

Orion Exploration Flight Test 1 (EFT-1): Review of Weather & Sea State Impacts

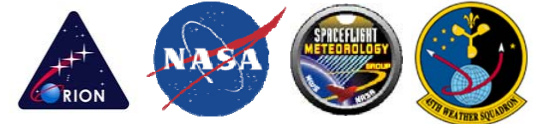
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Kathy Winters
45th Weather Squadron

8 April 2015

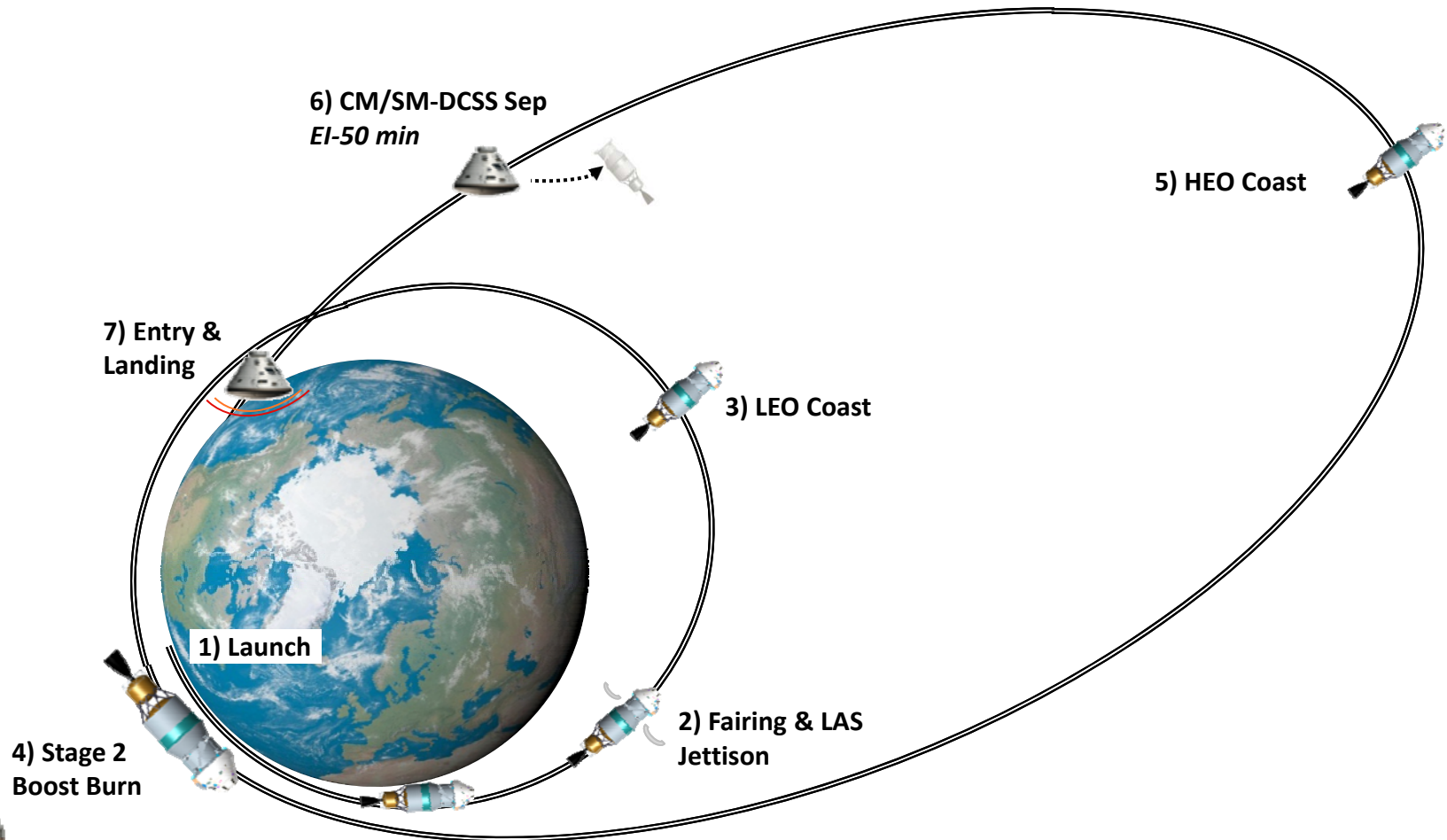
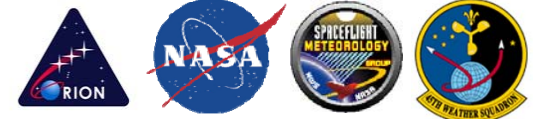
Spring 2015 Natural Environments Day-of-Launch Working Group



