The Profitable Model Failure: Using Forecasts to Settle Temperature Derivative Contracts

Brian J. Billings

Doane University, Lincoln, NE

July 15, 2020

Acknowledgments:

- Stephen Jewson, Risk Management Solutions (Ret.)
- David Whitehead, Speedwell Weather
- Shunondo Basu, BlackRock
- Bradley Hoggatt, MSI GuaranteedWeather

Weather Risk Management

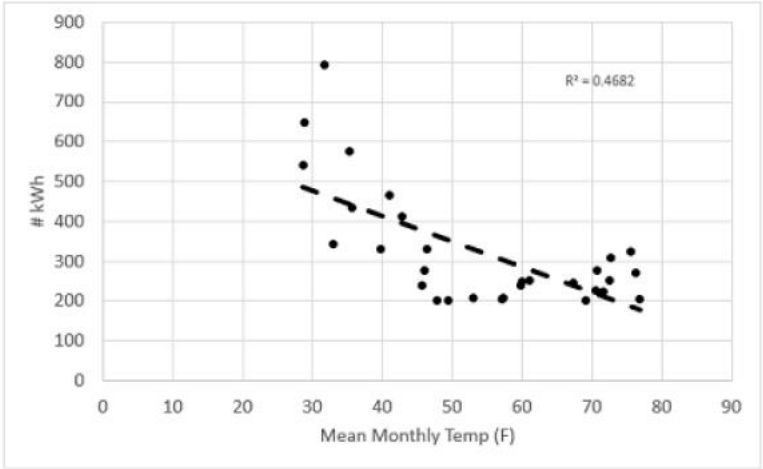
1. Weather affects profits
2. Volatile profits are bad

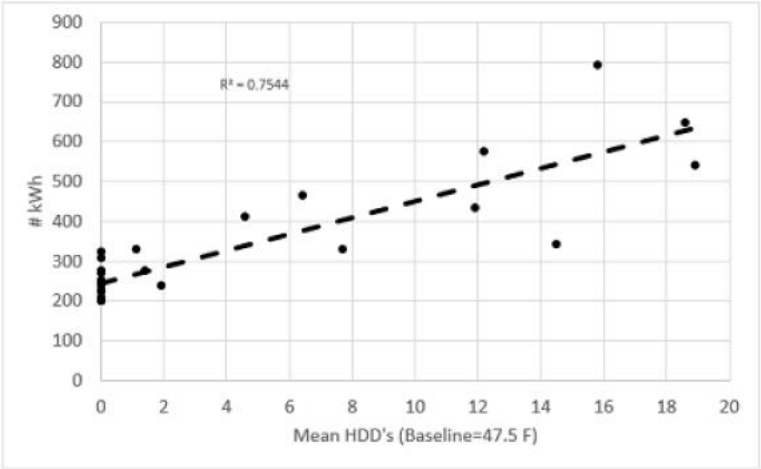
$\therefore$ Businesses must hedge against weather risk

- Insurance policies cover high-impact, low-probability events
- Derivative contracts cover lower-impact, high-probability events

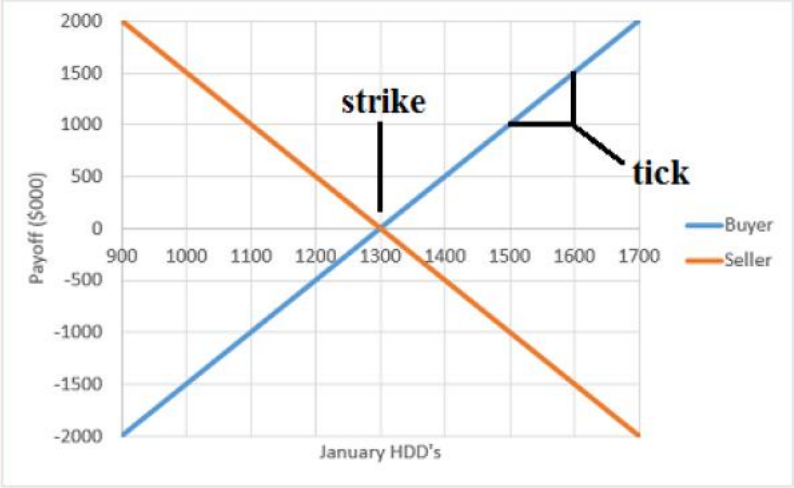
Weather Derivatives

- index - number summarizing a weather variable
  - ex: cumulative heating, cooling, and growing degree days





