The SFO Marine Stratus Forecast System:

Integration of Probabilistic Weather Information into the FAA Operational Decision Process

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NWS Boston Aviation Workshop
5 May 2010

Outline

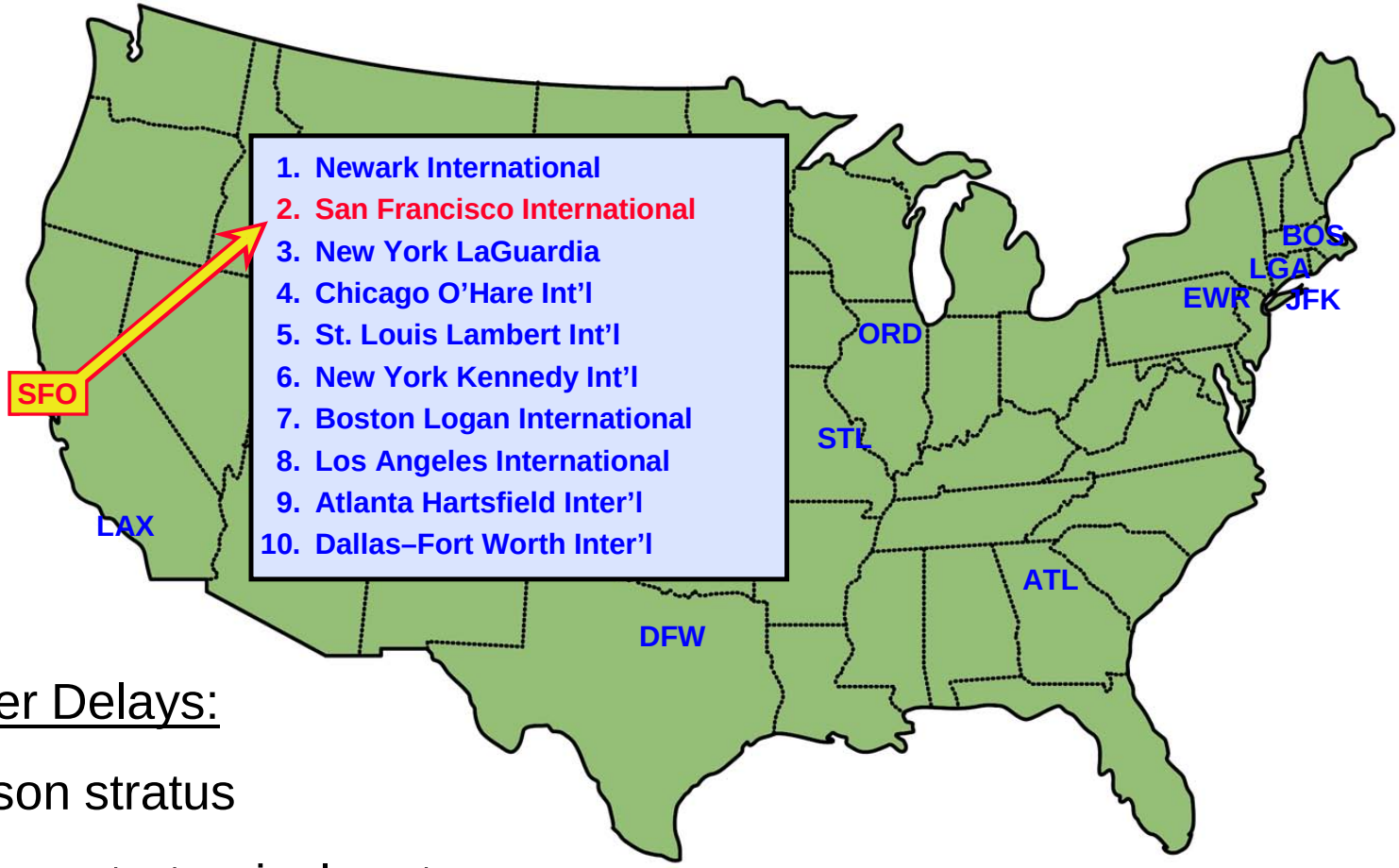
- Developing a Marine Stratus Forecast System for SFO
- Integrating a Ground Delay Program (GDP) Parameters Selection Model (GPSM)

Relevance

This is the Eastern Region…
Why do I care about SFO marine stratus?

- Example showing transition of weather forecasting research technology into daily operations
  - Collaboration between FAA and NWS
- Defined application of probabilistic information
  - Bridging the gap between a probabilistic forecast and an operational decision
  - Implications for ultimate weather implementation of NextGen
- Evolving role of operational meteorologists serving the FAA

