Meteorological Support in Scientific Ballooning

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Overview

- The weather affects every portion of a scientific balloon mission, from payload integration to launch, float, and impact and recovery.
- Forecasting for these missions is very specialized and unique in many aspects.
- CSBF Meteorology incorporates data from NWS/NCEP, as well as several international meteorological organizations, and NCAR.
- This presentation will detail the tools used and specifics on how CSBF Meteorology produces its forecasts.

Data, Data, Data….

- In meteorology, a forecaster can never have too much data.
  - Due to inherent remote locations of ballooning campaigns, obtaining a sufficient amount of data can often be a challenge
    - Surface observations (temperature, dewpoint, wind, pressure etc.)
    - Frequent and timely satellite imagery
    - Radar
    - Upper air observations
    - Model data
- Lack of data can often result in uncertainty in forecasts, so it is important to collect and distribute as much data as possible – how do we do that??

NOAAport

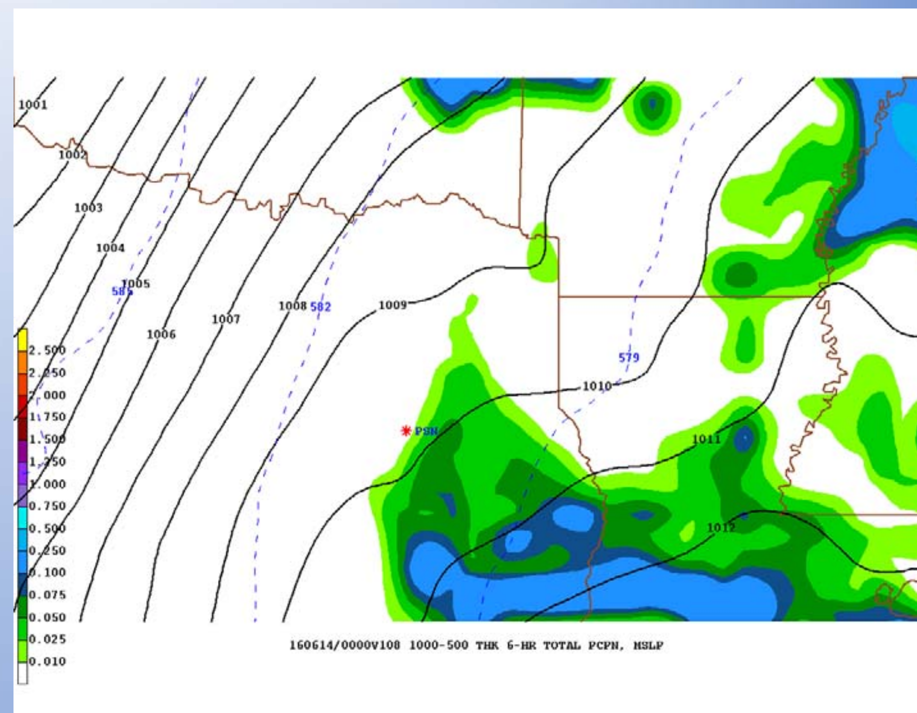
- Redundant Planetary Data Incorporated (PDI) NOAAport ingest systems in Fort Sumner, NM and Palestine, TX. Includes C-band dish, LNB, and Novra modem with TCP/IP connection to a Dell Centos 6.8 Linux server with PDI proprietary ingest software installed.
- Unidata Local Data Manager (LDM) used to send data to CSBF CentOS 7.2 and Oracle Solaris 11.3 Oracle Sun X3-2 servers.
- NOAAport data feed includes global surface and upper-air observations, terminal air field forecasts, and other text products, along with GOES satellite imagery and NWS Level III radar imagery and gridded binary model data output (GRIB), including GFS, NAM, RAP, and HRRR.

NOAAport Installation in Fort Sumner, NM

NOAAport Display Capabilities

- CSBF servers receive NOAAPort data via the LDM from the PDI ingestor. LDM parses the incoming feed and according to data headers either files the data (radar, satellite) or passes through decoders (model data, text data) which convert the data into GEMPAK format. GEMPAK is the data display and manipulation software we use for radar, text, and model GRIB data and display only of satellite imagery. In addition to servers, CSBF has dual-monitor Dell and Oracle Sun workstations in New Mexico and Palestine as well as a travel workstation that uses the NMAP2 and GARP GUIs from GEMPAK to display data.

