

# Stima di precipitazione mediante tecniche di integrazione di osservazioni satellitari, radar e pluviometriche“

Samantha Melani, CNR – IBIMET

"Il contributo della Rete Radar Meteorologica Transfrontaliera per la mitigazione del rischio idrogeologico: caratteristiche, potenzialità e sviluppi futuri"

**WORKSHOP**

Livorno 28 novembre 2012

La rete **radar meteorologica** transfrontaliera per la mitigazione del **rischio** idrogeologico



# Tre modalità principali per misurare/stimare la precipitazione

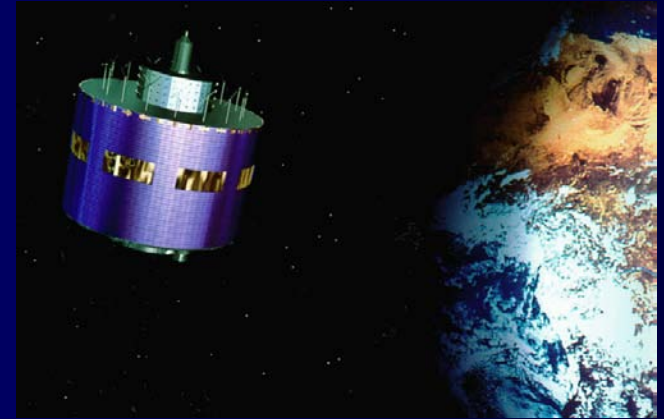
## PLUVIOMETRI



## RADAR



## SATELLITI



Altre modalità possibili:

- Cell phone network signals (Messer, 2007)
- Modelli numerici

# I. Pluviometri

# Sistemi di misura della precipitazione: PLUVIOMETRI

## Vantaggi:

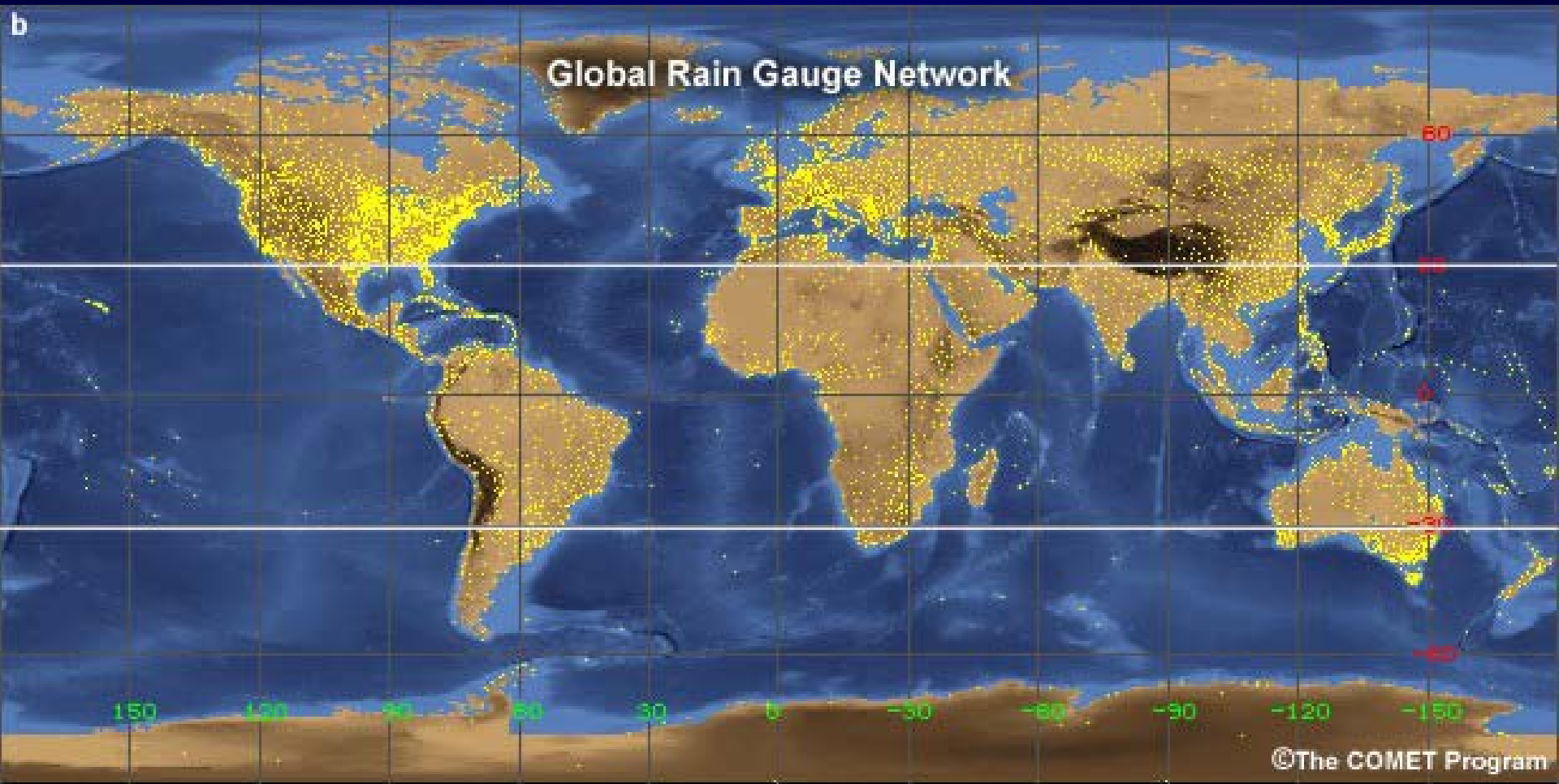
- Misura “vera” della precipitazione

## Limiti:

- Copertura assente sugli oceani e zone remote
- Misura puntuale non rappresentativa di un'area
- Vento -> sottostima della precipitazione
- Diversi designs



# RETE PLUVIOMETRICA GLOBALE



<https://www.meted.ucar.edu/>

# METODI di SPAZIALIZZAZIONE dei DATI PLUVIOMETRICI

Storicamente, i *metodi di spazializzazione* possono essere suddivisi in tre categorie:

*i. metodi grafici*, permettono di realizzare una cartografia principalmente di tipo pluviometrica, qualche volta in combinazione con analisi sulle correlazioni tra precipitazione e quota (isoiete e Thiessen)

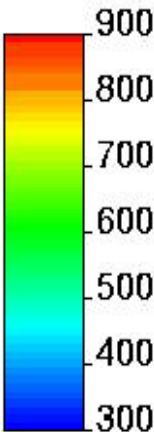
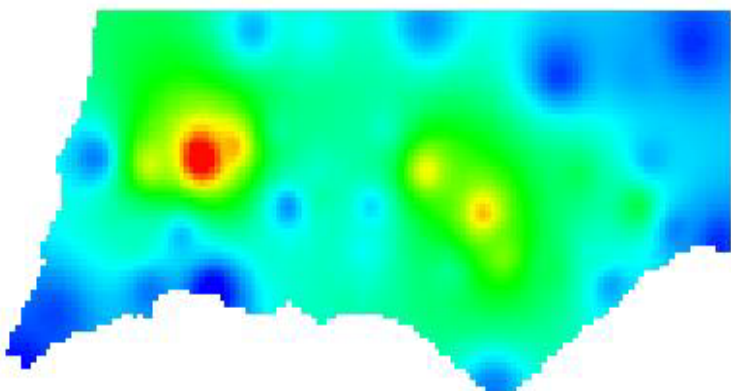
*ii. metodi topografici*, comprendono quelle tecniche che sono basate sulla correlazione esistente tra la variabile in oggetto e alcuni parametri topografici e sinottici come pendenza, esposizione, quota, velocità e direzione del vento, ecc. (analisi dei trend, modelli regressivi, ecc.)

*iii. metodi numerici*, si basano su funzioni numeriche che vengono utilizzate per pesare i punti-stazione irregolarmente distribuiti nello spazio, con lo scopo di ottenere una stima di una griglia a conformazione regolare (inverso della distanza, Kriging, cokriging, ecc).

# Esempi di Spazializzazioni dati PLUVIOMETRICI (Portogallo)

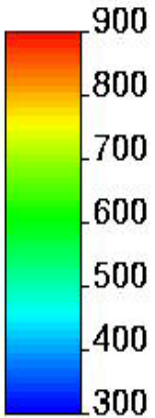
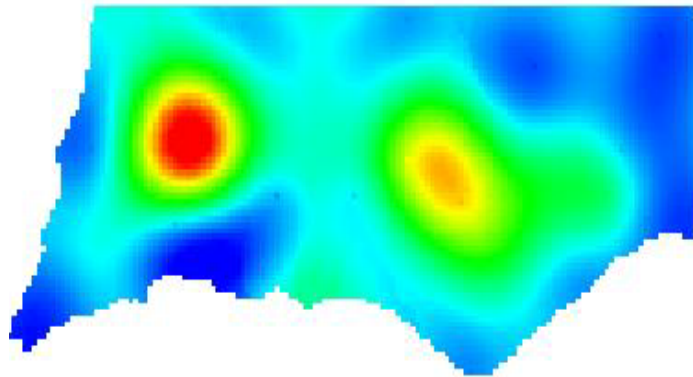
Annual rainfall map (mm)

Inverse Square Distance



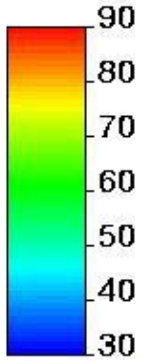
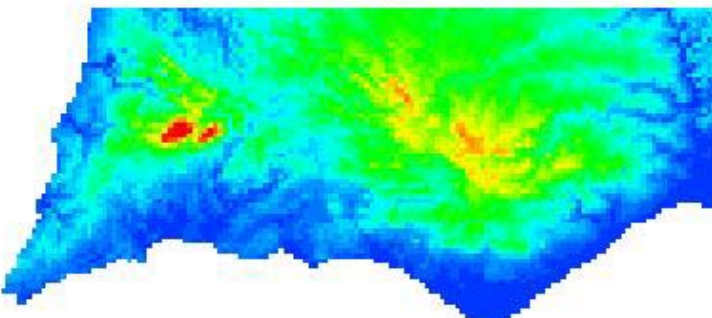
Annual rainfall map (mm)

Ordinary Kriging



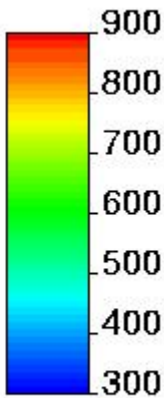
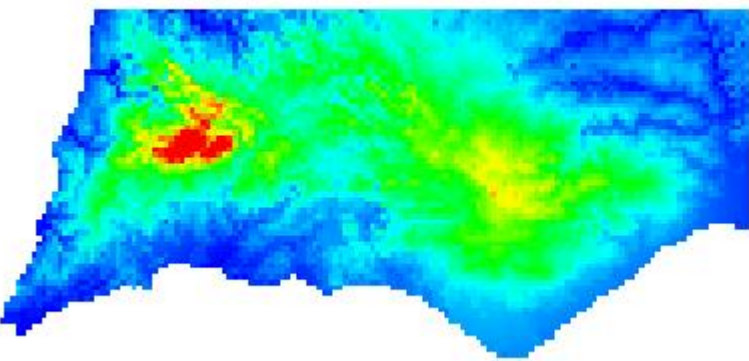
Annual rainfall map (mm)