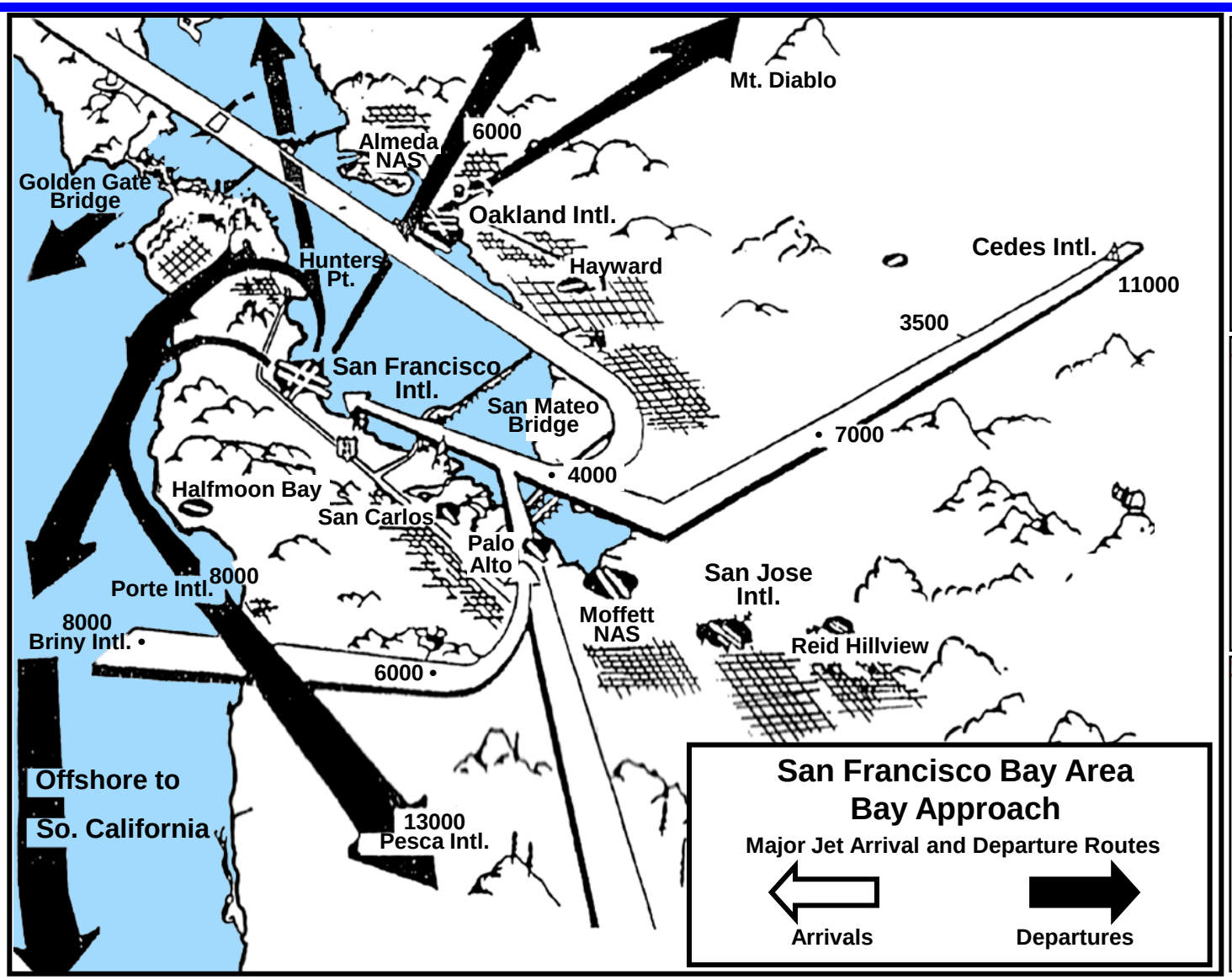
Most Delays per 1000 Operations

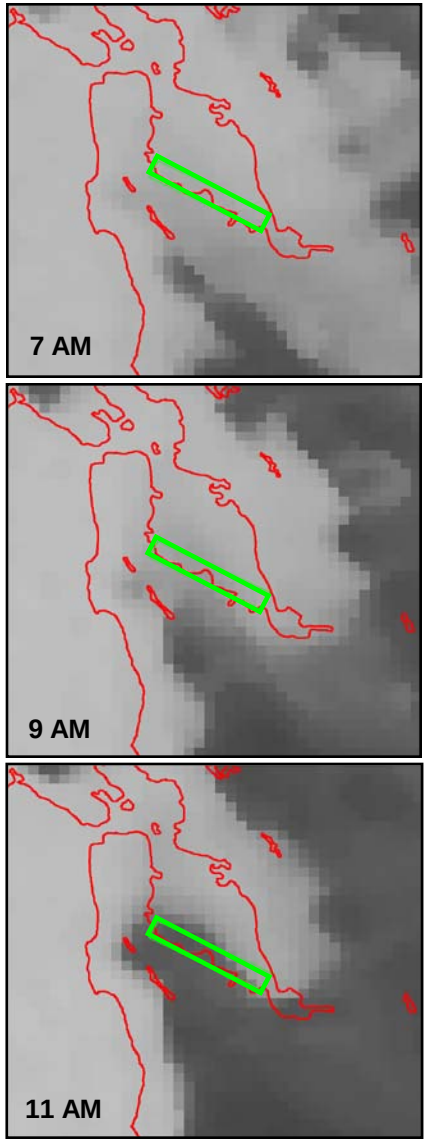


SFO Weather Delays:

- Warm season stratus
- Cold season extratropical systems

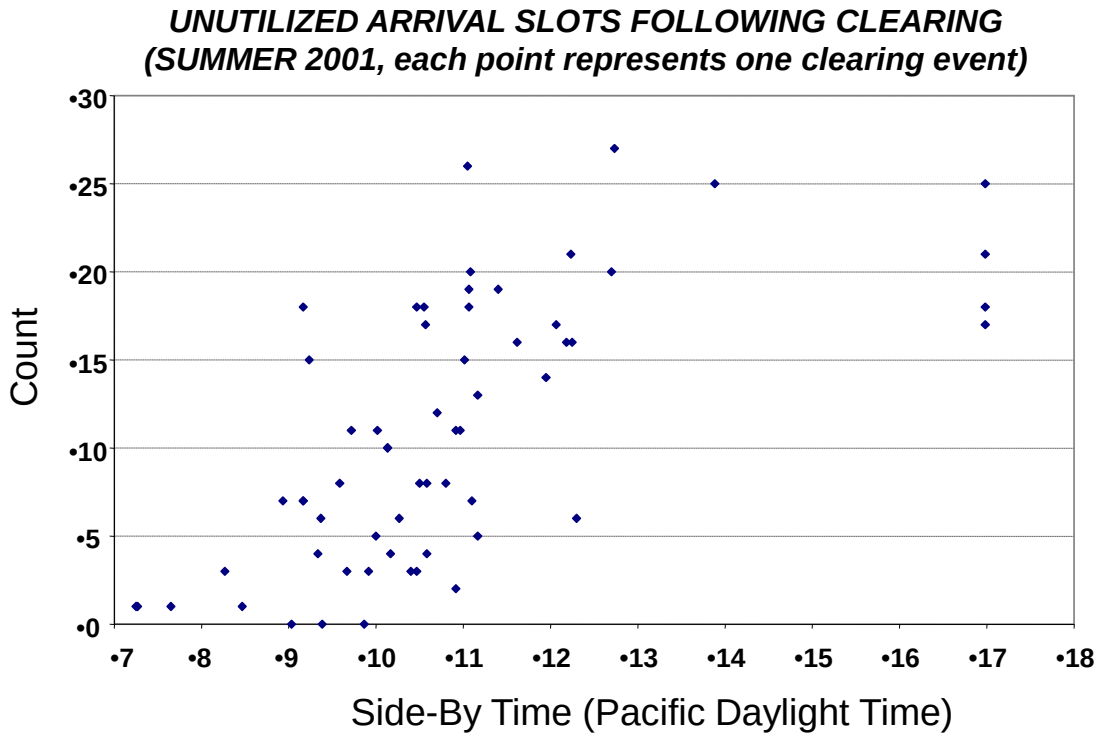
Summer Stratus Impact on SFO Approach



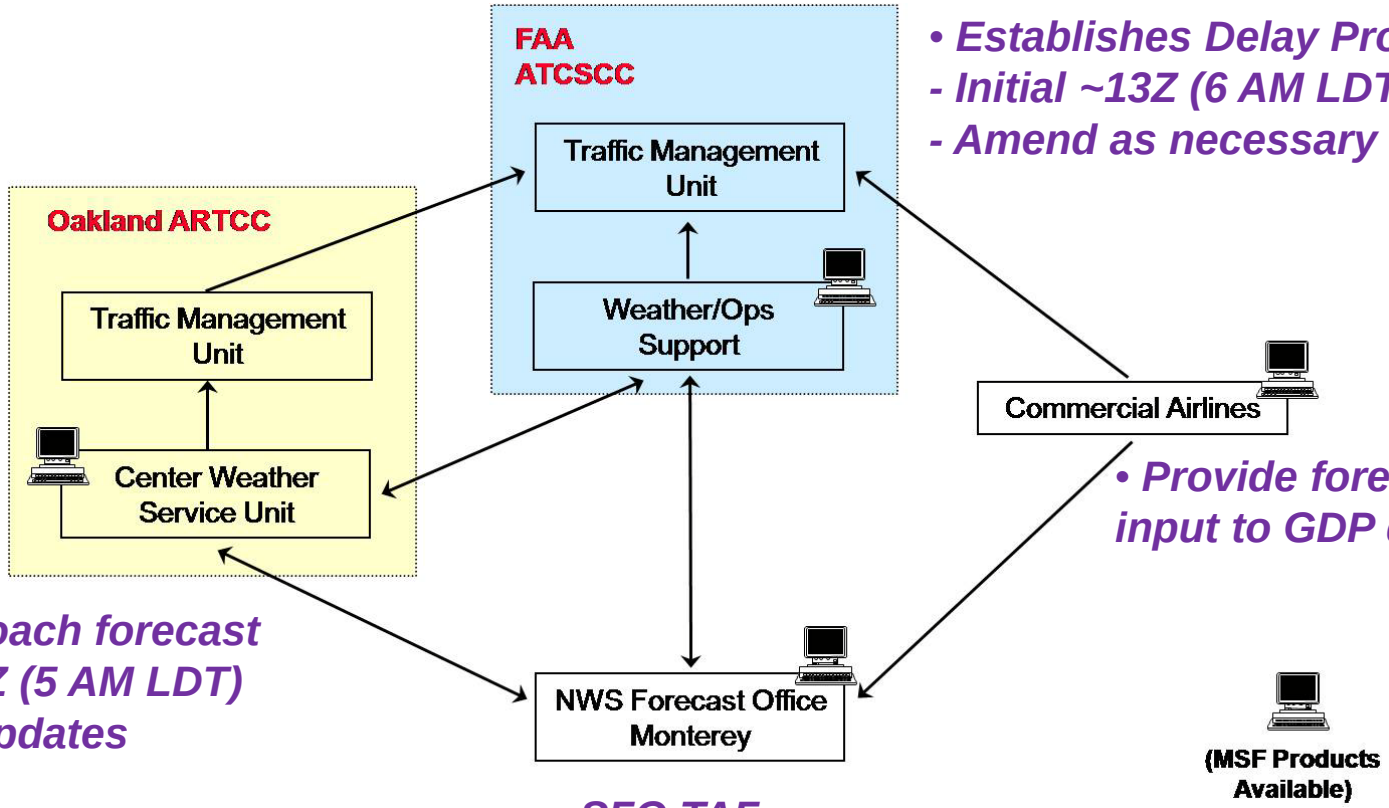


Opportunity for Delay Reduction

- There are often many (5-20) unutilized arrival slots following stratus clearing
- Anticipating clearing and proactive release of ground-held planes would utilize available capacity and reduce delay



Weather Information Flow in Decision Process



- *Establishes Delay Program*
  - *Initial ~13Z (6 AM LDT)*
  - *Amend as necessary*

