CWB現行同步衛星資料運用於空氣品質監測之進展

2020/10/15

第四組
劉豫臻

空汙監測產品簡介

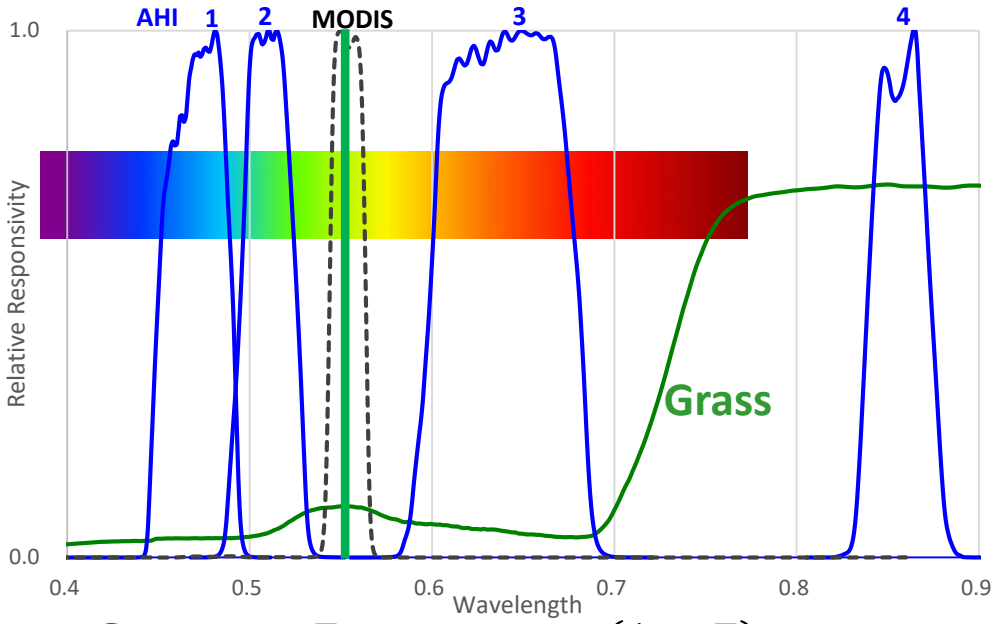
- 同步衛星向日葵8號，較上一代衛星擁有較高的時間、空間、波譜解析，可廣泛運用於空汙產品發展，空汙監測產品持續精進中，現行主要作業產品有：
  - 真實色影像
  - 日夜沙塵偵測
  - 火點偵測（略）
  - 氣膠光學厚度
  - PM2.5（AOD to PM2.5）

Observation area	Band number (see Table 1)	Spatial resolution at SSP (sub satellite point)[km]	Numbers of pixels	
			East-west direction	North-south direction
Full Disk	3	0.5	22,000	22,000
	1,2,4	1	11,000	11,000
	5-16	2	5,500	5,500
Japan Area (Region 1 + Region 2)	3	0.5	6,000	4,800
	1,2,4	1	3,000	2,400
	5-16	2	1,500	1,200
Target Area (Region 3)	3	0.5	2,000	2,000
	1,2,4	1	1,000	1,000
	5-16	2	500	500
Landmark Area (Region 4)	3	0.5	2,000	1,000
	1,2,4	1	1,000	500
	5-16	2	500	250
Landmark Area (Region 5)	3	0.5	2,000	1,000
	1,2,4	1	1,000	500
	5-16	2	500	250

Wave length [μm]	Himawari-8/9			
	Band number	Spatial resolution at SSP [km]	Central wave length [μm]	
			AHI-8 (Himawari-8)	AHI-9 (Himawari-9)
0.47	1	1	0.47063	0.47059
0.51	2	1	0.51000	0.50993
0.64	3	0.5	0.63914	0.63972
0.86	4	1	0.85670	0.85668
1.6	5	2	1.6101	1.6065
2.3	6	2	2.2568	2.2570
3.9	7	2	3.8853	3.8289
6.2	8	2	6.2429	6.2479
6.9	9	2	6.9410	6.9555
7.3	10	2	7.3467	7.3437
8.6	11	2	8.5926	8.5936
9.6	12	2	9.6372	9.6274
10.4	13	2	10.4073	10.4074
11.2	14	2	11.2395	11.2080
12.4	15	2	12.3806	12.3648
13.3	16	2	13.2807	13.3107

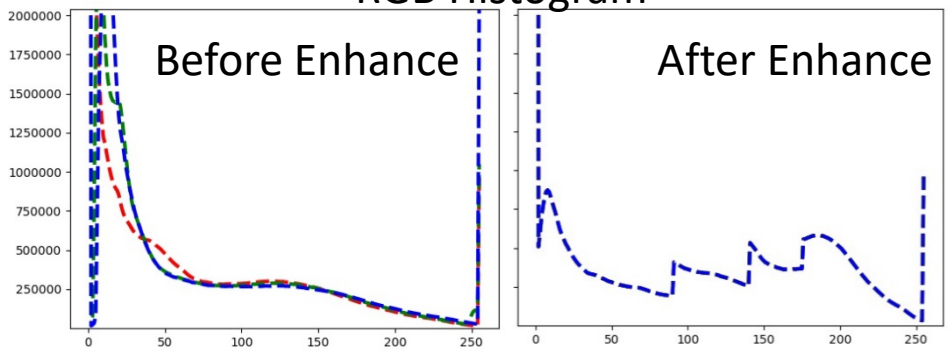
Figure from https://www.data.jma.go.jp/mscweb/en/himawari89/space_segment/spsg_ahi.html