Linear Regression

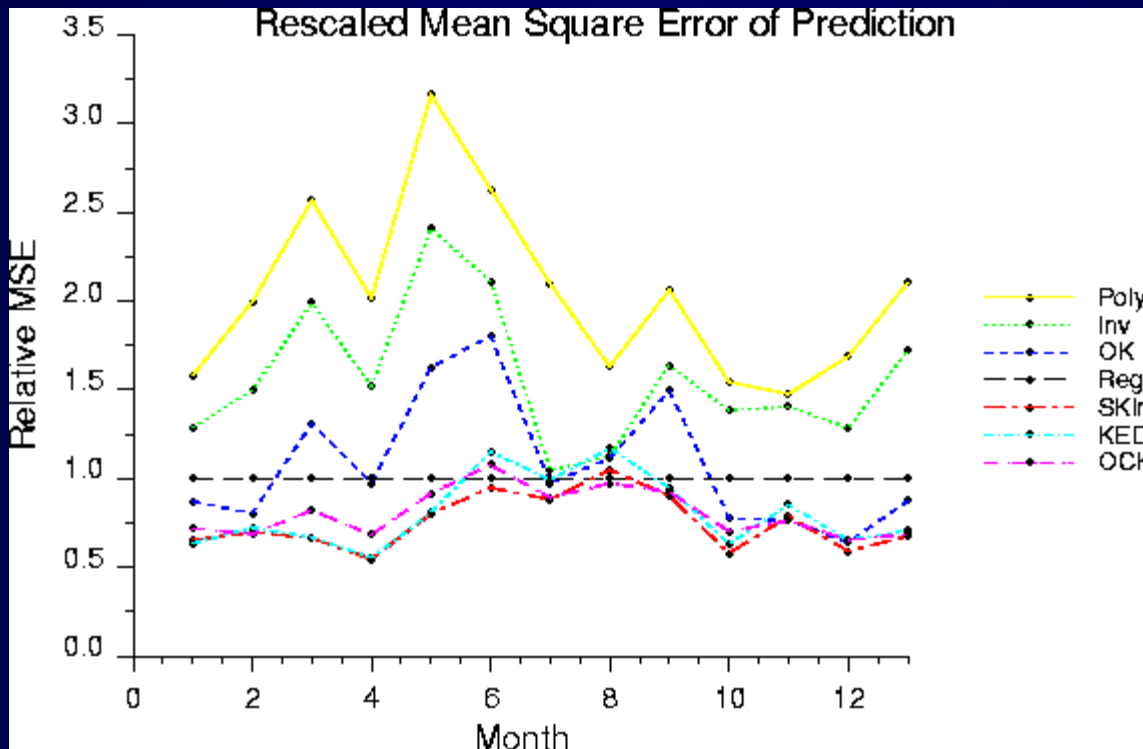


Annual rainfall map (mm)

Kriging with an External Drift



Mean square error of prediction produced by each of the seven interpolation algorithms for monthly (1-12) and annual rainfall. Results are expressed as proportions of the prediction error of the linear regression approach.



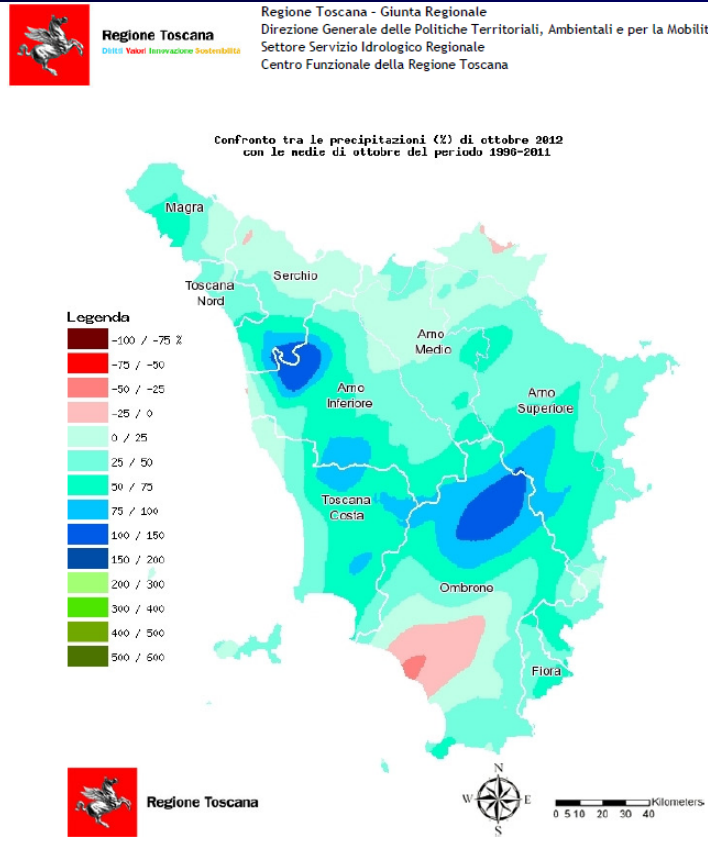
Performance Comparison of Geostatistical Algorithms for Incorporating Elevation into the Mapping of Precipitation

*Pierre Goovaerts*, Proceed. of the 4th International Conference on GeoComputation Mary Washington College Fredericksburg, Virginia, USA, 25 - 28 July 1999



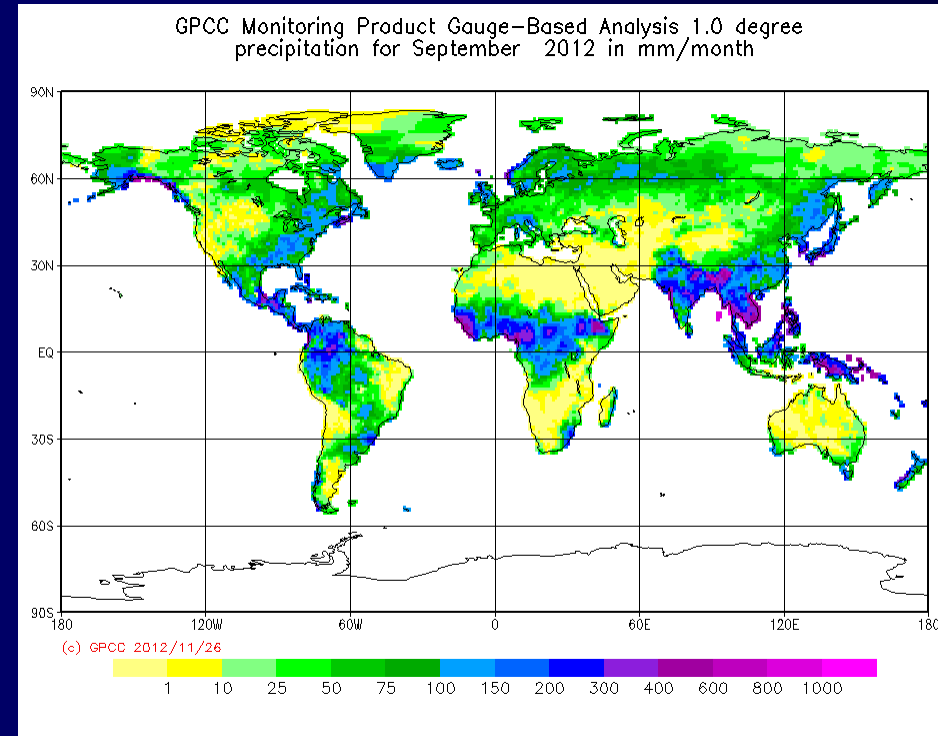
# Applicazioni

## Pluviometria regionale



<http://www.sir.toscana.it>

## Climatologia



<http://www.esrl.noaa.gov/psd/data/gridded/data.gpcp.html>

- Calibrazione (Z-R, satellite)
- Validazione
- Assimilazione modelli numerici

## II. RADAR

# Sistemi di misura della precipitazione - RADAR

## Vantaggi:

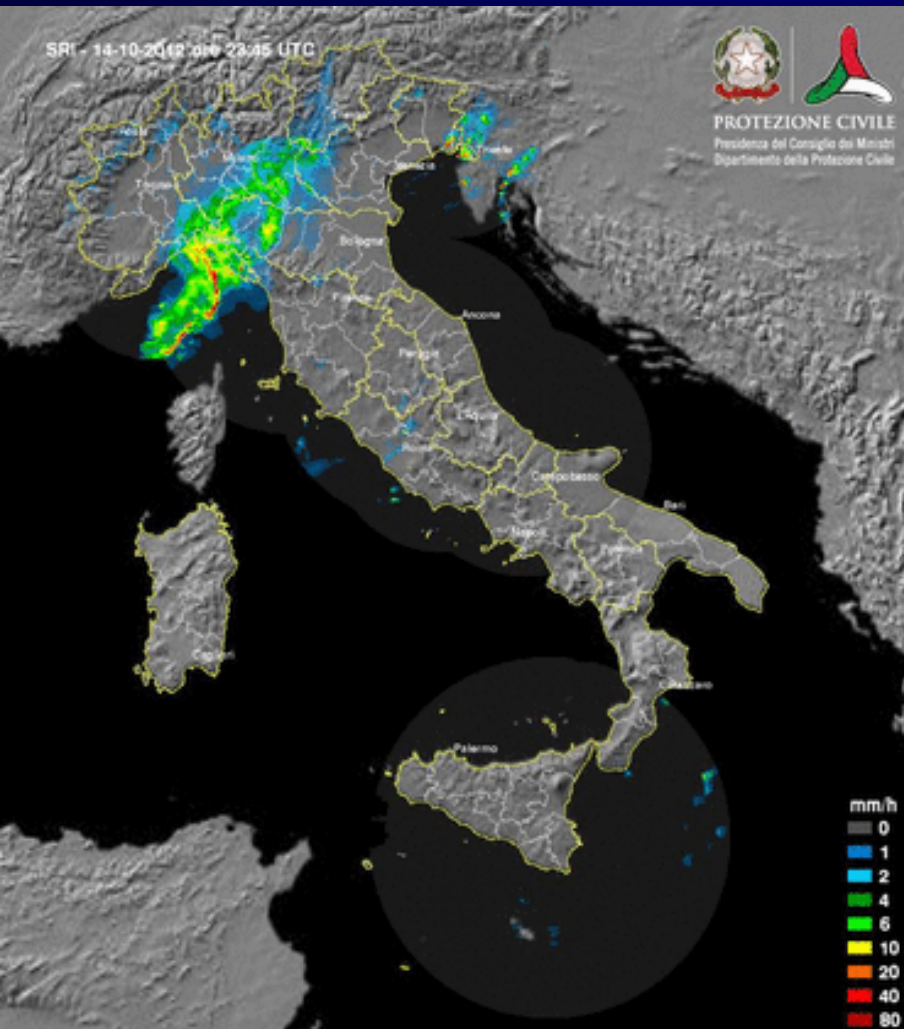
- Ottima risoluzione spaziale e temporale
- Osservazioni in tempo reale

## Svantaggi:

- Scarsa copertura su oceani o regioni remote
- Calibrazione del segnale
- Bright band, propagazione anomala, attenuazione, etc.
- Relazione Z-R
- Costi elevati

