Forecast performance of *NAQFC is highly sensitive to PBL prediction accuracy

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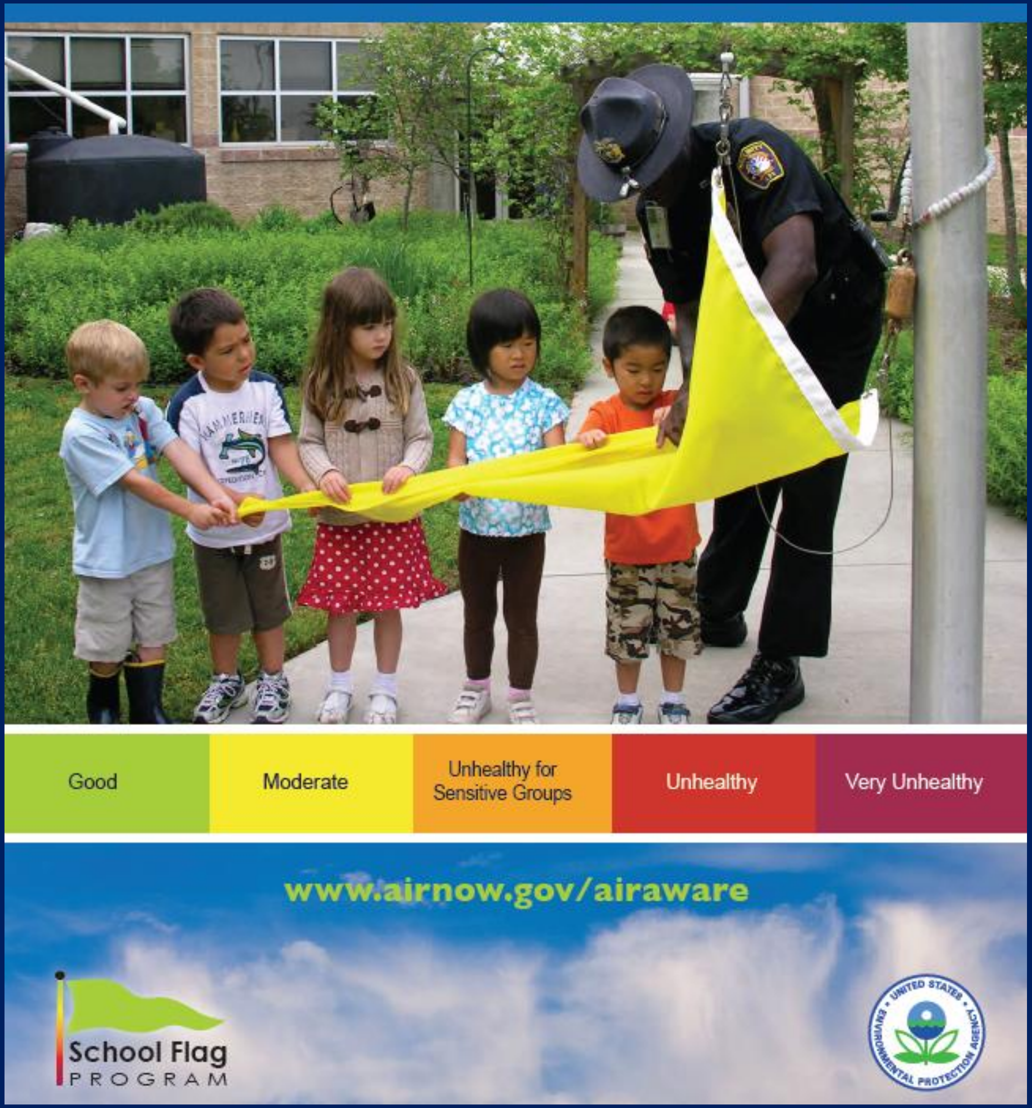
***National Air Quality Forecasting Capability**

Szykman-Delgado PBL Seminar, March 10 2017

2017

Air Quality Awareness Week

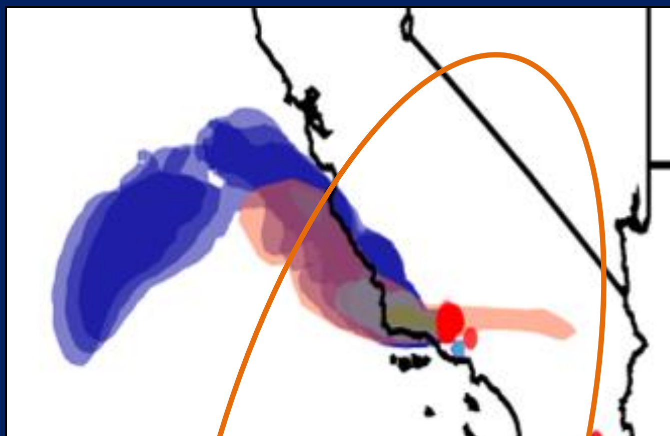
May 1-5 2017

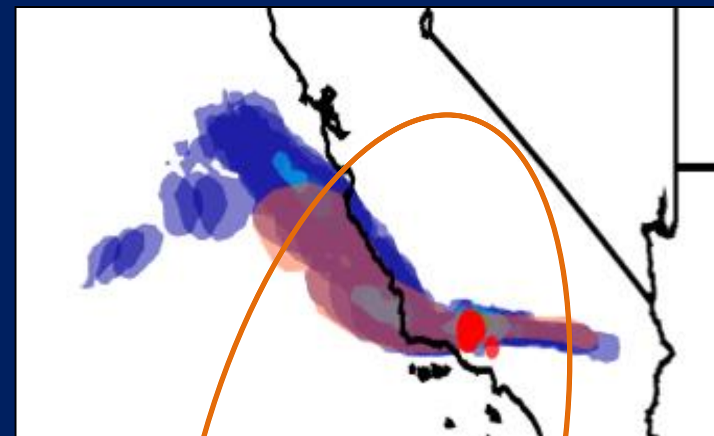


Attempt to consider an intermittent wild fire emission source: PBL height?

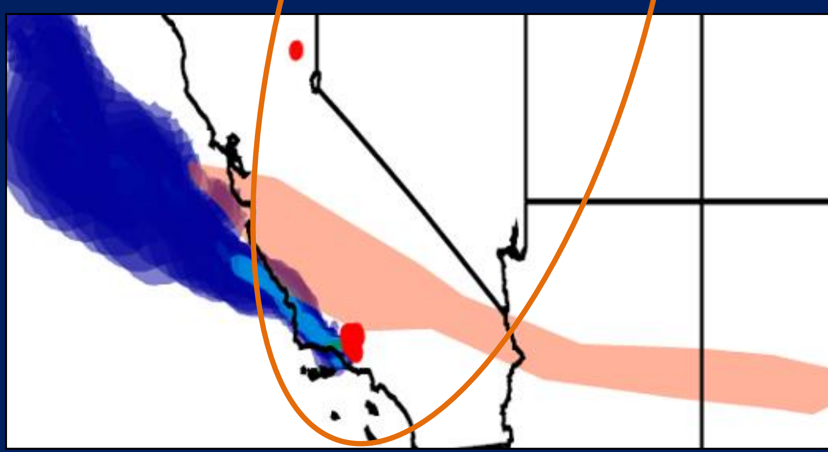
Inject within PBL | Inject 80% above PBL

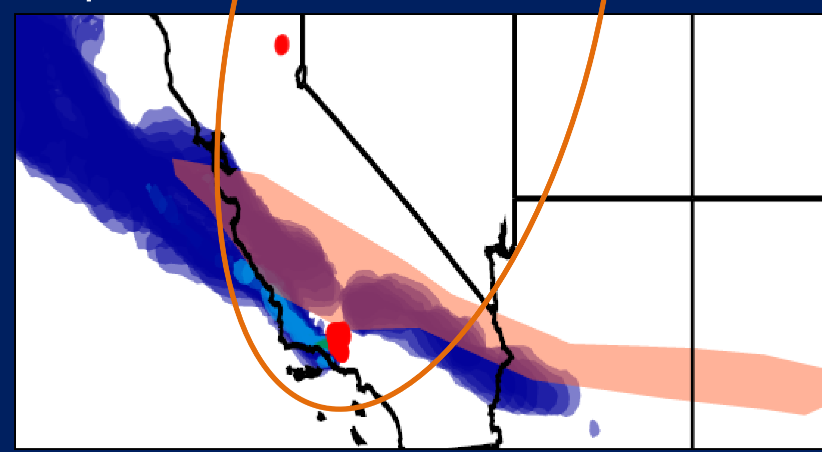
2215 to 0000 UTC on 23-24 September 2006





