



# Long-term cloud cover trends over the U.S. from ground-based data and satellite products

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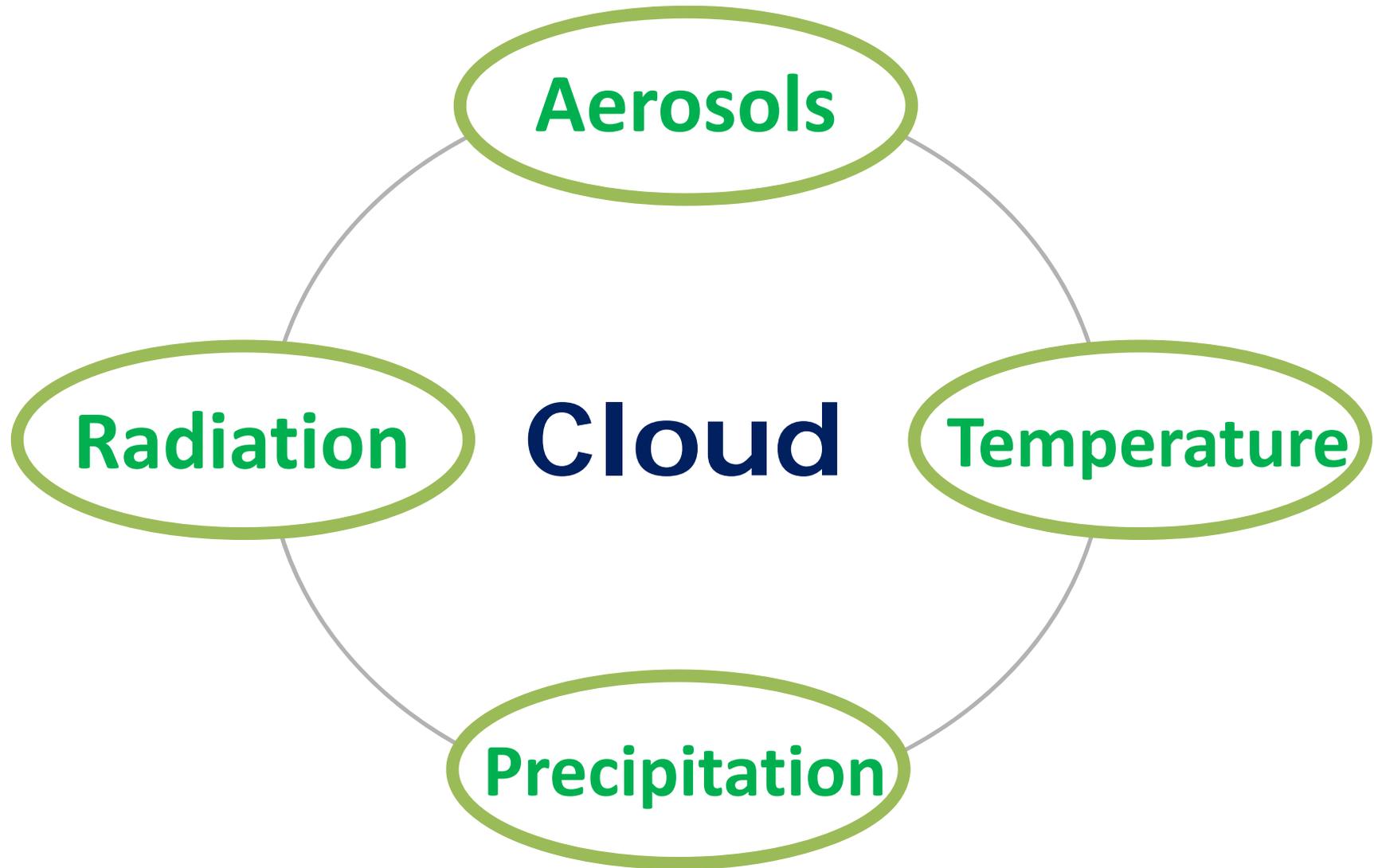
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# Introduction: importance of clouds