真實色彩影像



$$G_{Hybrid} = F \times \rho_{0.51\mu m} + (1 - F)\rho_{0.86\mu m}$$

RGB Histogram



Cosine Sun Zenith Correction

↓

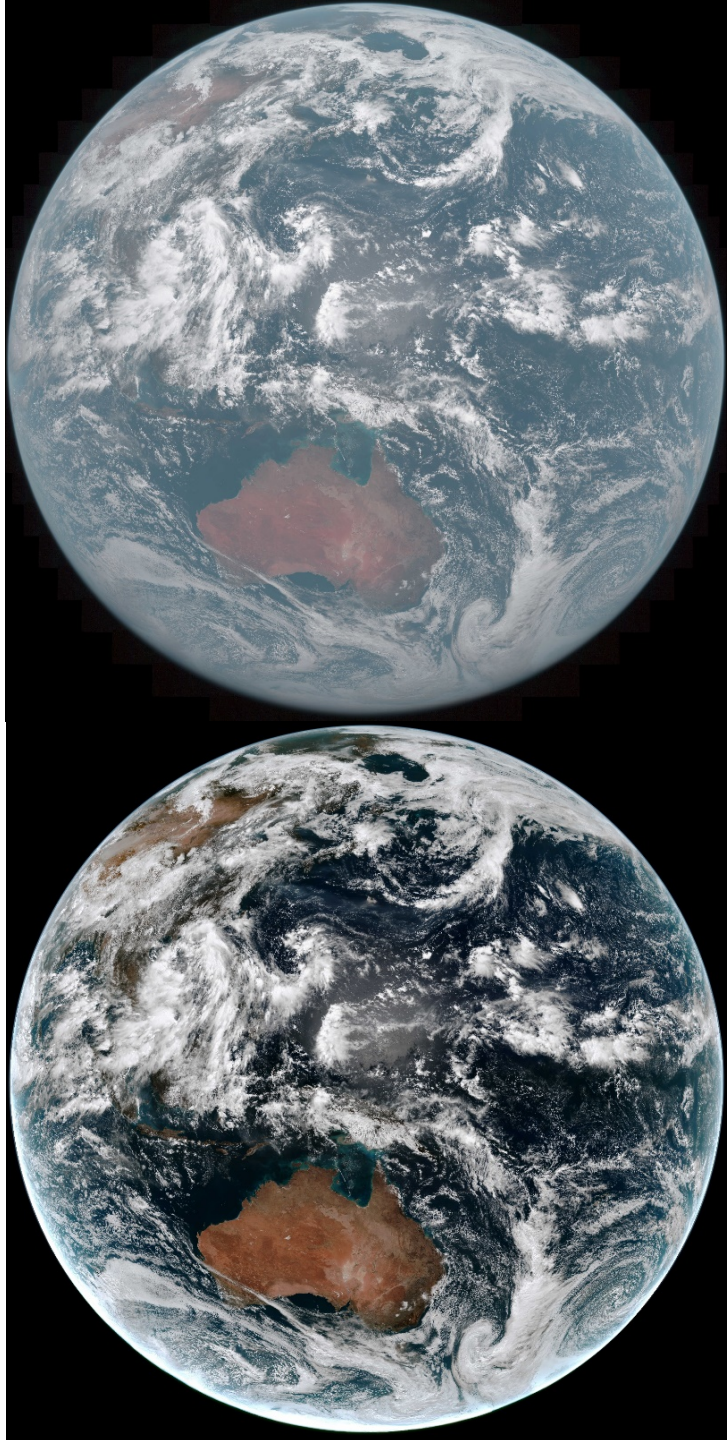
Hybrid Green

↓

Rayleigh Scatter Correction

↓

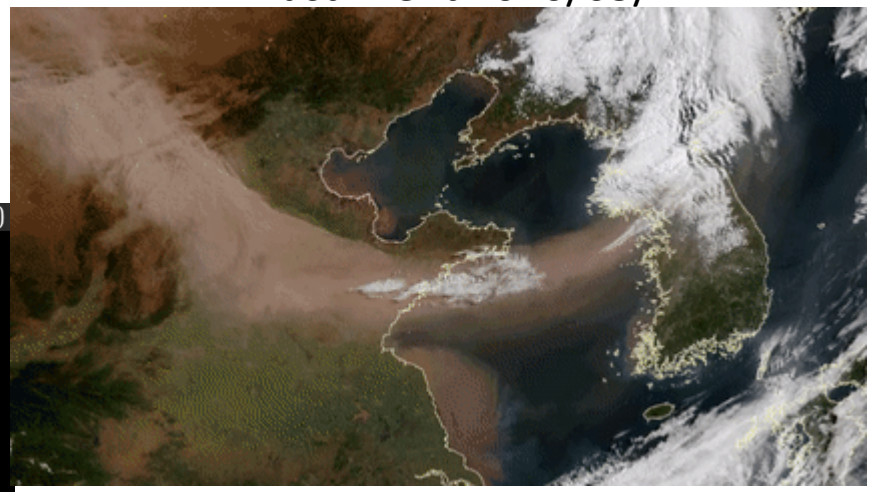
Color Enhancement



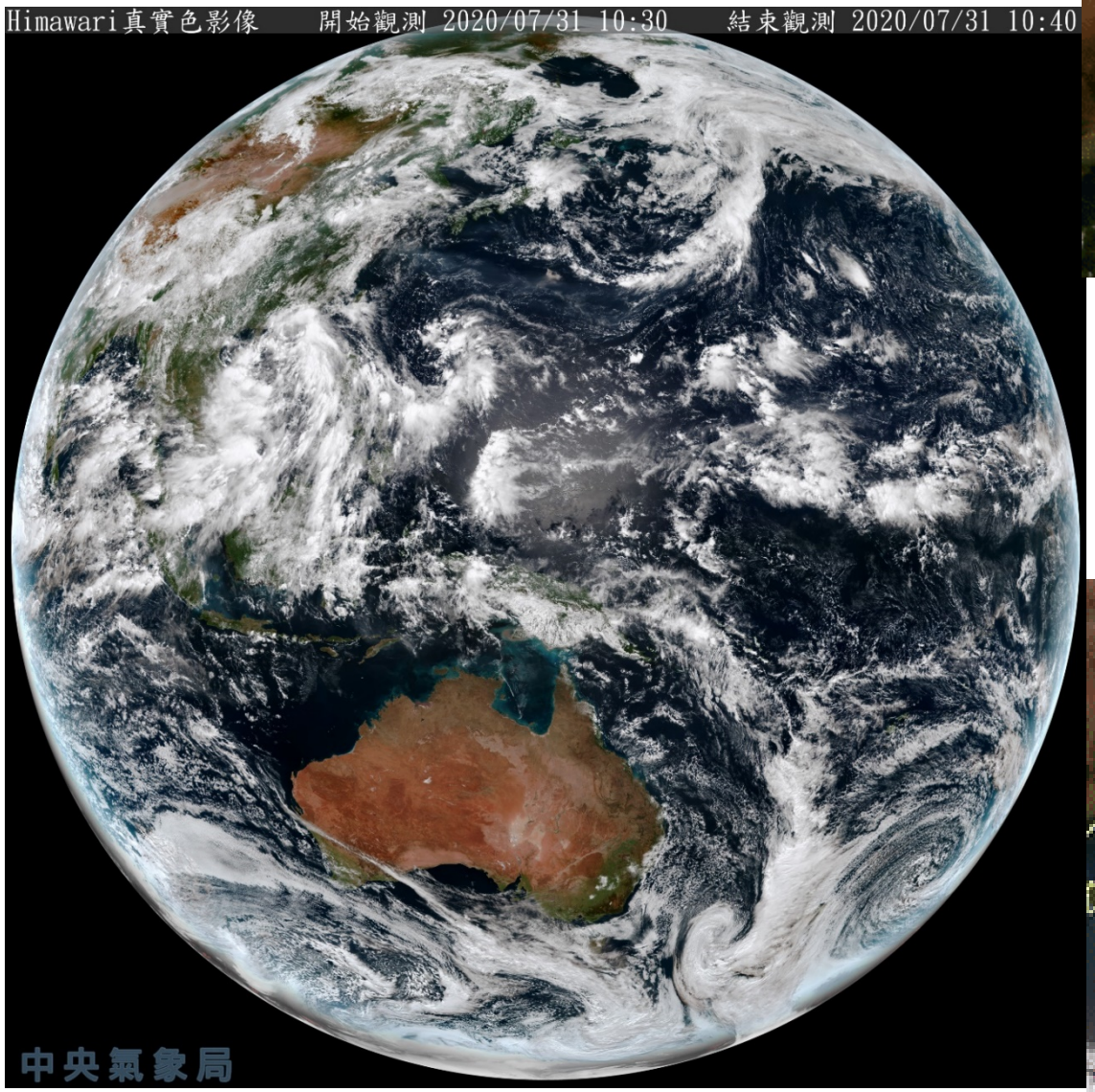
Reference: Stenven D. Miller et al. 2016

