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 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.
• 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.
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.
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 7 kts
  - Low-level winds to the top of the balloon less than 12 kts
- Surface and low-level winds in a stable and uniform direction
- No precipitation at launch site, and no thunderstorms within 50 nm
- 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.
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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.

Example PiBal Measurement

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

Warren-Knight Theodolite
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.
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.

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Example Descent Vector Text Output

DESSENT 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
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.
Questions??