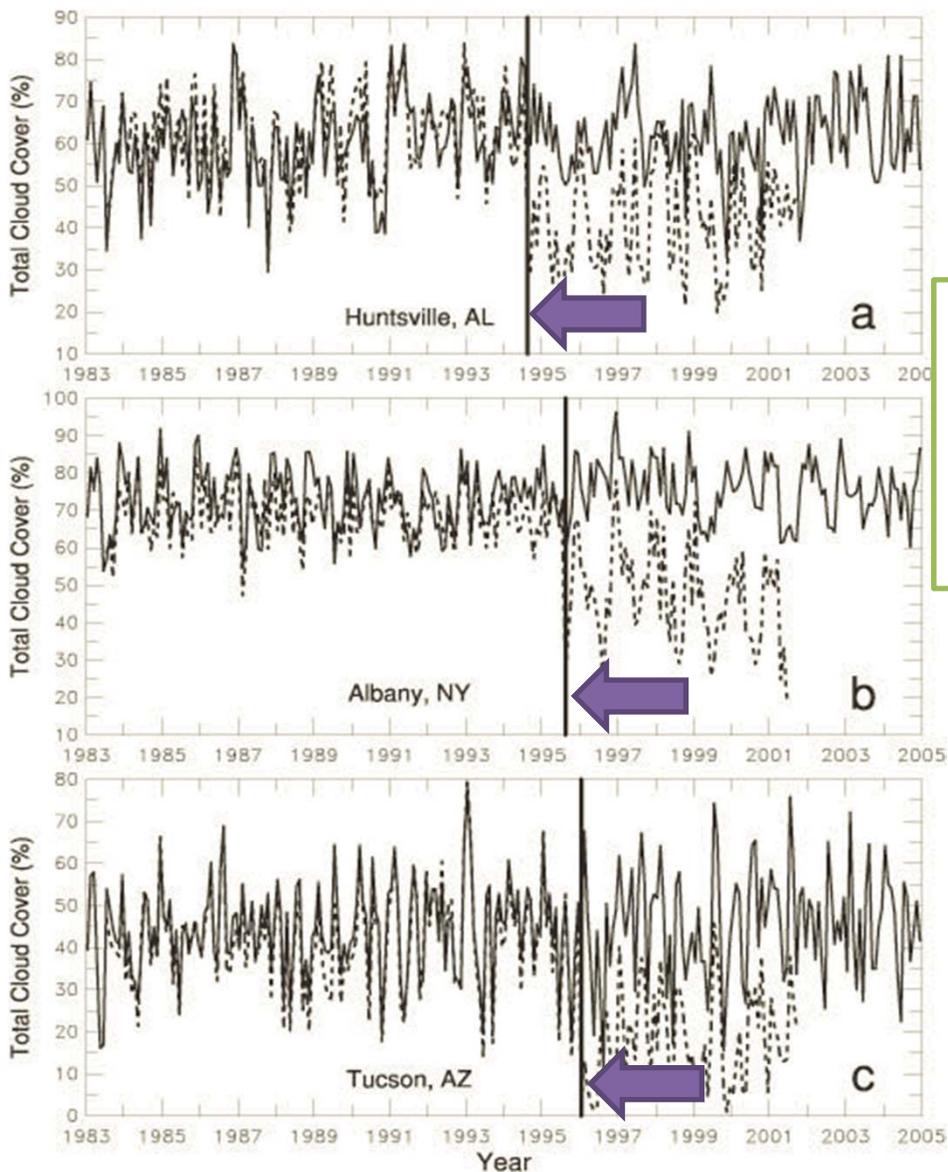


# Introduction: previous studies

Previous work	Time period	Data	Trend
Angell 1990	1950-1988	100 NWS stations	2 %/decade
Plantico et al. 1990	1948-1987	24 NWS stations	3.6 %/decade
Sun 2003	1948-1999	225 stations	0.55 %/decade
Elliott and Angell 1997	1973-1993	100 NWS stations	0.2 %/decade
Dai et al. 2006	1976-2004	124 military sites	1.4 %/decade

- **The surface cloud observations have provided the only historical record for establishing long-term cloud climatology, evaluating satellite cloud observations and model simulations.**
- **To know recent trends in cloudiness, we need to examine homogeneities in surface cloud record after the early 1990s.**

# Introduction: motivation



← Automated Surface Observation Systems (ASOS) introduction

## Problems

1. We can see apparent discontinuities induced by the introduction of ASOS at NWS site.
2. These discontinuities are often not removed in climate dataset.



**We need long-term homogeneity-adjusted surface climate records (visual cloud observation) to assess satellite products and model simulations.**



# Data: data production procedure

1. DSI-3280 for NWS stations (54) before 2005 and Integrated Surface Data after 2005. The ISD data is adjusted to match the rest of the dataset.
2. The changed METAR reporting system (July 1996) is applied to DATSAV3 for military stations (101) starting with 1949.
3. Use observations made every 3 hours in daytime to create monthly means. Removed data that was clearly from ASOS, not human observations.
4. Examine time series in comparison with precipitation days and diurnal temperature range (DTR) to determine accept or reject the adjustments.

	Trends 1976-2004
Dai et al. 2006 (military)	1.4 %/decade*
Unadjusted ISD data (mil+NWS)	1.5 %/decade*
Final adjusted data	<b>0.05 %/decade</b>

