Jet Propulsion Laboratory
California Institute of Technology

Assimilating DAWN winds: Impact on the precipitation and flow structure of the June 10th squall line

Sara Zhang, Svetla Hristova-Veleva, F. Joe Turk

(With acknowledgements to ***Ed Zipser and Mani Rajagopal)***

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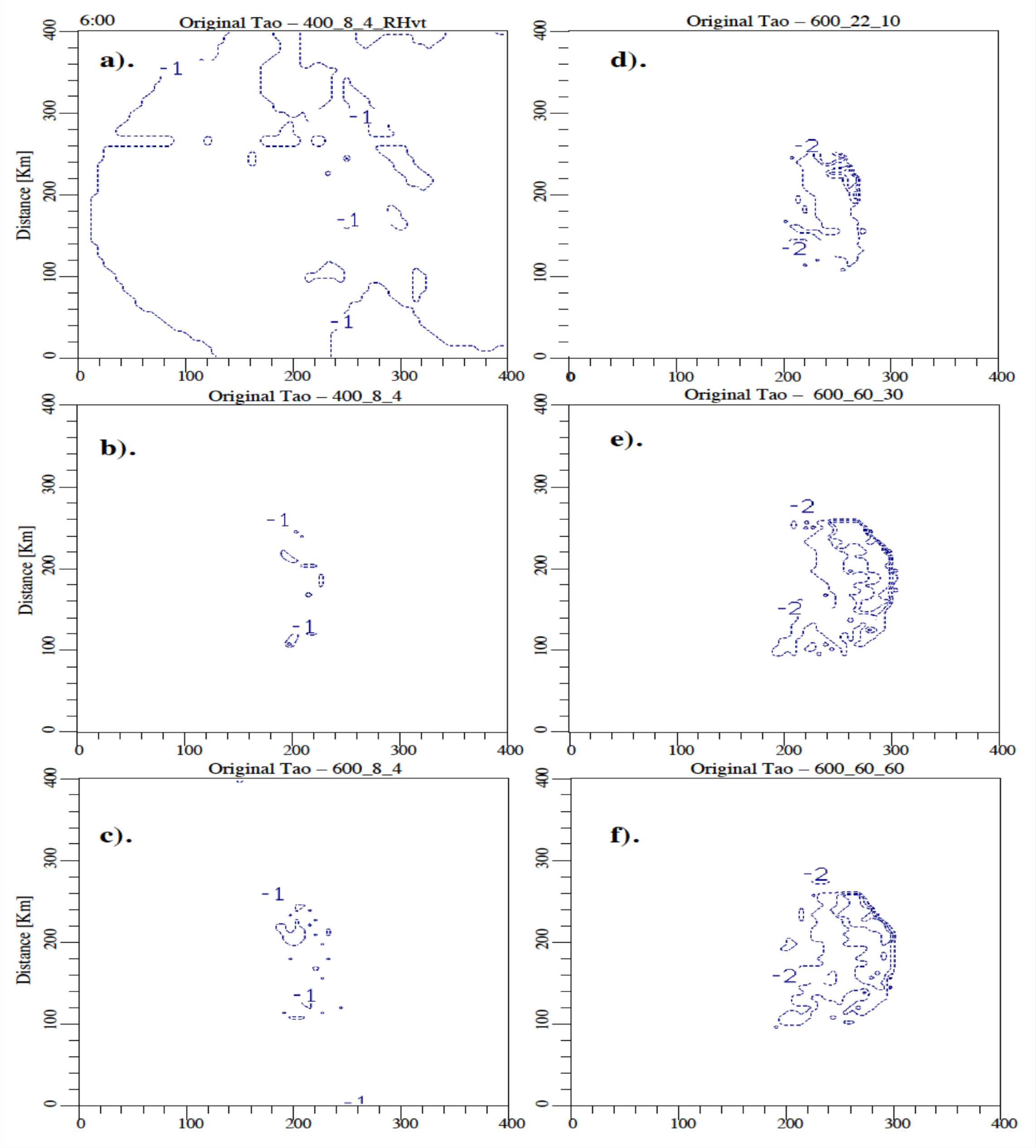
Science Goals:

- Most general goal: To understand how convection initiates, self-organizes and grows upscale
  - using airborne observations
    - from the Ku/Ka-band Airborne Precipitation Radar (APR-2)
    - the 2-um Doppler Aerosol Wind (DAWN) lidar
  - and model simulations.

S. Hristova-Veleva, 2000

The cold pools



Each of the six panels presents the surface temperature anomaly that corresponds to a particular model run that used the same thermodynamic and kinematic environment but differed in the microphysical representation of the simulated storms, assuming smaller and smaller frozen and liquid particles (hydrometeors).

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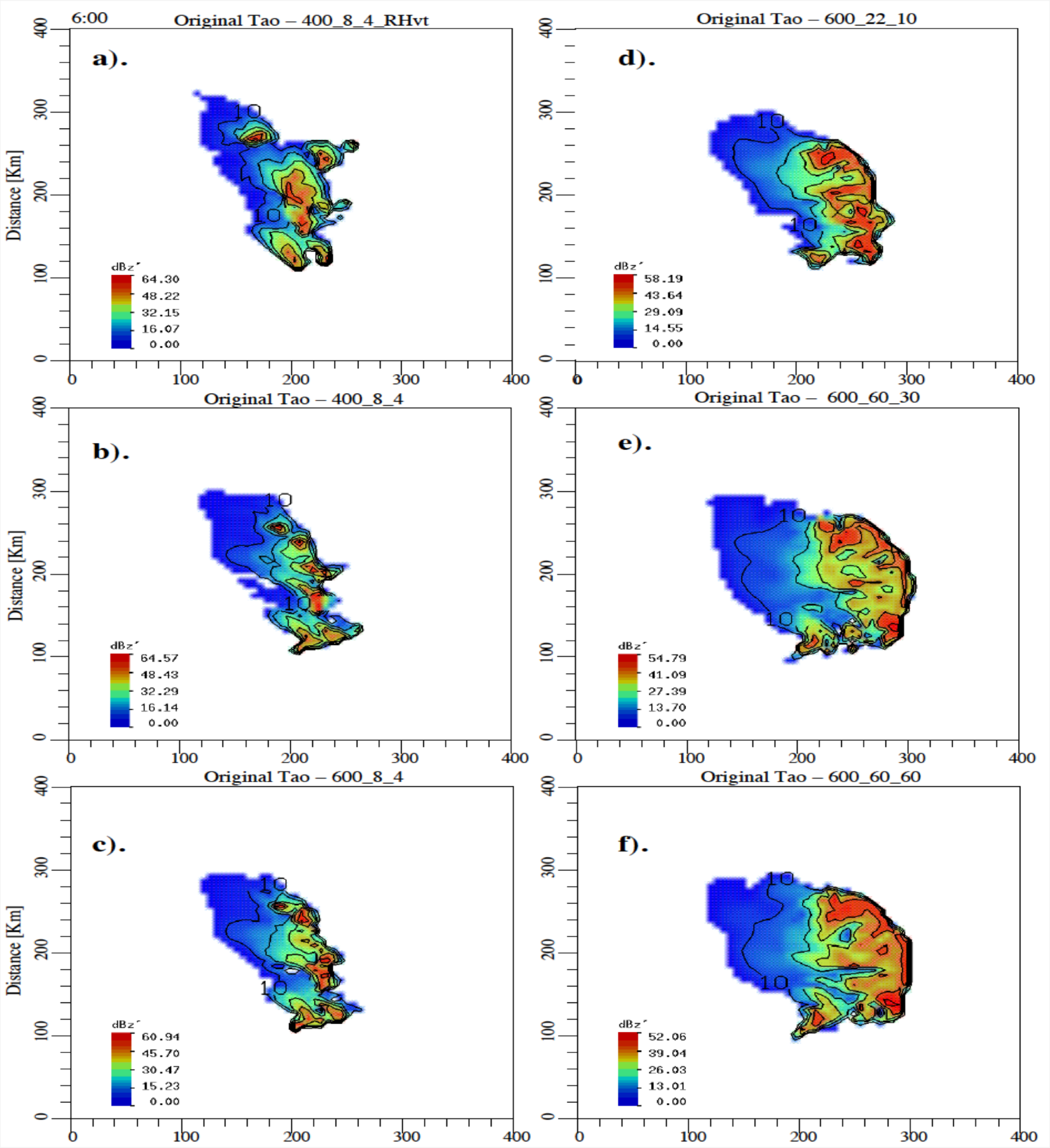
- This investigation will provide insight to the
  - role of the **environmental 3-D wind, thermodynamics, and aerosol loading**, in modulating the **strength and size of the convectively-generated cold pools**

Hristova-Veleva, S. M., 2000: "Impact of microphysical parameterizations on simulated storm evolution and remotely-sensed characteristics", *Ph.D. Thesis* Texas A&M University, pp 201, 2000, Available electronically from http : / /hdl .handle .net /1969 .1 /152150.

The storm organization



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- This investigation will provide insight to the
  - role of the **environmental 3-D wind, thermodynamics, and aerosol loading**, in modulating the **strength and size of the convectively-generated cold pools**
  - and the role of such cold pools in the upscale growth and the evolution of tropical convection.

Hristova-Veleva, S. M., 2000: "Impact of microphysical parameterizations on simulated storm evolution and remotely-sensed characteristics", *Ph.D. Thesis* Texas A&M University, pp 201, 2000, Available electronically from http : / /hdl .handle .net /1969 .1 /152150.

Science objectives and approach

- Observations
  - provide critical information to evaluate and validate the models
  - alone cannot provide full understanding of the multi-scale interactions
- Models provide significant insights on processes and interactions … but only when their forecasts are realistic
- **Proposed way: Use observations to inform and validate models**
  - **Assimilate DAWN winds**
  - **Compare to observations**
    - **Airborne**: compare model cloud field structure and vertical velocity with the APR-2 observations
    - **Satellite**:
      - GPM overpasses (DPR and GMI) - a coarser resolution but wider-swath depiction of the convective organization
      - Ocean wind vectors from ASCAT, SMAP winds, and ScatSat
      - Thermodynamics from AIRS, CrIS, IASI
  - **If realistic, then analyze the model fields to understand the relationship between**
    - **the 3D winds, the thermodynamic structure of the environment and the strength and size of the convectively-generated cold pools**
    - **the precipitation driven cold pools and the convective cloud organization and evolution**

Understanding the impact of the DAWN winds

1. **To quantify the impact of the DAWN measurements on the analyzed variables** when we assimilate the DAWN observations into the model

2. **To quantitatively assess the capability that DAWN observations bring to the representation of the wind and cloud field structure and variability**.

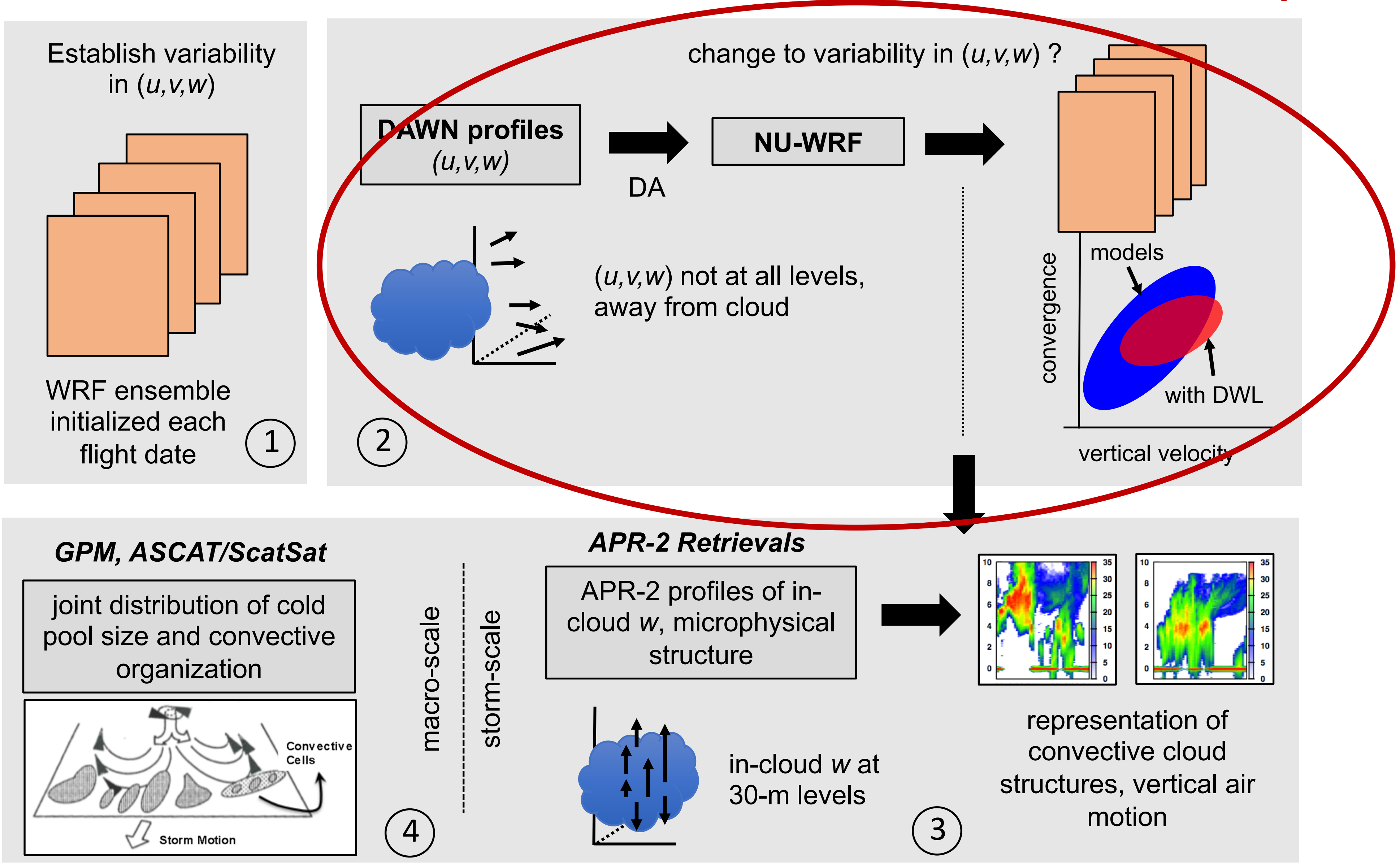
3. **To aid in assessing future requirements** and limitations on the

   a) **scale (horizontal and vertical) of the observations needed for a space-based DWL capability.**

   b) **The outcome of this study will be the resolutions required for such an instrument to resolve various scales of convective processes.**

From the proposal: (PI J. F. Turk, Co-Is S. Hristova-Veleva, S. Zhang)