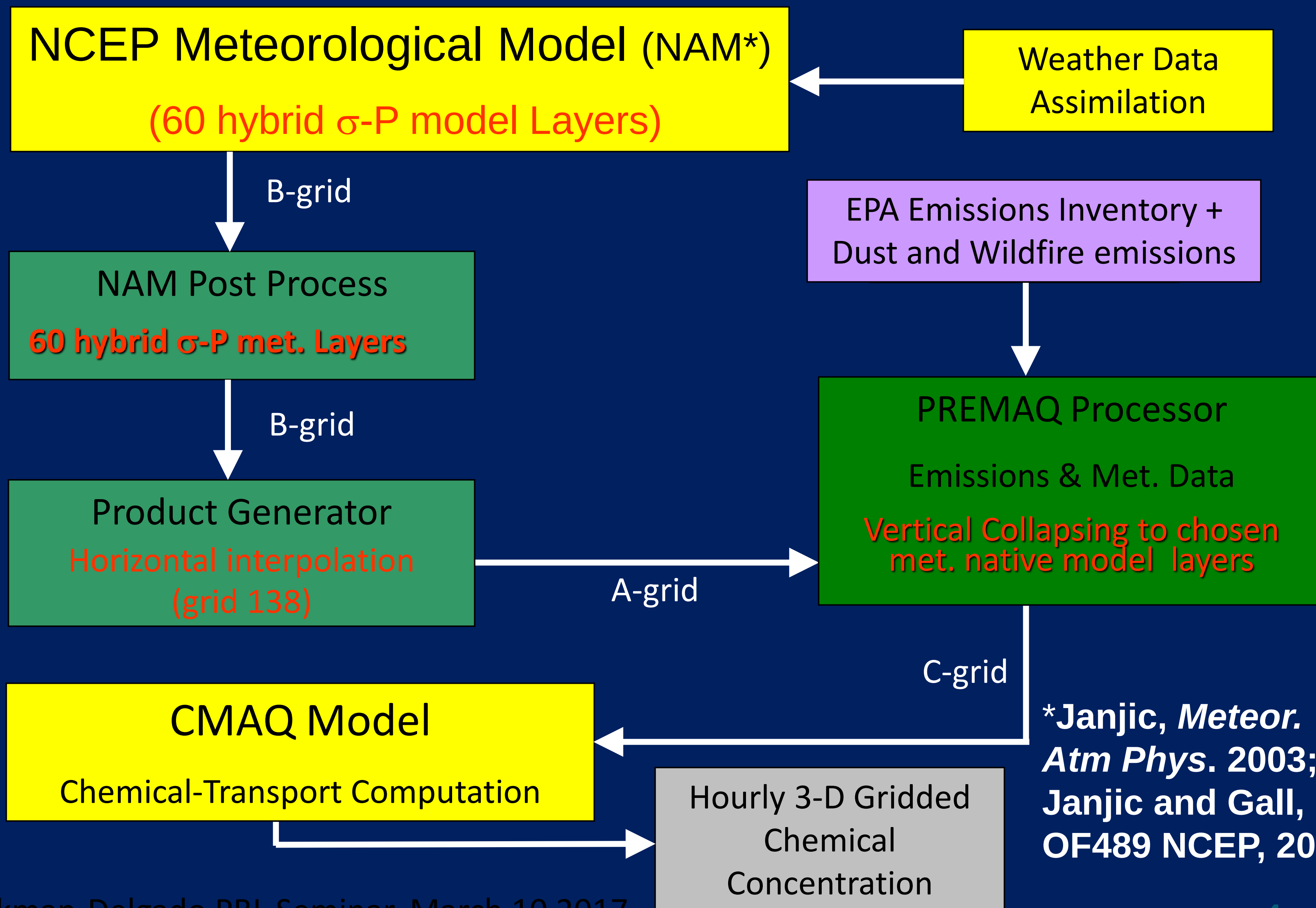
1100 to 1630 UTC 24 September 2006





Smoke column from the HYSPLIT model (blue) and satellite based Hazardous Mapping System (orange)

NAQFC: offline coupling *NMM & CMAQ

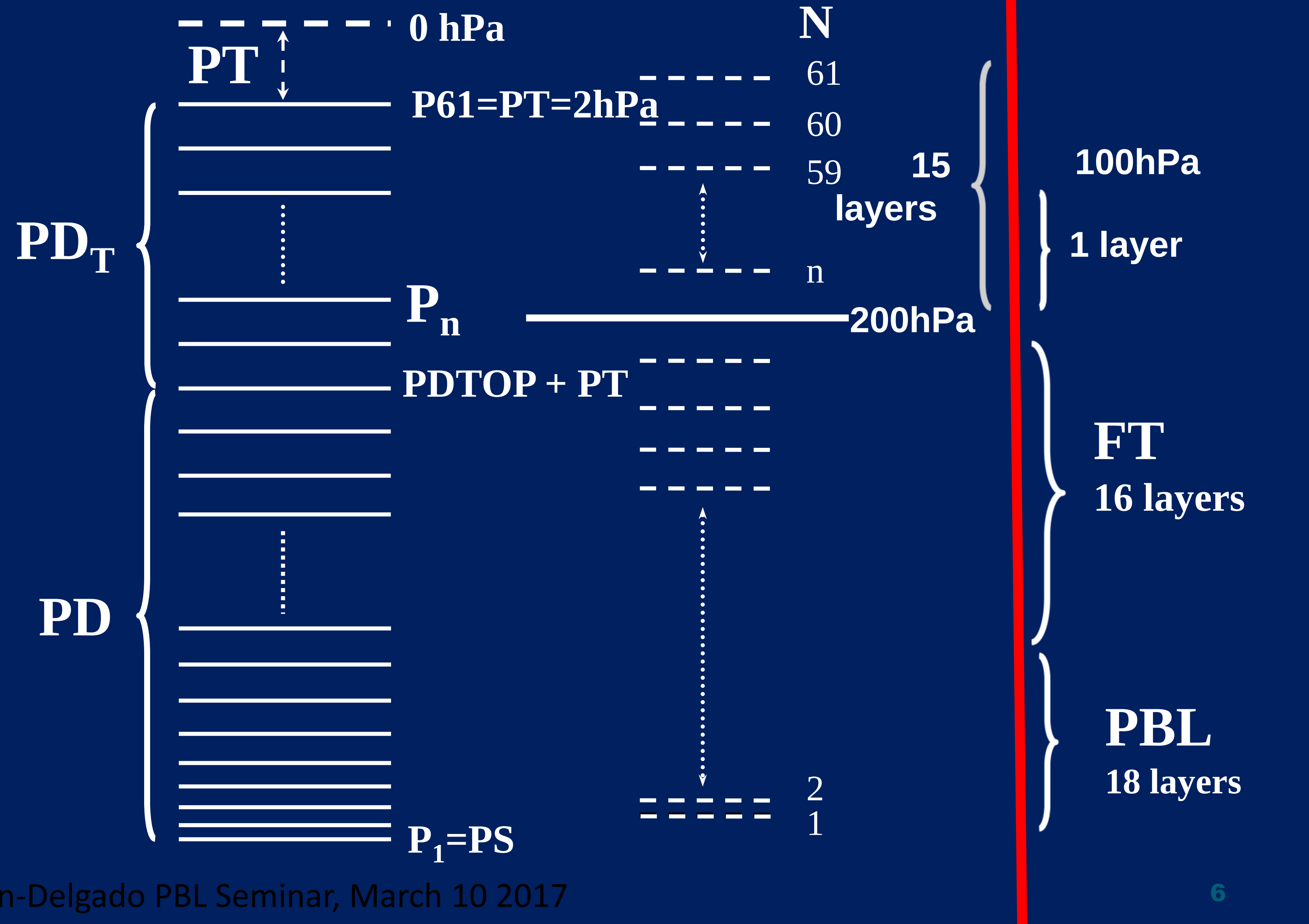


***Janjic, *Meteor. Atm Phys*. 2003; Janjic and Gall, OF489 NCEP, 2012**

NDAS Assimilates the following important variables

obs data stream	Data acquisition platforms
Wind profiles	Doppler radar, Satellites (QuikScat, ENVIRSAT, ADM, AVHRR,OMI,….), TDWR
Cloud top temperature & Z	AQUA, AIRS
Precipitable water	METNET GPS-based instrument, Satellites (EUMETSAT, IFLOWS..)
Snow cover	MIRS
Skin temperature	Mesonet, MADIS, MIRS
Temperature profile	TAMDAR, ACARS,
Surface emissivity	MIRS,…
radiance	Satellites (ENVIRSAT, METEOSAT,..)
PBL	ACARS, Satellites (GPS-RO)
O3 – column and profile	Satellites (AVHRR, AURA POES, TES, OMI)