- *Provide forecast input to GDP decision*

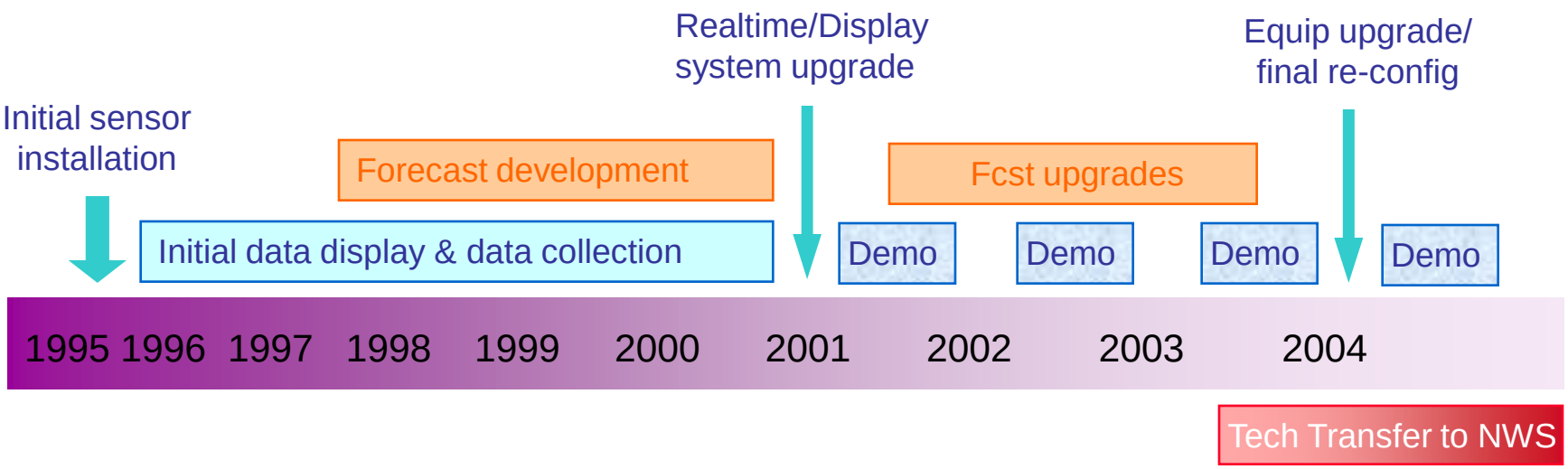
- *SFO Approach forecast*
  - *Initial ~12Z (5 AM LDT)*
  - *Morning updates*

- *SFO TAF*
  - *06Z, 12Z, 18Z*

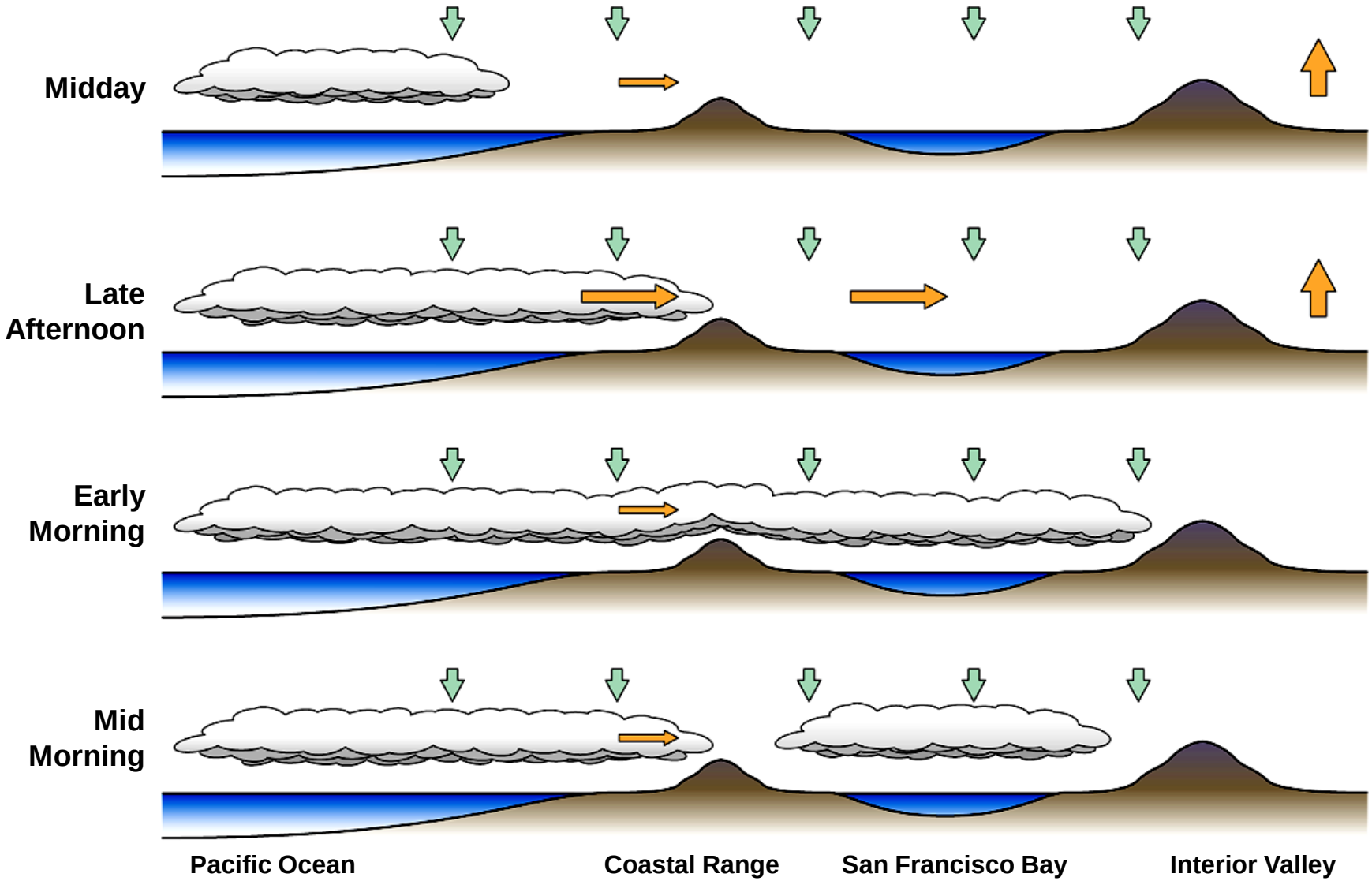
SFO Stratus Project Timeline

- Objective: Provide short-term forecast guidance (1-6 hours) of time of stratus clearing in Approach Zone, to anticipate increase of operating capacity

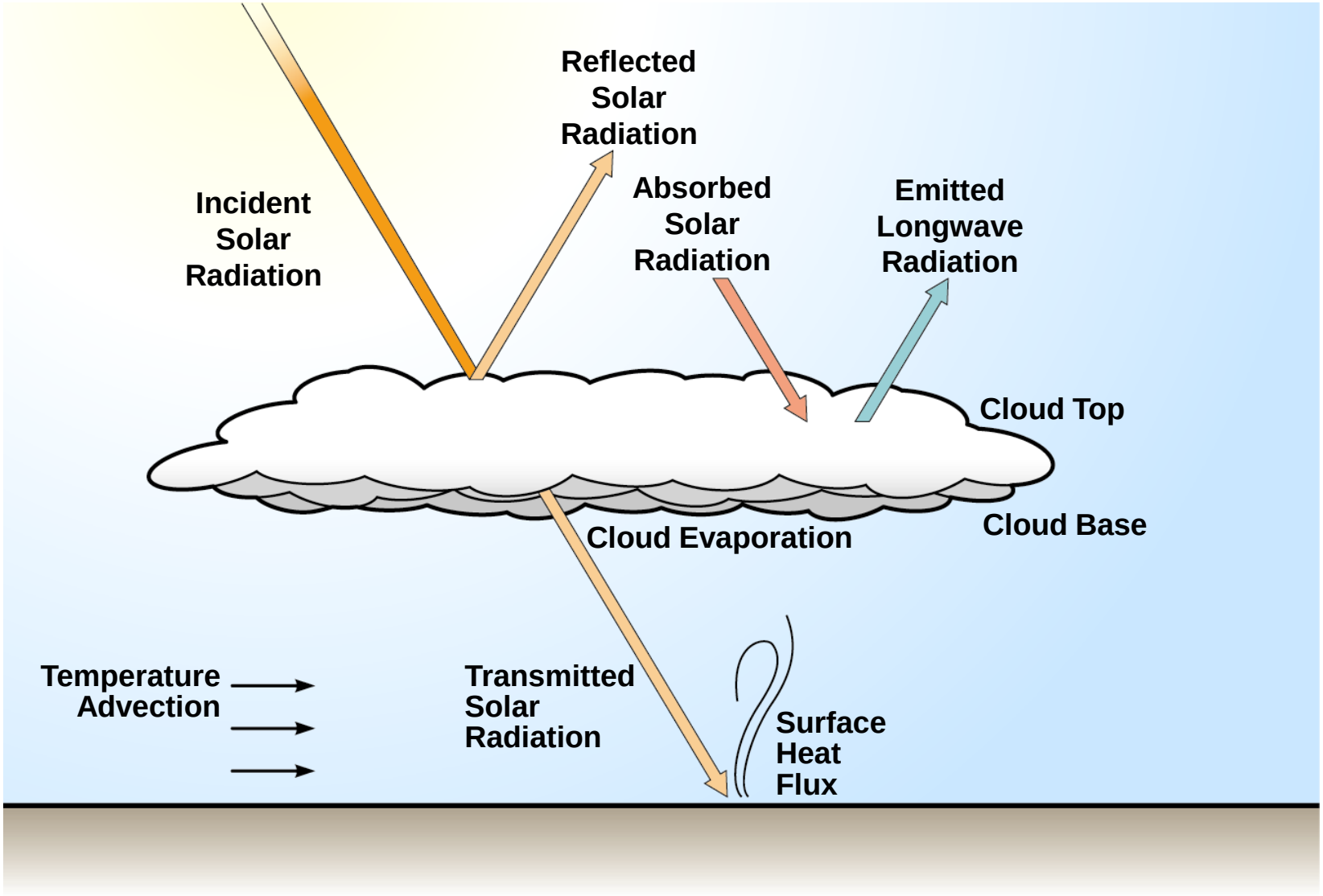
- Project Team
  - MIT Lincoln Laboratory
  - San Jose State University
  - Center Weather Service Unit, Oakland ARTCC
  - University of Quebec at Montreal