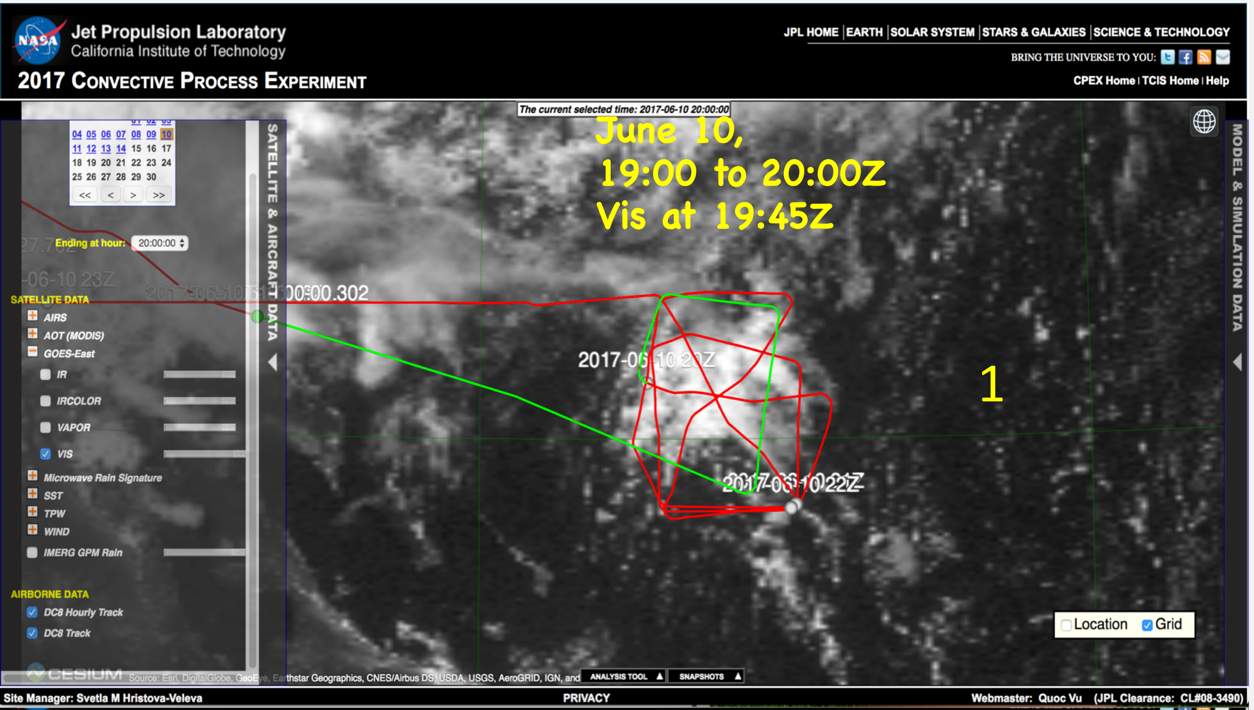
focus of this presentation

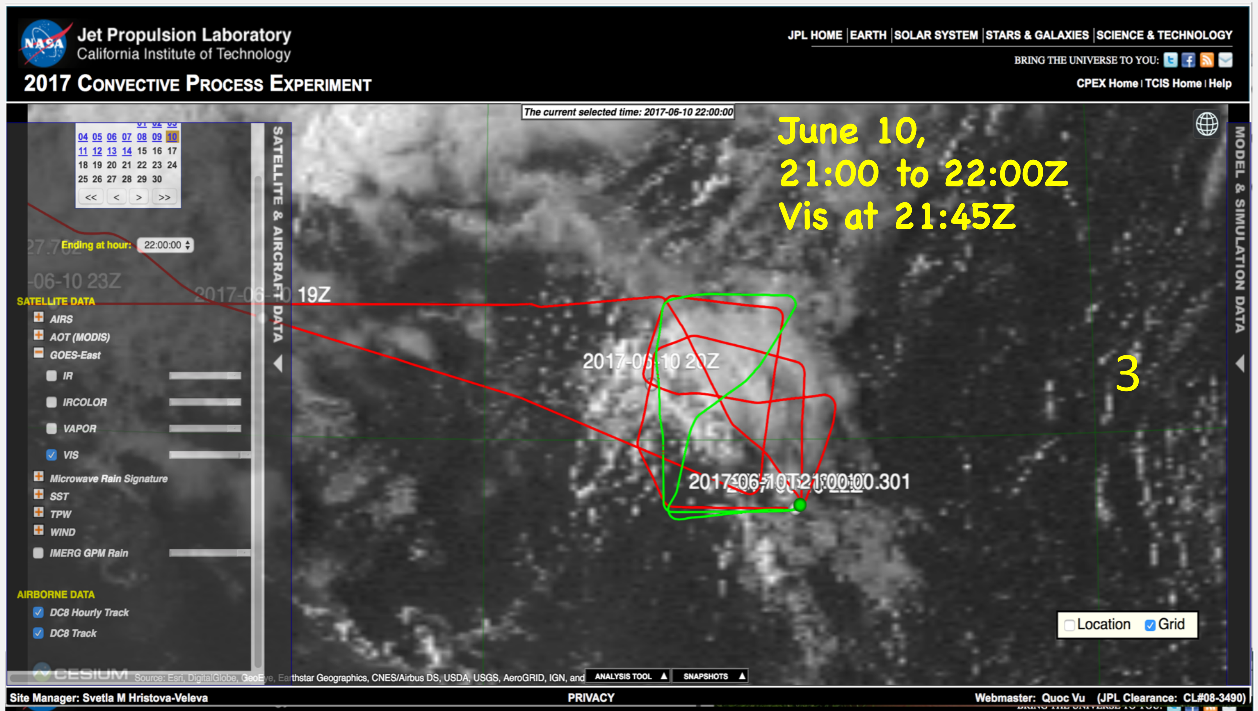


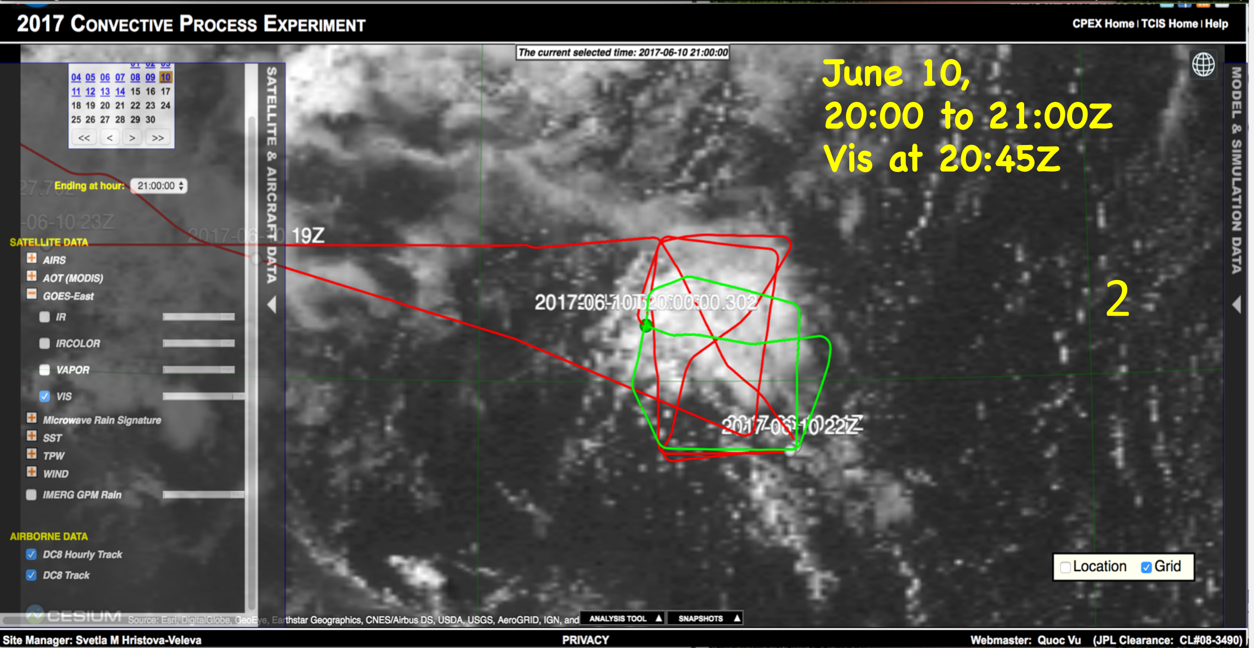
What observations do we need …

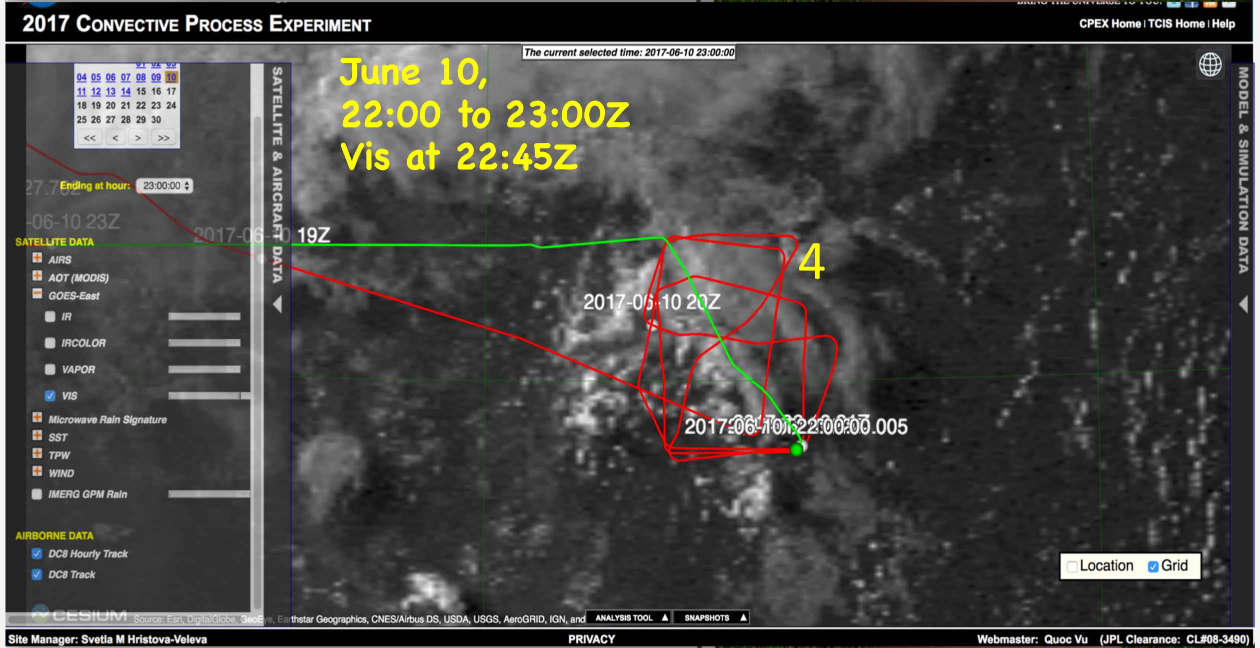
1. Observations of of the environment – **the area just outside the storm**
2. **Followed up by observations of the convection in the "box"**
3. **Repeated to see the development**
4. Followed up by the observations of the system by satellites
    - Precipitation: GPM-core, AMSR, SSMIS
    - Thermodynamics: AISR, CrIS, IASI
    - Surface winds: Scatterometers (ASCAT, ScatSat), SMAP
    - SST

Almost perfectly executed on June 10th!!!   Thank you Ed for pointing us to this case!



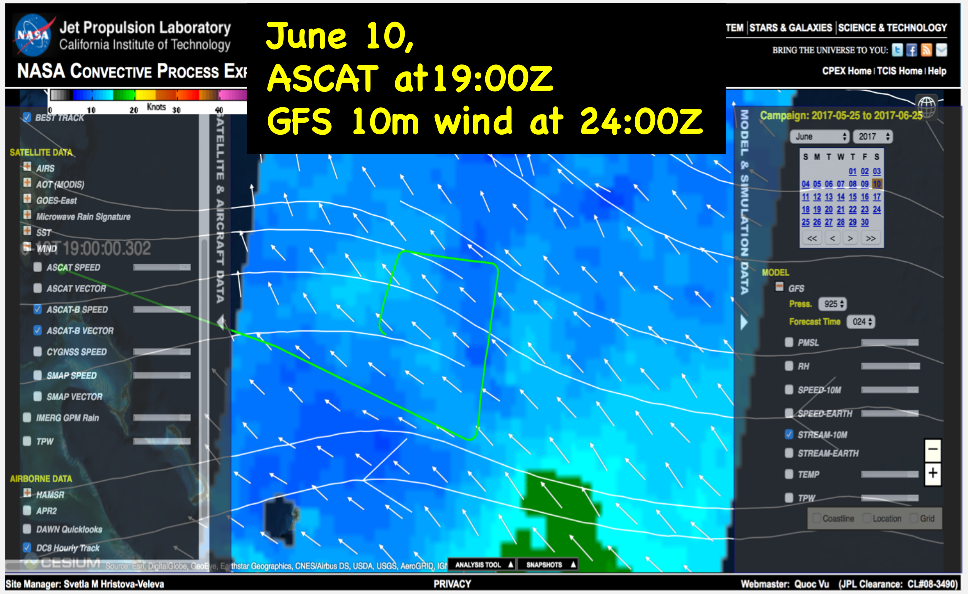


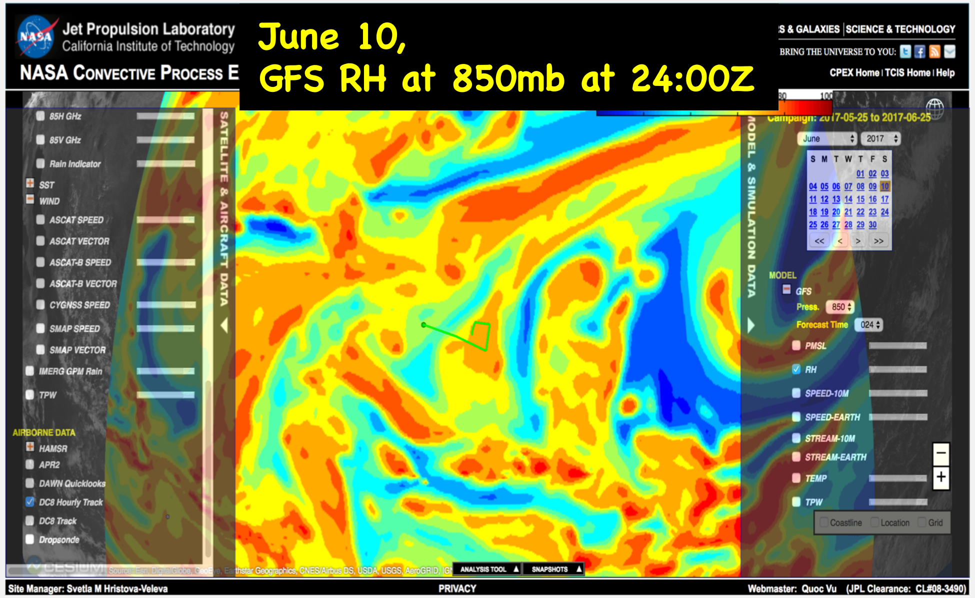


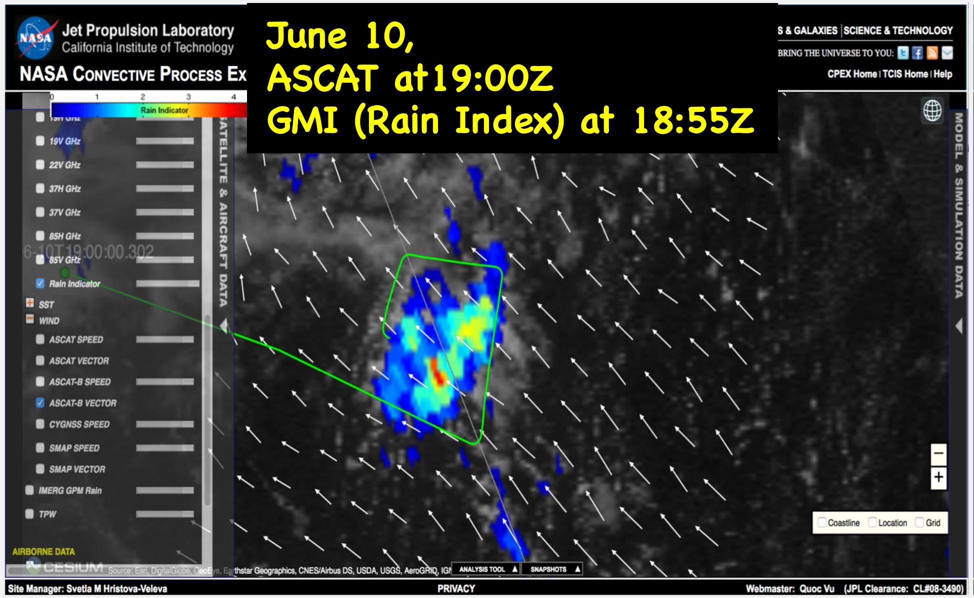


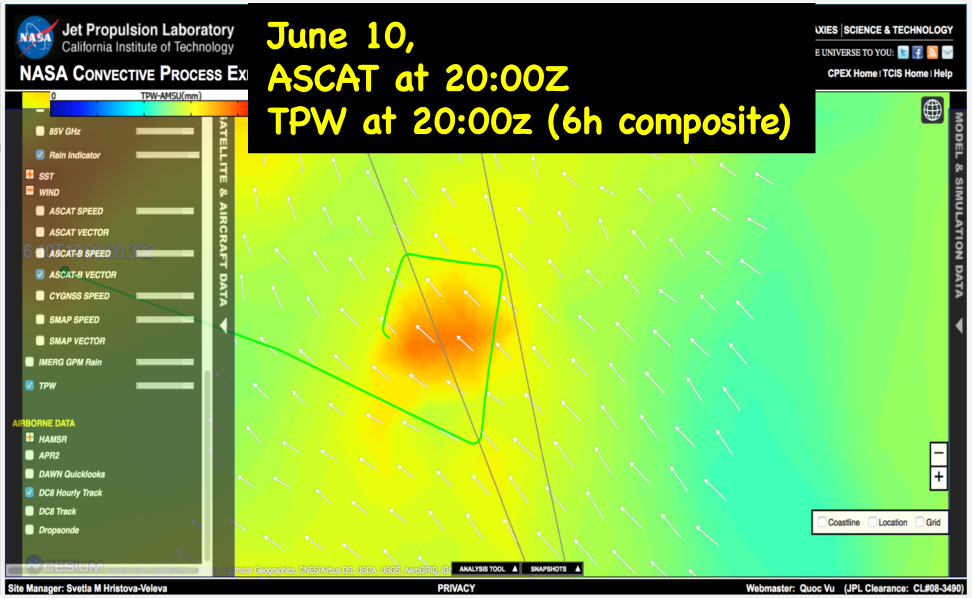
A view from the window
Between 21:45 and 22:05

