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# Climate Change and the Time Series and Distributional Properties of Weather Factors Influencing California Viticulture

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## Weather Contracts

### What are Weather Contracts?

- Weather contracts are financial contracts such as options and futures with payoffs based on the observation of a weather variable at a government weather station. Weather contracts are useful in hedging the cost of weather related risks not typically covered by weather insurance.

### How Do They Differ From Weather Insurance?

- Weather insurance is typically designed to cover major catastrophic weather events such as hail damage. Weather insurance involves filing a claim and providing proof of damage in order to be compensated.

### History of Weather Contracts

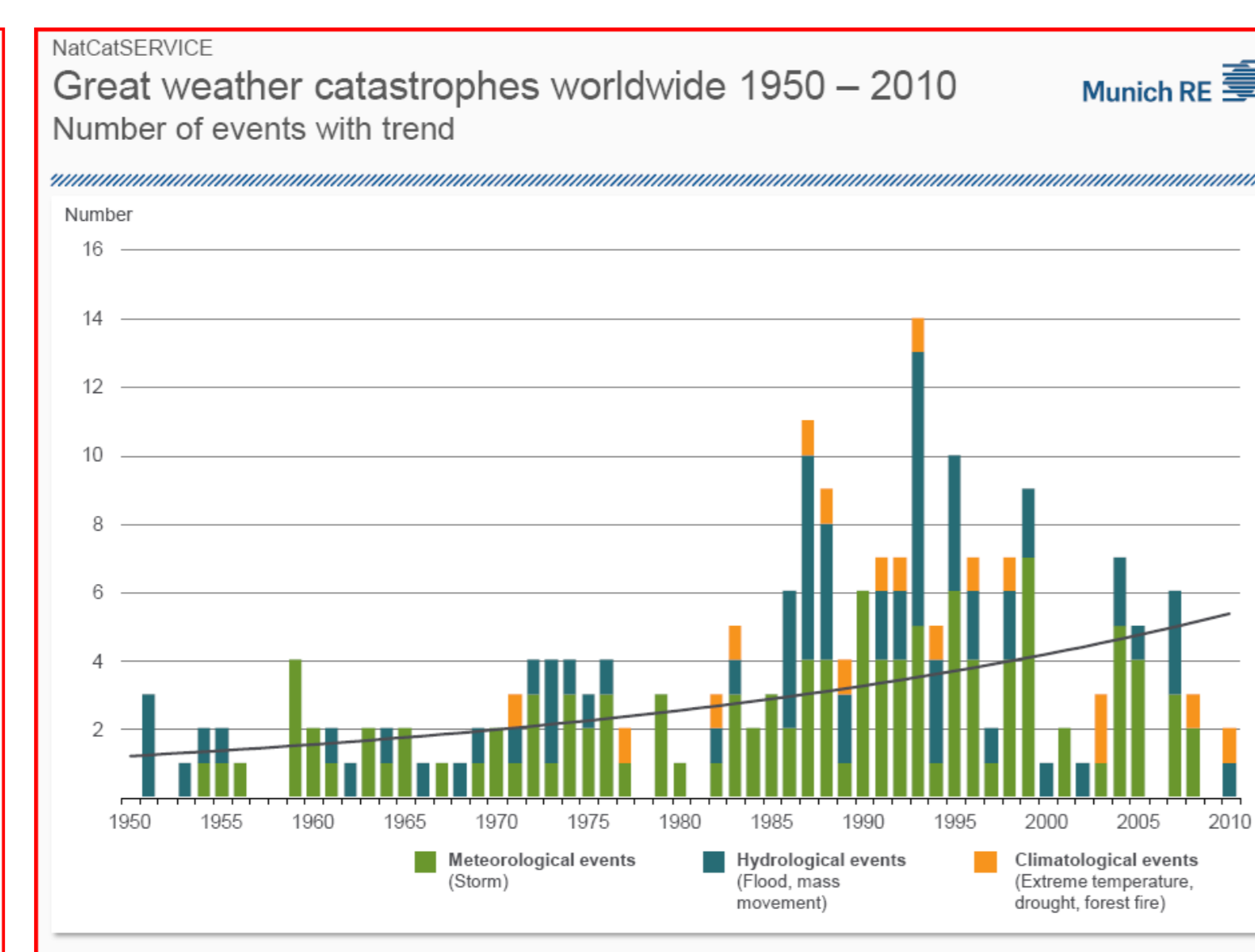
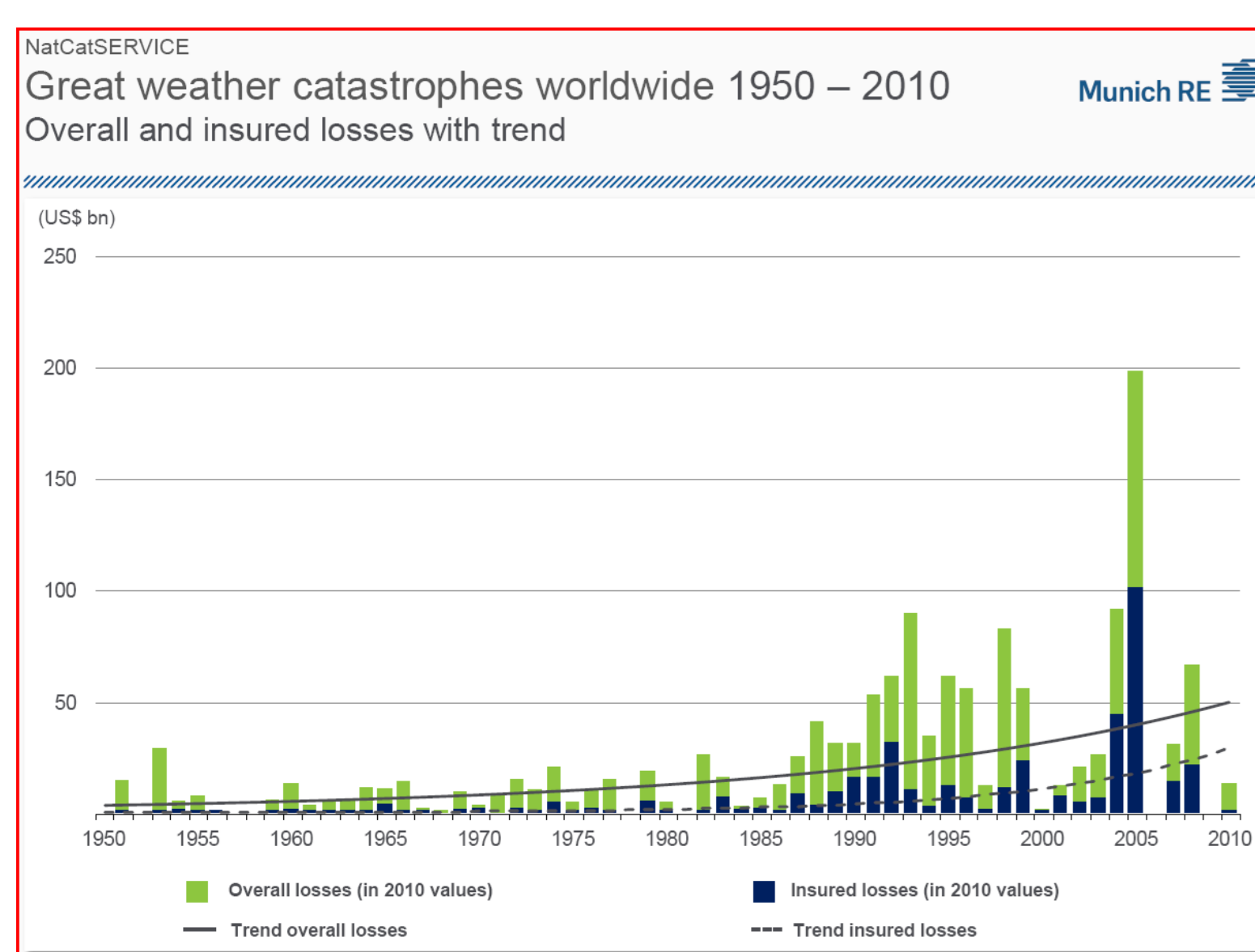
- 1996:** First weather contract based on temperature written between Enron Corporation and Koch Power and Light.
- 1998:** Exceptionally warm winter weather sparks interest in weather contracts on the part of the energy industry.
- 1999:** Chicago Mercantile Exchange starts trading standardized weather contracts on a few major US cities.
- 1999 – Weather Risk Management Association Established
- 2003 – Current:** Over the Counter (OTC) market grows as financial intermediaries realize the potential size of the weather contract market and its usefulness to many firms and sectors.
- 2006:** United Nations World Food Program purchases a US\$ 900,000 contract to hedge against low rainfall in Ethiopia over the growing season that would ultimately lead to famine and the need for intervention.
- 2007:** The Climate Corporation (formerly Weatherbill) an innovative online supplier of OTC market weather contract.
- 2010:** CME starts trading rainfall contracts on nine US cities.