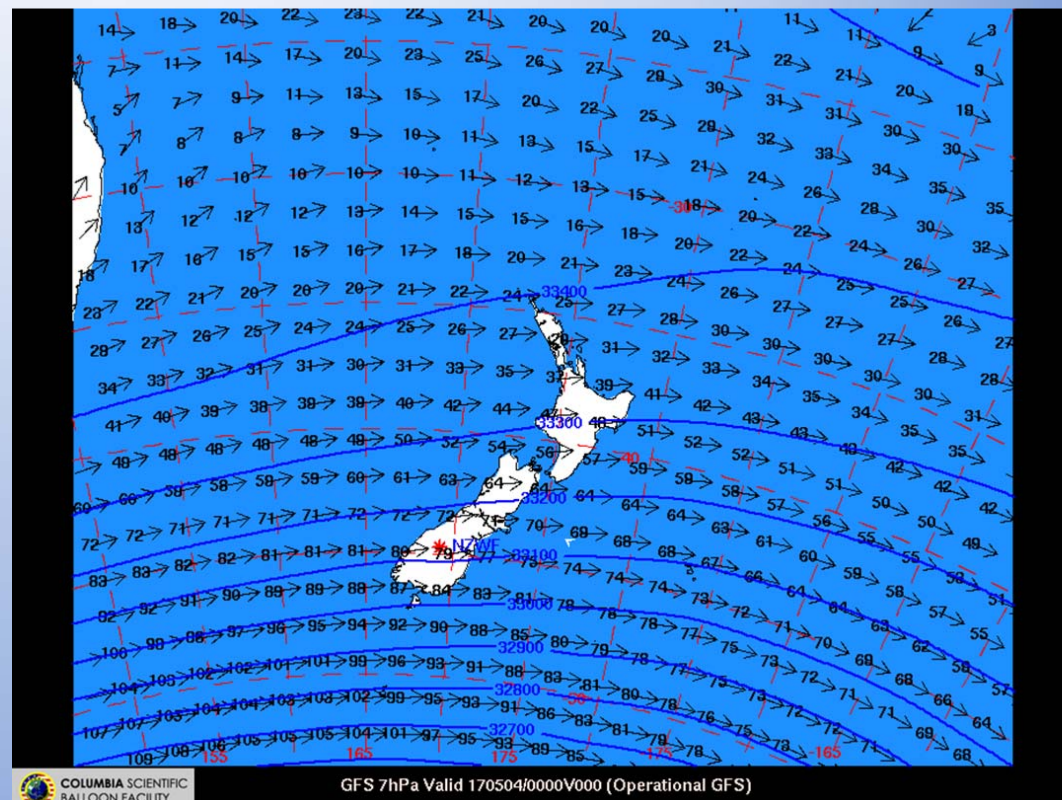
- GEMPAK has powerful scripting tools (GEMPAK command embedded in UNIX c-shell or bash scripts) that enable the creation of images for web display. This enables the CSBF Meteorologist to have access to data in low-bandwidth locations where a workstation is not feasible as is in the case in Antarctica.



