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NATIONAL RENEWABLE ENERGY LABORATORY

# Results of Recent and Historical Comparisons between Absolute Cavity Pyrgeometer (ACP), InfraRed Integrating Sphere (IRIS)

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# Overview

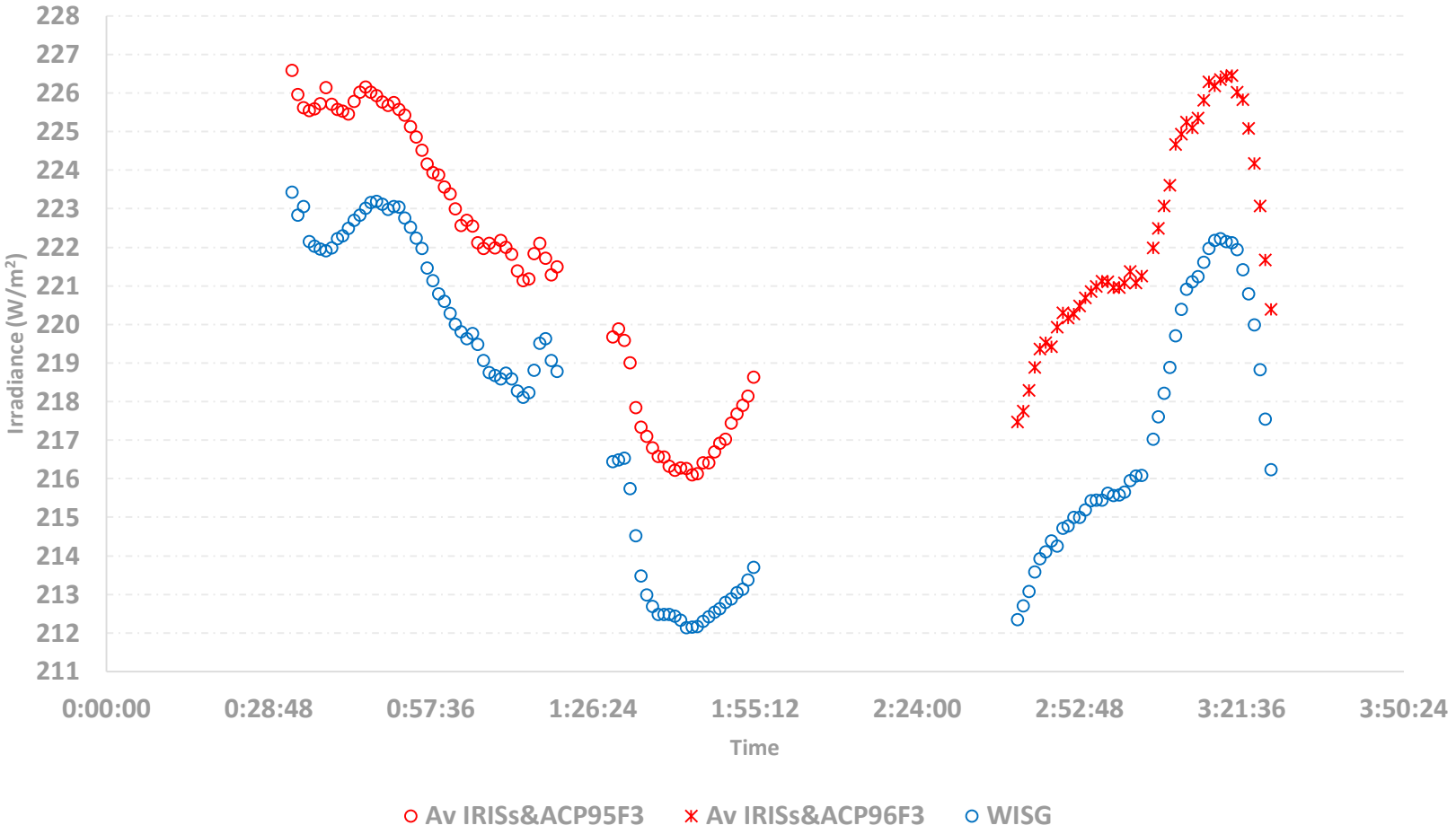
- Results of seven comparisons between ACPs and IRISs.
- Difference between the longwave irradiance measured by the ACPs and IRISs versus the irradiance measured by the WISG.
- The longwave irradiance measured by the ACPs, IRISs, and AERI versus the irradiance measured by the WISG.
- Recommendations to establish the world reference for measuring the atmospheric longwave irradiance with traceability to the International System of Units (SI).

# List of Instruments

| Instruments | Serial Number | Owner |
|---|---|---|
| IRIS | 001 | PMOD/WRC |
| IRIS | 002 | PMOD/WRC |
| IRIS | 004 | PMOD/WRC |
| ACP | 57F3 | German Meteorological Service |
| ACP | 95F3 | National Renewable Energy Laboratory (NREL) |
| ACP | 96F3 | Physikalisch-Meteorologisches Observatorium Davos World Radiation Center (PMOD/WRC) |
| **IRIS** | **003** | **BOM** |
| **IRIS** | **005** | **DWD** |

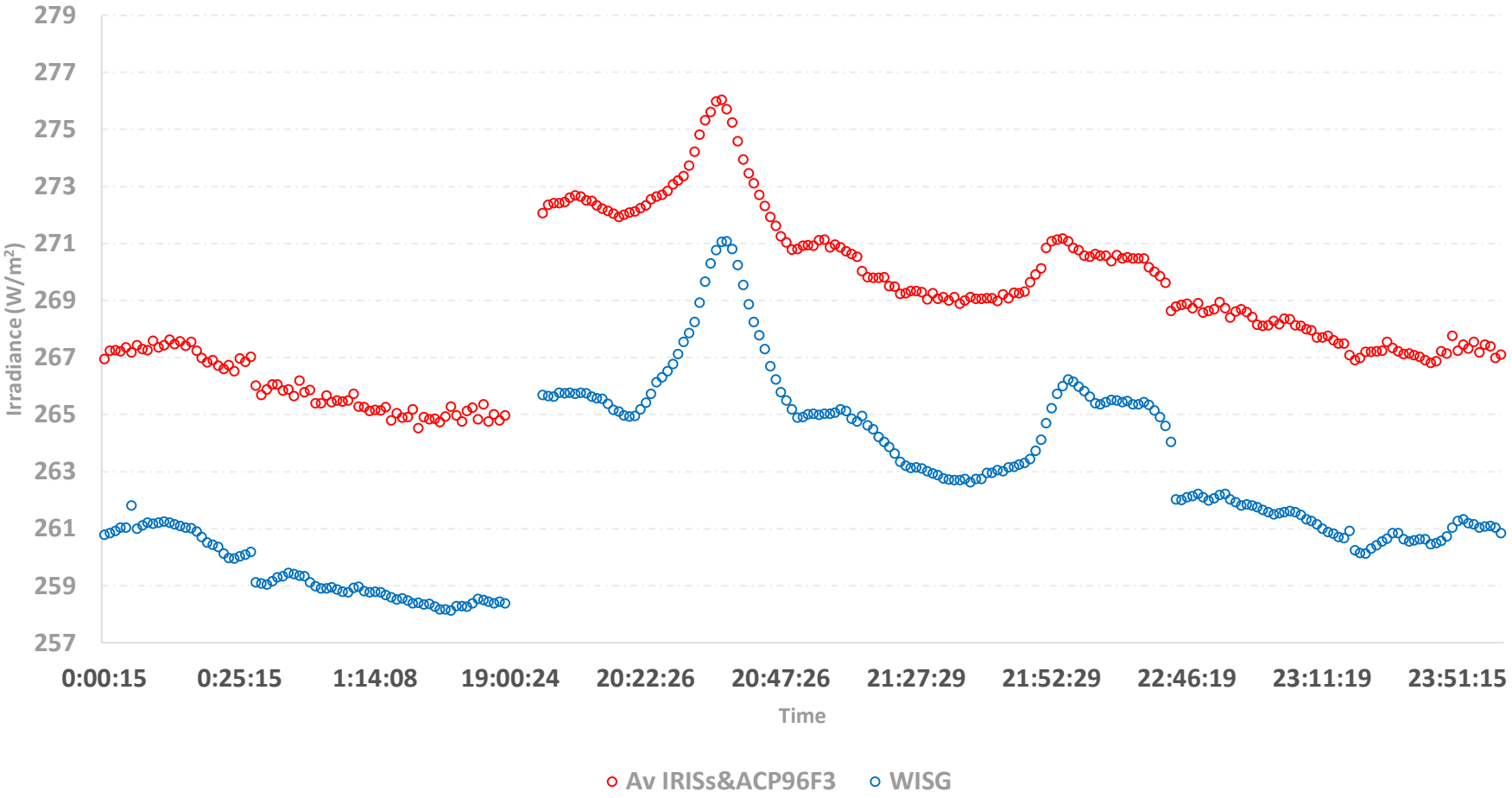
# Results of First Comparison between ACPs and IRISs-Davos

