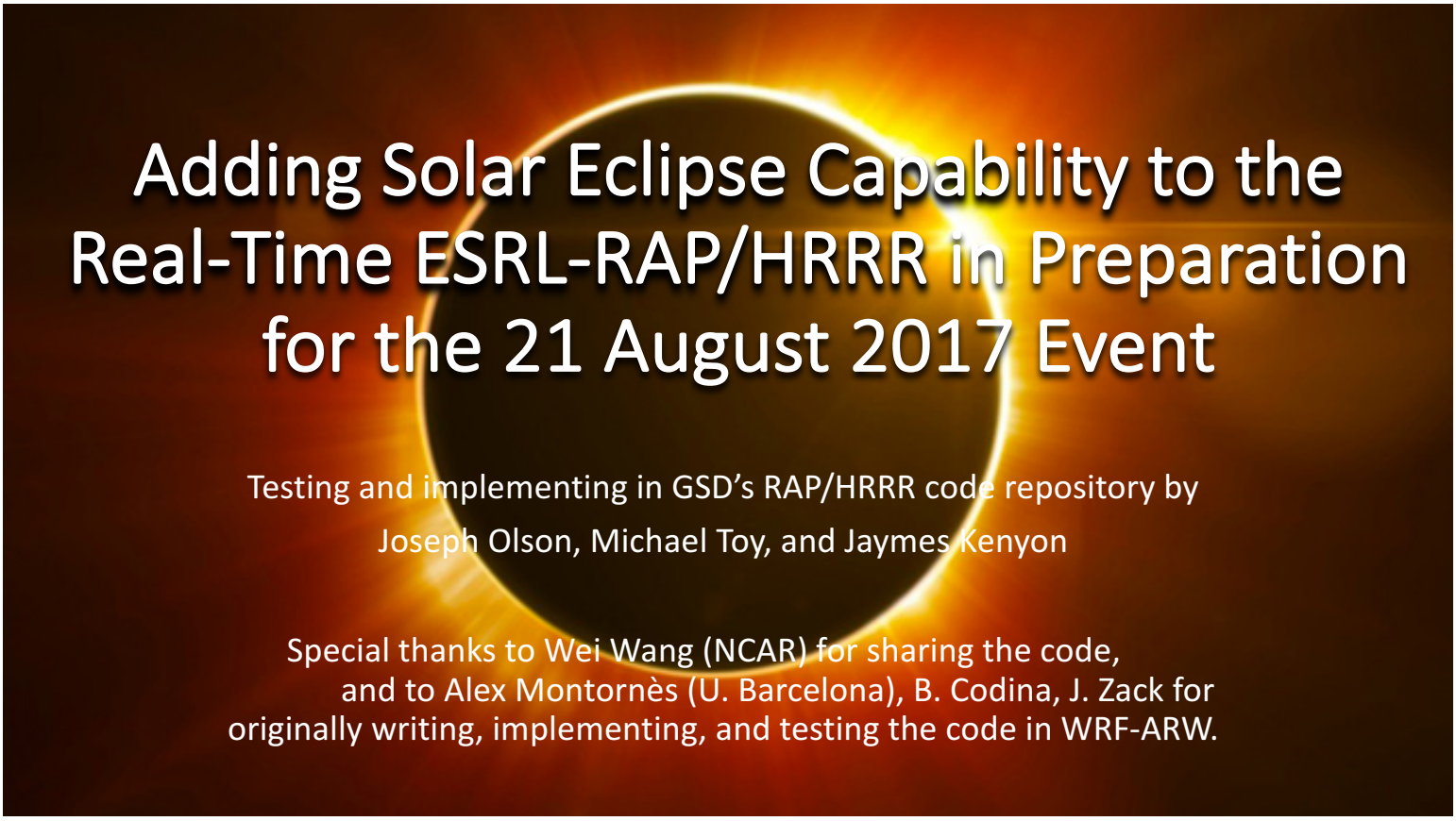


Adding Solar Eclipse Capability to the Real-Time ESRL-RAP/HRRR in Preparation for the 21 August 2017 Event

Testing and implementing in GSD's RAP/HRRR code repository by

Joseph Olson, Michael Toy, and Jaymes Kenyon

Special thanks to Wei Wang (NCAR) for sharing the code,
and to Alex Montornès (U. Barcelona), B. Codina, J. Zack for
originally writing, implementing, and testing the code in WRF-ARW.