EFT-1 OVERVIEW AND PROBABILITY ANALYSES

Presented by Karen Altino/MSFC Natural Environments Branch

EFT-1 Mission Overview



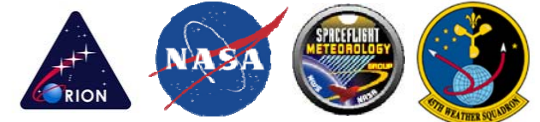
Delta IV Heavy

- 3 Common Booster Core
- DCSS Upper Stage

Objectives

- Demonstrate core CM systems performance
- Demonstrate high energy entry (~9 km/s) and TPS performance
- Demonstrate integrated entry, descent, and landing operations

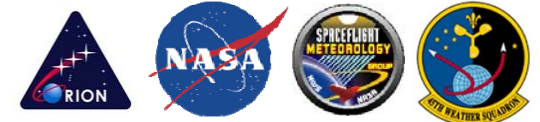
EFT-1 Mission Success



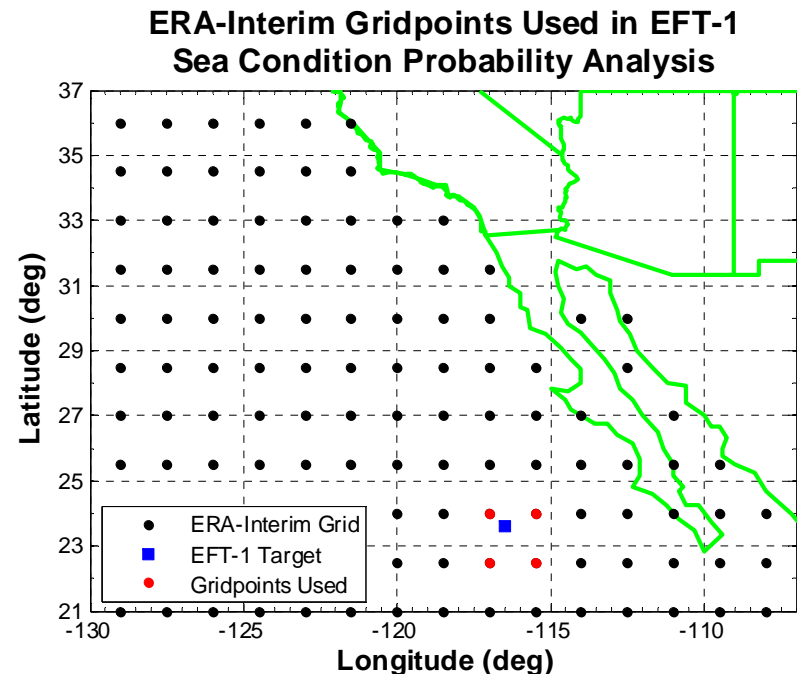
- **Orion Exploration Flight Test 1 (EFT-1)**
 - Launch site: CCAFS LC-37B
 - Launch vehicle: Delta IV Heavy (Delta IV-H)
 - Expected Launch Date/Time: 4 December 2014, 1205 UTC (7:05 a.m. EST)
 - Actual Launch Date/Time: 5 December 2014, 1205 UTC (7:05 a.m. EST)
 - Splashdown Location: ~ 625 miles south of San Diego, off the coast of the Baja Peninsula
 - Splashdown Time: ~ 1628 UTC (8:28 a.m. PST)
- **Mission was highly successful.**
 - Landed slightly off intended target due to winds, with some further drift.
 - Thermal Protection System (TPS) met its key objectives.
 - Parachute system performed well.
 - Issues with the Crew Module Uprighting System (CMUS) caused several objectives to not be met.