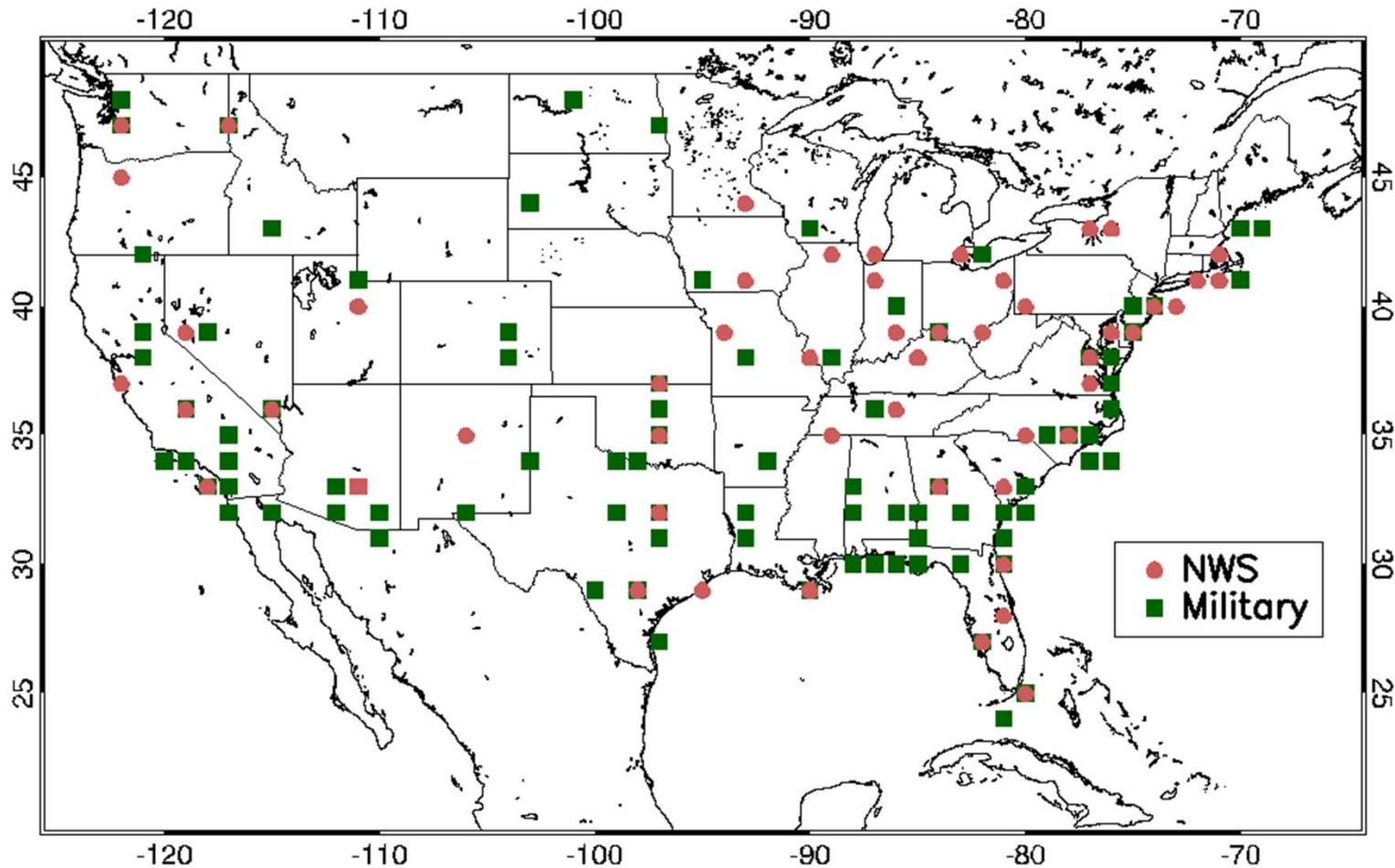


Adjusted data has **lower** trends.



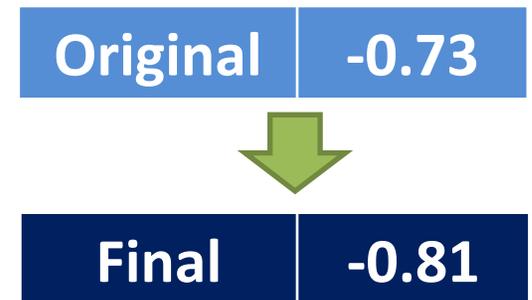
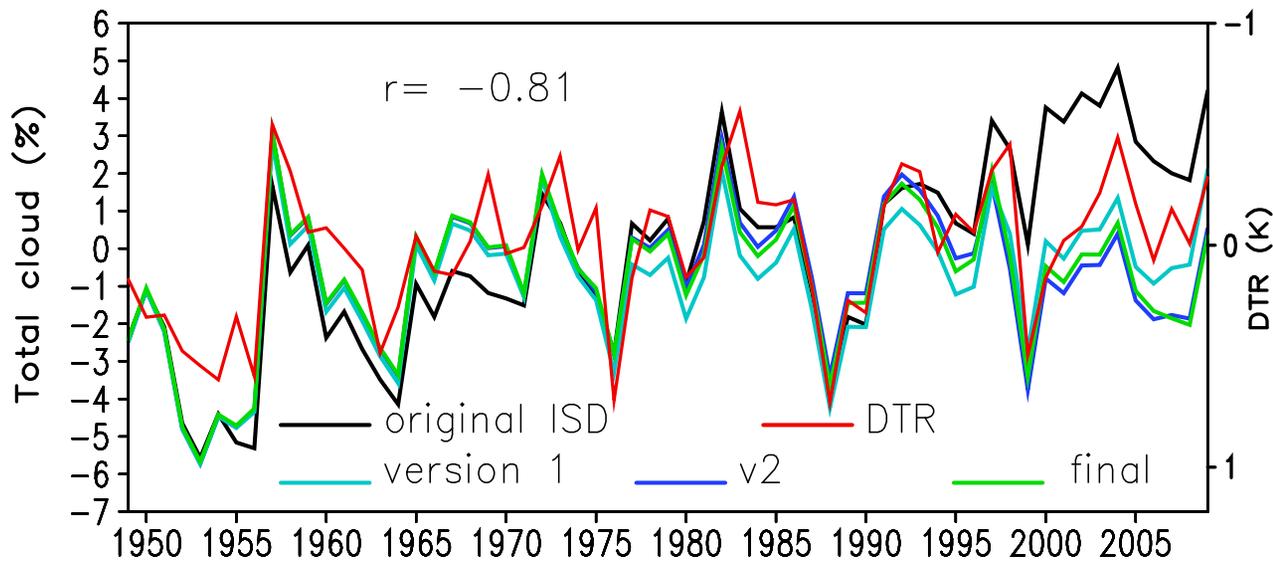
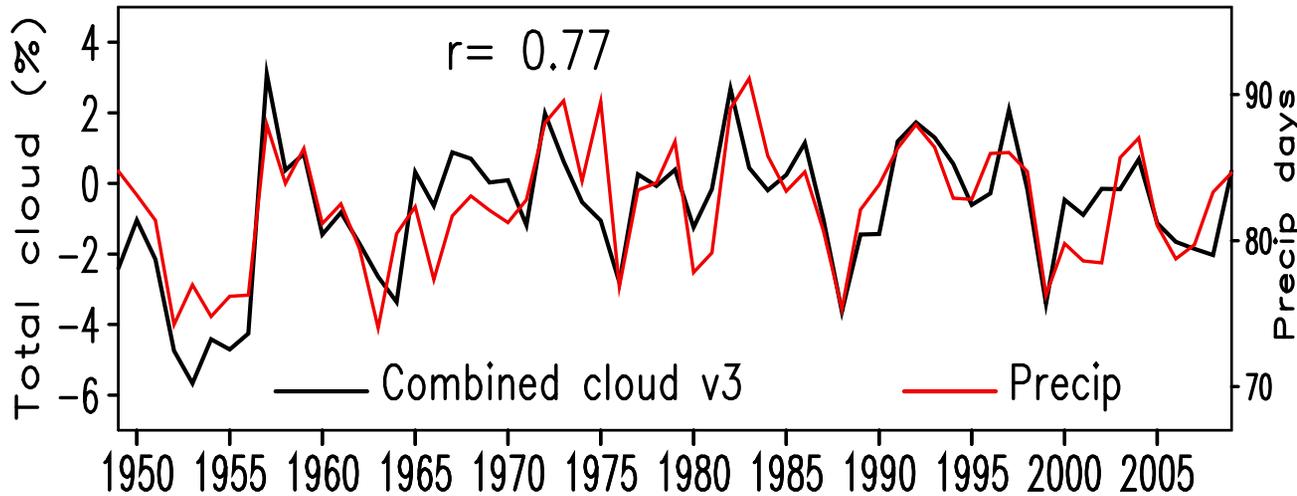
# Data: data location