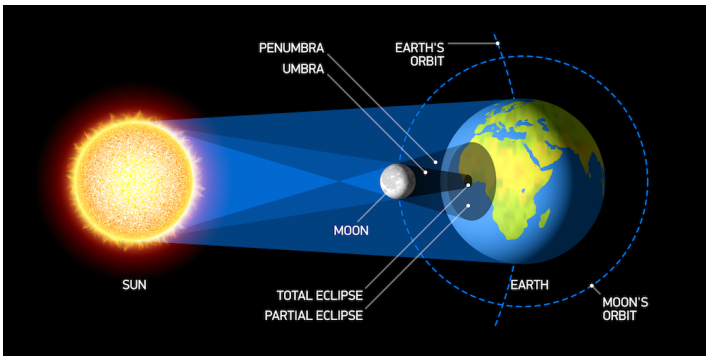
Background

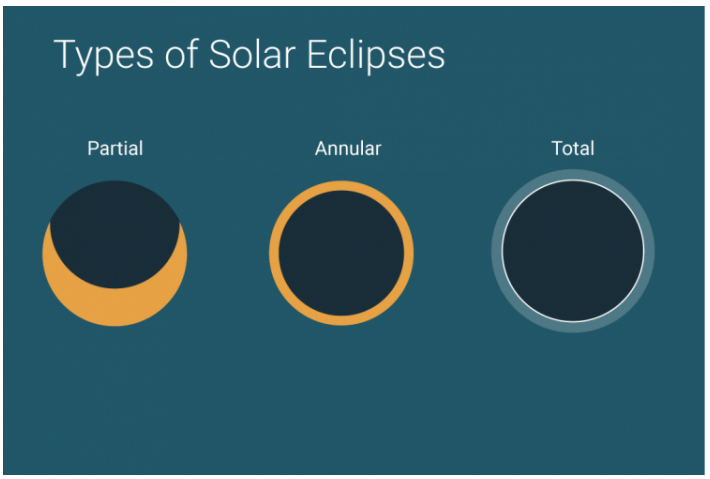
- A new module for computing the solar eclipses based on Bessel's method.
- The algorithm uses a look-up file where the besselian elements are stored from 1950 to 2050 (for any partial, annular, total and hybrid eclipse). This file can be easily modified in the future.
- The algorithm computes the degree of obscuration of the solar disk at each grid-point. Based on these variables the incoming solar radiation is modified for each solar scheme.
- WRF details:
  - The compatible radiation schemes are: Dudhia, Goddard, New Goddard, RRTMG, RRTMG fast, CAM and FLG.
  - Note that this module is not connected to the swint_opt capability.
  - Solar eclipse prediction is enabled/disabled in the namelist.input. **ra_sw_eclipse**: enabling (1) and disabling (0, default).

Taken from Montornes et al. 2015

New output variables:

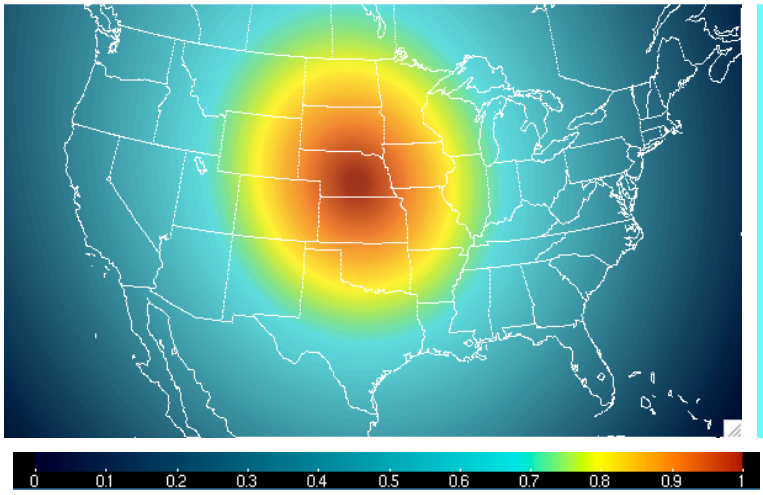
- **ECOBSC**: 2D variable representing the degree of obscuration at each grid-point.
- **ECMASK**: 2D variable representing the status of the solar eclipse at each grid-point (0: No eclipse, 1: Partial/ Penumbra region, 2: Total, 3: Annular).