# Monitoraggio in tempo reale della precipitazione

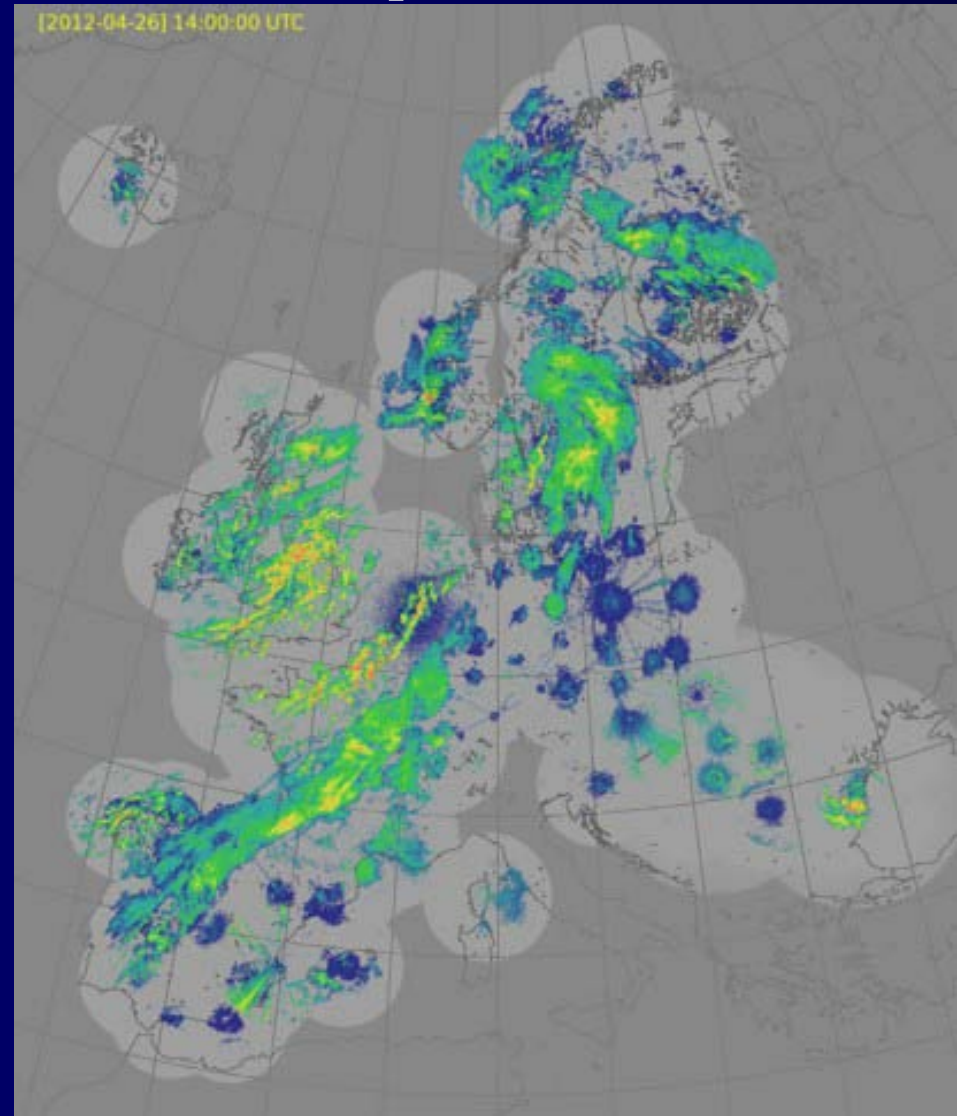
RETE RADAR NAZIONALE - DCPC



Intensità di precipitazione al suolo

[http://www.protezionecivile.gov.it/jcms/it/servizio\\_cfc.wp](http://www.protezionecivile.gov.it/jcms/it/servizio_cfc.wp)

OPERA - Copertura Marzo 2012



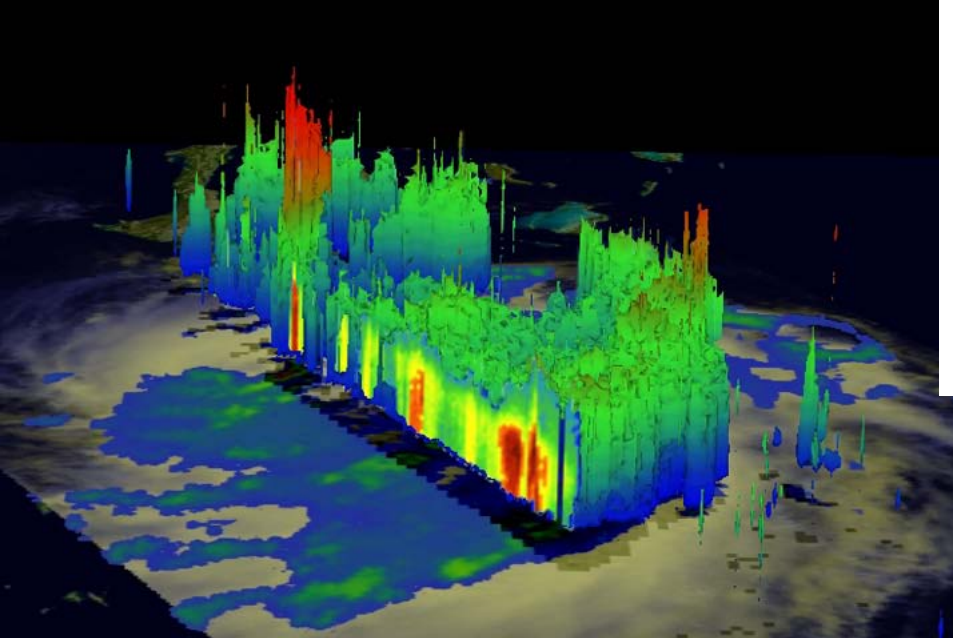
<http://www.knmi.nl/opera/>

# Sezioni verticali ed orizzontali

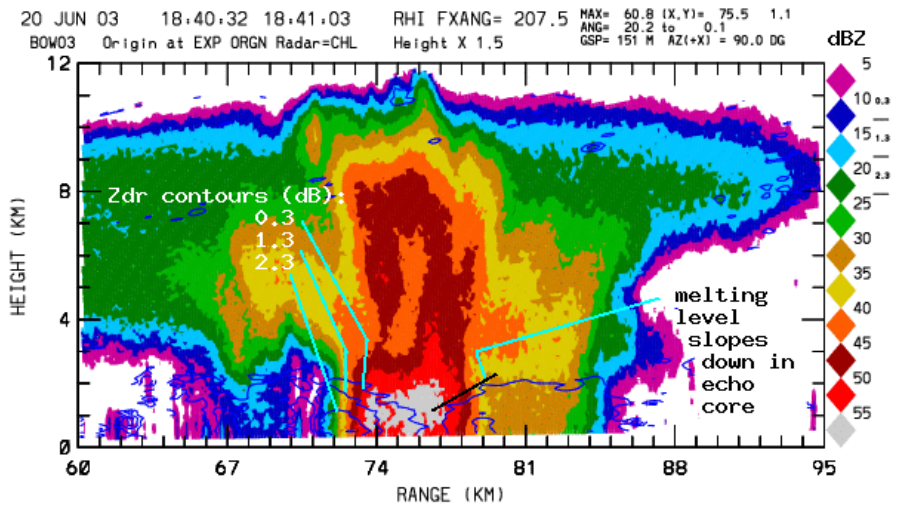
## RHI

### Hurricane Irene

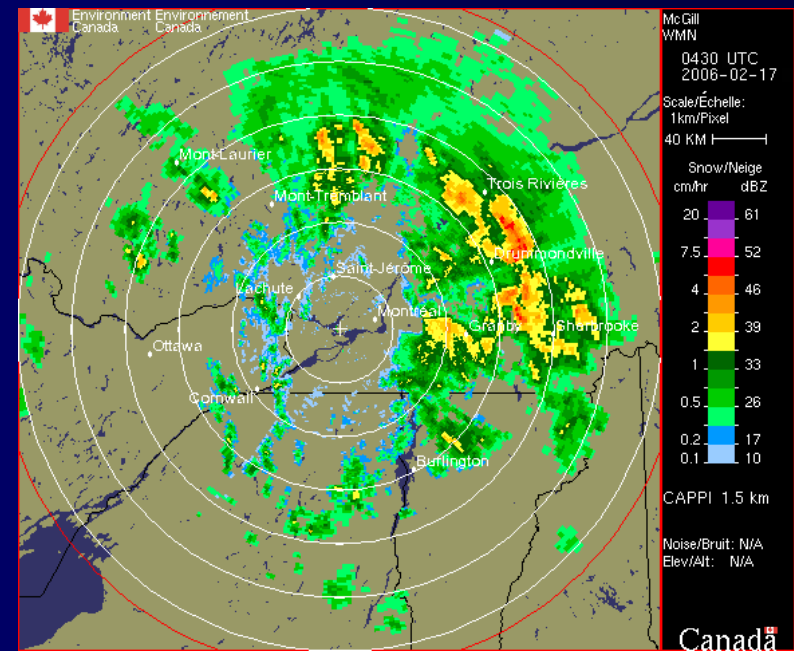
TRMM satellite 15:57 UTC, August 22, 2011



<http://news.discovery.com/>



<http://www.chill.colostate.edu/>



## CAPPI

(Source [Environment Canada](http://www.environment.ca))

# Riflettività- Intensità di Precipitazione (Z-R)

$$Z = \alpha R^\beta$$

$\alpha$ ,  $\beta$  costanti empiriche (dipendono fortemente dalla DSD),  $R$  è la precipitazione in  $[\text{mm}^6/\text{m}^3]$ , e  $Z$  è la riflettività in  $\text{dbZ}$

La relazione Z-R è dipendente dal tipo di precipitazione (convettiva, stratiforme, mista), dalla stagione (estate, inverno), dalla locazione (tropici, continentale, oceanica, medie-latitudini)...

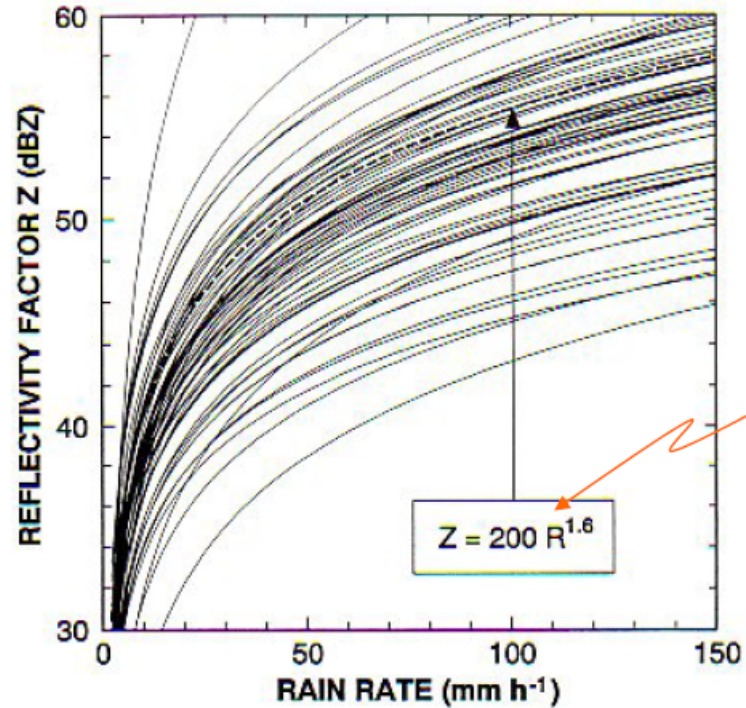


Fig. 8.6 Sixty-nine  $R, Z$  relationships from Battan (1973).