Satellite observations and GFS forecast





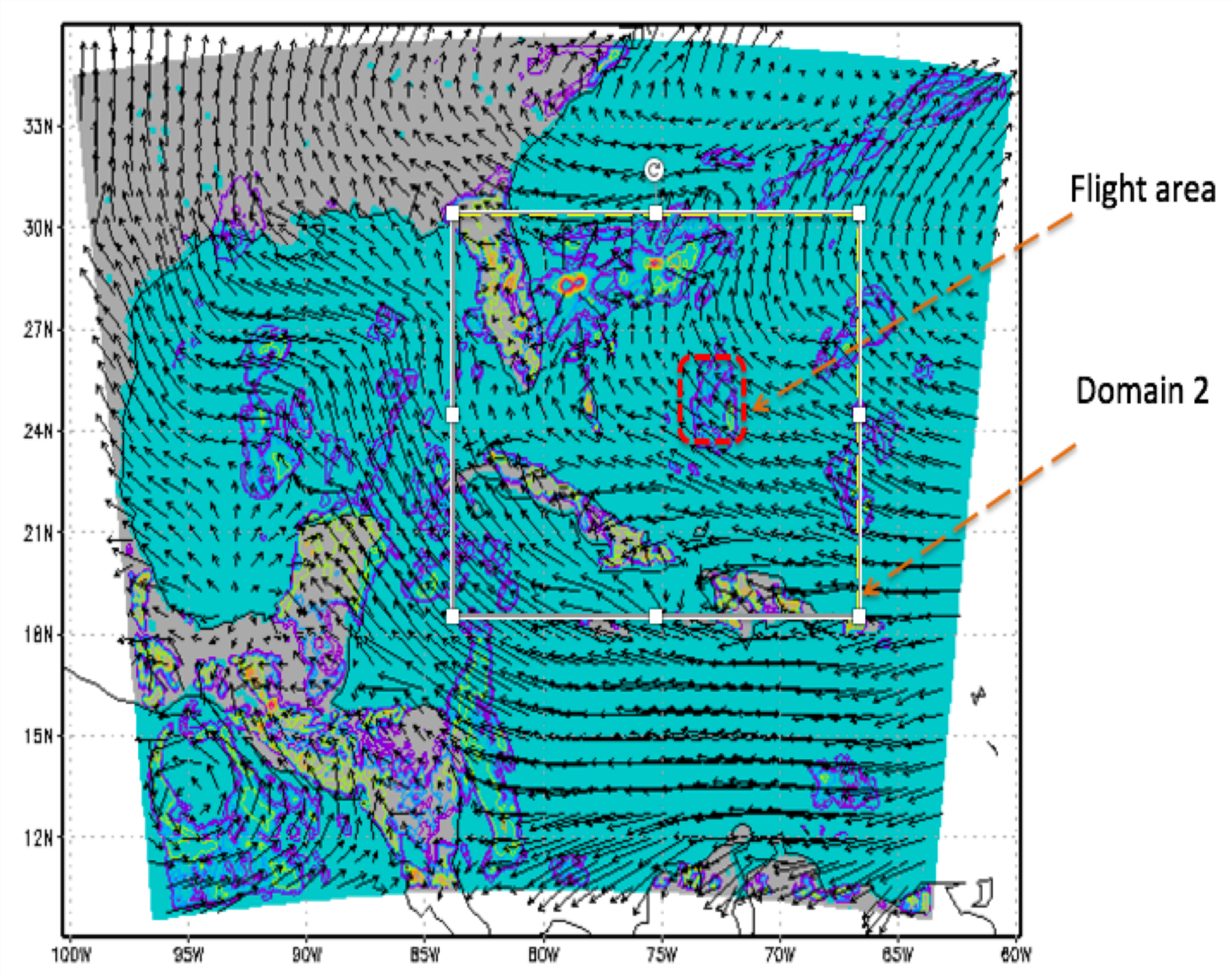




The CPEX control simulation: June 10th case (Flight sampling period: 19z to 22z)

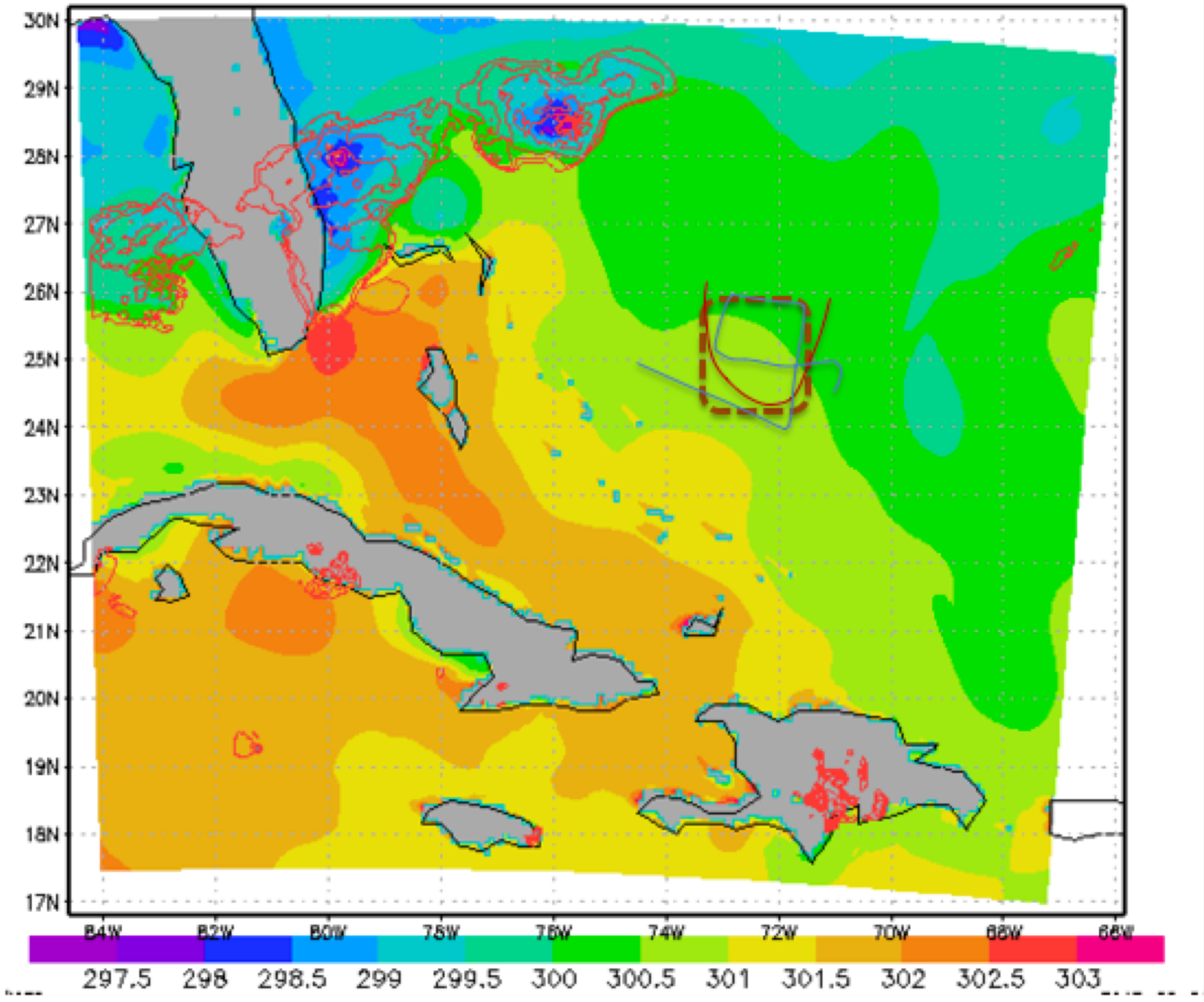
Model

- **Resolution**: horizontal 9KM(domain 1), **3KM (domain 2), vertical 55 levels**. time step 45sec (d01), 15sec(d02)
- **physics: Thompson 6 class microphysics, Grell 3D ensemble cumulus scheme**
- lateral boundary condition and forcing: **NCEP GDAS**
- experiment period: 20170610 00Z -- 20170611 00Z including spin-up



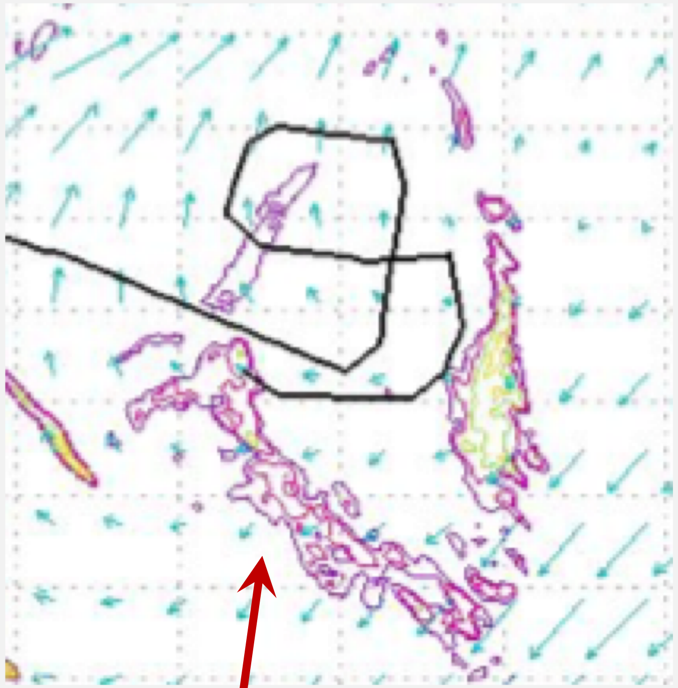
Pre-flight, I hour before precipitation formation (14Z)

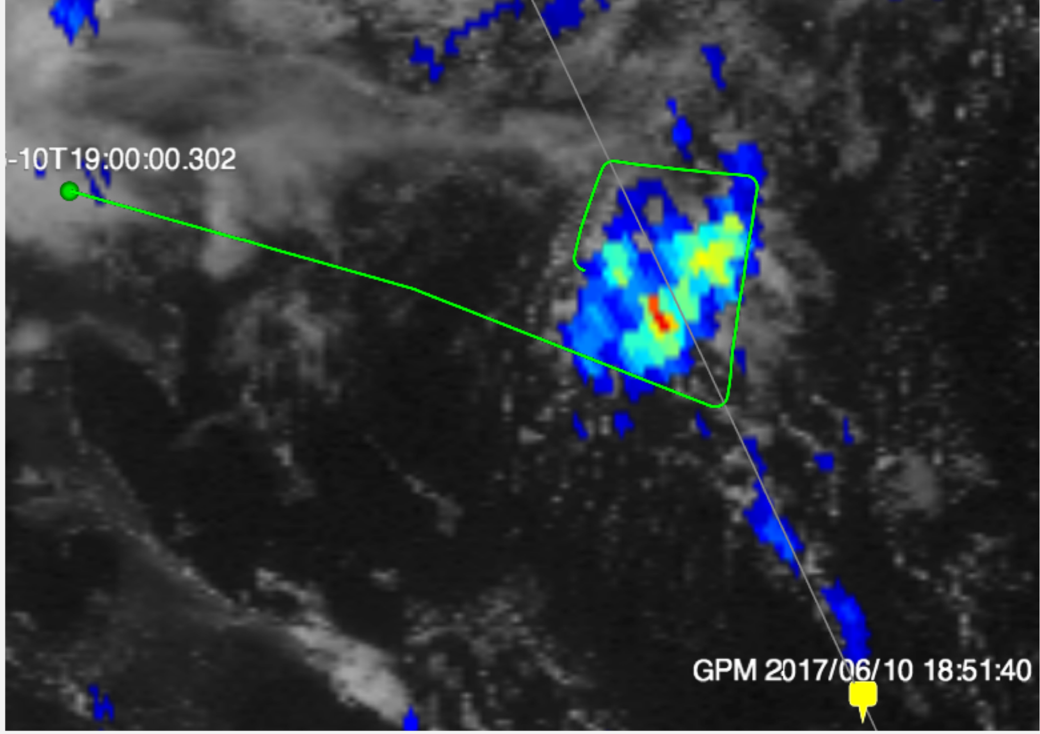
Inner domain : precipitation (contour); 2m temperature (shaded)

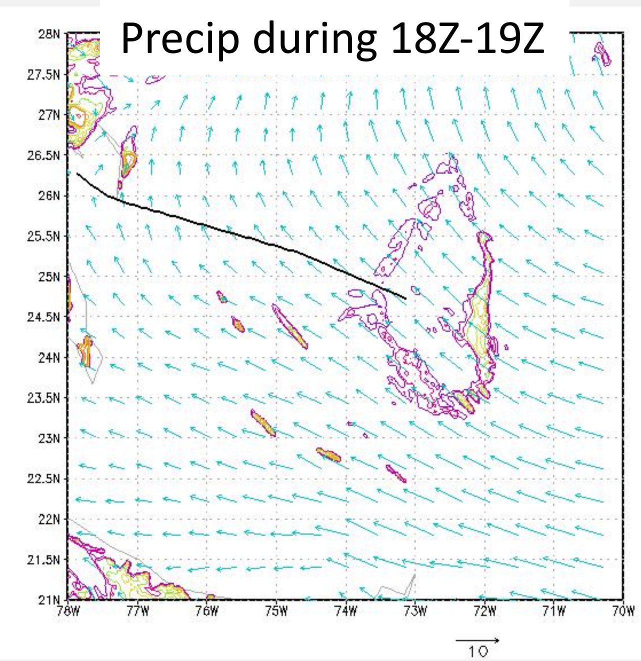


Control

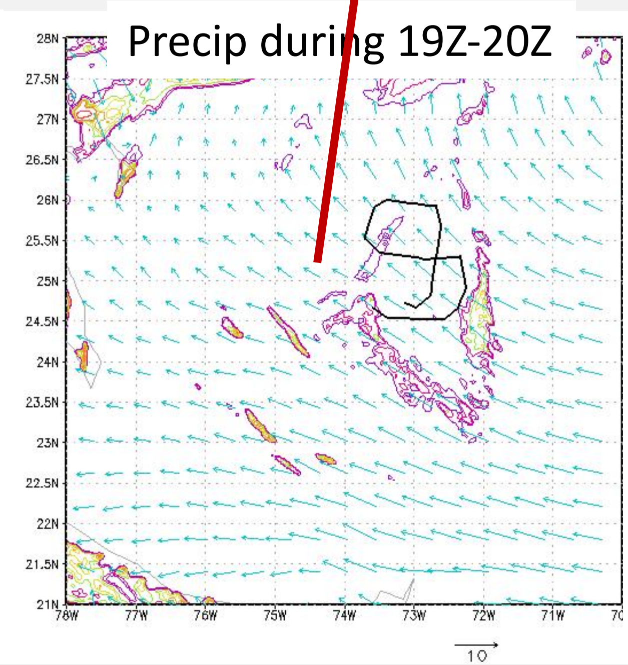
during the flight time (19,20,21,22z) precipitation (contour) and wind at level 500m (vector)