真實色彩影像空汙事件

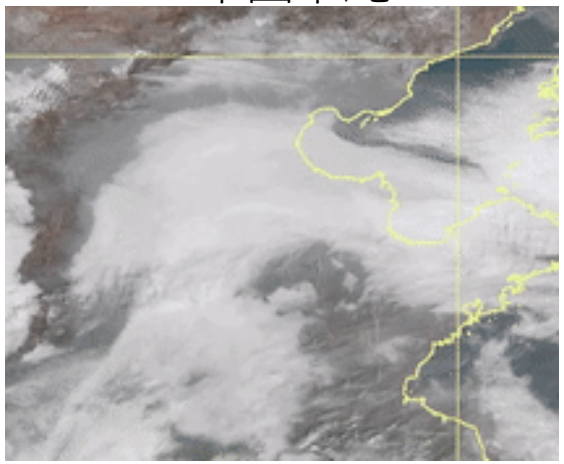
Dust Event 2020/05/12



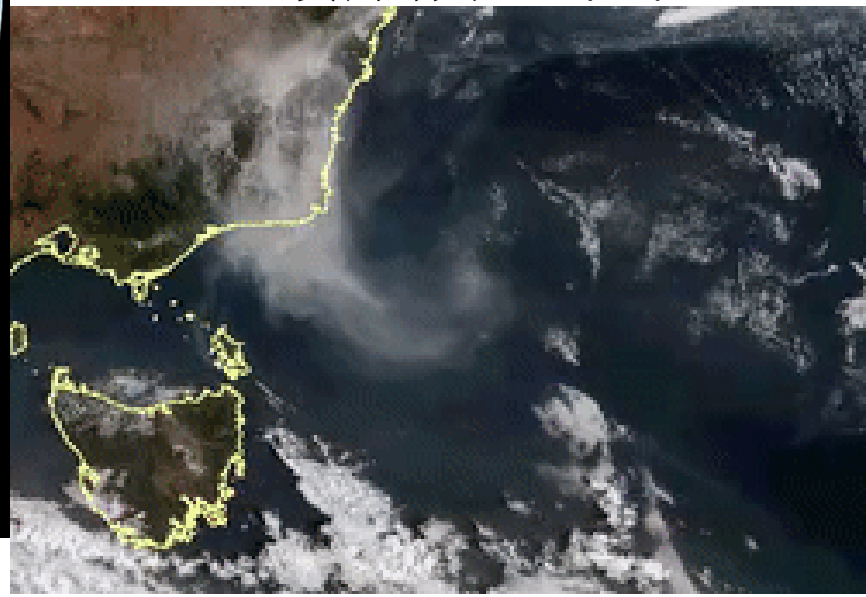
Ash Event 2020/07/30 西之島



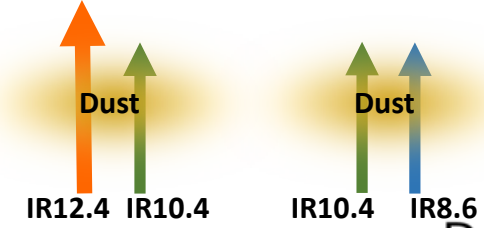
2020/02/07 Smoke or Haze
中國華北

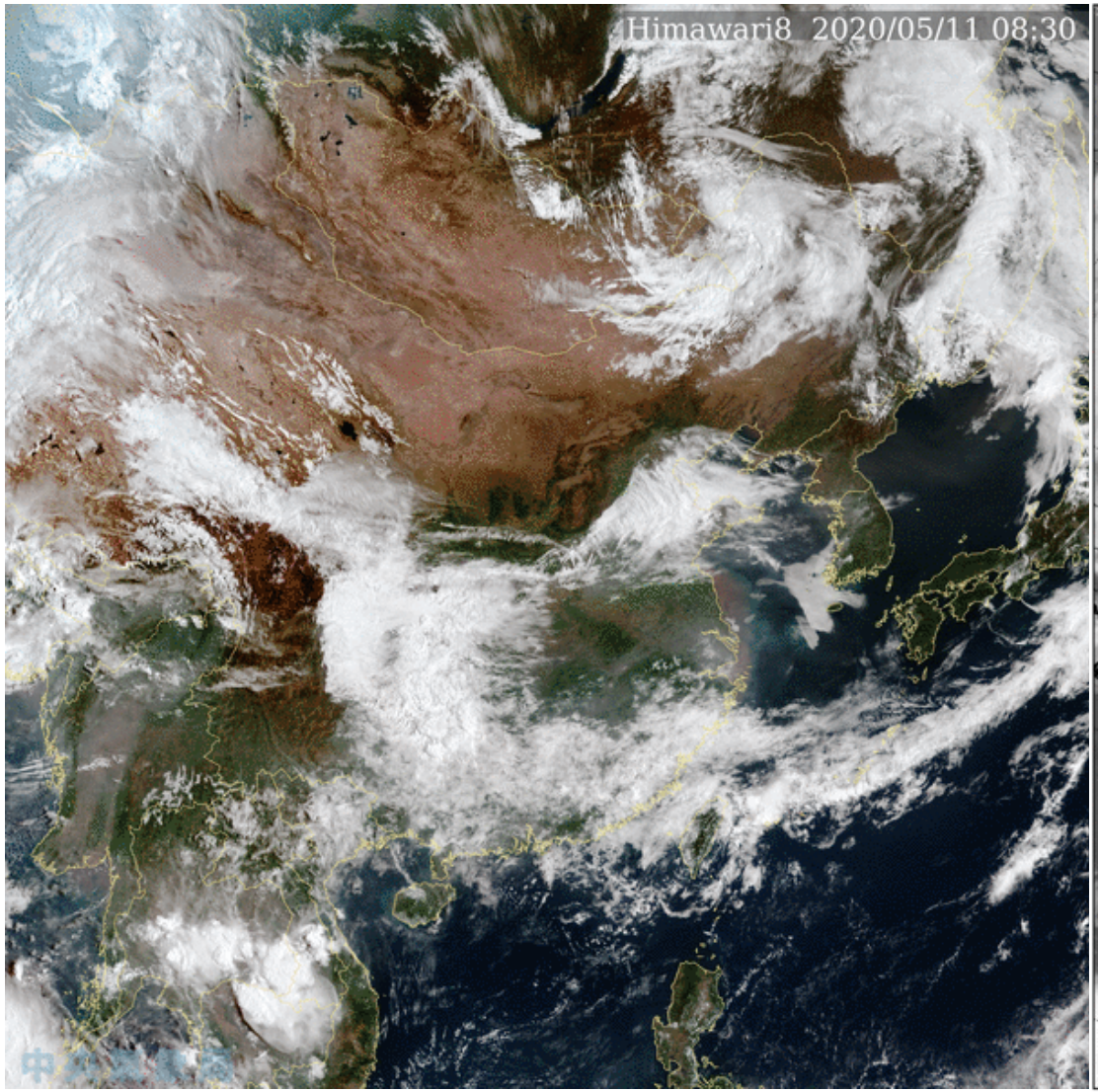


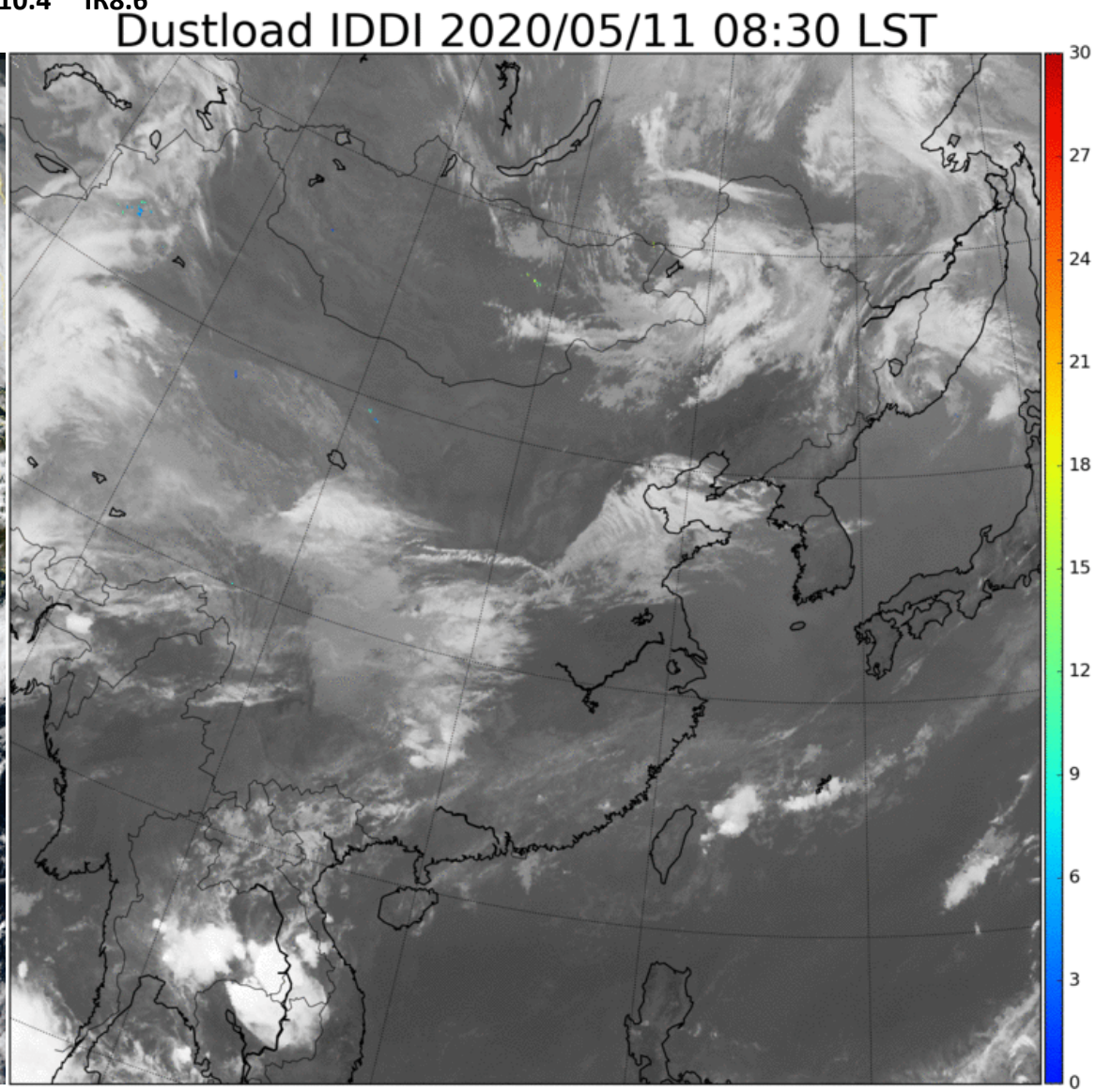
Smoke 澳洲野火 2020/01/30



日夜沙塵偵測



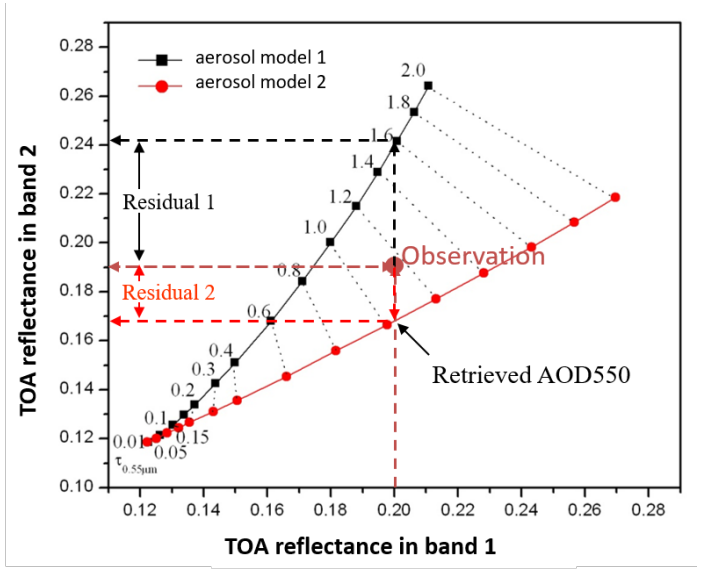




Reference: Hu et al., 2008 and DUST RGB Guide

氣膠光學厚度(NOAA-GOES-R演算法)

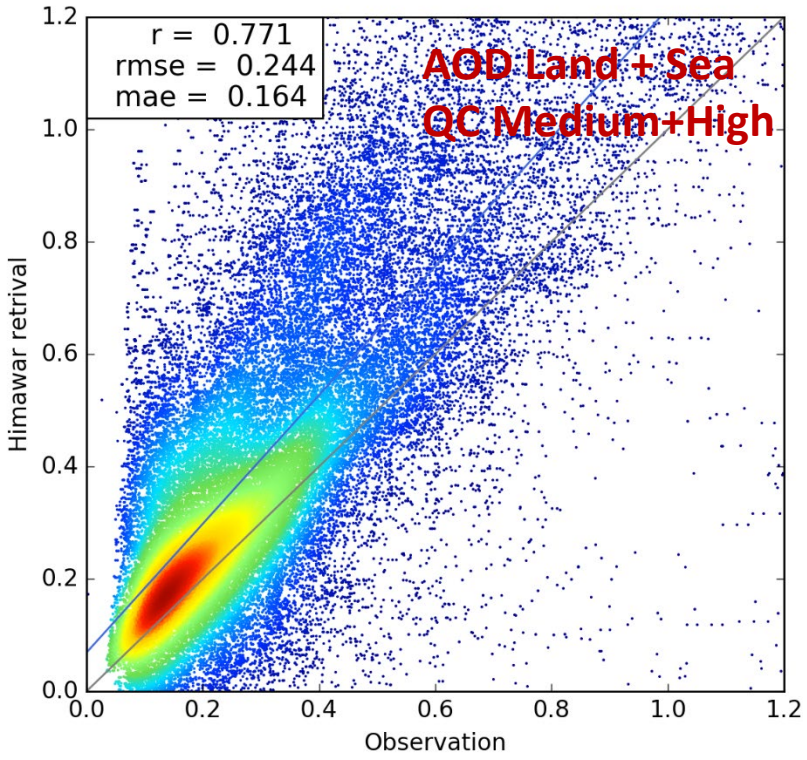
- 反演原理
  - $\rho_{toa} = \rho_{atm} + \rho_{surf}$ (ρ is reflectance, calculated from RTM)
  - Over Ocean
    - $\rho_{surf} = (1 - \rho_{wc})\rho_w - \rho_{wc}$ (ρ_{wc} from whitecap, ρ_w from water)
    - **Minimize** $\boldsymbol{residual = \sum_{i=1}^{n}\left(\rho_{\lambda}^{cal} - \rho_{\lambda}^{obs}\right)^2}$
    - $\rho_\lambda = \eta\rho_\lambda^f + (1-\eta)\rho_\lambda^c$ (different fine model ρ_λ^f, and coarse model ρ_λ^c)
    - if minimize $\tau_\lambda = \eta\tau_\lambda^f + (1-\eta)\tau_\lambda^c$ (τ_λ is aerosol optical depth at wavelength λ)
  - Over Land
    - $\rho_{surf} = (c_1 + c_2\theta_s) + (c_3 + c_4\theta_s)\rho_{2.25\mu m}$ (ρ_{surf} 0.47um and 0.64um using traditional dark-target (DT) relationships)
    - **Minimize** $\boldsymbol{residual = \left(\rho_{0.64\mu m}^{cal} - \rho_{0.64\mu m}^{obs}\right)^2}$
    - Searching $\tau_{550nm,i}$, when $\rho_{0.47\mu m,i} < \rho_{0.47\mu m}^{obs} < \rho_{0.47\mu m,i+1}$
    - If minimize $\tau_{550nm} = \tau_{550nm,i}\frac{\rho_{0.47\mu m,i+1} - \rho_{0.47\mu m}^{obs}}{\rho_{0.47\mu m,i+1} - \rho_{0.47\mu m,i}} + \tau_{550nm,i+1}\frac{\rho_{0.47\mu m}^{obs} - \rho_{0.47\mu m,i}}{\rho_{0.47\mu m,i+1} - \rho_{0.47\mu m,i}}$