**NWS stations: 54 & Military stations: 101 = 155 sites**





# Data: station data improvement





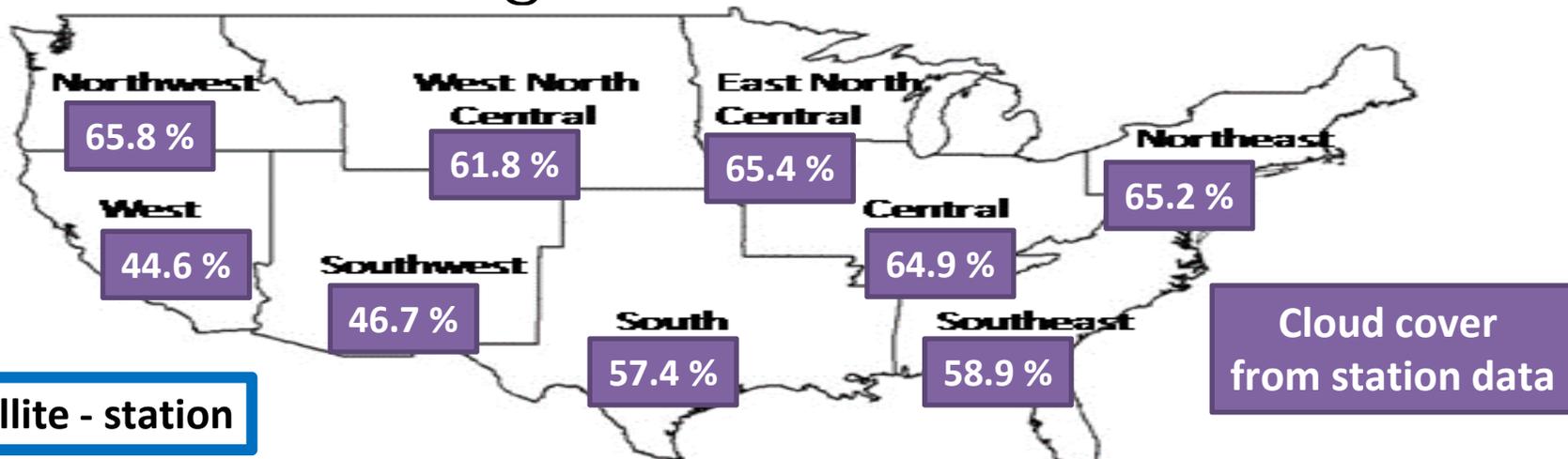
# Data: used satellite dataset

	ISCCP	PATMOS-x	PATMOS-x DCD	CLARA-A1
Time period	1984-2007	1982-2009	1982-2012	1982-2009
Observation time	9 AM, 3 PM	7:30AM, 1:30PM		Day and night
Resolution	2.5 ° x 2.5 °	1.0 ° x 1.0 °	1.0 ° x 1.0 °	0.25 ° x 0.25 °

- ❖ **ISCCP: International Satellite Cloud Climatology Project**
- ❖ **PATMOS-x: AVHRR Pathfinder Atmospheres Extended**
- ❖ **PATMOS DCD: AVHRR Pathfinder Atmospheres Extended diurnally corrected daily**
- ❖ **CLARA-A1: CM SAF Cloud Albedo and Radiation**