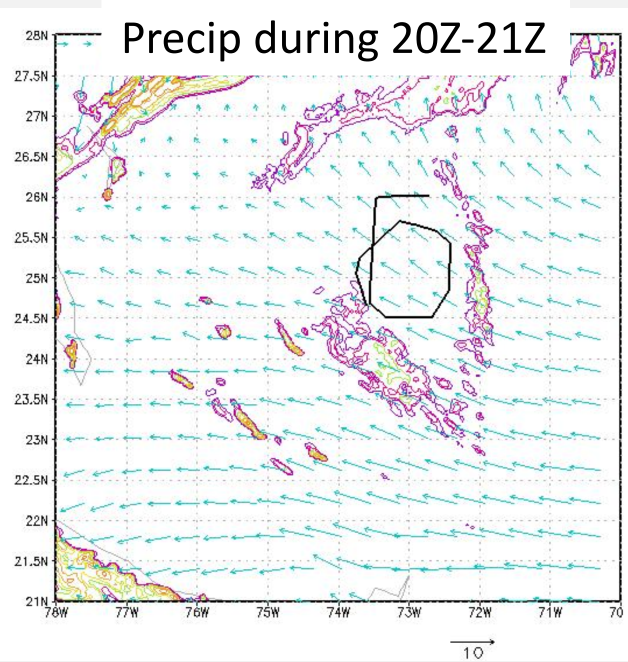




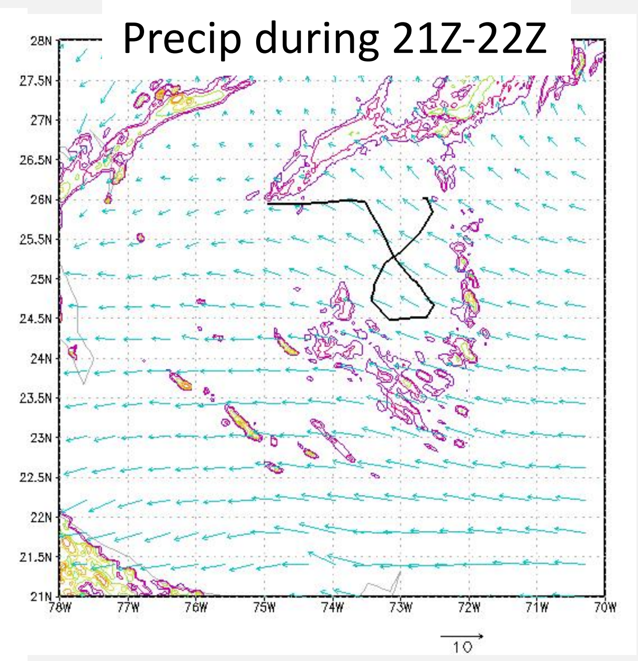
Precip during 18Z-19Z



Precip during 19Z-20Z



Precip during 20Z-21Z



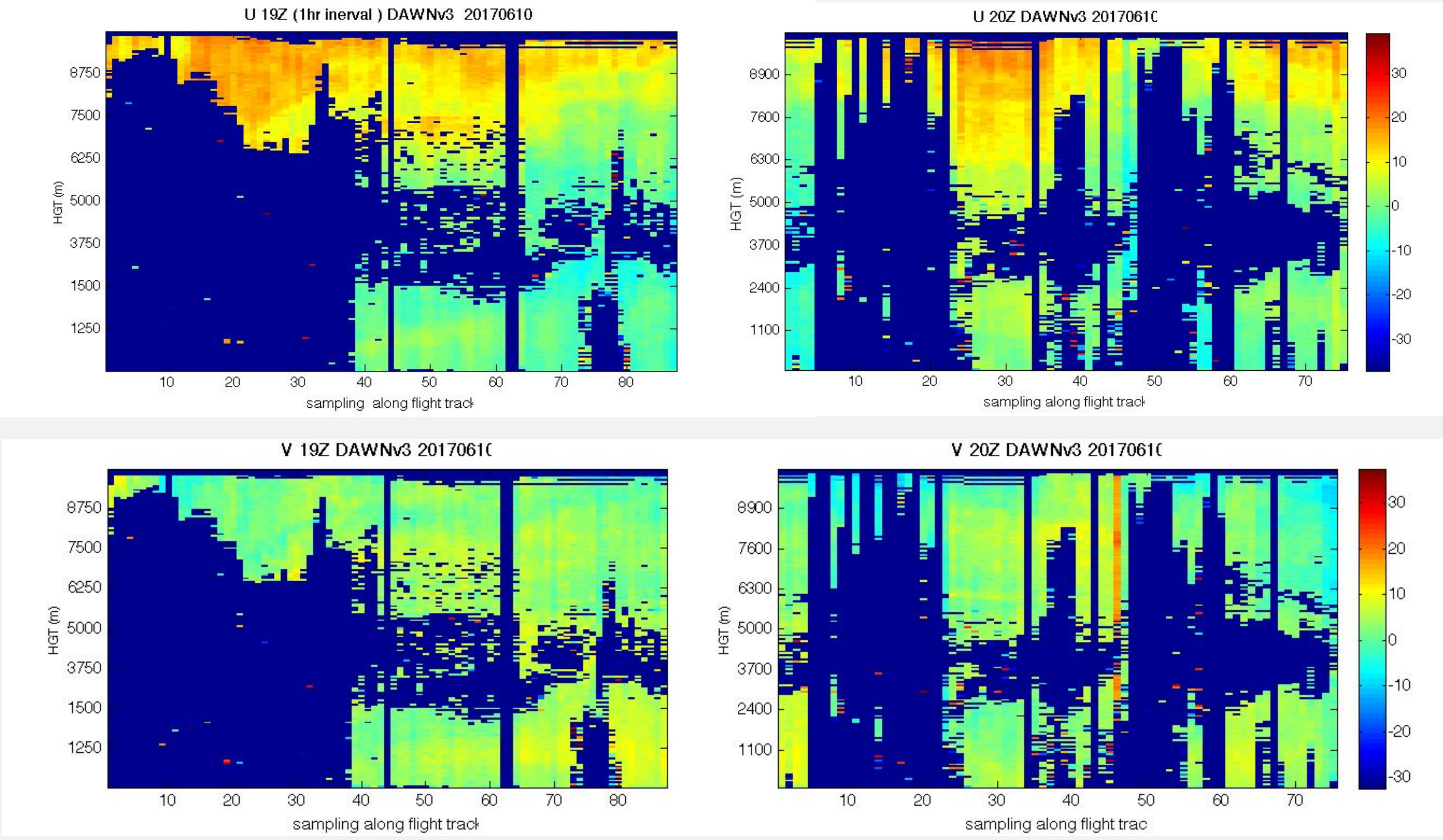
Precip during 21Z-22Z

Processes specific for DAWNv3 observations:

- **Observation error standard deviation specified as 1 (m/s) at the sampling time centered at analysis time**. Observation error standard deviation increases corresponding t the length of sampling time away from analysis time.
- **QC: Observations within statistical bounds and with departure less than 8 (m/s) are accepted**.
- Optional super-ob both in vertical and in frequency of profile sampling It is not applied in the current experiment.
- An new observation operator for DAWN data is developed and integrated into NU-WRF EDAS. It transforms/interpolates background wind to the observable profile.

DAWN DATA

DAWNv3 wind profiles (pre-processed to U V)



The CPEX data assimilation experiments using NASA Unified WRF Ensemble Data Assimilation System (NU-WRF EDAS)

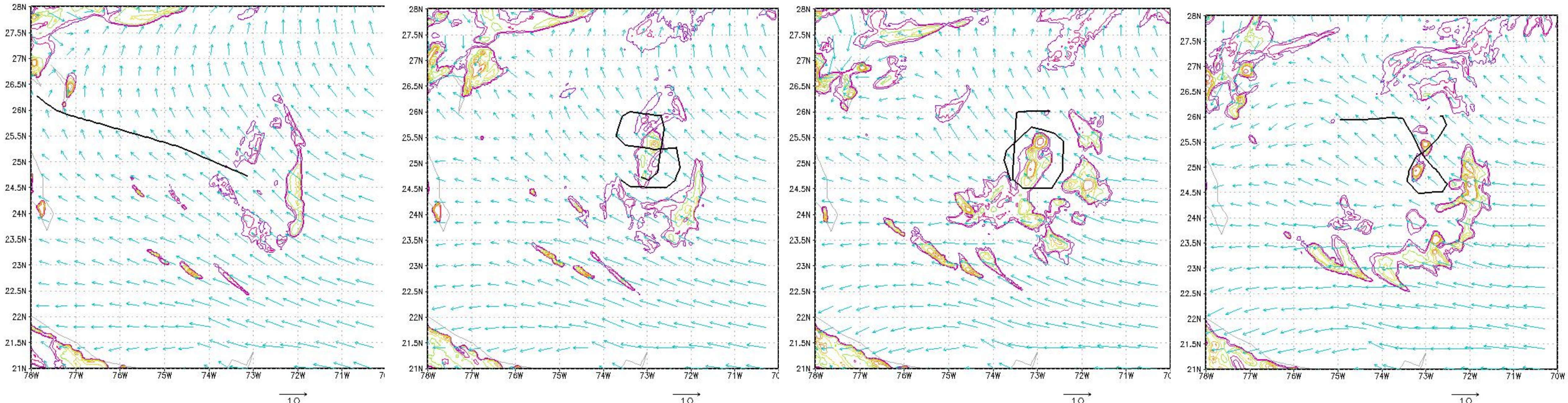
June 10th case (Flight sampling period: 19z to 22z)

Analysis

- **Algorithm: ensemble maximum likelihood filter**
- **Control variables: wind**, temperature, specific humidity, surface pressure, clouds and precipitation (liquid and frozen phase)
- Assimilation window: 1 hour
- **Ensemble size: 48**
- **Background error covariance: flow-dependent**, estimated from ensemble forecasts
- **Observation types assimilated:** NCEP conventional observations, **DAWNv3 wind profiles**

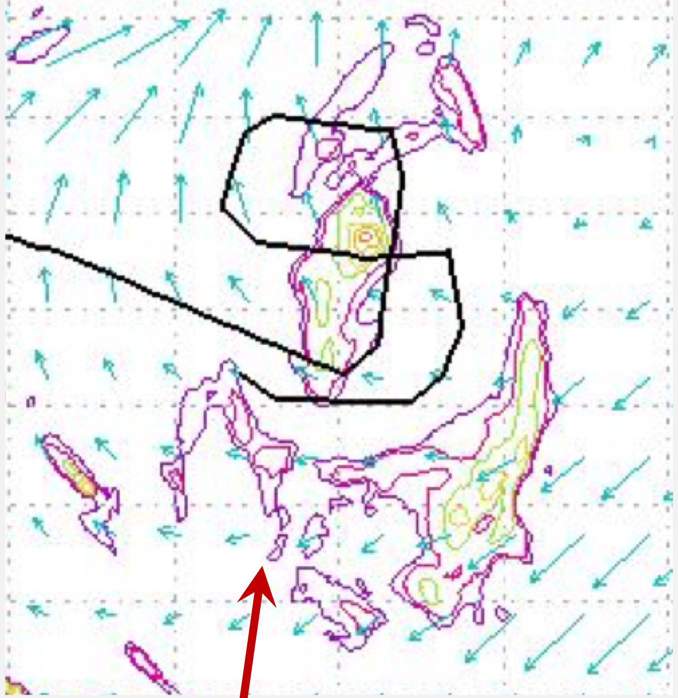
DAWN data assimilation during the flight time (19,20,21,22z) precipitation (contour) and wind at level 500m (vector)

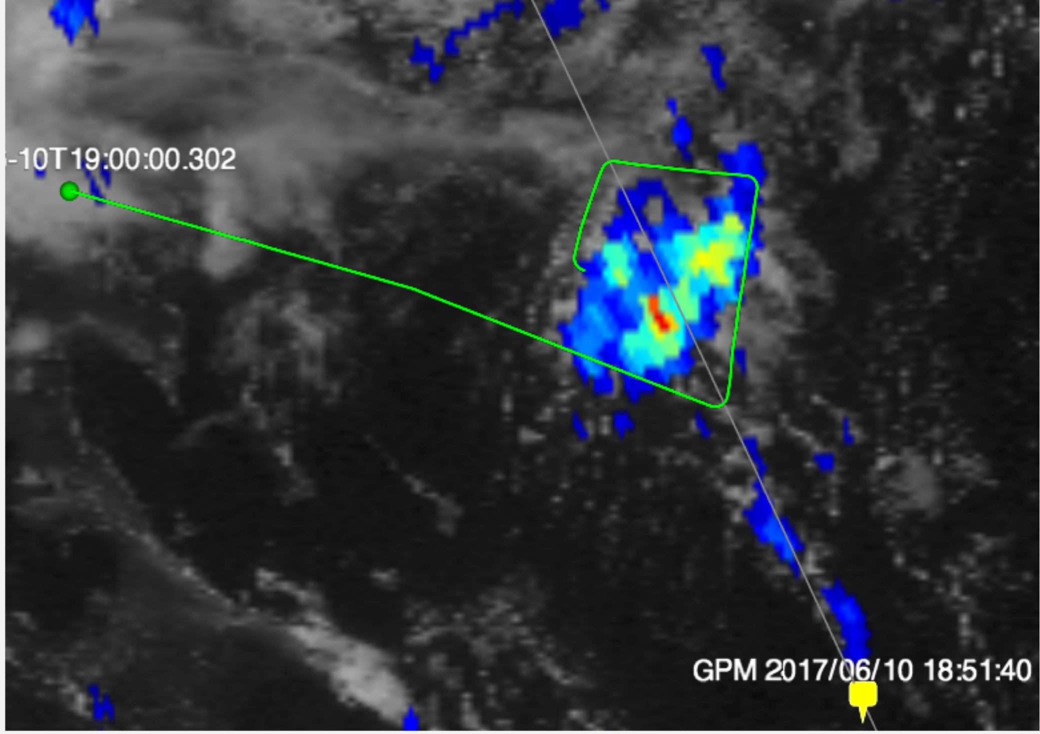
Assimilation

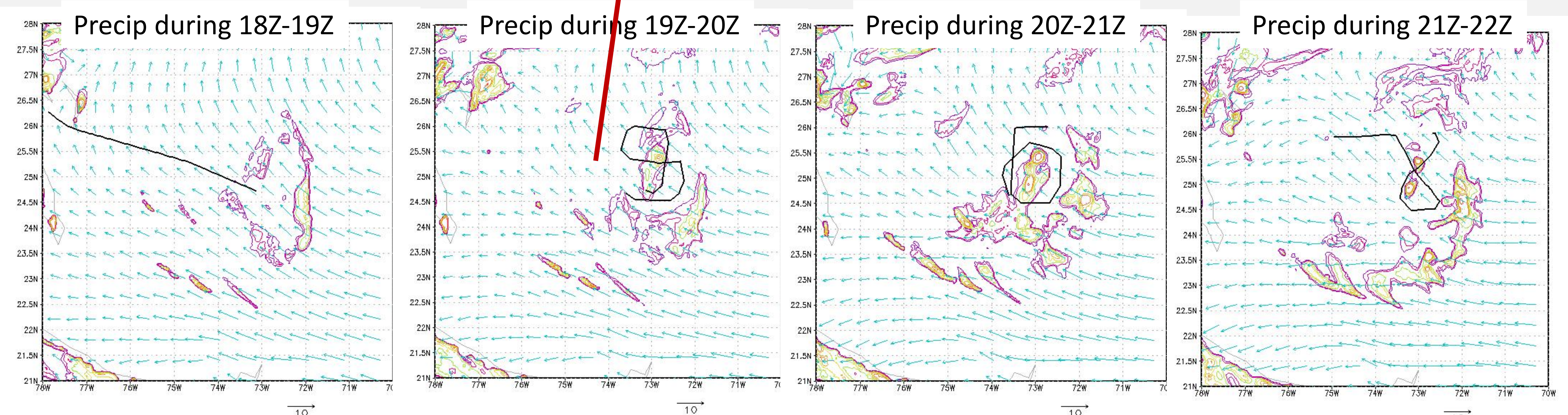


DAWN data **assimilation** during the flight time (19,20,21,22z) precipitation (contour) and wind at level 500m (vector)