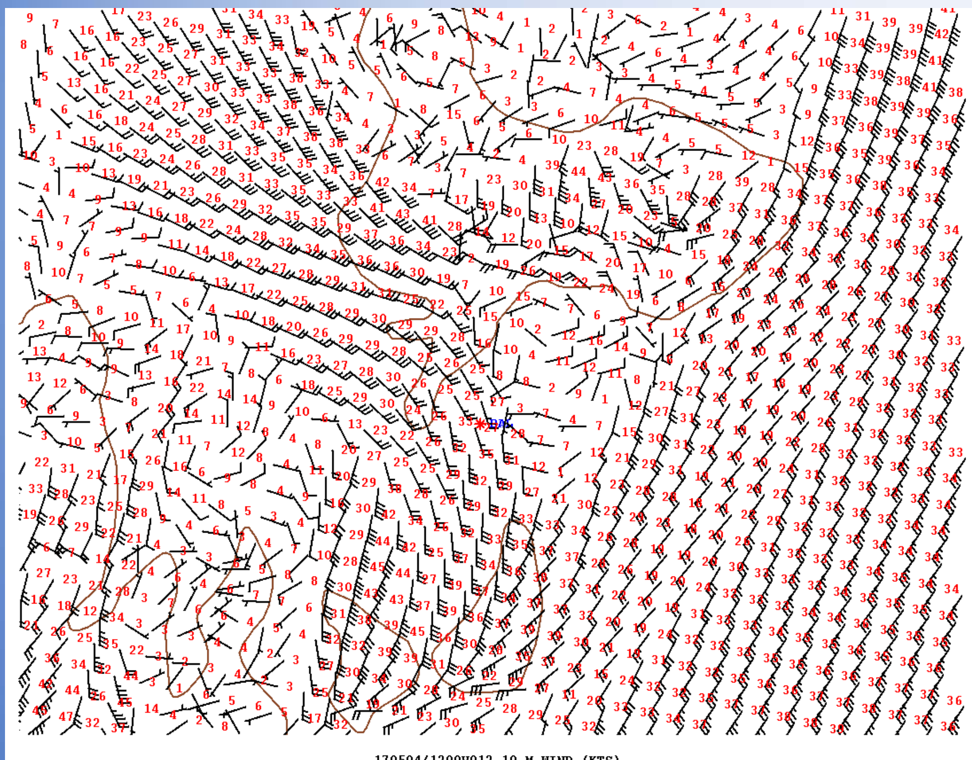
GEMPAK Image from NOAAport feed

Internet Delivery Model Data

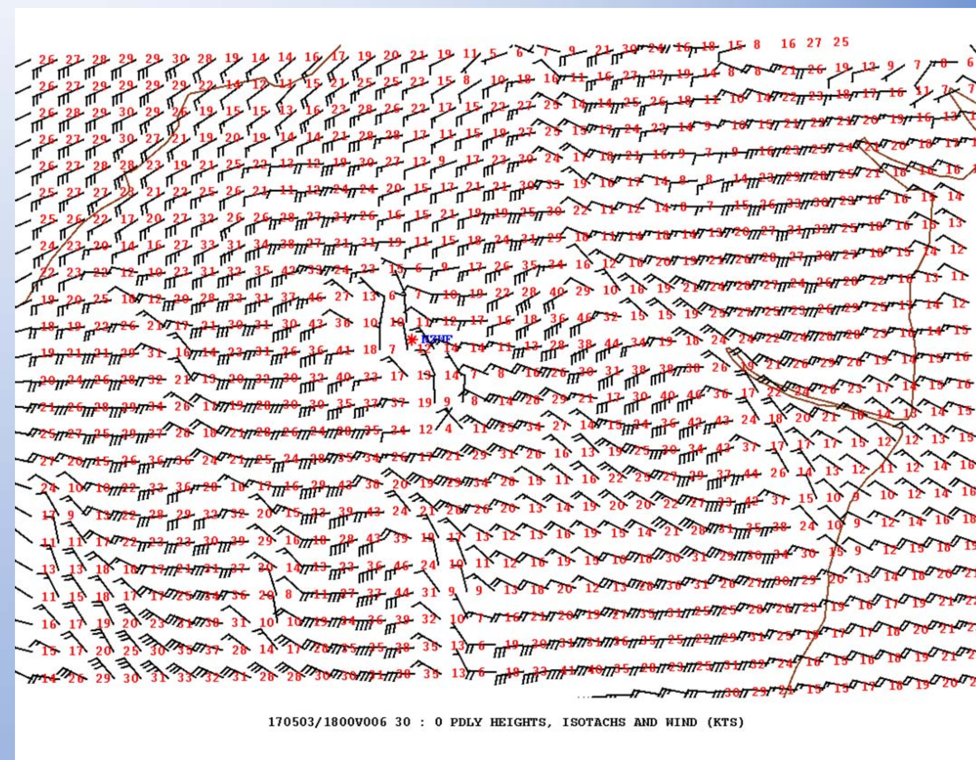
- The entire suite of model output from NCEP is too big to be placed on NOAAport. A large portion is only available via the Internet from NCEP servers. This is true of the full global output of the GFS and for all GFS output above 50 mb. The GFS has full global output to 1 mb.
- AMPS (Antarctic Mesoscale Prediction System) is a WRF-based model produced at UCAR for support of NSF-sponsored Antarctic programs in cooperation with NCAR and the Byrd Polar Research Center. CSBF obtains this data through an LDM feed from the U-W/SSEC Antarctic Meteorological Research Center and through the AMPS website. This data is critical in support of launch operations in Antarctica.
- CSBF also purchases high resolution model forecast data from Metservice New Zealand in support of Wanaka Super Pressure Campaigns, which is extremely critical for operations.



