# Sunset/Sunrise

# Phenomena

Greg Edwards 3 February 2017

### Overview

- An overview of the hundred of so different phenomena that can be seen around dawn and sunset.
- Photos of dozens of these phenomena
- References to apps, websites, books and tools to improve your understanding and ability to make photos of these phenomena
- Not everyone agrees on the naming of the different phenomena, nor the causes of them.

**DO NOT** look directly at the sun or photograph it unless you know what you are doing. You can ruin your eyes and/or camera!

#### **Introduction** Data and Timeline

- Differences between Sunset and Sunrise
- Clouds
- Pre-sunset Phenomena 2 hours before until 1 hour after
- Sunset Phenomena 15m before until 30m after
- Civil Twilight Phenomena 0-6 degrees down
- Nautical Twilight Phenomena 6-12 degrees down
- Astronomical Twilight Phenomena 12+ degrees down
- Tools, references

#### Differences Between Sunset and Sunrise

- Colors Sunsets generally more colorful due to more dust from afternoon winds
- Wind the wind is generally calmer at dawn
  - Lakes, ocean more mirror-like
  - Easier to take long exposures of flowers, trees
  - Less dust in air = less color in sky/clouds
- Red Skies at Morning Sailors Take Warning
  - Red clouds towards the sun at dawn not a rain/storm forecast
  - Bright red dense altocumulus and stratocumulus clouds all over the sky – rain/storm somewhat likely
  - Big red clouds at anti-dawn side of the sky rain/storm more likely
  - Over all the clouds at sunrise are not very good for weather forecasting.

#### **Clouds of Interest for Sun Rise/Sets**

- Cirrus very high, wispy halo crystals
- Cirrostratus Cs, more solid than Cirrus, very high
  halo crystals
- Altostratus As, long flat bottom, medium high
- Altocumulus Ac puffballs, medium high
- Stratocumulus Sc flat-fluffy, low to medium
- Cumulus Cu fluffy, low
- Nimbostratus Ns, ground to high, rain
- Cumulonimbus Cb, low to very high, rain
- Stratus Cu, low, wispy

#### **Pre-sunset Phenomena** 0-2 hours before

- Rainbows
- Golden Hour
- Pareidolia
- Halos
- Sundogs
- Sun Pillars
- Glories
- Cloud iridescence
- Virga

#### Rainbows

- Rainbows are caused by a combination of reflection, refraction and dispersion of light in water droplets
- Colors run from 5 to 100 depending on skill of observer
- Full circular diameter of a rainbow is 84 degrees
  - To photographed whole circle with a 35mm camera a 19mm (or wider) lens is needed
  - A glory looks similar but is 5-20 degrees wide

Variations:

- Alexander's band, the dark region between the two bows of a double rainbow.
- Double Rainbow (2<sup>nd</sup> order rainbow), also 3<sup>rd</sup> (2011), 4<sup>th</sup> and 5<sup>th</sup> (2014)
- Fogbow, sometimes with a glory at the center
- Monocrhrome rainbow or red rainbow (only red light from sunset)
- Moonbow or Whitebow (light is so little eye doesn't see color)
- Reflected rainbows (appears on the surface of water)
- Reflection rainbow (caused by the sun reflecting off surface of water)
- Rose of Rainbows (lab only so far)
- Supernumerary rainbows
- Twinned rainbow (two different water droplet clouds at different distances)

Circumhorizontal and circumzenithal arcs are similar to rainbows but are caused by ice crystals instead of water

## Rainbow

# Double Rainbow & Alexander's Band

#### **Surf Rainbows**

#### **More Rainbows**

- Many more kinds of rainbows
- What different ones have you seen?
- What is the rainbow you most want to see?
- My most desired rainbow is the "Red Bow" of sunset

#### **Golden Hour**

- The period when much of the illumination comes from indirect lighting from the sky
- Typically when the sun is about 12 degrees or less from setting (maybe an hour)
- The light is warmer, the indirect light reduces the shadows and makes faces, scenes less harsh.