assimilation







Control
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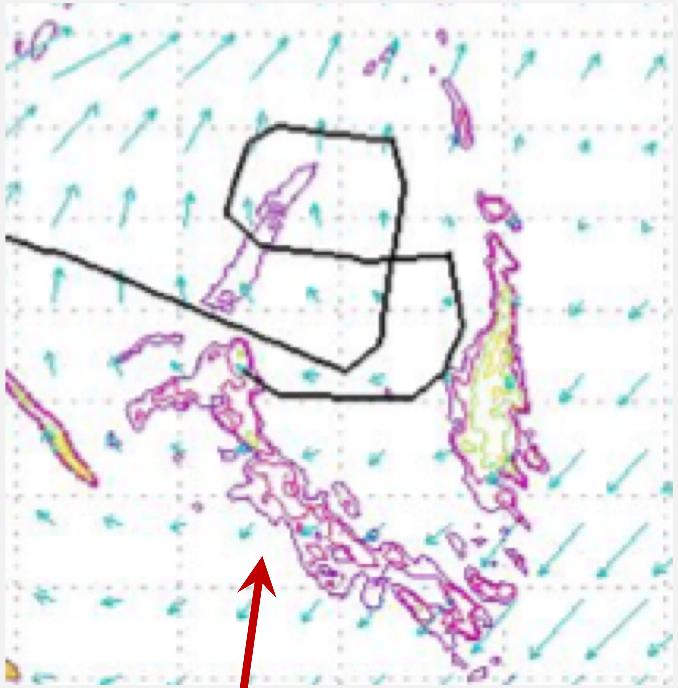
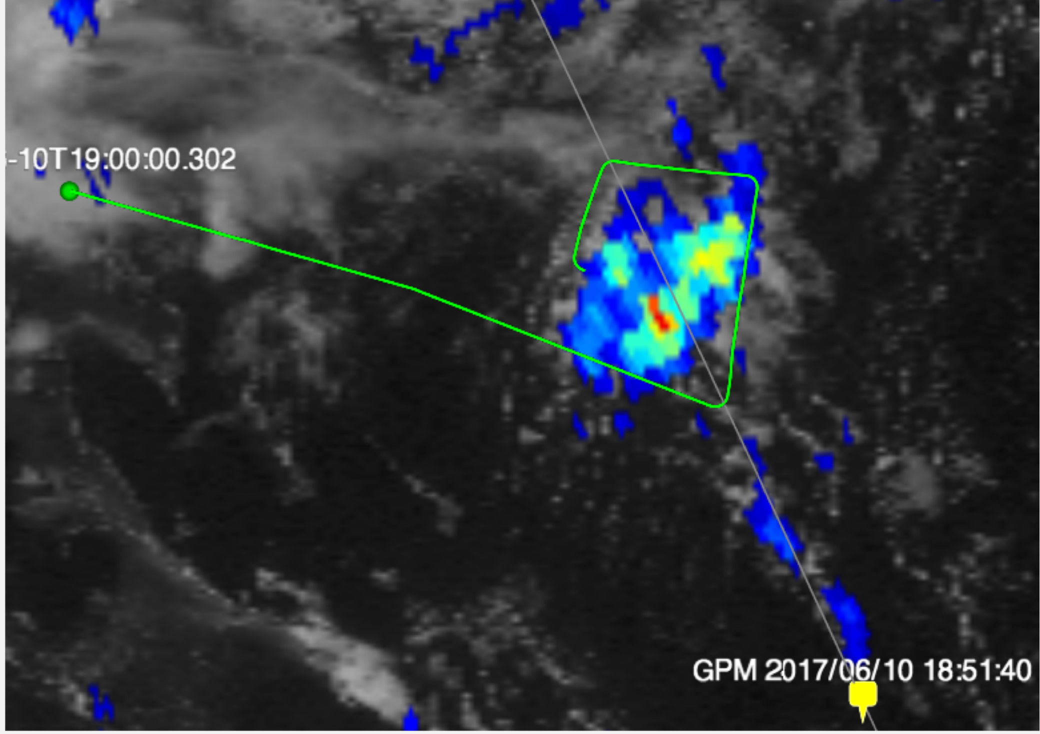
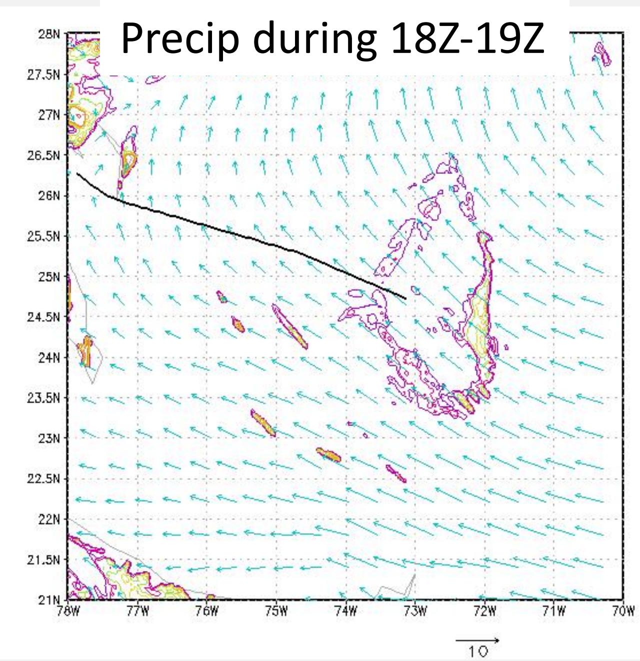
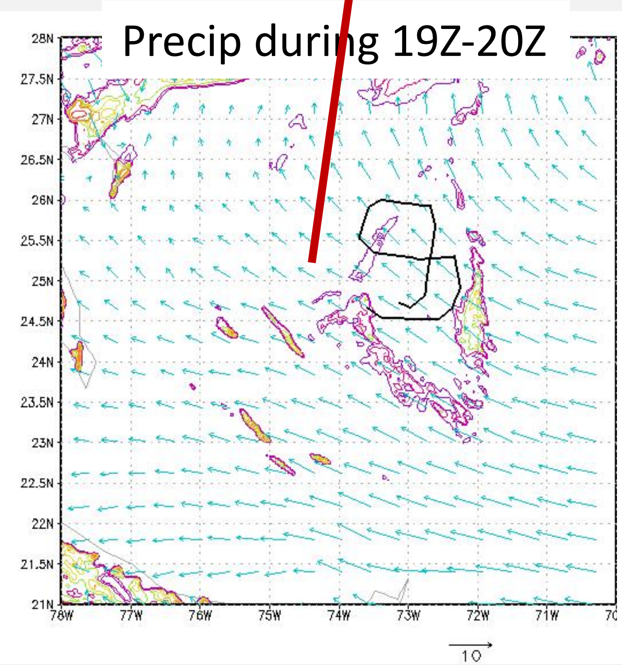
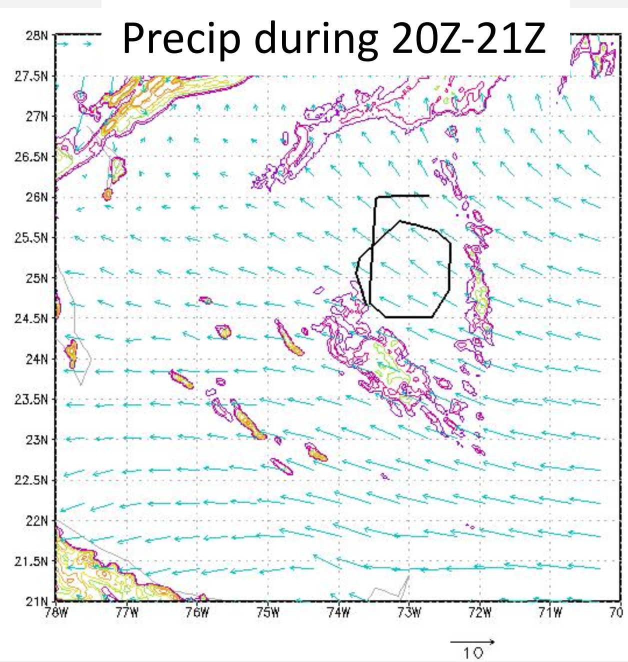
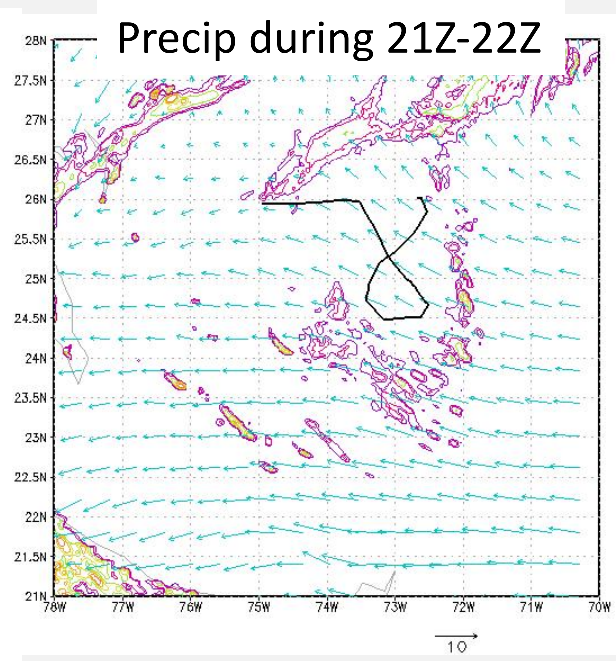








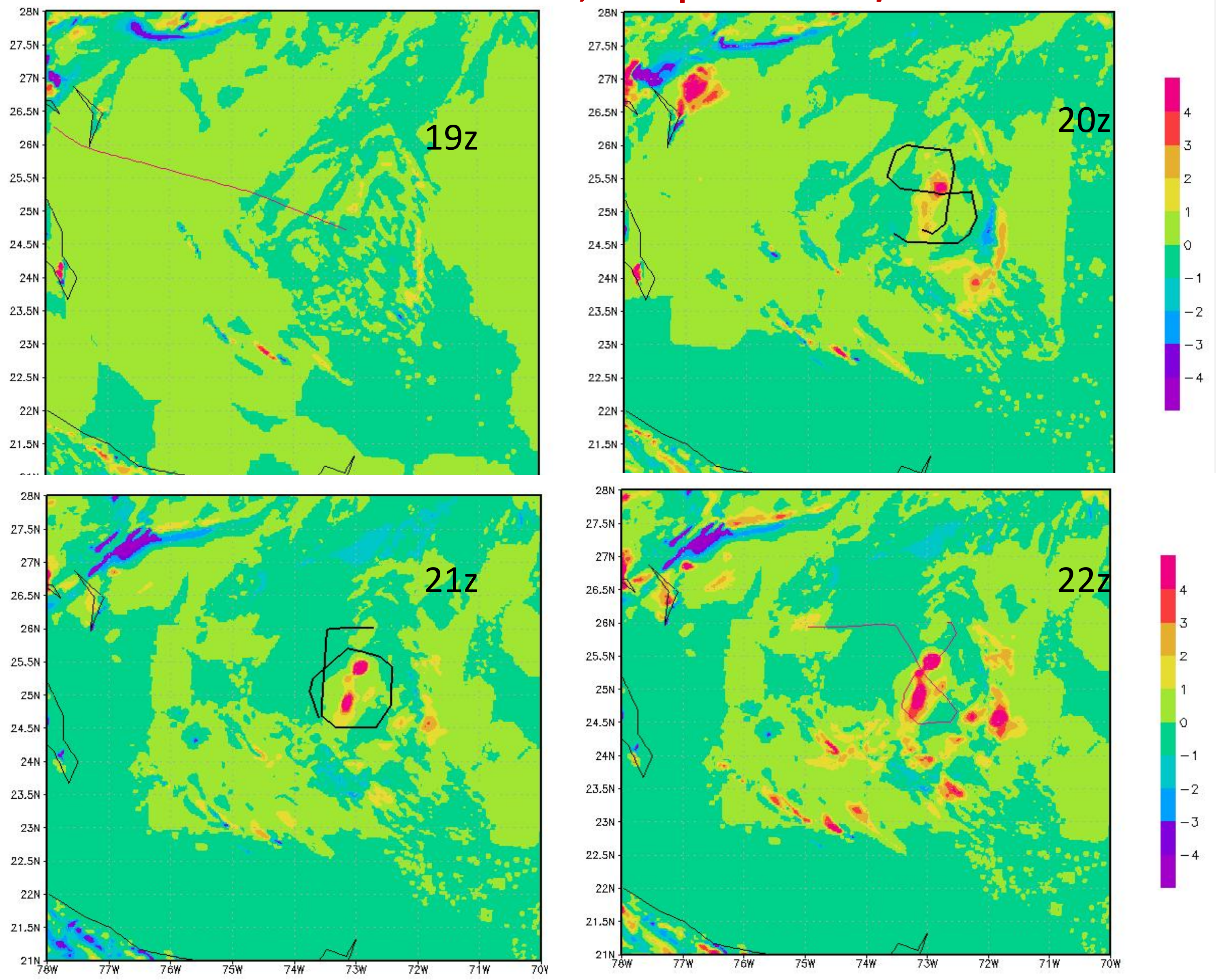




Impact of DAWN assimilation

Impact on the precipitation:
(zoom-in to the flight area in inner domain, flight path in black line)

Assim-Contr, Precipitation mm/h



Impact on the wind

- RMSE (b) - the departure of first guess and observation
- RMSE (a) - the departure of analysis and observation
- Num. obs. - only these accepted by the QC
- Norm. Jo is the least square departures normalized by observation error covariance and observation counts (before / after minimization)

Anal. time	RMSE (b)	RMSE (a)	Num. OBS	Norm. Jo
19z	3.10	2.85	11978	4.78/4.08
20z	3.43	3.27	9464	5.86/5.37
21z	3.41	3.15	4550	5.82/4.99
22z	3.64	3.44	10504	6.62/5.94

So … What happened after the assimilation at 19Z

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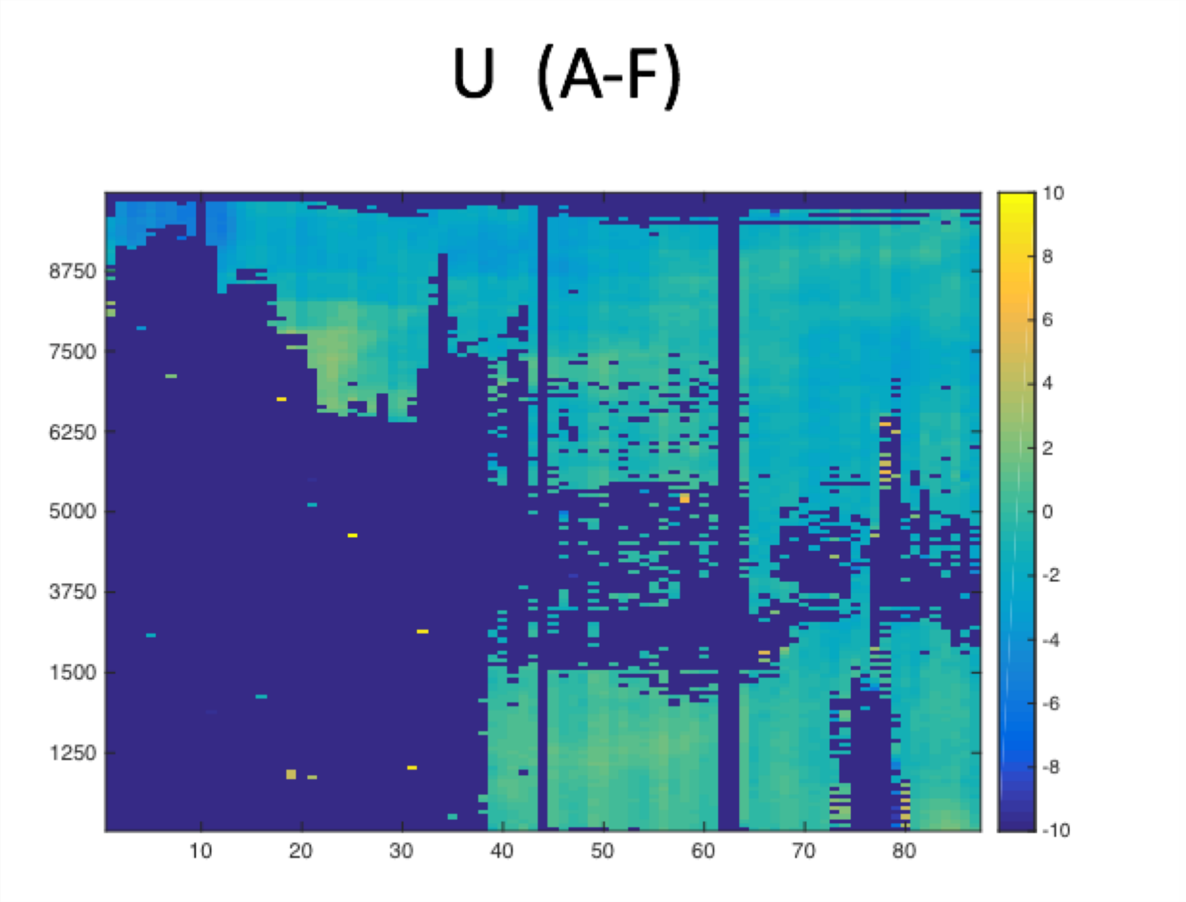
Analysis – Forecast