Launch/Landing Probabilities

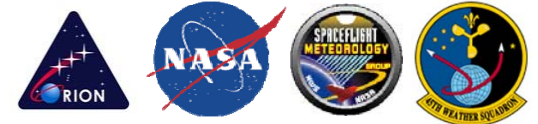


- Based on ULA/Delta LCCs, the launch availability based on SLF historical data was ~70%.
 - Combined with the landing sea state availability, the overall mission probability was ~30%.
- Landing sea state availability became a Program concern due to the launch slipping into December.
- Landing analysis: selected gridpoints surrounding the EFT-1 landing target.
 - Used Interim European Centre for Medium-Range Weather Forecasts Re-Analysis (ERA-Interim) dataset (timestamps at every 6 hours).
 - If data at any gridpoint failed, then the timestamp failed.
- Computed Probability of Not Exceeding (PNE) SLS-SPEC-159 DSNE nominal landing sea condition constraints.
 - Significant Wave Height (SWH): 2.0 meters
 - 10-meter steady state wind speed (WS): 8.2 meters per second
 - Wave period (WP) conditional based on SWH



Probability of Not Exceeding Nominal Sea Condition Constraints within EFT-1 Zone

	Sep	Nov	Dec
SWH ≤ 2 m	0.662	0.375	0.294
WS ≤ 8.2 m/s (15.9 kt)	0.937	0.912	0.857
SWH, WS, WP	0.653	0.371	0.290



ORION EFT-1 LAUNCH WEATHER OPERATIONS

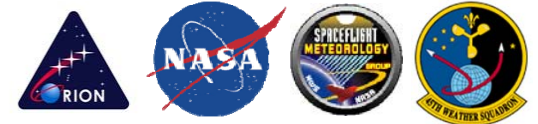
Presented by Kathy Winters, Launch Weather Office/45th WS

EFT-1 45th Weather Squadron Support



2014 EFT-1 Weather-Related Operations, KSC/CCAFS

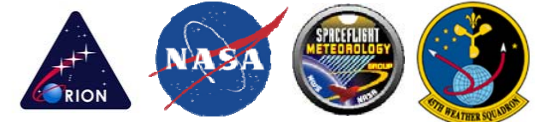
Mar	Initial Request for Triboelectrification Documentation
Aug	CX37 Swing arm & Umbilical Modifications
30 Sep – 1 Oct	*Launch Vehicle on Stand
15 Oct	Vehicle cleared from Triboelectrification Weather Rule
21-22 Oct, 12 Nov	JSC/ULA Joint Simulations
11-12 Nov	*Orion Transport, Hoist, and Mate
25 Nov	Mission Dress Rehearsal
5 Dec	<p>Launch</p> <p><u>3 Dec</u>: Mobile Service Tower Roll</p> <p>*<u>4 Dec</u>: Launch Scrub – Fouled Range, Wind, Fuel Valves</p> <p>-- Lift-Off Winds exceeded constraint during Fouled Range</p> <p>-- Frozen Valves caused by extended time in cryo conditions</p>
10–18 Dec	<p>Orion Transport from San Diego to KSC – 9 days</p> <ul style="list-style-type: none"> - 45 WS provided daily Weather Forecasts to transport team - Route set well in advance due to required DOT approval - Day/night-only transport depending upon state - Primary weather concern: Temps < 20F – no issues



ORION EFT-1 SPLASHDOWN OPERATIONS

Presented by Tim Garner/SMG

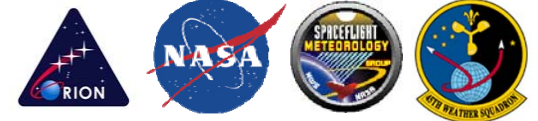
Operations Overview



- **Splashdown ~625 miles south of San Diego.**
- **USS Anchorage was prime recovery ship.**
 - Landing Platform Dock (LPD-23).
 - Backup ship was USNS Salvor
- **US Navy aerographers (meteorological technicians) and quartermasters provided surface weather and wind observations using ship's equipment.**
- **Yuma Proving Ground (YPG) meteorologist operated weather balloon system.**
 - Navy no longer releases weather balloons.
 - YPG Met Branch provides similar service on the range to NASA Capsule Parachute Assemble System (CPAS) tests.
 - Vaisala RS92-SGP radiosondes
 - Vaisala ground station
 - Laptop processing
 - Emailed data to SMG. Worked great!
- **Upper winds used for Best Estimate Trajectory**
- **Upper winds used for debris impact prediction**