Hybrid Vertical Coordinate

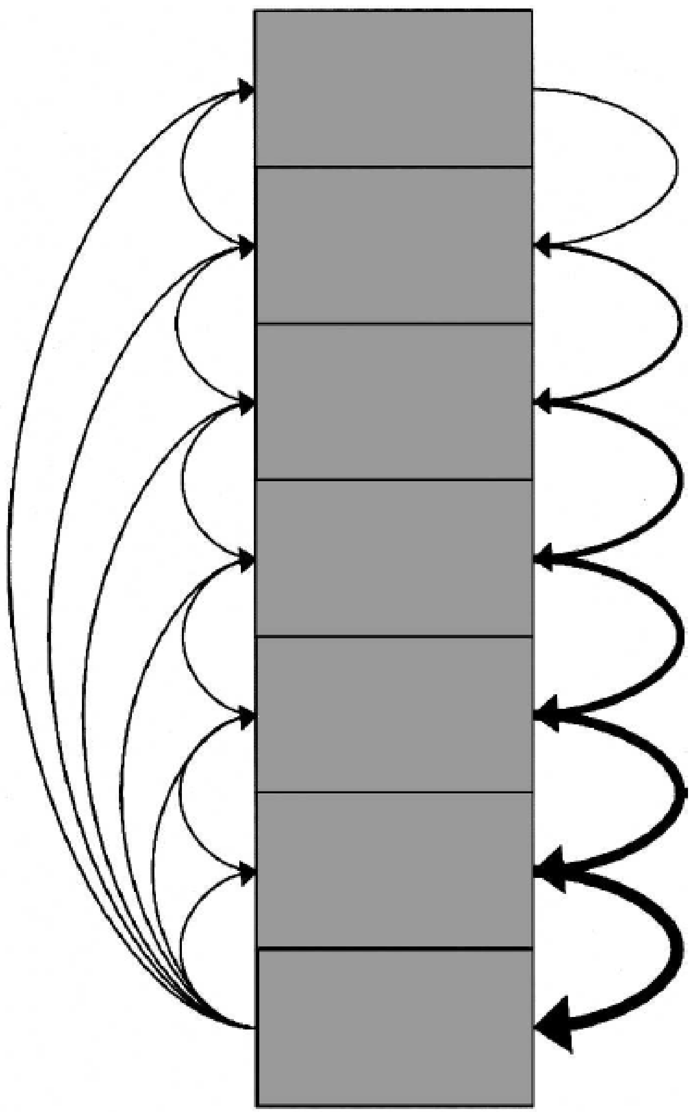


Physics Coupling

	Met Model (NMMB)	**AQ Model (CMAQ)**
Core/Dynamics	**Rotated Lat-Lon E Hybrid sigma-P**	**Arakawa C Grid Sigma-P**
Cloud micro-physics	**Full Ferrier Cloud Microphysics**	**rh-based cloud-column for aqueous chemistry**
Convective mixing	**Betts-Miller Janjic**	***ACM Non-local mixing scheme***
Radiation	**Lacis-Hansen SW & LW**	***CMAQ J Tables***
PBL	**Mellor-Yamada TKE**	***AMC2 PBL is a non-local & local turbulent mixing scheme**
Land Surface	**NOAH common**	**NAM canopy conductance terms for Pleim-Xiu LSM**

***Pleim JAMC 46, 2007,1383-1395**

NAQFC uses ACM2 local & non-local closure to prescribe turbulent mixing



ACM2 Highly dependent on h, the PBL height – an input from NMMB

Three descriptions of h are available from NMMB:

1. **TKE-based h:**
   when TKE < 0.01 $m^2 s^{-2}$
2. **Critical Bulk Richardson number based h:**
   when $R_{i,\,bulk}$ < 0.25
3. **Mixed layer height: buoyancy dissipation > turbulence production**