Source: Doviak and Zrnica (1993)

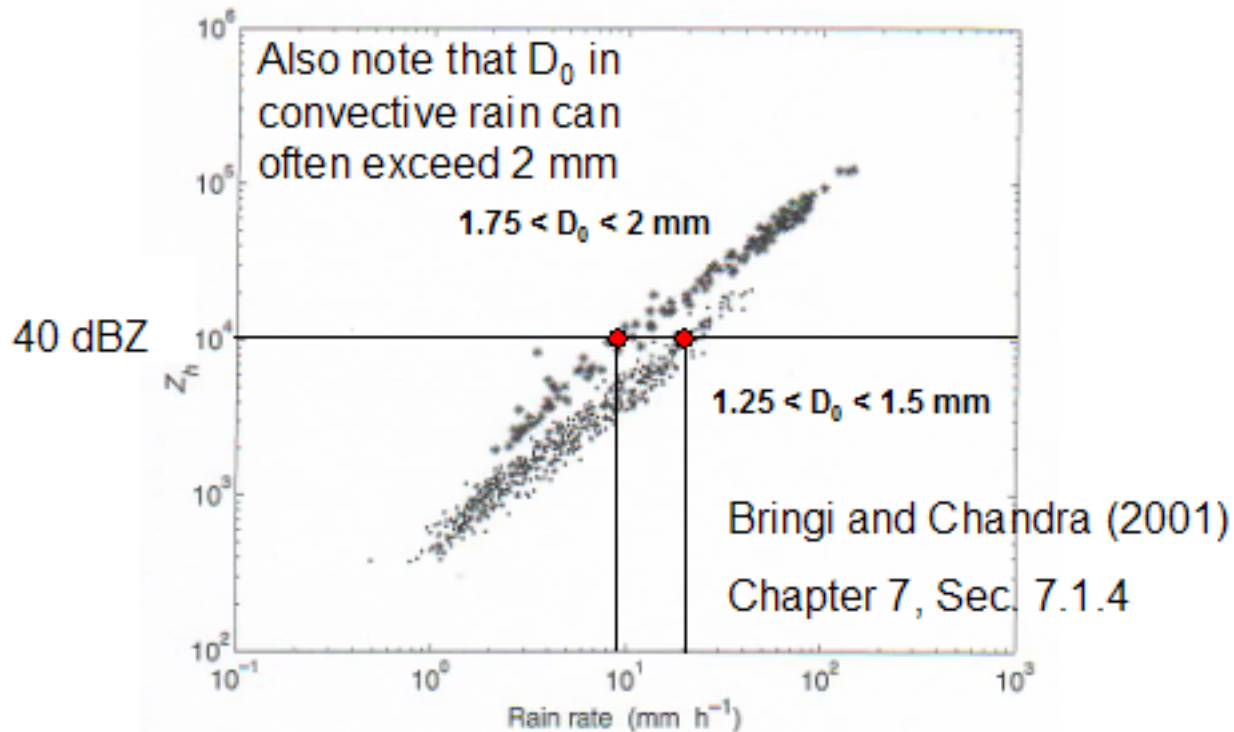
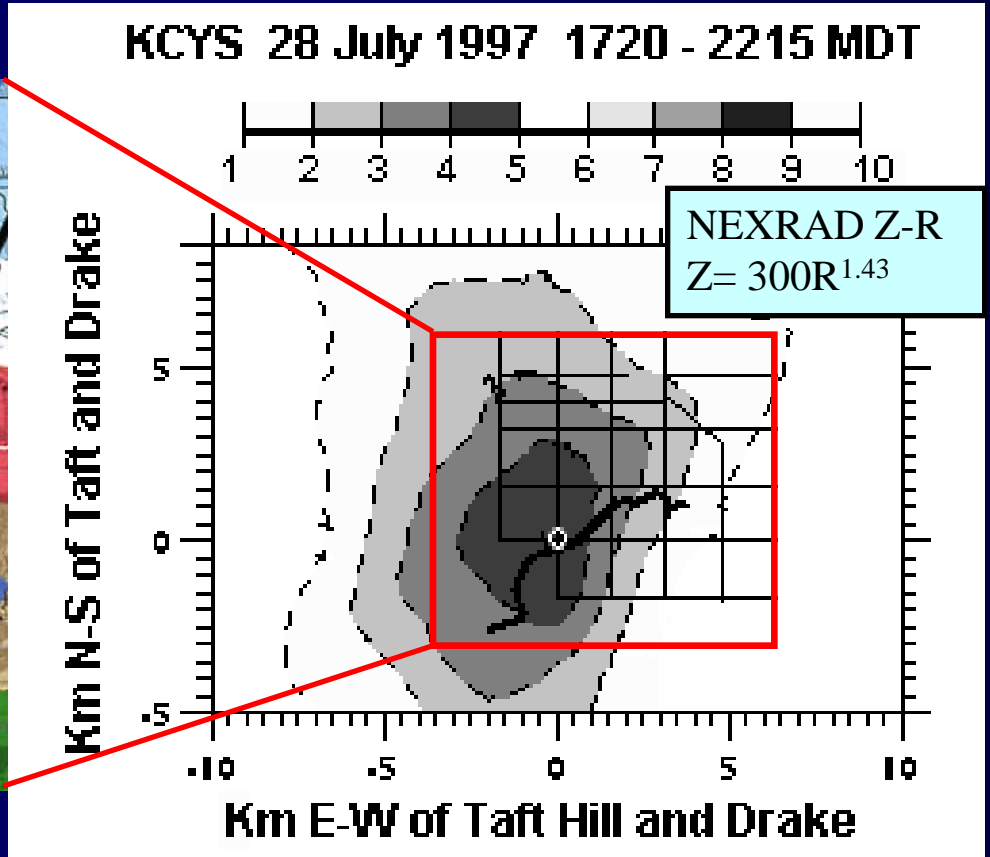
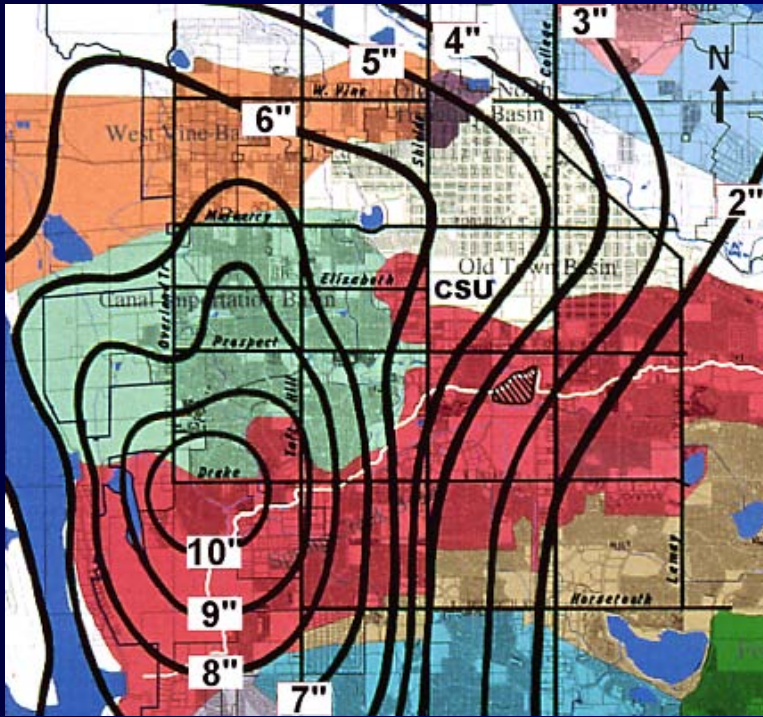


Fig. 7.19. Reflectivity (at horizontal polarization and 5.5 GHz) versus rain rate using normalized gamma fits to 3-minute averaged dsds from Darwin, Australia. Data are stratified into two different intervals of  $D_0$ : ( $\ast$ ) represents the range  $1.75 < D_0 < 2$  mm, ( $\bullet$ ) represents the range  $1.25 < D_0 < 1.5$  mm.

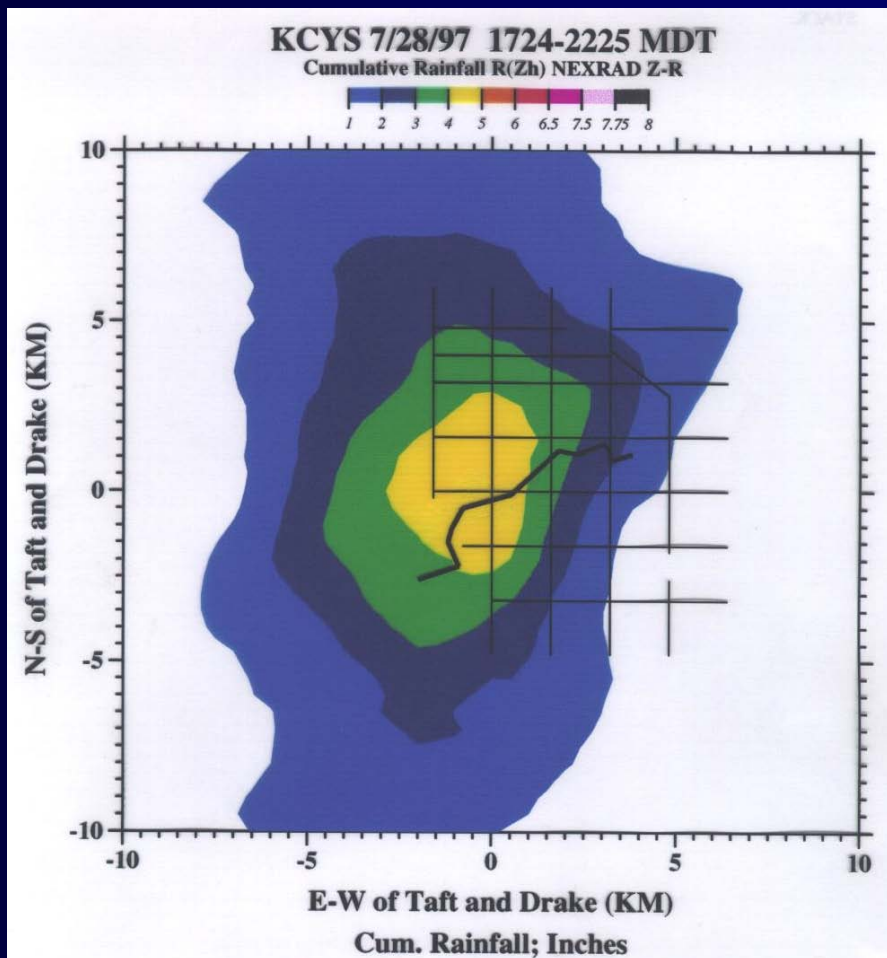
**Esistono differenze intrinseche (diversi  $D_0$ )  
per nubi convettive e stratiformi!**



Fort Collins flash flood case. **Radar calibration issues did not seem to be the problem (though this is often the dominant problem).** The NEXRAD Z-R underestimated precip by a factor of two in a tropical environment located over Fort Collins. This event resulted in WFO Denver receiving permission to use a “tropical” Z-R relationship ( $Z=250R^{1.2}$ ) under certain atmospheric conditions (e.g., the problem was assumed to be DSD related).

