

Lessons Learned from the SCOS97 Upper-Air Meteorology Measurement Program – Applications to Current and Future Programs



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Acknowledgments

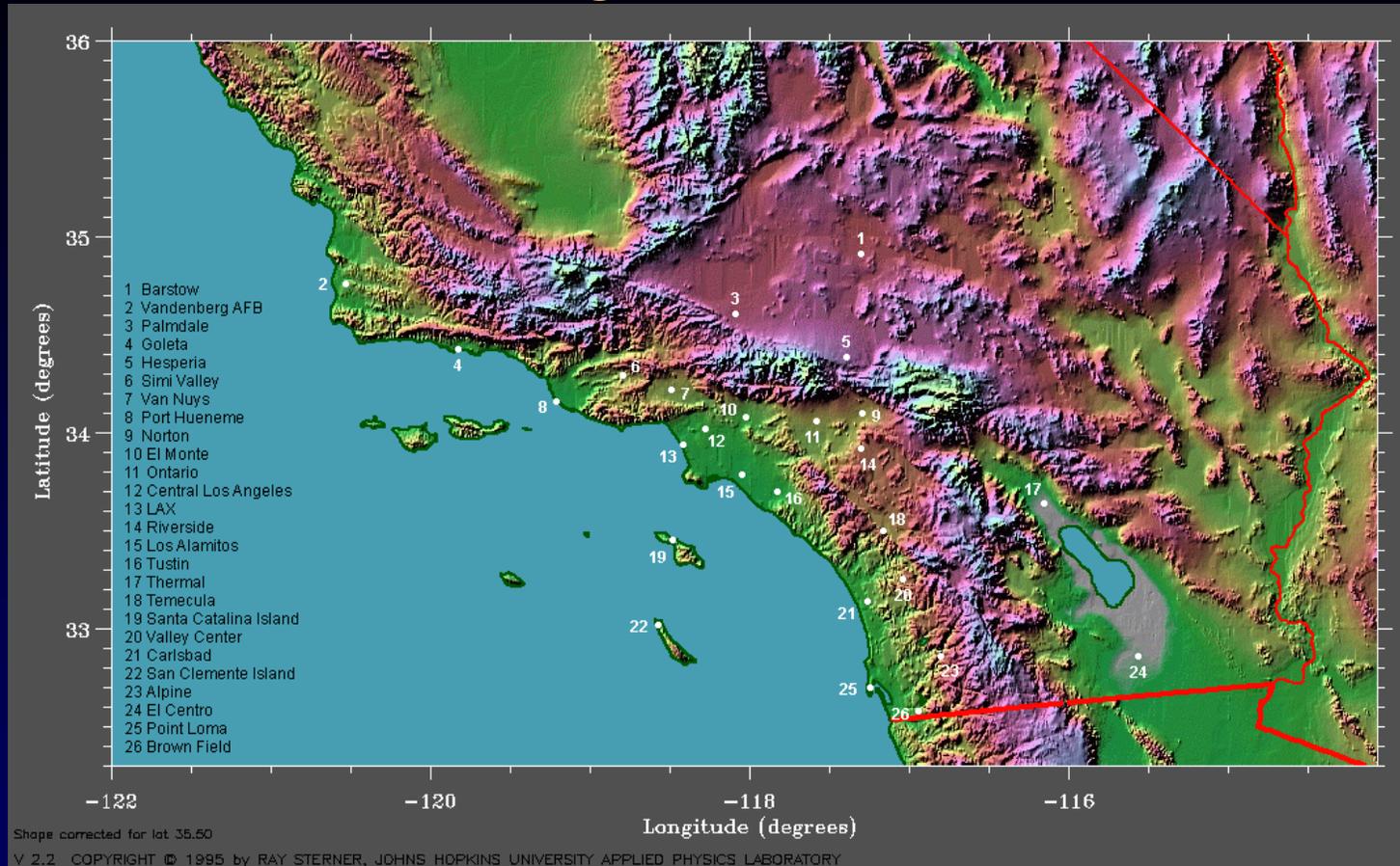
Cooperative effort of

- ⇒ California Air Resources Board
- ⇒ South Coast Air Quality Management District
- ⇒ National Oceanic and Atmospheric Administration

Presentation Overview

- ⇒ Background
 - Field program overview
 - Instruments and data processing
 - Data validation project
- ⇒ Project review
 - Quality assurance
 - Data processing
 - Data merging
 - Data validation
- ⇒ Recommendations
- ⇒ Audit, processing, and data product ideas

Field Program Overview



- ⇒ June through October 1997
- ⇒ 26 radar profiler and RASS (winds and temperature)
- ⇒ 6 sodars (winds)
- ⇒ Rawinsondes (winds, temperature, dew point)

Instruments and Data Processing Products

⇒ Radar profiler

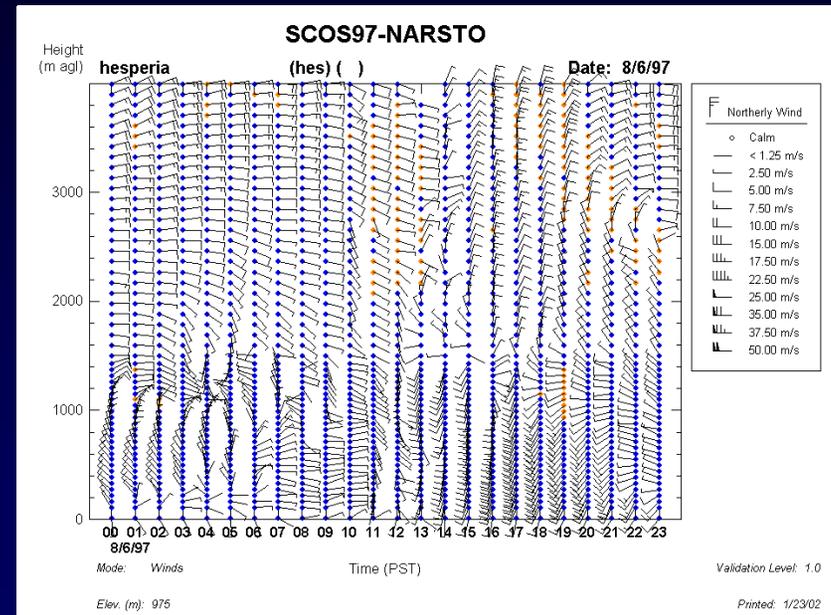
- Hourly or sub-hourly wind profiles
 - Low mode: 60 m resolution up to 2000 m agl
 - High mode: 100 m resolution up to 4000 m agl

⇒ RASS

- Hourly or sub-hourly temperature profiles
- 60 m resolution up to 1500 m agl

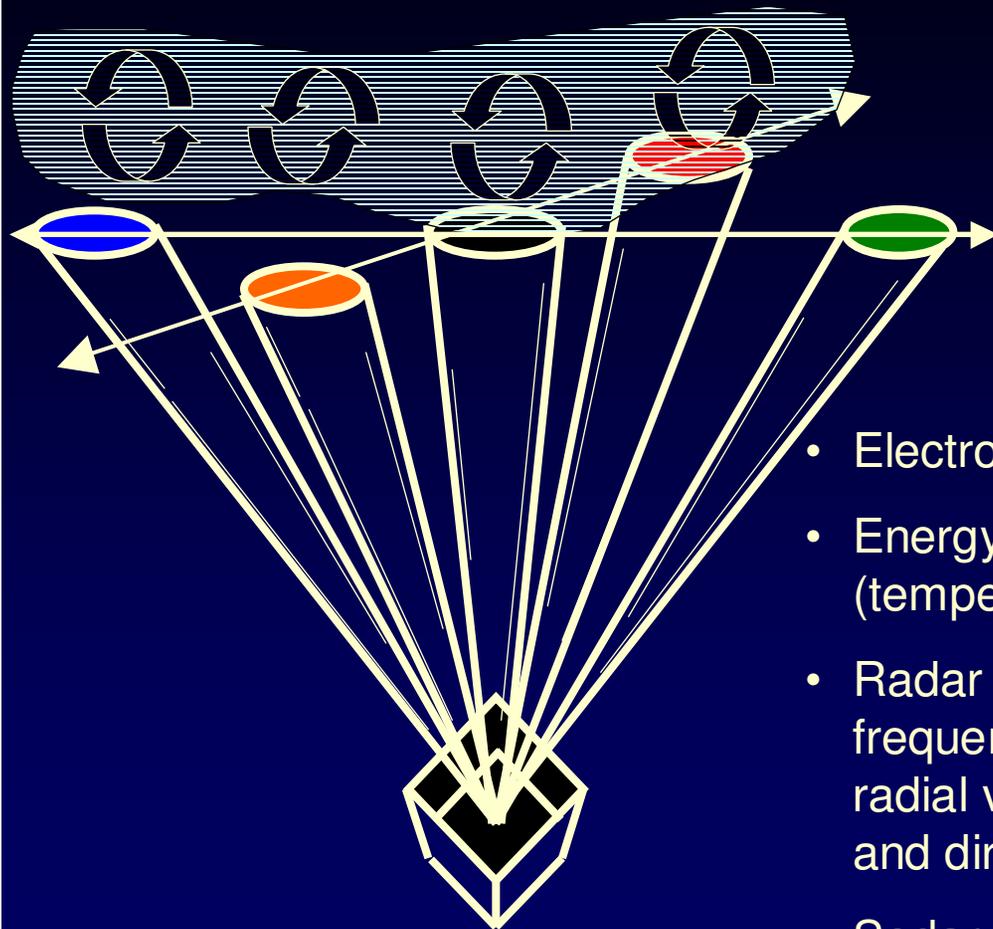
⇒ Sodar

- Hourly or sub-hourly wind profiles
- 20-30 m resolution up to 1000 m agl



Instruments and Data Processing

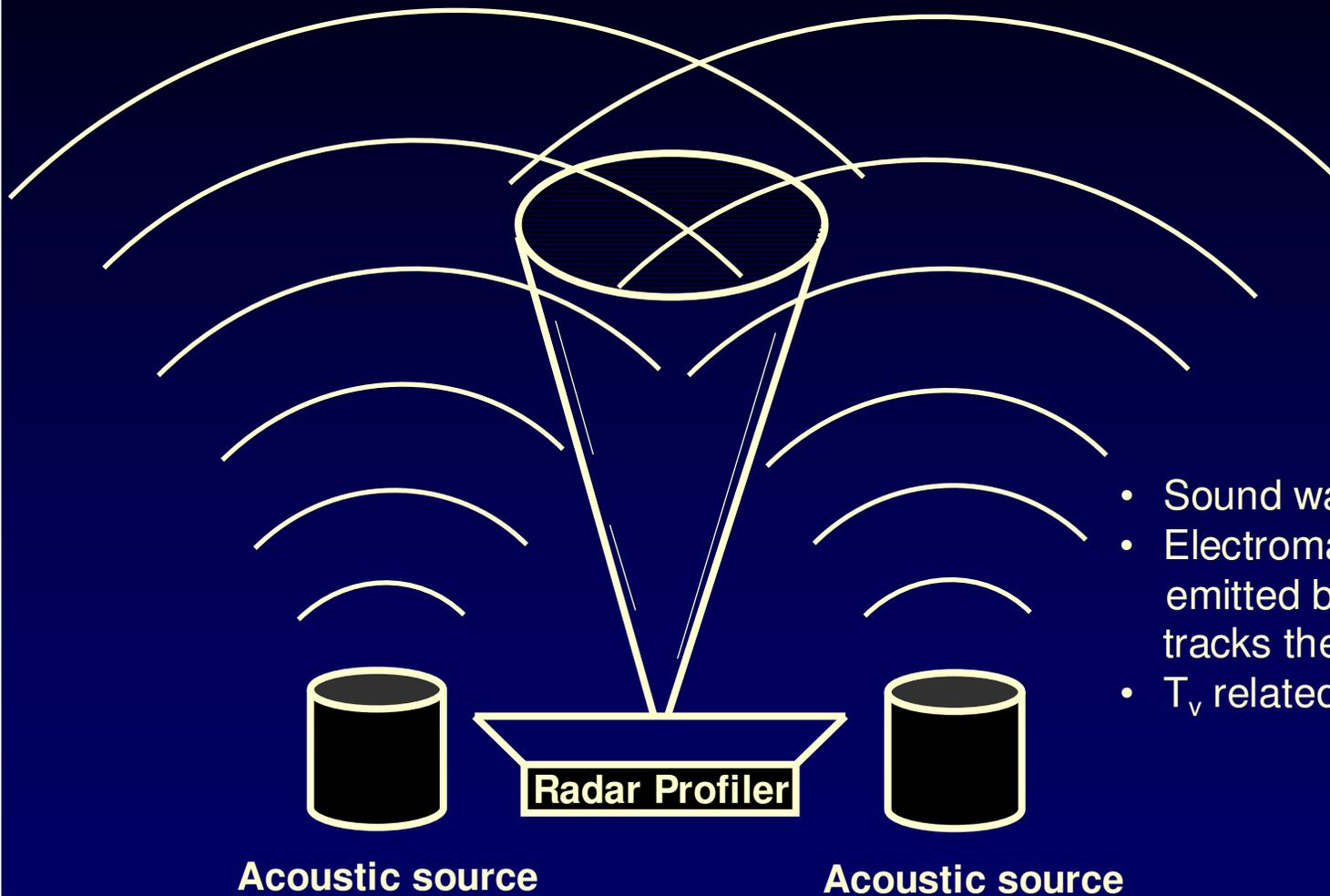
Radar Profiler and Sodar



- Electromagnetic (EM) energy is emitted by radar
- Energy scatters in all directions from turbulence (temperature and moisture irregularities)
- Radar profiler measures return signal and frequency shift and translates frequency shift to radial velocities, then to horizontal wind speed and direction
- Sodar uses sound instead of EM

Instruments and Data Processing

RASS

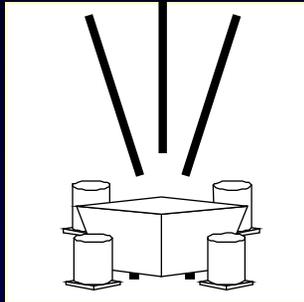


- Sound waves perturb the air
- Electromagnetic energy emitted by the radar profiler tracks the sound velocity
- T_v related to C_a & w

Instruments and Data Processing

Data Flow

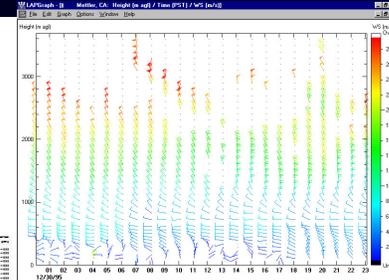
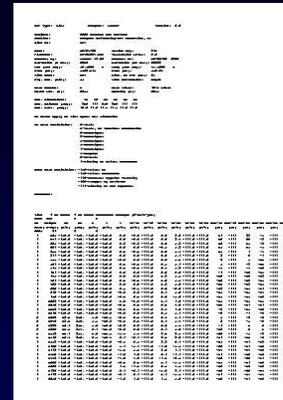
Field Processes



Radar Profiler

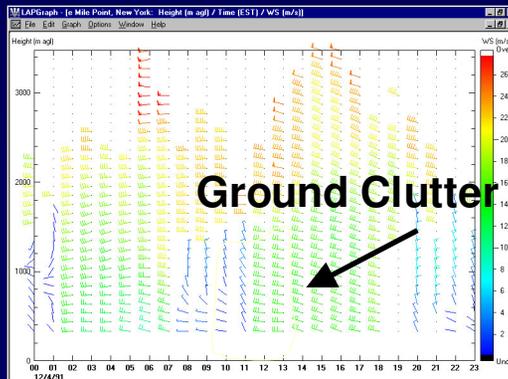
- System audit
- Collection of raw data
- Data processing
- Performance audits
- Data transmission
- Data backups