#### **Typical Color Temperatures**

- Midday 5500K
- Golden hour 3500K
- Sunset 2000K

### Golden Hour and Effects on Skin



#### Pareidolia

A psychological phenomenon where the mind sees a familiar

pattern when none exists.

A bat



### Halos (partial list)

Many kinds of Halos, some very rare, some probably still undiscovered

- 22 Degree halo ice bending light 22 degrees, most common
- 46 Degree halo ice bending light 46 degrees, best in cold weather for more ice crystals
- 120 degree parhelion
- Anthelion
- Circumscribed halo
- Heiligenschein
- Kern arc •
- Liljequist parhelion •
- Parhelic circle
- Rainbow (see rainbows on other pages as well) •
- Subhelic arc
- Subsun •

#### Circumhorizontal arc

Circumzenithal arc

Infralateral arc

#### Light Pillar

Lower tangent arc

Parry arc

- - Subparhelic circle
  - Supralateral arc
- *Sun dog*, aka mock sun, or parhelion. Caused by refracting off plate ۲ shapped ice crystals, part of 22 degree halos
- Tricker arc Upper tangent arc

#### **Halo Physics**

- A halo (also known as a nimbus, icebow or gloriole) is
- Light interacting with ice crystals in the atmosphere
- Results in many types colored and white rings, arcs and spots in the sky
- Many halos are near the Sun or Moon
  - others occur elsewhere or even in the opposite part of the sky
- Among the most well known halo types are the
  - Circular halo (properly called the 22° halo)
  - Light pillars
  - Sun dogs
  - Many more types; some of them fairly common, others (extremely) rare

#### Ice Crystals for Halos

- Ice crystals responsible for halos are typically suspended in cirrus or cirrostratus clouds high (5–10 km, or 3–6 miles) in the upper troposphere
- In cold weather they can also float near the ground, in which case they are referred to as diamond dust
- The particular shape and orientation of the crystals is responsible for the type of halo observed
- Light is reflected and refracted by the ice crystals and may split up into colors because of dispersion
- The crystals behave like prisms and mirrors, refracting and reflecting light between their faces, sending shafts of light in particular directions

Note: Other common optical phenomena from water drops include rainbows and glories

#### Sundogs with 22 Degree Halo

States and the states

#### Sundogs

Sun dogs (or sundogs), mock suns or phantom suns, scientific name parhelia (singular parhelion)

- An atmospheric phenomenon that consists of a pair of bright spots on either horizontal side on the Sun
- Often co-occurring with a luminous ring known as a 22° halo
- Member of a large family of halos, created by light interacting with ice crystals in the atmosphere
- Sun dogs typically appear as two subtly colored patches of light to the left and right of the Sun, approximately 22° distant and at the same elevation above the horizon as the Sun
- They can be seen anywhere in the world during any season, but they are not always obvious or bright.
- Sun dogs are best seen and are most conspicuous when the Sun is close to the horizon

### **Sundog Physics**

- Caused by the refraction of light from plate-shaped hexagonal ice crystals
- Either in high and cold cirrus or cirrostratus clouds or, during very cold weather, drifting in the air at low levels, in which case they are called diamond dust
- The crystals act as prisms, bending the light rays passing through them with a minimum deflection of 22°
- As the crystals gently float downwards with their large hexagonal faces almost horizontal, sunlight is refracted horizontally, and sun dogs are seen to the left and right of the Sun
- Larger plates wobble more, and thus produce taller sundogs
- Red-colored towards the Sun; farther out the grade through oranges to blue
- Colors can overlap considerably and so are muted, never pure or saturated
- The colors of the sun dog finally merge into the white of the parhelic circle (if the latter is visible)

#### Sundog



#### **Circumhorizontal Arc**

Also called circumhorizon arc or lower symmetric 46° plate arc

- An ice-halo formed by the refraction of sun- or moonlight in plateshaped ice crystals suspended in the atmosphere, typically in cirrus or cirrostratus clouds
- In full form, the arc has the appearance of a large, brightly spectrum-colored band running parallel to the horizon, located below the Sun or Moon
- The distance below the Sun or Moon is twice as far as the 22° halo
- Red is the uppermost color
- Often, when the halo-forming cloud is small or patchy, only fragments of the arc are seen (hence *fire rainbow*)
- As with all halos, can be Sun or Moon based
- Often not noticed as people seldom look up