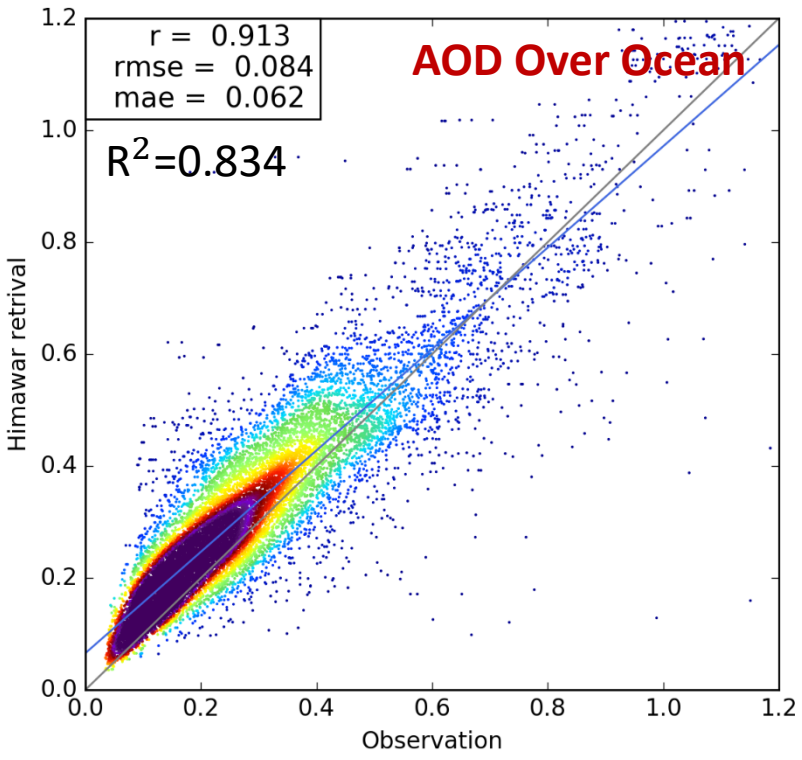


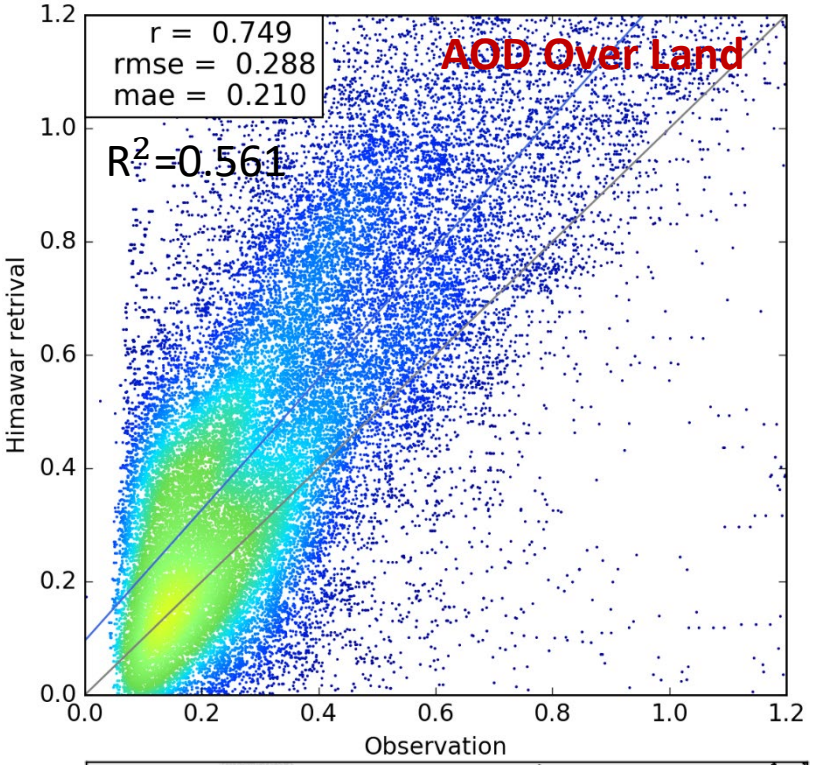
Search residual range next time.

If smallest residual.