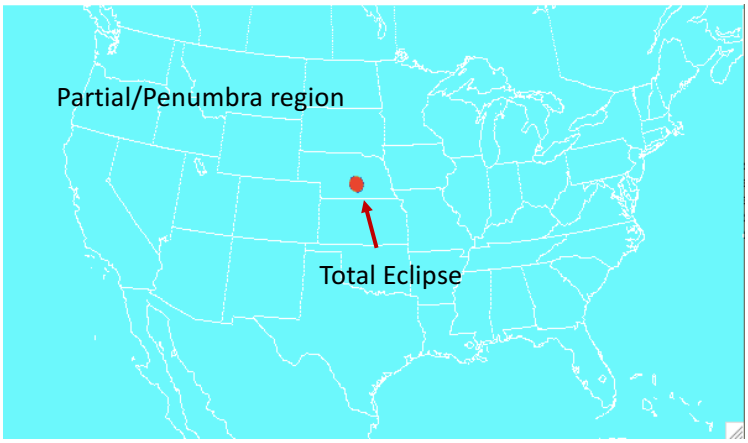
Example of new output variables:

ECOBSC valid at 18 UTC 21 Aug 2017



Degree of moon obscuring the sun (dimensionless; 0-1)

ECMASK valid at 18 UTC



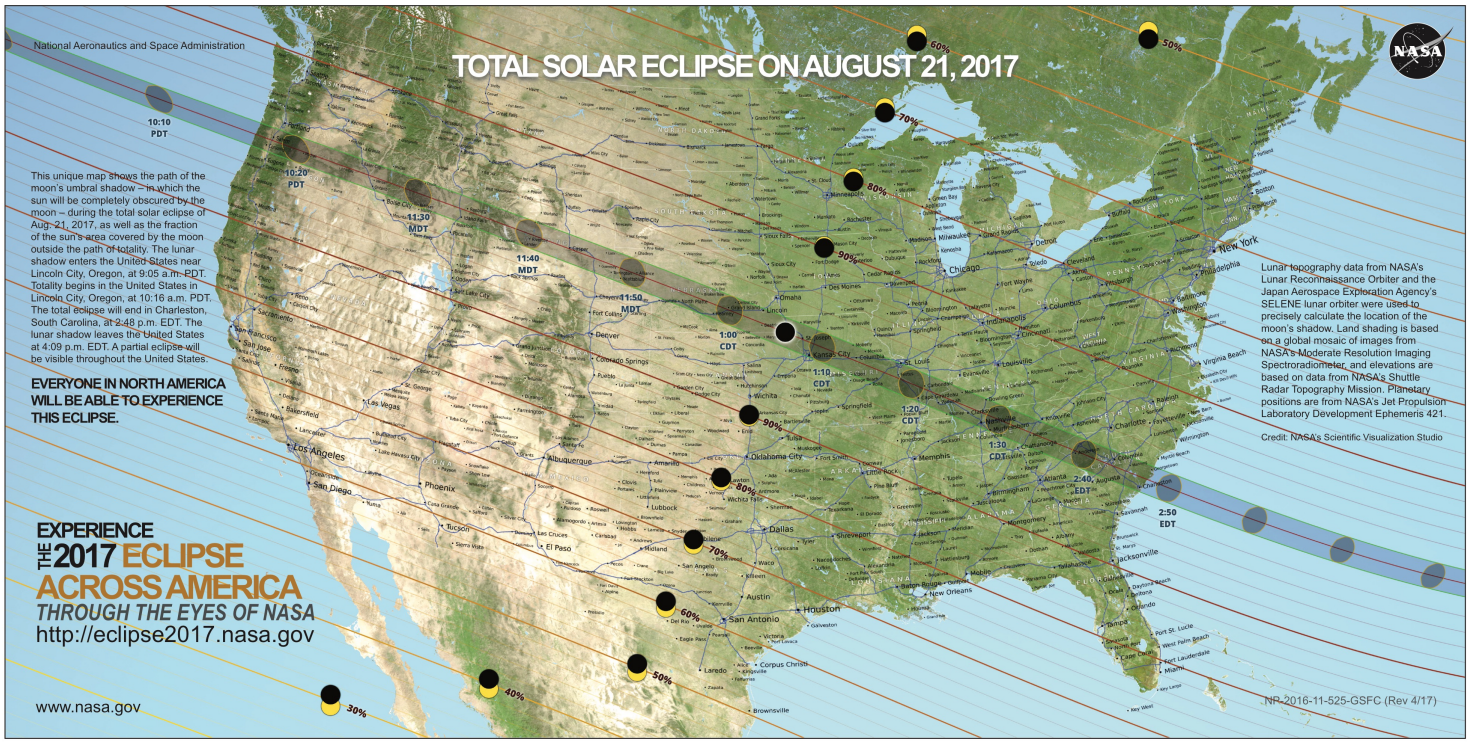
Testing Methodology

- Using initial conditions (wrfinput and wrfbdy) from 12 UTC 04 August 2017, with modified dates, tricking the WRF model to start at 12 UTC 21 August 2017. Thus, the solar forcing from 21 Aug will be applied to the meteorology of 04 Aug 2017.