**Over the Counter (OTC) Weather Contracts:** Can be designed for very specific weather variables and locations.

### Issues Remaining In the Use of OTC Weather Contracts

- What is the appropriate pricing model for a weather contract?
- What is the optimal design of a weather contract for a specialized use such as viticulture?
- What is the appropriate distributional assumptions for weather variable modelling?

## Climate Change – Increasing Volatility of Weather



## Viticulture – myriad of weather risks

**The viticulture industry faces a variety of weather related risks which weather contracts could be used to hedge:**

Some Weather Related Risk Factors			
Excessive Cold –Winter Damage	-Frost -Heavy Rain	-Excessive Heat Or Cool Rainy Conditions	-Heavy Rain -Early Frost
November – March	April-May	June - August	Sept - Oct

**Research Question – Has Climate Change Impacted the Stochastic Properties of Important Weather Related Measures (Growing Degree Days) for California Viticulture**

## DATA

### Growing Degree Days: April to September 1960 – 2010

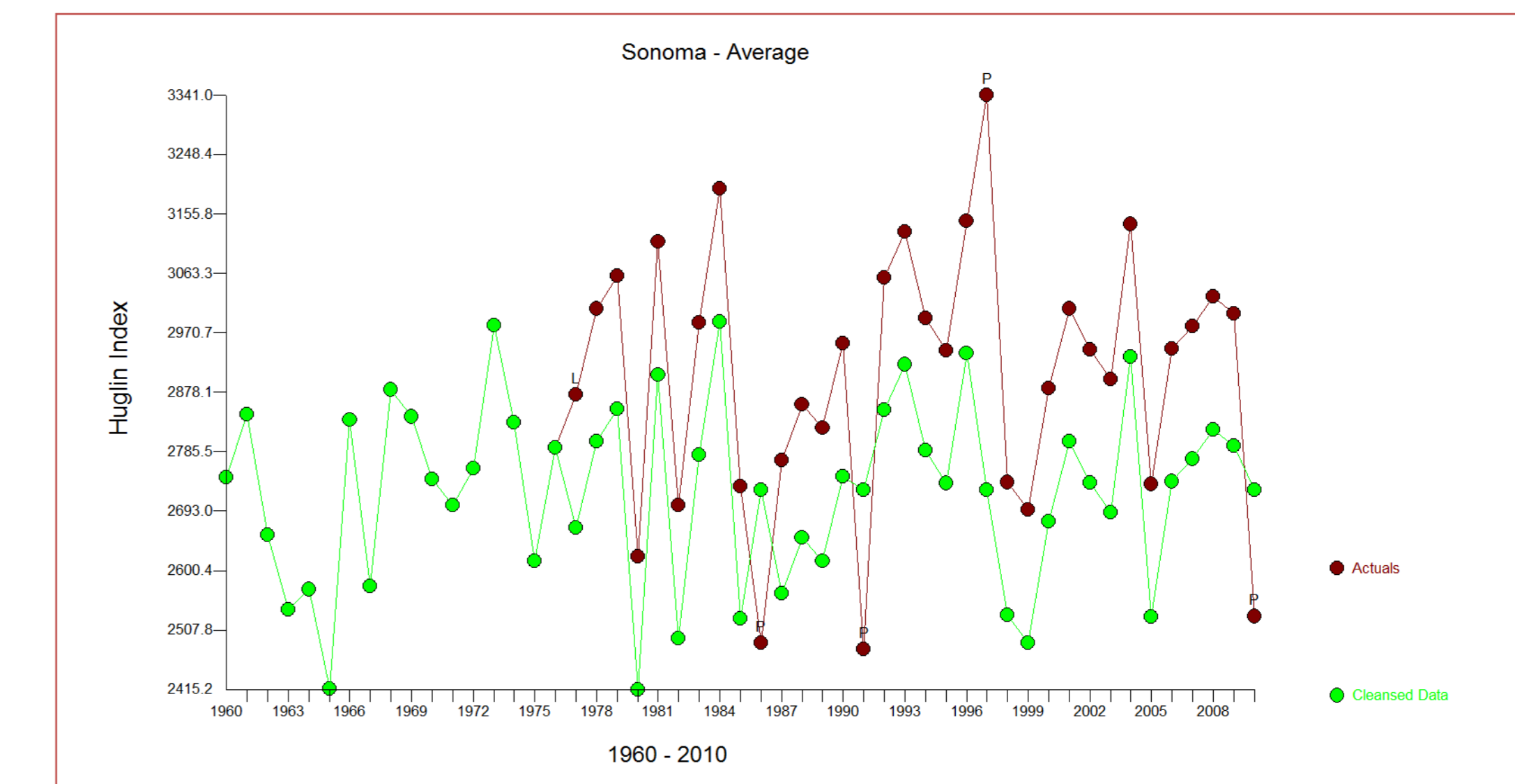
#### DISTRICTS

- Santa Barbara (5 weather stations)
- Napa (2 stations)
- Sonoma (5 stations)