- payoff function - converts index into amount payed or collected



- Swap contracts hedge for warm winters using profit from colder
- Addresses amount of demand, but not energy prices

Energy Spreads and Markets

- _____ spread = electricity price - cost of providing using _____

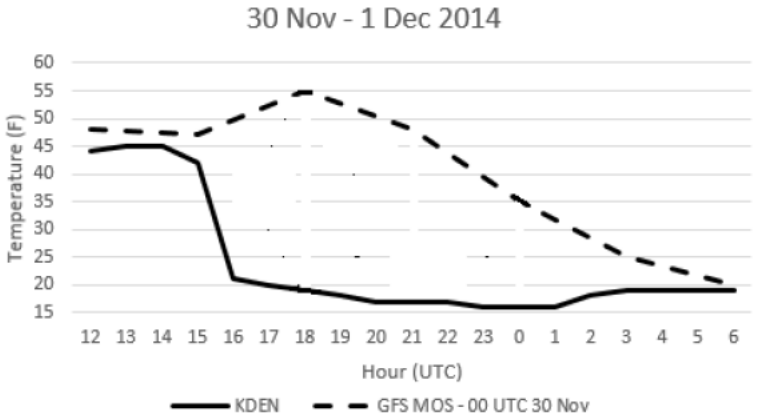
- spark; 
- dark; 
- crack; 
- quark; 

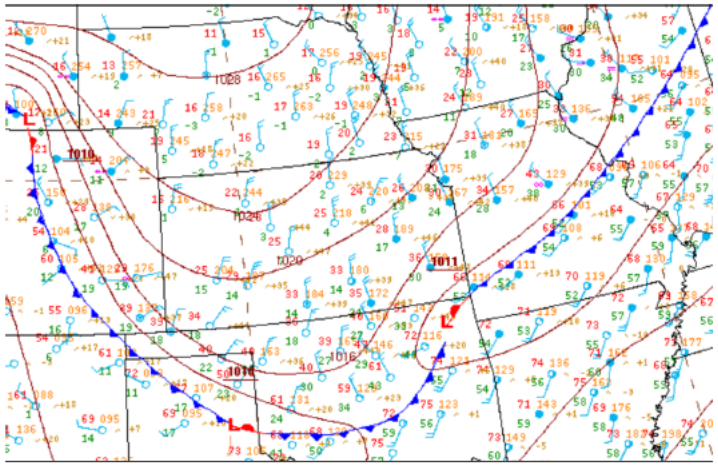
- Energy can also be purchased or sold on the open market
  1. Spot Market
     - for immediate delivery
     - price influenced by observed weather (among other factors)
  2. Day-Ahead Market
     - slightly higher for low demand; much lower for high
     - price influenced by Day 1 forecast (among other factors)

- Issue: Weather derivatives contract will not meet businesses needs IF Day 1 forecasts differ significantly from observations

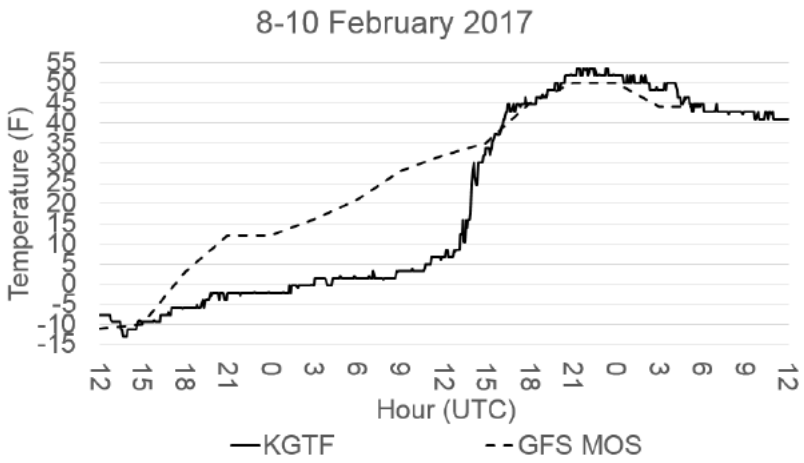
Billings (2018) - 18th Mountain Meteorology Conf.