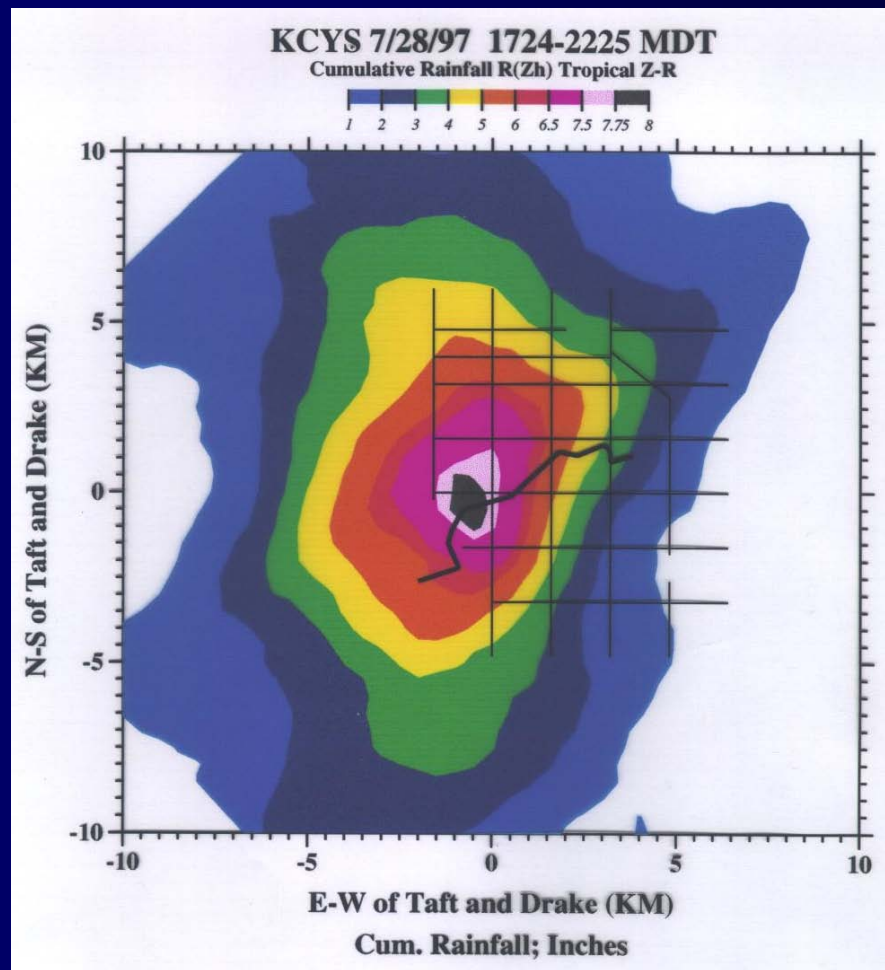


# Fort Collins Flood



**NEXRAD Z-R**

Default WSR-88D (Z= 300R1.4)

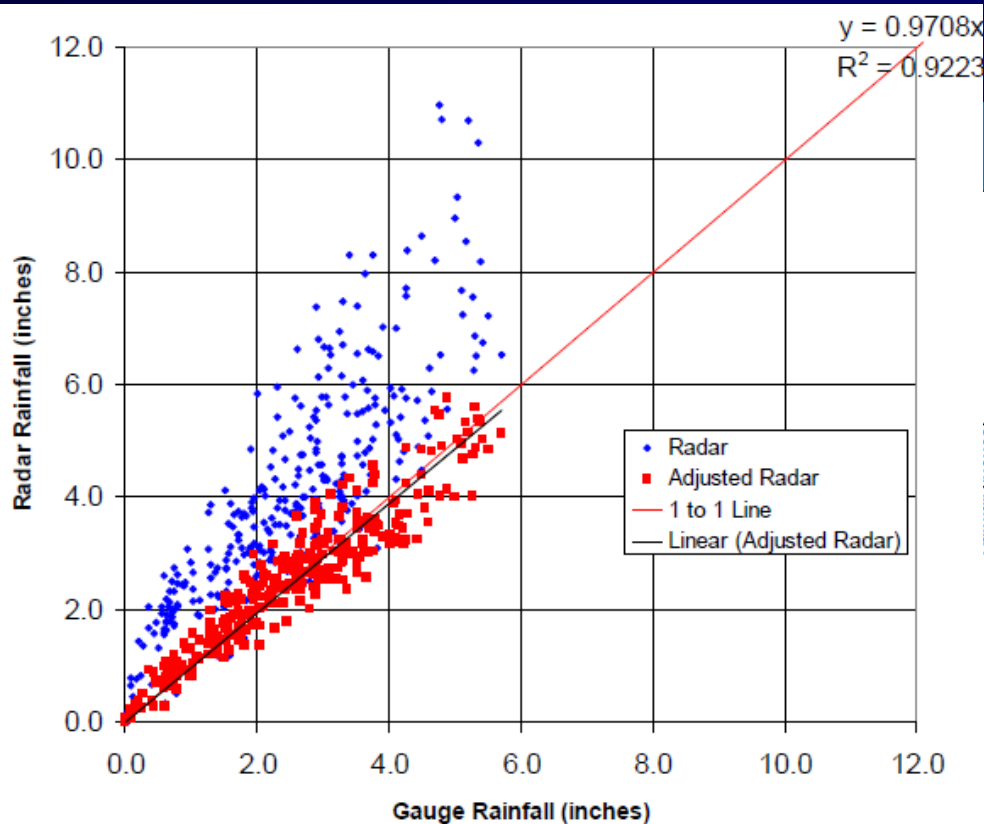


**Tropical Z-R**

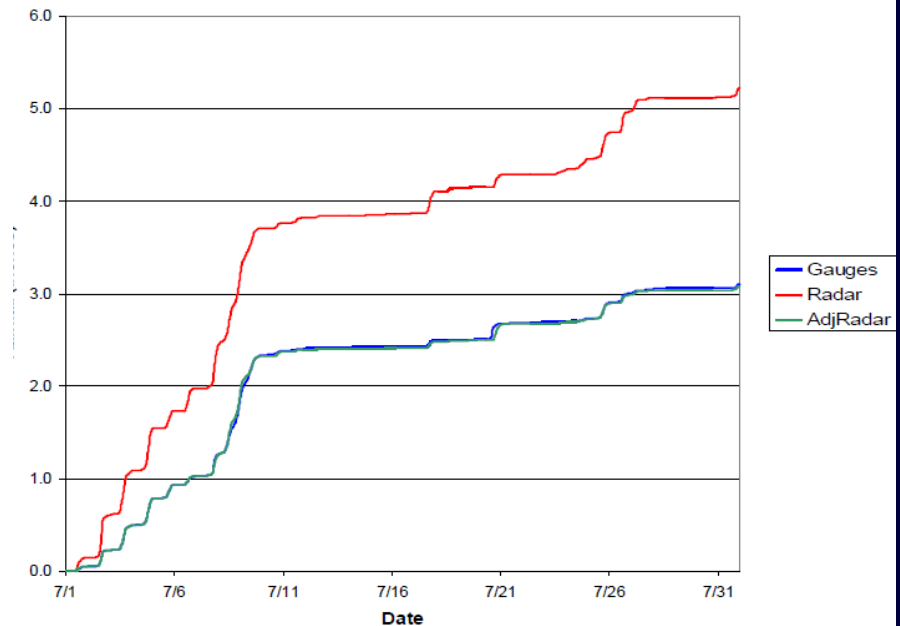
Tropical (Z=250R1.2)

# Gauge-adjusted Radar Rainfall - GARR

<http://www.onerain.com/solutions/gauge-adjusted-radar>



## July 2006 GARR



# **III. SATELLITE**

# Vantaggi/Limiti

<b>Sensore</b>	<b>Vantaggi</b>	<b>Limiti</b>
<b>IR</b>	<b>Alta risoluzione temporale e copertura spaziale ampia</b>	<b>Debole relazione con la precipitazione, contaminazione cirri</b>
<b>VIS</b>	<b>Alta risoluzione temporale e copertura spaziale ampia</b>	<b>Debole relazione con la precipitazione, nubi brillanti non precipitanti, non disponibile ore notturne</b>
<b>MW</b>	<b>Forte relazione con la precipitazione</b>	<b>Bassa frequenza, scarsa copertura spaziale, parziale beam filling</b>

# Sistemi di misura della precipitazione: SATELLITI

- I metodi di stima della precipitazione sono categorizzati in GEO e LEO
- Gli algoritmi di retrieval sono tipicamente classificati secondo lo spettro che osservano (VIS, IR, PMW, etc) o “multi-spettrali” (i.e., usano uno o più di questi spettri individuali)
- Se la metodologia utilizza differenti tipi di satelliti o altre informazioni come i radar e/o pluviometri è classificata come tecnica “mista” (i.e., blended)