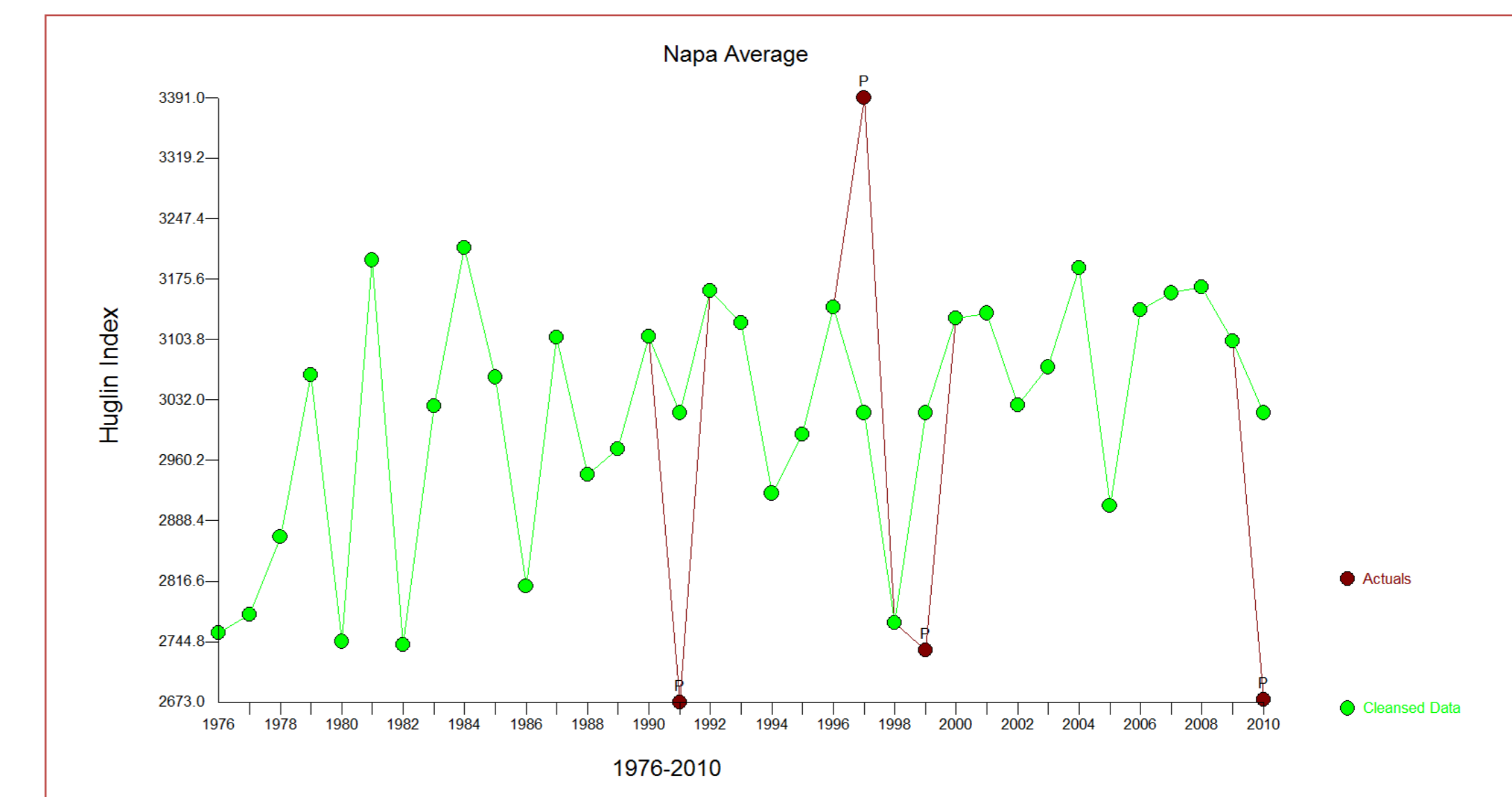
**Time Series Analysis with outlier (pulse and Level shift) detection analysis**