- Day 1 errors: 2014 November in Denver/Colorado Springs, CO
- Late Cold Surge

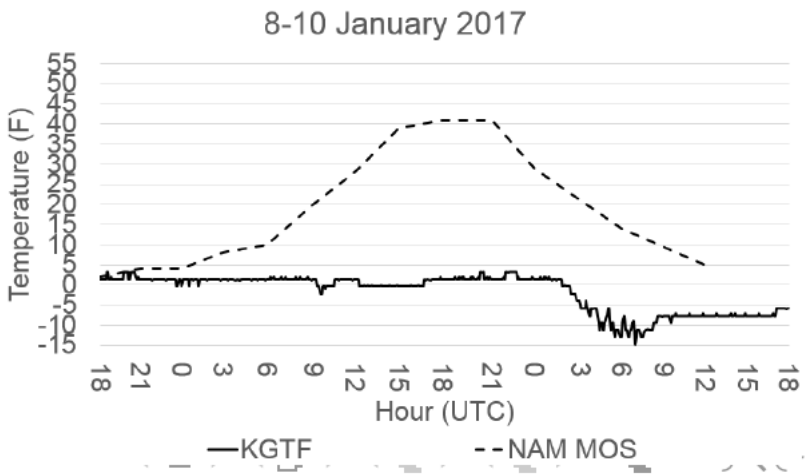




- Day 1 errors: 2016/17 winter in Great Falls/Billings, MT
- Onset Broadening

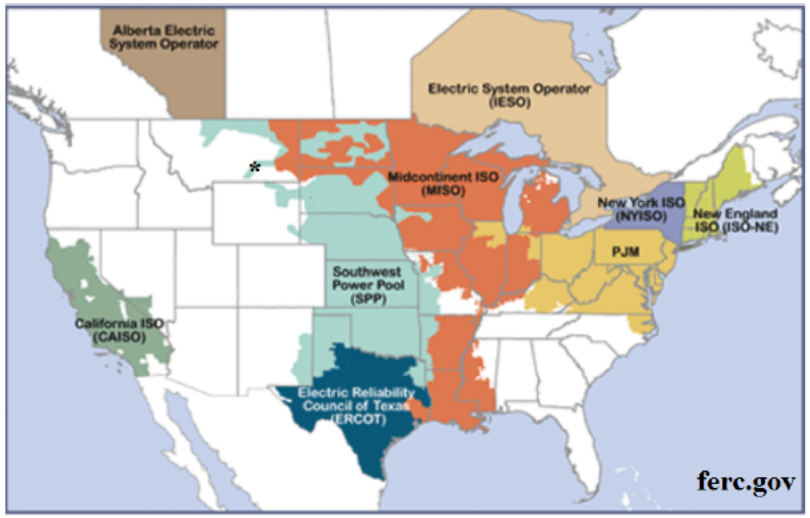


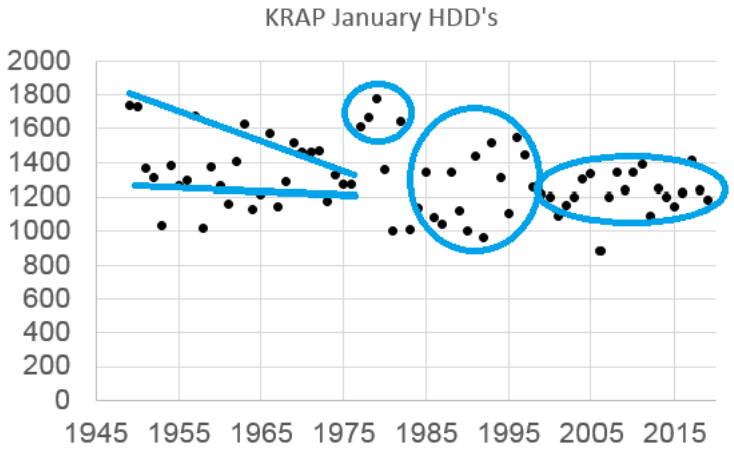
- Phantom Chinook



Available Archived Data

- Independent System Operators - manage transmission regions





- Rapid City, SD requires cleaning of January data
- Billings, MT joined Southwest Power Pool ISO in 2015