Balloon Release Area



Magnetic antenna mounts for Vaisala system

Photos courtesy of Mark Hendrickson



Release area



EFT-1 Upper Air Systems: iMET-3150/iMET-1-ABx



- Inexpensive.
- Evaluated during URT-1 for use in EM1, EM2 and subsequent missions.
- Worked similar as it did on land.
- Operator issues:
 - Short cable length from antenna to receiver to laptop makes it less practical to track the sonde.
 - User must get permission to roam around the ship to maintain signal. Cannot simply mount and track the sonde.
- Data gaps:
 - Appears system simply averages and smooths data.
 - No discernible data loss alert.
- Deployed to USNS Salvor as backup system for EFT-1.
 - Not used on day-of-landing.
- Will continue to evaluate for use.



Splashdown Weather: Dec. 5, 2014



- USN Surface Weather 1629Z
- Wind: VRB04KT (320°)
 - 1619Z Balloon:
 - » SFC (72ft): 010° / 07 KT
 - » 100ft: 008° / 09 KT
 - » 200ft: 016° / 11 KT
 - » 300ft: 024° / 13 KT
 - » 400ft: 029° / 14 KT
 - » 500ft: 031° / 15 KT
- Visibility: 7 NM
- Sky: FEW020 FEW050 (2/8)
 - Based upon balloon and video data this is more likely SCT012 (tops 1800ft) SCT150
- Pressure:
 - Altimeter Setting: 30.08 inHg (14.7739 psi)
- Sea State:
 - Swell: 4 ft from 310° @ 10s
 - Wind wave: 2 ft @ 2 s
 - Significant Wave Height: 4.5 ft
- Temp: 75F
- Dew Point / RH: 64F / 68%
- Sea Surface Temp: 75F

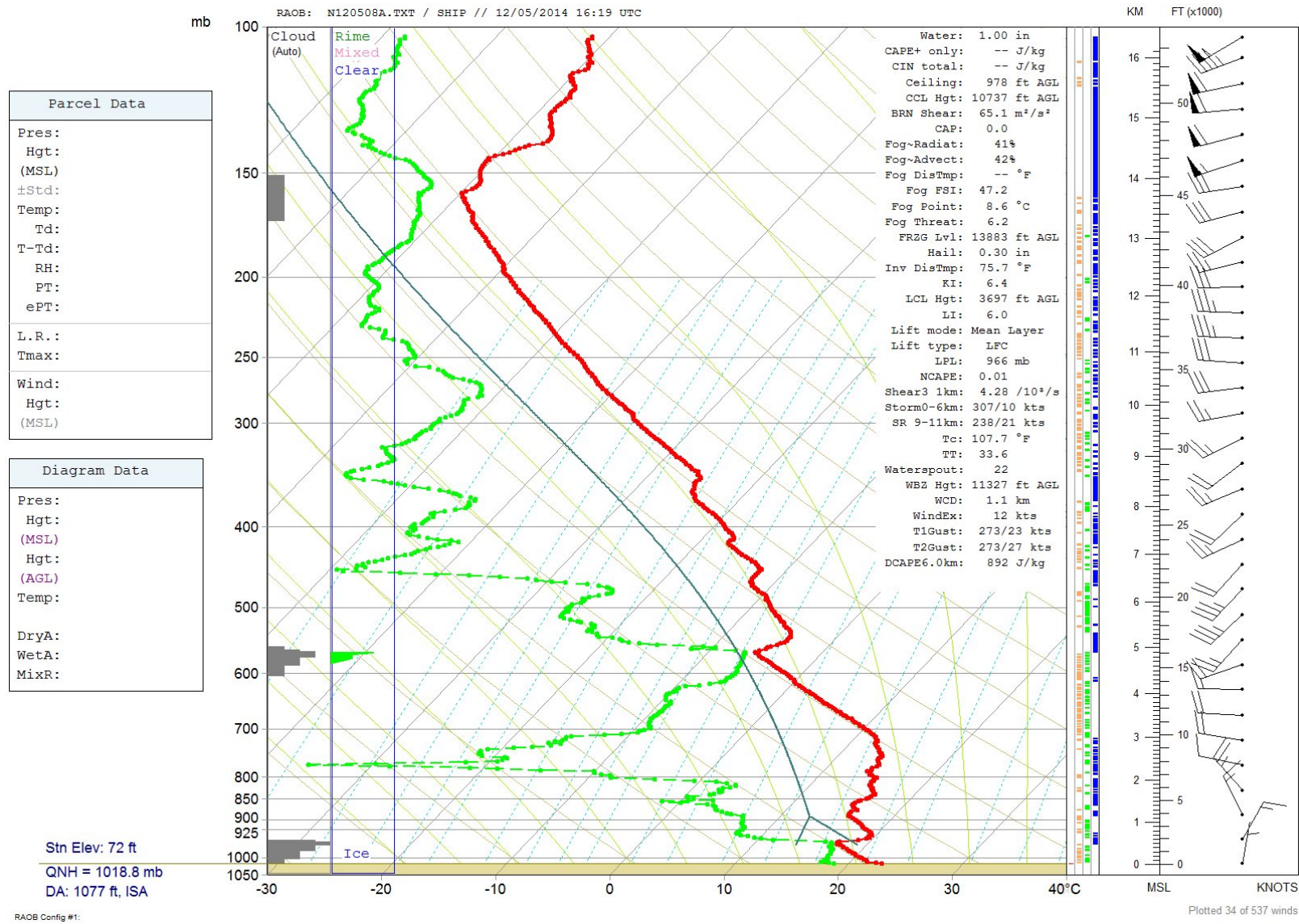
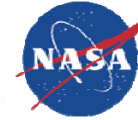
Balloon surface wind of 010° at 7 KT more representative of splashdown weather than ship observation