## Average Irradiance of Two IRISs&ACP95F3 or 96F3 versus the WISG Average Irradiance at night on Feb. 5, 2013 (~8 mm $H_2O$ vapor column)

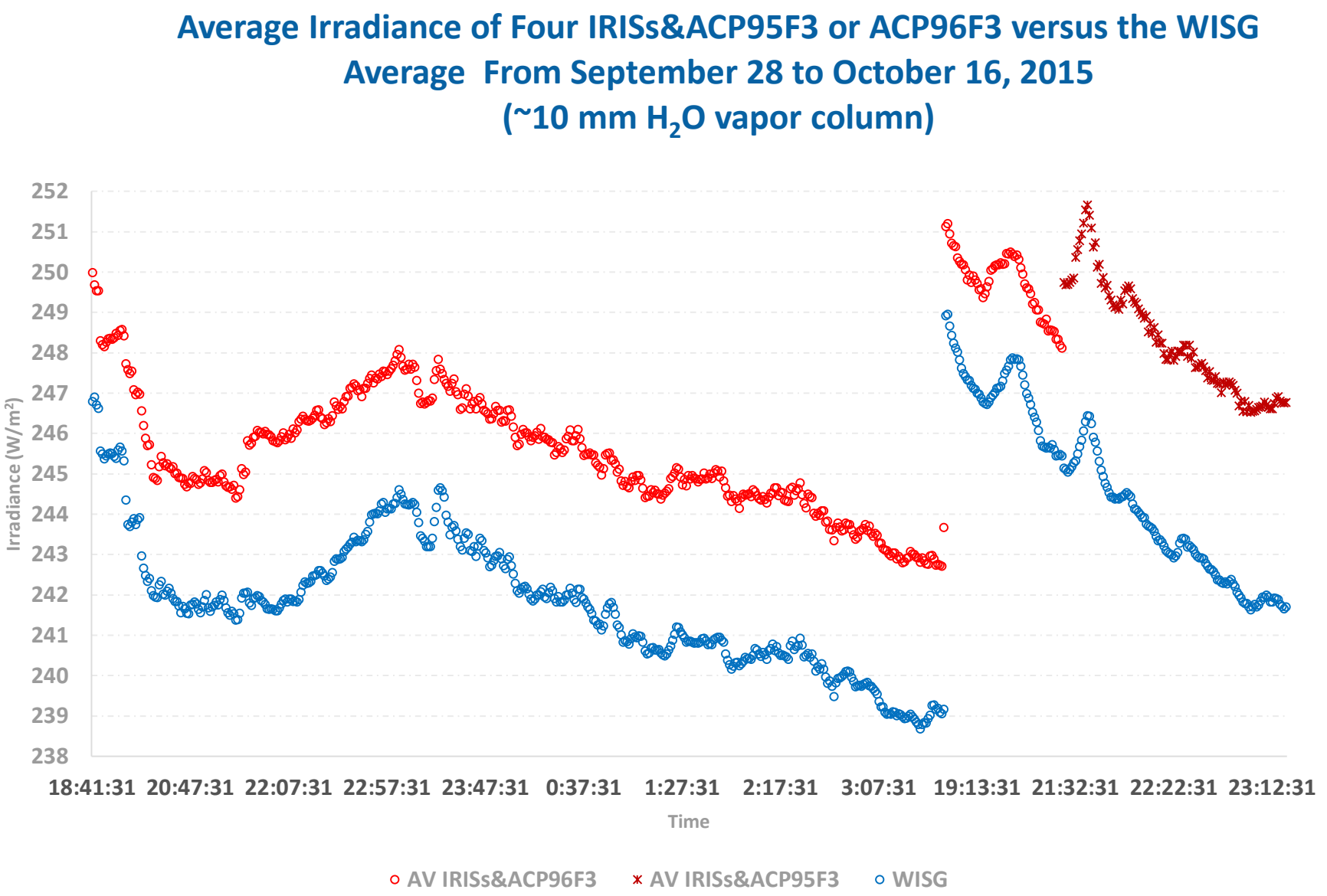


# Results of Second Comparison between ACPs and IRISs-Davos

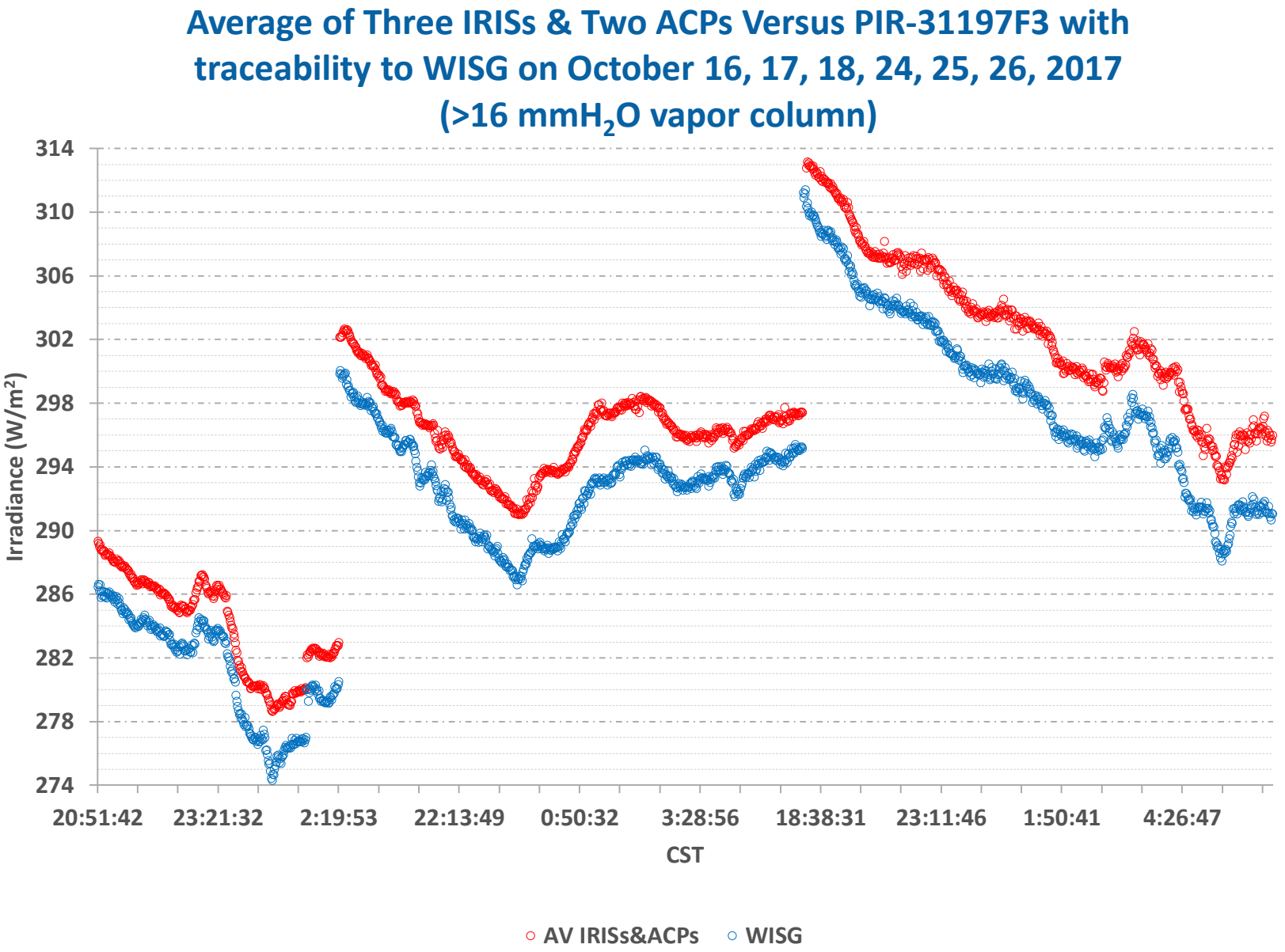
## Average Irradiance of Two IRISs&ACP96F3 versus the WISG Average Irradiance on Oct. 2&3, 2013 (~15 mm $H_2O$ vapor column)