Daily Marine Stratus Cycle



Important Cloud Burnoff Processes



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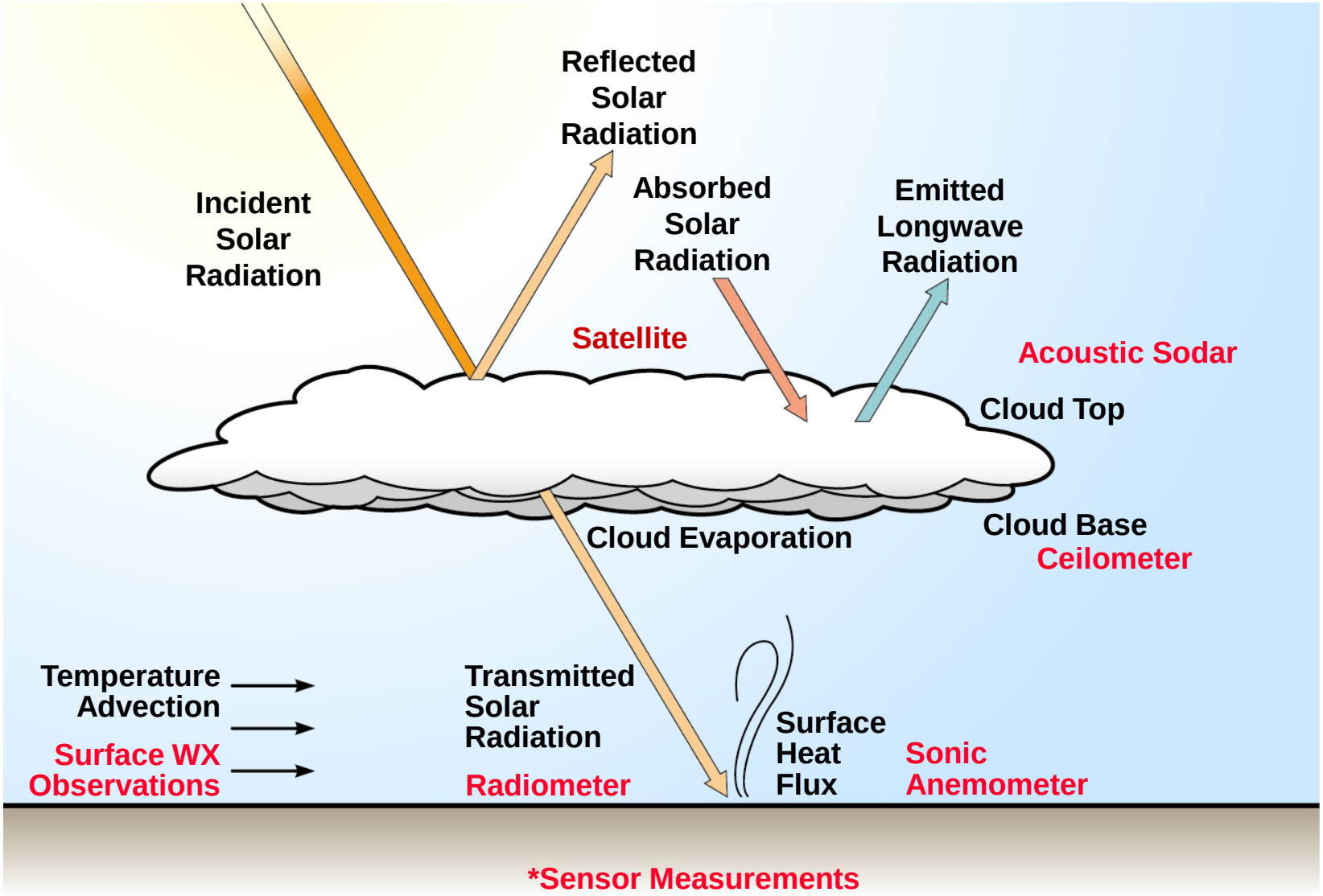
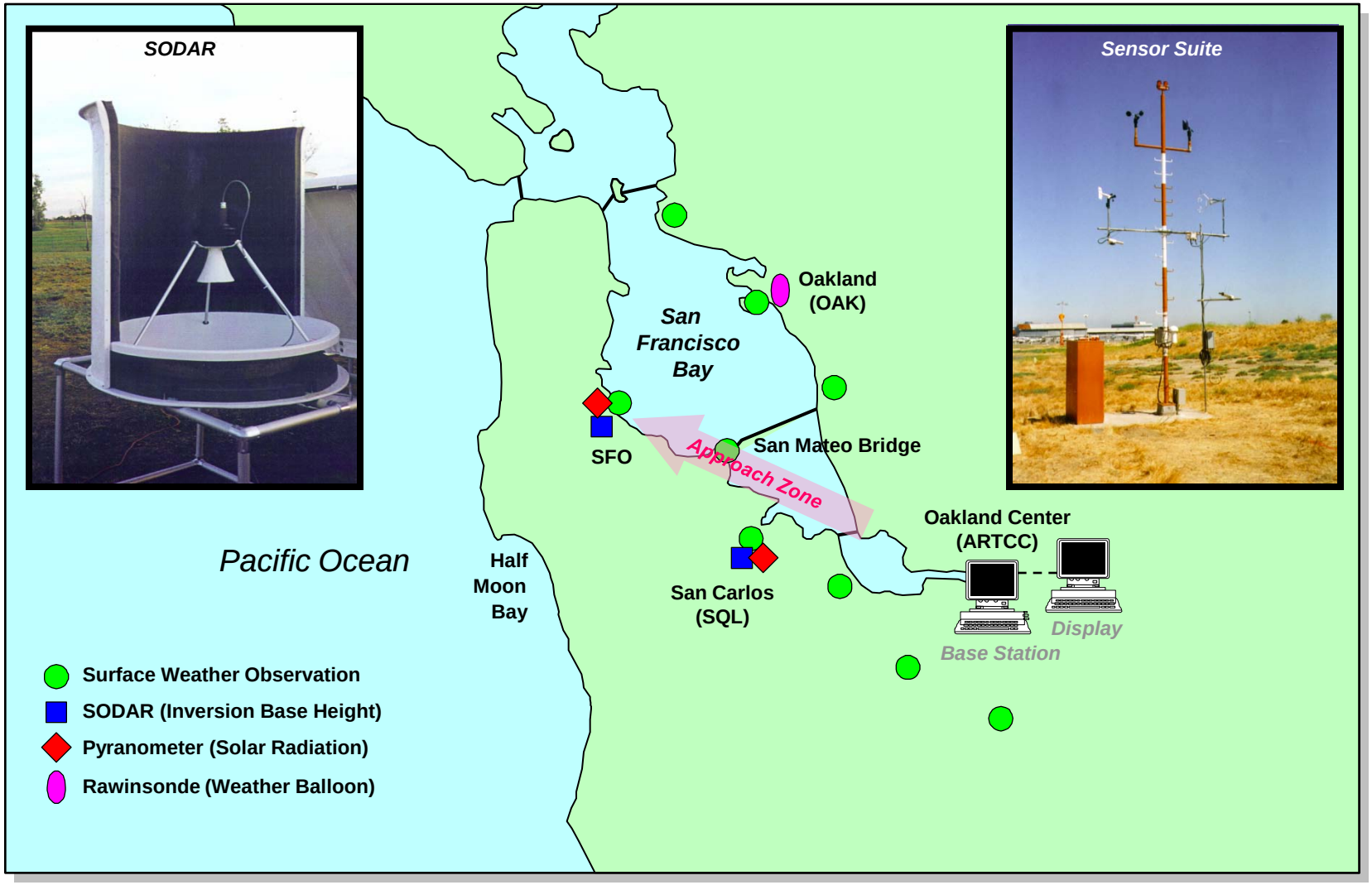
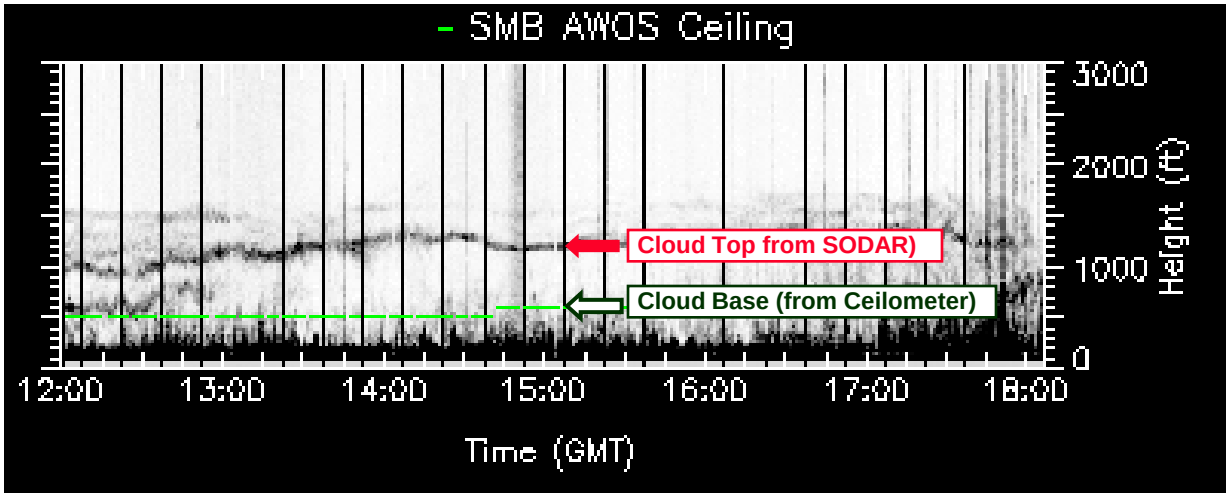
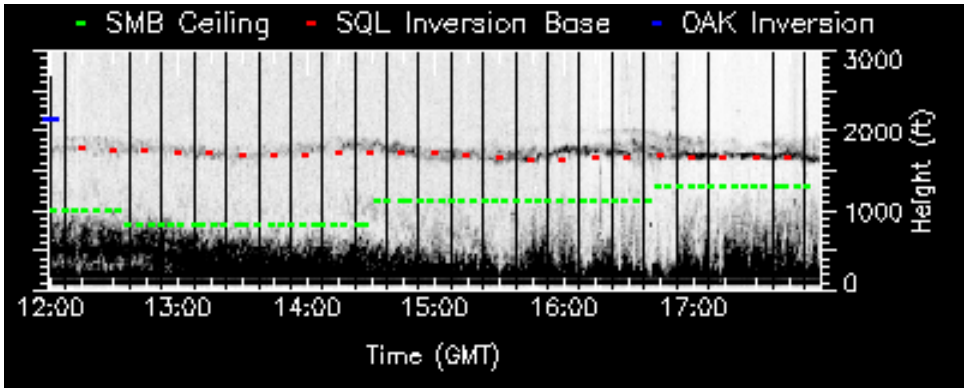


