsonde observations obtained within 120 minutes from satellite overpass; 2) spectrally by making sure that the retrieval residuals were within the total observation error (estimated as the IASI instrument noise inflated by 30%) as showed in figure 4.



Fig, 4 IASI retrieval residuals

Generation of Instability Predictors

In order to develop an automatic system to predict occurrence of atmospheric instability, principal component scores derived from IASI radiances, and instability indices derived from IASI retrievals, were both considered potential predictors. IASI Principal Components (Figure 5) were derived from a set of 39000 observed spectra collected globally (between 70N and 70S). While instability indices were derived applying Sound_Analys.py, a software package developed at OSMER, to the IASI-derived temperature and water vapor profiles. Bivariate analysis was applied to these predicotrs to evaluate their correlation with lightning occurrence. Results showed that some Principal Components Scores along with some of the Instability Indices carry valuable information regarding the potential instability of observed atmospheric states.



Fig, 5 Example of IASI Principal Components

Statistical relationship between predictors and occurrence of lightnings

Instability Indices derived from Retrieved temperature and water vapor profiles (listed in table 1) were divided into three main families: Indices heavily dependent on Lifted Parcel Theory (CAPE, CIN, UpDr); Indices dependent on Lifted Parcel Theory (LI, ShowI, DTC, DTC500, LFC, Tbase); Indices not dependent on Lifted Parcel Theory (KI, CAP, MRH, LRH, Θe, MaxBuo, PWE). Indices derived from retrievals were linearly correlated with those derived from rawinsonde provided by CNMCA (Table 1) and to lightning observations provided by CESI/SIRF (Table 2). Results showed that Indices belonging to the first family correlate poorly between rawinsondes and retrievals; indices belonging to the second family correlate better between rawinsondes and retrievals; Indices belonging to the third family correlate well between rawinsondes and retrievals. Evaluation of the posterior probability (FIgures 5 and 6) between individual predictors and lightning occurrence showed that longwave (LW) PC number 10, along with the indices weakly dependent on LPT are good candidates for Instability prediction.

- $\rho_{CAPE} = 0.44$
- $\rho_{CIN} = 0.51$
- $\rho_{UpDr} = 0.45$
- $\rho_{LRH} = 0.67$
- $\rho_{PWE} = 0.93$
- $\rho_{KI} = 0.88$
- $\rho_{MRH} = 0.78$
- $\rho_{\Theta e} = 0.94$
- $\rho_{CAP} = 0.22$
- $\rho_{MaxBuo} = 0.58$
- $\rho_{LI} = 0.81$
- $\rho_{DT500} = 0.79$
- $\rho_{ShowI} = 0.80$
- $\rho_{DTC} = 0.60$
- $\rho_{Tbase} = 0.86$
- $\rho_{LFC} = 0.26$
- $\rho_{LCL} = 0.61$

Table 1. Example of linear correlation found between Instability Indices generated from retrievals and raw-