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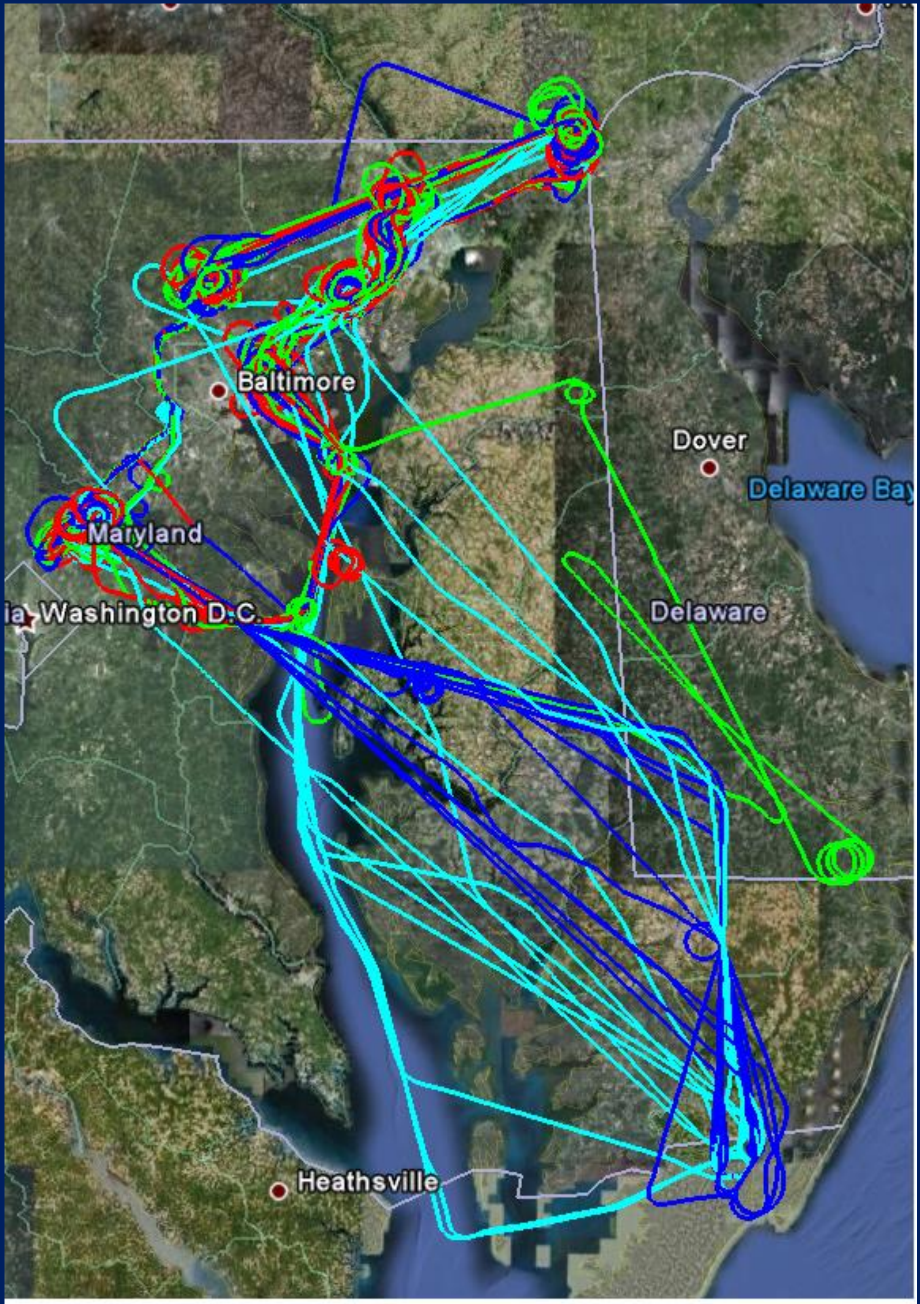
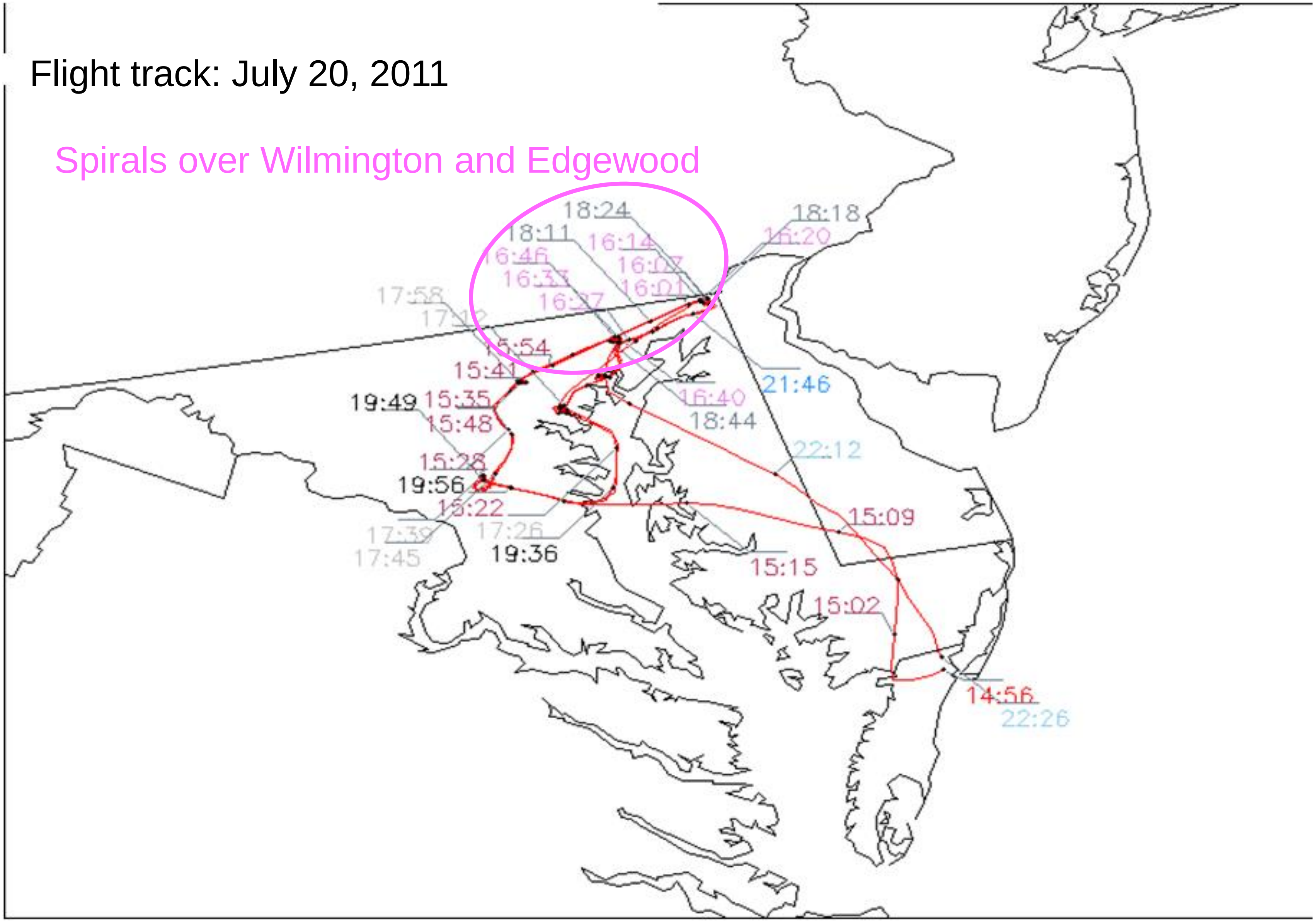
NASA P-3B Flight Paths July 1-29, 2011



DISCOVER-AQ_2011_ALL_P3B_July1-July29

Flight track: July 20, 2011

Spirals over Wilmington and Edgewood



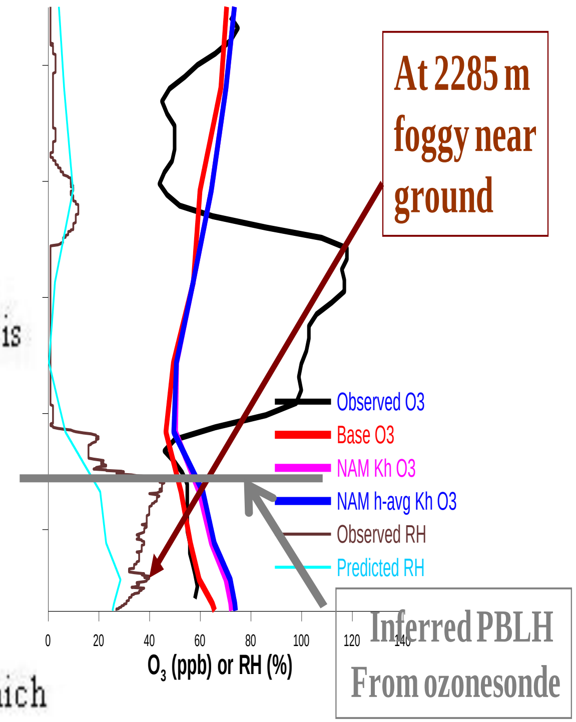
The Turbulent Kinetic Energy (TKE), $q^2/2$, equation may be written in the form

$$\frac{\partial}{\partial t}\left(\frac{q^2}{2}\right) + \vec{V} \bullet \nabla \frac{q^2}{2} - \frac{\partial}{\partial z}\left[Kh \frac{\partial}{\partial z}\left(\frac{q^2}{2}\right)\right] = Ps + Pb - \varepsilon \qquad (A1)$$

where q^2 is the sum of square of the wind turbulence fluctuations, $u'^2 + v'^2 + w'^2$; $\vec{V}$ is the mean wind; Ps is the shear production; Pb is production by buoyancy, and ε represents rate of dissipation of turbulent energy. Kh is given by

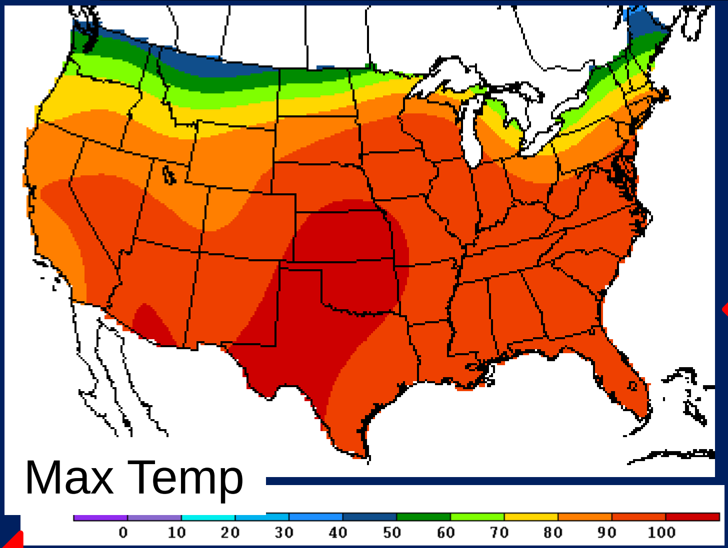
$$Kh = l\, q S_q \qquad (A2)$$

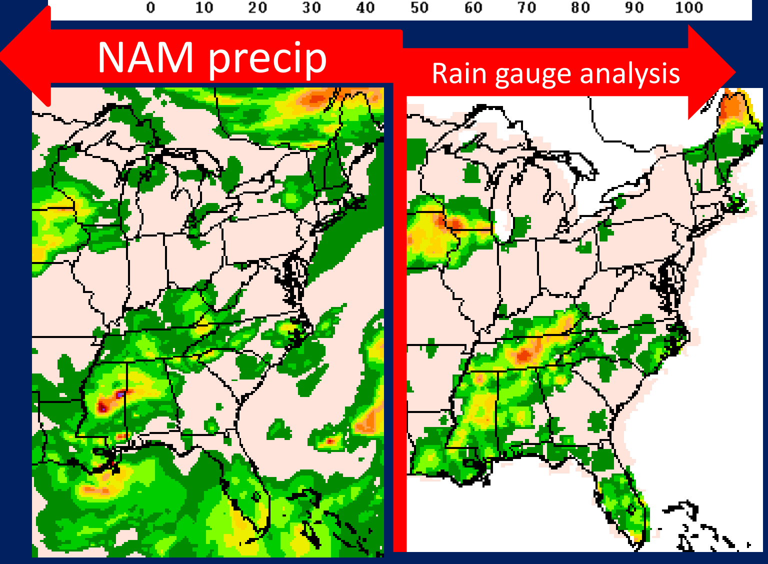
where l is the master length scale for turbulence, and S_q is an empirical constant for which the numerical value of 0.2 was found (Mellor and Yamada 1982) to optimize agreement between model results and observed data.