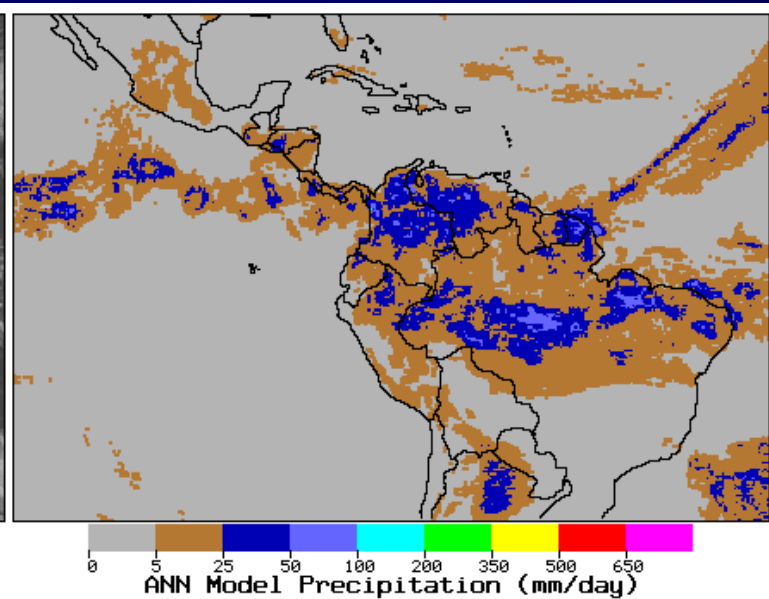
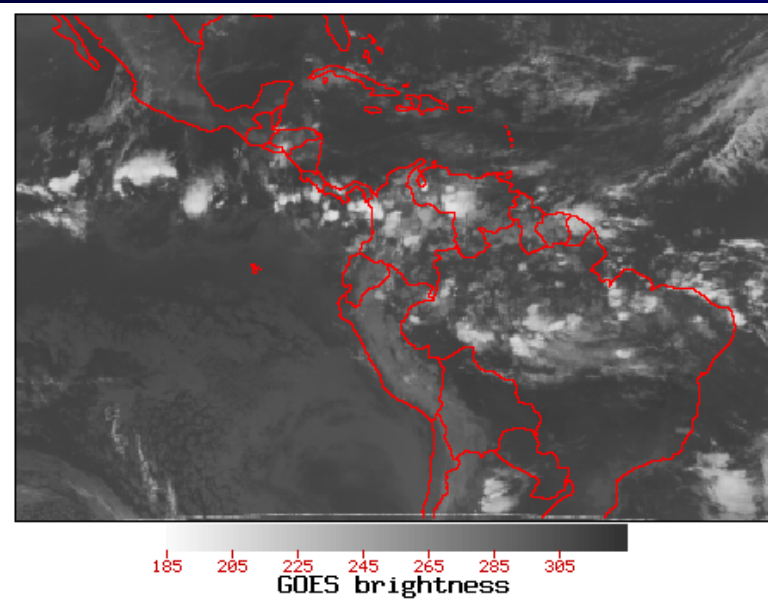
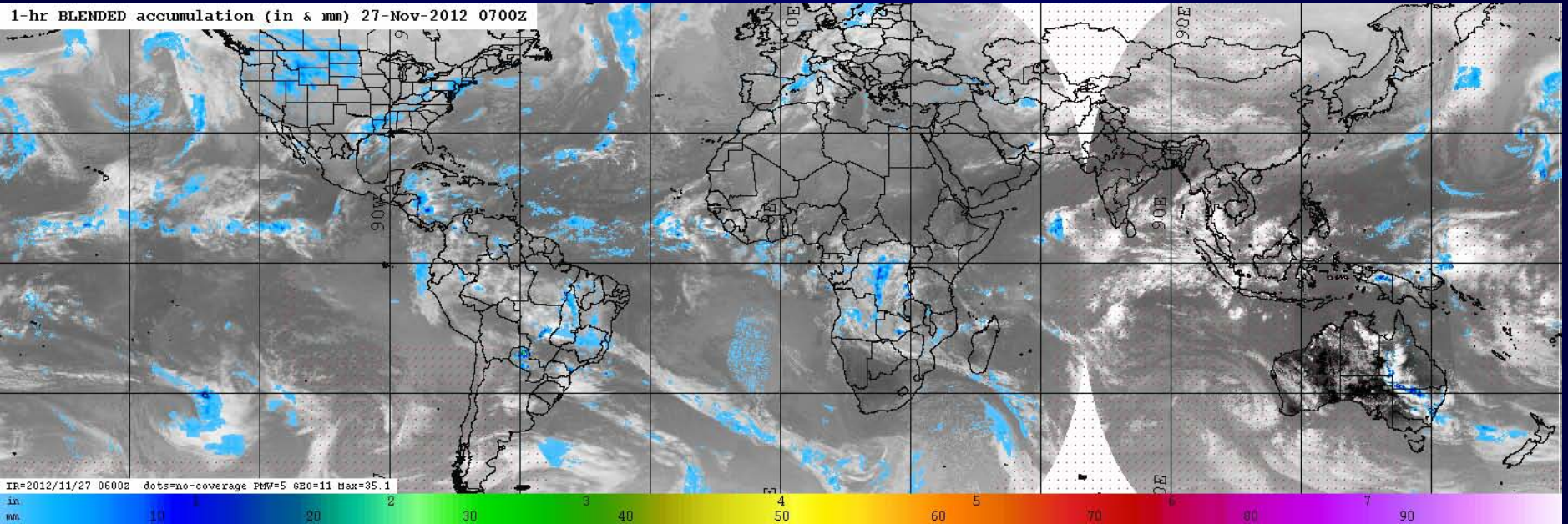
Observation Spectrum	Sensor Examples	Satellite Type	Strength	Weakness
Visible (VIS)	GOES Imager AVHRR	<b>GEO</b> <b>LEO</b>	Cloud type Cloud evolution	Cloud tops Indirect rain rate
Infrared (IR)	GOES Imager AVHRR	<b>GEO</b> <b>LEO</b>	Cloud temperature Cloud evolution	Cirrus contamination Indirect rain rate
Passive Microwave (PMW)	<b>SSM/I</b> AMSR-E <b>AMSU-MHS</b>	<b>LEO</b>	Direct measure of rain, especially over ocean	Temporal sampling Indirect rain rate (land)
Active Microwave (AMW)	TRMM PR <u>CloudSat CPR</u>	<b>LEO</b>	Direct measure of vertical structure of rain	Narrow swath width Rain rate sensitivity

# Alcuni prodotti di stima della precipitazione

<u>Product</u>	<u>Time Res</u>	<u>Space Res</u>	<u>Existence</u>	<u>PM</u>	<u>Gauge</u>
CMORPH	30-min	0.07 deg	2002-Pres	Y	N
NRL	3-hourly	0.25 deg	2003-2006	Y	N
PERSIANN	3-hourly	0.25 deg	2000-2006	Y	N
TRMM-3B42	3-hourly	0.25 deg	1998-Pres	Y	Y
TRMM-3B42RT	3-hourly	0.25 deg	2002-Pres	Y	N
CPC-RFE	Daily	0.1 deg	2001-Pres	Y	Y
CPC-ARC	Daily	0.1 deg	1995-Pres	N	Y
GPCP-1DD	Daily	1.0 deg	1996-Pres	nd	nd
TAMSAT	10-daily	~0.05 deg	1996-Pres	N	N
GPCP	Monthly	2.5 deg	1979-2007	Y	Y
CMAP	Monthly	2.5 deg	1979-2006	Y	Y
TRMM-3B43	Monthly	2.5 deg	1998-Pres	Y	Y

# Tecniche miste LEO-GEO

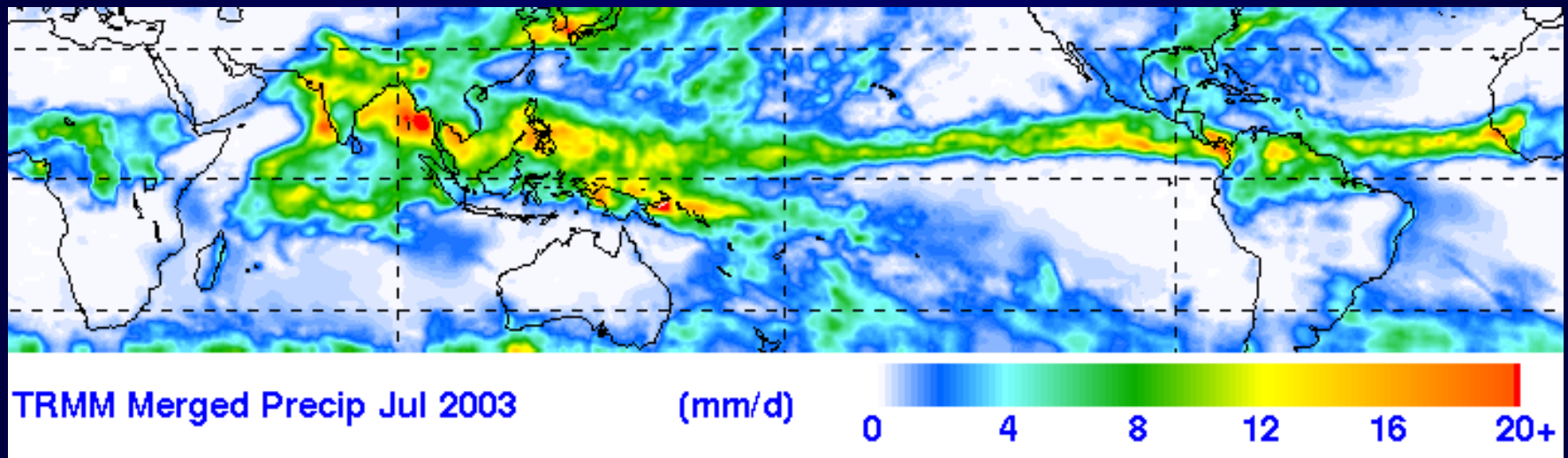
# NRL rainfall - "Blend"



**PERSIANN –  
Artificial  
Neural  
Network**

# Tecniche multi-sensore

## Monthly mean rainfall



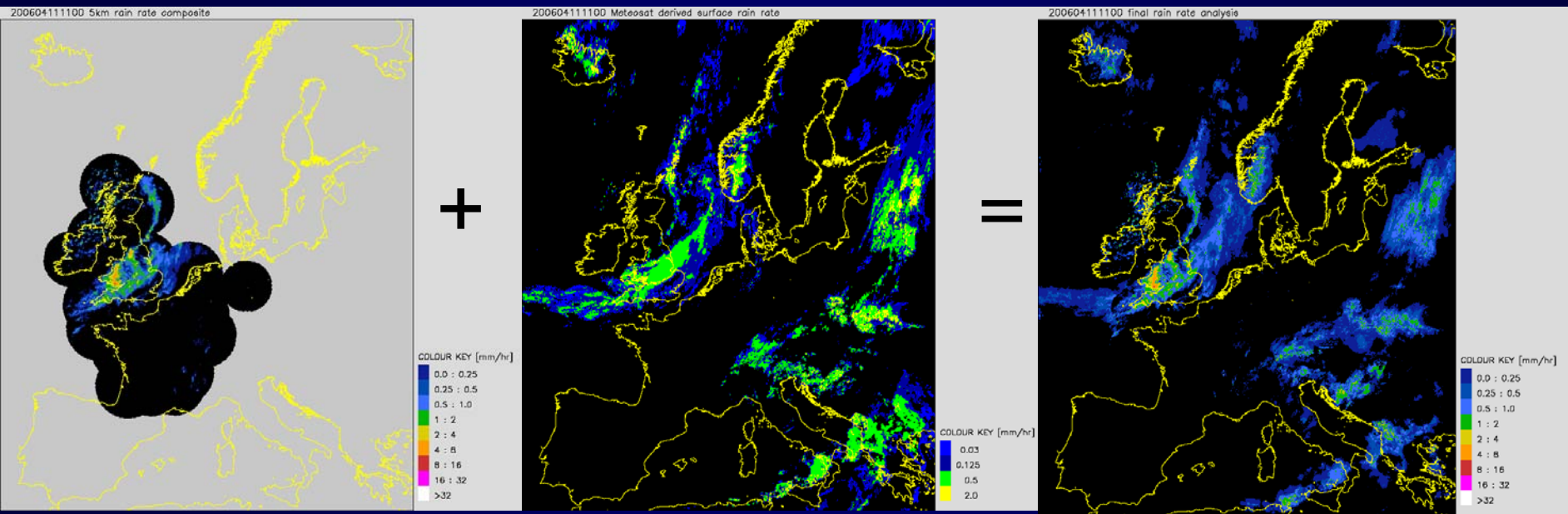
[http://trmm.gsfc.nasa.gov/images\\_dir/avg\\_rainrate.html](http://trmm.gsfc.nasa.gov/images_dir/avg_rainrate.html)