# Result: regional mean cloud cover

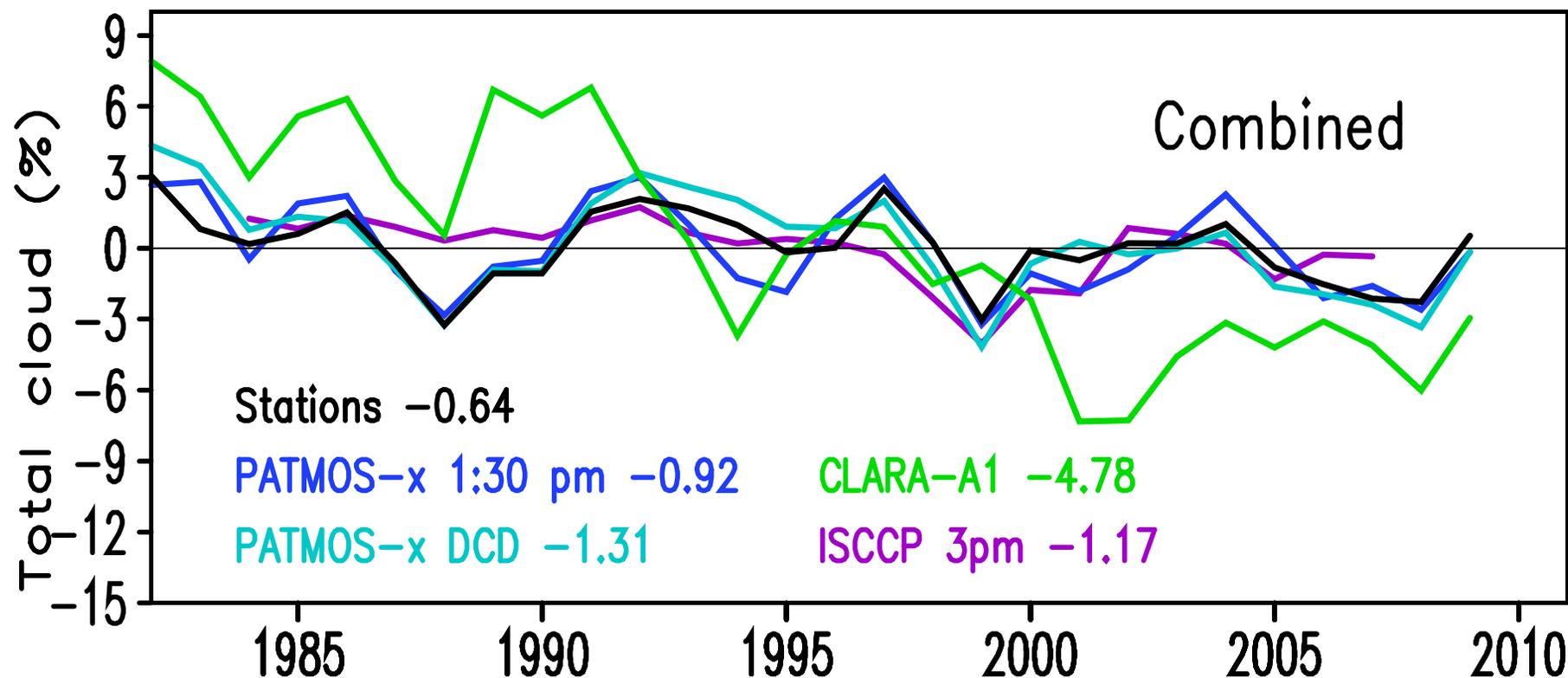


## Satellite - station

Region	ISCCP 3pm	PATMOS 1:30 pm	PATMOS DCD	CLARA day
Central (15)	4.7	-5.3	-6.7	-2.0
E.N. Central (6)	5.5	-4.1	-3.7	0.3
Northeast (19)	7.2	-3.9	-4.7	-2.3
Northwest (9)	9.4	-7.7	-4.5	-2.8
South (28)	4.5	-3.7	-8.1	-1.6
Southeast (43)	6.0	-1.3	-6.4	-3.9
Southwest (12)	14.3	-6.6	-2.1	12.6
West (19)	16.3	-9.6	-2.1	5.0
W.N. Central (4)	9.8	-7.4	-3.2	-0.6



# Result: cloud cover trends

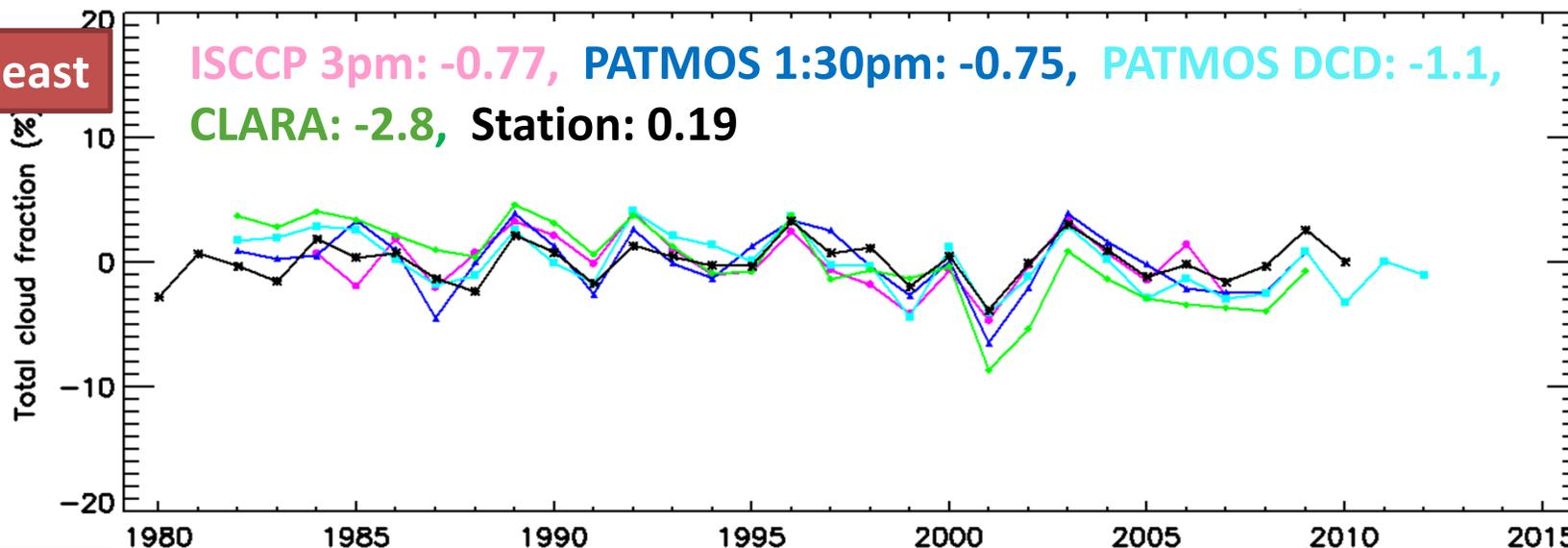


Annual mean U.S cloud cover anomalies from satellite data collocated with U.S weather stations trends are for 1982-2009, except for ISCCP which is for 1984-2007.