System Configuration



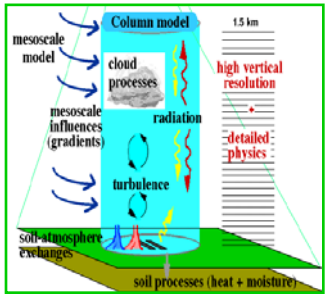
SODAR Inversion Base Height





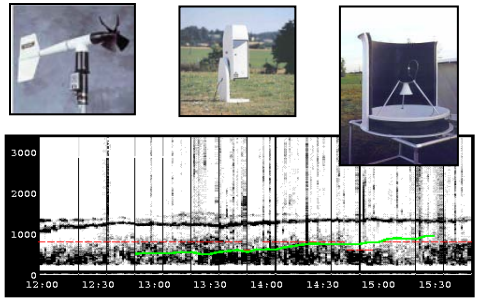
- Algorithm developed to identify inversion base height (red dashed line)

Forecast Model Development



COBEL – Physical Column Model

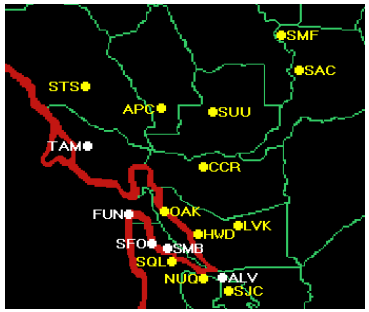
• Key Inputs: High resolution temp, humidity, wind, solar radiation



Local Statistical Forecast Model

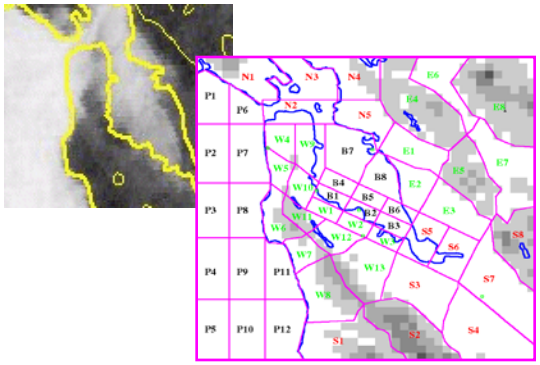
• Key Inputs: Local measurements of cloud base and inversion height, wind, pressure

Consensus Forecast



Regional Statistical Forecast Model

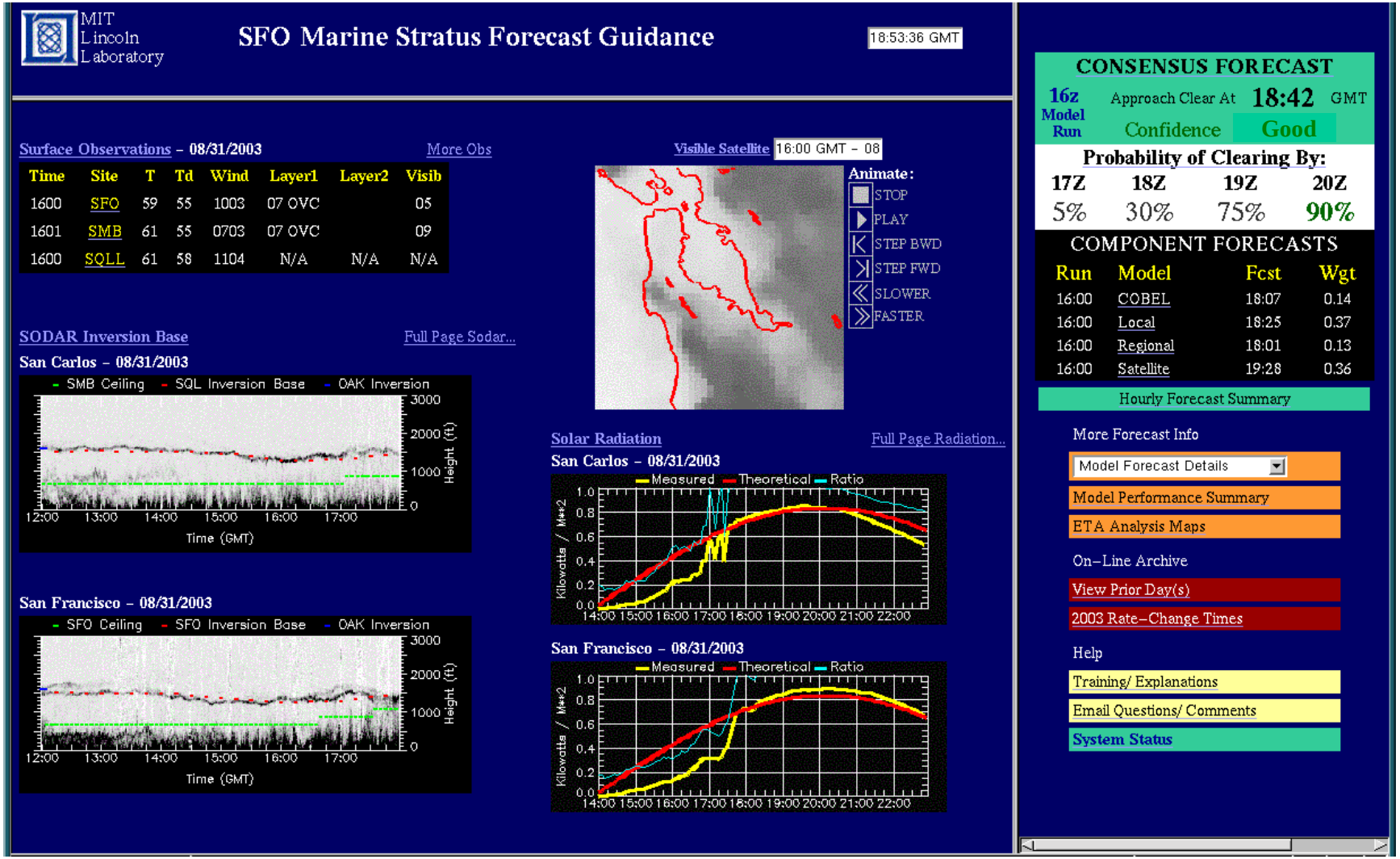
• Key Inputs: Regional hourly surface observations, 12Z Oakland sounding