Post Processing

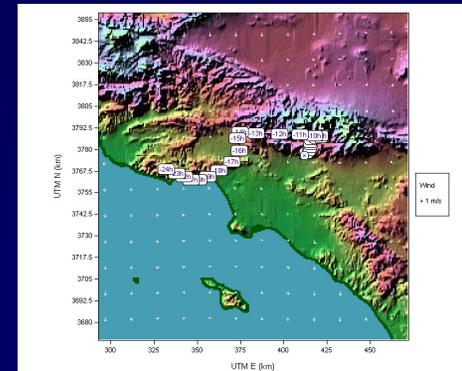


- Data display
- Data reviews
- Objective validation

Subjective Data Validation



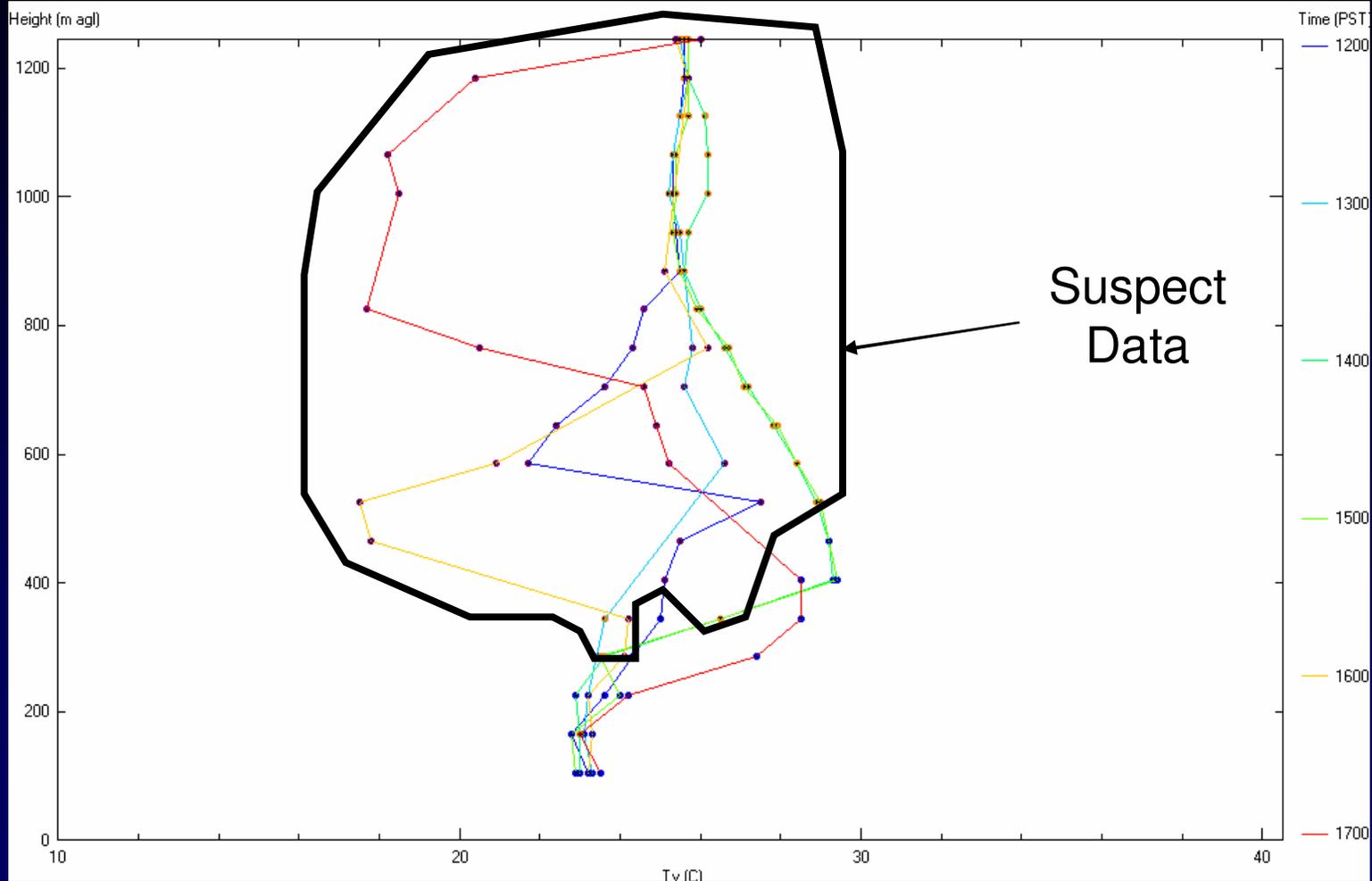
Data Analysis and Modeling



Data Validation Project

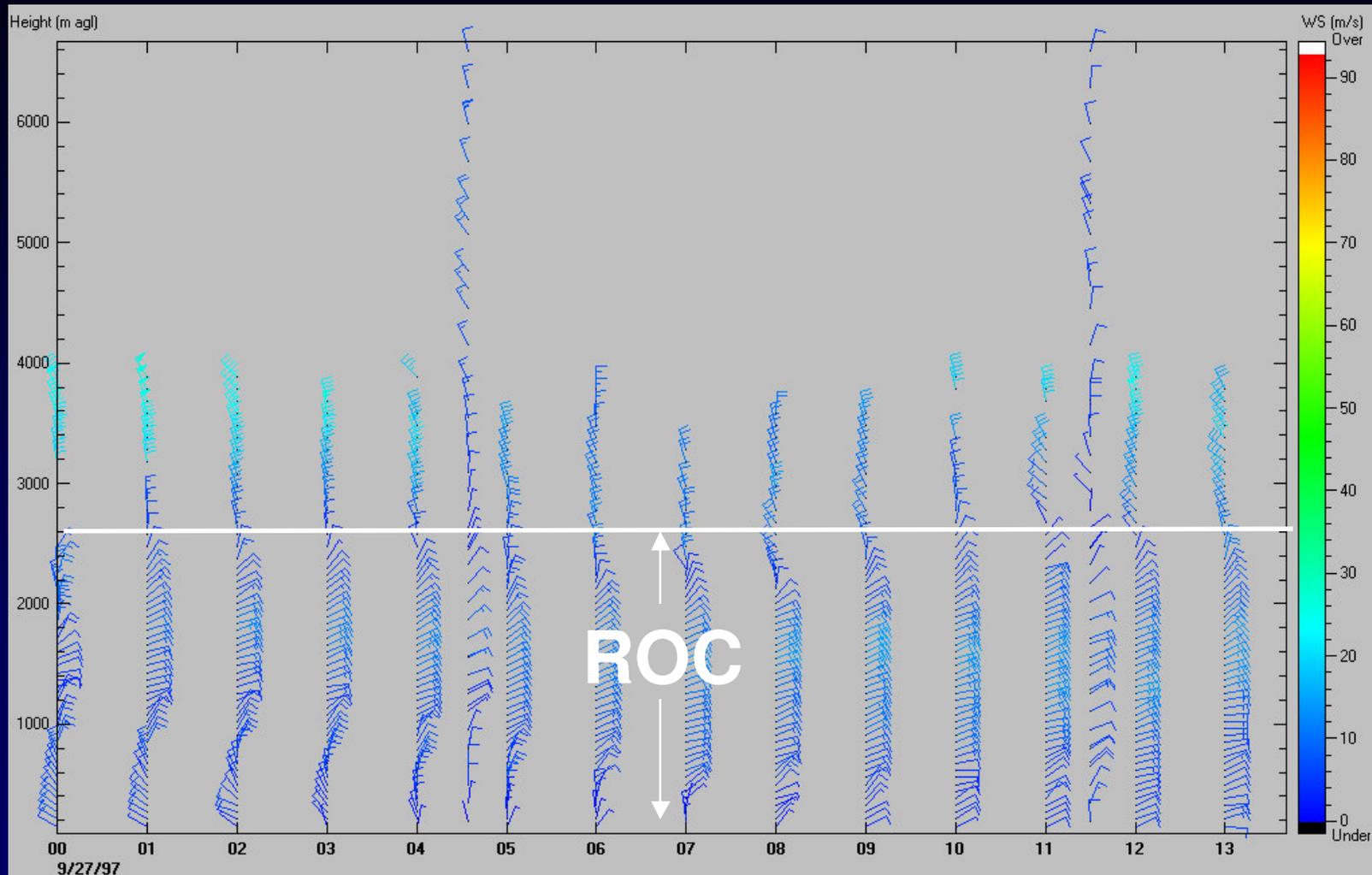
- ⇒ Audits revealed configuration problems with instruments
- ⇒ Preliminary analyses revealed bad data
- ⇒ Data from two processing methods (Met_0, Met_1) were submitted, with no determination as to which is best
- ⇒ Separate low- and high-mode data were submitted
- ⇒ Met_0 and Met_1 produced data when consensus did not
- ⇒ Objective QC alone was used, removing only some bad data

Data Validation Project RASS



Level 0.5 T_v data at Point Loma on August 4, 1997

Data Validation Project Winds



Example of poor radar profiler/RASS and rawinsonde wind comparison above the region of consensus (>2500 m)

Data Validation Project Effort

- ⇒ Corrected configuration problems
- ⇒ Reprocessed data
- ⇒ Determined which data set (Met_0 or Met_1) best represented the actual meteorological conditions
- ⇒ Merged high- and low-mode data
- ⇒ Set new data validation flags based on consensus
- ⇒ Performed subjective QC

Project Review Field Program Quality Assurance

- ⇒ Review candidate monitoring sites and aid in the site selection process
- ⇒ Perform system and performance audits early in the program to enable early identification and correction of potential problems
- ⇒ Assess the accuracy of the data collected

Field Program Quality Assurance Scope

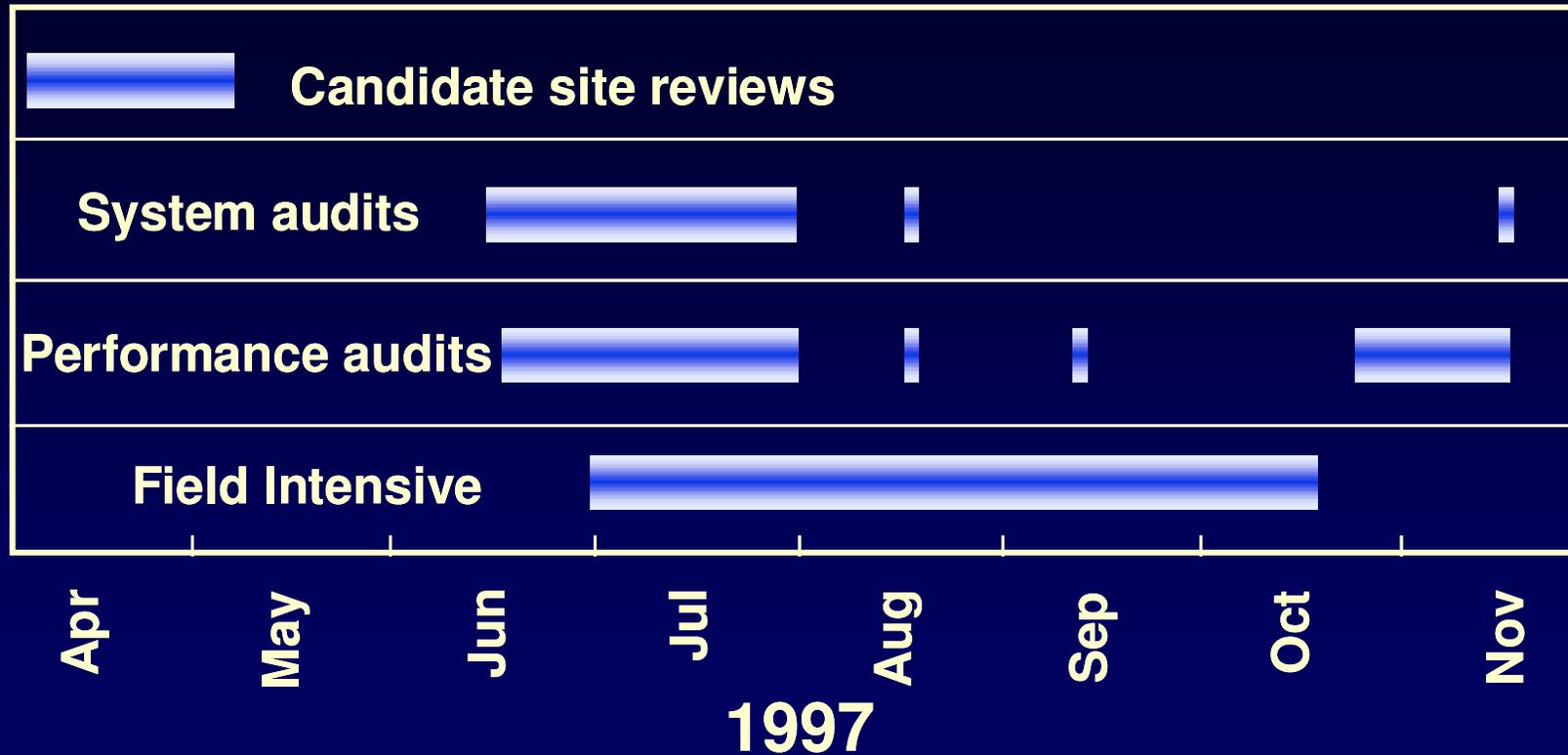
- ⇒ Candidate site reviews (16 sites)
- ⇒ System audits (26 stations)
- ⇒ Performance audits
 - 25 surface meteorological stations
 - 4 sodars
 - 10 radar profilers/RASS systems
- ⇒ Assessment of overall data quality from surface and upper-air measurements

Field Program Quality Assurance

Equipment and Variables Audited

- ⇒ Radar profilers with RASS
 - NOAA/ETL 915 MHz three-axis
 - Radian 915 MHz phased-array
- ⇒ Sodars
 - NOAA/ETL two-axis
 - Radian phased-array
 - AeroVironment three-axis
- ⇒ Surface meteorology (WS, WD, T, RH)

Field Program Quality Assurance Program Schedule



Field Program Quality Assurance Audit Activities

- ⇒ Candidate site reviews
- ⇒ System audits
- ⇒ Performance audits
- ⇒ Exposure for measurements
- ⇒ Noise sources
 - RF analysis
 - AF analysis
- ⇒ Power, security and communications
- ⇒ Compatibility with neighbors
- ⇒ Suitability for measurements
- ⇒ Suitability for audit instrumentation
- ⇒ Assessment of appropriate beam directions

Field Program Quality Assurance Audit Activities

- ⇒ Candidate site reviews
- ⇒ System audits
- ⇒ Performance audits
- ⇒ System audit checklist
 - Observables, equipment, exposure, operations
 - Procedures, training, data chain of custody
 - Preventive maintenance
- ⇒ Site vista evaluation
 - Orientation, level
 - Picture documentation
- ⇒ Operating environment
 - Background noise
 - Potential sources of interference

Field Program Quality Assurance Sample Picture Documentation



000°



045°



090°



135°



180°



225°



270°



315°

View of Site →



Field Program Quality Assurance Audit Activities

- ⇒ Candidate site reviews
- ⇒ System audits
- ⇒ Performance audits (surface)
 - ⇒ Wind speed
 - Response
 - Starting threshold
 - ⇒ Wind direction
 - Alignment to true north
 - Response
 - Starting threshold
 - ⇒ Temperature
 - ⇒ Relative humidity

Field Program Quality Assurance Audit Activities

- ⇒ Candidate site reviews
- ⇒ System audits
- ⇒ Performance audits (upper-air)
 - ⇒ Radar profiler (10 sites)
 - portable sodar
 - rawinsonde
 - ⇒ RASS (10 sites)
 - rawinsonde
 - ⇒ Sodar (4 sites)
 - simulated winds using APT

Field Program Quality Assurance

Audit Program Results

- ⇒ Site operation differences among contractors
- ⇒ Systematic problems with equipment alignment
- ⇒ Equipment orientation errors in the data
- ⇒ Differences in data validation procedures among reporting groups
- ⇒ Time zone differences among contractors
- ⇒ Antenna orientation documentation problems
- ⇒ Noise contamination of sodar data
- ⇒ Processing methodology questions

Field Program Quality Assurance

Sample Data Corrections

- ⇒ Offset corrected if over 5° (reported minus actual)
- El Monte (-5° prior to July 29)
 - Central Los Angeles (+19° prior to July 2)
 - Van Nuys (+6° prior to July 10)
 - Hesperia (-7° prior to July 17)
 - Point Loma (many changes)
 - Palmdale (+6° prior to July 5 indicated, but not implemented)

Data Validation Program

Quality Assurance Issues

- ⇒ Identification of system offsets
 - ⇒ Evaluation of post-processing algorithms
 - ⇒ Sodar data evaluation and validation
 - ⇒ Data quality descriptors
- ⇒ Audit report and data header information
 - Antenna orientation
 - Surface vane orientation
 - Time zone differences
 - Reporting interval differences