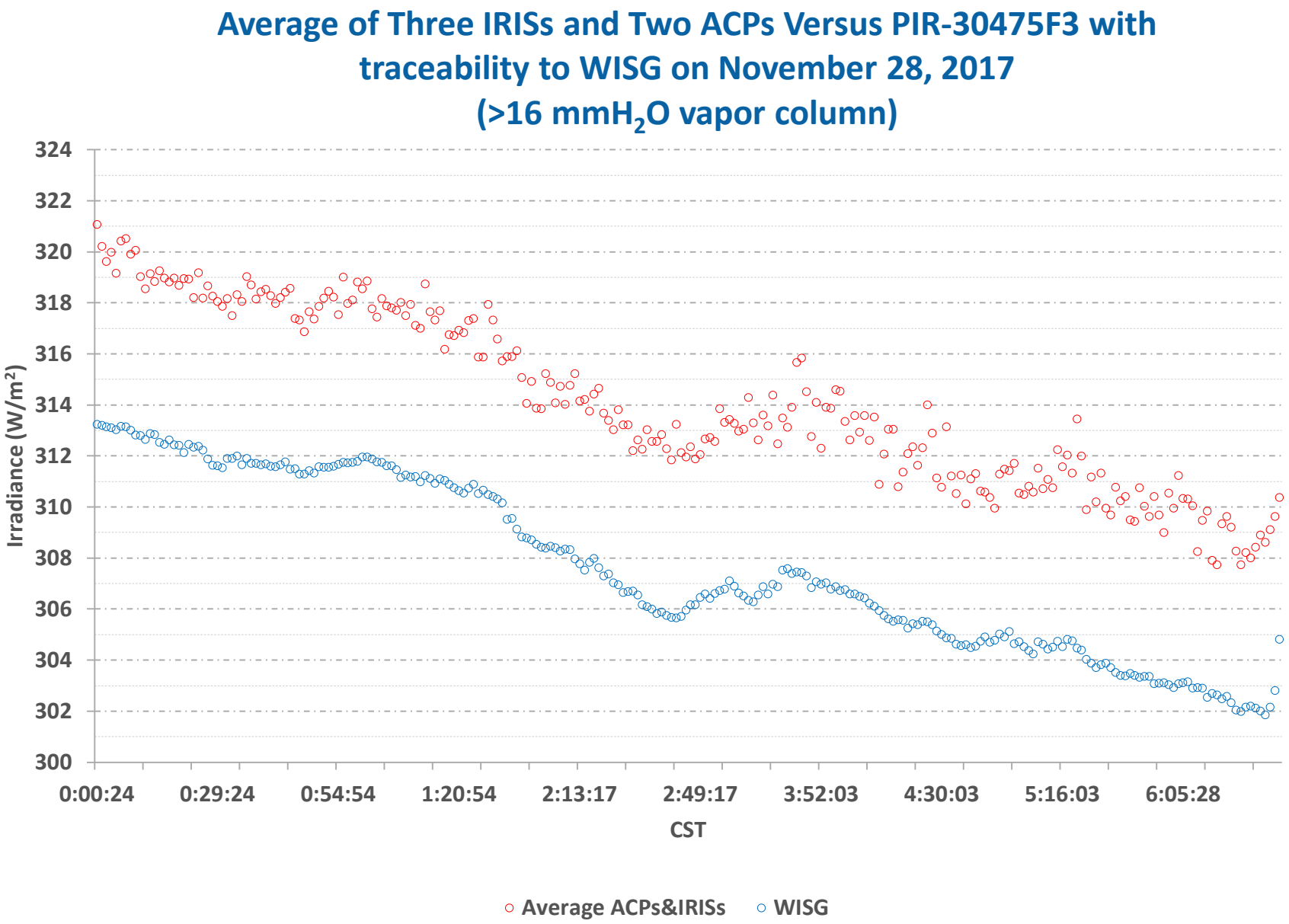
# Results of Third Comparison between ACPs and IRISs-Davos



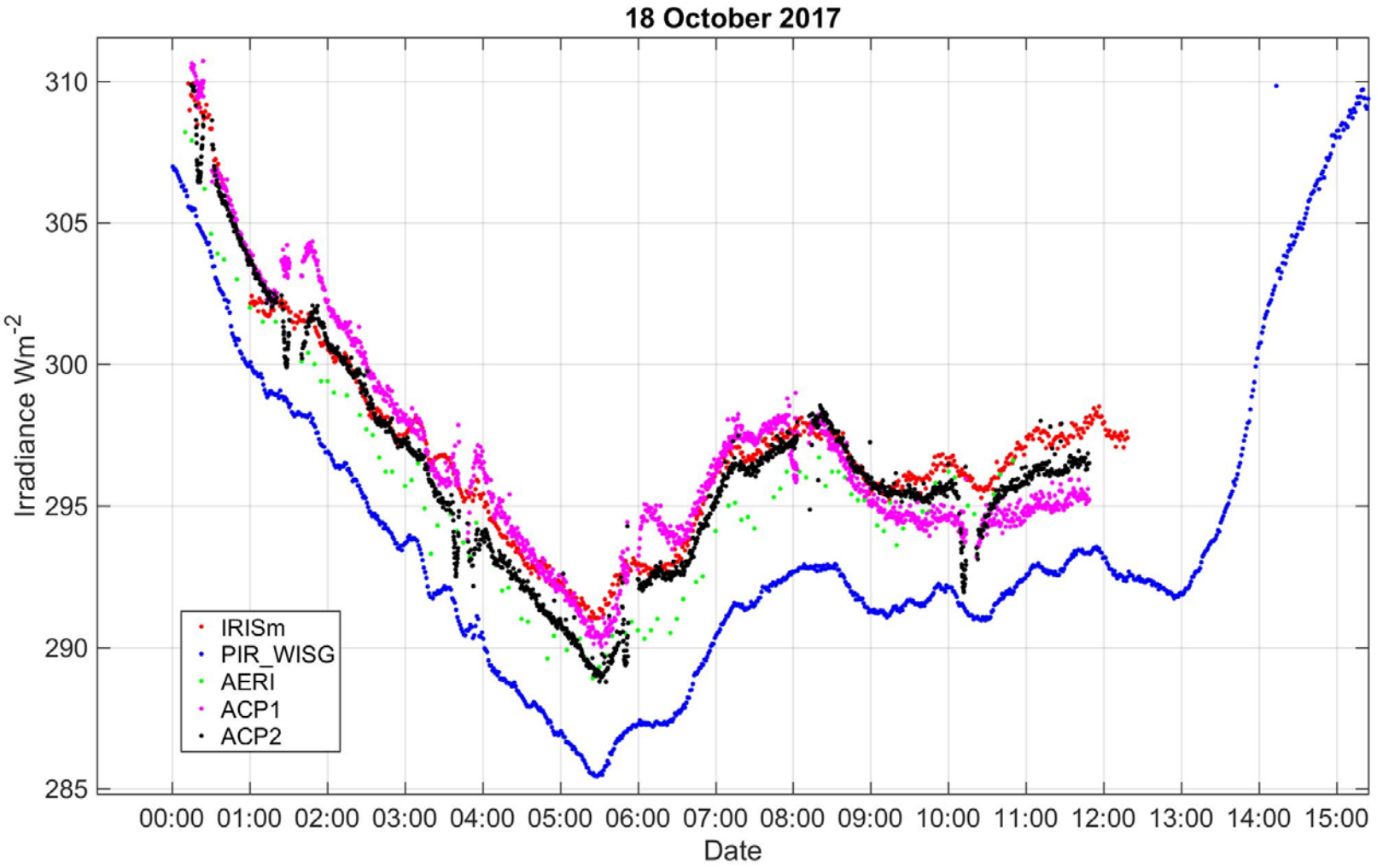
# Results of Fourth Comparison between ACPs and IRISs-SGP-Phase 1