GEMPAK GFS Stratospheric Wind Image



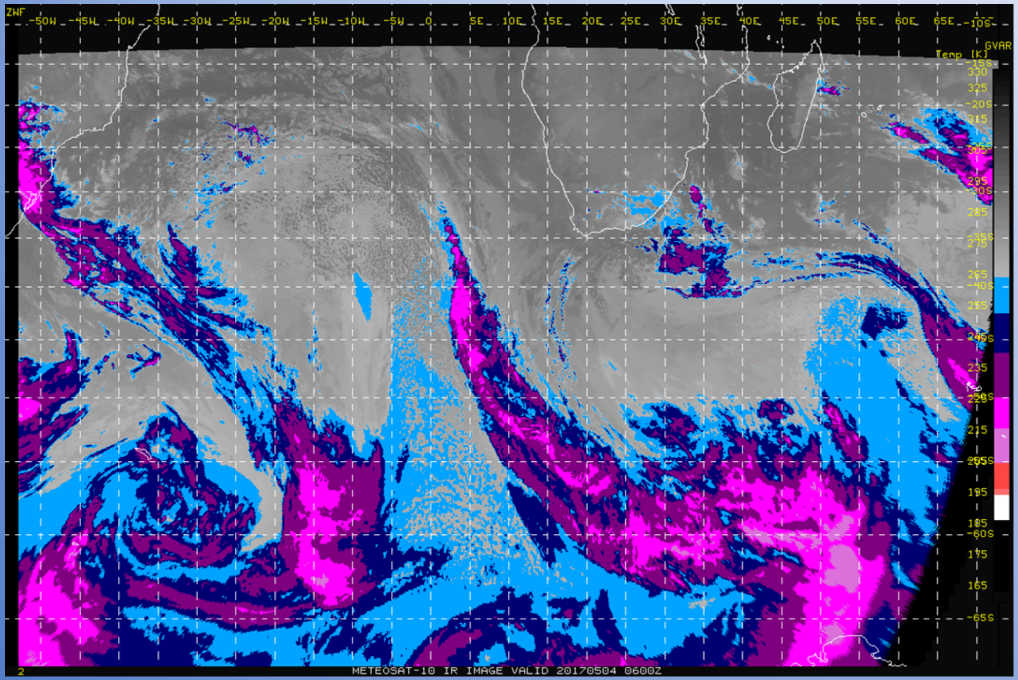
GEMPAK AMPS WRF Images



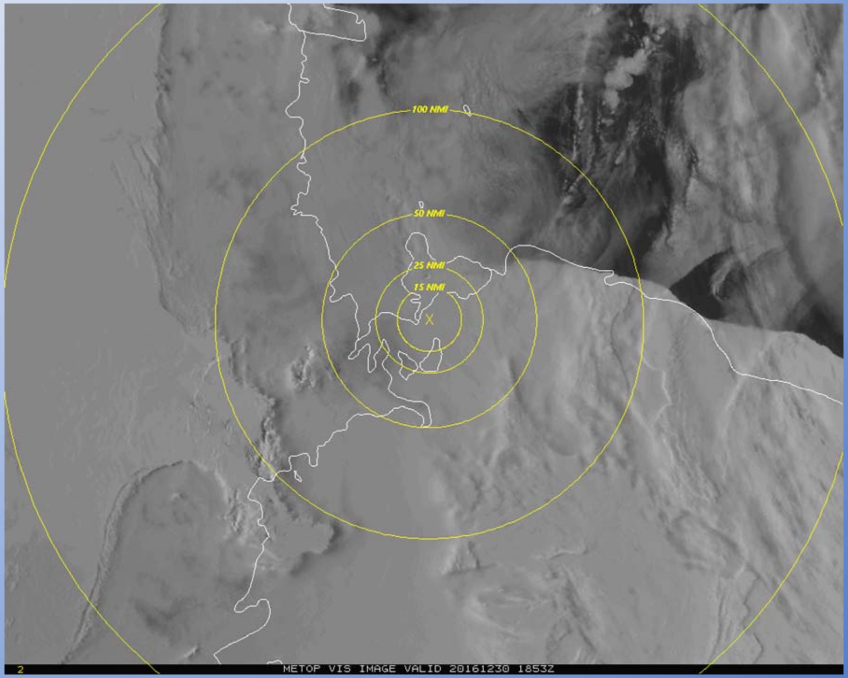
GEMPAK Metservice NZ WRF Model Image

Global Satellite Imagery/McIDAS-X

- Balloon performance is highly dependent on cloud cover, so satellite imagery is a mission critical item for the assured success of a flight. CSBF has access to the McIDAS-X ADDE servers at NESDIS that allow us to retrieve global satellite imagery in McIDAS format. McIDAS-X then allows us to remap and display the imagery. Satellites that CSBF uses include GOES series, METEOSAT-10, INDOEX(METEOSAT-8), Himawari-8, NOAA Polar Orbiter, and METOP Polar Orbiter.



McIDAS Meteosat-10 (Color Enhanced Infrared Image)



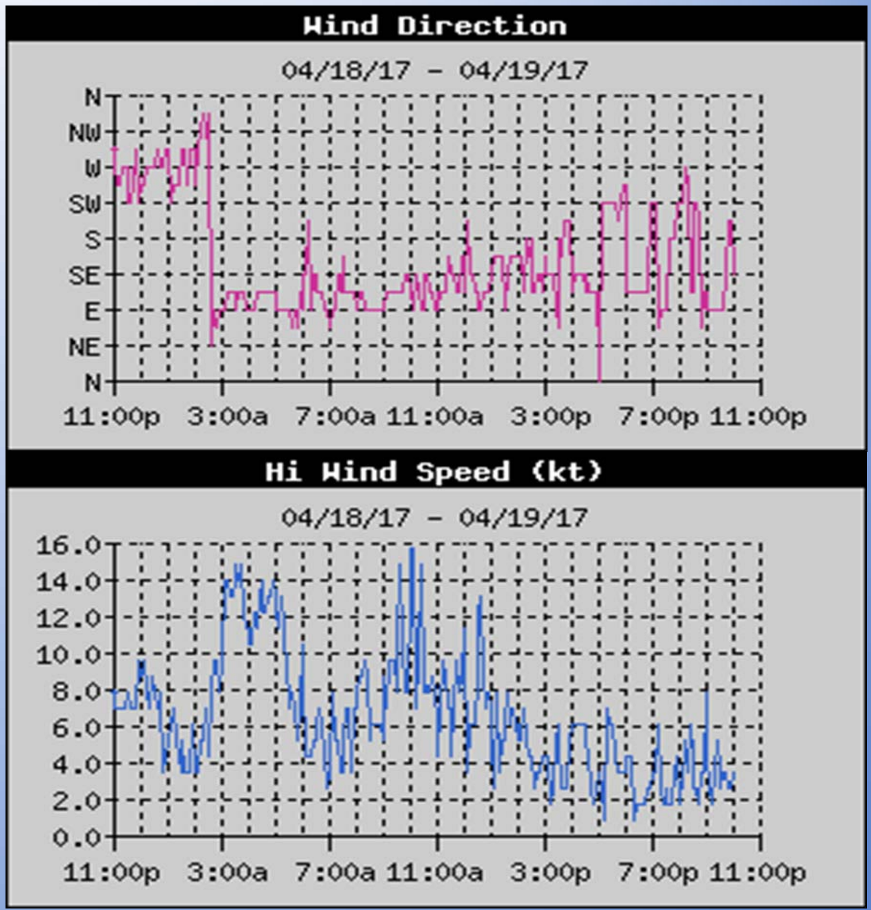
McIDAS METOP Visible Image Ross Island

Pre-Launch Day Forecasting

- Weather briefings are typically held every day once a payload is flight ready
  - Meteorologist uses weather computer models to identify a launch window for the following day, and will recommend a "show" or "no show". Campaign Manager has final decision on whether or not there will be a launch attempt the following day.
  - Extended range launch weather outlook will be given typically for 3 days out.
  - An ascent and float trajectory forecast will be produced and provided to Safety for a Go/No Go recommendation. Final Go/No Go comes from Safety on morning of the launch based on latest trajectory forecast.

Weather Criteria for a Balloon Launch

- Wind constraints can vary significantly based on balloon type and size but typically:
  - Surface winds less than 7kts
  - Low-level winds to the top of the balloon less than 12kts
- Surface and low-level winds in a stable and uniform direction
- No precipitation at launch site, and no thunderstorms within 50nm
- Thick fog and/or very low clouds can complicate launch operations



Wind conditions in Wanaka NZ for a cancelled launch opportunity

Ascent & Float Trajectory Forecast

- CSBF Meteorology uses a combination of legacy FORTRAN programs that date to the 1970's along with UNIX scripts and complicated Excel macros to produce ascent, float, and descent trajectory predictions in text and KML format.
- Raw data for each of these is obtained from model data wind forecasts (mainly GFS) in a text format using a UNIX script that uses the GEMPAK program, gdpoint.
- The meteorologist has the option of adjusting the model data wind forecasts manually.
- SINBAD is used to make pre-flight ascent rate predictions as well as zero-pressure balloon altitude projections