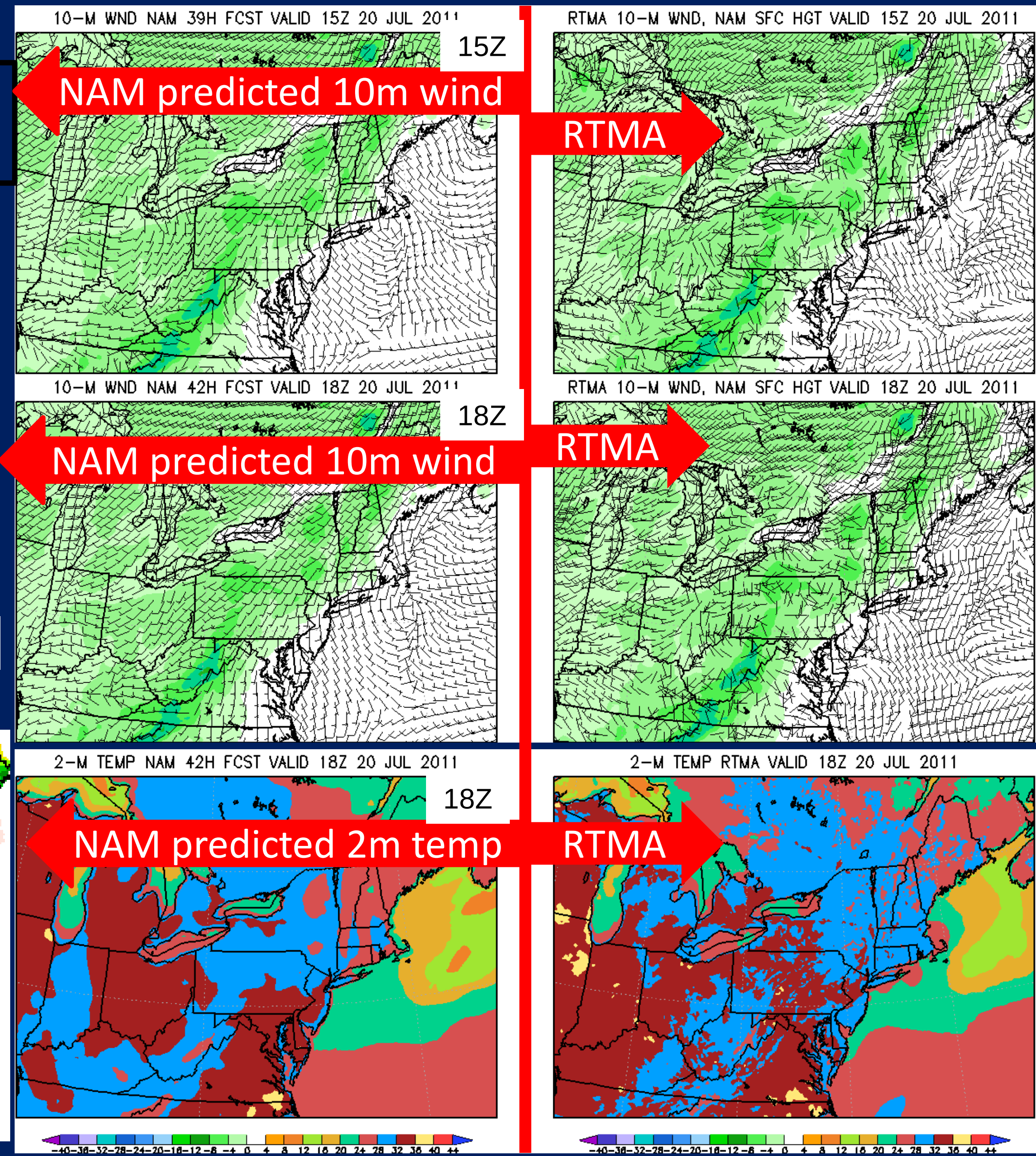


July 20 2011 19 UTC

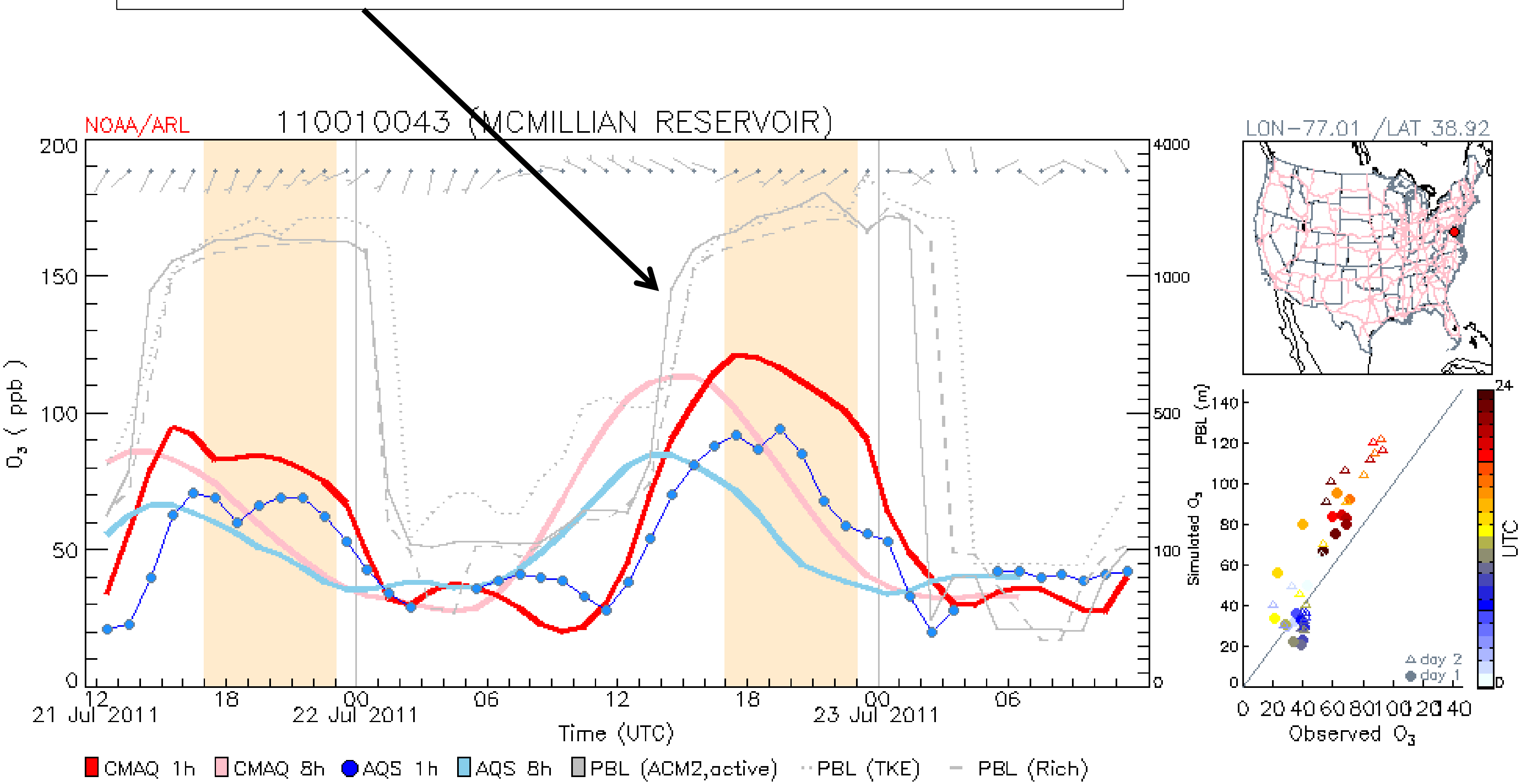
On July 20, 2011
heat index of 116 °F in D.C.