Satellite Statistical Forecast Model

• Key Input: GOES visible satellite

SFO Stratus Forecast System User Display



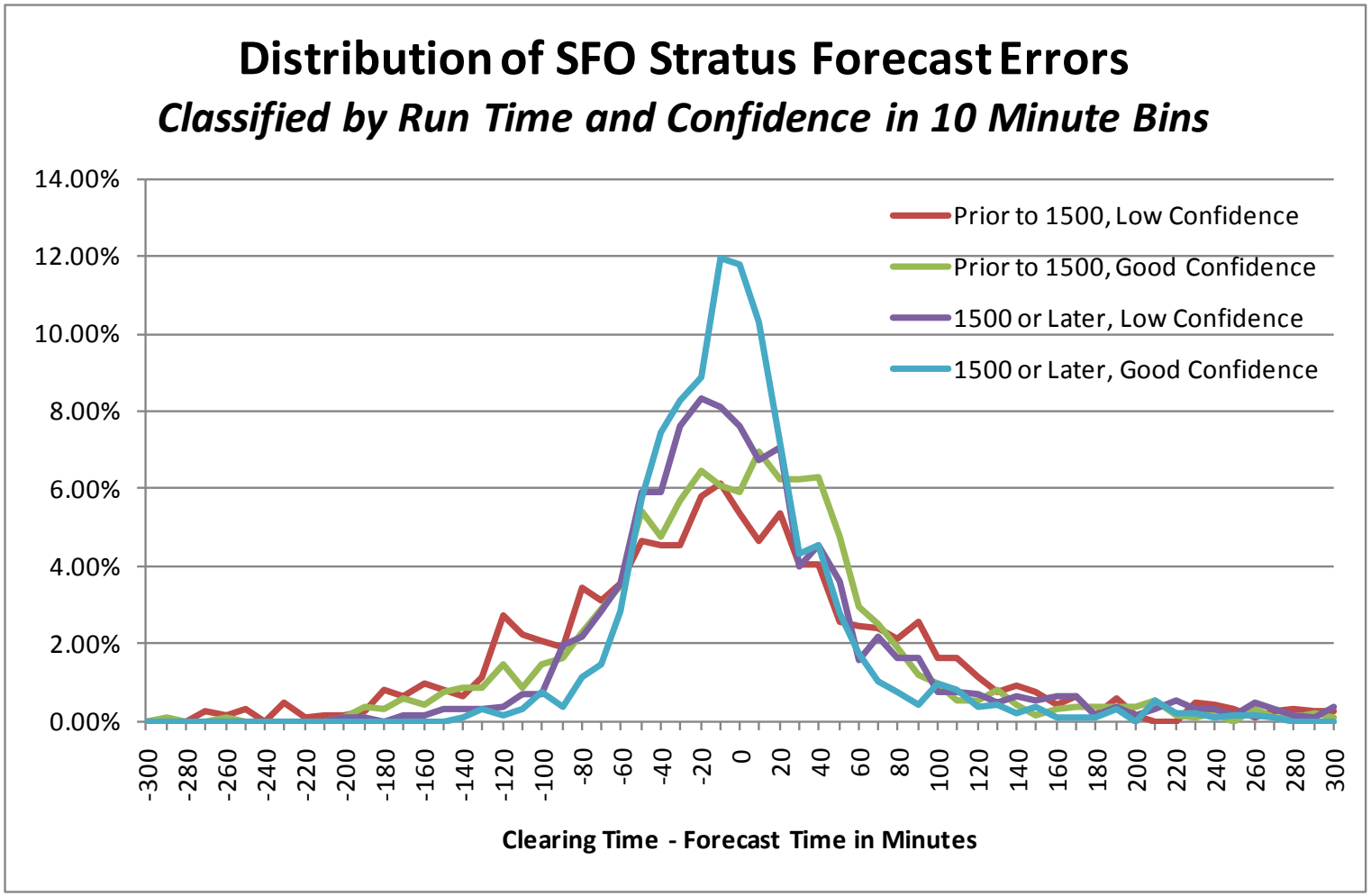
NWS/CWSU Experience 2004-07

- System was transitioned to NWS Monterey in 2004
- NWS performance analysis done in 2008 for 2004-2007 stratus seasons
- Two primary conclusions:
  - Probabilistic forecasts continued to verify reliably
  - ***Negligible operational benefits*** derived from system
- Exposed issue: Ineffective application of probabilistic forecast information by Air Traffic Flow managers

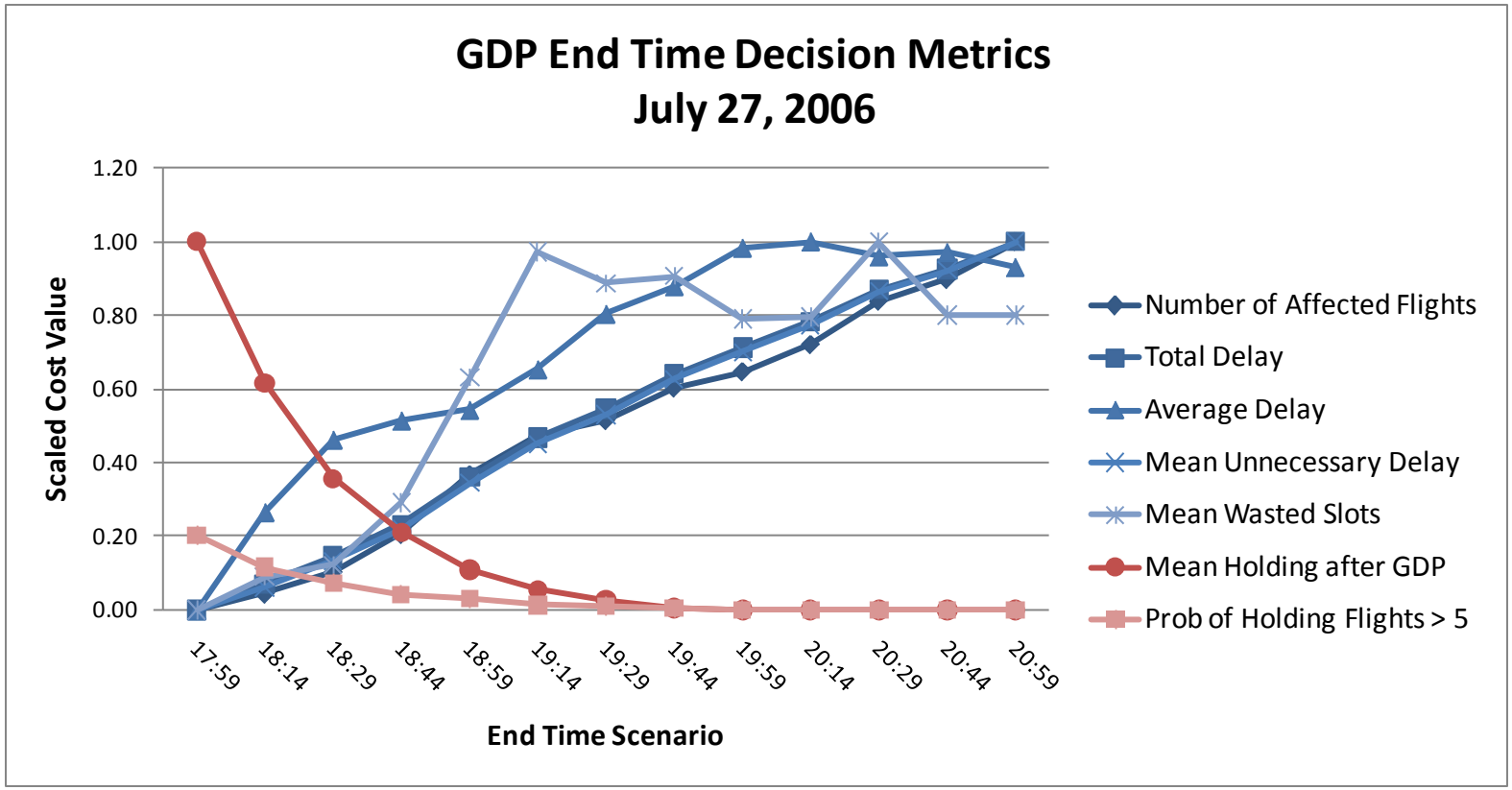
GDP Parameters Selection Model (GPSM)