Data Validation Program

Quality Assurance Issues

- ⇒ Identification of system offsets
- ⇒ Evaluation of post-processing algorithms
- ⇒ Sodar data evaluation and validation
- ⇒ Data quality descriptors

Goal is to determine the most appropriate processing method

- ⇒ Regional site classification
 - Coastal and offshore
 - Inland
 - Desert
- ⇒ Data set comparisons
 - Met_0, Met_1, CNS, Sonde
 - Case studies
 - Comparison statistics
 - RMS
 - Systematic differences

Data Processing

Traditional

Met 0

Met 1

Radar Sampling



Spectra Data (μs)



Moments Data (Avg Spectra, ~30-s)



Consensus Avg
hourly average radials &
RASS Ca (~30, 60 min)



Vert. correction
of hourly wind
& RASS w

Continuity QC algorithm
average radials
(~1 min)



Vert. correction of hourly
average radials

Continuity QC algorithm
average radials
& RASS Ca (~1 min)



Vert. correction
of sub-hourly wind & RASS w

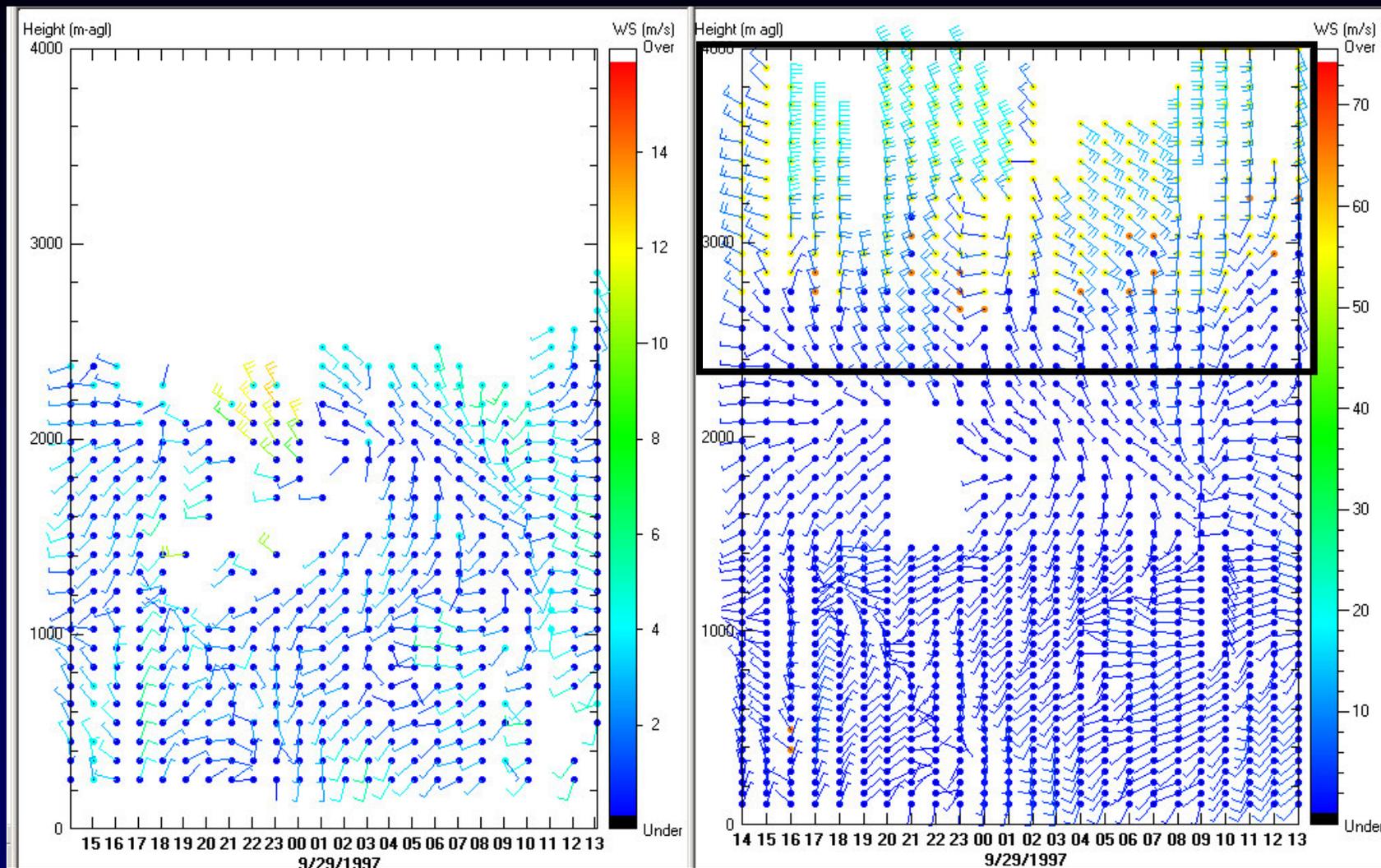


Derivation of WS, WD, & Tv



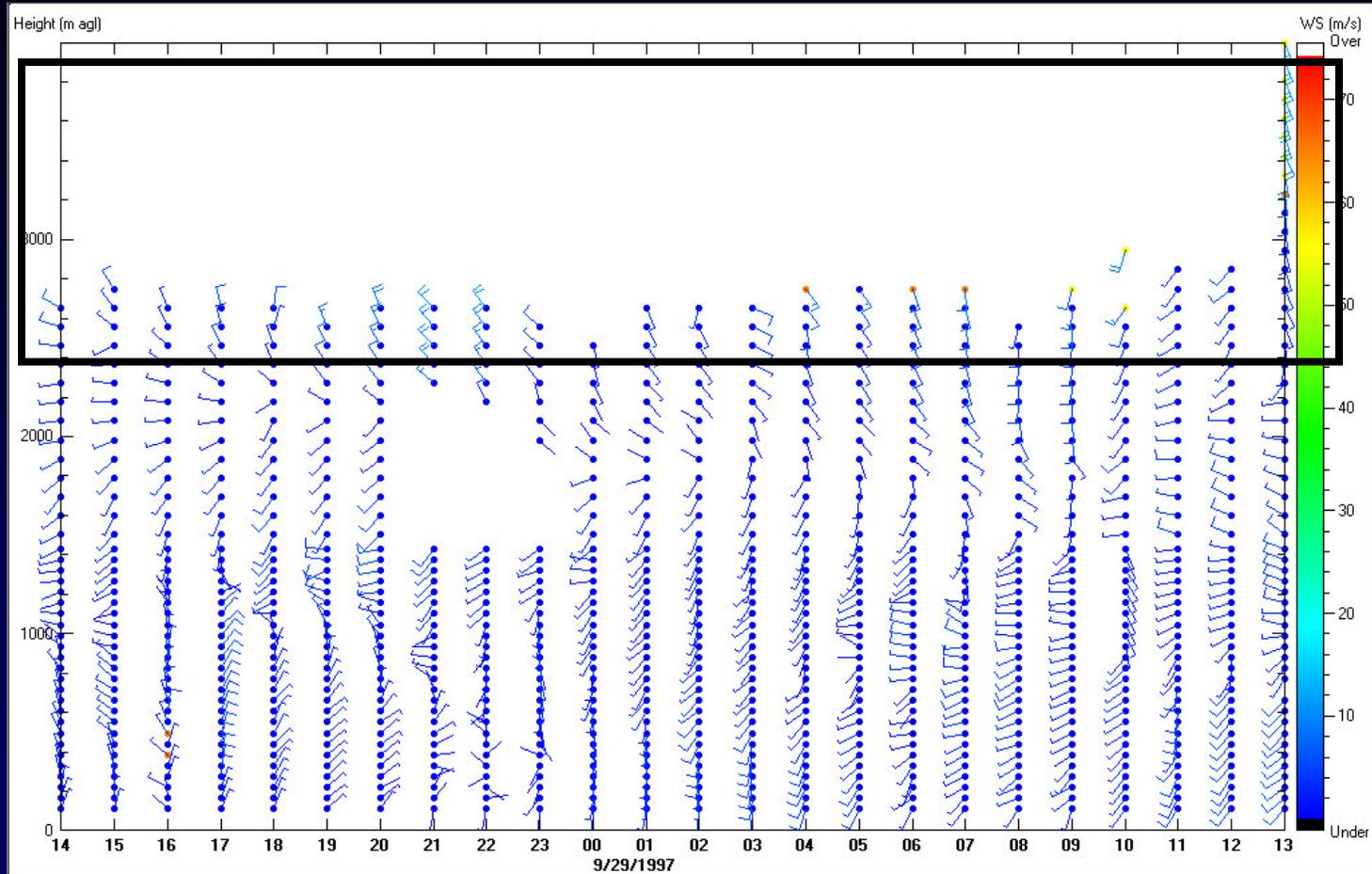
Continuity QC Algorithm

Processing Methods - Case Studies (1 of 3)



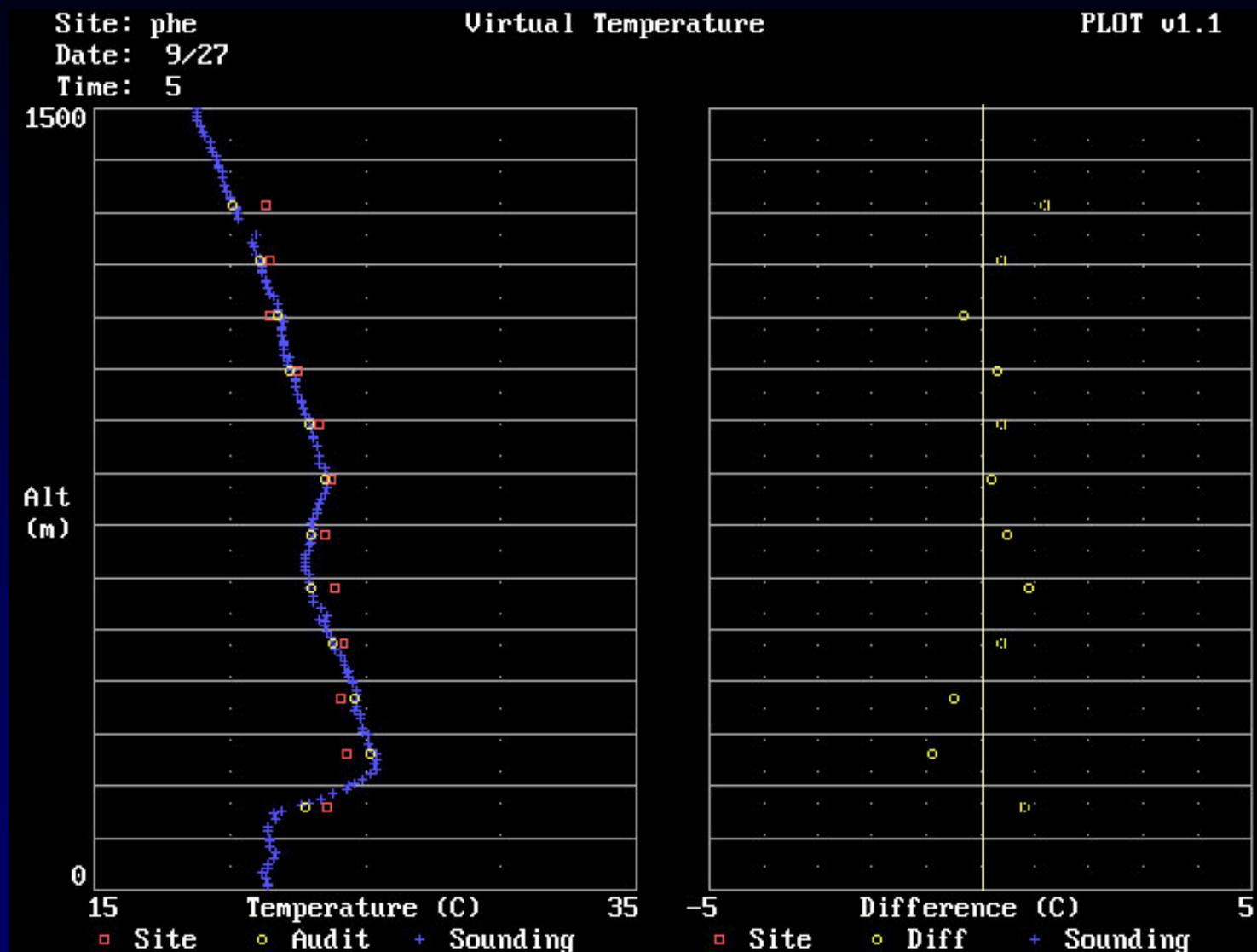
Hesperia Level 0 consensus winds (left) and Level 0.5 Met_1 winds (right) for September 28 at 1400 PST through September 29 at 1300 PST, 1997

Processing Methods - Case Studies (2 of 3)



Hesperia Level 1.0 Met_1 winds for September 28 at 1400 PST through
September 29 at 1300 PST, 1997

Processing Methods - Case Studies (3 of 3)



Processing Methods

Statistical Evaluations

	# of Data Points	Composite results -- 2 m/s threshold				Composite results -- 5 m/s threshold			
		Systematic Difference		RMS Difference		Systematic Difference		RMS Difference	
		Speed	Direction	Speed	Direction	Speed	Direction	Speed	Direction
Rawinsonde									
to low mode _0	421	1.4	21	3.8	51	2.0	25	4.7	35
to low mode _1	428	0.9	17	3.8	54	1.1	22	4.7	36
to high mode _0	397	1.1	14	3.3	47	1.3	16	3.9	32
to high mode _1	419	0.7	13	3.1	44	0.8	16	3.6	32
Radar only									
low mode _0 to _1									
27-Sep	909	0.5	2	1.8	17	0.7	1	2.3	9
28-Sep	905	0.4	0	1.9	21	0.4	1	2.0	15
29-Sep	909	0.4	0	1.3	26	0.3	3	1.5	14
30-Sep	866	0.3	0	1.0	22	0.2	1	1.0	12
high mode _0 to _1									
27-Sep	778	0.5	-2	2.0	17	0.6	-3	2.2	17
28-Sep	802	0.2	-5	2.0	34	0.0	-5	2.2	32
29-Sep	832	0.1	-3	1.5	23	-0.2	-6	1.8	22
30-Sep	785	0.2	-1	1.3	16	0.0	-2	1.4	11

Processing Methods

Overall Conclusions

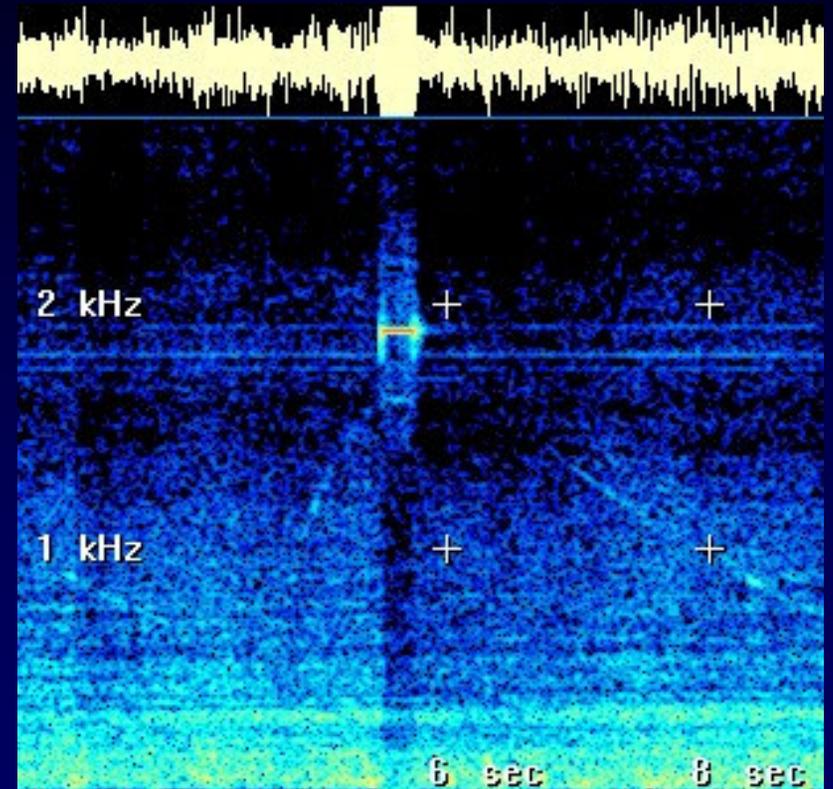
- ⇒ Met_1 processing technique provided the most robust data set with the smallest differences when compared to the rawinsonde values for both winds and temperature in each geographic region
- ⇒ Subsequent processing and data validation were performed using only the Met_1 data for each site, and additional flagging was implemented based on consensus and other criteria