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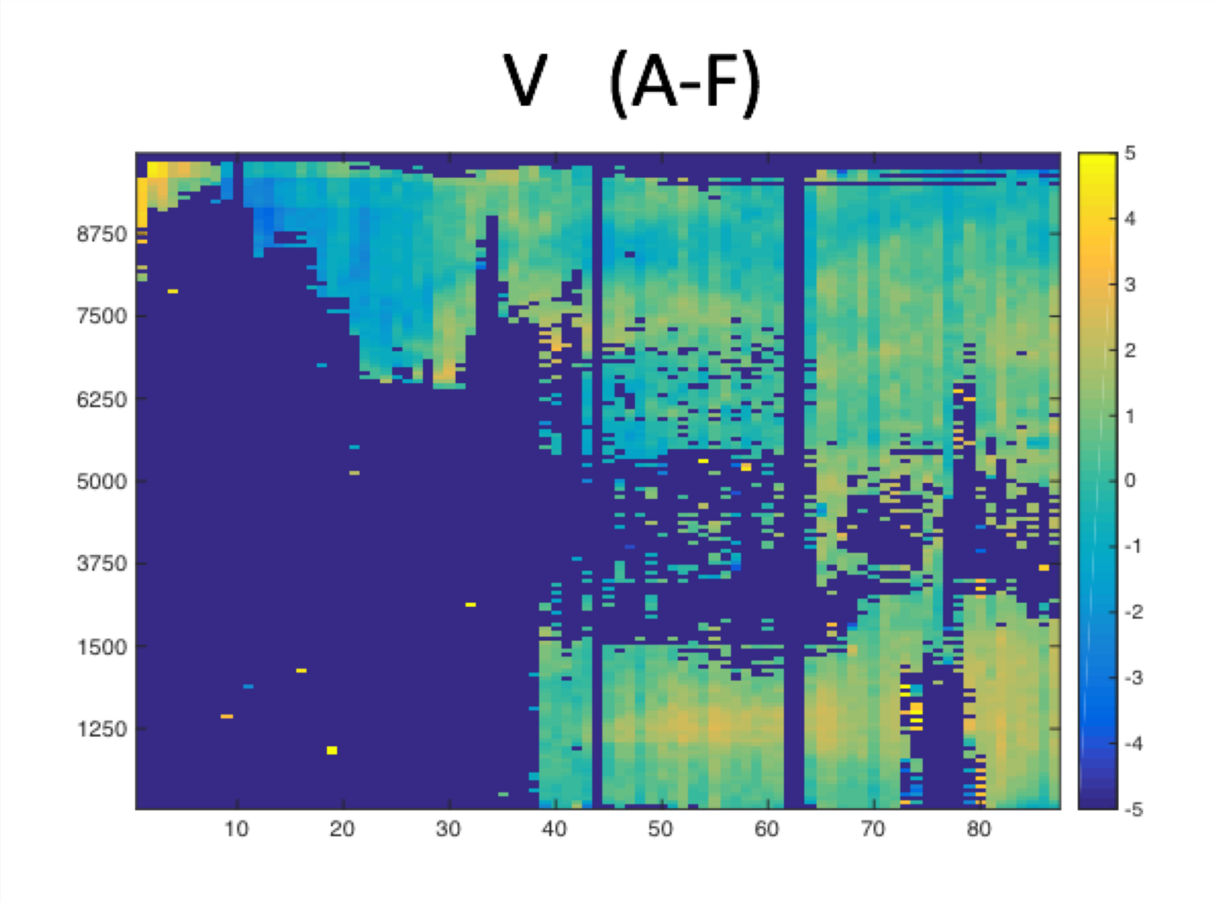
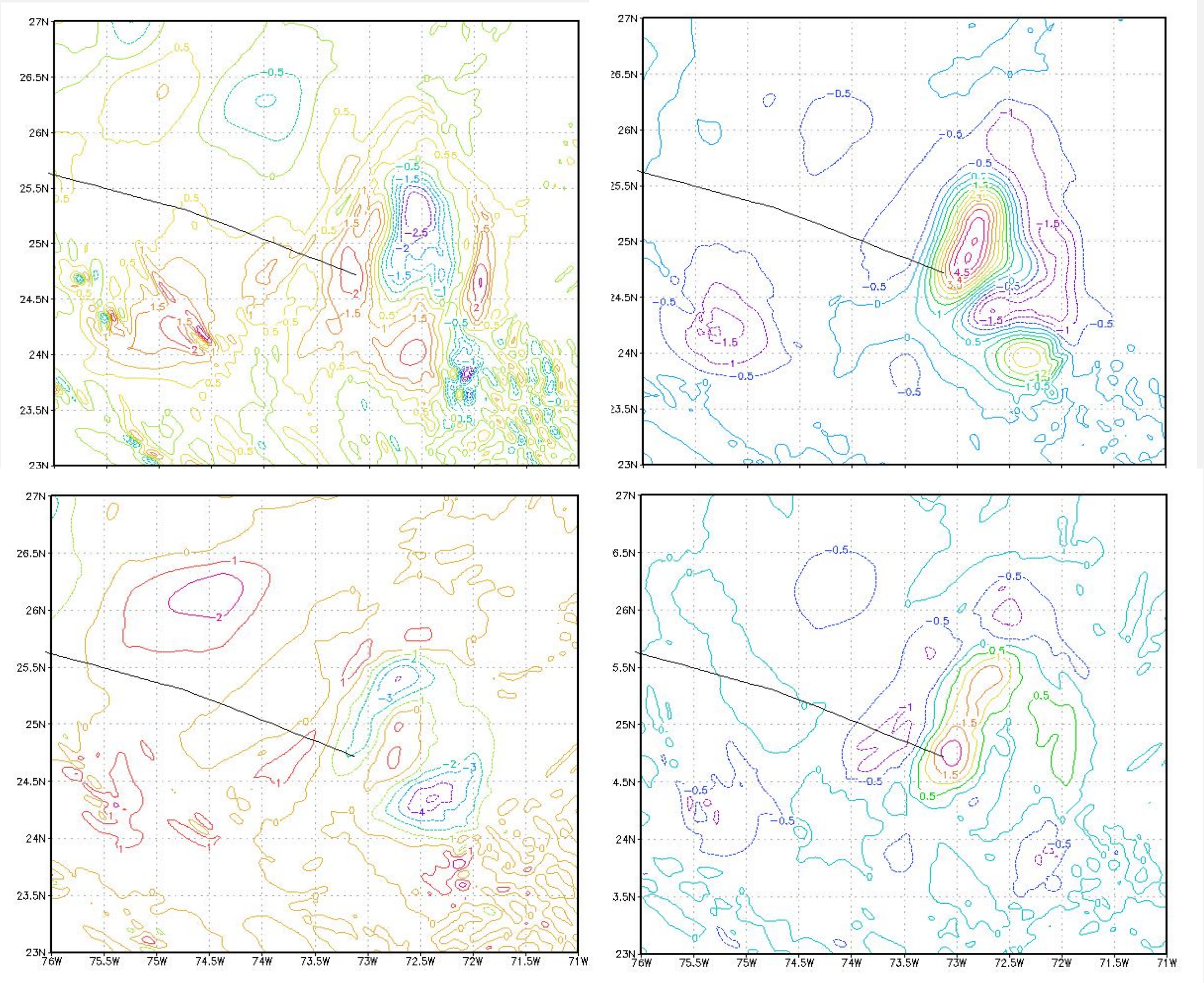


Near surface

U

V



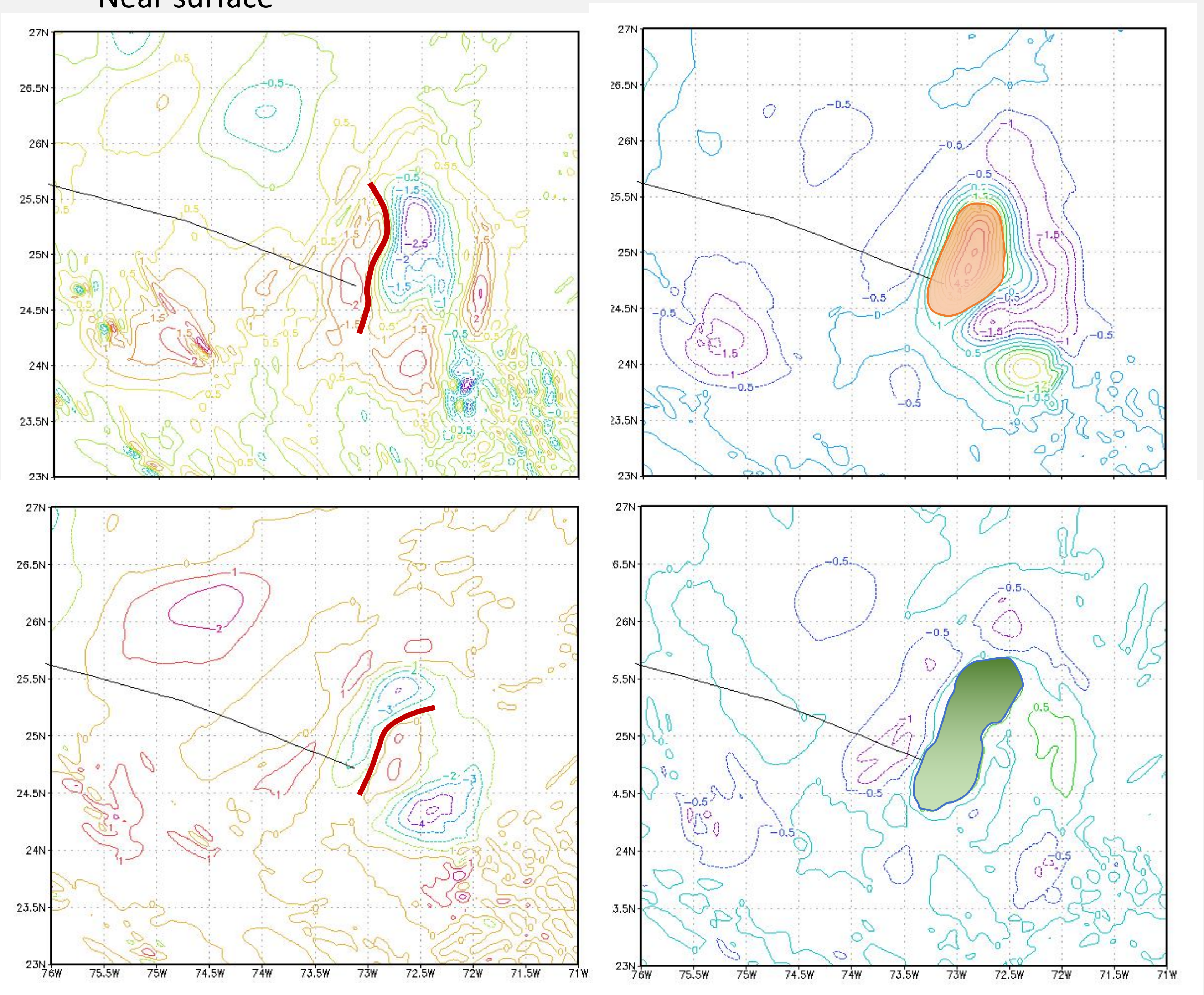
19Z Potential temperature difference (assim. – contr)

19Z water vapor difference (assim. – contr)

Near surface

U

V



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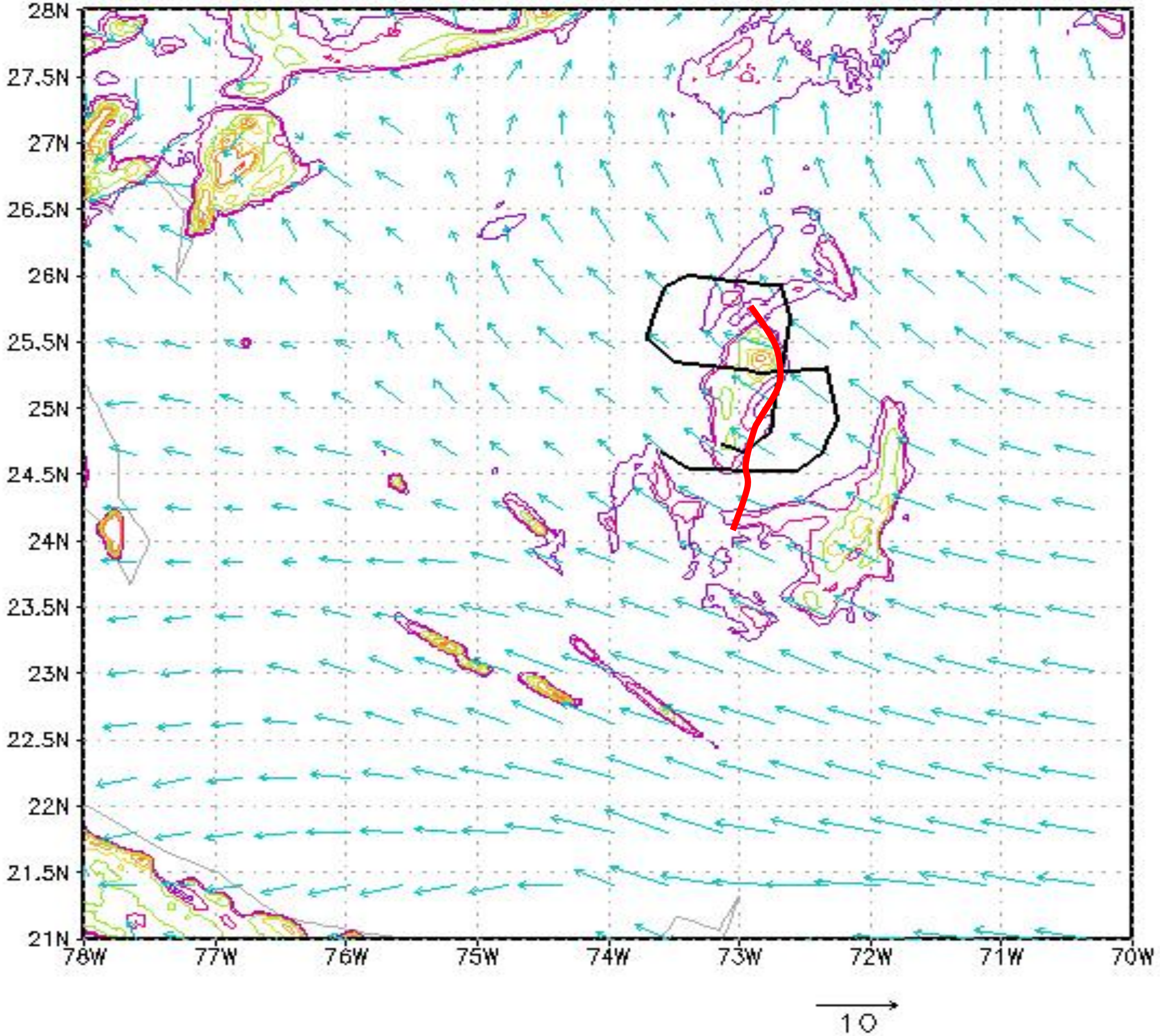