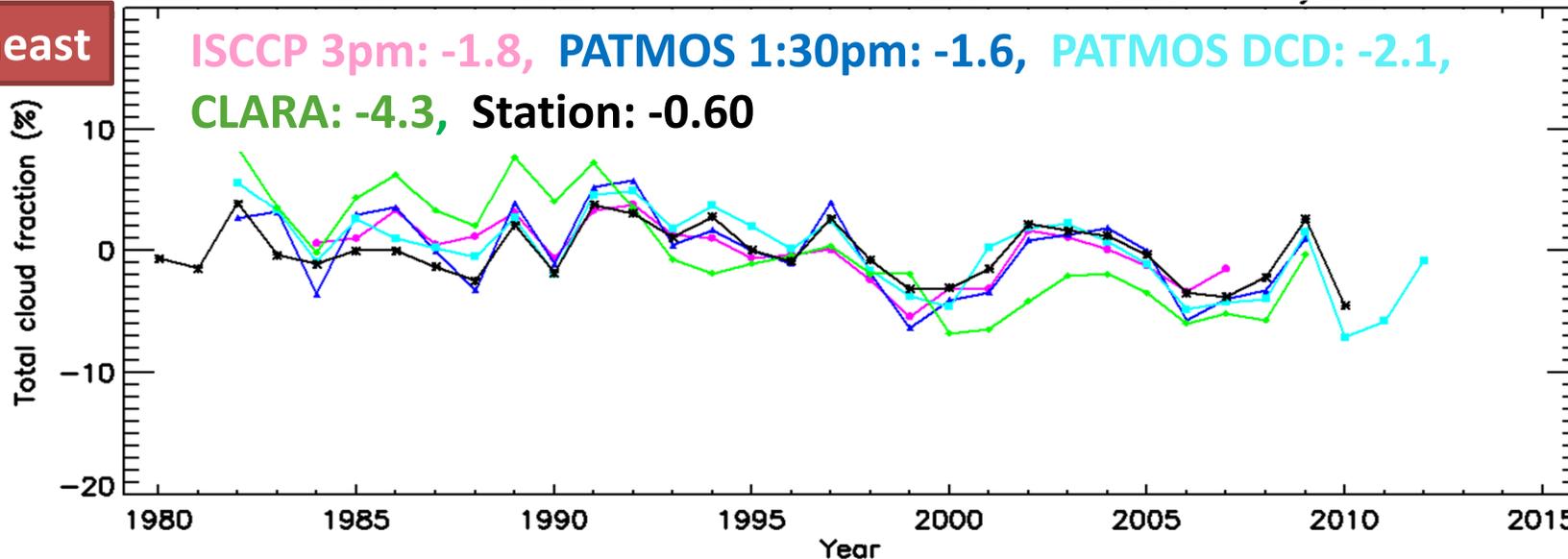


# Result: cloud cover trends for eastern

**Northeast**



**Southeast**

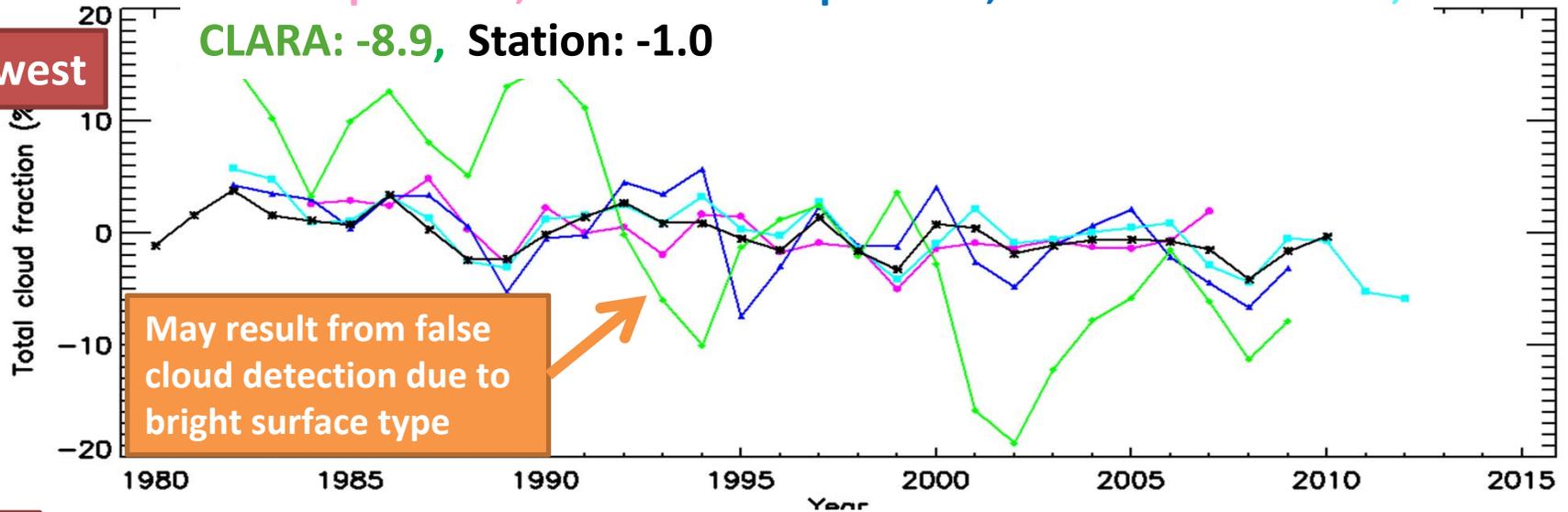




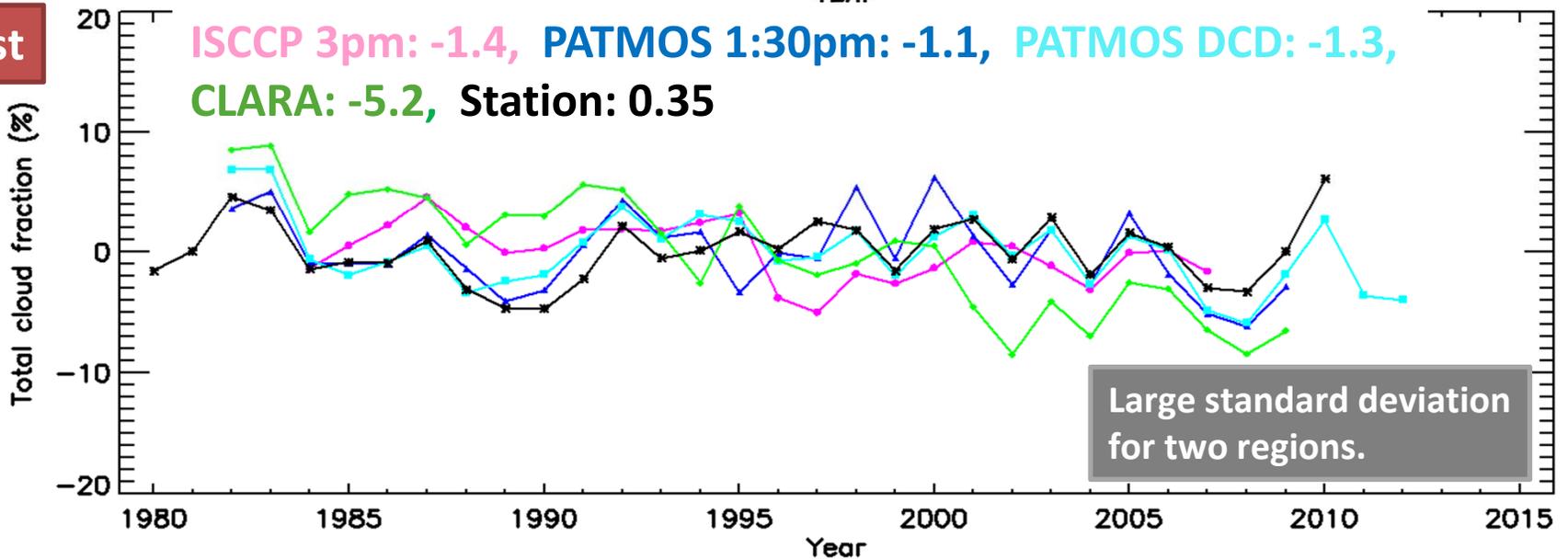
# Result: cloud cover trends for western

ISCCP 3pm: -1.5, PATMOS 1:30pm: -2.2, PATMOS DCD: -1.9,  
CLARA: -8.9, Station: -1.0