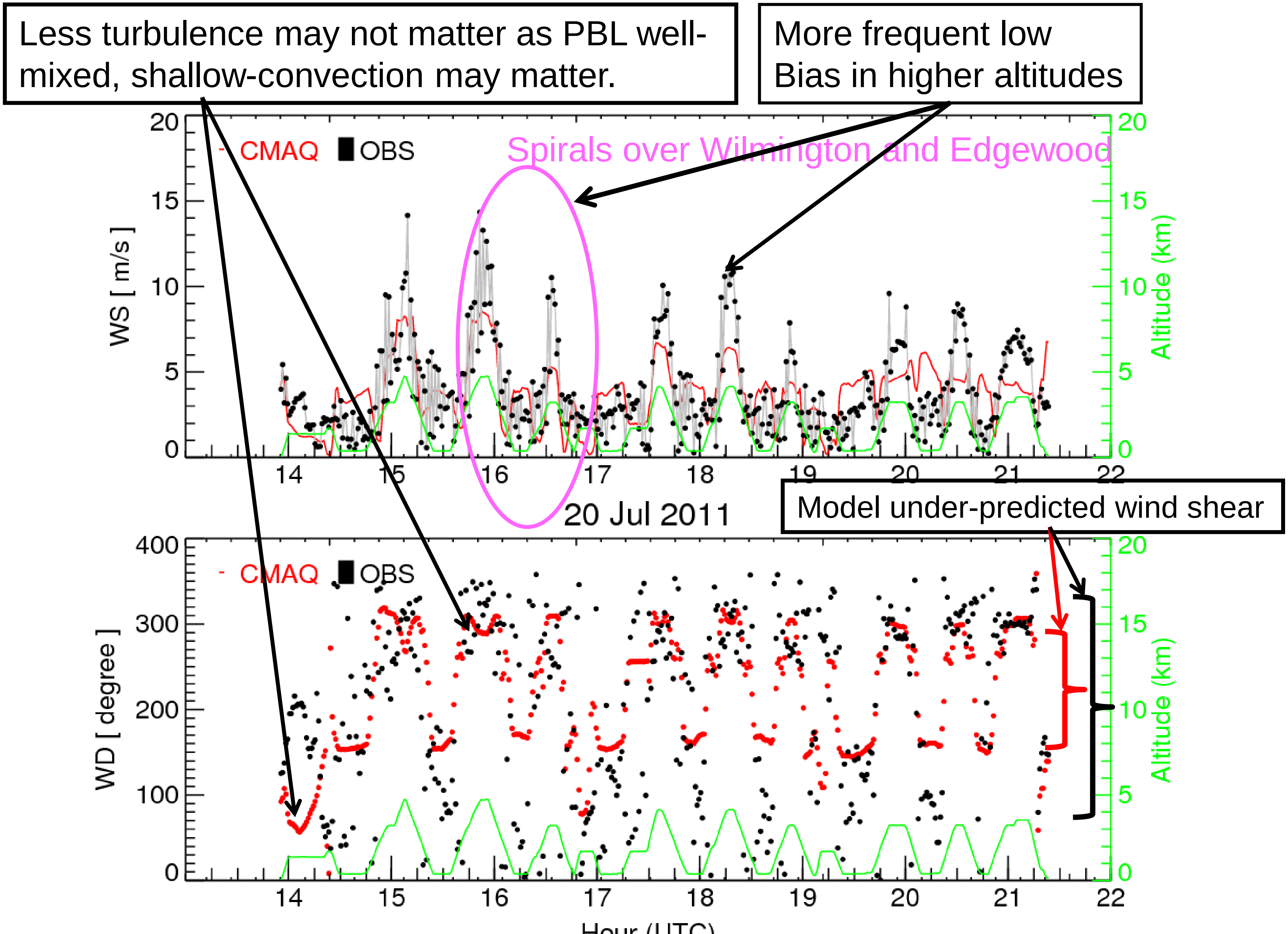




ACM2 PBL on July 20 2011 over D.C.



Comparison of Wind along flight track of P3B on July 20 2011



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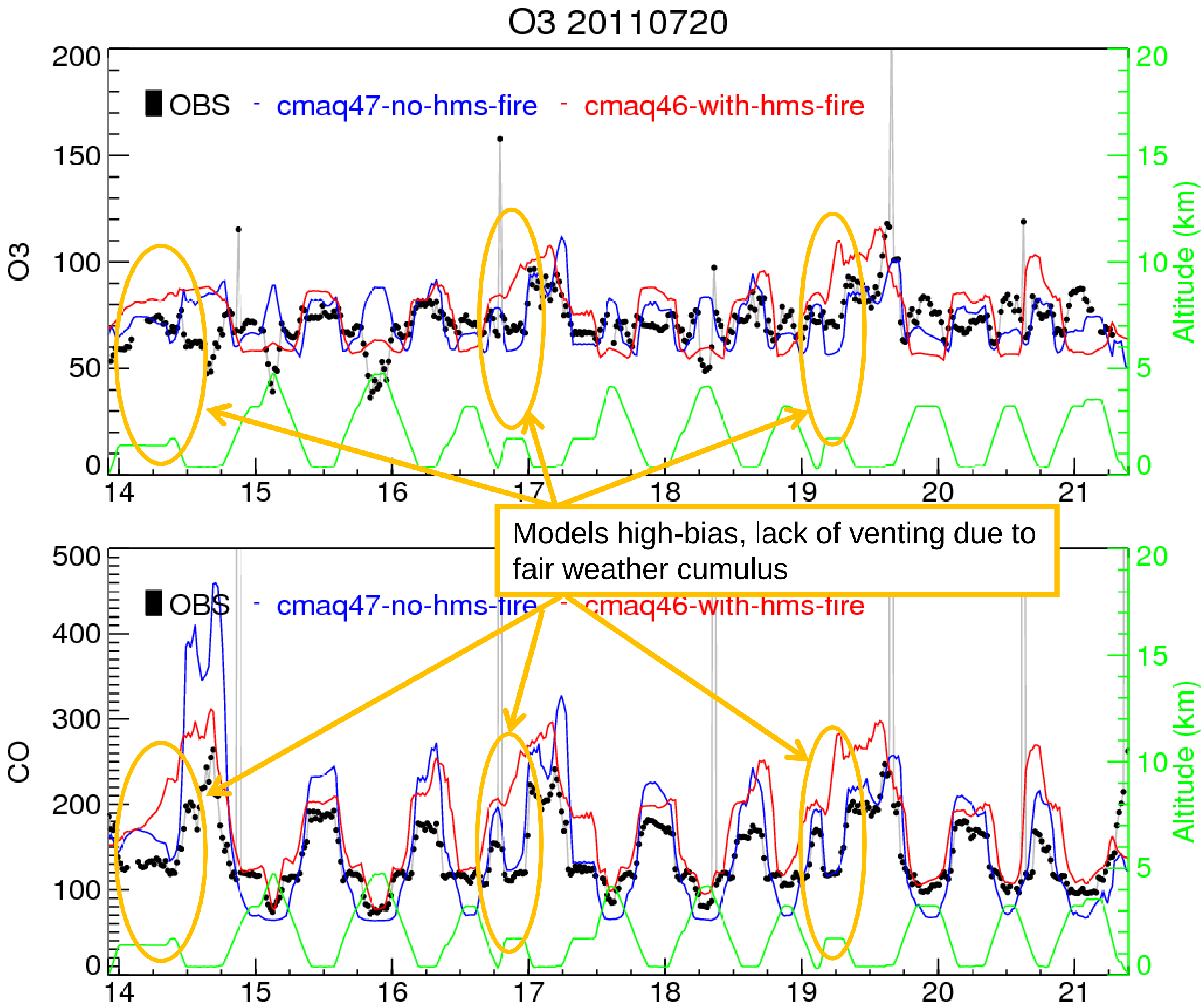