#### **Sun Pillar**

#### **Sun Pillar Physics**

- A light pillar, or sun pillar, appears as a vertical pillar or column of light rising from the sun near sunset or sunrise, though it can appear below the sun, particularly if the observer is at a high elevation or altitude
- Hexagonal plate- and column-shaped ice crystals cause the phenomenon
  - Plate crystals generally cause pillars only when the sun is within 6 degrees of the horizon, or below it
  - Column crystals can cause a pillar when the sun is as high as 20 degrees above the horizon
  - The crystals tend to orient themselves near-horizontally as they fall or float through the air, and the width and visibility of a sun pillar depends on crystal alignment
- Can also form using the moon, street lights or other bright lights
- Pillars forming from ground-based light sources may appear much taller than those associated with the sun or moon



### Glory

- An optical phenomenon that resembles an iconic saint's halo about the shadow of the observer's head
- Caused by light of the Sun or Moon interacting with the tiny water droplets of mist or clouds, about 5° to 20°
- The glory consists of one or more concentric, successively dimmer rings, each of which is red on the outside and bluish towards the center
- Due to its appearance, glories are sometimes mistaken for a circular rainbow, but rainbows are much larger and have a different cause
- Brocken Spectre, also called Mountain Spectre, is a glory in which the apparently magnified shadow of an observer is cast on clouds below

#### **Cloud Iridescence**

- The colors are usually pastel, but can be very vivid
- Iridescence is more commonly found in clouds near the sun or moon
  - The sun's glare can mask it
  - more easily seen by hiding the sun behind a tree or building
- Dark glasses, or reflections in a pool of water can aid in observing
- A diffraction phenomenon caused by small water or ice droplets scattering light
  - Larger ice crystals produce halos
- The cloud must be optically thin, so that most rays encounter only a single droplet
  - Mush have small water or ice droplets of similar sizes
- Mostly seen at cloud edges or semi-transparent clouds
- Newly forming clouds produce the brightest and most colorful iridescence



#### Virga or Failed Rain

- Precipitation falls from cloud but sublimates before reaching the ground
- Water or Ice typical on Earth
- Sulfuric Acid on Venus
- Snow on Mars
- Thought to happen on Jupiter, Saturn, Titan, etc



#### **Crepuscular rays**

- Backstays of the sun—a nautical term
- Buddha rays
- Cloud breaks
- Jacob's Ladder
- Ropes of Maui—originally. *taura a Maui*—from the Maori tale of Maui Potiki restraining the sun with ropes to make the days longer
- Shafts of light
- Sun drawing water—from the ancient Greek belief that sunbeams drew water into the sky Sunbeams
- Sunburst
- Volumetric lighting (used by the computer graphics industry)
- God rays (used by the computer graphics industry)
- Fingers of God
- Jesus Rays
- Devil's Rays (refers to anticrepuscular rays only)
- Tyndall rays

#### **Backstays of the Sun**

#### **Sunburst or Starburst**

- An "in-camera" or "in-eye" phenomena
- Consists of rays or "beams" radiating out from a bright central point
- A commonly used design in architectural ornaments, flags, and design patterns

#### Sunburst: Hickman Bridge at Dawn

#### **Cloud Colors Pre-Sunset**

- Bluish-grey is the result of light scattering within the cloud
- The short light rays are more easily scattered by water droplets, and the long rays are more likely to be absorbed
- The bluish color is evidence that such scattering is being produced by rain-sized droplets in the cloud
- A greenish tinge to a cloud is produced when sunlight is scattered by ice
- A cumulonimbus cloud emitting green is a sign that it is a severe thunderstorm, capable of heavy rain, hail, strong winds and possible tornadoes
- Yellowish clouds may occur in the late spring through early fall months during forest fire season
  - The yellow color is due to the presence of pollutants in the smoke
  - Yellowish clouds caused by the presence of nitrogen dioxide are sometimes seen in urban areas with high air pollution levels