Reference: GOES-R_Aerosol Optical Depth ATBD V4.2







衛星與AERONET Level 1.0觀測AOD比對

2020/01/01~2020/07/31, 00:00~08:00UTC

利用Angström exponent內插至550nm

衛星與地面站AOD配對方式

- 測站觀測 ±5分鐘
- 距離測站 8公里至少 5 pixel 平均值

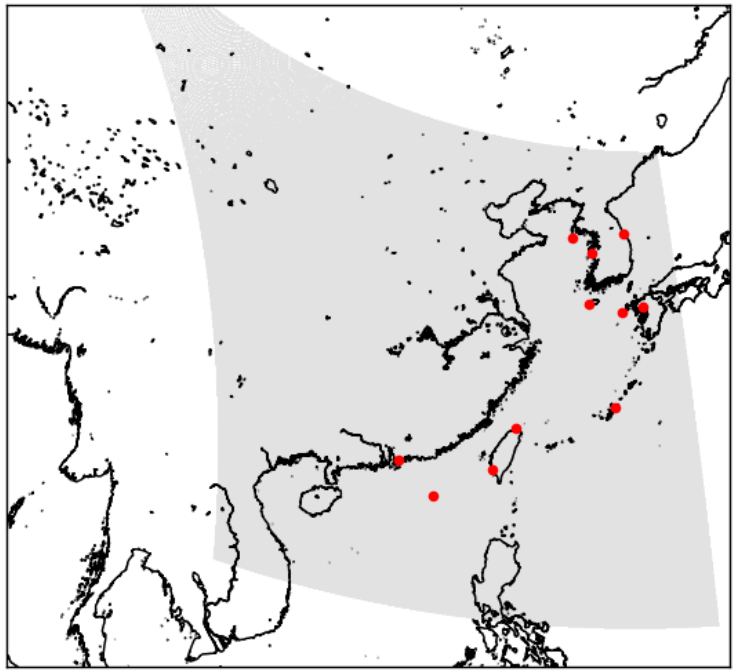
Over Land

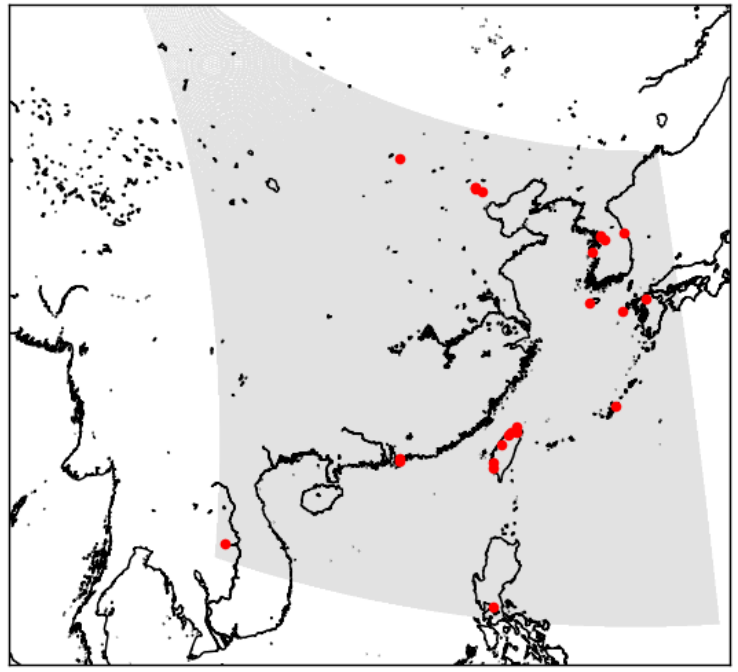
- 測站 8 公里為陸地且至少 5 pixel 平均

Over Ocean

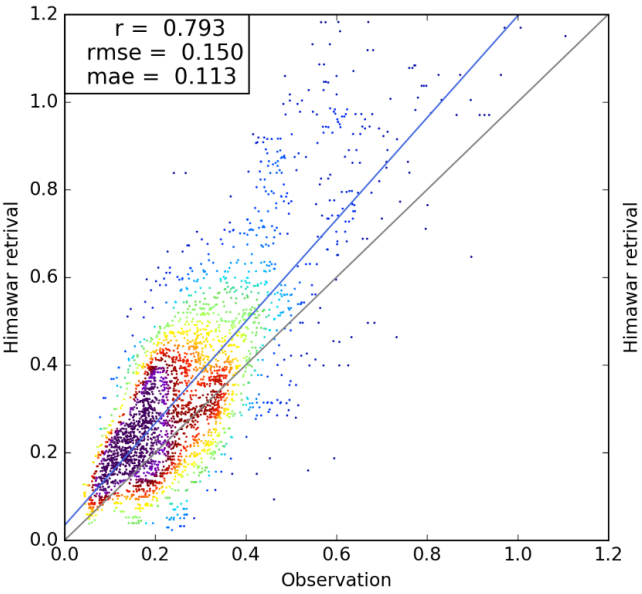
- 測站 8 公里涵蓋海且至少 5 pixel 平均

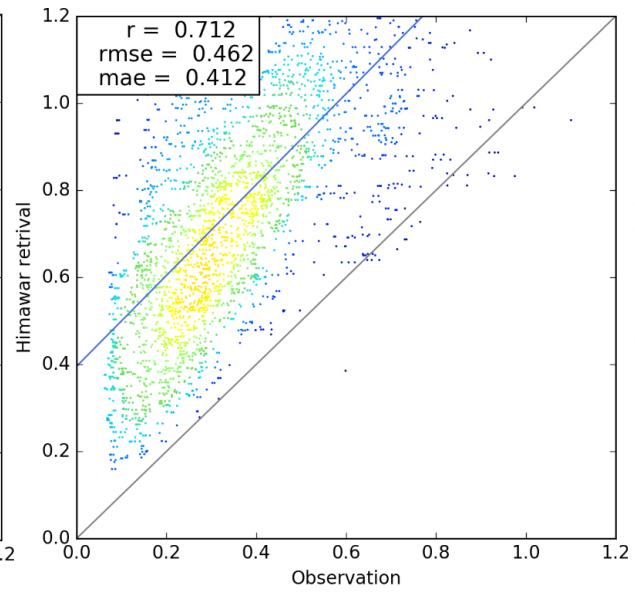
(Level 2.0有相同之結果，但測站較少。)

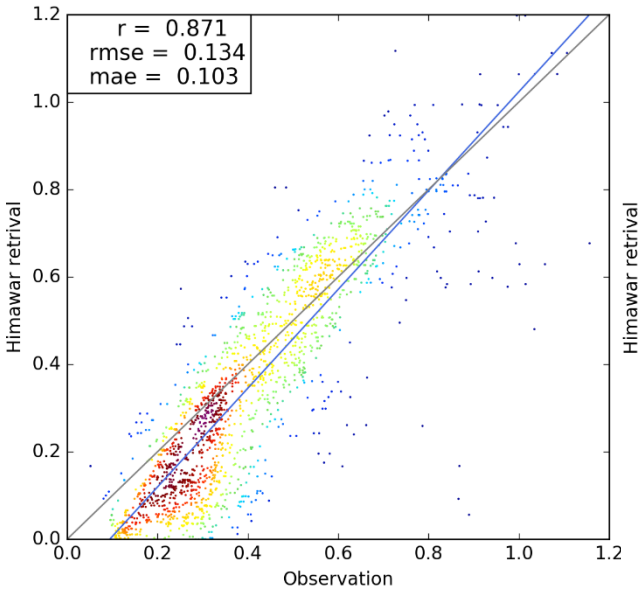


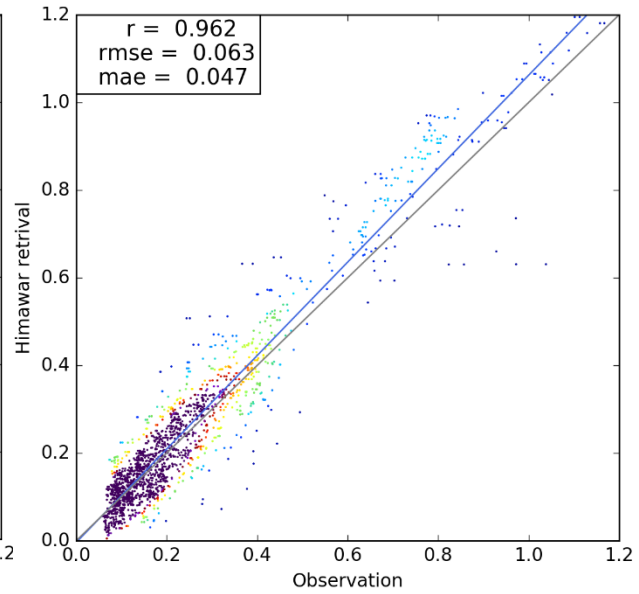


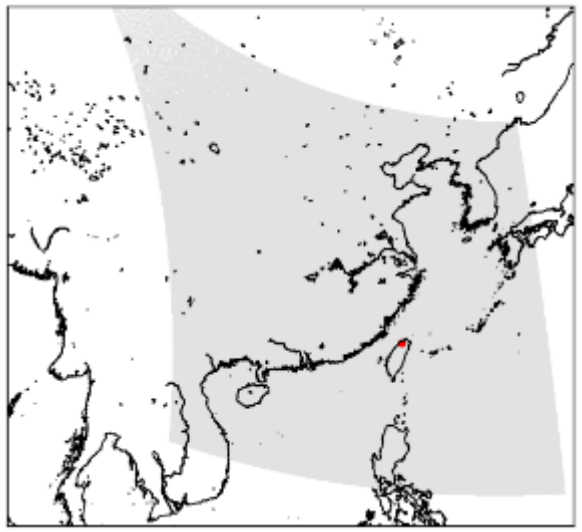
AOD over land at different site

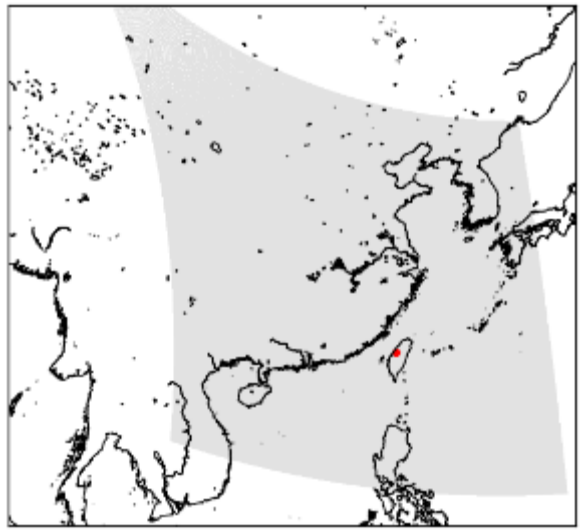


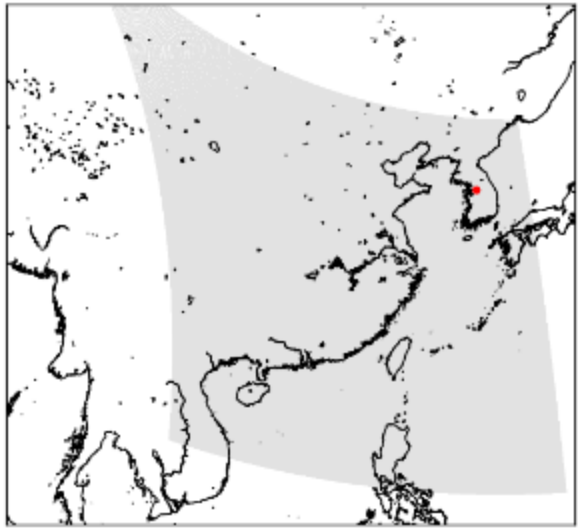


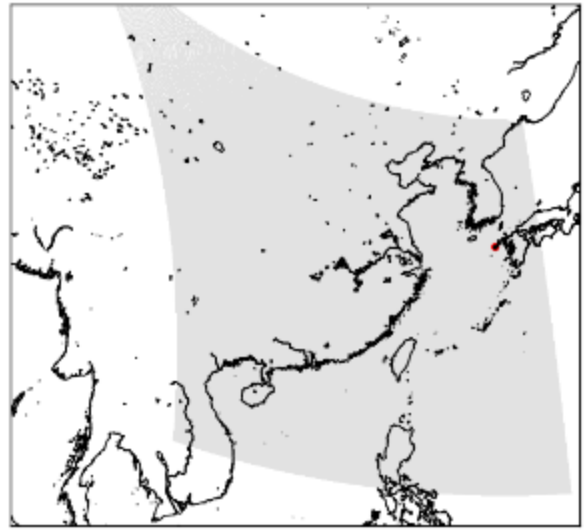






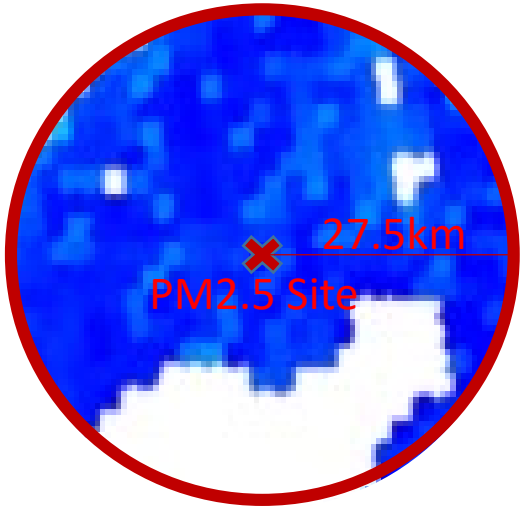






AOD to PM2.5

AOD 和 PM2.5 關係式會受到地面放射率、地形、汙染物傳輸、天氣等影響。
採用地面測站修正衛星AOD與PM2.5關係可以面化PM2.5並且可以達到一定準確度。
(Xie et al., 2015 and Lee et al., 2011)