Data Validation Program

Quality Assurance Issues

- ⇒ Identification of system offsets
- ⇒ Evaluation of post-processing algorithms
- ⇒ Sodar data evaluation and validation
- ⇒ Data quality descriptors
- ⇒ Review all sodar data (six sites)
- ⇒ Determine needed post-processing
 - Vertical velocity correction
 - Antenna rotations
 - Algorithm corrections
 - Interference problems (noise, reflections)

Data Validation Program Sodar Noise Interference



Data Validation Program Quality Assurance Issues

- ⇒ Identification of system offsets
- ⇒ Evaluation of post-processing algorithms
- ⇒ Sodar data evaluation and validation
- ⇒ Data quality descriptors

Metadata

- ⇒ Site-by-site descriptors
- ⇒ Data qualifiers (minor offsets, limitations)
- ⇒ Pertinent information from audits and validation

Data Merging

Objective

Merge low- and high-mode data into single data set while maximizing resolution and data coverage

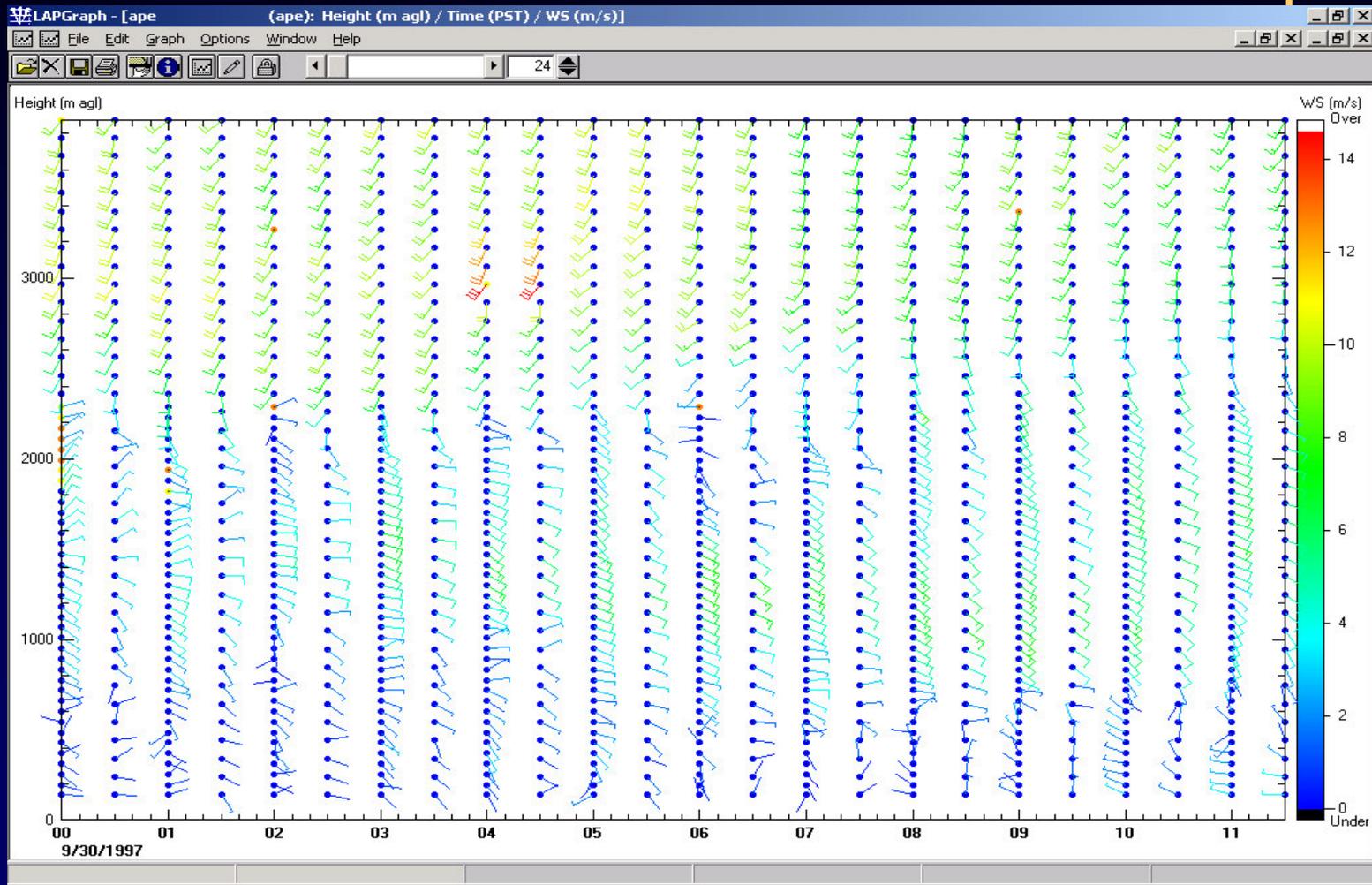
⇒ Options

- Fixed cut-point
- Variable cut-point

⇒ Choice

- Low-mode maximum altitude minus six range gates
- Determined by hour
- Surface data merged
- CCOS (set at 800 m agl)

Data Merging Example

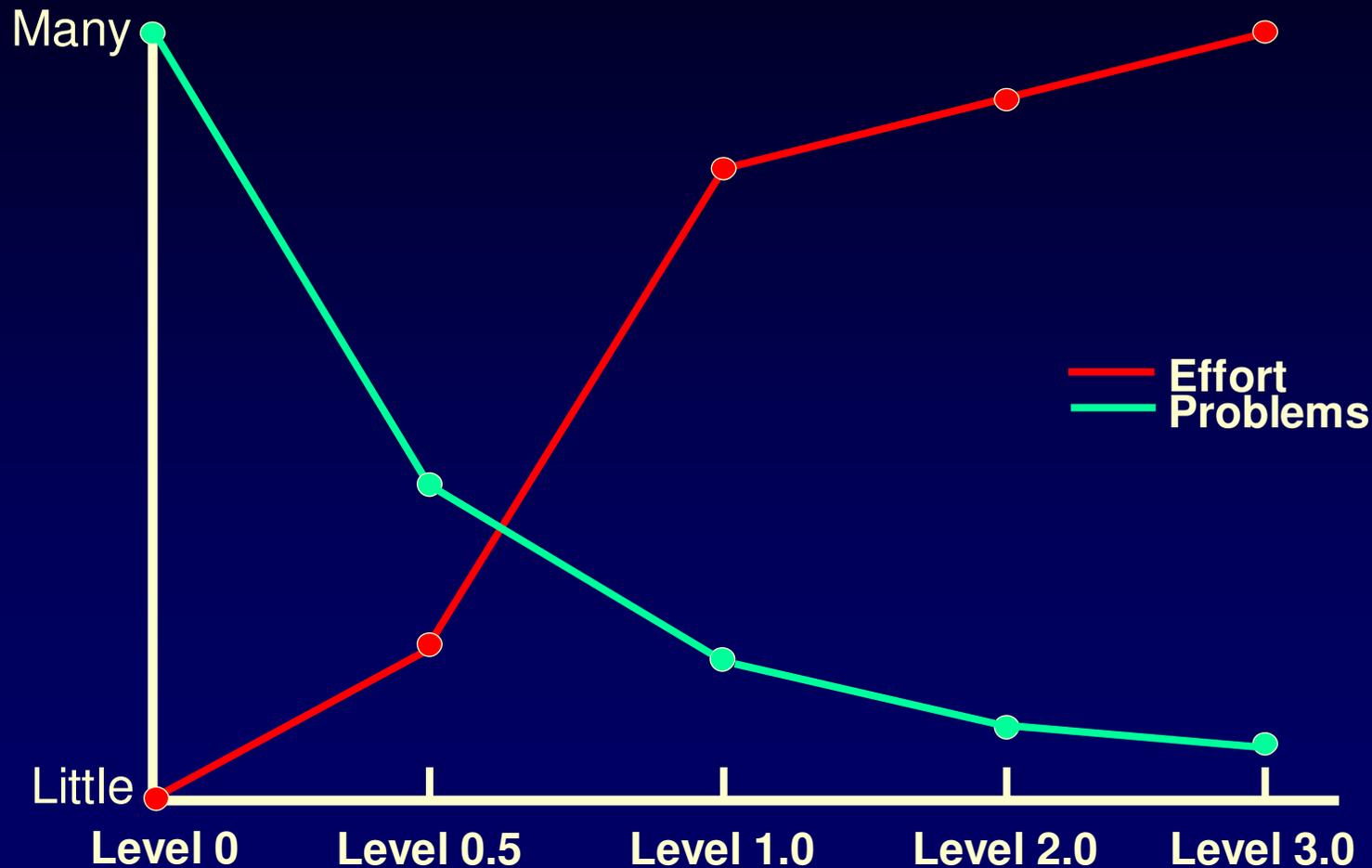


Alpine radar profiler merged and high mode (+30 minutes) Met_1 winds for September 30, 1997

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Subjective Quality Control

⇒ Objective: Bring data to a level where analysts and modelers can use the data without the need for additional quality control

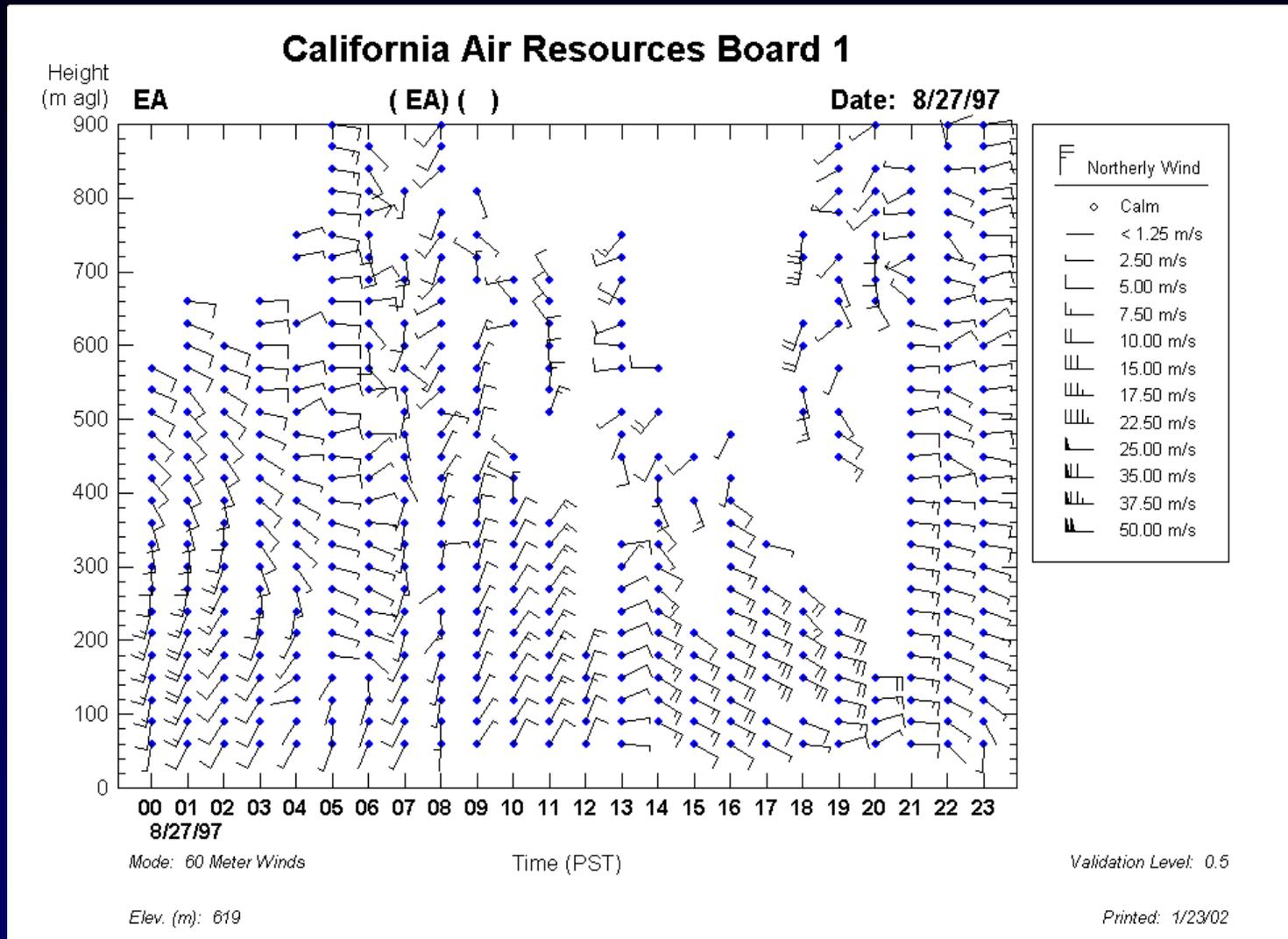


Subjective Quality Control

Potential Problems

- ⇒ Radar profiler
 - Interference from migrating birds
 - Precipitation interference
 - Ground clutter
 - Velocity folding
 - Differences as a result of processing methods
- ⇒ RASS
 - Temperature range setting
 - Radio interference
 - Cold bias (not well understood)
 - Vertical velocities
- ⇒ Sodar
 - Fixed echoes (ground clutter)
 - Noise interference

Subjective Quality Control Level 1 QC (1 of 4)