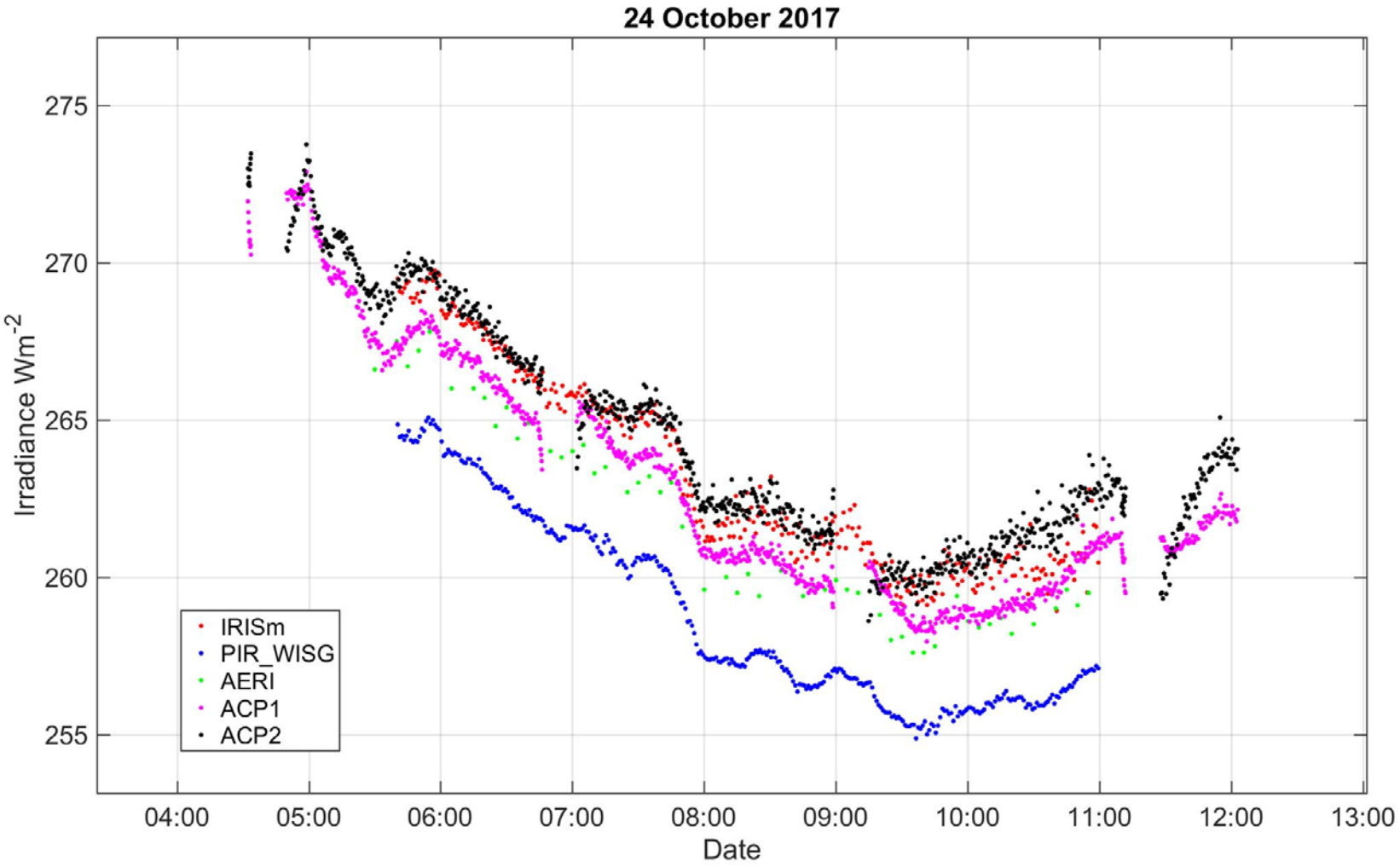
# Results of Fifth Comparison between ACPs and IRISs-SGP-Phase 2



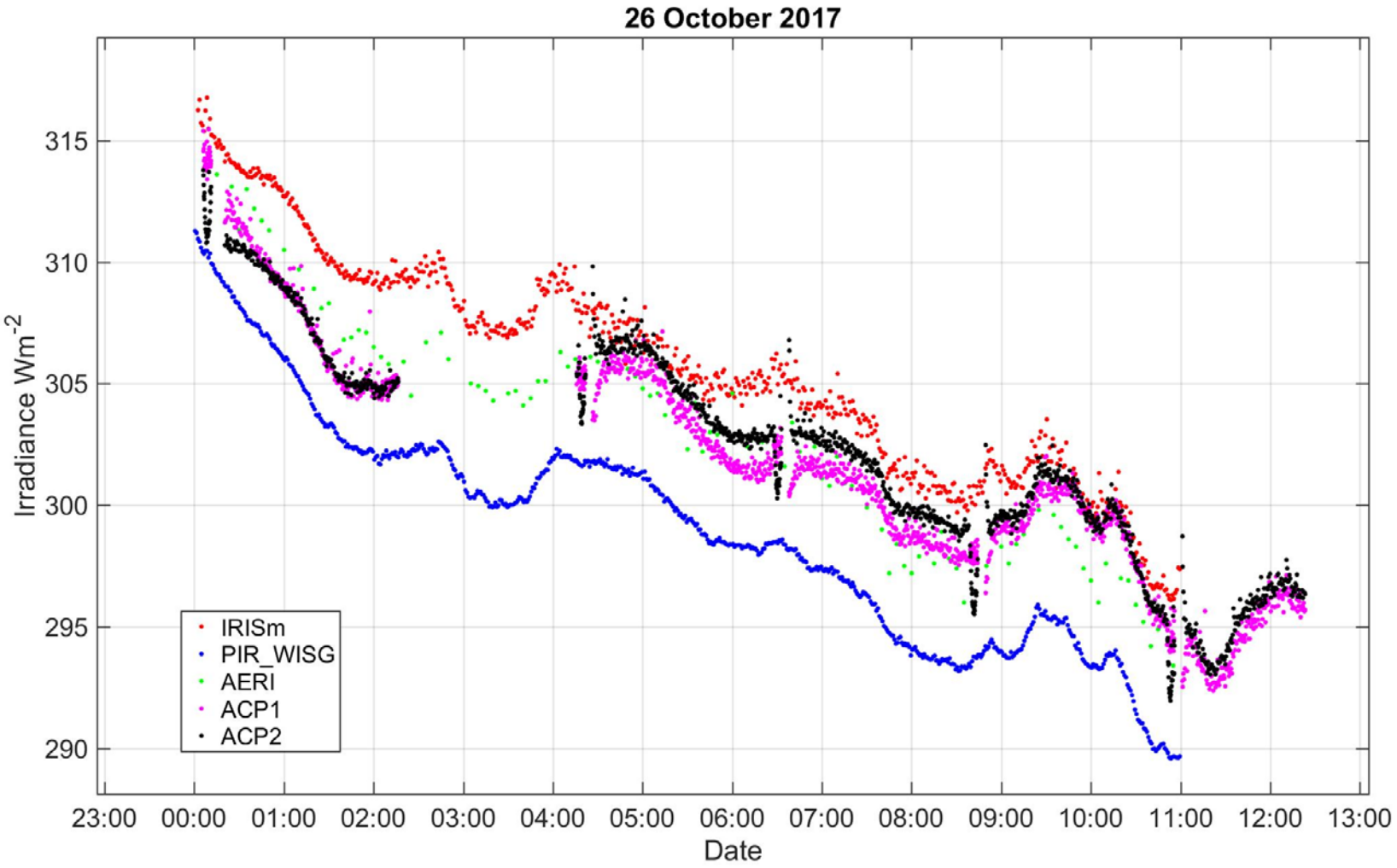
# Results of Comparison between ACPs, IRISs, and AERI at SGP