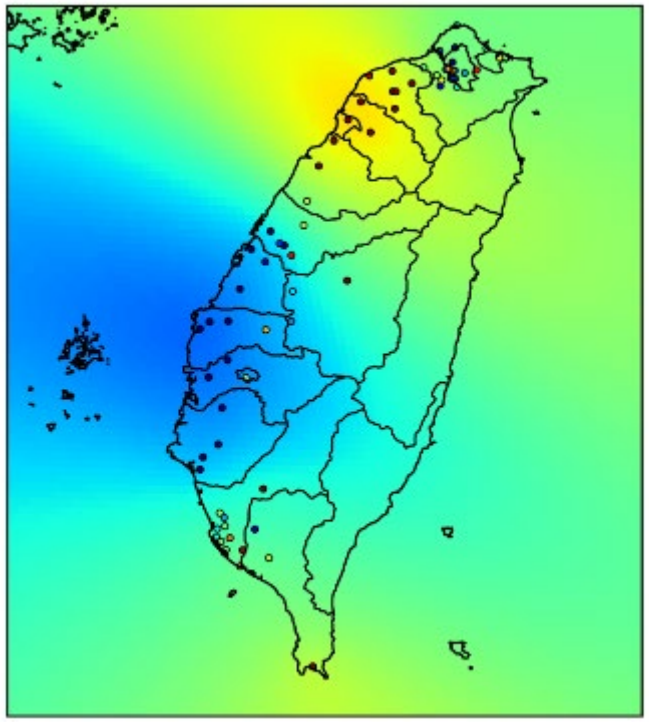
選取 27.5km 範圍最近一小時之衛星反演AOD與PM2.5觀測，求得slope和斜率。
原始AOD和PM2.5觀測擬和關係式公式為（base on pm2.5 = aod x 71.08 + 0.69），

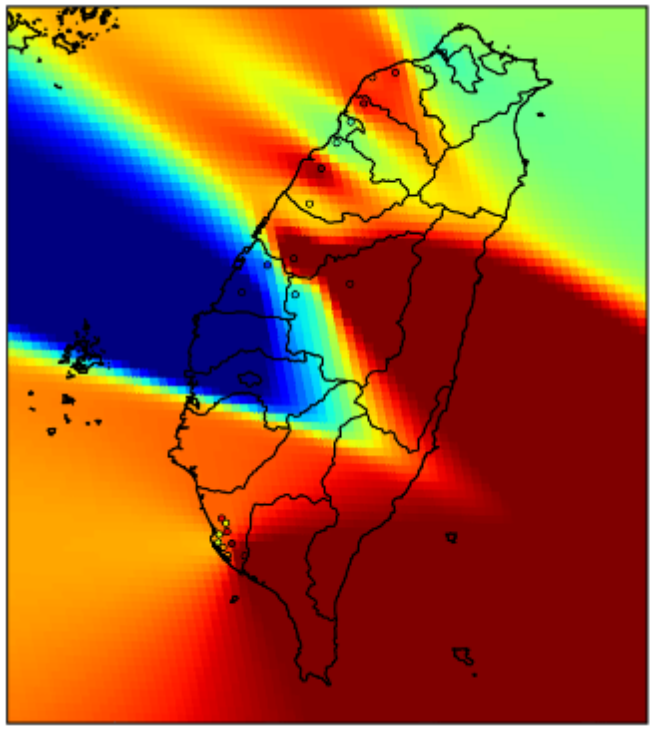
- AOD >0.1，固定offset=0.69，pm2.5 = aod x slope + offset
- AOD<=0.1，固定slope=71.08，pm2.5 = aod x slope + offset