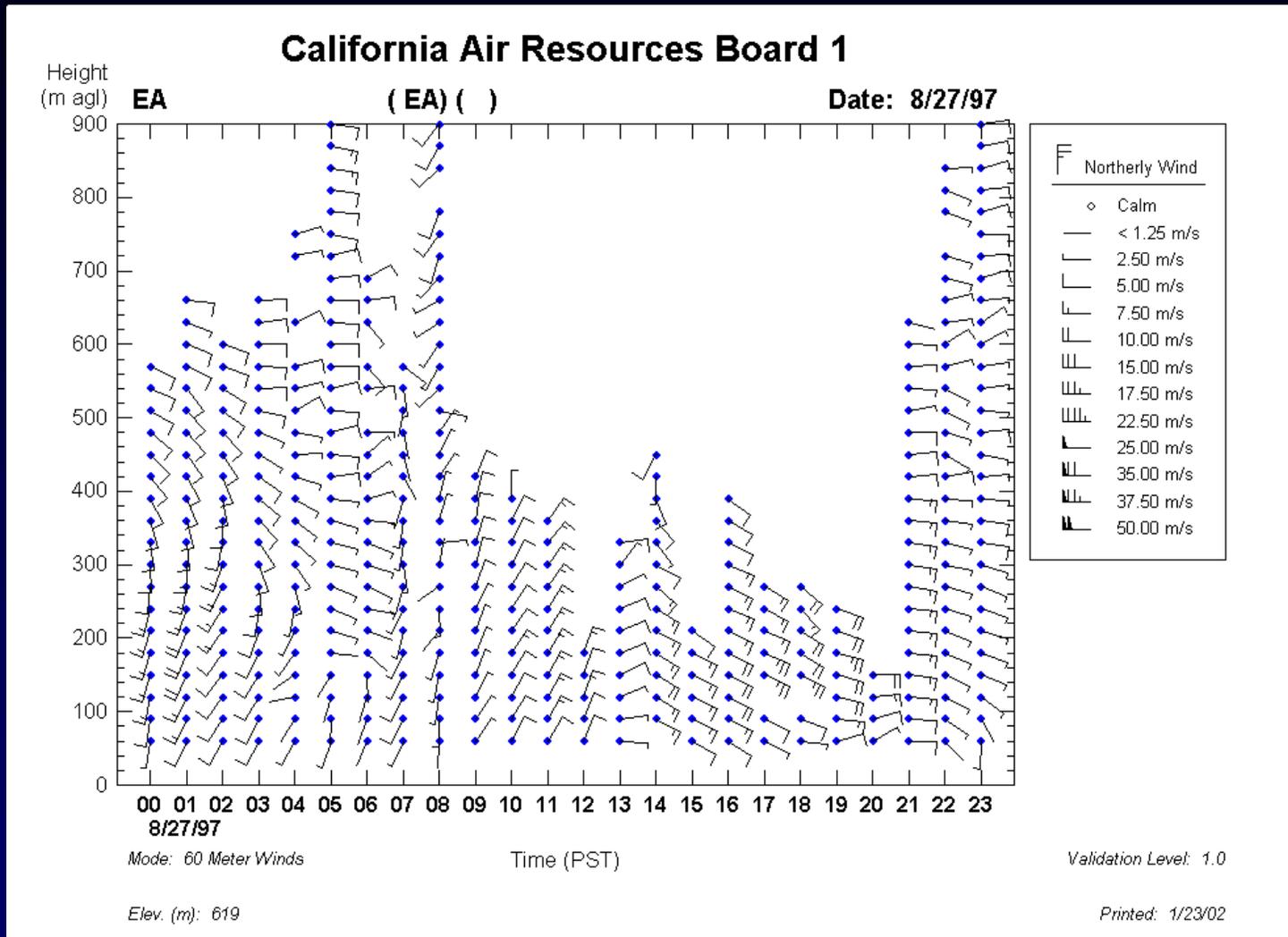


Level 0.5 validated sodar winds at 29 Palms–EAF2 on August 27, 1997

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Subjective Quality Control

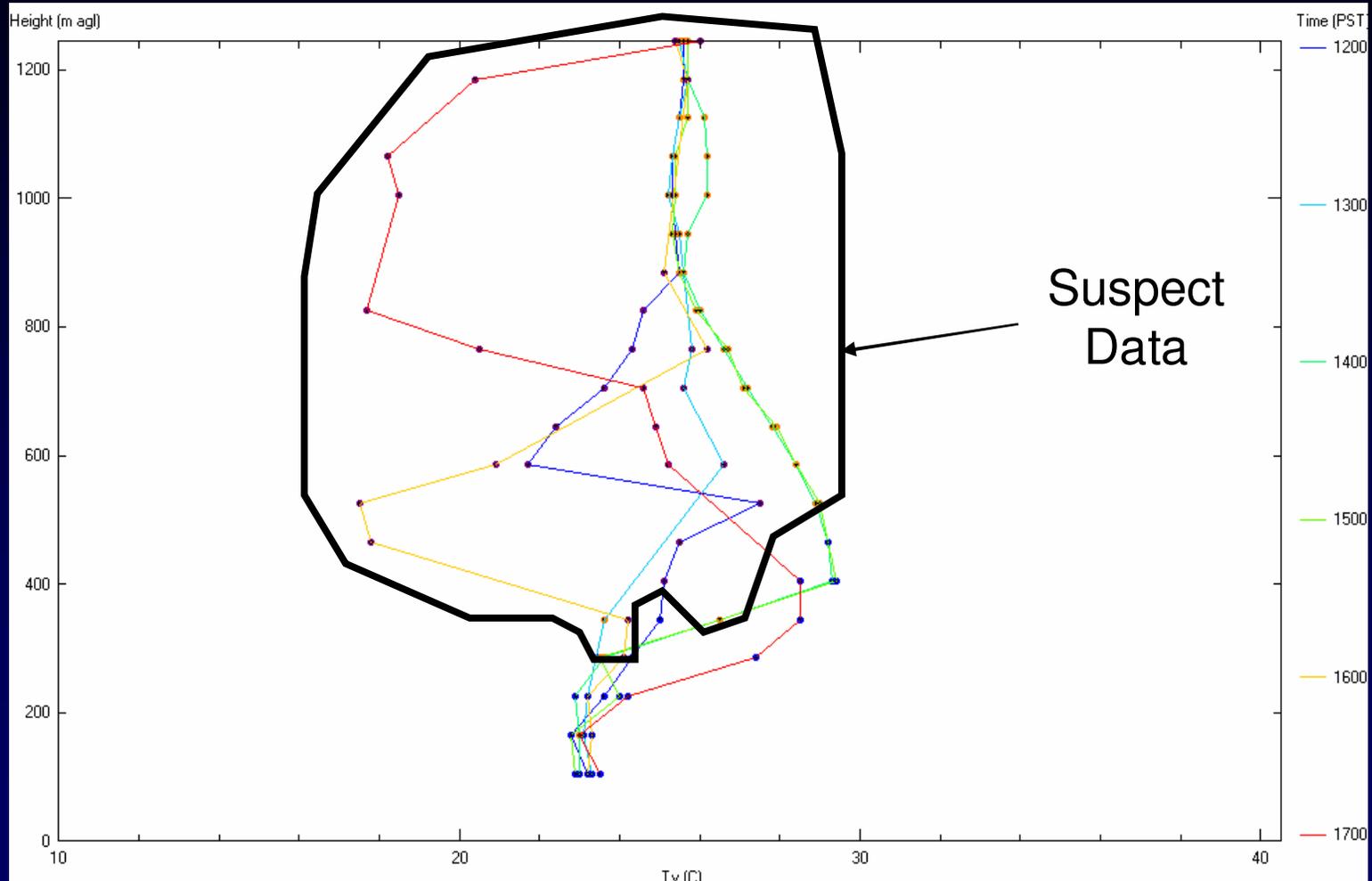
Level 1 QC (2 of 4)



Level 1.0 validated sodar winds at 29 Palms–EAF2 on August 27, 1997

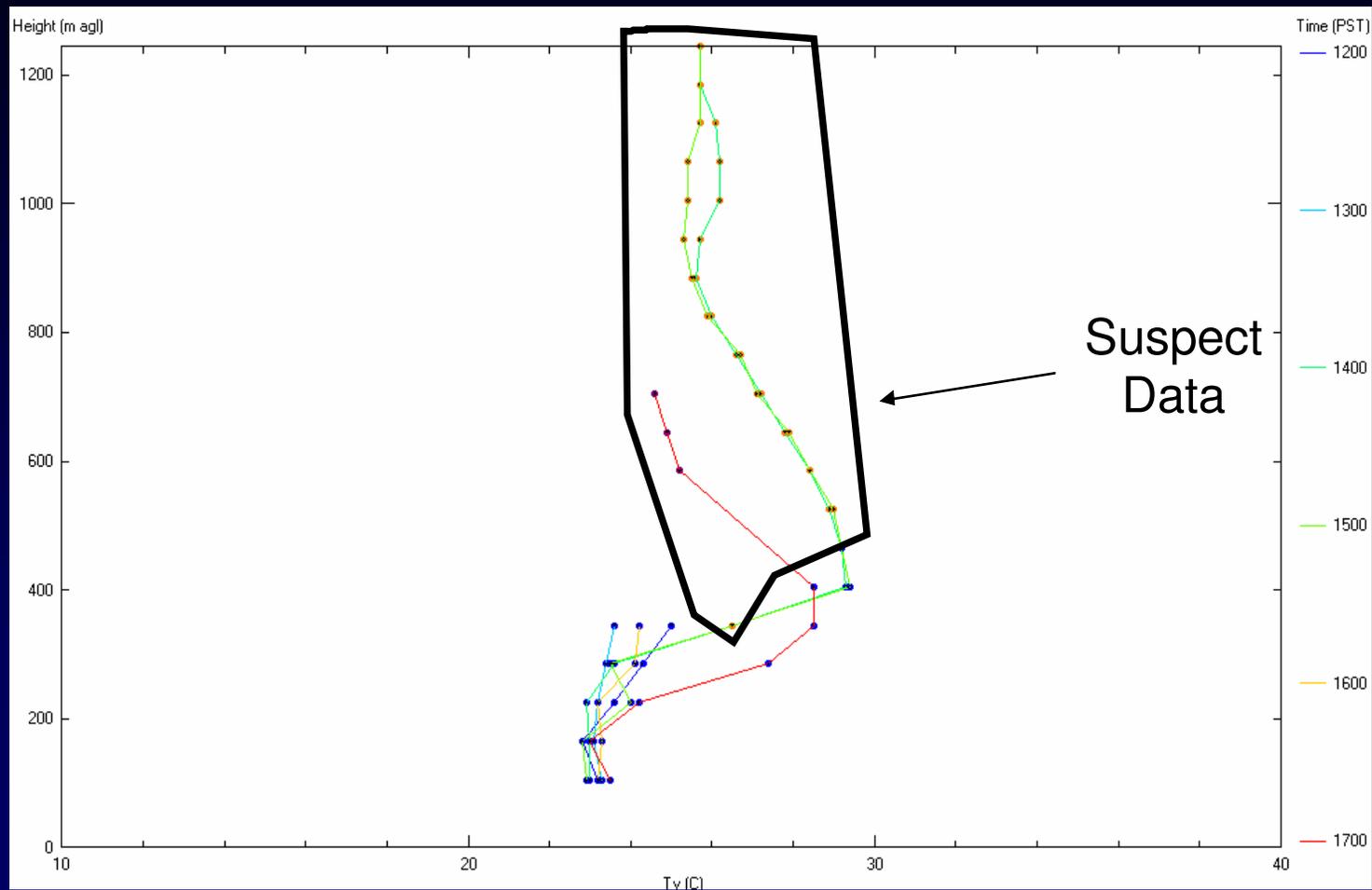
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Subjective Quality Control Level 1 QC (3 of 4)



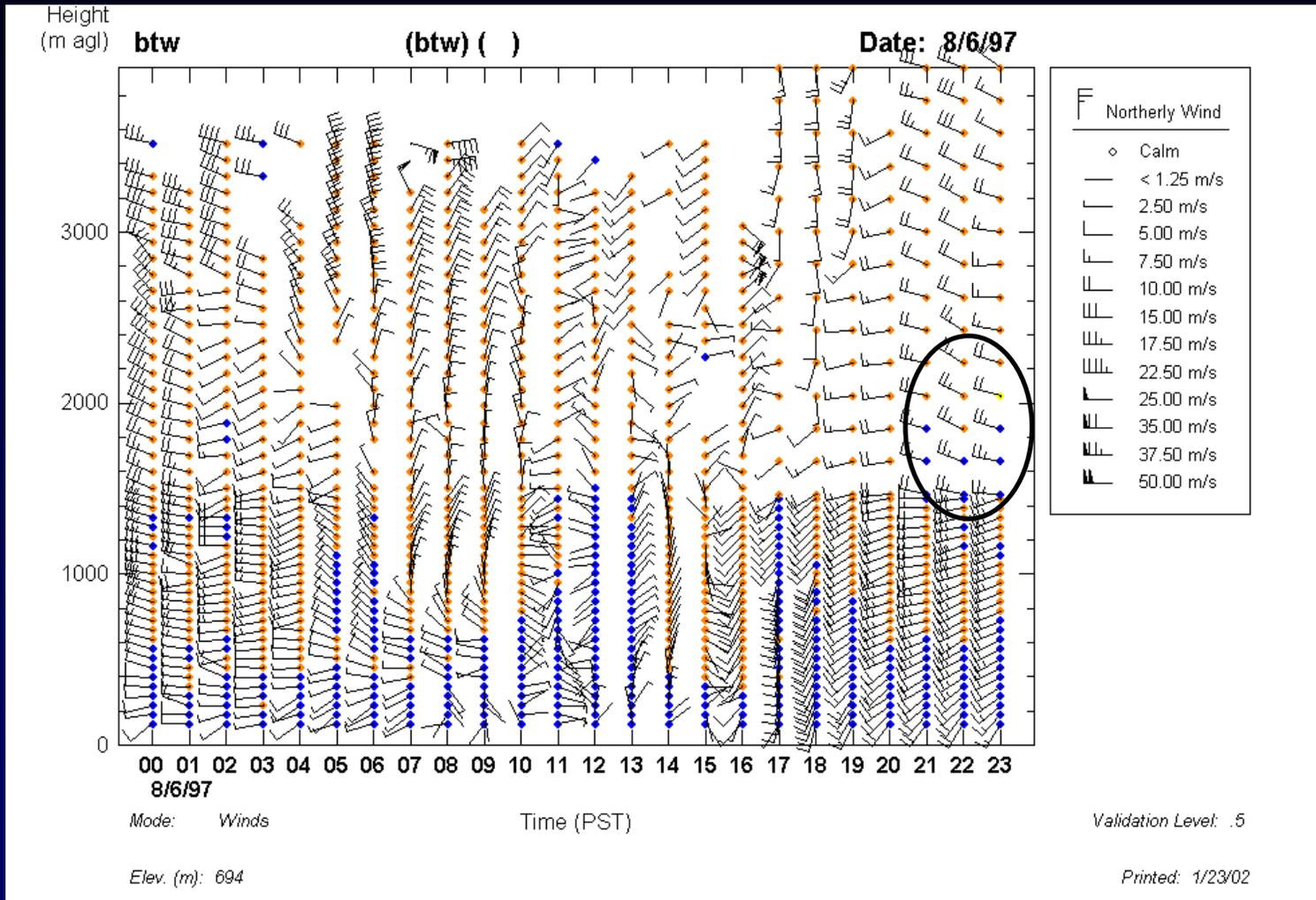
Level 0.5 T_v data at Point Loma on August 4, 1997

Subjective Quality Control Level 1 QC (4 of 4)



Level 1.0 T_v data at Point Loma on August 4, 1997

Subjective Quality Control Level 2 QC (1 of 3)



Level 0.5 wind data at Barstow on August 6, 1997. The orange dots indicate suspect data, and the blue dots indicate valid data.

Subjective Quality Control Level 2 QC (2 of 3)

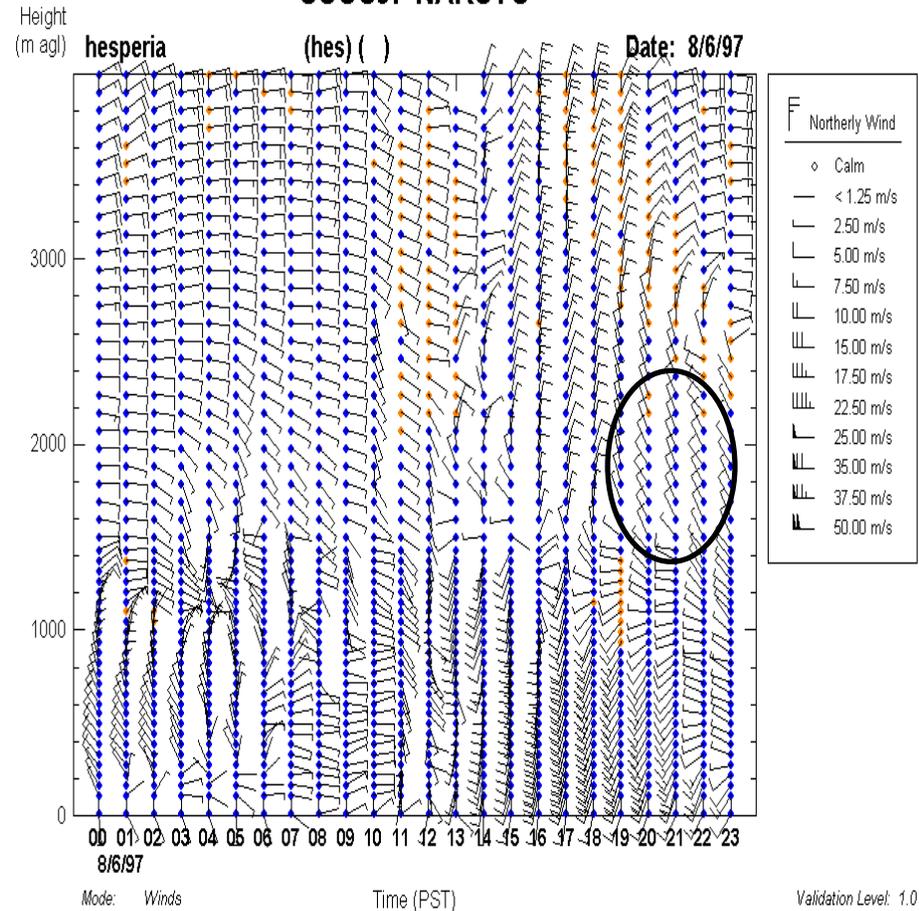
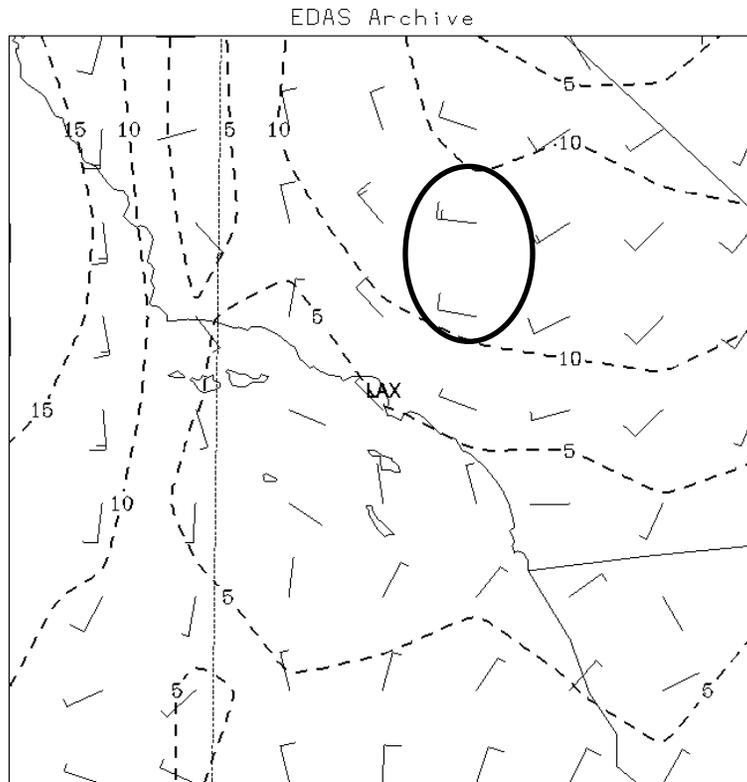