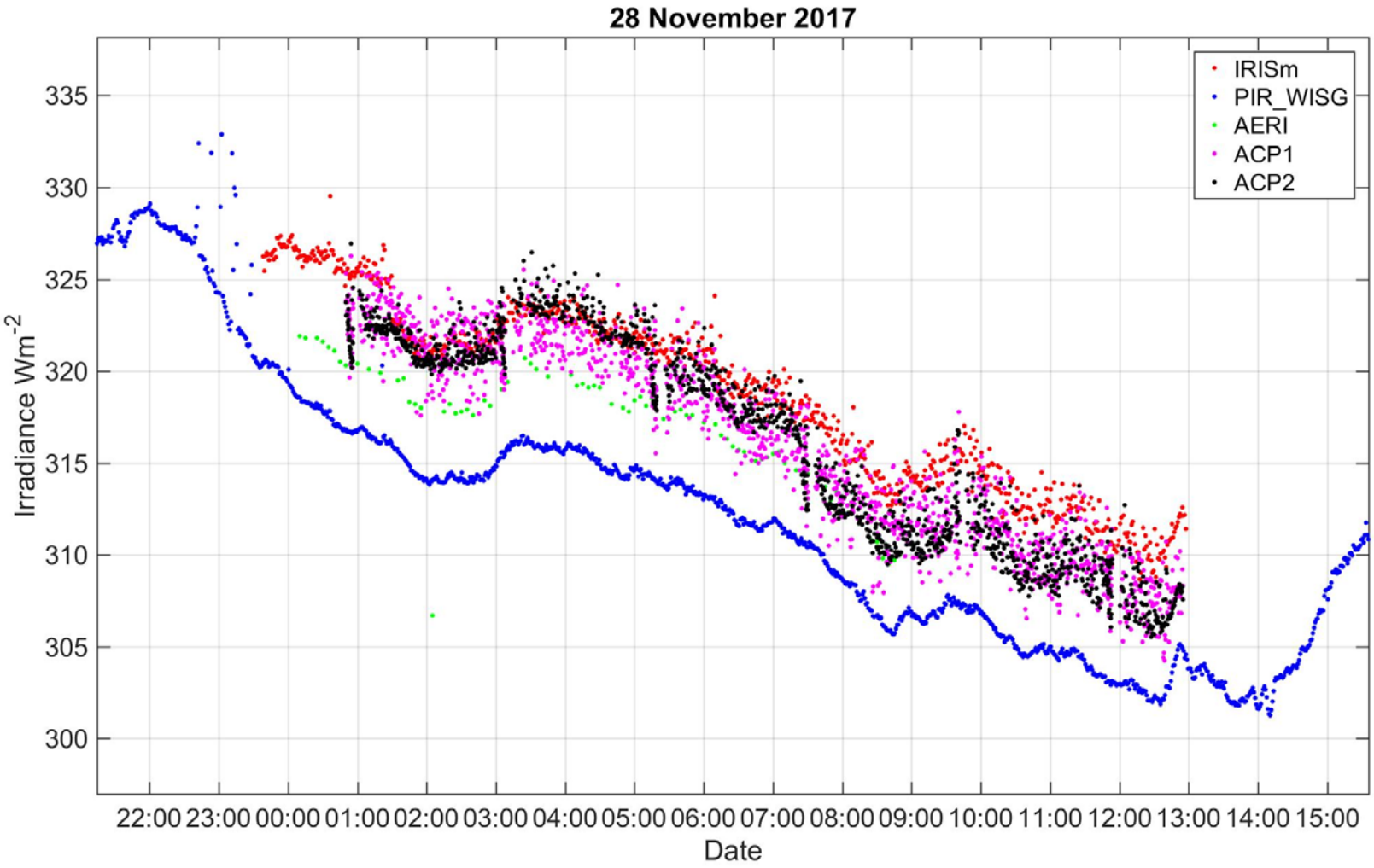
# Results of Comparison between ACPs, IRISs, and AERI at SGP



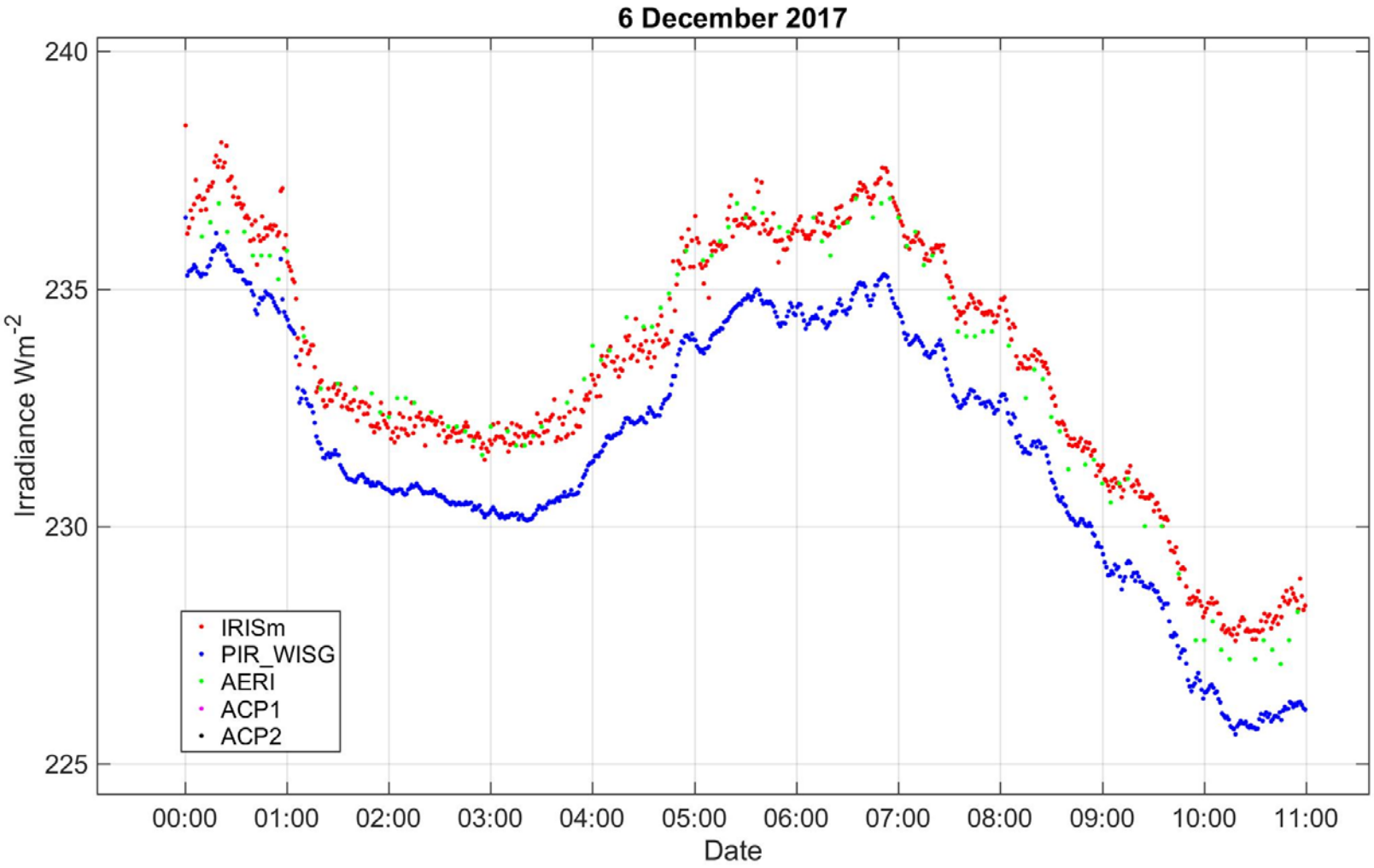
# Results of Comparison between ACPs, IRISs, and AERI at SGP