*Weighted average of TRMM, SSM/I, IR, rain gauges*



# Met office NIMROD nowcasting precipitation estimation product

- Stima di pioggia sull'Europa prodotta operativamente ogni 15 minuti



- Radar

Satellite

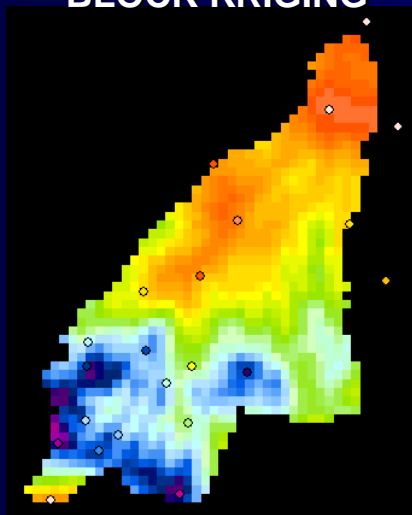
Analysis

# RAINMUSIC – Software

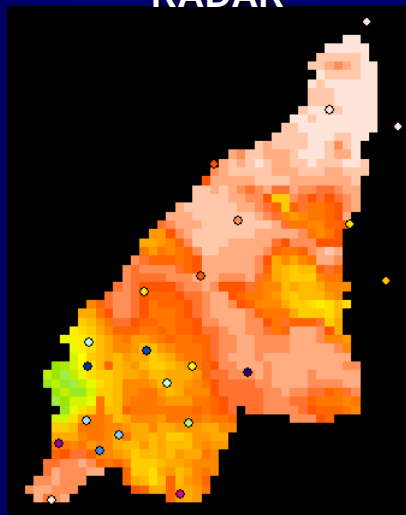
# Reno River basin

Source: Carpediem.ub.es

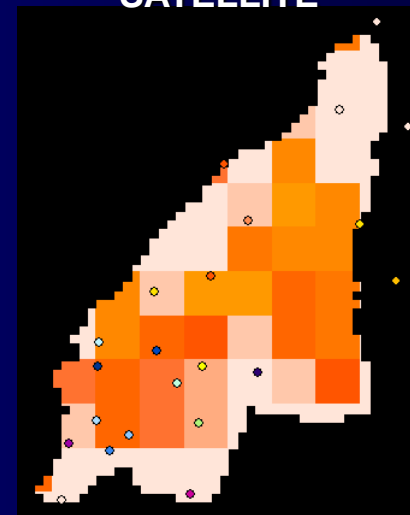
### BLOCK KRIGING



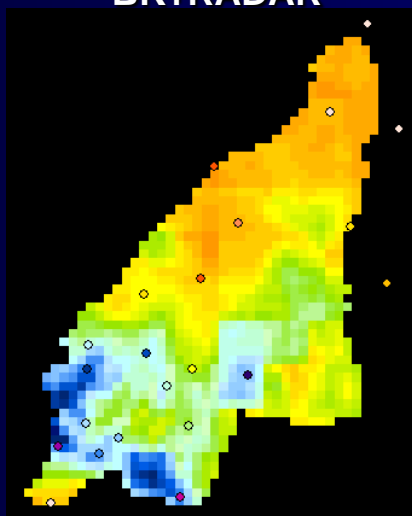
### RADAR



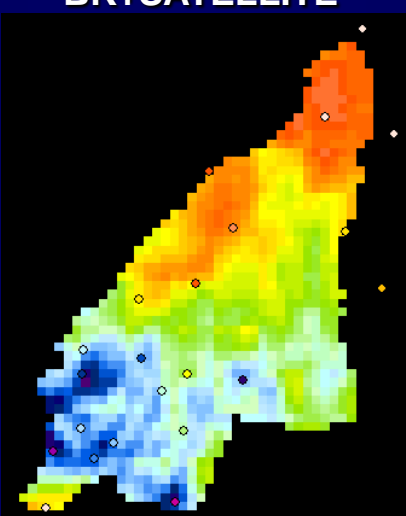
### SATELLITE



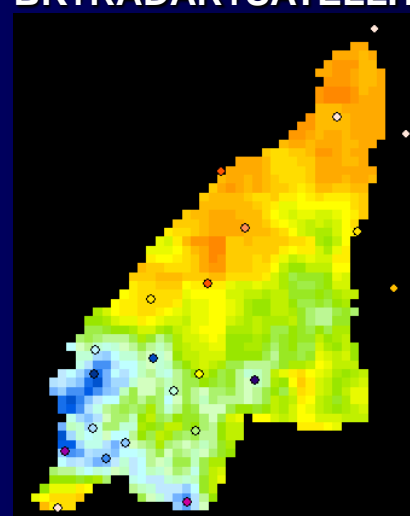
### BK+RADAR



### BK+SATELLITE



### BK+RADAR+SATELLITE



0.0 mm

2.2 mm

4.4 mm

6.5 mm

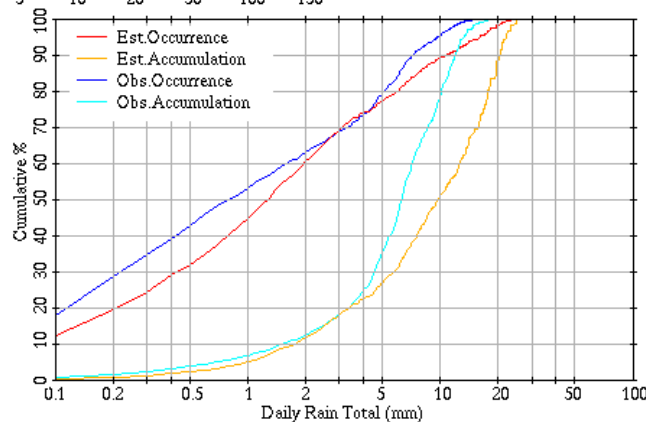
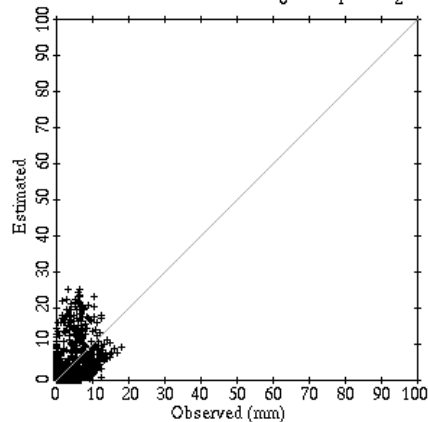
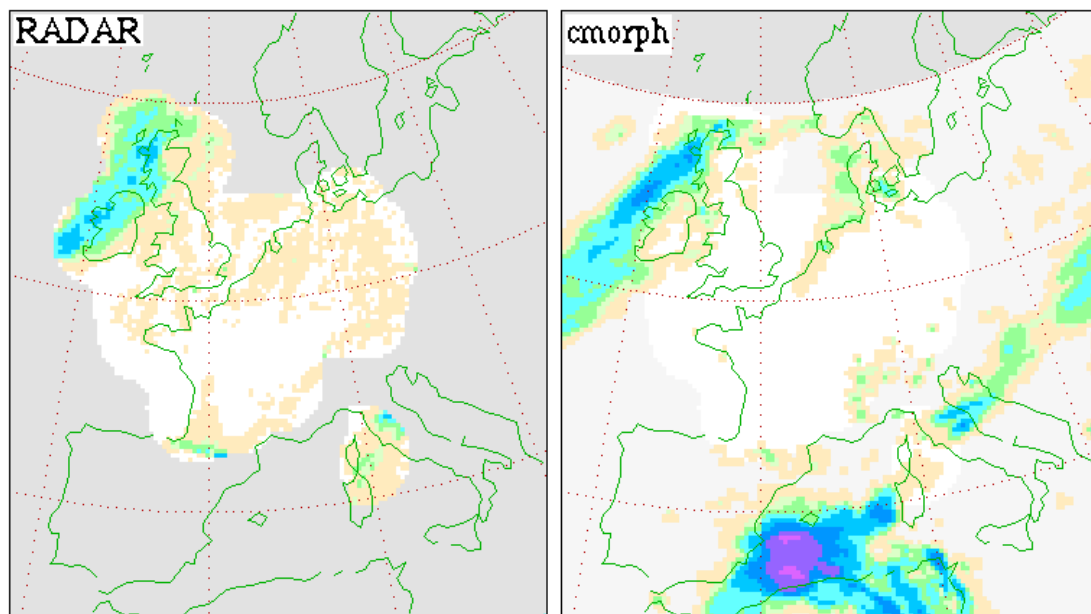


## RESULTS (1000 time-steps)

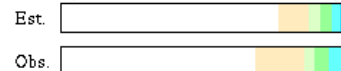
	BIAS	VARIANCE
RADAR	5.0449	19.4154
BLOCK KRIGING	-0.0051	30.5724
BLOCK KRIGING + RADAR (RADAR scale)	-0.0129	14.5419
SATELLITE	999.7988	34475.6368
BK+RADAR AGGREGATED (SATELLITE scale)	-1.1297	27930.3144
BK+RADAR + SATELLITE (SATELLITE scale)	-0.7325	16312.8517
BK+RADAR + SATELLITE (RADAR scale)	-0.0050	13.1567

# IPWG European Product Comparisons

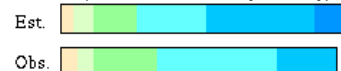
## Validation/intercomparison of precipitation estimates over Europe



Daily fraction by occurrence  
(cumulative occurrence: common data)



Daily fraction of total rain  
(rainfall accumulation by intensity)



Estimated zero rain		Estimated <1mm >=1mm	
Observed zero	1897.	294.	3771.
Observed >=1mm <1mm	1423.	1113.	294.
	POD 0.439		POD 0.603
	FAR 0.209		FAR 0.326
	HSS 0.335		HSS 0.076

	Observed	Estimated
Number of points	4727.	4727.
Raining points	2536.	1407.
Raining points >1mm	738.	662.
Mean rain total	0.85	0.88
Conditional rain total	1.58	2.96
Maximum rain total	17.84	25.15

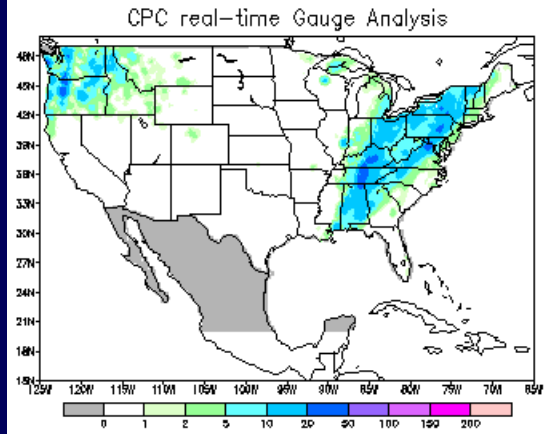
Bias	0.03
Ratio	1.036
RMSE	2.4
Correlation	0.604
#samples	4727.