NOAA Air Resources Laboratory

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SCOS97-NARSTO

METEOROLOGICAL DATASET INFORMATION
Initialization time: 00 UTC 01 AUG 1997



WIND SPEED
WIND FLAGS
WSPD (KNTS), LVL= 800., 06 UTC 07 AUG 1997 (+ 00 H)
FLAG (KNTS), LVL= 800., 06 UTC 07 AUG 1997 (+ 00 H)

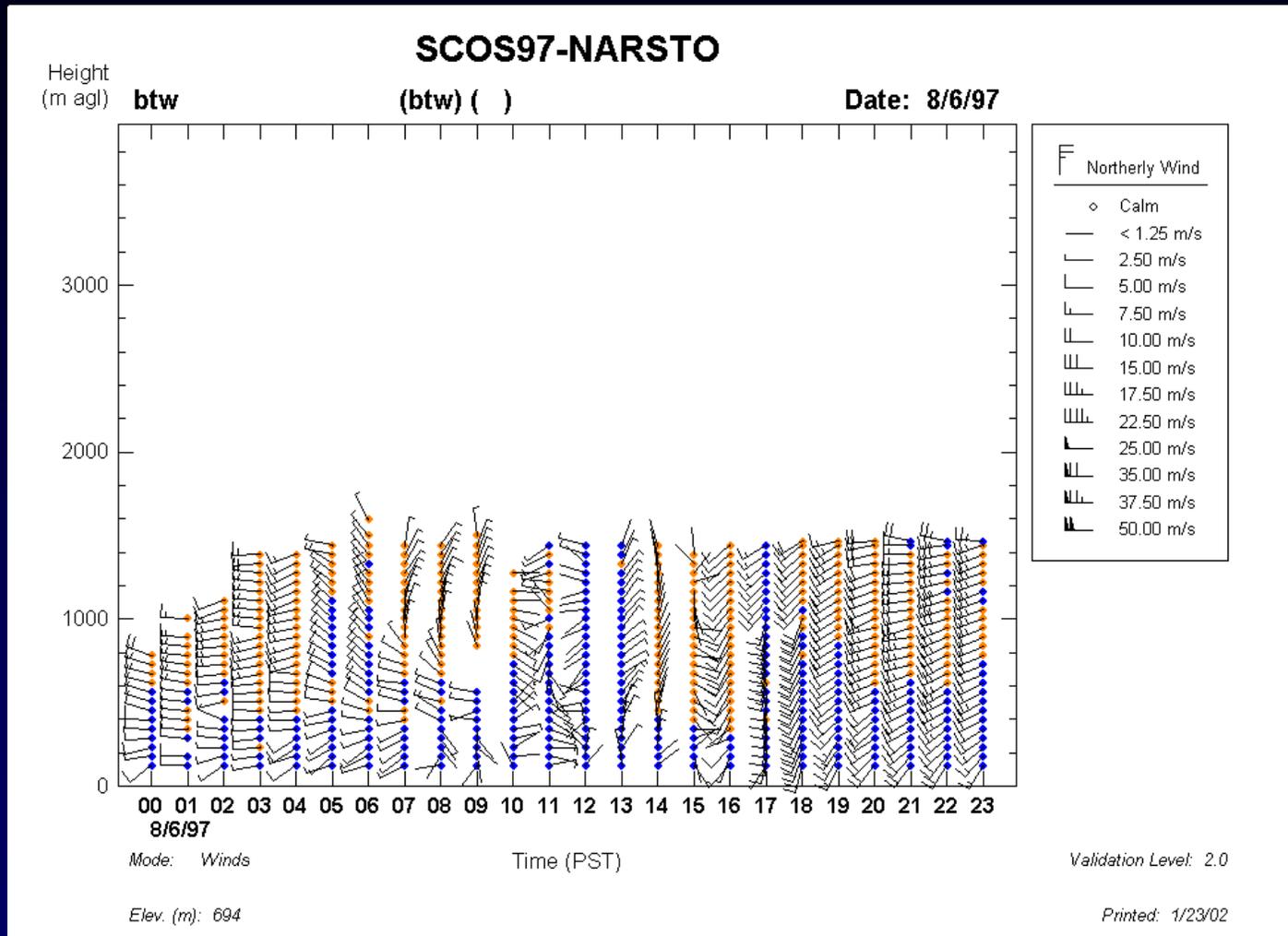
Elev. (m): 975

Printed: 1/23/02

EDAS model wind data at 0600 UTC (2200 PST) at 800 mb (right) and Level 1.0 wind data at Hesperia on August 6, 1997 (left).

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Subjective Quality Control Level 2 QC (3 of 3)



Level 2.0 wind data at Barstow on August 6, 1997. The orange dots indicate suspect data, and the blue dots indicate valid data.

Subjective Quality Control Flags

QC Flag	Meaning	Criteria	Notes	Recommendation for use of data
0	Valid	Passed all subjective and objective QC.		Can be used with high confidence at Level 1.0 and Level 2.0 validation*.
5	Suspect	Passed initial QC processing. Collected above 2000 m agl. Collocated consensus data was invalid. Passed signal-to-noise criteria. Passed all subjective QC.	Data below 2000 m agl was not addressed by this code because consensus might fail due to significant sub-hourly wind shifts often observed within the boundary layer.	Can be used with moderate confidence at Level 1.0 validation* and higher confidence at Level 2.0 validation*.
6	Suspect	Passed initial QC processing. Collocated consensus data invalid. Failed signal-to-noise criteria. Passed all subjective QC.		Can be used with moderate confidence at Level 1.0 validation* and higher confidence at Level 2.0 validation*.
7	Suspect	Passed all objective QC. Not clearly invalid or valid based on subjective QC or data appears valid but with unresolved processing issues.		Can be used with moderate confidence at Level 1.0 validation* and higher confidence at Level 2.0 validation*.
8	Invalid	Failed either objective or subjective QC.	Data values are -980.0.	Do not use.
9	Missing		Data values are -999.0.	Do not use.

Final Result

- ⇒ A data set ready for use by analysts and modelers
 - RASS T_v and radar profiler winds from 26 sites
 - Sodar winds from 6 sites
 - Level 1 data for ~150 days
 - Level 2 data for 35 days →
- ⇒ Metadata and QC flags
- ⇒ An evaluation of processing methods
- ⇒ Recommendations for other projects

Date	Episode Type	Number of Days
8/2 to 8/8	Ozone	7
8/26 to 8/28	Aerosol	3
9/2 to 9/7	Ozone (Aerosol)	6 (3)
9/9 to 9/13	Aerosol	5
9/26 to 9/30	Ozone (Aerosol)	5 (3)
10/2 to 10/5	Ozone	4
10/29 to 11/2	Ozone	5
Total		35

Data Validation Program

Overall Recommendations

- ⇒ Audits at each station
- ⇒ Consistent procedures implemented by each audit group
- ⇒ Implementation and adherence to SOPs by all study organizations
- ⇒ Thorough on-site documentation process in both the operations and QA
- ⇒ Use of proven data processing methods
- ⇒ Review of data in “real-time”
- ⇒ Frequent objective and subjective quality control
- ⇒ Production of one unified data set

Specific Ideas Plans and Audits

- ⇒ Realistic monitoring plans
 - Checklists
 - SOPs
 - Audit program
- ⇒ Cost-effective, alternative audit methods
 - Systems audits of all sites
 - Network assessment for number of performance audits
 - Simple pibal soundings
 - Simple tethered sensors
 - Adjacent towers or soundings



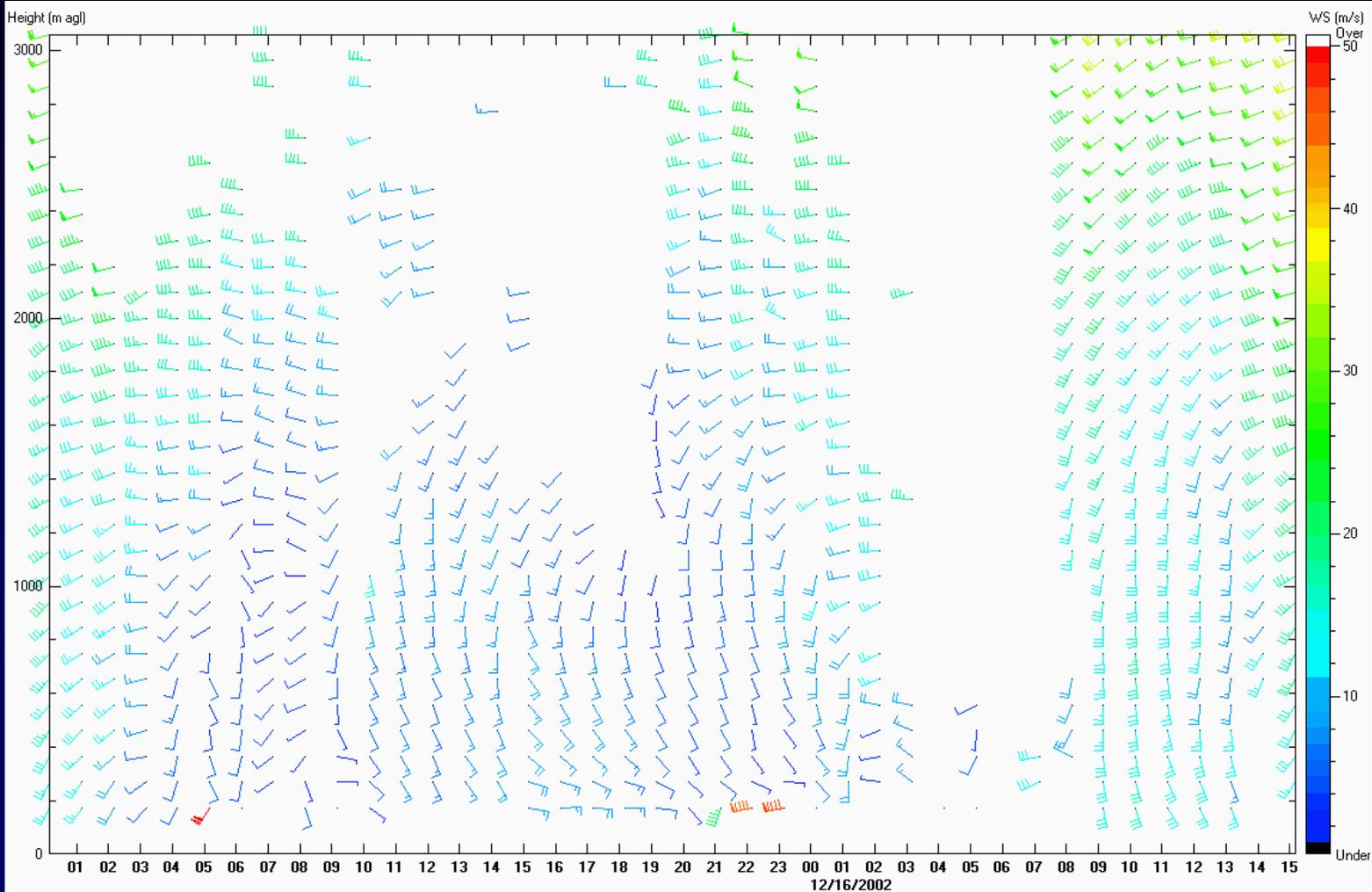
Specific Ideas

Advanced Data Processing Techniques

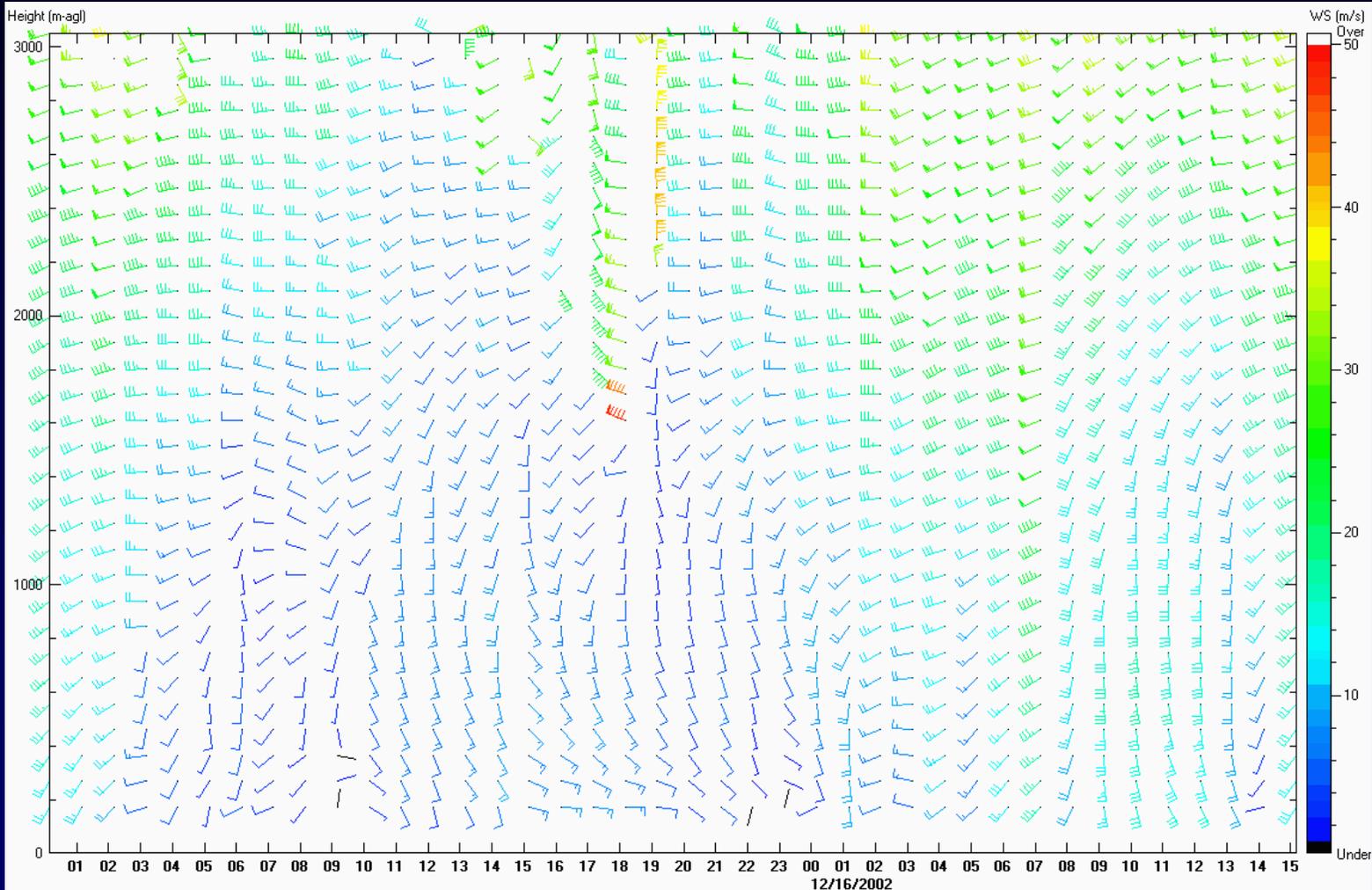
- ⇒ Uses the SCOS97 processing lessons learned
- ⇒ Implements techniques to recover data lost in the traditional (consensus) methods
- ⇒ Can be implemented in real-time to increase the efficiency in data collection and analysis