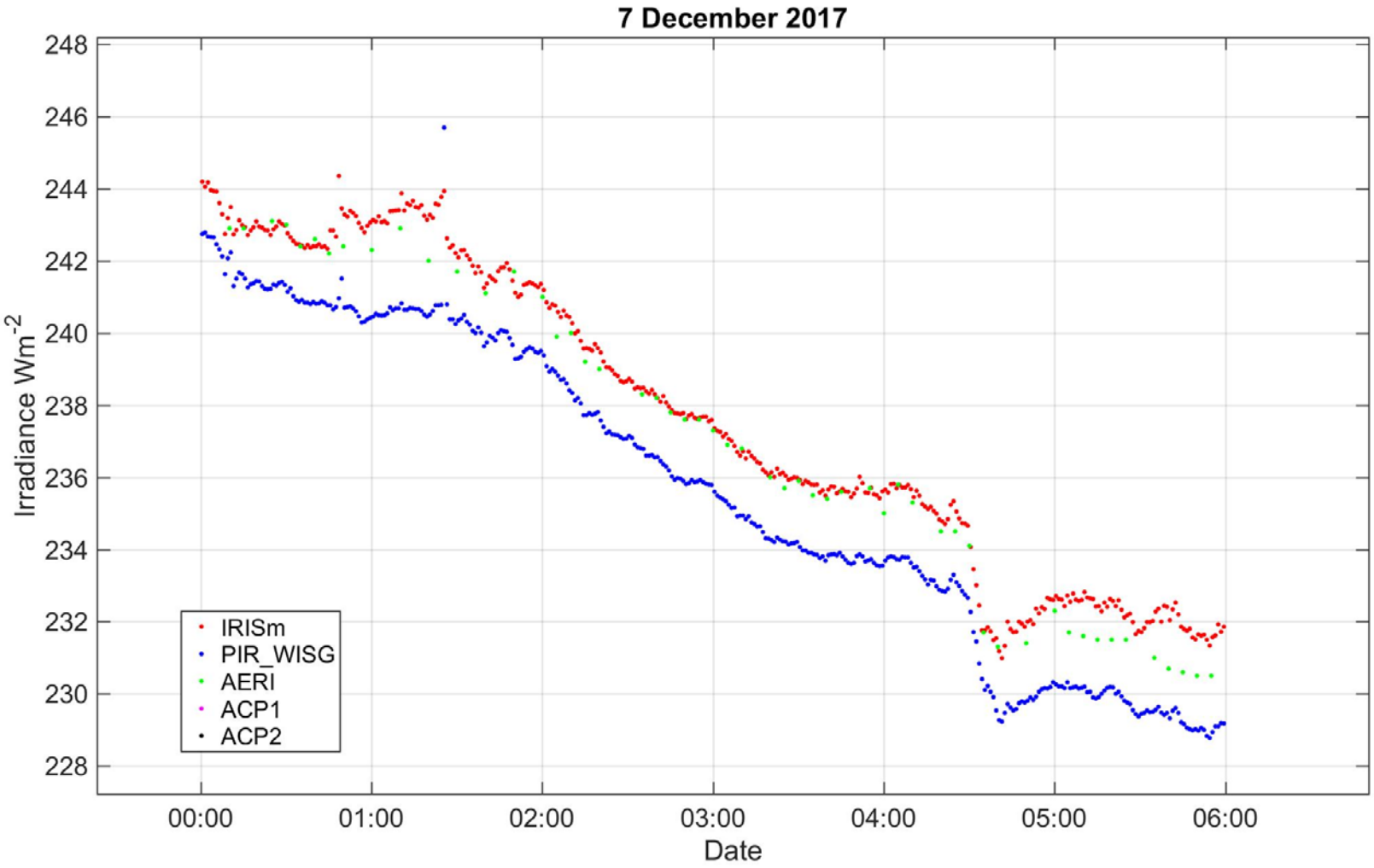
# Results of Comparison between ACPs, IRISs, and AERI at SGP



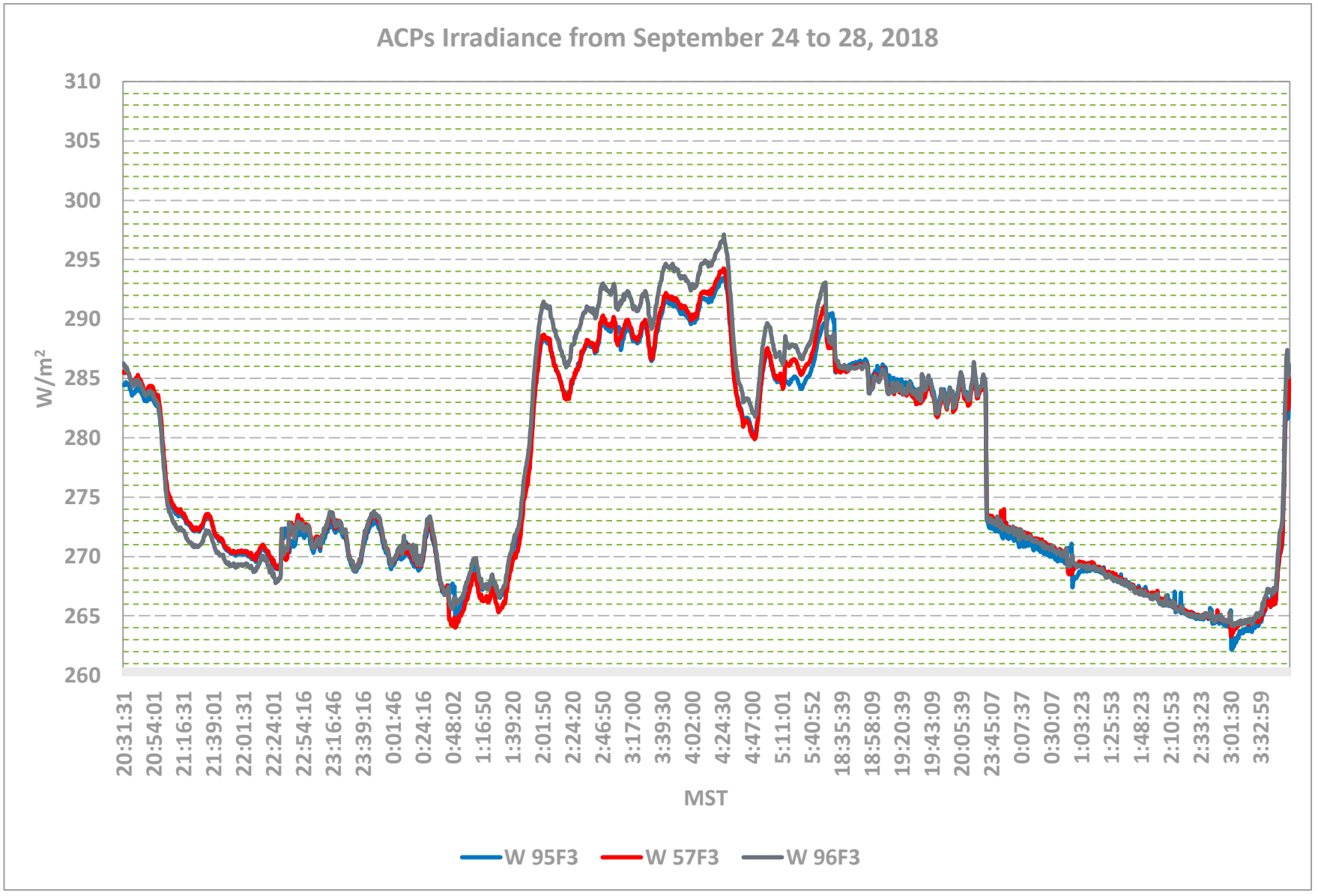
# Results of Comparison between ACPs, IRISs, and AERI at SGP