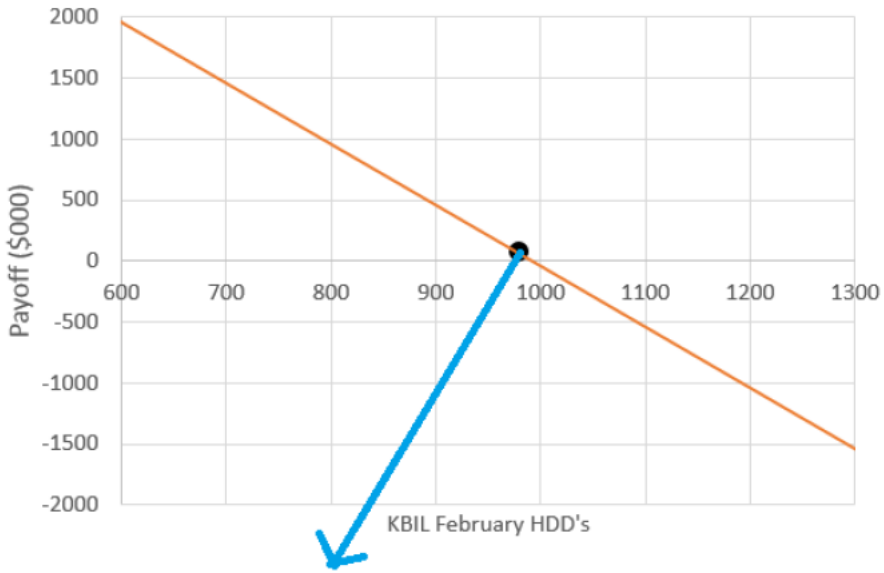
- Data taken from `http://climod.unl.edu`

- Regression ANOVA's show no significant trend in Feb

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	67397.75	67398	1.588	0.211164191
Residual	83	3522999	42446		
Total	84	3590397			

Burn Analysis

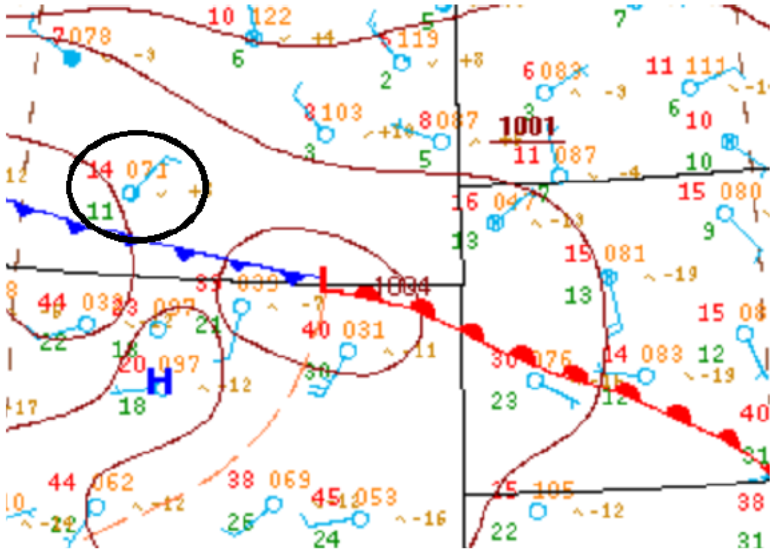
- Definition: Test contract performance using previous years
  - fair strike = \$0 mean payoff = expected (mean) index
  - risk loading = shifting strike toward hedger (e.g. $\bar{x} - 0.2\sigma_x$)
- Sell swap contract for Billings, MT February HDD's
  - strike = 992 HDD's; tick = 5000 \$/DD