P(mb)	HT(FT)	DRCT	SPD(KTS)	T(C)	DP(C)
1000	615	87	16	19	13
975	1325	86	16	16	13
950	2049	85	17	14	12
925	2787	82	16	12	11
900	3540	69	11	11	6
875	4313	33	6	12	-6
850	5110	44	6	13	-17
825	5932	73	8	13	-23
800	6778	83	12	13	-23
750	8549	95	16	12	-25
700	10428	111	17	9	-33
650	12423	121	17	5	-35
600	14547	127	18	1	-36
550	16822	136	18	-3	-30
500	19274	153	16	-8	-21
450	21936	170	21	-13	-19
400	24849	182	24	-19	-23
375	26419	171	22	-22	-25
350	28075	159	23	-25	-29
325	29833	155	25	-28	-37
300	31701	164	24	-33	-48
275	33689	175	25	-38	-52
250	35816	177	30	-44	-53
225	38106	174	40	-50	-54
200	40597	183	49	-56	-57
175	43334	193	57	-63	-63
150	46386	192	59	-70	-70
125	49889	185	49	-76	-76
100	54121	181	24	-74	-83
70	61022	174	9	-69	-85
50	67705	127	6	-64	-85
30	78128	232	6	-57	-85
20	86666	257	18	-51	-86
10	101671	280	43	-45	
7	109511	275	56	-43	
5	116993	271	51	-39	
3	128666	277	50	-32	
2	138193	272	68	-25	
1	154983	267	94	-18	

VALID TIME=170503/1200F027

GFS output for -29.96823;-129.30676 generated wed May 3 17:36:23 GMT 2017

GEMPAK Script GFS Text Sounding Output

Location	Wanaka,	New	Zealand
Latitude	-44.7213		
Longitude	169.2534		
Altitude	1 kft		
Science	Group	SPB	
Balloon	Type	SP	
Balloon	Size	18.2	
Chute	Size	130	
Weight	with	Ballast	5500
Weight	without	Ballast	4300

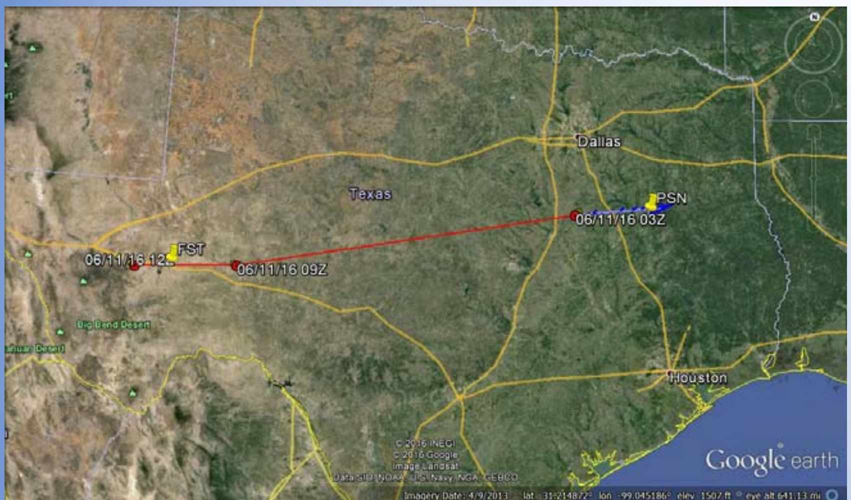
Climbout

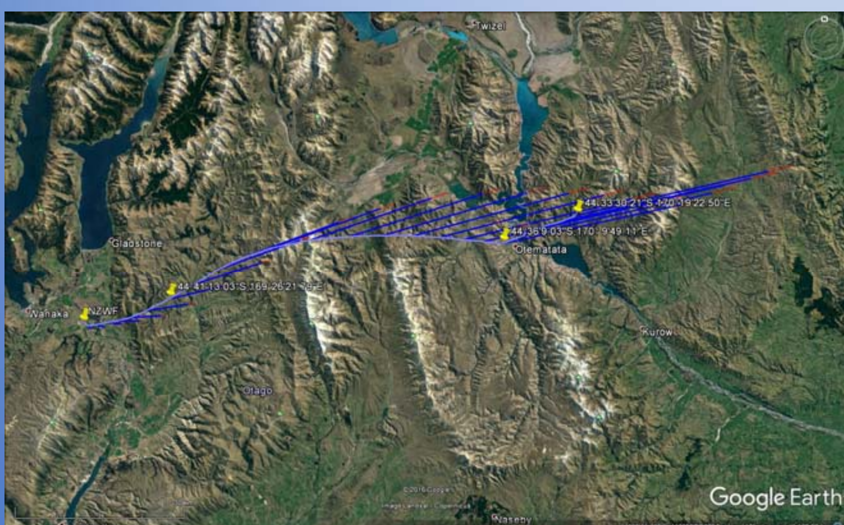
altitude	dir	spd	bearing	distance(nm)	time(min)	bearingvec
3	352	2	172	0.1	1.5	172
6	75	5	244	0.3	4.5	255
9	34	6	225	0.7	8.7	214
12	331	8	181	1.2	15.4	151
15	318	11	164	1.9	19.8	138
18	307	17	150	2.9	24	127
21	303	22	141	4.3	27.9	123
24	304	23	137	5.6	31.6	124
27	303	22	134	6.9	35.2	123
30	294	20	132	8	38.5	114
33	287	20	129	8.9	41.7	107
36	290	24	126	10.6	46.1	110
39	291	29	123	13.2	51.7	111
42	292	35	121	16.1	56.7	112
45	294	41	120	19.3	61.4	114
48	292	43	119	22.4	65.8	112
51	290	40	118	25.2	70	110
54	288	35	117	27.5	74	108
57	288	29	116	29.3	77.8	108
60	287	24	116	30.7	81.3	107
69	295	11	116	32.6	91.6	115
78	7	2	116	32.7	101.2	187
87	96	4	117	32.2	109.7	276
96	168	4	116	31.8	118.1	348
105	213	9	113	32.1	129.3	33
110	235	16	111	33	135.5	55