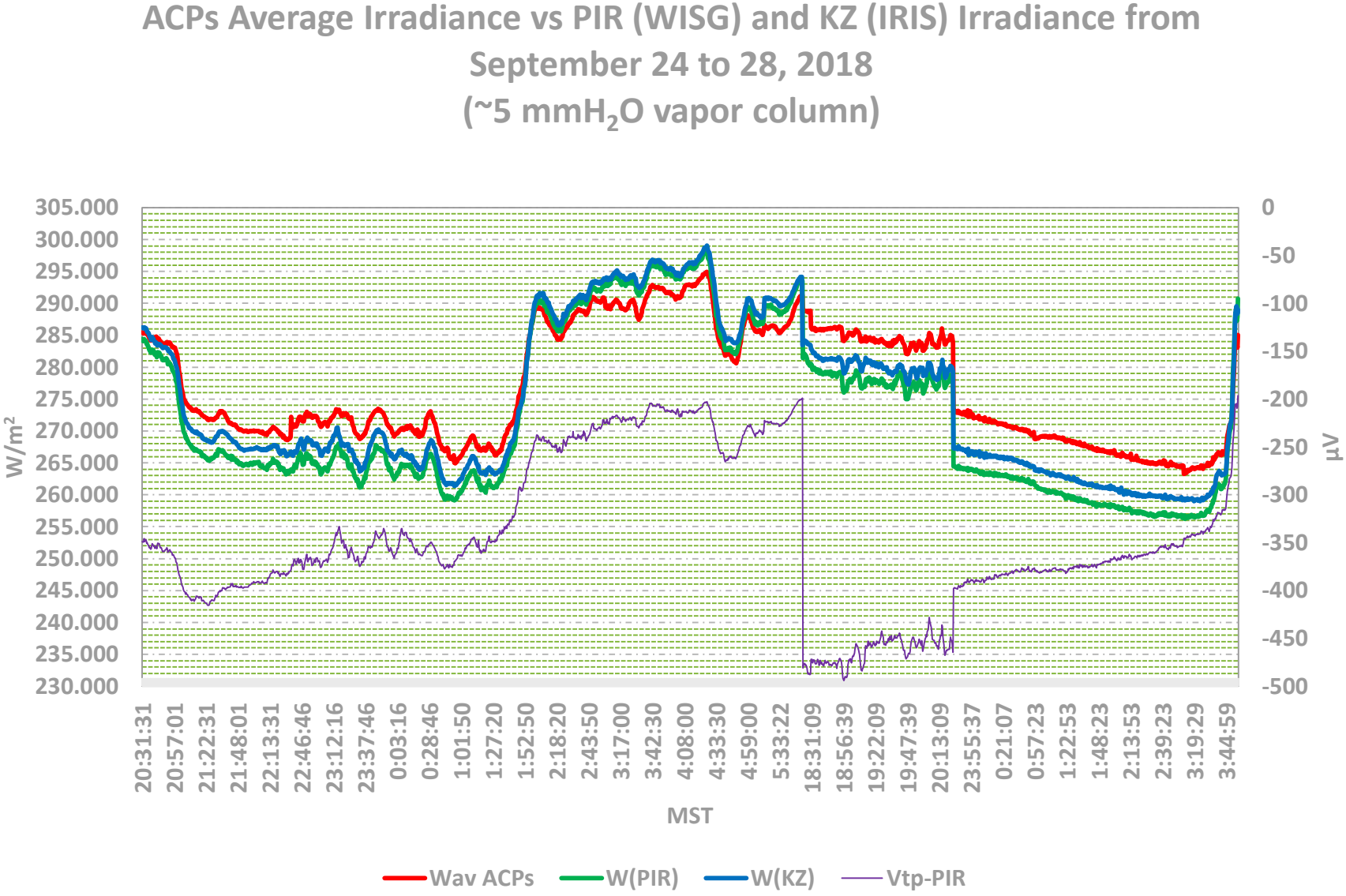
# Results of Comparison between ACPs, IRISs, and AERI at SGP



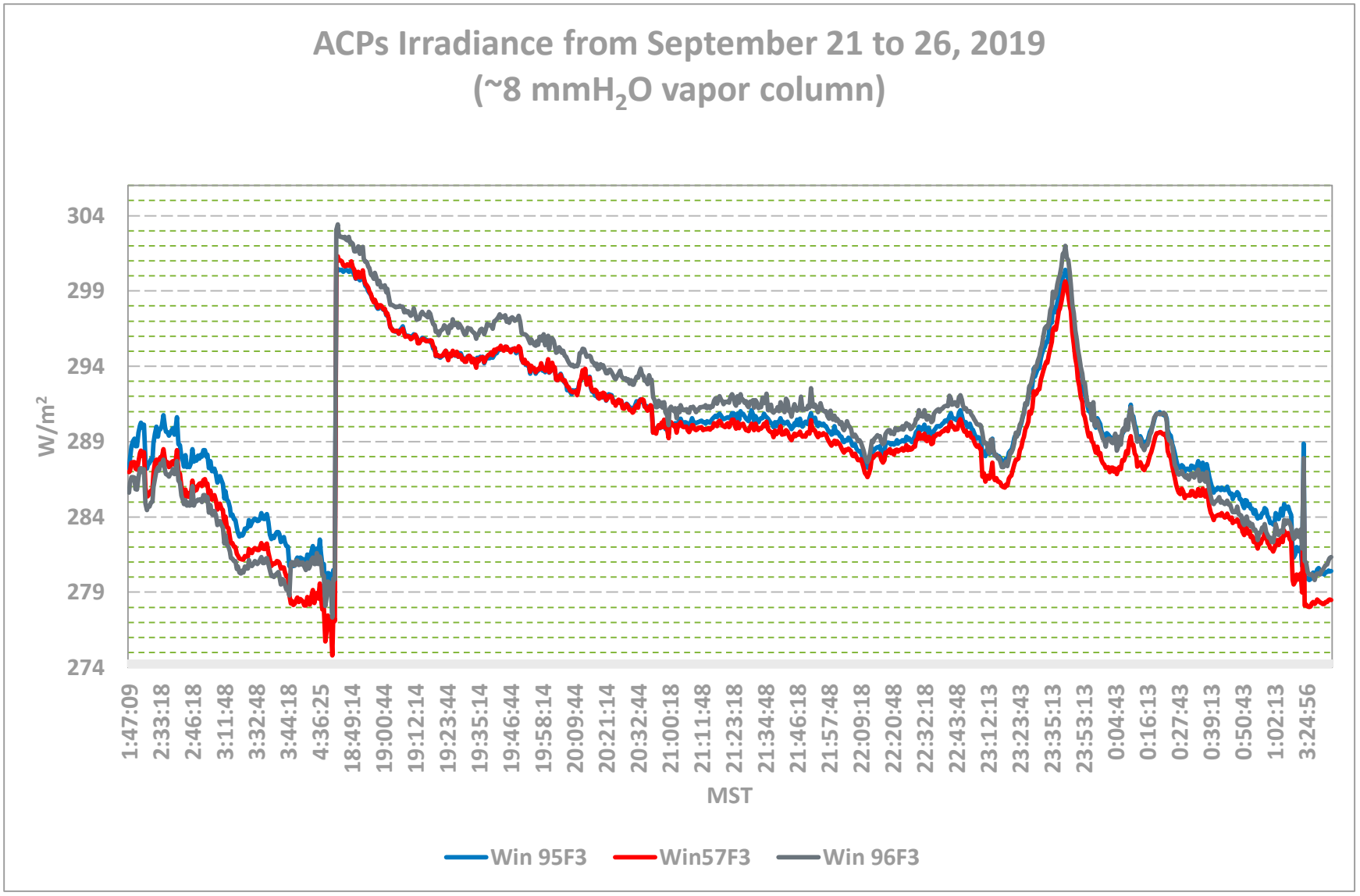
# Results of Comparison between ACPs during NPC-2018