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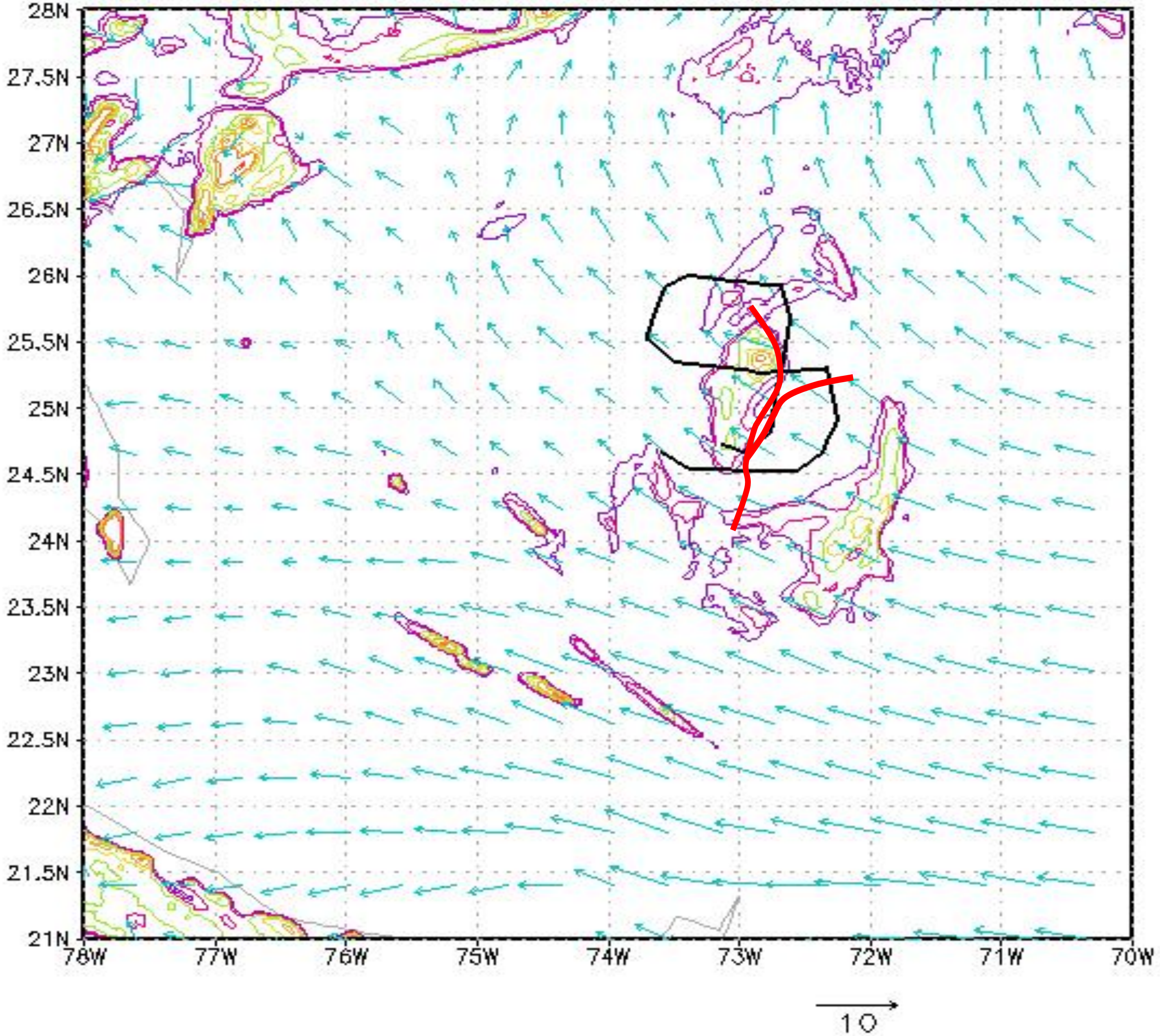

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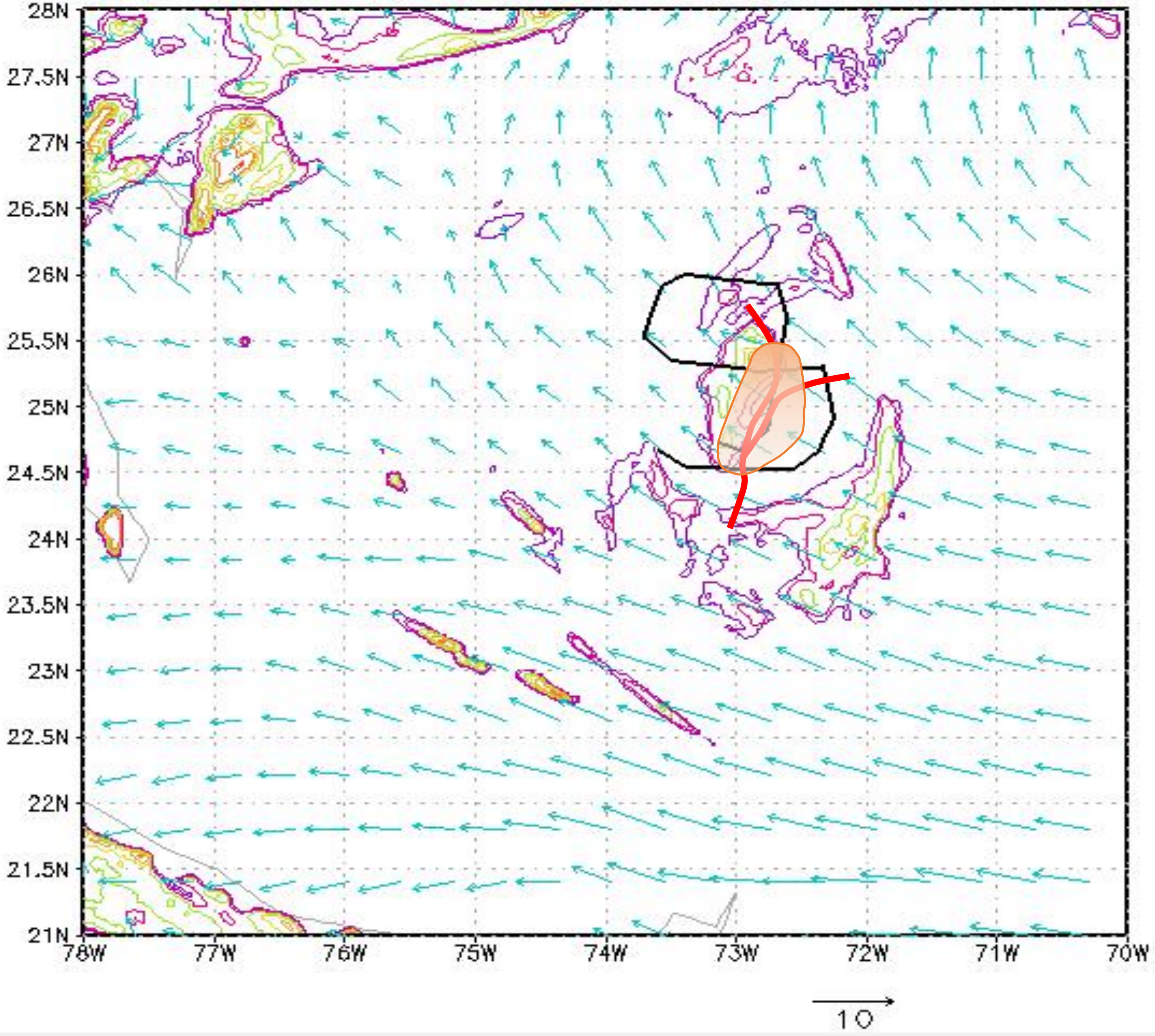

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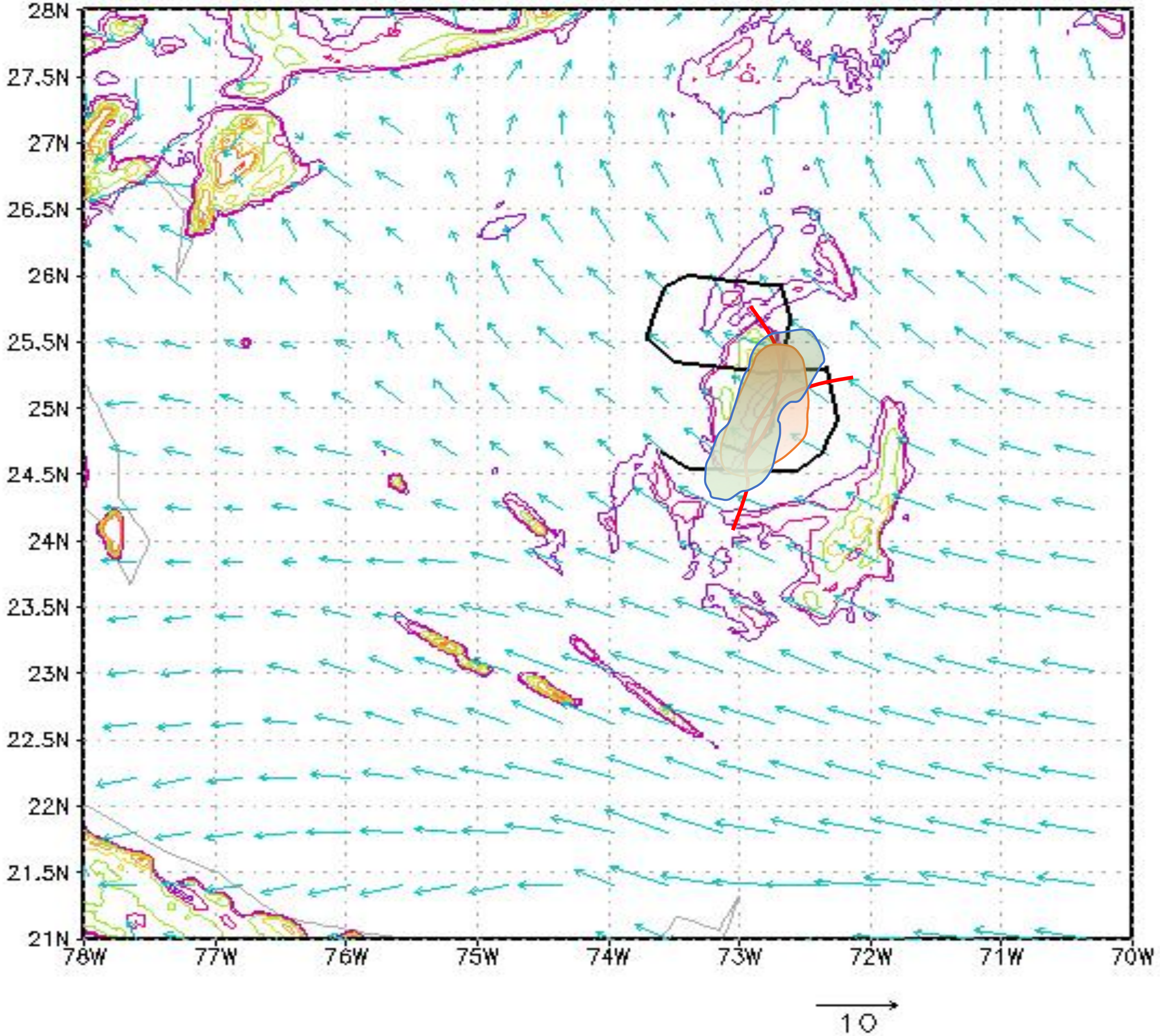
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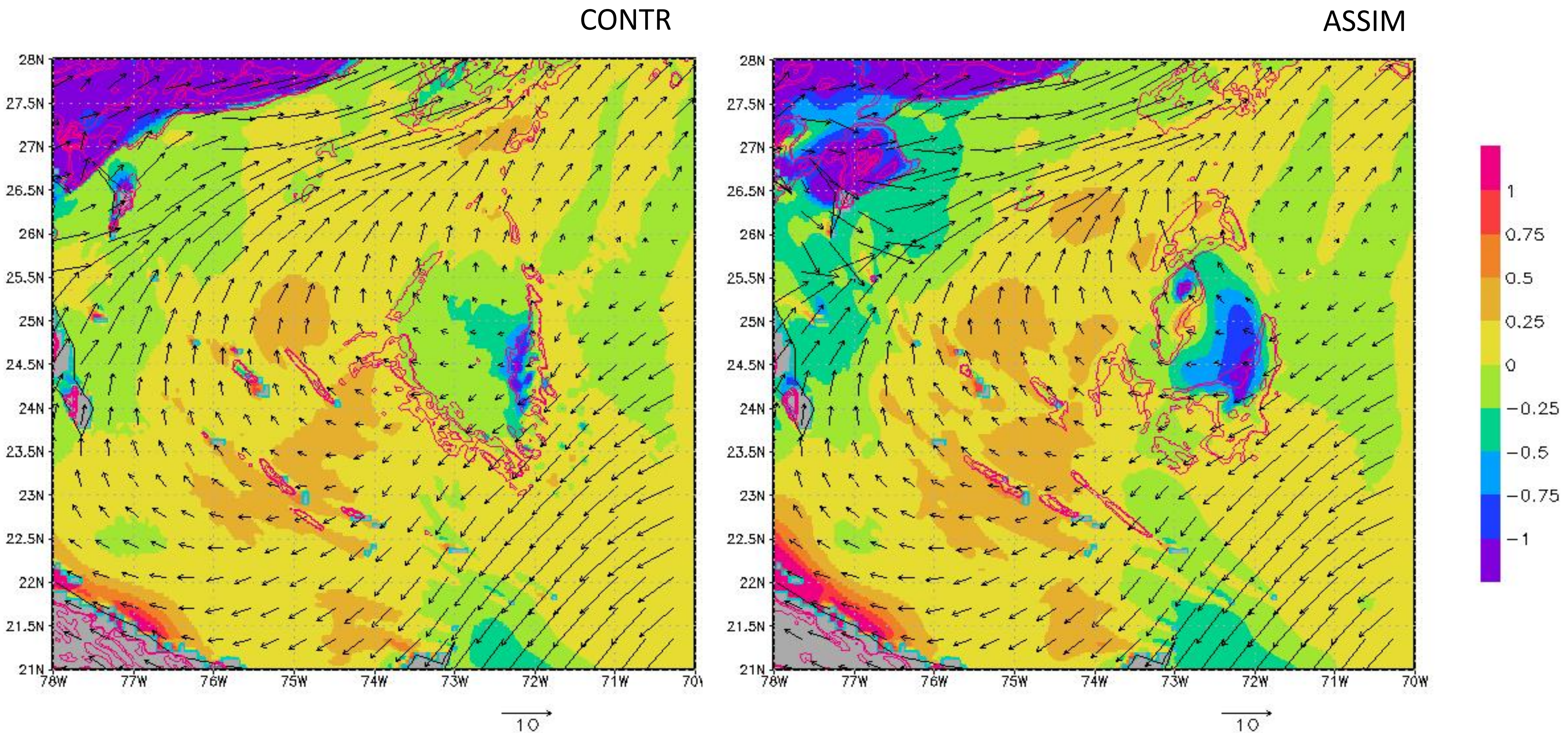
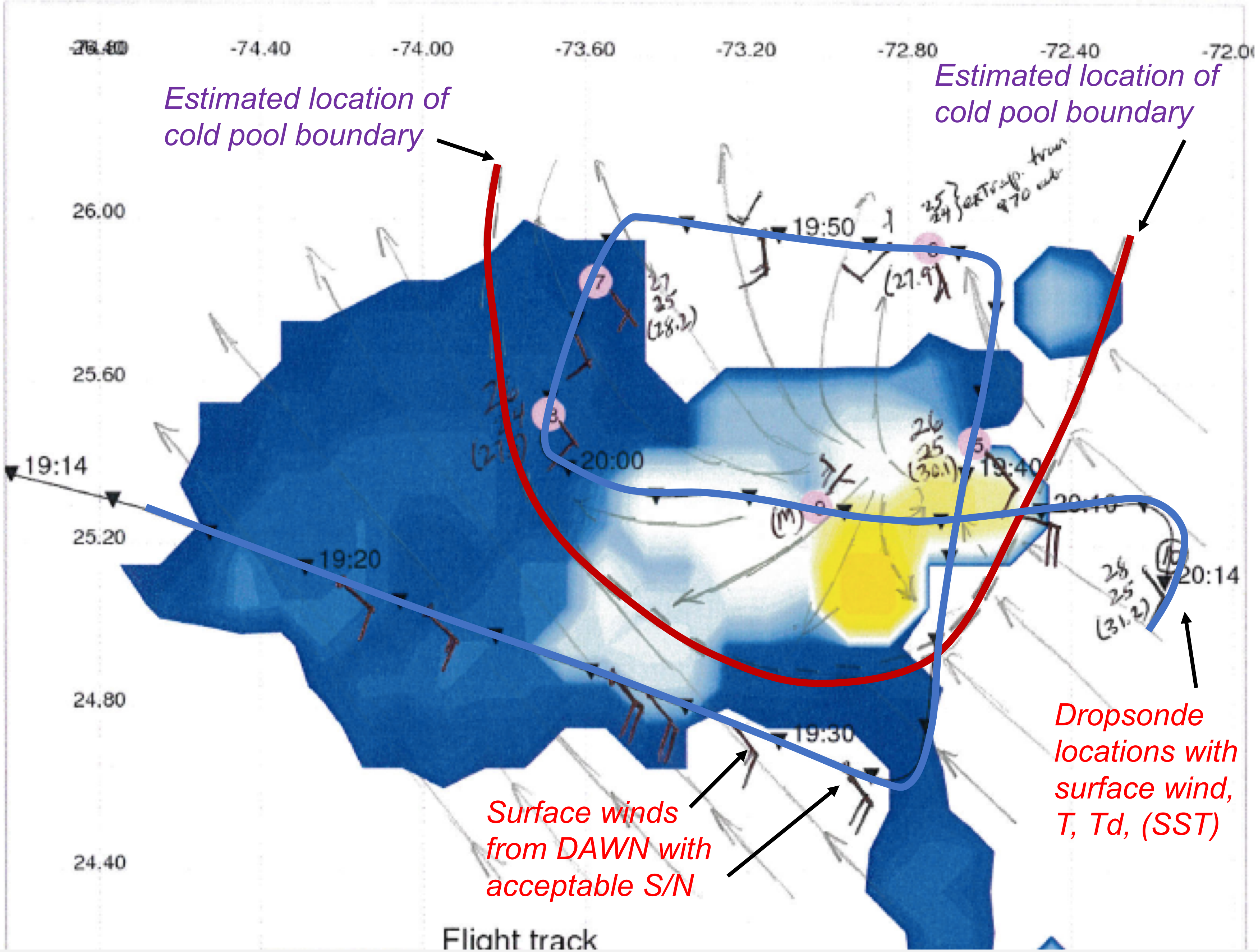
10