Processing Techniques - Consensus Data

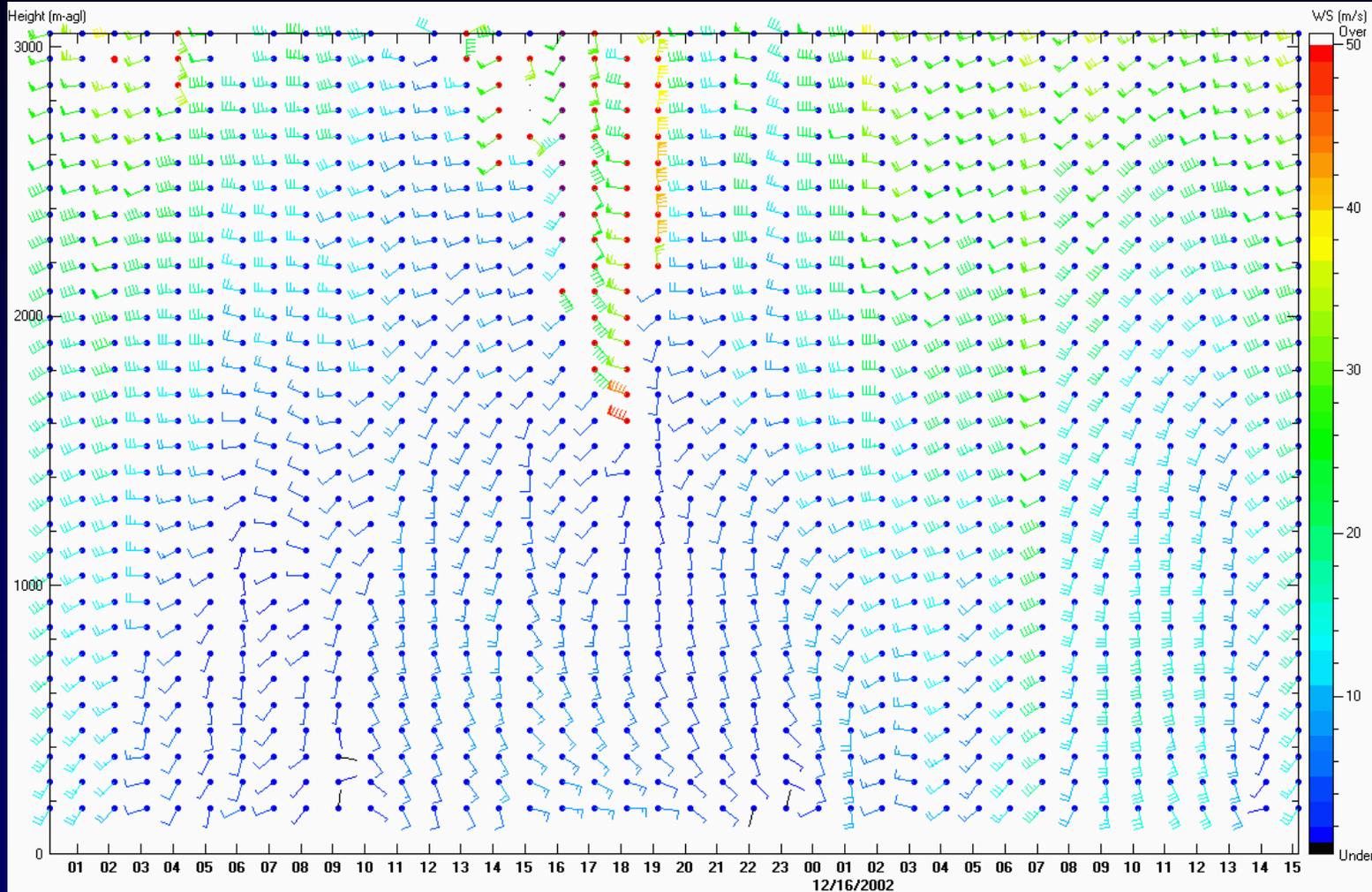
Specific Ideas



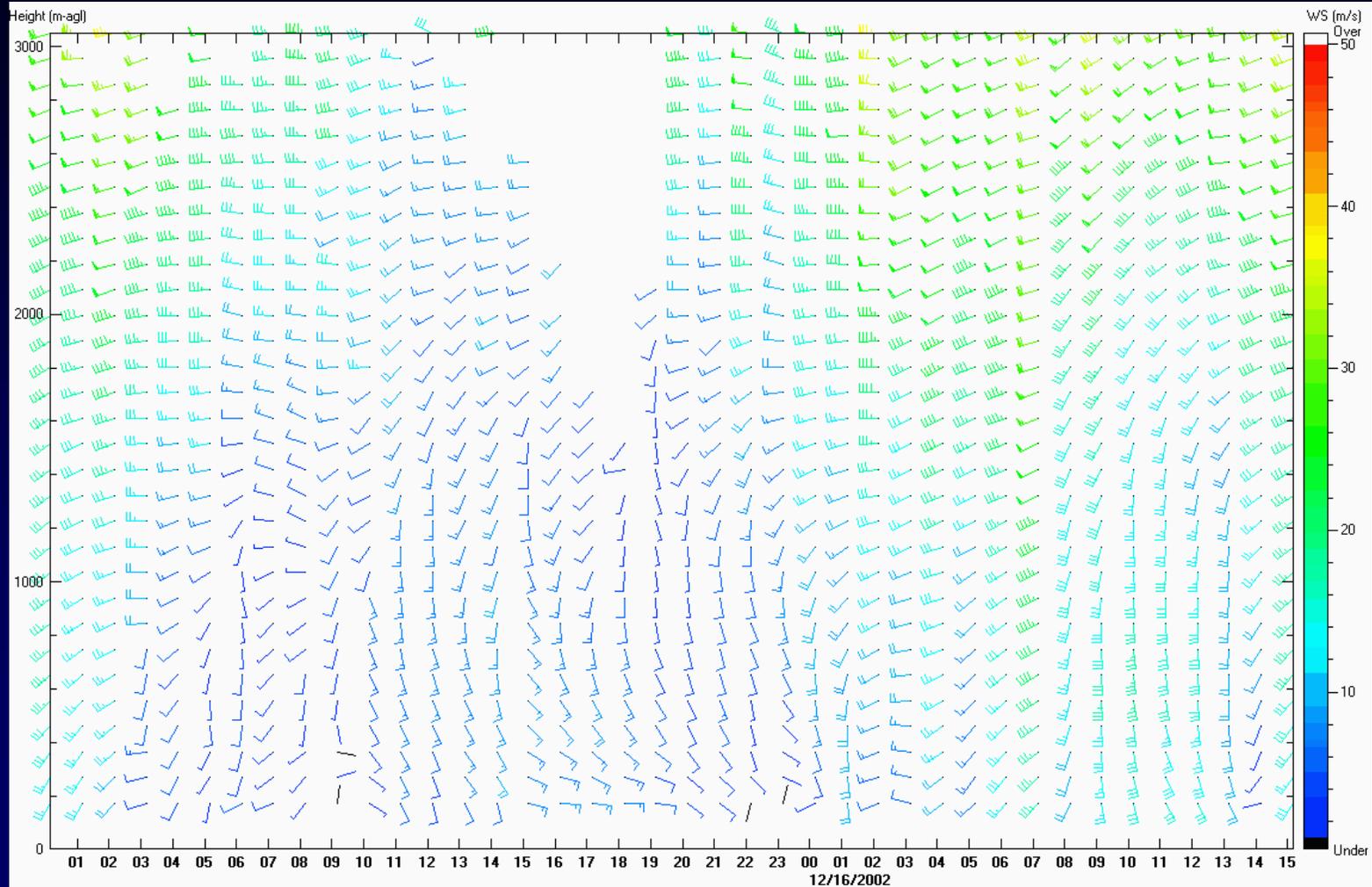
Specific Ideas Processing Techniques - Met_1 Data



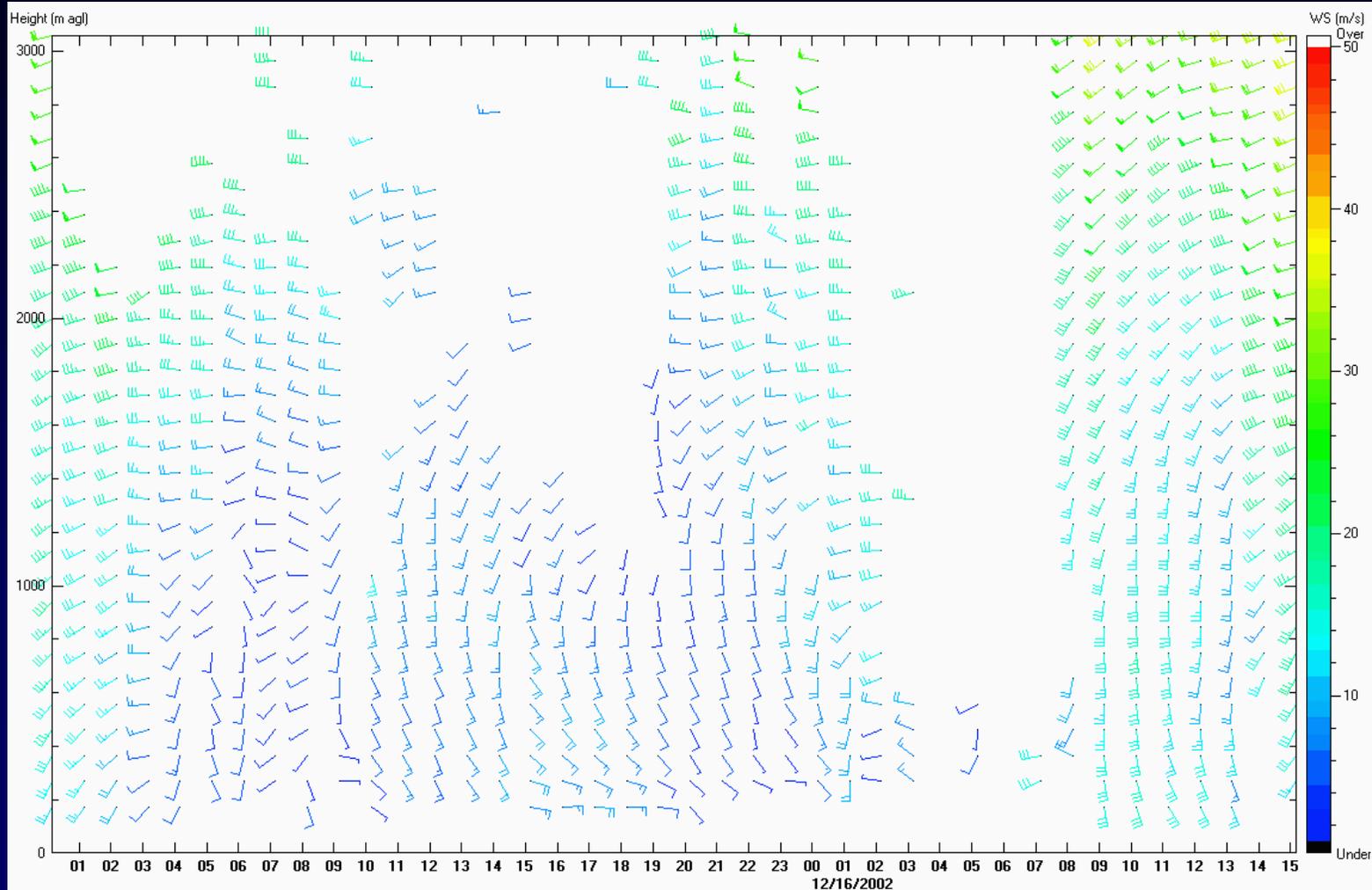
Specific Ideas Processing Techniques - QC'd (Met_1)



Specific Ideas Processing Techniques - Validated (_1)



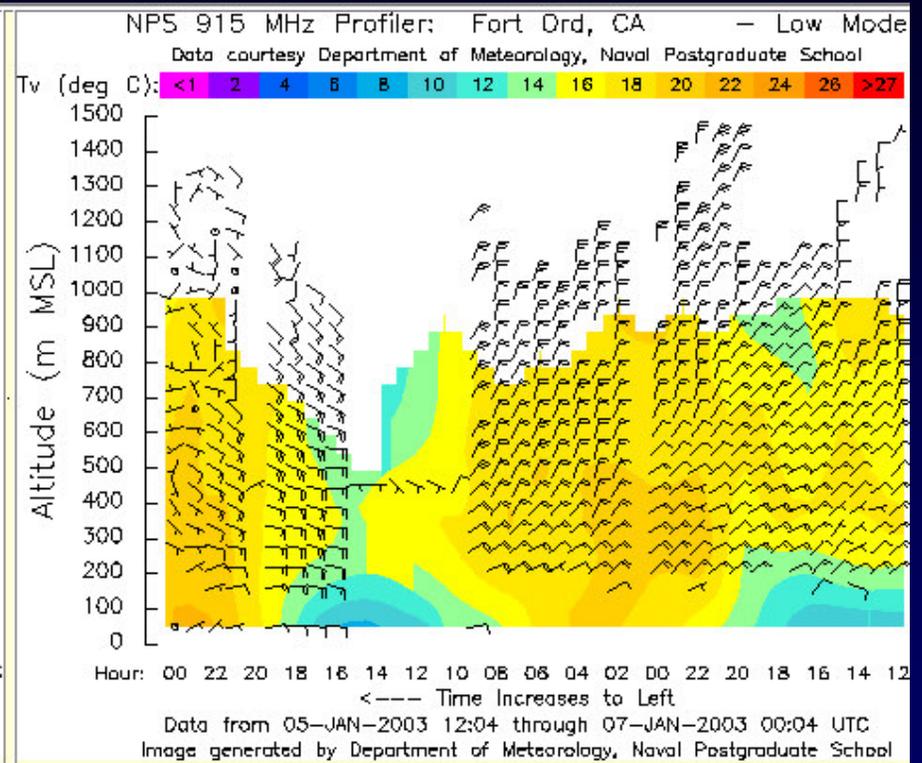
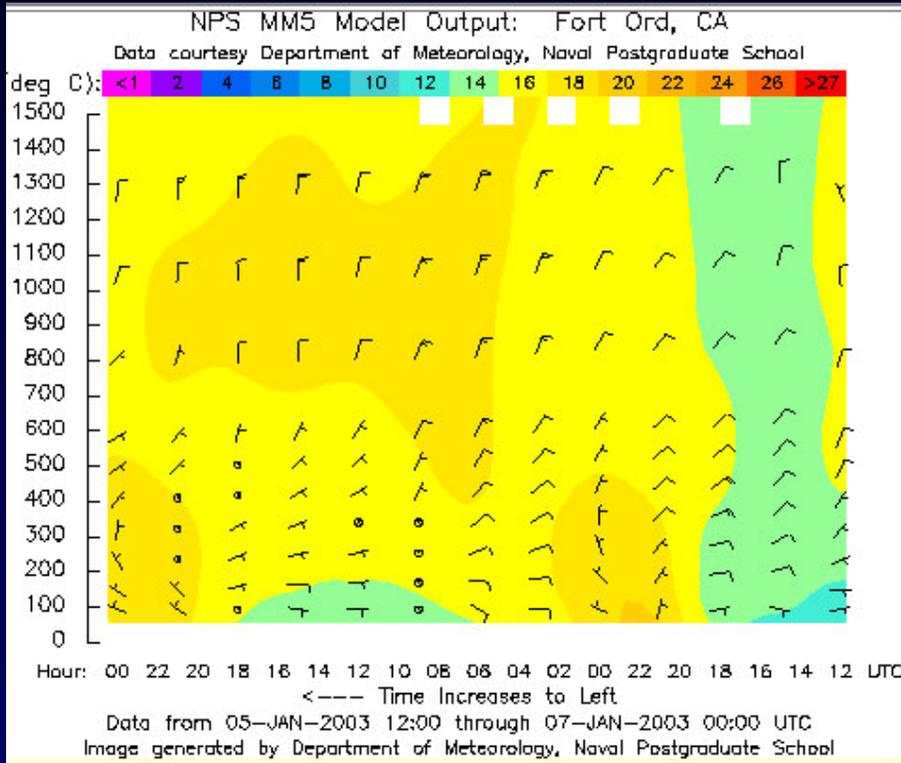
Specific Ideas Processing Techniques - Valid Consensus