#### Sunset Phenomena

#### 15m before until 30m after

- Yellower clouds before sunset
- Red-Green rim
- Blue/Green light absorption
- Red Rainbows or Redbows
- Pastel colors similar to some Maxfield Parrish pictures
- Sun rays
- >> Sunset <<
- Redder clouds after sunset
- Pastel colors similar to some Maxfield Parrish pictures
- Pink Time (not an official name)
- Red Time (not an official name)
- False Sunset/Sunrise
- Novaya Zemlya effect
- Atmospheric refraction
- Mirages
- Green flashes
- Blue and Violet flashes
- Crepuscular rays
- Blue Hour


# **Rayleigh v Mie Scattering**

- Air molecules and airborne particles scatter white sunlight as it passes through the Earth's atmosphere. This is done by a combination of Rayleigh scattering and Mie scattering.
- Rayleigh scattering changes the color of light
- Mie scattering changes the direction without changing the colors

# **Rayleigh Scattering**

- Removal of the shorter wavelengths of light is due to Rayleigh scattering by air molecules and particles much smaller than the wavelength of visible light (<50 nm in diameter
- Because the shorter wavelength components, such as blue and green, scatter more strongly, these colors are more removed from the beam
- At sunrise and sunset, when the path through the atmosphere is much longer, the blue and green components are removed almost completely leaving the longer orange and red hues we see at those times
- The remaining reddened sunlight can then be scattered by cloud droplets and other relatively large particles to light up the horizon red and orange

# Pescadero Beach 22m after sunset 2016-02-10

### **Mie Scattering**

 Scattering by cloud droplets and other particles with diameters comparable to or larger than the sunlight's wavelengths (> 600 nm) is due to Mie scattering

not strongly wavelength-dependent

- Mie scattering is responsible for the light scattered by clouds, and also for the daytime halo of white light around the Sun (forward scattering of white light)
- Without Mie scattering at sunset and sunrise, the sky along the horizon has only a dull-reddish appearance, while the rest of the sky remains mostly blue and sometimes green

### Mie Scattering Near the Sun and 22° Halo

# **Volcanoes and Sunset/Rise**

- Ash in *troposphere* tends (~7 to 17km) to mute colors
- Volcanic ejecta in *stratosphere* (~10-50km above surface) (typically small sulfuric acid droplets) tend to create vivid afterglows
  - Some eruptions, including those of Mount Pinatubo in 1991 and Krakatoa in 1883, have ejected enough high stratospheric sulfuric acid clouds to generate strong sunset afterglows (and pre-sunrise glows) world-wide
  - High altitude clouds bounce sunlight from the already set sun back down to the distant post-sunset surface

### **Optical Illusions**

- Atmospheric refraction allows the Sun to be seen while it is below the horizon
  - Light from the lower edge of the Sun's disk is refracted more than light from the upper edge
  - Therefore the Sun appears wider that high when it is just above the horizon
  - Similar to the moon illusion
- The Sun appears to rise above the horizon and circle the Earth, but it is actually the Earth that is rotating, with the Sun remaining fixed.
  - This effect results from the fact that an observer on Earth is in a rotating reference frame

#### **Green Rim-Red Rim**



# **Rim Optics**

- Green/Orange Rim is a refraction phenomena
- Best seen with Sun 1-3 degrees (2-6 diameters of the Sun) above horizon
  - When closer to horizon extinction removes green faster than red
- If Sun is higher it is a Blue rim
- A setting Sun's last section is the top of the green rim

Needs binoculars/telescope to see well

 Big bright green flashes need mirage(s) to improve the refracted color

# Mirages

- Mirages are an optical phenomenon caused by light rays being bent by temperature inversions or refraction effects that displace images of distant objects or the sky
- Mirage are a *real* optical phenomenon that can be captured on camera, not a hallucination
  - The human mind strongly tries to make sense of an image (Pareidolia)
  - Inferior images on land are often mistaken for water reflections

# Mirage Types

Name		Images	Description
•	Superior	2	Inverted Image ABOVE erect image
•	Inferior	2	Inverted Image below erect image
•	3-Image	3	Inverted Image between erect images
•	5-Image	5+	Known but not understood yet
•	Fata Morgana	Many	Complex of distorted erect and inverted