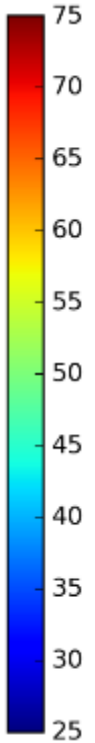
不規則網格內插
（圖為斜率）

Original

Weighting=
$e^{\frac{d}{50}}$







New

Weighting=
$e^{\frac{d}{5}}$

Original Code from Hai Zhang 2019

2020/01/01~2020/07/31, 00:00~08:00UTC
圖中衛星反演與地面站PM2.5配對方式

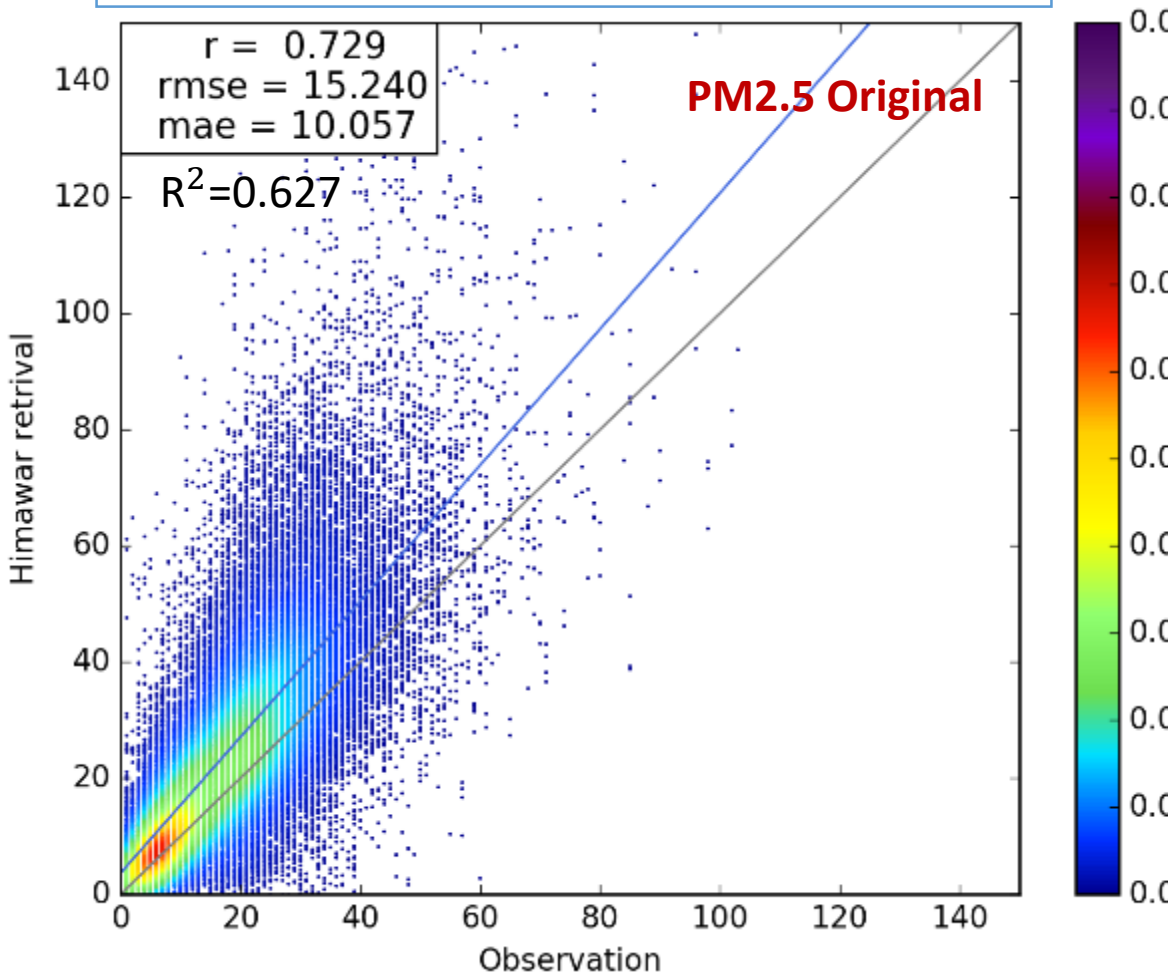
- 距離測站 8公里至少 5 pixel 平均值

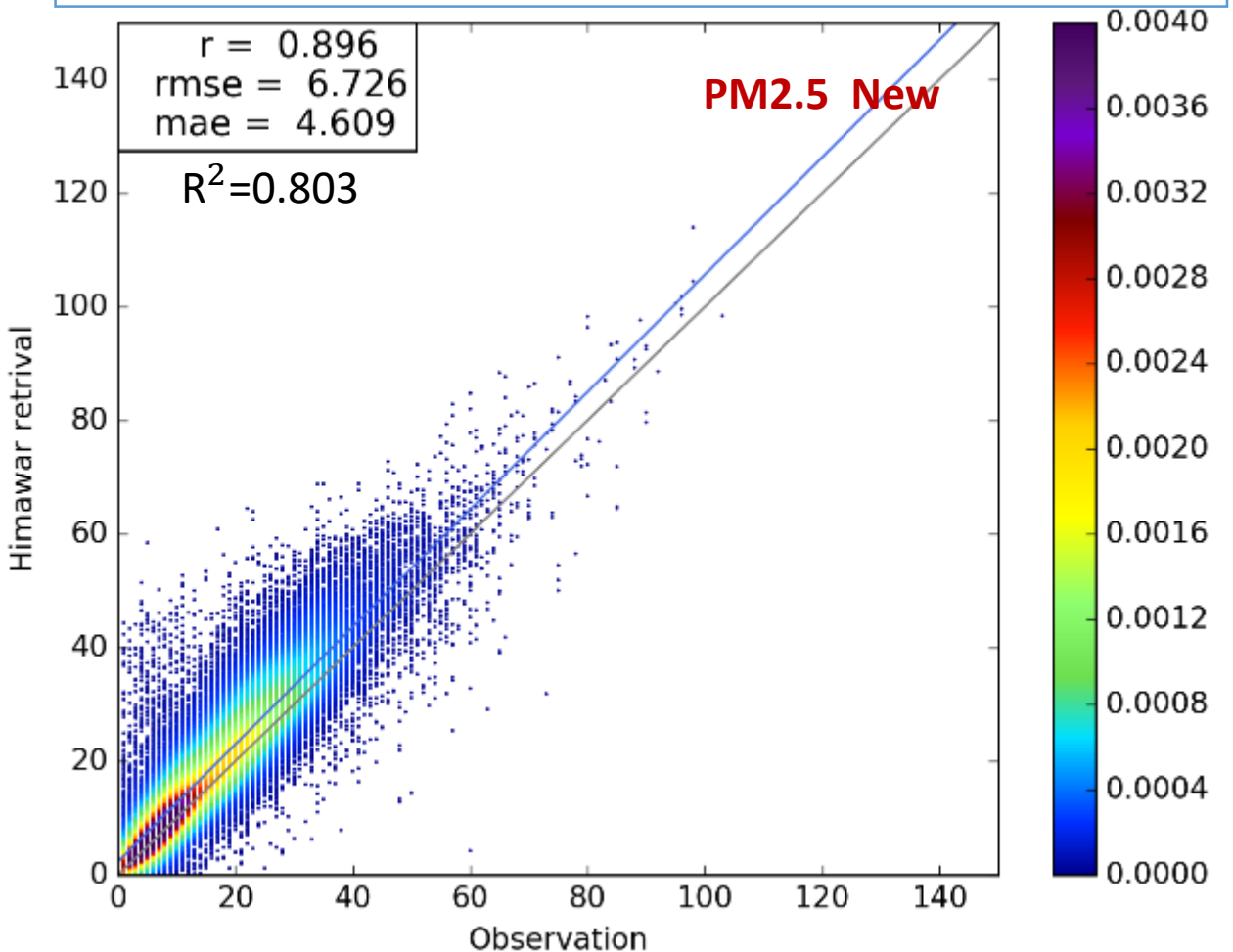
AOD Medium + High Quality

1. 一小時7筆，任1筆有值。
2. 不規則網格插到規則網格Weighting=$e^{\frac{d}{50}}$

QC 方式調整（不使用原始 AOD Quality Control）：

1. 一小時7筆，至少3筆有值之平均。
2. 地面測站距離27.5內至少20% pixel有值。
3. 如果slope>100，改採固定slope=71.08
4. 不規則網格插到規則網格Weighting=$e^{\frac{d}{5}}$
5. 5x5 至少 5 pixel 有值，且standard deviation>0.3
6. 5x5 至少 5 pixel 有值，且AOD-(5x5AOD_mean)>0.075