Impact due to DAWN DA at 19Z

- 2m temperature anomaly (shaded)
- precipitation (contour in red)
- wind at 6000m level (vector)

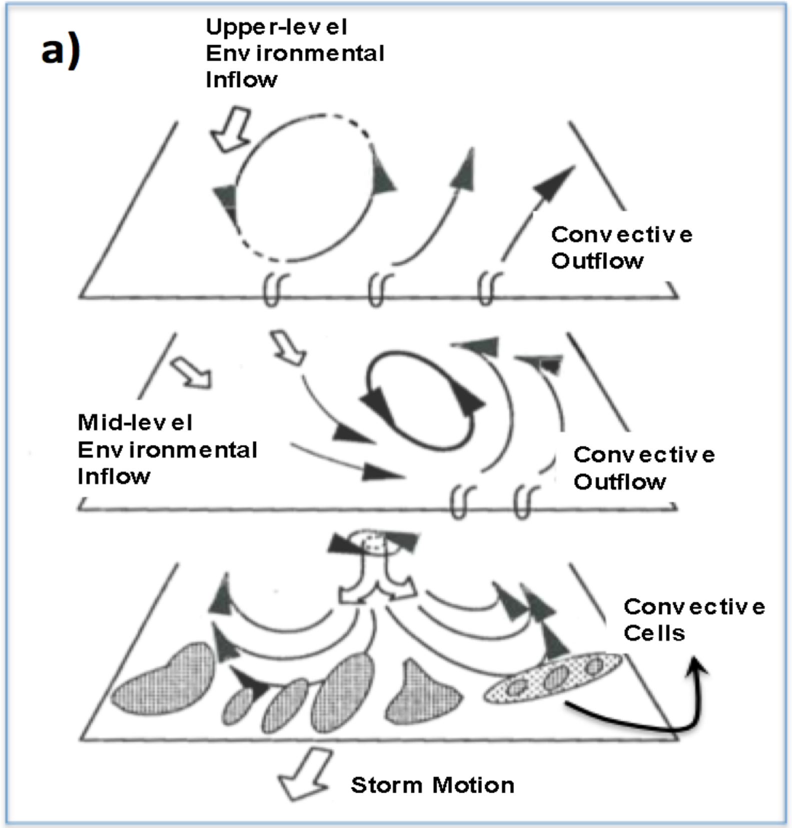


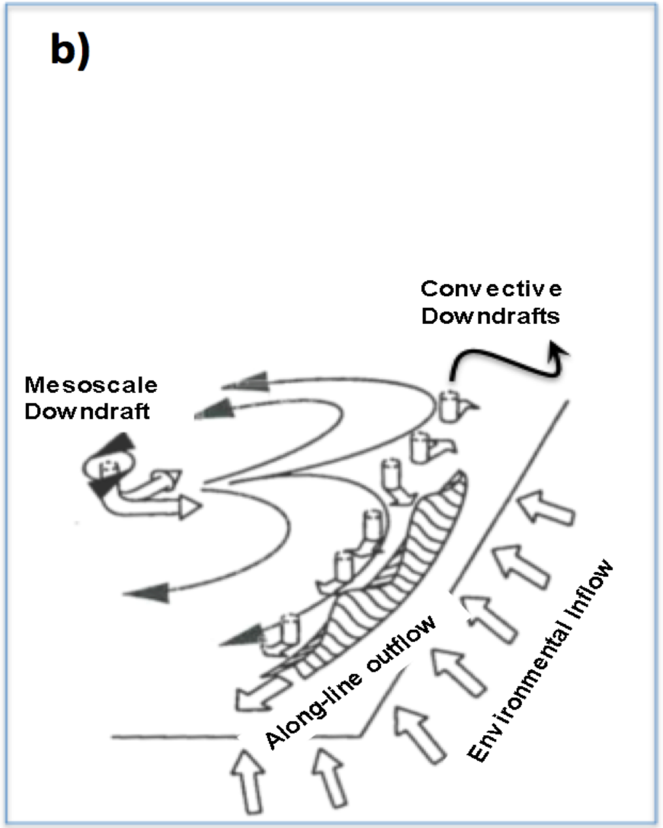
20170610 IMERG precip rate at 20:00 Z, Flight track & Dropsonde loc.

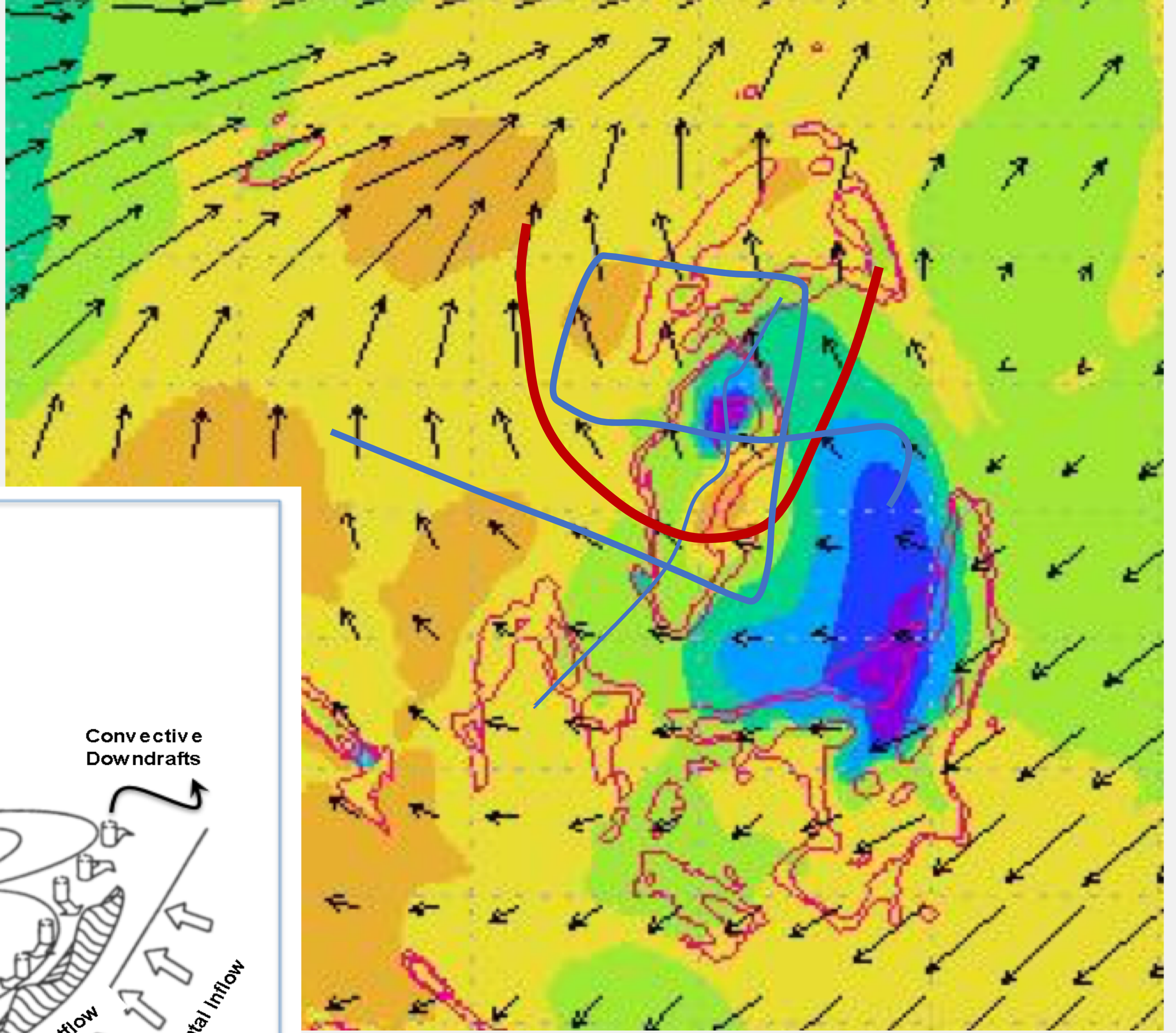


Conceptual model of outflow trajectories from a mesovortex and its affect on cold pool structure and forcing of secondary convection. The conceptual model was developed based on dual-Doppler analysis of an observed midlatitude squall line (Hristova-Veleva, 1994).

Front-view (a) and side-view (b) of the storm-relative flow, illustrating how the mesosvale flow organizes the convective outflow, affecting the location, strengths and organization of the convective cores.

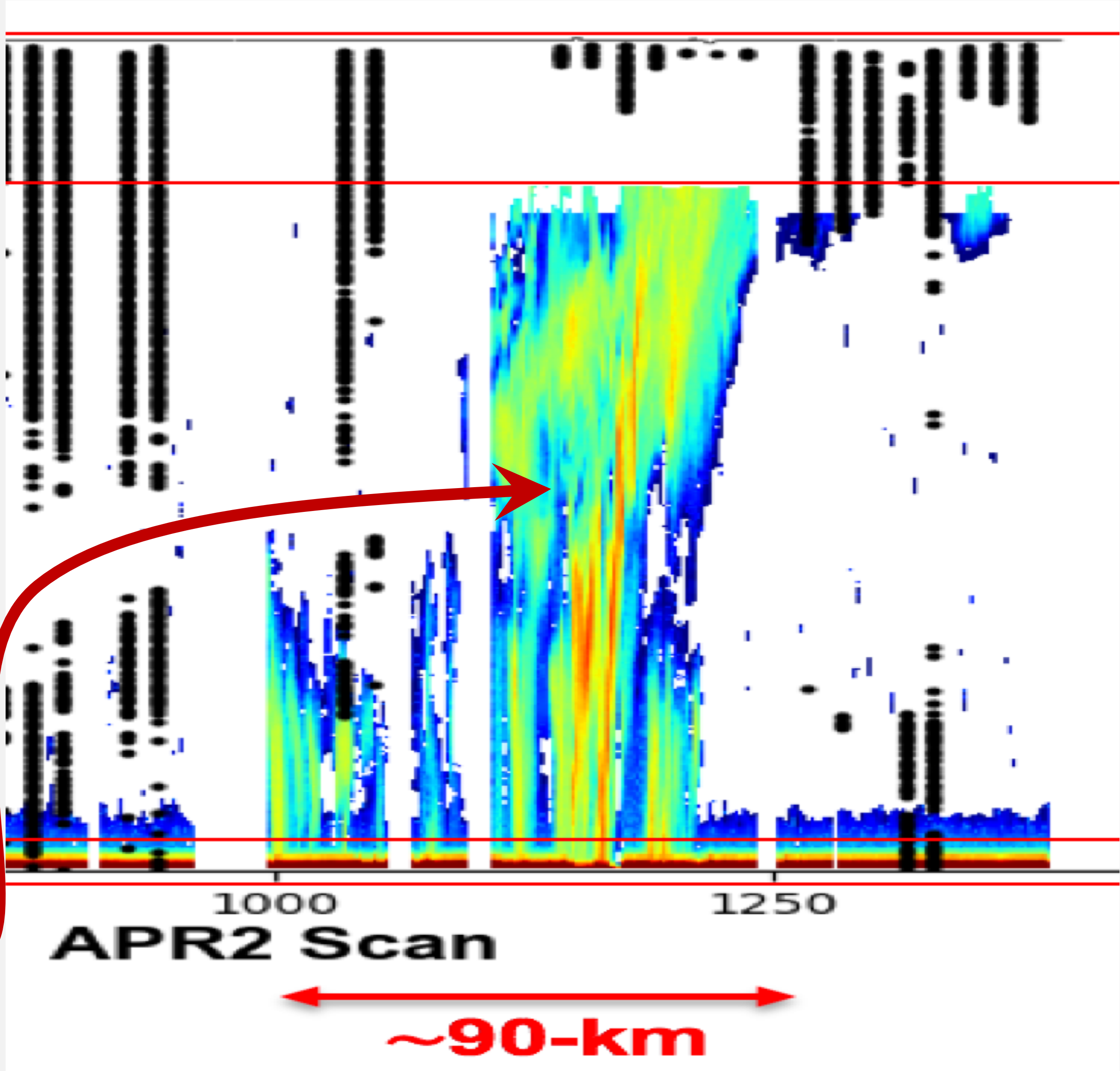






Summary

- Assimilation of the DAWN winds in NU-WRF EDAS, even at a single time step, produced a very significant impact.
- It resulted in modification of the near surface
  - Convergence - increased
  - Temperature – increased
  - Water Vapor - increased
- After the assimilation, the subsequent forecast produced
  - precipitation where there was none,
  - more organized precipitation where there was some
  - a much more intense and organized cold pool
- Comparison:
  - to satellite observations shows a much improved forecast after the assimilation of the DAWN winds
  - Next: comparison to APR2 observations to study the characteristics of the simulated and observed precipitation in terms of statistics of the reflectivity, the size and intensity of the cells.



What is next?

- **Analyze the model simulation** before and after the DA **to understand the relationship between**
  - **the 3D winds, the thermodynamic structure** of the environment **and the strength and size** of the convectively-generated **cold pools**
  - **the precipitation driven cold pools and the convective cloud organization and evolution**
- **Analyze the flow-dependent background error covariance at 19Z to see**
  - the magnitudes of control variable error standard deviation and
  - where were the areas in which the forecast uncertainties are most significant – **where was the sensitivity to potential correction by assimilating observations.**
  - these analyses would be important **to understand the generality of the our results** – were we very lucky this time or whether assimilating DAWN-type winds of the same quality would always be very beneficial.
- **Develop an OSSE experiment** (based on this case) to see the importance of:
  - **Location of the observations with respect to the storm** – would we get the same great result if we observed a similar type of a good DAWN cross-section (like the 18:30-19:30 one) but placed elsewhere in the domain – further in front of the system, further back, further north, earlier or later in time, etc.
  - **Completeness of the vertical profile** – i.e. being able to sense the entire profile, all the way to the surface, versus capturing only mid-to-upper level winds
  - **Horizontal and vertical resolution** of the DAWN winds

Background