- Fata Morgana Many Complex of distorted erect and inverted images
- Variants: *looming, towering, sinking* and *stooping* images

#### **Refraction Mirages**

- Mock Mirage Many Complex of distorted inverted images. Caused by looking down into an inversion layer and due to curvature of Earth up to the object on the horizon
- Late Mirage 2 Looking up through an inversion to object above observer

http://www-rohan.sdsu.edu/~aty/mirages/mirintro.html

### **Atmospheric Image Modifications**

#### **Optical Modification**

1 image Normal, refraction, looming, sinking, towering, stooping

Air as an Optical Element Prism, wedge, or weak lens

- 2 images Inferior or Superior mirage Strong lens or curved mirror
- 3 images "late", 3-image or mock mirage Strong lens
- 4+ images 5-image mirage, Fata Morganas Series of lenses

#### Optical Green Flash Type Observer Refraction

#### Effect

Normal, Refraction, Looming, Sinking, Towering, Stooping

Mirage Type	Event	<b>Observer Location</b>
Inferior mirage	Inferior-Mirage type	Anywhere
Superior mirage	Duct-edge	Below temperature inversion
"late" mirage	No Green Flash	Below temperature inversion
3-image mirage	No Green Flash	Below temperature inversion
Mock Mirage	Mock-mirage flash	Above inversion
5-image mirage	none or duct-edge	Inside or below strong inversion
Fata Morgana	none or duct-edge	Inside or below strong inversion

# **Superior Mirage**

- Temperature inversions have warm air above cold, the opposite of the normal atmospheric temperature patterns
- Superior mirages occur when the line of sight is lower than the air above the line
- Common in very cold regions with ice on the ground/water but weaker ones occur elsewhere
- If light rays bend at the same rate as the earth curves a mirage of an object very far away may occur (Novaya Zemlya mirage, first noted 1596)
- Example http://wwwrohan.sdsu.edu/~aty/mirages/bochoven/text.html

# **Inferior Mirage**

- In an Inferior Mirage the image is located under the real object, for example a "lake" on a desert or highway is actually the sky above
- Image is usually upside down
- Unstable as hot air rises and cooler air descends resulting in mixing of layers
  - Turbulence
  - Vibrating vertically or horizontally
- If there are multiple temperature layers there can be multiple mirages, possibly mixing and causing multiple objects
- Heat Haze (aka Highway mirage) is a form of inferior mirage
- Typically no more than 1 degree across

# nferior Mirage --Typically <1 degree

#### **Inferior and Mock Mirages**









# Fata Morgana Mirage

- A kind of superior mirage consisting of a series of unusually elaborate, vertically stacked images, which form one rapidly changing mirage
- Castles or Islands on the Edge or in the Sky
- Very common in Artic with cold air over frozen ice and summer sun warming the air
- Example

http://www.davewalshphoto.com/2010/01/17/fa ta\_morgana/

#### **Green Flash Causes**

- Diffraction of sunlight enhanced/stretched by various mirage
- Different mirages result in different kinds of enhancements and stretches
- Rayleigh scattering helps determine color
  - Blue flashes more common with cloud flashes as
    Sun is higher above horizon

- Multiple inversion layers resulting in multiple pancake shaped objects
- Two different kinds of Green Flashes in this picture (Inferior above solar disk, Mock at edges of solar disk)



# **Green Flash Types & Conditions**

**Kind** : Appearance : *Duration* : Why : *Where* 

- Inferior-Mirage : Oval, flat below : 1-2 second : Surface is warmer than air : Close to sea level
- Mock-Mirage : Thin point strips pinching off from sun : 1-2 seconds : Surface colder than air, inversion layer below eye level : best from higher up, most probable when eye is just above inversion layer
- **Sub-Duct** : Large upper part of Sun when hourglass shaped goes green : *up to 15 seconds* : observer below a strong inversion : *from any height but observer is just below a duct*
- **Green Ray** : Green beam shoots up from green flash or just after sunset : *a few seconds* : hazy air and any bright green flash : *not known where best to see*