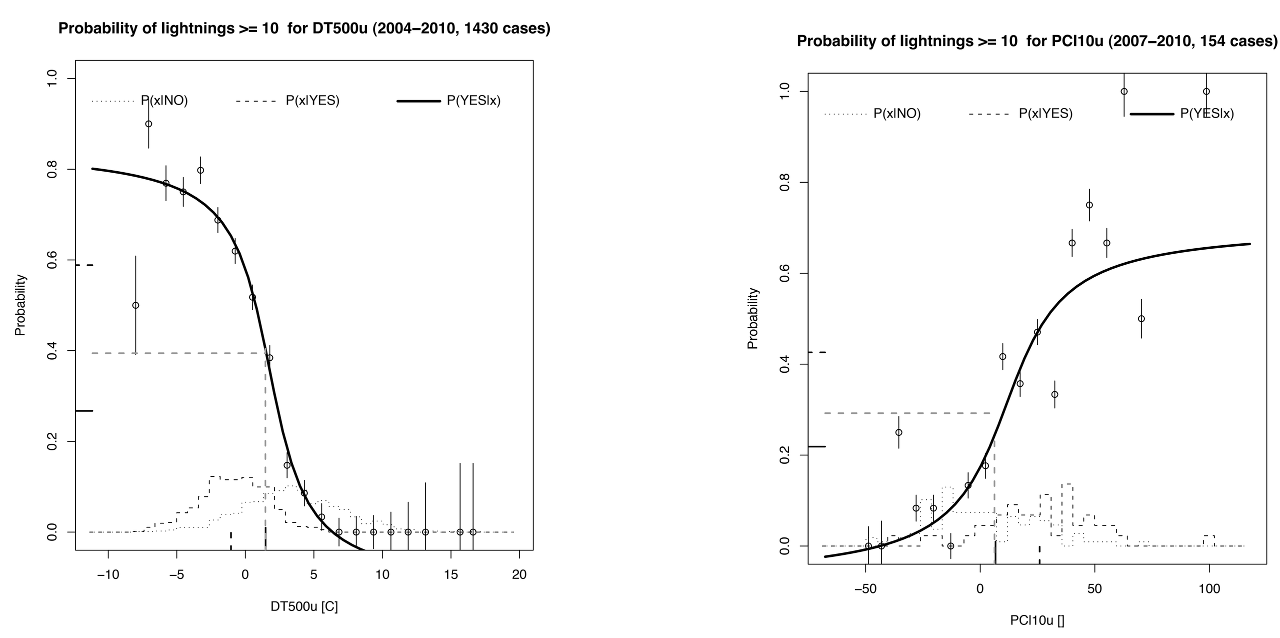


Figure 5 and 6. Estimated Posterior Probability for DT500 and PC LW 10 with respect to lightning occurrence.

Index	Units	Sonde R	IASI R	Sonde CEE	IASI CEE
CAPE	J/kg	0.51	0.46	1.60	0.26
CIN	J/kg	0.48	0.32	1.12	1.16
UdDr	m/s	0.53	0.45	1.84	0.31
LI	C	-0.53	-0.41	0.95	1.38
ShowI	C	-0.54	-0.43	0.94	1.38
DTC	C	-0.51	-0.47	1.02	1.31
DTC500	C	-0.55	-0.44	0.93	1.38
LFC	m	0.13	0.26	0.98	0.61
LCL	m	-0.36	-0.23	0.87	0.51
Tbase	C	0.43	0.30	0.94	1.19
MaxBuo	C	0.51	0.50	0.53	0.58
KI	C	0.49	0.39	0.87	0.78
CAP	C	-0.28	-0.29	0.96	0.50
MRH	%	0.27	0.28	0.72	0.64
LRH	%	0.21	0.21	0.84	0.94
PWE	mm	0.44	0.37	0.53	0.50
Θe	K	0.40	0.35	0.58	0.69

Table 2. Example of linear correlation and Cross Entropy Error found between Instability Indices generated from retrievals and rawinsonde, and occurrence of lightning.

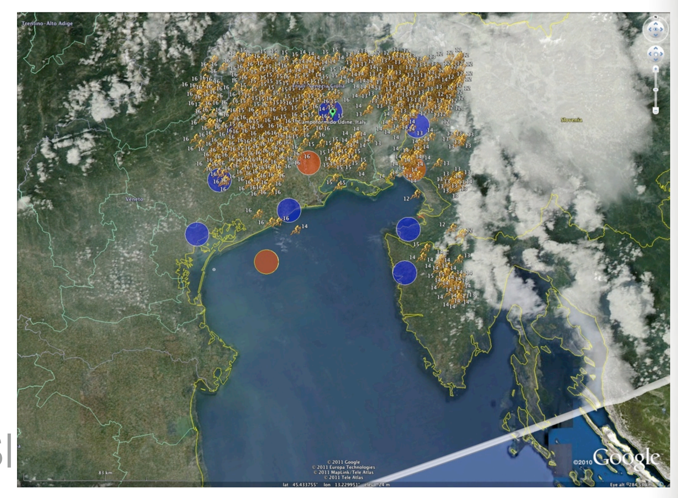


Fig. 7. Example Instability maps that could be generated from IASI

Conclusions

Bivariate analysis of the statistical links between instability indices derived from IASI level 2 products (retrievals) and IASI Principal Components showed high degree of correlation with the corresponding instability indices derived from rawinsondes, especially considering the average time differences between satellite overpass (9.30 UTC) and rawinsonde launch (11:00 UTC). Applying the same analysis interesting statistical correlation were found between some of the Instability indices (DTC500, LI, KI, ShowI) and occurrence of lightning in the 6 hours following the rawinsonde launch (between 11:00 and 17:00 UTC). Results of this study led to the conclusion that a multivariate analysis was needed in order to assess the value of combined IASI level 3 products (instability indices derived from retrievals) and Principal Component Scores (linear combination of radiances) in predicting convective events detectable by lightning activity to generate maps like the one showed in Figure 7 (please see poster 182 "*Forecasting thunderstorms on the Po Valley using sounding derived and satellite derived indicies with Neural Networks*" for the second phase of this project).

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