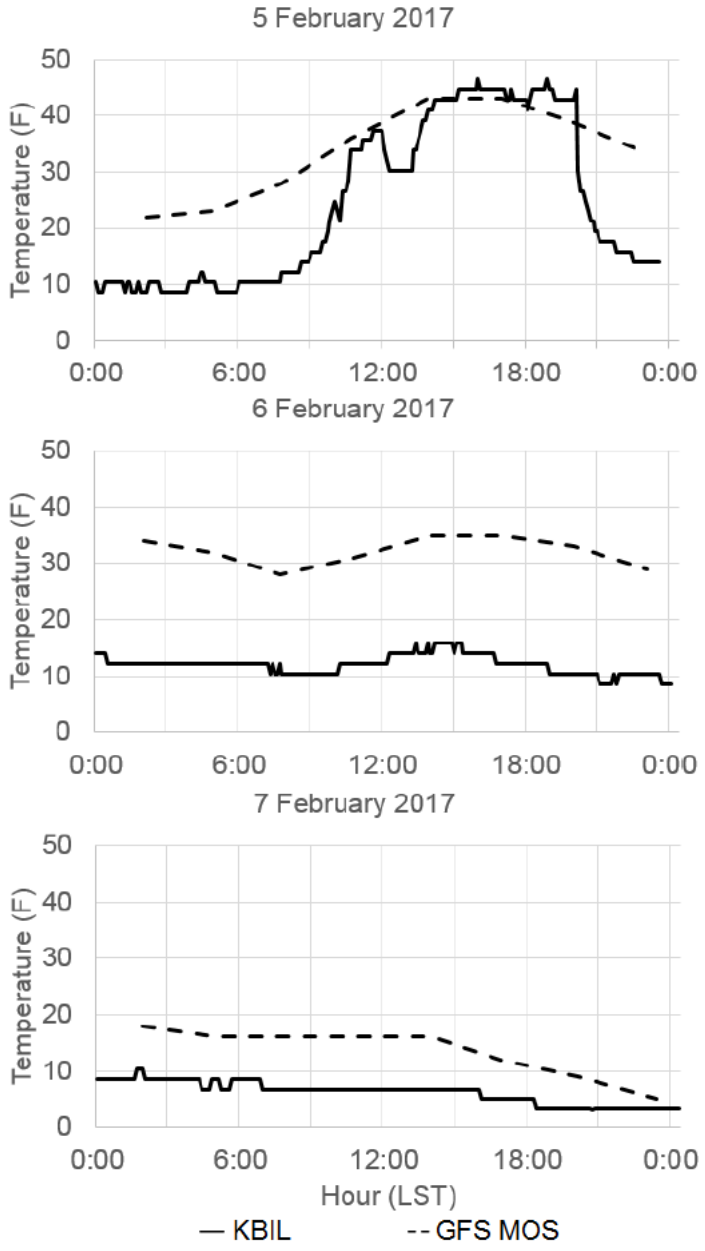


- Very small positive payoff for February 2017

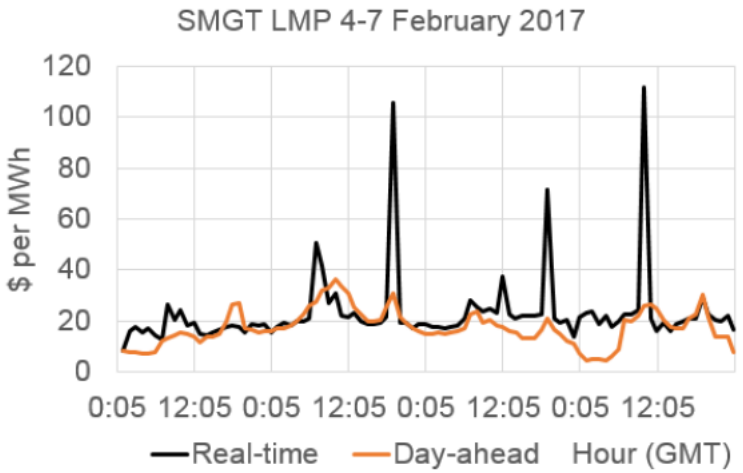
February 5-8, 2017

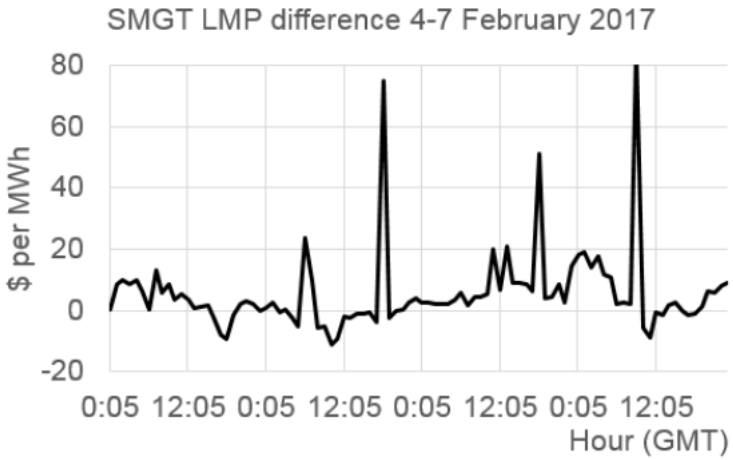
- Brief chinook produces >30F temps for 9-10 hours
- GFS MOS broadens onset slightly and termination significantly (>24 hours)





Energy Market Prices





- Locational Marginal Prices (LMP) for Southern Montana Electric Generation and Transmission (SMGT) settlement location
- Day-ahead prices generally lower than spot prices
  - Spot price also has multiple spikes over $60/MWh
- Price difference averages **$5.64/MWh**
- Total provider cost depends on several different buying scenarios
  - Not attempted in this study