- The focus will be on forecast hours 5-7, valid at 17-19 UTC, when the umbra passes over the US.

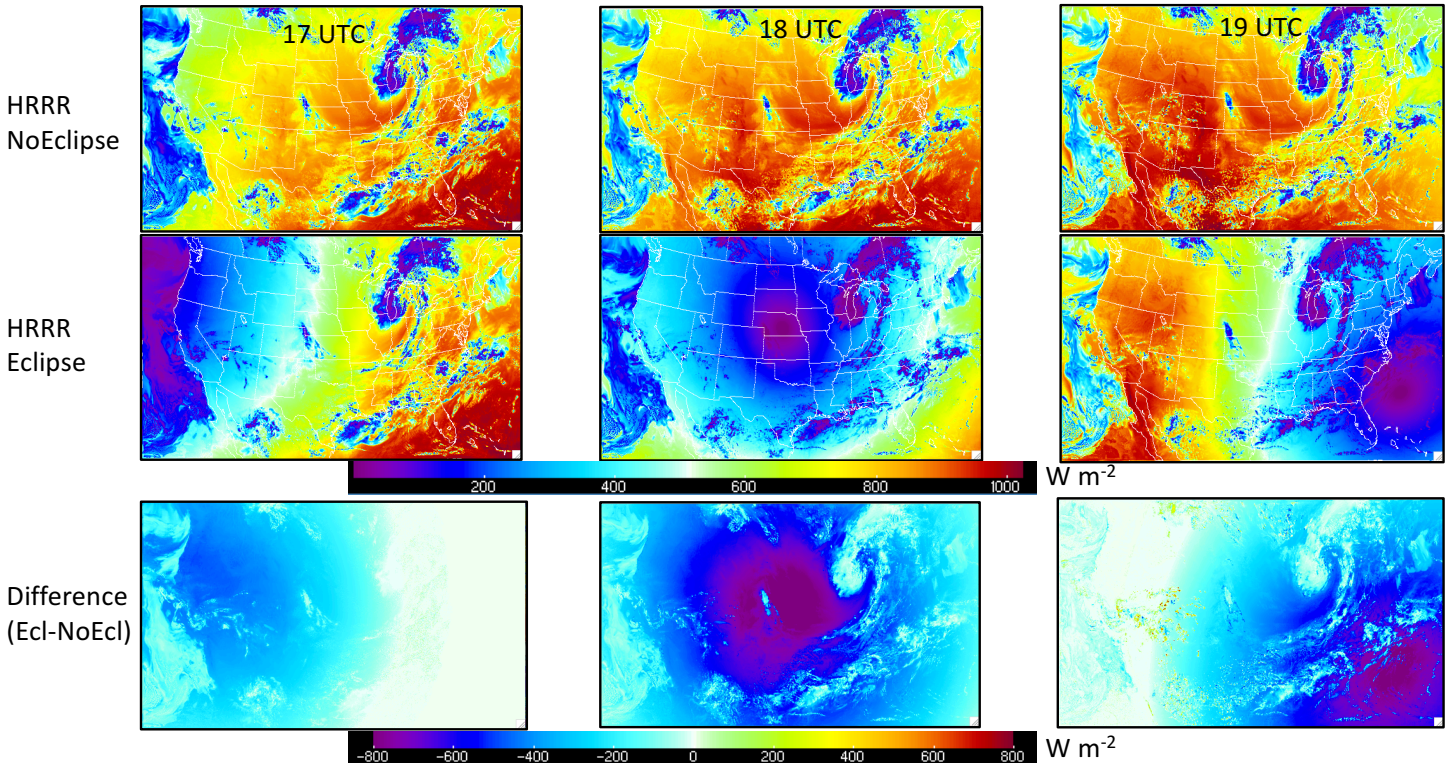
Questions:

1) Is the Eclipse module computationally stable for real-time applications?
2) Does the simulated eclipse track and degree of obscuration agree with expectations?
3) What is the general impact on low-level winds?
4) What is the general impact on 2-m temperature?