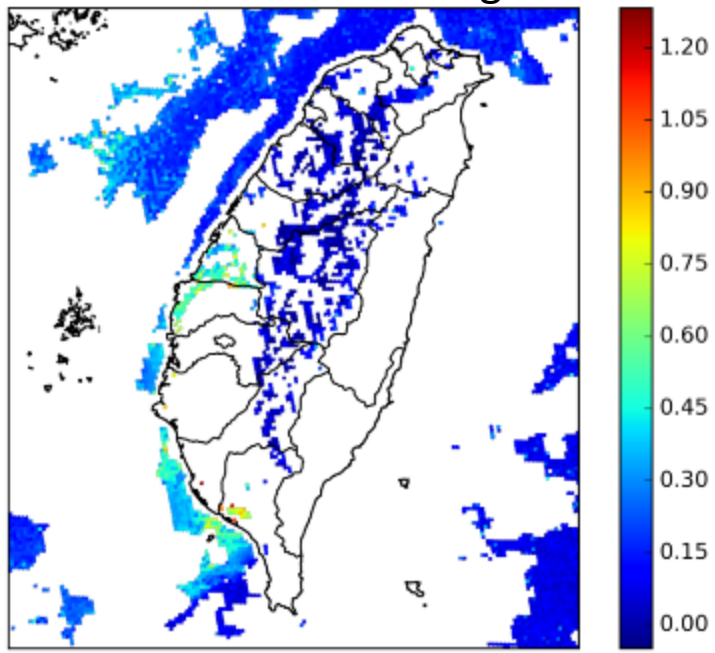




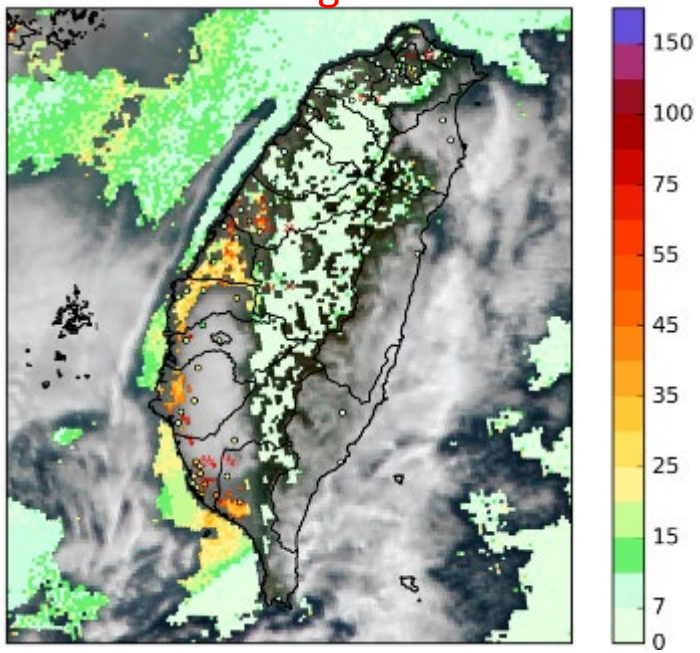
AOD to PM2.5

2020/01/02 01:00 UTC

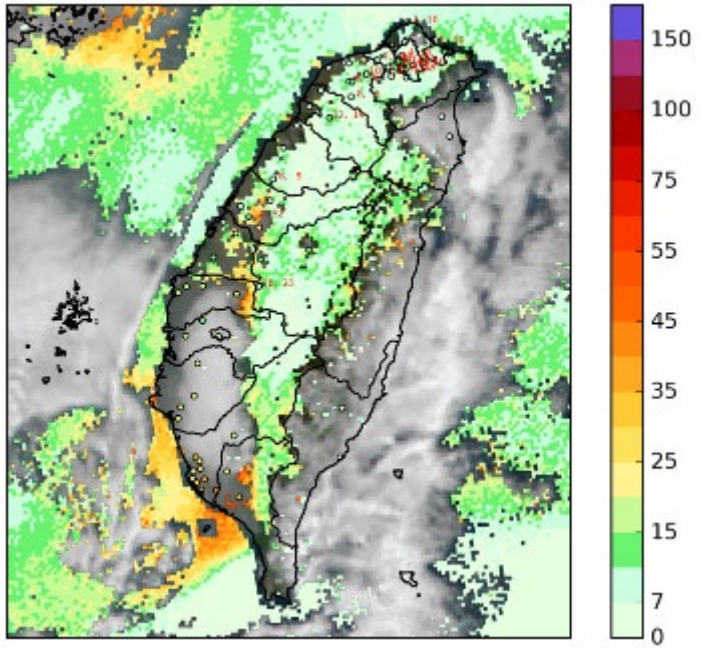
AOD QC Medium+High



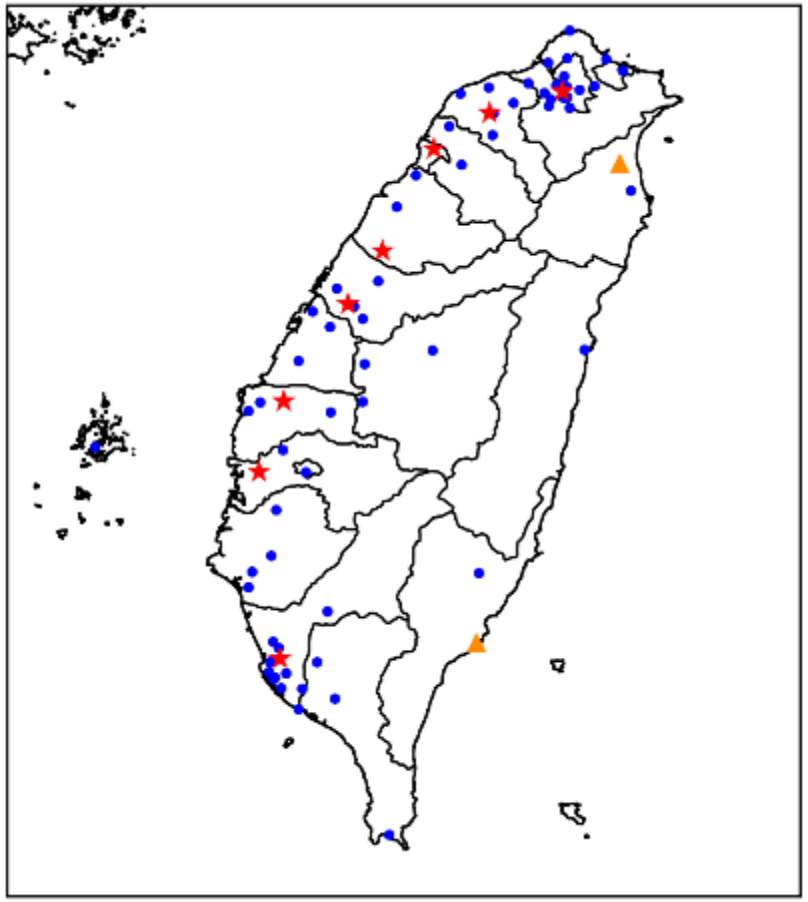
PM2.5 Original

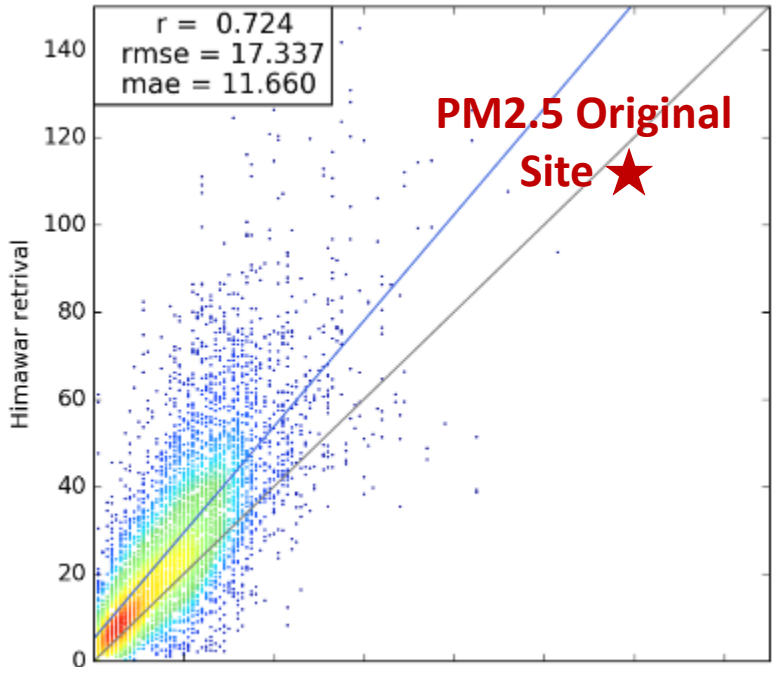


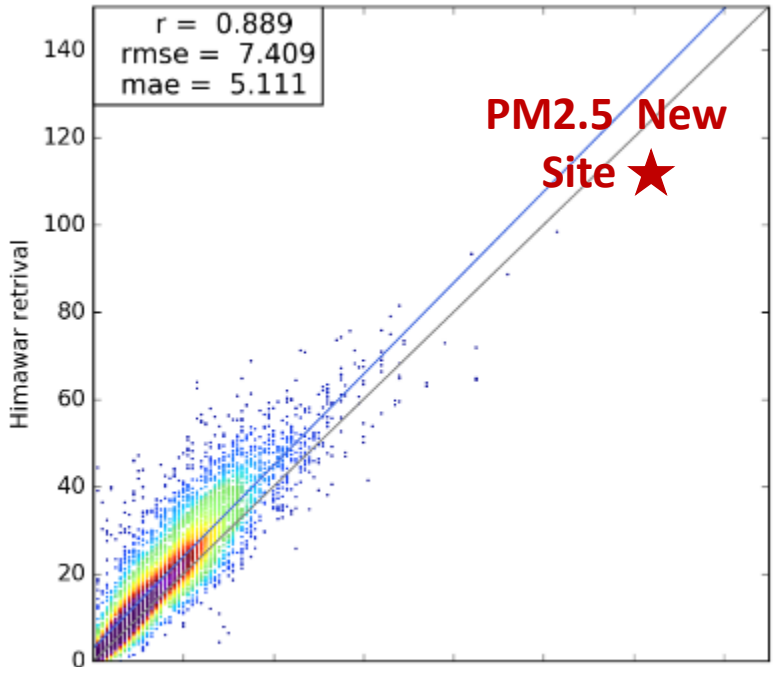
PM2.5 New

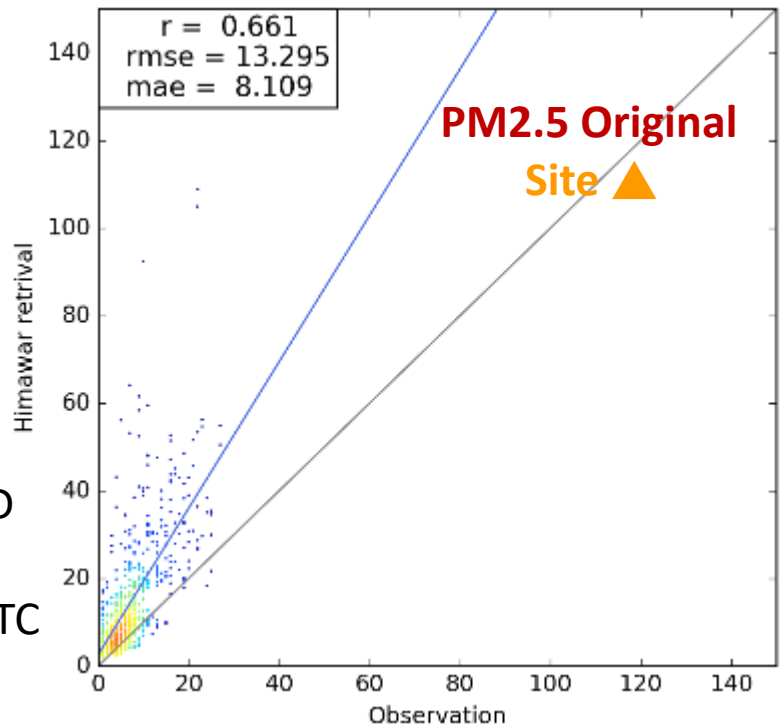


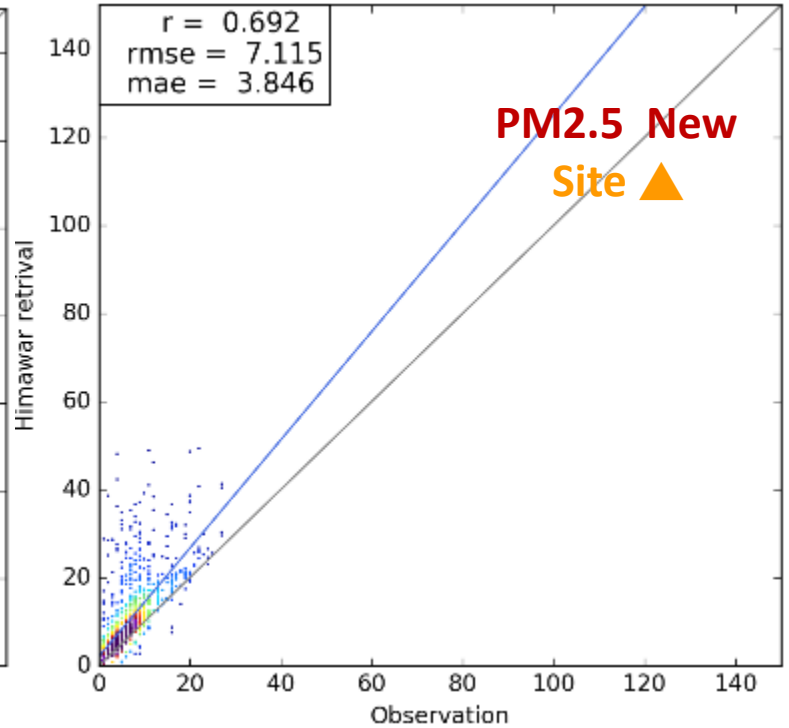
AOD to PM2.5











刪除圖上標記的站，並且重新計算AOD to PM2.5，再將結果與該站相比

2020/01/01~2020/07/31, 00:00~08:00UTC

- 距離測站 8公里至少 5 pixel 平均值

目前作業狀況總結

- 真實色彩影像運算效能優化，運算時間僅約需6min（傳輸延遲19min+運算6min)
- 真實色影像可用於沙塵、霾、煙、火山灰等汙染物辨識，但須人員主動判視。
- 日夜沙塵偵測可以即時自動辨識沙塵暴起源。
- 氣膠光學厚度經過優化後，東亞地區運算時間僅約需6min（傳輸延遲19min+CLAVRX 5min+AOD 1min）
- 目前氣膠光學厚度於海上有較佳的反演能力 R^2=0.834，陸地則為R^2=0.561。
- 未來新版氣膠光學厚度將利用Machine Learning方式改善陸地的地表反射率估算，將可有效提升陸地氣膠光學厚度準確度，目前正在測試中。
- 利用氣膠光學厚度轉換為PM2.5，在經過調整篩點及不規則網格內插到規則網格方式後，可有效改善反演結果R^2=0.803。
- 取部分站點做為校驗AOD to PM2.5結果，在PM2.5分布較密地區，氣膠光學厚度轉換為PM2.5 較為準確R^2=0.79。

Refrence:

Miller, S. D., T. L. Schmit, C. J. Seaman, D. T. Lindsey, M. M. Gunshor, R. A. Kohrs, Y. Sumida, and D. Hillger, 2016: A Sight for Sore Eyes: The Return of True Color to Geostationary Satellites. *Bull. Amer. Meteor. Soc.*, **97**, 1803–1816, https://doi.org/10.1175/BAMS-D-15-00154.1

Dust RGB Quick Guide https://weather.msfc.nasa.gov/sport/training/quickGuides/rgb/QuickGuide_DustRGB_MSG_NASA_SPoRT.pdf

Hu, X. Q., Lu, N. M., Niu, T., and Zhang, P., 2008: Operational retrieval of Asian sand and dust storm from FY-2C geostationary meteorological satellite and its application to real time forecast in Asia, *Atmos. Chem. Phys*., 8, 1649–1659, https://doi.org/10.5194/acp-8-1649-2008

GOES-R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document For Suspended Matter/Aerosol Optical Depth and Aerosol Size Parameter. https://www.star.nesdis.noaa.gov/goesr/documents/ATBDs/Baseline/ATBD_GOES-R_Aerosol_Optical_Depth_v4.2_Feb2018.pdf

Lee, H. J., Liu, Y., Coull, B. A., Schwartz, J., and Koutrakis, P. , 2011: A novel calibration approach of MODIS AOD data to predict $PM_{2.5}$ concentrations, *Atmos. Chem. Phys.,* **11**, 7991–8002, https://doi.org/10.5194/acp-11-7991-2011

Yuanyu Xie, Yuxuan Wang, Kai Zhang‖, Wenhao Dong, Baolei Lv, and Yuqi Bai. Daily Estimation of Ground-Level PM2.5 Concentrations over Beijing Using 3 km Resolution MODIS AOD. *Environ. Sci. Technol*. **2015**, 49, 20, 12280–12288. DOI: https://doi.org/10.1021/acs.est.5b01413