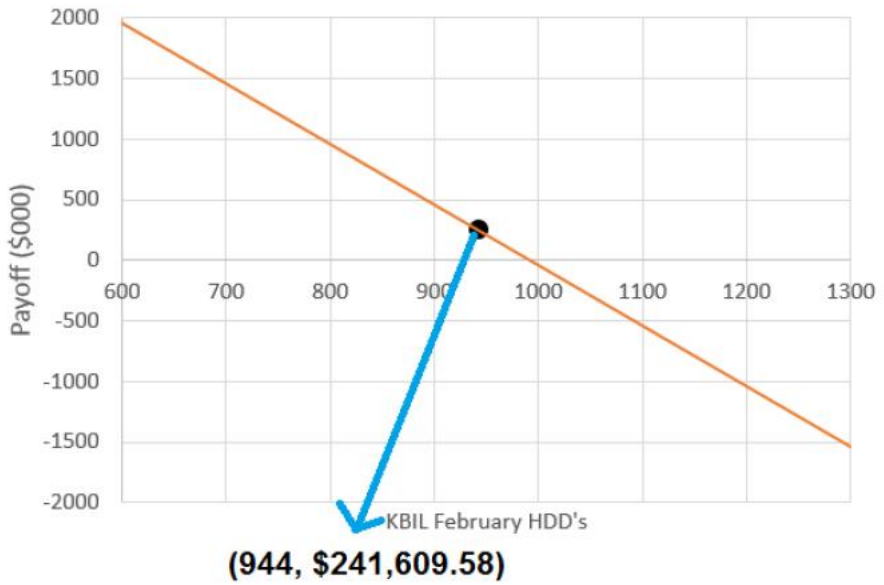
HDD Errors

- More specialized products already exist which settle using forecasts, instead of observed data
  - ex: an option contract pays the buyer increasing amounts after X number of forecast days w/ average temps $\leq 40^{\circ}$F
- How will the payoff change if the previous swap contract is settled with MOS temperatures?

	KBIL				GFS MOS			
	Max	Min	Ave	HDD	Max	Min	Ave	HDD
Feb 4th	31	8	20	45	28	20	24	41
Feb 5th	46	8	27	38	45	20	33	32
Feb 6th	15	9	12	53	36	27	32	33
Feb 7th	10	3	7	58	20	5	13	52
				194				158

- Lower the February monthly total by 36 HDDs

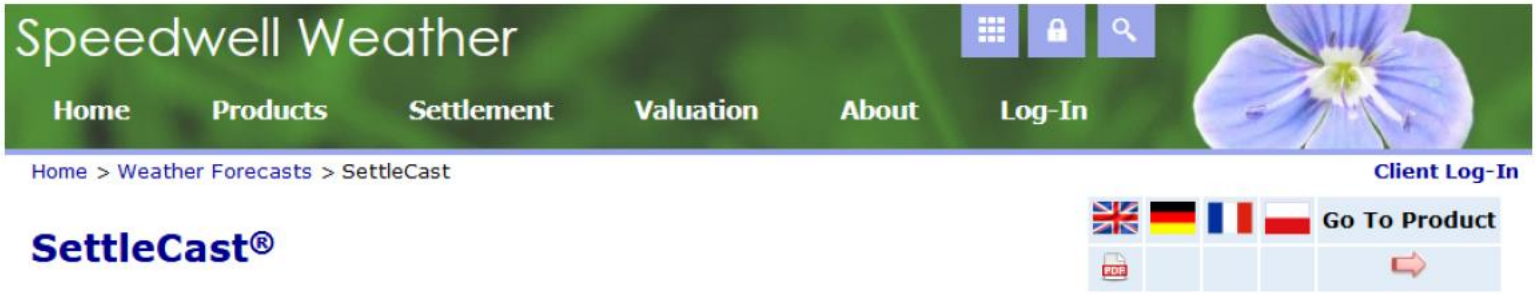
Forecast Derivative Settlement



- New settlement gives seller 4x larger payoff (≈$200k), which could offset increased costs
- Reversing model error (underchinooking) results in seller paying $118k
  - Costs are still higher due to selling unused day-ahead energy on the spot market!

Important Considerations

- Many technical considerations must go into preparing forecasts for derivative contract settlement



- Impact-based model evaluation can differ from quantitative methods
  - ex: smaller QPF errors can be more critical in identifying flood/no flood areas
- **Hedgers are less impacted by large errors on their short (lower profits) side**
  - More common in the US chinook belt