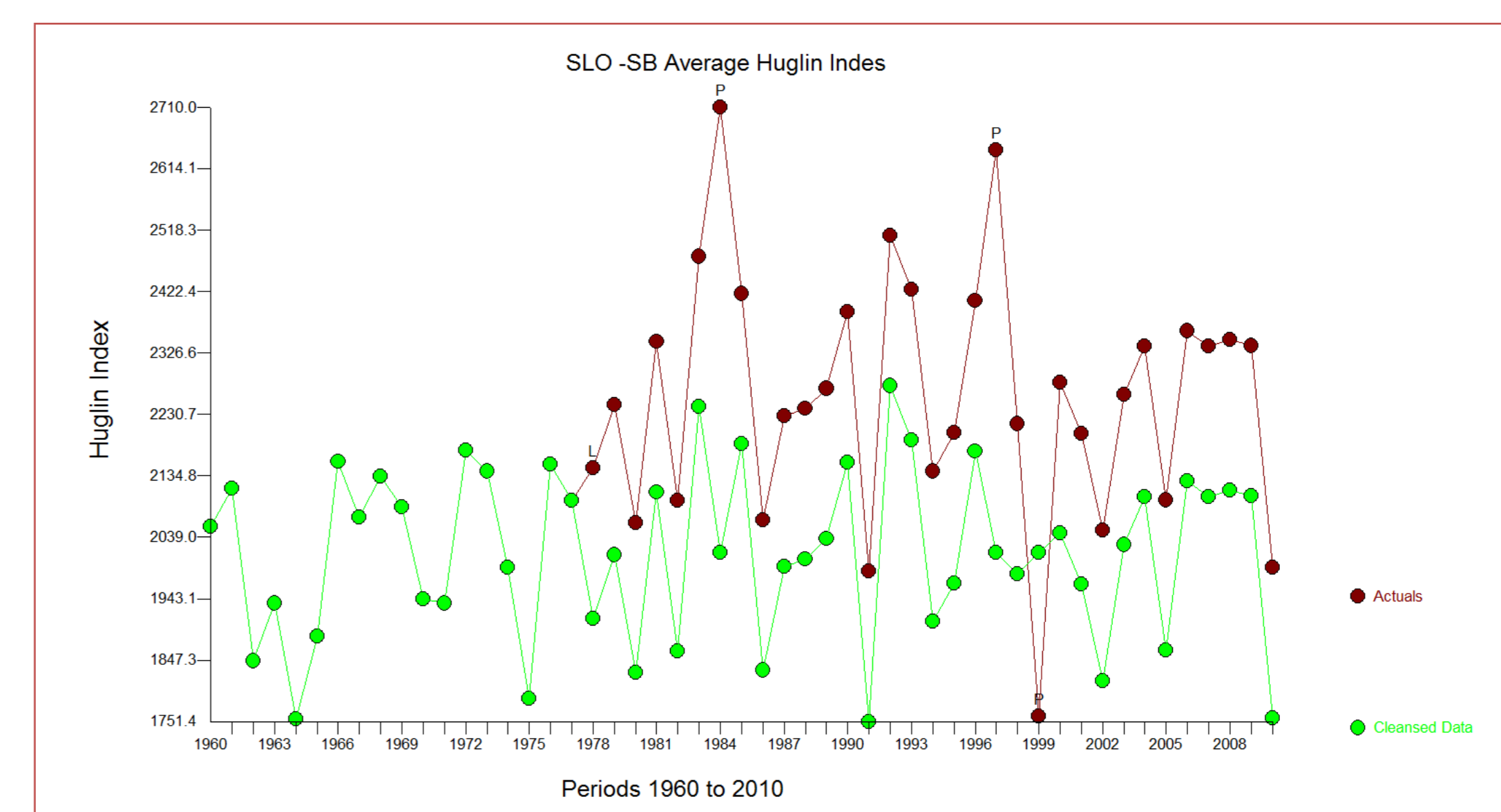
## Sonoma



## Napa



## Santa Barbara



## RESULTS

Notable changes in stochastic process of growing degree days:

- Statistically significant level shift (Sonoma, Santa Barbara)
- Significant increase in volatility and time series pulse outlier from late 1980's to early 1990's onward.

Modelling of weather variables for pricing of weather contracts may best be captured with a mixed jump diffusion process due to increase in extreme, seasonally based, weather events.