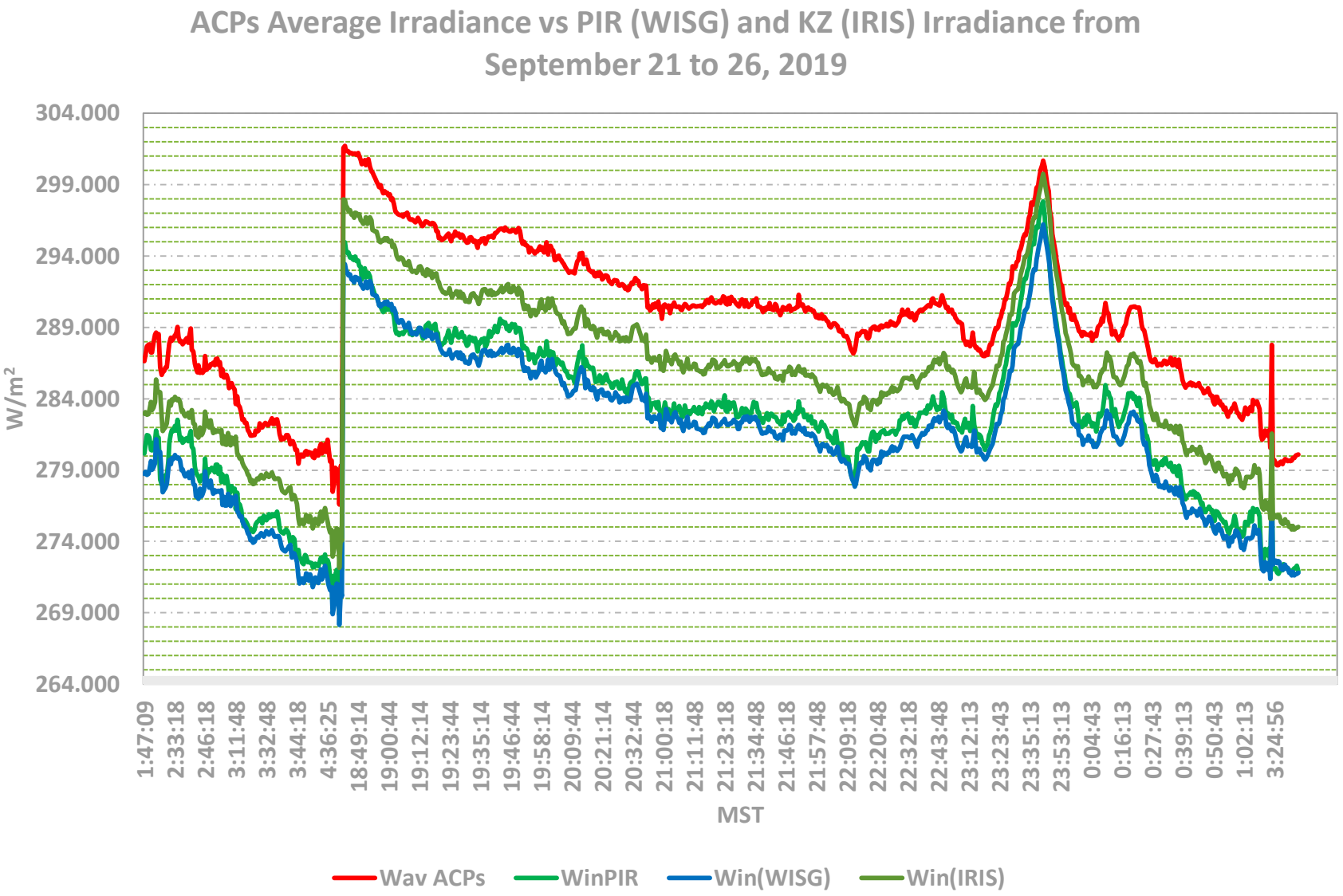
# Results of Comparison between ACPs during NPC-2018



# Results of Comparison between ACPs during NPC-2019



# Results of Comparison between ACPs during NPC-2019



# Summary of the seven comparisons

| | Comparison Number | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $W/m^2$ | 1 | 2 | 3 | 4 | 5 | 6 | | | 7 | | |
| | | | | | | 95F3 | 57F3 | 96F3 | 95F3 | 57F3 | 96F3 |
| Average difference between ACPs&IRISs Or Each ACP | 0.1 | 0.3 | -1.2 | -1.6 | -1.8 | 0.3 | 0.2 | -0.5 | -0.2 | 0.8 | -0.5 |
| StDev of difference | 0.1 | 0.7 | 0.7 | 1.2 | 0.9 | 0.6 | 0.5 | 0.8 | 0.7 | 0.4 | 0.8 |
| Difference within 95% | 0.2 | 1.3 | 1.8 | 2.8 | 2.5 | 1.2 | 1.0 | 1.7 | 1.5 | 1.0 | 1.7 |
| Average of ACPs&IRISs Or Avergae ACPs - WISG | 3.9 | 6.1 | 3.8 | 3.5 | 6.5 | 4.3 | | | 7.0 | | |
| StDev of difference | 1.0 | 0.8 | 0.7 | 0.8 | 0.7 | 4.2 | | | 1.0 | | |
| Difference within 95% | 4.4 | 6.3 | 4.1 | 3.9 | 6.6 | 9.3 | | | 7.3 | | |
| Average of ACPs - KZ traceable to IRIS | | | | | | | | | 4.0 | | |
| StDev of difference | | | | | | | | | 0.9 | | |
| Difference within 95% | | | | | | | | | 4.3 | | |

# Conclusion

- *The difference between the irradiance measured by the ACPs & IRISs varied from 0.2 W/m$^2$ to 2.8 W/m$^2$ based on the atmospheric conditions, which is within the stated uncertainties of ±3 W/m$^2$.*
- *The irradiance measured by the WISG is lower than the average irradiance measured by ACPs and IRISs, magnitude of the difference varied from 3.9 W/m$^2$ to 9.3 W/m$^2$ depending on the integrated water vapor.*

# WMO CIMO Task Team on Radiation References

- The measurements show convincingly that the WISG needs to be redefined.
- The TT-REF has identified several issues which need to be met before a redefinition of the WISG can take place:
  - Demonstrate traceability of IRIS and ACP.
    - Comparison to additional longwave reference instruments (AERI,...)
    - Validation of PMOD BB2008 (used as reference for IRIS and pyrgeometer characterizations)
  - Understand physics behind ACP, including its measurement equation.
  - Deployment of ACPs at additional sites (PMOD/WRC, DWD,...)

# Thank You

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