Descent Vectors Without Ballast

altitude	dir	spd	bearing	distance(nm)	time(min)	balloon(nm)
3	352	2	172	0.1	1.6	0
6	75	5	241	0.2	4	0.1
9	34	6	227	0.4	6.3	0.1
12	331	8	198	0.6	8.5	0.2
15	318	11	174	0.9	10.7	0.3
18	307	17	155	1.4	12.8	0.5
21	303	22	144	2	14.8	0.7
24	304	23	138	2.7	16.8	0.9
27	303	22	135	3.4	18.8	1.1
30	294	20	132	4.1	20.7	1.4
33	287	20	128	4.6	22.7	1.5
36	290	24	126	5.4	24.6	1.8
39	291	29	124	6.3	26.5	2.1
42	292	35	122	7.3	28.3	2.4
45	294	41	121	8.5	30.1	2.8
48	292	43	120	9.8	31.9	3.3
51	290	40	119	10.7	33.3	3.6
54	288	35	118	11.5	34.7	3.8
57	288	29	118	12.2	36.1	4.1
60	287	24	117	12.6	37.2	4.2
69	295	11	117	13.2	40.5	4.4
78	7	2	117	13.2	43.1	4.4
87	96	4	118	13.1	45.2	4.4
96	168	4	117	13	46.9	4.3
105	213	9	116	13.1	48.1	4.4
110	235	16	116	13.1	48.6	4.4

Climbout Prediction (Text Output)


Dallas
Texas
PSN
06/11/16 03Z
FST
06/11/16 12Z
06/11/16 09Z
Big Bend Desert
Houston
Google earth


Twizel
Otematata
NZWF
Wanaka
Kurow
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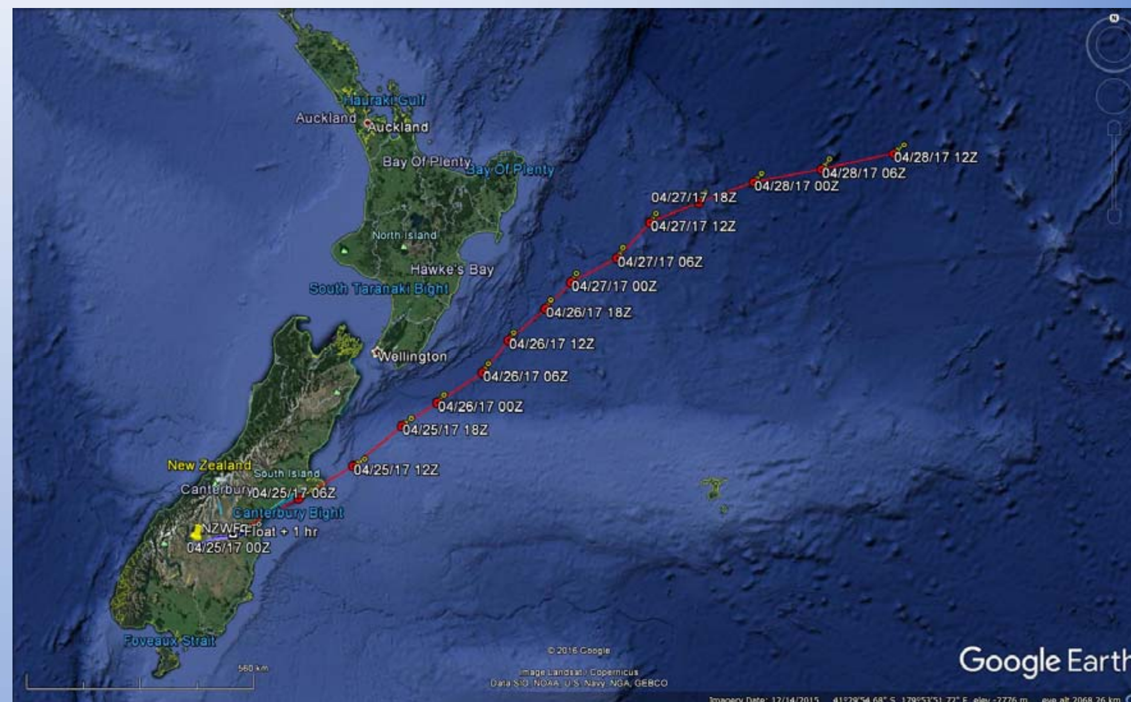
Hauraki Gulf
Auckland
Auckland
Bay Of Plenty
Bay Of Plenty
North Island
Hawke's Bay
South Taranaki Bight
Wellington
04/28/17 12Z
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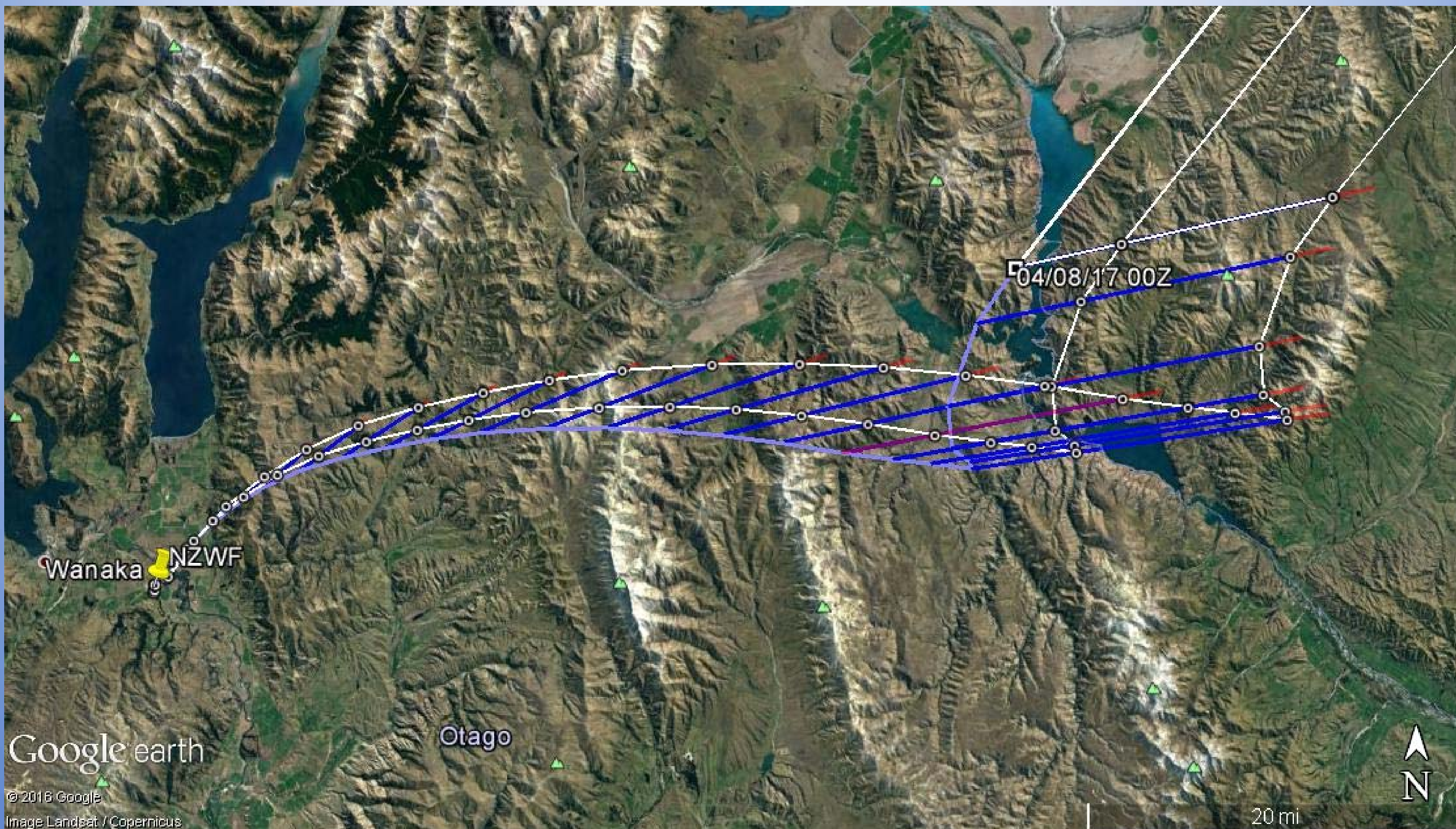
04/28/17 00Z
04/27/17 18Z
04/27/17 12Z
04/27/17 06Z
04/27/17 00Z
04/26/17 18Z
04/26/17 12Z
04/26/17 06Z
04/26/17 00Z
04/25/17 18Z
04/25/17 12Z
New Zealand
South Island
Canterbury
04/25/17 06Z
Canterbury Bight
NZWF
Float + 1 hr
04/25/17 00Z
Foveaux Strait
Google Earth