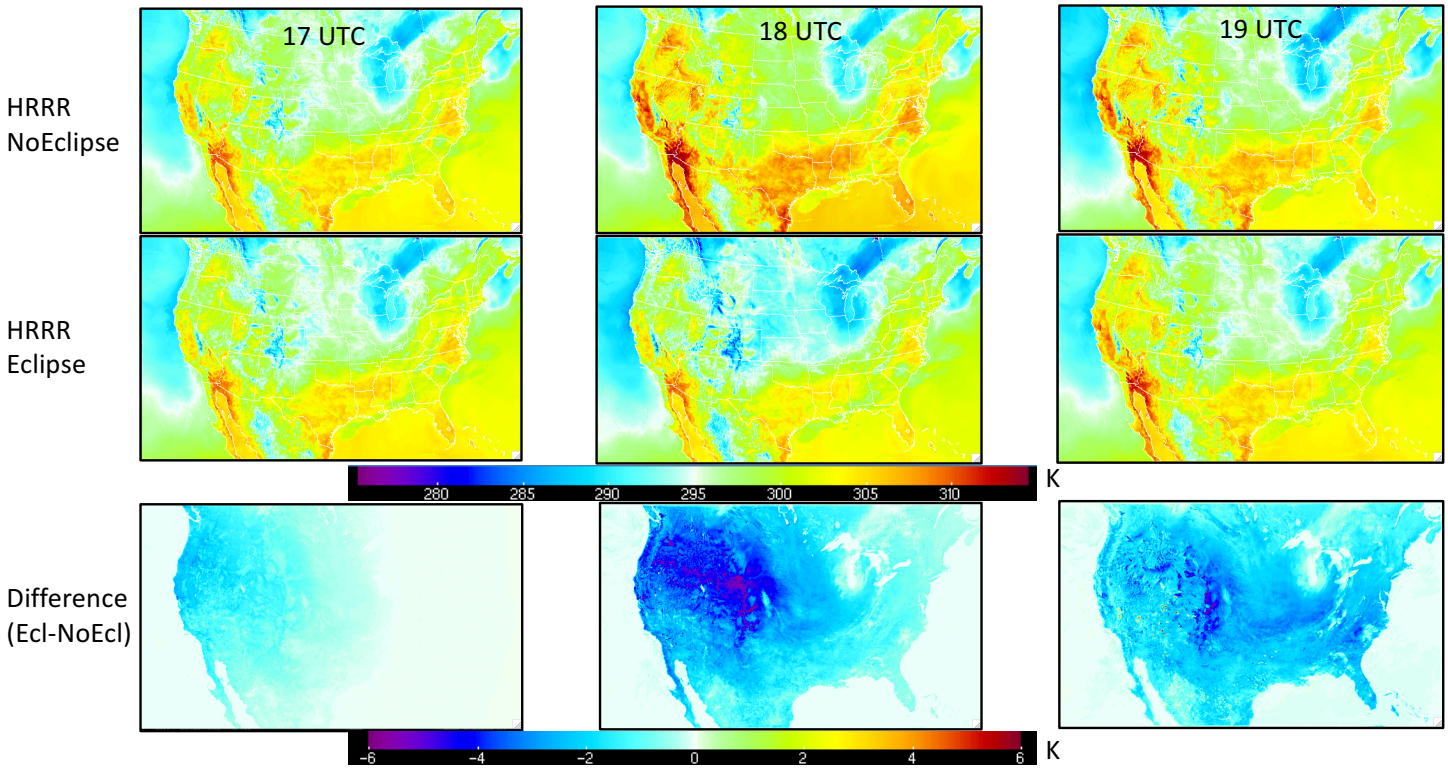
Expected Evolution of 21 August Event



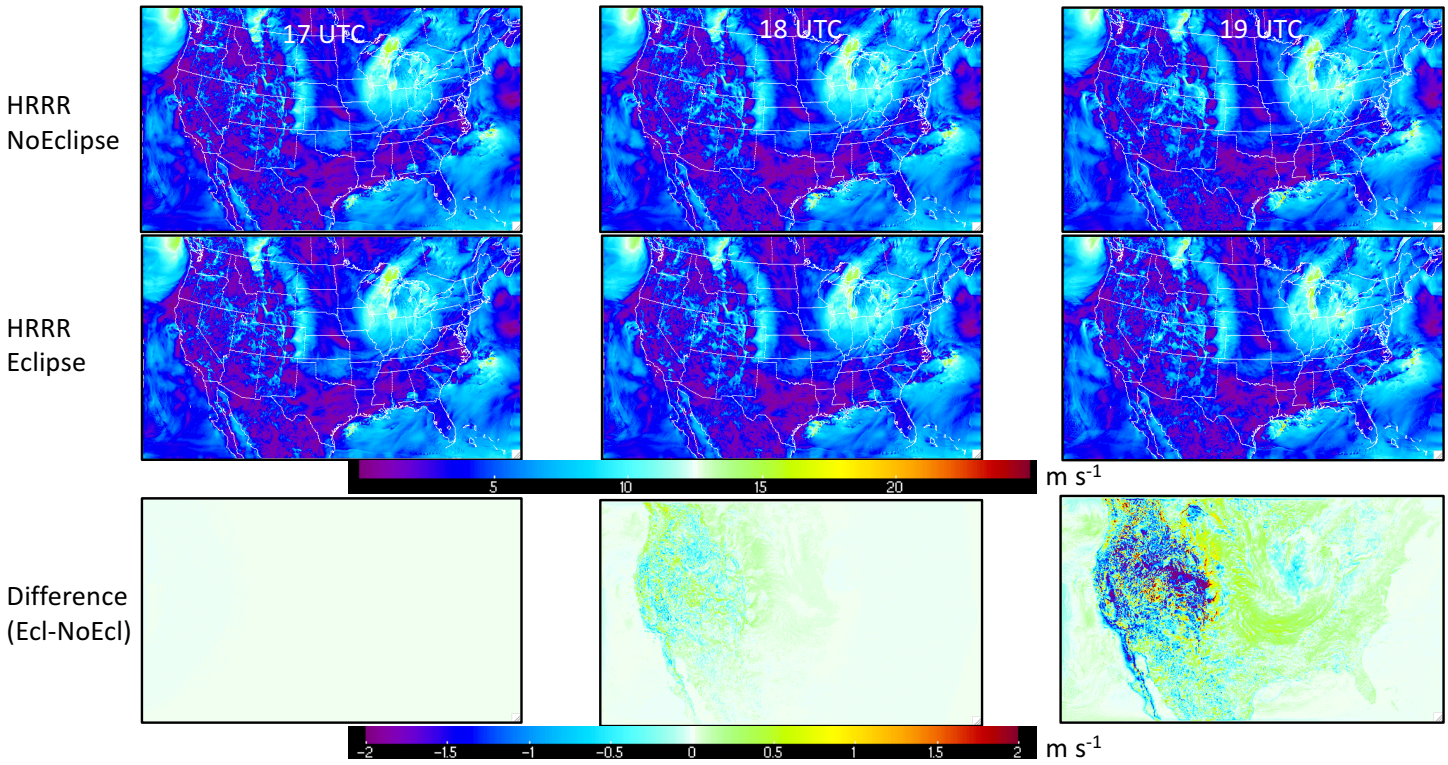
Evolution of Downward Solar Radiation



Evolution of 2m Temperature



Evolution of 80m Wind Speed



Summary

- The RAP/HRRR model code (using a refined version of WRF) is now eclipse-ready.
- The new executable will be inserted into the experimental versions of the HRRR and RAP models run at ESRL for the 21 August event.
- Experimental 48-h HRRR and RAP forecasts covering the eclipse period will start becoming available Saturday evening 19 August.
- The test results shown here used the meteorological conditions of 04 August 2017 with the solar radiative conditions of 21 August 2017, **so exact results presented here are not meant to be suggestive of what will happen on 21 August 2017**.
- The results found in this test show:
  - Up to 900 W m^{-2} reduction in downward shortwave radiation at the surface may occur on 21 August. The actual cloud cover on that day may determine the maximum reduction, rather than being caused by the eclipse.
  - Reductions of 2m temperature can reach the range of 5-7 C (9-12 F) in clear-sky regions.
  - The 80m wind speeds had a lagged effect, having large changes ($> \pm$ 2 m s^{-1}) two hours after the umbra passed over. Some of these changes were likely due to the interruption of the boundary layer development, but others may be due to a change in low-level pressure-driven flows in complex terrain.