Southwest



West



Air



# Result: trends for 1984-2007 (%/dec)

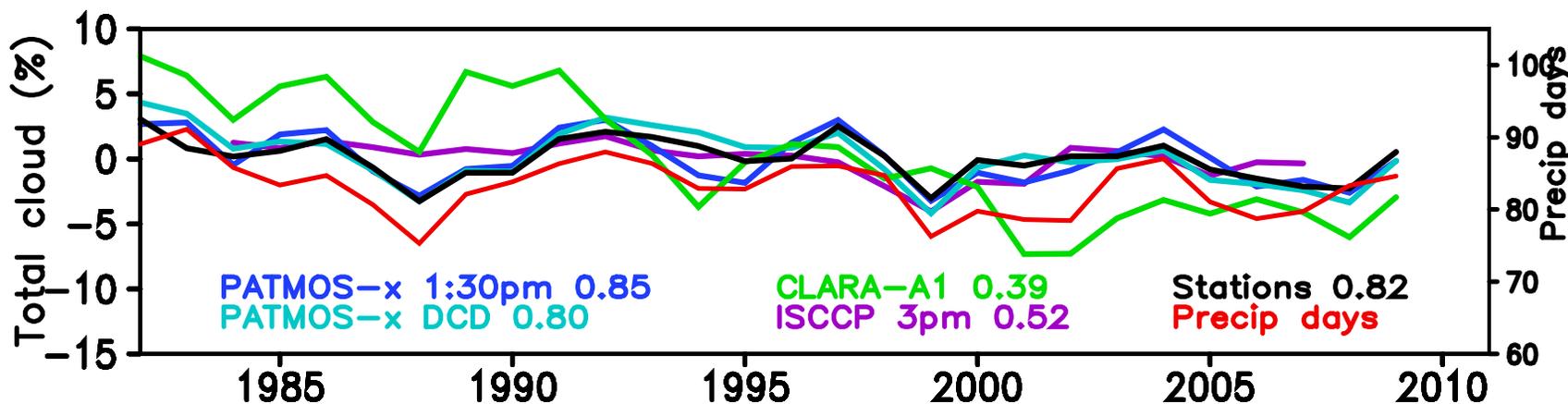
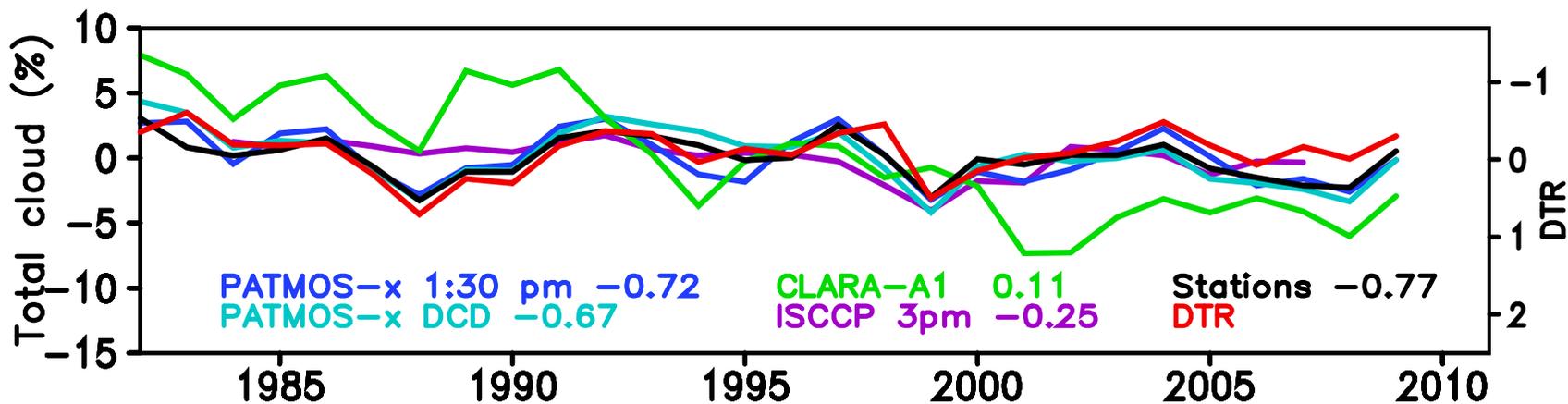
Products	JJA	SON	All months
NWS+Military	0.49	-1.66	-0.40
ISCCP 3 pm	-1.63	-1.56	-0.98
PATMOS 1:30 pm	-0.86	-1.52	-0.55
PATMOS DCD	-0.53	-2.16	-0.82
CLARA-A1 day	-6.83	-4.35	-4.98