Climbout Prediction with Safety Files

Launch Day Forecasting

- The Meteorologist typically arrives 1 hour before official “show time” to begin forecasting for the launch attempt.
- A final climbout and trajectory forecast is produced, and safety files are distributed as necessary.
- Forecasting is very detail oriented and is a continuous process that involves going over latest model data, checking available satellite and radar images, monitoring current weather conditions at launch site and surrounding areas, and measuring low-level wind conditions with pilot balloon (PiBal) releases.
- Meteorologist is in near constant communication with the Crew Chief and Campaign Manager, and there are many informal weather briefings throughout the launch attempt.

PiBals

- PiBal measurements are one of the most critical tools of the Meteorologist.
- 30 gram PiBals are typically released at 30 minute intervals throughout the launch attempt
- A theodolite is used to visually track the PiBal up to 4000ft, and CSBF software uses the output from the theodolite to generate wind measurements in 300ft layer averages.

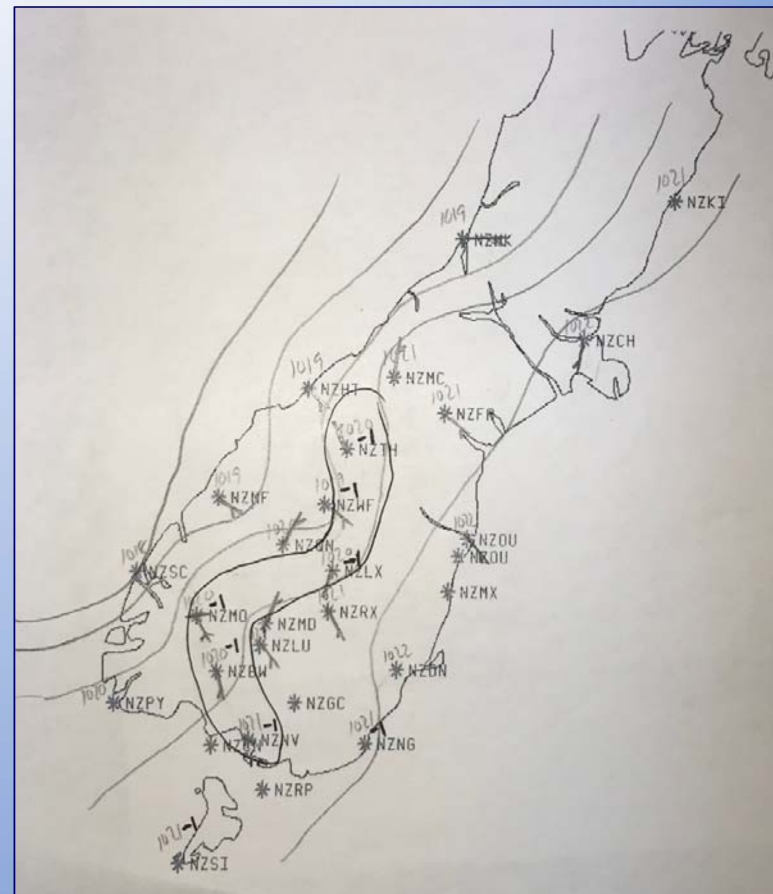
Warren-Knight Theodolite

Starting PiBall Run 2016/05/16 23:09:04
150ft 1.5 knots from 320.0 deg
450ft 2.4 knots from 338.1 deg
750ft 2.9 knots from 339.4 deg
1050ft 2 knots from 313.2 deg
1350ft 1.8 knots from 298.4 deg
1650ft 1.4 knots from 253.6 deg
VecSum = 1.8 knots from 317.5 Deg
1950ft 2.9 knots from 285.7 deg
2250ft 3.6 knots from 288.2 deg
2550ft 4.2 knots from 298.3 deg
2850ft 4.2 knots from 295.6 deg
3150ft 4 knots from 296.6 deg
3450ft 6 knots from 296.9 deg
3750ft 5.6 knots from 279.3 deg
4050ft 5.5 knots from 300.8 deg

Example PiBal Measurement

Surface Charts

- Hand plotted surface charts are another critical tool that the Meteorologist uses on launch days. These are generally produced every hour.
- Synoptic surface observations around the launch site are plotted on a map. These observations typically contain wind speed and direction, atmospheric pressure, temperature, dewpoint, and cloud cover.
- The meteorologist will analyze the surface chart, and hand plot lines of constant pressure (Isobars) to determine the pressure gradient in and around the launch site.



Surface chart from New Zealand

Post Launch Forecasting

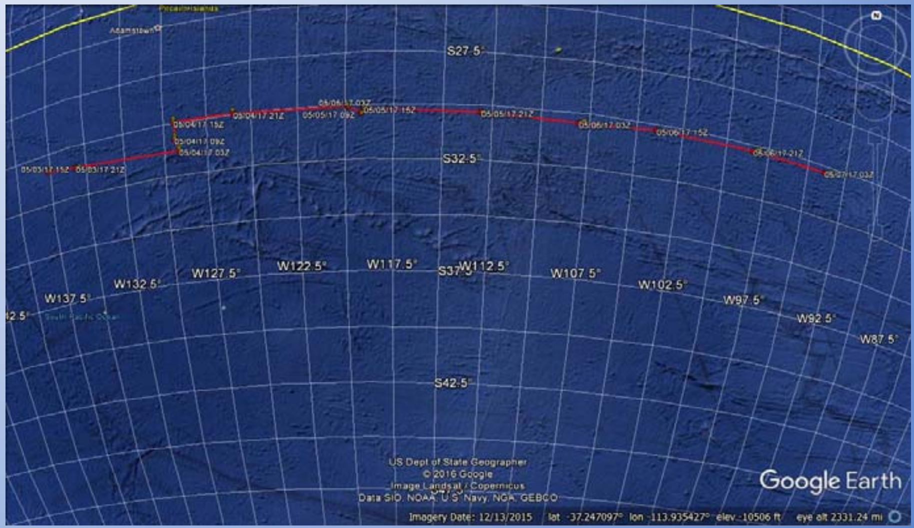
- Once the balloon is launched, the Meteorologist will monitor the balloon until it gets to float altitude to provide emergency descent vectors if necessary.
- Provide input to Crew Chief about ballasting and/or valving.
- When the decision is made to terminate the flight, descent vectors will be produced. Prior to Descent Notices will also be created for CONUS flights to be distributed to the FAA.
- Impact area forecasts are provided to recovery team as needed.

```
DESCENT VECTORS
    ***************
 FLIGHT#: 669NT
 GROUP: SPB
 VALID DATE/TIME: 18Z May 8

 PAYLOAD WEIGHT=4674. LBS
 PARACHUTE SIZE=130. FT
 CUTDOWN ALTITUDE=110. KFT

 ELAPSED TIME (MINUTES) TO:

 60 KFT=  8.1
 50 KFT= 12.6
 40 KFT= 18.3
 30 KFT= 24.5
 20 KFT= 30.9
 10 KFT= 37.8
 SURFACE= 45.4

 60 KFT TO SURFACE= 37.2
 TOTAL DESCENT TIME= 45.4

 FORECAST DESCENT VECTORS
 ************************
 ARG  131. DEGREES 20.1 NM
```

Example Descent Vector Text Output

After Float Predictions

- For longer flights, updated trajectory predictions will be produced daily.
- Required safety files will be generated and distributed as necessary.
- Cloud cover forecasts for flight path will be produced, and balloon performance predictions are made based on this forecast.
- Other in-flight weather data provided to Science Team throughout the flight, such as forecast soundings, and lightning forecasts.
- Post flight weather data, such as satellite imagery, can be provided to the Science Team after the flight is complete.



SPB Trajectory Forecast

Questions??