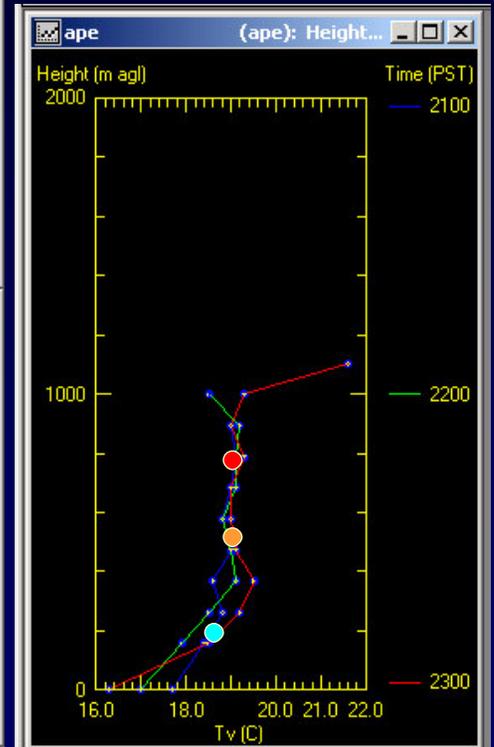
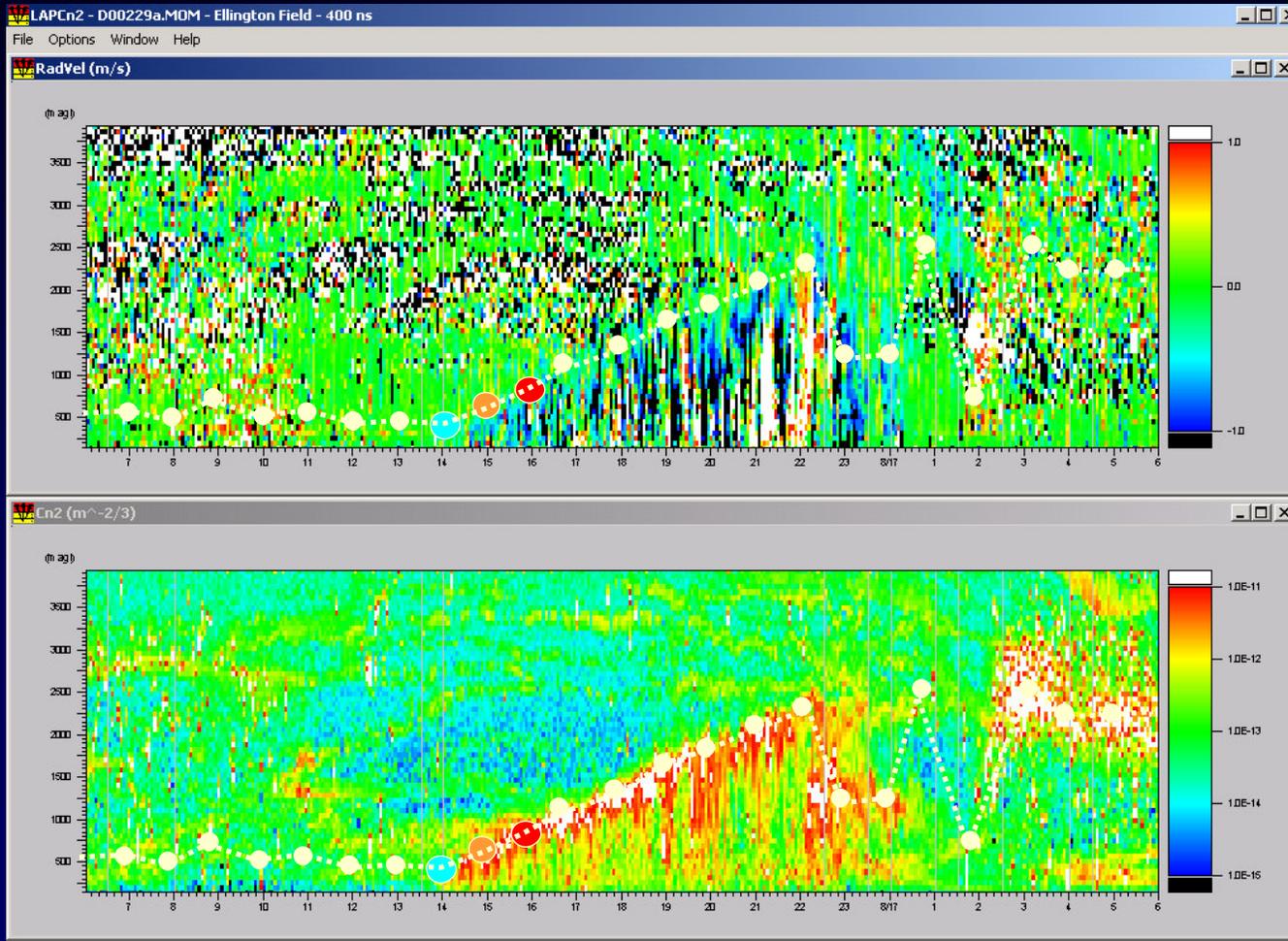
Specific Ideas Reviews and Products

- ⇒ Real-time data reviews (objective and subjective)
 - Automatic site-to-site comparisons
 - Model-to-site comparisons
- ⇒ Additional products (real-time and historic)
 - Site analyses
 - Wind runs
 - Mixing
 - Spatial analyses
 - Modeling (prognostic nudging or diagnostic)
 - Trajectories
 - Mixing

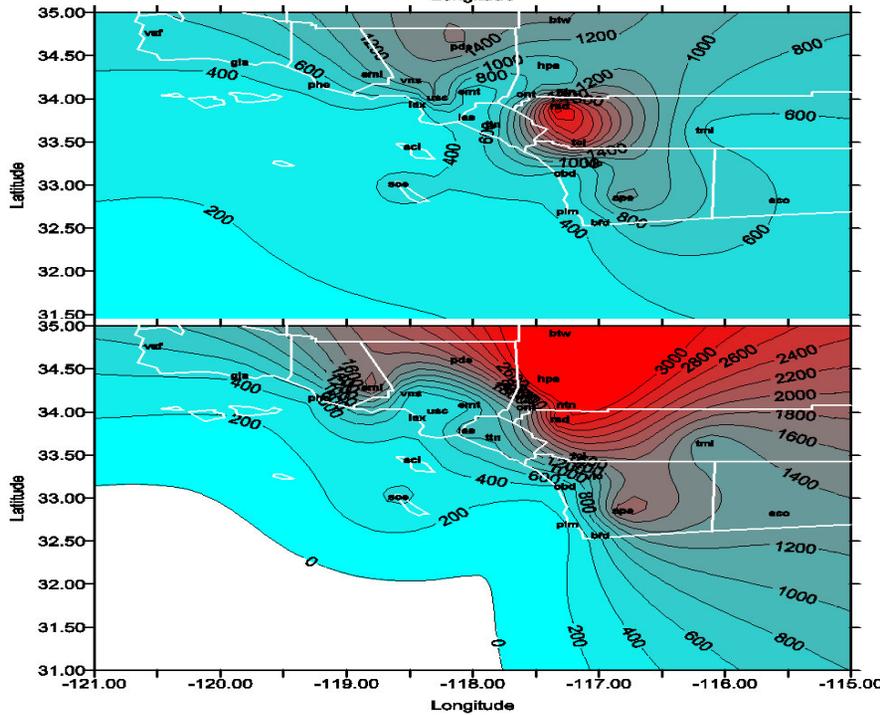
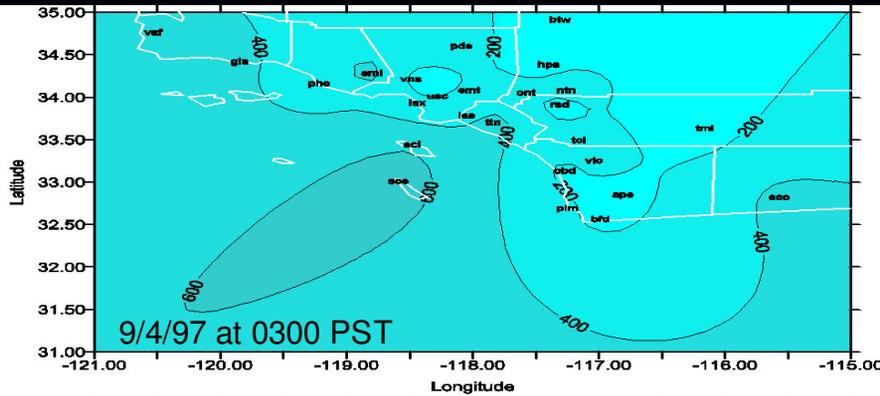
Specific Ideas Reviews



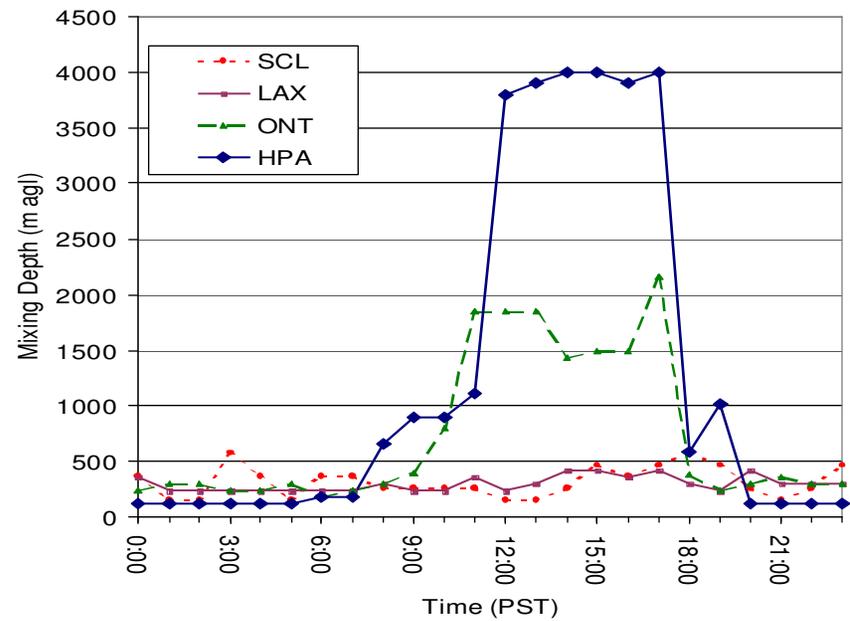
Specific Ideas Products – Mixing



Specific Ideas Products – Mixing



Mixing on 9/4/97 at 0300, 1000, and 1400 PST.



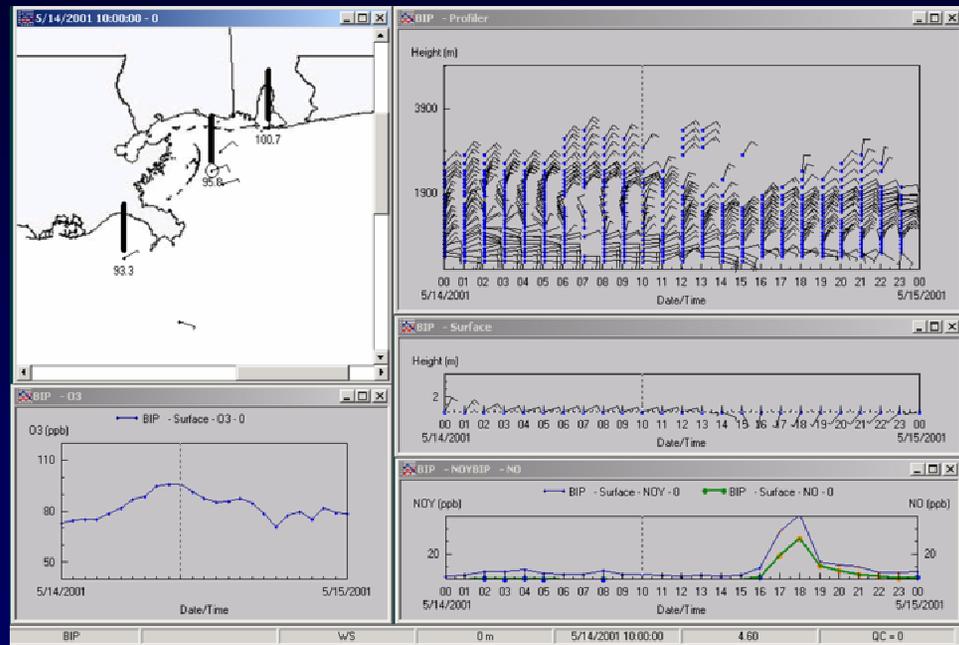
Specific Ideas Products – Spatial Analysis

⇒ EDAT displays radar profiler/RASS, rawindsonde, surface meteorological, and modeling data sets.

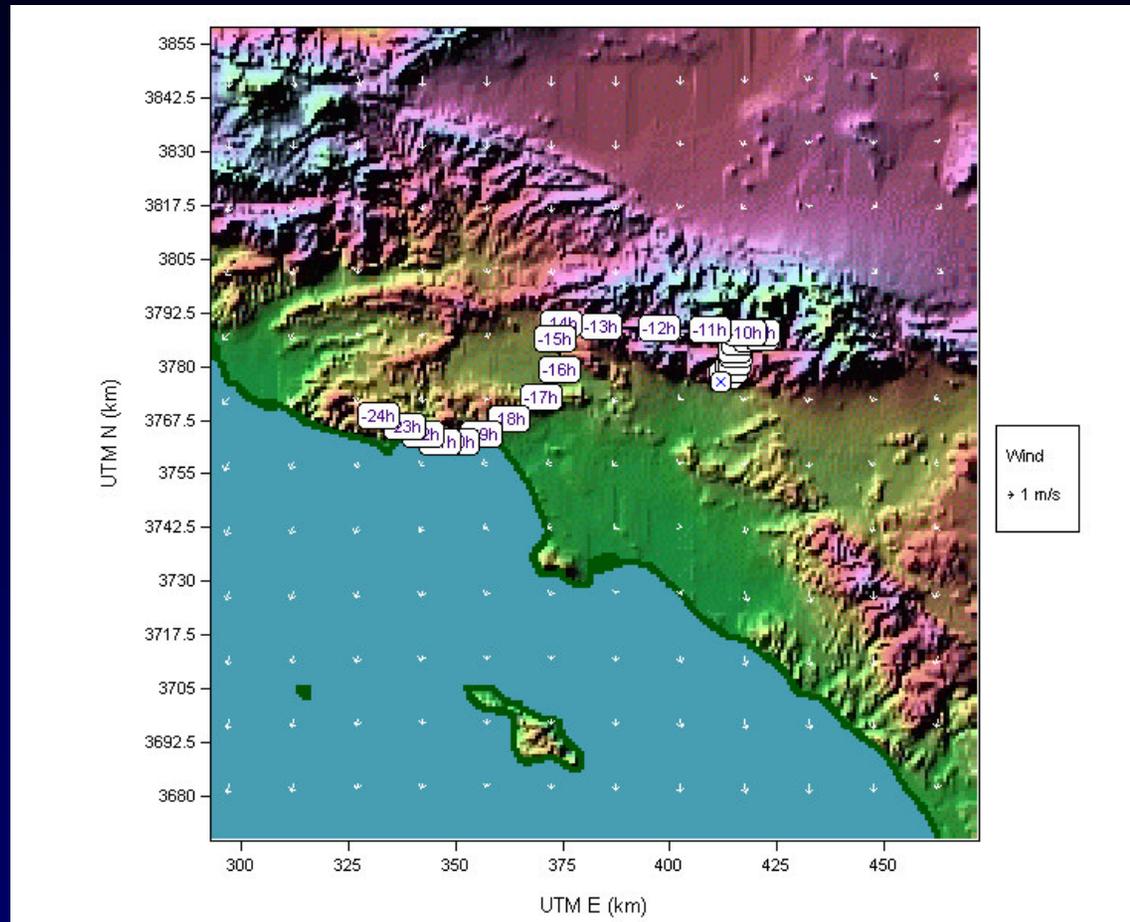
- Time series
- Time-height cross-sections
- Vertical profiles
- Spatial plots
- Images

⇒ Export to models

⇒ Reads from a Microsoft Access or Microsoft SQL Server database.



Specific Ideas Products – Trajectories



Twenty-four hour 158 m agl backward trajectory beginning at Azusa, California, at 0500 PST on August 5, 1997, going back to 0400 PST on August 4, 1997