JJA: June July August, SON: September October November

- ✓ The station data has the strong negative trend in fall and slight positive trend in summer.
- ✓ Overall, PATMOS-x products are the closest to the station data.



# Result: correlations with DTR & preci.



- ❖ DTR: Diurnal Temperature Range from Historical Climatology Network (HCN) at NCDC. For military stations, we used gridded adjusted HCN data.
- ❖ Precipitation data: NWS cooperative weather stations (COOP) (Groisman et al. 2004) kindly provided by Pasha Groisman of NCDC.



# Summary

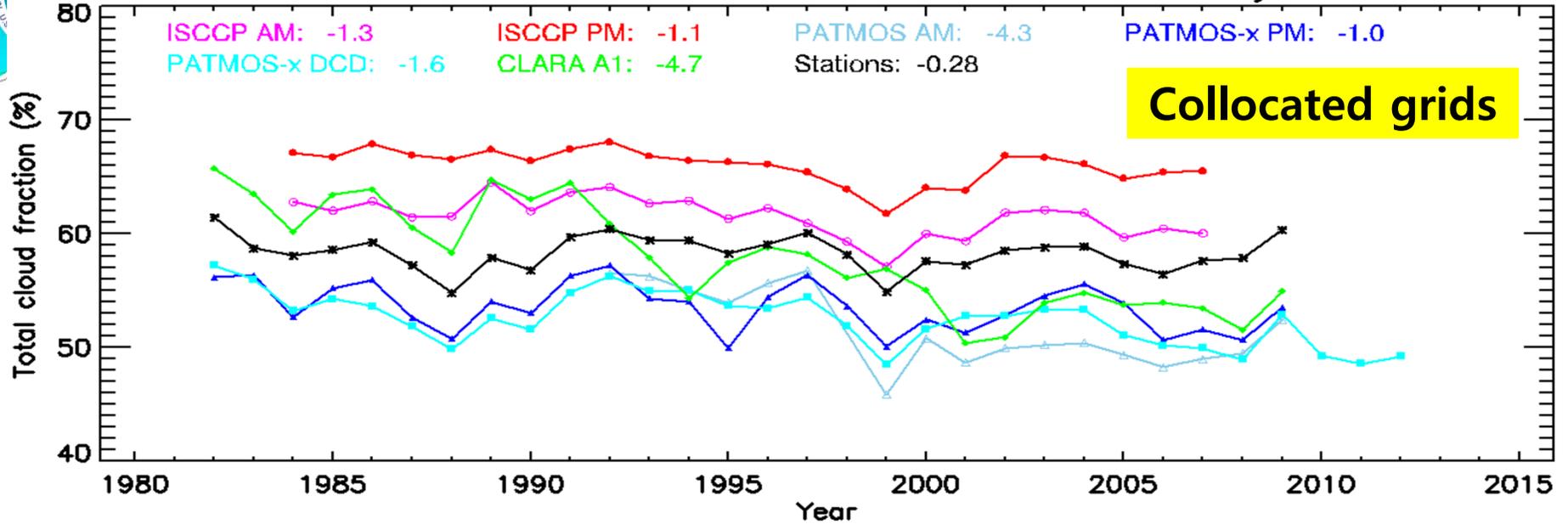
- Homogeneity-adjusted weather observations **reduce trends** in US total cloud cover **than those in original** dataset and **increases the agreement** between the cloud cover time series and those of physically related climate variables such as DTR and precipitation days.
- Trends for 1984-2007 are all **negative** in both adjusted-station and satellite products but satellite products are **more negative** than those from station data.
- Overall we find **good agreement** between inter-annual variability in most of the satellite data and that in our station data, with **PATMOS -x products showing the best match** and **less well with ISCCP**.

1. Time-varying biases in U.S. total cloud cover data (2013), *Journal of Atmospheric and Oceanic Technology*, 30, 2838-2849.
2. Trends in U.S. Total Cloud Cover from a Homogeneity-Adjusted Dataset (2014), *J. Climate*, 27, 4959–4969.
3. Observed variability and trends in U.S. cloud cover: ISCCP, PATMOS-x, and CLARA-A1 compared to homogeneity-adjusted weather observations, submitted to *Journal of Climate*.



# Back up slides

Cloud fraction from collocated satellites and NWS & Military stations



Cloud fraction from US all grid satellites and NWS & Military stations