Forecast Issued 0630Z

	Parameter	Forecast	Comment
Splashdown LCC			
1	Surface Wind Speed (Kts/fps) (WX-9)	12/ 20.27	
2	Thunderstorms within 30nm (Y/N) (WX-10)	N	
3	Non-Convective Precipitation Rate > 0.3 in/hr (Y/N) (WX-11)	N	
Splashdown			
4	Surface Wind Direction (from °TRUE)	030°	NE
5	Cloud Layer 1 – Coverage, Base/Top (100's ft)	SCT 025/030	
6	Cloud Layer 2 – Coverage, Base/Top (100's ft)		
7	Cloud Layer 3 – Coverage, Base/Top (100s ft)	SCT300/320	
8	Temperature (°F)	73	
9	Dew Point Temperature (°F)	65	
10	Relative Humidity (%)	76	
11	Visibility (n.mi)	10	
12	Restrictions to Visibility		
13	Altimeter (inHg/psi)	30.06/ 14.764	
Recovery			
14	Significant Wave Height (ft)	4 ½ to 5	
15	Wave Period (sec)	15 swell	10s wind wave
16	Wave Direction (from)	NW	300°
17	Sea State **	3	
18	Sea Surface Temperature (°F)	74	
Peak Heating Aircraft Location			
19	Cloud Layers: coverage base/top	SCT 025/030 BKN120/150 OVC 300/360	