Summary

- NAQFC is highly sensitive to the definition of the PBLH
- Currently several PBLH definitions are available for use in NAQFC (Ri based: either critical $R_{i,bulk}$ or ACM2, TKE threshold, and mixed layer height)
- Often in convective condition: TKE-based method over-predicts, Ri based method performed best
  - comparing to sondes the ACM2 PBLH predicted the best
- NMMB under-predicted shallow convection at PBL top and above compared to observations causing:
  - High bias in ozone and CO due to under-prediction in PBL venting

Backup slides

CMAQ schematics for process-based parameterizations

$$\frac{\partial(\overline{\varphi}_i J_\xi)}{\partial t} + m^2 \nabla_\xi \bullet \left(\frac{\overline{\varphi}_i \overline{\hat{\mathbf{V}}}_\xi J_\xi}{m^2} \right) + \frac{\partial(\overline{\varphi}_i \overline{\hat{v}^3} J_\xi)}{\partial \hat{x}^3}$$

$$+ m^2 \frac{\partial}{\partial \hat{x}^1}\left[\frac{\overline{\rho} J_\xi}{m^2} \hat{F}^1_{q_i} \right] + m^2 \frac{\partial}{\partial \hat{x}^2}\left[\frac{\overline{\rho} J_\xi}{m^2} \hat{F}^2_{q_i} \right] + \frac{\partial}{\partial \hat{x}^3}\left[\overline{\rho} J_\xi \hat{F}^3_{q_i} \right]$$

$$= J_\xi R_{\varphi_i}(\overline{\varphi}_1, \ldots, \overline{\varphi}_N) + J_\xi Q_{\varphi_i} + \left.\frac{\partial(\overline{\varphi}_i J_\xi)}{\partial t}\right|_{cld} + \left.\frac{\partial(\overline{\varphi}_i J_\xi)}{\partial t}\right|_{aero} + \left.\frac{\partial(\overline{\varphi}_i J_\xi)}{\partial t}\right|_{ping}$$

Quality of forecasting depends on both model formulations and inputs.

For NAQFC, daily meteorology is the main driver, but IC/BC & emissions can affect forecasting quality greatly.

Often current NAQFC do not have event-based emission inputs.

Demonstrate how NAQFC can be improved by re-initialization or further by improving episodic emission inputs

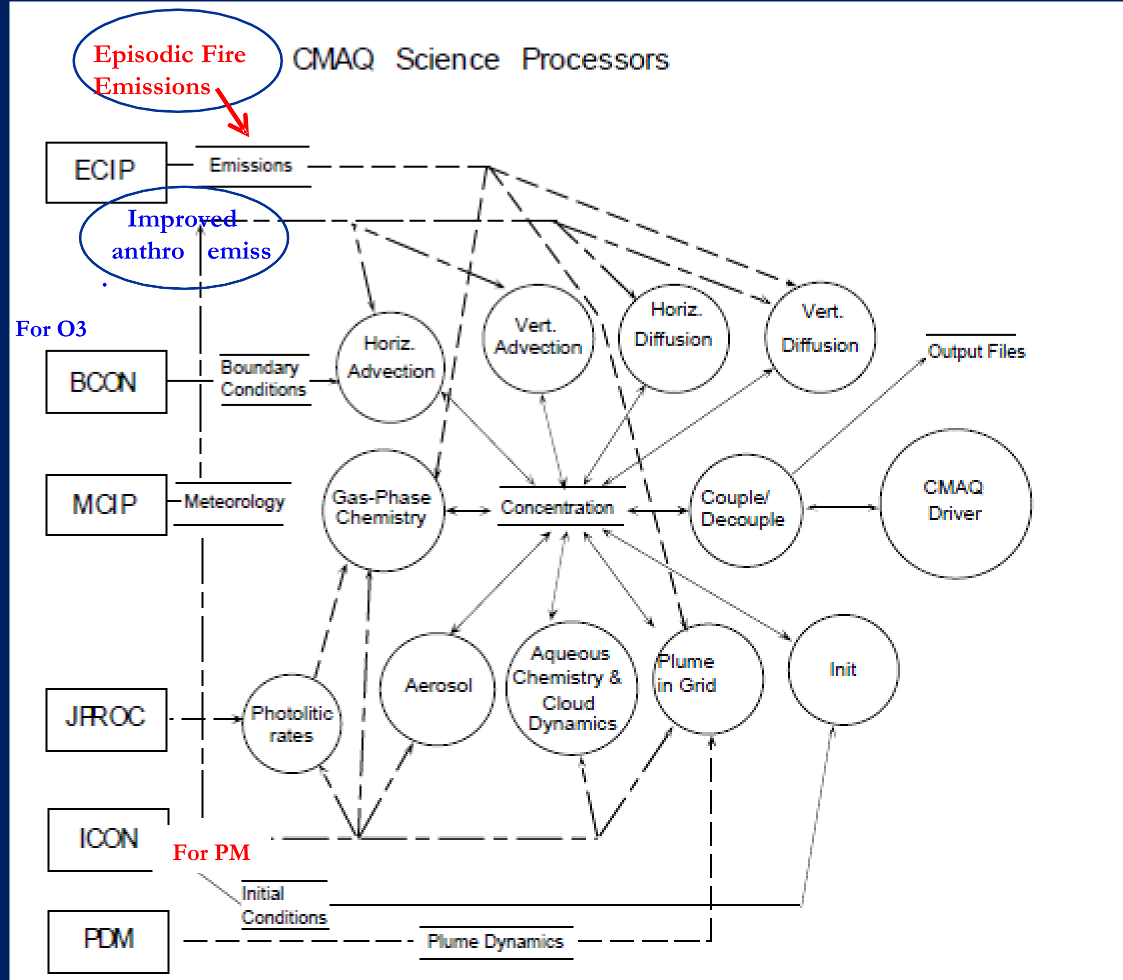
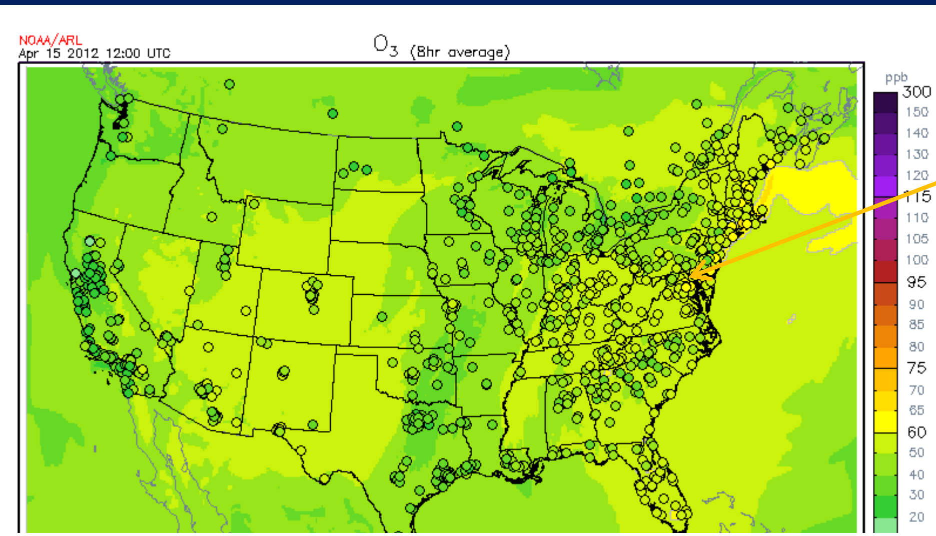
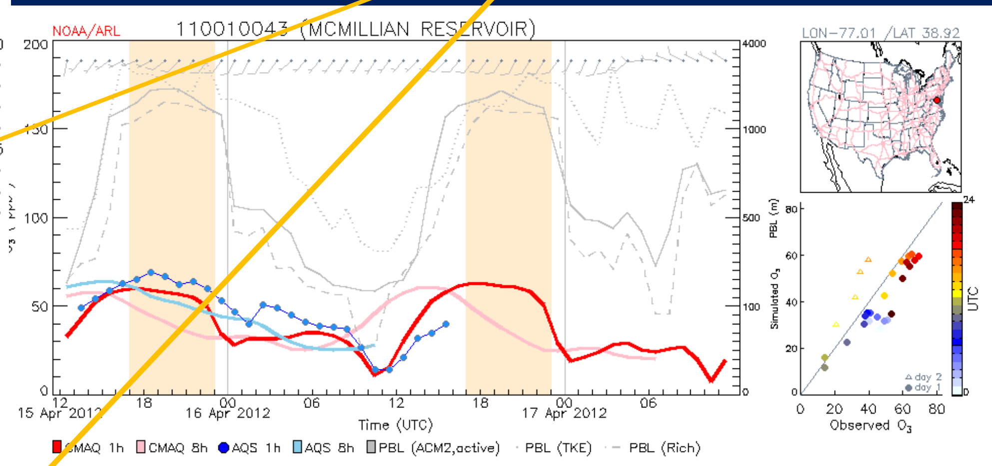
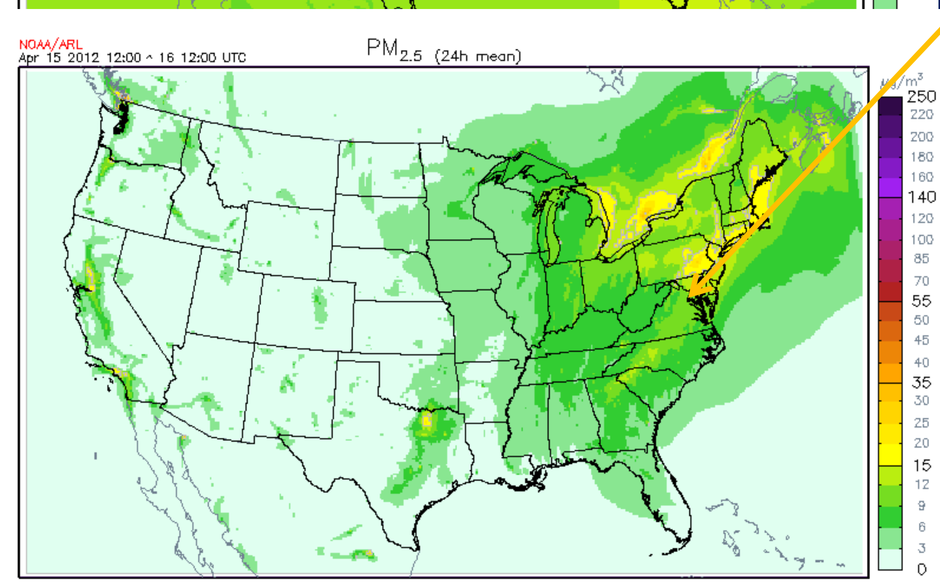