### Green Flashes, Most Common

- 99% of flashes are:
  - Inferior-mirage ~69%
  - Mock-mirage ~30%
- 1% of reported flashes are:
  - Sub-duct
  - Green ray
  - Blue/Violet
  - Cloud-top flashes
  - Alistair Frasier flashes (variant of mock-mirage flash with inversions over hills)
  - Other

#### Inferior-Mirage Green Flash Sequence

#### Scales and Times:

- All sub-photos to scale with main picture of the Sun
- Last 2 seconds of an Inferior-Mirage green flash
- Bottom of Sun is shows horizon for last of green flash images

#### Notes:

- All green flash images processed the same except the last which was brightened a bit for visibility
- Image of Sun f/96, 1/8000 sec, ISO50 and heavy postprocessing of RAW file to reduce over exposure
- Sunspots on sun
- Little green flashes on pointy strips on edge of Sun, these are Mock-Mirage green flashes



# Less Turbulence at Mid-day October 2014

# **Some Green Flashes**









# **Blue** Flash (also a Cloud-top Flash)




#### **Cloudtop Blue Flash**

#### **Cloudtop Green/Blue Flashes**

### **Green Flashes Are Simple**

- Diffraction of light
- Scattering of light
  - Rayleigh Scattering
  - Aerosol scattering
- Extinction of light
  - Most importantly Chappuis band molecular absorption (orange light) makes green more visible from red
- Intensification of light by lensing/mirages

http://wwwrohan.sdsu.edu/~aty/explain/extinction/Laplace.html

#### **Unknown Flash With Many Colors**



- Sunrise over White Mountain from Mt. Tom overlook on Highway 395
- 36x telescope then digitally zoomed in Photoshop
- Cause of colors unknown.

### Not a Solved Problem

- Green Flashes (of any color) are not fully understood
- Green Flashes are real

#### **Crepuscular Rays – After Sunset**

### **Civil Twilight Phenomena** 0-6 degrees down

- Pink Time (not an official name)
- Red Time (not an official name)
- Alpenglow
- Belt of Venus / anti-twilight arch
- Earth's Shadow
- Anti-solar point
- Anticrepuscular Rays

# **Cloud Colors Sunset/Sunrise**

• Yellow, red, orange and pink clouds occur almost entirely at sunrise and sunset

result of the scattering of sunlight by the atmosphere

- When the angle between the sun and the horizon is less than 10 percent, sunlight becomes too red due to refract any colors other than those with a reddish hue
- The clouds do not become that color; they are reflecting those colors
- Similar to shining a red spotlight on a white wall
- In combination with big thunderheads can result in blood-red clouds
- Clouds look darker in the near-infrared because of water absorption

#### Pink Time (not an official name)

### Red Time (not an official name)





# **Alpenglow vs. Belt of Venus**

- Alpenglow
  - Not direct sunlight
  - Sunlight just after sunset from reflected off clouds (ice, water) or dust in atmosphere and reddened in process
  - Reddened band seen on mountains and sometimes on dust and other particles
- Belt of Venus
  - Similar to alpenglow (backscattering of reddened sunlight) but lasts much longer after sunset
  - Most brilliant soon after sunset
  - Extends 10°–20° above the horizon
  - Underneath the Belt of Venus is a dark band, the shadow of the Earth

# Alpenglow on Mt. Tom

Alpenglow on Mt. Fairweather, Alaska

#### Belt of Venus & Earth's Shadow



### Looking Away From the Sunset

- Anti-solar point
- Anti-crepuscular Rays
- Belt of Venus
- Earth's Shadow Rising



#### Anti-crepuscular Rays Converging on Anti-Solar Point, Belt of Venus and Earth Shadow

#### Nautical Twilight Phenomena 6-12 degrees down

Afterglow Sunset clouds with the first stars above



### Astronomical Twilight Phenomena 12+ degrees down

- Lunar halo
- Lunar rainbows (Moonbows or White Rainbows)
- Earthquake light
- Space Weather
- Auroras
- Airglow
- Zodiacal Light
- Gegenschein

#### Lunar 22° Halo





# Summary of Sunset/Sunrise Phenomena

Almost all of these phenomena come from one or more of:

- Refraction
- Reflection
- Scattering

Which in turn leads to:

- Halos
  - Rainbows
  - Sundogs and 22° Halos
  - More
- Mirages
  - Mirages
  - Green Flashes (and yellow, blue, violet, etc.)
  - More

# **Photography Notes**

- Go out and look a lot!
- Sometimes the eye will see the phenomena first, sometimes the camera
  - The eye often see more detail than a simple picture. HDR is sometimes needed to equal an eye
- Look all around. Not just where the action is but also behind, above and below. There maybe something else going on
- Study the different kinds of phenomena, understand what causes them and identify clues for future pictures
- Sometimes just a few seconds in when you take the picture makes a big difference
- Careful post-processing can greatly improve many pictures
- Not everything is known or even photographed yet
- Go out and photograph a lot!

**Be careful**. Looking at the sun, being on cliff edges, night, strange areas all might lead to problems

### **Sunset Prediction Software**

- Escaype <u>http://www.escaype.com/</u>
  - "We officially forecast golden hour conditions, fog, and clear night skies, but we also do our best to give you a heads-up for excellent "blue hour" conditions, lightning and rainbow opportunities, snow and monsoon storms in the Sierra, pretty clouds and dramatic light, and just about anything else that a photographer might enjoy chasing."
- Skyfire <u>http://photoephemeris.com/skyfire-for-</u>
  <u>tpe</u>
- SunsetWx <u>https://sunsetwx.com/</u>

### Support Software - Sun/Moon

- TPE <a href="http://photoephemeris.com/">http://photoephemeris.com/</a> iOS
- The Photographers Transit digital field of view shot planning app
- Commander Compass iOS
- Spyglass iOS

## Support Software - Photography

- LensLab graphic depth of focus calculator, iOS
- Tilt Calculator for tilt-shift lenses, iOS
- TPE (again) iOS
- Easy Release (in case identifiable people are in scene) iOS
- ShotHotSpot finder Web site, free

### Support Software – Weather/Sea

- Dark Sky my fav weather forecasting app
- MyRadar fast displaying weather radar
- PWS Monitor personal weather station data
- Surf Report waves
- MSW (Magical Sea Weed) waves
- Tide Graph Pro tides (free version also ok)
- Strike Finder lighting

### **Interesting Books**

- Lights in the Sky Michael Maunder 2007 best of the bunch
- *The Cloud Collector's Handbook* Gavin Pretor-Pinney 2011
- Clouds in a Glass of Beer: Simple Experiments in Atmospheric Physics by Craig F. Bohren 2001
- *How to Use Your Eyes* James Elkins 2000
- Light and Color in the Outdoors M. G. J. Minnaeert 1974, translated 1993
- The Rainbow Carl Boyer, 2959, 1987
- *Rainbows, Halos and Glories* Robert Greenler 1980
- Science from Your Airplane Window Elizabeth A. Wood 1975
- *Window Seat* Gregory Dicum 2003

### **URLs of Interest**

- Wikipedia articles as needed
- Artifacts in Sunset Photography <u>http://www-</u> rohan.sdsu.edu/~aty/observing/artifacts.html
- An Introduction to Mirages <u>http://www-</u> rohan.sdsu.edu/~aty/mirages/mirintro.html
- Green/Red Rim <u>http://www-</u> rohan.sdsu.edu/~aty/explain/simulations/std/stdatmGF.ht <u>ml</u>
- Absorption, Diffraction and Extinction of light <a href="http://www-rohan.sdsu.edu/~aty/explain/extinction/extintro.html">http://www-rohan.sdsu.edu/~aty/explain/extinction/extintro.html</a> and <a href="http://www-nty/explain/extinction/Laplace.html">http://www-nty/explain/extinction/extintro.html</a> and <a href="http://www-nty/explain/extinction/Laplace.html">http://www-nty/explain/extinction/extintro.html</a> and <a href="http://www-nty/explain/extinction/Laplace.html">http://www-nty/explain/extinction/extintro.html</a> and <a href="http://www-nty/explain/extinction/Laplace.html">http://www-nty/explain/extinction/Laplace.html</a>