For more complete data contact: timothy.w.garner@nasa.gov

Splashdown Balloon Skew T log P: 5 Dec 2014 1619 UTC

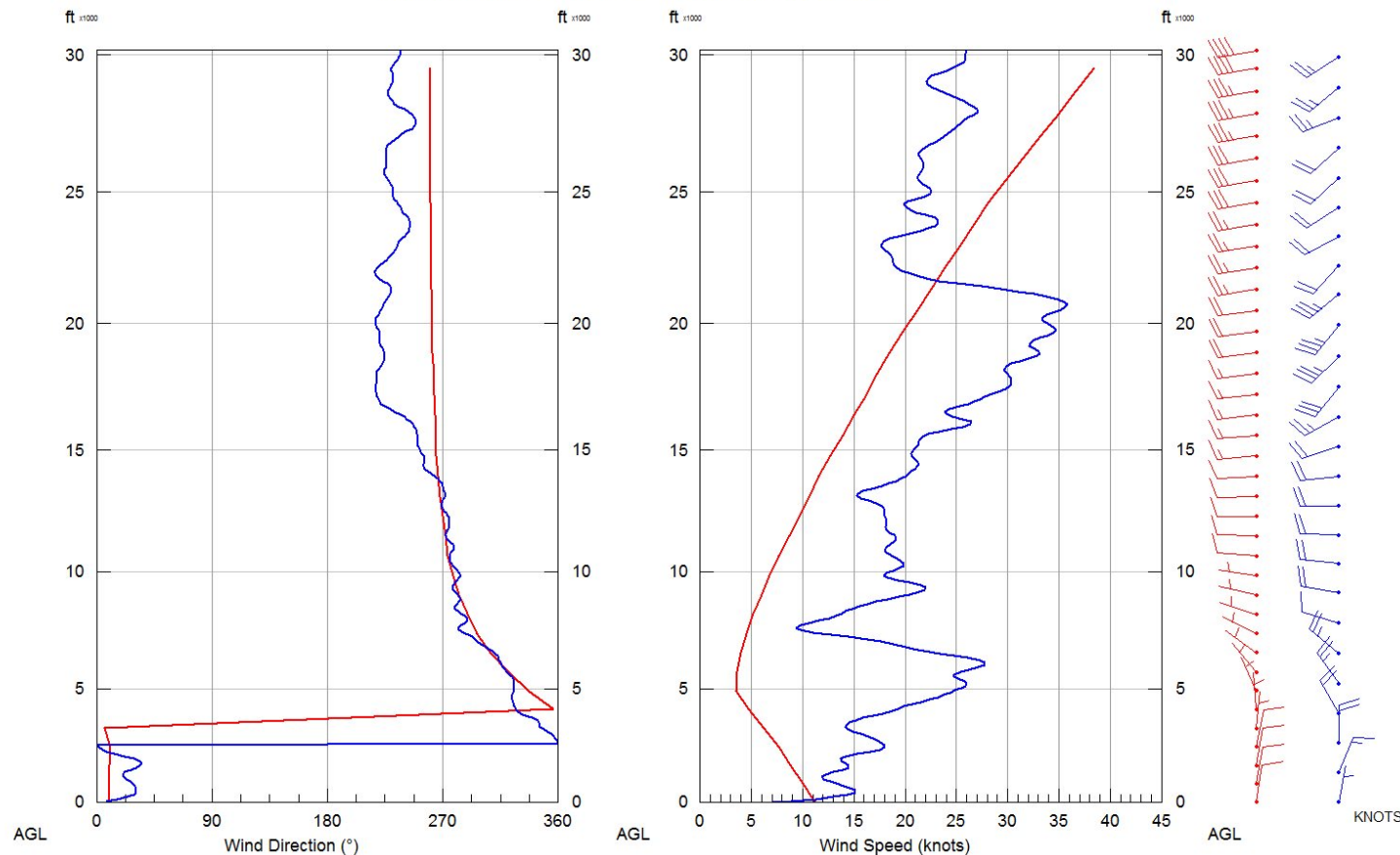


RAOB Config #1:

Earth-GRAM 2010 – Observed Balloon



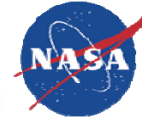
EFT-1_12Z_DEC_GRAM2010_ATM_4RAOB.CSV -- EFT-1 Dec 12Z GRAM
N120508A.TXT -- SHIP // 12/05/2014 16:19 UTC