- Work already in progress in 2008 by Mosaic ATM, Inc., funded by NASA NRA grant
  - Follow-on work funded by NASA/NWS, then FAA
- Stochastic model which runs Monte Carlo simulations to select recommended GDP parameters which minimize and objective cost function
- Relies on:
  - Historical error distribution of the stratus forecasts
  - Cost function model that accurately captures relative operational costs

Stratus Forecast System error distribution



Competing Goals

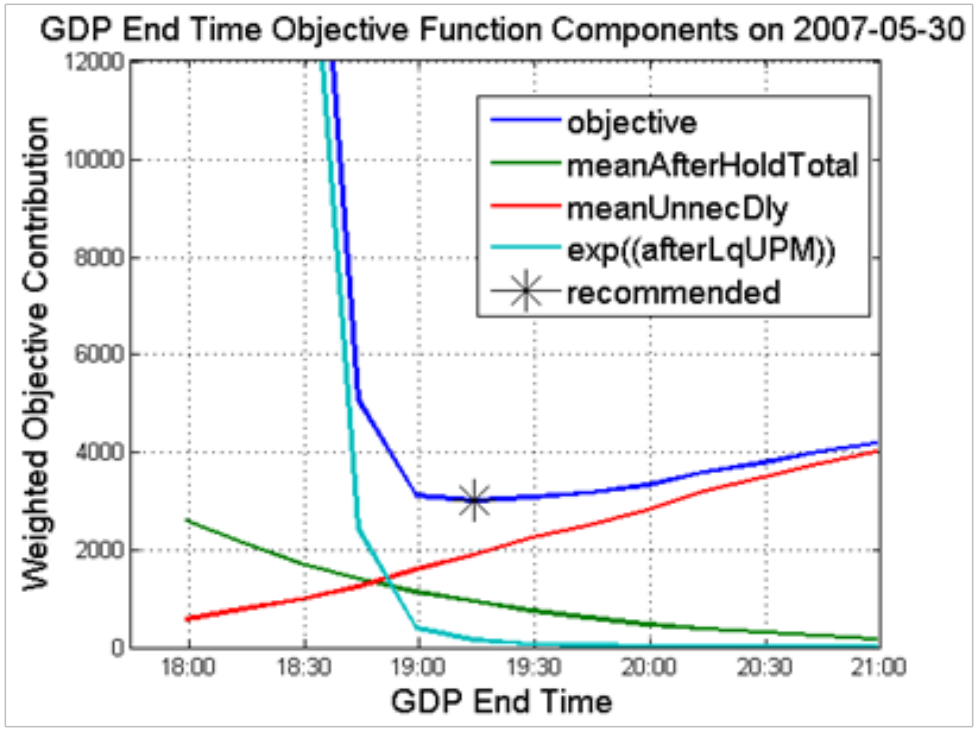


Some metrics increase in cost with later end times, while others decrease.

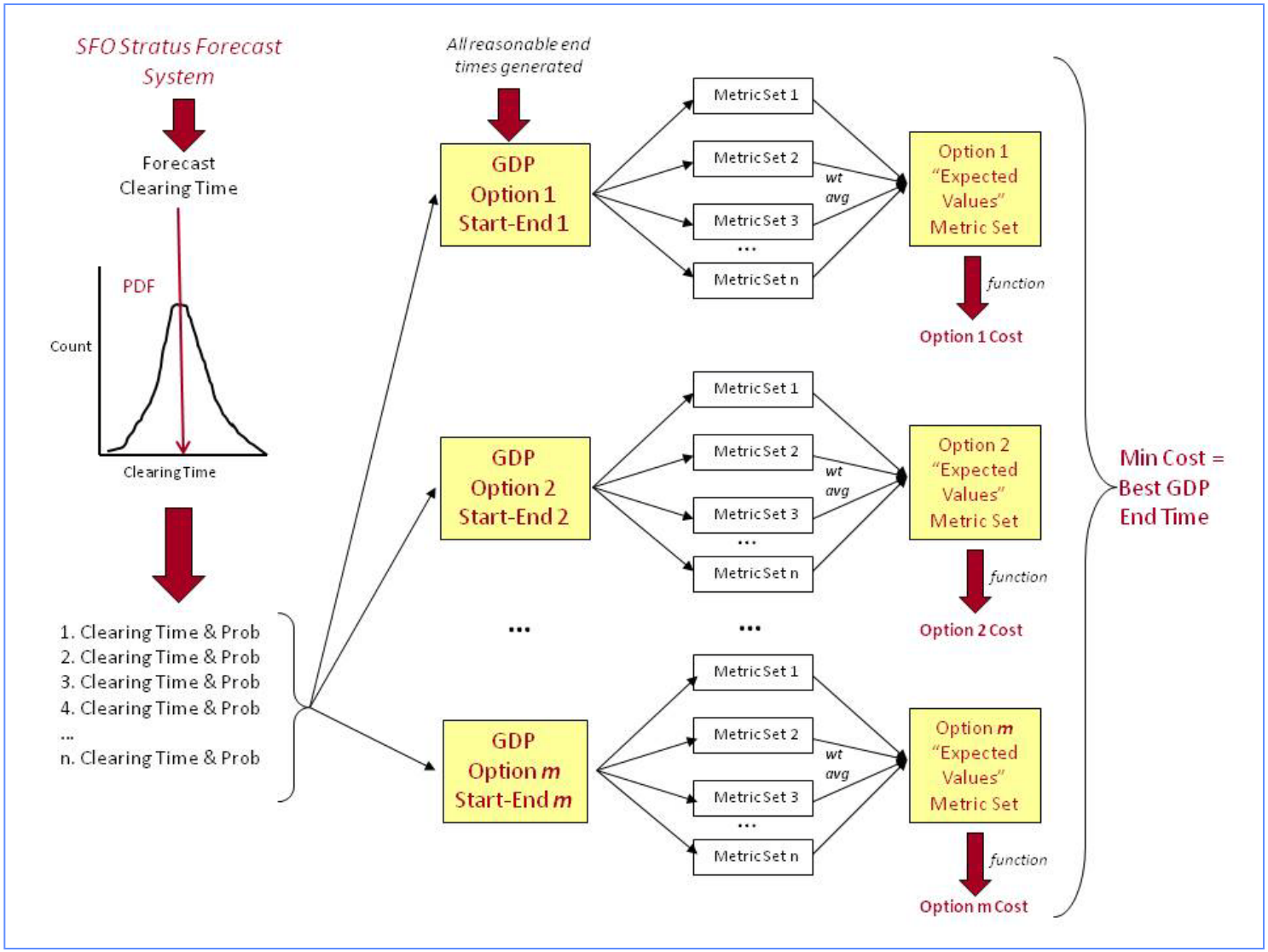
Must balance the risks of users (excess delay) and ATC provider (excess demand).