24h to 24Z  
20121113

C.Kidd'06

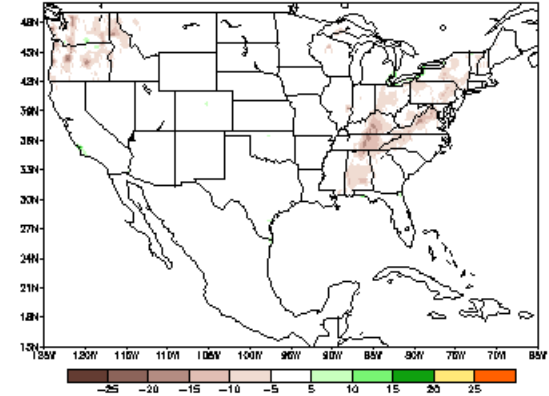
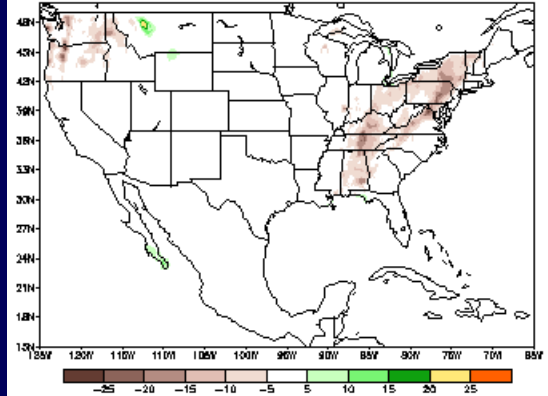
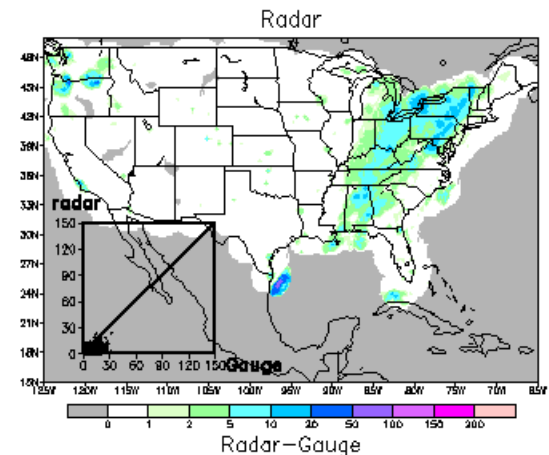
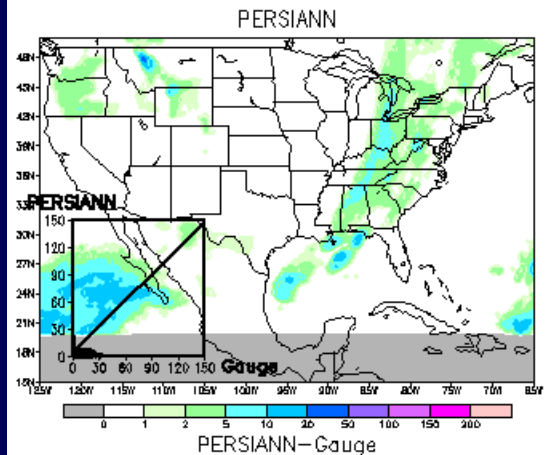
13Z 12Nov2012 thru 12Z 13Nov2012  
 Data on 0.25 deg grid (UNITS are mm/day)

# U.S. Validation



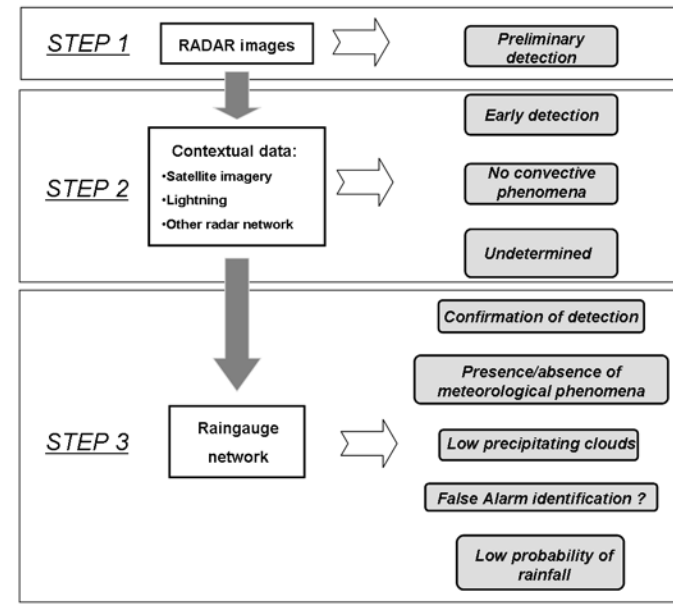
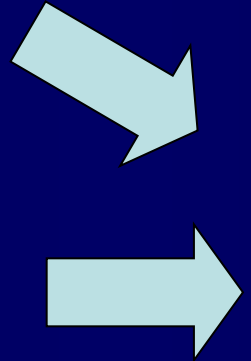
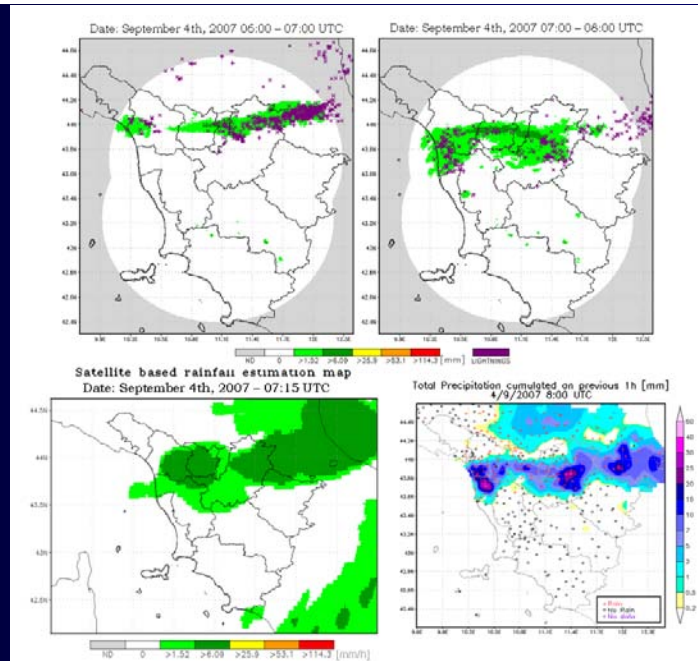
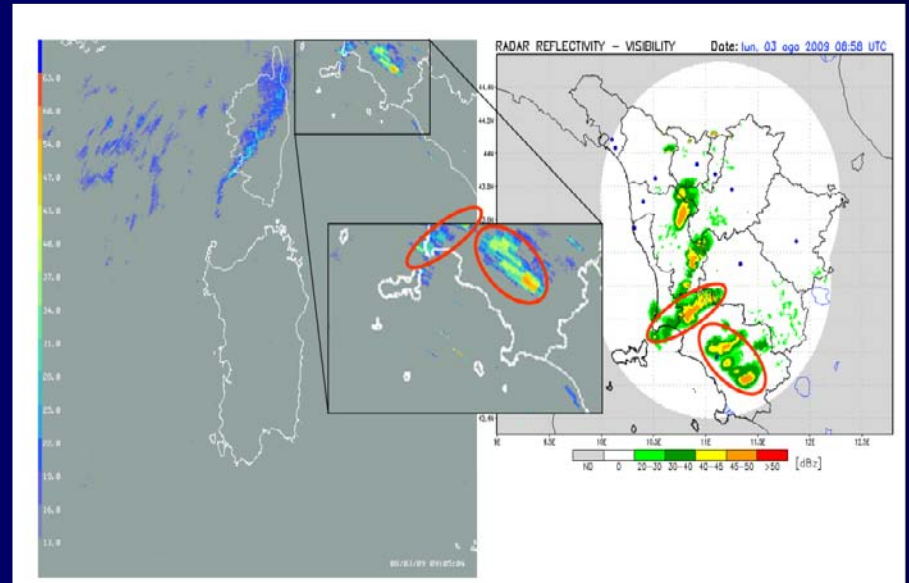
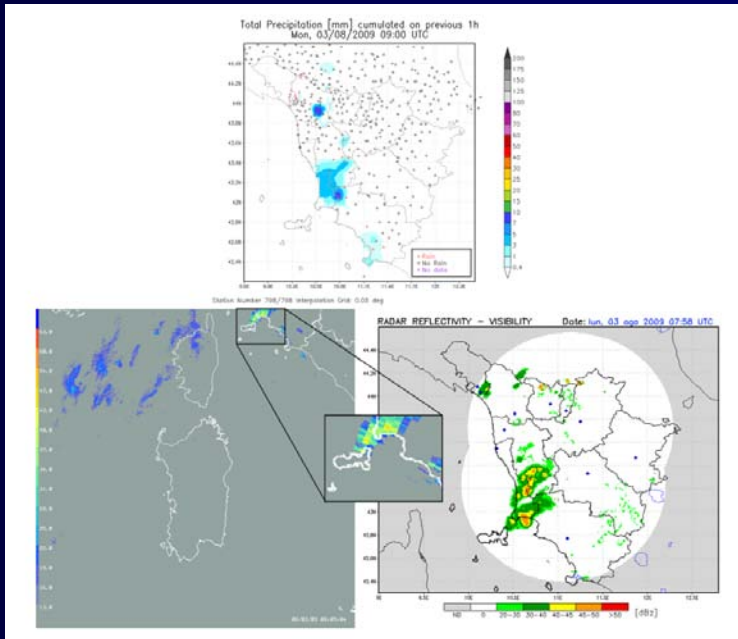
	(G) gauge	(S) PERSIANN	(R) radar
Number of points:	10085.	10085.	10085.
# points w/rain:	3108.	2060.	2331.
Mean rain rate:	2.41	0.58	1.00
Cond. rain rate:	7.71	2.87	4.45
Max. rain rate:	32.16	8.51	24.29
Correlation:	G-S 0.643	G-R 0.800	R-S 0.569
Mean Absolute Error:	1.95	1.55	0.79
RMSE (mm/day):	4.30	3.38	1.96
RMSE (normalized):	1.78	1.40	1.90
Probability of Detection:	0.592	0.678	0.659
False Alarm Ratio:	0.106	0.096	0.252
Bias Ratio (rain:no rain):	0.663	0.750	0.882
Heidke Skill Score:	0.619	0.694	0.618
Hanssen-Kuipers Score:	0.561	0.646	0.593
Equitable Threat Score:	0.448	0.531	0.447

PERSIANN		radar		
< 1	≥ 1	< 1	≥ 1	
gauge	6758.	219.	6753.	224.
gauge	1267.	1841.	1001.	2107.



# CASI STUDI

Antonini et al. (2012)  
JARS



# PROSPETTIVE

.....TOWARDS



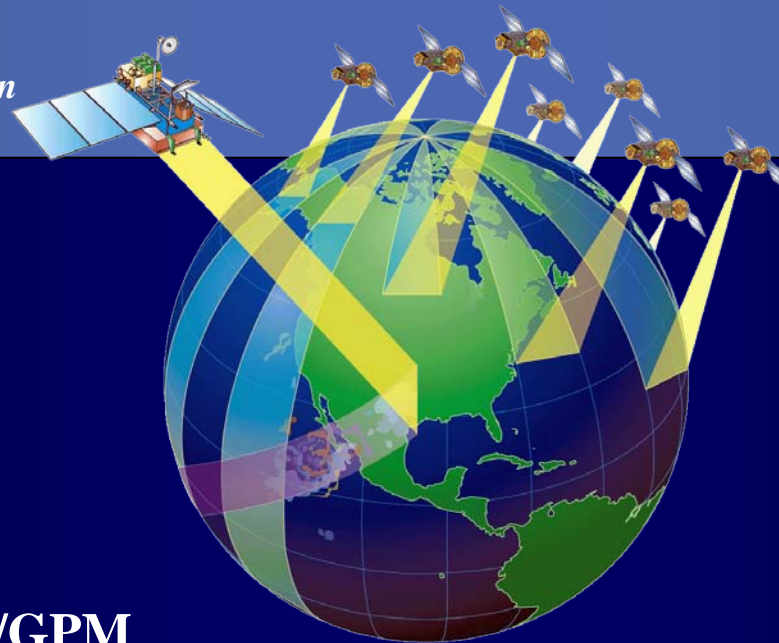
GPM Reference Concept

## OBJECTIVES

- *Understand horizontal & vertical structure of rainfall, its macro- & micro-physical nature, & its associated latent heating*
- *Train & calibrate retrieval algorithms for constellation radiometers*

Core

Constellation



## OBJECTIVES

- *Provide sufficient global sampling to significantly reduce uncertainties in short-term rainfall accumulations*
- *Extend scientific and societal applications*