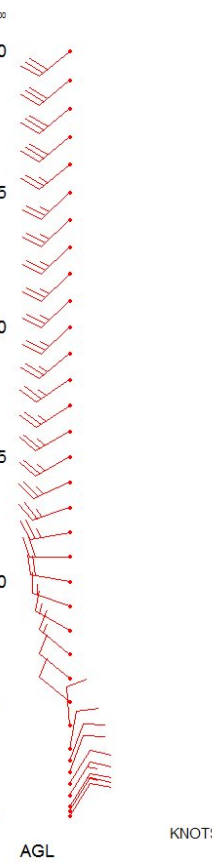
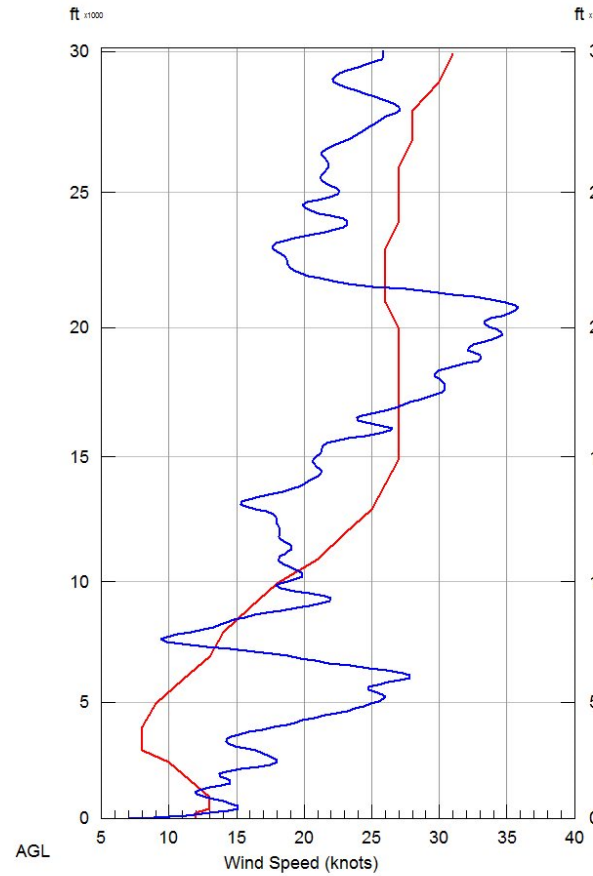
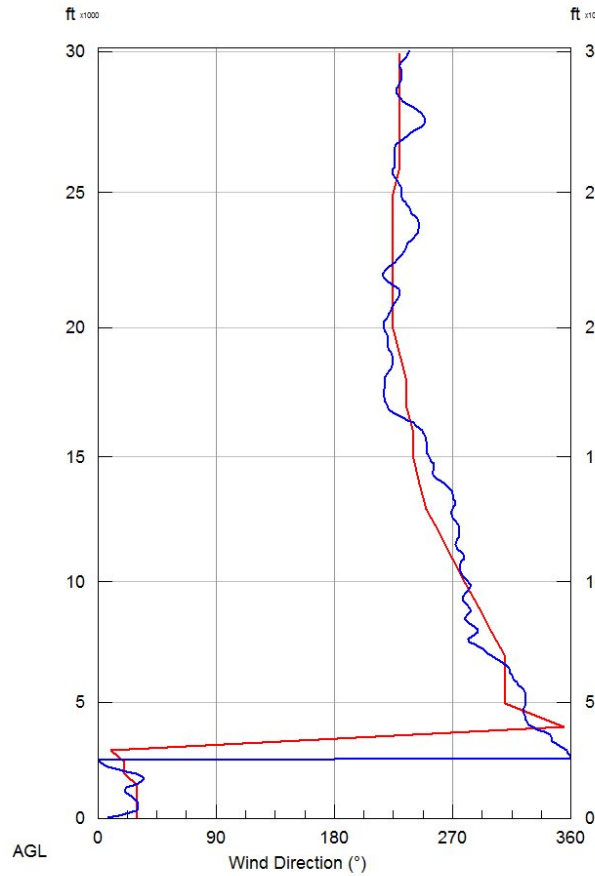
***Note: the red line indicates the Earth-GRAM 2010 monthly mean for December.**

Plotted 26 of 537 winds

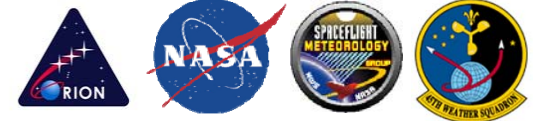
15 Hour Forecast to Observed



EFT1_SMG_FCST05DEC14.CSV -- EFT-1 SMG Forecast
N120508A.TXT -- SHIP // 12/05/2014 16:19 UTC



Lessons Learned from EFT-1 Operations



- **Trained balloon system operator critical to success.**
 - YPG met highly qualified and motivated for the job.
- **Coordination of various balloon data users requests needs to be coordinated.**
 - On-board user requested additional balloon without coordinating with SMG / MCC.
 - Consumables at-sea must be managed.
- **Needed a better understanding of ship's surface measurement capabilities and siting.**
- **Provide clear instructions and timelines for surface and upper wind observations.**
 - On-board operations can change this so be adaptable.
- **Satellite remotely sensed winds:**
 - Very helpful IF timely. Typically on LEO satellites.
 - RapidSCAT data from the ISS provided surface wind insight.
 - GOES Satellite wind profiles helpful but location/weather dependent.
- **Remain flexible as upper wind data users will magically appear very near the operations date.**