GDP Metrics Evaluated by Model

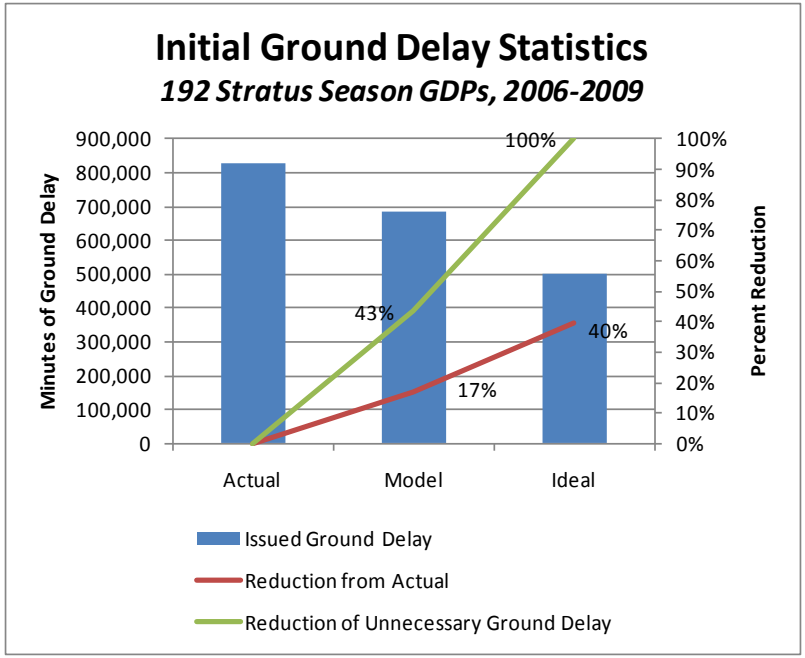
- **End Time Decision:**
  - Unnecessary Delay (when GDP end time is later than clearing time)
  - Airborne Holding (when GDP end time is earlier than clearing time)
  - Risk of 5 or more flights in simultaneous holding
  - Ability to extend the program at 1600 by an additional hour

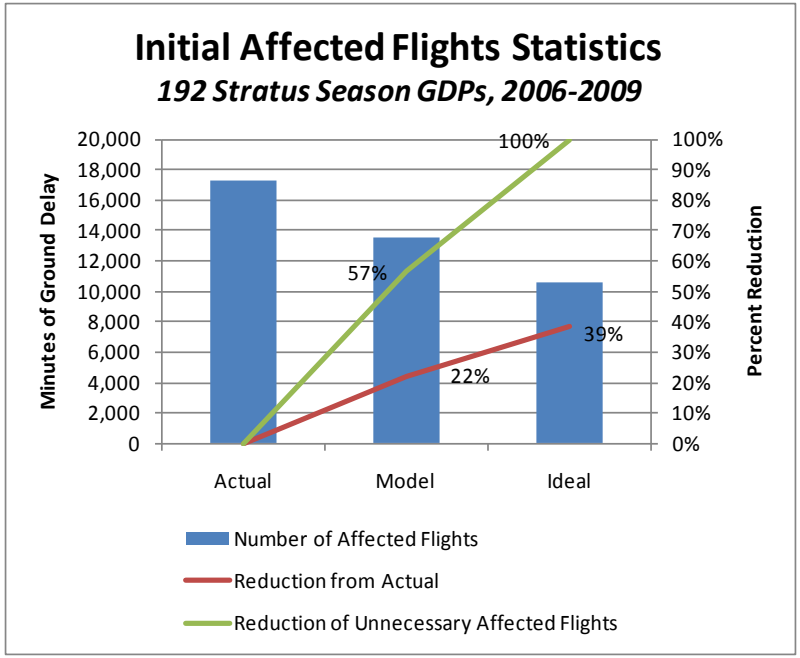


Scenario Generation



Model Benefits



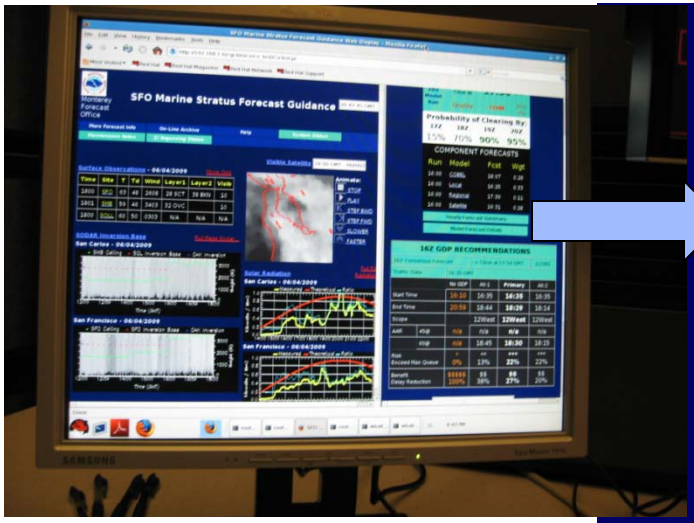


<u>Annual Estimated Savings</u>:

$4.86M per severe weather season

** Assumes $74.10 per minute delay, 75 GDPs per season*

Integration of GPSM into System



CONSENSUS FORECAST

16z Model Run — Approach Clear At **19:02** GMT

Quality — Good

Probability of Clearing By:

17Z	18Z	19Z	20Z
5%	10%	50%	**90%**

COMPONENT FORECASTS

Run	Model	Fcst	Wgt
16:00	COBEL	19:01	0.24
16:00	Local	17:17	0.28
16:00	Regional	18:43	0.14
16:00	Satellite	20:35	0.34

Hourly Forecast Summary

Model Forecast Details

15Z GDP RECOMMENDATIONS

15Z Consensus Forecast		-> Clear at 17:25 GMT			[GOOD]
Traffic Data		15:18 GMT			
		Current	Alt-1	**Primary**	Alt-2
Start Time		15:30	15:30	**15:30**	15:30
End Time		18:59	18:14	**18:29**	18:44
Scope		12West	12West	**12West**	12West
AAR	45@	18:00	16:45	**17:30**	17:45
	60@	19:00	17:45	**18:30**	18:45
Risk Exceed Max Queue		* 1%	* 9%	* **6%**	* 2%
Benefit Delay Reduction		$$ 24%	$$ 27%	**$$ 20%**	$ 17%

Expanded statistics

GPSM Detailed Forecast Summary - MIT Lincoln Laboratory

Close

GDP Parameter Statistics

15Z GDP RECOMMENDATIONS

15Z Consensus Forecast		-> Clear at 17:25 GMT			[GOOD]
Traffic Data		15:18 GMT			
		Current	Alt-1	**Primary**	Alt-2
Start Time		15:30	15:30	**15:30**	15:30
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Scope		12West	12West	**12West**	12West
AAR	45@	18:00	16:45	**17:30**	17:45
	60@	19:00	17:45	**18:30**	18:45
Risk Assessment					
Probability GDP End before clearing		8	15.3	**13.1**	10.1
Probability GDP End before clearing -30 min		4.6	10.1	**7**	6.1
Probability GDP End before clearing -60 min		3.4	6.1	**4.6**	3.7
CEDES - Probability Exceed Max Hold/Diversion		1/0	9/5	**6/1**	2/0
PYE - Probability Exceed Max Hold/Diversion		1/0	5/2	**3/0**	1/0
PIRAT - Probability Exceed Max Hold/Diversion		0/0	0/0	**0/0**	0/0
SKUNK - Probability Exceed Max Hold/Diversion		0/0	4/1	**2/0**	1/0
Delay Impact					
Number or affected flights		48	29	**33**	39
Max Ground Delay		83	103	**90**	97
Total Ground Delay		1729	1254	**1399**	1887
Average Ground Delay		36.0	43.2	**42.4**	48.4
Expected Airborne Holding		138	643	**351**	206

Done

Successful SFO Stratus Forecast System / GPSM installation and integration testing completed in the operational environment at the ZOA CWSU.

Current Status

- **Planning field trial for summer 2010**
- **Coordinating with ATCSCC, ZOA, and CWSU for planning and training**
- **<u>Important role for CWSU</u>**

  1) Identify instances when GPSM model recommendation should be rejected

  2) Provide guidance to ATM when selection of "aggressive" or "conservation" alternatives is warranted

Summary

- Marine Stratus Forecast System designed to provide automated guidance (deterministic <u>and</u> probabilistic) of stratus clearing for SFO approach
- Forecasts validated as reliable by users
- Measurable benefits found to be limited due to operational application
- New model (GPSM) developed to recommend GDP parameters; integrated into existing system
- Field trial during Summer 2010