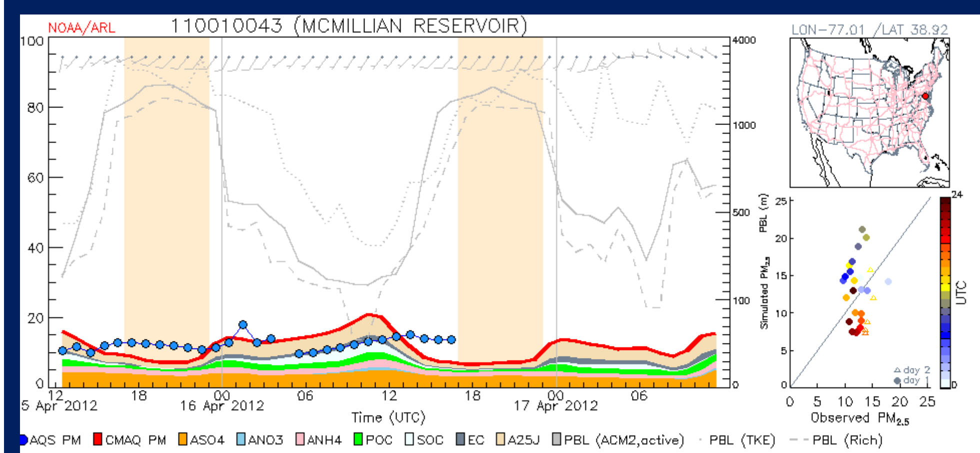
Figure 6-1. Science Process Modules in CMAQ. Interface processes are shown with rectangular boxes. Typical science process modules are updating the concentration field directly and the data-provider modules include routines to feed appropriate environmental input data to the science process modules. Driver module orchestrates the synchronization of numerical integration across the science processes. Concentrations are linked with solid lines and other environmental data with broken lines. (From Byun et al., 1998.)

Behind the scene Daily Monitoring & Analysis









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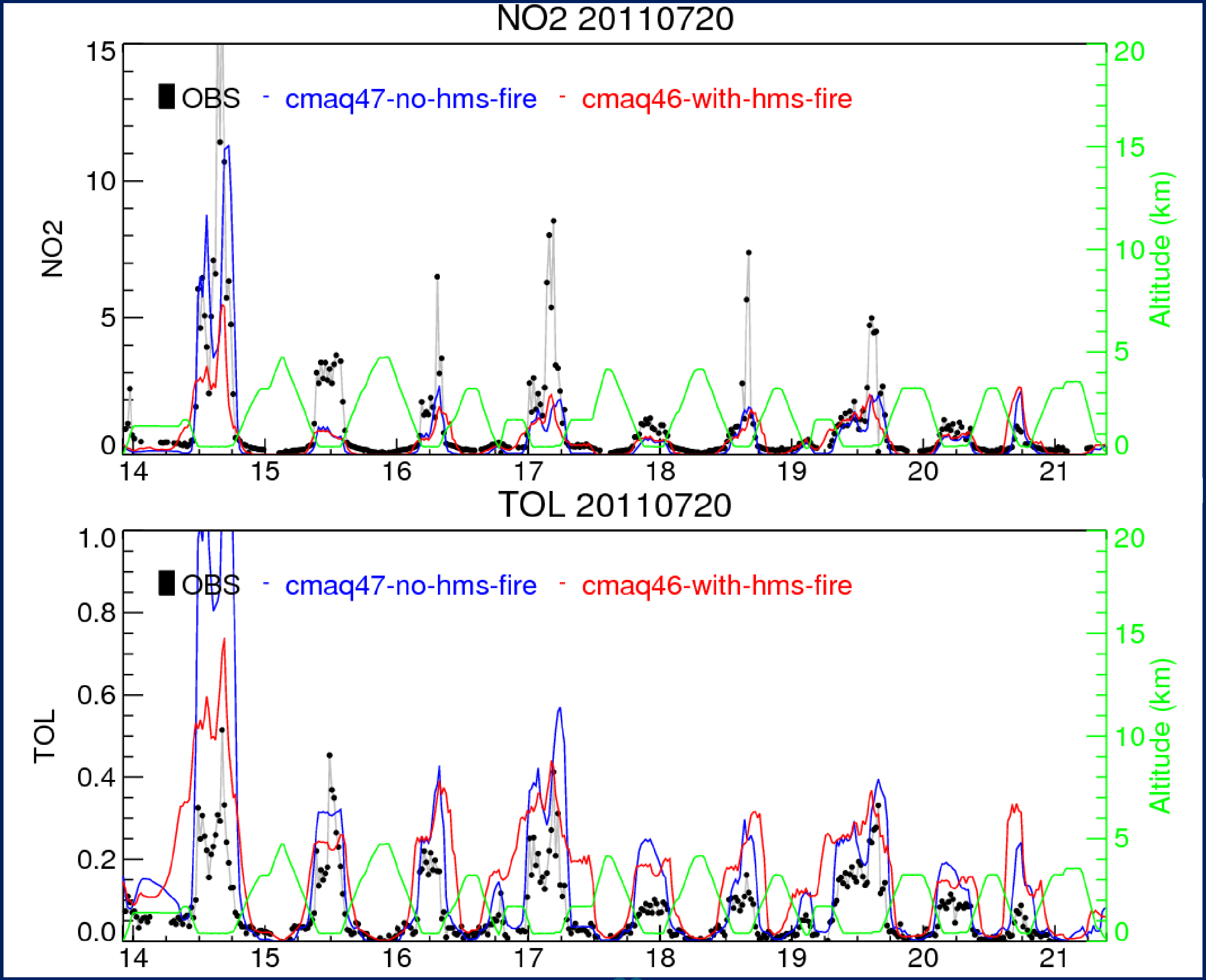

Comparison of Wind along flight track of P3B on July 20 2011